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High-speed National Research Network and its New Applications

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1 Introduction

The report presented herein describes the process of a solution for the research plan titled *High-speed National Research Network and Its New Applications* and the results achieved in 2002. This year was the fourth year of the research plan, which is expected to be terminated towards the end of 2003.

In February 2002, we celebrated the 10^{th} anniversary of the official launch of the Internet in Czechoslovakia. In commemoration, we held a seminar with international participation at Charles University, Prague. The event was met with vast publicity, emphasising the significant role of universities and the Academy of Science in the development of the Internet in the Czech Republic and Slovakia.

During the previous year, the key activity was the continuing development of the CESNET2 network, associated with the services offered by the pan-European GÉANT network in the Czech Republic. Thanks to the deregulated telecommunications market in the Czech Republic, we were able to make use of bids presented by several potential contractors for the lease of optical fibres and complete the network using the method known as Customer Empowered Fiber networks. During the implementation of this new principle of network construction, we checked and launched several long distance data circuits without any active elements in the line.

We decided to plan further development of the CESNET2 network topology, in the form of three rings with a preset maximum number of hops in each ring. Immediately after this decision, we entered into negotiations with potential suppliers of optical fibres, particularly the supply of the "first mile" (or last), which in most cases turns out to be the most problematic. In July, we announced an invitation for bids concerning the delivery of routers for the following stage of network construction. The deadline for the tender bids was in September, and in October, we selected the routers of Cisco Systems (a US-based company), supplied by Intercom Systems a. s.

Throughout the year, we focused on the arrangement of projects forming part of the research plan. In addition to in-house projects, the researchers became successfully involved in the arrangement of research activities of the GÉANT project, presented under the title of TF-NGN (Task Force – Next Generation Networking). In addition to the GÉANT project, researchers joined three other projects supported by the EU – DataGrid, SCAMPI and 6NET.

Among all projects, IPv6 proved to be the most dynamic, reporting a significant increase in capacities throughout the year, particularly among students. This was possible thanks to the understanding and support of some members of the association who created the necessary conditions for the involvement of students and postgraduate students in the solution of the research plan.

The following chapters comprise a detailed description of the solution of individual projects associated in the research plan. With respect to the wide thematic scope of these projects, individual sections of the documents were drawn up by different authors and the reader may therefore consider this document rather as a collection of papers related to a particular topic.

We consider necessary to mention the difficulties in the financing of the research plan. Even despite positive evaluation during the opposition procedures held in January 2002, and in spite of the positive assessment of the CESNET2 network by the international organization TERENA during its comparison of academic networks (June 2002), the financing of the research plan has not been safeguarded until now. We are convinced that finally, we will be able to gather the funds required. However, due to some delays in financing, some projects will have to be postponed until the second half of the year, which may have a negative impact on the quality of the research plan solution in 2003.

2 Brief Summary

The research plan titled *High-speed National Research Network and Its New Applications* includes the following fundamental objectives:

- To operate a high-speed national research network, CESNET2,
- To ensure its further development, in line with the needs of users and current technologies,
- To become involved in analogous projects at European and global levels,
- To carry out own research in network technologies and their application,
- To search for, adapt and develop corresponding applications.

A specific aspect of this research plan is that it has, to a great extent, the character of a service. Most of the finances are invested in the operation and development of communication infrastructure for science, research and education. The results are beneficial to a number of other projects and activities not directly associated with this research plan, which are, however, based on the automatic expectation of an existing adequate communication infrastructure.

Concerning the broad range of the research plan, the activities related to its solution were divided into thematically defined projects. The 2002 projects can be divided into the following three categories:

Strategic: Themes which we consider to be key themes for the solution of the research plan. Strategic projects were among the most extensive, both concerning the volume of work and the investments.

International: The association succeeded in becoming involved in several projects at a European level. In particular, these are the *GÉANT*, *DataGrid*, *SCAMPI* and *6NET* projects. We joined the last of the projects only in 2002 (it was solved within the strategic project concerning IPv6).

Other: Projects of smaller scope, without any international bonds to other institutions.

The remainder of this chapter includes a brief summary of the activities and outcomes of individual projects. For more detailed information, see the following chapters.

2.1 Operation of CESNET2 Network

During 2002, the stability of the backbone network improved. We succeeded in solving a number of problems and concluding a contract thanks to which we will have access to better information and higher priority in our collaboration with the manufacturer.

The load of backbone lines reported gradual increase, reaching an average of 10–13 % of their maximum capacity. This corresponds to the character of an "overprovisioned" network, typical for academic networks in a majority of the developed countries of the world. Another aspect worth mentioning is the positive data balance (approximately 2:1) within our international links. This means that our network includes an abundance of attractive data sources, particularly archives of free software.

We adopted some further steps for the development of our network. We made out a draft of a new concept for the backbone network and its nodes (attendance points, GigaPoP) and launched its implementation. The changes in the topology of circuits and the supplies of new technologies have already commenced. The CESNET2 network should be modified according to the new concept by summer 2003.

2.2 Strategic Projects

In collaboration with the technical group, the project of *Optical Network and its Development* made out a generic scheme of the CESNET2 network, which shall serve as a basis for further development. The network backbone will be formed by several short rings, which will ensure redundant connection of backbone nodes and also short transmission routes (measured by the number of hops).

Thanks to the use of the "nothing in line" technologies, we reached outcomes acknowledged worldwide. The application of a Gigabit Ethernet in combination with EDFA amplifiers along the Prague–Pardubice line was appreciated by our foreign partners. Our pioneering achievements include experiments with data transfers along a single fibre.

The results described above helped us become involved in the preparation of the *ASTON* international project, focusing on optical networks. The project will be submitted into the 6th EU Framework Program.

The activities concerning *IP version 6* aimed at the development of the IPv6 network within CESNET2 and the development of services available through this protocol. We modified the topology of the network in order to make sure that it corresponds to the topology of IPv4, consolidated the DNS and launched several services available for IPv6. One of them is the *www.ipv6.cz* server, for the presentation of the properties and capacities of the protocol.

The most demanding part of the project was the development of an IPv6 router on the PC base. This includes two parts: the *COMBO6* card for the hardware routing acceleration, and the router configuration system based on XML. During 2002, we designed the card, had it manufactured and installed the first specimen. We designed the basic concept of the software and launched its implementation. We present our results on the *www.openrouter.net* server. Several other projects have already expressed their interest in the COMBO6 card.

From an international point of view, our greatest success this year was our accession to the *6NET* project. Our share in this project consisted particularly in the development of the IPv6 router mentioned above.

The area of *Multimedia Transmissions* is rather varied and our activities aim in various directions. We have been developing the routinely used videoconference tools for MBone and H.323. Considering the fact that the MBone network is still not generally accessible in a number of locations, we devote our attention to the development of mirrors, enabling the use of MBone also within a network which does not support group addressing of datagrams.

We have developed and maintained a portal for easy control of mirrors. In order to provide more information to users, we reconstructed our website devoted to multimedia transmissions at *www.cesnet.cz* in 2002.

We have supported several distributed groups in their videoconference efforts and we try to make use of these examples to present the opportunities offered by videoconferences. We launched the development of access points of the *AccessGrid* network, offering subscribers the advantages of videoconferencing services with maximum quality. Another interesting project is the Internet broadcasting of Czech Radio, at high quality, which we launched earlier this year.

Within the *MetaCentrum* project, we have been developing an environment for demanding user's projects. The existing clusters of the MetaCentrum offer over 150 Intel Pentium III and IV processors. These services are currently used by approximately 200 users.

In 2002, we launched another extension of the computing capacity, purchasing 32 dual-processor stations. Unfortunately, the supply of these stations was delayed. This is why the new cluster will not be installed until the beginning of 2003. Furthermore, we have developed the software for MetaCentrum, particularly with respect to task planning and user administration.

We have contributed a great deal to the success of an international team that won during the *SC2002* fair in several categories of the High Performance Computing Challenge and High Performance Bandwidth Challenge.

One of the network applications that has lately reported a significant development is IP telephony. The strategic project of *Voice Services in CESNET2* includes two sections: an operational section and a research section. As regards the operational activities, we have been further developing the network for IP telephony which is used by the connected institutions for their standard phone communication. In 2002, we began to offer this service for routine operation, including calls to the public telephony network for reasonable rates.

The research part of the project focuses on new technologies and solutions in this area. We have focussed particularly on the search for a suitable platform for the operation of a wider network of IP phones and on experiments with the SIP signalling protocol. We have also been developing our own application for the registration and billing of calls in the IP telephony network.

As regards the research into the *Quality of Services in High-speed Networks*, we have focused in particular on the research of mechanisms for QoS. We measured the real parameters of several available solutions. In addition, we turned to simulating the behaviour of the TCP protocol and the possibilities of its optimisation in high-speed networks.

We have also become involved in the preparation of the European activity titled *Performance Response Team*, proposing a presentation of an *End-to-end performance cookbook*. We are now working on its content.

2.3 International Projects

Since 2001, we have been involved in the solution of the 5th EU Framework program, *DataGrid*, oriented on the creation of an extensive computing and data infrastructure. CESNET has taken care of the logging and security services.

Last year's work concerning the logging service was split into two parts. In one part, we maintained and developed version 1, extended by the project management to February 2003. In the other part, we were developing version 2 of this service, which will offer a range of new properties.

We became involved in the preparation of the continuation of our project within the 6th EU Framework Program. Together with our colleagues from Poland, Slovakia, Hungary and Austria, we decided to set up the Central European Grid Consortium, with the objective of strengthening our position in the project.

SCAMPI is one of the projects of the 5th EU Framework Program. The basic objective is to monitor high-speed networks and develop monitoring tools. The project was launched on 1 April 2002. We have participated primarily in a task aiming at verifications – experiments and facility testing. CESNET is the leader of this partial task.

Concerning the fact that the project has been left by a Greek supplier who was to develop a card for network monitoring, the researchers of the SCAMPI project expressed their interest in the COMBO6 card, developed in our IPv6 project. We are therefore considering the development of a special version of this card, adjusted for the needs of monitoring and measurement.

2.4 Other Projects

The objective of *Infrastructure and Technology for Online Education* is to support the use of the Internet for the purposes of education in Czech universities and other institutions involved in education. We have launched the *eLearning.cesnet.cz* portal, providing information concerning electronic education. We have also implemented several pilot projects, primarily in collaboration with FEL ČVUT Prague and the University of Pardubice.

The development of a *Distributed Contact Centre* was meant to check some of the advanced services provided by the IP telephony. We established two centres (one in Prague and one in Ostrava), which are interconnected and form a fully redundant unit. The resulting contact centre may serve the needs of a number of projects.

The development of the *NetFlow Intelligent Analyser* continued from previous years. In 2002, we decided to redesign the core of the system. In consequence, the output of the entire analyser reported a sharp increase. We also extended the range of the provided functions. In the meantime, we have been completing a version of the analyser for distribution, which we would like to offer to the public in early 2003.

The research in *Storage over IP* focused on iSCSI technology, enabling remote access to SCSI devices over the standard IP network. We tested several available solutions – both software solutions based on the Linux OS, and commercial hardware products. The conclusions are not very convincing. The available iSCSI implementations are very immature and suffer from a number of "teething troubles".

The objective of the *Presentation* was particularly to popularise the research activities pursued by the association and its achievements. In 2002, we published three professional monographs, 18 technical reports and almost 80 relevant contributions in proceedings and articles in both printed and electronic periodicals. We have also devoted considerable attention to updating the *www.cesnet.cz* server, serving as the main platform for the publication of the results of our research plan.

The *System for the Support of Solutions to Operational Problems and Requests* serves for the coordination of research teams. In addition to the routine operation of the current RT system, the project focused on its updating and modifications according to users' requests. We checked some new opportunities which we plan to implement next year. We have become members of a limited team of program localizers and so the currently developed version 3 will offer a Czech interface. Version 3 is to be launched next year, it is now in the process of alpha-testing.

Security of computer networks has become an issue of higher and higher importance. This is why we have come up with the project of *Security of CESNET2 Local Networks*, offering security tools to the administrators of networks connected to the academic backbone. Moreover, the tools which now help protect networks have witnessed significant development, sometimes based on truly unconventional methods. We try to provide information about these systems and their completions, which we have developed. In particular, we focus on the *NESSUS*, *SNORT* and *LaBrea* open source products.

The purpose of the *NTP Server Linked to State Time Standard* is to develop and offer out a high-quality server for time synchronization. The development work is carried out in collaboration with the Ústav radiotechniky a elektroniky (Institute of Radio-Engineering and Electronics) of the Czech Academy of Sciences, responsible for the state time and frequency standards. We have drawn up the concept of the entire system, comparing time information from various sources, designed the necessary proprietary hardware components and launched the pilot operation.

Within the project titled *Platforms for Streaming and Collaboration concerning Videocontent*, we succeeded in upgrading the association's streaming platform. This was particularly based on the launch of a proxy upload server and its linking to the CAAS system. We also tested devices for the shared production of videodata. As well, we participated in the broadcasting of prestigious international conferences and other activities, co-organized by CESNET or its members.

Special Videoconferences focus on the issues of high-quality videoconferences. In addition to the transmission of video signal for sectors requiring high quality of video data, we have also concentrated on the testing of available devices and the search for suitable technologies for videoconferences with the necessary parameters.

3 Operation of CESNET2

During 2002, the CESNET2 backbone network witnessed a number of significant changes. We managed to solve problems concerning the stability of the network and the backbone routers, caused particularly by errors in the router operating systems. The stabilisation of the network was successful thanks to the technical team comprising network administrators, members of the supplier's team and the representatives of the router manufacturer (Cisco Systems). We managed to solve long-term problems concerning the multicast distribution and identified a functional and stable solution within the MPLS environment.

Second stage of the implementation and the completion of the current network commenced in the second half of the year. We announced an invitation for bids and selected the technology and the supplier of powerful gigabit access routers of the MPLS network (PE routers).

We concluded a contract with the manufacturer of routers, for extra support to the backbone network operation, prompt solution to operating troubles, support concerning the design of the network topology, as well as for the proactive monitoring of the backbone network operation. There are more NREN networks that make use of this support and the experience gained during the previous period confirm, without any doubt, that – taking into account the research character of the network – it is necessary to solve problems with higher priorities and have better access to the manufacturer's internal sources.

The main objective of CESNET2 is to offer permanent and quick access to all sources within the Internet. It is therefore necessary to design and operate this network in order to make sure that no experiments threaten its stability and the reliability of the offered services.

3.1 GÉANT – European Backbone Network

During the first half of 2002, the basic infrastructure of the pan-European backbone GÉANT was completed (see Figure 3.1). Its core is built on 10 Gbps lines (STM-64/OC-192). Other circuits have a typical capacity from 2.5 Gbps (STM-16/OC-48) to 155 Mbps (STM-1). GÉANT's Prague node (GigaPoP) is connected to Germany (Frankfurt) with a 10 Gbps line and to Poland (Poznań) and Slovakia (Bratislava) with two 2.5 Gbps lines. The node is located directly on the premises of CESNET.

The GÉANT network is connected with North American research networks with two transatlantic 2.5 Gbps lines, terminated in a GigaPoP in New York, and another 2.5 Gbps line to the Abilene network. For the scheme of the transatlantic connection, see Figure 3.2.

For some European NREN, the GÉANT network also provides access to the Infonet network and commodity Internet, through the Telia and Global Crossing backbone networks (connection in more GigaPoPs within Europe).

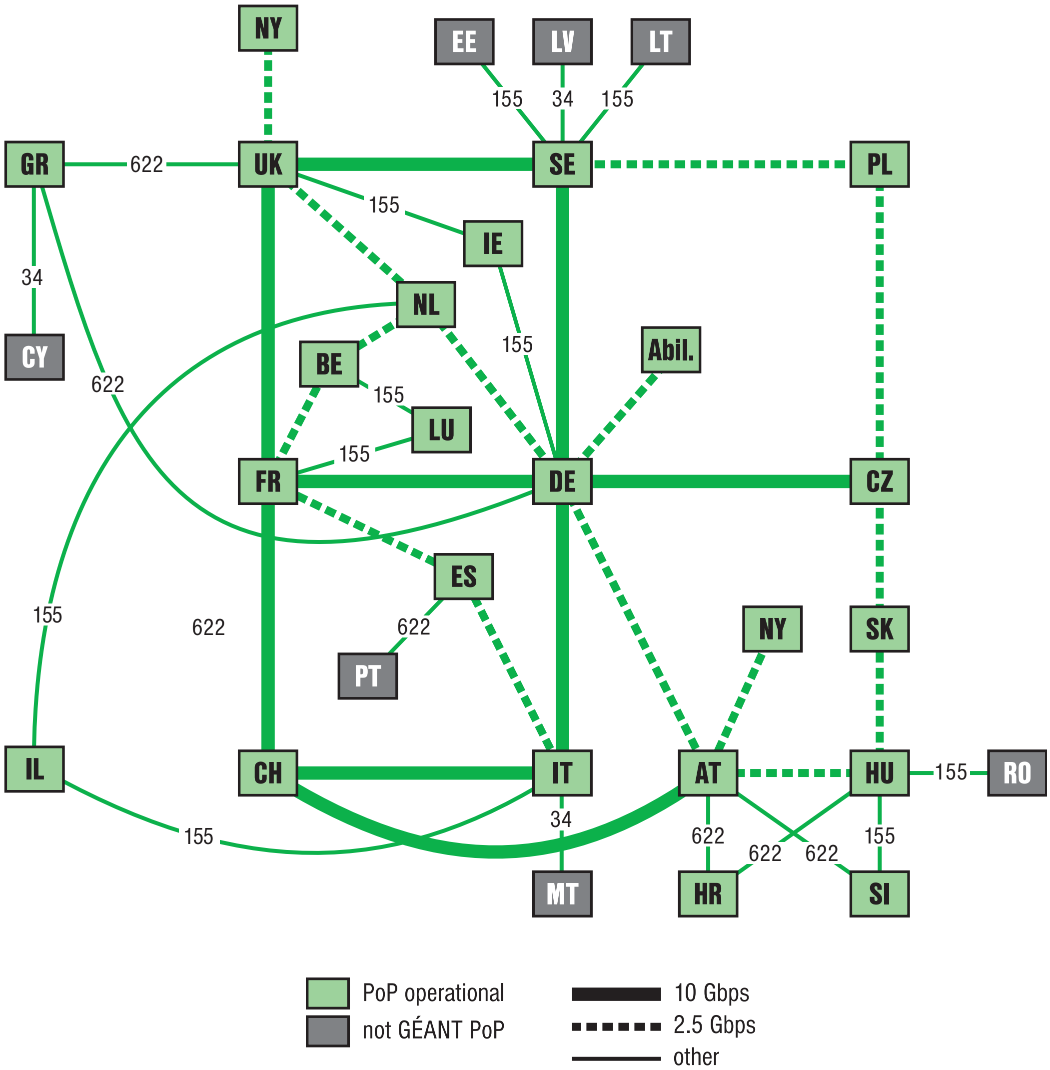


Figure 3.1: Infrastructure of GÉANT pan-European network

All GÉANT GigaPoPs provide multicast service, and MBone connectivity. The deployment of QoS (e.g., IP Premium) and other services is in progress. The connection to the 6bone is provided through separate backbone network dedicated to IPv6. The aim is to develop a backbone network supporting both protocols and providing IPv4 and IPv6 and other services. For details concerning GÉANT network and the related research projects, visit *www.geant.net*.

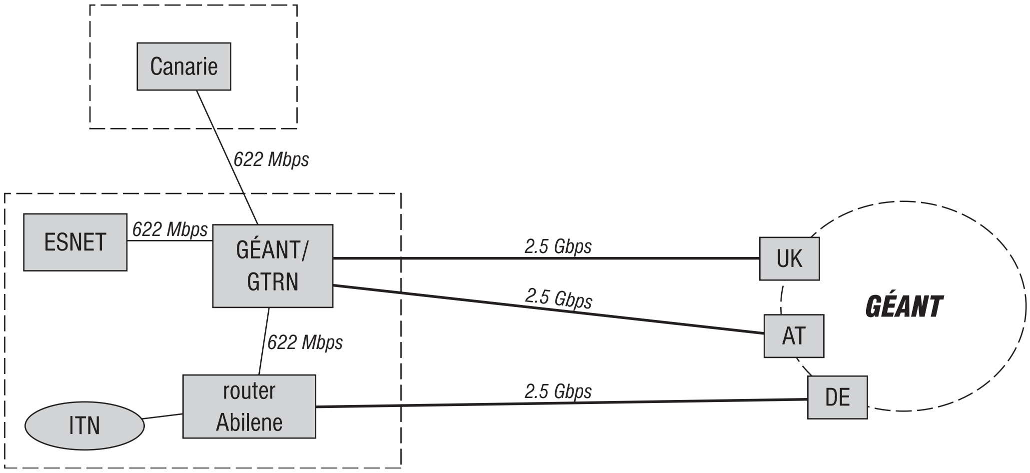


Figure 3.2: Interconnection of GÉANT and North American research networks

3.2 Current Situation concerning CESNET2 and its Development in 2002

We made a change in the physical topology of our backbone network, from the star-type to a ring network. All GigaPoPs are now connected with at least two lines. In addition, the number of leased fibres increased. For the current situation concerning the physical topology and a summary of the types of data circuits, see Figure 3.3.

The basic transport protocols are POS/SDH (2.5 Gbps) and a Gigabit Ethernet (1 Gbps). As regards the 2.5 Gbps circuits, we make use of leased SDH circuits (Aliatel, Český Telecom), or leased optical fibres, fitted with the Cisco ONS 15104 regenerators. We operate the circuits of the Gigabit Ethernet using leased fibres. In order to increase the operating distance, we are using two different technologies: EDFA amplifier or intermediate L2 switch (Catalyst 3524), fitted with GBIC-ZX, with a range of 70 km.

The use of an intermediate L2 switch is relatively inexpensive; however, it brings in trouble concerning the switching to the backup line in case of a circuit failure (this needs to be solved on layer 3). It is therefore not suitable as a common solution. It seems promising to use EDFA amplifiers at the line ends (without a need for an active element along the line), the use of which is also protocol transparent (POS/SDH STM-16/OC-48 and GE).

Along the Prague–Pardubice and Prague–Ústí nad Labem lines, we have been verifying the use of Keopsys amplifiers, available for reasonable prices. The use of these amplifiers has caused some troubles (e.g., short-time failures) which can be difficult to detect. The amplifiers offer no possibility for continuous monitoring of the signal quality (e.g., through SNMP) and they can be controlled only using a panel or a serial console (however, it is necessary to interrupt their operation). The manufacturer has been looking for a possible solution; however, it would be rather complicated to operate more EDFA amplifiers without complete diagnostics and a management system.

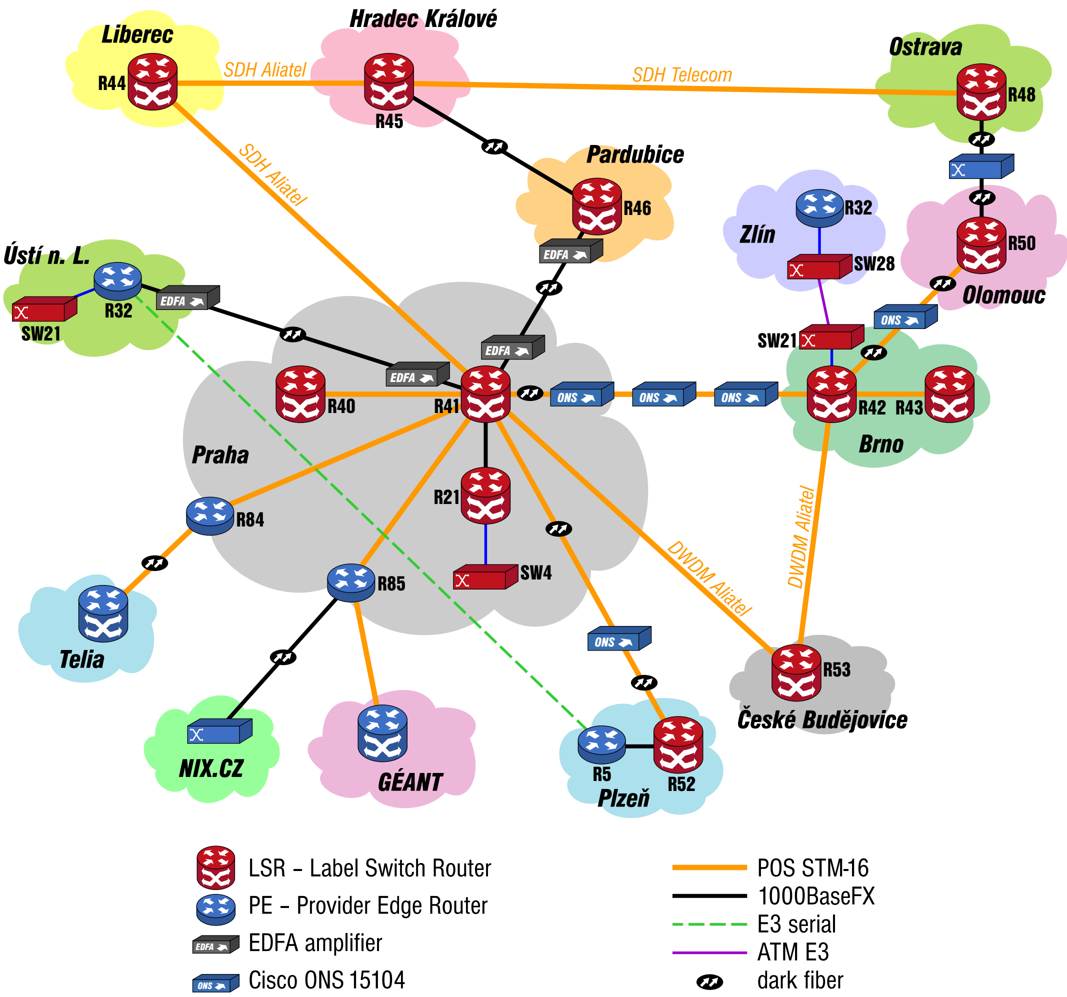


Figure 3.3: Existing topology of CESNET2 network

At present, we are preparing an optical line from Brno to Bratislava with the SANET network. We plan to use the Catalyst 3524 and CWDM-GBIC as an amplifier, at a wavelength of 1,550 nm (the lowest signal attenuation). CWDM-GBIC has a higher optical output (approx. 30 dB), longer operating distance (approx. 100 km) and it is even cheaper than the standard GBIC-ZX.

CESNET2 makes use of the Cisco GSR 12016 routers with redundant key components (power supply, processors, switching arrays). In the middle of the year, we launched two external routers Cisco OSR 7609 (R84, R85), connected to the central network core routers with the POS STM-16 interface (2.5 Gbps). These routers provide all international lines:

- Line to commodity Internet – 622 Mbps through Telia International Carrier (physically POS STM-16),
- Line to GÉANT network – 1.2 Gbps (physically POS STM-16), also serving as a backup commodity Internet connection,
- Line to NIX.CZ – 1 Gbps (physically Gigabit Ethernet)

Current backbone routers (Cisco GSR 12016) serve also as the access routers in the network nodes. Individual metropolitan and academic networks are connected directly through the Gigabit Ethernet. Slower access interface (10/100 Mbps) is provided by the Catalyst 3524 switches, using 802.1Q.

The current GigaPoP architecture and used interface types contribute to a number of problems and restrictions:

- It is impossible to configure the input and output filters at GE interfaces,
- It is impossible to configure CAR according to a particular filter,
- Filters are not supported on the logical 802.1Q interfaces.

The missing filtering capability means a serious security complication as we have no opportunity for protecting the backbone network and connected customers. This problem has been solved in the new concept of the PoP, described below.

These GSR 12016 access routers export NetFlow data, used for the statistical evaluation of traffic and for the solutions of security incidents in the network.

The basic transmission protocol in the backbone network is IP/MPLS. As the internal routing protocol of the MPLS network core, we make use of OSPFv2. Based on the metric adjustment, we ensure the load ballancing and activation of backup routes. The network blocks from individual GigaPoPs are announced via the iBGP protocol with two route reflectors on routers R84 and R85.

3.3 Distribution of MBone

CESNET2 provides the connection to MBone (multicast) through the GÉANT backbone network. We make use of the PIMv2 protocol in the sparse mode, MBGP (according to RFC 2283) for the notification of network prefixes (necessary for RPF mechanism) and MSDP (notification of active sources of multicast data).

The CESNET2 backbone network is divided into multicast domains (each GigaPoP represents an independent domain with independent RP). All interfaces of the backbone network use the PIMv2 protocol in the sparse mode. In addition, the GSR 12016 routers in GigaPoP form an interface between the sparse mode for the backbone and the dense mode, used for the connection of customers. The division of the backbone network into more separate domains enables more effective control over the multicast operation within the backbone network and the restriction of undesirable operation (e.g., filters at the level of the MSDP protocol restrict the Novell NDS traffic, ImageCast, etc.).

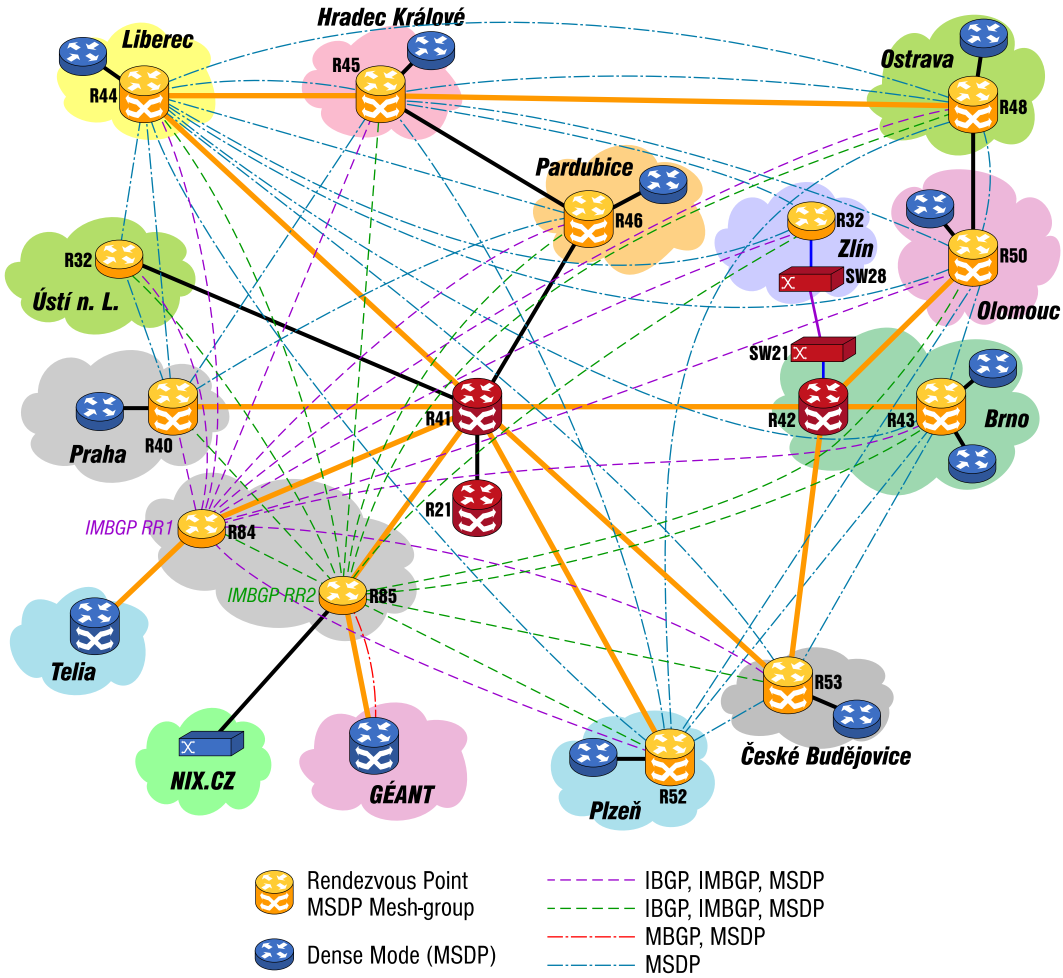


Figure 3.4: Logical topology of multicast

Within the backbone network, we make use of the iMBGP protocol with the same topology as iBGP (we have route-reflectors configured on R84 and R85), together with the iMSDP protocol within the full-mesh topology among all RP (full-mesh iMSDP is configured on all border routers in GigaPoPs). The full-mesh configuration of iMSDP enables the exchange of SA messages (Source Active) among all iMSDP routers, irrespective of the mechanism of the RPF check.

The application of this mechanism with iMSDP was the main cause of multicast related problems on the backbone. The core routers lack the routing information from iBGP, concerning the network availability, so the RPF check blocked sending SA messages to other routers.

The existing logical topology of multicast is not congruent (unicast is transmitted through MPLS, multicast without MPLS tags). In the future, we plan to verify the characteristics of multicast MPLS VPN, which are currently implemented in experimental versions of the router operating system (IOS).

3.4 Planned Changes in Backbone Network Topology and Services

The stabilisation of the backbone network and the deployment of the ring topology did not solve the remaining problems and missing features and services, which we had planned before. This is why we carried out an evaluation of the existing situation and possibilities for further solutions. During the first half of 2003, we plan the following fundamental changes in the backbone network architecture and services:

- Redundant backbone network
  - Distribution of foreign connectivity among various external border routers (Internet, Internet backup, GÉANT)
  - Double access to NIX.CZ (Gigabit Ethernet anticipated)
  - Double connection of all GigaPoPs in the backbone network through circuits with corresponding capacities
- Adjustment of the redundancy to new topology
  - Establishment of basic backbone rings
  - Termination of each ring in different backbone core devices (two central P routers in GigaPoP Prague)
- Changes in the topology of GigaPoP
  - Distribution of logical functions to various devices within GigaPoP (P and PE routers)
  - Connection of P and PE routers with a sufficient capacity (2 Gbps or more), depending on the necessary access capacity in GigaPoP
  - Implementation of MPLS VPN
  - Support of QoS, CoS, ACL at the input of the backbone network
  - Native distribution of IPv6
  - Multicast distribution

As regards the division of functions and management of network devices, the general topology of GigaPoP (Figure 3.5) is based on the following:

- Core backbone
  - Including P routers of the MPLS core, in which backbone lines are terminated,
  - Under the central management.

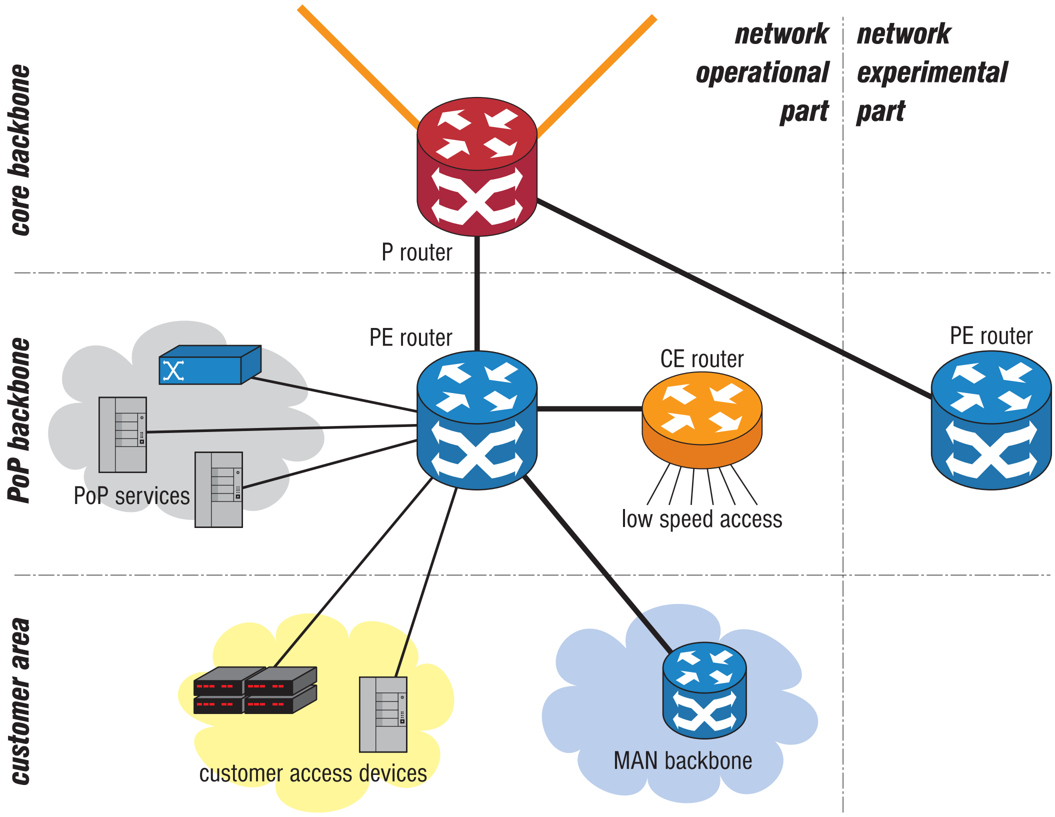


Figure 3.5: Draft of GigaPoP general topology

- PoP backbone
  - Including PE and CE routers of the MPLS backbone, other network access devices and service segments (e.g., servers),
  - Under the central administration,
  - Individual access points (ports on routers and switches) for an interface between the backbone and a customer,
  - For the purpose of experiments, we expect to be using reserved PE routers (logical and physical separation from the operational part of network).
- Customer area
  - Including routers, switches and other customer elements,
  - CE elements, from the point of view of MPLS,
  - Under the exclusive administration of customers,
  - Very often, these are devices with limited functionality (L2/L3 switches, PC routers, etc.)

With respect to the required services of the backbone network and simple devices on the side of the customer, it is necessary to ensure the required functions fully on the side of the PE routers. We also need to ensure an explicit interface between GigaPoP and the subscriber (filters, etc.), while maintaining sufficient capacity of the PE devices.

The logical core topology anticipates the establishment of three basic rings of P routers, connected through a pair of central routers. Each logical ring will connect not more that four P routers. We have set this number with respect to the dynamic behaviour of the network (particularly the packet delay) and the convergence of internal router protocols (quick convergence of the internal routing in case of a change). The used interface types and the transfer to GE will not enable the use of more effective and faster mechanisms for the traffic rerouting (Fast Rerouting, DPT) where the rerouting time is approximately 50 ms. In addition, we expect significant technological changes to be carried out within the defined rings.

During the second half of the year, tender procedures were carried out for the supplies of gigabit PE routers. The procedures also included tests for verifying the functions declared by the manufacturer and testing of compatibility with the existing Cisco technology (GSR 12016 and OSR 7609).

According to the size of the GigaPoP, we divided the required configurations of routers into three categories. The categories differ in the required numbers

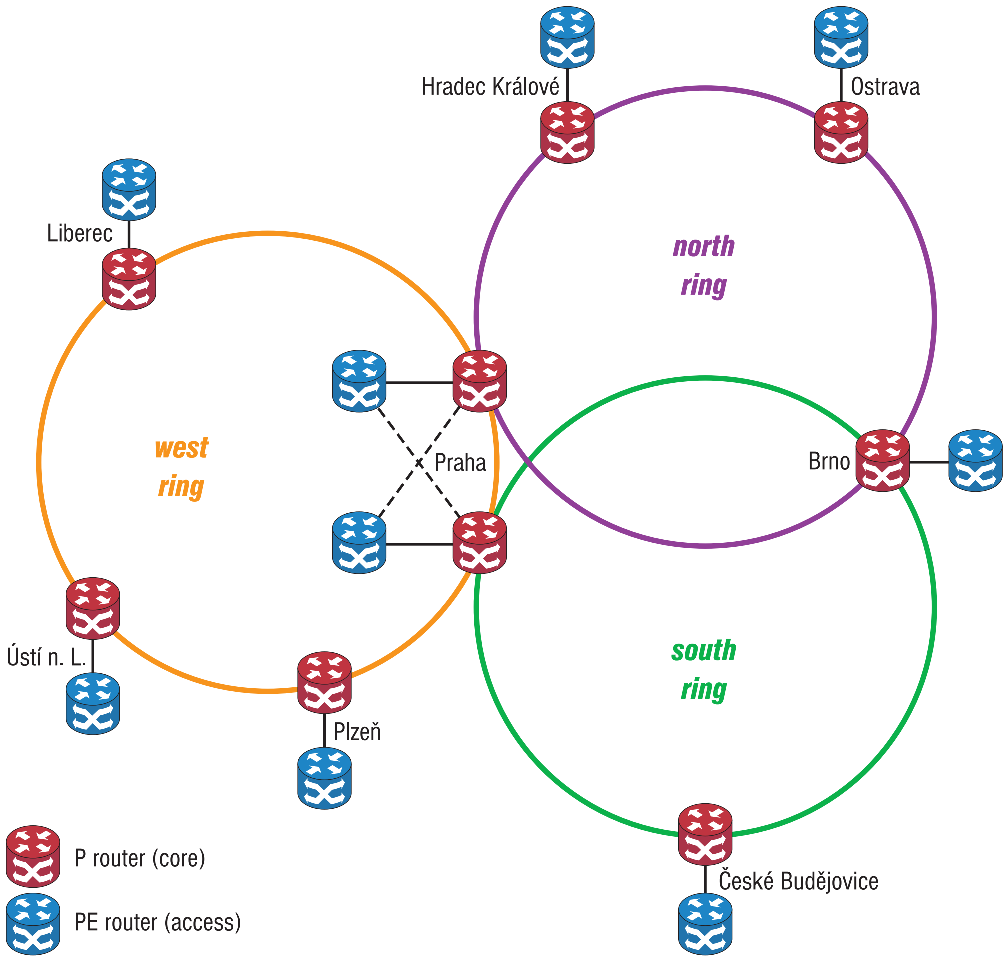


Figure 3.6: Planned logical topology of network core

and types of interfaces. The set of functional tests was divided into two parts: compulsory (unconditionally required) and informative (verification of the implementation of new characteristics, e.g., IPv6). Each applicant was required to present a set of two routers of the pertinent type (simulation of two GigaPoPs), together with technical support. Within the scope of the compulsory testing, we checked the following functions and characteristics:

- Presentation of router management and configuration, basic features and characteristics,
- Insertion of routers into the GTDMS measurement system and verification of supported SNMP MIB,
- Configuration of NetFlow and NetFlow export, functionality check,
- Verification of the function and compatibility of 802.1Q, including the possibility of filtration and QoS on logical sub-interfaces,
- Load ballancing on interfaces into the backbone network (Gigabit Ethernet and POS STM-16),
- MPLS (OSPFv2, BGPv4, LDP)
  - Configuration of approx. four MPLS VPNs among the tested routers and central OSR 7609, functionality check,
  - Checking of MPLS Traffic Engineering,
  - Implementation and verification of the MPLS QoS function in VPN,
  - MPLS according to the DiffServ model,
  - Configuration of service categories (Premium, Gold, Best Effort),
  - Verification of possible re-mapping of the ToS IP header (e.g., DSCP, IP precedence) from/to the CoS/priority of 802.1Q frame header
- Multicast
  - Creation of independent multicast domains,
  - Configuration of sparse-mode, MBGP and MSDP against backbone router,
  - Verification of the multicast function using system tools and the test sources/recipients,
- Router management
  - Verification of the possibilities for secure access, storage of configurations and operating systems,
  - Execution of a safety audit,
  - Verification of the quality of management support – SNMP MIB (GTDMS, HP OpenView 6.2),
  - Effects of the frequency of queries on the processor load,
  - Monitoring of individual functions and processes, and methods of troubleshooting,
  - Tests of general features (start-up time, redundancy)

Within the informative part, we required the presentation of the function implementation and other possible configurations, which can be offered by the routers in question:

- Presentation of features and characteristics that may require the use of experimental versions of operating system or which are not fully standardized,
- Verification of Ethernet over MPLS,
- Support of multicast in VPN,
- IPv6,
- Possibility of connection to CESNET2 IPv6 backbone,
- Verification of basic functions and routing protocols (RIP6, BGPv6, ICMPv6,...)

The tested devices were attached to the backbone network. According to the results of the tender, we selected the Cisco 7206 routers with the NPE-G1 processor for small nodes, and Cisco 7609 for medium and large nodes. The offered OSR 7609 configurations fulfilled the requirements; however, it turned out that the manufacturer is planning some radical technical innovations during the first half of the year 2003 and it makes no sense for us to purchase non-perspective devices. These are the following components:

- GE-WAN modules, Type I – to be replaced with modules of Type II, with the support of ATOM (Any Transport Over MPLS),
- Supervizor2/MSFC2 – a new type, Supervizor3/MSFC3, will soon be available, with an integrated switch matrix and, mainly, with hardware support for IPv6 routing.

According to our negotiations with the supplier, the entire supply was divided into two stages. Within first stage (to be completed before the end of 2002), we will purchase the 7206 routers with NPE-G1 for GigaPoP Ústí nad Labem and Zlín, as well as OSR 7609 routers without the modules mentioned above. In addition, we will borrow the modules of the current design for a necessary period of time. As soon as modules of the new generation are introduced, we will purchase them and upgrade the device.

We expect new PE routers to be gradually put into operation in January and February 2003. PE routers in the backbone network will provide the basic functions: MPLS VPN, support of QoS, multicast, ATOM (EoMPLS), IPv6 in IOS, possibility of configuring input/output filters and traffic shaping/CAR at all links to the backbone network, together with NetFlow export version 5 and 7.

The P and PE routers will be connected through two GE interfaces with load ballancing. In the large GigaPoPs (Prague and Brno), we will make use of 2 × POS STM-16 in order to reach sufficient capacity, also with load ballancing.

For the planned topology of the CESNET2 backbone for 2003, see Figure 4.4. In addition to the use of new PE routers, we plan to double the network core and other GE lines.

3.5 Backbone Network Management

The central management of the backbone network is provided by NOC CESNET (Network Operating Centre) on a non-stop basis (24 hours a day 365 days a year). For the purposes of backbone network administration, we make use of the following tools:

Backbone network management: *HP OpenView NNM 6.2* on the Sun UltraSparc 420R station with Solaris 2.8 operating system. It primarily serves for the monitoring of the network status.

Management of network devices (routers, switches, ...): *CiscoWorks 2000.*

Service monitoring: The *Nagios*[1] program, version 1.0., an follower of the formerly used *NetSaint*. We use it for the monitoring of service availability (mail, DNS, WWW and others). The server of the Nagios system is also used for the supervision of IPv6 network. For the purpose of monitoring, we make use of both protocols (IPv4 and IPv6), as the monitoring of some variables has not been ported to the IPv6 protocol yet.

Statistical systems: The *GTDMS* system contains a number of alarms for the exceeding of limits. It monitors routers (CPU load, free memory, power supply, internal temperature), as well as lines (overload, increased error rate, etc.). The GTDMS system and the backbone network statistics are described in details in the following section.

For the processing of NetFlow statistics, we make use of our own system, developed in one of our projects. It is intended for the statistical evaluation of individual customers traffic, as well as for the handling of safety-related incidents (evaluation of current flows according to the preset conditions). For a detailed description of the analyser, see Chapter 15. NetFlow data is exported by all network border routers.

Request Tracker (RT): Intended as a tool for request processing (their creation, solution monitoring and archiving) within the network operation. For a detailed description of this system, see Chapter 18. Several queues have been developed for the operation of CESNET2, used by the defined groups of users (network administrators, NOC, users, ...).

Out-of-Band management (OOB): Remote access to the network devices, available whenever they are inaccessible through the backbone network, is implemented in all network PoPs.

[1] *http://www.nagios.org/*

3.6 Statistical Traffic Analysis

3.6.1 Average Long-term Utilization of Backbone Network Core

From a long-term perspective, the core of the CESNET2 backbone network has the character of an over-provisioned network. In this case the QoS (Quality of Services) parameters are guaranteed by sufficient free capacity of the backbone lines and sufficient free processing capacity of active network devices (routers, switches). In addition to other aspects, this is a positive feature with respect to services operating on a real-time basis. Their quality depends on the time and time-capacity parameters of the network, e.g. absolute one-way or two-way delay, jitter, absolute current available free capacity, etc. From a global point of view, the rate of the CESNET2 backbone network core utilization reaches from 10 to 13 % of the overall available capacity.

3.6.2 Utilization of Backbone Lines

According to the outcome of long-term empirical monitoring, the average long-term rate of use reaches around 15 %, as a frequently mentioned limit for the over-provisioned networks. Even though the long-term average load of the CESNET2 backbone core is below this value, this does not mean in any case, that the network capacity is not used as it may seem at first sight.

When reviewing the results, it is necessary to take into account the method of operational long-term measurements.

The basic parameter influencing the results of measurement is the time interval between two successive measurements of a particular item – the time-step of measurement. In the operating mode, these measurements are usually carried out with a time-step of several minutes. As regards the CESNET2 backbone, the configured time-step is usually 5 minutes.

The results of such measurement express just the average utilization of a particular line during the entire time-step, i.e., for us, this means an average utilization during a five-minute interval. Having in mind that the range of hundreds of seconds is in fact an infinity from the point of view of short-term perspective in high speed networks, there is no chance to estimate the real usage of the line capacity within that time interval.

The two diagrams below demonstrate the dependence of the results on the measurement time-step. The measurement was provided during the same time interval with different time-steps. The Figure 3.7 shows utilization of the Prague–

GÉANT 1.2 Gbps line. The left diagram represents the measurement with five minute time-step, the right one measurement with three-second time-step. You see that the average load is not significantly different, however, the differences in peaks are considerable. The permanent peaks of 500–700 Mbps will completely change our idea of a load on what seem to be fairly free line.

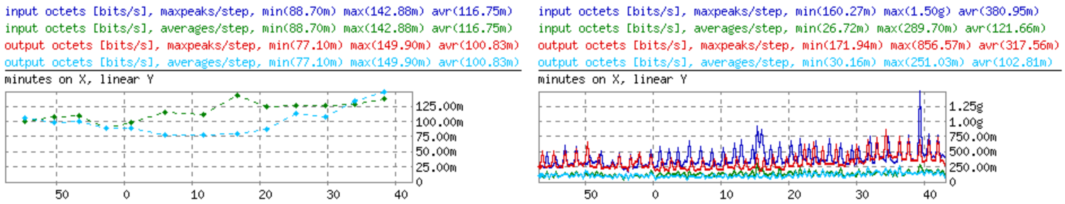


Figure 3.7: Influence of time step on line statistics – time step of 5 minutes (left) and 3 seconds (right)

At a certain point the 1.2 Gbps capacity of the line was even exceeded. The reason is that the physical capacity is 2.5 Gbps in fact and the 1.2 Gbps limitation is provided by the router. Statistical algorithms based on short-term history of interface load are used and therefore the short peaks may exceed the configured limit.

Even more significant differences can be seen in the comparison of a five-minute time-step with a one-second one. For the Prague–Liberec line, see Figure 3.8. The envelope peak curve is almost four times higher than the average values.

3.6.3 Development Tendencies in the Operation of Backbone Network

The rate of utilization concerning the backbone network core has reported an evenly increasing character. The increase in the utilization of individual backbone lines is similar and the average values of December 2002 are approximately twice or three times higher than the average values of January 2002.

The following diagrams of the backbone lines load depict both average values and the maximum peaks. These limit values are based on the highest values of an average five-minute load during a time interval representing a time unit on a time axis. For example, as regards year-long curves, this is the value of the highest average five-minute load during 24 hours therefore these values do not correspond with the real short-time load as it was described in the previous measurement analysis.

The first example worth mentioning is the Prague–Brno line, 2.5 Gbps. We would like to point out the peak utilization (a continuous flow of 2 Gbps for a period of two hours) of this line in the direction of Prague, reported in November 2002, caused by the traffic of a MetaCentrum from Brno to Baltimore (Mary-

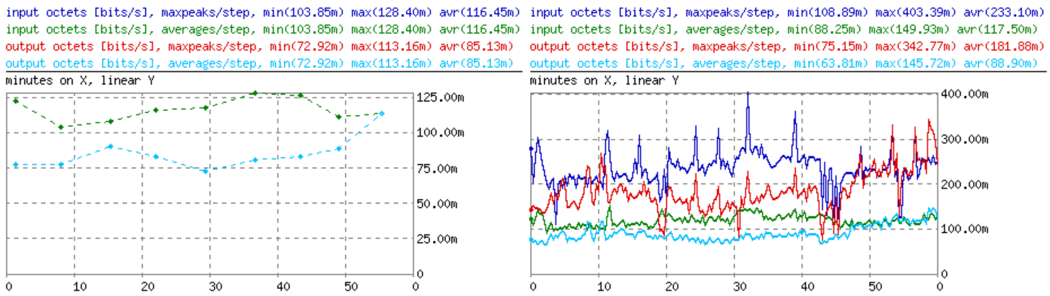


Figure 3.8: Influence of time step on line statistics – time step of 5 minutes (left) and 1 second (right)

land, USA), within the High Performance Bandwidth Challenge. Concerning the previous analysis of the measurement method, it is obvious that a sufficiently long, massive and particularly continuous data flow will show up also during the operating measurement mode.

The diagrams of high-capacity backbone lines report a steady increase in the volume, with a visible drop during the period of summer holidays. Lines with a lower speed report a solid and stabilized rate of utilization. Except for those which were upgraded during the year, there are no significant increases in the utilization. These lines directly connect smaller PoPs, therefore the traffic aggregation is considerably lower, but the oscillations higher.

3.6.4 Utilization of External Lines

During the year 2002, we managed to reach and maintain the situation in which the capacity of the lines in question was not limiting with respect to the naturally increasing traffic volume. Another development trend is the increase in the outgoing traffic compared to the incoming one, current reaching the rate of 2:1.

Line	*Input*	*Output*
CESNET2–GÉANT (October)	15.88 TB	19.22 TB
CESNET2–Internet (November)	40.77 TB	94.24 TB
CESNET2–NIX.CZ (November)	8.12 TB	10.11 TB

Table 3.1: Summary of the external lines

In general, we may say that the networks of members of the CESNET association and the CESNET2 backbone network offer an abundance of attractive sources of data which are subject to continuous interest among the community of users and which have a critical share in the long-term development of line load. This particularly concerns the distribution archives of free operating systems (Linux, BSD) and other free software. The quality of these internal sources considerably cuts down the requirements of our users concerning data transmission from external networks towards CESNET2.

