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        A framework for Management and Control of DWDM optical interface
                                parameters
                draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk-13

Abstract

   The control and management of DWDM interfaces are a precondition for
   enhanced multilayer networking. They are needed to ensure an
   efficient data transport, to meet the requirements requested by
   today's IP-services and to provide a further automation of network
   provisioning and operations. This document describes use cases,
   requirements and solutions for the control and management of optical
   interface parameters according to different types of single channel
   DWDM interfaces. The focus is on automating the network provisioning
   process irrespective on how it is triggered i.e. by Element Manager
   System (EMS), Network Management System (NMS) or Generalized Multi
   Protocol Label Switching (GMPLS). This document covers management
   and control considerations in different scenarios of single channel
   DWDM interfaces. The purpose is to identify the necessary
   information and processes to be used by control or management systems
   to properly and efficiently drive the network.

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Table of Contents

1. Introduction

   The usage of external single channel Dense Wavelenght Division
   Multiplexing (DWDM) interfaces (e.g. in routers) connected to a DWDM
   Network (e.g. router connected to a network of Reconfigurable Optical
   Add Drop Multiplexers (ROADM) and optical amplifiers) adds a further
   networking option for operators but requires an harmonised control
   and management plane interaction between the different network
   domains.

   Carriers deploy their networks today based on transport and packet
   network infrastructures as domains to ensure high availability and a
   high level of redundancy combining the Packet and Transport
   restoration. Both network domains were operated and managed
   separately. This is the status quo in many carrier networks today.
   In the case of deployments where the optical transport interface
   moves into the client device (e.g. router) an interaction between
   those domains becomes necessary (e.g. Lambda reprovisioning due to
   an optical restoration).

   This framework specifies different levels of control and management
   plane interaction to support the usage of single channel optical
   interfaces in carrier networks in an efficient manner. The
   interfaces between the two layers can be either gray or coloured.

   Although Optical routing and wavelength assignment based on
   Wavelenght Switched Optical Network (WSON) is out of scope, they can
   benefit from the optical parameters that are exchanged between the
   Client and the DWDM Network. Also, the wavelength ordering process
   and determining the demand for a new wavelength path through the
   network are out of scope. The GMPLS and PCE functions will use the
   information collected from the Client and the DWDM network, the
   definition on how PCE and GMPLS can use the information and cooperate
   to implement RWA and circuit/service provisioning ar aout of scope of
   this document.

   Note that the Control and Management Planes are two separate entities
   that may handle the same information in different ways.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP_14, RFC 2119 [RFC2119], RFC 8174 [RFC8174] when, and only when, they appear in all capitals, as shown here.

While RFC 2119 [RFC2119] RFC 8174 [RFC8174] describe interpretations of these key words in terms of protocol specifications and implementations, they are used in this document to describe design requirements for protocol extensions.

2. Terminology and Definitions

The current generation of Wavelenght Division Multiplexing (WDM) networks are single vendor networks where the optical line system and the transponders are tightly integrated. The DWDM interface migration from integrated transponders to third party transponders or colored interfaces change this scenario and introduces a standardized interface at the level of OCh between the DWDM interface and the DWDM network.

Black Link: The Black Link [ITU-T.G.698.2] allows supporting an optical transmitter/receiver pair (of a single vendor or from different vendors) to provide a single optical channel interface and transport it over an optical network composed of amplifiers, filters, add-drop multiplexers these being possibly from different vendors. Therefore the standard defines the ingress and egress parameters for the optical interfaces at the reference points Source side (Ss) and Receive side (Rs).

Single Channel DWDM Interface: The single channel interfaces to DWDM systems defined in [ITU-T.G.698.2], which currently include the following features: channel frequency spacing: 50 GHz and wider (defined in [ITU-T.G.694.1]); bit rate of single channel: Up to 100 Gbit/s. Future revisions are expected to include application codes for bit rates up to 400 Gbit/s.

Forward Error Correction (FEC): FEC is a way of improving the performance of high-capacity optical transmission systems. Employing FEC in optical transmission systems yields system designs that can accept relatively large BER (much more than 10^{-12}) in the optical transmission line (before decoding).

Administrative domain [ITU-T.G.805]: the extent of resources which belong to a single player such as a network operator, a service

provider or an end-user. Administrative domains of different players do not overlap amongst themselves.

Intra-domain interface (IaDI) [ITU-T.G.872]: A physical interface within an administrative domain.

Inter-domain interface (IrDI) [ITU-T.G.872]: A physical interface that represents the boundary between two administrative domains.

Management Plane [ITU-T.G.8081],: The management plane performs management functions for the transport plane, the control plane and the system as a whole. It also provides coordination between all the planes. The following management functional areas are performed in the management plane: performance management, fault management, configuration management, accounting management and security management.

Control Plane [ITU-T.G.8081]: Through signaling, the control plane sets up and releases connections, may restore a connection in case of a failure, and also performs other functions (e.g., neighbor discovery, topology distribution) in support of those.

Transponder: A Transponder is a network element that performs O/E/O (Optical /Electrical/Optical) conversion. In this document it is referred only transponders with 3R (rather than 2R or 1R regeneration) as defined in [ITU-T.G.872].

Line System: A Line System is a portion of the network including Reconfigurable Add Drop Multiplexers (ROADM) Line Amplifiers and the the fibers connecting them.

Client DWDM interface: A Transceiver element that performs E/O (Electrical/Optical) conversion. In this document it is referred as the DWDM side of a transponder as defined in [ITU-T.G.872].

3. Solution Space

The solution space of this document is focusing on aspects related to the management and control of single-channel optical interface parameters of physical point-to-point and ring DWDM applications on single-mode optical fibres and allows the direct connection of a wide variety of equipment using a DWDM link, for example

   1. A digital cross-connect with multiple optical interfaces, supplied by a different vendor from the line system

   2. Devices as routing, switching or compute nodes, each from a different vendor, providing optical line interfaces

   3. A set of Data Center Equipment and servers

   4. A combination of the above

3.1. Comparison of Approaches for Transverse Compatibility

   This section describes two ways to achieve transverse compatibility.
   Section 3.1.1 describes the classic model based on well defined
   inter-domain interfaces. Section 3.1.2 defines a model ensuring
   interoperability on the line side of the optical network.

