          A framework for Management and Control of DWDM optical interface
                                parameters
                  draft-ietf-ccamp-dwdm-if-mng-ctrl-fwk-03

Abstract

   To ensure an efficient data transport, meeting the requirements
   requested by today's IP-services the control and management of DWDM
   interfaces is a precondition for enhanced multilayer networking and
   for an further automation of network provisioning and operation.
   This document describes use cases and requirements for the control
   and management of optical interfaces 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 EMS, NMS or GMPLS. This document covers management
   as well as control plane considerations in different management cases
   of a single channel DWDM interface. The purpose is to identify the
   necessary information elements and processes to be used by control or
   management systems for further processing.

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1. Introduction

   The usage of the single channel DWDM interfaces in client nodes (e.g.
   routers) connected to a DWDM Network (which include ROADMs and
   optical amplifiers) adds a further networking option for operators
   opening to new scenarios and requiring more control/management plane
   integration.

   Carriers deploy their networks today as a combination of transport
   and packet infrastructures to ensure high availability and flexible
   data transport. Both network technologies are usually managed by
   different operational units using different management concepts.
   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), it is necessary to coordinate the
   management of the optical interface at the client domain with the
   optical transport domain. There are different levels of
   coordination, which are specified in this framework.

   The objective of this document is to provide a framework that
   describes the solution space for the control and management of single
   channel interfaces and give use cases on how to manage the solutions.
   In particular, it examines topological elements and related network
   management measures. From an architectural point of view, the
   network can be considered as a set of pre- configured/qualified
   unidirectional, single-fiber, network connections between reference
   points S and R shown in figure 2. The optical transport network is
   managed and controlled in order to provide optical connections at the
   intended centre frequencies and the optical interfaces are managed
   and controlled to generate signals of the intended centre frequencies
   and further parameters as specified for example in ITU-T
   Recommendations G.698.2 and G.798. The management or control plane
   of the client and DWDM network be aware of the parameters of the
   interfaces to properly set up the optical link. This knowledge can
   be used furthermore, to support fast fault detection.

   Optical routing and wavelength assignment based on WSON is out of
   scope although can benefit of the way the optical parameters are
   exchanged between the Client and the DWDM Network.

   Additionally, the wavelength ordering process and the process how to
   determine the demand for a new wavelength from A to Z is out of
   scope.

   Note that the Control and Management Planes are two separate entities
   that are handling the same information in different ways. This
   document covers management as well as control plane considerations in
   different management cases of single channel DWDM interfaces.

1.1. Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in RFC 2119 [RFC2119].

2. Terminology and Definitions

   Current generation WDM netwoks are single vendor networks where the
   optical line system and the transponders are tightly integrated. The
   DWDM interfaces migration from the Transponders to the Client
   interfaces changes this scenario, by introducing a standardized
   interface at the level of OCh between the Client DWDM interface and
   the DWDM network.

   Black Link: The Black Link [ITU.G698.2] 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 which may be from a different vendor. Therefore the
   standard defines the ingress and egress parameters for the optical
   interfaces at the reference points Ss and Rs.

   Single Channel DWDM Interface: The single channel interfaces to DWDM
   systems defined in 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 10 Gbit/s.
   Future revisions are expected to include application codes for bit
   rates up to 40 Gb/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 [G.805]: For the purposes of this
   Recommendation an administrative domain represents 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) [G.872]: A physical interface within an
   administrative domain.

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

Management Plane [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[G.8081]: The control plane performs neighbour
discovery, call control and connection control functions. Through
signalling, the control plane sets up and releases connections, and
may restore a connection in case of a failure. The control plane
also performs other functions in support of call and connection
control, such as neighbour discovery and routing information
dissemination.

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.G.872].

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.G.872].

3. Solution Space Client DWDM interface

The management of optical interfaces using the Black Link approach
deals with aspects related to the management of single-channel
optical interface parameters of physical point-to-point and ring DWDM
applications on single-mode optical fibres.

The solution allows the direct connection of a wide variety of
equipments 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. Multiple optical client devices, each from a different vendor,
    supplying one channel each

3. A combination of the above

Table 1 provides a list of management tasks regarding the
configuration of optical parameters.

Task	Domain	a	b	c	d
determination of centre frequency	optical	R	R	R	R
configuration of centre frequency at optical IF	client	NR	NR	R	R
path computation of wavelength	optical	NR	NR	R	R
routing of wavelength	optical	NR	NR	R	R
wavelength setup across optical network	optical	?	?	R	R
detection of wavelength fault	client	R	R	R	R
fault isolation, identification of root failure	optical	NR	R	R	R
repair actions within optical network	optical	R	R	R	R
protection switching of wavelength	optical	NR	NR	R	R
restoration of wavelength	optical	NR	NR	R	R

Note: R = relevant, NR = not relevant

Table 1: List of tasks related to Client - Network interconnection management

Furthermore the following deployment cases will be considered:

a. Passive WDM

b. P2P WDM systems

c. WDM systems with OADMs

d. Transparent optical networks supporting specific functions, nterfaces, protocols etc.

