D1.6 “Standardization activities during the second half of the project”

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1 Executive Summary

Photonic sub-wavelength technologies are being developed by multiple vendors (e.g Intune, Huawe, ZTE…) as a suitable solution for Metro Area Networks (MAN) and data center metworking. Many Optical packet switching (OPS) and optical burst switching (OBS) technologies and architectures have been proposed to support sub-wavelength services. However, photonic sub-wavelength standardization is just starting now.

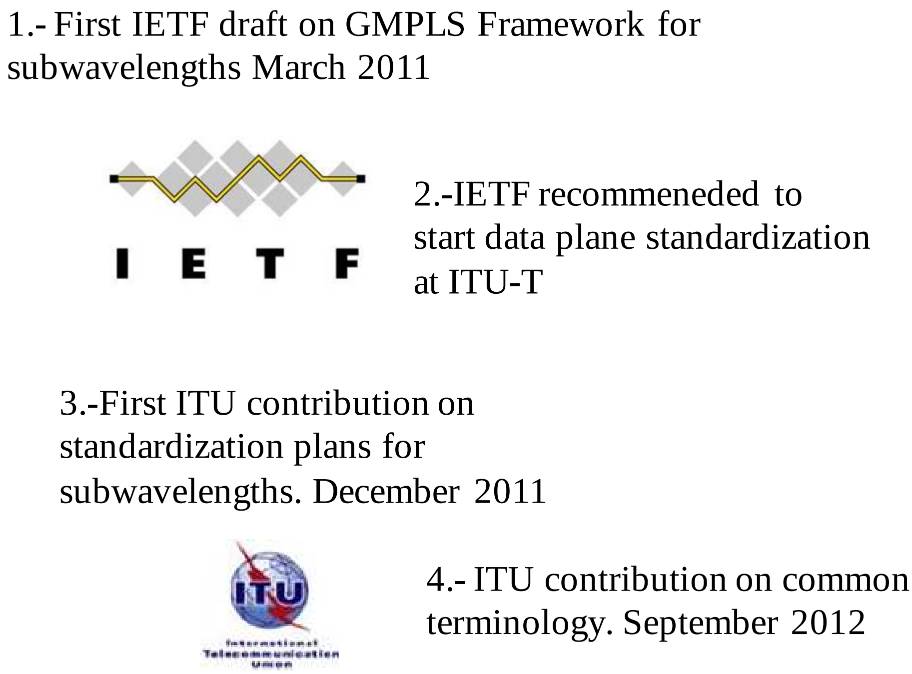

Figure 1 Steps already taken in subwavelegth standardization

MAINS have actively participated in all the standardization actions taken on subwavelength switching standardization. This document summarizes the results of the standardization activities done in MAINS:

- Subwavelength standardization at ITU-T
- GMPLS control plane extensions for sub lambda networks
- MAINS Transport Protocol
- E2E OAM and performance monitoring
- Multidomain Path Computation

2 Subwavelength standardization at ITU-T

The International Telecommunications Union (ITU-T) is in charge of the standardization of the optical transport technologies. The optical transport standards so far have been focused on the Automatically Switched Optical Network (ASON), which relies on the optical circuit switching (OCS) paradigm and the Optical Transport Network (OTN) architecture, which adds the digital switching. However, optical subwavelength technologies, as defined and demonstrated in MAINS, have not been considered so far. Moreover, there is not yet a common understanding among both industry and research community of the terminology regarding subwavelength networks. For example, terms such as Optical Burst Switching (OBS), Optical Packet Switching (OPST), OBS Transport (OBST) are used for a wide variety of technologies.

MAINS industrial partners have joined together experts from operators and system vendors and have prepared a contribution to ITU-T with a compilation of terms and abbreviations that could be used in Sub-Lambda Photonically Switched Networks (SLPSN) Recommendations. The contribution, named C2322R1, was presented the in the ITU-T SG-15 (in charge of Optical transport networks and access network infrastructures) plenary meeting in September 2012. Specifically, the document was discussed the 11th of September in question 3, in charge of the Characteristics of optical systems for terrestrial transport networks and the 12th of September in question 12, in charge of the Transport network architectures. A summary of the definitions presented to ITUT is shown below. First several definitions for the subwavelength terminology are presented. Next, the three main technologies are shown. Finally, the most important implementations are summarized.

