"Definition of interface between monitors and the control plane and requirements"

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Abstract:
This document presents the schematic architecture considered in the DICONET project highlighting the location of the different interfaces and their purposes between Optical Impairment Monitor and Optical Performance Monitor (OIM/OPM) and the Control Plane and the Management Plane (CP/MP). Different use cases such as provisioning, fault localization, degradation detection, and protection are discussed and their relative messages interchanges are listed. Finally, among different interfaces protocols and management systems, we define a unified functional architecture of the interfaces as well as the databases to store the monitoring information.

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Author Name	Affiliation
Davide Careglio	UPC
Annalisa Morea	ALF
Christian Simonneau	ALF
Uri Mahlab	ECI
Siamak Azodolmolky	AIT
Yabin Ye	Huawei
Ming Chen	Huawei
Eli Dolev	ECI

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Executive summary

This deliverable presents the definition of the interfaces between Optical Impairment Monitor and Optical Performance Monitor (OIM/OPM) and the Generalized Multiprotocol Label Switching (GMPLS) control plane and the Network Management System (NMS). A schematic architecture considered in the DICONET project is presented taking into account all approaches proposed in [1]: PCE model, signalling model, routing model, and hybrid (signalling/routing) model. This schematic architecture does not try to define the DICONET architecture but its aim is to highlight the location of the different interfaces and their purposes. In particular, the Connection Controller Interface (CCI) between OIM/OPM and CP, the Network Management Interface for transport (NMI-T) between OIM/OPM and MP are considered.

An analysis on the relationships between OIM/OPM and CP/MP for different application scenarios is discussed. We try to understand when and what CP/MP and OPM/OIM communicate with each other to obtain the necessary information. More emphasis is put on the interworking between GMPLS-CP and OPM/OIM since fast actions must be triggered in the CP.

According to these scenarios, 13 use cases are defined covering several aspects: provisioning, fault localization, degradation detection, protection, restoration, network upgrading, and impairment mitigation. For each use case, the list of operations and messages interchanged is presented.

Finally, a brief background about general network management system is provided followed by the sub-system definitions and descriptions. An example of conventional network management architecture adopted in the ECI network management-network element interface is illustrated. Among these different interfaces protocols and management systems, we define a unified functional architecture of the interfaces as well as the databases to store the monitoring information.

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1. Introduction

The network architecture evolution and migration aims at improved cost economics, reduced operations effort, scalability and suitability to future services. The main drivers for this network architecture migration are: a) requirement for high bandwidth and end-to-end QoS-guaranteed connectivity and b) dynamic (on-demand) technology-independent service provisioning.

Introducing optical transparency in the optical layer can cope with such a dynamic, flexible optical layer requirements with the possibility to add extra "intelligence" in this layer. Nevertheless, transparency reduces the ability of the digital electronics layer to interact with the optical layer. As a consequence, optical transparency has an impact on network design, either by adapting the size of WDM transparent domains in order to neglect physical impact on QoT, or by introducing physical considerations in the network process (e.g. additional rules for WDM systems, or performance monitoring). Thus, measurement databases and physical constraint based algorithms will have to be developed. Similarly, new network functionalities and new management and control planes must be defined for dynamic connection management and fault monitoring.

Work package 5 (WP5) of the DICONET project aims at the implementation of the most appropriate control protocols extensions which will be used by WP6 for the testbed experiments. In fact, for fast and effective impairment aware provisioning of traffic engineering, resiliency and QoS issues supporting automated and rapid optical layer reconfiguration, there is a need to extend the standard control plane protocols. This can be done in one of the four ways in single domain networks: by signalling based approach, by routing based approach, a combination of both (hybrid approach), or by centralized Path Computation Element (PCE) [1].

The first three options consist of extending the signalling (RSVP-TE), the routing (OSPF-TE) or both of them where appropriate depending on the complexity and feasibility considerations.

In the signalling based approach, a signalling protocol such as RSVP-TE is extended. In this method the route computation is done at the source node using some routing algorithm. After the route computation, signalling protocol is used to check the physical feasibility and to select a suitable wavelength before setting up the lightpath. In this method there is no need to extend the OSPF-TE as RSVP-TE is used for physical (optical) feasibility check.

In the routing-based option, extension of the routing protocol (for example some IGP protocols such as OSPF-TE or ISIS) to carry the wavelength availability and impairments information will be considered. In this case the route is computed using some Impairment Aware Routing and Wavelength Assignment (IA-RWA) algorithm at source node and wavelength is also selected at the source node. The constraints used in this case should be related optical feasibility and hence no modifications required for RSVP-TE to check optical feasibility.

The hybrid approach is something in between routing and signalling approaches where some extensions in both RSVP-TE and OSPF-TE may be required. It tries to take the benefits of them (such as optimum resource utilization of the routing approach, high scalability of the signalling approach) while avoids their drawbacks (low scalability of the routing approach, high provisioning delay of the signalling approach).

An emerging approach is based on the PCE architecture, which is considered as a mean to meet the scalability requirements while maintaining TE support.

These approaches will be compared and evaluated in Task 2.3 of the DICONET project and best performing will be implemented in Task 5.2 and validated in the test-bed experimentations of Task 6.1.

The objective of Task 5.1 is to define the interfaces and their purposes between Optical Impairment and Optical Performance Monitors (OIMs/OPMs) and the Control and Management Plane (CP/MP). This deliverable is the result of the activities performed in this task.

Section 2 presents a schematic architecture considered in the DICONET project taking into account all approaches discussed above. This schematic architecture does not try to define the DICONET architecture but its aim is to highlight the location of the different interfaces and their purposes. In particular, the Connection Controller Interface (CCI) between OIM/OPM and CP, the Network Management Interface for transport (NMI-T) between OIM/OPM and MP are defined.

Section 3 analyses the relationships between OIM/OPM and CP/MP for seven different application scenarios: provisioning, fault localization, degradation detection, protection, restoration, network upgrading, and impairment mitigation. These scenarios were originally introduced in Deliverable D2.2 [4]. In that deliverable, for each scenario the monitoring requirements in terms of acquisition speed and accuracy are given to accomplish the DICONET goals. In this deliverable, we try to understand when and what CP/MP and OPM/OIM communicate with each other to obtain the necessary information. More emphasis is put on the interworking between GMPLS-CP and OPM/OIM since fast actions must be triggered in the CP. In particular, 13 use cases are introduced. For each use case, the list of operations and the interchanged messages are discussed and represented in a schematic figure.

Finally, Section 4 defines the structural physical parameter measures data to be sent to the CP and MP and stored in a dedicated physical parameter database. Then, it provides a brief background about general network management system followed by the sub-system definitions and descriptions. An example of conventional network management architecture adopted in the ECI network management-network element interface is illustrated. Among these different interfaces protocols and management systems, we define a unified functional architecture of the interfaces based on a middle-box. The middle-box is a software/hardware translator; its aim is to aggregate and temporarily store the information provided by the OIM/OPMs, translate any protocol to standard XML language and deliver the information to the CP/MP in continuous, periodical, or programmable time.

2. Schematic architecture

2.1 GENERAL ARCHITECTURE

Figure 2.1 presents the architecture considered in this task. The three planes are illustrated: the Transport Plane (TP), the Management Plane (MP) and the Control Plane (CP).

In this representation, the TP consists of two different Network Elements (NEs): the Optical Cross Connects (OXC) and the Amplifier Site (AS) elements. Optical Impairment Monitors (OIMs) and Optical Performance Monitors (OPMs) are installed in each OXC while only OIMs are in the amplifier site. Types of monitors must installed in the network elements, is out of scope of this task. For the purposes of this task, we only refer to generic OIM and OPM.

Two databases are available in the MP and CP:

- Traffic Engineering Database (TED) which is the common database where the network resource availability is stored.
- Physical Parameter Database (PPD) which is the additional database where the physical performance and impairment information are stored.

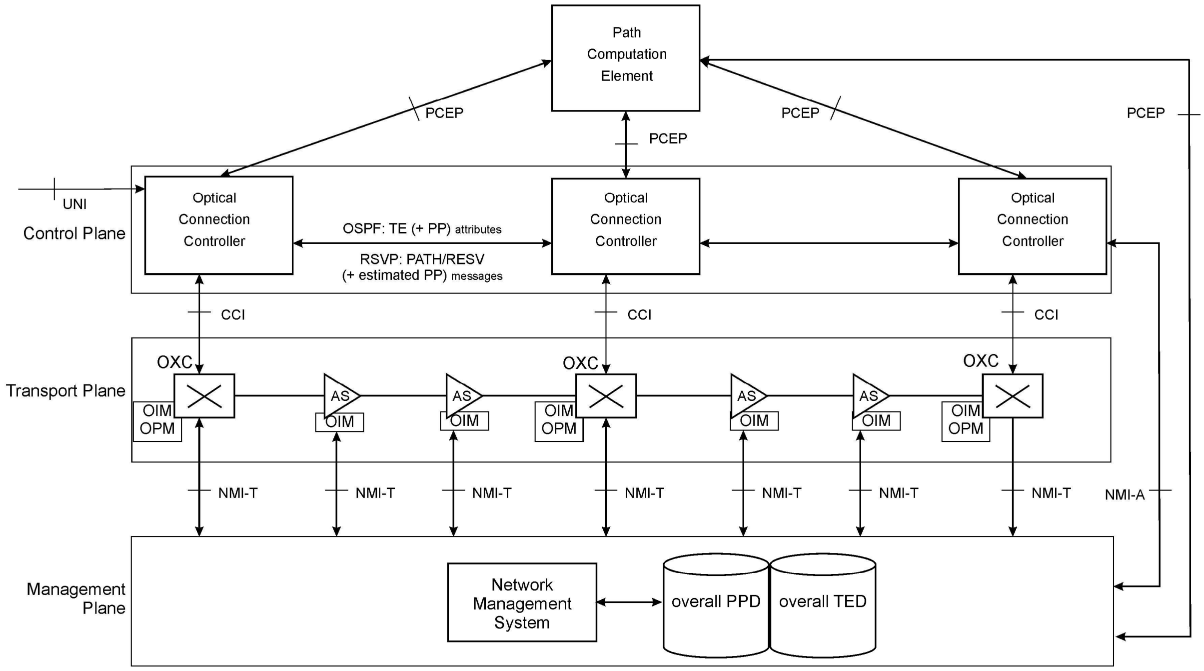


Figure 2.1: Schematic architecture for the DICONET scenario; CCI: Connection Controller Interface, NMI-T: Network Management Interface with Transport Plane, NMI-A: Network Management Interface with control plane, AS: Amplifier Site.

The Management Plane (MP) consists of a centralised Network Management System (NMS) and the global PPD and TED databases. Here *global* means that all information on the status of the network and of the network elements is stored.

A Network Management Interface for the control plane network (NMI-A) interconnects the MP and the CP. This interface is used to exchange provisioning requests and reports as well as alarm information between both planes [2]. Control plane nodes issue spontaneous notifications to report to the NMS any significant event that has occurred in the network. The NMS uses these messages to keep a consistent and complete view of the status of the network.

This is because the NMS requires to knowing exactly the correct behaviours of any network elements and, consequently, the status of the monitors, a ***Network Management Interface for the Transport network*** (NMI-T) connects any monitor in TP to the NMS. Section 4 defines this interface to transfer the monitors' states to NMS.

The Control Plane (CP) consists of several Optical Connection Controllers (OCCs) -one for each OXC-. It contains (see Figure 2.2):

- a Link Resource Management (LRM), which is responsible for the CP local link connection inventory and OCC configuration;
- a Connection Controller (CC), which is responsible for establishing connections across a domain;
- a Routing Controller (RC), which is responsible for providing paths between two nodes in the network. RC obtains the network status from the TED and PPD databases;
- a Call Controller (CallC), which is responsible for providing a service across the network.
- a Q-Tool (QT) which is an additional block in the OCC and is responsible to determine and compute the physical performance by means of analytical models [8].

A ***Connection Controller Interface*** (CCI) connects the OXCs and the monitors in TP to the CP. On the contrary to the MP, the amplifier sites do not interwork directly with the CP. This is because the functionalities of CP concerns automatic decisions (routing, re-routing, protection, failure notification, etc.) that only involve the OXCs.

Each OCC has its own TED and PPD databases. While TED stores global information on the network resource availability, PPD could store global, estimated or local physical performance information according to the approach applied (routing, signalling, or hybrid routing/signalling).

According to the GMPLS-CP, the control links between the OCCs transport the following information:

- Routing protocol information: the Traffic Engineering (TE) attributes in the Opaque Link State Advertisement (OLSA) messages for the dissemination of the resource availability
- Signalling protocol information: the PATH/RESV messages for the path establishment process.

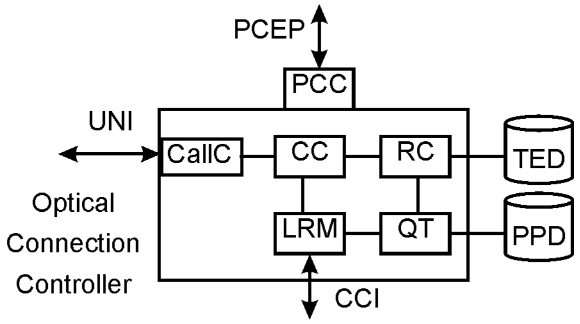


Figure 2.2: Building blocks of the Optical Connection Controller (OCC); CallC: Call Controller, CC: Connection Controller, RC: Routing Controller, LRM: Link Resource Management, QT: Q tool

To take into account the physical layer information we could either add this information to the routing protocol, to the signalling protocol or to both protocols. In this context:

- In the routing approach, Physical Parameter (PP) attributes are added to the LSA messages;

- In the signalling approach, each OCC calculates the PP according to an analytical model and current local status; the obtained estimated PP values are added to the PATH/RESV messages.