Case a) is added for illustration only, since passive WDM is specified in ITU-T Recommendations G.695 and G.698.1.

Case b) and case c)are motivated by the usage of legacy equipment using the traditional connection as described in Figure 1 DWDM interface integration on the client side.

3.1. Comparison of approaches for transverse compatibility

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], [ITU-T G.959.1], 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
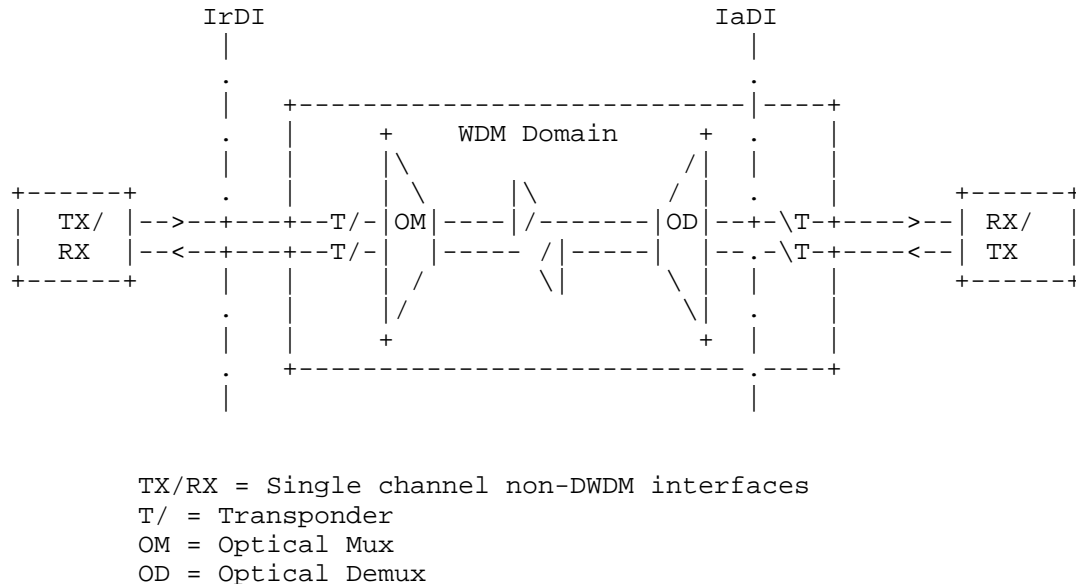
        Figure 1: Inter and Intra-Domain Interface Identification

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 IaDI. This interface
specifies the internal parameter set of the optical administrative
domain. In the case of a client DWDM interface deployment this
interface moves into the client device and extends the optical and
administrative domain towards the client node. ITU-T G.698.2 for
example specifies the parameter set for a certain set of
applications.

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

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
   single channel DWDM interfaces, multi-vendor interconnection can also
   be achieved while removing 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 OADMs.

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


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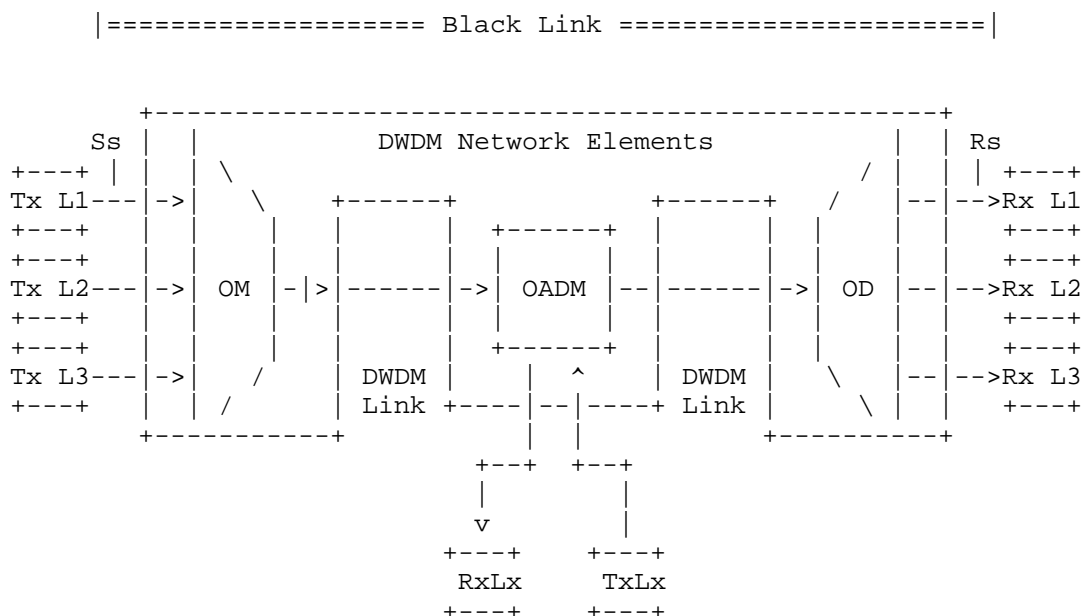
   Ss = Reference point at the DWDM network element tributary output
   Rs = Reference point at the DWDM network element tributary input
   Lx = Lambda x
   OM = Optical Mux
   OD = Optical Demux
   OADM = Optical Add Drop Mux