3.1.1. Multivendor DWDM Line System with Transponders

   As illustrated in Figure 1, for this approach interoperability is
   achieved via the use of optical transponders providing OEO (allowing
   conversion to appropriate parameters). The optical interfaces can
   then be any short reach standardized optical interface that both
   vendors support, such as those found in [ITU-T.G.957], [ITU-T.G.691],
   [ITU-T.G.693], etc.

```
              IrDI                          IaDI
               |                             |
               .                             .
               |    +---------------------------|----+
               .    |       +   WDM Domain   +  .    |
               |    |       |\              /|  |    |
 +------+      .    |       | \       |\   / |  .    |      +------+
 |  TX/ |-->--+---+--T/-|OM |----|/-------|OD |--+-\T-+---->--| RX/ |
 |  RX  |--<--+---+--T/-|   |-----  / |-----|   |--.-\T-+----<--|  TX |
 +------+      |    |   | /       \ |     \ |   |  .    |      +------+
               .    |   |/         \|      \|   |  .    |
               |    |   +                   +  |    |
               .    +---------------------------.----+
               |                             |
```
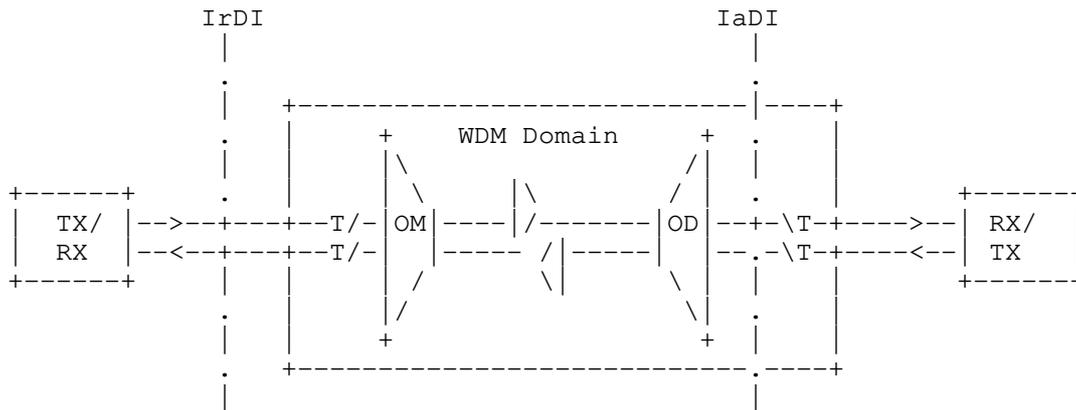
          TX/RX = Single channel non-DWDM interfaces
          T/ = Transponder
          OM = Optical Mux
          OD = Optical Demux

       Figure 1: Inter and Intra-Domain Interface Identification

   In the scenario of Figure 1 the administrative domain is defined by
   the Interdomain Interface (IrDI). This interface terminates the DWDM

domain. The line side is characterized by the Intradomanin Interface
(IaDI). This interface specifies the internal parameter set of the
optical administrative domain. In the case of a client DWDM
interface deployment this IaDI moves into the client device and
extends the optical and administrative domain towards the client
node. [ITU-T.G.698.2] for example specifies a set of parameter set
for a certain set of applications, see Section 3.1.2.

This document elaborates only the IaDI (Intra Domain Interface) as
shown in Figure 1 as DWDM transversely compatible and multi-vendor
interface within one administrative domain controlled by the network
operator.

SNMP/Simple Management Interface (SMI), NETCONF/RESTCONF and Link
Management Protocol (LMP) TLV to support the direct exchange of
information between the client and the network management and control
plane will be specified in further documents.

The YANG based NETCONF and RESTCONF protocol are better suited for
creating and modifying configuration state and thus RECOMMENDED to be
used over SNMP MIB. The SNMP MIB creating and modifying
configuration state could be used for legacy network.

3.1.2. Integrated Single Channel DWDM Deployments on the Client Site

In case of a deployment as shown in Figure 2, through the use of DWDM
interfaces, multi-vendor interconnection can also be achieved. Among
the possible use cases, it may be used to remove the need for one
short reach transmitter and receiver pair per channel (eliminating
the transponders).

Figure 2 shows a set of reference points, for single-channel connection (Ss and Rs) between transmitters (Tx) and receivers (Rx). Here the DWDM network elements include an optical multiplexer (OM) and an optical demultiplexer (OD) (which are used as a pair with the peer element), one or more optical amplifiers and may also include one or more ROADMs.

```
      |=================== Black Link =====================|


       +--------------------------------------------------+
    Ss |   |  \       DWDM Network Elements        / |  |Rs
+---+  |   |   \                                  /  |  | +---+
Tx L1---|->|    \    +------+          +------+    /  |--|-->Rx L1
+---+  |   |     |   |      |  +------+ |      |   |   |  +---+
+---+  |   |     |   |      |  |      | |      |   |   |  +---+
Tx L2---|->| OM |-|> |------|->| ROADM|--|------|->|  OD  |--|-->Rx L2
+---+  |   |     |   |      |  |      | |      |   |   |  +---+
+---+  |   |     |   |      |  +------+ |      |   |   |  +---+
Tx L3---|->|    /    | DWDM |    ^     | DWDM  |   \  |--|-->Rx L3
+---+  |   |   /     | Link +----|--|----+ Link |   \ |  |  +---+
       +----------+              |  |           +----------+
                            +--+ +--+
      |==== Black Link ====| |    |
                            v    |
                      +-----+ +-----+
                      |RxLx | |TxLx |
                      +-----+ +-----+
```
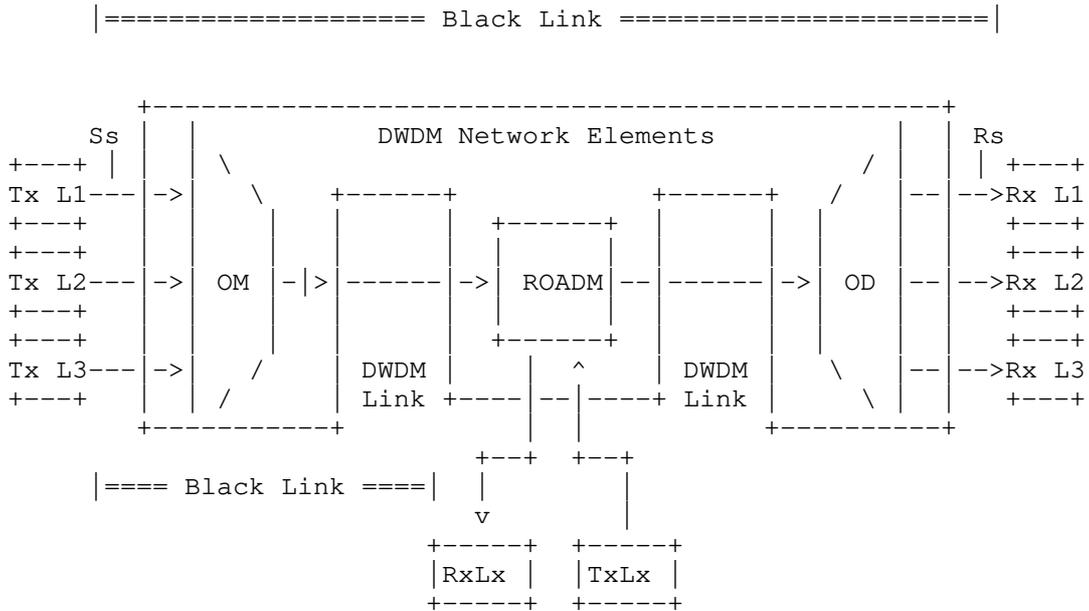
   Ss = Reference point at the DWDM network element tributary output
   Rs = Reference point at the DWDM network element tributary input
   Lx = Lambda x
   OM = Optical Mux
   OD = Optical Demux
   ROADM = Reconfigurable Optical Add Drop Mux

   Linear DWDM network as per ITU-T G.698.2

                     Figure 2: Linear Black Link

The single administrative domain may consist of several vendor domains. Even in that case a common network management and control is required to ensure a consistent operation and provisioning of the entire connection.

SNMP/SMI, NETCONF/RESTCONF and LMP TLV to support the direct exchange of information between the client and the network management and control plane will be specified in further documents.

4. Solutions for Managing and Controlling Single Channel Optical Interface

Operation and management of WDM systems is traditionally seen as a homogenous group of tasks that could be carried out best when a single management system or a hierarchical management system is used. Currently each WDM vendor provides an Element Management System (EMS) that also provisions the wavelengths. In a multi-vendor line system, such single-vendor EMS requirement is no more effective. New methods of managing and controlling line systems need to be looked at.