Finally, Figure 2.1 also includes the Path Computation Element (PCE) approach. It consists of one (or more) external element (the PCE) in charge of computing the paths. In this case, a PCE communication Protocol (PCEP) communicates between PCE and the Path Computation Clients (PCCs) available in the MP and in the OCCs. When a new path must be setup (either automatically in the CP or manually in MP), a request is sent to the PCE, which computes the path and replies to the client. A copy of the global TED and PPD databases could be necessary in the PCE to speed up the computation process. The Q tool could be also sited here if necessary (the decision is let for further study in Task 2.3). See Figure 2.3 for the detailed PCE block.

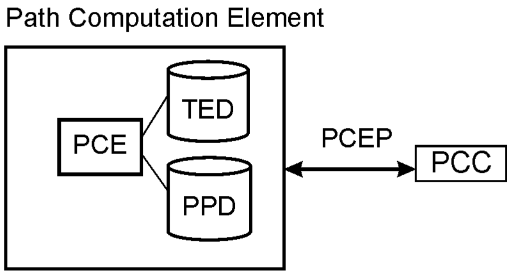


Figure 2.3: Building blocks of the Path Computation Element (PCE); PCEP: Path Computation Element communication Protocol, PCC: Path Computation Client

2.2 ARCHITECTURE WITH HARDWARE ACCELERATOR

In CP, the Hardware Accelerator (HWA) will deploy parallel programmable logic with embedded multi-processor to execute time critical processes in RC, CC and PCC in order to speed up the impairment-aware forwarding and path selection, mechanism as well as dissemination of the impairment information and fault localization and detection. Benefit and necessity of hardware accelerator for control and management of network has been shown in previous studies [5].

Furthermore, the HWA will accelerate the processing of proposed Extensible Markup Language (XML) message (in Section 4) forwarded by either GMPLS or NMS to exchange message between hardware monitors and control plane. The effect of the accelerating XML message process (40X speed up) has been proved in [6][7].

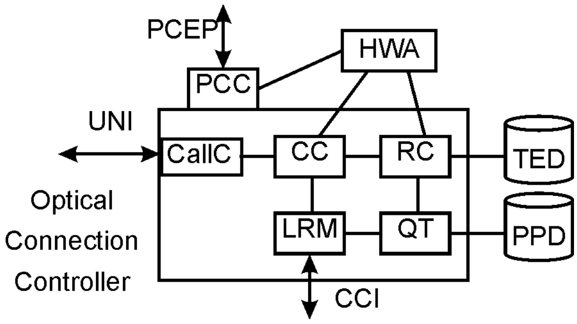


Figure 2.4: OCC with the external Hardware Accelerator (HWA).

3. Definition of use cases

In the DICONET project, we need to extend GMPLS control plane models with intelligent impairment aware routing and wavelength assignment algorithms which automatically consider the effects of high-speed transmission impairments when setting up a lightpath. To do that the control plane needs to know the physical impairment information. Therefore we need to define the interface between GMPLS-CP and optical impairment monitors so that the control plane can get the impairment information from this interface to compute the right route.

In the following section we will give some analysis on the relationships between optical layer monitoring and control plane for different application scenarios and try to understand when and what control plane and OPM/OIM communicate with each other to obtain the necessary information. More emphasis is put on the interworking between GMPLS-CP and OPM/OIM since fast actions must be triggered in the CP.

3.1 APPLICATION SCENARIOS

3.1.1 *Provisioning*

QoS-aware service provisioning is one of the most important applications for CP/MP integrated with optical layer monitors. Optical impairment information could be fed to CP/MP for setting up a lightpath that can meet the signal quality requirement.

Three types of connections can be usually setup in an optical network: permanent, soft-permanent or switched connection.

The MP is directly involved in case of permanent connection since the NMS is the entity in charge of configuring the path in the network. Two approaches can be followed:

- **(Use case 1)** NMS may allow a manual configuration of the path; in such a case it must verify the end-to-end signal quality performance by means of OPM and also the link performance by means of OIMs.
- **(Use case 2)** NMS may use the PCE to calculate an optimal path. PCE needs the optical impairment performance information between the source and destination nodes to verify if the lightpath can meet the signal quality requirement.

The soft-permanent connection consists of a permanent connection at the source user-to-network side, a permanent connection at the destination user-to-network side, and a switched connection within the network. NMS typically initiates the establishment of the switched connection by communicating with the ingress node that initiates the switched connection. The latter then sets the connection using the automatic and distributed GMPLS signalling protocol. In such a case, the CP is in charge of the verification of the signal quality performance. To compute the path, CP may use the routing controller of the ingress node **(Use case 3)** or the PCE **(Use case 4)**. NMS obtains path configuration after the establishment of the switched connection and configures the rest of the soft-permanent connection.

In the case of switched connection, CP is entirely involved in the process and notifies the path configuration to the NMS only to keep a consistent and complete view of the status of the network. Again, to compute the path, CP may use the routing controller of the ingress node **(Use case 5)** or the PCE **(Use case 6).**

LMP may contribute to auto-discovery. Task T5.2.1 of the DICONET project will decide whether extensions to LMP are necessary. If needed, LMP extensions/modifications are required to use the impairment information obtained from the monitors.

3.1.2 Fault Localization

After a failure happens, through the interface between monitors and GMPLS-CP, OIMs can notify the GMPLS-CP the failure entities in the network, which can help to localize exactly the link where the failure happens. This can increase the resource utilization, speed up the lightpath restoration and help to avoid the failure area during the lightpath provisioning (**Use case** 7).

In a less restrictive time requirement, an alarm in the MP must be activated. In this case, the MP must be also able to exactly localize the site of the failure. It could be in the OXC site, in the amplifier site, or in a link span between two sites. According to the failure type, a maintenance or replacement of the failed device must be performed.

3.1.3 Degradation Detection

Similar to fault detection and localization, the signal degradation sources should also be detected and located **(Use case 8)**. When the degradation level exceeds certain threshold, protection (or restoration) may be triggered.

If the signal degradation is not severe enough to influence the service and trigger protection or restoration, through the interface, monitors can inform GMPLS-CP the degradation sources and places, and the control plane can either mitigate the impairments by tuning some compensation devices or find a route round this area during the lightpath provisioning **(Use case 9)**.

3.1.4 Protection

In optical networks, when a failure occurs, it needs to be detected by monitors at the layer closest to the failure, i.e. the physical (optical) layer. After the failure is detected, protection is automatically triggered at data plane to protect the disrupted lightpaths. For this application scenario, through the interface between monitors and GMPLS control plane (GMPLS-CP), the optical performance monitors should be able to notify the GMPLS-CP about the changed status in the network, including the disrupted (tore down) lightpaths and the signal quality of the new lightpaths **(Use case 10)**.

A similar case should be triggered in case of degradation detection. The difference here is that the protection may not involve all paths crossing the degraded devices but only a number of paths sufficient to reestablish the correct behavior (degradation level above a given threshold) **(Use case 11)**.

Once the new configuration is achieved, it must be notified to the NMS through the NMI-A interface.

3.1.5 Restoration

For this application scenario, through the interface, OPM/OIM can help to detect and localize the failure and the control plane can obtain the fault information for accurate recovery. Once the failure has been localized, the control plane can start the restoration procedure including finding new routes for the disrupted lightpaths and calculating the signal quality. Compared with service provisioning, the restoration may need a faster monitoring data for faster restoration than provision. The time can vary from hundreds of milliseconds to several seconds depending on requirements from different customers **(Use case 12)**.

The CP may use the PCE to compute the path for restoring the lightpath **(Use case 13)**.

As for the protection scenario, once the new configuration is achieved, it must be notified to the NMS through the NMI-A interface.

3.1.6 Impairment Mitigation

As mentioned in DICONET D2.1, to improve the availability of successful impairment-aware lightpath routing, control plane should consider the compensation devices when setting up or rerouting lightpath. When the service degrades due to some factors like power, CD or PMD, etc., control plane should also know the degradation sources and their potential reason for optimizing the service lightpath.

Control plane has no capability to judge how to adjust the tuneable compensation devices for the physical impairment parameters. Assume there is an element who can judge how to adjust the compensation devices, control plane may carry the impairment parameters along a lightpath and the tuneable range supported by the compensation devices to it and the element can decide the right actions for the tuneable compensation devices. From this element, control plane again carries the adjustment information to the right tuneable compensation devices.

The impairment mitigation activity may occur in the service provision phase or restoration phase or maintenance phase after lightpath establishment. We should define the interface between optical layer monitors and control plane to collect the adjustable parameter range and impairment degrading information from optical layer and configure the compensation parameters in the optical layer.

3.1.7 Network Upgrading

For this application scenario, the monitored parameters can be integrated into the impairment modelling to estimate channel performance for network upgrading computation by some network planning tool. But from the perspective of control plane, the only potential relation between network planning tool and the control plane may be that network planning tool may output some parameters (e.g., ERO) to control plane for establishment of lightpath, thus there is no need for control plane to do anything special for this application scenario.

3.2 INTERACTIVE ACTIONS BETWEEN OPM/OIM AND CP

Based on the above application scenarios and also the specifications of the interface and extensions between OPM and GMPLS-CP (available in D2.2) [4], we have summarized the interactive actions between OPM/OIM and CP (see table 5.2 in D2.2). These interactions may occur in different situations.

3.2.1 Initialization

When control plane initializes or re-starts, control plane has no information about OIM/OPM. At this moment, control plane needs to send initiative command to OIM/OPM to inquiry the impairments information.

When OIM/OPM gets online from offline, control plane may have out-of-date information about OIM/OPM. At this moment, OIM/OPM should automatically report the impairments information.

3.2.2 Periodical Report

For reliability, OIM/OPM should report the impairments information to control plane periodically. The period can be a policy issue or can be configured by NMS.

3.2.3 Triggered Report

Some impairment parameters may change with time or lightpathes established or deleted, so we can define some thresholds, when parameters vary more than these thresholds, OIM/OPM should report the new impairment parameters to control plane.

3.2.4 *Real-time Report*

As we know, OIM/OPM can help to detect and localize the failure and the control plane can obtain the fault information for accurate recovery. For fast recovery OIM/OPM should report the failure or degradation as soon as possible.

3.3 DEFINITION OF USE CASES

In this section, we present the specific interactions between OIM/OPM and CP/NMS for the use cases defined in Section 3.1.

Use case code:	UC#1
Name:	Permanent connection provisioning
Goal	Establishing a lightpath from node A to B
Actors:	Network Manager
Systems components:	Network Management System (NMS)
Pre-condition:	Global PPD and TED databases are synched and stable (periodical reports).
Post-conditions:	Network management system updates its user interface to inform the network manager of the result of his/her request. PPD and TED databases are updated accordingly.
Trigger:	Network manager requests the NMS for lightpath establishment.

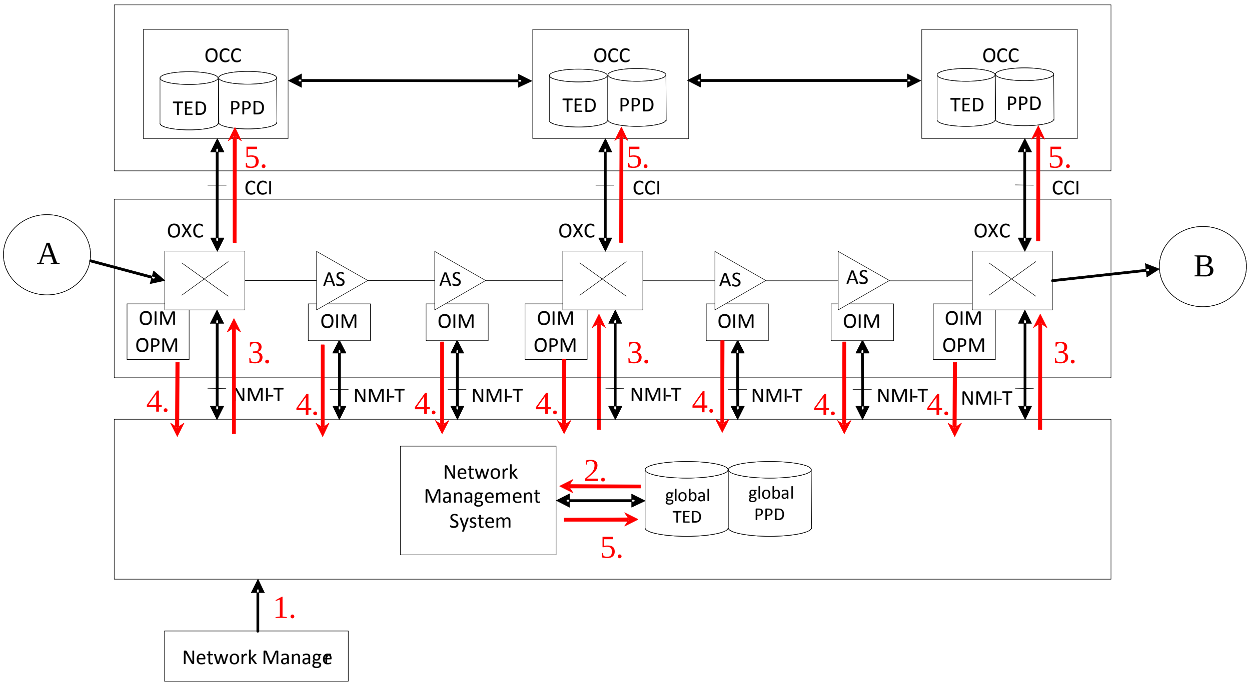


Figure 3.1: UC#1, permanent connection.

