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Single Fiber Lines in CESNET Backbone

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Abstract: CESNET is an association of universities and Academy of science of Czech republic. It is operating a national research and education network (NREN) interconnecting all university cities in the republic. Since ATM and SDH technologies were replaced by ethernet technology in WAN data networks CESNET maintains its backbone network mostly on dark fiber leased from various vendors. On some lines it it very reasonable to use only one single fiber line. In this paper we discusse technology used on such lines in the CESNET backbone.

Key–Words: single fiber, NREN, dark fiber, gigabit ethernet

1 Introduction

CESNET is an association originated by universities and Academy of science of Czech republic in 1996. Its main goal is to operate and develop academic backbone network of Czech republic. This network started on lines with bandwidth in hundreds of kbps and step by step interconnected all academic cities in republic. Contemporary generation of this network is named CESNET2 and offers bandwidth in order of gigabits per second on backbone lines.

Since beginning of its existence CESNET offers to its members internet connectivity and connectivity to scientific networks in Europe. In 1996 CESNET has build a high speed intercity infrastructure of academic and nonprofit institutions connected to European backbone TEN-34 which has interconnected European NREN networks on speed of 34 Mbps.

CESNET is a member of European research organisations like GEANT and is participating in a lot of research project in computer networks.

2 CESNET

In the beginning of the Internet in former Czechoslovakia the national backbone network was operated by Czech University of Technology in Prague. It was since 1991. From the beginning it was clear that all research and education intstitutions like universities and Academy of science will need to have access to international computer networks and that they have to participate on both funding and maintaining of common networking infrastructure which will offer data network services to all these institutions.

Because at that time there was great discussions in republic government about splitting republic to two pieces - Czech republic and Slovak republic - there were originated two associations: CESNET - Czech Education and Scientific NETwork and SANET - Slovak Academic NETwork. Technicians had proposed a common name of federal network - Federal Education and Research NETwork - FERNET. This proposal wasn't accepted because at the same time it is a name for well known alcoholic drink.

Since 1996 CESNET was solving project of Czech ministry of education named *TEN-34 CZ*. Goal of this project was to construct national backbone network with technical parameters corresponding to trans european research backbone named TEN-34. (34 is the nominal bandwidth used in backbone lines.) Backbone of TEN-34 CZ (how the network was named at that time) was build on ATM technology. Separate nodes was equipped with ATM switches and routers and interconnection of these nodes was done via ATM switches. In 1997 migration of CESNET members networks to ATM backbone was finished. At this time started discussions about possibilities for further development of network especially with respect to new transport protocols and new applications like ip multicast, IPv6, packet voice services and others.

3 History of Czech NREN

At the beginning of networking in former Czechoslovakia the network topology was rather poor. It was a tree structure with root in Prague. From Prague went IP line to Linz as a first international connectivity. Large cities like Brno, Ostrava, Pilsen or Hradec

