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A framework for Management and Control of optical interfaces supporting G.698.2

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Abstract

This document provides a framework that describes a solution space for the control and management of optical interfaces according to the Black Link approach as specified by ITU-T [ITU.G698.2] and further revisions. In particular, it examines topological elements and related network management measures.

Optical Routing and Wavelength assignment based on WSON is out of scope. This document concentrates on the management of optical interfaces. The application of a dynamic control plane, e.g. for auto-discovery or for the distribtion of interface parameters, is complementary. Anyway, this work is not in conflict with WSON but leverages and supports related work already done for management plane and control plane.

The framework document will not address the client mapping into G.709. This document only addresses the lower layers. Furthermore, support for Fast Fault Detection, to e.g. trigger Protection Switching is provided by the WDM interface capability of the client interface (e.g. ITU-T G.709) is out of scope for this work. 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.

Status of This Memo

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1. Introduction

The usage of the Black Link approach in carrier long haul and aggregation networks adds a further option for operators to facilitate their networks. The integration of optical coloured interfaces into routers and other types of clients could lead to a lot of benefits regarding an efficient and optimized data transport for higher layer services.

Carriers deploy their networks today as a combination of transport and packet infrastructure. This ensures high available and flexible data transport. Both network technologies are managed usually by different operational units using different management concepts. This is the status quo in many carrier networks today. In the case of a black link deployment, where the coloured interface moves into the client (e.g. router), it is necessary to establish a management connection between the client providing the coloured interface and the corresponding EMS (Element Management System) of the transport network to ensure that the coloured interface parameters can be managed in the same way as traditional deployments allow this.

The objective of this document is to provide a framework that describes the solution space for the control and management of WDM Black Links as specified by ITU-T [ITU.G698.2] and further revisions. In particular, it examines topological elements and related network management measures.

Optical Routing and Wavelength assignment based on WSON is out of scope. This document concentrates on the management of optical interfaces. The application of a dynamic control plane, e.g. for auto-discovery or distribute interface parameters, is complementary. Anyway, this work is not in conflict with WSON but leverages and supports related work already done for management plane and control plane.

Furthermore, support for Fast Fault Detection, to e.g. trigger Protection Switching is provided by the WDM interface capability of the client interface (e.g. ITU-T G.709) is out of scope for this work. 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 Control and Management Plane 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 colored 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

Black Link: The Black Link [ITU.G698.2] allows supporting an optical transmitter/receiver pair of one or different vendors to inject a DWDM channel and run it over an optical network composed of amplifiers, filters, add-drop multiplexers from a different vendor. Therefore the standard defines the ingress and egress parameters for the optical interfaces at the reference points Ss and Rs. In that case the DWDM network between the two colored interfaces is also referred to as Black Link. G.698.2 provides an optical interface specification ensuring the realization of transversely compatible dense wavelength division multiplexing (DWDM) systems primarily intended for metro applications which include optical amplifiers and leads towards a multivendor DWDM optical transmission network.

Coloured Interface: The term coloured interface defines the single channel optical interface that is used to bridge long distances and is directly connected with a DWDM system. Coloured interfaces operate on a fix wavelength or within a wavelength band (tunability). Coloured interface is a generic term and relates to WDM systems in general, not just black link systems.

Friendly Wavelength: A wavelength that is managed by the DWDM System.

Alien Wavelength: A wavelength that is not managed and known by the WDM system.

Forward error correction (FEC): FEC is an important way of improving the performance of high-capacity long haul 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.870]: A physical interface within an administrative domain.

Inter-domain interface (IrDI) [G.870]: A physical interface that represents the boundary between two administrative domains.

Vendor domain: tbd.

Management Plane: Management Plane: The management plane supports FCAPS (Fault, Configuration, Accounting, Performance and Security Management) capabilities for carrier networks.

Control Plane: The control plane supports signalling, path computation, routing, path provisioning and recovery.

Client Network Layer: The client network layer is the layer above (on top) the WDM layer, from the perspective of the WDM layer.