Steps:

1. Network manager interact with the NMS to establish a permanent connection between two clients connected to node A and B.
2. NMS (manually) computes a lightpath (working and backup) from node A to B.
3. NMS configures the lightpath (via NMI-T interfaces) from node A to B.
4. A verification of the end to end signal quality may be required.
5. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the NMS are also updated via NMI-T interface.

Use case code:	UC#2
Name:	Permanent connection provisioning
Goal	Establishing a lightpath from node A to B
Actors:	Network Manager
Systems components:	Network Management System (NMS) Path Computation Element (PCE)
Pre-condition:	Global PPD and TED databases are synched and stable (periodical reports).
Post-conditions:	Network management system updates its user interface to inform the network manager of the result of his/her request. PPD and TED databases are updated accordingly.
Trigger:	Network manager requests the NMS for lightpath establishment.

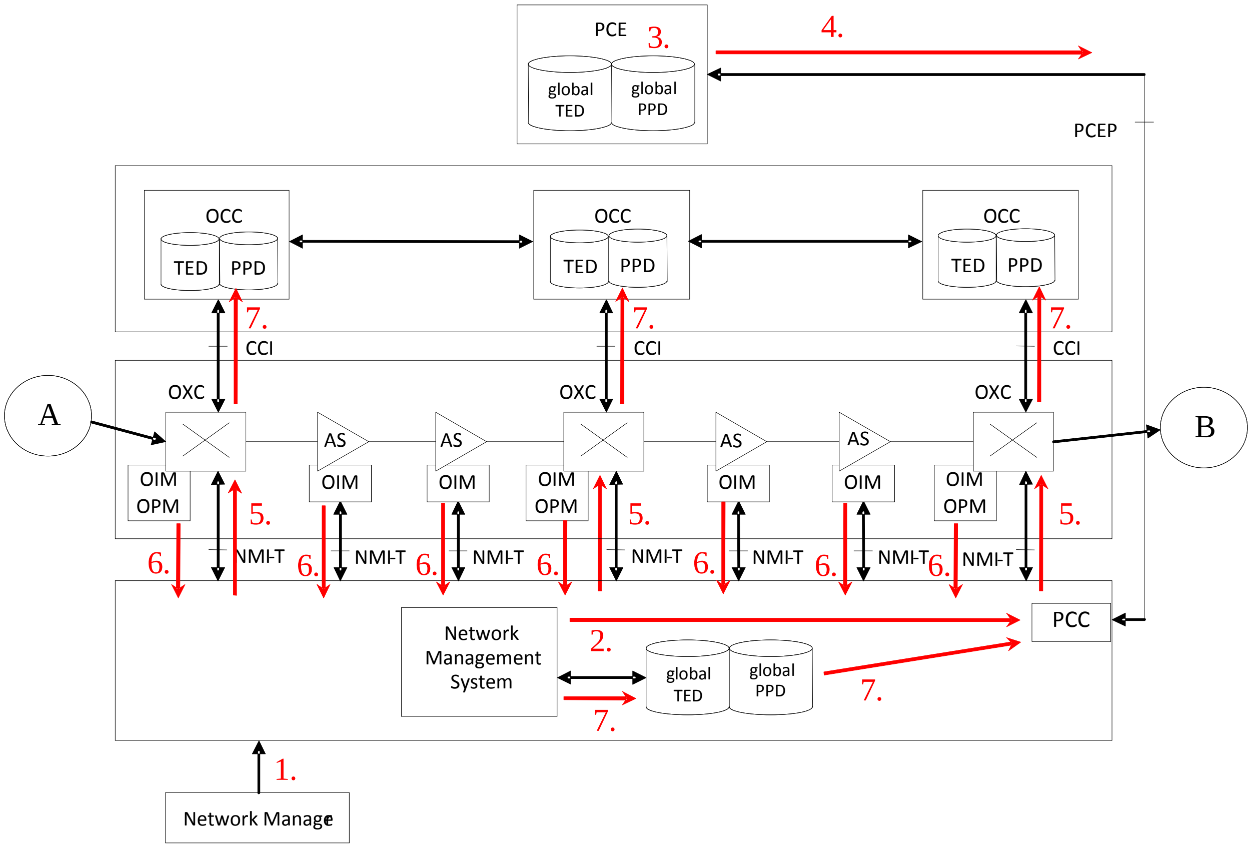


Figure 3.2: UC#2, permanent connection with support of PCE to compute the path.

Steps:

1. Network manager interact with the NMS to establish a permanent connection between two clients connected to node A and B.
2. NMS interacts with the PCE (via PCEP protocol) asking to compute a path from A to B.
3. PCE utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a path (working and backup) from A to B.
4. PCE interacts with NMS (via PCEP interface) to provide the computed path between nodes A and B.
5. NMS configures the lightpath (via NMI-T interfaces) from node A to B.
6. A verification of the end to end signal quality could be required.
7. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the PCE are also updated via PCEP protocol. Nodes and OIM/OPM components also update the global TED and PPD via NMI-T interface.

Use case code:	UC#3
Name:	Soft-permanent connection provisioning
Goal	Establishing a lightpath from node A to B
Actors:	Network Manager
Systems components:	Network Management System (NMS) Control Plane (e.g. GMPLS)
Pre-condition:	Local PPD and TED databases in the OXCs are synched and stable utilizing the proper extensions to the signalling and/or routing protocols inside the control plane (periodical reports).
Post-conditions:	Network management system updates its user interface to inform the network manager of the result of his/her request. PPD and TED databases are updated accordingly.
Trigger:	Network manager requests the NMS for lightpath establishment.

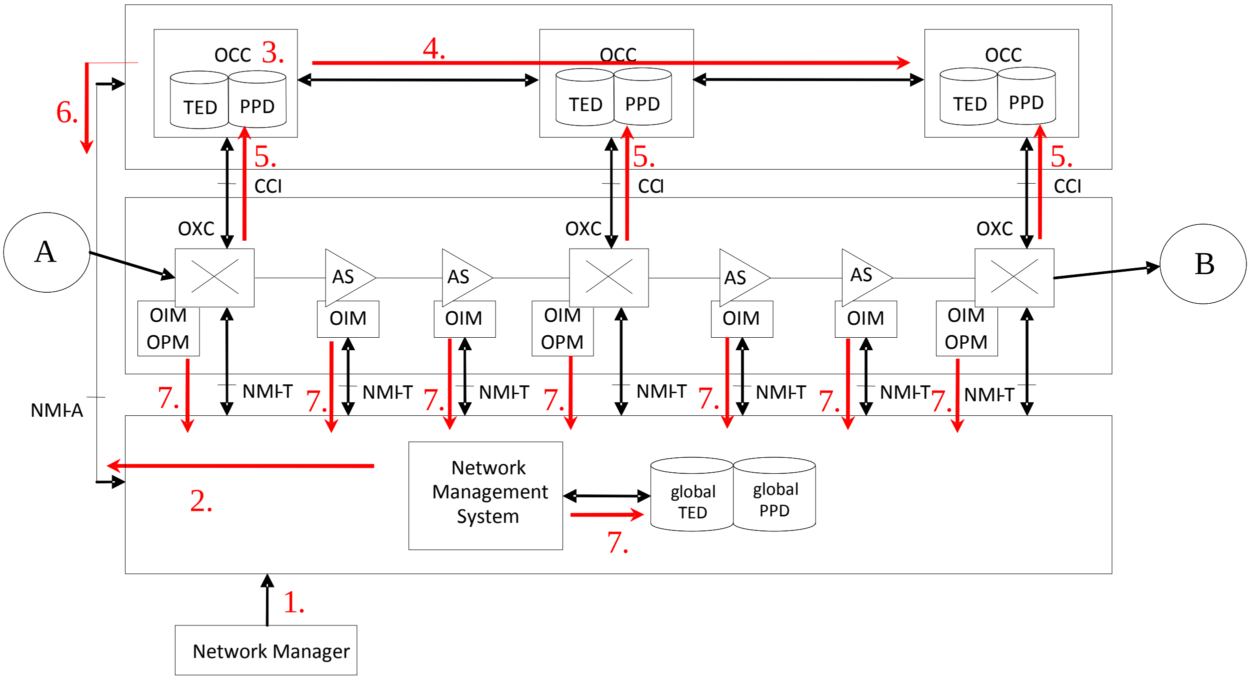


Figure 3.3: UC#3, soft-permanent connection.

Steps:

1. Network manager interact with the NMS to establish a soft-permanent connection between two clients connected to node A and B.
2. NMS interacts with the control plane of the ingress node (via NMI-A interface).
3. Control plane at the ingress node utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a path (working and backup) from node A to B.
4. The control plane signalling procedure reserve the lightpath from node A to B.
5. A verification of the end to end signal quality could be required.
6. The control plane notifies the lightpath establishment to the NMS.
7. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the NMS are also updated via NMI-T and NMI-A interfaces.

Use case code:	UC#4
Name:	Soft-permanent connection provisioning
Goal	Establishing a lightpath from node A to B
Actors:	Network Manager
Systems components:	Network Management System (NMS) Path Computation Element (PCE) Control Plane (e.g. GMPLS)
Pre-condition:	Global PPD and TED databases are synched and stable in the PCE. Local PPD and TED databases in the OXCs are synched and stable utilizing the proper extensions to the signalling and/or routing protocols inside the control plane (periodical reports).
Post-conditions:	Network management system updates its user interface to inform the network manager of the result of his/her request. PPD and TED databases are updated accordingly.
Trigger:	Network manager requests the NMS for lightpath establishment.

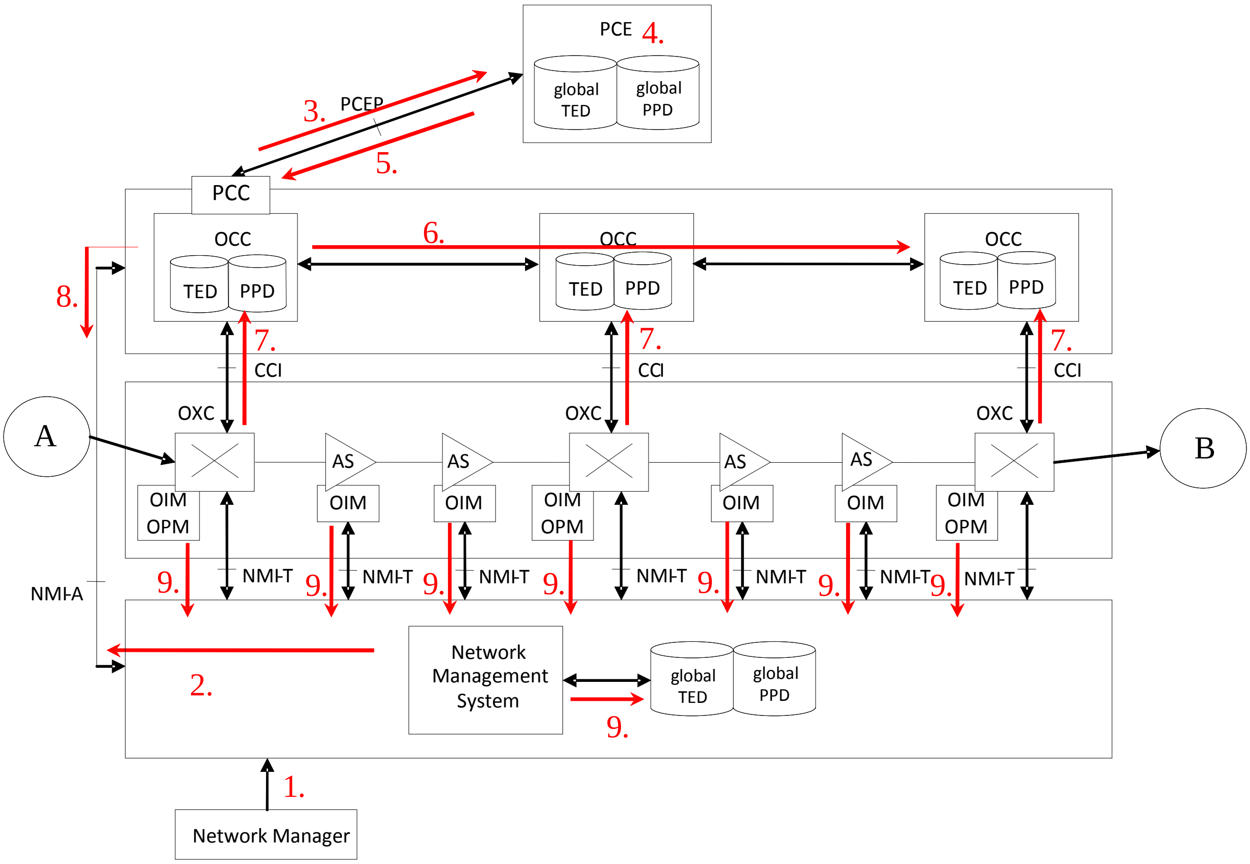


Figure 3.4: UC#4, soft-permanent connection with support of PCE to compute the path.

Steps:

1. Network manager interact with the NMS to establish a soft-permanent connection between two clients connected to node A and B.
2. NMS interacts with the control plane of the ingress node (via NMI-A interface).
3. Control plane at the ingress node requests the path computation to the PCE (via PCEP interface)
4. PCE utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a path (working and backup) from node A to B.
5. PCE forwards the path to the control plane of the ingress node.
6. The control plane signalling procedure reserve the lightpath from node A to B.

7. A verification of the end to end signal quality could be required.
8. The result of the path establishment is sent to the NMS which then completes the soft-permanent connection.
9. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the PCE are also updated via PCEP protocol. Nodes and OIM/OPM components also update the overall TED and PPD via NMI-T interface.

