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Enabling Next Generation Transport and Services using Unified MPLS

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Executive Summary

Multi Protocol Label Switching (MPLS) is a mature packet technology that is already widely deployed and plays an important role in service providers' packet-based networks to deliver a diverse, rich set of services and applications.

Initially MPLS was mainly deployed in core networks but since then has been extended into many aggregation networks. There is now a clear demand in the market to further extend MPLS into access networks to enhance operations thereby enabling a unified end-to-end technology.

Much of the original MPLS design, architecture and mechanisms can be used in transport networks. A transport network provides efficient, reliable, qualitative and scalable connectivity over which multiple services can be supported, with a clear separation between the operations and management of the service layer from those of the transport layer. However, additional architectural elements and mechanisms are needed to optimize MPLS operation in these transport networks, and the work on the Transport Profile of MPLS (MPLS-TP) extends the MPLS technology accordingly. These extensions are intended to strengthen the case for adopting MPLS technology in new market segments.

Section 1 of this paper introduces the key market drivers for extending MPLS.

Section 2 describes the MPLS extensions needed to support the transport profile (MPLS-TP), addressing transport requirements jointly provided by the IETF and ITU-T. The relationship with existing mechanisms is explained.

Section 3 shows how unified MPLS technology can be applied in Broadband Multi-Service Architectures and introduces some considerations regarding the choice between static and dynamic provisioning and management.

Section 4 presents the opportunities that the extended technology can bring to mobile backhauling, a key application now supported by broadband networks.

The MPLS architectural elements and mechanisms are defined by the IETF. The role of the Broadband Forum is to enable interoperable MPLS-based solutions to support broadband services (e.g. Mobile backhaul, Enterprise and residential services). The Broadband Forum fulfills this role by defining the end-to-end network architecture and specifying the appropriate nodal requirements. It also defines MPLS conformance tests, certifies compliant MPLS implementations and supports interoperability testing events.

1 Market Trends and Challenges

The market transition from circuit-switched networks such as TDM, ATM or other legacy networks to an all-IP network, also known as the IP transformation, has already started in fixed-line networks and is now moving to mobile networks. For example, both fixed and mobile voice are migrating towards VoIP; T1/E1 leased lines are migrating to Ethernet services, and 2G/3G mobile backhaul is transitioning to packet IP/Ethernet with the introduction of LTE, etc.

There is also a need to support new packet-based services which are bandwidth hungry and may require strict Service Level Agreements (SLAs). Such services include multimedia applications (IPTV, mobile TV), Enterprise services, cloud computing, data center virtualization, financial and video-conferencing services. Many of these services are expected to grow further more as more access bandwidth is offered to customers. The transition to Mobile Broadband will account for a doubling of traffic annually in the coming years.

Figure 1 shows a forecast of a dramatic increase in data traffic.

