100G Ethernet for Packet Transport Networks

Andreas Kirstädter
Nokia Siemens Networks, Otto-Hahn-Ring 6, D-81730 München, Germany
Tel.: +49-89-636-47484, Fax: +49-89-636-45814
andreas.kirstaedter@siemens.com

Abstract: This paper considers the functionality and standards required to enable carrier-grade core networks based on Ethernet-over-WDM. Possible Ethernet backbone network architectures will be discussed together with 100G transmission technologies.

1 Introduction

Backbone networks represent the top of the carriers' network hierarchy connecting networks of different cities, regions, countries, or continents. The complexity of these technologies imposes substantial financial efforts on network operators, both in the area of Capital Expenditures (CAPEX) and Operational Expenditures (OPEX).

Ethernet claims to be a possible enabler of cost-efficient networks, as it is characterized by simplicity, flexibility, interoperability, and low cost. While Ethernet is traditionally a Local Area Network technology, continuous developments already enabled its deployment in Metropolitan Area Networks. Recent research and standardization efforts aim at speeding up Ethernet to 100 Gbit/s and at resolving scalability issues, thus supplying Ethernet with carrier-grade features for core networks.

2 Carrier-Grade Ethernet-Based Core Networks

2.1 Carrier-Grade Requirements

In order to be suited for core networks, Ethernet needs carrier-grade performance and functionality. It has to offer and implement the required Quality-of-Service (QoS) and has to enable traffic engineering to fine-tune the network flows. Furthermore, it has to provide fast and efficient resilience mechanisms to recover from link and network element failures and has to enable various Operation, Administration, and Maintenance (OAM) features for the configuration and monitoring of the network. Last but not least, it has to provide secure network operation. Additionally, a high degree of scalability is needed for handling different traffic types and for user separation inside the network. This scalability in terms of address space, maximum transmission speed, and maximum transmission distance becomes an important issue for the next Ethernet generation. E.g., multi-layer operation and optimization can only be used if facilitated by reasonable values of the maximum transmission distance.

At a closer look, it becomes visible that many of these required features are currently implemented repeatedly at different network layers. E.g., resilience mechanisms are found in the WDM layer and in an intermediate Sonet/SDH layer as well as in the packet layers above them. A cost-efficient network and protocol architecture therefore has to evaluate these functional redundancies between the layers very carefully.

2.2 Forwarding Technology and Scalability

The necessary scalability requires new approaches to packet switching and forwarding within meshed end-to-end Ethernet networks. Traditionally, within Ethernet networks the Spanning Tree Protocol (STP) calculates a single tree structure based on configurable IDs of switches, configurable port weights, and priorities to connect any switch with each other. Although loop-less forwarding is guaranteed with this mechanism, STP provides only one path between two locations and a MAC address learning of any equipment is performed at the switches.

However, in the case of combining large networks and adding hundreds of customer networks with an Ethernet-based core network the number of MAC addresses will grow rapidly. Thus, scalability can no longer be provided with current layer-2 approaches and a separation of networks or an additional hierarchy between them has to be introduced to allow a scalable forwarding of data.

Also, the use of a single tree structure providing only a single path between two locations prevents the use of efficient traffic engineering and resilience mechanisms. Thus, several connection-oriented forwarding techniques for carrier-grade Ethernet transport networks are currently under discussion at standardization bodies: VLAN Cross-Connect (VLAN-XC), Provider Backbone Transport (PBT), and Transport Multi-Protocol Label Switching (T-MPLS) [1].

3 Multi-Layer Operation and Optimization

Another important aspect in the area of scalability is the maximum transmission distance of Ethernet signals. Multilayer network grooming approaches are very attractive for the purpose of reducing unnecessary packet processing in intermediate nodes [2] as transit traffic is allowed to bypass intermediate nodes. Traffic between two network edge nodes can either be transported transparently in the optical domain or can be converted to the electrical domain to allow electrical grooming along the path. The effort spent on extending the signal reach of Ethernet signals is rewarded by equipment savings. E.g., for a typical German reference network topology a maximum optical transmission distance of 600km already enables port count savings of around 30% [3].