Use case code:	UC#5
Name:	Switched connection provisioning
Goal	Establishing a lightpath from node A to B
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) Network Management System (NMS)
Pre-condition:	Local PPD and TED databases in the OXCs are synched and stable utilizing the proper extensions to the signalling and/or routing protocols inside the control plane (periodical reports).
Post-conditions:	PPD and TED databases are updated accordingly. Network management system updates its user interface to inform the network manager of the new configuration.
Trigger:	GMPLS automatically requests the lightpath provisioning.

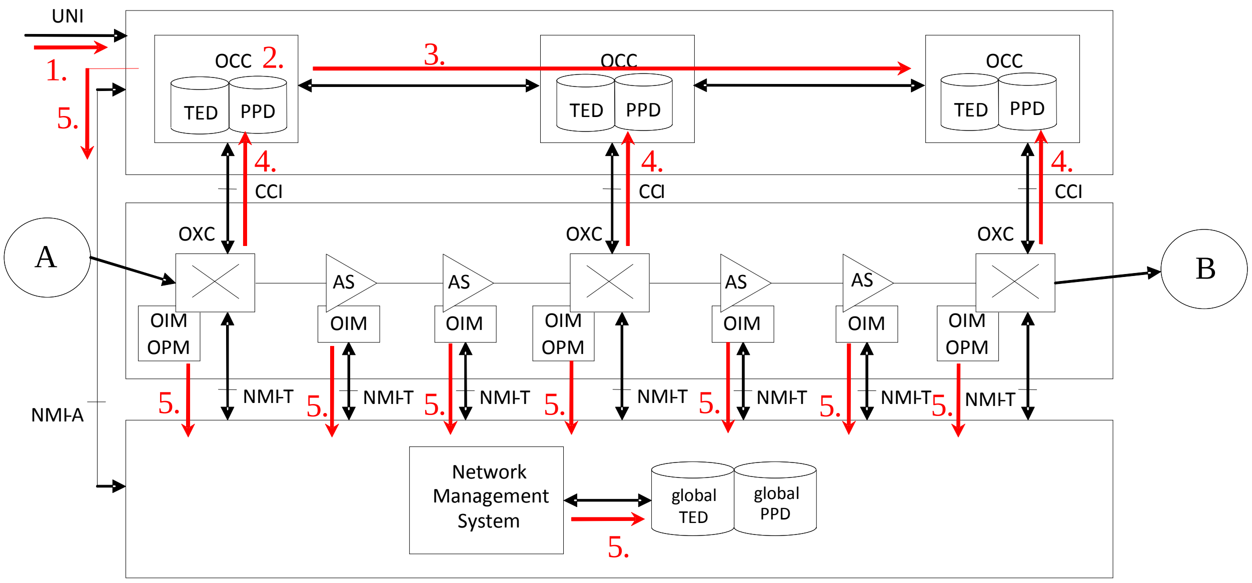


Figure 3.5: UC#5, switched connection.

Steps:

1. Some event (e.g., traffic overload) in the network generates a request to establish a switched connection between node A and B.
2. Control plane at the ingress node utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a path (working and backup) from node A to B.
3. The control plane signalling procedure reserve the lightpath from node A to B.
4. A verification of the end to end signal quality could be required.
5. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the NMS are also updated via NMI-T and NMI-A interfaces.

Use case code:	UC#6
Name:	Switched connection provisioning
Goal	Establishing a lightpath from node A to B
Actors:	Control plane
Systems components:	Network Management System (NMS) Path Computation Element (PCE) Control Plane (e.g. GMPLS)
Pre-condition:	Global PPD and TED databases are synched and stable in the PCE. Local PPD and TED databases in the OXCs are synched and stable utilizing the proper extensions to the signalling and/or routing protocols inside the control plane (periodical reports).
Post-conditions:	PPD and TED databases are updated accordingly. Network management system updates its user interface to inform the network manager of the new configuration.
Trigger:	GMPLS automatically requests the lightpath provisioning.

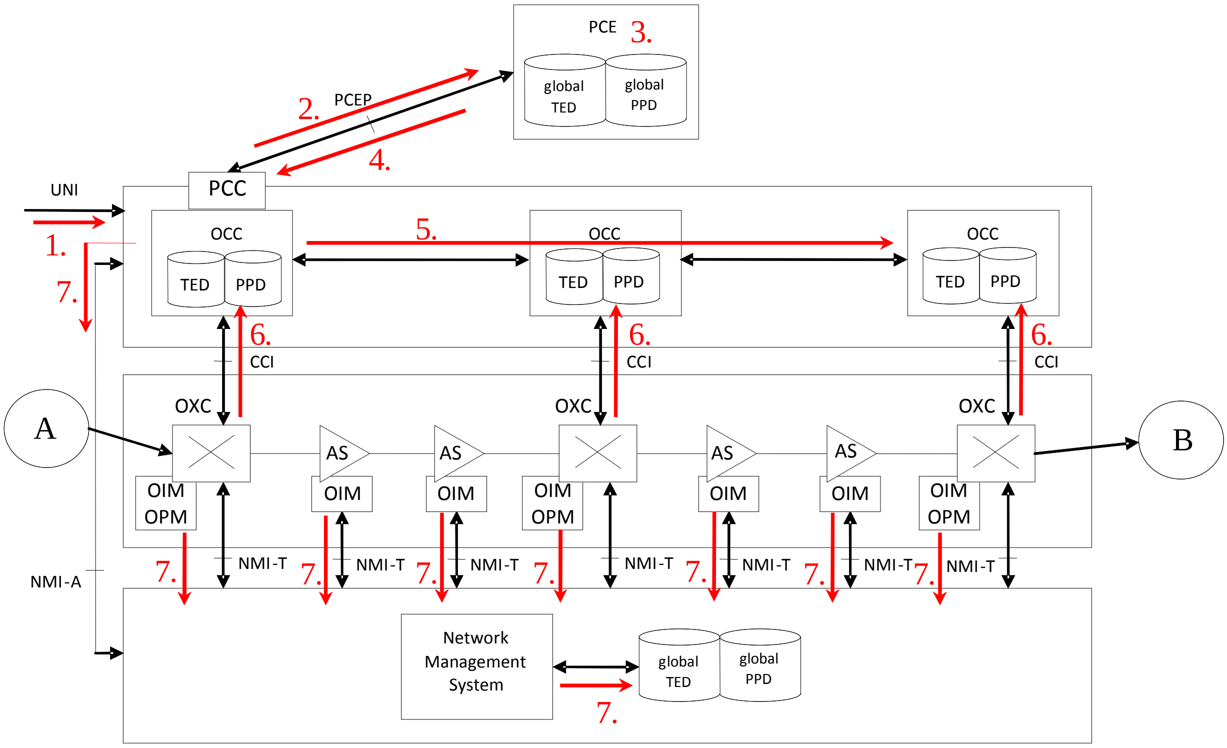


Figure 3.6: UC#6, switched connection with support of PCE to compute the path.

Steps:

1. Some event (e.g., traffic overload) in the network generates a request to establish a switched connection between node A and B.
2. Control plane at the ingress node requests the path computation to the PCE (via PCEP interface).
3. PCE utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a path (working and backup) from node A to B.
4. PCE forwards the path to the control plane of the ingress node.
5. The control plane signalling procedure reserve the lightpath from node A to B.
6. A verification of the end to end signal quality could be required.
7. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the PCE are also updated via PCEP protocol. Nodes and OIM/OPM components also update the global TED and PPD via NMI-T interface.

Use case code:	UC#7
Name:	Fault localization
Goal	A failure occurs in the network, it must be localized and protection/restoration must be triggered if some lightpaths are involved.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Network Management System (NMS)
Pre-condition:	OIMs in the failure site are working correctly.
Post-conditions:	The protection (#UC10) or restoration (#UC11/#UC12) is triggered. The failed device must be replaced or repaired.
Trigger:	An OIM device issues a trap to the CP and to the NMS, reporting a failure (triggered or real-time reports).

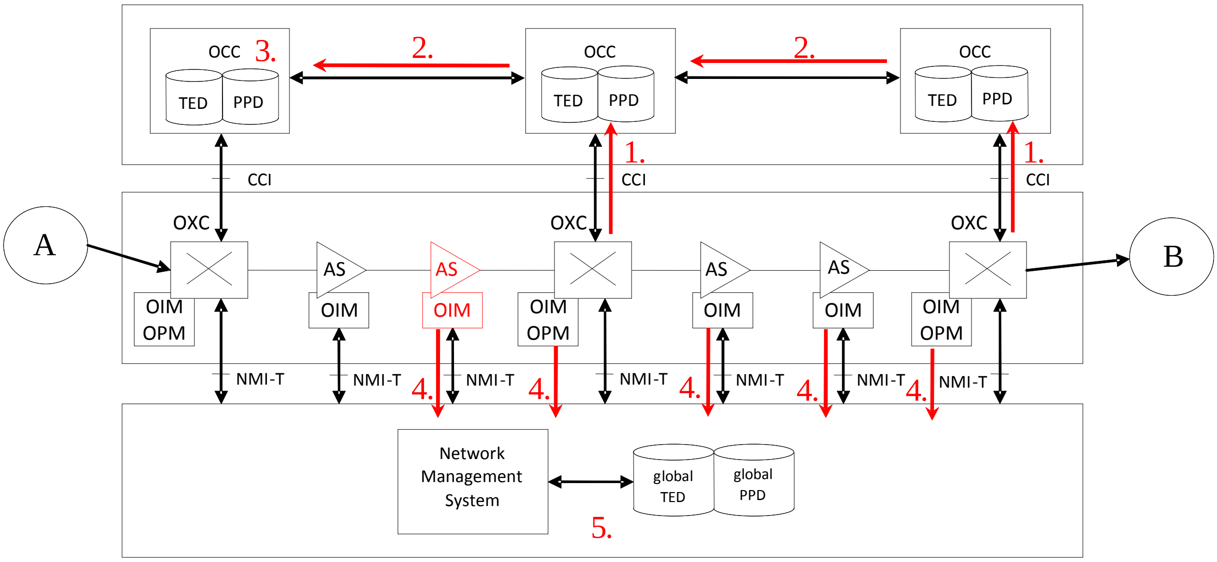


Figure 3.7: UC#7, failure localization in the CP.

Steps:

1. OIM devices issue a trap to the Control plane reporting a failure in the link or interface in some site between node A and B.
2. Control plane notifies the failure to all nodes
3. Control plane triggers the protection or restoration of all lightpaths crossing the failed site.
4. An alarm in the NMS indicates the exact location of the failure.
5. The failed device must be replaced or repaired.

Use case code:	UC#8
Name:	Degradation detection
Goal:	Degradation is detected in the network and its level exceeds a given threshold, it must be localized and protection/restoration must be triggered if some lightpaths are involved.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Network Management System (NMS)
Pre-condition:	OIMs in the degraded site are working correctly.
Post-conditions:	The protection (#UC10) or restoration (#UC11/#UC12) is triggered. The degraded device must be replaced or repaired. PPD database is updated accordingly
Trigger:	An OIM/OPM device issues a trap to the CP and to the NMS, reporting a degradation change (periodical or real-time reports).

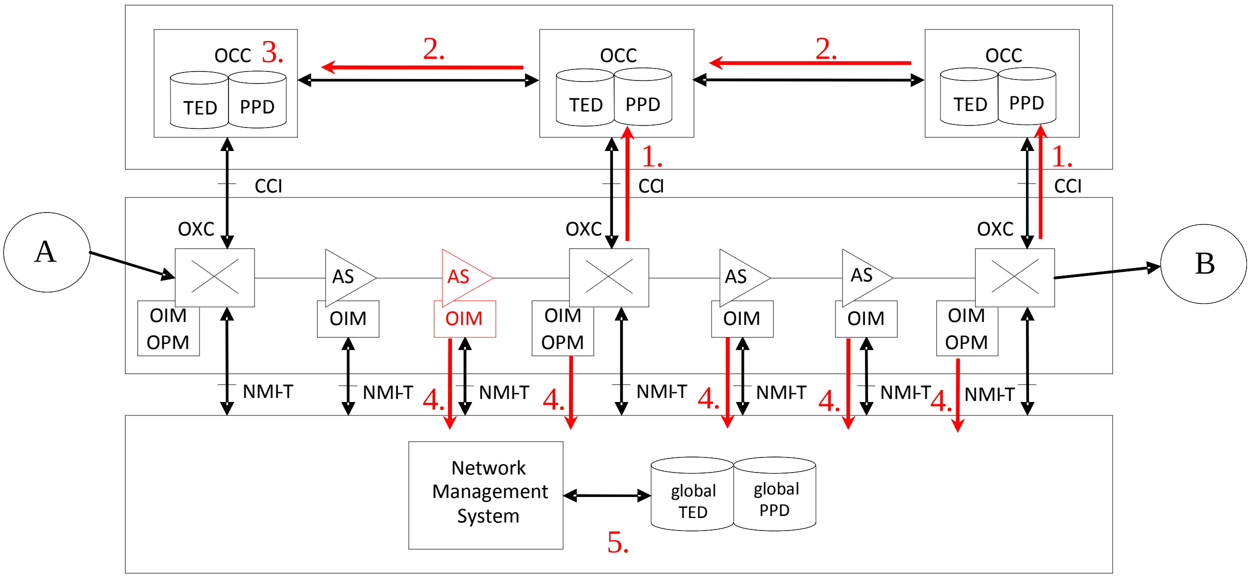


Figure 3.8: UC#8, degradation level exceeds a given threshold.

Steps:

1. OIM devices issue a trap to the Control plane reporting a degradation change in the link or interface in some site between node A and B.
2. Control plane checks the degradation level and, if it exceeds a given threshold, notifies the degradation problem to all nodes.
3. Control plane triggers the protection or restoration of some or all lightpaths crossing the degraded site.
4. An alarm in the NMS indicates the exact location of the degradation problem.
5. The degraded device must be replaced or repaired.

