IOP Conf. Series: Materials Science and Engineering **200** (2017) 012028 doi:10.1088/1757-899X/200/1/012028

Migration of optical core network to next generation networks – Carrier Grade Ethernet Optical Transport Network

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Abstract. In order to maintain the continuity of the telecom operators' network construction, while monitoring development needs, increasing customers' demands and application of technological improvements, it is necessary to migrate optical transport core network to the next generation networks - Carrier Grade Ethernet Optical Transport Network (OTN CE). The primary objective of OTN CE is to realize an environment that is based solely on the switching in the optical domain, i.e. the realization of transparent optical networks and optical switching to the second layer of ISO / OSI model. The realization of such a network provides opportunities for further development of existing, but also technologically more demanding, new services. It is also a prerequisite to provide higher scalability, reliability, security and quality of QoS service, as well as prerequisites for the establishment of SLA (Service Level Agreement) for existing services, especially traffic in real time. This study aims to clarify the proposed model, which has the potential to be eventually adjusted in accordance with new scientific knowledge in this field as well as market requirements.

1. OTN/DWDM network

The current topology of main cable OTN/DWDM transport network of one operator in Bosnia and Herzegovina is shown in the Figure 1.

As it is shown, all equipment is from one manufacturer (Alcatel-Lucent), and on most locations is mounted equipment 1830PSS-32. This equipment offers a significant capacity and performance to transfer large amounts of data over long distances in order to fulfill needs of a growing number of services and capacity. They should be used to add equipment that prepare transport network for further development of existing, but also technologically more demanding, new services. Also, it is necessary to realize the preconditions for the support real-time services.

At four locations, beside DWDM equipment, IP / MPLS core routers are installed.

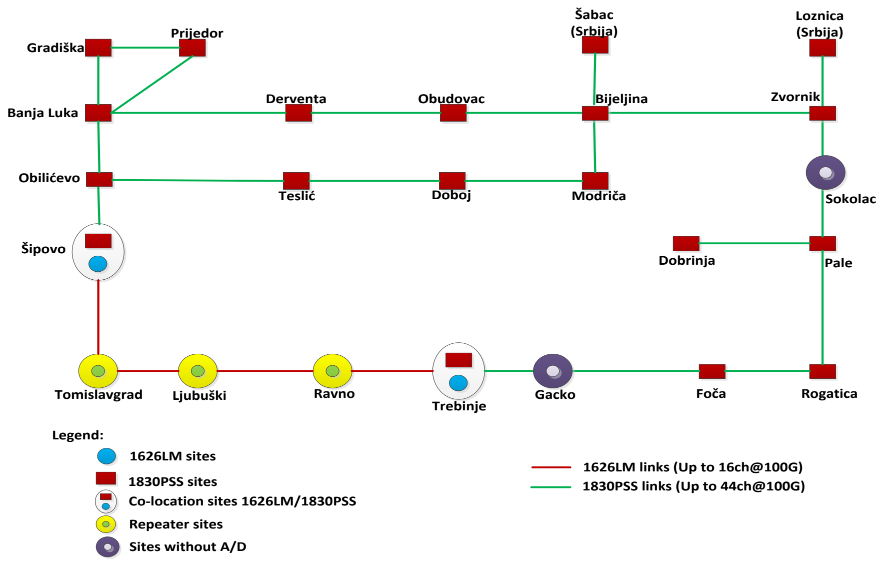

Figure 1. Topology of OTN/DWDM network

1.1. Existing IP/MPLS of transport network

Architecture is typical two-layer MPLS network with four routers in core and eighteen edge routers, as shown in Figure 2.