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]

3. Solution Space for optical interfaces using a DWDM Black Link

Basically the management of optical interfaces using a Black Link deals with aspects needed for setup, tear down and maintenance of wavelengths and all related optical parameters, which are demanded by a client network layer (the layer above WDM) or by a different administrative domain. The following types of WDM networks are considered for a management of optical interfaces using a black link:

a. Passive WDM

b. Legacy point to point WDM systems

c. Legacy WDM systems with OADMs

d. Transparent optical networks supporting specific IPoDWDM functions, interfaces or protocols

Table 1 provides a list of tasks, which are related to BL management, It is indicated which domain (optical or client) is responsible for a task. The relevance of a task for each type of WDM network is also indicated.

Task	Domain	a	b	c	d
determination of centre frequency	client	R	R	R	R
configuration of centre frequency at colored IF	optical	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	client	?	?	R	R
detection of wavelength fault	optical	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 BL management

Furthermore the following deployment cases will be considered:

a. Exclusive Black Link deployment

b. Black Link deplyoment in combination with grey client network interfaces

Case b) is motivated by the usage of legacy equipment using the traditional connection as described in Figure 1 combined with the BL approach.

3.1. Description of Client Network Layer - WDM connection

3.1.1. Traditional WDM deployments

The ordinary connection of a client layer network towards a WDM system is based today on client interfaces (grey) bridging short or intermediate distances between client and WDM system. The Optical Signal incoming into the WDM system must be converted (OEO conversion) to corresponding WDM wavelength grid and the power level that is applicable for the WDM transmission path. This conversion is done by a component termed as transponder (see Figure 1).

After that OEO conversion the signal complies with the parameters that are specified for a certain WDM link.

Figure 1 shows the traditional Client - WDM interconnection using transponders for wavelength conversion. IrDI and IaDI as defined in [Section 2](#) specifying the different demarcation areas related to external and internal connections

```
            IrDI                            IaDI
             |                                |
             .                                .
             |   +----------------------------|---+
             .   |     +    WDM Domain     +  .   |
             |   |     |\                 /|  |   |
+------+     .   |     | \     |\        / |  .   |          +------+
|  CL  |-->--+---+--T/-|OM|----|/-------|OD|--+-\T+------->--| CL   |
|      |--<--+---+--T/-|  |----- /|-----|  |--.-\T+-------<--|      |
+------+     |   |     | /       \|      \ |  |   |          +------+
             .   |     |/                 \|  .   |
             |   |     +                   +  |   |
             .   +----------------------------.---+
             |                                |

        CL = Client
        T/ = Transponder
        OM = Optical Mux
        OD = Optical Demux
```

Figure 1: Inter and Intra-Domain Interface Identification

This document refers only on the IaDI Interface as specified in ITU-T G.698.2 as transversely compatible and multi-vendor interface within one administrative domain controlled by the network operator. This administrative domain can contain several vendor domains (vendor A for the DWDM sub-network, and vendors B1 and B2 at the transmitter and receiver terminal side).

The management and control of WDM and client layer is done by different control and management solutions. Different operational units are responsible for client and WDM layer.

3.1.2. Black Link Deployments

In case of a black link deployment Figure 2 the DWDM transceiver is located directly at the client and the grey interfaces will be saved. In that case a solution must be found to manage that coloured interface in the same way as in the traditional case. This requirement must be fulfilled especially in the cases where legacy equipment and Black Link Wavelength interfaces will be used in parallel or together and the operational situation is unchanged.