Use case code:	UC#9
Name:	Degradation detection
Goal:	Degradation is detected in the network, but its level does not exceed a given threshold. It could trigger the element in charge of impairment mitigation and compensation.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Network Management System (NMS) Impairment mitigation and compensation element
Pre-condition:	OIMs in the degraded site are working correctly.
Post-conditions:	The degraded device must be readjusted, repaired or replaced. PPD database is updated accordingly
Trigger:	An OIM/OPM device issues a trap to the CP and to the NMS, reporting a degradation change (periodical or real-time reports).

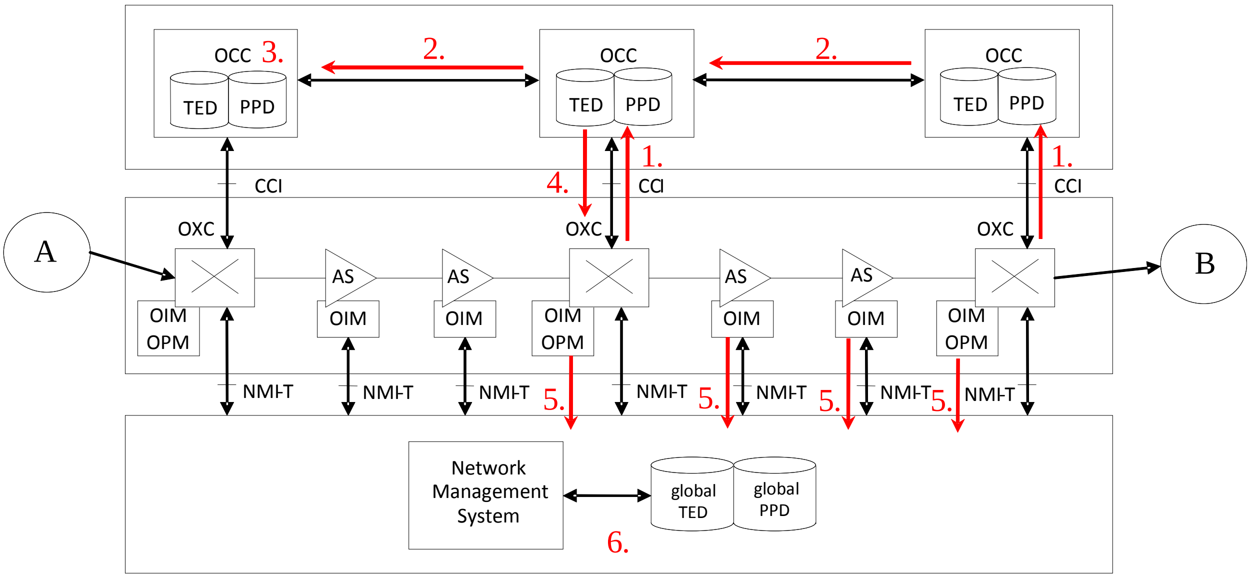


Figure 3.9: UC#9, degradation level not exceeding a given threshold.

Steps:

1. OIM devices issue a trap to the Control plane reporting a degradation change in the link or interface in some site between node A and B.
2. The control plane checks the degradation level and, if it does not exceed a given threshold, notifies the degradation change to all nodes.
3. If exist, the control plane triggers the element in charge of impairment mitigation and compensation.
4. The degraded device could be automatically readjusted.
5. If not exist or the problem cannot be solved, an alarm activates in the NMS indicating the location of the degraded device.
6. In such a case, the degraded device can be manually readjusted, repaired or replaced.

Use case code:	UC#10
Name:	Protection
Goal:	A currently established lightpath from node A to B is switched to backup path.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Network Management System (NMS)
Pre-condition:	Local PPD and TED databases are stable and update. A failure triggers the protection. A backup path is available.
Post-conditions:	PPD and TED databases are updated accordingly. Network management system updates its user interface to inform the network manager of the new configuration. The failed device must be replaced or repaired.
Trigger:	A failure in the link or interface between node A and B is detected in node A. GMPLS triggers the automatic protection.

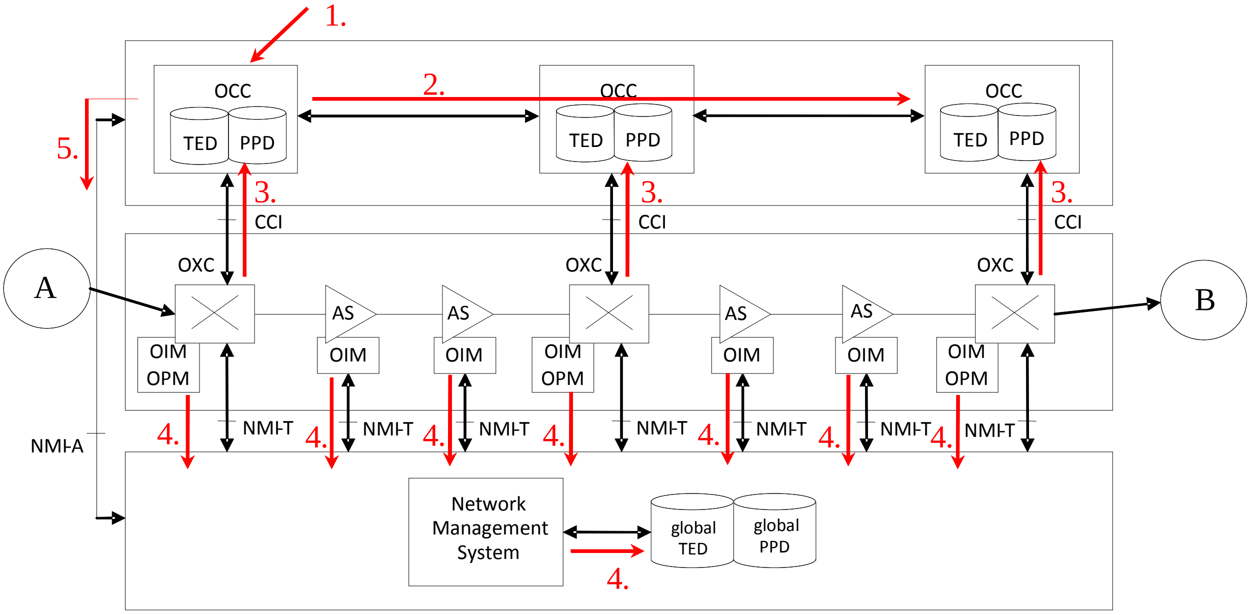


Figure 3.10: UC#10, protection.

Steps:

1. A failure in the link or interface between node A and B is detected in node A.
2. The control plane at node A switches the lightpath from node A to B to backup path.
3. A verification of the end to end signal quality could be required.
4. The local PPD and TED databases are updated (via CCI interface). Nodes and OIM/OPM components also update the global TED and PPD in NMS via NMI-T interface.
5. The control plane notifies the backup path setup to the NMS and an alarm activates in the NMS indicating the exact location of the failure. The failed device must be replaced or repaired.

Use case code:	UC#11
Name:	Protection
Goal:	A currently established lightpath from node A to B is switched to backup path.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Network Management System (NMS)
Pre-condition:	Local PPD and TED databases are stable and update. A degradation change exceeding a given threshold triggers the protection. A backup path is available.
Post-conditions:	PPD and TED databases are updated accordingly. Network management system updates its user interface to inform the network manager of the new configuration. The degraded device must be replaced or repaired.
Trigger:	A degradation level exceeding a given threshold in the link or interface between node A and B is detected in node A. GMPLS triggers the automatic protection.

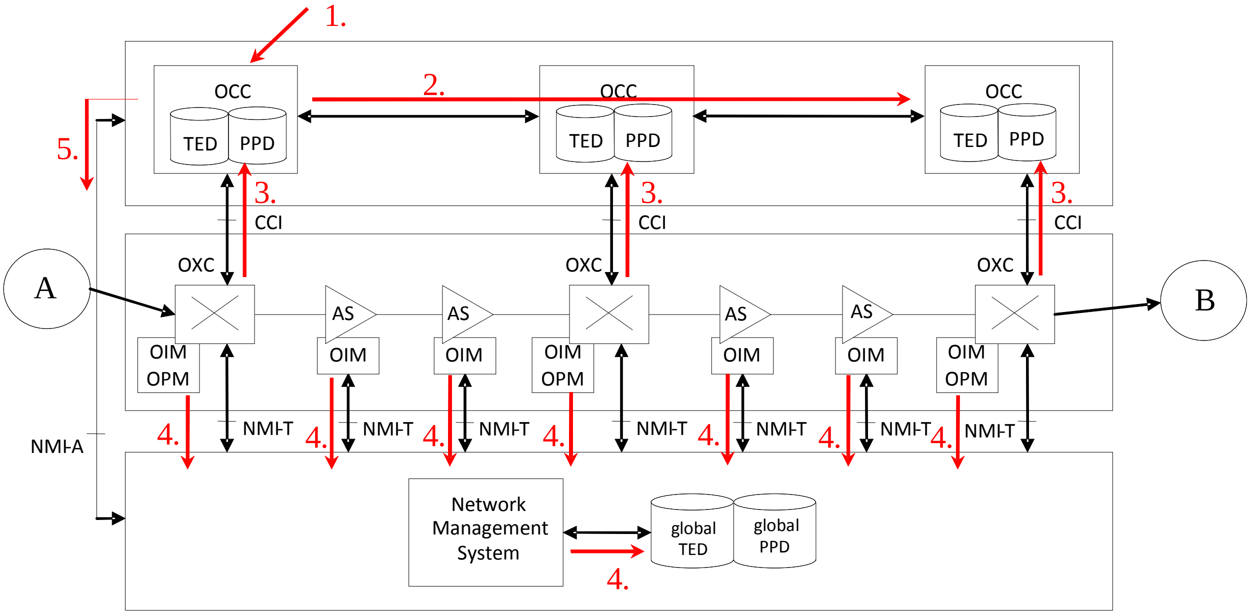


Figure 3.11: UC#11, protection.

Steps:

1. A degradation level exceeding a given threshold in the link or interface between node A and B is detected in node A.
2. The control plane at node A switches the lightpath from node A to B to backup path.
3. A verification of the end to end signal quality could be required.
4. The local PPD and TED databases are updated (via CCI interface). Nodes and OIM/OPM components also update the global TED and PPD in NMS via NMI-T interface.
5. The control plane notifies the backup path setup to the NMS and an alarm activates in the NMS indicating the exact location of the failure. The failed device must be replaced or repaired.

Use case code:	UC#12
Name:	Restoration
Goal	A currently established lightpath from node A to B is re routed.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Network Management System (NMS)
Pre-condition:	Local PPD and TED databases are stable and update. A degradation change exceeding a given threshold or a failure triggers the protection. A backup path is not available.
Post-conditions:	PPD and TED databases are updated accordingly. Network management system updates its user interface to inform the network manager of the new configuration. The failed/degraded device must be replaced or repaired.
Trigger:	A degradation level exceeding a given threshold or a failure in the link or interface between node A and B is detected in node A. GMPLS triggers the re-routing request via automatic intervention.

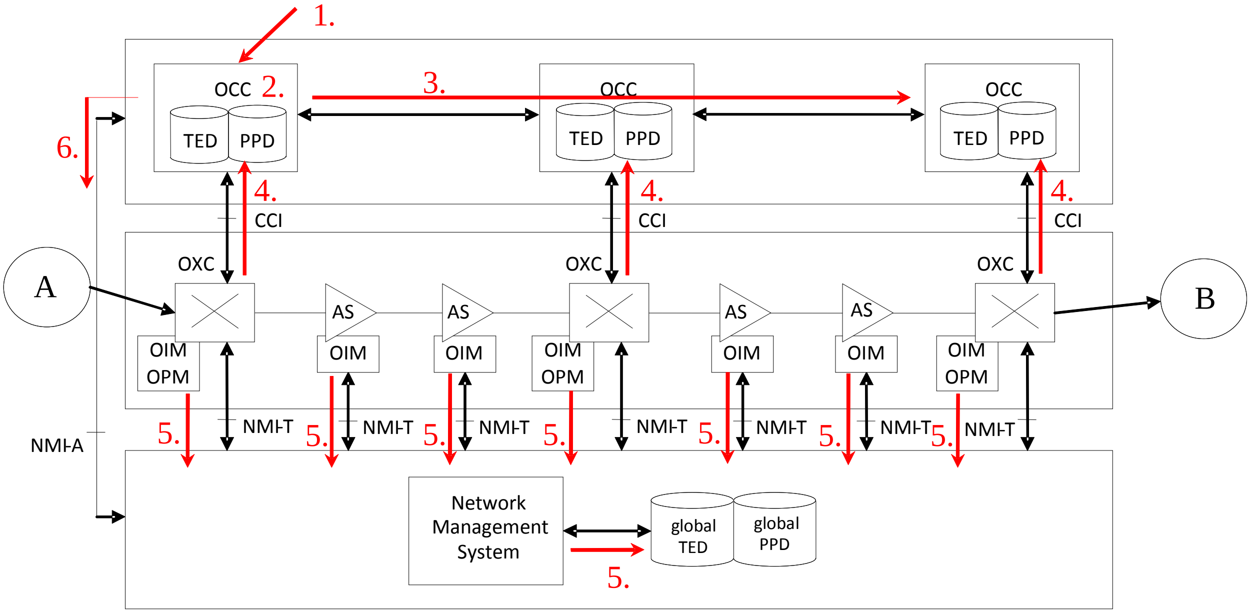


Figure 3.12: UC#12, restoration.