Therefore from the operational point of view the following approaches will be considered to manage and operate optical interfaces.

1. Separate operation and management of client device and the transport network whereas the interface of the client belongs to the administrative domain of the transport network and will be managed by the transport group. This results in two different approaches to send information to the management system

   a. Direct connection from the client node to the transport management system, ensuring a management of the DWDM interface of the optical network (e.g. EMS, NMS)

   b. Indirect connection to the management system of the optical network using a protocol (e.g. LMP) between the client device and the directly connected WDM system node to exchange management information with the optical domain

2. Common operation and management of client device including the single channel DWDM part and the Transport network

The first option keeps the status quo in large carrier networks as mentioned above. In that case it must be ensured that the full FCAPS Management (Fault, Configuration, Accounting, Performance and Security) capabilities are supported. This means from the management staff point of view nothing changes. The transceiver/receiver optical interface will be part of the optical management domain and will be managed from the transport management staff.

The second solution addresses the case where underlying WDM transport network is mainly used to interconnect a homogeneous set of client nodes (e.g. IP routers or digital crossconnects). Since the service creation and restoration could be done by the higher layers (e.g.

   IP), this may lead to an efficient network operation and a higher
   level of integration.

4.1. Separate Operation and Management Approaches

4.1.1. Direct Connection to the Management System

   As depicted in Figure 3 (case 1a) one possibility to manage the
   optical interface within the client domain is a direct connection to
   the management system of the optical domain. This ensures
   manageability as usual.
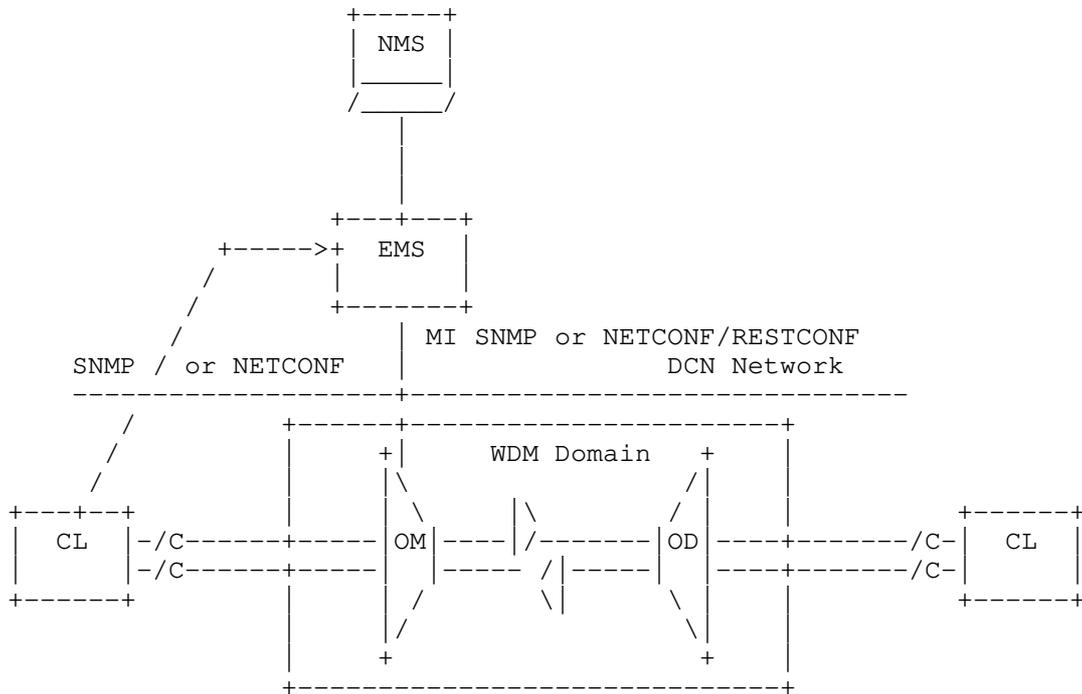
```
                             +-----+
                             | NMS |
                             |_____|
                             /_____/
                                |
                                |
                                |
                          +---+---+
                +----->+   EMS  |
               /        |       |
              /         +-------+
             /            | MI SNMP or NETCONF/RESTCONF
      SNMP / or NETCONF   |            DCN Network
      ------------------+----------------------------
         /          +------+--------------------+
        /           |   +|   WDM Domain    +   |
       /            |   |\                 /|   |
  +---+--+          |   | \      | \      / |   |
  |  CL  |-/C------+-----|OM|----|/-------|OD|----+-------/C-|  CL  |
  |      |-/C------+-----|  |----- /|-----|  |----+-------/C-|      |
  +------+          |   | /      \|      \ |   |
                    |   |/                \|   |
                    |   +                  +   |
                    +--------------------------+
```

         CL = Client Device
         /C = Single Channel Optical Interface
         OM = Optical Mux
         OD = Optical Demux
         EMS = Element Management System
         MI = Management Interface
         DCN = Data Control Network

      Figure 3: Connecting Single Channel optical interfaces to the
                    Transport Management system

The exchange of management information between client device and the management system assumes that some form of a direct management communication link exists between the client device and the DWDM management system (e.g. EMS). This may be an Ethernet Link or a DCN connection (management communication channel MCC).

It must be ensured that the optical network interface can be managed in a standardized way to enable interoperable solutions between different optical interface vendors and vendors of the optical network management application. [RFC3591] defines managed objects for the optical interface type but needs further extension to cover the optical parameters required by this framework document.

Is to be noted that the CL (client device) and the DWDM network are belonging to the same operator so the DWDM EMS and the Client devices are connected to the same DCN and the communication security considerations are applicable to CL as per DWDM devices.

Note that a software update of the optical interface components of the client nodes must not lead obligatory to an update of the software of the EMS and vice versa.