2.1 Definitions

2.1.1 SLPSN

Sub-Lambda Photonically Switched Network (SLPSN) is a switching technology which handles, at the data plane level and in a photonic way, temporal slices of individual or multiple wavelengths. SLPSN incorporates the optical time domain in addition to the wavelength/frequency and space domains.

2.1.2 SLPSU

A sub-lambda photonic switching unit (SLPSU) is an optically sliced unit of a wavelength in time domain, such as an optical time slot, an optical burst, or an optical packet.

2.1.3 Nodes

SLPS network has two types of node functionality: namely Edge Node (EN) functionality and Core Node (CN) functionality. A node in PSLN may have either or both of the two functionalities.

Edge nodes are naturally hybrid (electric and photonic data planes) in charge of assembling data coming from different sources (i.e. IP, CBR, Ethernet …) which are sent to an optical circuit, burst or packet and vice-versa. Edge nodes can deal SLPSU within one or two directions in the optical domain: unidirectional ring, bidirectional ring, termination of a meshed network …

Core nodes can have the same functionalities as Edge nodes, but moreover they are able to deal with SLPSU coming from more than two directions as in a meshed network, in an all optical environment: note that the control plane is generally processed at the electronic level.

When control plane is mentioned in this document, this refers to a transmission of partial or total control information (including or not, reservation protocol, signaling protocol, routing protocol…) between different nodes and in some cases, a centralized system.

For example, in a network built from rings Core Nodes are necessary to interconnect different rings in the optical data domain. If the interconnection is done at the electric level, Edge nodes could be sufficient.

2.2 Technologies to be used in SLPSN

SLPSN can use three mains types of technologies:

Circuit technology:

An optical circuit is established for data transmission. This is named OCS (time of duration is minutes or more) or DOCS (Dynamic Optical Circuit Switching, time of duration is tens of millisecond). The optical path is established via a control plane (ASTN…).

Burst technology:

A burst is built by assembling several data packets which have the same destination node and sent through an optical path. The duration of this burst is generally ranging from 1 microsecond to 10 milliseconds, in order to aggregate a certain number of packets but not too much to avoid excess of building delay, which leads to propagation delay. This is named OBS (Optical Burst Switching). A burst can have a header or not, a fixed or a variable length, padding or no, a maximum time of building or not, fragmented packets or not, delineation between packets or not, a preamble to allow clock recovery or not. The transmission of partial or total control information (including or not, reservation protocol, signaling protocol, routing protocol…) of the burst can be done in band (Labeled OBS, when the header sticks to the payload) or out of band (Conventional or Emulated OBS). This label can be optically overwritten (photonic MPLS, for example) during core node crossing, this technology is then called Burst Optical Label Swapping (B-OLS).

Packet technology:

Each packet is processed in the Edge Node and sent to destination, through the Core Nodes, where routing is achieved in the photonic domain. The duration of an optical packet is generally less than a microsecond, when referred to Ethernet at 10G, for example. This is named OPS (Optical Packet Switching). The control of the packet is done by processing the header of the optical packet. This label can be optically overwritten (photonic MPLS, for example) during core node crossing, this technology is then called Packet Optical Label Swapping (P-OLS).

2.3 Implementations:

2.3.1 lossy and lossles

SLPSN can use two mains types of implementation: lossy and lossless, as far as the SLPSU losses inside the nodes (due to SLPSU contention) are considered.

Lossy Implementation

When lossy implementations are achieved, the data transfer can suffer from very high loss rate (for example, ratios in the range of 10% are mentioned in some configurations when throughput approaches a threshold rate, which is a fraction of the nominal rate of the link). Solutions as FEC or retransmission can enhance such loss rate, but generally with a degradation of some other transmission features (delay, jitter, throughput …). This implementation is used typically in Conventional OBS, Emulated OBS, and Labelled OBS. In lossy implementation, control plane information can be transmitted In Band: that is to say in the same optical path as data. A control plane transmitted on a dedicated path (Optical Supervisory Channel: Out of band, in a different optical path from data, but possibly on the same fiber) is also possible.

Lossless

To avoid these concerns, lossless implementation can be a solution. This is achieved by a control plane (distributed or centralized) to coordinate SLPSU emission and reception by the nodes (or by a centralised manager), in order to avoid blocking and contention issues in the data plane. In Lossless implementation, the control plane must be separated from the data plane and must be transmitted Out of Band.