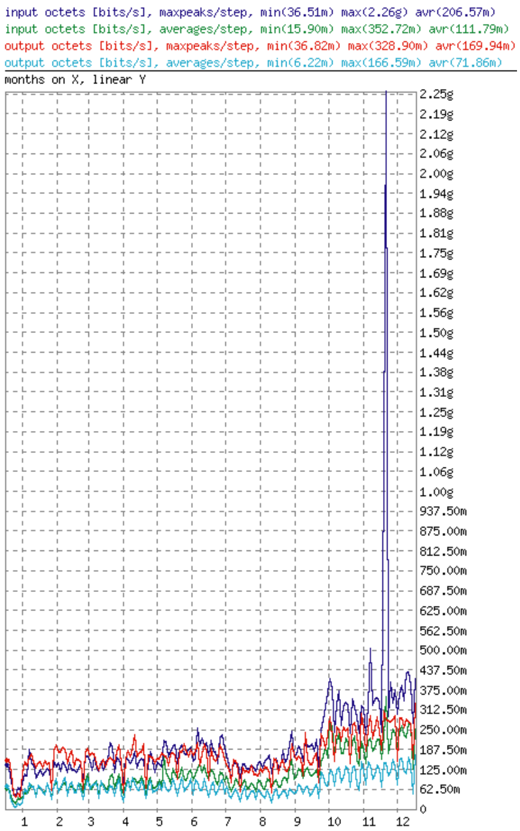


Figure 3.9: Prague–Brno line, 2.5 Gbps in 2002

3.6.5 Development of Tools for Long-term Infrastructure Monitoring

For the purpose of long-term monitoring of the network infrastructure, we use the *GTDMS-II* system, which is subject to further development. In 2002, we focused on the extension of the spectrum of measured devices and on an analysis of the possibilities for system development from its current architecture, according to the objectives specified in an interim report concerning solutions in 2001.

The most significant extensions of the system include support for the measurement of the standby power supply units, with a particular focus on products used in the backbone network, or precision of the measurements of profiled channels. Also the methods concerning the initiation analysis of measured devices reported considerable changes towards an decrease in the measurement aggressiveness.

The analysis of the possibilities for further system development showed the necessity to begin the year 2003 with a proposal for the next generation. This is particularly due to the vast implementation variability and dynamics of the

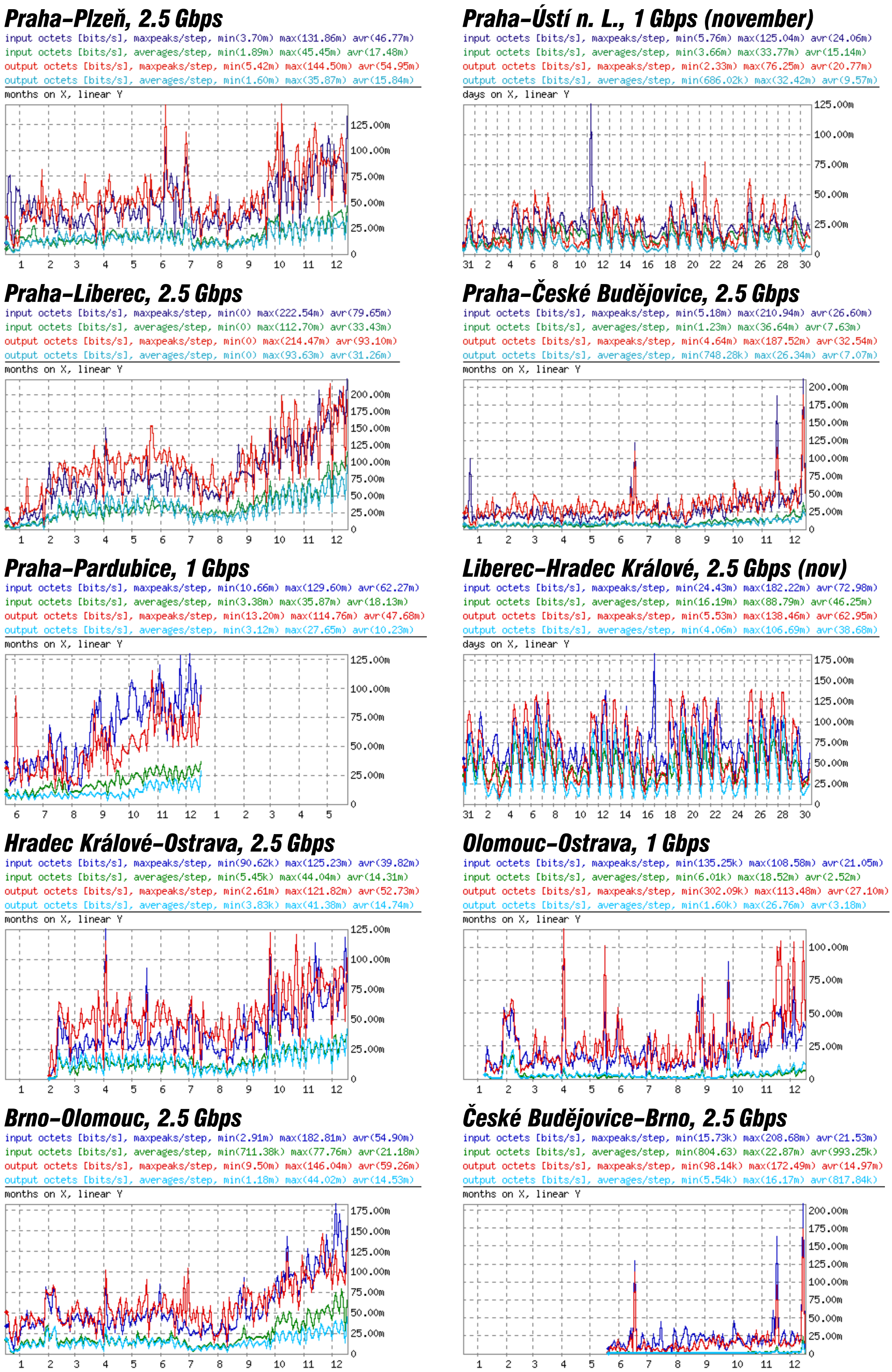
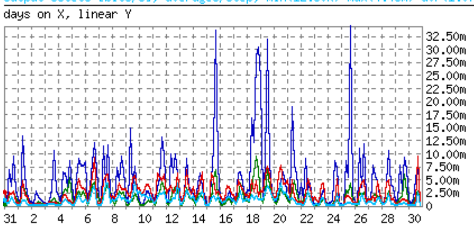


Figure 3.10: Load on backone lines – gigabit lines.

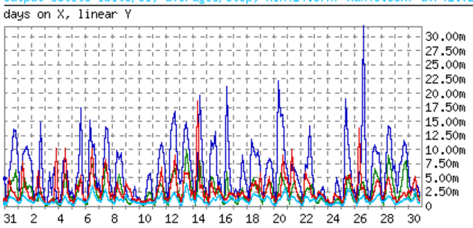
Karviná-Ostrava, 34 Mbps (november)

input octets [bits/s], maxpeaks/step, min(50.44k) max(34.48m) avr(4.88m)
input octets [bits/s], averages/step, min(12.37k) max(9.47m) avr(1.60m)
output octets [bits/s], maxpeaks/step, min(24.03k) max(9.48m) avr(2.38m)
output octets [bits/s], averages/step, min(12.50k) max(4.48m) avr(1.07m)



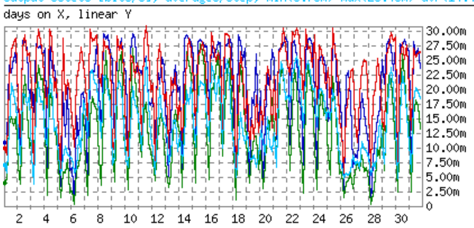
Opava-Ostrava, 34 Mbps (november)

input octets [bits/s], maxpeaks/step, min(74.99k) max(31.85m) avr(5.97m)
input octets [bits/s], averages/step, min(28.62k) max(9.86m) avr(2.35m)
output octets [bits/s], maxpeaks/step, min(30.80k) max(18.41m) avr(2.68m)
output octets [bits/s], averages/step, min(14.57k) max(3.83m) avr(1.02m)



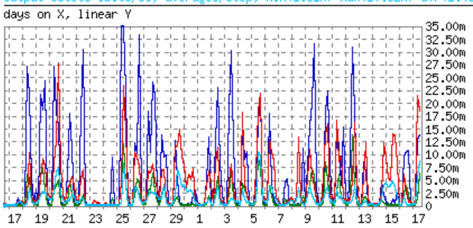
Zlín-Brno, 34 Mbps (november)

input octets [bits/s], maxpeaks/step, min(351.40k) max(29.37m) avr(20.50m)
input octets [bits/s], averages/step, min(300.42k) max(27.59m) avr(12.90m)
output octets [bits/s], maxpeaks/step, min(5.31m) max(30.85m) avr(21.66m)
output octets [bits/s], averages/step, min(3.73m) max(25.48m) avr(14.41m)



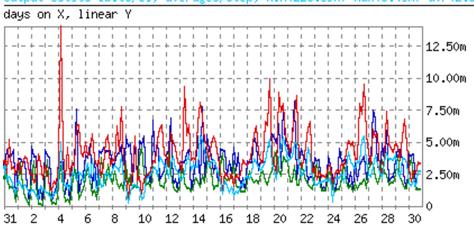
Děčín-Ústí n. L., 34 Mbps (november)

input octets [bits/s], maxpeaks/step, min(10.98k) max(35.05m) avr(6.14m)
input octets [bits/s], averages/step, min(9.07k) max(13.79m) avr(1.42m)
output octets [bits/s], maxpeaks/step, min(2.96k) max(27.65m) avr(4.30m)
output octets [bits/s], averages/step, min(1.31k) max(10.32m) avr(1.45m)



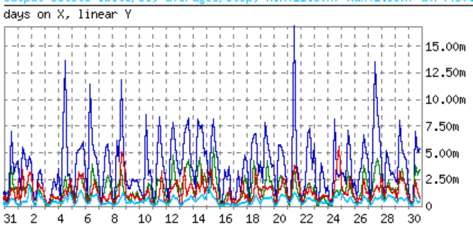
Plzeň-Cheb, 34 Mbps (november)

input octets [bits/s], maxpeaks/step, min(151.77k) max(8.11m) avr(3.36m)
input octets [bits/s], averages/step, min(72.07k) max(4.62m) avr(1.98m)
output octets [bits/s], maxpeaks/step, min(580.86k) max(14.07m) avr(4.03m)
output octets [bits/s], averages/step, min(226.39k) max(5.45m) avr(2.53m)



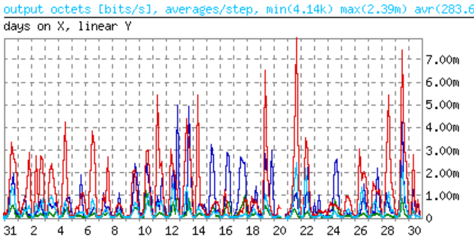
J. Hradec-Č. Budějovice, 34 Mbps (nov)

input octets [bits/s], maxpeaks/step, min(44.14k) max(16.86m) avr(3.72m)
input octets [bits/s], averages/step, min(14.77k) max(5.42m) avr(1.49m)
output octets [bits/s], maxpeaks/step, min(27.35k) max(5.55m) avr(1.30m)
output octets [bits/s], averages/step, min(11.50k) max(1.99m) avr(480.00k)



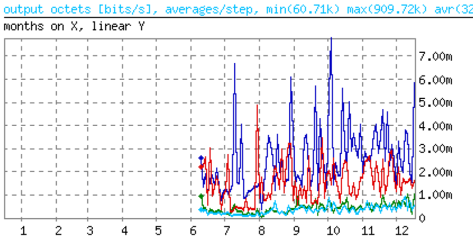
Praha-Tábor, 10 Mbps (november)

input octets [bits/s], maxpeaks/step, min(15.03k) max(4.95m) avr(632.08k)
input octets [bits/s], averages/step, min(4.74k) max(1.16m) avr(147.82k)
output octets [bits/s], maxpeaks/step, min(20.63k) max(7.94m) avr(1.08m)
output octets [bits/s], averages/step, min(4.14k) max(2.39m) avr(283.60k)



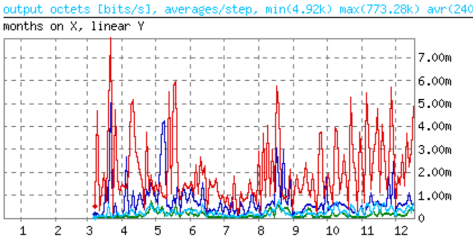
Poděbrady-Praha, 10 Mbps

input octets [bits/s], maxpeaks/step, min(359.84k) max(7.78m) avr(2.52m)
input octets [bits/s], averages/step, min(47.81k) max(984.56k) avr(405.67k)
output octets [bits/s], maxpeaks/step, min(261.25k) max(4.81m) avr(1.49m)
output octets [bits/s], averages/step, min(60.71k) max(909.72k) avr(321.86k)



Hradec Králové-Česká Třebová, 10 Mbps

input octets [bits/s], maxpeaks/step, min(11.45k) max(4.96m) avr(703.79k)
input octets [bits/s], averages/step, min(1.95k) max(701.62k) avr(121.23k)
output octets [bits/s], maxpeaks/step, min(58.30k) max(7.85m) avr(1.99m)
output octets [bits/s], averages/step, min(4.92k) max(773.28k) avr(240.85k)



Brno-Lednice, 10 Mbps

input octets [bits/s], maxpeaks/step, min(29.74k) max(7.92m) avr(2.95m)
input octets [bits/s], averages/step, min(993.37) max(6.33m) avr(758.88k)
output octets [bits/s], maxpeaks/step, min(72.10k) max(7.29m) avr(3.20m)
output octets [bits/s], averages/step, min(6.04k) max(933.73k) avr(263.78k)

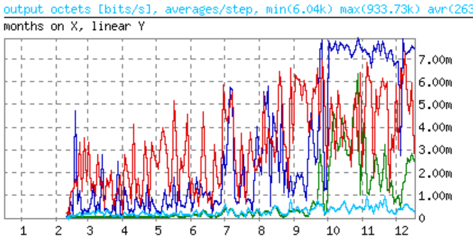


Figure 3.11: Load on backbone lines – megabit lines

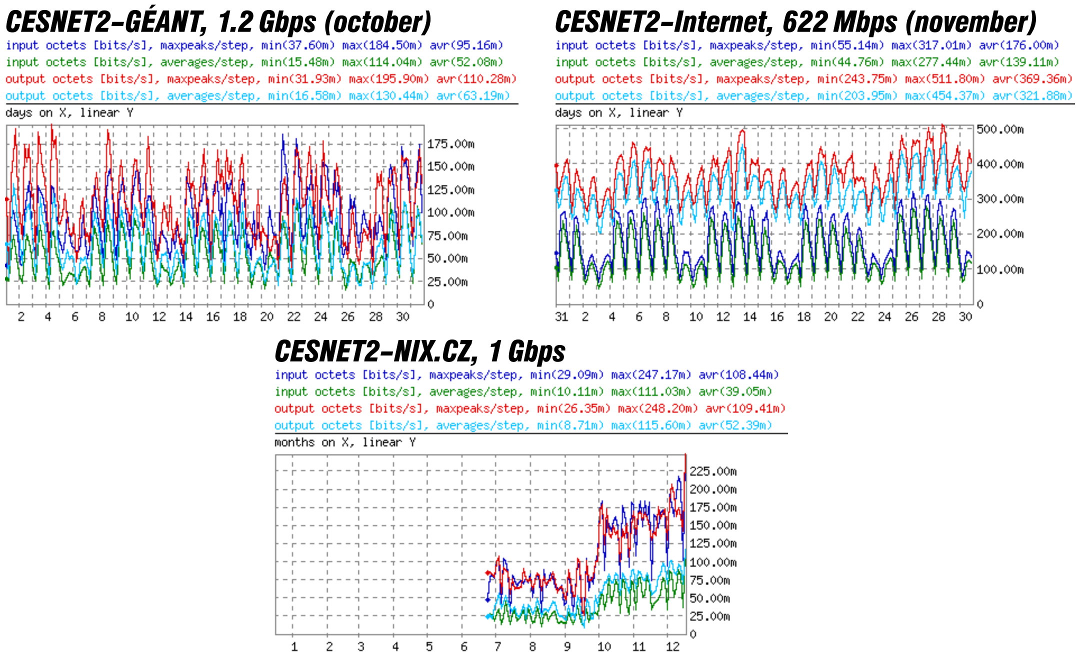


Figure 3.12: Load on external lines of CESNET2.

changes in attitude of individual producers. The system we have been developing attempts to become universal, i.e. independent, to a maximum extent, of the producers of particular network devices. Ideally, this effort would mean the implementation of mechanisms according to the related RFC documents or pertinent IETF recommendations.

Unfortunately, the reality is different and the global tendency towards unification and standardization in this area is relatively low and so we are forced to accommodate this and pursue a higher level of general abstraction on one hand, and particular and targeted support for specific devices on the other hand. The final architecture is likely to result in a general universal skeleton and a number of specific drivers for individual products with a permanently reducing share of generally applicable mechanisms. This will be the direction of our strategy in 2003.

Part I
Strategic Projects

4 Optical Networks and their Development

Within the project *Optical Networks and their Development*, we focused on the development of optical research and education networks in the world, and participated in international projects concerning the construction and application of these networks. After we presented our achievements during the TERENA conference in July 2002, some foreign partner networks expressed their interest in the application of the results achieved during the designing and deployment of long optical lines without intermediate devices, and in further collaboration concerning the development of this method for the construction of optical networks, also referred to as the "Nothing-In-Line (NIL) approach".

In addition, we have become one of the few countries with access to the international lambda services for research purposes and the possibility of participating in its development. We designed the topology for further development of the CESNET2 optical network and ensured the necessary data circuits, particularly optical ones.

As regards the development of long optical circuits without an in-line amplification or regeneration for the National Research and Education Networks (NRENs) our researchers seem to have reached the world-leading position. We hope to achieve a similar result in the field of single-fibre long-distance circuits usage. Among the best results achieved, there was the acquisition of the first optical mile leading to a number of other nodes, including the network centre, as this problem is still considered throughout the world to be one of the most demanding ones.

The preparation for the application of WDM systems is also worth mentioning. Their deployment (after a validation of their reliability of course) will enable us to split the leased fibre traffic into more colours. One colour may be used for the CESNET2 common traffic, other colours for the access to CzechLight or other experiments and yet other colours e.g, for the projects concerning a collaboration with the producers of optical devices. In addition, there were experiments commenced for the provision of access to CzechLight using PC routers, developed as part of our research.

In conclusion, we may say that the researchers of the project titled *Optical Networks and their Development* managed to make use of advantageous price conditions for the lease of fibres and the purchase of telecommunication services, and that the success exceeded previous expectations, particularly as regards:

- Establishment of CzechLight,
- Incorporation in TF-NGN and the international SERENATE project,

- Establishment of gigabit NIL CESNET2 circuits, 189 and 169 km long
- Acquisition of the first optical mile in other CESNET2 nodes
- Preparation of long-distance single-fibre circuits

4.1 International Collaboration and Global Lambda Network

The solution witnessed a significant change, as we succeeded in contracting the lambda service for 6 months, 2.5 Gbps from the CESNET2 Prague site to *NetherLight* in Amsterdam (particularly thanks to successful tender procedures and a drop of prices for an international connectivity), and in ordering an optical transport system, Cisco 15454, used already in NetherLight, CERN, StarLight and Canet4. After a period of six months, the service may be extended or upgraded to 10 Gbps. We named the node of the lambda network in Prague *CzechLight* and its deployment is currently in progress. As a result we are becoming one of the few countries in the world with access to international lambda services for the research.

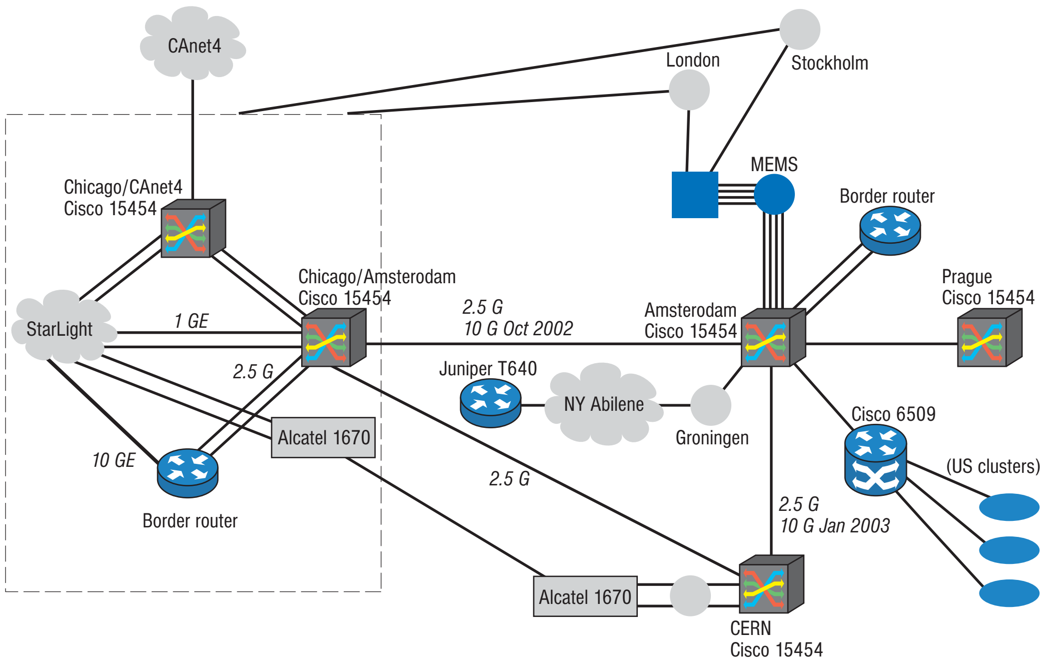


Figure 4.1: Global lambda network

In the first stage, CzechLight will be available by means of four GE connections and it will be used particularly for research in network services, for data transmissions between CERN or Fermi-Lab and the Centre for Particle Physics in Prague, and for the connection of supercomputer networks in Europe and the

US (TeraGrid with backbone 4×10 GE between Chicago and L.A. will probably be the largest of them).

While analysing other opportunities for the utilization of this service, we focus particularly on identifiyng the requirements for transfers of large data volumes (both domestic and international), i.e., from/to Czech research centres, and the barriers for their usage. In order to establish contacts with other potential users, we have sent out a letter to the representatives of CESNET members, together with a survey form. We plan to provide access to CzechLight from Brno, Plzeň and Ostrava, using experimental fibre lines, and also through VPN within CESNET2.

Access to CzechLight can be provided to foreign partners under similar conditions which we were provided for with access to NetherLight and StarLight, i.e., they should participate adequately in the associated expenses. Preliminary interest has been expressed in Poland and Slovakia. For these purposes, we can make use of the fibres of the Prague–Brno–Český Těšín line and the G.655 fibres on the long-distance Prague–Brno line (all other fibres mentioned in this report are classical, i.e., type G.652), acquired by the researchers for experimental purposes. We have also been finding ways to acquire financial support from the EU for this international project of interconnecting lambda services.

4.1.1 Preparation of the ASTON Project

Following the original offer of FLAG Telecom, operating transatlantic optical cables, the project participants became involved in the preparation of the *ASTON (A Step Towards Optical Networking)* project, coordinated by TERENA. Unfortunately, FLAG Telecom witnessed some financial troubles and it now operates at a limited scope (e.g., it has not yet started the building the node in Frankfurt a. M. which we planned to use).

The draft project was used as a basis for TERENA's Expression of Interest (EoI) for the 6th EU Framework Program. Thanks to the initiative of the European Commission, the authors of EoI met in Torino, on 15 October 2002, and the conclusion was that the project is in compliance with their requirements. With respect to the fact that the projects of this thematic group will not be commenced until the summer of 2004, the representatives of ASTON agreed that, until then, all pertinent activities would be covered by the TF-NGN research program.

During a TF-NGN meeting, held on 17 October 2002, the researchers presented their speeches and were invited to develop a proposal for year 2003 activity, titled "10 GE over Long Distance". The proposal was submitted on 15 November 2002. As part of the ASTON preparations, the project manager also took part in a TERENA SERENATE project meeting with the manufacturers of optical devices.

For the purposes of preparing an original proposal for the ASTON project, we also received an offer for international fibres which illustrates the possibilities for an international lease of fibres.

Within the scope of our international collaboration, being invited by the Max Planck Institute of Physics in Munich we took part in the preparation of the project for regional research and education network in South-Eastern Europe. For the situation in this region, see Figure 4.3.

A quote from the final recommendations expressed during the seminar:
"Preference is expressed to establish sustainable cross-border connections on new dark fibre with low running costs. The technical model of the Czech academic network is considered as a guiding example in defining technical solutions."

Line	*Fibre length [km]*	*Installation Price [Euro]*	*Lease price [km/pair/month]*	*Lease period [years]*
Prague–Vohburg (D)	390	0	40	0
Vohburg–Frankfurt a. M. (D)	632	53,745	100	5
			65	15
Vohburg–Munich (D)	135	32,247	54	5
			32	15
Prague–Ropice	525	0	40	1
Ropice–Bielsko Biala (PL)	70	0	50	1
Ropice–Warsaw (PL)	550	0	40	1
Prague–CZ/SK border	390	0	40	1
CZ/SK border–Bratislava	139	0	40	1
CZ/SK border–SK/A border	186	0	40	1
SK/A border–Vienna (A)	106	0	100	5

Table 4.1: International lines

4.2 Optical National Research and Education Network – CESNET2

In 2002, intensive efforts were made in order to convert the CESNET2 network to optical technologies. We succeeded in simplifying relationships between the development of network topology and routers, thanks to the proposal of a *generic scheme of CESNET2 network*, specifying the network characteristics that are considered invariable. Based on this model, we made out a proposal of an implementation scheme, which was then discussed during researchers' workshops. The collaboration with the network operators and administrators of the most important PoPs, although it was not easy, brought its rewards.

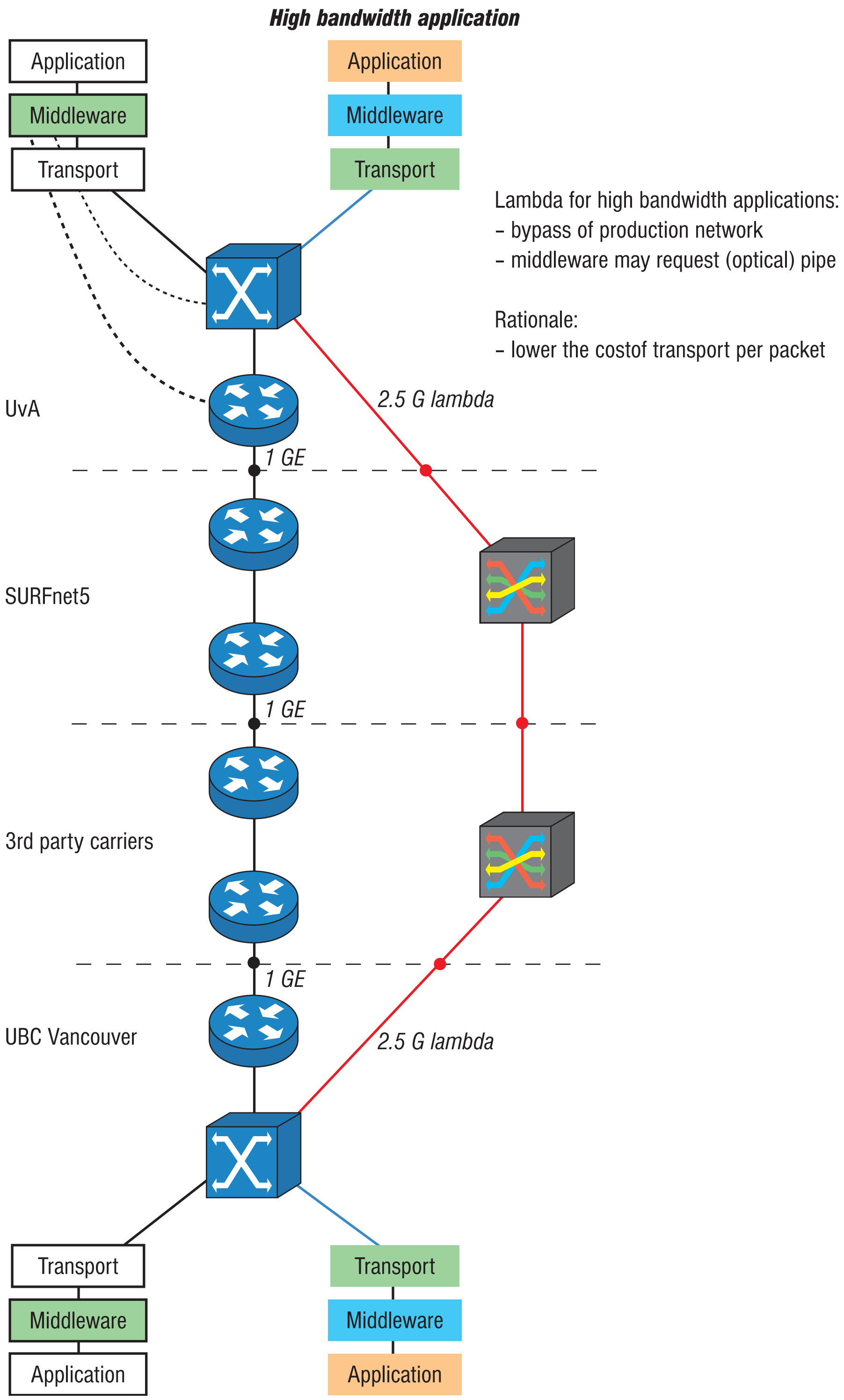


Figure 4.2: Example of the application of lambda services

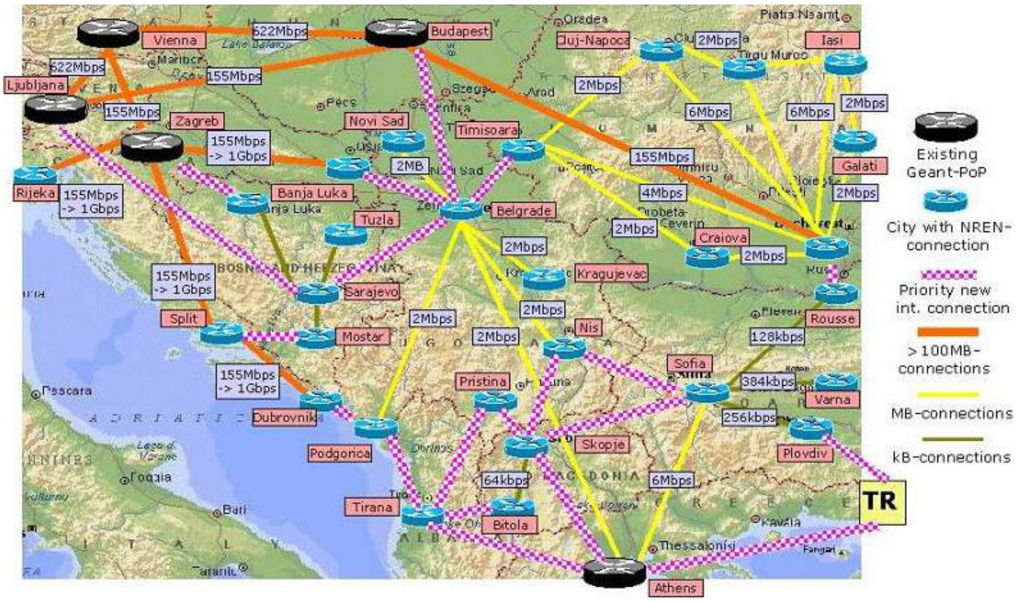


Figure 4.3: Situation concerning the regional network in South-Eastern Europe

4.2.1 Generic Network Structure

The generic network structure is a model defining the basic types, functions and methods of router interconnection, within the range of CESNET competences – i.e., routers which are its property or have been leased, lent, etc.

Backbone Structure

The backbone is formed by several rings, each with 3–4 backbone nodes (P routers). The number of backbone nodes is limited, particularly due to the high price. The access abroad and to CZ.NIX is provided from Prague, where a pair of backbone routers is installed in order to increase the reliability.

P routers are "dumb". They ensure just the basic routing functionality, without any complicated features. On the other hand, they are very fast and able to cope with a considerable data load.

Access Interface

The access to the backbone is provided exclusively through PE routers – local or remote (approx. up to 300 km). One PE router can be connected to more than one P router (if necessary and economically feasible). It is possible to connect the PE router to P routers on different rings.

PE routers provide the "smart" network services, e.g., virtual private networks, packet filtering, etc. They identify datagrams with MPLS tags and prepare them for fast transmission through P router network.

4.2.2 User Interface

Subscribers (members and directly connected participants or their branches) connect to PE routers or CE routers. CE routers may not provide full services (e.g., VPN) and are connected to a single PE router. More CE routers may be connected to the same PE router. CE routers may be connected to PE routers either locally or at longer distances (approximately up to 100 km).

4.2.3 Changes in Generic Structure

The generic structure is a stable characteristic of the network. Changes in the generic structure are considered a significant intervention in the network topology, hardware and software, and must therefore be designed sufficiently in advance (e.g., one year). The following modifications are not considered as changes in the generic structure: increase in the number of CE routers, PE routers, deploying multiple accesses for PE routers, increase in the number of backbone rings or an increase in the number of P routers (however, not exceeding four in one ring). The acceptability of such changes is particularly an economic aspect.

4.2.4 Application of R&D Results

The generic structure makes it possible to evaluate new types of routers, circuits and other devices (e.g., optical amplifiers) in the real operation. This is possible in nodes connected via an alternate route. Particular procedures are specified according to an agreement of the operating staff and researchers.

4.3 Deployment of Generic Structure

After reaching an agreement concerning the generic structure of CESNET2, we also agreed on the procedures for its deployment. For the target stage to be reached in 2003, see Figure 4.4.

The aforesaid modifications of the topology may be carried out using the existing GSR 12016 routers as backbone routers, and without having to purchase any more costly OC-48 cards. The backbone lines to Ústí n. L. will be based on the Gigabit Ethernet.

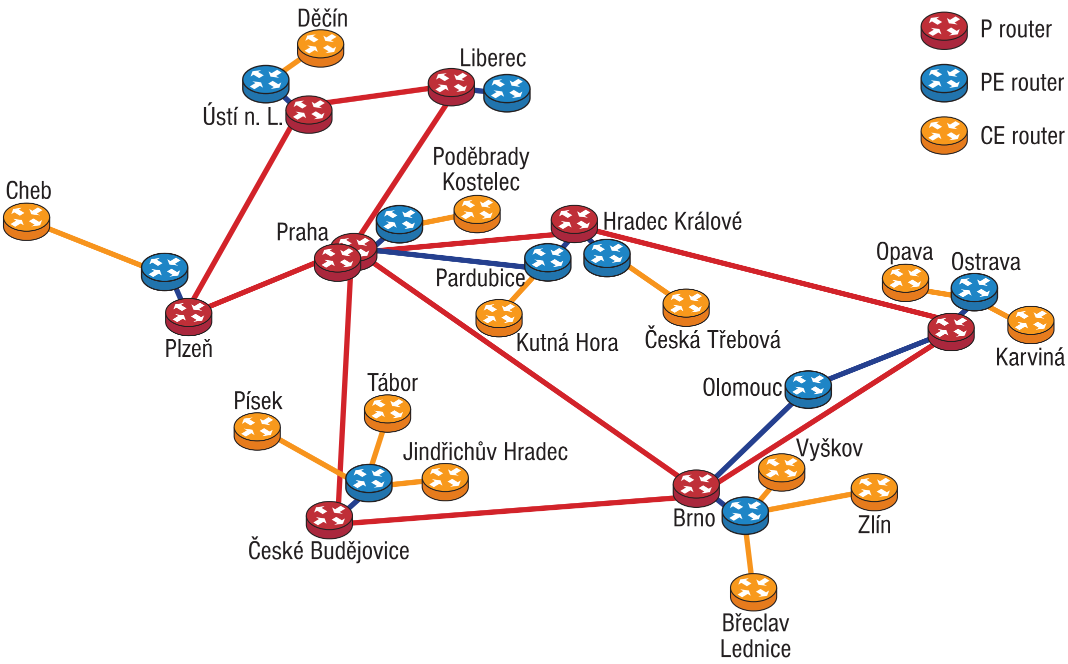


Figure 4.4: Desired structure of CESNET2 for the year 2003

After discussing the budget for the year 2003 and acquiring additional offers for the lease of fibres, it is obvious that it will be necessary to carry out some minor adjustments in the implementation; however, without having to change the generic structure.

4.4 Transition of CESNET2 to Optical Fibres

Based on the previous selection procedures and international comparisons, the need to convert the CESNET2 lines to leased optical fibres turned out to be obvious. The most advanced research and education networks own their fibres or lease them for a period of 10 to 20 years. This is a common strategy for lines which are dozens and hundreds of kilometres long. The new project titled *National LightRail* in the USA leases fibres of several thousands kilometres (the line between San Diego and Seattle is just about to be finished, the Seattle–New York line will be put in operation next summer).

The monthly lease rates are lower for long-term contracts. With respect to the situation in the telecommunication market, the offers are not expected to drop in the future, which is why it appears beneficial to conclude contracts for longer periods (20 years). On the other hand, there is the risk that other lines will be required with respect to future development of the network, that some members will move and that other types of fibres will be needed for higher speeds (10 Gbps and higher) on long distances (e.g., G.655). After considering theses benefits and risks, researchers recommend 5 years to be the most suitable period of lease.

All the foreign projects mentioned above make use of optical amplifying or optoelectronic regeneration along the line. The "Nothing-In-Line approach" of the project researchers is unique in the area of research and education networks (as far as the researchers have been informed). So far, NRENs from Denmark, Ireland, Netherlands, Poland, Serbia and CERN have expressed their interest in this approach.

In 2002, optical fibres were put into operation for the following lines: Ostrava–Olomouc, Prague–Plzeň, Prague–Pardubice and Prague–Ústí n. L. In all the cases, the deadline for implementation depended on the completion of the first mile on these lines. Wherever it was impossible to lease fibres for the first mile, we opted for the lease of lambda 2.5 Gbps for 12 months.

Operators of cable TVs and municipal authorities are important partners for the lease of fibres for the first mile, as they either develop optical infrastructure or own companies established for this purpose.

During the first half of 2002, we also succeeded in terminating the operation of costly circuits established at the beginning of the gigabit network development, even though in one case (Prague–Liberec line), this meant a conversion from leased fibres to a purchase of the lambda services. The optimisation of the economic and technical design of the CESNET2 topology was a success which helped us hold one of the leading positions in Europe (see new TERENA Compendium).

For the prices of services for research and education in the Czech Republic, valid during the first half of 2002, see Table 4.2 (exchange rate: CZK 32/EUR 1).

Service	*Capacity*	*Length[km]*	*Price[EUR/month]*
Microwaves 2 jumps	34 Mbps	up to 80 km	2,077
Microwaves 3 jumps	34 Mbps	up to 120 km	3,084
SDH	34 Mbps	100–500	3,811–9,934
Colour	2.5 Gbps	100–500	8,143–13,029
Fibre	up to 40 Gbps	30–500	779–16,286

Table 4.2: Prices of services for research and education in the Czech Republic, first half of 2002

For a review of the gigabit circuits of CESNET2 and the methods of their application, see Table 4.3 The *Regeneration* column specifies the method of signal regeneration: ONS 15104 is a two-way STM-16 generator, Cisco 3512 is an L2 switch used as a regenerator. Lines marked with an asterisk do not make use of regeneration along the line, only an additional amplification for one colour.

Line	Service type	Road distance [km]	Fibre length [km]	Line type	Regeneration	In operation since
Prague–Č. Budějovice	colour	139	N/A	2.5 G	supplier	22/2/01
Liberec–H. Králové	colour	96	N/A	2.5 G	supplier	21/1/02
Ostrava–H. Králové	colour	247	N/A	2.5 G	supplier	1/2/02
Č. Budějovice–Brno	colour	226	N/A	2.5 G	supplier	22/5/02
Prague–Liberec	colour	108	N/A	2.5 G	supplier	1/6/02
Prague–Brno	fibre	202	323.3	2.5 G	3×ONS 15104	10/1/00
Brno–Olomouc	fibre	81	124.3	2.5 G	1×ONS 15104	24/5/01
Ostrava–Olomouc	fibre	105	149.0	1 GE	1×Cisco 3512	7/1/02
Pardubice–H. Králové	fibre	22	30.0	1 GE	no	15/1/02
Prague–Pardubice	fibre	114	188.6	1 GE	*	17/5/02
Prague–Plzeň	fibre	80	176.7	2.5 G	1×ONS 15104	1/6/02
Prague–Ústí n. L.	fibre	92	169.6	1 GE	*	10/9/02

Table 4.3: Gigabit circuits of CESNET2

Line	Fibre length [km]	BIP	NIL	UU
Prague–Č. Budějovice	colour	No	No	No
Liberec–H. Králové	colour	No	No	No
Ostrava–H. Králové	colour	No	No	No
Č. Budějovice–Brno	colour	No	No	No
Prague–Liberec	colour	No	No	No
Prague–Brno	323.3	Yes	No	No
Brno–Olomouc	124.3	Yes	No	No
Ostrava–Olomouc	149	Yes	No	No
Prague–Plzeň	176.7	Yes	No	No
Pardubice–H. Králové	30	Yes	Yes	Yes
Prague–Pardubice	188.6	Yes	Yes	Yes
Prague–Ústí n. L.	156.2	Yes	Yes	Yes

Table 4.4: Types of gigabit circuits of CESNET2

As regards the development and operation of the network, an important aspect was to what extent the circuit upgrade depends on the supplier. For the classification of circuits, see Table 4.4. *UU* means a circuit which may be upgraded independently by the user. *NIL* are circuits without elements in the line, and *BIP* signals that the price for the circuit is independent of the bandwidth.

The resulting topology is depicted on a figure from October 2002. Towards the end of 2002, the additional fibres for the Olomouc–Zlín line (70.2 km long) will be put in operation for the deployment of a Gigabit Ethernet. It is obvious that the price for the lease of fibres along the Olomouc–Zlín line is much lower compared to that for the Brno–Zlín line. The original 34 Mbps circuit from Prague to Ústí n. L was replaced by the Plzeň–Ústí n. L. one.

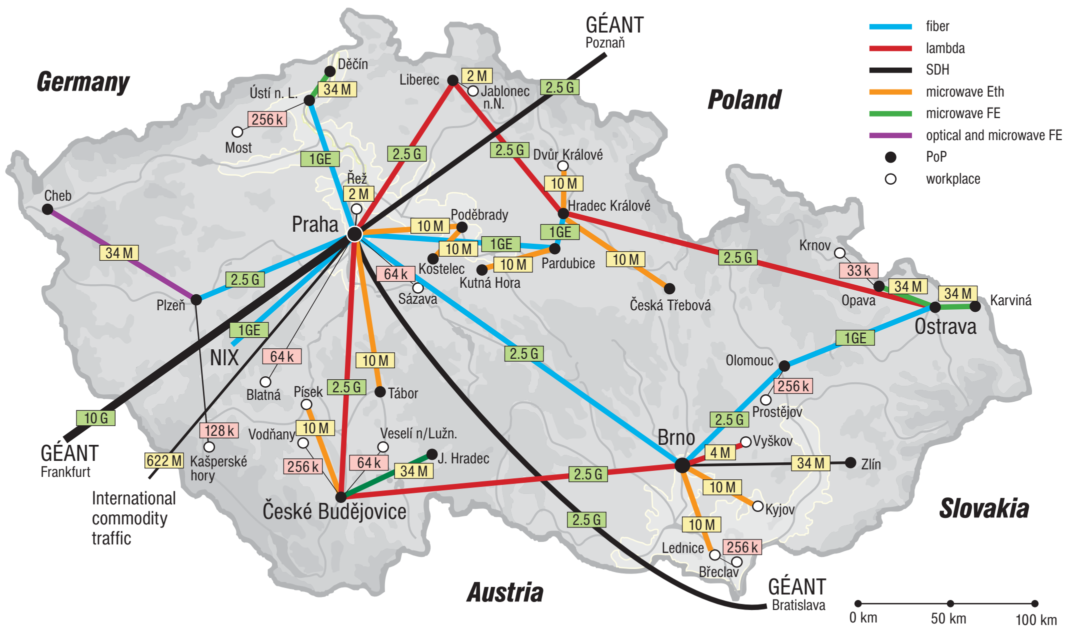


Figure 4.5: Topology of CESNET2, October 2002

The backbone nodes of CESNET2 are now interconnected with at least two gigabit circuits to their neighbours. The only exceptions are Plzeň and Ústí n. L., interconnected at the speed of 34 Mbps (which is sufficient even in the case of a failure on the Prague–Plzeň or Prague–Ústí n. L. gigabit circuits). This makes it possible to evaluate new technology on the operational circuits without any considerable limitation of the node operation. All the changes were implemented without having to purchase costly OC-48 cards (approx. EUR 80,000 per card).

Based on our experience with time-consuming testing and error detection within operational circuits (it is necessary to transport devices and instruments repeatedly to circuit ends), an arrangement was made with fibre providers for the establishment of the *Prague field fiber testbed* with test loops of 200, 100, 50 and 25 km, terminated in the CESNET Prague site. The prepared Prague–Brno 10GE circuit, with the G.655 fibres (long-distance section) and G.652 (local loops) will be also tested during its first stage as a Prague–Prague loop.

4.5 First Mile

The first mile of optical circuits is considered to be the most complicated problem in the development of optical networks worldwide. Researchers frequently fail to reach a satisfactory solution. Commercial companies usually find this investment to bear very high risks (with a possible exception of cable TV operators). A relatively successful approach is based on the assistance of municipal authorities in the fibre investments; however, there are only a few cities that have reported good results so far (for the Czech Republic, the situation is even worse than in the USA or countries of Western and Northern Europe).

CESNET seeks ways for collaboration with municipal authorities, cable TV operators, owners of metropolitan or regional optical networks, as well as with companies involved in the installation of cables. One of the achievements, which is very successful as compared to the situation abroad, is the conclusion of a general agreement for the supply of first miles of long-distance circuits (with the delivery period of up to 6 months, depending on the season and local specific aspects). According to this agreement, it is possible to lease optical fibres both for long-distance lines, and for the first mile in CESNET2 localities for reasonable prices, similar to those in the USA.

The contracted price of a single fibre is also worth mentioning. For instance, for a 5-year contractual period, the price equals 60 % of the monthly fee for a pair of fibres. For the development of the first miles, CESNET may also make use of other fibres for future access to its PoP through additional optical circuits. This possibility is particularly important in cities where it is difficult to arrange the first mile under the existing circumstances. The contract also enables the construction of the first mile in places where a solution has been, so far, very complicated, which meant difficulties for the construction of long-distance lines (e.g., Plzeň), or for the connection of customers.

We expect that the construction of the first mile will be carried out along with the construction of long-distance lines. The anticipated localities are Brno, Zlín, České Budějovice, Plzeň, Cheb, Česká Třebová, Jindřichův Hradec, etc. As regards transactions related to long-distance contracts, it is possible to also implement local fibre circuits under advantageous conditions (in Prague, an independent second circuit to CZ.NIX was contracted, together with the connection to the Prague "fiber meeting point" in Sitel).

As regards the implementation of the first mile using optical fibres, we focused on the verification of new types of converters, implementing 100 Mbps two-way transmission on a single single-mode fibre and improving the connection parameters for selected subscribers.

For the purposes of the experiment, we chose a 3,900 m long line from CESNET to the National Library. For this purpose, we acquired a card with an FE interface into the Cisco 4700 router of the National Library and purchased metallic–optical converters made by NBase-Xyplex. These converters are available for Ethernet, Fast Ethernet and Gigabit Ethernet. They are produced for transmission using one or two fibres (as a general rule, devices for single-fibre transmission have shorter reach).

It is also possible to implement the transmission of up to four Gigabit Ethernets along a single pair of optical fibres (a single line may be used for several independent transmissions). We opted for two-way transmission along a single fibre, using different wavelengths for both directions. According to the available information, this transmission system is more reliable than the system that makes use of the same wavelength for transmission in both directions.

As a results of the floods that paralysed the country in the middle of August, the commissioning of the line was postponed and finally, the operation was launched in early October. The entire operation of the National Library was switched to the new line on 9 October 2002.

Since the very beginning, the operation of this testing line has been free of any complications. There have been no problems reported during the first three months of its operation and National Library users are happy about the quality of data transmission. During the next stage, we plan on setting up a single-fibre route of CESNET–City Library–State Technical Library–National Library (as these customers are on the route of leased fibre) and checking single-fibre two-way converters for the Gigabit Ethernet.

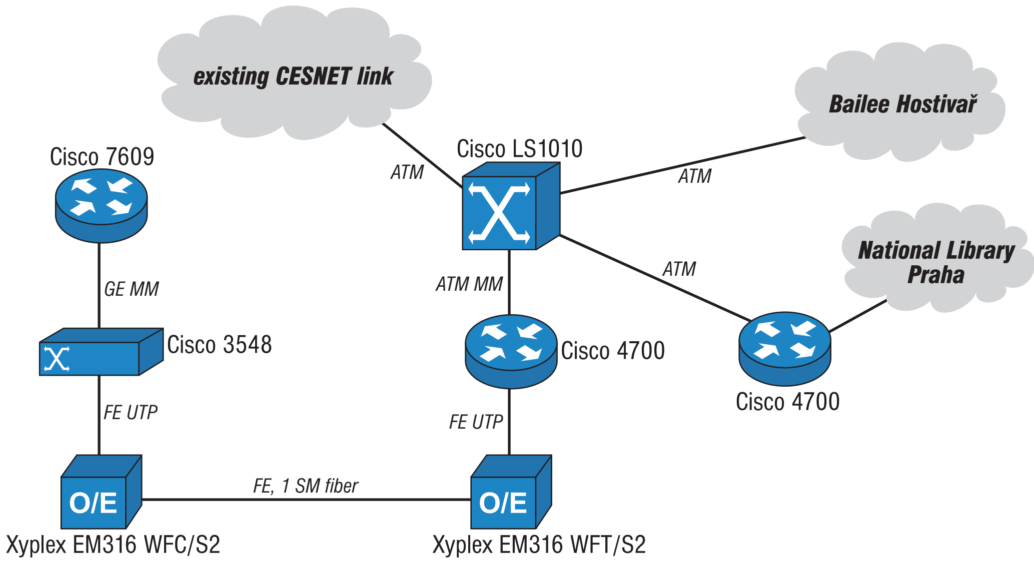


Figure 4.6: CESNET–National Library connection using single fibre

As regards financial requirements, we may say that wherever there is a corresponding router available on both ends of a line, it is more advantageous to lease an optical fibre and purchase converters (for periods exceeding two months), rather than to purchase the STM-1 service. Another advantage is that it is not necessary to make any payment to the line provider for any increase in the bandwidth.

Fibre length [km]	*Fibre lease [EUR/month]*	*Pair of converters [EUR]*	*Lease of pair [EUR/month]*	*Return on Investment [months]*
10	267	5,552	417	37.0
20	467	5,552	833	15.1
30	700	5,552	1,250	10.1
40	933	7,773	1,667	10.6
50	1,167	7,773	2,083	8.5
60	1,400	14,133	2,500	12.8
70	1,633	14,133	2,917	11.0
80	1,867	14,133	3,333	9.6
9	2,100	14,133	3,750	8.6
100	2,333	14,133	4,167	7.7
110	2,310	15,301	4,583	6.7
125	2,625	15,301	5,208	5.9
Example of an implemented circuit:				
4.4	880	5,257	1,467	9.0

Table 4.5: Return on investments concerning single-fibre converters

EM 316WFC/S2 & EM 316WFT/S2	100 Mbps, SM, 1,520&1,560 nm, 1–30 km
EM 316WFC/S3 & EM 316WFT/S3	100 Mbps, SM, 1,520&1,560 nm, 20–50 km
EM 316WFC/S4 & EM 316WFT/S4	100 Mbps, SM, 1,520&1,560 nm, 40–100 km
EM 316WFC/S5 & EM 316WFT/S5	100 Mbps, SM, 1,520&1,560 nm, up to 125 km

Table 4.6: Types of single-fibre converters (NBase-Xyplex)

The first experience with the design and operation of single-fibre optical lines reveals that it is possible to make use of this method in order to connect points which could not be otherwise connected with a pair of fibres due to a lack of available fibres or for financial reasons.

The price for fibre lease in the Czech Republic reaches from 51 to 70 % of the lease for a pair. With the use of NBase-Xyplex converters for 100 Mbps, the return on investment is usually from 4 to 10 months and the reach without regeneration is 125 km. Using converters for 1 Gbps, the return of investment is approximately 6 to 15 months. Single-fibre circuits are available for prices lower than the purchase of SDH services 2–622 Mbps or FE and GE services. In addition, their parameters may be better, as well as the expenses of future bandwidth increase. The converters mentioned above do not allow for in-line amplification.

Single-fibre circuits are suitable for shorter intercity lines and for the connection of customers or members' branches. So far, the following single-fibre circuits have been contracted: Ostrava–Opava (46.7 km, January 2003) and Ostrava–Karviná (54.4 km, May 2003). In collaboration with the Institute of

Chemical Technology and PASNET, we are preparing a single-fibre circuit ICT Dejvice–Jižní město. The savings of one fibre usually reaches from CZK 0.50 to CZK 5 per metre and month, depending on the locality and the provider. The project researchers are most likely to reach the leading position in the use of single-fibre long-distance lines in NREN (we have not been informed about any other operated single-fibre NREN line).

Next year, we would like to test other converters for single-fibre lines, i.e., converters produced by NBase-Xyplex, EM 316WFC/S3 & EM 316WFT/S3 with a reach of 20–50 km, EM 316WFC/S4 & EM 316WFT/S4 and EM 316WFC/S5 & EM 316WFT/S5 with a reach of up to 125 km.

Another result of the work described above was the successful deployment of converters with a reach of 2 km within a multimode fibre from the headquarters of CESNET to the Faculty of Civil Engineering, Czech Technical University (to microwave antennas).

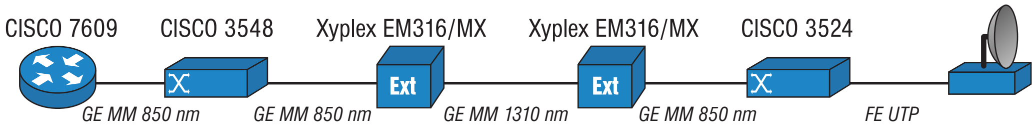


Figure 4.7: Extension of GE reach on MM fibre

4.6 Microwave Networks

Based on the selection procedures for the installation of lines in cities, where it was necessary to increase the bandwidth from the existing 2 × 2 Mbps to 34 Mbps, we selected the ALGON microwave devices and established Ostrava–Opava, Ostrava–Karviná and Ústí n. L.–Děčín lines, with the interface Ethernet/Fast Ethernet + E1 in sideband (overall, it is possible to make use of 36 Mbps) and combined optical/microwave 34 Mbps lines to Jindřichův Hradec and Cheb. Another microwave circuit of 34 Mbps in Vyškov has faced difficulties in the licensing procedure.