4.1.2. Indirect Connection to the DWDM Management System (First Optical Node)

An alternative as shown in Figure 4 should be used in cases where a
more integrated relationship between transport node (e.g. OM or OD
or ROADM) and client device is aspired. In that case a combination
of control plane features and manual management will be used.

```
                          +-----+
                          | NMS |
                          |_____|
                          /_____/
                             |
                             |
                          +---+---+
                          | EMS   |
                          |       |
                          |       |
                          +-------+
                             |  MI   SNMP or NETCONF/RESTCONF
                             |
          LMP          +------+---------------------+
        +------------+---+ +|                  +    |
        |            |   | ||\                 /|   |
        |            |   | +-+ \              / |   |
  +---+--+           |   +-+ |OM|----|\      / |OD|--- +-------/C-|  CL  |
  |  CL  |-/C------+--- -|OM|----|/-------|OD|--- +-------/C-|      |
  |      |-/C------+--- -|  |----- /|----- |  |----+-------/C-|      |
  +------+           |   |  | /     \|      \ |  |   |        +------+
        |            +     |/       |        \|   |
        |            |   |/                   \|   |
        |            |   +                    +    |
        +----------------------------+
```

```
        CL = Client Device
        /C = Single Channel optical Interface
        OM = Optical Mux
        OD = Optical Demux
        EMS= Element Management System
        MI= Management Interface
```
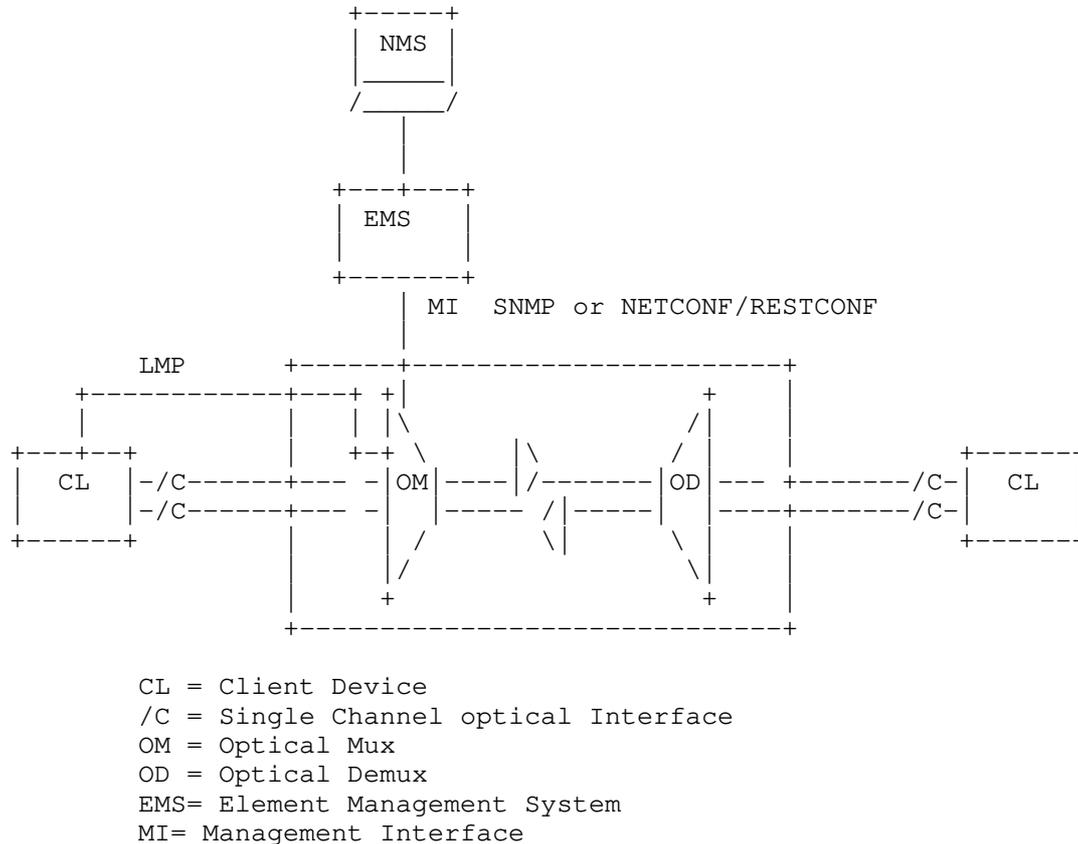
Figure 4: Direct connection between peer node and first optical
                    network node

For information exchange between the client node and the direct
connected node of the optical transport network LMP as specified in
RFC 4209 [RFC4209] should be used. This extension of LMP may be used
between a peer node and an adjacent optical network node as depicted
in Figure 4.

At the time of writing this document, LMP does not yet support the
transmission of configuration data (information). This functionality
is addressed by draft-ietf-ccamp-dwdm-if-lmp extending the RFC 4209
[RFC4209]. The use of LMP assumes that some form of a control

channel exists between the client node and the WDM equipment. This
may be a dedicated lambda or an Ethernet Link.

4.2. Control Plane Considerations

The concept of integrated single channel DWDM interfaces equally
applies to management and control plane mechanisms. GMPLS control
plane protocols have been extended for WSON, e.g. RFC 7689 [RFC7689]
) for fixed grid signal and for flexi-grid RFC 7792 [RFC7792]). One
important aspect of the Black Link [ITU-T.G.698.2] is the fact that
it is specific to the wavelength that is supported by the given link.
Therefore, the link can logically be considered as a fiber that is
transparent only for a single wavelength. In other words, the
wavelength becomes a characteristic of the link itself.

Nevertheless the procedure to light up the fiber may vary depending
on the implementation. Since the implementation is unknown a priori,
different sequences to light up a wavelength need to be considered:

1. Interface first, interface tuning: The transmitter is switched on
    and the link is immediately transparent to its wavelength. This
    requires the transmitter to carefully tune power and frequency
    not overload the line system or to create transients.

2. Interface first, Optical Line System (OLS) tuning: The
    transmitter is switched on first and can immediately go to the
    max power allowed since the OLS performs the power tuning. This
    leads to an intermediate state where the receiver does not
    receive a valid signal while the transmitter is sending out one.
    Alarm suppression mechanisms shall be employed to overcome that
    condition.

3. OLS first, interface tuning: At first the OLS is tuned to be
    transparent for a given wavelength, then transponders need to be
    tuned up. Since the OLS in general requires the presence of a
    wavelength to fine-tune its internal facilities there may be a
    period where a valid signal is transmitted but the receiver is
    unable to detect it. This equally need to be covered by alarm
    suppression mechanisms.

4. OLS first, OLS tuning: The OLS is programmed to be transparent
    for a given wavelength, then the interfaces need to be switched
    on and further power tuning takes place. The sequencing of
    enabling the link needs to be covered as well.

The preferred way to address these in a Control Plane enabled network
is neighbour discovery including exchange of link characteristics and
link property correlation. The general mechanisms are covered in RFC

4209 [RFC4209] and RFC 4204 [RFC4204] which provides the necessary
protocol framework to exchange those characteristics between client
and Black Link. LMP-WDM is not intended for exchanging routing or
signaling information nor to provision the lambda in the transceiver
but covers:

1. Control channel management

2. Link property correlation

3. Link verification

4. Fault management

Extensions to LMP covering the parameter sets (e.g. application
codes) are needed, see draft-ietf-ccamp-dwdm-if-lmp. Additionally,
when client and server side are managed by different operational
entities, the link state may be useful to help the management system
to do troubleshooting or alarm correlation.

4.2.1. Considerations Using GMPLS Signaling

The deployment of single channel optical interfaces is leading to
some functional changes related to the control plane models and has
therefore some impact on the existing interfaces especially in the
case of a model where the edge node requests resources from the core
node and the edge node do not participate in the routing protocol
instance that runs among the core nodes. RFC 4208 [RFC4208] defines
the GMPLS UNI that can be used between edge and core node. In case
of integrated interfaces deployment additional functionalities are
needed to setup a connection.

It is necessary to differentiate between topology/signalling
information and configuration parameters that are needed to setup a
wavelength path. Using RSVP-TE could be used for the signalling and
the reservation of the wavelength path. But there are additional
information needed before RSVP-TE can start the signalling process.
There are three possibilities to proceed:

a. Using RSVP-TE only for the signalling and LMP as described above
    to exchange information on the configured optical interface
    within the edge node

b. RSVP-TE (typically with loose ERO) to transport additional
    information

   c. Leaking IGP information instead of exchanging this information
       needed from the optical network to the edge node (UNI will be
       transformed to a border-peer model, see RFC 5146 [RFC5146])

   Furthermore following issues should be addressed:

   a) The transceivers of peering edge nodes must be compatible. For
   example, it may be required to know about FEC, modulation scheme, The
   modulation format, the baudrate and many other parameters described
   in the drafts reported in the Annex. Depending on where the
   information is available, compatibility check may either happen
   before signaling, when the signaling reaches the optical network
   (e.g. at path computation time), or in the tail end node. An
   extended version of LMP is needed to exchange this information in
   case a. above, and to RSVP-TE as well in b. It would be helpful to
   define some common profiles that will be supported (e.g. the
   "application identifier") to summarize interface capabilities: if
   both profiles match, signaling can succeed and provisioning be
   achieved.

   b) Due to the bidirectional wavelength path that must be setup, the
   upstream edge node must include a wavelength value into the RSVP-TE
   Path message. But in the case of a UNI model the client device may
   not have full information about which wavelength must/should be
   selected, whereas this information must be exchanged between the edge
   and the core node. The special value defined in
   [Network-Assigned-Upstream-Label] allows the optical network to
   assign the actual wavelength to be used by the upstream transponder,
   which is a simple and efficient solution to this issue.

