THE OPTICAL NREN OF SERBIA AND MONTENEGRO – NEW SOLUTIONS IN INFRASTRUCTURE AND MONITORING

Zoran Jovanović, Slavko Gajin, Mara Bukvić, Pavle Vuletić, Djordje Vulović

Računarski Centar Univerziteta u Beogradu (Belgrade University Computing Center), Kumanovska bb., 11000 Belgrade, Serbia and Montenegro

Tel.: 381 11 3031258, Fax: 381 11 3031257, email: zoran@rcub.bg.ac.yu

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Abstract: *A new national backbone is in development, based predominantly on the optical infrastructure of Telekom Serbia. It will connect 19 towns in Serbia in a Gbps network by the end of 2004. The basic concept is to avoid any active components belonging to the telecom operator, by using the "nothing in line" concept. There are exceptions to that concept in cases where dark fiber was not available and in that case 1 Gbps Ethernet over SDH was used. Private CWDM of our NREN is implemented in the network for point to point n*1 Gbps channels and for making additional logical channels by using lambdas. A Web based network information system used for network monitoring, NetIS, was developed by the NREN team. It is being implemented for network monitoring, both for Serbia and Montenegro and for the SEEREN network.*

1 Introduction

Serbia and Montenegro, only two years ago, had a slow national backbone with 2 Mbps channels between the main nodes. With a monopoly in fixed telecommunications, poor funding (as a result of the devastated economy) and low penetration of Internet, the country had few chances to develop a decent NREN. The EU SEEREN and the bilateral SINSEE projects gave the important initial momentum for establishing international connectivity and the initial dark fiber intercity connections. Telekom Srbija, after long negotiations, finally decided to offer dark fiber, under favourable conditions for our NREN.

Faced with all the mentioned obstacles, the team of the NREN tried to find a low cost solution that could use the existing dark fiber. Using traditional SDH Telecom services was unacceptable, due to low speed and high price, even with large discounts. Other inputs relevant for our final decision how to build the network were:

- Experiments in CESNET related to the "nothing in line" concept
- Appearance of 1 Gbps GBIC's that can be used for intercity connections up to 130 km on G.652 standard single mode fiber.
- Appearance of low cost CWDM equipment for long distances
- Our experiments with CWDM
- Detailed analysis of available optical amplifiers

2 Our experiments with CWDM

The appearance of CWDM equipment for 1Gbps Ethernet for long distances (link budget of 33 db for GBIC) opened a chance to efficiently use dark fiber that we planned to lease for our network. We made experiments on the Belgrade – Novi Sad line during summer of year 2003, with CISCO CWDM equipment, for more than a month. These were conducted on G.652 fiber with the overall dark fiber length (95 km) between university computer centers in Belgrade and Novi Sad. Along the line were several optical patch panels that introduced additional attenuation. The tested 4 lambdas were 1470, 1510, 1550 and 1590 nm. Add and drop multiplexers were used on both ends and introduced additional insertion losses (adding and dropping lambdas) at both ends.

We expected that errors might appear at the 1470nm lambda, due to larger attenuation of the G.652 fiber in that part of the optical window. However, it worked as a very reliable link, with a very low error rate even for that lambda. All four 1 Gbps channels appeared as a logical 4 Gbps channel (four GBIC ports were used both on Catalyst 6509 at one end and 3550-12G at the other). Since this 4 Gbps channel was one of our backbone connections, we didn't create test traffic that could thoroughly test the solution under heavy traffic load.

The results of the experiment gave us the following guidelines:

- With intercity lengths of dark fiber less than 100 km, CWDM is an exceptional solution with the following advantages. The initial connection could be one CWDM GBIC (typically at 1550 nm) until the 1 Gbps Ethernet channel becomes overloaded. After that moment, CWDM add and drop multiplexors can be introduced and additional lambdas offer the possibility creating n*1 Gbps ($n \leq 8$) logical channels. The price of the solution is much lower than the 2.5 Gbps SDH solution in the equipment cost, especially taking in mind the available low cost layer 2 / layer 3 switches with GBIC ports.
- Optical amplifiers are unfortunately almost incompatible with CWDM. The EDFA amplifiers can cover only two CWDM lambdas. Other solutions, like the linear semiconductor optical amplifiers (LOA's) offer a low cost solution covering 3 lambdas, but the technology is almost exclusively dependent on one company. The amplification of LOA's is rather low and they could be used only at the receiving end in the "nothing in line" concept.
- Optical-Electrical-Optical (OEO) conversion with repeating must be done for spans larger than 100 km. CESNET tested that type of repeating by using layer 2 switches two years ago. It was done by using the two GBIC ports for a repeater equivalent and not using the 100 Mbps electrical ports. They decided not to use such solutions, due to the problems concerning the switching to the backup line in case of a circuit failure (which needs to be solved on layer 3) and that they could not control and monitor the "repeater" at IP level. An improvement of the CESNET concept to avoid the main drawback of the OEO conversion had to be found.
- If a feasible solution for OEO repeating is found, the preferred dark fiber spans are <100km. In that case, repeating could be done in the buildings of research and education institutions, without involvement of the telecom operator. In that case, additional lambdas open a possibility to create n*1 Gbps ($n \leq 8$) logical channels that can be added even for long distances > 100 km with OEO repeating.