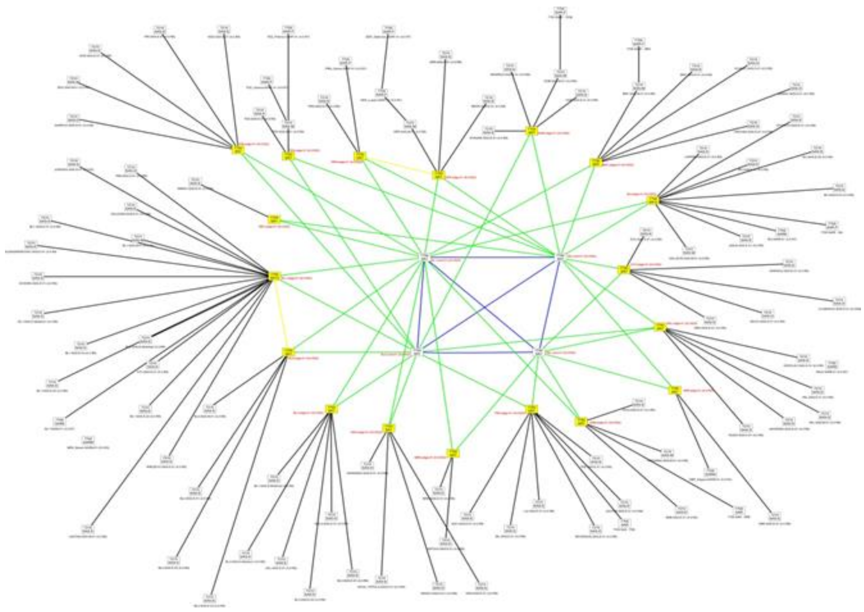

Figure 2. Topology of transport MPLS network

It can be seen that topology of grid type is from core to edge routers. Each edge router has an interface to two core routers, and there is a double connection as the basis of physical reliability.
Because tandem network elements increase network price, operators provide a different level tolerance cancellation for edge routers and network core. For example, core network is protected from router failure with grid topology, as shown in Figure 2. In this way, alternative routes are quickly establish and prevent losses. Network core use additional routers and links in order to ensure fault tolerance.

In contrast, thousands of users often have connection via one end router which is the most sensitive part of network. In that case, instead of additional routers and links, pairs of panel control processors are used, duplicate liner board are used or Tandem links are used (such as SDH APS - Synchronous Digital Hierarchy Automatic Protection Switch) to provide tolerance [1], [2].

In addition, edge routers could be directly linked to each other, and that should be aim, where it is economically feasible.

According to one-year study IP router core network availability, conducted by University of Michigan in the study of regional IP services provider, it is found that average cancellation time ruter interface is 955 minutes per year, which present interface availability of just 0,998 [3].

As reference value is taken cancellation time of 5.2 minutes per year, because it gives the availability 99.999% of time [4]. This is standard value of availability for telecommunication systems.

In listed study reason of network cancel is reached, and in 23% because router cancellation (software or hardware, "denial of service attack"), 32% due to a link termination (termination of optical cables, network congestion), 36% because router maintenance (error while configuring, upgrading software or hardware), 9% from other reasons [5].

From these data it can be observed that most networks cancellation hapened as a result of the router cancellation. According to another study, failures of routers software are the biggest reason (35%) of router cancellation. More precisely, the control plane failures represent 60% of software cancellation [6]. Calculations of routers reliability and availability and their control levels, indicate the necessity of software and hardware control level redundancy, in order to obtain a high level of services availability [7], [8].

According to information obtained from operators sources, over 90% mobile and fixed networks traffic is done via the MPLS network, mainly using VPLS (Virtual Private LAN Service) mechanism, typical for traffic management on line-level in Ethernet type networks.

A key part of physical layer IP operator's network is fiber network, presented in Figure 1.

Integrated Packet Transport is based on the integration of the Alcatel-Lucent Service Router Operating System (SR OS) into multiservice WDM Alcatel-Lucent 1830 Photonic Services Switch (PSS). Integrated Packet Transport (IPT) is leaning on the end-to-end transport layer 2 architecture, using a common management model and operational guidance from core to user equipment.