Figure 2 shows a set of reference points, for the linear "black-link" approach, for single-channel connection (Ss and Rs) between transmitters (Tx) and receivers (Rx). Here the WDM network elements include an OM and an OD (which are used as a pair with the opposing 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
```

from Fig. 5.1/G.698.2

Figure 2: Linear Black Link

Independent from the WDM networks that are considered the usage of colored interfaces must perform as well in mixed setups with both legacy and colored interface equipment using the BL.

4. Operational aspects using G.698 specified coloured interfaces

A Comparison of the black link with the traditional operation scenarios provides an insight of similarities and distinctions in operation and management. The following four use cases provide an overview about operation and maintenance processes.

4.1. Bringing into service

It is necessary to differentiate between two operational issues setting up a wavelength path within an optical network. The first is the preparation of the link if no optical circuit on the system exits. This configuration is then the first task of the transport management. Therefore it is necessary:

a. to define/calculate the path of the connection

b. to configure all involved network elements and

c. to verify software versions and alarms.

This task could be done manually supported by the EMS/NMS of the optical transport network or automated.

The second step is to setup the circuit. From the operation point of view it is the same task in a black link scenario and in a traditional environment. The circuit must be setup logically at first. In the traditional case, where no control plane is in use this is a task of the operational staff as well. It must be known what type of framing is used to setup the link and which nodes are involved. Furthermore it must be decided and specified if an alternative path has to be configured for protection. An additional wavelength path could be specified for protection purposes.

From this point now the operational stuff needs access to the client to configure the optical interface. The optical interface must be patched to the right ingress port of the optical transport node (e.g. ROADM or OADM/OM) and must be known in the inventory of the transport management system.

The transport staff must know for example the router name, the interface type, name and address to ensure to configure the right interface. This is needed in the transponder case as well. After configuring all parameters the connection will be monitored for a certain time period. If monitoring is successful then the connection will be announced in the IGP and is in use then.

The only difference in case of a black link scenario is that the

coloured interface that moved into the client is belongs to the optical path (creation and termination of the optical wavelength path) and must be configured ideally by the optical transport operation stuff too.

The two last steps could be automated in a case of black link setup. After patching the router towards the first transport node a management connection will be established over a different control channel using an extended UNI to exchange configuration information (see chapter xyz)

Due to the fully tuneable interfaces used in the Black Link scenario it is possible to define a second wavelength for restoration/ resilience that can be tested and stored in backup profile. In fault cases this wavelength can be used to recover the service.

4.2. Configuration Management

tbd.

4.3. In service (performance management)

tbd.

4.4. Fault Clearance

tbd.

5. Solutions managing and control the optical interface within BL sceanrios

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. Each WDM vendor provides a management system that also administrates the wavelengths.

This old operational approach was based on a high amount/rate of connection oriented traffic in carrier networks. This behaviour has been changed completely. Today IP is the dominating traffic in the network and from the operating perspective it is more beneficial to use a common management and operation approach. Due to a long history of operational separation it must be possible to manage and operate the optical interface using a Black Link with the traditional approach too.

Therefore from the operational point of view in a pure Black Link or in a mixed setup with legacy equipment (transponders) there are two

approaches to manage and operate optical interfaces.

1. Separate operation and management of client and Transport network

    a. Direct link to the management from the client system to the optical domain (e.g. EMS, OSS)

    b. Indirect link to the management system; using a protocol between the peer node and the directly connected WDM system node to exchange management information with the optical domain

2. Common operation and management of client and 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 option should be favoured if the underlying WDM transport network is mainly used to interconnect IP nodes and the service creation and restoration will be done on higher layers (e.g. IP/ MPLS). Then it is more beneficial have a higher level of integration and a common management will be more efficient.

5.1. BL Separate Operation and Management Approaches

5.1.1. Direct connection to the management system

As depicted in Figure 3 one possibility to manage the optical interface within the client is a direct connection to the management system of the optical domain. This ensures manageability as usual.

```
                    +------+
                    | OSS  |
                    |______|
                    /______/
                       |
                       |
                       |
                   +---+---+
            +------>+  EMS  |
           /        |       |
```

```
              /        +--------+
             /             | MI
       SNMP /              |               DCN Network
       --------------------+-------------------------------
          /         +-------+----------------------+
         /          |      +|     WDM Domain   +     |
        /           |      |\                 /|     |
   +---+---+        |      | \     |\        / |     |          +-------+
   |  CL   |-/C------+--- -|OM|----|/-------|OD|--- +-------/C-|  CL   |
   |       |-/C------+--- -|  |----- /|-----|  |----+-------/C-|       |
   +-------+        |      | /       \|      \ |     |          +-------+
                    |      |/                 \|     |
                    |      +                   +     |
                    +------------------------------+

