Integrated Performance Monitoring of hybrid IP/MPLS over Wavelength Division Multiplexing (WDM) networks

KOSTAS VAXEVANAKIS
Ellemedia Technologies, Ltd
223 Sygrou Ave., 17121 Athens
GREECE

LAMPROS RAPTIS, MICHALIS ELLINAS
Department of Electrical Engineering and Computer Science
National Technical University of Athens
9, Heroon Polytechniou, 15773 Zografou, Athens,
GREECE

Abstract: - Due to fierce competition and application of new network technologies most of network and service providers are targeting to increase their market share through the differentiation of their offered services posing new requirements to their network and service management systems. Between the aforementioned requirements, the application Performance Management functionality as part of a whole network management system is becoming more and more significant. The purpose of this paper is to present a network management solution which allows the integrated performance monitoring of hybrid IP/MPLS over Wavelength Division Multiplexing (WDM) networks. The proposed solution is part of a more complicated Integrated Network Management System (INMS), which incorporate Configuration as well as Fault Management functionalities, allowing the provisioning of IP Connectivity Services (ICS), which are realised as MPLS Label Switched Paths (LSPs) over optical connections.

Key-Words: - Integrated Network Management, Performance Monitoring, IP, WDM

1 Introduction

Nowadays, operators wish to provide a wealth of new multimedia services to their customers in a cost effective, rapid and reliable way. Their ability to offer premium-grade services such as guaranteed bandwidth, voice over IP, and VPN are dependent on the ability to define personalised user policies that map users to the class of service to which they are subscribed. To achieve this, an intelligent, module and robust Network Management System (NMS) should be deployed, which should be embodied features like fast service provisioning, support for flow-through automation in conjunction with other operations support system (OSS), management of heterogeneous technologies, etc.

In [1] a novel Integrated NMS (INMS) has been proposed, which provides an integrated and automated provisioning solution for network service providers that offer IP/MPLS-based network services (IP-VPN, VoIP, MoIP) over WDM networks. The proposed solution allows the provisioning of MPLS Label Switched Paths (LSPs) over optical connections (lambdas)[1] in an automated way with guarantee Quality of Service (QoS) based on Service Level Agreements (SLA) as well as allows the integration and correlation of fault and performance information across the two different technological domains, namely the IP/MPLS and the WDM sub-networks. The purpose of this paper is to extend the work of [1] and present an integrated network management solution which allows the performance monitoring of hybrid IP/MPLS over Wavelength Division Multiplexing (WDM) networks.

The rest of the paper is structure as follows: section 2 describes briefly an overview of the whole system architecture, focusing on the performance management requirements and Use Cases. Then, section 3 focuses on the performance management functionality and especially on the performance

[1] In the rest of the paper the term IP/MPLS Connectivity Service (ICS) will be used to refer to the provided services.

monitoring describing the performance parameters as well as the key components that implement this functionality. Section 4 describes the adaptation that was carried out in order to "connect" the proposed management solution with the underlying Element Management System(s) (EMS) and finally section 5 summarizes the main issues from our work accompanied with issues for further study.

2 System Architecture

2.1 System Overview

The proposed management solution covers the network management layer, as described in the Telecommunications Management Network (TMN) pyramid, and incorporates a technology dependent sub-layer, inside the Network Management Layer (NML) that includes the IP-NMS and WDM-NMS, and a technology independent sub-layer, which constitutes the Integrated–NMS. The detail architecture of all three NMSs is based on the same prototype [2], which was appropriately adapted to the specific requirements of each NMS. It is worth mentioning that the proposed solution implements functionality pertaining to the configuration, fault and performance management.

