Ethernet OAM 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 fibre leased from various vendors. On some lines it is very reasonable to use external mediaconverters with special SFP modules. It allows us to employ ethernet OAM technology for better monitoring of these lines.

Key–Words: dark fibre, OAM, NREN

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 institutions 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.

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 transeuropean 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 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 con-
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. 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 fibre. 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 of dark fibre and leased line POS STM-16.

A next step was movement to complete dark fibre infrastructure. The reasons for this step are the following: at speed of GE and STM-16 dark fibre is more economical than leased lines and bandwidth improvement and technology migration. More over the backbone moved to NIL (Nothing In Line) technology on mostly all lines. By usage of fibre optical amplifiers it is no more necessary to maintain any regenerators 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 Dark Fibre in CESNET Backbone

Dark fibre 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...
tion 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 1. 

CESNET is leasing dark fibre lines from many vendors. On certain lines is used DWDM technology bought as a complete solution including in-line 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 Doped Fibre 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 Karvina or Jindrichuv Hradec are constructed as a single fibre lines. The reason for usage of this type of lines is partially price of leased dark fibre lines and partially pure dark fibre lines availability in some areas.

5 Cost-effective solution for midsized lines

Today smart SFP modules with power budget of 36dB are available on the market. Such SFPs can be used on lines with length about 160km. However main networking equipment vendors used to limit spectrum of gigabit ethernet pluggables (GBICs or SFPs) usable in their routers and switches to a relatively small number of approved types. Till now it prevented us for utilising of a lot of interesting SFP modules with high power budget or another special properties suitable for utilisation in CESNET backbone network.

For utilisation of new models of SFPs which are not yet tested by our networking equipment manufacturer we propose to use small external equipment serving as a "transponder". The idea is easy to understand from the picture 2.

There are some basic requirements for "transponder" equipment:
- redundancy of power supply and central processor unit if any is necessary
- reasonable level of modularity
- manageability via SNMP

For many possible applications of this technology in CESNET network we appreciate ethernet OAM as specified by IEEE 802.3ah. For this reason we have concentrated on equipment supporting this protocol. We have tested SFP-to-SFP media converter MRV model EM316-GRMAHSH. Now we are performing production testing of this equipment on line Brno-Zlin which has about 130km in length and 33dB attenuation.

6 Ethernet OAM

Ethernet OAM (Operations, Administration and Maintenance) was originally introduced by EFMA
(Ethernet in the First Mile Alliance) and later standardised by IEEE in 802.3ah specification. The main purpose of this protocol was to overcome some inefficiency or weakness of traditional enterprise management protocol i.e. SNMP. Although SNMP provides a very flexible management solution sometimes it is inadequate to management task. First of all it assumes operational underlying network because it relays on IP connectivity. However we need management functionality even if (and first of all if) the underlying network is not operational.

Carriers looked for management capabilities at every network layer. The ethernet traditionally doesn’t offer management capabilities so the 802.3ah is mostly the only way for management of this layer. Though it was originally intended for EFM (ethernet in the First Mile) applications it is very suitable for ethernet base backbone lines.

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<th>Octets</th>
<th>Field</th>
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<td>DST Address</td>
<td>01-80-c2-00-00-02</td>
</tr>
<tr>
<td>6</td>
<td>SRC Address</td>
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<td>2</td>
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<tr>
<td>42-1494</td>
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</tr>
<tr>
<td>4</td>
<td>FCS</td>
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</tr>
</tbody>
</table>

Figure 3: The OAMPDU structure

OAM information is conveyed in slow protocol frames called OAM Protocol Data Units (OAMPDU). OAMPDUs traverse a single link only, MAC clients like bridges and switches do not forward them. The overview of OAMPDU structure is on figure 3. There are six types of OAMPDUs distinguished in the Code filed of OAMPDU:

- Information OAMPDUs
- Event Notification OAMPDUs
- Variable Request OAMPDUs
- Variable Response OAMPDUs
- Loopback Control OAMPDUs
- Organization Specific OAMPDUs

Once link comes up on the interface the OAM discovery begins. It allows local DTE to detect OAM on the remote side. Once OAM support is detected both ends of the link exchange state and configuration information e.g. mode, PDU size, loopback support etc. and OAM is enabled on the link. After loss of link signal or not hearing OAMPDUs for more than 5s the discovery process is restarted. The OAM mode is either Active or Passive. Active mode should be on provider end of the link. Device in this mode initiates the OAM discovery, sends Information OAMPDUs and may send Event Notification, Variable Request and Loopback Control OAMPDUs. Passive mode should be configured on customer end of the link. Device in this mode waits for remote side to initiate OAM discovery process, sends Information OAMPDUs, may send Event Notification OAMPDUs, respond to Variable Request by sending Variable Response OAMPDUs and react to received Loopback Control OAMPDUs. This device may not send Variable Request and Loopback Control OAMPDUs.