          CL = Client
          /C = Coloured Interface
          OM = Optical Mux
          OD = Optical Demux
          EMS = Element Management System
          MI= Management Interface
```

Figure 3: Connecting BL on Transport Management

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

It must be ensured that the optical interface can be managed in a standardized way to enable interoperable solutions between different optical interface vendors and vendors of the optical network management software. RFC 3591 [RFC3591] defines manage objects for the optical interface type but does not cover the scenarios described by this framework document. Therefore an extension to this MIB for the optical interface has been drafted in [Black-Link-MIB]. In that case SNMP is used to exchange data between client and management system of the WDM domain.

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

5.1.2. Indirect connection to the WDM management system

The alternative as shown in Figure 4 can be used in cases where a more automated relationship between transport node and router is aspired. In that case a combination of rudimentary control plane features and manual management will be used. It is a first step into a more control plane oriented operation model.

```
                        +------+
                        | OSS |
                        |_____|
                        /_____/
                           |
                           |
                           |
                       +---+---+
                       | EMS    |
                       |        |
                       +--------+
                           | MI
                           |
                           |
           LMP(XML) +------+-----------------------+
       +------------+---+ +|                  +    |
       |            |   | |\                 /|    |
   +---+--+         |   +-+ \     |\        / |    |          +------+
   |  CL  |-/C------+--- -|OM|----|/-------|OD|--- +-------/C-|  CL  |
   |      |-/C------+--- -|  |----- /|-----|  |----+-------/C-|      |
   +------+         |     | /       \|      \ |    |          +------+
                    |     |/                 \|    |
                    |     +                   +    |
                    +------------------------------+
```

CL = Client
/C = Coloured 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 client and the direct connected node of the optical transport network LMP as specified in RFC 4209

[RFC4209] can (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.

Recently LMP based on RFC 4209 does not support the transmission of configuration data (information). This functionality has to be added to the existing extensions of the protocol. The use 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 a DCN. It is proposed to use an out of band signalling over a separate link or DCN to ensure a high availability.

5.2. Control Plane Considerations

Basically it is not mandatory necessary to run a control plane in Black Link scenarios at least not in simple black link case where clients will be connected point to point using a simple WDM infrastructure (multiplexer and amplifier). As a first step it is possible to configure the entire link using the standard management system and a direct connection of the router or client to the EMS of the transport network. Configuration information will be exchanged via a network management protocol. This could be SNMP(see sections Section 5.1.1).

Looking at the control plane the following two scenarios may be considered:

a. A control plane is only used on the packet layer, transport in further managed using a traditional management system EMS/NMS.Its called Stub-Control plane.

b. A common control plane for transport and client network; this implies a single operation unit responsible for both client and transport network management.

c. A separate control plane for client and optical network without any interaction

As mentioned in chapter Section 5.1.2 some control plane features like LMP in an enhanced version could be used.

In such simple scenario it is imaginable to use only LMP to exchange information between the nodes of the optical domain. LMP must be run between the both end-points of the link and between the edge node and the first optical network node.

5.2.1. Stub Control Plane on the packet network

Stub control plane means here that a control plane is used in the packet network only and the optical transport uses a management system for configuration. The type of control plane that is used in that case doesnt matter. It could be an IP or IP/MPLS control plane for example.

This scenario is used when no fully control plane is supported by the optical transport network. In this case an extended version of LMP for example could be used to monitor the link between transport management system and the client hosting the optical interfaces. This makes it possible to exchange configuration parameters towards the node hosting the coloured interface and on the other side send important FCAP information towards the transport management system.

An additional control plane is not needed initially. A communication channel (out of band) must be used to automate the configuration and setup process.

This model could be seen as an evolutionary step into the direction of a GMPLS Control plane and only the edge node and the first core node need to run this protocol. The wavelength that should be used by the coloured interface can be assigned manually.If the connection comes up the IGP announces it and the metric will be adapted that the link is in operation.

This horizontal communication is needed to virtually integrate the optical part of the interface towards the optical transport system keeping the status quo as today.In case of more static networks using the current paradigm of network design this model has a lot benefits. It keeps the network simple and adds some beneficial features to the network to automate the operational processes and make operation easier.

5.2.2. Deployment of a common control plane

The deployment of coloured interfaces is leading to some changes related to the control plane models and has 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 a black link deployment this UNI moves into the client that hosts the coloured interface. This means that the overlay starts at the same node that is as well part of the transport infrastructure starting and terminating the wavelength channel.

Lets differentiate between topology/signalling information that must or could be exchanged and configuration parameters needed to setup a wavelength path like wavelength, modulation scheme, FEC and other important parameters. RSVP-TE could be used for the signalling and the reservation of the wavelength path. But there is more information needed in case of a wavelength path setup. Now there are two 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)

In any case the classic overlay moves into the edge node or client and in any case of using the overlay model additional parameters need to be exchanged between edge node and optical core node. The following issues must be solved:

Communication between peering edge nodes using an out of band control channel. The two node have to exchange their optical capabilities (LMP:do we need to extend LMP in that case), FEC Modulation scheme, etc 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.

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 has not the information which wavelength must should be selected and this information must be exchanged between edge and the core node.

Other points

5.2.3. Black Link deployment with an separate control plane

tbd.

6. Requirements for BL and FW deployments

This section raises requirements from the carrier perspective and will be removed in a separate requirements draft if necessary.

6.1. Interoperability Aspects

For carrier network deployments, interoperability is a key requirement. Today it is state-of-the-art to interconnect e.g. clients from different vendors and a WDM transport system using short-reach, grey interfaces. Applying the Black Link (BL) concept, clients (e.g. routers) now become directly connected via transport interfaces which must be interoperable to each other.