   Linear DWDM network as per ITU-T G.698.2

                   Figure 2: Linear Black Link

As shown in Figure 2, the administrative domain may consists of several vendor domains. Even a in that case a common north bound management interface is required to ensure a consistent management of the entire connection.

The following documents[DWDM-interface-MIB], [YANG], [LMP] define such a protocol- FIX-THE-REFERENCE specific information using SNMP/ SMI, Yang models and LMP TLV to support the direct exchange of information between the client and the network control plane.

4. Solutions for managing and controlling the 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 an umbrella management system is used. Currently each WDM vendor provides an Element Management System (EMS) that also administers the wavelengths.

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

<vspace>:

1. Separate operation and management of client device and the transport network whereas the single channel 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 to the management system,ensuring a management of the single channel of the optical network (e.g. EMS, NMS)

    b.Indirect connection to the management system of the optical network using a protocol (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.
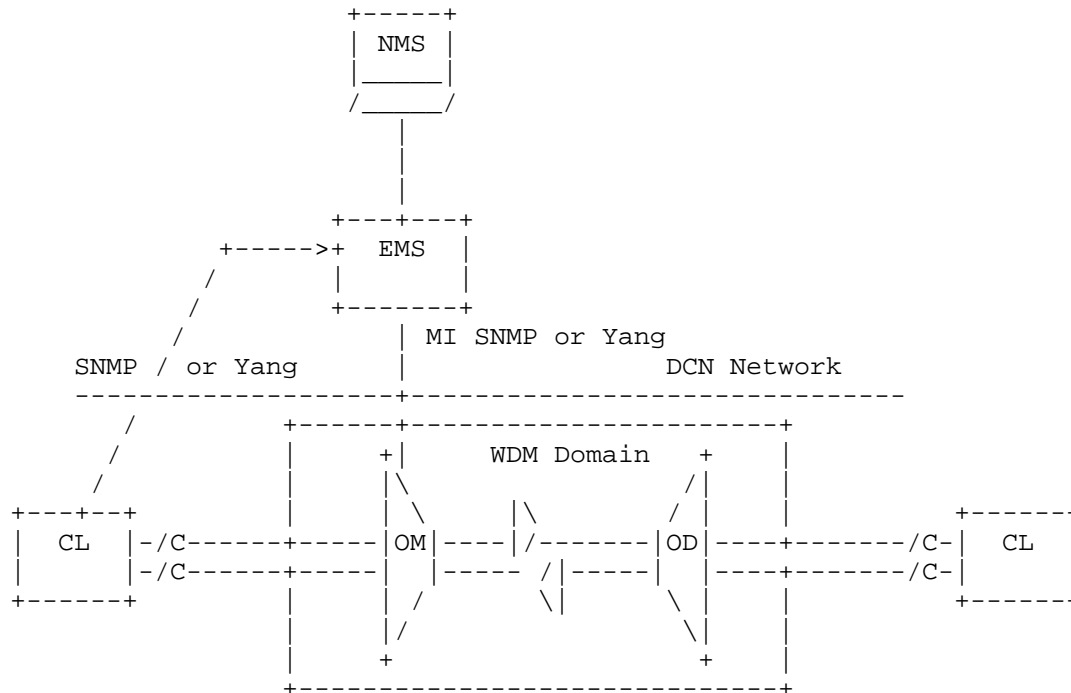
```
                          +-----+
                          | NMS |
                          |_____|
                          /_____/
                             |
                             |
                             |
                          +---+---+
                   +----->+  EMS  |
                  /       |       |
                 /        +-------+
                /         | MI SNMP or Yang
         SNMP / or Yang   |                  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

      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 standardised way to enable interoperable solutions between

different optical interface vendors and vendors of the optical
network management application. RFC 3591 [RFC3591] defines managed
objects for the optical interface type but needs further extension to
cover the optical parameters required by this framework document.
Therefore an extension to this MIB for the optical interface has been
drafted in [DWDM-interface-MIB]. SNMP is used to read parameters and
get notifications and alarms, netconf and Yang models are needed to
easily provision the interface with the right parameter set as
described in [YANG]

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. Direct connection to the DWDM management system

An alternative as shown in Figure 4 can be used in cases where a more
integrated relationship between transport node (e.g. OM or OD) 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 Yang
                            |
            LMP         +------+---------------------+
          +------------+---+ +|                  +   |
          |            |   | || |\               /|  |
  +---+--+ |           | +-+ \ |OM|----|\-------|OD|--- +------/C-| CL  |
  | CL  |-/C------+--- -|  |----- /|-----| |----+------/C-|     |
  |     |-/C------+--- -| | |----- /|-----| |----+------/C-|     |
  +-----+         |   | | / \|    \ |  |            +------+
                  |   |/           \|    |
                  |   +             +    |
                  +----------------------------+
```