5. Requirements

   As network architectures become more complex, management and
   operations, including the the provisioning process, need progress
   towards automation. Simplifying and automating the entire management
   as well as the network provisioning process while enabling higher
   link utilization and faster restoration times are the main targets of
   this section.

   Supporting network management protocols such as NETCONF [RFC6241] or
   RESTCONF [RFC8040] is the base for the communication among EMS/NMS,
   centralized controller and network elements. This implies to speficy
   the corresponding IETF YANG modules to fully and consistently manage
   the feature discussed on this document.

   Data plane interoperability as defined for example in [ITU-T.G.698.2]
   is a precondition to take full benefit from standardized interfaces
   between network and control/management plane.

The following requirements are focusing on the usage of DWDM
interfaces using IETF technologies. Obvisouly, a common set of
solutions must be consistently supported by both the devices hosting
DWDM interfaces and the WDM network (i.e., the WDM line). The
solutions addressing the following requirements will be discussed in
further documents.

1 A YANG data model MUST define the optical parameters to be
   exchanged (e.g., power setting) between the network elements and
   the management plane so as to configure single channel interfaces
   through NETCONF/RESTCONF.

2 LMP MUST allow to convey the relevant optical parameters between
   two nodes to correlate neighbor characteristics and identify
   common capabilities or compatible ranges between the WDM line and
   single channel interfaces.

3 RSVP-TE MUST support the relevant parameters to be exchanged
   between the device hosting the DWDM interface and the optical node
   (e.g. the label value),
   without preventing the network to remain in charge of the optical
   path computation.

4 Power monitoring functions at both ends of the DWDM connection
   MAY be used to further automate the setup and shutdown process of
   the optical interfaces. LMP SHOULD suppport a way to carry
   associated measurement from the client devices to the edges of the
   WDM network.

5 In fault cases, the network SHOULD be able to recover wavelengths.
   RSVP-TE extensions MUST remain compatible with [RFC4873] features.
   The Yang modules should mimic a similar level of capability.

6. Gap Analysis

   To enable a centralized control function, several gaps in existing
   RFCs have been identified:

1 RFC 8343 defines a generic YANG model for interface management.
   However, to control DWDM interfaces, an augmentation needs to be
   defined which allows to configure DWDM specifics such as wavelength
   or FEC-type.

2 RFC 7224 defines iana-if-type YANG modules and needs extension to
   include DWDM interfaces.

3 RFC 4204 defines the Link Management Protocol (LMP) to correlate
   link properties between two adjacent nodes. Extensions are required
   to cover the use cases described such as the correlation between a
   Transponder and a ROADM node.

4 RFC 8454 defines an information model for Abstraction and
   Control of TE Networks (ACTN). However it does not support
   impairment aware path selection or computation.

5 RFC 7823 describes Performance-Based Path Selection for Explicitly
   Routed Label Switched Paths (LSPs) Using TE Metric Extensions,
   but does not define Metric extensions suitable for Impairment
   aware routing in optical transport Networks

6 RFC 7471 in turn defines OSPF Traffic Engineering (TE) Metric
   Extensions covering several use cases but lacks Imairment
   awareness.

7 RFC 6163 provides a Framework for GMPLS and Path Computation
   Element (PCE) Control of Wavelength Switched Optical Networks
   (WSONs). While it describes methods for communicating RWA relevant
   information, it does not identify such information.

8 Yang Models describing the optical parameter to be used to control
   the network ad allow an external controller (like ACTN) to are
   missing although are defined by ITU and reported in the

As this framework is focusing on the single operator use case, the
security concerns can be relaxed to a subset compared to a setup
where information is exchanged between external parties and over
external interfaces.

Concerning the access control to Management interfaces, security
issues can be generally addressed by authentication techniques
providing origin verification, integrity and confidentiality.
Additionally, access to Management interfaces can be physically or
logically isolated, by configuring them to be only accessible out-of-
band, through a system that is physically or logically separated from
the rest of the network infrastructure. In case where management

interfaces are accessible in-band at the client device or within the optical transport network domain, filtering or firewalling techniques can be used to restrict unauthorized in-band traffic. Authentication techniques may be additionally used in all cases.

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Appendix A. Use Cases

   A comparison with the traditional operation scenarios provides an
   insight of similarities and distinctions in operation and management
   of DWDM interfaces. The following use cases provide an overview
   about operation and maintenance processes.

A.1. Optical interface parameter collection

   It is necessary to identify the Optical interface characteristics and
   setting in order to properly calculate the ent to end path and match
   the Head End interface against the Tail End interface compatibility.
   The optical parameters may have multiple possible values that the
   Controller (SDN or GMPLS) can use and select for the best network
   optimisation.

A.2. DWDM client - ROADM interconection discovery

   Being the the DWDM port and ROADM port belonging to different domains
   and Network Elements, the interconnection between them is not
   embedded in the Optical Nodes and can not be shared to the EMS and
   the Controller. The Controller needs then to retrieve the
   connectivity using data coming from the two domains correlating them
   to discover the relationship. The methods to discover the
   interconnection can be LMP, LLDP, installation provisioning or any
   other mechanism checking using the light transmitted by the DWDM
   transmitter and detecter by the ROAMD port photodiode. This use case
   is fundamental to build the interconnections between the DWDM and
   Client layer (e.g. Routers) and calculate the multilayer network
   topology.

A.3. Service Setup

   It is necessary to differentiate between different operational issues
   for setting up a light path (a DWDM connection is specific in having
   defined maximum impairments) within an operational network.

   The first step is to determine if transceivers located at different
   end-points are interoperable, i.e. support a common set of
   operational parameters. In this step it is required to determine
   transceiver capabilities in a way to be able to correlate them for
   interoperability purposes. Such parameters include modulation
   scheme, modulation parameters, FEC to name a few. If both
   transceivers are controlled by the same NMS or CP, such data is
   readily available. However in cases like Figure 4, a protocol needs
   to be used to inform the controlling instance (NMS or CP) about
   transceiver parameters. It is suggested to extend LMP for that
   purpose.

The second step is to determine the feasibility of a lightpath
between two transceivers without applying an optical signal.
Understanding the limitations of the transceiver pair, a path through
the optical network has to be found, whereby each path has an
individual set of impairments deteriorating a wavelength traveling
along that path. Since a single transceiver can support multiple
parameter sets, the selection of a path may limit the permissible
parameter sets determined in previous steps.

The third step is then to setup the connection itself and to
determine the Wavelength. This is done using the NMS of the optical
transport network or by means of a control plane interaction such as
signaling and includes the path information as well as the parameter
set information necessary to enable communication.