```
                  <========= Black Link =========>
                   +---------------------------+
                   |   Black Link (vendor A)   |
+-----------+      |   +                   +   |      +-----------+
|CL #1      |     -+---|\                 /|---+-     | CL #2     |
|    +------+-+    |   | \   +-------+   / |   |    +-+------+    |
|  --|  Tx    |    |   |  |  |       |  |  |   |    |   Rx   |--  |
|  --|(vendor +--+-+---|OM|--  OADM  |--|OD|---+-+--+(vendor |--  |
|  --|   X)   | Ss |   |  |  |       |  |  |   | RS |   Y)   |--  |
|    +------+-+    |   | /   +-------+   \ |   |    +-+------+    |
|           |     -+---|/                 \|---+-     |           |
|(vendor B1)|      |   +                   +   |      |(vendor B2)|
+-----------+      |                           |      +-----------+
                   +---------------------------+
```

```
CL = Client
/C = Coloured Interface
OM = Optical Mux
OD = Optical Demux
        EMS= Element Management System
MI= Management Interface
```

Figure 5: Interoperability aspects

In practice, a network operator may not use five different vendors when implementing black link systems. A simplified use case could be to choose the same vendor B for the client equipment on both sides (i.e. vendor B1 = vendor B2 = vendor B) and to choose the same vendor X for the Tx and Rx (i.e. vendor X = vendor Y) thus enabling to use universal pluggable modules for the optical transmitters and receivers.

An even more simplified use case could be to choose the same vendor B for all client equipment and Tx/Rx (i.e. B = B1 = X = B2 = Y) thus having only two vendors for the whole set-up, namely vendor A and

vendor B, but to give up the possibility to use universal pluggable modules.

Other vendor combinations could also be realized (e.g. vendor X = vendor Y = vendor A).

7. Acknowledgements

The author would like to thank Ulrich Drafz for the very good teamwork during the last years and the initial thoughts related to the packet optical integration. Furthermore the author would like to thank all people involved within Deutsche Telekom for the support and fruitful discussions.

8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

This document has no requirement for a change to the security models within GMPLS, associated protocols and management interfaces. As well as the LMP security models could be operated unchanged.

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