2. Technical demands

Taking into account current state of the operator’s transport network, and the need to maintain continuity of further construction, with monitoring of development needs and the application of technological improvements, idea is to do a project of migration existing main optical networks to next generation networks - Carrier Grade Ethernet Optical Transport Network (OTN CE), which implementation would be a prerequisite for the development of many other operator’s services.

The primary objective of OTN CE is to realize an environment that is based solely on the switching in the optical domain, i.e. the realization of transparent optical networks and optical switching to the second layer of ISO / OSI model.

First, it is necessary to make a detailed analysis of equipment condition in the operator’s transport network and choose one of the possible approaches to migration: upgrading existing transport networks or building parallel overlapping networks. For the purposes of the above it is necessary to do the following activities:

- Basic authentication, ie. measurement of all throughput parameters, availability and QoS (Baseline) which has to be done before the implementation of new applications, as well after implementation, because of measurement of expectations for new solution. Result of these activities should be information about performance, particularly critical infrastructure segments that should be urgently addressed;
- Setting up technical model OTN. Due to the prevailing representation of equipment from one manufacturer's in transport operator’s network, it is assumed equipment expansion from same

manufacturer. Architectural basis for migration approach is existing IP/MPLS/SDH/DWDM network.

- Setting up financial model OTN. Cost model include investment costs (CAPEX) for the purchase of basic equipment, implementation costs of the installed devices (IMPEX) and operating expenses (OPEX).

The new technical solution should indicate operators ability to provide greater scalability, reliability, security and quality of service QoS, as prerequisites for the establishment of SLA (Service Level Agreement) for existing services, especially traffic in real time.

It is necessary to provide the following functionality [9]:

- Resistance to certain errors of network sections - Possibility of network dynamic reconfiguration, without flow limitation for end-users on primary routes, backup routes and ability to overcome multiple sequential or parallel faults on connections in the network topology.
- Flexibility - Ability to dynamically or programmed network configuration or changing topology depending on current needs.
- Priorities - Possibility of higher priority channels transmission, instead of the channel with lower priority, in case of network failure.
- Project should be done in accordance with applicable technical regulations, complying with the current plans for cable and wireless access networks construction and operators service platforms.

3. Set up a technical model for introduction Carrier Ethernet OTN transport network

The operator should have strategic vision to realize the main network center in one central location and another redundand center.

In these centers all service platforms equipment hould be concentrate, OSS and BSS. Also, these centers would contain strong OTN/CE nodes from which real-time traffic from regional hubs should be direct to service platforms (IPTV hedendom, Softswitch, SGSN, GGSN, etc.). These hubs will be based on the 1830 PSS switches.

This assumes and aimes for a solution where each switch PSS 1830 is going to be connected with two pairs of optical fibers (by separate routes) to each of the central 1830 switches.

The basic idea of real time services migration project is in first phase, gather real-time traffic at the edge PSS 1830, instead of the edge 7750 SAR, and direct traffic with special fiber on two central PSS 1830 in a central location and the second redundant center . The same traffic would be directed to the edge MPLS routers 7750 SAR with one 10 Gbps port, instead of many GE and FE ports that are used in the present state on some locations. MPLS shuold networks serve as a backup in case of failure in the OTN/CE network.

Control plane should be based on ASON/GMPLS management, from the physical to the transmission network layer. In accordance with the declared capabilities of 1830 PSS switch, Ethernet frames switching can be based on PBB (Provider Backbone Bridging) combined with ELS (Ethernet Label Switching) and GMPLS techniques.

In the second phase, OTN/CE network should be spread to DSLAM/MSAN nodes and base stations. There, existing hubs (TSS 7210 and 7705 SAR and other) would be replaced or upgrade to give OTN/CE outputs to edge nodes 1830 PSS. Existing cascade DSLAM configurations would be replaced EPON structures, where from EPON nodes shuold come out OTN/CE. For better utilization of the existing optical fiber in the access network can be used ROADM 1626LM, which would be dismantled from the network after the introduction of 1830 PSS switches.