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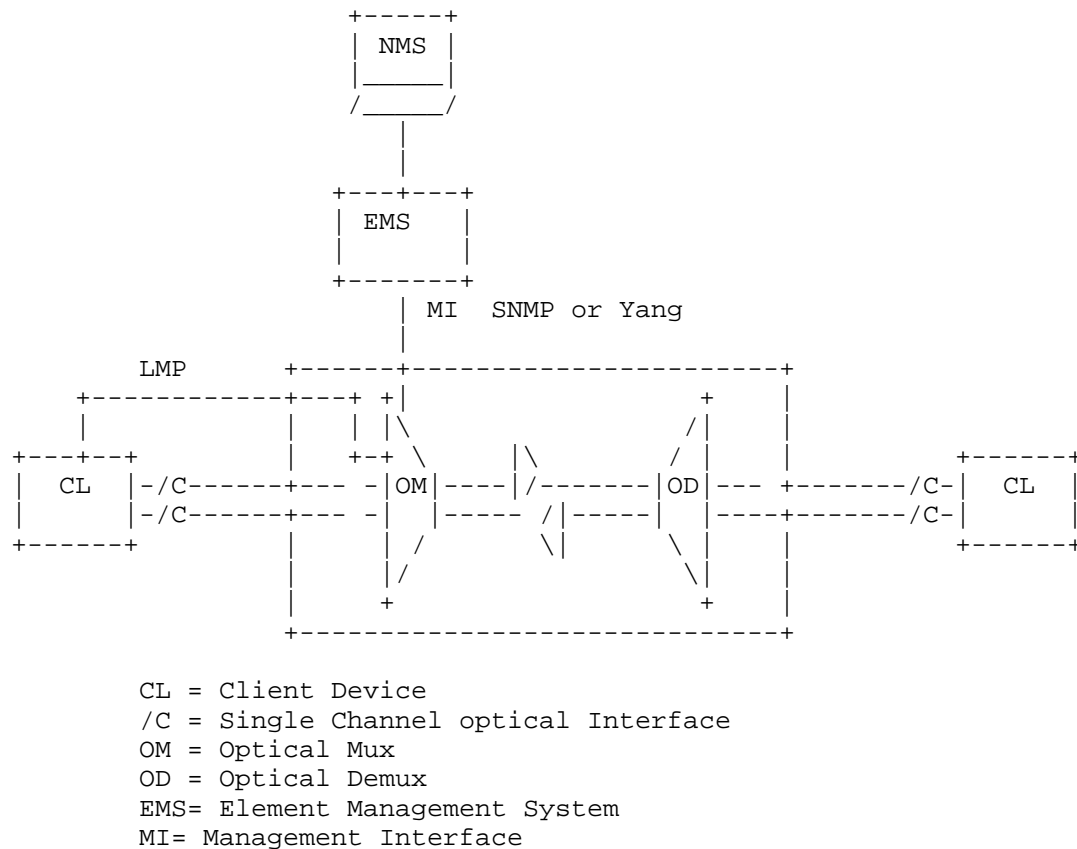
      Figure 4: Direct connection between peer node and first optical
                            network node

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.

The LMP based on RFC 4209 does not yet support the transmission of
configuration data (information). This functionality must be added
to the existing extensions of the protocol. The use of LMP-WDM
assumes that some form of a control channel exists between the client

node and the WDM equipment. This may be a dedicated lambda, an
Ethernet Link, or other signalling communication channel (SCC or
IPCC).