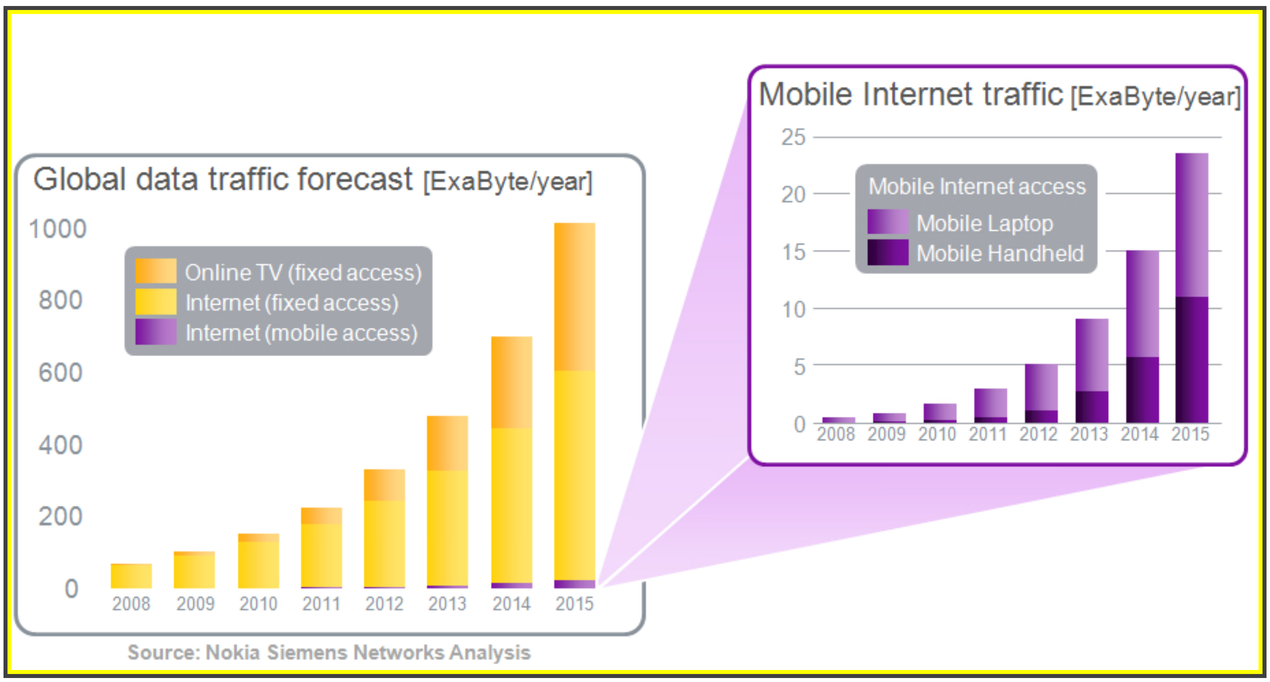

Figure 1: Data Traffic Forecast

There is a clear need to scale networks in a cost-efficient manner in order to cope with this traffic growth. Network functions such as fault management, performance monitoring and resiliency are also increasingly necessary to ensure a good quality of experience for users.

Network convergence, i.e. supporting different services such as mobile, enterprise and residential services on the same network, opens up opportunities for high efficiency and cost effectiveness. It allows service providers to:

- Have the flexibility to rapidly deploy new revenue-generating services in an economic way.
- Transport any service, at any scale.
- Enable the migration towards new wireless technologies (e.g. LTE).
- Provide improved throughput and reduce delay.
- Benefit from a smooth migration path from legacy towards next generation packet networks.

2 MPLS - A Unified Technology

MPLS is a mature and widely deployed packet technology, which plays an important role in the ability of service providers' packet-based networks to deliver a rich set of services.

MPLS supports separation of service delivery from the underlying transport infrastructure, which provides cost-efficiency, scalability and security. It is built on an architecture that handles framing, forwarding and packet processing and a comprehensive set of tools that can be used to:

1. Set up and maintain reliable and quality long-lived paths (Label Switched Paths - LSPs) to efficiently aggregate and carry multiple services across.

2. Enable the delivery of various services (Ethernet, IP, MPLS, TDM, ATM, etc.) with different connectivity types (e.g. point-to-point, point-to-multipoint, multipoint-to-multipoint) over the MPLS paths. Pseudowires (PWs) and Service-LSPs (an LSP on top of a transport LSP) can be used to adapt the services and multiplex them over the MPLS paths.

The MPLS paths provide connectivity between service termination and service switching points and are transparent to service creation and modification. This also ensures good scalability because within the MPLS network the provisioning, bandwidth management, QoS, resiliency and OAM mechanisms are all done per transport paths and not per-service. Packet forwarding is based on service providers' controlled mechanisms and addresses, ensuring secured networks and services.

MPLS is a carrier-grade technology which supports Traffic Engineering for ensuring determinism and predictability in efficient utilization of the network resources. MPLS also includes mechanisms that address QoS needs, guaranteed bandwidth and a set of recovery mechanisms capable of meeting the requirements of the most demanding services.

With the move towards packet-based services, the transport network has to evolve to encompass packet capabilities while enabling service providers to leverage their installed transport infrastructure investment. An automatic network control structure can simplify network operation and management in a way that preserves the look-and-feel of legacy transport networks, while also having the following capabilities:

- End-to-end service provisioning and network resource management.

- Ability to address various levels of QoS and ensure fast protection switching, which are needed especially by the new services.

- A comprehensive set of OAM fault management and performance monitoring capabilities supporting the network and services at different nested levels. Network-oriented mechanisms allow monitoring of the network infrastructure in order to enhance the general behavior and performance of the network, while service-oriented mechanisms allow monitoring of the services offered to the end user, enabling rapid response in the event of failure, and verification of SLA parameters.