Existing TDM transmission systems (SDH, PDH) would be transformed into EoSDH and EoPDH systems. On existing SDH and PDH multiplex equipment would add appropriate adapters which preserve existing investments in TDM. This would enable CE diagnostics and synchronization to endpoints, unified implementation and management services on packet technology.

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In the third phase, in addition to existing DSLAM, based on the ATM over ADSL to ADSL modems or concentrators, would set CE-based DSLAM, from which CE over ADSL go to CE-based user-Gateway, which beside telecommunications terminals (STB IPTV and VoIP phone), should support telemetry devices and smart meters (water, electric and gas). This will provide the MAC operational management, synchronization and diagnostics to the end devices.

3.1. Technical model of CE OTN network

As noted above, future transport network topology model will be redundant PetaWeb Model [10]. This means that should form a star redundant structure (double star with interrelated major nodes connected with all boundary nodes). Transport network architecture practicaly adjusts for future Software Defined Network (SDN) network [11].

This structure will be based on 100 Gbps links which connect two central nodes 1830 PSS-32 with eighteen regional nodes 1830 (PSS 32, 16, 4 and 1). It is similar with typical backhauling architectures, as shown in Figure 3.

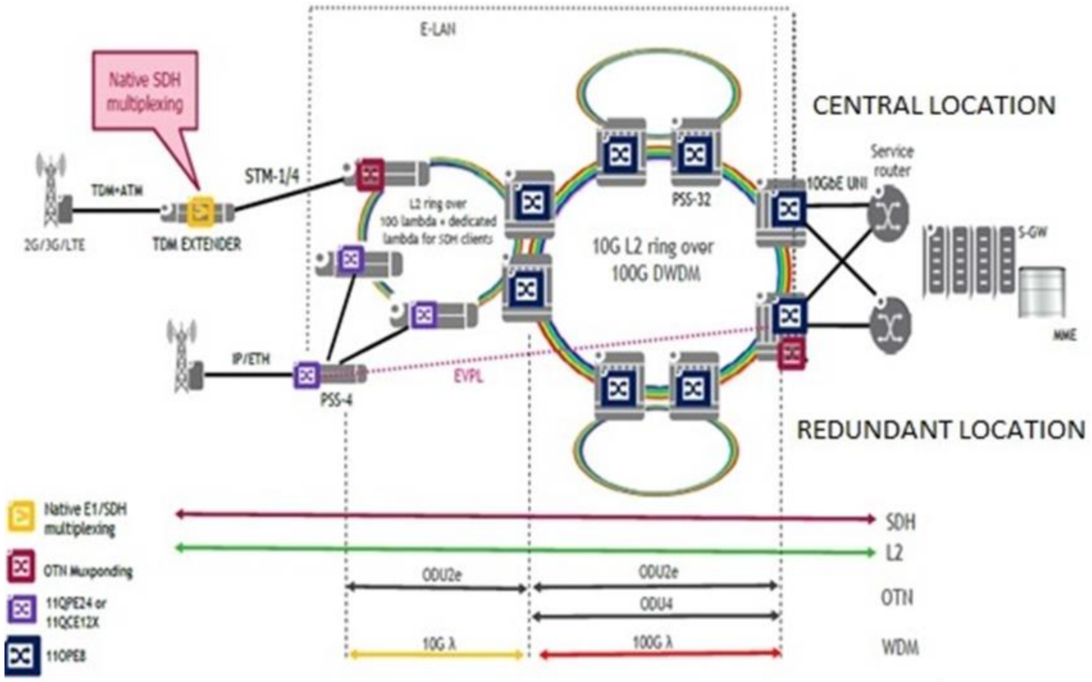

Figure 3. Topology of transport MPLS network Model of future CE-OTN networks as backhauling network for RT services

On the right side is, with core elements of the mobile network, represented total service platform which will in future be concentrated core elements of all network operators, including OSS/BSS. Elements of service platform will be with Ethernet ports connected to two main 1830 PSS-32 switches. On the two main 1830 PSS-32 switches (central location and the redundant center) are connected two main service routers 7950 XRS, which will have all functions of BNG's (Border Network Gateway) for real time services. They are MEF certified, so they are going to be connected on 1830 PSS with two OTU-4, 100 Gbps.