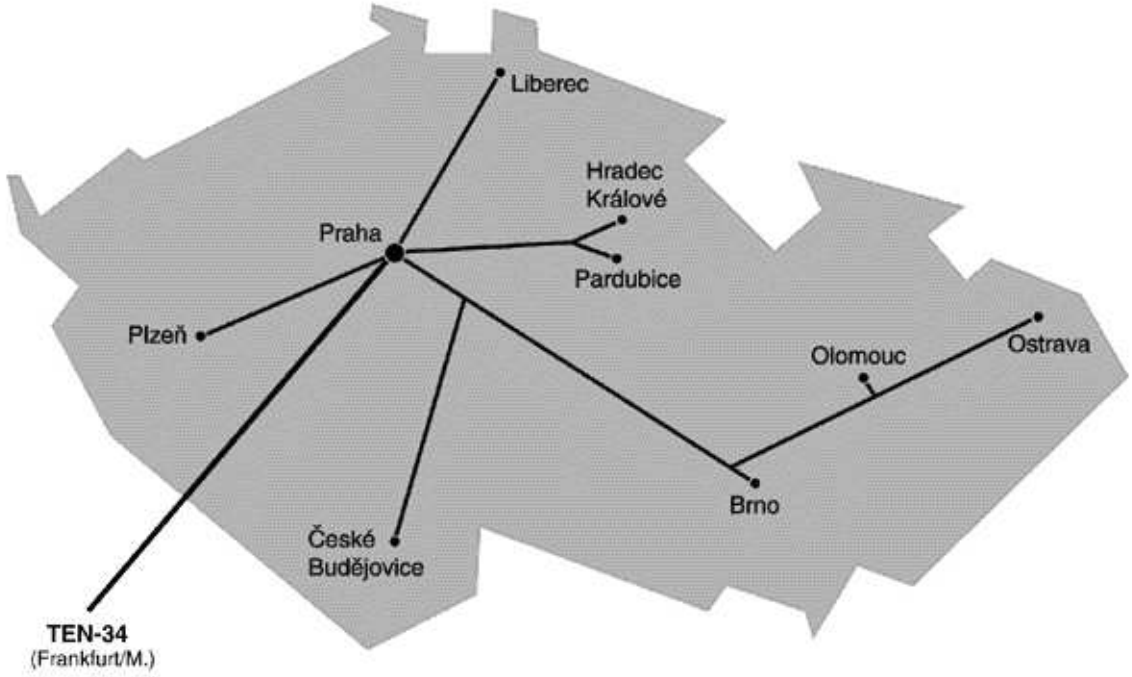

Figure 1: CESNET ATM Backbone. Status of 1997 year.

Kralove was connected to Prague via leased lines with typical bandwidth 128 - 512 kbps. Smaller cities was connected via leased lines to the ”second level” nodes mentioned above. Typical bandwidth of such connection was 19.2 kbps.

In the next step main lines were upgraded to 1 - 2 Mbps and mostly all university cities was connected to Prague. At the same time the topology of backbone was a little bit improved. From tree structure we have moved to some kind of ring topology. At least connectivity for largest cities was done not only to Prague but also to another suitable city of similar size. Connectivity to smaller cities was upgraded to 64 - 256 kbps. At the beginning of internet in our republic the was no other ISP than academic community so first commercial users of internet had no other possibility than to use CESNET as an ISP. On the other side CESNET approach was to deploy internet to public for education purposes and use revenue from internet customers for improvement of backbone and deployment of internet to more cities.

Since 1996 when TEN-34 CZ project started the backbone of NREN started using ATM technology. At that time the ATM backbone was a tree structure based on microwave E3 lines. For price optimisation some ATM switches was housed at E3 lines provider locations. Backup connectivity was solved on legacy technologies i.e. leased lines with bandwidth 2 Mbps. Because this project was funded by government - ministry of education - it was necessary to separate academic traffic from the rest of internet traffic. Whenever the academic network in the city was separated from commodity traffic it was reconnected to the ATM backbone. The topology of ATM CESNET backbone in on picture 1. In 1997 migration of CESNET members networks to ATM backbone was finished. As a next step was upgrade of main backbone lines to STM-1 speed. This step didn't provide more benefit than bandwidth improvement.

In 2000 LANE protocol in backbone network was replaced by MPLS on ATM transport layer. The main goal of backbone network at that time was to provide reliable and stable IP connectivity to its members. Next to his main goal are in terms of research plan started experimental and supplemental services. In this year was build first line based on dark fiber. It was line Prague - Brno and POS STM-16 was used on this line. The line is about 300km in length and 3 regenerators was placed in proper locations along the line.

In 2001 was ATM step by step replaced by POS and gigabit ethernet (GE). It was run on a mix environment with dark fiber on some lines and leased line POS STM-16 on some other lines. It was done due optimisation of number of regenerators and of course maintenance of regenerator in remote locations.

A next step was movement to complete dark fiber infrastructure. The reasons for this step are the following: at speed of GE and STM-16 dark fiber is more economical than leased lines and bandwidth im-

provement and technology migration. More over the backbone moved to NIL (Nothing In Line) technology. By usage od fiber optical amplifiers it is no more necessary to maintain any regenerator somewhere in line. The maintenance should be done only in network nodes which are located at universities so that problems with transport of staff and material to remote locations somewhere in field disappears.

4 Metropolitan Networks

CESNET is maintaining only republic backbone network and international connectivity. In a typical city where is some institution connected to CESNET has CESNET one single Point-of-Presence (PoP). If there are many cesnet customers in the city everyone should maintain its connection to the CESNET PoP. A typical Czech university has a lot of buildings spread across the whole city. This geography scale of CESNET users caused origination of metropolitan networks in most academic cities in our country. These metropolitan networks are maintained or by local universities or by another associations like PASNET.

Let us briefly describe metropolitan networks in five largest cities. These metropolitan networks we can classify into three different groups: Prague which is the city with more users of CESNET than any other city but doesn't have the larges metropolitan network. Brno is the second largest city from point of view of number of users and has the largest fiber optics network. Third group are Plzen, Hradec Kralove and Olomouc. These cities are significantly smaller whats concerning number of universities in the city and number of university locations inside the city as well.

All metropolitan networks are build since similar time. All of them are based on fibre optics and are using microwave technology mainly WIFI for some minor locations beyond the scope of fibre network. All metropolitan networks went through the same technology evolution from 10 Mbps ethernet through STM-1 ATM to gigabit ethernet (GE).