Microwave circuits of 155 Mbps or a parallel group of such circuits with GE interface can be deployed within approximately 2–3 months, if necessary. Taking into account results in the lease and usage of fibres, and the sensitivity to atmospheric disturbances, additional microwave lines will be deployed only where necessary (e.g., 10 Mbps circuits on customer's request or for price reasons). Wherever fibres are successfully deployed (e.g., in Opava), it is possible to keep the original microwave circuit as a backup or reinstall it elsewhere.

During the year, we investigated potential suppliers of microwave devices operating at 155 Mbps. We identified the following potential suppliers and devices:

1. Coprosys – Ceragon FibeAir 155 Mbps
   - System available in the following bands: 18–38 GHz
   - The error rate is lower than 10^{-13} (comparable to that of an optical fibre)
   - Price: EUR 55,000 + EUR 5,000 for installation (VAT not included)
   - Delivery period: 4–6 weeks from date of order
2. CBL – Ceragon FibeAir 1528
   - Device working within bands of 18, 26 and 38 GHz, with the transmission capacity of 155 Mbps, in a full duplex mode
   - Designed for the transmission of STM-1, ATM, Fast Ethernet and combinations of E1 and E3
   - Price: EUR 42,000 + EUR 5,000 for installation
   - Delivery period: 6–8 weeks from signing a contract
3. CBL – NERA City Link STM-1
   - Device working within bands of 18, 23 and 25 GHz, with a maximum transmission capacity of 155 Mbps, in a full duplex mode
   - Designed for the transmission of STM-1, ATM, Fast Ethernet
   - Price: approx. EUR 63,000 + EUR 5,000 for installation
   - Delivery period: 10 weeks from signing a contract

We expect that we shall keep updating this list of devices. We plan to use this technology only when an upgrade of an existing microwave circuit would be necessary and a lease of optical fibres would be impossible.

4.6.1 First Mile according to IEEE 802.11a

Wireless links based on the new IEEE 802.11a standard make it possible to communicate at speeds of 50–100 Mbps in the so-called free band of 5 GHz. They represent a new generation of wireless technology that is now commonly used, based on the IEEE 802.11b standard, working in the free band of 2.4 GHz with bandwidth up to 11 Mbps.

Wireless devices may work in the point-to-point or point-to-multipoint modes. They usually include access points or devices with a PCMCIA card for wireless communication (e.g., a PC computer configured as a router). In order to create a wireless connection between remote points, it is necessary to connect an external antenna to the wireless card, with the corresponding gain and output. The approximate price for an access point based on the IEEE 802.11b standard is EUR 600, the price of a separate wireless PCMCIA card is roughly EUR 125. This technology is quite appreciated particularly thanks to a good price/performance ratio.

During the first months of the project, we checked the details concerning the offered devices and found out that none of the manufacturers of IEEE 802.11a

Manufacturer	*Location*
www.accton.com	802.11a only for US, Canada and Japan
www.actiontec.com	802.11a only for US, Canada and Japan
www.dlink.com	802.11a only for US
www.netgear.com	802.11a only for US, Canada and Japan
www.intel.com	802.11a only for US, Canada and Japan
www.proxim.com	802.11a only for US, Canada and Japan

Table 4.7: Products of IEEE 802.11a for 5.3 GHz band

devices offer products using the 5.8 GHz frequency band, assigned for European countries. Manufacturers offer only products designed for the US market, running in the 5.3 GHz band.

We inquired among Czech distributors representing the manufacturers mentioned above who all claimed that no production of devices for the European band of 5.8 GHz has so far been planned. Most of them do not offer even the "US" versions. The only exception is Barco s. r. o. – an official distributor of Proxim devices, which offered the "US" devices for the following prices:

- Harmony Access Point 802.11a, EUR 1,000
- Harmony CardBus PCMCIA Card 802.11a, EUR 350

For the purpose of comparison, the prices for similar devices offered by Intel on the US market are as follows:

- Intel PRO/Wireless 5000 LAN Access Point, USD 450
- Intel 802.11a PCMCIA card, USD 180

Unlike in common 802.11b cards (e.g., Orinoco), it is impossible to connect the available 802.11a PCMCIA cards to an external antenna, necessary for long-distance wireless connection. An external antenna can be connected to access points. For the 5 GHz band, there are antennas available with a gain of 5, 7 and 12 dB. It is less than for the 2.4 GHz band, for which antennas of 17, 21 and 24 dB are available.

Barco also offers special devices by Proxim – *Tsunami*(TM) Wireless Ethernet Bridges, the only device working in the approved 5.8 GHz band. It reaches the speed of 45 Mbps (full duplex). This device also includes an internal antenna, an external antenna may be connected as well. Using the internal antenna, the reach is 2–8 km; using the external antenna the reach exceeds 10 km (even though the output power exceeds the limits approved by the Czech Telecommunications Office). The level of the output power is software controlled. The price for this device for a single point is quite high – approx. EUR 12,500 for Tsunami and EUR 800 for the external antenna.

During the second half of the year, we maintained contacts with Czech distributors of the world's leading manufacturers of wireless technologies, looking for a device communicating within the European band. The situation improved to a certain extent, i.e., distributors confirmed that manufacturers intended to supply devices for the 5.8 GHz band in 2003.

One of the anticipated products is the *Cisco Aironet 1200* access point. At present, it is available only for the 5.3 GHz band; however, a version for the 5.8 GHz band will be introduced during the first quarter of 2003. Unlike a number of lower models, this product is modular, i.e., the PCMCIA/CardBus Cards are used. The price for a single PCMCIA card is approximately USD 500, the overall expenses on a point-to-point connection based on Cisco Aironet 1200 (i.e., two Cisco Aironet 1200 access points with cards and antennas) should be approximately USD 4,000.

In November, another product was announced that appears to be very promising for our project. It is an *Orinoco 802.11a/b ComboCard* with the speed up to 54 Mbps in a single channel or up to 108 Mbps on two channels. It supports both the 802.11b standard (i.e., 2.4 GHz band) and the 802.11a standard (i.e., in both 5.3 and 5.8 GHz bands). The card and the access point are available in the USA and the distribution in the Czech Republic will start after the completion of the certification process. It should be introduced in the market during the first quarter of 2003. The price for a single PCMCIA card is approximately USD 160 and the access point with the support of 802.11a is worth USD 800. The overall expenses of a point-to-point link should not exceed USD 3,000.

It seems likely that there will be at least two products available during the first quarter of 2003 (Orinoco ComboCard and Cisco Aironet 1200) usable to achieve the objectives of this task – to identify a wireless technology suitable for the deployment of high-speed links (50–100 Mbps) for acceptable prices and with the possibility of legal public operation in the Czech Republic.

We expect that this technology may be attractive for a number of potential applicants interested in establishing a connection to CESNET2. We would like to verify the real capacities of these technologies (reliability, sensitivity, operating distance, throughput), together with the possibility of using removable PCMCIA cards in Linux routers (as a replacement for commercial access points).

4.7 Optical Devices for CESNET2

4.7.1 Deployment of Optical Amplifiers for Long-Distance Lines of CESNET2

The experiments with EDFA amplifiers carried out during the first half of 2002 were based on the theoretical knowledge gained during the previous year of this project. Our achievements in this part of project were the most significant, particularly based on the fact that optical amplifiers were necessary for the deployment of some lines exceeding 80 km (particularly the Gigabit Ethernet).

In January and early February, negotiations were held with Keopsys concerning the testing of their EDFA amplifiers in the CESNET2 network. Our aim was to test the possible operation without any in-line device (also referred to as "nothing-in-line" or "repeaterless line"). This mode makes the maintenance of the operated line much easier, and it also represents an interesting and technically novel method. In parallel, we carried out research in the area of 10GE and its possible deployment. In the second half of February, we managed to arrange testing days of EDFA technology with Keopsys.

The brief technical outcome of the testing is given below:

- EDFA amplifier can be deployed as a booster within CESNET's optical lines, for distances up to 188 km, without any notable increase in the bit error rate. The attenuation limit of a fibre span using an 18 dBm booster is 46 dB.
- The line with the length given above may be used – in configuration with a booster – both with the POS 2.5 Gbps technology and with the Gigabit Ethernet based on the long reach modules. All technologies must make use of the wavelength of 1,550 nm.
- In combination with an EDFA booster, it is also possible to make use of pre-amplifier. In this combination, it is possible to compensate attenuation of the line up to 60 dB, corresponding to approximately 230 km of an optical fibre. However, it is always necessary in this configuration to insert an optical ASE filter behind the preamplifier in order to cut off an excessive quantum noise spectra which is originated in a physical function of EDFA and as such is any time present.
- The experiments also included testing a Raman amplifier, which makes it possible to cover an additional attenuation of 15 dB, thus enabling the span of a total distance up to 290 km in combination with other amplifiers (EDFA booster on the input, EDFA preamplifier on the output).

The testing proved the functionality of the EDFA technology. Immediately afterwards, we ordered three EDFA boosters with a saturation output power of 21 dBm – two for the routine operation of the Prague–Pardubice line and one for the laboratory, serving for the purpose of further experiments and as a backup.

In collaboration with the network operation centre, we installed both amplifiers in the line mentioned above. The installation was without any complications and the saturated output power was adjusted at 19 dBm. According to the network monitoring, the function appears to be free of problems, without any increase in the bit error rate of the transmitted Gigabit Ethernet frames.

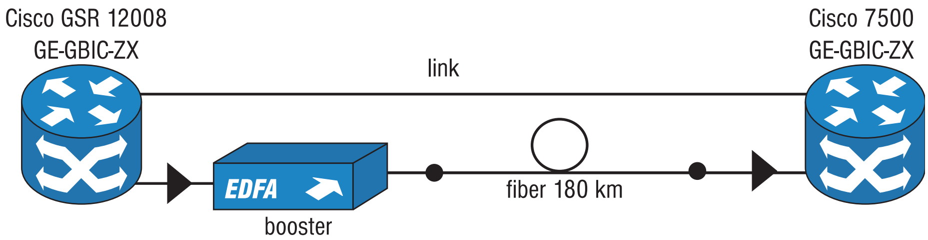


Figure 4.8: Testing configuration for GE, with booster only

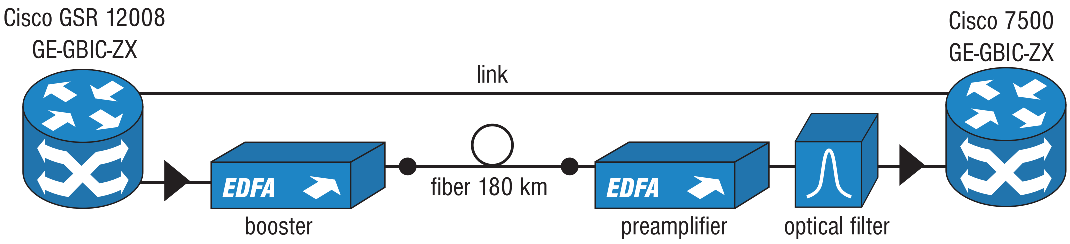


Figure 4.9: Testing configuration for GE, with booster and preamplifier

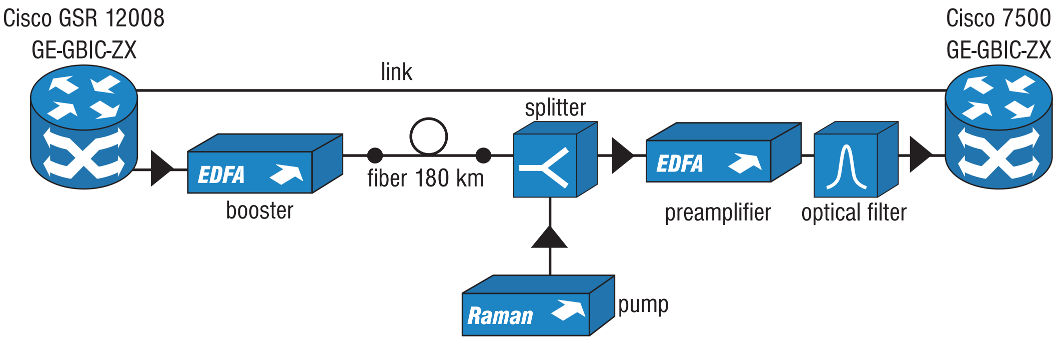


Figure 4.10: Test configuration for GE, with booster, preamplifier and Raman pump

The Prague–Pardubice line was further monitored in order for us to identify the behaviour of optical amplifiers under the conditions of a long-term operation. The line reported very good results and we therefore decided to continue and install two EDFA 24 dBm boosters on another line, Prague–Ústí n. L., again using the Gigabit Ethernet technology.

There were some problems reported on this line – the card in the new Cisco 7609 router behaved in a non-standard manner after its connection to the line with optical amplifiers, resulting in a loss of the connectivity. It turned out later that this was caused by short-term signal dropouts (30 ms), which occured due to an error in the firmware of Keopsys optical amplifiers. Keopsys and Cisco debugged their software and at present, both lines are free of errors.

During the second half of the year, we also began to make a more intensive use of Optisim and Artis simulating programs, particularly for the simulation of tests

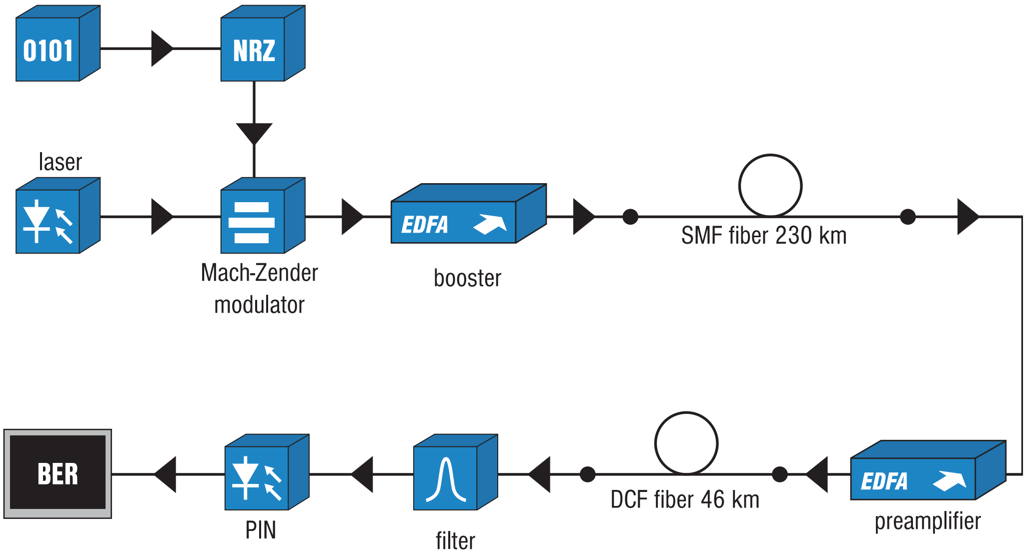


Figure 4.11: Scheme for simulating the effects of chromatic dispersion compensation

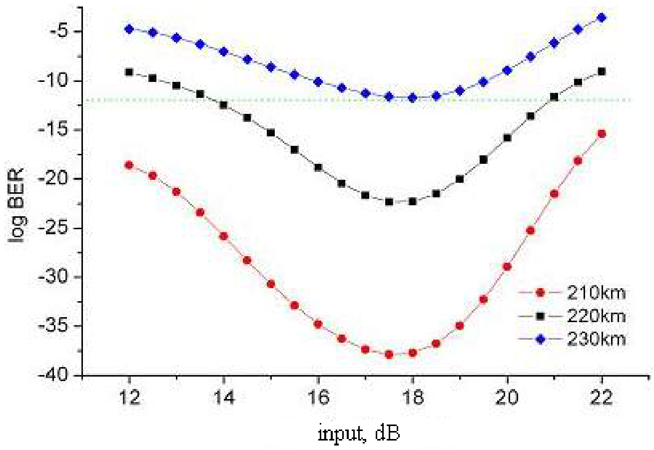


Figure 4.12: BER as input performance function, dispersion post-compensation

on 10 Gbps (it was impossible to carry out real experiments as the necessary hardware was not available). At this bandwidth, chromatic dispersion is one of the limiting factors and its optimal compensation is necessary.

4.7.2 Preparation for Use of WDM in CESNET2

As regards the deployment of wave multiplexers during the first half of the year, we focussed on an acquisition of available information concerning this technology and we also looked at the possibilities of testing some of the devices directly in CESNET2. We succeeded in borrowing some devices from Cisco and Pandatel.

During the second half of the year, we tested the Cisco and Pandatel DWDM systems on the Brno–Olomouc line. The optical fibres on this line are approximately 115 km long. At this distance, the impact of chromatic dispersion of the optical fibres does not fully develop, particularly thanks to the applied transmission technologies. However, this distance is already beyond reach of standard SWDM devices and an optical amplifier must be used.

At first, we tested the Cisco 15540 system, with Cisco 15501 optical amplifiers, as well as with Keopsys optical amplifiers. There were four neighbouring channels available with transponders configurable from Fast Ethernet, through SDH STM-1, STM-4 to STM-16 and Gigabit Ethernet.

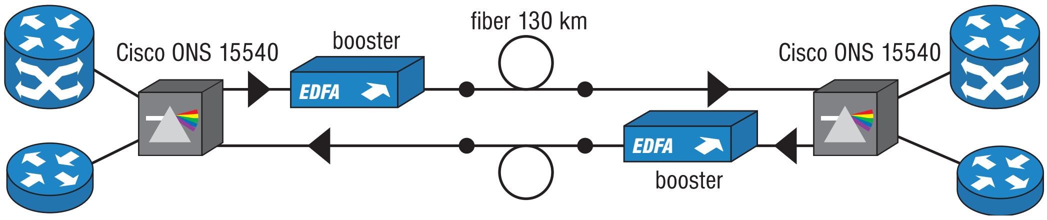


Figure 4.13: Testing configuration – Cisco 15540

We made use of one STM-16 channel for common traffic, one Gigabit Ethernet channel, which we tested using Schomiti analyzer, and two STM-1 channels for the testing of bit error rate, using HP 37717 analyzer. The configuration of this device is very user-friendly as it includes the standard Cisco IOS.

In the same way, we carried out the testing of the Cisco 15200 system, which is smaller device (available for a reasonable price). We had one Cisco 15252 modular multiplex at our disposal, together with three single-channel Cisco 15201 multiplexes. This solution proved to be fully functional as well. It is convenient, particularly, for channel branching within the course of a line. An advantage of this device is that in the case of any power supply failure, transit channels remain fully operational. The system configuration is not as user-friendly as in Cisco 15540.

During the testing of a Pandatel Fomux 3000 DWDM system we used the Keopsys amplifiers, as the manufacturer offers no optical amplifiers. In this case, it was possible to make a successful use of amplifiers intended for the amplification of a single channel. However, there were some problems concerning the output power regulation of individual cards (SDH and Gigabit Ethernet), which is why the deployment of this system in the network does not appear to be a perspective option.

Another objective was to find out whether it is possible to make use of Keopsys optical amplifiers intended for single-channel transmissions, together with the DWDM system, with a relatively low number of channels (4 to 8). The results confirmed our expectations and the line was running without any complications, using both types of amplifiers. We may therefore say that the tested sys-

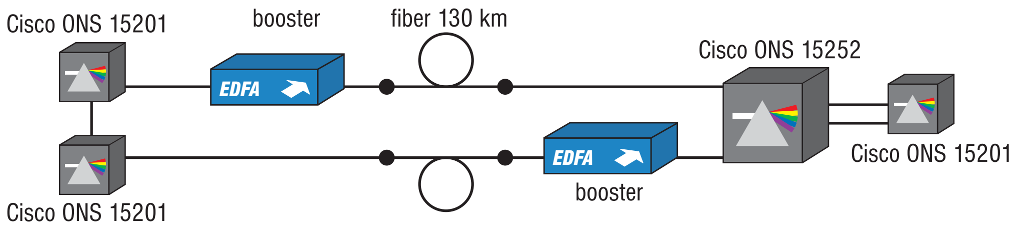


Figure 4.14: Testing configuration – Cisco 15200

tem can be used in operational environment and we also checked the interoperability of the tested products.

We also measured the spectral characteristics for all the tested systems. See Figure 4.15 for the generation of a four-wave mixing and own phase modulation, caused by the high power level inserted into the fibre. In this case, no information could be transferred (distortion is too high).

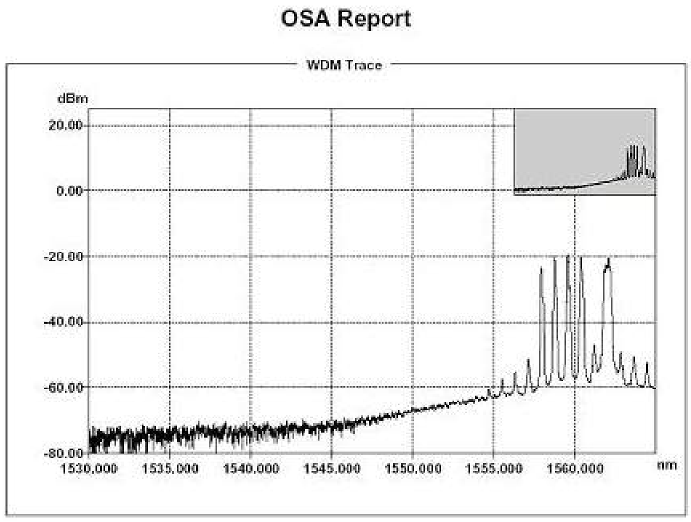


Figure 4.15: Spectral characteristics of Cisco 15540, with input power of 30 dBm, input of the receiver

4.7.3 Components for Switching on Optical Layer

The last area is associated with optical switching. Considering the fact that this type of a device is very costly and it is not generally available, the work has been carried out so far at the theoretical level (information search, computer simulations).

We presented the issues of optical switches and optical networks during a workshop of the optical research group. In April, we participated in the ICTON conference with a speech on the issue of optical switching. We arranged a short-term and long-term lease of a selected optical line for our testing with Sloane

Park Property Trust, a.s. We have a map of the lines and their parameters, according to which we are able to set up a testing loop, as necessary.

We have also evaluated the possibilities of 10GE transmission over a distance of up to 800 km. Based on theoretical analysis, we simulated this line and presented our results during a subsequent meeting of researchers.

In addition, we focused on the possibility of deployment of optical switches in the optical infrastructure of CESNET. We explored the availability and prices of individual components and compared the prices of the system based on WDM and CWDM technologies. In November, we carried out measurements at a WDM multiplexor of 1,330/1,550 nm. These measurements served for the demonstrative verification of a single-fibre transmission within the access networks. We made an inquiry for the price, availability and possible collaboration in the deployment of an optical switch in the testing section of the CESNET network, and distributed this inquiry to the selected manufacturers. We are now evaluating their replies.

5 IP version 6

Further expansion of IPv6 has so far suffered from a lack of interest from potential users, at least in Europe and Northern America. IPv4 addresses are still relatively easily available and other advantages of IPv6 are not likely to outweigh the inevitable expenses and complications associated with the transfer to the new technology.

As there is no demand, it is natural that the offer of IPv6 applications also develops rather slowly. The support of IPv6 among leading router manufacturers has improved significantly (Cisco Systems, Juniper Networks, etc.); however, this progress is still insufficient as long as the number of networks with routine IPv6 operation remains very low. Upgrading to IPv6 is generally considered inevitable and necessary for the new development of the Internet – future generations of mobile communication devices, use of IP in consumer electronics, car systems, etc.

In this situation, it is important to see the increasing explicit support of IPv6 "from above", i.e., from institutions financing research programs at national and international levels. Towards the end of 2001, the steering council of the research plan decided to include IPv6 among its strategic projects, also with the objective of joining the consortium of the European project 6NET.

The project is divided into six partial tasks, described in the following sections.

5.1 Project Coordination and International Collaboration

During 2002, the strategic project IPv6 became one of the largest projects within CESNET's short history, aim is also to assist in improving this support. The management of such an extensive team requires news methods and it has revealed some weak points within the system of technical and administrative project support by CESNET, z.s.p.o. Our aim is also to assist in improving this support.

5.1.1 Team of Researchers

By the end of 2002, the project team consisted of 45 collaborators including 22 students. The largest part of the team are people from Brno universities (Masaryk University and the Technical University), others are from Prague, Ostrava, Plzeň, Liberec and České Budějovice. We also have one external collaborator in Seattle (USA).

In order to ensure effective collaboration in such a team, we have been organising regular videoconferences, in addition to personal meetings and e-mail conferences. Videoconferences are very popular, even though we have to tackle some technical problems arising, particularly, from the doubtful quality of the *MBone* videoconference applications. We are therefore looking intensively for other solutions that may be more reliable, easy to install and suitable also for data circuits with a lower capacity.

We have also been considering the possibility of applying other tools for the support of online collaboration and project coordination, e.g., the TUTOS[2] system.

5.1.2 Involvement in 6NET Project

Since early 2002, we have been in intensive negotiations with members of the 6NET[3] consortium concerning our accession to the project. Due to the relatively tedious approval procedures, CESNET was officially adopted as a member of the consortium as of 1 September 2002.

We make every effort in order to concentrate the operating capacity within the 6NET project to a single task: development of an IPv6 router on a PC platform. This approach has proved to be perspective, as the consortium is now looking for a possible solution of the extensively fragmented capacities of individual partners, which result in ambiguities concerning responsibilities.

We also try to become involved in other activities of the 6NET project. For instance, we have contributed to the deliverable concerning the migration of national research networks.

Beginning in 2003, CESNET will be connected to 6NET with a PoS STM-1 (155 Mbps) circuit, which will be the very first Czech native (non-tunnel) international link of IPv6.

5.2 IPv6 Network Architecture

Within the CESNET2 network, the IPv6 protocol is considered experimental and the IPv6 backbone network is designed with the use of tunnels as an overlay network above the IPv4 infrastructure. For details concerning the current situation of the network, visit *http://www.cesnet.cz/ipv6/*.

[2] http://www.tutos.org/
[3] http://www.6net.org/

5.2.1 IPv6 Network Topology

For the scheme of the IPv6 backbone network by the end of 2002, including the international circuits, see Figure 5.1. Eight nodes of the CESNET2 network are linked.

The logical structure is formed by IPv6 tunnels over IPv4, which, however, copy to a maximum extent the physical topology of CESNET2. In most nodes, the IPv6 router is directly connected to the IPv4 backbone routers and tunnels usually correspond to the physical circuits of CESNET2, leading from the node in question. With this arrangement, the transition to an IPv4 and IPv6 network (with dual-stack routers) will be relatively easy – both IPv4 and IPv6 backbone routers will merge.

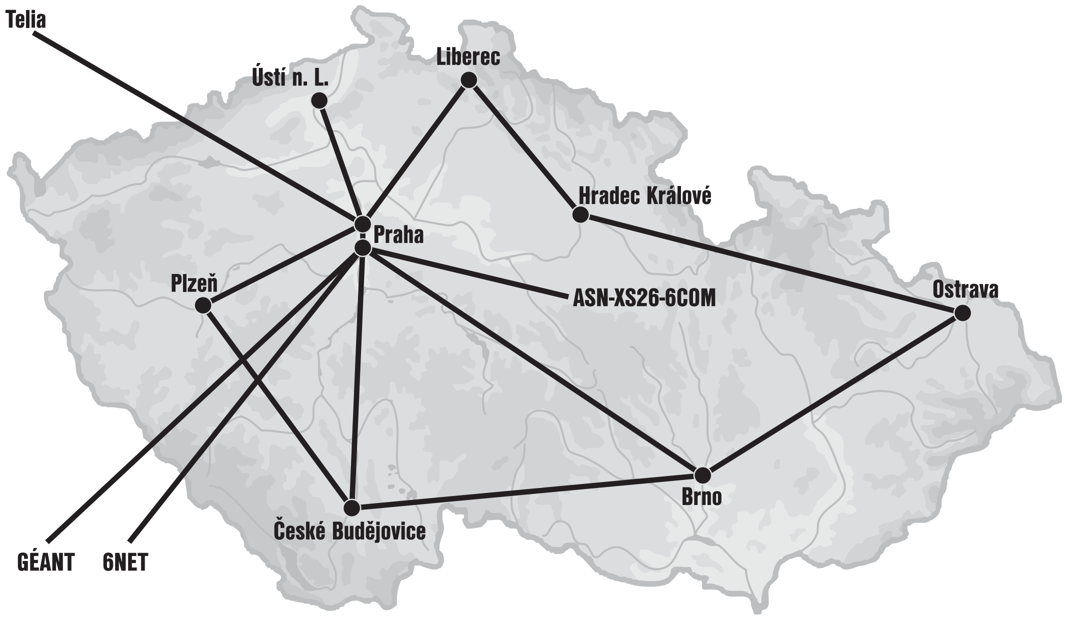


Figure 5.1: Scheme of the IPv6 backbone network topology

Another principle of the designed topology of the IPv6 backbone network is based on the requirement for a redundant linking of each backbone router. This is why there are two large circuits within the network: Prague–Plzeň–České Budějovice–Brno–Prague and Prague–Brno–Ostrava–Hradec Králové–Liberec–Prague, connected in Prague to two different routers, as indicated in Figure 5.1. Both Prague routers are also the terminal point of independent international circuits, which means that even in case of a failure of one router, both internal and external connectivity is maintained.

5.2.2 Backbone Routers

Within the IPv6 backbone network, we make use of the following router platforms:

- PC with Linux (Prague, Ostrava, Plzeň, Č. Budějovice)
- PC with NetBSD (Brno)
- Cisco 3640, 7200 or 7500 (Prague, Liberec, Hradec Králové, Ústí nad Labem)

PC-based routers utilize of the *Zebra* routing daemons. All routers are incorporated in a unified authentication and authorization system, based on the TACACS+ protocol.

5.2.3 Addressing

In 2001, CESNET obtained an address prefix (known as *SubTLA*) from RIPE *2001:718::/35*. Based on our request, this prefix was extended in 2002 to *2001:718::/32*. The prefix *3ffe:803d::/34*, which we were using previously in our *6Bone* testing network, is no longer being used.

Each of the nodes has been allocated a 42-bit prefix from the address area *2001:718::/32* and from this, prefixes are allocated to end institutions, usually 48 bits long. For the summary of allocated prefixes, see Table 5.1. This distribution is based on the previous prefix /35. With respect to its shortening to 32 bits, we are now considering the corresponding modification of its distribution to individual nodes.

Institution	*Prefix*
CESNET, Prague	2001:718:1::/48
Czech Technical University, Prague	2001:718:2::/48
Masaryk University, Brno	2001:718:801::/48
Brno University of Technology	2001:718:802::/48
Technical University of Ostrava	2001:718:1001::/48
Institute of Geonics CAS, Ostrava	2001:718:1002::/48
SBU Silesian University, Karviná	2001:718:1003::/48
Faculty of Pharmacy CU, Hradec Králové	2001:718:1201::/48
TGM Hospital, Ústí n. L.	2001:718:1601::/48
University of West Bohemia, Plzeň	2001:718:1801::/48
Service for Schools, Plzeň	2001:718:1802::/48
Technical University in Liberec	2001:718:1C01::/48
University of South Bohemia, Č. Budějovice	2001:718:1A01::/48

Table 5.1: Allocated IPv6 prefixes

Missing in this list are especially universities and institutes of the Czech Academy of Science, connected through the Pasnet – Prague metropolitan network, which does not support IPv6. We have already initiated some negotiations and, hopefully in 2003, we will manage to connect these institutions through Pasnet.

The prefix *2001:718::/48* has been reserved for the needs of backbone network addressing. Individual backbone connections are allocated networks with the mask length of 64 bits. Loopback interfaces are addressed from the prefix *2001:718::/64*.

5.2.4 Internal Routing

As the interior routing protocol (IGP) we use *RIPng* combined with *BGP*. The RIPng protocol is the only IGP supported for IPv6 by both platforms used in the backbone network (Zebra and Cisco IOS). Its disadvantages (particularly the slow convergence) are, to a great extent, eliminated by the method of use: RIPng is used only for propagating information about the reachability of the backbone prefixes, while external networks are routed with the use of an internal BGP. In other words, RIPng serves only for the identification of the next hop for BGP. Next year, we would like to test other alternative IGP's whose implementations have lately appeared in the beta versions of Cisco IOS and Zebra – OSPFv3 and IS-IS.

The IBGP protocol is configured in the backbone network with the use of reflectors according to [RFC2796] (*BGP route reflector*). Two reflectors are used in order to ensure higher robustness – *prg-v6-gw* and *r1-prg*. Other backbone network routers have BGP sessions only with these two reflectors.

5.2.5 External Connectivity

The exchange of routing information with neighbouring autonomous systems is subject to the rules of the 6NET network, enabling individual partners to inform the 6NET core about the prefixes of their own National Research and Education Network (NREN), as well as the prefixes of other networks, with which NREN maintains peering. Other partners can make use of the 6NET network transit for their access to these external entities. However, two external entities cannot communicate with each other through 6NET.

In order to implement these rules, 6NET uses the BGP community mechanism [RFC 1997] within its autonomous system 6680:

- The `6NET-NRN` (6680:10) community identifies prefixes that belong directly to partner NREN.
- The `6NET-OTHER` (6680:99) community identifies all other prefixes that NREN advertise to 6NET.

Our autonomous system 2852 may therefore advertise prefixes identified by the `6NET-NRN` community to all other autonomous systems, with which we peer; however, all prefixes identified with the `6NET-OTHER` community always have to be filtered.

So far, our AS 2852 has agreed on IPv6 peering with the following autonomous systems (in all cases with the use of a tunnel):

1. AS 6680, 6NET: connection to 6NET, this link should be transferred to the native circuit STM-1 in early 2003.
2. AS 2200, Renater: this connection to the GTPv6 network is used for testing within TF-NGN[4].
3. AS 1299, Telia International Carrier: quality transit connectivity.
4. AS 25336, 6COM: the first national IPv6 peering in the Czech Republic.

Our objective is to maintain the number of links to other autonomous systems at a reasonable level, either in the form of native circuits or high-quality tunnels with low delay. This way, we want to avoid problems that have completely degraded the 6Bone experimental network.

5.2.6 IPv6 Network Monitoring

At present, connectivity and basic IPv6 services are monitored from the standard monitoring system *saint.cesnet.cz*. The monitoring is carried out with the use of modified modules supplied together with the *Nagios*[5] monitoring software, or newly developed modules. This system is linked to the IPv6 network directly at the second layer. The following areas are monitored:

- Availability of backbone routers,
- Availability of border routers for peering neighbours,
- Status of significant services within IPv6,
- Router information in BGP protocol.

We monitor the network load with the use of the *GTDMS*[6] software. For the map of the current load, see *http://www.cesnet.cz/provoz/zatizeni6/*.

[4] *http://www.dante.net/tf-ngn/*
[5] *http://www.nagios.org/*
[6] *http://www.cesnet.cz/doc/zprava2001/sled.html*

5.2.7 Connecting End Site Networks

In order to increase the number of IPv6 subscribers, it is necessary to support this network protocol in the local network routers of linked institutions. Subscribers only need to activate IPv6 in their operating system, and all the necessary configuration details (IPv6 address, mask and default gateway) will be acquired through stateless autoconfiguration.

IPv6 is currently available, to some extent, in the local networks of all connected nodes. Due to the considerable variety of router hardware and software in local networks and the understandable caution of local network administrators, IPv6 is usually routed with the use of a separate router that does not route IPv4. It is connected either directly, or through virtual LANs, according to the IEEE 802.1Q standard.

For all the important details concerning the IPv6 backbone networks and international links, see Figure 5.2.

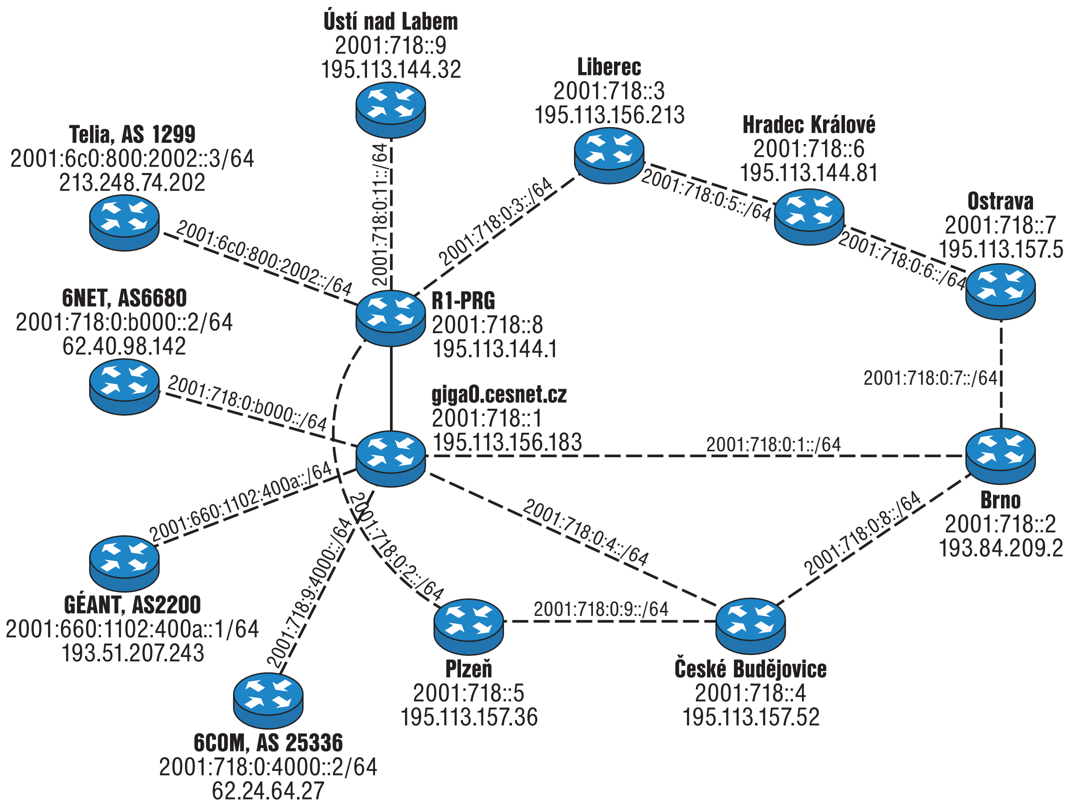


Figure 5.2: IPv6 backbone of CESNET2 – detailed view

5.3 Basic IPv6 Services

In addition to the stateless autoconfiguration mentioned above, the following two services are necessary for an effective operation of IPv6: DNS and, less importantly, DHCP. These three pillars of clients' automatic configuration should make sure that end users do not even know whether they are using IPv4 or IPv6 for their access to certain services.

However, this ideal situation is not within easy reach. This is because not all applications support IPv6 and it is necessary to complete a lot of tasks concerning the standards and implementations of DNS and DHCP services.

5.3.1 DNS

The DNS service for IPv6 within CESNET2 was significantly reorganised in 2002. The primary name server of the *cesnet.cz* domain and reverse domains was retained in the Prague node and the secondary IPv6 name server was moved to Ostrava. With respect to the current schism concerning reverse domains, we have all records doubled in both trees, i.e., under *ip6.arpa* and *ip6.int*.

In every node of the IPv6 network, there was a separate name server established for IPv6 or records for IPv6 were added to existing name servers of local domains. The relevant reverse domains were also delegated to these name servers.

A majority of the name servers mentioned above run the *BIND* daemon, version 9; however, we are testing other alternatives, too, e.g., *DJBDNS*[7]. With respect to the frequent errors in the BIND program, its monoculture represents a security risk that should be neutralized in the future by additional implementations of DNS servers.

5.3.2 DHCPv6

The protocol of the clients' autoconfiguration, DHCPv6, has not been standardized in the form of RFC in IETF. Testing carried out within the 6NET projects has also shown that none of the available implementations of DHCPv6 are really applicable, as they usually lag behind even the draft standard, realize only part of the protocol or include substantial errors. This is why we decided not to implement this protocol, which, fortunately, means no serious limitations with the existing number of end users of IPv6.

[7] *http://www.djbdns.org/*

5.4 IPv6 User Services and Applications

It is obvious that IPv6 will attract new users only providing that there are attractive applications available at least within the quality in which they are now available through IPv4. Even though this is not the main objective of the project, we also attempt to migrate, with our own forces, some application servers to IPv6 or implement entirely new services based upon this protocol.

5.4.1 WWW and FTP Services

During the year 2002, an alternative access through IPv6 was implemented in a wide range of significant servers within the CESNET2 network, e.g.:

- Main web server of *www.cesnet.cz*
- FTP server *ftp.cesnet.cz*
- Server of the NoseyParker search service, *parker.cesnet.cz*
- Official mirror of Debian Linux distribution, *debian.ipv6.cesnet.cz*
- FTP server of Masaryk University, Brno, *ftp.muni.cz*

The software for data mirroring at *ftp.cesnet.cz* was upgraded in order to enable mirroring of data through IPv6, which can be quite an interesting option taking into account the low load on IPv6 lines.

The *parker.cesnet.cz* search server witnessed similar changes. In the collection section, we also completed the IPv6 support and the presentation section indicates which data are available through IPv6.

5.4.1 Other Applications

Services for online discussions are particularly popular among students. After their implementation and possible connection of student hostels, we expect a wave of new IPv6 users.

From the available application protocols, IPv6 is available only for *IRC (Internet Relay Chat)*. The server for this service, also supporting the IPv6 access, has been established at *irc.ipv6.cesnet.cz*.

In Ostrava, there is the *BBS (Bulletin Board System)* server available through Telnet and IPv6.

Another interesting area of IPv6 applications is network gaming, which may take advantage of end-to-end connectivity that was usually not available in IPv4. We therefore try to concentrate games with the support of IPv6 at the *game.ipv6.cz* server (at present, there is the *FICS*[8] chess server and the *GTetrinet*[9] game).

In the future, we would like to focus on other areas of application, e.g., videoconferences.

5.5 IPv6 Routers on PC Platform

This partial task stems from the last year's project titled *Routers on PC Platform* and also the long-term experience with the application of software PC routers in Brno academic computer network.

Basically, the following two factors are obstructing further expansion of PC routers in modern gigabit networks:

1. Performance: as regards standard PCs, we are limited by the throughput of the PCI bus (approx. 1 Gbps) and the slow response of the interrupt system.
2. User interface for configuration: Parameters and commands configuring the network subsystem of the Linux or BSD operating systems and various daemons are dispersed in a number of files and scripts. In addition, these files and scripts of various systems differ and there are considerable differences, also, between various distributions of the same operating system. On the other hand, commercial routers have sophisticated command-line and other configuration interfaces.

5.5.1 Hardware Routing Accelerator

A pure software solution of PC routers is based on the PC architecture, suitable network interface cards and an operating system of the Unix type (NetBSD, FreeBSD, Linux). Packet switching (*data plane*) and the router control (*control plane*) takes place in software. On the other hand, we have designed packet switching in the hardware accelerator, with control functions provided by the host computer software. The advantages of this architecture are in the combination of the high performance of the hardware accelerator with the flexibility, user-friendly control and reliability of software routers.

The COMBO6 Card

The main requirements concerning the hardware accelerator were as follows: high performance in packet switching, simple and flexible implementation, pos-

[8] *http://www.freechess.org/*
[9] *http://gtetrinet.sourceforge.net/*

sible reprogramming of functions, also applicable at the end user's site and a reasonable price. These requirements were ideally fulfilled by the technology of field-programmable gate arrays (FPGA).

During the initial stage of the project, it was our plan to make use of commercially available boards with FPGA circuits for the accelerator, complemented by an interface board designed by us. However, we carried out market research and found out that commercially available boards were not up to our requirements and that the price for these boards was also relatively high. We therefore designed our own hardware accelerator, *COMBO6 (COmmunication Multiport BOard for IPv6)*, and made arrangements for its production.

The designed COMBO6 card includes the following electronic circuits:

- A gate array of VIRTEX II family, produced by Xilinx,
- SRAM, CAM and DDRAM memory,
- PCI interface circuits,
- Communication port interface circuits,
- Power supply and auxiliary circuits.

The accelerator is divided into two interconnected parts:

1. Basic PCI card,
2. Communication interface card, connected with the basic card through a connector.

The advantage of this solution is the separation of the technologically complicated motherboard and the relatively simple interface board. If another type of interface is required (optical, metallic), we need not develop the entire card again, it is enough just to design a new interface card instead.

The entire project is designed as fully open with public access to all information. The COMBO6 card will, therefore, also be available for other projects. We

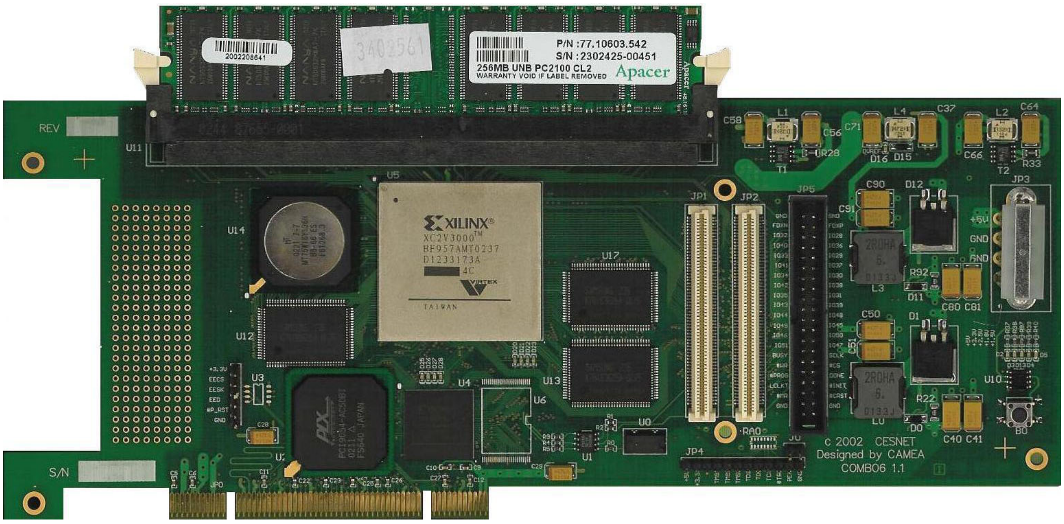


Figure 5.3: COMBO6 motherboard

have already discussed some possibilities, e.g., within the SCAMPI project or optical network testing.

At first, we are planning to design a communication interface card with 4 ports, using the usual communication circuits for Gigabit Ethernet 1000BASE-T (metallic cables of category 5). This will be followed by a card with four optical interfaces and VIRTEX II PRO circuits. Optical transceivers will be installed in SFP cages and so their replacement with another type (single-mode or multimode fibres with various wavelengths, possibly also with WDM) will be very simple.

At present, the basic draft of the COMBO6 motherboard is complete, the printed circuit board has been produced and the card has been populated – see Figure 5.3.

Firmware for COMBO6 Card

For the purposes of programming the gate array firmware, we make use of the VHDL language. The development system of VHDL also includes the *Leonardo Spectrum* translator and *ModelSim* simulator produced by *Mentor Graphics*.

Our objective is to enable a wider community than just the project team to participate in the development. Most potential contributors may find the high expenses on the acquisition of VHDL development system unacceptable. We therefore introduced an abstraction in the form of logical functional blocks realized inside FPGA, which we call *nanoprocessors*. These represent a transition between programmable state automata and microprocessor cores, have only few instructions and the length of their "nanoprograms" does not exceed several dozens of instructions. We expect that these "nanoprograms" may also be modified by external developers, without access to the VHDL development system.

The designed firmware for packet switching in the COMBO6 board includes the following functional blocks (see also Figure 5.4):

- Input packet buffer memory (IPB)
- L2 and L3 header field extractor (HFE),
- Look-up processor (LUP),
- Packet replicator and block of output queues (RQU),
- Output packet editor (OPE),
- Output packet buffer (OPB),
- PCI interface (PCI),
- Dynamic memory controller (DRAM)

After being accepted and processed, packets are stored in IPB, and proceed to the HFE block, where information necessary for routing and packet filtering are extracted. The data content of the packet is then stored in a dynamic memory. The HFE, LUP and OPE blocks are realized by nanoprocessors.

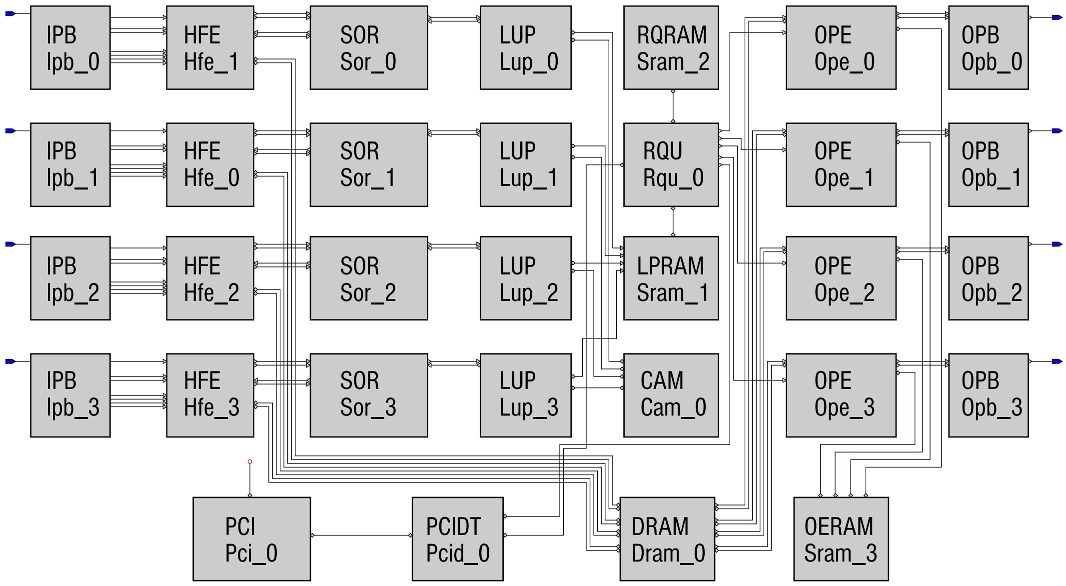


Figure 5.4: Functional blocks of COMBO6 board

Packets which are not classified by the hardware accelerator, or which include unsupported exceptions (e.g., IPv6 extension headers), are further processed by the software of the host computer. The first version of the firmware will focus exclusively on IPv6, which is why IPv4 datagrams will be considered as exceptions and therefore processed by the software. The hardware support of IPv4 routing is planned for the next version.

The draft has already been completed and the first version of the HFE unit tuned. In addition, the design for the LUP unit has also been completed and the designing of the OPE unit is in progress.

Software Drivers for COMBO6 Card

The software equipment of PC routers is being developed for the NetBSD and Linux operating systems. Our goal is to make maximum use of the software available for both systems (without having to carry out further modifications). The drivers of the COMBO6 card are therefore designed so that it appears to the operating system as a standard multi-port communication card. The card can thus be configured and controlled by means of the standard operating system commands (*ifconfig*, *netstat*), routing daemons, etc.

The communication between the COMBO6 card and the host operating system is implemented in the software driver. Its block diagram is shown in Figure 5.5. The driver mediates the communication between the card, router daemons, programs for card configuration and control, and the *tcpdump* type packet analyser.

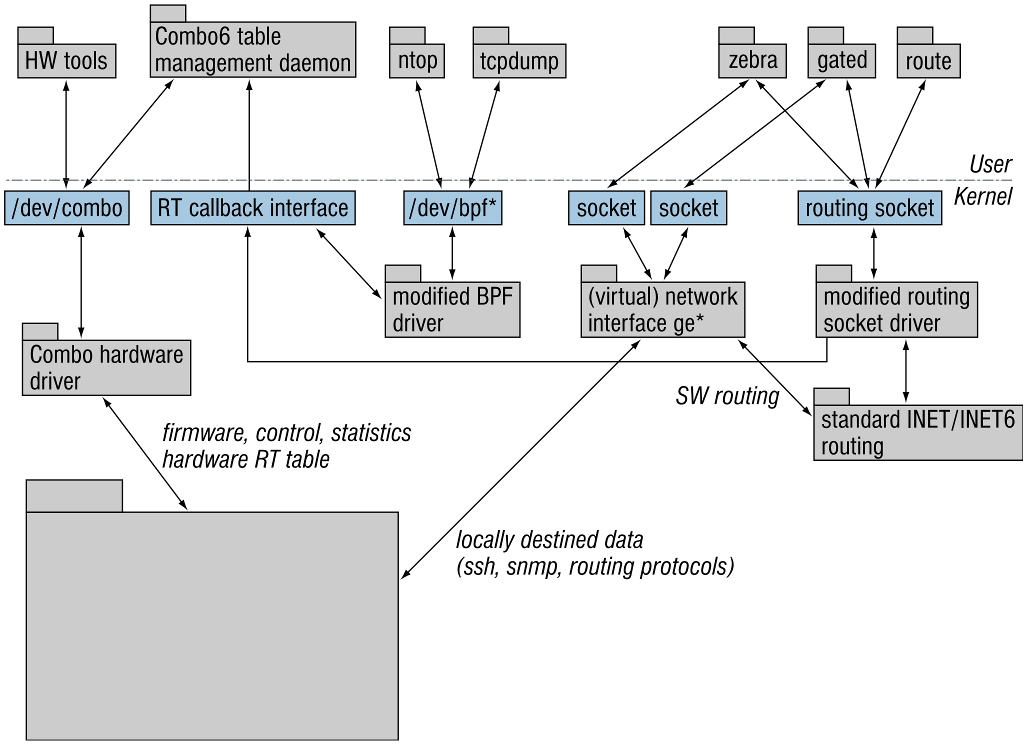


Figure 5.5: Scheme of the COMBO6 card driver

Routing information, packet filter rules, etc. are taken out of the operating system core table and stored in the forwarding and filtering table. After the necessary processing, a nanoprogram for the look-up processor is made out of this table (including the data for the CAM memory) and downloaded to the COMBO6 card.

At present, we are just about to complete the lowest levels of the software interface for the COMBO6 card (library of basic operations for input and output) and planning the division of the software architecture into blocks, so that programmers are able to start processing it.

Formal Verification of the Design

The development team includes a group for formal verification, whose task is to verify individual hardware and software blocks using deductive methods. The group draws up recommendations for the system designers, and methodology for general collaboration with design teams.

5.5.2 Router Configuration System

Commercial routers usually integrate all configuration and operating functions in a single user interface. The user is, in fact, isolated from the technical details of the router's operating system.