A great deal of the current MPLS design, architecture and tools can also be used in transport networks. However, a few additional capabilities are needed in order to optimize MPLS operation in these networks. The IETF (bringing IP and MPLS packet expertise) and ITU-T (bringing transport expertise) agreed to work together to define these capabilities according to the IETF standard processes in order to ensure compatibility with the MPLS architecture and mechanisms.

The work on MPLS in transport environments extends the MPLS architecture and mechanisms. These can then be used for any application and in any network segment (core, aggregation and access). MPLS-TP is a subset of the extended MPLS technology.

MPLS is being extended in the following areas to fully support the transport's requirements:

1. Architecture:
    a. MPLS supports both Operation Support System (OSS) based and dynamic control plane based provisioning or/and management, so that the look-and-feel of legacy transport networks operation can be preserved.
    b. MPLS is being enhanced to allow functioning independently of the way in which the network is provisioned or managed and without relying on IP functionality. This is explained below in 3, 4, and 5.
    c. Transport networks need to transmit OAM messages in-band, i.e. along with the data traffic, subjecting them to the same treatment. This was already supported at the PW level using Associated Channel (ACh) and Virtual Circuit Connection Verification (VCCV), but was extended to support in-band control channels also at the LSP and the MPLS link level [RFC 5586].
2. Data-plane
    a. Since transport networks required paths to be bidirectional and co-routed, MPLS can be configured to allow each node along the path to be aware of the pairing relationship between the forward and backward directions.
    b. Path merging features such as multipoint-to-point and Penultimate Hop Popping (PHP) are disabled to ensure there is a unique label to identify a path, as some of the OAM operations require an end-to-end labeled path context.
3. Resilience
    a. All the MPLS and GMPLS recovery mechanisms are applicable, but the management plane is being extended to enable the provisioning of the protection entities and functions.
    b. A linear protection mechanism protects the network and services at different nested levels. It provides fast and simple protection switching and supports bi-directionality. A data-plane based protocol is being defined to coordinate the protection state between the edges of a protected element, and thus enable bi-directional protection switching. The mechanism also supports hold-off timers to

coordinate the timing of protection switching at multiple layers or across cascaded, protected domains.

c. Since physical rings are used in some transport networks, and point-to-multipoint path protection can be implemented more easily in a ring topology, work is ongoing to optimize the protection operation of MPLS-TP in ring topologies.

4. OAM
    a. Extensions to provide more OAM tools which meet the transport requirements, in particular:
        - Continuity Check (CC) and Connectivity Verification (CV)
            1. CC is used to proactively monitor the continuity between endpoints.
            2. CV: is used to validate that the connectivity is only between the intended endpoints.
        - Alarm notification
            1. Alarm reporting allows an intermediate node to notify of a failure in the server layer to the endpoints of the path.
            2. Remote defect indication is used by an endpoint to notify its peer that a defect has been detected on a bidirectional path between them.
            3. Client failure indication.
        - Diagnostics
            1. Route tracing is used to determine the route of a path across the MPLS network.
            2. Loopback is used to measure throughput, bit error rates, etc..
            3. Locked report is used to notify at path's endpoints that a server layer entity has been administratively disabled from carrying client traffic.
        - Performance monitoring
            1. Packet loss measurement is used to measure the packet-loss ratio between endpoints.
            2. Delay measurement is used to measure one-way or two-way delay of packet transmission between endpoints.
    b. OAM messages are supported at the LSP, PW and MPLS link levels. They are forwarded in-band with the data traffic and thus receive the same treatment. Bi-directionality and point-to-multipoint connectivity are supported.
5. Management-plane and control-plane

    Management-plane and control-plane can be used in conjunction or independently. They support fast and automatic provisioning of paths (LSPs) and services (PWs or service LSPs) through single or multiple domains. Mechanisms are provided to provision and manage QoS and performance measurement parameters.

    a. It was already possible to provision and manage LSPs and PWs via network management systems. In order to ensure decoupling of the data-plane capabilities from network is provisioning and management, MPLS is being extended to support NMS-based provisioning of the OAM and protection functions and entities.