3 OEO repeating and building complex logical topologies by using CWDM

The basic idea for how to avoid the drawbacks of OEO conversion was to introduce low cost layer 2 / layer 3 switches with GBIC ports instead of layer 2 switches. There were two main reasons for such a decision:

- The price per port for GBIC ports is lower when a layer 2 / layer 3 switch with GBIC ports

- One port (typically 10/100/1000 Ethernet) could always be devoted to a layer 3 control channel for supervising the switch and all of its ports. This port will be denoted as the control port and its role will be explained for the northern part of our NREN.

The control port suggests that the layer 2 / layer 3 switches with GBIC ports should be located at backbone nodes of the NREN.

With the previous guidelines in mind, we decided to build a network with the largest optical span of 100 km. Whenever a larger span was necessary, an intermediate town with its research and education main node was included in the optical backbone. In the intermediate town – the OEO repeating was done. With this design rule, the whole backbone was planned.

The logical and physical topology of the 2004 phase of the backbone is in fig. 1. This backbone should be completed by September of 2004. The main delays appear due to putting optical cables for the "last mile" in cities for each backbone node. Full fault tolerance exists only for the 7 towns on the south ring of the backbone. At the northern part of the network, the logical triangle, the international connection and the 2 Gbps channel are created by using CWDM. This will be explained in more detail later in the paper.

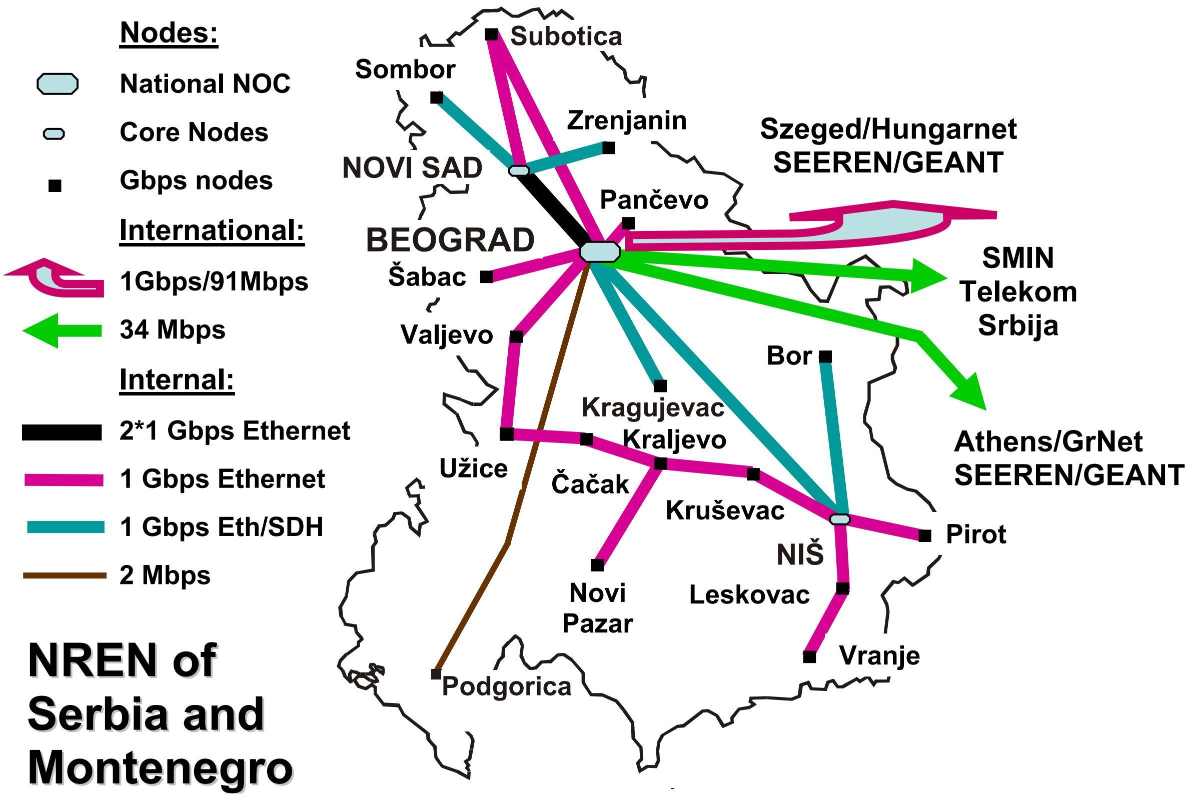

Figure 1. The topology of the backbone – year 2004 phase

The 1 Gbps/SDH lines were introduced for the following two reasons:

- There were no available pairs of fiber in the existing cables on a specific intercity cable (Bor, Sombor and Zrenjanin)
- The length of the line was larger than 100 km (Kragujevac and Niš)

With this backbone and extensions to Podgorica and several other cities, we plan to make backbone gigabit nodes for connecting nearby towns and distribution nodes within towns. In all towns except Belgrade, Niš and Novi Sad, the layer 2 / layer 3 switches with GBIC ports are used as repeaters and central nodes at the same time. This is how we created a very low cost solution for our gigabit backbone.

The logical triangle Belgrade – Novi Sad – Subotica, with OEO repeating in Novi Sad and multiplexing two 1 Gbps channels between Belgrade and Novi Sad, is the best illustration of the concept. In Novi Sad, there is a combination of one Catalyst 6509 and one 3550-12G for creating the northern backbone topology. The 3550-12G has primarily the OEO repeating role. The Belgrade – Subotica link lambdas for both directions are OEO repeated by using two GBIC ports. The Belgrade - Novi Sad – Subotica - Hungary link lambdas for both directions will use additional two ports of the 3550-12G. One 10/100/1000 Ethernet port of the 3550 is used for additional control of the OEO repeating and is connected to a 10/100/1000 Ethernet port of the Catalyst. Two additional lambdas on the Belgrade-Novi Sad dark fiber are directly connected to the Catalyst 6509, as well as one lambda on the Novi Sad – Subotica connection. Additional flexibility in separation of management domains is an additional feature of this configuration in Novi Sad.

In Subotica, the 3550 will be used for repeating lambdas for connecting Hungary (2 GBIC ports), but at the same time has ports for the Subotica – Belgrade link and for the Subotica – Novi Sad link. It also has GBIC ports for the future Subotica MAN and a 10/100/1000 Ethernet port for the Faculty of Economy building. This is an illustration of the multiple functionalities of layer 2 / layer 3 switches in the adopted concept of our network. The logical triangle Belgrade - Novi Sad – Subotica is illustrated on figure 2.

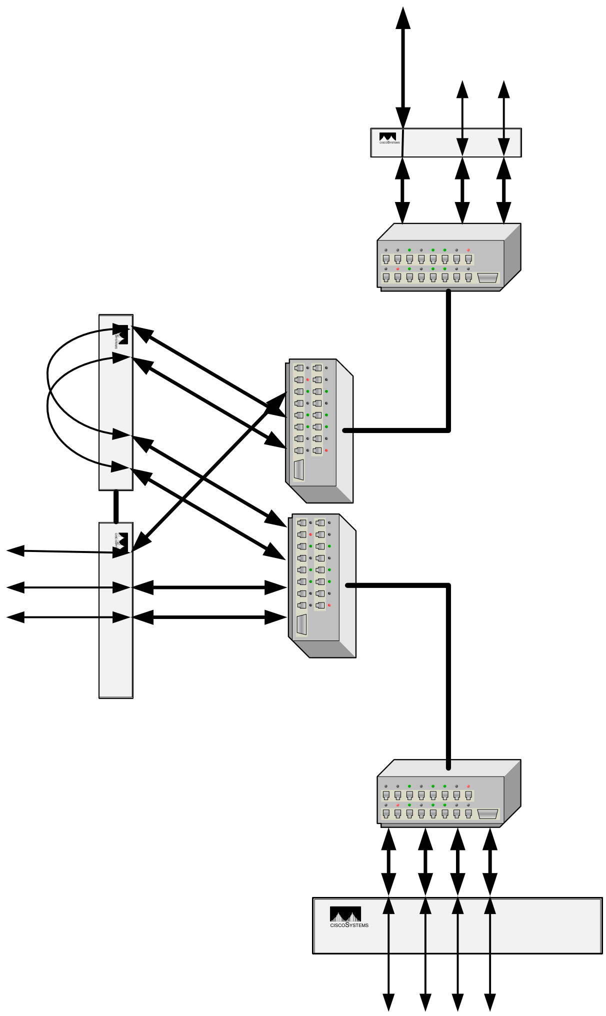

Figure 2 Northern part of the network with CWDM

4 MANs of the NREN

The dark fiber network is used also for the MAN backbones. The central node of each town should be connected through GBIC ports to several distribution nodes in the town. The final goal is to have at least one distribution node for each PSTN exchange in the town. Other research and educational institutions can be connected to the distribution nodes by using xDSL modems on copper lines passing through only one exchange. This leads to typical xDSL speeds of at least 2 Mbps for institutions connected to distribution nodes.