As regards our router on the PC platform, we do not expect the user interface integration to reach such a level, as we expect a wide use of the available software for Linux or BSD. Instead, we want to create a software system, in which it would be possible to enter full router configuration in a consistent manner and at a single place. Further operations with the router would make use of standard tools and commands offered by the operating system.

On the other hand, we wish to implement some new functions and possibilities:

- Central configuration storage,
- System of version control, which will enable administrators to keep the history of router configurations and work simultaneously on two configuration branches, etc.
- Metaconfiguration, during which it will be possible to specify some setups (e.g., routing policy within an autonomous system) at the level of the entire network. From there, specific configuration for individual routers will be automatically generated.

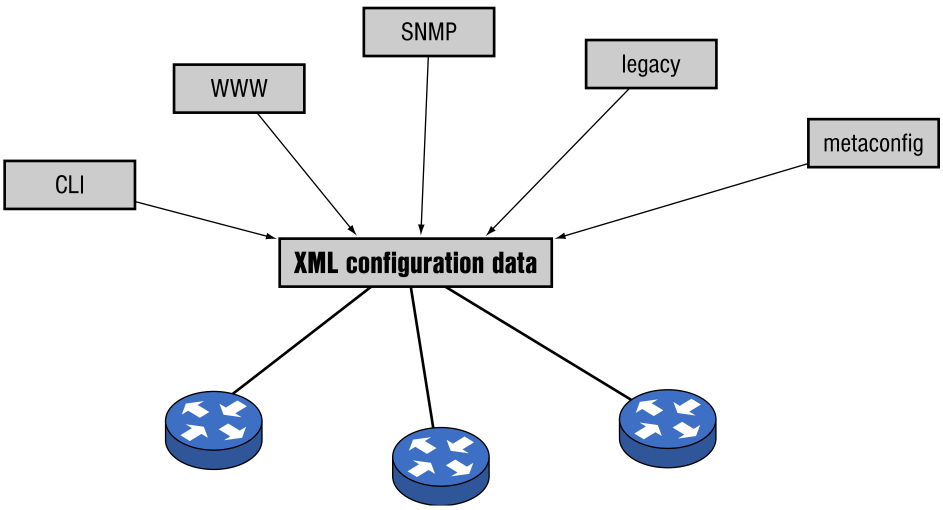


Figure 5.6: Scheme of configuration system

For the software architecture of the configuration system, see Figure 5.6. It includes the following blocks:

- User interfaces (*front-ends*) process the input of configuration commands and carry out their syntactic validation.
- The objective of the system core is to carry out (partial) semantic validation of the submitted configuration, and to provide tools for manipulation with the configuration data repository.
- Output blocks (*back-ends*) attach specific data of a particular target router to a selected configuration and transform the configuration to its “native” language or script files.

We plan gradual implementation of these front-ends: own linear interface, web interface, command-line interface of Cisco IOS and JUNOS and SNMP. As regards back-ends, we intend to support Cisco IOS, JUNOS, SNMP in addition to PC routers, or also methods of direct communication between processes, e.g., XML-RPC.

5.6 Project Presentation

Within our presentation activities, we have made efforts to present the IPv6 protocol and the results of our project to the general professional public.

5.6.1 Web

Some years ago, we set up a section focusing on IPv6 within the *www.cesnet.cz* server. The section provided general information concerning the protocol and

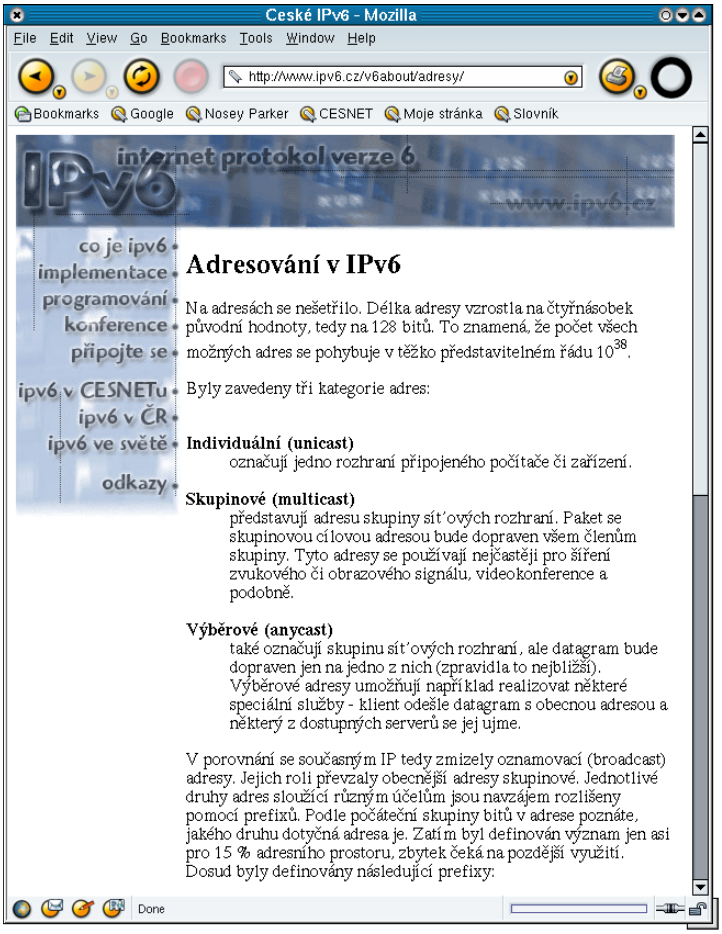


Figure 5.7: Server at *www.ipv6.cz*

the activities of our project. In 2002, we decided to change the structure of this presentation.

We set up a new independent server at *www.ipv6.cz*, in order to popularise IPv6 in the Czech Republic. The server provides information concerning the protocol and its implementations, description of the current situation and offers some interesting links. The server also includes mailing lists: *ipv6@ipv6.cz* serves for discussions concerning the practical aspects of IPv6 and the objective of the *ipv6-peering@ipv6.cz* list is to discuss the recommended rules for IPv6 peering.

We moved general information concerning the protocol from *www.cesnet.cz* to *www.ipv6.cz* and kept there only the pages describing the project. The section devoted to IPv6 at *www.cesnet.cz* thus offers an information concerning the activities pursued by CESNET in this respect.

As the *PC-based Router* subproject witnessed a prompt development, it was necessary to come up with a corresponding presentation and communication platform. As this is a logically integrated issue, to be solved also by researchers outside CESNET, we considered it adequate to create another independent server at *www.openrouter.net*.

Figure 5.8: Server at *www.openrouter.net*

This server focuses mainly on the PC router project. It presents information concerning the project, results achieved so far and it also serves the internal communication of the team. In addition, there are several mailing lists concentrated here: *announce* for the presentation of news, *xmlconf* for discussions concerning the configuration XML system and *combo6* for those involved in the development of a router card.

5.6.2 Publications and Presentations

The most significant publication created with respect to the project is the [Sat02] book, presenting a comprehensive explanation of characteristics and principles of the protocol, as well as the related mechanisms. The book of 238 pages was published in early October 2002, with 3,000 copies.

In addition, we published nine articles in professional periodicals, both printed (*Softwarové noviny*), electronic (*Lupa*) and combined (*Bulletin of the Institute of Computer Science, MU Brno*). Six technical reports document some of the achievements.

The organisers of the *EurOpen 2002* conference, held in September in Znojmo, asked us to organise a one-day tutorial on the issue of IPv6. The tutorial comprised a theoretic introduction to the protocol and a practical demonstration of its use. The reaction of the audience was positive and the organisers expressed their wish to repeat the tutorial again.

In addition to this action, we presented three speeches during various conferences in the Czech Republic, two presentations for the *6NET* project and a wide range of presentations during internal seminars organised by the association.

6 Multimedia Transmissions

6.1 Objectives and Strategies

The project titled *Multimedia Transmissions in CESNET2* was launched at the beginning of 2002 as an effort of integrating various activities in this area. With respect to the importance of this issue, the project also became a strategic project.

The long-term objective of the project is to create systems for support of routine and natural use of multimedia applications, both in the area of videoconferences and video on demand, as well as to search for systems and platforms for implementation of transmissions with special demands.

Our main goal is to provide potential users with better information, develop and stabilise the infrastructure for providing videoconference services and services on demand, and to find a platform for high quality video services. We understand the involvement of the project in international activities and establishing contacts with similar projects abroad as necessary for the fulfilment of common objectives.

6.2 Project Structure

The strategic project is a combination of several independently filed projects. The aim was to coordinate activities in this area. We decided to divide it into four partial tasks:

1. Videoconference infrastructure for routine use.
2. Video transmissions with special demands and new methods of acquisition.
3. Media streaming and support for online education.
4. Special presentation events and support for special projects.

Each area was solved by a single team under the supervision of a partial task leader (key researcher in that area). The project was implemented at this level for the whole first half of the year. In the second half of the year, the project was restructured, based on an approval of the research plan management. For instance, the area of media streaming was separated. We cancelled the redundant positions of partial task leaders. The remaining researchers also worked on tasks defined at the beginning of the project.

As regards the presentation of the achieved results, the issues of concern can be divided into two categories:

- Collaboration environment support,
- Special projects and events,

6.3 Collaborative Environment Support

The infrastructure of the computer networks and high-speed connections have become a standard in most academic centres. The network is used not only for data transmission and the operation of remote computers, but it also serves for the transmission of multimedia data and their real-time sharing. Thanks to computer networks, geographically distributed teams find their work easier and faster and now, another quality step forward is required – to make use of network and IT infrastructure for the creation of a virtual shared workspace, where geographical distance is no longer significant.

In order to solve this complex tasks, it is necessary to solve a number of partial tasks and problems, tackled by the members of the research team during the year 2002. It is possible to divide these tasks into the following categories:

- Systems for network support of group communication,
- Tools for shared collaborative environment,
- Portal for management and administration of group communication environment,
- Knowledge base and direct support for pilot groups,
- Establishment of access points for communicating groups.

6.3.1 Network Support on MBone Basis

In IP networks, group communication is usually provided using multicast, created by the MBone virtual network. Over the past few years, MBone, unfortunately, has been unavailable to a number of places. It was therefore necessary to look for another solution that may partly replace multicast and offer a reliably available service instead of a rather unreliable one.

In order to solve the problem of multidirectional communication, it is possible to make use of an element (software or even hardware one), for the replication of data from a single source and forwarding of such data to other members of the communicating group. This device is usually referred to as a reflector or a mirror.

Within our solution, we have developed a software reflector, based on the *RTP Unicast Mirror* program. In this case, the otherwise practically endless multicast scaling is considerably restricted; however, the number of participants taking part in network meetings is limited by the very nature of such a meeting. The original simple reflector has been extended with a number of new characteristics. The motivation leading to the modifications can be described simply as follows:

- Sometimes, meetings need to be held behind closed doors, i.e., with data sent only to a defined number of participants who prove their identity.
- It is useful to record important moments that will be replayed directly on the server, not by individual participants.
- Scaling, as a limiting characteristic of the mirror, has been solved in the form of interconnecting reflectors with tunnels.
- It is possible to adjust to various bandwidth with the use of a special reflector mode, where individual data flows are combined into one flow. Interconnection of this type reflector with a tunnel enables users' communication on lines with different throughput.
- In addition, we added the possibility to log important activities on the reflector and to monitor quality of data passing through.

The extended reflector covers the user requirements and it has proved to be reliable and sufficient.

Based on another modification of the reflector, we are able to synchronize more flows with the use of accurate timestamps sent in the RTCP control protocol. The synchronized video flows are the basic element for the transmission of 3D video signal, where separate flows are sent for each eye.

6.3.2 H.323 Infrastructure in CESNET2

We are continuing in the activities commenced during the previous period. We have set up a team comprised of CESNET's employees and researchers from the projects titled *Multimedia Transmissions in CESNET2*, *Voice Services in CESNET2*, and *Quality of Services in High-speed Networks*. The objective of this team is to create a concept for further development of our H.323 infrastructure, to coordinate procedures for the verification of this technology, support the use of software clients and create a secure and stable H.323 infrastructure.

We have achieved some successes in the support of independent IP clients (Polycom ViewStation, PictureTel, GnomeMeeting). Important success of this group lays in identification of problems associated with the security of access in the existing H.323 infrastructure, and proposals for a solution of these problems in coordination with projects of distributed AAA services (Shibboleth). Furthermore, there are several versions of numbering plans which can significantly facilitate the access to H.323 infrastructure within the Internet2 project (ViDe initiative).

Pursuant to information search and testing carried out during the previous period, we purchased several stationary videoconference sets for H.323 this year (Polycom ViewStation, FX, SP128 and ViaVideo). These sets are designed for standard videoconferences with an international community of researchers (SURFnet, Megaconference IV, TERENA, Dante, etc.) and for the provision of support to notable events supported by the CESNET association (ISIR). Selected sets serve researchers in the H.323 team for the verification of tested mechanisms in the H.323 infrastructure.

The multipoint H.323 videoconferences have so far been solved in the form of a compromise. Videoconferences with four linked IP clients are solved directly by one of the videoconference sets (Polycom ViewStation FX) and – pursuant to an agreement with the supplier of these stations – there is also MCU's available with the possibility of twelve connected IP clients. The portfolio of these services may be further extended by MCU in the Internet2 and some other foreign partners.

6.3.3 Tools for Shared Collaborative Environment

Concerning the character of business meetings and conferences, it is obvious that good quality of sound is very important. The human ear is so sensitive that even some minor dropouts and low quality of sound recording will make the use of the system rather complicated. The research group decided not to develop their own tools for sound handling but tested various versions of the *rat* program and various types of microphones. During the year, the team managed to get hold of an instrument for echo cancellation, test it in combination with omni-directional microphones and introduce it in routine operation.

Other important information shared during a business meeting is the image of individual participants. Even though this information source is demanding in terms of amount of transmitted data, it proved to be quite robust with respect to the quality of transmission and the signal, as this information is not so substantial for a virtual business meeting.

Shared workspace is a tool for which users express various requirements – from sharing static images with a large number of details, to sharing animations and moving images, MS PowerPoint presentations and TEX. Modifications of the shared whiteboard tool, *wbd*, described in last year's report were implemented in the new version, i.e., *wbd* dynamically links functions for imaging, rotation and size changes from the *Imlib2* library, depending on the format of the loaded

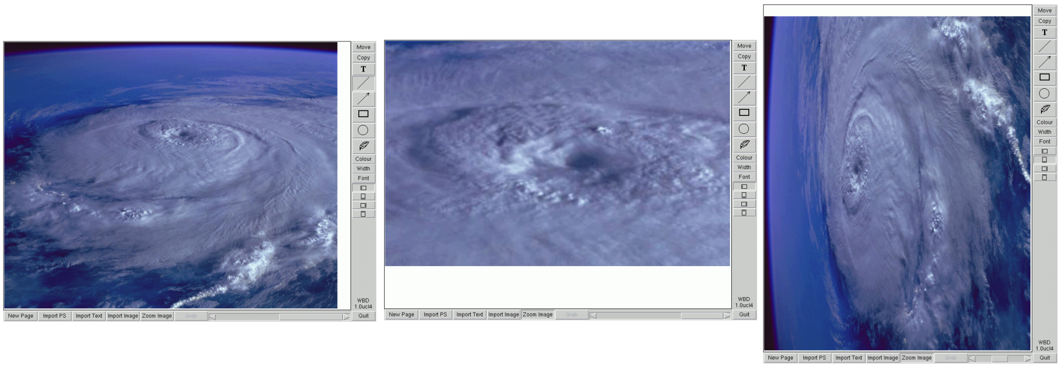


Figure 6.1: Modified program for shared workspace, *wbd*

data. The user interface also has been subject to overall changes. We removed the limitation of the data receiving speed (originally 32 kbps), and so presentation of large files is now limited only by the network bandwidth and the computer performance.

6.3.4 Portal for Management and Administration of Group Communication Environment

For user-friendly and intuitive control of a mirror or a group of mirrors, the WWW environment was selected, as it is widely known and requires no other knowledge from the users. The availability of a web browser on users' computers is considered as standard.

The communication portal includes information and administration sections. We created the portal with the use of the *gdbm* database. Users' secure access is implemented using an SSL connection. The descriptions of individual functions available through the portal are in English, as the portal has also been planed for international communication. In addition, we have completed detailed instructions in Czech.

The information section is available to the public, presenting information about the running mirrors and the planned conferences. Design of the website is effective and rather simple.

The administration section is available only to users who have set up their account. It serves for the operation of a mirror or a group of mirrors and the storage of time and other data concerning videoconferences. As users start up a mirror, it is possible to restrict the access to conference data flows through permitted IP addresses, or by defining a group of user names and creating a file for the monitoring of activities within the mirror. Those who are authorized have access to creating new accounts and administering existing ones.

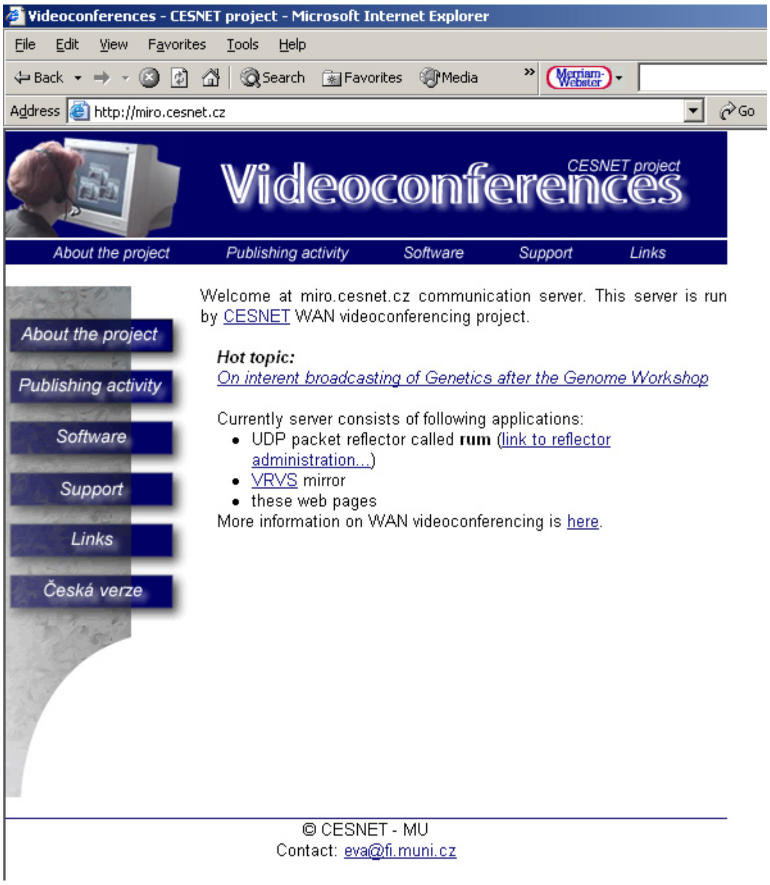


Figure 6.2: Portal at *miro.cesnet.cz*

Videoconferences are created using portal described above. Videoconference organisers will be connected to the portal using the WWW browser on their workstations, and carry out authentication in order to get through to the administration section. According to the planned number of tools, the same number of mirrors is initiated, and the possible access restrictions entered, together with the name of the file for the recording of mirror activities. The rules for the restriction of access must be entered prior to the creation of the mirror, using *Access (IP)*, *Access (users)* and *Users* links.

Only some of the videoconference tools for MBone are capable of recording. Copies are saved locally on the user's workstation. Creating a central copy for all types of tools can be a very useful feature. We therefore created the reflector in order for saving to be started/stopped through the portal, by sending the SIGUSER1/SIGUSER2 signal (Start recording and Stop recording). In case that the name of a file with a protocol (log) is entered, the system enables users to save information concerning all activities carried out within the mirror, including time stamps.

The videoconference portal and software for mirrors is running on *miro.cesnet.cz* server and it is primarily intended for use by Czech academic community.

6.3.5 Direct Support for Pilot Groups

The key element of each solution is informing potential users about your efforts. In 2002, we innovated the websites concerning videoconferences. We are planning a new system of administration and editing for these pages and we are wokring on further simplification of link categorization. We thus continue in the development of a presentation web, in which those who are interested in videoconference technologies will find information concerning a number of systems both for videoconferences, and for digital transmission and processing of video and audio signal. The new Web is straightforward and easy to navigate. The graphic design is common with the Web server of CESNET. It is available at *http://www.cesnet.cz/videokonference/*.

Even well informed users usually need assistance in their use of systems for collaboration support. As regards videoconferences, there is an extensive group of well-proven products; however, the number of real applications is not very high. Except for the usual point-to-point videoconferences used by some specialised scientific research teams, most other applications have been initiated or participated by a relatively narrow group of specialists who are deeply involved in this issue. The main reason is the lack of information concerning the real opportunities offered by videoconference services and sometimes rather exaggerated fears of how complicated videoconference tools may be. We therefore appreciate new applications thanks to which we are able to prove that videoconferences do not need to be complicated or expensive.

One of the groups supported by our researchers is the group of blind people or visually impaired people. This case concerned an audioconference between the TEREZA centre at Czech Technical University and the Theresias centre at Masaryk University. These centres provide various types of consultations, and students have to travel to attend the lecturers between Brno and Prague. The objective was to check the possibility of organising consultations in the form of audioconferences. Resultion sessions are of sufficient quality for this type of applications. The testing was carried out by Mr. Ing. Svatopluk Ondra on the side of Theresias and Mr. Ondřej Franěk representing TEREZA.

Another special support concerned the solution for the needs of a research project of FRVŠ *Philosophy and Methodology of Science* (research leader: Doc. Pstružina), where the requirement was "to provide videoconference support for consultations within distance studies in arts".

Requirement in this case was a multipoint videoconference for a small group of up to ten members, with minimum expenses. In addition, it was necessary to ensure easy installation and operation of the videoconference product, even for a user without technical skills. The proposed technology was supposed to also be used for low-capacity lines.

We are convinced that the tasks have been successfully fulfilled – we have chosen *iVisit* as our basic videoconference tool. Users managed to install and activate their videoconference products, and to communicated repeatedly (audio, video, text) with the consultant, irrespective of the type of their communication line. The consultant managed to control the group effectively, fulfilling his pedagogical goal.

We published details about the solution in technical report No. 17/2002. The aforesaid research task also created opportunities for the recording video and audio conferences and seminars using digital technology, editing, finalisation and distribution of the digital recording.

In addition, we cooperated with two teams involved in natural sciences. The first was the *Laboratory of Structure and Dynamics of Biomolecules (LSD-Bio MU)*. This centre operates at a top European level, with a number of international contacts. The objective was to help in the use of a reflector and MBone tools. At present, the team is using the system in the Czech Republic, and next year, we plan to share 3D applications among more points and to communicate with partners in Japan. Both topics will help us introduce new innovating elements in our communication system.

Another group involved in this area was the team of *Computer Image Processing in Optical Microscopy*. Our aim was to enable communication between FI MU, Biophysical Institute of the Czech Academy of Science and centres at Heidelberg University. The system has already been working in the Czech Republic. Next year, we will assist in the connection and support of Heidelberg locations and solving of problems concerning sharing microscope outputs.

In the long term, we also support communicating groups within a research plan, i.e., our traditional partner – Czech section of the *DataGrid* project – and now also the IPv6 project. Researchers working on the project are also using routinely the videoconferencing tools.

6.3.6 Access Points for Communicating Groups

During work on a videoconference portal, adjustment of mirrors and their use by various groups, a group of communicating individuals and a group of communicating groups tackle qualitatively different problems. We therefore carried out an information search on this issue and selected the technology of *Access-Grid (AG)* nodes for further research.

AccessGrid is an integrated set of software and hardware resources, supporting human integration with the use of a grid. The main objective is to ensure that the integration is as natural as possible. This is enabled by tools for the transmission of video and audio signal, presentation sharing, visualization tools and programs which control the integration process. More participants in a videoconference room, and an emphasis on presentation and on sharing visualized tools, require more projection technologies, cameras and a higher quality of sound processing, i.e., more computer technologies for coding/encoding of image and sound.

It is obvious from the required characteristics of AG that the volumes of data exchanged along the network will be significant and that the minimum acceptable connection of the entire AG is 100 Mbps, with individual AG components connected with a fully switched link of 100 Mbps. AG makes use of the service offered by the MBone network, wherever it is available. Otherwise, bridging was provided to the nearest available MBone node. Wherever it is impossible to make use of bridging, a mirror is used (UDP Packet Reflector), similar to that described above.

Video is therefore developed on tools with the H.261 protocol and as regards the quantity, it is necessary to be able to accept, process and present at least 18 × QCIF (177 × 144 pixels) and 6 × CIF (352 × 288 pixels) and read, encode and transmit 4 × CIF. Transmission is carried out using the RTP protocol.

It is necessary to make sure that the audio section can accept, decode and present at least six 16-bit 16 kHz audio-streams and accept, encode and send one audio stream of the same quality. It is necessary to realize that echo and other sound effects may become a problem inside a room. The quality of the outgoing sound must be ensured with suitable equipment – from microphones to echo-cancellation devices.

Presentations can be shared with the use of *MS PowerPoint*, enabling users to control PowerPoint applications within more remote computers in the server–client mode. Progress of computation or dynamic visualization can be shared using the *VNC (Virtual Network Computing)* tool. This system allows to display of the desktop of a remote computer or share this desktop with more users, independent of the operating system and architecture. VNC contains two components: the image-generating server and a viewer, presenting the image on the screen of a connected client. The server may be run on architecture different from that of the viewer. The protocol connecting the server and the viewer is simple and platform independent. No status is saved in the viewer, which means that in case of an interrupted connection, no data get lost and connection can be restored again.

AccessGrid nodes form a worldwide network concentrated particularly at locations with grid infrastructure and at places of “big” users, i.e., particularly the high energy physicists and astrophysicists. At present, there are 132 nodes in operation, of which more than 40 serve for international communication. None of them has been installed in the Czech Republic, as of yet. The nearest nodes are at TU Berlin and CERN. In addition, a new node is being constructed in

Figure 6.3: Visualization of outcome and beginning of AccessGrid Node construction at FI MU.

Poznań. During the time of this report, the Laboratory of Network Technologies, Faculty of Informatics, MU Brno has been undergoing some reconstructions, with an AG node installed including a 3D projection. We are also preparing the implementation of a minimum mobile node. These installations will enable to master complicated technologies of AG nodes by the development and user team, not only in the area of grid computing.

6.4 Special Projects and Events

This year, we have supported several special events.

6.4.1 Peregrine Falcons in the Heart of the City 2002

We resumed the support of similar projects pursued in the past (*Peregrine Falcons in the Heart of the City 2001*, *Millennium Young*, *Kristýna Live*, etc.). These are projects organized by Czech Radio, also connected with the CESNET association. This enabled us to cooperate more intensively.

The goal of the project titled *Peregrine Falcons in the Heart of the City 2002* was to draw the general public in the project and inform them about the protection of rare and endangered peregrine falcons and predators in general. In addition to video transmission, the project also resulted in a number of articles (e.g., Datagram No. 3), presentation of CESNET in connection with this project in propagation materials of Czech Radio, during broadcasting of Czech Radio and references in professional publications about the monitoring of endangered species in the nature.

The project also enabled us to verify and adjust the filtering mechanisms of the new system for the analysis of IPv4 operation (high attendance from all over the world, usually several thousand accesses a day). For more details concerning the project, visit *http://www.cro.cz/sokoli/*.

Figure 6.4: Example of broadcast from peregrine falcon's nesting

6.4.2 Live Broadcasting of Public-Service Media

The collaboration with Czech Radio, we continued predominantly in the area of audiostreaming. The objective was to design and implement a system which would enable non-stop live broadcasting of Czech Radio stations via the Internet, at a very high quality.

Czech Radio runs a live Internet broadcast of its largest stations, with the use of Real Audio and Windows Media technologies, at speeds of 10–32 kbps. This speed does not enable broadcasting at high sound quality. During 2002, the CESNET association and Czech Radio concluded an agreement concerning their mutual collaboration in the development of an experimental system which will enable live broadcasting of Czech Radio stations via the Internet at a high quality.

After the evaluation of the required objectives, we decided to implement the entire system on the basis of the technologies for audio signal broadcasting in the MPEG compression formats (MP3) and Ogg, with the bandwidth of 128 kbps. For these purposes, we made use of the *Icecast2* application server and the *DarkIce* coder. Both applications are developed as open source projects so they are free to use. The resulting audio signal suffers from a certain loss due to the compression algorithm; however, it is almost impossible to recognise between this signal and the original one.

At present, the entire system is running on two servers located within the premises of the CESNET association. The encoding server (configuration: DELL PowerEdge 2600) serves as a stream producer. There are tuners connected to the sound card inputs, tuned to the broadcasting of the following stations:

ČRo1 – Radiožurnál and ČRo3 – Vltava. The input sound signal is processed by the DarkIce application, for the reading, sampling (44.1 kHz, 16 bits, 2 channels), encoding simultaneously in both required formats (MP3 and Ogg) and broadcasting on a streaming server.

The streaming server (configuration: DELL PowerEdge 350) operates as a server for the connection of individual clients who wish to receive the broadcast. The server now receives four input streams from the coding server and provides stream distribution to the connected clients. Data are transmitted in streams with a bandwidth of approximately 128 kbps. For comparison – the transmission of the same uncompressed signal, it would be necessary to provide a channel with bandwidth of 1,411 kbps.

Clients connect using links on WWW page of the streaming sever. CGI scripts behind the links will send a response to the client, with a header according to which the user's sound player will automatically run, i.e., receive and play the stream.

We decided to broadcast in two formats, as MP3 is now the most popular format in the world and it is automatically expected to be used. The second format, i.e., Ogg, is rather new and it can be considered the format of the future. It has been developed as an open source project, and it is therefore not subject to any licences, unlike MP3. In addition, we consider it to be more sophisticated, as it reports comparable or even better sound characteristics with the same or lower bandwidth. The Ogg format is now supported by the most widespread sound players (e.g., *xmms*, *winamp*, *zinf/freeamp*).

The stream in MP3 is broadcast at a constant bit rate (CBR) of 128 kbps. The stream in the Ogg format is broadcast at a variable bit rate (VBR), with the centre oscillating around 128 kbps. This technique enables us to increase the quality, as with a thinner frequency spectrum and low dynamics of the actual coded signal, the coder generates less data, while with a dynamic signal and wide frequency spectrum, the coder may use higher data rates.

The entire system is now in the stage of verification. We expect Czech Radio to place links to this experimental high-quality broadcasting at its website with live broadcasting and then we will be able to check the operation of the system under heavy load. The entire system is designed as adequately robust, with the possibility of simple extension in case of its application in the production mode.

Finally, we would like to replace the acquisition of input signal from the existing tuners with the direct link input from the master control room of Czech Radio. Thus we would achieve the quality known from CDs and reach higher quality compared to that of classical tuners/radios. To achieve this, it will be necessary to move the coding server to the premises of Czech Radio and make fixed band-

Figure 6.5: Set of tuners and servers in rack

width reservation on Czech Radio's Internet connection with streams broadcast to the streaming server in CESNET.

During the following period, we will extend the existing system configuration and introduce the processing and broadcasting of other Czech Radio stations. After we launch an experimental operation of the system, we expect the number of listeners to increase significantly (i.e., clients connected to the server), and therefore increased load of server.. We intend to elaborate a methodology for the measurement and evaluation of the results acquired in the actual operation.

Furthermore, we expect further development of the navigating and documentation Web pages for this part of project, where we will also promote the progressive format – Ogg. We would also like to carry out an experimental implementation of the Audio-on-Demand service, which would allow to broadcast a required programme (usually radio news) at request.

We will also devote our attention to verification of new coding and transcoding technologies, which could be used for the system operation – e.g., for transmission of streams at various speeds and bandwidths.

6.4.3 Support of Special Events

Among other events which we helped organise or support, there are:

- *Open Weekend II*, second series of lectures focusing on security in open systems (Prague),
- *Genetics after Genome EMBO Workshop*, a conference concerning genetics (Brno),
- *ISIR*, an international symposium concerning intervention radiology (Prague).

During these events, CESNET provided connectivity and project researchers implemented audiovisual transmission in collaboration with project *Platforms for Streaming*.

6.5 Future Plans

Project is aimed to further develop a system for the support of long-distance collaboration using multimedia applications, with different requirements on quality of audio and video transmission. The purpose is utilize further development of videoconference systems, video tools and tools for desktop sharing, and cover various areas of collaboration, from cooperating individuals to interconnected specialised centres.

We plan to continue in further solution of issues solved in 2002. We would particularly like to focus on the following areas:

- Platforms for the transmission of audio and video signals at a high quality. We will select the suitable platforms for the transmission of AV signals at high quality, in order to use these technologies for the connection of Access Grid Point, videoconference and lecture rooms.
- 3D imaging and synchronized broadcasting. We would like to check the interoperability with the existing implementations in *vic* with H.261 and H.363 protocols and with the use of the *RUM* reflector. In addition, we plan to check the possibilities of a 3D output from specialised programs for scientific computing.
- Support for pilot groups using videoconference tools. As during the previous period, we would like to ensure close collaboration and support with selected groups of users. We plan to suggest an effective form of feedback, indicating the problematic points in the use of videoconference tools and enable their targeted modification.
- AGP and Personal Interface to Grid (PIG) and their use for teaching purposes. We will complete the realization of AGP and PIG at FI MU Brno

and transfer the solution to an operating mode. We will become actively involved in the worldwide network of AGP nodes. We intend to make out a set of tests for 3D projections with the use of the *RUM* reflector. We also aim at optimising individual scenarios for the use of rooms, with respect to the current potential of the installed technology.

- Network support for group communication. As regards MBone tools and the *RUM* reflector, we are considering the possibilities of integrating all the existing adaptations in a unified code. We intend to carry out further improvements of the mirror, e.g., controlled combination of more video streams in a single image, streaming of videoconferences in progress, possibility of videoconference recording, switching streams between individual conferences and their duplication as a preparation for the mode of directed videoconference. Moreover, we are planning to support IPv6, to upgrade hardware in use and to measure performance and scaling of individual versions. As regards the H.323 infrastructure, we will complete the stipulated tasks.
- Systems for the support of collaboration. We plan to complete the existing portal for the support of videoconferences with other elements supporting team collaboration (calendar, sharing files, contacts and bookmarks, integration of discussion forum, procedure planning, monitoring of task status).
- Support building of AGP and presentation rooms. During the following period, we intend to make even stronger efforts in order to support building of at least one more AGP room. The construction of such a room will be necessary for further development of used technologies. In this respect, our support will consist of education, assistance for design and selection of components and activation of these rooms.

7 MetaCentrum

The objective of the MetaCentrum project is to develop the infrastructure of the academic high-speed network and extend it with the support of applications that require extensive computing capacities. The aim of MetaCentrum is to interconnect the existing computing capacities of the largest academic centres in the Czech Republic and ensure their further expansion.

The systems administered by the project form a virtual distributed computer, recently also referred to as the *Grid*. The purpose of these activities is to liberate users of irrelevant differences between individual particular systems, forming the Grid, and to enable their synchronous utilization and thus provide a computing capacity exceeding the potential of individual centres.

The project includes an operating section, responsible for the functioning of the infrastructure, and a development section, in which new methods and techniques for the generation and support of Grids are developed and tested. The project also includes support for international activities of the CESNET association and other academic subjects, particularly with respect to the involvement in the 5th EU Framework Program. For information concerning MetaCentrum, including access to all administrative functions, visit the MetaCentrum portal, available at *meta.cesnet.cz*.

The following centres were incorporated in the solution of MetaCentrum project in 2001:

- Institute of Computer Science, Masaryk University in Brno
- Institute of Computer Science, Charles University in Prague
- Centre for Information Technology, University of West Bohemia in Plzeň
- Computing Centre, Technical University of Ostrava

Except for the last centre, all the previously mentioned centres contribute with their computing capacities, particularly large computing systems from SGI and Compaq.

7.1 Operation

The computing capacities of MetaCentrum are situated in the following four localities and three cities: Brno (ÚVT MU), Prague (CESNET and ÚVT UK) and Plzeň (CIV ZČU). The systems at ÚVT MU, CESNET and CIV ZČU are directly connected to the high-speed backbone of CESNET2, via a reserved line, with the capacity of 1 Gbps. The systems at ÚVT UK are directly linked to the PASNET metropolitan network and further to the backbone of CESNET2.

The actual computing capacity of MetaCentrum is formed by clusters and Intel Pentium processors (architecture IA-32), purchased in 2000 and 2001 (in 1999, a high-capacity tape library was purchased, providing a total of 12 TB online uncompressed capacity for data backup for all nodes of MetaCentrum). All clusters include dual-processor units in rack design, with the capacity of 1 GB central memory per unit. Each cluster is formed by 64 Intel Pentium III processors, with a frequency of 750 MHz and 1 GHz. The capacity of the disk is 18 × 9 GB and 18 × 18 GB.

At the turn of 2002/2003, a new cluster will be supplied, again with 64 processors in a dual CPU rack design (height 1U), with Intel Pentium 4 Xeon processors, frequency 2.4 GHz and the disk capacity of 18 × 36 GB (the price for each cluster is gradually decreasing, even though the performance and the disk capacity increased, as well as the capacity of the network connection – see below). This cluster is produced by HP (same as the cluster purchased this year); however, there were some complications concerning the delivery period this year.

In 2001, 128 cluster processors were divided among ZČU, CESNET and MU, in the ratio 32:32:64. Towards the end of the year, 32 of the processors purchased in 2000 were moved to Prague and new processors will be installed in Brno. In 2003, the distribution of MetaCentrum's performance will be 32:64:96.

Even though these systems are physically separate, all clusters will be logically equipped with the same version of Linux OS (distribution Debian) and administered by the PBS system. In early 2002, a licence was purchased (using the MU funding) for the extended version of PBSpro, which is gradually replacing the previous PBS system (complete replacement will be finished in 2003). All cluster nodes are separately addressable and accessible directly from the Internet. However, extensive (long-term) utilization of the nodes is possible only through the PBS system, in order to enable optimal planning of resources.

All cluster nodes were equipped with Fast Ethernet interfaces (100 Mbps). For high-speed transmissions, there were Myrinet high-speed networks available in Brno and Plzeň (always 16 nodes) and a Gigabit Ethernet (16 nodes in Brno). The PBS batch system also enables the selection of nodes with a particular high-speed interconnection, and users can thus easily choose the required characteristics without having to know the exact placement of particular nodes.

In the cluster purchased in 2002 (to be installed in 2003), each unit includes two integrated Gigabit Ethernet interfaces. We therefore decided not to extend the Myrinet network and purchased HP ProCurve 4108gl switches with 90 GE interfaces. Together with the existing GE switch, this will enable us to link all 48 units (96 processors) in Brno to the GE network (of this, 32 units will be linked through dual GE connection). We will thus create the largest cluster in the Czech Republic with such a fast interconnection.

In addition to PC cluster, we purchased the first server with a 64-bit architecture in 2002 (IA-64) by Intel, with 2 Itanium II processors, 6 GB central memory and a total of 100 GB of directly connected disk capacity. The server was produced by HP which supplied it in a fully functional configuration only by the end of the year. In 2003, we will connect the server to the infrastructure of MetaCentrum and provide access for the Czech academic community, so that those who are interested in this architecture can test it before purchasing their own.

This approach has already proven practical with previous clusters, when the Faculty of Natural Sciences, MU Brno purchased its own cluster with 80 processors (also Intel Pentium 4 Xeon), based on their experience with the utilization of MetaCentrum clusters. Like a similar cluster in Plzeň, this cluster will be fully integrated in MetaCentrum and administered analogically to other computing sources.

In 2002, the backup capacities of the large-volume tape library in Brno were further used. Regular backup is carried out with the use of the NetWorker system by Legato. The backup includes all systems of MetaCentrum, and the transmission capacity of CESNET2 is still sufficient, even despite the increasing volumes of backup data. The capacity of the tape library is currently used at over 75 %.

The infrastructure provided by MetaCentrum also includes basic software. A full and up-to-date summary is available at the website of MetaCentrum. We have already purchased, and we now keep updated, particularly, compilers by Portland Group (predominantly the important Fortran compilers, used for a significant part of the used application software), debugging and tracing tools for parallel programs running on clusters, i.e., TotalView, Vampir and Vampir Trace by Etnus, and Matlab – an extensive package for engineering computations. MPI is also a necessity, both in the form of free versions (LAM and MPICH) and commercial versions MPIpro, with Myrinet controllers.

MetaCentrum has still been using the AFS system of files; however, we are currently using the Open Source version almost exclusively (OpenAFS).

7.1.1 Security

Authentication of users within MetaCentrum is provided by the Kerberos 5 system. In 2002, we carried on with full integration of the used instruments and the Kerberos system, and with the transparent interlinking of Kerberos and PKI systems (based on certificates). MetaCentrum makes use of CESNET's certification authority, enabling direct access for users who have its valid certificate.

During 2002, individual nodes of MetaCentrum were upgraded to the new versions of the Heimdal system (non-US implementation of Kerberos 5, in which members of MetaCentrum are involved) and the OpenSSH system (3.4).

7.1.2 Information Services

MetaCentrum runs a MetaPortal at *meta.cesnet.cz*, providing general information to users and the public in its open section, as well as specific information for users and administrators in an authenticated section. In line with the price policy of MetaCentrum, authentication is carried out through the Kerberos system. There are also extensions available for the Mozilla viewer, able to make use of the user's active tgt ticket for purposes of authentication.

For primary storage of information, the website of MetaCentrum makes use of the CVS version of administering system. The web pages are generated from these data (on request or automatically). This enables us to also provide an effective approach to semidynamic data where pages are not generated for each access, but only after a change in the primary "database".

The information structure is based on the "kerberized" openLDAP, what has been fully functional and in operation since the second half of 2002. This system provides access to all dynamic information and user data. We have also tackled problems associated with data replication and backup. The results described in the technical report will be applied during the year 2003.

By means of MetaPortal, users gain access to all personal data that they provide. Users can thus check all their data through MetaPortal, together with the necessary updates and corrections. Users can also select systems to which they wish to gain access within MetaCentrum.

The validity of accounts is limited to a single year. It is possible to extend it with the use of MetaPortal (users need to write a short message and confirm their personal data. Without this, accounts cannot be extended).

The administration of personal data and account details is provided by the Perun system, fully developed within MetaCentrum. In 2002, the development continued, particularly in its administration section, used by the administrators of individual nodes, together with the full integration with the openLDAP infrastructure. At present, the system allows for distributed confirmation of an application for a new account, authorization changes, and checking and extending accounts and other activities, including notifications of pending requirements.

7.2 Globus, MDS and International Activities

We have installed the Globus[10] system version 2 within the main MetaCentrum systems and activated its MDS information system, version 2.2. The Globus sys-

[10] *http://www.globus.org/*

tem forms the basic infrastructure for remote task running, which makes it possible to interconnect our computing capacities in extensive international Grids. The security of the Globus system is based on PKI (we have already solved its linking with the Kerberos system). MetaCentrum provides much more extensive services than Globus, which is therefore not used internally.

In 2002, MetaCentrum supported several international activities, both within CESNET and for its members. Among the most important projects, there is the participation in the DataGrid project (see a separate section devoted to this issue), and the support of the GridLab project (solved at ÚVT MU, see *www.gridlab.org*) and the involvement in experiments within the international conference SC2002. In 2002, the conference was held in Baltimore (USA, Maryland) and as usual, there were several challenges announced. MetaCentrum, or its nodes, participated in two groups: the so-called High Performance Computing Challenge and the High Performance Bandwidth Challenge (see also *http://scb.ics.muni.cz/static/SC2002*).

The High Performance Computing Challenge included three sections:

- Most Innovative Data-Intensive Application
- Most Geographical Distributed Application
- Most Heterogeneous Set of Platforms

We took part in the challenge as part of a team, headed by Prof. Ed Seidel, Albert Einstein Institute for Gravitation Physics, Potsdam (Germany), taking care of the security of Grid. We succeeded in creating a Grid of 69 nodes in 14 countries, with 7,345 processors, of which 3,500 were available for the purposes of the experiment. PlayStation 2 was also one of the nodes, with installed Linux OS (in Manchester). For the geographic locations of this Grid's nodes, see Figure 7.1. Application used consisted of a distributed computation of certain black hole characteristics. Thanks to this Grid, we won two out of the three categories given above, i.e., the most distributed application and the most heterogeneous Grid.

The objective of the *High Performance Bandwidth Challenge* was to demonstrate the application requiring the largest data flows at the conference site. There were 3 × 10 Gbps available. The team was led by J. Shalf from Lawrence Berkley Laboratory (LBL), making use of the same basic application as described above, only that this time, the application was used as a generator of primary data for visualization – the data sent were unprocessed and rendered directly on site with the use of a cluster with 32 processors (each processor with 1 Gbps connection, the theoretical capacity was therefore 32 Gbps).

The data were primarily generated by large LBL and NCSA computers in the US, plus two systems in Europe: in Amsterdam (Holland) and Brno. While the Amsterdam cluster made use of a reserved transatlantic line (with a capacity of 10 Gbps), data from Brno were transmitted with the use of CESNET2, Géant

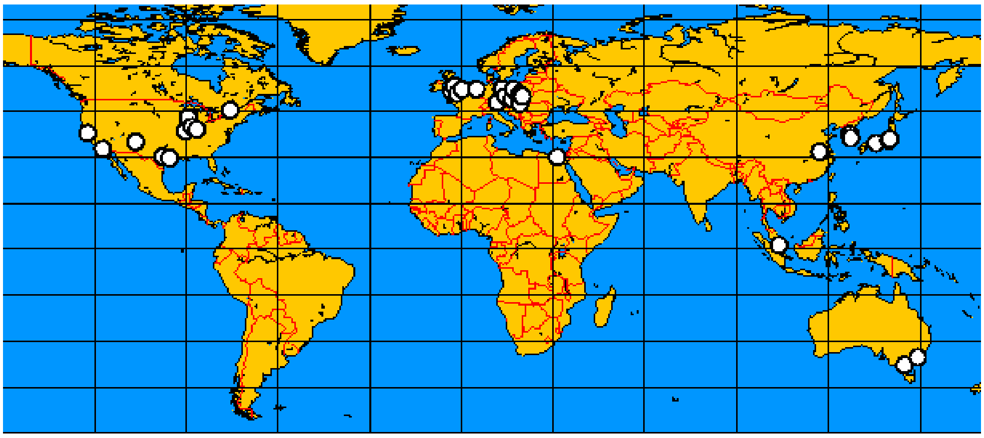


Figure 7.1: Grid nodes for SC2002

and Abilene networks. Instead of a reserved IP service, we decided to make experimental use of the LBE (Less than Best Effort) service, which allows for data to be sent with maximum speed (without protection from congestion), and the network itself will drop out some data in case that the line gets overloaded. The application made use of the UDP protocol and the used real-time visualization is not actually prone to occasional data dropouts (human eye is not able to notice short-term dropouts, while long-term dropouts can be approximated thanks to data from other sources).

Thanks to help of the CESNET operating team, we installed a three-port GE card in the PoP node of CESNET2 in Brno, and connected it with the cluster, which thus reached a theoretical external connectivity of 4 Gbps. In addition, we temporarily upgraded the Prague–Frankfurt international link to 2 Gbps. Within the experiment, the team succeeded in generating a persisting flow of 2 Gbps between Brno and Baltimore, over a period of two hours (for the load of CESNET2 lines, see Figure 7.2). This represented almost 12 % of the data flow of 16.811 Gbps with which the team won.

7.3 Users and Computation

For a complete review of users, distribution of the utilization of MetaCentrum and other parameters, see the MetaCentrum Yearbook for the year 2002, which will be issued during the first half of the year 2003. At present, only the Meta-Yearbook 2001[11] is available; however, the overall trends are similar to those in 2002.

At present, MetaCentrum has approximately 200 active users, administered in three administration nodes at ZČU, UK and MU, roughly at a ratio of 1:2:3. The biggest users are members of the Czech Academy of Science and MU Brno

[11] *http://www.meta.cz/yearbooks/*

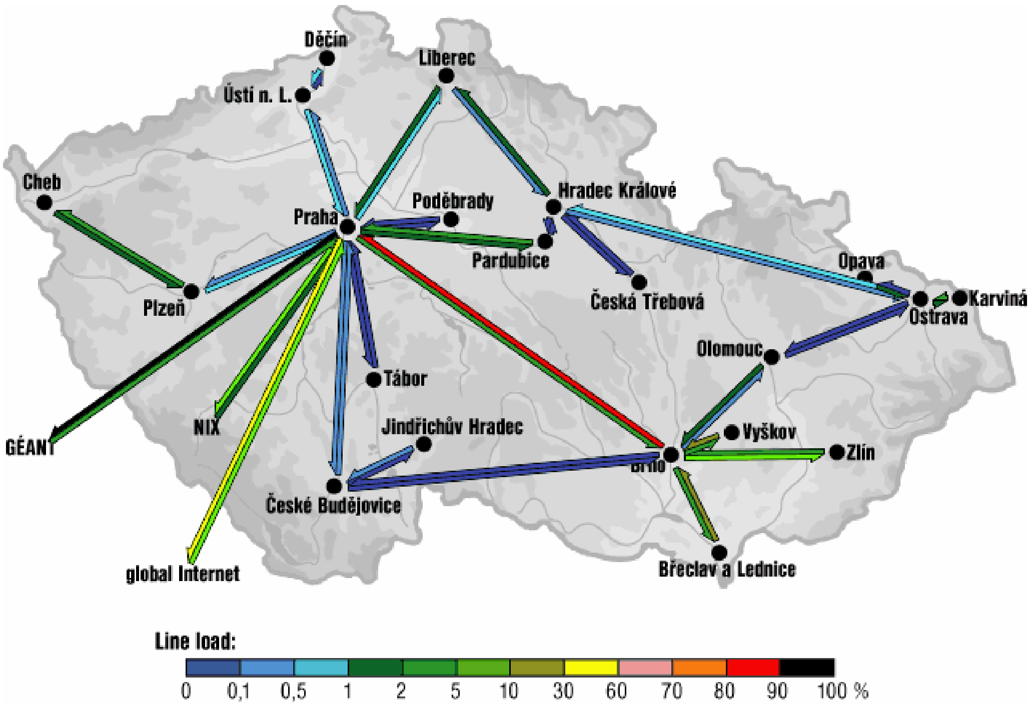


Figure 7.2: Load of CESNET2 during SC2002

(both approx. 1/3 of the overall capacity of MetaCentrum, the third biggest user is UK with approx. 1/6 of the overall capacity). On the other hand, MetaCentrum sources are not much used by students and employees of technical universities (particularly ČVUT and VUT). We have focused on this situation in 2002, based on close collaboration with the University of West Bohemia in Plzeň. We decided to check the applicability of MetaCentrum (particularly its clusters) for the solution of significant technical tasks, in order to make use of the outcome for propagation among the community of users from technical universities.

In November and December 2002, we carried out testing of the performance of MetaCentrum PC clusters, with respect to the application of a CFD software package FLUENT 6.0 by Fluent International. This product focuses on simulations in computational mechanics of fluids and some of its parts have already been used in supercomputers or the network of UNIX stations in a parallel run. This product is now also fully tailored for the PC-Linux platform. After its testing, the installation of PC clusters has been rendered for routine use by other users during the first stage, particularly from ZČU Plzeň.

Before testing, we had examined – since autumn 2002 – the possibilities of FLUENT concerning parallel and distributed run on PC clusters of MetaCentrum. Based on the given knowledge, we made out suitable tasks in collaboration with Škoda Auto a.s. Mladá Boleslav and NTC ZČU Plzeň. We also obtained, in collaboration with with TechSoft Engineering, s. r. o., a supplier of FLUENT, an unlimited number of licences for FLUENT, valid over a limited period of time

(December 2002). This was one of the main prerequisites for the testing, as during parallel run, each processor participating in the computation allocates a single floating licence. TechSoft Engineering expressed an interest in the testing and its outcomes and we expect that the response will not be limited to the country itself.

The tasks that we have prepared represent a certain portfolio of typical tasks of various complexity. The largest task concerns the simulation of the external aerodynamics of Škoda Fabia Combi, with the computational grid comprising 13 million 3D cells. This grid was created on the supercomputer Compaq GS140 at ZČU Plzeň. For the purpose of solving this task, it is necessary to have approximately 13 GB of memory, which exceeds the capacity of the supercomputer described above. This task is demanding even on the global scale. Other tasks are less demanding, however, their parameters rank them among the type of tasks that users usually do not encounter.

We made use of FLUENT 6.0.20, installed on an AFS cell of ZČU Plzeň. During the testing, we monitored the computing time of a single iteration (due to a lack of time, only several dozen computations were carried out, not always the entire task), the task load time for the metacomputer of a selected configuration and, in some cases, also the start-up time of FLUENT on the metacomputer. During distributed run, FLUENT can be set up with different communication protocols, which is why we also changed these parameters during the testing. For the *nympha* cluster (in Plzeň), we had to carry out a downgrade of drivers for special Myrinet communication cards, version 1.5, as FLUENT with upgraded drivers installed originally (1.5.1) refused to cooperate.

It was our original intention to make use of the PBS batch system for the administration of the testing tasks running on PC clusters; however, we succeeded only in a part of the tests. The main reason was in the use of the openPBS version, which does not provide for running tasks with the support of Kerberos (this is solved within MetaCentrum by the PBSpro batch system), we therefore had to make use of ssh, instead of (Kerberized) rsh. However, Network MPI and Myrinet MPI communicators failed to function in FLUENT, which is why we carried out some testing outside PBS, when part of PC clusters was in a special mode.

We also witnessed failure in the case of some testing, which we wanted to have processed through the PBS system, with the use of a larger part of PC clusters: PBS allocated the number of nodes correctly but the task did not start up and the testing was not initiated. Also, in this case, we carried out testing outside PBS. This problem was also related to situations when we needed eight and more nodes from each cluster (concurrently in Plzeň, Prague and Brno). We made use of the results of this testing while debugging the PBSpro system, so that the new version of the used batch system is free of such problems.

In version 6.0, there was some news that we wished to also test in the extensive distributed environment of MetaCentrum PC clusters. This includes the possibility of using what is known as “dynamic load balancing”, which will allow for reasonable utilization of the available sources in case of an nonhomogeneous computational environment (as regards the performance).

Tasks are loaded by FLUENT on individual computing nodes, each node is allocated a part of the task of an identical volume. The problematic situation (typical for MetaCentrum clusters) is when the performance of allocated computing nodes differs. The entire computation waits after each iteration in the computation convergence process for the weakest node and the computation is therefore delayed.