4.2. Control Plane Considerations

The concept of integrated single channel DWDM interfaces equally
applies to management and control plane mechanisms. The general
GMPLS control plane for wavelength switched optical networks is work
under definition in the scope of WSON. One important aspect of the
BL is the fact that it includes the wavelength that is supported by
the given link. Thus a BL 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, 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 it is internal facilities there may be a
    period of time 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
RFC4209 [LMP-WDM] and RFC 4204[LMP] which provides the necessary
protocol framework to exchange those characteristics between client

and black link. LMP-WDM is not intended for exchanging routing or
signalling information but covers:

1. Control channel management

2. Link property correlation

3. Link verification

4. Fault management

Extensions to LMP/LMP-WDM covering the code points of the BL
definition are needed. Additionally when client and server side are
managed by different operational entities, Link state exchange is
required to align the management systems.

4.2.1. Considerations using GMPLS UNI

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 an overlay model where the edge node requests resources from
the core node and the edges node do not participate in the routing
protocol instance that runs among the core nodes. RFC 4208 [RFC4208]
defines the GMPLS UNI that will 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. 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 to configure the optical interface within
    the edge node or

b. RSVP-TE will be used to transport additional information

c. Leaking IGP information instead of exchanging this information
    needed from the optical network to the edge node (overlay will be
    transformed to a border-peer model)

Furthermore following issues should be addressed:

a) The Communication between peering edge nodes using an out of band
control channel. The two nodes have to exchange their optical
capabilities. An extended version of LMP is needed to exchange FEC
Modulation scheme, etc. that must be the same. It would be helpful
to define some common profiles that will be supported. Only if the
profiles match with both interface capabilities it is possible start
signalling.

b) Due to the bidirectional wavelength path that must be setup it is
obligatory that the upstream edge node inserts a wavelength value
into the path message for the wavelength path towards the upstream
node itself. But in the case of an overlay model the client device
may not have full information which wavelength must/should be
selectedand this information must be exchanged between the edge and
the core node.

5. Use cases

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

5.1. Service Setup

It is necessary to differentiate between two 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 the preparation of the connection if no optical signal
is applied. Therefore it is necessary to define the path of the
connection.

The second step is to setup the connection between the client DWDM
interface and the ROADM port. This is done using the NMS of the
optical transport network. From the operation point of view the task
is similar in a Black Link scenario and in a traditional WDM
environment. The Black Link connection is measured by using BER
tester which use optical interfaces according to G.698.2. These
measurements are carried out in accordance with [ITU-TG.692]. When
needed further connections for resilience are brought into service in
the same way.

In addition some other parameters like the transmit optical power,
the received optical power, the frequency, etc. must be considered.

If the optical interface moves into a client device some of changes
from the operational point of view have to be considered. The centre
frequency of the Optical Channel was determined by the setup process.

The optical interfaces at both terminals are set to the centre
frequency before interconnected with the dedicated ports of the WDM
network. Optical monitoring is activated in the WDM network after
the terminals are interconnected with the dedicated ports 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 last step. After
connecting the client device towards the first control plane managed
transport node a control connection may e.g. be automatically
established using LMP to exchange configuration information.

If tunable interfaces are used in the scenario it would be possible
to define a series of backup wavelength routes for restoration that
could be tested and stored in backup profile. In fault cases this
wavelength routes can be used to recover the service.

5.2. 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 (OXC1) has a value of 0dBm and the ROADM interface measured
power (at OLS1) is -6dBm the fiber patch cord connecting the two
nodes may be pinched or the connectors are dirty. More, the
interface characteristics can be used by the OLS network Control
Plane in order to check the Optical Channels feasibility. Finally
the OXC1 transceivers parameters (Application Code) can be shared
with OXC2 using the LMP protocol to verify the transceivers
compatibility. The actual route selection of a specific wavelength
within the allowed set is outside the scope of LMP. In GMPLS, the
parameter selection (e.g. central frequency) is performed by RSVP-TE.

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 considered to be
external to the DWDM network. This so-called 'black link' approach
illustrated in Figure 5-1 of G.698.2 and a copy of this figure is
provided below. 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 in this contribution. Based on the definition in G.698.2
it is considered to be part of the DWDM network. The access link
typically is 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 as long as the optical transmitter can still be
operated within its output power range defined by its application
code.