The number of distribution nodes depends on the size of the city. The best illustration of the concept is Belgrade, which will have a gigabit MAN backbone with more than 15 distribution nodes by the end of the 2004. The existing nodes at the time of writing are: Belgrade University Computing Center, the Rector's office, Vinča Institute, Dean’s office of the Medical Faculty, the Faculty of Business Administration, Students' town (10,000 students), Institute of Physics, the building of the faculties of natural sciences, and the Mechanical Engineering Faculty. The Belgrade MAN backbone is illustrated on Figure 3. The typical distribution node is the same as central nodes in smaller towns – the CISCO 3550-12G. The GBIC Lasers + Gbps Ethernet ports are less expensive than HDSL modems + 2 Mbps ports! Again, the main effort is related to building the “last mile” of dark fiber.

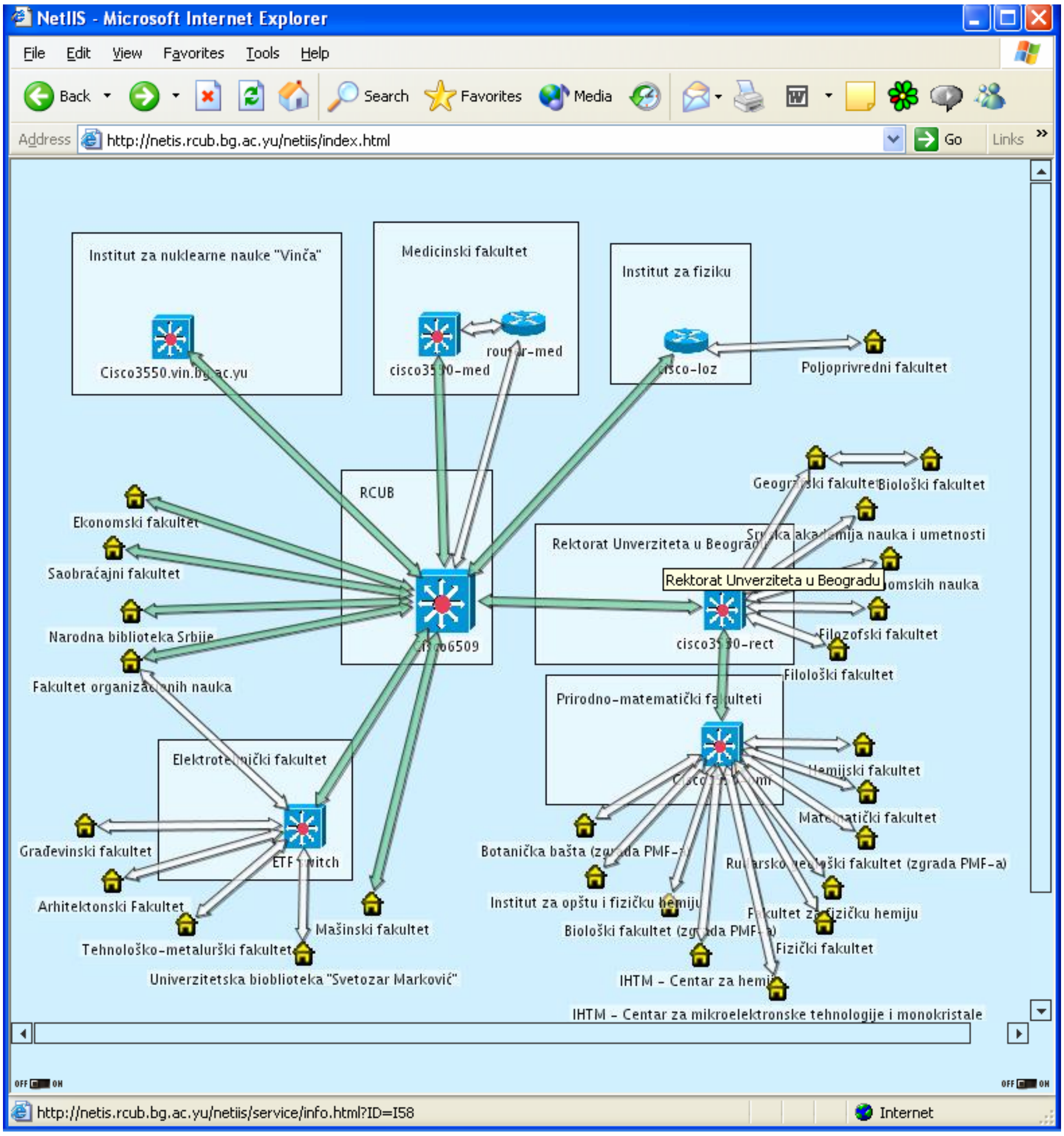

Fig. 3 Belgrade MAN backbone in NetIS

5 Logical structure of the network

An all-Ethernet network of this size offers great possibilities for logical organization. However, as Ethernet is primarily a LAN and MAN technology, careful logical design must provide scalability, availability and manageability comparable to the existing MAN and WAN solutions (such as SDH or RPR).