With the use of the dynamic load balancing, FLUENT ensures a relative capacity of individual nodes and reorganizes task allocation, so that the computing time is identical within individual nodes. Unfortunately, we found out that this method is not functional within Fluent version 6.0, notwithstanding the fact that it requires the use of a graphic user interface, which is inconvenient for practical computations of extensive tasks, administered by the batch system.

Problems were also encountered with testing tasks with approx. 5 million cells, which we made out with what are known as nonconforming network interfaces. For parallel automatic loading to individual nodes, the interfaces should not cause any problems in a case where no network adaptation is carried out. We found out that such automatic task distribution was completed only for one metacomputer configuration, failing elsewhere. This is why no further testing with this task was carried out. This does not mean that it would be impossible to compute the given type of task on PC clusters, it is only necessary to divide this task into a particular number of computing nodes in advance. This is convenient for the computational engineers; however, not for our testing of application performance scaling.

Within a single part of clusters (up to 32 processors) FLUENT reports a relatively good scaling (linear acceleration), even for extensive tasks. After exceeding this limit, computing times shorten slightly (for 40, 48, 56 processors); however, with higher numbers the time increases again and with all the processors used (158), the computing time is worse than with 32 processors on one part of the cluster. The nonhomogeneity of a cluster may also prove to be disadvantageous for the metacomputer configurations, as we used computers with Intel Pentium II processors, 700 MHz, as well as ADM Athlon 1.9 GHz (*minos*, PC cluster at ZČU).

The use of high-speed networks (Myrinet, Gigabit Ethernet) is distinctive, particularly for the start-up of FLUENT and task loading. When we used the standard network communicator (sockets), the FLUENT start-up period for a higher number of linked computing nodes in a metacomputer (over 40 processors) is alarming. In some cases, it reached several hours (approximately 7 hours with the use of 158 processors). When we made use of the Network MPI, FLUENT started up in this metacomputer configuration in several minutes. However, the negative aspect is the longer period of a single iteration, lasting 49 seconds instead of 44 seconds (sockets).

The two Tables show partial results for the extensive tasks, with 13 million cells – car airflow.

Notes to Table 7.1: For the number of 8–32 processors, measurements are carried out at the *nympha* cluster (Plzeň), for 8–15 processors per single CPU on a machine, and further on with the use of both machine processors.

Note 1: For 32–158 processors, there are 4 parts of the cluster *nympha*, *minos*, *skurut*, *skirit*, always evenly distributed number of allocated computing nodes.

Note 2: This configuration is 16 machines by two processors at each of the *nympha*, *minos* and *skurut* clusters.

Note to Table 7.2: For 32–158 processors, there are 4 parts of the cluster *nympha*, *minos*, *skurut*, *skirit*, always evenly distributed number of allocated computing nodes.

We see that the use of Myrinet for the *nympha* cluster is negligible for a small number of CPUs, unlike with a higher number of CPUs (the difference is obvious already with 20 CPUs), when communication is likely to increase during the computation. We have seen the influence of Myrinet when monitoring the time of task loading to a metacomputer, which is up to two times shorter. As regards the overall computing time, this is a marginal aspect.

The Network MPI (i.e., use of MPI through the entire distributed system – with the use of LAM implementation) is worse as regards both task loading and the computation itself. The only positive aspect is the FLUENT start-up time, which is considerably better compared to the socket communication. This is again a rather negligible advantage with respect to a "reasonable" number of CPUs (approx. up to 40) and a usually demanding task (i.e., a task computed over a period of several days).

Due to the low number of measurements, we are unable to formulate more precise conclusions and recommendations – this will be the goal of our efforts in the first half of 2003.

In conclusion, we would like to point out that even a part of a PC cluster, i.e., 16 dual-processor nodes with 16 GB memory, can be used as a powerful tool for highly demanding CFD tasks. The positive aspect is also the possibility of using a supercomputer for the definition of extensive tasks – in come cases, it is impossible to prepare tasks directly in the parallel run of FLUENT (this section has not been parallelized).

Number of CPU	*Sockets*	*Network MPI*	*Myrinet MPI*	*Note*
8	98.431	–	96.206	by 1 CPU
12	–	–	63.701	
16	59.667	–	58.566	by 2 CPU
20	50.095	–	46.915	
24	–	–	39.285	
28	–	–	35.067	
32	–	–	30.936	
32	41.200	48.878	–	see Note 1
40	35.917	43.533	–	
48	33.914	44.238	–	
56	30.700	42.814	–	
64	32.299	44.515	–	
80	29.981	44.553	–	
96	36.767	59.578	–	
96	32.574	47.894	–	see Note 2
112	32.565	49.600	–	
120	41.613	–	–	
140	44.345	–	–	
158	47.046	–	–	

Table 7.1: Time of single iteration for various numbers of CPU (in seconds)

Number of CPU	*Sockets*	*Network MPI*	*Myrinet MPI*	*Note*
8	21	–	11	by 1 CPU
16	20	–	13	by 2 CPU
32	30	37	–	see Note
64	37	45	–	
112	52	58	–	

Table 7.2: Task loading lime (in minutes)

8 Voice Services in CESNET2

The project of *Voice services in CESNET2* is one of the applications for the next generation network (NGN). Its main goal is to create prerequisites for the convergence of voice and data services..

The project includes a research and an operational part. Within the *operational part*, we carry out tasks related to the service operation, connection of new users, availability guarantee, service quality and provision of data for the billing. The project offers an advantage concerning the saving of telephone charges – calls within the CESNET2 network are free. Connection terminated in a public telephony network is charged according to exclusive tariffs. The project generates an advanced experimental platform applicable also for other projects.

The general objective of the *research part* is to verify and develop new technologies. Some of them have already been used in routine operation (e.g., IPTA for billing or the *gk-ext.cesnet.cz* gatekeeper for H.323 logging).

8.1 Conditions for Operation of the IP Telephony Network in 2002

We laid the foundation stones for the IP telephony network towards the end of 1999, interconnecting the central exchange of TU in Ostrava and CTU Prague, through a voice gateway VoGW AS5300 and ATM PVC circuits. In 2000, we used the same technology to connect the central exchanges of Masaryk University in Brno and University of South Bohemia in České Budějovice. In 2001, the ATM PVCs were replaced with autonomous VoGW MC3810. We gradually extended the network by additional gateways and in summer 2001, we carried out a connection through Aliatel – a public telecommunications operator.

The technical solution of interconnection with the public telephony network required no investments by CESNET2 (connected through the NIX.CZ exchange point). We launched a pilot project for calling in the public network in October 2001 at TU in Ostrava and TU in Liberec. In January 2002, the test run was successfully evaluated and we also offered the public switched telephony network (PSTN) access as a service to other members involved in the IP telephony project.

Since 2002, we have been offering calls to PSTN within the IP telephony project, based on a contract concluded with an association member. Contracts are concluded for an indefinite period of time, with a one-month notice period. The call pricelist is an integral part of the contract.

In September, we succeeded in reducing the price and extending the call destinations to sixteen selected international destinations. See the table below for several examples of call charges (a complete price list is available at request). We inform all the connected institutions about any changes in the prices according to the valid contractual terms. The price is charged by seconds, without any minimum charged length.

Prague	420 2	CZK 0.82/min (Mon–Fri, 7:00–19:00)
		CZK 0.52/min during offpeak hours
Austria	43	CZK 1.93/min
US	1	CZK 2.01/min

Table 8.1: Call charges (examples)

Technical conditions concerning the connection to a private branch exchange:

- A branch exchange can be connected only with a digital interface (ISDN BRI, ISDN PRI),
- The exchange must provide the identification of the caller,
- The operator of the private branch exchange (PBX) makes modifications of the charges in the tariff application and in the exchange, authorizing branches for access to IP telephony,
- The terminal point of the VoIP network interface is the voice gateway interface, connection of PBX to the VoIP network interface is carried out by the operator of PBX, the type and the interface setting must be specified prior to the deployment (type of interface ISDN/BRI or ISDN/PRI, Network-side or User-side setup, PRI with or without CRC4).

Technical conditions concerning the connection to a voice gateway:

- Authorized employees of CESNET must have access to the voice gateway,
- The voice gateway must provide information concerning the calls made using the RADIUS protocol,
- The gateway must be compatible with the existing VoIP solution (Voice Gateway on Cisco platform, series AS5300, MC3810, C36xx, C26xx, C17xx).

In addition to the advantages of free calls through the CESNET2 network, entities residing outside Prague can make use of IP telephony to access the PSTN and reach up to a 50 % reduction of the long-distance call charges. Entities in Prague may reach savings of approximately 30 %.

Universities pay for their PSTN calls. A bill is made out on a monthly basis, comprising the overall number of calls made, minutes called and the total amount charged. We provide a detailed summary of individual calls only by request. However, CESNET has the necessary data at its disposal and in case of any

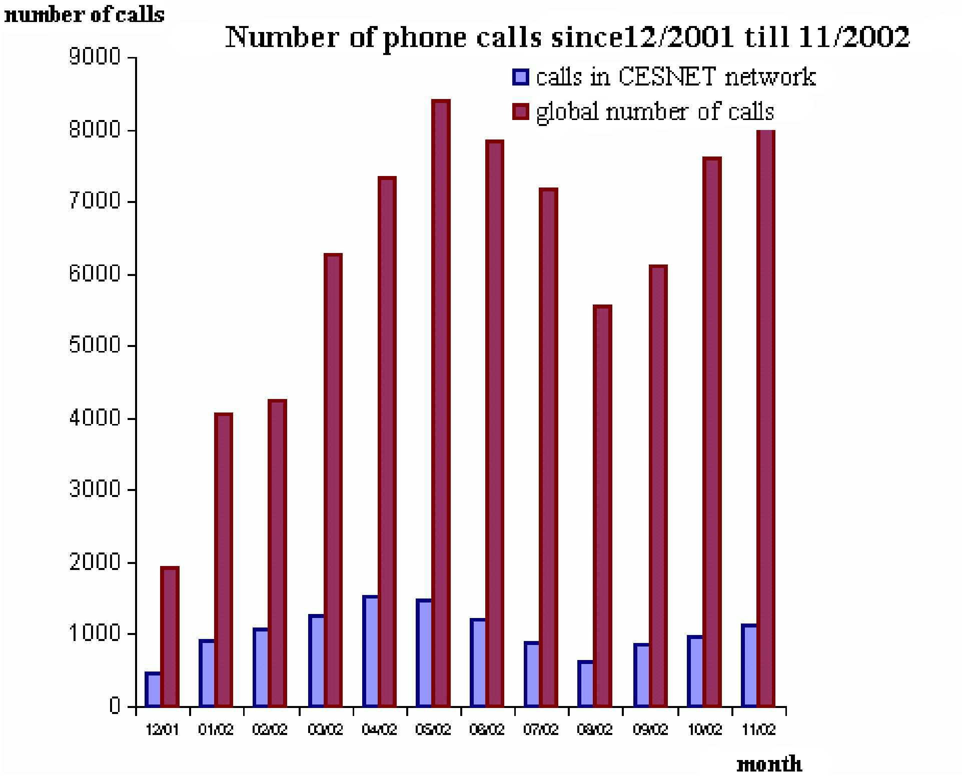


Figure 8.1: Number of phone calls in IP telephony network

discrepancies, we are able to prove present evidence of the amounts charged. CESNET charges no monthly tariff payment or any extra charge on the prices contracted with the public telecommunications operator, it merely re-invoices the cost of calls.

It is necessary to make sure that the connected entity, which makes use of the PSTN calls, has its private branch exchange modified so that it is able to distinguish between charges per individual branches. CESNET will provide the same summary as e.g., Český Telecom.

It is impossible to make calls to mobile networks and/or the special services at 90x.

8.2 Connection of New Organisations in 2002

In 2002, we established connection at the following locations:

- VUT Brno, connected through ISDN/PRI in March 2002
- UP Olomouc, connected through ISDN/PRI in October 2002
- University of Pardubice, Česká Třebová, connected through ISDN/BRI in November 2002

- VŠE Prague, connected through ISDN/PRI in December 2002
- University of Ostrava, connected through ISDN/BRI (to be completed in January 2003)

The project researchers have also participated in the process of connection designing and carried out configurations of the access VoGW. The purchase and selection of a supplier of required equipment is ensured directly by the applicant.

We recommend using an explicit prefix for an access in the IP telephony. In addition, the service availability is being successfully tested in order to allow reliable automatic call routing.

In September 2002, we changed the numbers in the IP telephony network, in line with the changes in the numbering plan of the Czech public telephony network.

CTU/ICHT/CESNET	42022435xxxx
CESNET	4202259815xx
CU Praha, rector‘s office	420224491xxx
TU Ostrava	42059699xxxx, 42059732xxxx
SLU Opava	420596398xxx
SLU OPF Karviná	420553684xxx
University of Pardubice	420466036xxx, 420466037xxx, 420466038xxx
TU Liberec	42048535xxxx
MU Brno	420541512xxx
Brno UT	42054114xxxx
CU FPh, Hradec Králové	420495067xxx
University of Hradec Králové	420495061xxx
Univ. of South Bohemia	42038777xxxx, 42038903xxxx
Univ. of Economics Praha	420224905xxx
University of Ostrava	420596160xxx
PU Olomouc	42058563xxxx, 42058732xxxx, 42058744xxxx
CAS, Inst. of Physics Praha	420266059999
For internal needs	42076xxxxxxx

Figure 8.2: Free inland phone numbers

CERN (*www.cern.ch*)	412276xxxxx
Fermilab (*www.fnal.gov*)	1630840xxxx
SLAC (*www.slac.stanford.edu*)	1650926xxxx

Table 8.3: Free international phone numbers

For the currently valid list of free dial numbers, visit *www.cesnet.cz*.

VoGWs of members involved in the project are usually connected via ISDN, which allows for the storage of detailed records concerning the calls in the SQL database on the RADIUS server. The IP telephony network has been oriented on the H.323 protocol (min. version 2). The internal elements of the VoGW and GK (Gatekeeper) network are based on the Cisco platform, which proved to be beneficial with respect to the extension and management of the network.

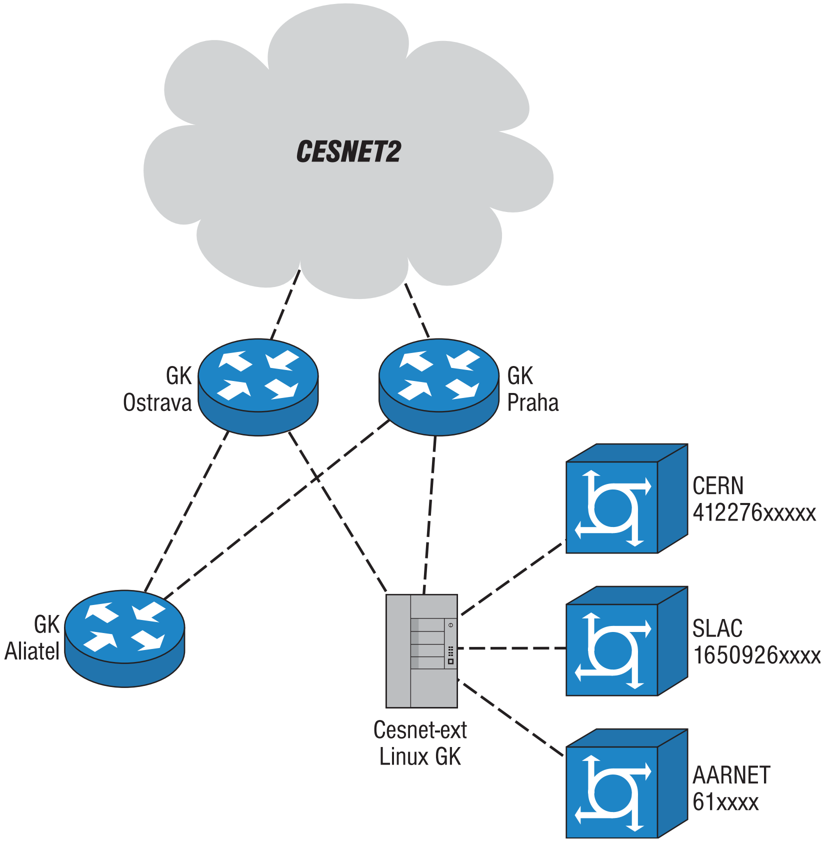


Figure 8.2: Scheme of interconnection among control elements

For purposes of foreign H.323 connectivity of other entities, there is the external Linux GK located in Prague. As regards the hierarchy, this GK is linked over the internal GKs in Ostrava and Prague. Each internal GK is provided with a backup and all GWs in the network log in to both elements with a priority according to their geographic location. In the usual operation mode, logging with a higher priority is active. The requirements for calls outside VoIP network of CESNET2 are rerouted by the Internet (NIX.CZ) to the Aliatel GK.

Figure 8.3 shows a scheme of the IP telephony network. Many thousands of users connected to private exchange branches have access to the services after dialling the required prefix. Dialing in CESNET2 is carried out according to the public numbering plan, in accordance with the valid telephone directory (without 420). For international calls, 00 is dialled before the code of the country, e.g., 0043 for Austria.

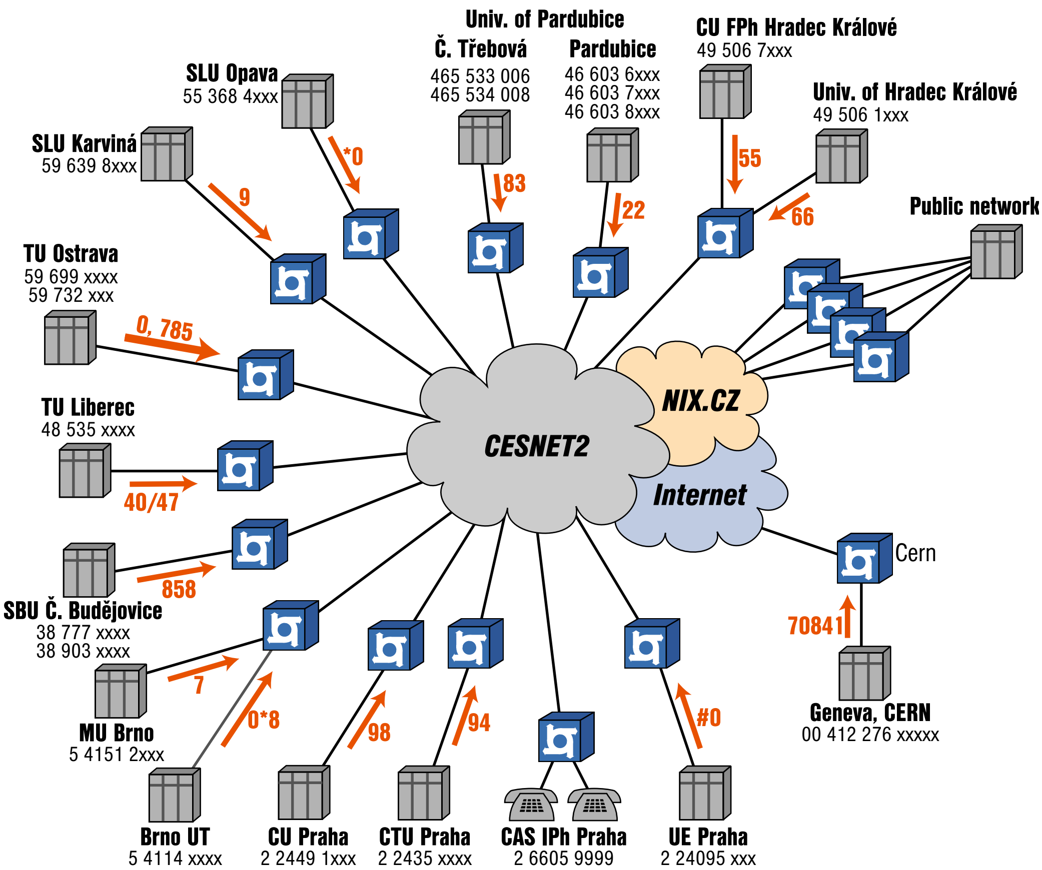


Figure 8.3: Scheme of IP telephony network

8.3 IP Phones Support

During 2002, we further concentrated on the issues of IP phones, based on H.323. For internal needs, we reserved 76xxxxxxxx numbers in the numbering plan of the IP telephony network. In order to increase the availability and security of the service, it is necessary to make use of a distributed architecture of interconnected GKs, forming zones that will refer to redundant central GKs. In case of a failure in the connection at the central GK, calls can only be made within the local zone.

We focused on the testing of convenient GKs, in close collaboration with Kerio, which has been developed the GK application. Kerio provided the GK for use in CESNET's network free of charge. In the laboratories of TU in Ostrava, we tested calls from IP phones among zones formed by four GKs, linked to the central GK at *gk.ext.cesnet.cz*, located at CTU Prague.

We deployed the Kerio VoGW voice gateway for Linux, with a passive ISDN/BRI card connected to the central exchange. Our aim was to find a less expensive connection and compare the features with the existing Cisco solution. The connection was functional, with very good quality of two parallel calls; however, it is not suitable for application in CESNET2 at present. A number of call codecs, series CELP, are not supported; the used ISDN/BRI card made by AVM did not support the DDi prefix but only MSN numbers. The researchers have been further monitoring the development of VoGW solutions for Linux.

Towards the end of 2002, we found an IP phone *LAN Phone 101*, available for a very reasonable price (EUR 150), which appears after initial testing to be suitable for wide use in the IP telephony network. It is produced by Welltech (Taiwan). The set can also be used as an analogue phone, which increases the efficiency of the investment. The phone includes a 10/100BASE-T switch for PC connection. We also found the range of supporting codecs to be surprising (G.711 a/μlaw, G.723.1, G.729, G.729a).

Figure 8.4: LAN Phone 101 – both IP and analogue phone

We have already successfully tested three types of H.323 IP phones:

- optiPoint 300 Advance
- optiPoint 400 Standard
- LAN Phone 101

At present, we are trying to solve the method of authentication, concerning the logging of IP phones in CESNET2 using the H.235 standard.

8.4 IP Telephony Cookbook Project

During the second half of 2002, we joined the international project titled *IP Telephony Cookbook*, organised by Terena. The objective of the project is to create a reference document for experts from Europe's NRENs, concerning the opportunities associated with IP telephony, including recommendations for the selection, configuration and use of individual components.

The project includes seven institutions from five countries. It will last 11 months – from November 2002 to October 2003. The output of the project will be constructed in the form of four documents (deliverables). The last one will be a reference document, including e.g.: summary of technologies in IP telephony, proposal of possible configuration scenarios and instruction for configuring basic and additional voice services, description of integration with public telephony network and the summary of legislative issues. This reference document will be available at *www.terena.nl*.

8.5 IPTA – IP Telephony Accounting

During the previous year, we created our own *IPTA (IP Telephony Accounting)* application, for the purpose of monitoring and accounting in the IP telephony network. The application allows for detailed summaries of calls made by selected customers during a selected period, together with complete summaries. In 2002, we extended the application with new demanded functions. These new functions include:

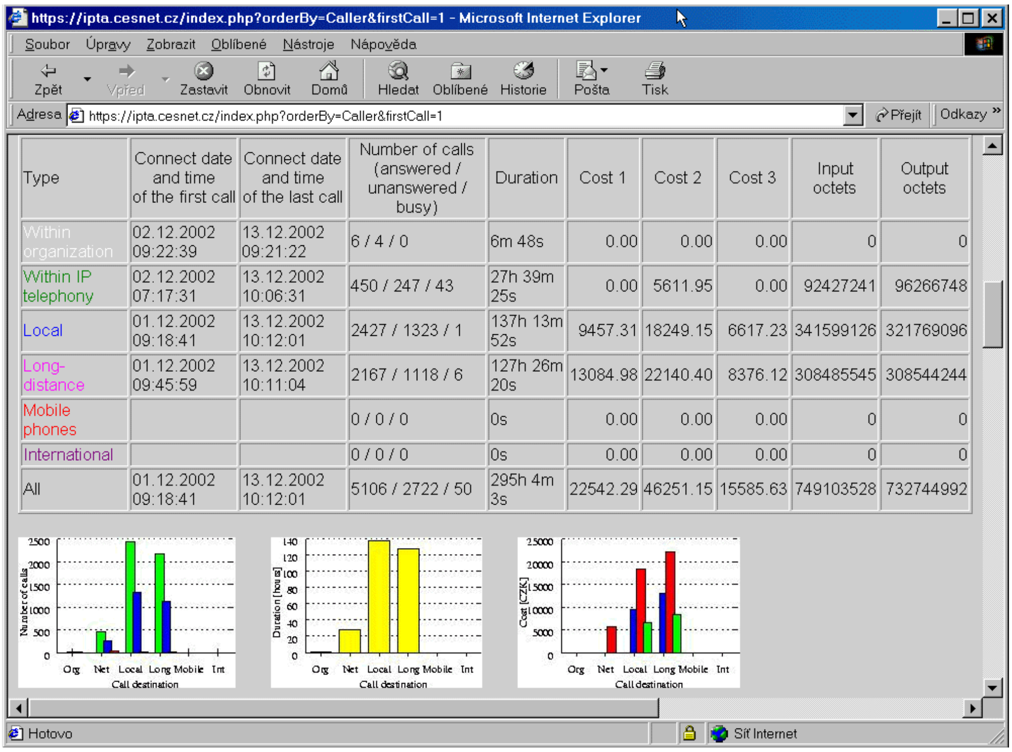
- Statistics of engaged and unanswered calls.
- Statistics of various types of error messages, with the possibility of summaries and deletions, sorted by periods, callers, the called numbers and types of errors.
- Increased reliability of locking data for concurrent access and an increase in the speed of processing call details.
- Graphic illustration concerning individual types of calls (within the IP telephony network, long-distance calls through PSTN, etc.), for individual rates, according to alternative pricelists and depending on the success rate (answered, unanswered). For these diagrams, it was necessary to carry out some internal adjustments in the monitoring application, necessary for further types of graphic outputs, which we wish to apply during the following period.

For a detailed description of the new version of this application, see Technical Report No. 11/2002.

The main features of the monitoring application consist of the following:

- Possibility of parallel application of more accounting plans for their comparison or for the comparison of possible locations of gateways to PSTN.

- Extensive possibilities for the rewriting of the identification of callers and called lines, following the needs of private branch exchanges.
- Graphic presentation of data.
- Monitoring and administration of various types of error and warning messages.
- The application is based on open software – Linux, MySQL, PHP4, Apache Web server.



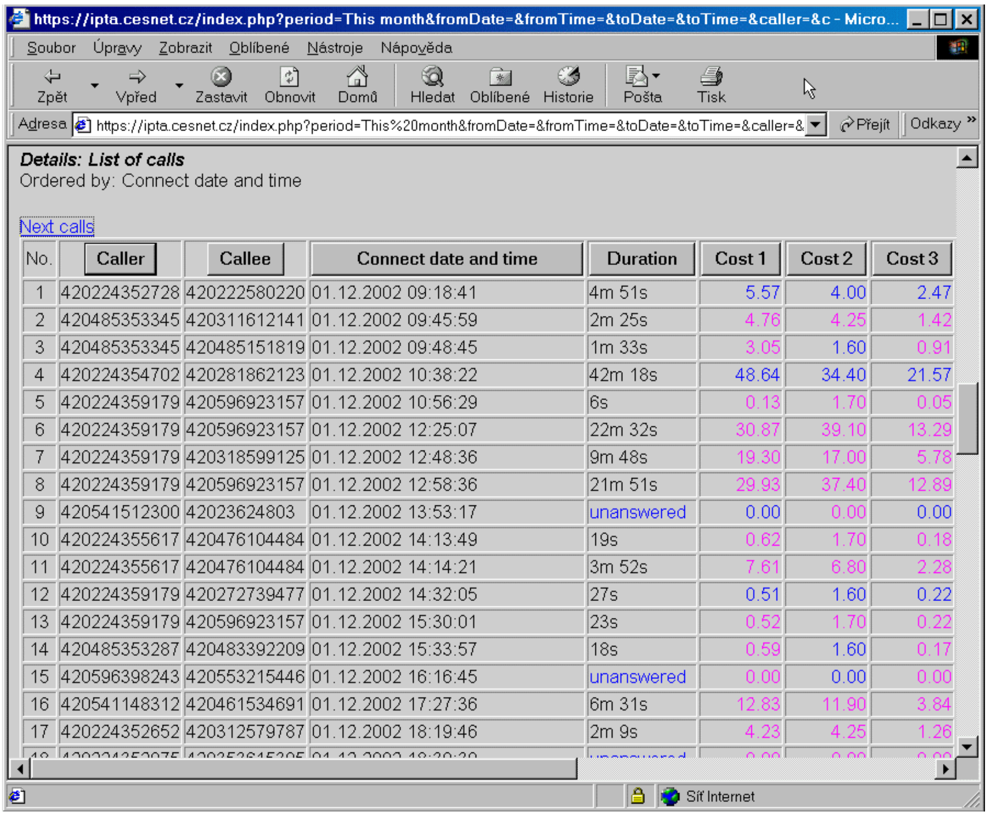
Type	Connect date and time of the first call	Connect date and time of the last call	Number of calls (answered / unanswered / busy)	Duration	Cost 1	Cost 2	Cost 3	Input octets	Output octets
Within organization	02.12.2002 09:22:39	13.12.2002 09:21:22	6 / 4 / 0	6m 48s	0.00	0.00	0.00	0	0
Within IP telephony	02.12.2002 07:17:31	13.12.2002 10:06:31	450 / 247 / 43	27h 39m 25s	0.00	5611.95	0.00	92427241	96266748
Local	01.12.2002 09:18:41	13.12.2002 10:12:01	2427 / 1323 / 1	137h 13m 52s	9457.31	18249.15	6617.23	341599126	321769096
Long-distance	01.12.2002 09:45:59	13.12.2002 10:11:04	2167 / 1118 / 6	127h 26m 20s	13084.98	22140.40	8376.12	308485545	308544244
Mobile phones			0 / 0 / 0	0s	0.00	0.00	0.00	0	0
International			0 / 0 / 0	0s	0.00	0.00	0.00	0	0
All	01.12.2002 09:18:41	13.12.2002 10:12:01	5106 / 2722 / 50	295h 4m 3s	22542.29	46251.15	15585.63	749103528	732744992

Figure 8.5: Example of a complete summary

8.6 SIP Signalling

The IP telephony network within CESNET2 was constructed on the basis of the H.323 signalling protocols. In order to provide access also to users making use of clients with an SIP protocol and to allow for calls from/to these clients, we decided to support also the SIP protocol in our network.

We have installed, and run in a trial mode, an SIP server – *SIP Express Router (SER)*, developed in Fokus (Berlin). The server is modular and powerful, and free to use thanks to its GPL licence. In addition, our team maintains friendly relationships with the server developers and has some experience with its usage. SER can run on various operating systems (Linux, BSD, MS Windows,...) and various HW platforms, including iPAQ.



No.	Caller	Callee	Connect date and time	Duration	Cost 1	Cost 2	Cost 3
1	420224352728	420222580220	01.12.2002 09:18:41	4m 51s	5.57	4.00	2.47
2	420485353345	420311612141	01.12.2002 09:45:59	2m 25s	4.76	4.25	1.42
3	420485353345	420485151819	01.12.2002 09:48:45	1m 33s	3.05	1.60	0.91
4	420224354702	420281862123	01.12.2002 10:38:22	42m 18s	48.64	34.40	21.57
5	420224359179	420596923157	01.12.2002 10:56:29	6s	0.13	1.70	0.05
6	420224359179	420596923157	01.12.2002 12:25:07	22m 32s	30.87	39.10	13.29
7	420224359179	420318599125	01.12.2002 12:48:36	9m 48s	19.30	17.00	5.78
8	420224359179	420596923157	01.12.2002 12:58:36	21m 51s	29.93	37.40	12.89
9	420541512300	42023624803	01.12.2002 13:53:17	unanswered	0.00	0.00	0.00
10	420224355617	420476104484	01.12.2002 14:13:49	19s	0.62	1.70	0.18
11	420224355617	420476104484	01.12.2002 14:14:21	3m 52s	7.61	6.80	2.28
12	420224359179	420272739477	01.12.2002 14:32:05	27s	0.51	1.60	0.22
13	420224359179	420596923157	01.12.2002 15:30:01	23s	0.52	1.70	0.22
14	420485353287	420483392209	01.12.2002 15:33:57	18s	0.59	1.60	0.17
15	420596398243	420553215446	01.12.2002 16:16:45	unanswered	0.00	0.00	0.00
16	420541148312	420461534691	01.12.2002 17:27:36	6m 31s	12.83	11.90	3.84
17	420224352652	420312579787	01.12.2002 18:19:46	2m 9s	4.23	4.25	1.26

Figure 8.6: Example of a detailed summary

For the deployment in CESNET2, we opted for a Linux PC server. Functionality of some modules can be improved by a SQL database. We decided to use *MySQL*. Server is controlled by a scripting language, so its configuration is quite complicated. Later on, a web server will be activated, in which it will be possible to create and administer accounts.

The server is intended for calls from SIP clients, to phone lines connected to the private branch exchange at CTU + CESNET + ICHT. In addition, there is another server at the Strahov student hostel, ready for use. The hostel will be connected to the IP telephony network after we solve the issue concerning the authentication of calls from SIP clients.

The existing H.323 network and its clients need to be interconnected with the new SIP infrastructure. As it is impossible to transfer the entire network to the SIP protocol (for both organisational and technical reasons), we decided for an incremental implementation of SIP in our network, with the use of a H.323/SIP translating gateway and a dual configuration of H.323 + SIP within voice gateways. The testing environment, which we are using for the verification of features and restrictions of individual products, is described in Figure 8.7.

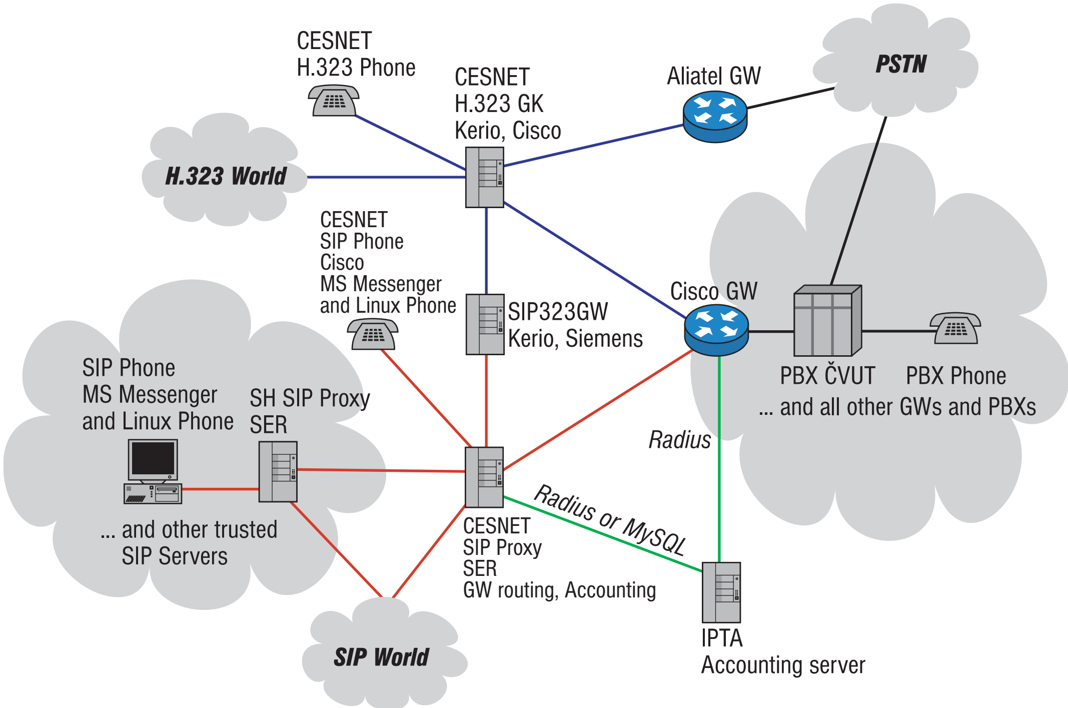


Figure 8.7: Configuration of IP telephony with SIP signalling

We carried out a survey among the existing products, which allow for certain interoperability of H.323 and SIP protocols, and decided to check the possible deployment of three translating gateways by Kerio, Siemens and Darmstadt University.

8.6.1 Kerio

The first tested gateway was produced by Kerio. This version runs under Linux. In CESNET, we use a Kerio Gatekeeper for Windows 2000 with very good results. One of the disadvantages is the need to use a Windows-based management software. No management console has been developed for Linux so far.

The gateway was originally designed to the translate SIP signalling into PSTN, usually through ISDN. However, it was later extended with the translation into the H.323 signalling. Only a test version is available, but thanks to very good collaboration with the developing team, we managed to correct all problems identified so far and the gateway is fully functional. On the other hand, the configuration of the gateway is rather complicated. In addition, the software operates as a media gateway, even though it is not necessary.

This means that voice data are not transmitted directly between end stations, but pass through a gateway, which produces an unwanted delay. However, testing did not reveal any subjective deterioration of the voice quality. Another problem encountered during testing was caused by H.323 Optipoint 400 Standard phones, produced by Siemens. Complications concerned the use of mulaw codec and FastStart mechanism. This problem is solved in the new version of firmware. So far, we have tackled this problem by adjusting the gateway configuration.

8.6.2 Siemens IWU

The gateway of Siemens is a commercial product which can be used free of charge for a limited evaluation period. It is a relatively extensive system with many features, also including an H.323 gatekeeper and SIP proxy. Similarly to the Kerio gateway, this one also serves for translation into PSTN. However, it runs only under Windows 2000 SP3. Only by the end of the year, did we acquire such a machine. Testing will be soon completed.

8.6.3 KOM Darmstadt

We have been promised a gateway from Darmstadt University; however, we have not received the full version, yet. This software is distributed under GPL licence, making use of *Vovida SIP* stack and *OpenH.323* stack, running under Linux. In addition, there were some improvements incorporated in the software.

8.6.4 Clients for SIP IP Telephony

We expect the use of both hardware and software clients. As regards hardware clients, we have so fare tested only *Cisco IP Phone 7960*, with satisfactory results. The only problem is the occasional loss of connectivity in one phone, usually after some larger configuration changes and moving of the device. This is specifically a problem of the particular specimen, which we will try to solve by replacing the firmware. An SIP version of *Siemens Optipoint 400 Standard* is now going to be tested. New SIP firmware, version 2, has not been provided so far.

Among the disadvantages of hardware phones is the typically high price. We have initiated some exploration in this area in order to identify reliable phones available for reasonable prices which may be deployed at a larger scale.

There is a sufficiency of software clients available, some of them can be used free of charge. We also plan some research in this area, particularly in collaboration with students at the Strahov student hostels, where the use of software clients is likely to be extensive. *Microsoft Messenger* is probably the best-known software client. However, we would like to point out the problem of the new version 5, where it is impossible to configure servers other than .NET. We therefore recommend using version 4.6.

8.7 Peering with Foreign Networks

Based on the positive experience with peering with the CERN network in Switzerland, we decided to extend peering to some other localities. We encountered two complications. First, there were not enough interesting localities available for IP telephony. Except for AARNET (Australian Network for Research and Education), it is difficult to find a larger installation of IP telephony that we could use for mutual peering, in line with the status of CESNET2. Another complication is associated with interoperability – various networks make use of various types of components (gatekeepers and voice gateways) and their mutual communication can be problematic.

We deployed trial international peering to five universities of the IP telephony testbed in Internet2, together with the Australian AARNET network. We also connected to the international hierarchy of gatekeepers, arised from the initiative of the project titled Welsh Video Network and the SURFnet network. Again, one of the problems is that there are not enough interesting call destinations.

8.8 Definition of Future Objectives

The project will further consist of two sections – an operational and a research one. We intend to continue in the verification of new technologies and protocols, implementation of new services and extension of the VoIP infrastructure according to users' requirements:

Operating section:

- Connection of other customers according the users' requirements, continuous project evaluation and monitoring the operation of the VoIP network.
- Peering with other networks.

Research Section:

- Experiments in IP telephony with SIP signalling.
- Connection of IP phones.
- OpenH.323 project.
- Statistical evaluation of traffic.

- Pilot connection of a selected locality through SIP signalling.
- Research into the possibilities of implementing new types of services, e.g., conference calls, IVR, voice mail.

The outcome of our efforts will be published in the form of technical reports, magazine articles and presentations during conferences and seminars.

9 Quality of Service in High-speed Networks

This project deals with theoretical and practical aspects of implementing services with defined quality (Quality of Service, QoS) in high-speed networks. A particular emphasis is on the high performance of the entire network communication, or the end-to-end performance.

The project has its own website[12], where visitors can find articles, presentations, results of experiments and created software. For a summary of the most important project outputs, see below:

9.1 QoS Implementation on Juniper Routers

In the previous work, we have learned about the possibilities of implementing QoS on Cisco routers, on which the CESNET2 network is based. Among other significant producers of routers, there is Juniper Networks. Routers produced by this company are used within some backbone lines of the European network Géant. The Premium IP service is being considered for implementation in the Géant network, in order to provide for priority to certain data packets with respect to the rest of network traffic. We therefore checked the possibilities of implementing QoS on Juniper routers.

For the purposes of experimentation, we used M10 type, with a performance and offer of ports comparable to that of the Cisco 7500 model. All Juniper routers have almost identical hardware architecture and make use of the same operating system – JUNOS. We therefore expect that the collected data are also valid for other types of routers.

We based our experiments on the latest available version of the operating system, JUNOS 5.0. At present, there is a newer version available, offering several other functions useful for the purpose of QoS implementation. For the experiment configuration, see Figure 9.1.

We measured the basic characteristics of QoS, i.e., throughput, loss rate, delay and jitter, with the use of the *RUDE/CRUDE* programs, together with *qosplot*, which we created during the project.

As an example of an evaluated feature, we would like to point out the *WRR (Weighted Round Robin)* algorithm, used by Juniper routers for the control of

[12] *http://www.cesnet.cz/english/project/qosip/*

queues, for the division of output interface bandwidths to various classes of traffic. An advantage of the WRR algorithm – compared to the WFQ algorithm (Weighted Fair Queuing), used by the Cisco 7500 router for the same purpose – is the lower computation complexity, together with a lower processor load. A disadvantage is that the WRR algorithm will systematically prefer data flows with a higher content of longer packets, compared to data flows comprising mostly shorter packets (e.g., transmission of files is preferred to voice communication). However, this preference is not too strong and it is therefore irrelevant in practical terms.

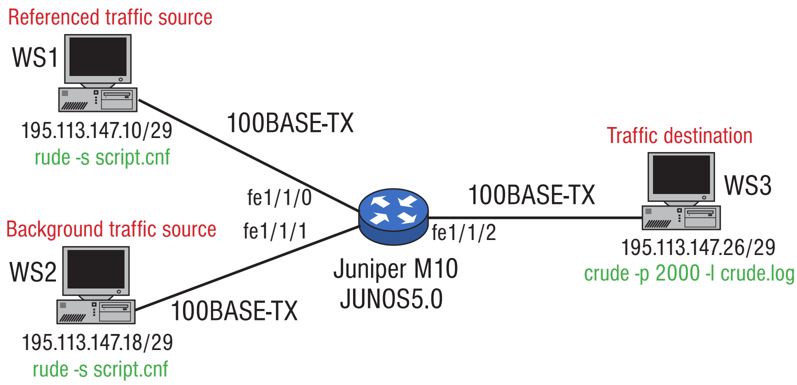


Figure 9.1: Configuration of experiments with Juniper routers

Some Cisco routers, for example the GSR series, solve this problem with a DRR algorithm (Deficit Round Robin), adding any unused capacity of a certain traffic class from one queue cycle to the next cycle, thus eliminating the preferences to longer packets.

Figure 9.2 (left) shows the development of throughput in two data flows, competing for a capacity of 100 Mbps in one output interface, without any QoS configuration. The first data flow includes 1,500-Byte packets (dotted line); the packets of the second one are 256 Bytes long (full line). The second data flow was applied over a period of 5 to 25 seconds. We can see that the development of throughput was pseudo-random.

The right side of the figure depicts the development of throughput after WRR activation, i.e., each data flow was allocated a bandwidth of 50 Mbps. The second data flow was applied at 5 to 10 seconds. We can see the development of throughput settling down and the data flow of 1500-Byte long packets reports a slightly higher throughput than the data flow of 256-Byte long packets.

Juniper routers provide a programming interface (API), allowing for the sending of configuration commands and receiving their responses over the network. Commands and responses are structured as XML documents. Connection can be provided through SSH.

In addition, Juniper routers make use of an operating system based on BSD under which user processes can be run. These processes are able to communicate over the network using any protocol. Implementation of a certain type of signalling, for example communication with a bandwidth broker, is therefore much easier with Juniper routers than with Cisco routers, which are a completely closed system.

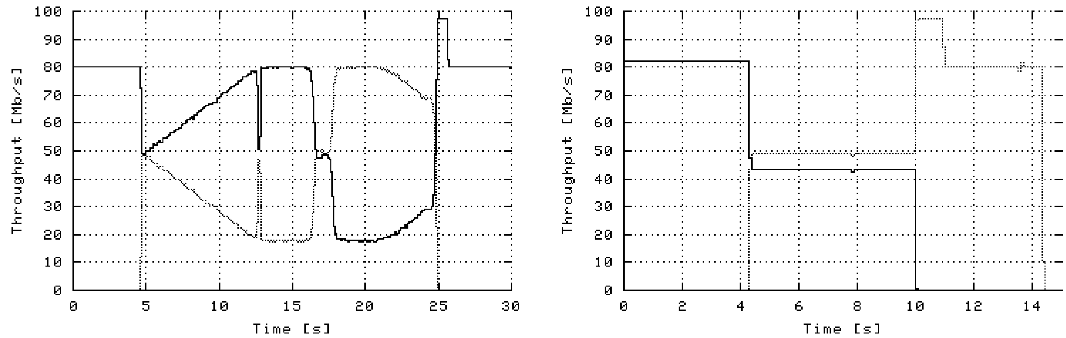


Figure 9.2: Throughput without QoS (left) and with the use of WRR (right)

The operating system JUNOS 5.0 did not provide a strict priority to a selected data flow, necessary for the implementation of the Premium IP service. The latest versions of the JUNOS system include this feature. We may say that the offer of functions for QoS implementation is comparable to the Cisco 7500 router and that the Juniper M10 router may be therefore applied wherever it is necessary to implement QoS using the standard methods.

9.2 MDRR on Cisco GSR with Gigabit Ethernet Adapter

The objective of this experiment was to verify the capabilities of QoS implementation of Cisco GSR routers, with adapters for Gigabit Ethernet. It is a typical configuration of our border routers at individual network access points (PoPs).

For the configuration of this experiment, see Figure 9.3. An adapter for Gigabit Ethernet was installed in each PC. The testing data flow of 350 Mbps, generated on PC1, was directed to port 1 with a target address of PC3. The background flow of 800 Mbps, generated on PC2, was directed to port 2 with a fictious target IP address in the subnet of port 3. This IP address was manually entered in the router's MAC table. Both data flows thus shared the capacity of the output port 3. Both flows included packets with the length of 1,500 Bytes.

At first, we used the IOS operating system, version 12.0(18.5)ST, already installed on the router. Unfortunately, we faced a problem of non-functional ping from the router to PC3. We carried out an analysis and found out that the router was sending ARP queries to the IP address of PC3, which responded correctly with its MAC address; however, the router failed to process this response.

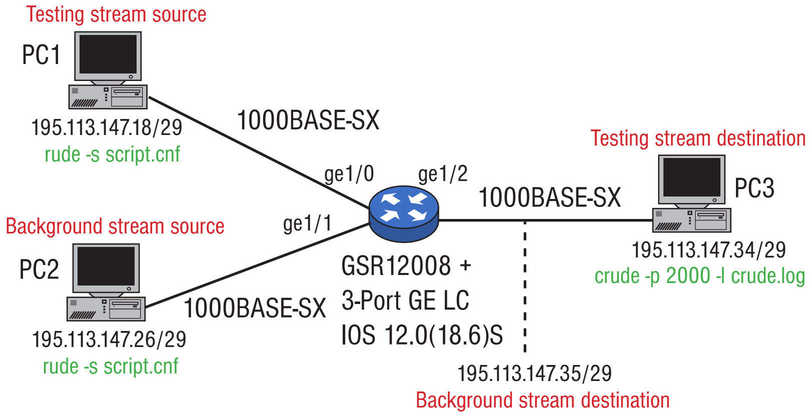


Figure 9.3: Configuration of experiments with Cisco GSR router

After many hours of debugging and repeated contacts with the representatives of Cisco Systems, we came to the conclusion that the problem was caused by an improper version of the IOS system. We therefore replaced this system with version 12.0(8)S and the problem no longer appeared (we replaced one development version – early deployment – with another development version, as there is only development software available for the router worth approx. USD 120,000).

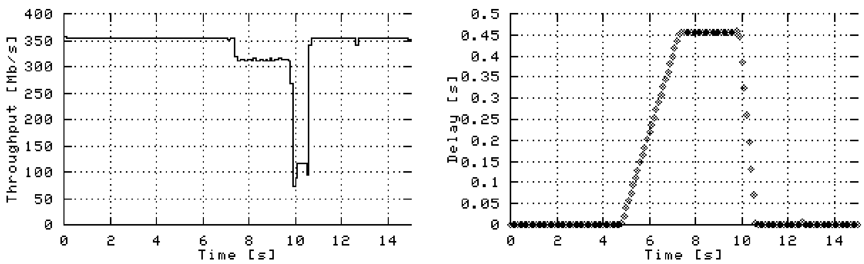


Figure 9.4: Throughput (left) and delay (right) without QoS configuration

For the development of throughput and delay of the testing flow without QoS configuration, see Figure 9.4. The background flow was applied at 5 to 10 seconds. The router maintained full throughput of the test flow two seconds after the start of the background flow, thanks to the queuing. The delay of the tested flow increased to 0.45 seconds. As the entire input traffic equalled 1,150 Mbps and the output flow was 1,000 Mbps, a difference of 150 Mbps was accumulated in the queue. As a result, the queue size is 300 Mb, i.e., 37.5 MB. Unfortunately, we did not find how to configure the queue size. At the end of the background flow, there was a dramatic fall in the test flow throughput, to approximately 100 Mbps, for a period of approx. 0.7 s. We are not aware of the reason for this phenomenon.

We tried to divide the capacity of the output line to 35 % for the test flow and 65 % for the background flow, by configuring the MDRR algorithm. We sent the test flow packets with an IP priority set to 1 (the value of TOS Byte was 0x20). The background flow packets had a standard IP priority, that is 0. We used the following configuration:

```
interface GigabitEthernet0/2
    ip address 195.113.147.33 255.255.255.248
    no negotiation auto
    tx-cos group1
!
cos-queue-group group1
    precedence 1 queue 1
    queue 0 65
    queue 1 35
```

The development of the throughput and delay of a testing flow with the MDRR configuration was entirely identical to that without MDRR configuration. The division of the line capacity was therefore ineffective. The possible reason was that we exceeded the capacity of „tofab" queues before the packet switching engine, which are available for packets of a certain size scope always at a limited number. Both used data flows comprised packets of an identical length, which was unfortunately necessary, as the performance of the used PCs was not sufficient to generate large data flows even in shorter packets.

We tried adding a WRED algorithm, designed primarily for the prevention of data flow control synchronization for parallel TCP flows. But it can be also used for the discarding of packets, depending on the volume of incoming data. We used the following configuration:

```
cos-queue-group group1
    precedence 0 random-detect-label 0
    precedence 1 random-detect-label 1
    random-detect-label 0 1000 2000 1
    random-detect-label 1 2000 3000 1
```

For the development of throughput and delay of the test flow with MDRR and WRED configuration, see Figure 9.5. The throughput of the test flow was maintained even with the application of a background flow, with exception of a short drop toward the end of the background flow. This was, however, not thanks to the MDRR algorithm. Because we configured WRED so that the dropping probability of 1 was reached for the background stream just at the beginning of the dropping range for the testing stream (when its dropping probability was still 0), as much traffic of the background stream was dropped as needed to forward all testing stream traffic.

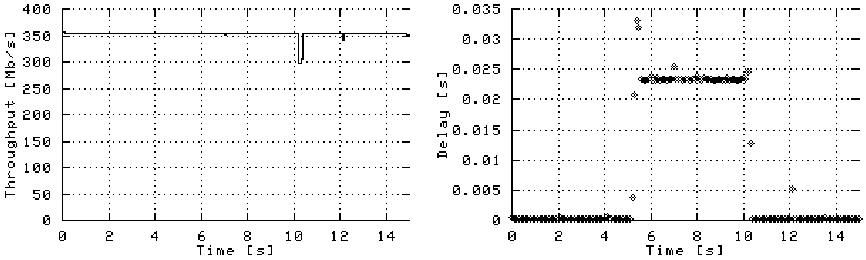


Figure 9.5: Throughput (left) and delay (right) with MDRR and WRED configuration

We changed the division of the line capacity to 30 % to 70 % and set up of queue filling and the corresponding probability of packet discarding to be the same for both flows:

```
cos-queue-group group1
   random-detect-label 0 100 200 1
   random-detect-label 1 100 200 1
```

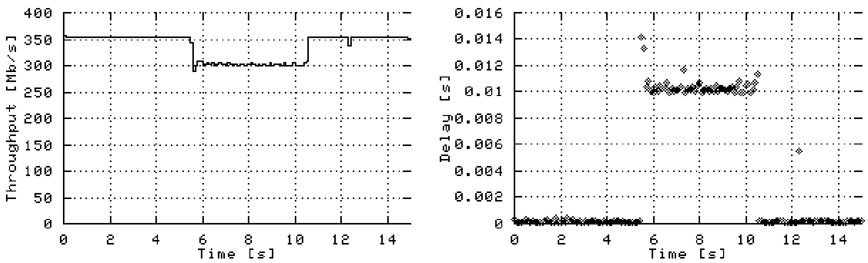


Figure 9.6: Throughput (left) and delay (right) with MDRR and WRED configuration, identical interval of discarding

For the development of the throughput and the delay of the testing flow, see Figure 9.6. The function of the MDRR algorithm is now clearly observable; the testing data flow has been allocated the exact required share in the line capacity. We can also see lower delay during the period of applying background flow, thanks to the lower limits for the area of packet discarding in WRED configuration.

9.3 Influence of QoS Network Characteristics on Transmission of MPEG Video

High-quality multimedia transmission is one of the perspective applications of computer networks in the future. For these transmissions, we usually use the coding in the MPEG format (MPEG1, MPEG2 or MPEG4). The required bandwidth oscillates from several to several dozen Mbps and it is therefore relatively low with respect to the capacity of backbone lines of existing networks, reaching several Gbps. However, multimedia transmissions are also used between points connected at a lower capacity lines with higher loss rate. As an example, we may use a transmission of a lecture from a hall, connected to the Internet with a temporary wireless device. We were therefore interested in the influence of QoS network characteristics on the quality of multimedia transmissions in the MPEG format.