b. The control-plane of choice is GMPLS which is the unified control-plane for core tunneling technologies, supporting common, single operation across multi-layer and multi-technology. GMPLS already supports Traffic Engineering, constraint-based routing, protection and fast restoration, multiple hierarchical and peering control domains.
    - OSPF-TE or IS-IS-TE is used to disseminate the topology and the available resource information.
    - RSVP-TE is used to signal the paths. RSVP-TE is being extended to support the provisioning of the OAM tools and entities, and the new protection tools and entities.
    - LDP is used to signal the PWs.
c. Note that GMPLS supports in-service transfer of control of LSPs between the management-plane and the control-plane. Thus, deployments can start by using network management and then be enhanced with a control-plane without service interruption.
d. Note that it is possible to split the control and management functions. For example the network management can be used to calculate the paths, having a global view of the network resources, and the control-plane can be used to signal the paths.

3 Unified MPLS Applicability in Broadband Multi-Service Architectures

MPLS supports many architectural elements and mechanisms (also known as tools) that can be operated with different options (e.g. OSS, control-plane) and configurations.

A specific set of MPLS tools can be used in a certain way to enable a particular service or application. Different sets of tools can be implemented in different network domains and MPLS enables therefore simple, flexible and scalable network architecture. Means such as PW or LSP stitching can be used to interconnect these network domains.

MPLS is widely deployed in service provider networks around the world. It has been extended from core networks into many aggregation networks, and there is a clear demand in the market to further incorporate it into access networks to enable a unified network architecture.

The extensions currently being defined as part of the work on the MPLS Transport Profile provide additional tools that help to optimize MPLS operation. These tools can be used in any deployment environment or network domain (access, aggregation and core) and can be used to enhance IP/MPLS networks, or to provide efficient traffic engineered paths.

As shown in Figure 2, end-to-end unified MPLS can be used from the core through the aggregation to the access, providing flexible and scalable network architecture, which is capable of efficiently delivering any service (including legacy services).