Figure 5 Access Link Power Monitoring
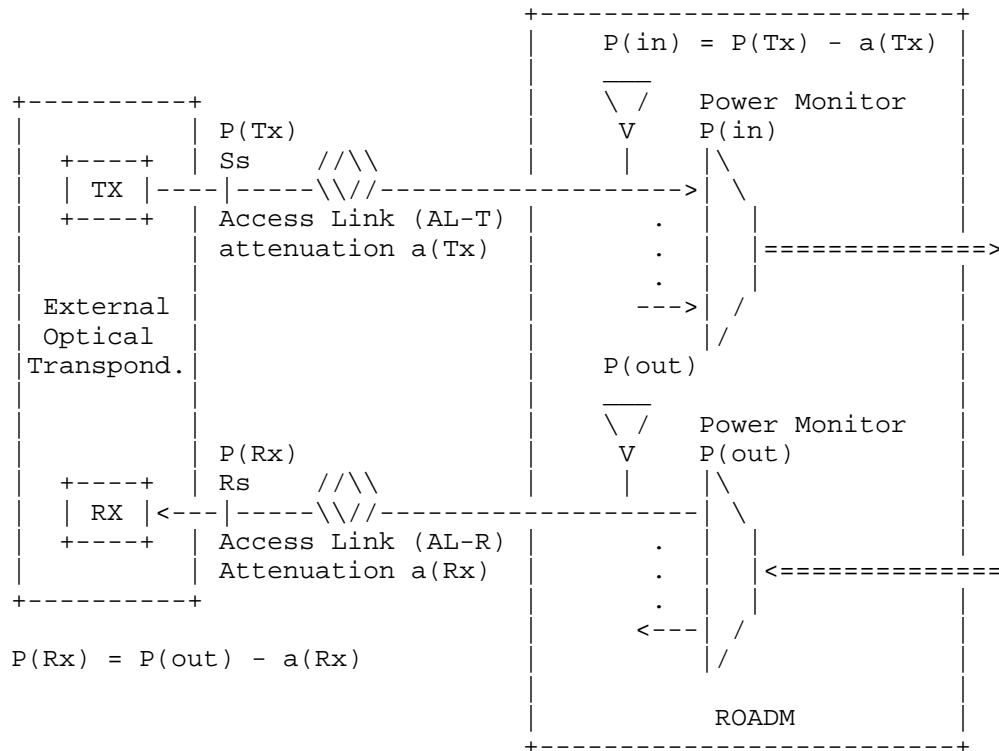
```
                                       +------------------------+
                                       | P(in) = P(Tx) - a(Tx)  |
                                       |  ___                   |
     +----------+                      | \ /   Power Monitor    |
     |          | P(Tx)                |  V    P(in)            |
     |  +----+  | Ss    //\\           |  |    |\              |
     |  | TX |--|-----\\//------------------->|  \             |
     |  +----+  | Access Link (AL-T)   |   .  |  |             |
     |          | attenuation a(Tx)    |   .  |  |=============>
     |          |                      |   .  |  |             |
     | External |                      |  --->|  /             |
     | Optical  |                      |      | /              |
     |Transpond.|                      | P(out)                |
     |          |                      |  ___                   |
     |          |                      | \ /   Power Monitor    |
     |          | P(Rx)                |  V    P(out)           |
     |  +----+  | 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)

                        Figure 5: Extended LMP Model

5.2.1. 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 the same.
- A threshold value t has been configured by the operator. This
  should also be done during commissioning.
- A control plane protocol (e.g. this draft) 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 Pin and Pout as defined in G.697 by power monitoring points
  depicted as yellow triangles in the figures below.

Access Link monitoring process:
- Tx direction: the measured optical input power Pin 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.

Figure 6 Use case 1: Access Link monitoring
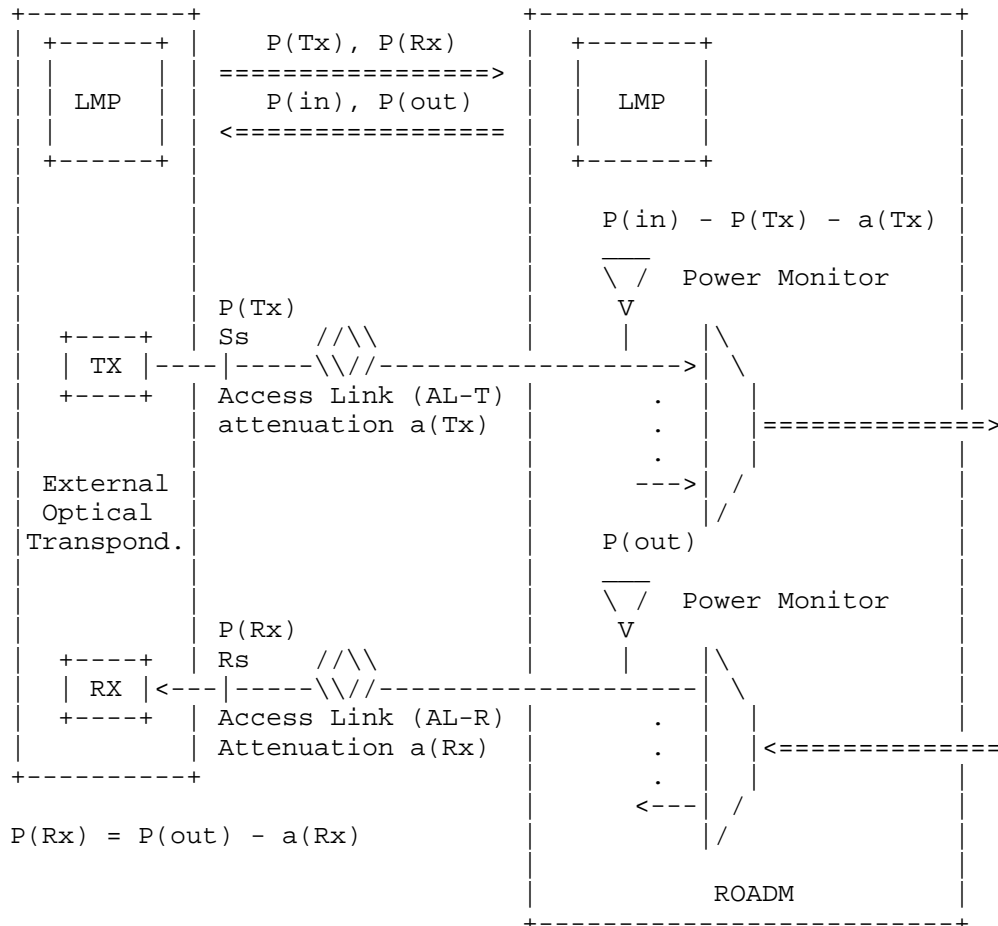