For the configuration of the experiment, see Figure 9.7. The sending PC was equipped with an *Optibase MPEG MovieMaker 200* card, the receiving PC with an *Optibase Videoplex Xpress* card. Both cards used MPEG1 and MPEG2, formats SIF, QSIF, Full-D1 and Half-D1. The MovieMaker 200 card is capable of sending real-time encoded data in MPEG1, from the S-video port, or it can use previously encoded data in MPEG1 or MPEG2, saved in a file on the disk. We used different combinations of the formats mentioned above, with different speeds of the sent data flows. The observations described below were almost identical under all circumstances.

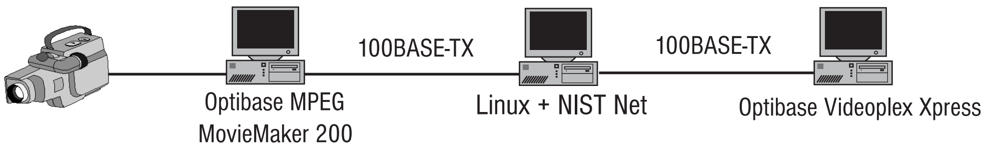


Figure 9.7: Configuration of experimental transmission of MPEG

The sending and receiving PCs were linked through a router running the Linux OS. We installed *NIST Net* on this router, for the emulation of QoS network characteristics. The program makes it possible to set up the required throughput, loss rate and delay, including the distribution.

As we had expected, the packet loss rate proved to be a critical parameter. MPEG transmission without an error correction code (FEC) does not tolerate any loss of packets at all. For instance, with the data flow of 10 Mbps, the loss rate of 0.02 % for 1,500-Byte long packets means that one packet gets lost every 6 seconds. Such a single lost packet was visible as a pixelization. We used relatively dynamic scenes from a demo video presented by Optibase. It is likely that the effect would not be as visible in less dynamic scenes. For the effect observed at the loss rate of 0.02 % and 0.1 %, see Figure 9.8 and 9.9, respectively.

On the other hand, MPEG transmission proved to be resistant to delay and jitter. Delays of up to 1 second, fairly common in real networks, were without any problem.

See Figure 9.10 for the development of loss rate on the Prague–Poděbrady wireless line, measured during a period of five days. The loss rate reached approx. 1.7 %. Unfortunately, we did not have the chance to try multimedia transmission through this line, even though it is very likely that such a transmission would be very difficult, given the identified sensitivity to packet loss. We believe that the situation may improve with the use of another decoder on the receiving side. For instance, if the decoder presents a duplicate data image instead of a damaged image (during signal dropouts), the subjective impression would most likely improve.

Figure 9.8: Effect at loss rate of 0.02%

Figure 9.9: Effect at loss rate of 0.1%

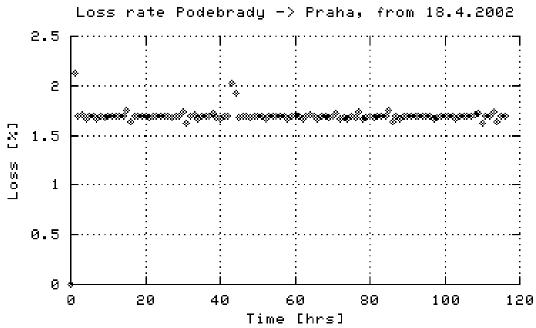


Figure 9.10: Loss rate on Prague–Poděbrady line

9.4 TCP Protocol Simulation

While we focused on experiments for what is known as the passive QoS in the previous sections, related to the protection of data transmission from the impact of other data transmissions, we now enter the issue of end-to-end performance, or what is known as the proactive QoS. The objective is to reach the highest possible throughput between end points, based on their configuration or based on a sutable configuration of the network. The research has not been completed; the results presented below are therefore preliminary.

More than 95 % of data are currently transmitted via the Internet using the TCP protocol. This protocol was designed at times when networks operated at much lower speeds than today. It is therefore obvious that using the TCP protocol within extensive high-speed networks can be problematic to a certain extent. One of the possible ways to study these problems is to simulate a protocol and situations that would be difficult to test in real networks.

We have therefore developed a simulation centre based on the *ns2* program and created an informative Web interface with demonstrations of simple simulation tasks. Ns2 is an open source application. It has been developed since the 1980s. Since then, developers have been intensively trying to improve its simulating abilities and implement new standards, for example for wireless networks. The availability of source code also makes it possible to understand the secrets of implementation in various protocols. The basic ns2 package implements almost all of the most frequently used protocols and mechanisms. Thanks to the fact that the ns2 project is open, we are able to implement other protocols, and end applications or strategies for packet processing in routers.

Ns2 includes two programming tools – C++ and the OTcl scripting language. Entities within the data path (agents, queues, lines, etc.) are implemented in C++ with respect to its efficiency. The purpose of the scripting language OTcl is to control these entities and specify the topology. This method enables us to change the simulation environment easily and flexibly without any further compilation.

We made sure to set up the simulation environment for a realistic simulation of the TCP protocol, with a possibility of acquiring information concerning the protocol's dynamics, i.e., the throughput, changes in congestion control on the sender, changes in RTT and other data.

It was necessary to generate a number of scripts and adjust the simulation entities in C++. We also focused on the possibility of dynamic parameterization of the congestion control, i.e., the possibility to change parameters of the AIMD (Additive Increase Multiplicative Decrease) algorithm in use during the period of connection. This will enable us to study the behaviour of the TCP protocol in large high-speed networks, where the standard algorithm of congestion control is insufficient due to the large volumes of data along the route.

Figure 9.11 shows an example of the development of the congestion window (cwnd, upper part of the picture) and the development of the limit between the slow start and congestion avoidance phases (ssthresh, lower part of the picture) during a single TCP connection. We are preparing a technical report on the topic.

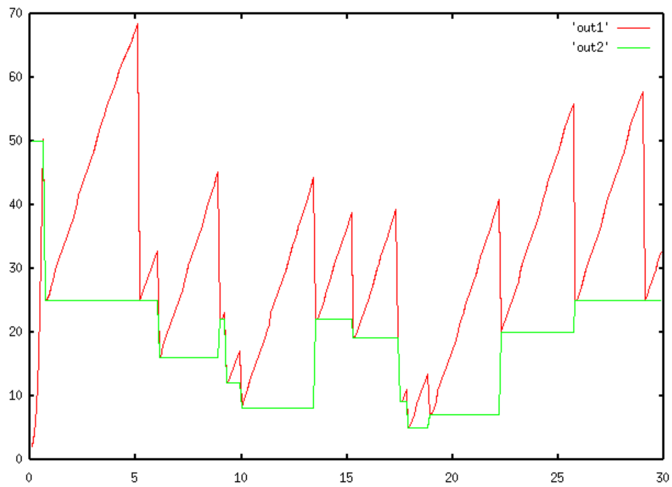


Figure 9.11: Example of the development of cwnd and ssthresh

9.5 Analysis of TCP Protocol Behaviour in High-speed Networks

Sender using TCP has to regulate the speed of segment transmission, so that the buffer does not overflow on the receiver or in any of the routers. Regulation is carried out by restricting the volume of sent and yet to be acknowledged data (outstanding window, owin), which may be on the way at a given moment. For these purposes, the TCP protocol uses two mechanisms (see Figure 9.12).

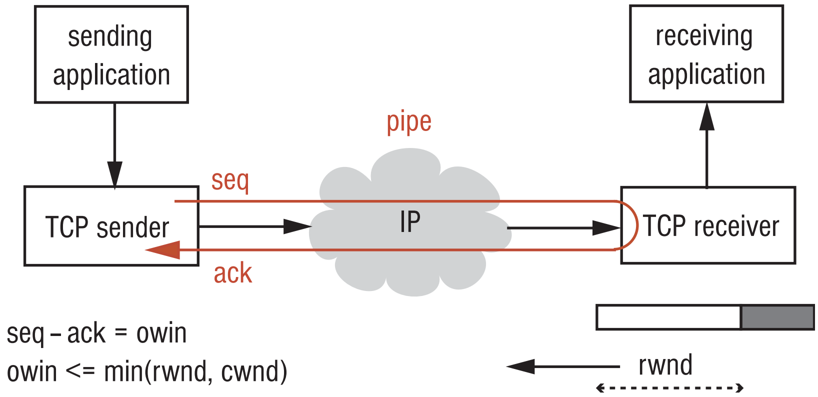


Figure 9.12: Flow and congestion control in TCP protocol

The mechanism of data flow control makes sure that the speed of segment sending adapts to the receiver's speed. The receiver informs the sender about the remaining size of its buffer (receive window, rwnd). The following must be true: owin <= rwnd.

In addition, the sender calculates its additional internal limit for the window size according to the various types of signals referring to any imminent or actual congestion of the network (congestion window, cwnd). This mechanism is referred to as the congestion control. The following must be true: owin <= cwnd.

The standard buffer size for individual TCP connection is set at 64 kB in the existing operating systems, both on the sender and the receiver. The maximum window size during connection also corresponds to this size. For large high-speed networks, with a high volume of data that may be on the way at a moment, this buffer memory size is insufficient and it is necessary to increase it.

The buffer memory size can be adjusted to the route capacity in three ways: manually for a single TCP connection at the application level, manually for all TCP connections on the operating system level and automatically for individual TCP connections. In each case, it is necessary to switch on the window scaling option (an operating system feature), enabling the use of windows larger than 64 kB, and set up the maximum buffer memory size. For instance, you can use the following commands in the Linux OS (an example for a limit of 8 MB):

```
sysctl -w net/ipv4/tcp_adv_win_scale=1
sysctl -w net/core/rmem_max=8388608
sysctl -w net/core/wmem_max=8388608
```

A manual setup for a single TCP connection must be carried out by the application itself, i.e., it needs to be modified. In the C language, it is possible to use the following commands (an example for a limit of 2 MB):

```
int size=2097152;
setsockopt(sock, SOL_SOCKET, SO_RCVBUF, (char *)&size, sizeof(int));
setsockopt(sock, SOL_SOCKET, SO_SNDBUF, (char *)&size, sizeof(int));
```

The advantage of a manual setup for all TCP connections on the operating system level is that it works with every application, without any need to modify it. On the other hand, wasting memory is a disadvantage, as only some TCP connections actually need large buffer memory. An example is again given for the Linux OS, the values indicate the minimum, standard, and maximum size of the buffer, which the operating system allocates to individual connection according to heuristics, based on the actual memory consumption and other configuration parameters (an example for an initial setup of 2 MB):

```
sysctl -w net/ipv4/tcp_rmem="4096 2097152 8388608"
sysctl -w net/ipv4/tcp_wmem="4096 2097152 8388608"
```

It is obvious that this solution is almost unacceptable for a server with hundreds of active TCP connections. For more or less automatic configuration for individual TCP connections, there are several alternative extensions of the operating system kernel, in the form of patches or auxiliary daemons, developed as part of special projects. These mechanisms are now being further developed.

Unfortunately, increasing the buffer memory and the sender window is not enough to ensure reliable and high throughputs in large high-speed networks. It is necessary to adjust the algorithm of congestion control at the sender, and analyse and solve a number of phenomena encountered during high-speed transmissions.

We are now intensively working on these issues. Some of the phenomena can be analysed by analysing the packet flows, recorded by the *tcpdump* program. Data are analysed by the *tcptrace* program after the connection is terminated. Another possibility is a real-time analysis of state variables maintained by the *web100* kernel extension.

We created several scripts for the correlation of information acquired from these two sources. For instance, the diagram in Figure 9.13 shows the development of rwnd (upper part of the diagram), acquired from the data flow traced by tcpdump and the development of cwnd (lower part of the diagram), acquired through the programming interface to the web100 extension. The figure shows rwnd window moderated by the TCP receiver in Linux in order to prevent network congestion with sudden data bursts from the sending application. The sender carries out similar moderation with its cwnd calculated window.

It is also useful to estimate the available bandwidth of the route. The tools for these purposes are the subject of active research. As an example, there are the *pathload* and *ABwE* programs. Further outcome will be presented during the *PFLDnet 2003* conference at the beginning of the next year.

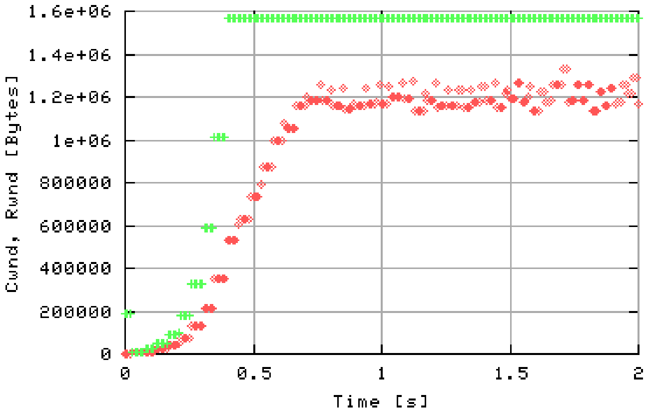


Figure 9.13: Example of a course of cwnd and rwnd

9.6 Other Activities in Progress

We have participated in preparation of the European *PRT (Performance Response Team)* activity, proposing the elaboration of an “End-to-End Performance Cookbook”, on which we are now working. In December, there will be a meeting concerning further proceedings in the PRT activity in 2003. Among the participants, there is expected to be Dante and the NRENs of five countries (Czech Republic, Ireland, United Kingdom, Switzerland, Italy).

Part II
International Projects

10 GÉANT

Since 1996, CESNET has been participating in several international projects dealing with the setting up and operation of a communication infrastructure interconnecting the National Research and Education Networks (NRENs) within Europe. After successful *TEN-34* and *Quantum* projects (TEN-34 and TEN-155 networks), the international consortium of 26 partners (including CESNET) is working on the *GÉANT* project, the goal of which is to build up and operate an infrastructure with backbone bandwidth of 10 Gbps.

10.1 GÉANT Network

The Géant project was initiated in November 2000 as a project of the 5th EU Framework Programme in the IST (Information Society and Technology) group. The total budget of this four-year project amounts to 200 million Euro, of which 80 millions will be provided by the EU. The project coordinator is DANTE Ltd. with headquarters in Great Britain.

The objective of the project has been defined as providing of a pan-European infrastructure interconnecting European NRENs with speeds in Gbps. The bandwidth of the GÉANT core should initially have been 2.5 Gbps and should have been upgraded to 10 Gbps in the shortest time possible. From the geographical point of view, the network should represent a follow-up to the original TEN-155 network and should be extended with points of presence in Bulgaria, Estonia, Lithuania, Latvia, Romania, and Slovakia.

In addition to standard IP service, the network should also provide the Premium IP service, guaranteed bandwidth service, Virtual Private Network service, multicast, and other new services that will emerge as a result of the development in the area of communication technologies. An integral part of the project is also ensuring a quality interconnection of European research centres and similar organizations outside the GÉANT network.

In the previous paragraph, we described the project objectives planned. And what is the current status? The GÉANT network was officially put into operation on 1 December 2001. Even then, the network core was formed by lines with the speed of 10 Gbps, which was a unique world phenomenon at that time. Thus, Europe even surpassed USA in the development in this sphere. The US Abilene network used backbone lines with the bandwidth of 2.5 Gbps in those days.

Currently, the GÉANT network interconnects 28 NRENs and serves more than 30 thousand research institutions.

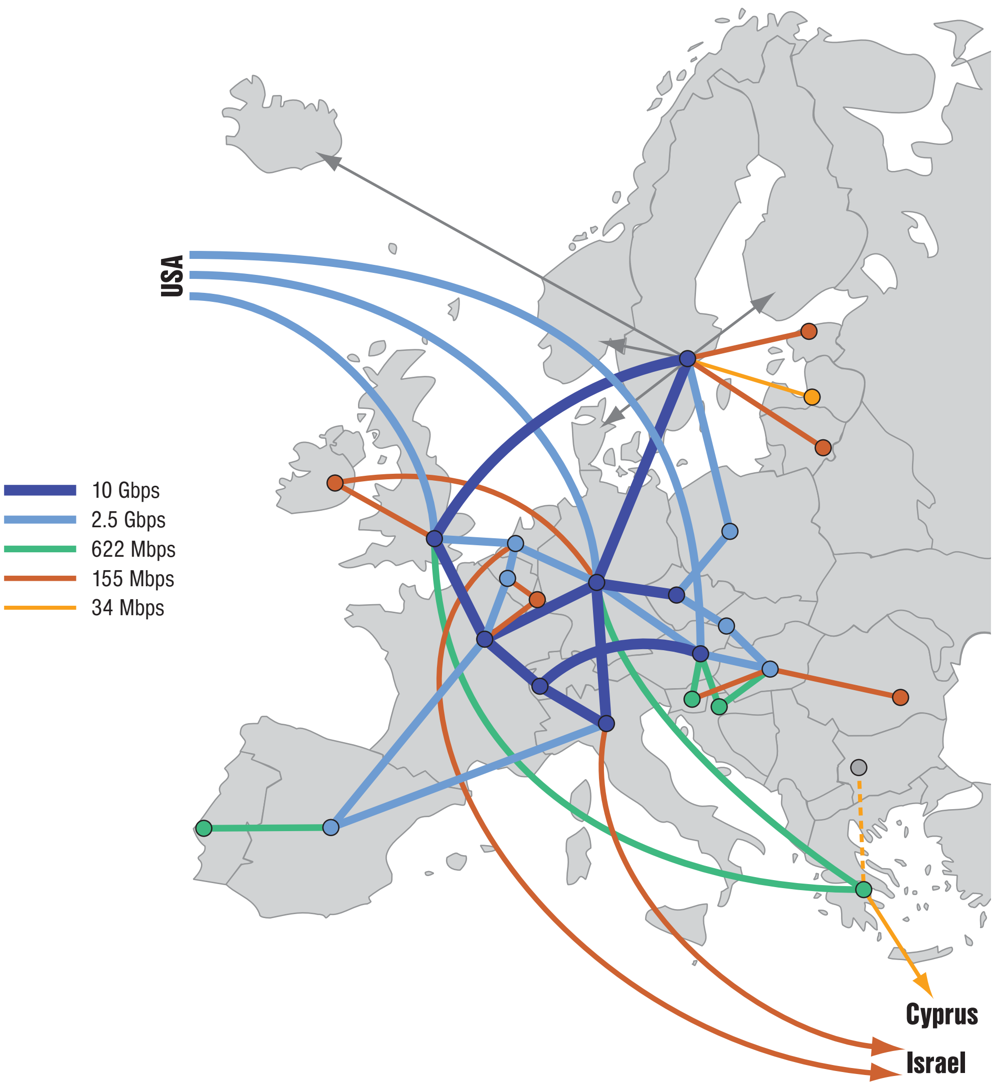


Figure 10.1: GÉANT network topology in December 2002

One of the network PoPs is located also in the premises of CESNET in Prague. This node is connected with other GÉANT network PoPs in the following way:

- Frankfurt, Germany – 10 Gbps
- Bratislava, Slovakia – 2.5 Gbps
- Poznaň, Poland – 2.5 Gbps

The location of the network PoP directly in the premises of CESNET brings us certain advantages. The reliability of our connection to the GÉANT network is increased substantially and costs for this connection are minimized as well.

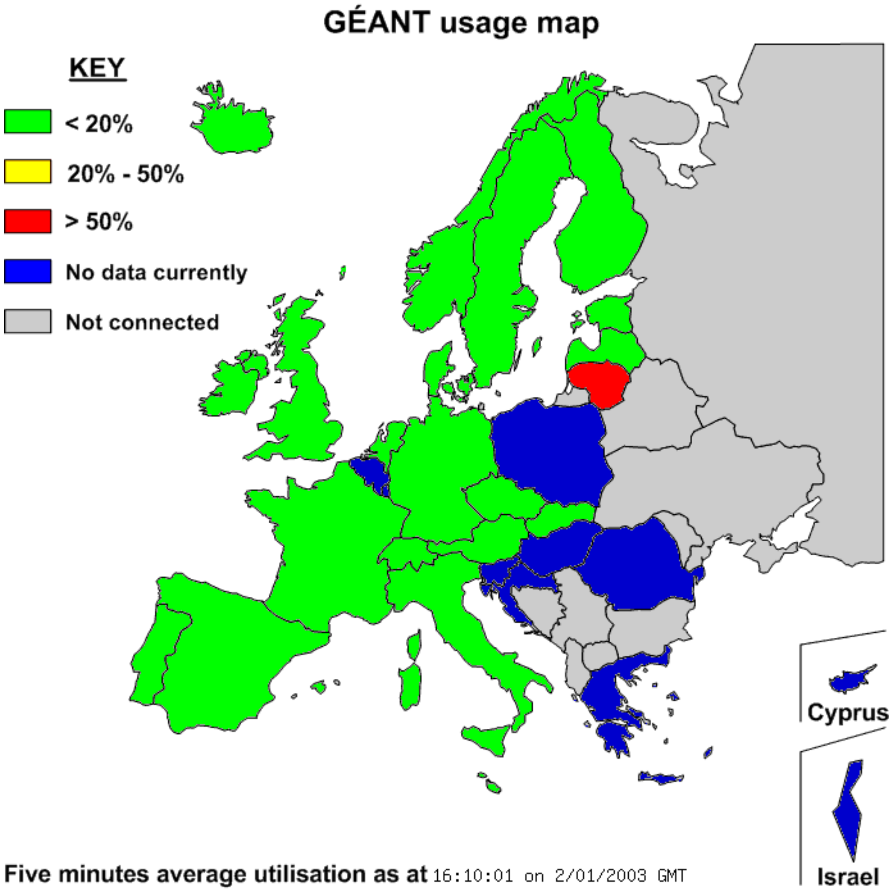


Figure 10.2: Utilization of individual GÉANT network nodes

10.2 CESNET Involvement in the GÉANT Project

Besides the setting up and operation of the GÉANT network, the GÉANT project involves research in the area of information and communication technologies as well. To maintain this research, workgroups entitled TF-NGN (Task Force – Next Genaration Network) have been established. Research teams CESNET actively participate in the following workgroups:

10.2.1 TF-LBE

The TF-LBE group (Less than Best Effort Services) deals with the LBE service implementation issues. By making use of this service, it is possible to send data to the network at maximum speed without degrading the connection quality of other subscribers. This can be done since data are marked to be thrown away preferentially by routers when network saturation occurs. Therefore, if the lines become congested, LBE data are thrown away, while the traffic of other subscribers continues in an undisturbed way.

10.2.2 User-oriented Multicast

The primary goal of this workgroup is to provide end users with information and instructions for configuring this service in their network and implement tools used for monitoring of the multicast status in large network.

10.2.3 Network Monitoring and Analysis

The task of the group is to develop and apply methods and tools for the statistical evaluation and monitoring of large backbone networks such as NREN or GÉANT.

10.2.4 IPv6

The aim of this group is to provide a quality backbone network supporting IPv6 and gain practical experience with the IPv6 protocol operation. The group is very closely connected with the international *6NET* project and most of their activities are done in collaboration.

10.3 Conclusion

The participation of CESNET in the GÉANT project brings the advantage of a very high-quality interconnection with research and educational institutions, not only within Europe but also on the global level, to institutions connected to the CESNET2 network. A benefit for CESNET is the possibility to take part not only in the designing of this international network but also in its development through the collective research in the area of network technologies.

11 DataGrid

Since 2001, our research plan includes also the work on the *DataGrid* international project of the 5th EU Framework Program. The objective of this project, in which more than 20 partners from most of the European countries led by CERN are engaged, is to create an extensive computing and data infrastructure. This infrastructure will be utilized by scientists when evaluating experiments being prepared using new devices in CERN. The experiments will produce several PB or tens of PB of data per year. The infrastructure constructed within the DataGrid project must offer tools for storing, providing (including creation of replicas) and processing of these data – in a distributed form.

CESNET is involved in the activities of the workpackage 1, which is responsible for the resource management. Besides, CESNET participates in ensuring of an operating testbed (in collaboration with the Institute of Physics of the Academy of Sciences of the Czech Republic (Fyzikální ústav AV ČR)) and also in several aspects of the network infrastructure. Within the workpackage 1 (which is an activity directly financed by EU), CESNET is responsible for the logging and bookkeeping service and security mechanisms in use.

11.1 Logging Service

Activities of 2002 can be divided into the following three areas:

- Maintenance and development of the so-called operating version 1.x
- Development and gradual implementation of the new version 2.0
- Logging service integration with R-GMA (Grid monitoring architecture)

11.1.1 Operating Version 1.x

According to the original project schedule, this service should have been maintained only in the first half of the year and gradually replaced, with version 2.0 being prepared. However, at the end of the first half-year, the project management decided to continue in maintenance of version 1.x up to the second project evaluation (February 2003). On one hand, this decision allowed for a substantially deeper implementation testing, but on the other hand, implementation of new features required by applications according to the original development plan became complicated – most of the required extensions cannot be integrated into the conceptually obsolete version.

11.1.2 Version 2.0

We concentrated our main activities on the complex reconstruction of the logging service concept and implementation of new functions. The logging service is based upon the event-driven model, where individual components send information on particular events to a remote database and task states are (re)constructed accordingly.

The basic logging service is asynchronous, i.e., neither timely delivery of events, nor their order is guaranteed. Nevertheless, this approach becomes insufficient in situations where the logging service is used internally within the resource management system for transferring information, e.g., when recovering the status after a certain component collapsed. For this purpose, we have extended the model with the support of the priority and synchronous event logging, within which a logging function call is not ended until the event transfer to the (remote) database is confirmed.

The most essential modification is the extended support of types of logged events that will also allow logging of so-called user events, i.e., events generated directly by a user and/or the application itself. This support virtually required a complete reconstruction of the existing implementation, which supports easy integration of new event types in version 2.0.

For version 2.0, we also changed the event processing concept and implementation of the so-called state automaton. The state automaton in version 2.0 now processes all incoming events and stores the resulting state accompanied with a timestamp to the database. We expanded the state cache concept, in which states of events that are most frequently requested by users are stored. The full version 2.0 functionality (including C and C++ API) is described in appropriate documents of the DataGrid project.

In addition to our other activities, we started to deal also with the issue of a permanent logging service, which will be capable of storing information about tasks for very long time periods (years). The first version of the appropriate document is currently subject to our internal review procedure.

11.1.3 R-GMA and Logging Service

R-GMA, i.e., the Relational Grid Monitoring Architecture, represents a general concept of working with monitoring information within the DataGrid project. R-GMA should provide an infrastructure that will be used to collect monitoring information and make them available. Basically, the monitoring information includes information on task states as well.

Therefore, we organized a meeting with representatives of workpackage 3, which is responsible for the monitoring service, in the first half of the year and agreed on the form of our collaboration. Within this model, the R-GMA infrastructure should ensure availability of the information on event states, including a so-called notification service, thus significantly lowering the utilization of the logging database itself.

Unfortunately, the delay in conversion to version 2.0 negatively influenced the implementation of needed R-GMA components as well. The components do not have a fully functional form yet. Therefore, we currently have only a data generator for R-GMA available and are able to send task state information to this infrastructure. The R-GMA infrastructure is, however, not yet able to store these data reliably and send them to users who are interested in them – the service retains its non-guaranteed character for now. Besides, the R-GMA infrastructure data security issue has not been satisfactorily resolved yet. The communication via secured SSL channels affects the overall performance too negatively.

11.2 Security

In the first half of 2002, we launched a service for extending the validity of certificates with the myProxy server. Modifications performed in the myProxy server have been included in the new official distribution.

During the preparation of version 2.0, we unified approaches used within WP1 to ensure the secure communication of remote components and created a new library that includes functions for handling certificates as well.

11.3 Project Continuation

In 2002, the 6th EU Framework Program was announced. Together with other DataGrid project co-researchers, we submitted what is known as an Express of Interest for the pan-European Grid infrastructure. Since autumn, we have been intensively participating in preparation of a consortium that is going to submit the project draft already upon the first announcement from 17 December 2002.

At the end of the year, representatives of Poland, Slovakia, Hungary, Austria, and the Czech Republic agreed on creation of the Central-European Grid Consortium, which will have its first constituent meeting at the beginning of January 2003. The aim behind the creation of this consortium is not only to gain a stronger position within the pan-European consortium, but also to identify and subsequently resolve common problems, which often differ from those that are handled by constituent EU countries. These issues mainly include the intensive interest in truly distributed heterogeneous environments (environments analogical to the environment developed within the MetaCentrum project), concerns about the excessive monopolization by the Globus system and also the effort to utilize results of their own research, which had often been quite unknown in Europe previously.

12 SCAMPI

SCAMPI (Scaleable Monitoring Platform for the Internet) is a project of the 5th European Union Framework Program (IST-2001-32404). CESNET is one of the partners in this project (Principal Contractor) and has been involved in the project since the beginning of its preparations in early 2001. The project was launched on 1 April 2002 and its total duration is 30 months.

12.1 Project Researchers

There are ten organizations from seven European countries taking part in the SCAMPI project in total. The project coordinator is TERENA. Besides CESNET, the other partners are:

- IMEC (Belgium)
- LIACS (The Netherlands)
- NETikos (Italy)
- Uninett (Norway)
- FORTHnet (Greece)
- FORTH (Greece)
- 4Plus (Greece)
- Siemens (Germany)

12.2 Main Objectives

The project has the following objectives defined:

- Development of a powerful network monitoring adapter for speeds of up to 10 Gbps.
- Development of an open and expandable architecture for network monitoring.
- Development of measuring and monitoring tools for DoS (Denial of Service), QoS monitoring, SLS audit, traffic analysis, traffic engineering, and accounting applications.
- Collaboration with relevant projects and standardizing activities (IETF).
- Publishing of results achieved.

The basic block diagram of the SCAMPI adapter is presented in Figure 12.1. Components of the software part of the project and connections between these components are illustrated in Figure 12.2.

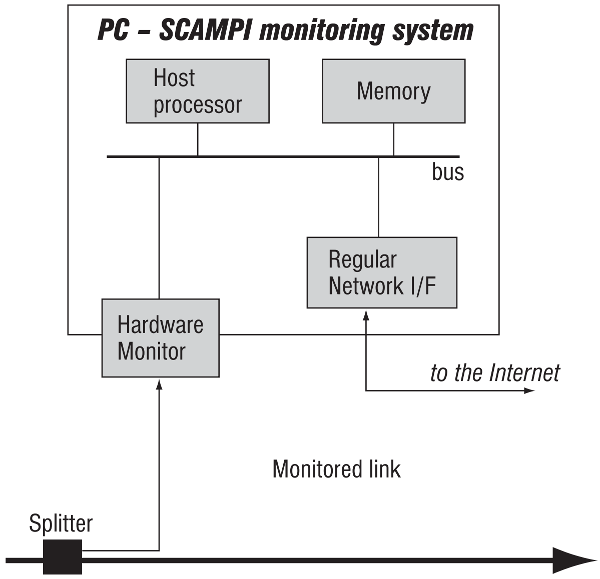


Figure 12.1: SCAMPI adapter

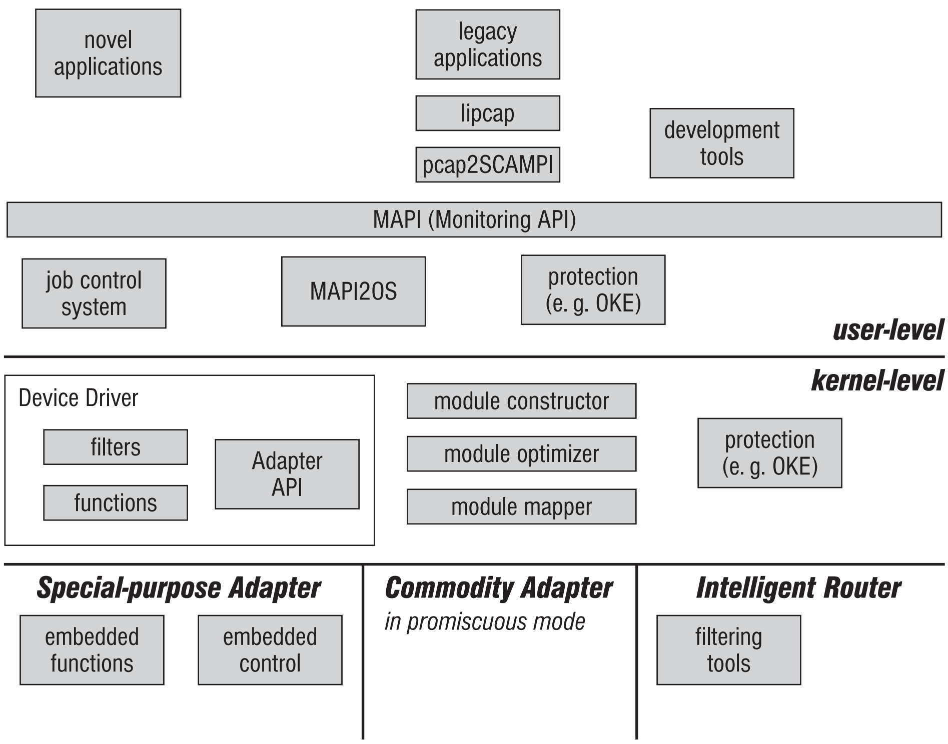


Figure 12.2: SCAMPI software structure

12.3 Project Organization Structure

Like the other IST projects, the SCAMPI project is divided into several workpackages (WP). These workpackages are then divided in individual tasks:

12.3.1 WP0 – Requirement Analysis

The task of WP0 is to compile a general overview of the current status of relevant tools and platforms. On the basis of this list, existing and future requirements for individual SCAMPI project components were identified and analyzed.

WP0 is internally structured to these tasks:
- overview of tools, platforms, and technologies that are in some way related to SCAMPI
- definition of requirements
- unification of requirements

The output of WP0 is represented by two documents:
- D0.1 – Description and Analysis of the State-of-the-art
- D0.2 – Measurement-based Application Requirements

12.3.2 WP1 – Architecture Design

The task of WP1 is to create a basic design of the monitoring adapter architecture, define an application level interface (Monitoring Application Programming Interface – MAPI) and perform analysis of the operating system requirements.

The following documents will represent the WP1 output:
- D1.1 – High-level SCAMPI Architecture and Components
- D1.2 – SCAMPI Architecture and Component Design
- D1.3 – Detailed Architecture Design
- D1.4 – Recommendations for Next-Generation Monitoring Systems

12.3.3 WP2 – System Implementation

WP2 is the key part of the entire SCAMPI project. The main WP2 goal is to implement the core of the designed architecture on the software and hardware level and integrate all components. Another task is the development of applications using the SCAMPI platform. The internal WP2 structure is as follows:
- lower layer implementation
- middleware implementation
- system integration
- application development

Documents:
- D2.1 – Preliminary Implementation Report
- D2.2 – SCAMPI Prototype Implementation
- D2.3 – Enhanced SCAMPI Implementation and Applications

12.3.4 WP3 – Experimental Verification

The main task of this section is to perform experiments, tests, and measurements to verify the functionality and properties of the SCAMPI architecture. The results achieved will be used both for improving the SCAMPI design and implementation, and for the overall project results demonstration.

The WP3 is internally divided into the following tasks:

- definition of experiments and requirements for the evaluation infrastructure
- plan of experiments and evaluation infrastructure setup
- evaluation of components and the whole system based on the experiments performed
- security and risk analysis

WP3 documents:

- D3.1 – Experiment Definition and Infrastructure Requirements
- D3.2 – Description of Experiment Plans and Infrastructure Setup
- D3.3 – Risk and Security Analysis
- D3.4 – Description of Experiment Results
- D3.5 – Assessment of Architecture and Implementation

12.3.5 WP4 – Project Management and Presentation

The main task of WP4 is the general project management, including preparation of reports for the European Commission and organization of meetings for project researchers. In addition, WP4 takes care of the project presentation and external relations, such as collaboration in the standardization area. Two workhops will be organized during the course of the project.

WP4 outputs includes:

- D4.1 – 1st SCAMPI Workhop
- D4.2 – Monitoring BOF Meeting
- D4.3 – 2nd SCAMPI Workhop
- D4.4 – Exploitation and Use Plan

12.4 Project Time Schedule

The SCAMPI project structure is rather complex. The individual workpackages begin at different times, in connection with the outputs accomplished so far, but the work is also done simultaneously as much as possible. The time schedule is illustrated in the Figure 12.3.

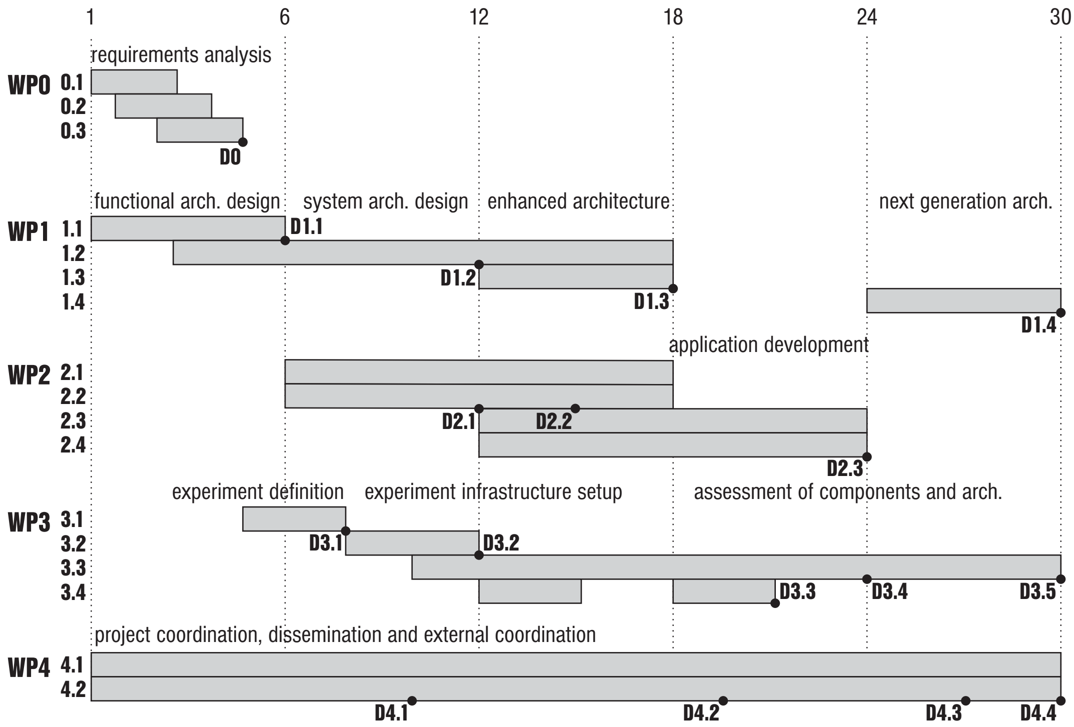


Figure 12.3: SCAMPI project time schedule

12.5 CESNET Participation in the SCAMPI Project

The total amount of work on the project and the amount of work on the project of every partner are expressed in man-months (MM). The planned distribution of these man-months up to the level of individual WP tasks for every partner is included in the basic document that describes the project (Work Description). Furthermore, one partner is appointed as the leader of each WP. In a similar way, a responsible partner for every document or other output is defined.

The share of CESNET is 34 MM of the total number of 483. We are involved in all WPs but the focus of our work lies in WP3. CESNET is the leader of WP3 and is responsible for documents D3.2 and D3.4.

12.6 Project Progress in 2002

The project started at the beginning of April. According to the time schedule, four documents (D0.1, D0.2, D1.1, and D3.1) were elaborated in 2002 (i.e., during first 9 months of the project work). However, soon after the project began, we discovered that one of the partners, the 4Plus company, is not able to contribute to the project with the development and manufacture of the high-speed monitoring adapter, based on the specification prepared during the project, which was originally promised.

Other members of the consortium have to deal with the risen situation. One of the alternatives is to use existing DAG adapters produced by Endace. A more promising alternative seems to be to adapt the routing card for IPv6, which is currently being developed by our colleagues from Masaryk University in Brno, within the 6NET IST project.

During 2002, three meetings of researchers took place: in Leiden in April, in Kristiansand in July, and in Prague in October.

12.7 2003 Plan

2003 will be the key year for the SCAMPI project activities. The D3.2 deliverable, for which CESNET is responsible, must be completed by the end of March. At that time, planned tests organized by CESNET will start as well.

For January 2003, the first SCAMPI workhop is planned, where results obtained so far will be published.

If the alternative of developing the adapter on the basis of the IPv6 HW router is accepted, the involvement of CESNET in the SCAMPI project work will increase substantially in the next year. The expected increase is 10 man-months, which will require more researches to join the project.

Part III
Other Projects

13 Online Education Infrastructure and Technology

13.1 Online Education Support

The objective of the sub-project entitled *Online Education Support using Multimedia Applications in the Environments of Technical Universities* was to create and prepare a system concept for the remote education support including appropriate education materials in the electronic form that could be used for full-time study, but mainly for combined study.

The group of researchers determined to focus the project on partial issues resulting from the online education deployment methodology, which concerns technical approaches and means, manager approaches, and the creation of didactic programs. The main goal of this entry project stage was to implement some applications as pilot examples that could inspire other workplaces and other applications.

In the initial project stage, we created a remote education support system concept, only in the local conditions of the Department of Telecommunication Engineering of the Czech Technical University in Prague, Faculty of Electrical Engineering (Katedra telekomunikační techniky ČVUT v Praze, FEL) for the time being. We considered various eventualities in terms of the workplace location, its technology, software, and knowledge of the workers involved.

13.1.1 Creation of Multimedia Didactic Products

For creating a pilot online course, we chose the topic called *Safety and Health Protection by Work in FEE Laboratories (SHPW)*. This program does not make use of multimedia elements because of its content character. It is, however, complemented with a component that allows testing of students' knowledge. The program can generally be used for the purposes of SHPW training, which forms a part of compulsory content of initial seminars in laboratories with electrical equipment. In the current academic year, we have been using the program in several courses at the Department of Telecommunication Engineering.

In addition, we have created a pilot example of a specialized online multimedia course, the use of which is characteristic for a more specific scope of study. We chose the topic entitled *ISDN Protocols*. For this topic, we processed the content of chapters, scenarios of individual pages with the possibility to potentially utilize all basic types of multimedia elements (text, still graphics and photographs, spoken comments, accompanying music, animations illustrating functional principles, combined animation, video sequences). Later on, we completed this multimedia program and tested it on a small sample of students. After several minor flaws had been removed and certain elements added, we prepared the program for its further, wider use.

The initial analysis, which dealt with the identification of didactic forms suitable for the distance learning, resulted in the conclusion that the form of "the conservation of live university lectures" and their subsequent reproduction from video cassettes or their distribution via telecommunication network has been used very rarely so far.

As a pilot example of this form – an audiovisual record of a university lecture – we chose the topic entitled *SDH Transmission Systems*, which may be useful in the specialized part of the study at the Faculty of Electrical Engineering. We designed an outline and scenario of this specialized lecture and performed preliminary recording tests for a part of the scenario in the real environment of an occupied lecture hall at the faculty. After evaluating flaws of the testing record control, we recorded the complete lecture using a digital video camera. The recording is now prepared in the form of streamed video data to be stored on the multimedia server.

Furthermore, we gathered the electronic education materials that had been created in the previous years. Based on the technical and content analysis of these materials, we chose a set of programs that could be integrated into the distance learning system in environments of technical universities (or high schools as well). Special attention was paid to the category of programs that could be used within the existing or future teaching in the environment of our department. Testing of both newly created and older multimedia programs with the participation of students were carried out both in regular courses and in the Research and Development Centre for Mobile Communications (RDC – joint project of OSKAR, Ericsson and CTU).

Within the project, we also assessed the possibilities of using the *WebCT* didactic platform for online education support. Specifically, we tested capabilities of this didactic platform with the SHPW training and examination. We concluded that the WebCT system is not suitable for the given purpose. The reasons include: the system is proprietary, more or less closed, with its own user identification; possibilities for employing multimedia elements are limited; the evaluation apparatus for knowledge testing does not meet our needs; for the given purpose, solutions based on open platforms seem to be more appropriate.

In order to improve the quality of the acquisition stage of the supportive education materials preparation, we completed the current configuration with a multimedia workstation and a mobile workplace for transmission of the video sequences over LAN and wireless LAN.

13.1.2 Construction of a Teleinformatic Environment

Considering our analysis of existing possibilities of the electronic support for routine activities of teachers and students at technical universities, we have concluded that it is desirable to create a new concept of teleinformatic resources, which would streamline activities both in the teleinformatic, and scientific/research area.

Our findings show that there is support of such activities on the level of CTU and its faculties. However, on the level of basic pedagogical and scientific/research units, i.e., particularly departments, this support is implemented only at a relatively small number of workplaces. That is why we have initiated preparation of a development project of a sample Web system suitable for supporting the work of individual departments at our university. The work is carried out in the environment of the Department of Telecommunications Engineering of FEE (Katedra telekomunikační techniky FEL), which is a typical example of an end-branch department. Thus, our work is based on the actual needs of both teachers and students.

The system has been constructed as an open one from the beginning, with a modular concept based on purpose sections, which can be further hierarchically segmented. Firstly, we created a basic structure, description of its characteristic features and design of a differential access system including access rights. To implement all the aforementioned requirements for constructing the education and information system, we purchased a sufficiently equipped server within the project, which was installed in the RDC premises. In the following stage, we dealt with several technical precautions and started implementation of individual pages of selected sections.

The basic structure is built up in a way allowing creation of the following communication forms:

- simple transfer of information from the centre to a user
- user can send reply to the centre from a reserved location
- centre queries
- general or thematic mailing board
- storing and picking up of electronic didactic materials
- information exchange within a specific group of users

The system allows storing of supportive didactic materials in the most common formats, as well as some special formats, such as:

- plain text document (TXT)
- formatted text document (RTF)
- PDF document
- PowerPoint presentation

- general application (EXE)
- multimedia program (Macromedia Authorware)
- video stream (RM)

One of the main contributions of the system is its intuitive interface for adding new educational materials. Because there are many teachers who are not IT experts, it is useful to provide them with an option for creating supportive materials in an environment which they are used to and placing such materials on the server even without more in-depth knowledge of the system function and structure. Thus, virtually all teachers of the department can be involved in the online education support process.

Another important aspect is the experimental publishing of lecture records in the video stream form. For this purpose, we have made use of the offer to place the records on the streaming server of CESNET.

The system is primarily designed for online education support in several categories. Via the Web interface, students will obtain both the access to administrative and technical information relating to their study, and the possibility to express their opinions in a discussion board. However, students will, above all, have a continuously updated and extended database of primary and secondary educational materials available – not only in the form of text documents but also multimedia didactic programs and lecture records in RealVideo format. Prospectively, we are also considering the option to use the system for live broadcasting of the lectures via the Internet.

We are currently completing the development of the portal at *web.comtel.cz*. The full operation of the portal is expected to start in the first quarter of 2003. The portal will then be moved to *www.comtel.cz*.

13.1.3 Integration of Teleinformatic Resources of K332 and CESNET

The intentions described above, and their partial implementation, make it possible to define other possibilities for streamlining the teleinformatic support of routine activities in the environment of CTU in the future. One of the possible directions is the integration of the complex department server with the powerful technical equipment managed by CESNET.

An example can be creation of a database of educational programs on high-capacity hard drives linked to the multipurpose department server. The basic idea of how this connection is utilized for creating didactic programs and using these programs for the distance learning online support is illustrated in diagram 13.1. Appropriately equipped department servers can be coupled with high-capacity disk memories containing a relatively extensive complex of didactic materials. Students are then provided with the possibility to use these programs. Nevertheless, it will be necessary to create a suitable methodology for accessing these servers from classrooms of the department and faculty and student dormitories.

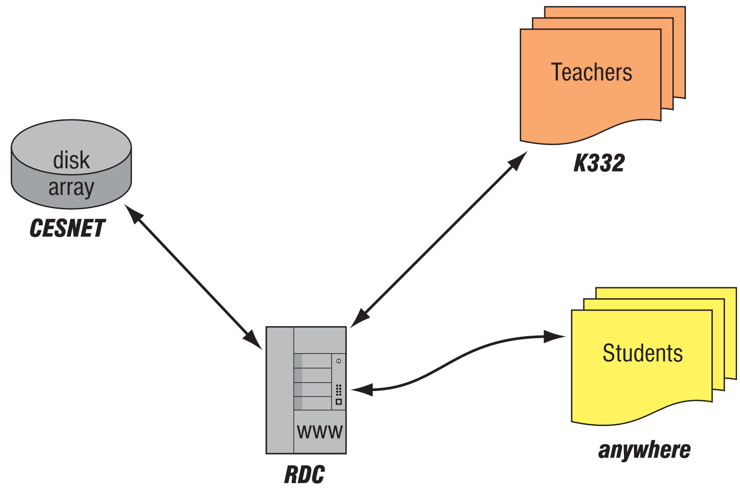


Figure 13.1: Integration scheme of K332 and CESNET resources

13.1.4 Final Recommendations

The project represents a contribution in the area of the didactic programs creation and teleinformatic support of routine activities connected with both the education and the scientific and research practice. In the following period, it will be necessary to systemize testing of didactic programs and their availability for students, create new educational materials, promote creation of similar multipurpose servers at other departments, and consider convergence of various local and network resources on various organization levels.

13.1.5 Sub-project Future

We assume that the sub-project will continue on several levels. On the technical level, the project will involve gradual completion of the environment (portal) and expansion of its functions. The pedagogic level will concern filling with educational materials of various types for the purpose of remote education support. We also have to provide training and educational activities for the pedagogic staff. After extending the acquisition possibilities, we expect a higher use of the streaming server of CESNET for storing lecture records.

On the general level, we would like to concentrate on technical experiments with various forms of the remote access, generalization of our conclusions and experience for applications of similar systems on a wider scale and finally on publishing and enlightenment activities in the remote education support sphere.

13.2 Distance Learning Support by CESNET

The objective of this sub-project was to create and publish information on proven methods and products for the efficient creation and use of materials and services for eLearning, especially in the form of a Web portal.

Currently, a fast development in the usage of Internet technologies within education (eLearning) is evolving in the Czech Republic. Leading Czech universities integrate these didactic methods into the practical teaching, as well as spend considerable resources (both financial and personal) for the development of online courses. Therefore, it is possible to assume that other educational institutions will join this effort.

For the CESNET association, as an organization providing network services, mainly to the academic society, it seems promising to engage in this area and attempt to gain an important position in coordination of eLearning activities in the Czech Republic and – depending on possibilities – also in provision of accompanying services.

One of the existing problems of eLearning development in the Czech Republic is the high level of fragmentation of activities not only among different universities, but often even inside the universities. Many workplaces do not have information on what is being created at other universities and are totally unable to monitor news from world leading workplaces. Besides, there is no grasp of the possibilities as to where to obtain support for one's activities.

That is why the need arose to create an information server that will enable interested persons from a given branch to easily and quickly find important information on eLearning. The portal is created mainly for Czech universities. These institutions are also offered the possibility to participate in its data content. Concerning the depth of information provided, the portal focuses on the whole spectrum of users – i.e., from beginners who seek general information on modern education forms, up to top professionals who need to gain up-to-date data about new trends and world development in their branch.

Keeping track of the latest information and knowledge or searching for the information needed in dozens of existing sources is very time consuming. Individual universities were therefore invited to work together on the portal data content.

If the collaboration of individual universities successfully develops to the expected extent, the portal will become:

- a source of information about basic online education principles
- a source for drawing up-to-date information from the eLearning and distance learning area
- a place for eLearning community meetings
- a platform for exchanging opinions and experience

Pages in HTML format are generated dynamically and stored in the system cache memory for a certain time. The advantage of this solution is that data are stored in a reliable database, where they can be processed easily, and users can utilize a simple data management interface at the same time.

13.2.1 Portal User Roles

There are three types of users created in the application:

Moderator: manages all portal submissions and data.

Independent correspondent: contributes on his/her own and manages his/her submissions. He/she needs no approval from any of moderators to publish the submissions on the Web.

Dependent correspondent: his/her submissions must be authorized by a moderator before they are published.

The registration of new users is automated. Given registration requests are confirmed by a moderator who assigns the dependent or independent correspondent role to the registered person. Prospectively, we are considering having professional experts working as moderators, who will primarily take care of the administration of the server as a whole. Independent correspondents will be renowned authors from cooperating universities, for whom the high quality of submissions is guaranteed because of their previous activities. Dependent correspondents will be represented by other authors who are interested in contributing to the portal but where it is not certain yet what the quality of their submissions will be.

The creators of the portal attempted to create such a concept that would help a higher number of professionals with different qualifications participate in the data content and create a space for exchanging experiences and expanding the sphere of sources of new information.

13.2.2 Portal Data Content

The server operates at *eLearning.cesnet.cz*. In the home page, users can obtain general information about the portal and register or log on to contribute as well.

The portal and its individual categories can be accessed using the *Portal Map* item (*Mapa portálu*) or the centrally situated picture with a graphic symbol. After clicking this symbol, a data tree structure is displayed to the user.

The main portal items are: Events ("Události"), Online Education Introduction ("Úvod do online výuky"), Online Education Use ("Využití online výuky"), eLearning Community ("eLearning komunita"), Online Courses ("Online kurzy"), Governmental Support ("Podpora vlád"), News and Trends ("Novinky a trendy"), Cisco Academy ("Cisco Akademie").

Individual pages usually contain explaining texts and a menu with other lower-level items located on the right side. Furthermore, in the main section of the page, an overview of commented hyperlinks to external sources may be included as well. Comments are intended to introduce the issue to those who are not sufficiently skilled in the area yet.