In a fourth step, optical monitoring is activated in the WDM network
in order to monitor the status of the connection. The monitor
functions of the optical interfaces at the terminals are also
activated in order to monitor the end to end connection.

Furthermore it should be possible to automate this step. After
connecting the client device to the neighbor control plane-enabled
transport node, a control adjacency may be automatically established,
e.g. using LMP.

A.4. Link Monitoring Use Cases

The use cases described below are assuming that power monitoring
functions are available in the ingress and egress network element of
the DWDM network, respectively. By performing link property
correlation it would be beneficial to include the current transmit
power value at reference point Ss and the current received power
value at reference point Rs. For example if the Client transmitter
power has a value of 0dBm and the ROADM interface measured power is
-6dBm the fiber patch cord connecting the two nodes may be pinched or
the connectors are dirty. As discussed before, the actual path or
selection of a specific wavelength within the allowed set is outside
the scope of LMP. The computing entities (e.g. the first optical
node originating the circuit) can rely on GMPLS IGP (OSPF) to
retrieve all the information related to the network, calculate the
path to reach the endpoint and signal the path implementation through
the network via RSVP-TE.

[ITU-T.G.698.2] defines a single channel optical interface for DWDM
systems that allows interconnecting network-external optical
transponders across a DWDM network. The optical transponders are
external to the DWDM network. This so-called 'Black Link' approach
illustrated in Fig. 5-1 of [ITU-T.G.698.2] and a copy of this figure

is provided below in Figure 5. The single channel fiber link between
the Ss/Rs reference points and the ingress/egress port of the network
element on the domain boundary of the DWDM network (DWDM border NE)
is called access link. Based on the definition in [ITU-T.G.698.2] it
is part of the DWDM network. The access link is typically realized
as a passive fiber link that has a specific optical attenuation
(insertion loss). As the access link is an integral part of the DWDM
network, it is desirable to monitor its attenuation. Therefore, it
is useful to detect an increase of the access link attenuation, for
example, when the access link fiber has been disconnected and
reconnected (maintenance) and a bad patch panel connection
(connector) resulted in a significantly higher access link
attenuation (loss of signal in the extreme case of an open connector
or a fiber cut). In the following section, two use cases are
presented and discussed:

        1) pure access link monitoring
        2) access link monitoring with a power control loop

These use cases require a power monitor as described in G.697 (see
section 6.1.2), that is capable to measure the optical power of the
incoming or outgoing single channel signal. The use case where a
power control loop is in place could even be used to compensate an
increased attenuation if the optical transmitter can still be
operated within its output power range defined by its application
code.

Use case 1: Access Link monitoring
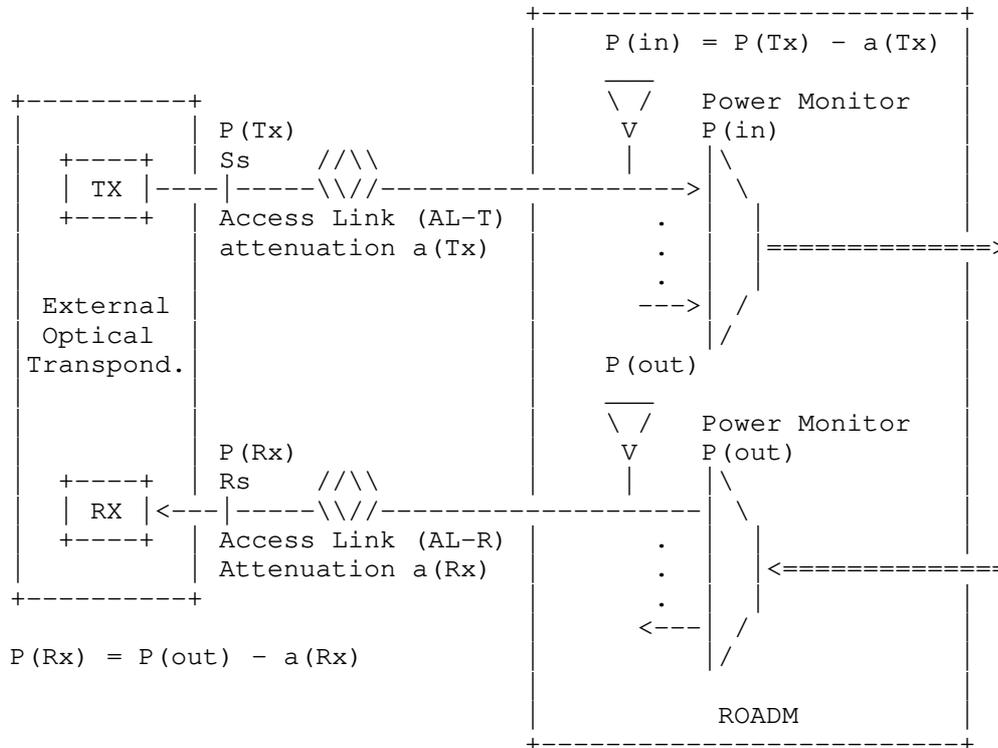
```
                                    +------------------------+
                                    │    P(in) = P(Tx) - a(Tx) │
                                    │     __                   │
      +----------+                  │     \ /   Power Monitor  │
      │          │  P(Tx)           │      V    P(in)          │
      │  +----+  │  Ss    //\\      │      │    │\             │
      │  │ TX │--│----│-----\\//---------------->│ \           │
      │  +----+  │  Access Link (AL-T) │    .    │             │
      │          │  attenuation a(Tx)  │    .    │  │==============>
      │          │                  │    .    │  │             │
      │ External │                  │    --->│  /             │
      │ Optical  │                  │       │ /              │
      │Transpond.│                  │     P(out)             │
      │          │                  │     __                 │
      │          │  P(Rx)           │     \ /   Power Monitor  │
      │  +----+  │  Rs    //\\      │      V    P(out)         │
      │  │ RX │<---│-----\\//---------------│    │\            │
      │  +----+  │  Access Link (AL-R) │    .    │ \           │
      │          │  Attenuation a(Rx)  │    .    │  │<==============
      +----------+                  │    .    │  │             │
                                    │    <---│  /             │
      P(Rx) = P(out) - a(Rx)        │       │ /              │
                                    │        /               │
                                    │                        │
                                    │         ROADM           │
                                    +------------------------+
```

  - For AL-T monitoring: P(Tx) and a(Tx) must be known
  - For AL-R monitoring: P(RX) and a(Rx) must be known

  An alarm shall be raised if P(in) or P(Rx) drops below a
  configured threshold (t [dB]):
  - P(in) < P(Tx) - a(Tx) - t (Tx direction)
  - P(Rx) < P(out) - a(Rx) - t (Rx direction)
  - a(Tx) =│ a(Rx)

Alarms and events can be shared between Client and Network
via LMP.

                  Figure 5: Access Link Power Monitoring

A.4.1. Pure Access Link (AL) Monitoring Use Case

   Figure 6 illustrates the access link monitoring use case and the
   different physical properties involved that are defined below:

 - Ss, Rs: Single Channel reference points
 - P(Tx): current optical output power of transmitter Tx
 - a(Tx): access link attenuation in Tx direction (external
           transponder point of view)
 - P(in): measured current optical input power at the input port
           of border DWDM NE
 - t: user defined threshold (tolerance)
 - P(out): measured current optical output power at the output port
           of border DWDM NE
 - a(Rx): access link attenuation in Rx direction (external
           transponder point of view)
 - P(Rx): current optical input power of receiver Rx

   Description:
 - The access link attenuation in both directions (a(Tx), a(Rx))
   is known or can be determined as part of the commissioning
   process. Typically, both values are very similar.
 - A threshold value t has been configured by the operator. This
   should also be done during commissioning.
 - A control plane protocol is in place that allows
   to periodically send the optical power values P(Tx) and P(Rx)
   to the control plane protocol instance on the DWDM border NE.
   This is illustrated in Figure 3.
 - The DWDM border NE is capable to periodically measure the optical
   power P(in) and P(out) as defined in G.697 by power monitoring
   points depicted as triangles in the figures below.