```
   +---------+                         +------------------------+
   | +------+ |     P(Tx), P(Rx)       | +-------+              |
   | |      | | ================>      | |       |              |
   | | LMP  | |    P(in), P(out)       | | LMP   |              |
   | |      | | <================      | |       |              |
   | +------+ |                        | +-------+              |
   |         |                         |                        |
   |         |                         |   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)

                      Figure 6: Extended LMP Model

5.2.2. Power Control Loop Use Case

This use case is based on the access link monitoring use case 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 5 below illustrates this use case utilizing the LMP
protocol with extensions defined in this draft.

Figure 7 Use case 2: Power Control Loop

```
    +----------+                     +-------------------------+
    | +------+ | P(Tx),P(Rx),Set(Pout)| +-------+  +--------+ |
    | |      | | ===================> | |       |  | 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)               |
    |          |                     |                        |
    |          |                     |   __                   |
    |          | P(Rx)               |   \ /  Power Monitor    |
    |  +----+  | Rs   //\\           |    V   VOA(out) |\      |
    |  | RX |<---|-----\\//--------------------<|-------| \    |
    |  +----+  | Access Link (AL-R)  |         .    | |        |
    |          | attenuation a(Rx)   |         .    | |<=======
    +----------+                     |      VOA(out) | |       |
                                     |    <--<|-------| /       |
    P(Rx) = P(out) - a(Rx)          |               |/         |
                                     |                         |
                                     |        ROADM            |
                                     +-------------------------+
```
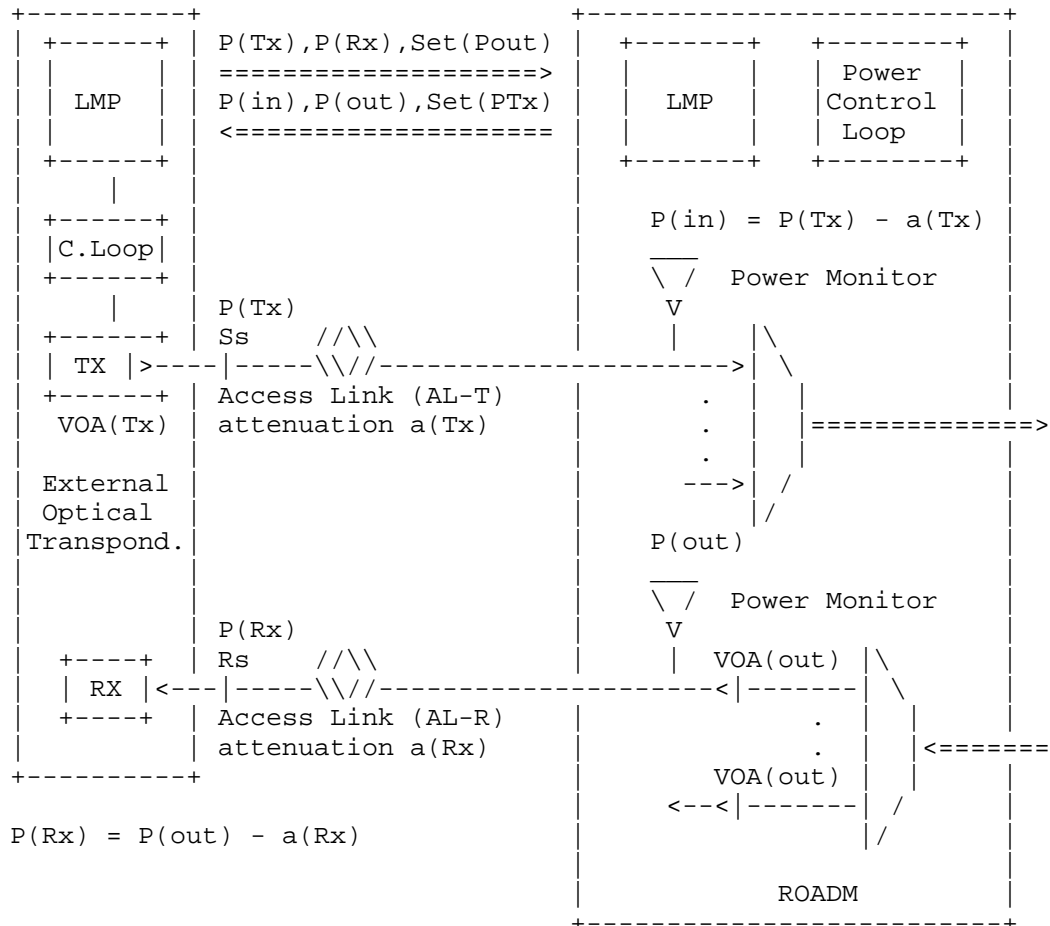
                Figure 7: Power control loop