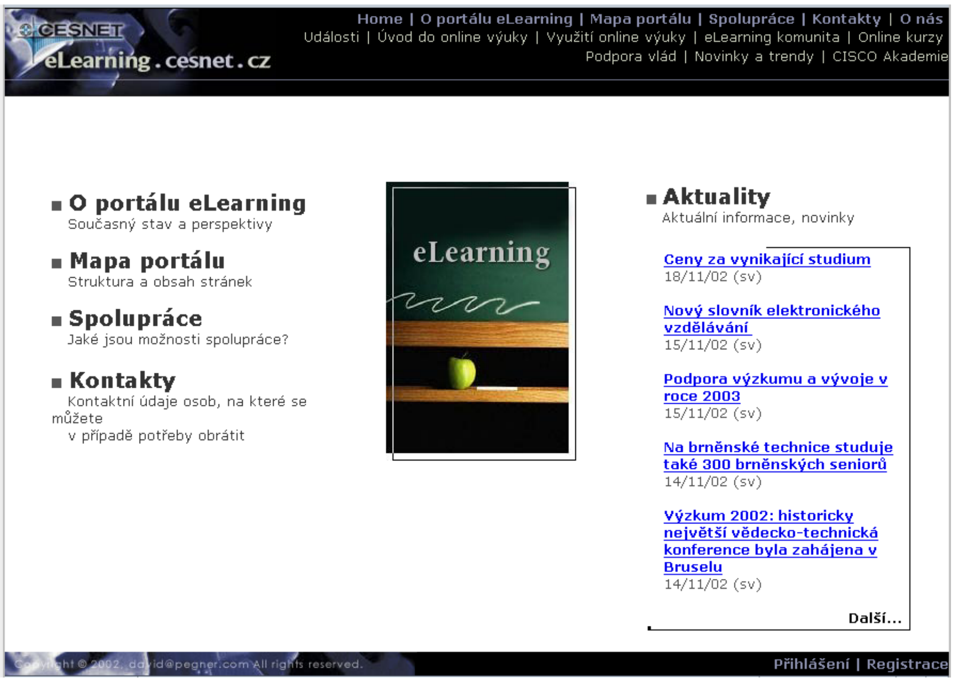


Figure 13.2: Home page of the *eLearning.cesnet.cz* portal

Hypertext links and menus are designed to allow easy navigation among internal and external documents. Their most important difference is that menu items are managed by the portal moderator and should not be changed too often, whereas items in the hyperlink list can also be managed by an independent correspondent and are expected to be continuously updated.

Special attention is paid to the Cisco Academy, the operation of which CESNET is engaged in.

Because to the nature of these project activities, i.e., the necessity to administer the portal and ensure its technical maintenance along with updates, the work on the portal will continue in the following years, as well. We are exerting effort to extend the spectrum of the information provided here and increase user comfort of the portal.

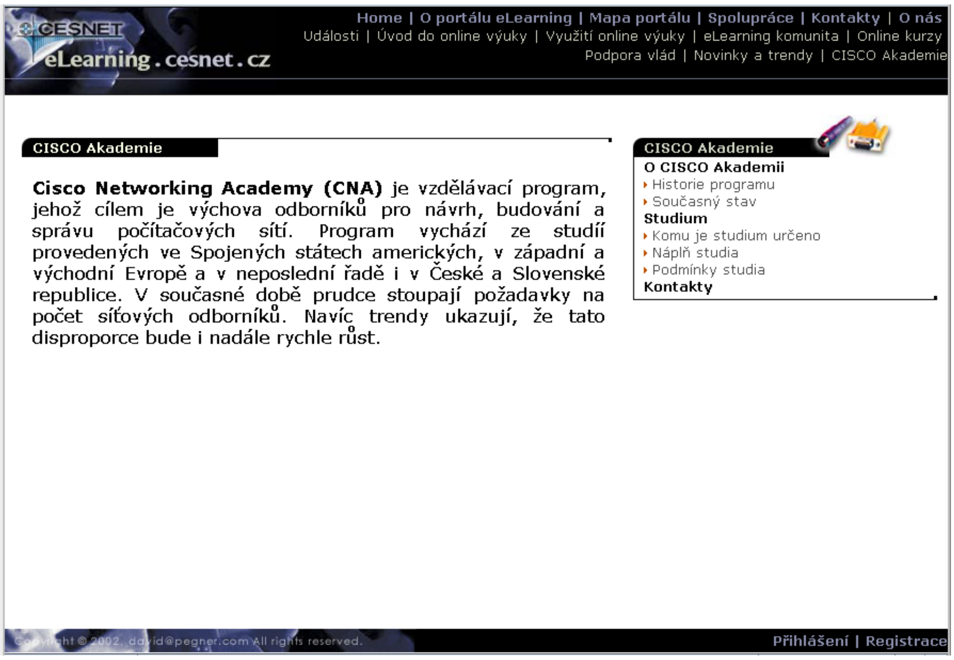


Figure 13.3: Example page with a lower-level menu

13.3 Interactive Data Presentation Seminar for the Distance Learning

The objective of this sub-project was to design a way for ensuring a practical seminar for the *Interactive Data Presentation* subject with respect to distance learning needs.

Within the aforementioned subject, students get familiar with different Internet geographic systems (map servers) and technologies for accessing database data using Internet technologies. The individual systems require different operating systems (MS Windows or Linux/Unix) and different Web servers.

However, it is not possible to expect that students will have all the software equipment available in their home environments, which is why all seminars must be maintained by the university. Moreover, in the case of the distance learning form, seminar severs should be available 24 hours a day and 7 days a week, with minimal operation failures. This is the main requirement bringing problems that this project was trying to help resolve.

Within the project, we have designed a potential way for maintaining the practical seminar for the Interactive Data Presentation subject with respect to the requirements of the distance learning form, while keeping the financial costs and time consumption as low as possible. Within the project, we have also built a supportive workplace for creating multimedia educational materials and an Internet directory. We also searched for an optimal solution for the Internet directory, especially from the viewpoint of time and financial demands. On the other hand, the solution should allow control of presented information.

13.3.1 Internet Map Servers for the Seminar

To maintain the IDP subject teaching under the aforementioned conditions, we selected the *VMware Workstation* software that allows creating several virtual computers within one physical server. Normally, 3–4 virtual servers can be running on one computer. The backup of virtual servers is easy, since the whole virtual server is represented by only a few files. The VMware Workstation program is affordable and universal for these purposes – it can be run both in the MS Windows and Linux environment.

In the winter term of the academic year 2002/2003, the testing operation is taking place – servers are used for teaching the Interactive Data Presentation subject offered to full-time students and voluntaries from the category of combined learning students. In the summer term, testing operation of the servers within a compulsory subject for students of the combined learning program will take place.

13.3.2 Preparation of Multimedia Educational Materials

Within the project, we have also established a multimedia workplace for acquiring and processing multimedia materials. At the *GIS in Public Administration (GIS ve veřejné správě)* conference, Seč 2002, we acquired first testing shots to be converted to the digital record, which were processed at the workplace for trial.

Besides that, we processed some lectures from previous conference years stored on videocassettes. The materials – presentations of individual GIS Internet solutions – are now used (with the approval of the lecturers) within the Interactive Data Presentation subject.

13.3.3 Internet Directory Based on Link-Base

Within the project, we have also begun development of a supportive directory for teaching (not only), which is constructed using the *LinkBase* system. This directory concentrates links to interesting Internet sources sorted by categories. All links must be approved by the editorial board before they are incorporated, which allows ensuring of the correct assignment of the links to the categories and considering their relevance. Practical results are available at *tns.upce.cz*.

14 Distributed Contact Centre

The goal of the pilot project entitled *Distributed Contact Centre Utilizing the VoIP Technology* is to practically test a demanding voice application in a high-speed network environment. For the technology, we chose *IP Contact Center (IPCC)* by Cisco Systems.

One of its main components is the *Cisco Intelligent Contact Management Server (ICM)* – a software that ensures the distribution of calls (including monitoring and control of the status of agents – or operators, to put it differently), routing and queuing of contacts, real-time data communication, operation history reporting, etc.

The Cisco ICM server allows intelligent communication of operators/specialists with users/customers via the Internet and/or a public telephony network using the ACD subsystems, Interactive Voice Response (IVR), Web and e-mail servers, etc. We planned to install a workplace covering at least two localities and test basic and advanced functions of this workplace.

The Cisco IPCC system is integrated in the Cisco Architecture for Voice, Video, and Integrated Data (AVVID) product. IPCC features include the intelligent contact routing, ACD functionality, network-to-desktop telephony integration (computer telephony integration – CTI), interactive response to user data (IVR), queuing of incoming calls, and centralized administration. IPCC can be used both in the environment of one network (site), and within two or more workplaces with a distributed function.

To create a testing IPCC centre, the following components had to be ensured:

- Cisco CallManager (CCM) server
- Cisco Internet Protocol Interactive Voice Response (IP-IVR) server
- Cisco Intelligent Contact Management (ICM) server
- Cisco Agent Desktop workstation

In order for the system to be usable in real operation, it was necessary to ensure a Voice over IP (VoIP) gateway, Call Manager Peripheral gateway, and CTI server as well. These elements are integrated in the IP telephony infrastructure in the CESNET2 network and therefore we did not have to build them.

14.1 Cisco CallManager

CallManager is an analogy of PBX systems (classic telephone exchanges) that are currently used for routing of the large majority of both analogue and digital phone calls. The main function of this system is to handle all control and basic functions provided by the IPCC system.

CallManager was designed using open standards and protocols for the multimedia communication based on the packet exchange, such as TCP/IP, H.323, and Media Gateway Control Protocol (MGCP). CallManager creates suitable conditions both for the development of voice applications, and for the integration of telephony systems with Internet applications.

A drawback of CallManager is the restriction of its installation only to selected hardware, i.e., only to the Cisco Media Convergence Server (MCS) device. For remote administration within a Web browser, the CallManager system is integrated with the Microsoft Internet Information Server (IIS).

14.2 Cisco IP-IVR

Cisco IP-IVR is a technology for interactive voice communication that uses open and extensible standards. IP-IVR also supports, among other things, the management of telephone contacts and the possibility to create applications responding to HTTP requests, or applications that respond to a specified condition by sending an e-mail message. IP-IVR is a component of the Customer Response Solutions (CRS) platform. The function of the IP-IVR system is to automate the call management by unattended user interaction.

IP-IVR functions therefore include, for example, the user password request or account identification request, user-selectable call routing, content processing of Web pages for their presentation in an IP phone, etc. To facilitate data storage, selection, and replication, IP-IVR uses an SQL database via Open Database Connectivity (ODBC).

14.3 Cisco ICM Software

The ICM software provides the intelligence necessary for decisions on routing of calls within the contact centre. By using the ICM server, it is possible to achieve merging of the interaction with users, accomplished through different methods, such as the Internet, PSTN, Interactive Voice Response, e-mail and Web services, desktop applications, etc.

On the network level, ICM employs profiles for all users. The suitable profile selection is based on the dialled number (DN), caller number (CLID), sent numbers (CED), data sent via a Web form, and information obtained from the database. In addition, the ICM server provides the capability of the agent status monitoring and control, routing and queuing of calls, and also event history management.

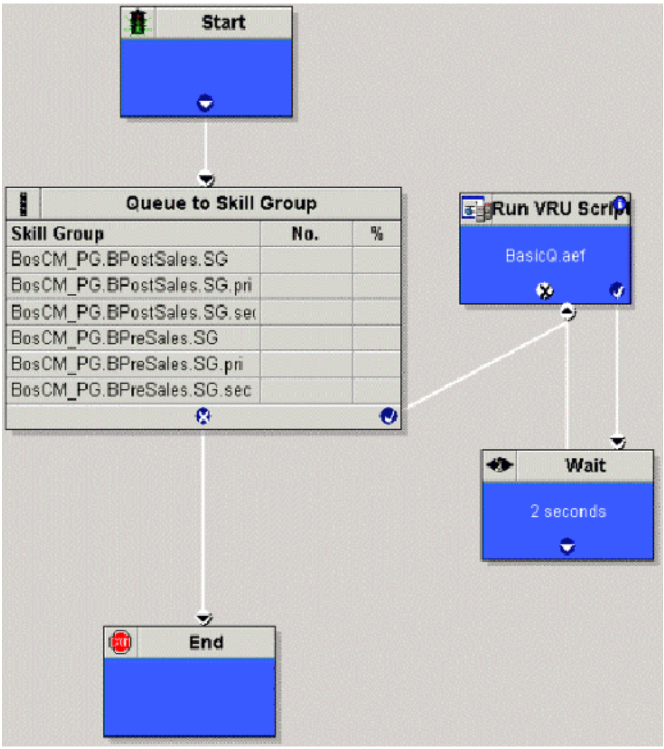


Figure 14.1: Call distribution information display

The basic ICM components are CallRouter, Logger, Peripheral Gateway, and CTI Server. If ICM is running only on one server, it works in sprawler mode.

14.4 Cisco Agent Desktop

Cisco Agent Desktop (CAD) provides tools for agents (operators) and supervisors (administrators). An example can be the screen pop (possibility for an administrator to communicate with operators), software IP phone, and supervisor software.

The Desktop supervisor software features a detailed display of information on agent statuses and call statuses, the possibility to send messages to agents, calls recording, and extended monitoring functions.

14.5 Progress of Work

The entire system is very demanding in terms of configuration, which was proved many times during the installation. In the first half of 2002, we implemented a basic distributed workplace of the VoIP-based contact centre (IPCC). After the difficult installation of all components of the distributed contact centre, when we were forced to handle the installation of some components in collaboration with experts from Cisco Systems, we managed to implement the contact centre in its minimal functional form. Our further step was to test the actual IPCC function in a testing environment.

The automatic call distribution system works in the following way – operators register their phones into the IPCC system through a workstation and incoming connections are then forwarded to them using a round-robin method. If all operators are processing a phone call, i.e., no operator is free, music is played for the caller until one of the operators becomes available. Operators can forward calls to one another – if one of the operators cannot handle a client's request, he/she can forward the call to his/her colleague. The configuration of scripts, such as "what shall I do with an incoming call/call in progress", is not difficult. The scripts can be modified in quite a simple way using a graphic editor and then are sent directly to the ICM server.

Within the tests, we tested a simulated failure of each component of the contact centre. In the case of the CallManager operation failure, phones were automatically reregistered to the CCM2 backup server. While performing the tests, we did not encounter any connection breakdowns, i.e., none of the active calls were disrupted. Concerning the IVR or ICM server failure, we did not detect any connection breakdown, either. In this case, however, we noticed a temporarily prolonged response (up to 5 seconds) when establishing a new connection. The delay was probably caused by the time necessary for the transition from the primary server to the backup one. In this way, we tested redundancy of the whole solution and obtained satisfactory results.

We prepared our testing workplaces at ČVUT, where we could not integrate them to the operating VoIP network, however, as we did not have the dialing prefixes assigned that are needed for making the service available to the outside world.

After all tests were completed, we installed the operating configuration of the contact centre. In the second half of 2002, we made both workplaces operational – one of them in Prague (CESNET) and the second one in Ostrava (Technical University of Ostrava). In both localities, there are currently three of the above described basic components installed, i.e., the CCM server, IVR server, and ICM server.

After performing the installation at the defined localities, we tested the practical functionality of the basic distributed IPCC solution again, including the resistance of this solution to simulated breakdowns (failures of individual components). Call Manager, operating as a publisher, is located in Prague, ensuring distribution/replication of databases in collaboration with the backup server at the Ostrava workplace (subscriber).

After the tests, we deployed hardware IP phones to three different localities – Prague, Ostrava, and Plzeň. Call Managers were temporarily registered to public dialing prefixes. By doing so, the whole solution became available within the public telephony network. Unfortunately, after certain changes in our provider, we lost the arranged prefix, and therefore the contact centre became inaccessible for the external testing.

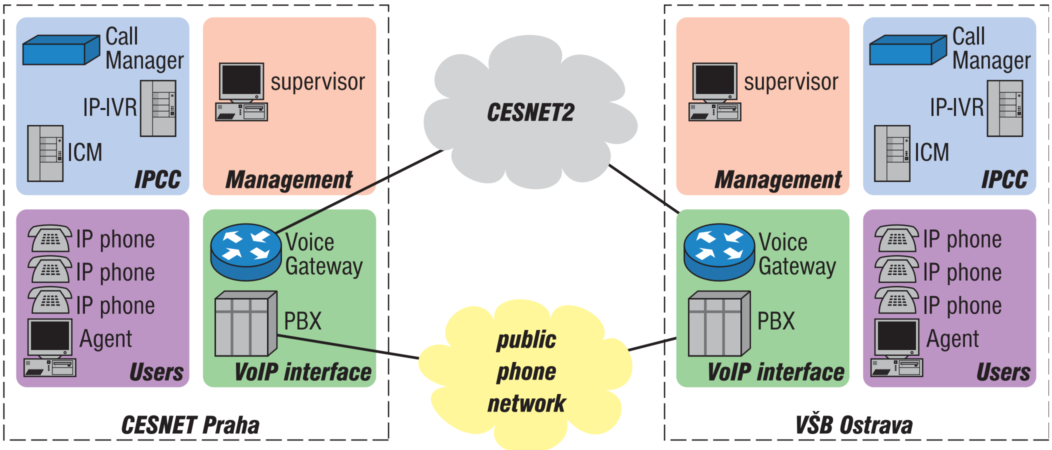


Figure 14.2: Current distributed IPCC connection

IPCC operates currently at private dial numbers, where the system is working, including the definition of waiting queues and operators. At the end of the year, we managed to obtain dialing prefixes from the Ostrava range. We will make the entire system available again, within the newly assigned prefixes, at the beginning of the next year.

In the future, we expect utilization of this solution for the needs of CESNET and/or its members. The solution can be used as a branch exchange or help-desk.

15 Intelligent NetFlow Analyser

The specification of the *Intelligent NetFlow Analyser* required developing of a modular distributed system entitled *NetFlow Monitor* that would allow evaluation of the network traffic by processing NetFlow statistics exported from Cisco routers.

The monitor should make it possible to perform the traffic analysis almost in real-time mode. Besides that, the intelligent filtration, aggregation, and statistic data evaluation should be provided and the system should offer the multi-criteria data selection on the level of individual data flows, as well (e.g., by source/target IP address, protocol, ports, etc.). The system is also comprised of heuristic methods allowing processing of protocols with dynamically changing ports. In addition, the system should be able to intelligently notify about suspicious network traffic activities (for example security incidents, routing errors, etc.) by sending warning messages.

The whole system is divided into three blocks:

- executive core – NetFlow Collector
- user interface – NetFlow Monitor
- sending of warning messages – NetFlow Event.

15.1 NetFlow Collector

The first component is written completely in the C programming language and performs the actual processing of data received. In this half-year, we integrated support for the NetFlow export version 6 processing. Thus, NetFlow Monitor currently supports versions 1, 5, 6, and 7. The support for certain types of statistics from version 8 is under development. We are also working on the NetFlow export version 9 support, which is available in selected Cisco Systems devices since June 2002.

The NetFlow Collector already supports some basic modules. An example can be the module for forwarding a data flow to a different target (NetFlow Forwarder module). This module ensures sending of the NetFlow exports to one or more IP addresses and selected ports.

Another module is, for example, the input data filter, which uses input access lists (ACL) for its operation – i.e., lists of subjects from which the NetFlow exports can be received. The last module example is a part of the database storage of received and processed NetFlow exports. Besides storing data from the internal cache memory into the MySQL database, the functions of the export module also include aggregation of individual pieces of information about data flows with time.

The model of creating regular non-aggregated hourly tables from which aggregated daily, weekly, and monthly tables are compiled is completed and verified by tests. The number of individual tables is theoretically limited only by the disk space available. However, it can be restricted by configuration as well. For example, it is possible to define that we want to have hourly tables for the last 3 days available plus tables with aggregated data – for example daily tables for the last 14 days, weekly tables for the last 6 weeks, and monthly tables for the last 2 years.

The model in which tables are divided into tables with aggregated and non-aggregated information is useful for various user views. Network administrators often need to view detailed information on network activities in the last hour. In this case, it is useful to look at an hourly table.

At other times, it is important to have a global overview of the network trends, including, for example, information about the proportional share of individual protocols within one day, week, or month. It is better to generate these overviews from pre-prepared daily, weekly, or monthly tables, which do not need to contain detailed information.

15.2 NetFlow Monitor

The second component of the system for NetFlow statistics processing is written in the PHP programming language. Its goal is to present results in a user-friendly manner, create graphs and statistics, and – last but not least – to allow easy configuration of NetFlow Collector and NetFlow Event via the Web.

At the beginning of the year, we completed the basics for a new user interface, which allowed easy creation of new dynamic Web pages in the future. The existing Web interface is comprised of seven main menus: Main, Tables, Graphs, Events, Statistics, Options and Help.

The *Main* menu contains a basic search for information about data flows, IP addresses and autonomous systems, etc. In the *Tables* and *Graphs* menu, options for the management of predefined profiles for searching criteria used to generate tables and graphs will be provided. The *Events* menu allows the management and viewing of events that are generated by NetFlow Collectors.

Under the *Statistics* item, you can find options for getting information on statuses of individual processes, sizes and statuses of individual tables, etc. The *Options* item contains all settings of the entire system. Here, it is possible to create users, allocate access rights, add new Collectors, etc. The *Help* menu, unfortunately, remains empty for now. We hope that we will manage to complete the entire online documentation for the whole system in 2003.

In the second half-year, we completed the support for the simultaneous access of multiple users with different access rights. In the current version, the Statistics, Search, Global Profiles, User Profiles, Config and Admin rights can be allocated to users. The Admin rights represent the highest level and include all other lower-level rights.

NetFlow Monitor recognizes two parts that are managed by the NetFlow Analyser system core: NetFlow Unit and NetFlow Collector. NetFlow Unit is a single computing unit, i.e., a standalone computer. NetFlow Collector is a daemon working under a specific unit. Every Collector processes data and is controlled by the common NetFlow Unit component. Configuration dialogues from the NetFlow Monitor Web environment correspond to this design, too.

When setting up a Collector, the port at which NetFlow exports are received is specified, plus some other parameters.

Plug-in modules used by NetFlow Collector can be configured in the same way. However, some modules cannot be configured via the Web environment, or these modules work with predefined parameters. In the future, we are considering having the parameters of all modules as adjustable as possible.

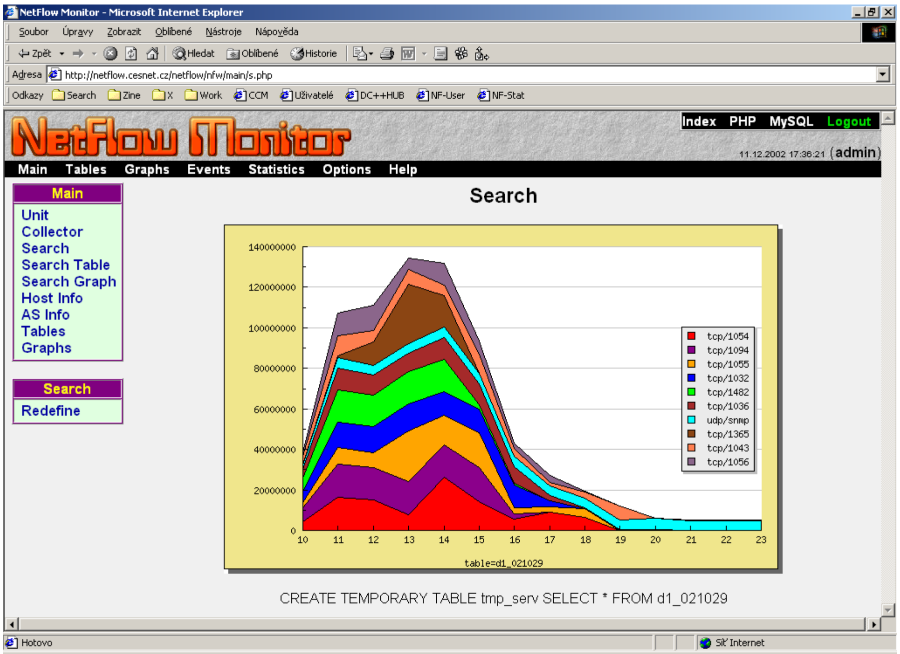


Figure 15.1: Generated statistics sample

In the *Main* item, you can find functions for displaying reports on data flows and generating graphic outputs. For generating statistics about aggregated data flows, the *Search* item is used. When you select this item, you can choose the statistics type (Bytes, Services, TOP IP, Sessions, etc.), source table, and other parameters.

For displaying detailed information about a data flow, it is more convenient to use statistics generated from non-aggregated data that are stored in hourly tables. In this case, you can also choose from much more search criteria than those contained in the statistics generated from aggregated information, which is described above. The output is formatted as a table with links pointing to detailed information about used IP addresses or autonomous systems.

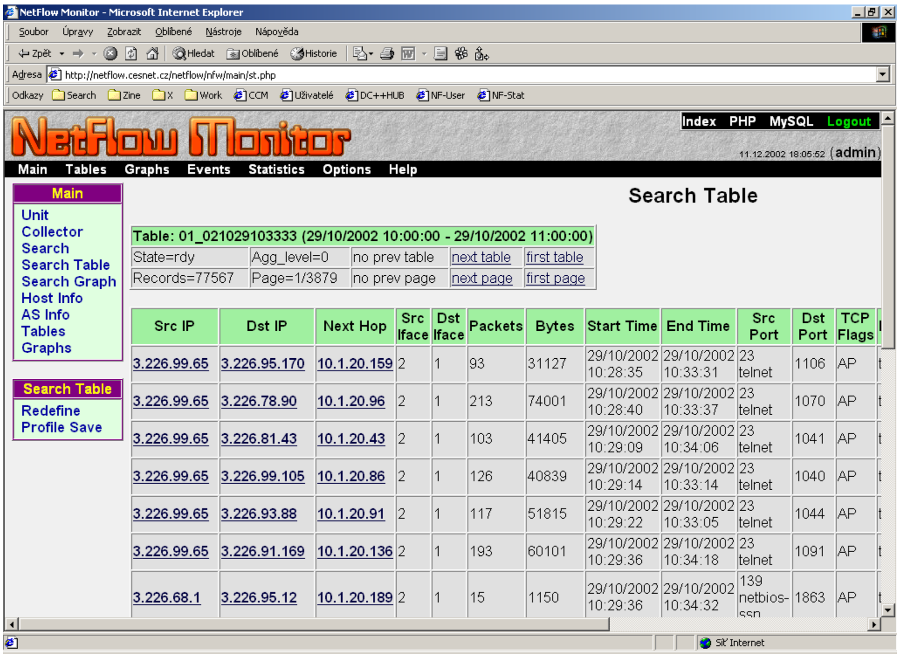


Figure 15.2: Statistics based on non-aggregated data

15.3 NetFlow Event

The third component of the NetFlow Analyser system maintains sending of information to selected targets. For a given message, multiple addressees and the message type (e-mail, SMS) can be specified in the system. Event types to which specific rules should apply are optional. For example, it is possible to define that all information should be sent by e-mail, but critical errors should be sent to a mobile phone.

In the future, we plan to add the support for sending messages to pagers and to a directly connected SMS gateway. Unfortunately, we did not manage to implement any information aggregation this year. Currently, every item is sent individually, which may lead to the unpleasant mailbox overflow effect.

15.4 Conclusion

During 2002, our team successfully created the main core of the monitoring system, which could efficiently search for network problems and which actually provides means for avoiding such problems. The developed analyser is currently under testing performed by Mr. Valencia Scott from the AT&T corporation and Mr. Rich Polyak from the pharmaceutical company Aventis. In order to speed up the application development, we established a closed development mailing list at *netflow-l@cesnet.cz* in December.

16 Storage over IP (iSCSI)

The iSCSI technology described in the [SSC02] document encapsulates the SCSI communication into the IP protocol, thus allowing access to SCSI devices via an existing network and consequent implementation of something known as a storage area network (SAN).

This technology is now standardized and provided by first commercial manufacturers. One of these manufacturers are also *Nishan Systems (Nishan IPS3300)* and *Cisco Systems (Storage router SN 5428)*, whose devices were tested.

The project objective is to

- test usability of Linux iSCSI implementations and first commercial devices (Nishan, Cisco)
- test data throughput of individual solutions in comparison with a directly connected disk space
- test mechanisms for authentication/authorization of operations within the iSCSI protocol

The experience gained within the project was described in three technical reports.

16.1 iSCSI Technology Use

Unlike the existing technologies of the file-oriented access to remote data, this technology is based on access to block devices. A connected remote device is therefore displayed as a common physical device with block access.

The encapsulation of the SCSI protocol in the IP protocol brings new possibilities for implementing a data storage infrastructure:

- Creation of a shared technology for the data transfer and data storage – possibility to utilize an iSCSI adapter using the Gigabit Ethernet or a TCP/IP stack.

- Long-distance extensibility – using WAN and routers, the data storage network can be extended and used at any distance.

- Various topology options – dedicated storage network, private network, or Internet use.

- Support for the data storage consolidation to one place with unified technology – reduced prices for the management and maintenance.

Because of this, iSCSI can be utilized, for example, for

- data space consolidation (easy transition from a local, directly connected disc space to a disc space connected via an IP network)
- storage area networks (local, distributed)
- data replication
- backup on the level of physical devices
- network boot and its use for high availability data systems
- data space provision services and remote data access

16.2 Testing of iSCSI Devices

Within the configurations described below, we tested the individual iSCSI implementations in the Linux operating system, and Nishan and Cisco devices. Our measurements focused on the basic functionality and performance characteristics. In addition, we tested several other functions (authentication, iSCSI netboot) and summarized the results in the CESNET technical reports No. 5/2002, 12/2002, and 15/2002. From the previously mentioned reports, selected performance characteristics and some other facts revealed during testing are provided below.

Considering that every measurement took place at a different time, different client devices and network elements were available. Therefore, measurements cannot be compared directly with one another. However, it is possible to compare measured characteristics with the situation when a hard drive is connected directly to a client as a local device.

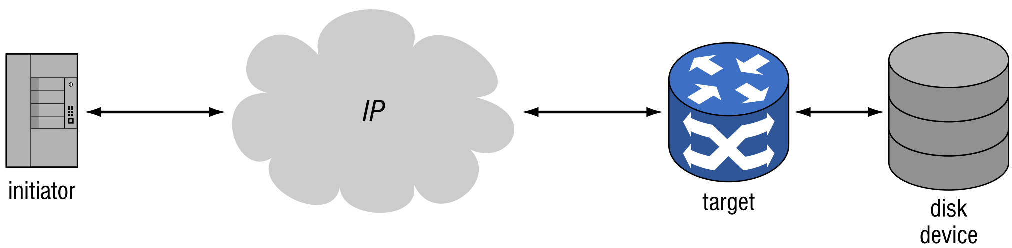


Figure 16.1: Testing configuration

As in the case of the classic SCSI, the command sender is called the initiator and the command executor is called the target. The network entity referred to as the client includes one or more initiators and network interfaces, the server entity includes one or more targets and network interfaces. Every node has its unique world identification. Both parties communicate with each other via the TCP protocol, the server listens at port 5003 according to [SSC02].

For measuring the iSCSI performance, we employed the *utest* tool, which was a part of the Intel implementation source, and a standard *iozone*[13] benchmark.

[13] *http://www.iozone.org/*

In the Linux OS, we used three different implementations during our tests:

- Intel
- University of New Hampshire (UNH) InterOperability Lab
- Cisco

16.2.1 Linux–Linux

In the first test, both the target and the initiator were running on a PC with the Linux operating system. We used the ext2 file system in Linux within this test, as well as in the further tests.

Performance Characteristics Measurements

We were only able to measure the performance for the Intel implementation, which turned out to be the only one functional. For comparison, we carried out our measurements in a 100 MB Ethernet network and a gigabit network. The target utilization in the gigabit network reached up to 70 % at peak times during measurements.

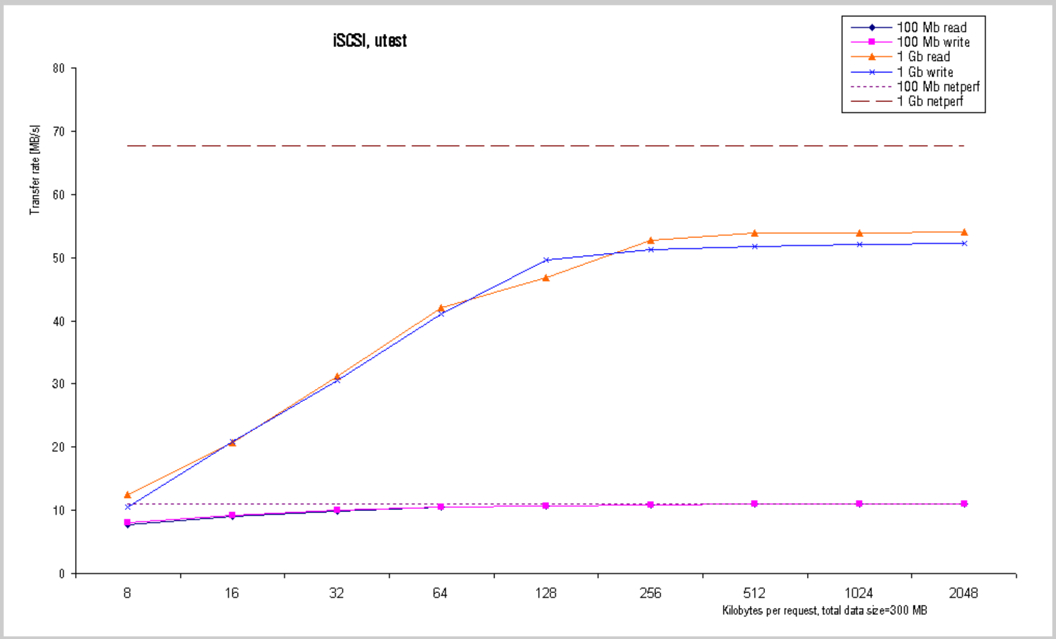


Figure 16.2: Linux–Linux measurement results

For comparison, we measured the data throughput within the access to data located on a directly connected hard drive and the access via NFS with the same equipment. At the same time, we measured the processor utilization for individual data access types (lines marked as SCSI/L and NFS/L).

record size [kB]	*256*	*512*	*1024*	*2048*	*4096*	*8192*	*16384*
iSCSI read	14473	25849	29185	30233	30254	31080	27051
local read	21193	28629	31751	34477	35170	35888	37550
NFS read	15291	23236	27448	29824	31973	34167	30208
iSCSI write	8665	10975	11833	12344	11952	13141	11799
local write	17269	17633	18981	20660	18642	23639	22230
NFS write	10124	12203	12425	12742	16412	12390	16152

Table 16.1: Reading and writing of individual alternatives [kBps]

record size [kB]	*256*	*512*	*1024*	*2048*	*4096*	*8192*	*16384*
iSCSI/L	68 %	90 %	92 %	88 %	86 %	87 %	72 %
NFS/L	72 %	81 %	86 %	87 %	91 %	95 %	80 %
iSCSI/L	50 %	62 %	62 %	60 %	64 %	56 %	53 %
NFS/L	59 %	69 %	65 %	62 %	88 %	52 %	73 %

Table 16.2: Network and local access comparison

Practical Experience

The development of the reference Intel implementation is either done with a compiler for the 64-bit platform, or only with historic SCSI devices. This results in a substantial restriction of the hard drive capacity to the *int* type value (hence, the drive capacity is limited to approx. 2 GB). We tried to modify the code and replace the *int* type with the *long* type. However, the modification was not trivial. Exceeding the 2 GB limit caused the file system to crash. We decided to continue in our testing with this restriction in mind and not to exceed the limit.

The code available at the UNH InterOperability Lab website was in fact not functional. After a connection is established, the operating system's kernel on the target side freezes.

The implementation of Cisco cannot be used in collaboration with the Intel target – the initiator handles the drive geometry incorrectly. Although we managed to remove the previously mentioned effect by modifying the source code of the Cisco initiator, the Intel target kept indicating errors within the communication. These errors were also caused by the fact that the Cisco initiator was sending non-standard requests (e.g., text strings about the software manufacturer), too.

The results and practical experience we gained with the target and initiator implementation in Linux are summarized in the CESNET technical report No. 5/2002.

16.2.2 Nishan–Linux

In this test, the target was represented by the Nishan Systems IPS3300 commercial device. The initiator was running on a PC with the Linux operating system.

The iSCSI router was connected to the disk array by the Fibre Channel interface. For the needs of the test, we divided the disk into four sections with sizes of 1 GB each. Client PCs were connected to the iSCSI router directly with the Gigabit Ethernet without any intermediate devices that could affect the system performance.

In client PCs having the initiator role, we used the iSCSI implementation of Cisco Systems. Other implementations contain a different iSCSI protocol version and therefore turned out to be unusable.

Performance Characteristics Measurements

The measurements were carried out using the *iozone* program with the following parameters:

```
iozone -Rb iscsi.wks -n 900m -g 900m -z -c -a
```

Modification of the TCP window size both for reading, and writing did not have any substantial effect on the read/write performance compared to standard Linux kernel values (version 2.4.18 and 2.4.19). Modifications of the standard TCP socket buffer size for writing (16 kB replaced with 64 kB) and reading (85 kB replaced with 1 MB) were performed.

record size [kB]	*4*	*8*	*16*	*32*	*64*	*128*	*256*
write	18060	17906	17780	18156	17909	18072	18020
read	19916	17956	19602	19700	19865	19687	19774

record size [kB]	*512*	*1024*	*2048*	*4096*	*8192*	*16384*
write	18161	18084	17874	17693	17612	17708
read	19390	19011	19579	19480	19228	19260

Table 16.3: Read/Write values of Nishan IPS3300 [kBps]

Practical Experience

The Nishan IPS3300 device seems to be a usable technology for the implementation of a storage area network (along with an appropriate disk array) utilizing the iSCSI protocol.

From the tested firmware versions, only the last one could be used for iSCSI. However, in this version, the part concerning SNS was unusable, hence the functionality of this protocol could not be tested.

Figure 16.3: Nishan–Linux measurement results

A detailed description of all measurements performed and our experience relating to the Nishan IPS3300 device can be found in the CESNET technical report No. 12/2002.

16.2.3 Cisco–Linux

The target in the third test series was represented by the Cisco SN 5428 commercial device connected with the Fortra disk array. A PC with the Linux operating system was used as the initiator. The Cisco SN 5420 and 5428 devices support iSCSI in accordance with the IETF draft version eight.

Performance Characteristics Measurements

The measurements were done using the *iozone* program with the following parameters: (output to a binary file in the MS Excel format, with the minimum and maximum file size of 3 GB, utilizing the *close()* function and automatic measurement, with transferred block sizes from 4 kB to 16 MB)

```
iozone -Rb iscsi.wks -n 3g -g 3g -z -c -a -i 0 -i 1
```

Practical Experience

We had to replace the SN 5428 firmware with the version 2.3.1.3-K9, since the originally provided firmware version 2.3.1 caused inconsistent results in the repeated reading speed tests.

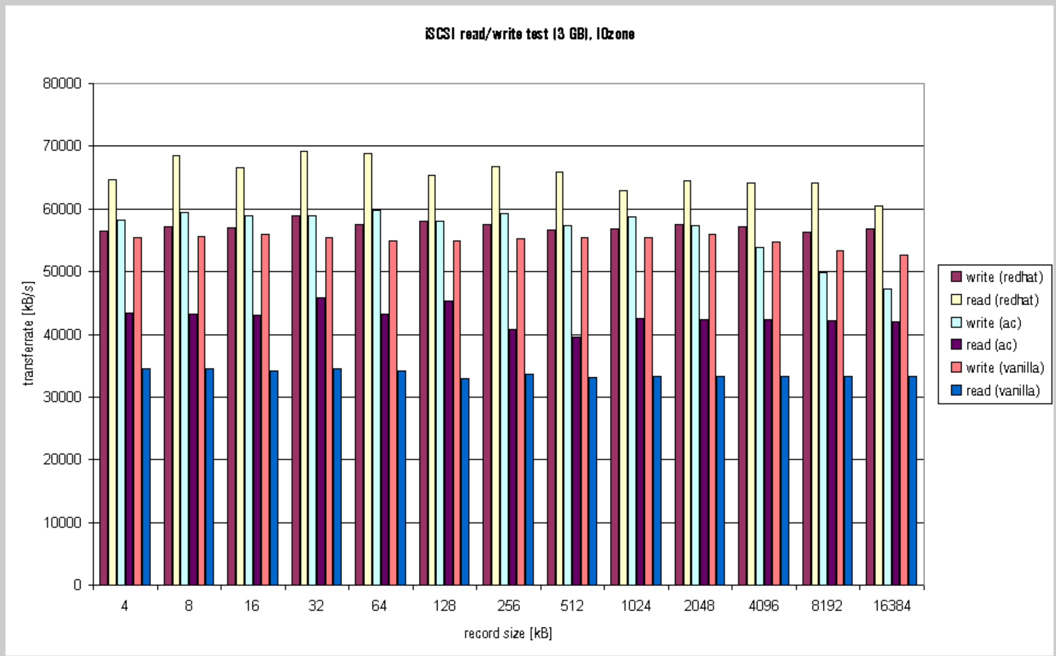


Figure 16.4: Cisco–Linux measurement results

The graph clearly illustrates that the highest performance was reached with a modified kernel by RedHat. This kernel significantly differs from the standard kernel in some aspects (the kernel is obtained by applying 215 patches with the total size of 35 MB). Unfortunately, we were unable to find out which of the modifications has the essential influence on the transfer speed increase. An important part of the RedHat kernel modifications is a set of patches by Alan Cox. That is why we also tested the standard kernel with these patches applied. The results were better than those of the standard kernel, though not as good as in the case of the RedHat kernel.

A detailed description of all measurements performed and our experience with the Cisco SN 5428 device can be found in the CESNET technical report No. 15/2002.

16.3 iSCSI Security

iSCSI employs two independent security mechanisms, which complement each other:

- target–initiator authentication in the iSCSI link layer
- data packets protection on the IP layer (IPSec)

If the iSCSI implementation is to comply with the [SSC02] draft, both the target and the initiator must support authentication. The existing security levels of individual iSCSI implementations can be characterized by several approaches.

16.3.1 No Security

The initiator is not authenticated and transferred data and commands are not encrypted in this mode. This approach can only be applied in situations where potential security risks are minimal and configuration flaws are not likely.

16.3.2 Initiator–Target Authentication

In this mode, the target authenticates the initiator (or/and vice versa). This approach prevents unauthorized access to data spaces by faking the identity of the initiator (spoofing). After completing the authentication process, all other commands and data are sent in an unencrypted form. This method can be used only if man-in-the-middle attacks, wiretapping, and modifications of data sent are excluded.

The iSCSI draft (see [SSC02] and [ATW02]) assumes authentication forms in accordance with table 16.4.

KRB5	Kerberos V5
SPKM1	Simple public-key generic security service (GSS), application programming interface (API) mechanism
SPKM2	Simple public-key GSS API mechanism
SRP	Secure Remote Password
CHAP	Challenge Handshake Authentication Protocol
None	No authentication

Table 16.4: Available iSCSI authentication types

16.3.3 Authentication and Encryption

Within this solution, the authentication is secured using one of the previously mentioned mechanisms and the data transfer security is maintained with the encryption on the IP level.

From the viewpoint of the draft, a device is considered iSCSI-compatible if it has the IPSec support implemented. With respect to the demands for bandwidth and relating difficulties within the encryption, the draft permits the IPSec implementation in a front-end device. The pair of devices (iSCSI router and the IPSec device) is then considered to be a device complying with the draft requirements. None of the tested devices had the IPSec technology implemented.

Linux: Authentication using a locally defined list of initiators, CHAP protocol.

Cisco: Authentication using a locally defined list of initiators, the RADIUS and TACACS+ servers. The CHAP protocol is used. In addition, access lists and virtual networks can be used.

We tested the configuration and operation of the previously mentioned authentication mechanism and found them functional. The Nishan device was borrowed only for a limited time, which was further reduced by searching for a working firmware version. Therefore, we did not test authentication mechanisms of this device.

16.4 Conclusion

16.4.1 Linux as Initiator/Target

During the preparation of this report, authors of the document were aware of three software-based partial or complete iSCSI solutions on the PC GNU/Linux platform. None of them seems to be suitable for the routine use yet. This area is however still under development.

As it is obvious from the table provided above, there is a substantial speed degradation occurring if very small blocks are transmitted over iSCSI. NFS provides higher speeds for high data volume requests.

The previously mentioned measurements indicate that the Linux kernel version and installation of patches considerably affect the performance.

16.4.2 Commercial Products

Both tested products (IPS 3300, SN 5428) meet the basic functionality requirements.

Only the last one of several tested firmware versions for the Nishan device was usable for iSCSI. However, in this version, the part concerning SNS was unusable and therefore the functionally of this protocol and its implementation could not be tested.

16.5 Further Work Progress

In the following period, we intend to perform testing of other iSCSI features, which have not yet been tested or satisfactorily implemented in borrowed devices. These features mainly involve the implementation of the iSCSI *fail over* and *bootstrap* (see [SMS02]) of client devices via SCSI. Concerning the *fail over* function, we will focus on measuring the speed of the backup route establishment time. In addition, we plan testing of the performance of iSCSI transfers when using IPSec.

As far as new technologies are concerned, we will test the usability and implementation properties of the HyperSCSI2 protocol[14] designed for encapsulating the SCSI protocol into IP packets and the interconnection of data stores within a metropolitan network utilizing the iFCP protocol.

[14] *http://nst.dsi.a-star.edu.sg/mcsa/hyperscsi*

17 Presentation

The objective of the *Presentation* project is to provide information about activities relating to the research plan and results achieved. In addition to the actual presentation activities, we also provide other researchers with support in this area. Because of the character of the research plan, we concentrate primarily on electronic presentation forms.

17.1 Web Server

The basic electronic presentation platform for the research plan is the server *www.cesnet.cz*. Most of the results achieved are available here – either directly, or as links to other servers of the association.

The server has three different sections in total:

Czech public section: The most extensive section, where we provide public information on the CESNET2 academic network, research plan, and other activities of the association.

English public section: This section is intended for our foreign partners and those who are looking for information. From a thematic point of view, this section is similar to the previous one, though its content is in the English language and its extent is smaller.

Private section: This section is used for the internal communication of researchers involved in the research plan. Only users who prove their identity with the CAAS authentication system are allowed to enter this server section.

All three sections are based on a common design that connects them visually. However, the sections also differ enough so that a user is able to immediately recognize in which section he/she is currently located.

Besides continuous content updates and publishing of new documents, the following more essential changes occurred in the content of the *www.cesnet.cz* server in 2002:

- We have removed the section dedicated to Web proxy cache servers from the main menu. This technology is fading away from the environment of the academic networks and CESNET does not develop it anymore.
- We have significantly reorganized the sections dedicated to the videoconferencing (thematic range was extended to multimedia transmissions in general) and IPv6.

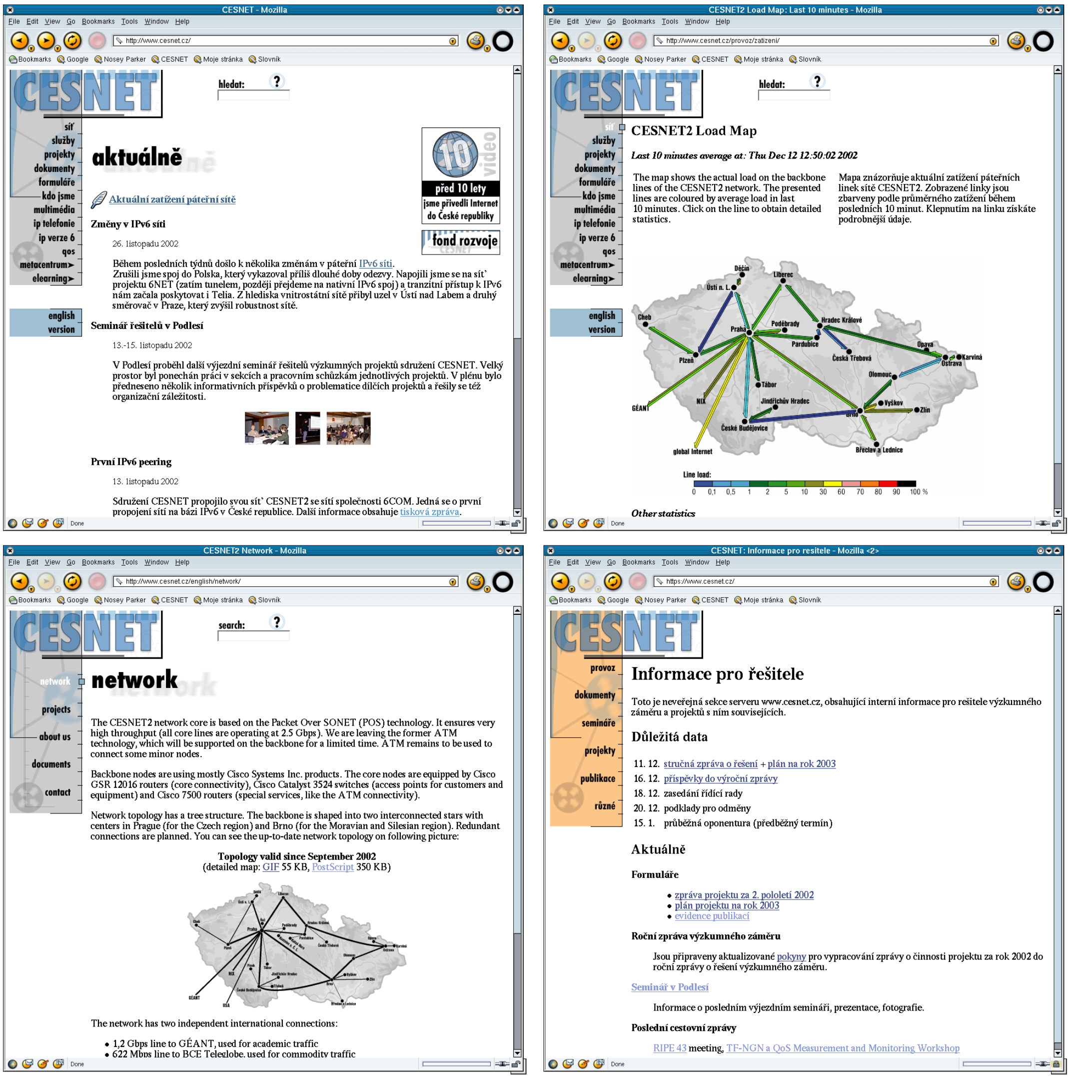


Figure 17.1: *www.cesnet.cz*

- We have highlighted the existence of CESNET's servers *meta.cesnet.cz* and *eLearning.cesnet.cz* by incorporating them into the main menu.
- The video archive has grown significantly. At the end of the year, the archive offered nearly 100 records.

Besides IPv4, the server is now available via the IPv6 protocol as well.

17.2 Publishing Activities

In connection with the work on the research plan, three publications in book-form were created in 2002:

- publicly available annual report of the research plan work in 2001

- MetaCentre 2000–2001 yearbook
- book about IPv6

With the last mentioned publication, the association commenced collaboration with the *Neocortex* publisher, which publishes specialized computer literature. The CESNET edition has been formed – its authors should be represented by the researchers working on the research plan. This creates a new space for publishing books dealing with the topic of advanced network technologies and their applications. The books will be distributed through standard distribution channels for specialized literature and thus easily available to readers.

In 2002, we continued in our collaboration with the *Lupa* online magazine, focusing on the Internet topic. We published nearly 30 articles here that are thematically linked with the research plan. The articles dealt mainly with the advanced network technologies and services.

The number of technical reports from 2002 roughly matches the numbers from 2001. We published 18 technical reports. Approximately one half of the reports are written in English, and the rest in Czech.

We continued publishing the *Datagram* newsletter, in which we inform association members and other institutions about capabilities of the CESNET2 network and activities related to the network development. Four issues of the newsletter were published in 2002.

Most of the aforementioned publications (with the exception of the book about IPv6) are freely available in electronic form on the websites of the association at *www.cesnet.cz* and *meta.cesnet.cz*.

17.3 Public Events and Other Presentation Forms

The most important public presentation event was the commemoration of the 10th anniversary of the Internet start in the Czech Republic. On this occasion, the association organized a celebratory meeting called *10 Years of the Internet in the Czech Republic*.

The meeting took place in the Prague Karolinum on Wednesday, 13 February, exactly ten years after the ceremonial initiation of the Internet network operation in the former Czech and Slovak Federative Republic. In the afternoon block of lectures, both foreign and home guests presented a set of lectures focused on the history and prospects of this network. The afternoon part of the meeting was dedicated to panel discussion with the topic “Where is the Internet heading?”

The meeting was broadcast live via the Internet and records of individual lectures and the panel discussion are available in our video archive. The tenth inland Internet anniversary received a significant response from the specialized press.

Figure 17.2: 10 Years of the Internet in the Czech Republic meeting

The association also participated in organization of the traditional conference entitled *Broadband Networks and Their Applications*, which is hosted by Palacký University in Olomouc. On this occasion, as well as at other specialized conferences and seminars, members of the research team presented many reports dedicated to the results achieved within work on the research plan.

17.4 2003 Plan

We assume that our activities will continue in the same direction in the next year. We will concentrate mainly on the continuous updating and development of *www.cesnet.cz* and publishing of the *Datagram* newsletter and technical reports. We would like to expand our multimedia archives with an archive of free-to-use high-quality digital photographs.

18 System for Dealing with Operating Issues and Requests

The *Request Tracker (RT)* system is intended for coordinating work on problems and requests. The system allows monitoring of the development of a request, participating in work on this request and providing information about results. The main task of the system is to inform the group working on the given issue about the contributions of individual group members and the current status. We use the system to coordinate the operating team of the CESNET2 network as well as for other related purposes.

18.1 Work Progress

In 2002, we planned to transfer the database part of the system to a standalone server. However, we could not perform this transfer due to the temporary lack of investment resources. Thus, we reassessed the material requirements of the project instead, and decided to at least upgrade the existing server.

To be specific, we added a second processor, i.e., we employed two 800 MHz processors instead of a single 500 MHz processor, and expanded the memory to the maximum of 512 MB. We moved the original processor to a development workstation, which could now function as the front-end of the whole system in a critical situation, thus significantly boosting the total performance.

Other tasks included continuing of system modifications according to the requests determined by the operation and collaboration with our foreign colleagues. In this sphere, we managed, for example, to implement the conversion of all commonly used national character encodings to a single internal encoding. Besides the clarity and readability of the messages sent (both within the mail interface and the Web interface, of course), content-based searching now works as well.

An important step in the international collaboration field is that we became involved in the small team of system localizers. In the near future, users will enjoy the Czech language directly on the system level in RT version 3 (at the Web interface, the appropriate language will be selected automatically based on the language preferrence specified by the user).

The current development version of the system contains a slight modification in the management of access rights. It offers user-definable items and the current system of *keywords* (formerly *area*) is hidden, instead. This ongoing modification caused a delay in the planned migration of the old Trouble Ticket system.

Most of the problems connected with the migration of the existing operation were resolved in the end (e.g., implementation of operations such as *Fix* or *Description*, which appear in RT as a new transaction type). We keep on work on adapting of the Web interface needed and creating operating reports.

For operating reasons, we changed the server name to *rt.cesnet.cz* and established new certificates as well. We preserved the backward compatibility of links and old URLs, which occur in the archive-type mails, remain functional. In addition, we managed to migrate to a newer authentication subsystem (we also fixed the problem with setting of the `REMOTE_USER` variable) and tested acquisition of the basic user authorization data (including the proper national encoding representation) from LDAP.