OAMPDUs are send at maximum rate of 10 frames per second as defined in Annex 43B of IEEE 802.3. Some properties of OAM like remote loopback control are designed mainly for service providers and are not used in Cesnet environment. We are using only Variable Request/Response types of OAMPDUs for status monitoring and part of Organization Specific OAMPDUs for setting up properties of remote mediaconverter interfaces like speed and duplex on UTP interface.

7 OAM MIBs

Ethernet OAM is operating on MAC client to MAC client basis. The device running active mode of OAM should communicate with network management station and provide status information on both local and remote end. The networking device running OAM in active mode uses Variable Request OAMPDU to retrieve status information from the remote side. The principle is illustrated on picture 4.

Figure 4: Management of remote mediaconverter via OAM

Structure of variables that can be retrieved Variable Request OAMPDU is defined by IEEE 802.3 standard in the Annex 30A. The structure of
this variable list corresponds to SNMP MIB tree. The Variable Request OAMPDU contain one or more (limited by frame size) Variable Descriptors. Variable descriptor consists of two fields: one octet Variable Branch and two octets Variable Leaf. This approach assumes that network management station will ask for MIB variables of the format iso(1).member-body(2).us(840).ieee802dot3(10006).csmacdmgmt(30).branch.leaf. Where branch is one of

- managedObjectClass 3
- package 4
- nameBinding 6
- attribute 7

Most important information are in the attribute branch. Here are items like FramesTransmittedOK, FramesReceivedOK, OctetsTransmittedOK, OctetsReceivedOK, etc.

Network management station uses legacy SNMP for retrieval of information from networking device running OAM. SNMP MIB variables may be mapped into OAM variables which are retrieved from remote side of the link via Variable Request/Response OAMPDUs. Not all vendors of networking devices use MIB branch iso.member-body.us.ieee802dot3.csmacdmgmt. The reason is that some networking equipment were delivered before IEEE and IETF finished corresponding standards.

In the case of MRV a combination of vendor specific branch of MIB tree and standard .iso.org.dod.internet.mgmt.mib-2.interfaces.ifTable with special ifIndex is used. If the ifIndex of local interface is \( N \) then the ifIndex of corresponding remote interface is \( 5000 + N \). This approach is used for all traditional status information and statistics counters like ifAdminStatus, ifOperStatus, ifInOctets, ifInUcastPkts, ifInNUcastPkts, ifInErrors, ifOutOctets, ifOutUcastPkts, ifOutNUcastPkts, etc. The vendor specific branch of MIB tree is used for obtaining SFP related information like SFP vendor, serial number, in case of SFPs equipped with management information interface yes optical TX and RX power, laser bias etc. All these information can be accessed via .iso.org.dod.internet.private.enterprises.nbase.nbsCmmc.nbsCmmcPortGrp.nbsCmmcPortTable.

8 Conclusion and future work

Originally external mediaconverters was considered only as an economically more suitable solution for mid-range fibre optics lines. In the second step properties of ethernet OAM were evaluated and counted as very interesting for application on Cesnet gigabit ethernet backbone lines. OAM is very useful tool for monitoring and management of dark fibre lines equipped with gigabit ethernet technology. Because this technology starts to be deployed to most of today’s dark fibre lines instead of traditional time division multiplexing technology (SDH/SONET) it is extremely important to provide to ethernet technology management capabilities comparable with SDH/SONET.

We have successfully tested such kind of management on one intercity line. As a next step we plan to deploy ethernet OAM technology to most of single-channel backbone lines in Cesnet network. Especially on lines which needs some external mediaconversion or signal amplification equipment this technology will be very useful because it can provide us basic management information of the topologically nearest remote device.

References:

[1] Yearly reports of projects and scientific research plan solved at CESNET available at www.cesnet.cz
[2] IEEE 802.3ah standard