Using Ethernet in all network layers does raise some questions about availability and fault tolerance, as the Ethernet is not known for fast convergence due to the traditional Spanning-tree algorithm. However, recent advances in that area (802.1w Rapid Spanning-Tree), and Layer 3 capabilities of Ethernet devices, make Ethernet MANs and even WANs viable, and implementable. Moreover, having Layer 3 switches in the core and distribution layers of the network enables design solutions on Layer 2 and Layer 3 level (e.g. Rapid Spanning-Tree against link-state IP routing protocol). The problem with fast circuit break detection with Layer 2 switches used as a OEO conversion points still remains, but is not of a great importance, because of the nature of NREN applications which are not mission critical.

It should be noted that Ethernet-based NREN has certain differences, when compared with commercial Ethernet MAN networks. The number of customers (here NREN members) changes relatively slowly, so the network can be planned ahead (e.g. customer VLAN assignment). Also, time for service provisioning is not the primary issue in NRENs, and overall availability may not be so strict as in the service provider environments with SLAs.

The first question that arises is about the network logical structure. How structured i.e. how hierarchical a network should it be on the logical level? Others questions follow: How should we define VLANs? Where are the boundaries of the VLAN domains? Where are the Layer 3 routing points for the defined VLANs? Design decisions may greatly affect the network. For example, large VLAN domains allow greater flexibility. One can imagine a professor from Kragujevac, plugging his laptop to Belgrade LAN and automatically connecting to the network keeping his IP parameters with the help of 802.1x VLAN assignment. Unfortunately, on the other hand that could lead to increased Layer 2 broadcasts (imagine on the other hand an ARP request traveling through half of the country) and can be hard to manage.

The current design solution, implemented in the Belgrade MAN relies on the well-known concept of "per-customer VLAN". VLAN domains are spanned through the Belgrade MAN, which is justified because a vast majority of institutions belong to the University of Belgrade. Also, since many institutions have several locations throughout the city, this allows for LAN unification utilizing double 802.1Q encapsulation using QinQ technology. As the topology of current Belgrade MAN does not have any redundancy, spanning-tree operation has not been tested in a real production environment.

6 NetIS monitoring

Rapid network development and technology changes forced the new approach in network management and monitoring.

For this purpose, special software called NetIS has been developed at Belgrade University Computing Center. This software is actually a network information system with integrated monitoring modules and tools. The software is running on the Linux web application server, with a separate SQL data server.

Software configuration and management is allowed through a special Windows application, but frequent user access is Web based. Protected data and login with username and password is also supported, with arbitrary user/group read/write permissions. According to that concept, contact information about NREN members are offered publicly, while other technical information are protected and shared by technical staff. Moreover, NetIS usage is distributed among regional and local networks.

NetIS has an auto-discovery capability which enables complex network topologies to be translated into the equivalent logical form, with all necessary technical information (IP/MAC address, host and port names, descriptions etc.). Network items and links from the database can be presented graphically, allowing efficient topology overview, information access and performance monitoring.

Within NetIS, configured monitoring tasks are periodically running, reading the results (current status), storing it in database and generating well-known MRTG statistics. Moreover, alarms can be assigned to monitors which by email alert network administrators about events, based on the collected data (for instance – links status down, not established BGP session, etc.).

Monitoring elements of interests in the networking environment are the following:

- Traffic throughput statistics (traditional MRTG graph)
- Checking router/switch interface status (up/down)
- Collecting arbitrary SNMP OIDs (variables), such as BGP session status, router CPU load, router memory usage, MPLS status etc.
- Pinging arbitrary IP nodes (from central monitoring server), collecting ping loss in percent and minimum/maximum round trip time
- Checking service status by NMAP tool (for instance, availability of DNS service)
- Checking arbitrary looking glass output (for instance, collecting "show interface" parameters)

Monitoring results are organized in groups and they are presented as web based table reports. Moreover, combining graphical capability with monitors in groups, these graphs work as "weather-map" graphs with web sensitive MRTG daily statistics and alarm notifications.