Metropolitan network in Prague is maintained by PASNET. PASNET is association of main consumers of networking services. Fibre optics used in this network is partially in ownership of PASNET members but not PASNET it self and partially leased from several vendors. This networks is providing largest number of networking protocols and is using largest number of technologies including CWDM and single fiber lines. The reason for this is the fact that PASNET is renting fibre optics and should very carefully study economical parameters of every new line.

Brno has larges academic fibre optics network in our country. It consists of about 100km of fibre optics cables typically with 48 fibre optics lines in the cable. All optics cables are in ownership of universities. The ownership of fibre optics cables is mandatory and provides the universities with capability of developing new applications because for these applications the metropolitan network in Brno can provide dedicated fibre optics networking infrastructure. A good example of such application is the Regional PACS (Picture Archiving and Communication System) Archive. This is and archive of medicine picture images like X-ray, Computer Tomography etc. opened for all hospitals who want to participate on this project. Another example may be new GIS system for documentation of cable topology and interconnection developed at Masaryk university in Brno.

Smaller cities i.e. Plzen, Olomouc and Hradec Kralove have very similar metropolitan networks. The network consists of about 20 - 30 km of fibre optics typically in ownership of local university. This network is connection about 20 - 30 locations around the city and provides connectivity to PoP of CESNET both to local university which is maintaining the metropolitan network and other institutions who may be connected to NREN. These smaller institutions typically are not participating on network maintenance and the reason why they are using university optics is simply that they was "on the road" when the fibre optics cables were led in the city.

5 Dark Fiber in CESNET Backbone

Dark fiber especially with combination with NIL technology provides a lot of advantages. Wen can freely use whichever networking technology we want. CESNET is using this technology on all backbone lines except lines with DWDM technology. The reason is simple: DWDM is used to provide data channels going through several backbone nodes. The real length of data channel may be several hundreds of kilometres. For this reason we can't use optical amplifiers with too high amplification because the higher amplification the bigger signal distortion. Of course DWDM is used on dark fiber lines as well. The schema of "L1" topology i.e. dark fibre infrastructure is on picture 2.

CESNET is leasing dark fiber lines from many vendors. On certain lines is used DWDM technology bought as a complete solution including inline optical amplification.

On lines without DWDM we use optical amplifiers on data termination points only. First real usage of this principle in CESNET backbone is run on line Prague - Pardubice. This line is 189km in length and is equipped with EDFA (Erbium Dopped Fibre