2.3.2 Synchronous vs. asynchronous

SLPSN can be synchronous: an accurate mean of synchronization is available through the network. This synchronization is used to define slots in a cyclic process (often used in rings), or to time-stamp SLPSU in order to avoid contention, for example.

SPLSN can also be asynchronous : in that case, no synchronization is needed between nodes, which simplifies the design of such a network.

2.3.3 Reservation vs. no reservation

SLPSN can use different resource reservation protocols: a BCP or a label is then addressed to a node to make this reservation for the data path.

It is possible in some cases to have no in band BCP or label when simple routing is achieved (for example, based on wavelength: a same destination is set for a given lambda).

It is also possible to have no in band BCP or label when using a control plane which can be centralized or distributed. Blocking (the same emitter would have to emit in the same time on two different lambdas, for example) could be an issue in distributed control plane.

It is also possible to use protocols as CSMA-CA to insert SLPSU in the available lambdas. In this case, Optical Packet Switch and Transport (OPST) could be a control function that is added directly between the CSMA-CA function and the burst creation and injection function of an asynchronous OBS system port. The OPST function provides control constraints on burst and gap injection. The OPST control function controls the skew distribution of burst length about an average and the total volume of data from a source to any and all destinations per scheduling interval. The addition of an OPST layer modifies basic asynchronous OBS to a system that provides deterministic packet flow switching at sub lambda bandwidths. There are more than one OPST methodology. Examples are statistical flow bounding based on blocking probability and signalled back pressure from nodes downstream on a shared optical path.

2.3.4 Summary of implementations

Figure 2 shows the summary of the most relevant OBS implementations that were presented.

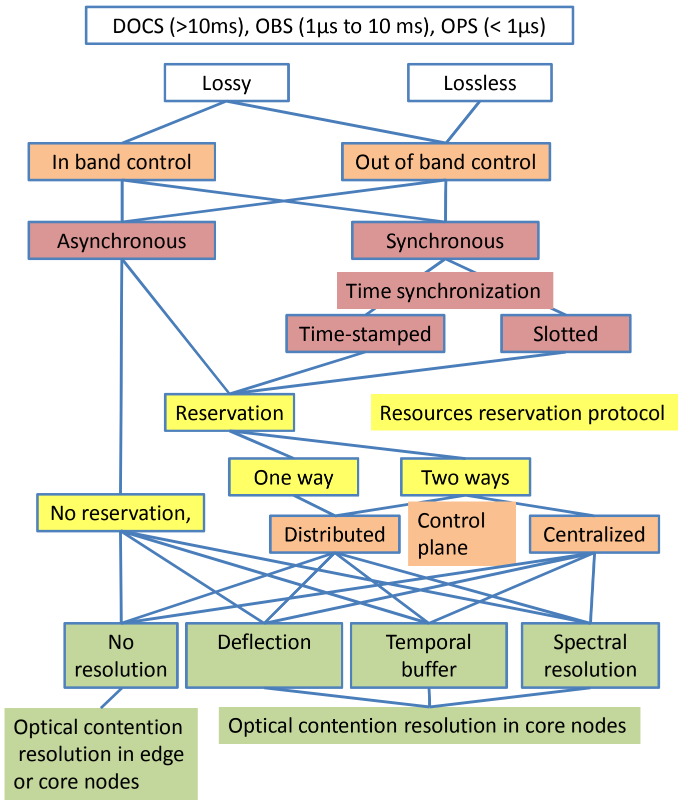

Figure n°1 : Common Implementations of SLPSN

Figure 2 Summary of some common SLPSN implementations

3 GMPLS Control Plane extensions for sub lambda networks

The GMPLS architecture is designed to provide automatic provisioning of connections with traffic engineering, traffic survivability (i.e. protections, restorations), and automatic resource discovery and management. The GMPLS specifications are fully agnostic of specific deployment models and transport environments. Specific procedures have been defined to control transport networks as diverse as SDH/SONET, OTNs incorporating G.709 encapsulation, WSON, and Ethernet.

Current standard GMPLS specification does not support switching granularities and capabilities exposed by the sub-wavelength optical networks. In particular, the GMPLS signaling procedures does not support the provisioning of sub-wavelength optical LSPs, where a single wavelength in a link can be shared among multiple LSPs. Moreover, the GMPLS routing procedures does not allow to advertise any sub-wavelength network resource availabilities, and therefore to take them into account in the end-to-end path computation process.