   Access Link monitoring process:
 - Tx direction: the measured optical input power P(in) is compared
   with the expected optical input power P(Tx) - a(Tx). If the
   measured optical input power P(in) drops below the value
   (P(Tx) - a(Tx) - t) a low power alarm shall be raised indicating
   that the access link attenuation has exceeded a(Tx) + t.
 - Rx direction: the measured optical input power P(Rx) is
   compared with the expected optical input power P(out) - a(Rx).
   If the measured optical input power P(Rx) drops below the value
   (P(out) - a(Rx) - t) a low power alarm shall be raised indicating
   that the access link attenuation has exceeded a(Rx) + t.
 - to avoid toggling errors, the low power alarm threshold shall be
   lower than the alarm clear threshold.

Use case 2: Access Link monitoring through LMP
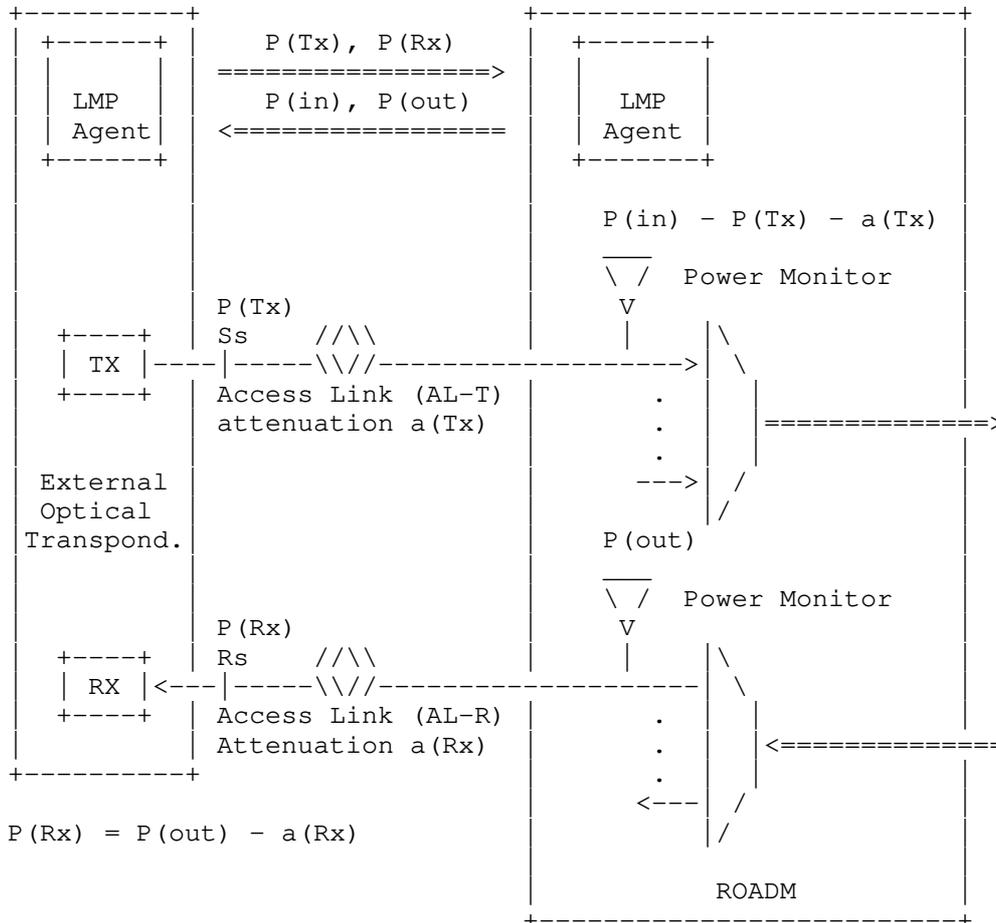

```
      +---------+                           +------------------------+
      | +------+ |      P(Tx), P(Rx)        | +-------+              |
      | |      | |    ================>     | |       |              |
      | | LMP  | |      P(in), P(out)       | | LMP   |              |
      | |Agent | |    <================     | | Agent |              |
      | +------+ |                          | +-------+              |
      |         |                           |                        |
      |         |                           |   P(in) - P(Tx) - a(Tx)|
      |         |                           |   ___                  |
      |         |                           |   \ /    Power Monitor |
      |         |     P(Tx)                 |    V                   |
      | +----+  |     Ss    //\\            |    |    |\             |
      | | TX |--|----|-----\\//-------------------->|  \            |
      | +----+  |     Access Link (AL-T)    |    .   |   \          |
      |         |     attenuation a(Tx)     |    .   |    |=============>
      |         |                           |    .   |   /          |
      | External|                           |    --->|  /           |
      | Optical |                           |        |/             |
      |Transpond.|                          |   P(out)              |
      |         |                           |   ___                 |
      |         |                           |   \ /   Power Monitor  |
      |         |     P(Rx)                 |    V                   |
      | +----+  |     Rs    //\\            |    |    |\             |
      | | RX |<---|-----\\//-------------------- |  \            |
      | +----+  |     Access Link (AL-R)    |    .   |   \          |
      |         |     Attenuation a(Rx)     |    .   |    |<=============
      +---------+                           |    .   |   /          |
                                            |   <---|  /            |
   P(Rx) = P(out) - a(Rx)                   |       |/              |
                                            |                       |
                                            |         ROADM         |
                                            +------------------------+
```

   - For AL-T monitoring: P(Tx) and a(Tx) must be known
   - For AL-R monitoring: P(RX) and a(Rx) must be known
   An alarm shall be raised if P(in) or P(Rx) drops below a
   configured threshold (t [dB]):
   - P(in) < P(Tx) - a(Tx) - t (Tx direction)
   - P(Rx) < P(out) - a(Rx) - t (Rx direction)
   - a(Tx) = a(Rx)

   Alarms and events can be shared between Client and Network
   via LMP according to [RFC4204] and [RFC4209]

Figure 6: Extended LMP Model

A.4.2. Power Control Loop Use Case

     This use case is based on the access link monitoring as
     described above. In addition, the border NE is running a power
     control application that is capable to control the optical output
     power of the single channel tributary signal at the output port
     of the border DWDM NE (towards the external receiver Rx) and the
     optical output power of the single channel tributary signal at
     the external transmitter Tx within their known operating range.
     The time scale of this control loop is typically relatively slow
     (e.g. some 10s or minutes) because the access link attenuation
     is not expected to vary much over time (the attenuation only
     changes when re-cabling occurs).
     From a data plane perspective, this use case does not require
     additional data plane extensions. It does only require a protocol
     extension in the control plane (e.g. this LMP draft) that allows
     the power control application residing in the DWDM border NE to
     modify the optical output power of the DWDM domain-external
     transmitter Tx within the range of the currently used application
     code. Figure 7 below illustrates this use case utilizing
     LMP with the extensions identified in this document.