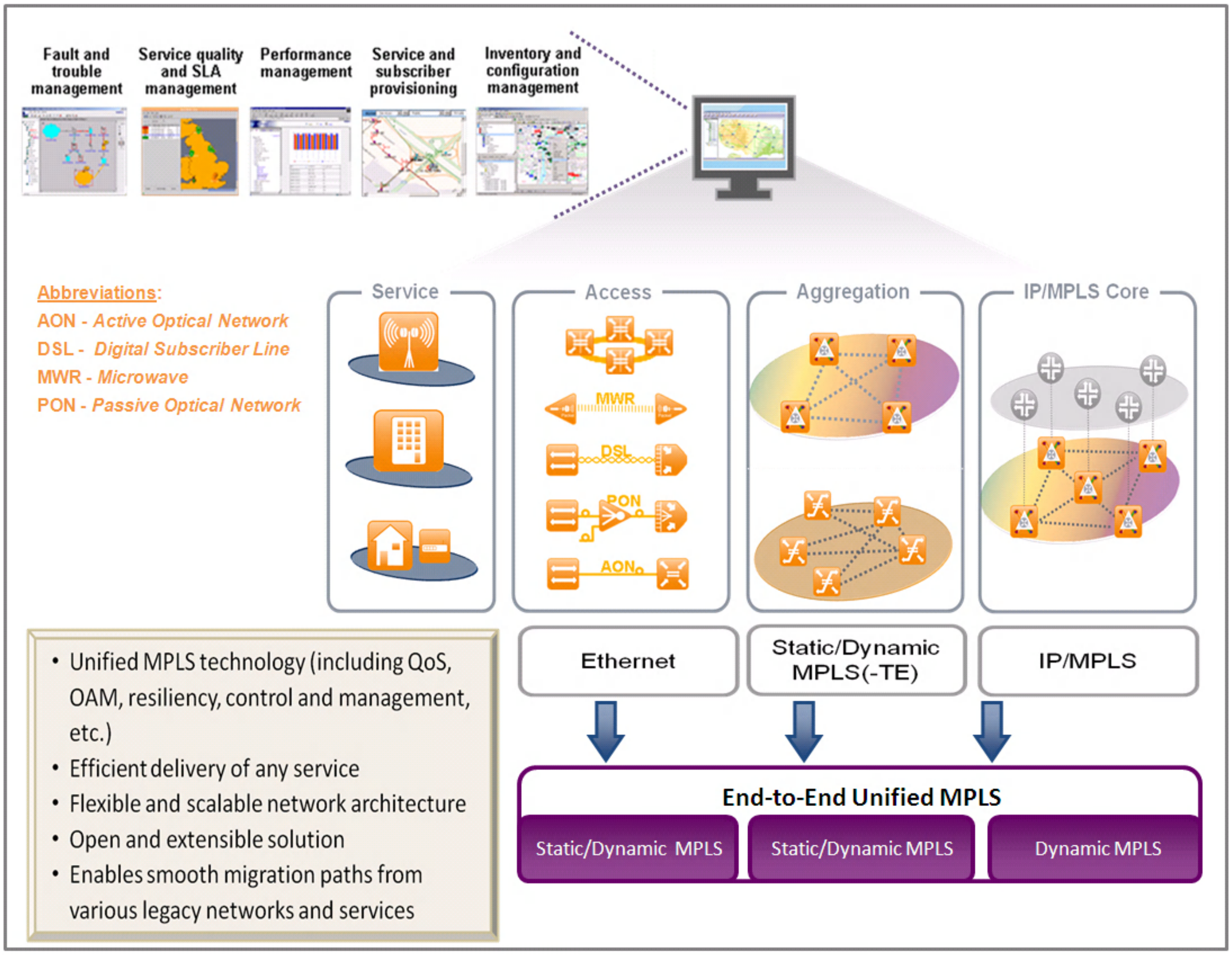

Figure 2: End-to-end unified MPLS Technology

Note that service providers can start deploying their network with a specific set of mechanisms, and later on extend their network capability as needed.

The choice of static provisioning versus dynamic signaling in MPLS is based on the flexibility required in terms of service placement and integration of functionalities and assorted control planes, among other considerations.

4 Unified MPLS Applicability to BBF's Work on Mobile backhaul

This section presents the opportunities that extended MPLS can bring to mobile backhauling, a key application now increasingly supported by broadband networks.

Mobile backhaul connects base stations to the radio controller and the mobile core network. Typically, it consists of the access and aggregation portions of a mobile network, as shown in Figure 3 .

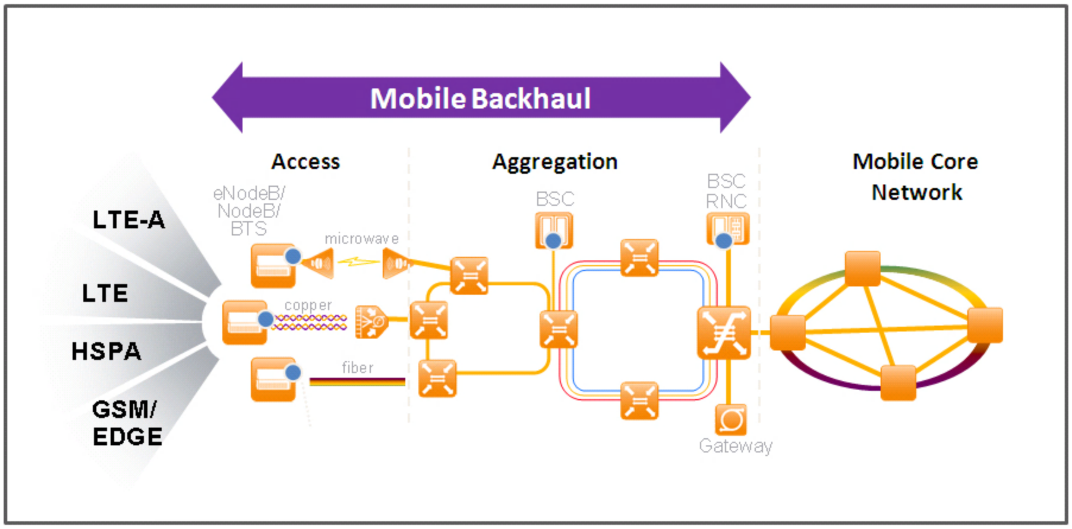

Figure 3: Mobile Backhaul

Mobile backhaul traffic is increasing dramatically in response to the new data and video capabilities available on smart devices, new user services and flat-fee pricing. The introduction of LTE (Long Term Evolution), the next generation radio technology, promises higher throughput, lower latency and richer quality of experience, as provided by advanced applications such as VoIP, high-definition video streaming, mobile gaming, etc.