MAINS has architected and implemented a GMPLS control plane capable of providing specific routing and reservation procedures to support the sub-wavelength switching granularity in the metro network. The MAINS GMPLS is conceived as an enhancement of the ASON/GMPLS control plane architecture, by extending the legacy GMPLS signaling and routing protocols to both reserve and advertise sub-wavelength resources in the metro domain. The architectural work assisted by the software development has produced solid outcomes for standardization. In the first half of the project, the MAINS consortium started the standardization of the framework for GMPLS and PCE support of sub-wavelength switching in IETF, by proposing an IETF Internet Draft in which the major architecture elements and requirements are presented [GON].

3.1.1 Results achieved during the second half of the project

The MAINS derived IETF Internet Draft [GON] has been updated and extended in the second half of the project to include frequency-based sub-wavelength technologies in the framework for GMPLS and PCE support of sub-wavelength switching. Indeed, the scope of first IETF Internet Draft version was limited and focused on the time-based sub-wavelength technologies, such as the Time Shared Optical Network (TSON) implemented by the University of Essex in MAINS.

This update of the MAINS IETF Internet Draft has been driven by two main factors: first, by the feedbacks received at the IETF80 meeting when the Draft was presented. Moreover, the MAINS control plane approach, and in particular the sub-wavelength network resource modeling in GMPLS, is generic enough to be adopted for other sub-wavelength switching technologies, e.g. in the frequency domain. The description of the sub-wavelength availabilities in the GMPLS with a hierarchical resource structure built by the composition of data-link identifier, channel identifier (e.g. the wavelength identifier) and sub-channel aggregated availability (e.g. total number of free time-slices) can be applied to those switching technologies able to treat the optical channels as sharable resource pools. As an example of applicability of the MAINS concepts to the frequency domain, the support of the OFDM sub-wavelength switching technology is briefly analyzed in the updated version of the MAINS IETF Internet Draft.

The outline of the first IETF Internet Draft version is:

1. Introduction
    - research and applicability scenarios
2. Sub-wavelength optical network
    - overview of sub-wavelength optical networks from a data plane point of view
3. Sub-wavelength network resource control
    - control functions and time-scales, network resource modeling.
4. GMPLS implications:

- o impact on GMPLS signaling (sub-wavelength resources and labels) procedures and protocols
- o impact on GMPLS routing (sub-wavelength resource advertisement) procedures and protocols

5. Route computation and sub-wavelength resource assignment scenarios

The new version of the MAINS IETF Internet Draft mainly provides updates to section 1 and section 3 to include the frequency domain in the concept of sub-wavelength switching technology. In particular, a new sub-section has been added in section 3 to investigate the applicability of the MAINS control approach to the frequency domain, mainly in terms of sub-wavelength network resource modeling.

The updated MAINS IETF Internet Draft has not yet been submitted to IETF: it is the next step as detailed in the following sub-section.

As soon as the standardization process of sub-wavelength networks at ITU-T (see section 2) will be mature enough to let a liason between ITU-T and IETF be established, the new version of the MAINS Internet Draft will be submitted to IETF. According to this plan, MAINS is looking for some industrial support from those companies currently interested on sub-wavelength technologies such as France Telecom, Alcatel-Lucent, NTT, Huawei, with the aim of pushing for the wide acceptance in the IETF community of requirements and concepts specified in the MAINS Internet Draft.

4 MAINS Transport protocol

4.1.1 Subject

The MAINS transport protocol (MAINS-TP) was designed and implemented as a means to achieve 10 Gbps line rate with large packet sizes. This is because the large packet size is better suited to the optical transmitters, which do not have to switch on and off for a small burst. MAINS-TP achieves line rate of 10 Gbps with a reduction of more than 70% ACK packets in the anti-transfer direction when compared to plain TCP.

4.1.2 Results achieved during the second half of the project

The consortium has produced a detailed specification of the user to network data interface that allows applications to swiftly transfer 10 Gbps line rate in the optical fiber. The plans for standardization and dissemination are to address IETF on the one hand and to open a sourceforge project on the other hand.

As a first approximation, the plan is to open a public git repository in sourceforuge or similar to check whether there is an interest in the research community. If contributors appear, then the protocol will be enhanced with contributions and the final specification will be sent for consideration to IETF. We believe that the more researchers involved from different institutions the more chances to be approved by IETF. Therefore, the previous step of producing an open GIT repository seems to us necessary.