Next to IP services, VPN business services transfer increasing traffic and generate high revenues for network providers. In particular, Ethernet services (E-Line and E-LAN) are evolving. Today these layer-2 services are commonly transported via IP/MPLS tunnels. However, the complex functionalities and protocols of the IP layer are often not required to transport these pure layer-2 services. Native End-to-end Ethernet structures will arise where Ethernet business services will be transported on pure layer-2 infrastructures without the need of complex data transformations and changes in the functional layer structure. In continuation, also a merger between Ethernet-based packet transport and IP networking appears on the horizon further reducing superfluous functional redundancies between the single packet protocol layers – just in the sense of the current clean-slate thinking for the future Internet.

4 CAPEX and OPEX Performance

In order to calculate the total CAPEX of specific network architectures, future traffic loads, network device counts, and network device prices were estimated following a careful analysis of market data and price developments [3] for a German backbone - assuming a homogenous traffic growth rate of 40% per annum 2009-12. A shortest-path routing algorithm was then applied to determine the single link loads from which the number of switches, routers, and line card ports were finally obtained depending on the network architecture. The following *generic* network architectures were considered:

(a) IP/PoS-over-WDM: Label Edge Routers (LERs) and Label Switch Routers (LSRs) connected pt2pt via Packet-over-Sonet (PoS) links. 1+1 protection.
(b) IP/PoS-over-SDH-over-WDM: SDH grooming.
(c) IP/PoS-over-OXC-over-WDM: OXC grooming.
(d) IP/MPLS-over-Ethernet-over-WDM: MPLS-enabled Ethernet switches within the core. 1:1 protection.
(e) Ethernet-over-WDM: Native Ethernet switches both at edge and core. A small share (30%) of traffic requires IP routing at edge. 1:1 protection.
(f) Ethernet-over-WDM with service-level protection: Only premium traffic (share set to 30%) is protected.

SDH (b) and WDM (c) grooming provide cost reduction potential compared to the expensive PoS interfaces used in (a). In the MPLS-Ethernet case (d), still a considerable amount of CAPEX is related to LERs and their interfaces. A native 100 Gbit/s Ethernet over WDM network (e) enables higher savings – also at the edge. Applying a service-level differentiated protection scheme (f), the CAPEX can be reduced even further.

OPEX were evaluated via a process-oriented approach [4] for the network repair process since the impact of 100 Gbit/s Ethernet gets most visibly in this process category. For each of the network architectures described above, the OPEX were evaluated using availability figures [5] for the equipment and weighting the average repair time with the average salary of a field or point-of-presence technician. As a general result, in 100 Gbit/s Ethernet networks are more economical terms of OPEX due to the reduced device count (less switches and line cards). A service-level protection scheme further reduces the required network transport capacity, the network element count, and thus the related OPEX.

5 100Gbit/s Transmission Aspects

Ethernet transmission at speeds of 100 Gbit/s over long distances is very desirable in terms of architecture-related network cost. The transmission of high speed data rates above 100 Gbit/s is well understood although second degree (slope) chromatic dispersion has to be exactly compensated, birefringence effects become grave, and the signal-to-noise ratio of 100 Gbit/s signals is generally lower as fewer photons are transmitted per optical impulse. Additionally, recent trials demonstrated the ability to process electronically the required bit rates of 107Gbit/s [6]. Still, the major problem is to find efficient optic-electrical and especially electro-optical conversion techniques for these high speeds. Pure electrical solutions are preferable to handle the data at the transmitter and receiver.

6 Conclusions

In the past, Ethernet evolved from LAN into Metro areas covering speeds from 10 Mbit/s up to 10 Gbit/s. Next-generation Ethernet with transmission-speeds of 100 Gbit/s will facilitate cost-efficient Ethernet transport. As soon as carrier-grade issues like scalability, network resilience, QoS, and OAM of Ethernet-based core network architectures are solved we might see a complete Ethernet-over-WDM core-network infrastructure with resolved redundancies between the single layers.

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8 References

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