On the left side of larger ring in Figure 3 are shown nodes 1830 PSS in regional centers that will be located along existing MPLS edge routers. All access lines on edge MPLS lines, coming from the DSLAM/MSAN or the base stations (Figure 2), directly or agregate (via access routers or 7705 SAR

7210 SAS switches), were 1Gb Ethernet. They should be transferred to Carrier Ethernet. This will enable Carrier Ethernet OAM and synchronization possibilities to end devices.

MPLS transport network transmit only non real-time Internet traffic. In new architecture, every edge router would through its edge 1830 switch connect to every other router in the network. This would virtually establish connection between edge routers each with each, which would achieve far greater reliability than existing. In case of failure of any MPLS routers, his role can take over any other regional router.

With releasing MPLS transport network from real time traffic, it could be much more favorable to offer Internet access, hosting, virtualization, data centers and so on. It will free a large number of GbE ports on the edge MPLS routers for this purpose. In the next 5 years is expected migration of the majority of internet access on mobile devices, through micro, pico and femto cells. This new blow broadband Internet traffic will be able to accept MPLS transport network. MPLS transport network, also can serve as a backup in case of failure of the Carrier Ethernet OTN network.

3.2. 1830 PSS switch as a key node in the OTN-CE network

Integrated Packet Transport is based on the integration of Alcatel-Lucent Service Router Operating System (SR OS) into multiservice WDM Alcatel-Lucent 1830 Photonic Services Switch (PSS). Integrated Packet Transport (IPT) is leaning on the end-to-end transport layer 2 architecture, using a common management model and operational guidance from core to user equipment.

Need for sophisticated point-to-point and multipoint services is realized through the integration of Ethernet (L2) into WDM. Applying statistical traffic multiplex and services from multiple locations provides better utilization of bandwidth/wavelength and supports delivery of E-LAN and E-Tree multipoint services.

1830 PSS switch has a key role in integrated packet transport IPT, offering by Alcatel-Lucent, which is base of migration proposal, shown in Figure 4.