5 E2E OAM

5.1.1 Subject

OAM (Operation, Administration and Maintenance) protocols are used for in-service fault detection, fault localization and performance monitoring for transport networks. Currently, there isn't any OAM standard for sub-wavelength networks. However, there exists a strong standardization effort in advanced OAM protocols for packet based transport networks. In particular, current OAM standardization activities within ITU-T and IETF are mainly focused on the MPLS-TP framewok.

OAM protocols to be used in GMPLS sub wavelength transport networks, as the one to be designed in MAINS, might include some MPLS-TP based specifications in order to provide:

- Fault detection
- E2e QoS monitoring
- E2e OAM interworking between future MAINS based networks and "legacy" MPLS-TP networks

According to it, MAINS OAM standardization activities are mainly focused on MPLS-TP OAM functions (i.e. failure detection and QoS monitoring) that could be implemented in future OAM protocols enabling e2e OAM interworking between OBS and MPLS-TP networks.

5.1.2 Results achieved during the second half of the project

MAINS is proposing a new E2E OAM architecture for Telco networks including a Sub-wavelength domains [FUNEMS 2012]. The proposed architecture addresses two main issues: compatibility between MPLS networks and different Sub-wavelength technologies, and scalability of the OAM flows across the whole network. Next steps

MAINS e2e OAM architectuire proposes specific packet trains for delay measurement tools. Telefonica I+D is currently working on an IETF draft on MPLS-TP OAM which is expected to include the packet train defined in MAINS.

6 Multidomain PCE

6.1.1 Subject

Currently, there are different architectural approaches for multi-domain PCE interworking: BRPC (Backward Recursive Path Computation), hierarchical architectures, etc.

MAINS multi domain PCE vision is based on a "Full-state" hierarchical approach as the one shown in next figure:

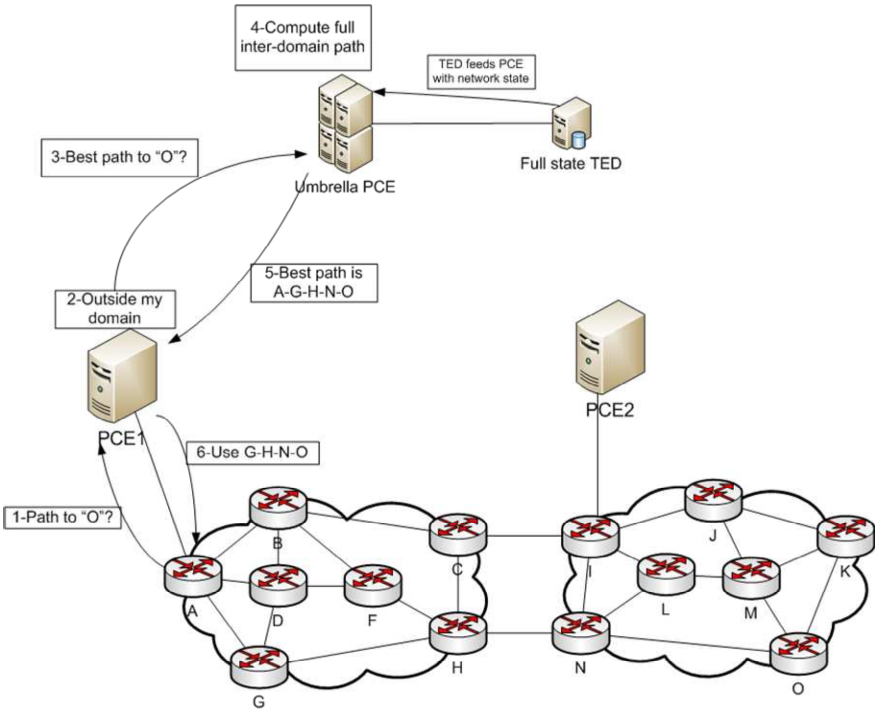

Figure 3: MAINS multi domain PCE approach

Main advantages of this approach are as follows:

- Optimal end-to-end path calculation is feasible in single carrier networks
- Network size is controlled by the operator: scalability may not be an issue
- Easier integration and interoperability between technologies (e.g. OBS, MPLS-TP,OTN, etc) and equipment providers

6.1.2 Results achieved during the second half of the project

MAINS PCE and H-PCE standardization activities have been done in collaboration with STRONGEST. In particular main joint STRONGEST-MAINS contributions on PCE and H-PCE standardization are :