Use case 3: Power Control Loop

```
+---------+                              +------------------------+
| +------+ |P(Tx),P(Rx),Set(P(out))|     | +------+   +--------+ |
| |      | | ====================>  |     | |      |   | Power  | |
| | LMP  | | P(in),P(out),Set(PTx)  |     | | LMP  |   |Control | |
| |      | | <==================    |     | |      |   | Loop   | |
| +------+ |                        |     | +------+   +--------+ |
|    |     |                        |     |                       |
| +------+ |                        |     |  P(in) = P(Tx) - a(Tx)|
| |C.Loop| |                        |     |   __                  |
| +------+ |                        |     |   \ /  Power Monitor   |
|    |     | P(Tx)                  |     |    V                   |
| +------+ | Ss    //\\             |     |    |   |\              |
| | TX |>----|-----\\//--------------------->| \            |
| +------+ | Access Link (AL-T)     |     |    .   |  |             |
|  VOA(Tx) | attenuation a(Tx)      |     |    .   | |==============>|
|          |                        |     |    .   |  |            |
| External |                        |     |   --->| /            |
| Optical  |                        |     |       |/             |
| Transpond.|                       |     |  P(out)                |
|          |                        |     |   __                  |
|          |                        |     |   \ /  Power Monitor   |
|          | P(Rx)                  |     |    V   VOA(out) |\     |
| +----+  | Rs    //\\             |     |    |   VOA(out)  | \    |
| | RX |<---|-----\\//--------------------------<|------- | \   |
| +----+  | Access Link (AL-R)     |     |    .   |  |            |
|          | attenuation a(Rx)      |     |    .   | |<======   |
+---------+                         |     |  VOA(out) |  |           |
                                    |     | <--<|------- | /        |
 P(Rx) = P(out) - a(Rx)            |     |           |/            |
                                    |     |    ROADM               |
                                    +------------------------+
```
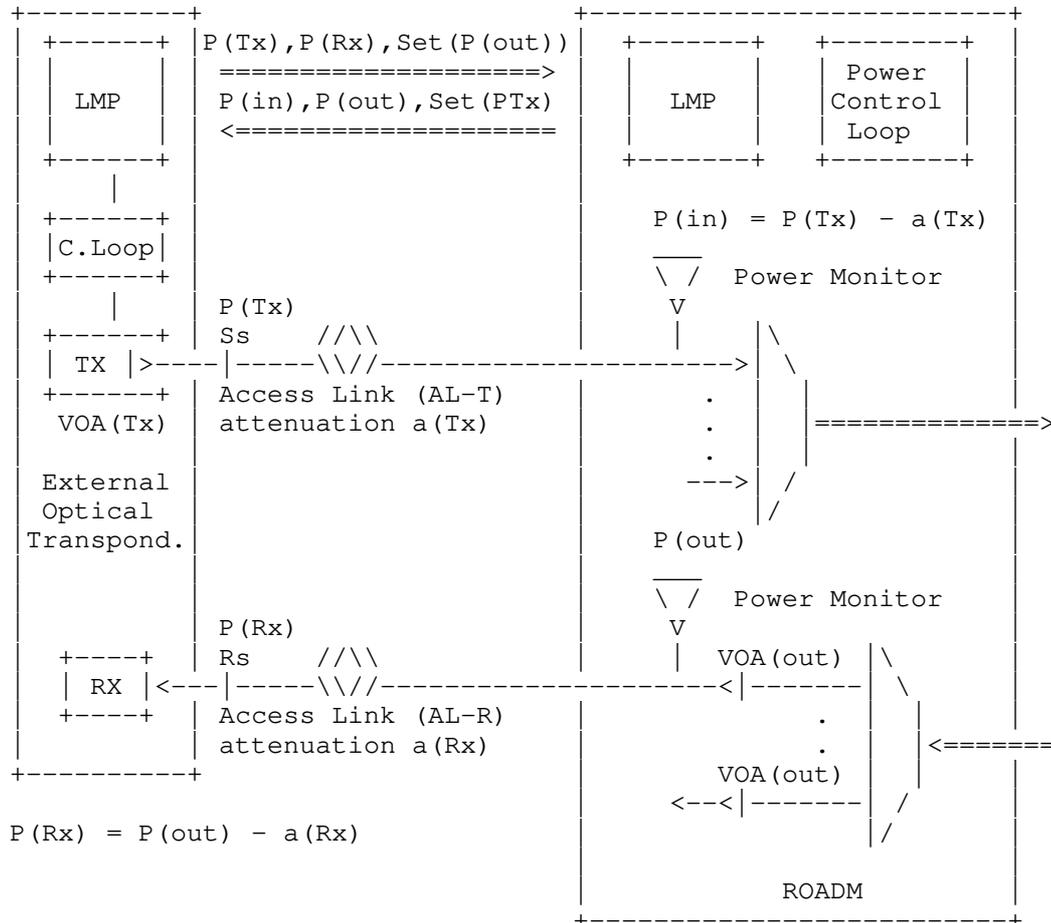
Figure 7: Power control loop

- The power control loop in transponders and ROADMs controls
  the Variable Optical Attenuators (VOA) to adjust the proper
  power in base of the ROADM and Receiver characteristics and
  the Access Link attenuation

A.5. Optical Circuit restoration

   Upon an network failure (e.g. fiber cut) the Controller or GMPLS can
   initiate an Optical Path restoration process. Other than reroute the
   optical path the controller may need to retune the wavelength and
   modify the DWDM Transceiver working parameters (e.g. FEC, Modulation
   Format, etc.). This operation is done in realtime and can benefit of
   Netconf/Yang interface or RSVP signallin on the UNI interface.

A.6. Multilayer restoration

   A network failure can be due to an DWDM port failure. The Controller
   is the only actor able to fix issue setting a new circuit terminated
   on a good Client port (GMPLS is not able to make an new path choosing
   a different end-point). Other than reroute the optical path the
   controller may need to provision the wavelength and modify the DWDM
   Transceiver working parameters (e.g. FEC, Modulation Format, etc.).
   This operation is done in realtime and must be supported by Netconf/
   Yang interface.

Appendix B. Detailed info drafts

   In this section are reported some examples and references on the MIB,
   Yang and LMP usage. The MIB and TLV defining the parameters
   described above are reported in the drafts below and are intended as
   informative data:

draft-ietf-ccamp-dwdm-if-lmp
   Extension to the Link Management Protocol (LMP/DWDM -rfc4209) for
   Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems
   to manage the application code of optical interface parameters in
   DWDM application

draft-ggalimbe-ccamp-flex-if-lmp
   Extension to the Link Management Protocol (LMP/DWDM -rfc4209) for
   Dense Wavelength Division Multiplexing (DWDM) Optical Line Systems
   to manage the application code of optical interface parameters in
   DWDM application

draft-ietf-ccamp-dwdm-if-param-yang
   A YANG model to manage the optical interface parameters for an
   external transponder in a WDM network

draft-ietf-ccamp-flexigrid-yang
   YANG data model for Flexi-Grid Optical Networks

draft-ietf-ccamp-wson-iv-info
   Information Model for Wavelength Switched Optical Networks (WSONs)
   with Impairments Validation

draft-ietf-ccamp-wson-iv-encode
   Information Encoding for WSON with Impairments Validation

draft-galimbe-ccamp-iv-yang
   A YANG model to manage the optical parameters for in a WDM network

NOTE: the above information is defined at the time of publication of
this document and thus subject to change.

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