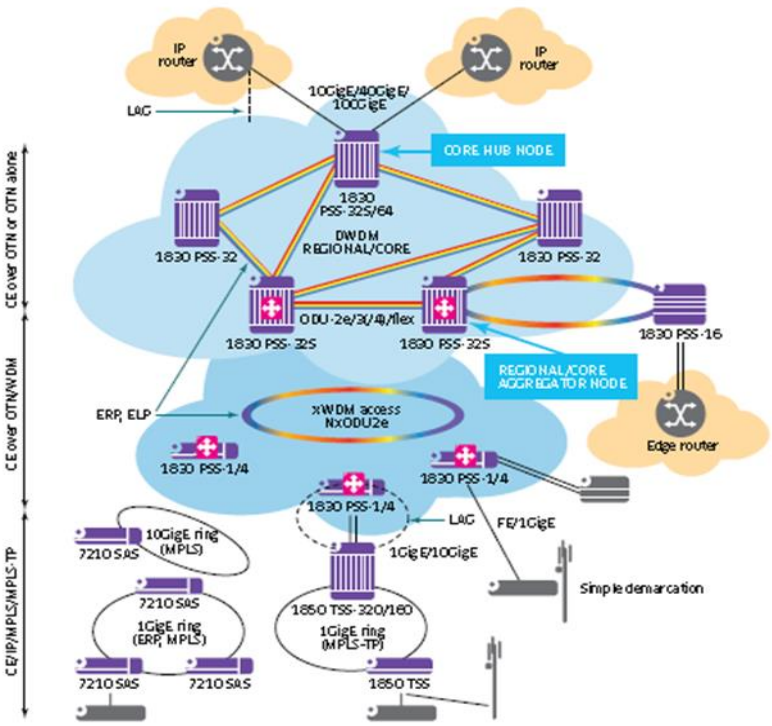

Figure 4. IPT concept

Service providers must develop its network to fulfill demands for bandwidth due to increased deployment of FTTx networks. Growth of bandwidth, as a result of the transition from Digital Subscriber Line (DSL) to Gigabit - capable Passive Optical Network (EPON, GPON), requires implementation WDM aggregation rings, as shown in Figure 4.

By introducing 1830 PSS in regional hubs, operator will be able to dismantle a significant amount of existing ROADM 1626LM because 1830 PSS has already builted Add-drop multiplexers. Dismantled equipment will be used to resolve aggregation rings in the access network, where necessary.

The key electro-optical elements of 1830 PSS switch are shown in Figure 5:

- Point-to-point Ethernet service muxponders,
- Ethernet switching muxponders,
- Ethernet switching OTN client cards,
- Network interface demarcation devices, miniaturized in a Small Form Factor Pluggables (SFPs).

Point-to-point (P2P) muxponders perform L2 statistical multiplex in order to aggregatie Gigabit Ethernet (GigE) traffic in the access network. Improved P2P muxponders offer greater scalability of services and a higher level of Maintenance and Operational Management (OAM), protection and Synchronous Ethernet possibility (SyncE).
Options: EPL, EVPL services, flexible classification, MEF input range profile, CE OAM (IEEE 802.1ag and ITU-T Y.1731), Performance monitoring (PM), Link aggregation (LAG), SyncE, 1588v2 P2P phase timing.

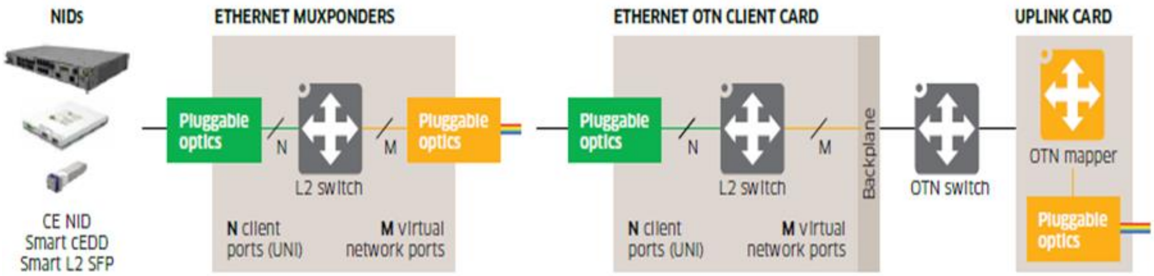

Figure 5. Key E/O elements of 1830 PSS switch

Ethernet switching muxponders and Ethernet switching OTN client cards are guided by SR OS. They perform L2 switching in order to aggregate traffic from the access network and the optional higher-capacity line, for providing optimal scalability aggregation and optional commutation of clients and lines for optimization of OTN applications, for example between the router and 100G WDM lines. Beside these features P2P muxponders have: full opportunities of networking with other node elements that support Carrier Ethernet (Alcatel-Lucent 7750 Service Router, Alcatel-Lucent 1850 Ethernet Service Switch, Alcatel-Lucent 7210 Service Access Switch), E-Line, E-LAN and E-Tree services, SR OS service model (service access point [SAP], virtual private LAN services [VPLS]), MEF CE 2.0, QoS classification at the entrance, measuring and policing per service class (class 8, 8 rows per port with deployment and preventing congestion).