- F. Zhang, Q. Zhao, O. Gonzalez de Dios, R. Casellas, D. King, Extensions to Path Computation Element Communication Protocol (PCEP) for Hierarchical Path Computation Elements (PCE), draft-zhang-pce-hierarchy-extensions-01
- C. Margaria, O. Gonzalez de Dios, F. Zhang, PCEP extensions for GMPLS, draft-ietf-pce-gmpls-pcep-extensions-05.
- F. Zhang, Q. Zhao, O. Gonzalez de Dios, R. Casellas, D. King, Extensions to Path Computation Element Communication Protocol (PCEP) for Hierarchical Path Computation Elements (PCE) draft-zhang-pce-hierarchy-extensions-01
- F. Zhang, Q. Zhao, O. Gonzalez de Dios, R. Casellas, D. King, Extensions to Path Computation Element Communication Protocol (PCEP) for Hierarchical Path Computation Elements (PCE) draft-zhang-pce-hierarchy-extensions-01

7 Conclusions

Although the first subwavelength switching solutions are appearing in the market, the standardization process of this technology is still in a very early stage. MAINS have actively participated in the very first steps taken on subwavelength switching standardization at ITU-T and IETF.

- Working Document: Terminology for Sub-Lambda Photonically Switched Network (SLPSN)- ITU-T SG15
- Internet Draft: O. González de Dios, G. Bernini, G. Zervas, M. Basham, "Framework for GMPLS and path computation support of sub-wavelength switching optical networks", draft-gonzalezdedios-subwavelength-framework-00.txt

Furthermore MAINS have also collaborated with FP7 STRONGEST in the standardization of multidomain control plane (H-PCE) and OAM mechanisms which would enable a smooth integration of subwavelength domains into operators networks.

8 References

FANG http://tools.ietf.org/html/draft-fang-mpls-tp-oam-considerations-01

GON http://tools.ietf.org/html/draft-gonzalezdedios-subwavelength-framework-00

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OGF www.ogf.org

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NSI-WG http://forge.gridforum.org/sf/projects/nsi-wg

ZHANG http://tools.ietf.org/html/draft-zhang-pcep-hierarchy-extensions-00

FUNEMS2012 Juan Fernandez-Palacios, Mark Basham, Michael Georgiades, "E2E-OAM in convergent Sub-wavelength-MPLS environments". Future Network & Mobile Summit 2012, Berlin, Germany, July 2012.

9 Acronyms

AN	Access Node
BCP	Burst Control Packet
B-OLS	Burst Optical Label Swapping
BORA	Burst Overlap Reduction Algorithm
C-OBS	OBS Conventional (without Offset Time)
CN	Concentration Node
CO	Central Office
CAPEX	Capital Expenditures
CPE	Customer Premises Equipment
CS	Concentration Switch
CSMA-CA	Carrier sense multiple access with collision avoidance
DOCS	Dynamic Optical Circuit Switching
DWDM	Dense Wavelength Division Multiplexing
E2E	End to End
EN	Edge Node
E-NNI	External Network-to-Network Interface
E-OBS	Offset Time Emulated OBS
FDL	Fiber Delay Line
FEC	Forward Error Correction
FTTH	Fiber To The Home
GbE	Gigabit Ethernet
GMPLS	Generalized Multi-Protocol Label Switching
L2VPN	Level 2 Virtual Private Network
NCS	Network Centric Services
OAM	Organization Administration and Management
OBS	Optical Burst Switching
OBST	Optical Burst Switching Technology
OCS	Optical Circuit Switching
OLT	Optical Line Termination
OPEX	Operational Expenditures
OPS	Optical Packet Switching
OPST	Optical Packet Switching and Transport
PCE	Path Computation Element
QoE	Quality of Experience
QoR	Quality of Resilience

QoS	Quality of Service
SC	Sub-wavelength Concentrator
SLPSN	Sub Lambda Photonically Switched Network
SLPSU	Sub Lambda Photonically Switched Unit
SOAP	Simple Object Access Protocol
TAG	Tell-and-Go
TAW	Tell-and-Wait
TE	Traffic Engineering
TMF	Telemanagement Forum
TNA	Transport Network Address
VM	Virtual Machine
VoD	Video on Demand
WADL	Web Application Description Language
WR-OBS	Wavelength-Routed OBS
WSON	Wavelength Switched Optical Networks
XML	eXtensible Markup Language
XSLT	eXtensible Style sheet Language Transformations