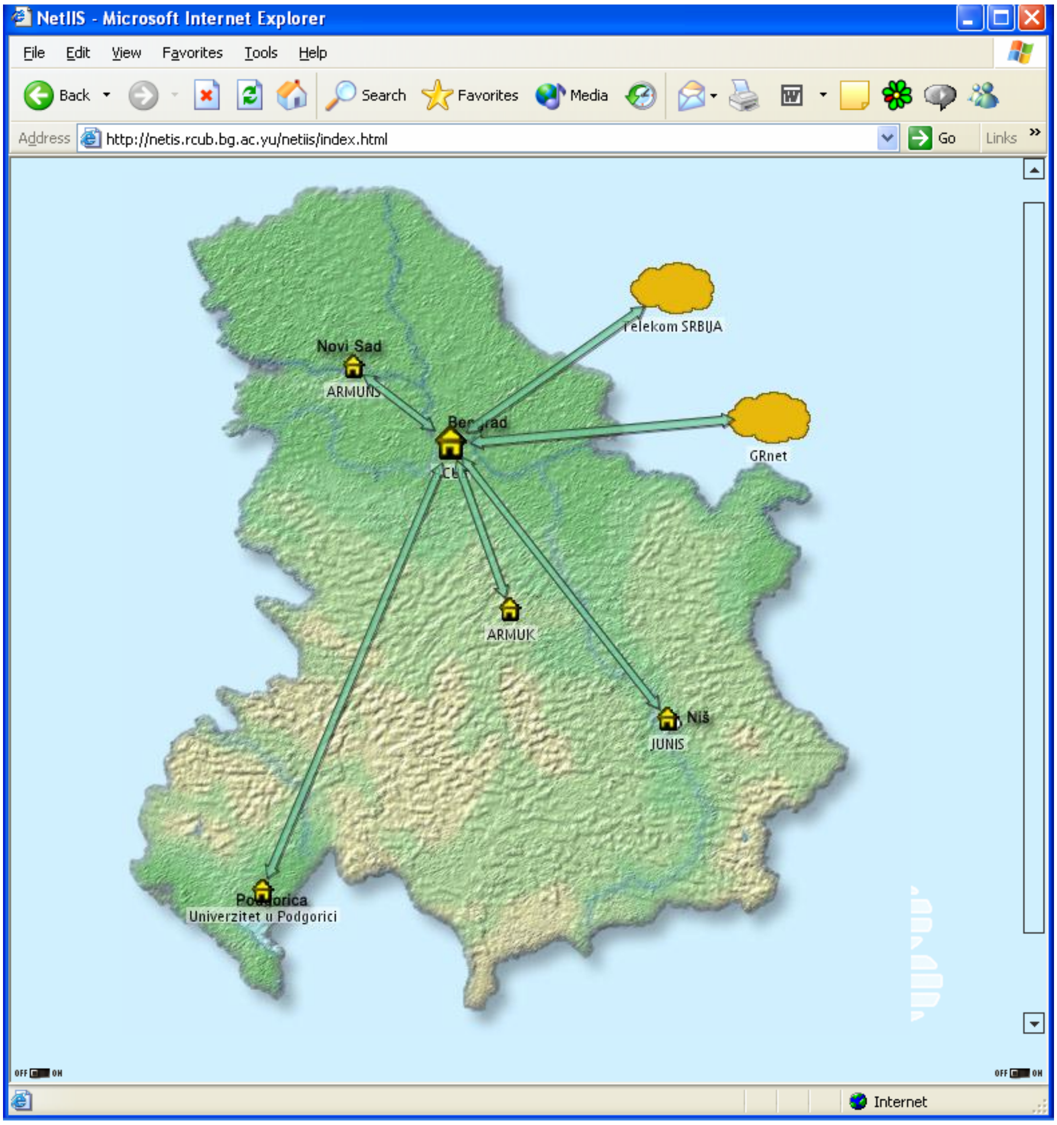

Figure 4 Monitoring of main intercity links in NetIS

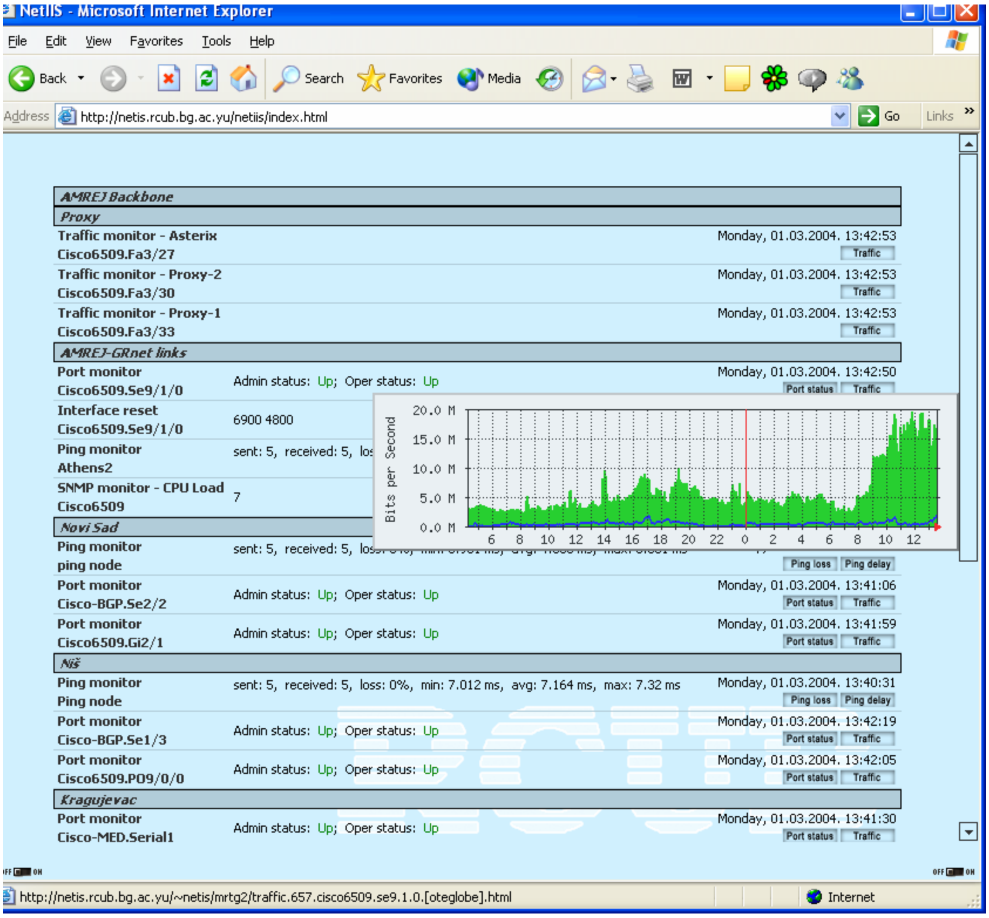

Figure 5 Detailed monitoring of router ports

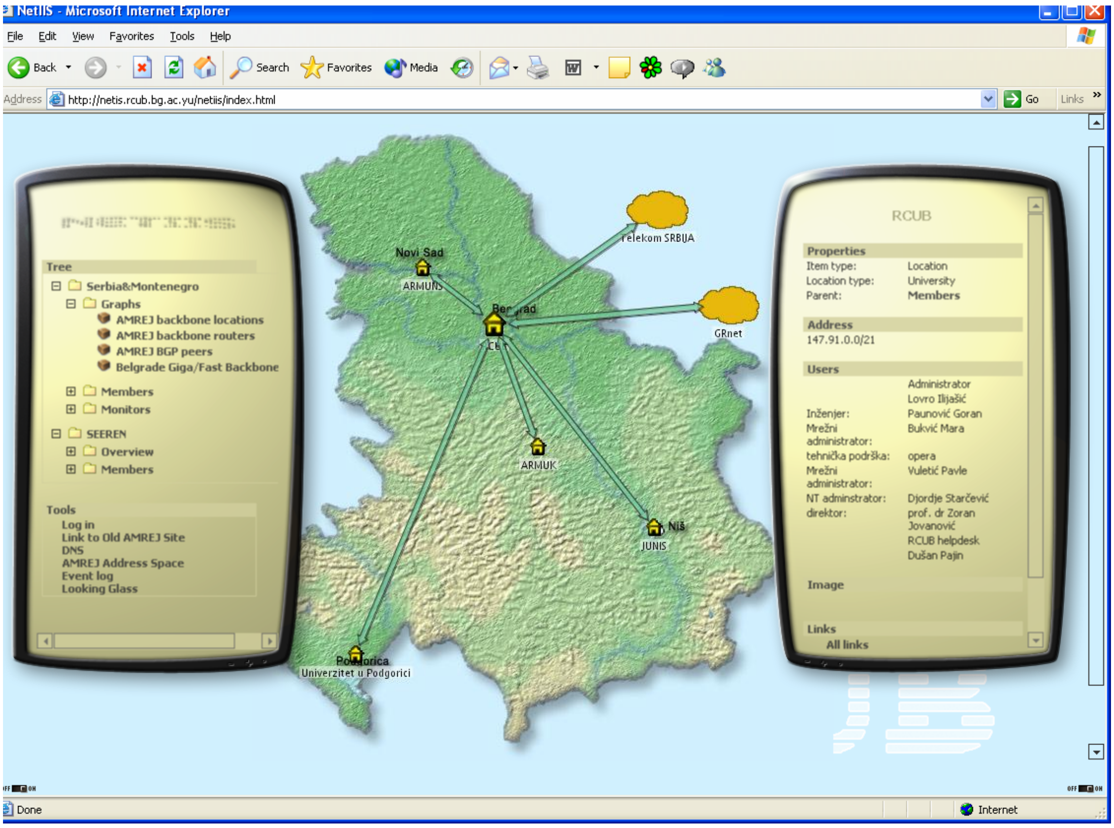

Figure 6 Selecting options and displaying monitoring results

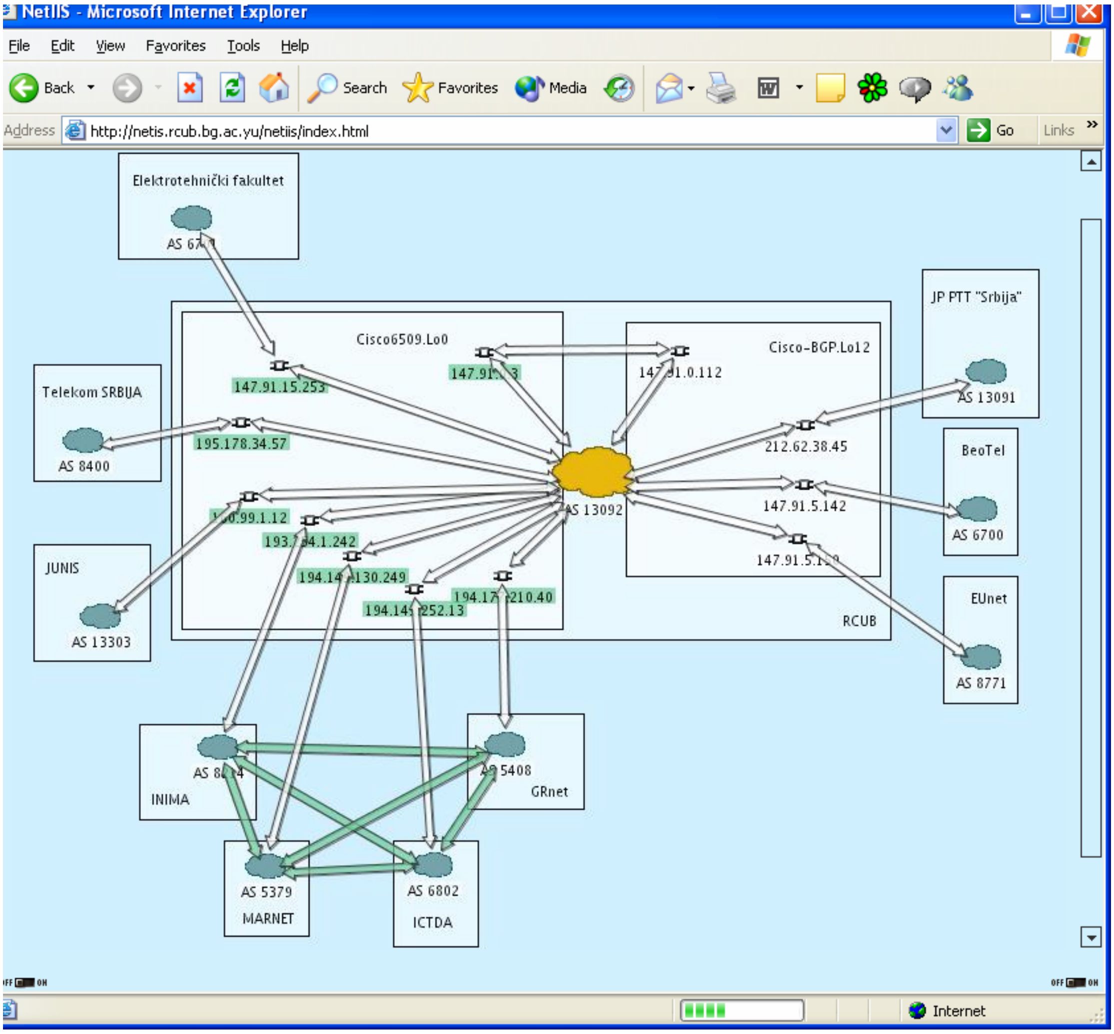

Figure 7 BGP monitoring

7 Conclusions

The development of the NREN in Serbia and Montenegro had many obstacles and a gigabit backbone seemed to be far in the future only two years ago. Foreign support through SEEREN and SINSEE and joint efforts of all universities, the Ministry of Science, Technology and Development of Serbia and Telekom Srbija removed most of the obstacles. Using results of experiments in advanced GEANT NRENs, especially CESNET, and the appearance of new technologies, together with our own experiments, created guidelines for building our network. Although the original concepts and guidelines were an attempt to create a gigabit backbone with less than 1 Meuro, we believe that our solutions may be a guideline also for other NRENs. There has to be a lot of work to get building permitting licences for last miles of fiber, and thousands of other efforts to make a dark fiber network like in Serbia and Montenegro. Once it is in place, speeds on each link can be easily upgraded according to needs.

The developed and implemented monitoring software, NetIS, offers efficient and successful support in network monitoring and technical administration. This original approach is also accepted in SEEREN network monitoring.

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