3.3. Subnet models for real-time services

3.3.1. Mobilne Backhaul. MPLS network should be unloaded from mobile traffic or it should be serve as a backup in case of failure DWDM Ethernet mobile backhaul network. SDH lines can be directly implement into the 1830 PSS and native transmitt through fiber network to controller or service platform. In an effort to support migration from TDM to packet solution for all mobile network traffic, these backhaul architecture resolves challenges such as: high resistance/availability, highly precise synchronization of clocks and management from end to end. This is achieved by supporting earlier and packet synchronization approaches, such as Synchronous Ethernet SyncE (frequency) and IEEE 1588v2 (phase/time) synchronization. Beside this, solution provides advanced troubleshooting and SLA (Service Level Agreement) monitoring.

3.3.2. Broadband (BB) backhaul and Triple Play distribution. Convergences of packet and WDM in a single platform improves economics from CAPEX perspective - based on reducing number of ports and network elements, as well as due to the increased utilization of fiber. Operational efficiency is also increased because of a large number of services on the same transmission basis.

1830 PSS is essential for this purpose because they are more efficient than purely electronic CE switches with multiple 10Gbps capacity with external filters, colored optic, and multiple stacked 10G WDM rings.

PSS 1830 features for the purpose of broadband aggregation:

- Termination: IP DSLAM, GPON OLT, CMTS / CCAP cable backhaul
- E-LAN and E-Tree perfectly suitable for multicast and dual of homming router
- A wide range of options for protecting interconnection
- IPTV (streaming and on-demand video distribution) in combination with internet access for residential users, and LAN interconnect for enterprise
- Better utilization of wavelength and bandwidth using L2 multicast and IGMP snooping, the IGMP Proxy and Fast Leave for complete optimization and QoE.

4. OTN CE network investment

4.1. Current status

Operator has about 20 locations (nodes) at which aggregation of traffic is carried. Since the aforementioned locations at the same time are part of the MPLS and DWDM networks as their hub, they should be used as a hubs of ONT network.

Currently, corporate services are provisioning differently on various network levels. The largest number of network services are L2VPN (usually VPLS) type, shown in Figure 6.

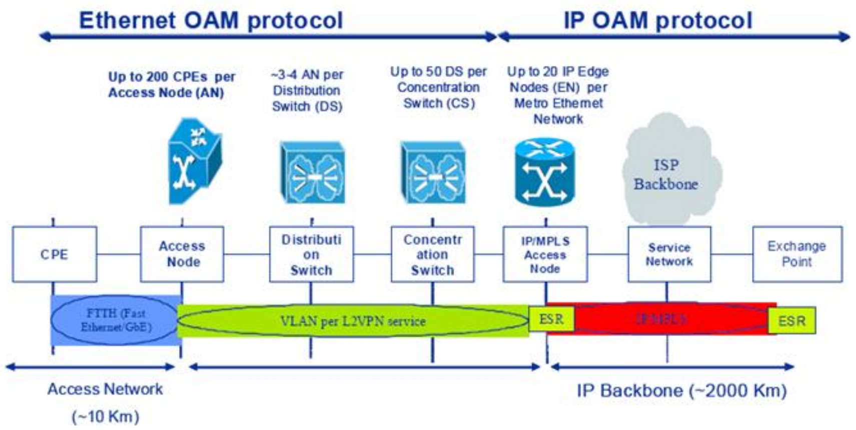

Figure 6. Referent network for L2VPN services

As can be seen, each P2P connection between two access nodes use L2 VLAN in access network to the access node (DSLAM or OLT), L2-MPLS (VPLS) from the access node to the edge router in the MPLS network, and tunnel in the IP/MPLS network.

This approach requires a lot of manual configuration.

On the other hand, it is used many different protocols for maintenance and operational guidance in any part of the network. The number of network elements (potential point of failure) is also great. Therefore, the complexity of operational management and maintenance (OAM) L2VPN service is currently unresolved issue.

4.2. Future status

As shown in Figure 7, with introduction of L2 switching technology, as it was proposed, it should be get unique end-to-end OAM system, as well as multi-domain control plane mechanisms, which enable the dynamic establishment, recovery or realocation GMPLS tunnels between different access domains.