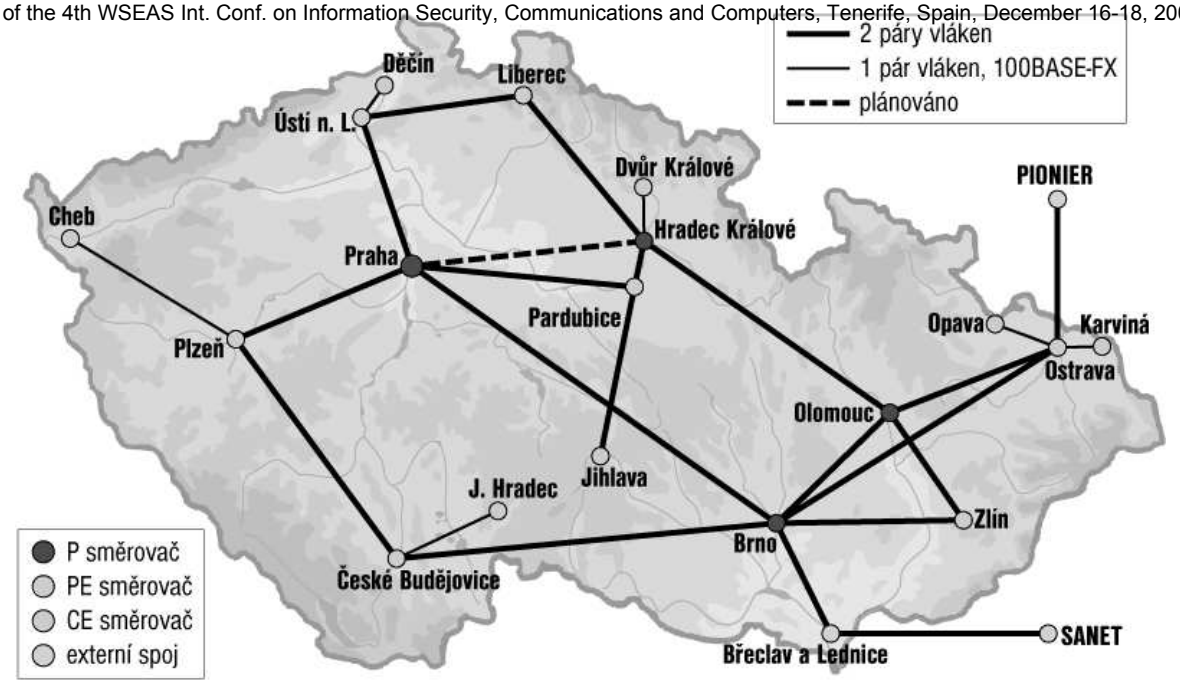

Figure 2: Physical Dark Fibre Topology of CESNET Backbone

Amplifier) since 2001. EDFAs on this line are used as boosters i.e. are connected below transmitter on both sides of the line. The longest line equipped with this technology is line Brno - Ostrava. The length of this line is about 235 km. This line is equipped with 4 EDFAs: output of each transmitter is connected to EDFA booster. Output signal of the booster is about +22dBm. Before each receiver is connected EDFA preamplifier. This line is now used for transport of Gigabit ethernet. With similar setup it was used for POS STM-16 type of traffic. It was replaced by gigabit ethernet due to cost of data termination equipment.

Lines up to 110 km usually have attenuation below 30dB. On such lines is transported unamplified gigabit ethernet. For this type of lines the CWDM GBICs or SFPs are used. The reason is they have about 2dBm better power budget than traditional ZX gigabit ethernet pluggables.

Lines to some smaller locations like Karvian or Jindrichuv Hradec are constructed as a sigle fiber lines. The reason for usage of this type of lines is partially price of leased dark fibre lines a partially not so good dark fiber lines availability in certain locations.

6 Single Fiber Lines

The most interesting single fiber line in CESNET Backbone is line Ostrava - Karvina. All other single fiber lines are used for 100 megabit ethernet and are based on commercially available equipment i.e. mediaconvertors which convert data signal from 100Base-TX to single fiber optics. The line discussed in this section was earlier constructed in the same way. As the traffic going through the network is increasing it was necessary to upgrade this line to gigabit ethernet.

Of course it it possible to do it on commercially available equipment as in case of fast ethernet. Similar equipment for gigabit ethernet are too much expensive. Instead of it we decided to use some kind of home made wdm for this line. We utilise the fact that the receiver of gigabit ethernet pluggables (GBIC) is wideband. This allows us to use transmitter 1550 nm on one side and transmitter 1590 nm on the other side of the same line. Of course we should put optic filter in from of each receiver to filter out transmitter of the same node. The schema of this line is on picture 3.

This approach is used on the line OStrava - Karvina. The fibre optic line is 70 km in length and has attenuation about 23dB. This solution allows us to utilise single fiber line with a reasonable length for about the same capital expenditures like legacy two fibre lines. In the two fibre case we have to buy two peaces of GBIC. In case of single fiber line we need two peaces of GBIC as well plus two peaces of fibre optic splitter witch pass band filter. Typical price of such splitter is about $ 250 so it is not meaningful in comparison with cost of GBICs operating in 1550nm window, cost of data termination equipment etc.

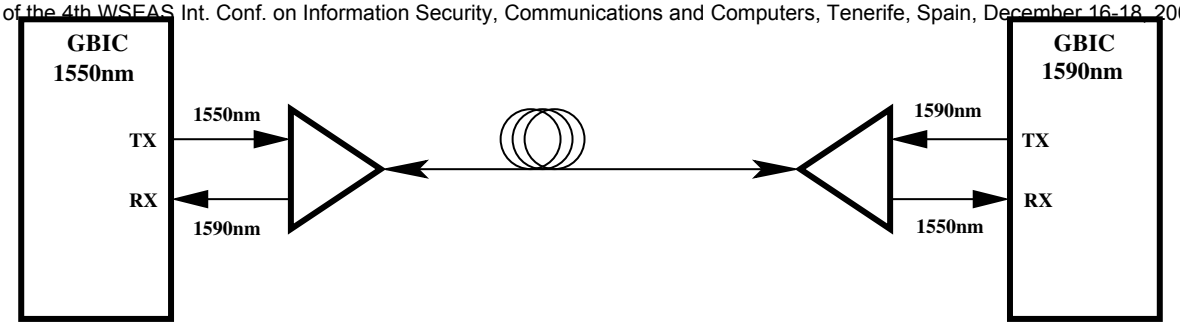

Figure 3: Schema of home made single fiber solution

7 Conclusion

Single fiber lines seem to be perspective for connecting end nodes of backbone network. This technology is really usable on fibre lines which have several ten's of kilometres in length. In CESNET backbone we are successfully operating a low cost solution for single channel gigabit ethernet line and we assume to extend this technology to some other lines.

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