By modifying the *enhanced_mailgate*, we prepared the system for collaboration with the planned authenticated e-mail correspondence. One of our outputs was the elaboration of a new RT2 user documentation. The benefits of the existence of this publicly available documentation was proven in a short time, since we were contacted by several other persons interested in the local modifications we performed. A similar situation occurred in the world after the Forward function in the new RT2 was published in the mailing list of RT users and developers.

Consequently, before elaborating an extensive and detailed technical report, we dealt with minor tasks, which represent the cornerstones of the final form of the support system. These tasks included, mainly, the final implementation of the automated user creation upon their first authentication with CAAS, which sets appropriate RT records according to the basic user data obtained from LDAP and defines, as a minimum, the basic access rights for the new user. Users therefore immediately get the possibility to search and view all requests in RT and comment them (or reply to the requesting person), without having to ask the administrator of corresponding queues for allocation of the basic rights. This, naturally, does not mean that users automatically become queue manipulators.

Thus, a way for possible further automation of the authorization information exchange is created. The management of the authorization information depends on administrators of individual request queues for now (this solution has been sufficient so far). We have published the developed source code, as well as the code that allows display of keywords in the request search results in the output Web page (here, the topic area is configured specifically).

Another very important step was the successful implementation of all our local modifications to the latest stable RT version (2.0.15, to be specific). In this way, we also removed several minor bugs (for example double display of merged requests) and mainly obtained better possibilities for applying potential patches to bugs found by other developers in this long-accepted stable version. When merging the versions, we added several new items into the RT configuration file. These items can be used to change the behaviour of selected local modifications.

While testing the implementation of the aforementioned *Description* and *Fix* operations, we discovered an ideal possibility for their application if a request for creating outputs in the FAQ form arises (we originally considered an implementation based on the keywords, which did not offer such a simple adaptability and mainly such a clarity).

We decided to continue in using this stable system as the basis, and put off the transition to the RT 3 system, which has not been completed yet (although at the time of writing this document, alpha testing of the RT 3 system is already being done).

With our colleagues working on the secure infrastructure for exchanging information among the researchers, we reconsidered the use of the S/MIME standard and decided to use the PGP standard instead (this standard is now equally well supported by e-mail clients). Moreover, the selection of this solution is supported by the common PGP (or GnuPG) usage by many researchers who regularly sign their keys to one another.

As the most suitable solution for the management of signed keys, we chose the alternative of maintaining the set of keys by a central authentication authority, which will sign this set and provide it to the system. As the result, RT will be able to trust control commands embedded in e-mail messages and unsigned messages will be regarded as normal user correspondence.

18.2 Results Achieved

We have created the *RT System in the CESNET Environment* technical report, which describes the current deployment status of the RT-based system for dealing with operating issues and configuration requests, the system configuration and its future development. The document initially defines the specialized terminology needed and describes the implementation and configuration of both the server and clients in the chapter entitled *Current RT Deployment Status in the CESNET2 Network*. The *System Configuration* chapter describes *Makefile* modifications for RT and modifications of the RT configuration file *config.pm*, adjustments of *httpd.conf* for the Web interface, modifications of *aliases* for the e-mail interface, and the basic settings of *crontab*. The remaining part of the report represents a small handbook structured by user types:

User (applicant): Description of the creation of a request and its processing up to its resolution.

Standard manipulator (privileged user): Detailed description of the request processing capabilities, request search, working with bookmarks, and links between requests.

Queue administrator: Brief description of the requests processing supervision, queue manipulators administration, and administration of keywords with respect to the importance of these individual activities.

System administrator: This section contains a very detailed description of the most important and most frequent tasks of the administrator of the entire system (creation, modification and deletion of user accounts, known restrictions of user accounts, adding of a new queue, removement of an unused queue, performing of modifications and upgrades).

The last part of the document outlines the future system development (physical database separation, PGP integration, GnuPG generally with PKI, migration to RT 3.0, FAQ generation) and also reminds of the existing documentation in the conclusion.

Basic information about the RT system will be published in the *root* Internet daily in the near future with the possibility to further cooperate on a more detailed description of the installation, configuration, and operation of this application.

18.3 Future Plans and the Work Progress Expected

We plan to keep on running and further developing this system. Our first step will be to complete the trouble tickets migration into the existing RT system and provide the possibility of creating the reports required.

We intend to keep pace with the world in the area of the development and testing of the new RT system version 3 and plan to create a project for migrating to this version.

We want to put the authenticated e-mail correspondence with the RT system using the PGP (or GnuPG) standard into the routine operation.

To speed up the responses, we plan to transfer the database part of the system to a separated database server. This server can also perform the function of a hot-swap backup.

The changes performed will be reflected both in the appropriate documentations intended for users, and in the reference technical report.

If our capacity allows, we would like to experimentally open a part of the system to third parties, which is, moreover, closely related to the aforementioned possibility of generating FAQ outputs.

Also, we would like to concentrate on issues concerning the transfer of old records/requests into archives in order to speed up searching for up-to-date information.

19 Security of Local CESNET2 Networks

CESNET2 consists of a number of standalone local networks containing computers with various operating systems. Ensuring the security of a large heterogeneous network brings about great demands for the work capacity of their administrators, and it is known that especially large university networks often have insufficiently secured machines. The objective of the second year of this project was to make the unenviable job of administrators easier by providing them with the access to the security audit technology, a system for detecting unauthorized accesses to the network, and a system for an unconventional fight against network viruses and hackers.

19.1 Security Audit

During 2001, we started running the *NESSUS* program, which can be freely distributed within the GNU licence, under the Linux operating system (kernel 2.4, Debian, RedHat, and SuSE distributions) at all three workplaces. The program performs the actual network security audit – in the graphical or line mode (running the program in the graphical mode is more user-friendly). NESSUS allows selection of the audit category (only safe or also potentially unsafe tests), detailed selection of individual security tests, scanning of TCP and UDP ports including the range, specification of the maximum number of simultaneously tested machines, etc. New security tests are published regularly on the NESSUS FTP server (*ftp.nessus.org*) and can be downloaded from this location automatically.

All machines that are to be tested within one NESSUS session have a common configuration file. If the machines need to be tested using different types of tests, the tested machines can be divided into several groups and their audits can be run separately. To facilitate the program control and distribution of results, we have added the following functions:

- inspection of machines in a protected network and reporting of differences from the last detected status (*Front End* program)
- distribution of the audit results to appropriate persons (*PTS*, *BackEnd*)
- other auxiliary functions (results sending – *REP*, results decoding – *DEC*)

Based on the requirements of administrators of the CESNET network in Dejvice, the *WebBackEnd (WBE)* was created, as well. This program significantly simplified access to the audit results: the results are no longer sent to individual administrators by e-mail as in the BE program, but they are published by the

HTTPS server. After the identity verification, every authorized person can access all results of the audit of all machines that the person administers.

Results are displayed in two forms:

- only the latest audit results
- comparison of the latest and reference audit results (reference data are usually represented by the previous session results).

In addition, a brief unencrypted notification about the delivery of new audit results to the HTTPS server is sent to administrators by e-mail, including a brief summary of results for every machine tested.

19.2 Intrusion Detection System – IDS

The second part of the project was the installation of a system for detecting the unauthorized access to the network (Intrusion Detection System). The selected *SNORT* program, which can be freely distributed thanks to the GNU licence, is operating in the networks of Czech Academy of Sciences in Praha-Krč and Technical University of Ostrava. The program is used particularly when a suspicion of attacks to other systems exists and for detecting network viruses and/or viruses spreading through e-mail.

19.3 LaBrea

LaBrea is a program inspired by the asphalt deposit in LaBrea (Los Angeles, California, USA), which has been working as a trap for victims passing by for tens of thousands of years.

The LaBrea system can detect attempts to access nonexistent machines in a local network – such attempts are usually caused by network viruses or hackers searching for security holes. The LaBrea server responds to these queries instead of the nonexistent machines and establishes a connection with the attacker, while only a minimum data volume is transferred (typically 0.34 Bps when communicating with Windows NT systems). This connection lasts until the program or attacker realizes that "nothing is happening" and closes the connection. This may take a very long time and, during this whole period, the attacker (or this attacker's thread) cannot cause harm anywhere else.

The LaBrea program has many other positive features. Network administrators will welcome, among other things, that the program installation is quite simple and requires virtually no attendance. The LaBrea program is generally assessed as a very efficient method for fighting network viruses (CodeRed, Nimda, etc.).

Moreover, the program was complemented with the *LBbe* and *LBrep* (*LaBrea BackEnd* and *LaBrea Report*) programs by the Dejvice project team members. LaBrea BackEnd will process the output file of the LaBrea program and create a number of files containing information on attacks to the protected network. The number of these files is minimized so that reports on all attacks, for which the same group of network or domain administrators is responsible, are provided in one letter. The number of these files can be also reduced by specifying command line parameters. The number of queries to Whois servers performed when searching for information on responsible administrators is minimized as well. The LaBrea Report program sends files created by LaBrea BackEnd to appropriate administrators and notifies them about the probable existence of compromised machines in their network.

19.4 Results

We offer three alternatives of the security audit: using *PTS*, classic *FE/BE*, and new *FE/WBE*.

PTS provides the easiest way to run the *NESSUS* program with the possibility to choose the configuration file used for every machine tested. The program itself sends the audit results to appropriate administrators by e-mail.

FrontEnd (FE) performs the inspection of machines in the IP address ranges specified by a network administrator. The program creates a list of all machines that are to be audited, determines their statuses by their response type (Broadcast, Loss, OK, TimeOut, WrongResponse), records the reference status, reports differences from the reference status (including potential changes in the reverse domain), and creates a list of machines that will be tested by *NESSUS* as well as a configuration file usable for *BE* or *WBE*. The program offers the possibility to work in the interactive or batch mode, select working directories (with different configurations of tested network), and write out detailed debug reports.

BackEnd (BE) maintains the secure distribution of the audit results. The program creates a standalone file for every administrator containing the audit results for all administrators' machines tested (every machine can have several different administrators). These encrypted files are then sent by the *Rep* program.

Decode (DEC) is designed for decoding the audit results sent by the *Rep* program.

WebBackEnd (WBE) distributes the audit results in a secured form in a way similar to that of *BackEnd*. However, this program uses a method that is substantially easier for end users – the results are published on the *https://spider.cesnet.cz/* server.

The security audit of machines in the CESNET Dejvice network is carried out regularly every 14 days. The audit is divided into the following stages:

1. Audit using virtually all "Denial of Service" tests available (approximately 760 machines in two separate groups)
2. Audit using only the safe "noDOS" tests (25 machines).

Administrators are notified by letter that another security audit took place. The letter looks approximately like this:

```
From: AuditAdmin <audit@cesnet.cz>
Date: Wed, 24 Jul 2002 18:52:33 +0200
To: (...)
Subject: AUDIT 24.7.2002 - noDOS

Hello,
the https://spider.ten.cz/app/nessus server contains
complete security audit results for these machines:
195.113.134.aaa (noDOS # aaaaa.cesnet.cz): Security warnings found
195.113.134.bbb (noDOS # bb.cesnet.cz): Security warnings found
195.113.144.ccc (noDOS): No response
195.113.144.ddd (noDOS): Security holes found

Changes in the audit results of the following machines
have been detected:
195.113.134.bbb (noDOS # bb.cesnet.cz)
195.113.144.ccc (noDOS)
195.113.144.ddd (noDOS)

Good luck!
Yours,               AuditAdmin.
```

Researchers of this project tested NESSUS and its auxiliary programs in different alternatives and configurations and have been using them regularly in three local CESNET2 networks (AV ČR Praha-Krč, CESNET Praha-Dejvice, and TU Ostrava). Every project researcher runs an auditing system with a configuration according to his own needs and requirements of administrators of machines in the local network.

During this time, we located a large number of security holes in tested machines thanks to NESSUS and its auxiliary programs, thus making the tasks of network administrators easier to accomplish. Network administrators now have a system available that regularly and automatically provides them with reports on security issues newly detected in tested machines, usually also including recommendations for removing these problems.

For now, the IDS SNORT system is running only in the networks of AV ČR Praha-Krč and TU Ostrava. It is successfully used when monitoring the communication to and from a network, for which the suspicion exists that the network is being attacked from outside or inside, is needed. The program proved useful – e.g., in the network of AV ČR Praha-Krč, the program helped detect spreading of network viruses in shared directories of computers with the Windows OS. The system has been tested with a Fast Ethernet adapter so far. In the next year, we would like to test its performance with a gigabit adapter.

The LaBrea system was successfully implemented at all three research workplaces of this project. The graph provided in Figure 19.1 shows how many external attacks the system detected in a single small sub-network of the CESNET network in Dejvice at the end of November 2002 and how many threads it managed to capture:

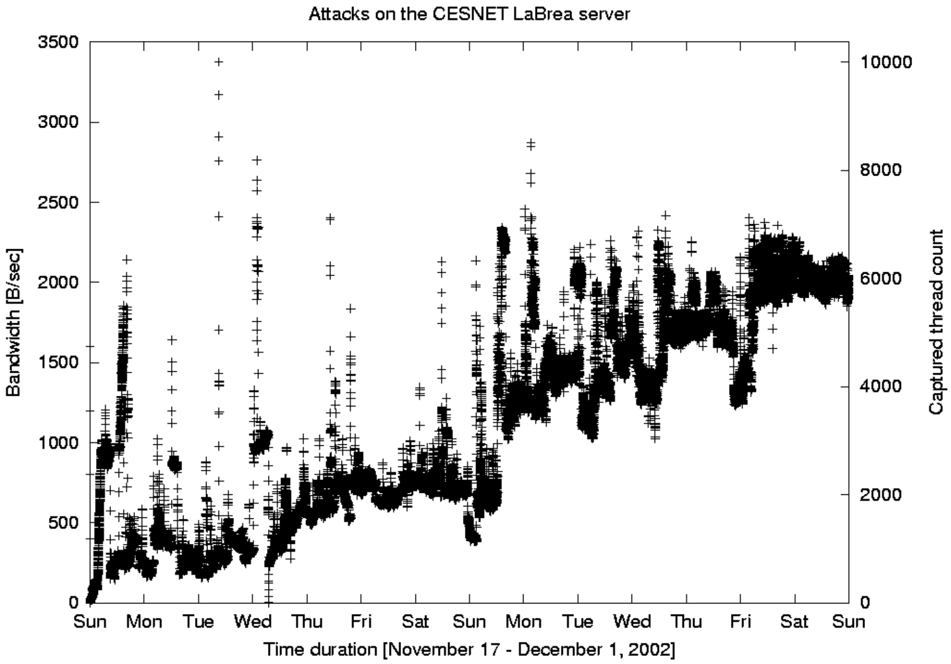


Figure 19.1: Graph of attacks detected by the LaBrea system

The LaBrea Report program installed in the Dejvice network sends results generated by the LaBrea system to responsible persons once a week and notifies them about the probable existence of compromised machines in their network. The typical letter looks approximately like this (shortened version):

```
To: (...)
From: IDS <ids@cesnet.cz>
Subject: [IDS021206.0042] Please check your network integrity
Date: Mon, 6 Dec 2002 10:36:08 +0100

Dear Administrator,
I have detected security hole probes coming from your IP
or domain space. This means someone is probing the Internet
looking for security holes and this is a strong indicator that
someone or something is misusing your computing facilities.
The person(s) doing this may be the owner(s) of account(s) at
```

```
the originating address(es) listed or someone who has broken
into your system(s) and is launching further attacks from your
network. Your computer(s) may also be infected by a network worm.
Would you please try to investigate this and/or inform all parties
responsible that their system(s) may be compromised?

Please find below the appropriate IDS log excerpt(s).
Time zone used: Central European Time (GMT+1).

Yours sincerely,
Intrusion Detection System, CESNET, Prague, The Czech Republic.

P.S.: I am only a machine and there is no need to respond.
However, should you need to contact my master, please do not
hesitate to 'reply' to this letter. :-)

**********************************************************
351 connections from a.b.115.230 (pc2-eswd1.....com)
Start of scan: 1038521917 = Thu Nov 28 23:18:37 2002
1038521917 a.b.115.230 3844 -> 195.113.xxx.2 1433
... skipping 349 lines ...
1038601444 a.b.115.230 4919 -> 195.113.xxx.2 1433
End of scan: 1038601444 = Fri Nov 29 21:24:04 2002.
Duration: 22:05:27. Frequency: 0.265 [conn/min].

**********************************************************

302 connections from a.b.240.140 (pc1-oxfd1.....com)
Start of scan: 1039015945 = Wed Dec 4 16:32:25 2002
1039015945 a.b.240.140 24908 -> 195.113.xxx.2 21
... skipping 300 lines ...
1039017922 a.b.240.140 25362 -> 195.113.xxx.121 1080
End of scan: 1039017922 = Wed Dec 4 17:05:22 2002.
Duration: 0:32:57. Frequency: 9.165 [conn/min].

**********************************************************

16 connections from a.b.80.136 (pc1-hudd1.....com)
Start of scan: 1038793330 = Mon Dec 2 02:42:10 2002
1038793330 a.b.80.136 2942 -> 195.113.xxx.28 80
... skipping 14 lines ...
1038794681 a.b.80.136 3906 -> 195.113.xxx.28 80
End of scan: 1038794681 = Mon Dec 2 03:04:41 2002.
Duration: 0:22:31. Frequency: 0.711 [conn/min].
```

Judging from reactions of those administrators who replied to these letters, it is obvious that they are grateful for this service.

All software created within this project is continuously published on the FTP server at *ftp://ftp.cesnet.cz/local/audit/*. Information about the progress of work and new versions of programs are delivered to all persons interested who registered to the *AUDIT-L@cesnet.cz* mailing list.

19.5 Future Plans, Expected Further Steps

We originally expected that the audit project would end in 2002. However, at the meeting of researchers in Podlesí, the decision was made to improve the system, so that administrators do not receive reports in the existing "plain text" format, which may not seem clear enough to administrators of larger numbers of machines. Instead, a form configurable by the administrators themselves according to their needs will be used. Workers from the network services operation department promised to provide their remarks and participate in work on some parts of this project. We plan further improvement of auxiliary programs for the LaBrea system as well.

On this occasion, special thanks should be given to Ing. Dan Studený from the aforementioned department, who contributed to the implementation of the WebBackEnd system in the HTTPS server, although he was not a member of this research team.

20 NTP Server Linked to the National Time Standard

The objective of the project is to build and operate a time server bound to the national time standard. The server was created as the result of the collaboration of CESNET and the Institute of Radio Engineering and Electronics of the Academy of Sciences of the Czech Republic (Ústav radiotechniky a elektroniky Akademie věd České republiky), which is responsible for the National Time and Frequency Standard.

20.1 Functional Components of the Server

The server, as a whole, is a system which does not only provide time information via the network, but also checks itself using the time standard with the accuracy of more than 1 microsecond and compares its time with other independent sources – a GPS receiver and an external time server. If a suspicion of a malfunction or improper functioning arises, the provision of time information to the network is blocked. We have applied a strictly defensive approach and our basic thesis states "better no time data provisioning than potentially inaccurate data".

The server is formed by three basic functional blocks:

- NTP computer
- KPC control system
- FK microprocessor system

20.2 NTP Computer

The NTP computer is the most essential component of the entire system. The *ntpd* process (version 4.1.71) is running in this computer. The process synchronizes the internal time with the external signal and delivers time information to clients via the NTP protocol. In addition, time information is also provided via the TIME and DAYTIME protocols.

From the hardware viewpoint, this computer is a standard PC (Pentium III 1.2 GHz), in which a new oscillator and a special card for processing the PPS signal were installed. The computer is equipped with two network adapters (10/100 Mbps Ethernet) – one with a public IP address, one for peer-to-peer com-

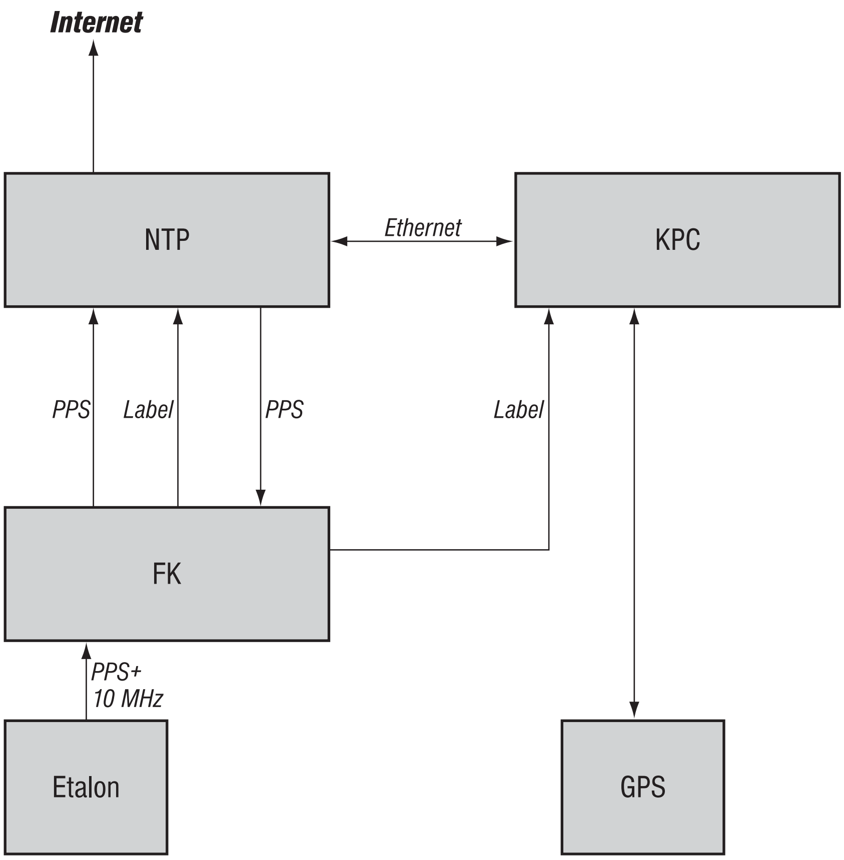


Figure 20.1: Functional components of the server

munication with the KPC control computer. For communicating with the FK microcomputer, a serial port is utilized.

We applied so called nanokernel patch to the Linux operating system kernel (2.4 family). The patch contains the support for the PPS signal processing and modifies the kernel so that it works with time in nanosecond resolution. Moreover, the kernel has been extended with our own driver for the special PCI card.

Furthermore, there are two processes running on the computer:

- *pps_gen* is designed to generate a second signal derived from the internal NTP server time. This signal is compared with the time standard in FK and the deviation measured determines the internal time error of the NTP server. The measurement is done with the accuracy of 100 ns.
- *ntp_deny* is the process that enables or disables the output of all time information from the NTP server (i.e., the NTP, TIME, and DAYTIME service) to the public network depending on the requirements of the *kpctrl* process from KPC.

20.3 KPC Control Computer

This computer is an older PC (Pentium 150 MHz) with the Linux operating system. For communicating with the outer world, the computer uses two network adapters (its public IP address and the peer-to-peer connection with the NTP computer) and two serial ports (the FK microcomputer and the GPS receiver).

KPC system processes:

- *kpc2* is the basic control multi-thread process, which collects and evaluates information about the current time and NTP server status.
- The *kpclie* process takes the data from the *kpc2* process and presents them to a user in a well-organized form. Several *kpclie* processes can be running simultaneously, allowing for the system to be monitored from multiple locations at the same time.
- The *kpctrl* process implements the algorithm that decides on enabling or disabling the provision of time services based on data provided by the *kpc2* process. The *kpctrl* process hands its decisions over to the *ntp_deny* process using UDP datagrams.

20.3.1 kpc2 Process

This process is the core of the KPC system. It collects the following data:

- local KPC time
- time labels from the FK microcomputer
- measured deviation of the internal NTP server time (from FK)
- time provided by all time services of the NTP server (i.e., the NTP, TIME, and DAYTIME protocol)
- time from the external independent time server
- time from the GPS receiver

Concerning the aforementioned data, their availability and value is treated separately. The *kpc2* process evaluates and sorts the data obtained and provides them to other processes every second. It is necessary to emphasize that the GPS receiver is used only for the verification, not as a source of the reference signal for the NTP server. Thus, the time server is not dependent on GPS.

20.4 FK Microprocessor System

The FK system is a single-board microcomputer. Its input is represented by second pulses from the time standard, accurate 10 MHz signal, and second pulses generated by the NTP server. Its output is the PPS (pulse per second) signal for the NTP server and two serial ports connected to the KPC and NTP server. The FK system has the following functions:

- generation of the PPS signal on the TTL level for the NTP server
- measurement of the NTP second pulse shift comparing to second pulses from the standard
- possibility to set date and time using buttons and a display
- possibility to enter information that a leap second will occur at the end of the current month
- generation of the output sentence containing the current UTC second label, measured shift of the second generated by the NTP server and the leap second flag

20.5 Special NTP Server Hardware

20.5.1 PPS Signal Processing Card

The standard way of working with PPS is to transfer the signal on the RS-232 level to the DCD serial port input and process interrupts generated by changes of the DCD input. In the interrupt handling procedure, a timestamp is assigned to this input signal edge. Problems are caused by the delay in the interrupt processing, which results in timestamp errors depending on the operating system type, processor speed, and current utilization. A typical delay is 10–25 microseconds. This issue is described in detail in the technical report No. 18/2001.

We designed a special PCI card, which can record the exact PPS signal arrival time, and had it manufactured. In this way, we obtain timestamps with the accuracy of 50 ns.

20.5.2 Temperature-Compensated Oscillator

In contemporary PCs, all frequencies are derived from a single 14.318 MHz oscillator. However, standard quartz is usually used, the temperature dependence of which is high even on the level of normal operating temperatures. The oscillator circuitry fortunately allows connecting directly a source of a TTL signal with the voltage of 3.3 V instead of the quartz. This enabled us to replace the quartz with a temperature compensated oscillator.

20.6 Further Work on the Project

The project work was already initiated by the end of 2001. Unfortunately, we did not receive the temperature compensated oscillators and the custom card until the second half of 2002. The NTP server has been operating in a closed testing mode since September 2002, when we completed the first version of the FK microcomputer. Since that time, we have been continuously monitoring the operation of the entire server and storing the data obtained for a long-term system behaviour analysis. At the beginning of 2003, we plan to put the server into routine operation and we want to focus on the evaluation of its characteristics from the metrological point of view.

21 Platforms for Streaming and Video Content Collaboration

Our group worked as a part of the strategic project entitled *Multimedia Transmissions in the CESNET2 Network* in the first half-year. In the second half-year, our group separated and formed a standalone project. Our research objectives remained unchanged throughout the year.

21.1 Streaming Server

Our main task was to establish a streaming platform for a higher-quality video (PAL format). In the beginning, we considered purchasing a special MPEG-2 streaming device (for example from vBrick or Optibase). However, such a step was assessed as inefficient. New versions of streaming systems that are already run by the association (Real Video 9 and Windows Media 9) allow PAL-quality streaming. That is why we rejected the special and proprietary hardware and concentrated on the development of the existing platform of the association.

During the year, we performed three broadcasts in PAL quality on our platform. The first one was the broadcast of the *10 Years of the Internet in the Czech Republic* event that was tainted by insufficient performance on the side of clients. The other two broadcasts (*INVEX2002* and *TERENA Mini Symposium*) were done with maximum satisfaction; hence, we can say that the CESNET's streaming platform is ready for PAL quality streaming.

We have added an external disk array to the CESNET's streaming platform to increase its content capacity. The capacity of the disk array is approximately 1.5 TB, which allows storage of about 1,500 hours of records in standard quality. This disk array utilizes inexpensive discs (ATA 133) with the u160 SCSI output in the RAID5 setup. The performed tests showed that the read and write speed of our setup is sufficient (read approx. 540 Mbps, write approx. 330 Mbps).

Because large amounts of the multimedia material suitable for streaming (for educational purposes, for example) started to emerge in CESNET and premises of its members (as an example, the University of Veterinary and Pharmaceutical Sciences in Brno), the manual content adding ceased to be satisfactory.

We had to create a content adding system. Its primary parameter was the online connection with the streaming server (no replication, data stored only at one location), linkage with CAAS (no user accounts outside CAAS) and preservation of flexibility during upgrades of the streaming server (running under Windows 2000).

The easiest way – direct interconnection of the streaming server with CAAS – was not possible since the GINA library that maintains AAA services in Windows changes with every Windows version (often also with different service packs). We would not be able to keep the system in a consistent state in terms of security and upgrades would not be possible. That is why we chose the alternative in which a proxy upload server is connected in front of the streaming server. This proxy server mediates communication between the client and the streaming server.

We chose Linux as the proxy server platform, because there is a PAM library developed within CAAS for authentication using LDAPS. Since only authentication data are stored in LDAPS, the authorization works on the basis of access rights in the file system of the proxy server. Every user can only access one directory in the streaming server. Data are transferred between the proxy and streaming server using the SMB protocol (transfer rate offered by SMB is approx. 50 Mbps per client).

Suitable selection of the protocol for transfers between clients and the proxy server turned out to be the biggest problem. User names and passwords need to be transferred in an encrypted form, whereas the remaining communication should be encryption-free (large volume of virtually uncompressible data). The protocol must easily pass though firewalls and there must be clients for this protocol for most of the operating systems normally available.

After considering several alternatives (Kerberos FTP and standard FTP, SMB, SSH/SCP, HTTP), we selected SSH/SCP. Its disadvantage is its low transfer performance (less than 10 Mbps in the tested configuration) given by the necessity to encrypt the entire communication. On the other hand, SSH/SCP normally passes through firewalls (if the port 22 is enabled) and there are a large number of clients for various operating systems available for it. Nevertheless, we do not consider the SSH/SCP alternative to be the optimal one and are looking for a protocol that could offer higher transfer rates while preserving the security.

Another extension considered is the direct connection of the proxy server to the disk array (the disk array can be connected to two independent servers).

The current streaming system configuration includes:

- *streaming server* – DELL 4000 (Pentium III Xeon, 1.25 GB RAM, 100 GB internal disk array, 1000BASE-SX)
- *proxy server* – SuperMicro 6012-P8 (Dual P4 Xeon, 512 MB RAM, 36 GB disk capacity, 1000BASE-T)
- *external disc array* – Proware Simbolo 3140 (15 × 120 GB HDD, u160 SCSI)

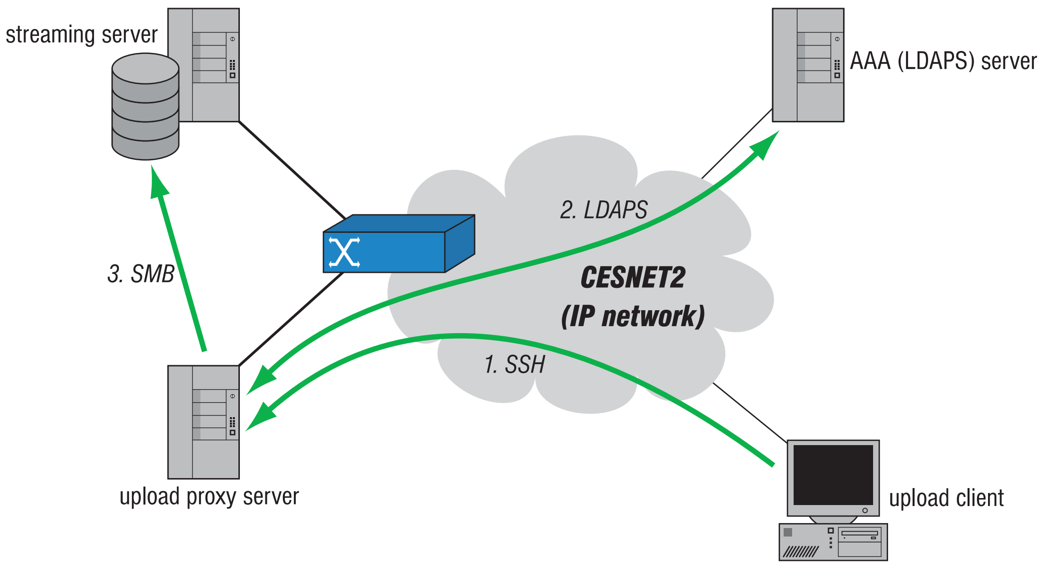


Figure 21.1: Upload system scheme

21.2 Announcing Portal

During this year, we started to actively participate in the preparation of a program of the TERENA association entitled *Academic Netcasting Working Group (TF-NETCAST)*. To provide groundwork for discussions, we launched the announcing portal, which is a Web application allowing announcements of live broadcasts of events.

The application is open; anyone with an access account in CAAS or in the portal system can contribute to the system. Submissions can also be uploaded off-line via e-mail. The submitted data are in XML format and the respective DTD is freely available at *http://prenosy.cesnet.cz/dtd/event.0-3.dtd*. The portal is located at *prenosy.cesnet.cz*.

21.3 Broadcasts of Events

In 2002, we maintained live broadcasts of events or provided the technological platform or technical support for these broadcasts. The most important of these events were the medical conferences *Genetics after Genome* and *International Symposium on Interventional Radiology*. From the viewpoint of the technological development of the streaming platform, the most essential events were broadcasts in the PAL quality of the *10 Years of the Internet in the Czech Republic* and *TERENA Mini Symposium* seminars and the broadcast of the *Invex 2002* exhibition.

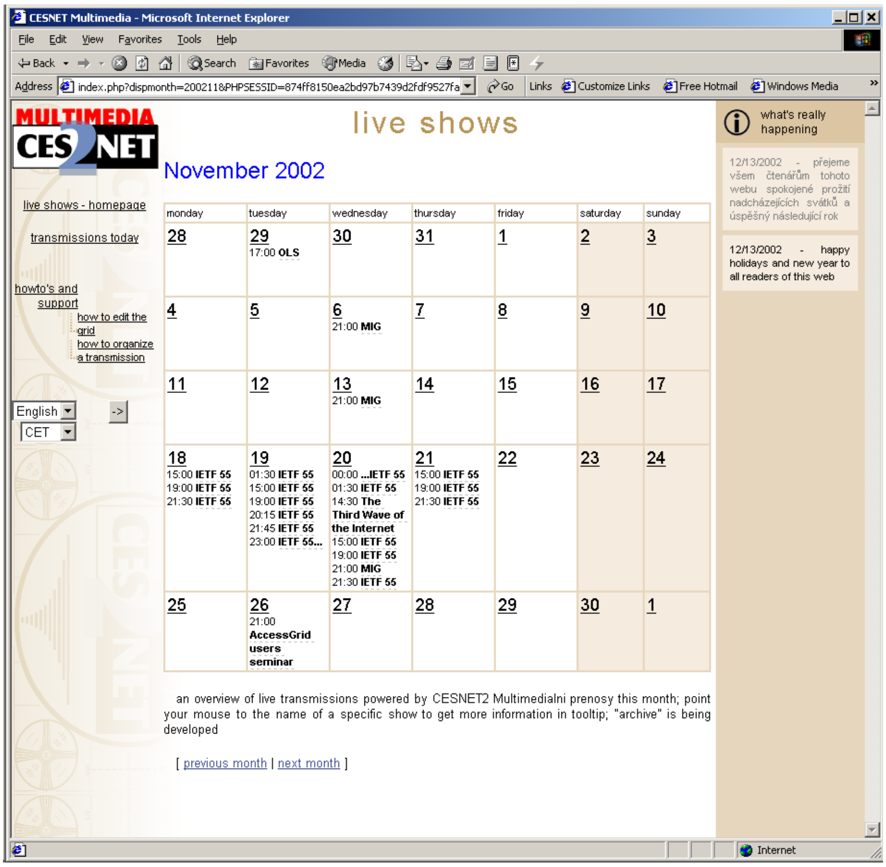


Figure 21.2: Announcing portal

As far as the normal operation is concerned, broadcasts of the *Ostrava Linux Seminars*, *Windows vs. Linux* dispute, *Open Router* group lectures or *Open Weekend* (two-day seminar with the topic of the Open Source software) were interesting, for example.

From the viewpoint of international collaboration, the most crucial was streaming of the *Megaconference IV*, the biggest H.323-based videoconference in the world. Our group was one of the three partners (and the only partner outside USA) that offered passive connection to this videoconference via the streaming technology. Thanks to this contact, we started to cooperate on the Internet2 streaming project.

21.4 Video Archive

There are records of most of the events we broadcast available that can be viewed in the video archive at *http://www.cesnet.cz/archiv/video/*.

21.5 Video Content Collaboration Platform

Due to the floods, our opportunities to cooperate with Prague media schools were delayed and therefore we tested the platform on our own. Although its producer offers the platform as a LAN solution, the platform can be used in the CESNET2 network. The equipment (*Avid LanShare EX*) will be delivered by the end of the year and put into routine operation at the turn of January and February 2003. This will enable us to offer our members a non-trivial disk capacity for media editing and tools for working with this capacity.

21.6 Assessment of this Year

Considering the results, we believe that this year can be assessed as successful. We managed to extend the streaming platform both in terms of quantity (disk space), and quality (PAL streaming). We have intensified the international collaboration and tested the video data-sharing platform.

In addition, we participated in the broadcasting of a large number of various events with scientific, research or academic topics.

21.7 Plans for the Next Year

The objective of the next year is to extend the production system with a transcoding subsystem (conversion from the production format to streamable formats) and a search subsystem (the metadata issue relates to this as well).

22 Special Videoconferences

This project was focused on high-quality videoconferences. Our goals can be divided into two categories. The first one is to design a suitable testing methodology based on findings achieved in 2001 and prepare appropriate testing materials for it. The second objective is to utilize these materials for the actual evaluation of selected devices. As a final consequence, our activities lead to building of the infrastructure needed, which will allow expanding the spectrum of services provided by CESNET.

As their name indicates, the special videoconferences are intended for a certain (special) category of users, which is delimited clearly enough in these days. This is given by the specific needs of this category of users and especially the technical requirements resulting from these needs. The devices involved are not easily available or routinely used, but utilize state-of-the-art technologies. This brings both the corresponding technical demands for the operators and significant expenses for the equipment and for ensuring the actual video broadcasts.

Special videoconferences are currently applied mainly in the area of human and veterinary medicine, biology, chemistry, pharmacology, etc. Their great demands are determined by several key parameters.

The first parameter is the high resolution. The TV PAL standard is considered to be the minimum, i.e., digital processing of 720×576 pixels at the frequency of 50 frames per second according to CCIR 601. However, the required resolution that we have to take into account for the future corresponds more to the HDTV standard.

Another important parameter is the colour accuracy. A video recording or broadcast with distorted colours is useless for medical diagnostics. The most important is the dynamic behaviour of the entire video chain. In this type of videoconference, image degradation that would cause image disintegration must not occur. A video that becomes "pixelated" is, of course, unsuitable and useless.

The digitalized TV signal has high bandwidth demands. The transfer of raw data would be very demanding for the network throughput. That is why the data have to be compressed substantially. Lossy compression methods are used, which have a strong negative effect on the resulting quality of the video transferred. It is the most crucial modification of data throughout their path.

The migration to new IP-based technology represented the essential problem for operation of high-quality videoconferences and video broadcasts. The IP behaviour, wide range of technologies in the market and definition of minimal parameters for specific ways of use influenced the selection of a suitable device.

First of all, we had to define an appropriate testing methodology. Initially, at the end of 2001 and the beginning of this year, we were attempting to transmit static or computer generated images in laboratory conditions. This simplified approach turned out to be useless. Results were degraded by significant errors. In this period, we tested several borrowed devices. However, because the subsequent evaluation indicated that we did not use suitable tests, we have to repeat this testing.

After a new problem analysis, we defined the testing methodology and prepared several testing video sequences in compliance with the experience of leading European and world workplaces (such as GDM). The video sequences are oriented on the most common errors that occur in practice. We also recorded several testing videos where no problems should arise. These videos are used as reference/comparative materials.

By the time this report was written, we had created video sequences for testing dynamic states, colour representation and shape accuracy, and other potential flaws. All testing videos are now available at the workplace of VFU Brno.

The following tests were created:

1. tests of dynamic states
   - snail with vertigo
   - straw movement
   - sewer rat blood collection
2. colour representation tests
   - cow surgery (white, red, green)
   - crocodile surgery (red shades, skin colour component)
   - snake surgery (white, red)
3. shape distortion tests, colour distortion tests
   - endoscopy of reptile airways with a halogen bulb
   - endoscopy of reptile airways with a xenon bulb
4. tests of improperly illuminated videos
   - lecture with a strong side illumination
   - lecture with a low-level illumination, recorded from a greater distance (degraded by noise)
5. comparative tests
   - lecture with normal illumination
   - chemical laboratory recording (clear liquid, blue shades)

In the following period, we plan to further increase the number of testing records according to our needs. We practically evaluated the new tests using borrowed equipment and a testing workplace of a cooperating company. For the tests, we used several cards by Optibase with different performance levels.

The simplest tested device in its standard operation mode with the data flow of 5 Mbps provides a quality that is far below the requirements. However, it might be suitable for certain special cases, such as broadcasting a lecture to a large hall. For demanding broadcasts, it is necessary to focus on the ML@P422 devices.

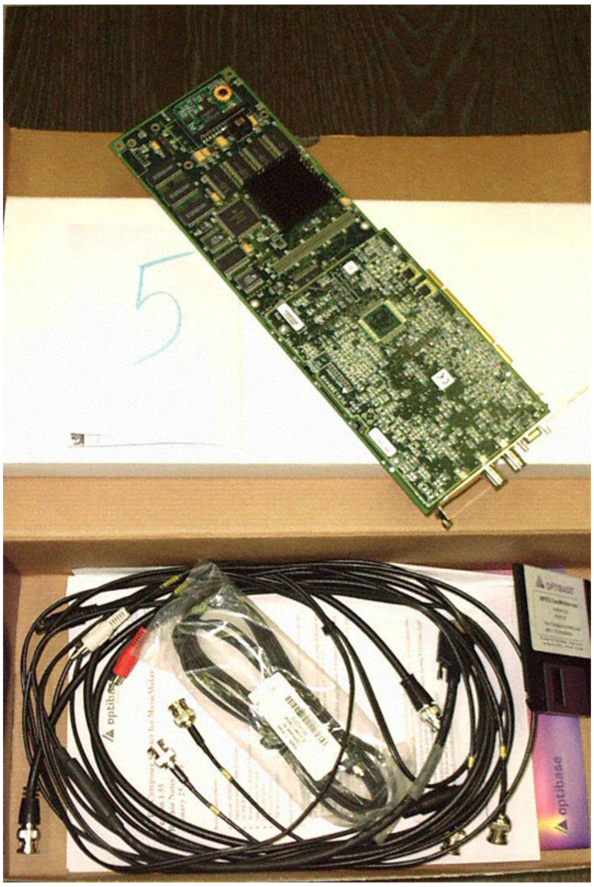


Figure 22.1: Optibase card

Besides the preparation and evaluation of the actual tests, we performed practical video transmissions as well. Within real operation, many other problems will arise. Therefore, we established an ATM line between VFU Brno and the Mendel University of Agriculture and Forestry in Brno (MZLU Brno) in 2002. This line is utilized mainly for performing comparative tests. As a reference technology, we use the AVA/ATV 300 device. For the same purpose, we use also the infrastructure of VFU Brno.

In the second half-year, the activities of the group were partially suppressed. Due to certain unclear aspects, the technical equipment needed was not purchased. Therefore, we did not carry out the intended long-distance broadcast. Despite this fact, we continued in the work we started. If the further continuation of the project is justified, the planned test will be performed in 2003 and the international-scale broadcast will be tested subsequently. Within our collaboration with Slovak colleagues, a broadcast between VFU Brno and the Veterinary University in Košice (Veterinární univerza v Košicích) will be performed.

We have ensured optimal conditions for creating professional TV broadcasts at the CIT VFU Brno. We have built a quality AV centre with professional equipment. Other workplaces are being created at cooperating schools – the Natural Science Faculty of Charles University in Prague (PřF UK Praha), the Brno University of Technology (VUT Brno), MZLU Brno.

In accordance with project objectives, the group of researchers elaborated several documents. The basic document is the technical report describing technical characteristics of the TV signal and providing a summary of used standards and compression levels organized by their usage area (from professional systems to simple consumer and amateur systems).

We processed materials describing the testing methodology. We carried out a survey of the interest of universities in special videoconferences and elaborated a summary about suitable devices.

The individual members of the group were involved significantly in promotion of these technologies. We actively participated in a number of events both in the Czech Republic, and abroad. In addition to our standard publishing activities, we organized a specialized seminar focused on multimedia broadcasts at Charles University (Univerzita Karlova) in Prague. Because of the high interest in this seminar, we plan to continue and expand this event.

Part IV
Conclusion and Annexes

23 Conclusion

The current development of the National Research and Education Networks in the world is heading towards optical networks established by customers (Customer Empowered Fibre network, CEF). CESNET set off on this journey as one of the first organizations at the time when only a few supported this trend – CESNET prepared the 311 km long Prague–Brno line with the bandwidth of 2.5 Gbps employing leased optical fibres in 1999 and started operation of this circuit in 2000.

In 2002, the association established two lines utilizing the state-of-the-art technology created with a method entitled NIL (Nothing-In-Line approach): a 189 km long line of Prague–Pardubice and a slightly shorter line of Prague–Ústí n. L. with the transfer rate of 1 Gbps (2.5 Gbps was tested as well). The results achieved were presented at the TERENA conference. In connection, CESNET started to deal with the issue of installing dispersion compensers, optical amplifiers, and switches. At the end of 2002, CESNET leased more than 1,000 km of fibre pairs and it has other leasing plans prepared for 2003.

Also in 2003, an important obstacle in the development of optical networks in the world will be represented by the last mile – from a user to the nearest network access point. CESNET managed to enter into collaboration with a supplier that is able to construct the optical access lines within an order and received an offer for constructing optical lines from another partner at the end of 2002. There are probably only two reasons preventing the creation of optical access points that remain: lack of financial resources or the requirement of mobility. The demand for mobility will obviously be permanent, which is why CESNET is examining possibilities of utilization of a wireless connection according to the 802.11a standard.

CEF construction brings changes to the view of designing large computer networks, the consequences of which are now gradually analysed. For example, the interconnection of four biggest supercomputing centres in USA is driven by the effort to create a single supercomputer. Another characteristic phenomenon is that, besides the conversion of the Abeline network to 10 Gbps, the UCAID association started to build the National LightRail, which should interconnect the east and west coasts of USA with leased fibres. In Europe, the best ways for further development are examined by the *SERENATE* project. Within this project, we recommended a new way for selecting deliveries:

1. Accept new principles for network topology and architecture, based on fiber leasing or owning. Work with preliminary knowledge of fiber maps and types, and include alternative lines or network topologies.
2. Procure fiber leasing or building only (not telecommunication services), including first mile on both sides. Evaluate bids for each line independ-

ently, but taking into account offered quantity discounts. Preferred fiber type is G.655.
3. Select fiber lines to create core rings.
4. Procure lambda services for PoPs, for witch there is no acceptable offer of fiber leasing.
5. Procure lambdas for "continental distances", e.g., more than 2000 km, and for intercontinental lines.

In 2002, the researchers expanded their foreign contacts with the direct collaboration with researchers of the Netherlands SURFnet network, which is the best network in Europe in many of its parameters and applications. The researchers participate in the *DataGrid*, *SCAMPI*, and *6NET* projects supported by the EU, and preparation of the ASTON project within the 6th EU Framework Program, which concentrates on the support of innovations of the pan-European research and education network – GÉANT.

The researchers commenced their collaboration on the research and development of a global lambda network at the end of 2002. The centre of the global lambda network in Prague is called *CzechLight*. This gives scientists and researchers from the Czech Republic further possibilities for participating in the world effort to assemble international scientific and research teams using a powerful communication and information infrastructure. Involvement in such teams will considerably contribute to the increase in utilization of gigabit circuits and development of new applications.

In 2003, we want to concentrate principally on the following areas, which have a strategic importance for the development of the high-speed network and its applications according to our opinion:

- Optical networks and their development
- IP version 6
- MetaCentrum
- Videoconferencing
- Voice services
- End-to-end performance

An essential task within all areas is the application of the results of our work abroad, participation in international projects and related expansion of presentation and publishing activities.

A List of connected institutions

A.1 CESNET members

institution	*connection [Mbps]*
Academy of Performing Arts in Prague	10
Academy of Sciences of the Czech Republic	1000
Academy of Fine Arts in Prague	10
Czech University of Agriculture in Prague	1000
Czech Technical University in Prague	1000
Janáček Academy of Musical and Dramatic Arts in Brno	155
University of South Bohemia in České Budějovice	1000
Masaryk University in Brno	1000
Mendel University of Agriculture and Forestry in Brno	155
University of Ostrava	155
Silesian University in Opava	34
Technical University of Ostrava	1000
Technical University in Liberec	1000
University of Hradec Králové	155
University of Jan Evangelista Purkyně in Ústí nad Labem	155
Charles University in Prague	1000
Palacký University in Olomouc	1000
University of Pardubice	1000
Tomáš Baťa University in Zlín	34
University of Veterinary and Pharmaceutical Sciences in Brno	100
Military Academy in Brno	100
Purkyně Military Medical Academy in Hradec Králové	155
Institute of Chemical Technology in Prague	1000
University of Economics in Prague	155
Academy of Arts, Architecture and Design in Prague	10
Military College of Ground Forces in Vyškov	4
Brno University of Technology	1000
University of West Bohemia in Plzeň	1000

A.2 CESNET non-members

institution	*connection [Mbps]*
Czech Radio	34
University Hospital with Policlinic Ostrava	10
Internet of Schools of Hradec Králové, association of legal entities	10
Medical Personnel Education Institute	2
Technical and Test Isntitute for Constructions Praha	0.128
Military Secondary School Brno	0.064
State Technical Library	10
Masaryk Hospital in Ústí nad Labem	34
Czech Medical Association J. E. Purkyně	0.033
Research Institute of Geodesy, Topography and Cartography	2
General University Hospital	10
National Museum	0.128
Institute of Agricultural and Food Information	0.064
Nuclear Resaerch Institute Řež	2
National Library of The Czech Republic	155
Moravian Library in Brno	10
University Hospital in Hradec Králové	155
University Hospital Královské Vinohrady	10
Higher Professional School of Information Services	10
National Scientific Library	10
University Hospital Bulovka	10
The Ministry of Education, Youth and Sports	10
National Scientific Library in České Budějovice	100
Ministry of Interior of The Czech Republic	10
University Hospital Brno	2
Observatory and Planetarium of Prague, Štefánik Observatory Center	0.064
Scientific Library of North Bohemia	2
Scientific Library of Moravia and Silesia	34
Elementary School	0.064
District Library in Tábor	10
University Hospital Olomouc	100
Na Homolce Hospital	2
High School	0.256
The Fire Research Institute Praha	0.128
National Scientific Library in Olomouc	10
High School Brno	2
Central Military Hospital Praha	34
New York University in Prague	0.512
AG Systems	10
Secondary Technical School and Higher Professional School	10

institution	*connection [Mbps]*
Institute for Information on Education	10+2+2
National Scientific Library Liberec	10
F. X. Šalda High Scool	10
Museum of Arts, Architecture and Design in Prague, Library	0.064
Anglo-American College	2
Hospital Liberec	34
Theatre Institute	2
Food Research Institute Prague	2
Prague City Library	10
University Hospital Plzeň	155
Jiří Mahen Library in Brno	10
University Hospital u Svaté Anny in Brno	10
Research Institute for Organic Syntheses	2
School Service Liberec	10
Research Institute of Agricultural Economics	10
Southern Moravia Region	10
Traumatological Hospital in Brno	10
University of New York in Prague	2
The City Třeboň	10
Hotel School and Higher Professional School of Hoteling and Tourism	10
Higher Professional School, Secondary Industrial School and Commercial College Čáslav	10
Information Technologies Management of Plzeň City	10
Computer Users Association – Local Basic Organization Praha-střed	4
Ministry of Defence	10
Community Centers of City České Budějovice	10
District Hospital Kyjov	10
High School, Nerudova 7, Cheb	4
School Service Plzeň	10
Tiny Software ČR	100
Higher Professional School and Secondary Industrial School	10
District Office Plzeň-Sever	10
Secondary Industrial School and Higher Professional School Písek	10
Czech Helsinki Committee	1
Regional Office of the Region Plzeň	10

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C Own Publishing Activities

For the publications written in Czech language the English translation of the title is appended in parentheses.

C.1 Standalone Publications

team of authors: *Vysokorychlostní síť národního výzkumu a její nové aplikace (High-speed national research network and its new applications).*
CESNET, 2002, ISBN 80–238–8174–4

team of authors: *MetaCentrum - ročenka 2000–2001 (MetaCenter - yearbook 2000–2001).*
CESNET, 2002, ISBN 80–238–9195–2

Satrapa P.: *IPv6 (IPv6).*
Neokortex, 2002, ISBN 80–86330–10–9

C.2 Opposed Research Reports

Chown T. (Ed.), Lhotka L., Savola P., Schild C., Evans R., Rogerson D., Samani R., Kalogeras D., Karayannis F., Tziouvaras C.: *IPv4 to IPv6 migration scoping report for organisational (NREN) networks.*
EC - project 6NET (IST–2000–32603), 2002

C.3 Contributions in Proceedings and other Publications

Altmannová L., Šíma S.: *Development of the CESNET2 Optical Network.*
in proceedings *Proceedings of TERENA Networking Conference 2002*, TERENA Organization, 2002

Boháč L.: *Použití EDFA optických zesilovačů v síti CESNET (Usage of EDFA optical amplifiers in CESNET network).*
in proceedings *COFAX - Telekomunikácie 2002*, D&D Studio, 2002, page 24, ISBN 80–967019–5–9

Burčík J.: *Optické přepínání v sítích MAN (Optical switching in MAN networks).*
in proceedings *COFAX - Telekomunikácie 2002*, D&D Studio, 2002, ISBN 80–967019–5–9

Burčík J.: *Optické přepínání v sítích LAN (WAN) (Optical switching in LAN (MAN) networks).*
in proceedings *Informačné a komunikačné technológie pre všetkých XXV.*, Bratislava, ISBN 80-968564-6-4

Dvořáčková J., Hanák J.: *Technické vybavení pro tvorbu videopořadů (Technical equipment for videocast creation).*
in proceedings *Multimediální podpora výuky*, CIT Univ. of Veterinary and Pharmac. Sciences, 2002, page 8–9,
ISBN 80-7305-453-1

Feit J., Hladká E.: *Multimedia in Pathology.*
in proceedings *Proceedings of Internationat Conference on Information Technology Based Higher Education and Training 2002*, Budapest Polytechnics, 2002, page 193, ISBN 963715407800X

Hladká E., Holub P., Denemark J.: *Teleconferencing Support for Small Groups.*
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