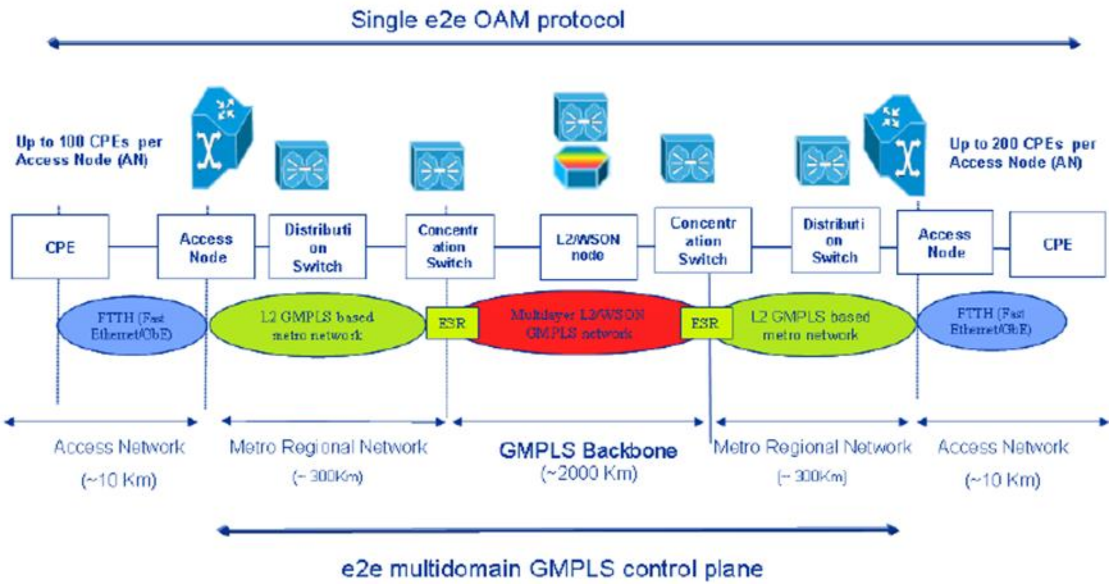

Figure 7. Unique L2 switched network with GMPLS

Beside this, PSS 1830 node combines switchings on the first (optical) and on the second electrical level (OTN-CE) with one ASON/GMPLS control plane. With this it is achieved significantly reducing management complexity, maintenance and operational management, on a much smaller number of network elements.

For ease of handling of L2 switches, operator's expert teams can concentrate in two operational centers, one center and one redundant center, where daily maintenance in rest of the network can be left to the technician teams. This will reduce OPEX by 50%.

5. Conclusions

The first paragraph after a heading is not indented (Bodytext style). At the present time, the development of telecom operators is often dictated by the requirements of the user. It is necessary to maintain the continuity of the telecom operators' network construction and application of the latest technological solutions to meet the changing requirements of users. In this connection, it is necessary to migrate optical transport core networks to the next generation networks - Carrier Grade Ethernet Optical Transport Network (OTN CE). These are transparent optical network-switched exclusively to the optical domain - the second layer ISO / OSI model. Such networks enables higher scalability, reliability, security and quality of service QoS, as well as prerequisites for the establishment of SLA (Service Level Agreement) for existing services, especially traffic in real time.

The idea is, in the first phase, gather real-time traffic at the edge OTN/CE nodes and and direct traffic with special fiber on two central OTN/CE nodes in a central location and the second redundant center. In the second phase, the OTN/CE network should be spread to the DSLAM / MSAN nodes and base stations. Existing nodes (TSS, 7210 and 7705 SAR and other) would be replaced or upgrade to give OTN/CE outputs to edge OTN/CE nodes. In the third phase would be set CE-based DSLAM's, which bind to CE-based Gateway user. This will provide the MAC operational management, synchronization and diagnostics to the end devices.

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