Steps:

1. A degradation level exceeding a given threshold or a failure in the link or interface between node A and B is detected in node A. A backup path is not available.
2. The control plane at node A utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a new path from A to B. Note that we have assumed that PPD and TED databases are updated, so the control plane will compute a new lightpath.
3. After computing a lightpath, node A sets up a lightpath from A to B.
4. A verification of the end to end signal quality could be required.
5. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the NMS are also updated via NMI-T and NMI-A interfaces.
6. The control plane notifies the backup path setup to the NMS and an alarm activates in the NMS indicating the exact location of the failure/degradation change. The failed/degraded device must be replaced or repaired.

Use case code:	UC#13
Name:	Restoration with support of PCE
Goal	A currently established lightpath from node A to B is re routed.
Actors:	Control Plane
Systems components:	Control Plane (e.g. GMPLS) OIM/OPM Path Computation Element (PCE) Network Management System (NMS)
Pre-condition:	Local PPD and TED databases are stable and update. A degradation change exceeding a given threshold or a failure triggers the protection. A backup path is not available.
Post-conditions:	PPD and TED databases are updated accordingly. Network management system updates its user interface to inform the network manager of the new configuration. The failed/degraded device must be replaced or repaired.
Trigger:	A degradation level exceeding a given threshold or a failure in the link or interface between node A and B is detected in node A. GMPLS triggers the re-routing request via automatic intervention.

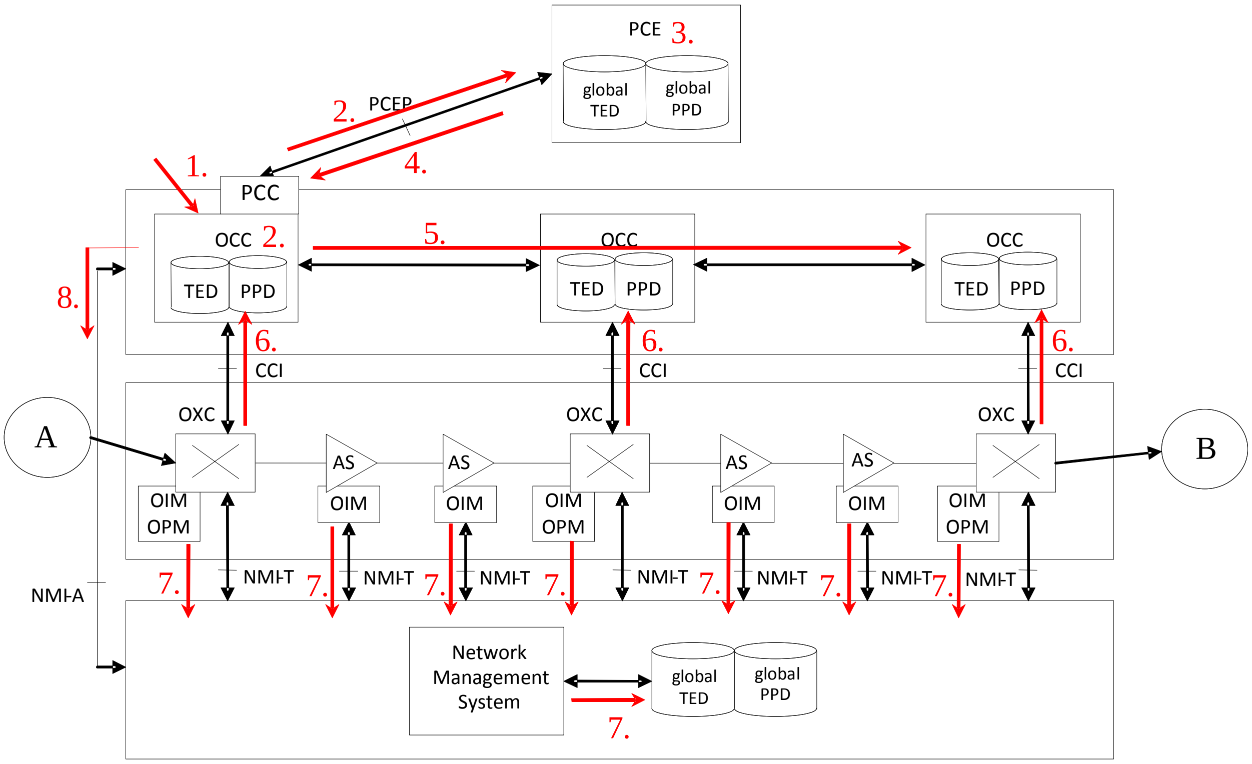


Figure 3.13: UC#13, restoration with support of PCE.

Steps:

1. A degradation level exceeding a given threshold or a failure in the link or interface between node A and B is detected in node A. A backup path is not available.
2. Control plane at the ingress node requests the path computation to the PCE (via PCEP interface).
3. PCE utilizes the IA-RWA and PP performance evaluator (Q-Tool) engine in order to compute a new path from node A to B.
4. PCE forwards the path to the control plane of the ingress node A.
5. The control plane signalling procedure reserve the lightpath from A to B.

6. A verification of the end to end signal quality could be required.
7. The local PPD and TED databases are updated in the OXCs (via CCI interface) and the global PPD and TED databases in the PCE are also updated via PCEP protocol. Nodes and OIM/OPM components also update the global TED and PPD via NMI-T interface.
8. The control plane notifies the backup path setup to the NMS and an alarm activates in the NMS indicating the exact location of the failure/degradation change. The failed/degraded device must be replaced or repaired.

4. Interfaces Definition between monitors and CP/MP

4.1 INTRODUCTION

This chapter defines the interface between the monitors and the CP/MP. First, we define the structural PP measures data to be sent to the CP and MP. Then, a brief background about general network management system is provided followed by the sub-system definitions and descriptions of the following: A *Network management system and its architecture, the system manager and the management information model. This section will be followed by an example of conventional network management architecture proposed ECI.* The end of this chapter summarizes monitoring interface protocol as provided by the industrial partners in the DICONET project namely Huawei, ALF, and ECI.

4.2 DEFINITION OF THE DATABASES (ALF)

In this section, we want to define how physical data are up-loaded and sent to CP and MP. Once the network status information is gathered to the CP and MP, it must be abstracted, organised, and stored in the TED and PPD databases. Today there are a lot of recommendations indicating how information about the network occupation is sent to upper layers (CP/MP). The TED database is the common database defined in GMPLS/MPLS architecture and stores the information on the network resource availability. It should be compliant with the structure described in [2].

In transparent/hybrid networks, routing is not only limited to routing and wavelength assignment, but information about the physical impairments are required [4]. Today, what needs to be specified is how physical network state has to be disseminated: the PPD database requires to be defined since it is a novelty of the DICONET project. PPD could be a separate database but also part of the TED. It should contain all information regarding the physical layer performance and impairments.

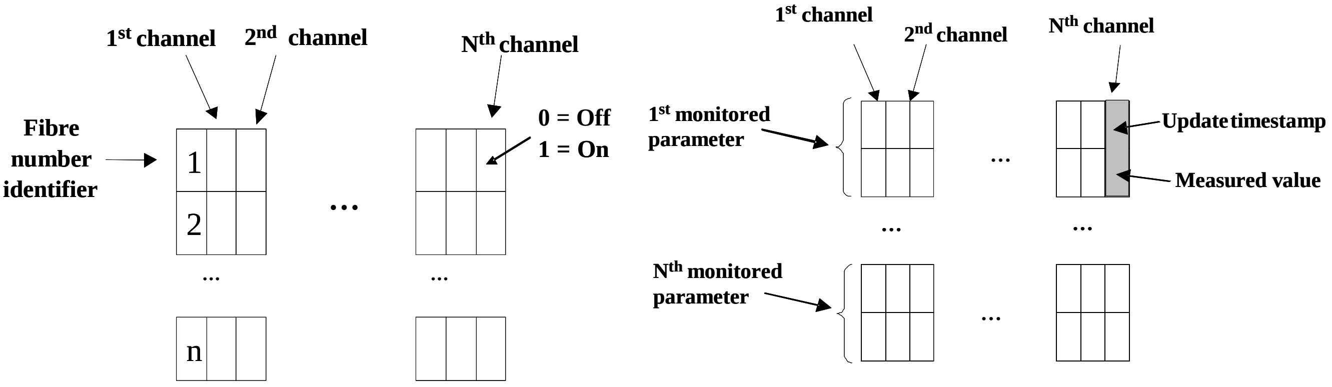
Several types of monitors could be considered:

- Monitor at node
    - Channel power monitor
    - OSNR monitor
    - Q monitor
    - PMD monitor
    - Chromatic Dispersion (CD) monitoring
- In line monitor
    - Total input and output power of each EDFA
    - Individual channel power every 5-6 spans where Wavelength Selective Switch (WSS) are positioned for channel power equalizing purpose.

OSNR, Q and PMD monitors will be shared among all the fibre/channel connected to a node to reduce the overall cost, and power consumption of the node. These three parameters are fibre and wavelength dependant, so each working channel has its own corresponding value for each parameter.

The general structure to store these parameters could be organised with two tables.

Figure 4.1 shows an example of structure for the PPD. The first table indicates for each fibre connected to a node which channel is lightened. The Second table enumerates for each fibre and for each lightened channel, the value of each monitored parameter and the timestamp of the last update.



a)

b)

Figure 4.1: Structure of the PPD database; a) selection of the fibre/channel pair, b) value of the monitored parameters and the update timestamp, the matrix here depicted is given for each fiber.

4.3 BASICS OF NETWORK AND MANAGEMENT

In this sub-section we introduce a concept of a general network management system which includes the following network management sub-system units: Network management system model, Network management architecture, network manager and interface and manger interface protocols.

4.3.1 Network Management System Model

The main purpose of a network management is to provide a connection and configuration between hardware units to be managed and controlled by a central unit. Due to the evolution of the computer networks and the physical monitoring units maturity, the monitoring should provide an efficient capabilities for maintaining daily operation of the network. Moreover the goal of network monitoring is also to detect and point out about potential problems. Network management must provide alarms about problems before system breakdown, reduce the complexity of network management and ensure the maximum rate of data transmission.

The International Organization for Standardization (ISO) has defined five functions of network management (ISO 7498-4) shown in Figure 4.2.

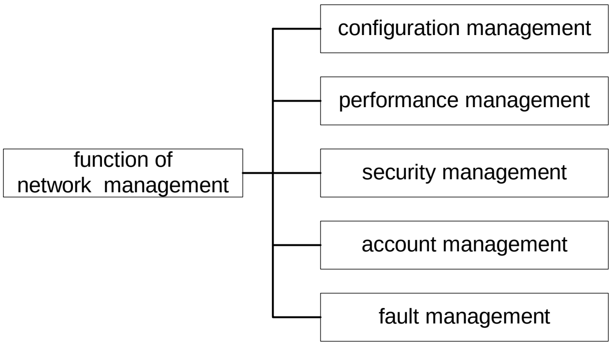


Figure 4.2: Typical Network Management System Functionality

1. *Configuration Management*: Record and maintain network configuration, parameter updating for ensuring correct network operation.
2. *Fault Management*: Finding problems or errors from network. Including detection and repair.
3. *Security Management*: Control the process of message access in the network. Provide protection for network resources, services and data to avoid danger. It also provides user privacy.

4. *Performance Management*: Including performance measurement of hardware, software and the media of transmission in the network. For example, Input, Output flow, error rate.
5. *Accounting Management*: Handle users charging record by using personal network usage log, and provide necessary service for user when he monitors the network.

4.3.1.1 Common Network Management Architecture

Figure 4.3 introduces the basic network management architecture. The management station is mainly consisted of a *display* and *network management application* components. The *Display* unit displays the information to the operators and gets control from operators, whereas the *network management application* unit communicates with the agent to get information from the managed devices. *Agent* serves as the broker between the management station and managed device, which implements a specific protocol for communication, for example, SNMP. This architecture simplifies the management application design by separating the design of "managed-device part" and the "managing part".

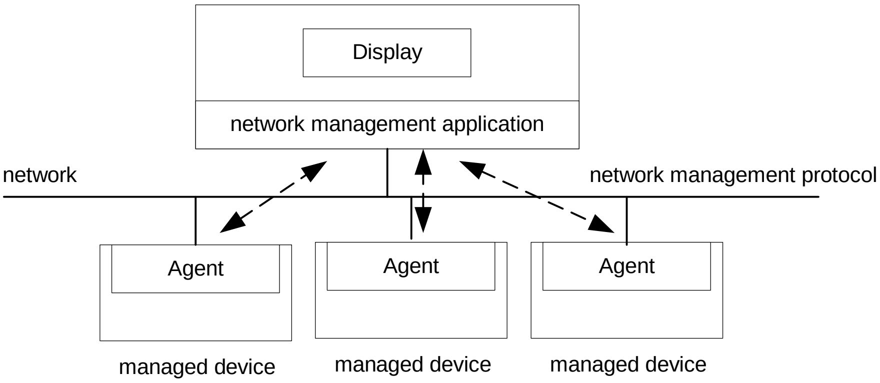


Figure 4.3: Typical two tier structure for network management

4.3.1.1.1 Manager and Agent of SNMP

There are two entities in SNMP - Manager and Agent. A manager is a server, which executes specific programs to manage networks. An agent is a tiny-software, which works in the managed network device. We present the relation to Network Management System (NMS) and its agents in Figure 4.4.

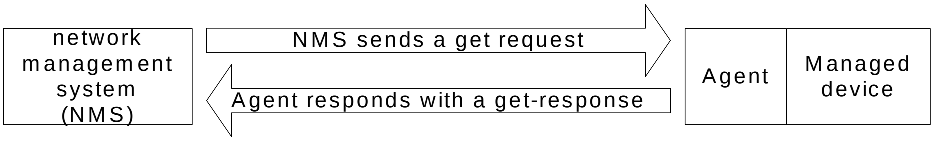


Figure 4.4: The architecture of the SNMP

4.3.1.1.2 System Management

System Management is a set of functions that make enterprise can more easily to support the hardware and software of IT architectures in their life cycle. System management functions include Software and hardware configuration.

