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A framework for Management and Control of DWDM optical interface parameters
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Abstract

To ensure an efficient data transport, meeting the requirements requested by today's IP-services the control and management of DWDM interfaces are a precondition for enhanced multilayer networking and for a further automation of network provisioning and operation. This document describes use cases, requirements and solutions 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 single channel DWDM interfaces. 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 (e.g. in routers) connected to a DWDM Network (which include ROADMs and optical amplifiers) adds a further networking option for operators allowing new scenarios but require harmonised control and management plane interaction between different network domains.

Carriers deploy their networks today based on transport und packet network infrastructures as domains to ensure high availability and a high level of redundancy. 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.

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 objective of this document is to provide a framework for the control and management of transceiver interfaces based on the corresponding use cases and requirements to ensure an efficient and optimized data transport.

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. Also, the wavelength ordering process and the process how to determine the demand for a new wavelength path through the network is out of scope.

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

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

The current generation of 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 colored interfaces change this scenario, by introducing a

standardized interface at the level of OCh between the 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

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 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], [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 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 |-|>|------|->| 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.

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 management and control plane.

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 an umbrella 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 to the 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 (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
        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. 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. Indirect connection to the DWDM management system (first optical node)

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 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 Yang
                           |
           LMP      +------+-----------------------+
       +------------+---+ +|                  +    |
       |            |   | |\                 /|    |
   +---+--+         |   +-+ \     |\         / |    |         +------+
   |  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 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 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. [RFC7689] for fixed grid signal and for flexi-grid [RFC7792]. One important aspect of the [G.698.2] is the fact that it includes 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, 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 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 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/LMP-WDM covering the parameter sets (application codes) 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 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 edges 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. 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 (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)

Furthermore following issues should be addressed:

a) The Communication between peering edge nodes using an out of band control channel. The two nodes should 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 signaling.

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. 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.

5.1. 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 Fig.4 a protocol need 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 route through tho optical network has to be found, whereby each route has

an individual set of impairments deteriorating a wavelength traveling along that route. Since a single transceiver can support multiple parameter sets, the selection of a route may limit the permissible parameter sets determined in step1.

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 route 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 towards the first control plane managed transport node a control connection may e.g. be automatically established using LMP.

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 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 route 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.

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 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 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.

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 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 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)                |
|          |                       |    ___                   |
|          |                       |    \ /  Power Monitor    |
|          | P(Rx)                 |     V                    |
|  +----+  | 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 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 DWDM interfaces.

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 standard-based northbound API (to network management system) based on Netconf should be supported, alternatively SNMP could be supported too.

3 A standard-based 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 power setting

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 LMP may be used to adjust the output power of the single channel DWDM interface to ensure that the interface works in the right range.

7 RSVP-TE may be used to exchange some relevant parameters between the client and the optical node (e.g. the label value), without preventing the network to remain in charge of the optical path computation

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

9 A standardized procedure to setup an optical connection should be defined and implemented in DWDM and client devices (containing the single channel optical interface).

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

11 LMP may be used to monitor and observe the access link.

7. Acknowledgements

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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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