The backhaul network technology must efficiently support these bandwidth-intensive services, guaranteeing quality and adherence to per service, end-to-end SLAs. The technology must cost effectively support any service, from any point to any point, at any scale.

To date, Ethernet has been the key technology to enabling mobile operators carrying the growing user mobile traffic in a more cost efficient way than TDM or ATM based systems. 3GPP introduced IP and Ethernet base stations and RNCs for HSPA+ and LTE.
With the introduction of IP and Ethernet services in the mobile backhaul network, there is a need to meet the same stringent SLA requirements in terms of delay, delay variation, packet loss and resilience in a packet network, as with traditional SONET/SDH or ATM/TDM networks.

MPLS can provide reliable and efficient transport to backhaul various types of mobile traffic with the appropriate quality, e.g. Ethernet and IP services for HSPA+ and LTE and TDM or ATM services for 2G and 3G.

This involves the following capabilities:

- ***Traffic engineering*** for efficient utilization of the network resources, while ensuring determinism and predictability. QoS mechanisms to guarantee bandwidth allocation and address per-service traffic performance requirements (delay, jitter, packet loss, etc.). The ability to set a deterministic path with known delay is an important aspect when planning Timing over Packet (ToP) solutions such as IEEE1588v2.

- A wide range of ***Carrier grade OAM*** tools for fault management and performance monitoring at different nested levels of the networks. Such mechanisms enable both rapid response in the event of a failure and verification of the SLA parameters.

- A comprehensive set of ***resilience mechanisms*** (protection and fast restoration).

MPLS is already deployed in many mobile core and backhaul networks, as described in MR-238, *MMBI White Paper on Use of MPLS in LTE*. The deployment of MPLS-TP is a new option, compatible with existing MPLS networks and enabling an end-to-end MPLS-based unified network architecture. This will produce operational efficiency, synchronization transport, latency control, QoS management, SLA verification, end-to-end provisioning, and fault and performance management.

Furthermore, MPLS can run over various transport infrastructures such as SDH/SONET, Ethernet and OTN, allowing operators to smoothly upgrade their networks towards packet transport. The use of MPLS also enables service providers to migrate from 2G/3G to LTE, thereby allowing them to rapidly deploy new services.

5 Conclusion

MPLS is a mature technology unifying various types of backhaul traffic and offering various migration choices to service providers, enabling them to follow the evolution path that best suits their needs and preserve their existing operating environment.

While already supporting the convergence of a wide range of applications and services, MPLS is now being extended to address new transport requirements, further strengthening the case for its adoption in new market segments.

Unified MPLS technology can fully support the IP transformation, i.e. enabling smooth migration from various legacy networks to a single converged packet-based network in a simple and cost-effective way. This technology provides quality solutions, supporting per service SLA, and allows the optimization of the broadband network Total Cost of Ownership (TCO).

***MPLS** - any service, any scale, and a global reach.*

6 Abbreviations

3GPP	3rd Generation Partnership Project
ACh	Associated Channel
ATM	Asynchronous Transfer Mode
BBF	Broadband Forum
CC	Continuity Check
CV	Connectivity Verification
GMPLS	Generalized MPLS
HSPA+	Evolved High-Speed Packet Access
IETF	Internet Engineering Task Force
IS-IS-TE	Intermediate System to Intermediate System – Traffic Engineering
LDP	Label Distribution Protocol
LSP	Label Switched Path
LTE	Long Term Evolution
MPLS	Multi-Protocol Label Switching
MPLS-TP	Multi-Protocol Label Switching-Transport Profile
OAM	Operations Administration and Maintenance
OSPF-TE	Open Shortest Path First – Traffic Engineering
OSS	Operation Support System
PHP	Penultimate Hop Popping
PW	Pseudo-wire
QoE	Quality of Experience
QoS	Quality of Service
RNC	Radio Network Controller
RSVP-TE	Resource Reservation Protocol – Traffic Engineering
SLA	Service Level Agreement
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
TCO	Total Cost of Ownership
TDM	Time Domain Multiplexing
VCCV	Virtual Circuit Connection Verification
VoIP	Voice of Internet Protocol

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