System manager will face the challenge of system configuration and monitoring at any point of time the system operates. It can send error message before error will occur. It can help system managers solve problems as soon as possible so they can modify all system configurations in shortest time.

4.3.2 Desktop Management Interface (DMI)

DMI was the first desktop management standard and has been developed by the Distributed Management Task Force (DMTF).

DMI is an industry framework for managing and keeping track of hardware and software components in a system of personal computers from a central location. It is a layer between system components and the software that manages them. DMI information can only be collected under SMBIOS (System Management - Basic Input Output System) specification that define how to display product manage information.

DMI is hardware and operating system-independent, independent of specific management protocol, easy for vendors to adopt, map able to existing management protocols such as the SNMP, and used on network and non-network computers. DMI consists of four components:

1. Management Information Format (MIF): An MIF is a text file that contains specific information about the hardware and software being used on a computer. An MIF file consists of one or more groups containing attributes, which describe each component. By default, each MIF file contains the standard component ID group. This group contains the product name, version, serial number, and the time and date of the last installation. The ID number is assigned based on when the component was installed in relation to other components. This information is then sent to an MIF database.
2. Service layer: The service layer is memory-resident code that acts as a mediator for the management interface and the component interface and allows management and component software to access MIF files in the MIF database. The service layer is available as an operating system add-on and is a shared resource for all programs. Because the service layer must run all the time, it is designed not to use a lot of memory. The service layer also includes a common interface called the local agent, which is used to manage individual components.
3. Component interface (CI): The CI is an application program interface (API) that sends status information to the appropriate MIF file via the service layer. Commands include the Get and Set command that modifies the MIF as needed and the Event command that notifies management software of critical events.
4. Management interface (MI): The management software communicates with the service layer using the MI application program interface. The MI allows administrators to issue the Get and Set command and the List command that lists all the DMI-manageable devices by sending data in MIFs (Management Information Files) or activating MIF routines.

4.3.2.1 Information Model

We need to select a language in which to express the concepts for managing devices and monitoring. The language must be rich enough to include the complex and abstract relationships between items, but should be simple enough for software to handle efficiently. This chapter will introduce the Common Information Model, the model used to represent the managed object in Web-Based Enterprise Management (WBEM) architecture. The Web-Based Enterprise Management is a set of management and Internet standard technologies developed to unify the management of distributed computing environments.

A model represents the abstract of real elements in a real world. We use model to store the interesting needed parameters of the real world elements to be managed and to be controlled.. For an example, Optical amplifier in the real world has it input and output power parameters, or Reconfigurable Optical Add Drop Unit can be modeled by it configuration mode, number of ports, data, wavelength and other attributes.

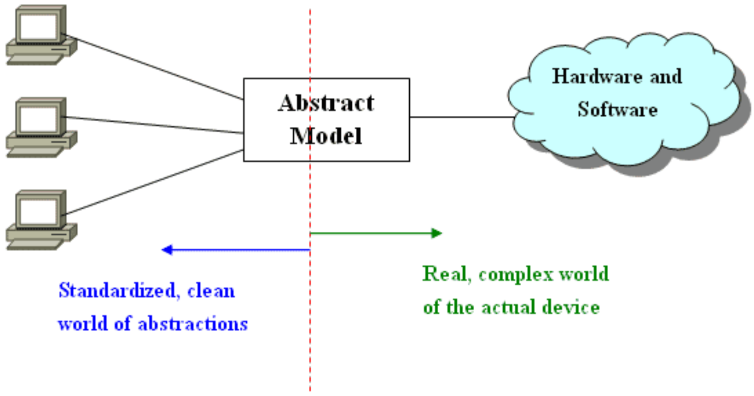


Figure 4.5: Model representation concept

Figure 4.5 shows a projection of a real complex network element into a simple model for the network management.

4.3.2.2 Common Information Model (CIM)

CIM is a model for describing overall management information in a network/enterprise environment. It is comprised of a specification and a schema. The specification defines the details for integration with other management models, while the schema provides the actual model descriptions. The latter can be described in one of the following formats: Unified Modeling Language (UML) diagram, Managed Object Format (MOF), or Extensible Markup Language (XML). However, MOF is popular and is machine-readable.

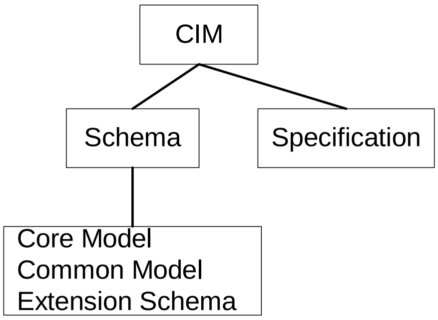


Figure 4.6: Common Information Model structure

For an example CIM specification describes an object-oriented meta model based on the Unified Modeling Language (UML), however it can use any model. This model includes expressions for common elements, object classes, properties, methods and associations that must be clearly presented to management applications. The specification defines the syntax and rules, a CIM syntax language based on Interface Definition Language (IDL) called Managed Object Format (MOF) as well as the CIM Naming mechanism.

Meta model is a model of model, that is, the model to describe and define a model. Sometimes we call the meta model as meta schema, and model as schema. CIM meta schema is a formal definition of the model. It defines the terms used to express the model and its usage and semantics.

A schema is a collection of class definitions used to represent managed objects that occur in every management environment, for example a *LogicalDisk* is a class defined in the schema. CIM Schema includes the core model, the common model, and the extension schemas. The core model is the first layer of the CIM Schema, including the top-level classes, their properties as well as associations, and is implementation independent. The common model, the second layer of the CIM Schema, includes a series of domain-specific but platform-independent classes. The domains are systems, networks, applications, and other management-related data. The extension schema, the third layer of the CIM Schema, includes platform-specific extensions of the CIM Schema.

4.3.3 Corba Network Management

Corba means Common Object Request Broker Architecture. This is a standard that was defined by the OMG, which is the Object Management Group. Corba is a standard that allows software components written in multiple computer languages and running on multiple computers to all work together. Corba network management is the basic network management software that has the capabilities of Corba.

The Corba network management is the choice for a lot of small to large businesses because it is embedded into their network devices and is capable of managing a large number of clients at high hit rates on the internet. Corba integrates machines from many vendors, from sizes ranging from mainframes to desktops to hand-helds. It allows all of these machines to be able to communicate with each other very easily.

4.3.4 XML Network Management Interface

The XML network management interface is intended for use in diverse network environment where transport and data model requirements vary greatly. It is unlikely that a single transport and data model specification will meet the needs of all anticipated service operators. Therefore, the XML network management interface is partitioned into the following (Figure 4.7) layered components.

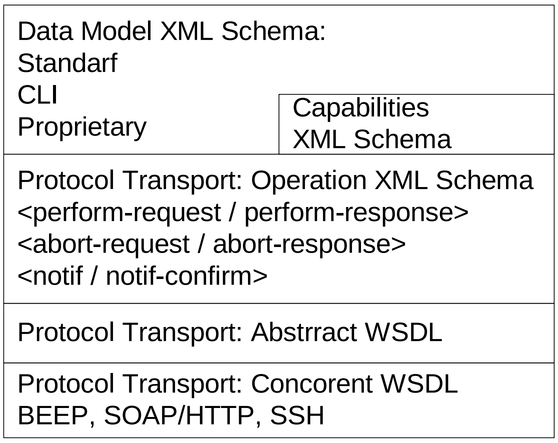


Figure 4.7: XML structure

The protocol transport is divided into two components: abstract WSDL and concrete WSDL. WSDL (Web Service Description Language) is a formal specification language for XML-based Web service. WSDL describes the message interaction such as request and response. Concrete WSDL describes the actual transport protocols mapping. The protocol operations are specified in XML schema, which describes the operations message construct and is referred by transport WDSL. The capabilities of optional function are described in capabilities XML schema. It allows peers to exchange the actually functionality implemented in other end. The management data models are described in XML schema too.

4.3.5 *Embedded interface*

Programmable logic controller (PLC) is a microprocessor computer for process control attached to a process control network. Custom-built software programs running in the PLC handle complex sequence control of machinery. Figure 4.8 shows an approach example of power monitoring.

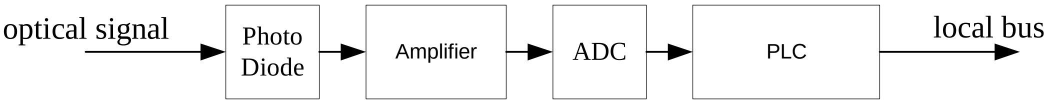


Figure 4.8: Embedded monitoring approach

4.3.5.1 *Network Monitoring Interface Card*

Network Card, also known as LAN Adaptor, Network Adaptor or NIC is simply a computer hardware, which enables other computers or system in the network to communicate with it. This card can be classified as OSI layer 1 or Physical Layer and Layer 2 that are Data Link type Layer Device. This is because the device can enable the communication to the medium of the network present physically and it also enables a low level system so that the addressing can be done using MAC address. Therefore it enables many other users to connect through cables or even using wireless technology.

MAC address, also known as Ethernet Hardware Address, or Media Access Control Address or Hardware Address or Adapter Address is basically a unique type of identification to many network adaptors. It is just like a name or address of the given adapter. Therefore, any two Network Adapters or Cards in any network belonging to different Systems will be having different MAC addresses. But, due to MAC spoofing, the MAC address of any hardware can be changed.

Enhanced or advanced Network Monitoring Interface Cards must have some specific features including the system ability to reduce the load of the CPU Intensive Processing from the CPU of the system, determination of the time with very high accuracy, filtering the network traffic and the capability to perform any other kind of processing which is specific to the application.

Network Monitoring Interface Card or NMIC is mainly used for detection and/or prevention of any kind of intrusion, monitoring the network, Lawful Interception, Flow Analysis and Protocol Analysis.

4.3.5.2 *Network Tap*

Network Tap is simply a hardware device, which gives a way for accessing the data, which is flowing through the network. Network Tap is probably the best method to read the data between two points if there is a physical cable between the given points. It has three ports, Port A, Port B and Monitor Port. For tapping between port A and B, one needs to replace the cable between Port A and Port B with Cables connecting the two ports with their corresponding port in the Network Tap. This Tap passes all the data between port A and B without providing any hindrance.

4.3.6 ECI general network management-network element interface

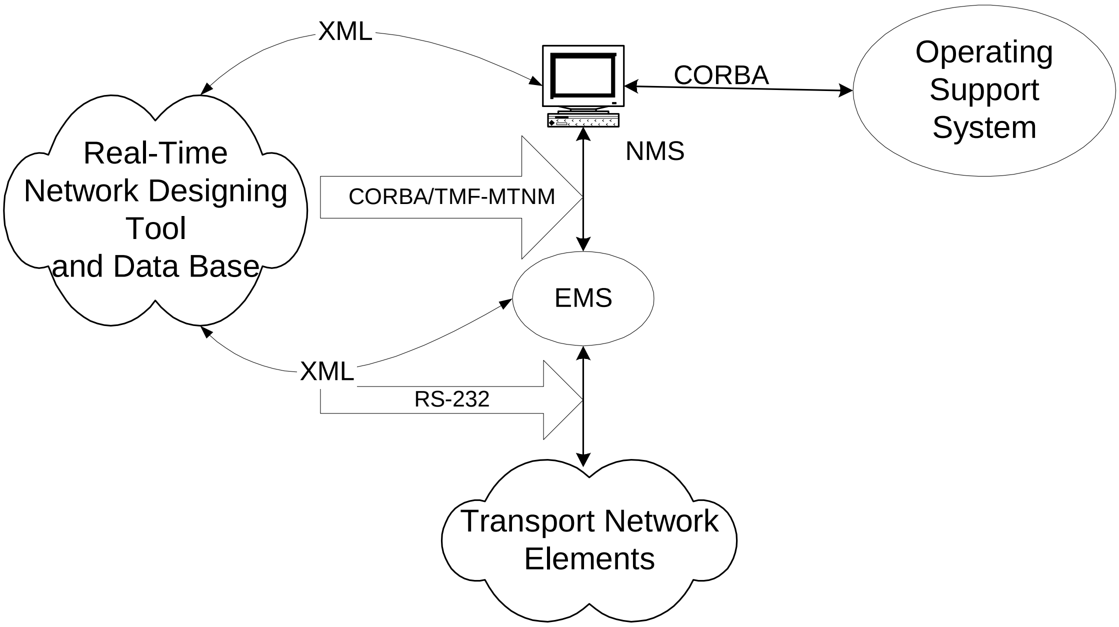


Figure 4.9: ECI general network management-network element interfaces

In Figure 4.9, a transport network element is managed and controlled by RS-232 protocol via the embedded management system (EMS). The relevant parameters of the monitors element are reported to network data base where via XML protocol for example, and these parameters (in general – optical parameters, configuration etc) will be for a future network design or as in DICONET for defining the constraint for the RWA algorithm of network element. These parameters are reported as well to the NMS for operating and support ayatem using the CORBA/TMF-MTNM protocols.

4.4 REQUIREMENTS FOR THE INTERFACE

The refreshing time of the protocols depends on the type of network. If the network is static, that is connections are established once and then there are few pre-planned changes per year . This means that OSPF can perform a resource availability update each 30 minutes without risk to have not reliable information about the network state. But, if the network works dynamically, the update period can be reduced, decreasing it up to 3 seconds because the network configuration can change in any moment although very frequent updates can make heavy all the process of protocol treatment. Such information is obtained by node by node flooding and the maximum delay between the update of the first node and the last node should be less than 3 seconds. Often Open Short Path First (OSPF) allows an expiration time that is associated to each broadcasted information: when a timer ends, an update of the selected information is required.