  - The Power Control Loops in Transponder and ROADM controls
     the Variable Optical Attenuators (VOA) to adjust the proper
     power in base of the ROADM and Receiver caracteristics and
     the Access Link attenuation

6. Requirements

   Even if network architectures becomes more complex the management and
   operation as well as the provisioning process should have a higher
   degree of automation or should be fully automated. Simplifying and
   automating the entire management and provisioning process of the
   network in combination with a higher link utilization and faster
   restoration times will be the major requirements that has been
   addressed in this section.

   Data Plane interoperability as defined for example in [ITU.G698.2] is
   a precondition to ensure plain solutions and allow the usage of
   standardized interfaces between network and control/management plane.

   The following requirements are focusing on the usage of standardised
   integrated single channel interfaces but also valid in other
   environments.

   1 To ensure a lean management and provisioning process of single
      channel interfaces management and control plane of the client
      and DWDM network must be aware of the parameters of the
      interfaces and the optical network to properly setup the optical
      connection.

   2 A standardized northbound API (to network management system)
      based on Netconf must be supported, alternatively SNMP should
      be supported too.

   3 A standardized data model for single channel interfaces must be
      supported to exchange optical parameters with control/management
      plane.
   4..Netconf should be used also for configuration of the single
      channel interfaces including the setting of the power.

   5 LMP should be extended and used in cases where optical
      parameters need to be exchanged between peer nodes to correlate
      link characteristics and adopt the working mode of the single
      channel interface.

   6 Legacy operational models should be supported (parameters must
      be exchanged with the DWDM transport EMS to manage the
      configuration and the transmission of alarms and other FCAPS
      messages.

   7 LMP should be used to adjust the output power of the single
      channel DWDM interface to ensure that the interface works in
      the right range defined by the application code.

8   Parameters e.g. PRE-FEC BER should be used to trigger a FRR
    mechanism on the IP control plane to reroute traffic before
    the link breaks.

9   LMP should be used to automate the end to end connection
    setup of the optical connection.

10 Power monitoring functions at both ends of the DWDM connection
    should be implemented to further automate the setup and
    shoutdown process of the optical interfaces.

11 A standardized procedure to setup an optical connection should
    be defined and implemented in DWDM and client devices
    (containing the single channel optical interface).LMP should be
    used to ensure that the process follows the right order.

12 Pre-tested and configured backup paths should be stored in so
    called backup profiles. In fault cases this wavelength routes
    can be used to recover the service.

13 LMP should be used to monitor and observe the access link.

7. Acknowledgements

   The authors would like to thank all who supported the work with
   fruitful discussions and contributions.

8. IANA Considerations

   This memo includes no request to IANA.

9. Security Considerations

   The architecture and solution space in scope of this framework
   imposes no additional requirements to the security models already
   defined in RFC5920 for packet/optical networks using GMPLS, covering
   also Control Plane and Management interfaces. Respective security
   mechanisms of the components and protocols, e.g. LMP security
   models, can be applied unchanged.

   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 netork 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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