To exchange network state information, an easier solution is the exchange of information between OPM/OIM and the NMS. Management Information Base (MIB) functions are used to remotely execute get/set information of monitoring. NMS collects all data and then spread them to the control plane using the Simple Network Management Protocol (SNMP). This solution enables a simplification of operations that the control plane has to perform and also enables the possibility to update data with refresh time different from the OSPF. But this solution is above all proprietary being related to the implementation of the NMS.

Alternative solutions for the interface between NMS and monitors are given by the knowledge plane (KP) [6]. It is possible to refresh information as a function of the monitored parameter and also of the zone where the data has to be transported. But this last solution is not standardised and still under study.

4.5 ARCHITECTURE AND FUNCTIONAL DESCRIPTION OF INTERFACE

The architecture of the interface between the OIM/OPM and the CP/NMS is shown in the Figure 4.10. According to this architecture, a “middle-box” is used as an interface between the CP/NMS and the different monitors.

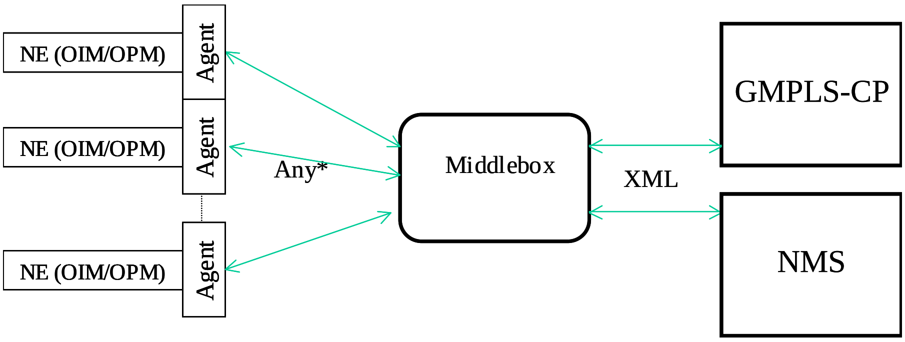


Figure 4.10: Architecture for the interface

This middle-box is used to aggregate and temporarily store the information provided by the monitors. This middle-box uses the XML language to format and transfer the information to the CP/NMS. The value of the monitored parameters is stored together with the time of the update. In this way, any kind of software/hardware interface used by monitors could be easily adapted and connected to the common CP/NMS interface side.

It is not needed to have a middle-box in each site; a middle-box per OXC is enough. The parameters monitored in the amplifier sites (required by NMS) could be transported through a control channel to the closest OXC. This information has not strict time requirements and the delay due to the propagation has not impact on the network efficiency.

The middle-box is a software translator from any protocol to XML and possible from any hardware interface.

This structure is very practical for system point of view and makes sense, since the monitor points are used along with the NMS/GMPLS software for parameter conversion and can be added into design considerations, monitoring and debug options for the network The hardware details of the interface currently used in monitors (SMA, Ethernet, RS-232, proprietary, etc.) depend on the type of monitors. Each hardware interface has its own protocol standard available at the ITU-T community. It is recommended to place the middle box after the EMS. Table 4.1 provides a list of different interfaces for various monitoring available. The table of the monitor techniques is derived from WP3.1 [8].

Impairments to monitor	Technology capability		Protocol		Communications Timing
	Based Module	Based TEQ	Based Module	Based TEQ	
Optical power	Yes	Yes	RS-232	Ethernet, GPIB	Programmable
OSNR	Yes	Yes	I2C	Ethernet, GPIB	Periodic
WL	Yes	Yes	I2C	Ethernet, GPIB	Periodic
True OSNR	Yes	YES	RS-232	Ethernet, GPIB	Periodic
Channel accounting	Yes	Yes	I2C	Ethernet, GPIB	Programmable
Synchronous Q factor	No	Yes	☒	Ethernet, GPIB	Periodic
Asynchronous Q factor	No	Yes	☒	Ethernet, GPIB	Periodic
CD	No	Yes	☒	Ethernet, GPIB	Only if it changes
PMD	No	Yes	☒	Ethernet, GPIB	Periodic
Attenuation losses	No	Yes	☒	Ethernet, GPIB	Only if it changes
Extinction Ratio	No	Yes	☒	Ethernet, GPIB	Only if it changes
Optical Amp Gain Tilt	Yes	Yes	RS-232	Ethernet, GPIB	Periodic
Sign of CD	No	Yes	☒	Ethernet, GPIB	Only if it changes
Cross talk	No	No			
SPM	No	No			
XPM	No	No			
FWM	No	No			
SRS	No	No			

Table 4.1: Interface protocols for different monitoring.

- Based Module – Possible to acquired modules to be assembled to a card.
- Based TEQ – External Test equipment (such as OSA, BER tester) that can be substitute at different site connected via IP protocol or other means to the network management.

Communications Timing: includes the following

- Programmable – Parameter by demand, i.e., user invokes fetch and therefore can be accessed any time (for example monitoring optical channel(s) power).
- Periodic – a predefined period of time for which an access to a parameter can be monitored.
- Only if it changes – interruptible monitoring fetch request. It occurs on a sudden change in one of the network parameters (such as power and dispersion where a user action is needed immediately).

We can distinguish two classes of monitored parameters depending on the communications timing at which the parameters are monitored.

- The first class contains channel power and total input-output power of EDFA. These monitors work in a continuous way and data can be sent and stored to the middle-box as soon as the measurement is made. As these parameters are updated very often there is no need for the NMS or the CP to require a new measurement at a specific time. It is enough to ask for the last updated value temporarily stored in the middle-box. In EDFA channel power is monitored; to measure channel by channel parameters a periodic scanning is performed, the time required between two scans of the same channel depends on the total number of wavelengths that a fibre can contain and also on the monitoring techniques; for more details, please see [8]. On the other hand, an average measurement of the power at the amplifier input and output is done continuously. Monitoring measures are done all time, what we propose is save in the local data base the measured information and its measure time, as indicated in Figure 4.1(b). The spread of this information depend on the CP/MP requests.
- The second class concerns the monitors which are shared among all the fibres recorded at the node. For these monitors their measurement take more time and moreover the different fibres/wavelengths should be scanned; so the value of the parameters temporarily stored in the middle-box are updated with less periodicity than the other parameters. For these parameters, it is therefore necessary to allow the NMS or the CP to ask for a specific update of a specific parameter for a particular fibre. For instance if the CP/NMS needs to know the OSNR for a specific wavelength for a particular direction, it can first ask to the middle-box the time of the last updated of this value. If this updated is considered not “fresh” enough it can ask to the middle-box to require this specific value from the monitor. Usually in each node, the parameter monitoring can be: shared by all fibres joining the node or obtained for each fibre separately. Naturally, the sharing choice is economically the more advantageous. The shared monitors are the ones measuring CD, PMD and Q-factor. The speed at which each channel parameter is measured depends on the number of fibres connected to the node, the number of wavelength per fibre and the monitoring technology; information about monitoring measure delays is given in [8].

The frequency of the exchange of the PP values depends on the choice of the IA-RWA type and of the PPD that better perform. Monitored information is stocked in a data base internal to each monitor; these parameters will be gradually integrated in the PPD.

Monitored Parameter	Measured element	Measurement Frequency
Average power in amplifier	All lighted channels in the fibre	Continuous
Power	Single channel	Periodic
CD	Single channel	Periodic
OSNR	Single channel	Periodic
PMD	Single channel	Periodic
BER/Q-factor	Single channel	Periodic

Table 4.2: Kind and periodicity of measured parameters.

4.6 IMPAIRMENTS MONITORING INFORMATION CONTENTS AND FORMATS FOR THE INTERFACE

Monitoring techniques can be divided into optical impairment monitoring (OIM) techniques (such as CD, PMD and signal power) and optical performance monitoring (OPM) techniques (which covers the OSNR monitoring, bit-error monitoring and Q-value monitoring primarily, i.e. methods for direct signal quality estimation). Therefore, we have two monitor types (MT), and the different impairment types (IT). GMPLS-CP needs to distinguish the parameters belong to which monitor type and impairment type, and the MT and IT fields need to be included. Since there would be many kinds of impairment types, the interface should be general enough to avoid defining one interface for each impairment type. Monitor can only provide the impairment information for one link or an end-to-end lightpath, so the interface needs to include the fields that can indicate the scope of the impairment information.

Parameters	Parameter values	Remarks
MT	*OIM: 0; OPM: 1*	
IT	*Channel Power: 0;* *OSNR: 1;* *Q_VALUE:2;* *PMD : 3;* *BER: 4* *CD: 5;* *…*	*Other impairment types can be assigned other values based on this definition.*
SCOPE	*Link Id: 32 bits (can be consistent with the link Id of the definition of current Control plane).* *Waveband: 8 bits;* *Wavelength: 32bits;*	*If the impairment is irrelative to waveband or wavelength, the waveband or wavelength field can be zero denoting insignificance.*
VALUE	*Upper limit: 32bits;* *Lower limit: 32bits;*	*When the interface denotes the OIM, we can also provide the impairment range using upper limit and lower limit. If only one value is needed, lower limit can be zero denoting insignificance.*

Table 4.3: Content and Format of Impairment Monitor Information (basic) for the interface.

Table 4.3 gives the main content and format which the interface between GMPLS-CP and OPM should contain. Besides this, failure localization and impairment compensation also need to use the interface between GMPLS-CP and OPM, which may be optional. So we extend this interface illustrated in Table 4.4.

Parameters	Parameter values	Remarks
Application	*Normal: 0* *Adjust range:1* *Degradation:2* *Configuration: 3* *….*	*"Normal" means this kind of impairment is the measurement value from monitor.* *"Adjust range" means this kind of impairment information is the adjustable range for computing compensation.* *"Degradation" means this kind of impairment is useful for trigger failure localization or restoration or maintenance depend on the local policy.* *"Configuration" means this kind of impairment information is useful for configurating compensation.* *Other value can be added for more application.*
MT	*OIM: 0; OPM: 1*	
IT	*Channel Power: 0;* *OSNR: 1;* *Q_VALUE:2;* *PMD : 3;* *BER: 4* *CD: 5;* *…*	*Other impairment types can be assigned other values based on this definition.*
SCOPE	*Link Id: 32 bits (can be consistent with the link Id of the definition of current*	*If the impairment is irrelative to waveband or wavelength, the waveband or wavelength field can be zero denoting insignificance. If the impairment is for a node, while not a*

	Control plane). *Waveband: 8 bits;* *Wavelength: 32bits;*	*link, link Id can be zero.*
VALUE	*Upper limit: 32bits;* *Lower limit: 32bits;*	*When the interface denotes the OIM, we can also provide the impairment range using upper limit and lower limit. If only one value is needed, lower limit can be zero denoting insignificance.* *When impairment has no range but only one value, we can also provide the impairment range using upper limit and lower limit. If only one value is needed, lower limit can be zero denoting insignificance.*

Table 4.4: Content and Format of Impairment Monitor Information (extensional) for the interface..

4.7 CONCLUSIONS

This chapter introduced the basic network management system architecture. Using this architecture we recommended different interfaces protocols that can be use in the DICONET system to communicate with the control/management plane taking into account relevant information derived from different monitoring units. These monitoring units provide the management information about the network status and the elements status that enables the management to operate IA-RWA algorithm based on the current network situation. From Table 4.1 to Table 4.4, we provide a summary of the monitoring parameters to be monitored as well as the relevant protocols to be used and the priorities from system vendor point of view.

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6. Glossary

AS	Amplifier Site
API	Application Program Interface
BER	Bit Error Rate
CallC	Call Controller
CC	Connection Controller
CCI	Connection Controller Interface
CD	Chromatic Dispersion
CI	Component Interface
CIM	Common Information Model
CORBA	Common Object Request Broker Architecture
CP	Control Plane
DMI	Desktop Management Interface
DMTF	Distributed Management Task Force
EDFA	Erbium Doped Fibre Amplifier
FWM	Four Wave Mixing
GMPLS	Generalized Multiprotocol Label Switching
HWA	HardWare Accelerator
IA-RWA	Impairment Aware Routing and Wavelength Assignment
IDL	Interface Definition Language
ISO	International Organization for Standardization
IT	Impairment Type
ITU-T	International Telecommunication Union Standardization
KP	Knowledge Plane
LRM	Link Resource Management
MI	Management Interface
MIB	Management Information Base
MIF	Management Information Format/Files
MOF	Managed Object Format
MP	Management Plane
MT	Monitoring Type
NMI-A	Network Management Interface for control plane
NMI-T	Network Management Interface for transport plane
NMS	Network Management System
OCC	Optical Connection Controllers

OIM	Optical Impairment Monitoring
OLSA	Opaque Link State Advertisement
OPM	Optical Performance Monitoring
OSNR	Optical Signal to Noise Ratio
OSPF-TE	Open Short Path First with Traffic Engineering
OXC	Optical Cross Connect
PCC	Path Computation Client
PCE	Path Computation Element
PCEP	Path Computation Element Protocol
PLC	Programmable Logic Controller
PMD	Polarization Mode Dispersion
PP	Physical Parameter
PPD	Physical Parameter Database
RSVP-TE	Resource Reservation Protocol with Traffic Engineering
QT	Q-Tool
RC	Routing Controller
ROADM	Reconfigurable Optical Add Drop Multiplex
RWA	Routing and Wavelength Assignment
SNMP	Simple Network Management Protocol
SPM	Self-Phase Modulation
SRS	Stimulated-Raman Scattering
TE	Traffic Engineering
TED	Traffic Engineering Database
TP	Transport Plane
UC	Use Case
UML	Unified Markup Language
WSS	Wavelength Selective Switch
XML	eXtensible Markup Language
XPM	Cross-Phase Modulation