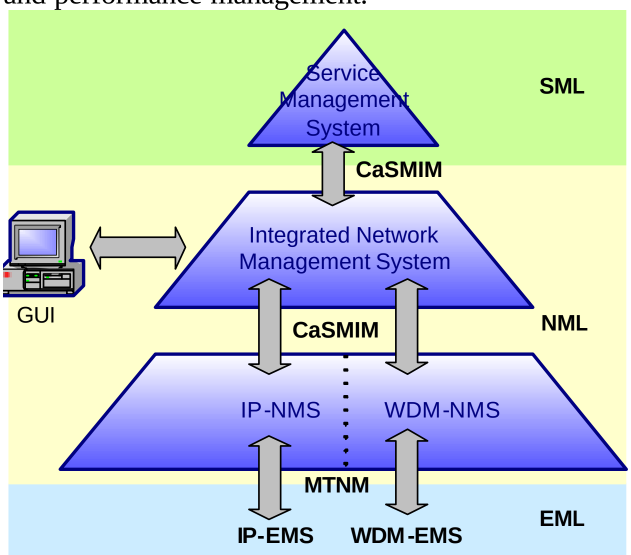

Fig.1: System Architecture

The positioning of the proposed management system in the TMN pyramid and the interfaces adopted are depicted in Figure 1. The northbound system interface towards third-parties Service Management System APIs, as well as the internal interfaces from the INMS towards the IP and WDM NMSs have been based on the TeleManagement Forum (TMF) CaSMIM specification [3]. The system southbound interfaces towards the Network-Element layer have been based on the TMF MTNM interface proposal [4]. No direct interactions are foreseen between the IP and WDM NMS, which are only viable through the INMS either in a top-down direction (mainly for configuration management purposes) or bottom-up direction (mainly for fault and performance management purposes).

Due to the complexity of the system a systematic approach of 5 steps was used in order to reach the proposed functional architecture, define the interfaces between the different components of the system architecture and finalise the software design, This five-step approach includes the definition of the business model, the requirements capture, the Use Cases (UC) specification and finally the UML Message Sequence Charts and Class Diagrams design. The results from step 2, the performance management requirements, and step 3, the performance use cases, are presented in the following 2 subsections.

2.2 Performance Management Requirements

For the requirement capture and identification of the system the TMF Telecom Operations Map (TOM) [5] approach was used, making the proper selection, where needed. The TOM is the framework for accomplishing the "end-to-end process automation of telecommunications and data services operations processes" and defines the business processes and their interactions used by Service Providers in the Customer, Service and Network Management areas. The Business Processes defined in TOM Business Process Framework (BPF) are identified in Fig.2.

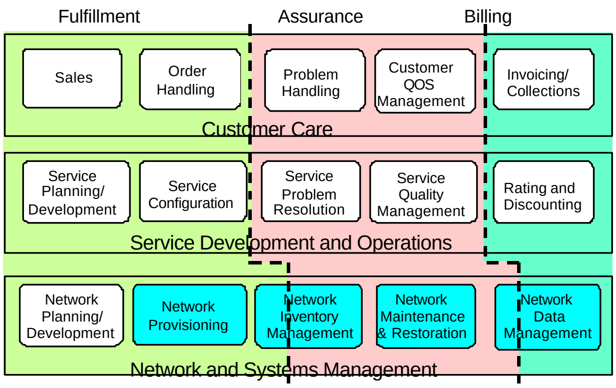

Fig.2: TOM Processes

From the above processes, the coloured ones were addressed by the proposed solution. Specifically the requirements in the next paragraph are based on the Network Data Management (NDM) process.

The aim of the Network Data Management Process is to ensure that network performance goals are tracked, and notifications are provided when they are not met. The process must provide sufficient and relevant information to verify compliance to SLAs and QoS levels. The main requirements are the following:

- The system should monitor the QoS parameters of the active connectivity services (ICS).
- The system must be able to generate alarms when previously established QoS thresholds are crossed, and the fulfilment of the connectivity services, as agreed with the user, is in danger.
- The system should trigger, if necessary, Network Maintenance & Restoration processes to prevent the non-fulfilment of QoS guarantees.

2.2 Use Cases

NDM UCs incorporate the functionality for Performance Management (PM) of the system. These are the use cases providing means to collect and analyse performance data. The operator can basically produce reports and configure the way the system collects performance information. The configuration can be on a counter-by-counter manner or by an ICS. The system intends to support a set of pre-configured data collection policies to be used by operators that don't want to get into the glory details of each counter.

Fig.3 depicts the NDM Use Cases considered by the proposed system.

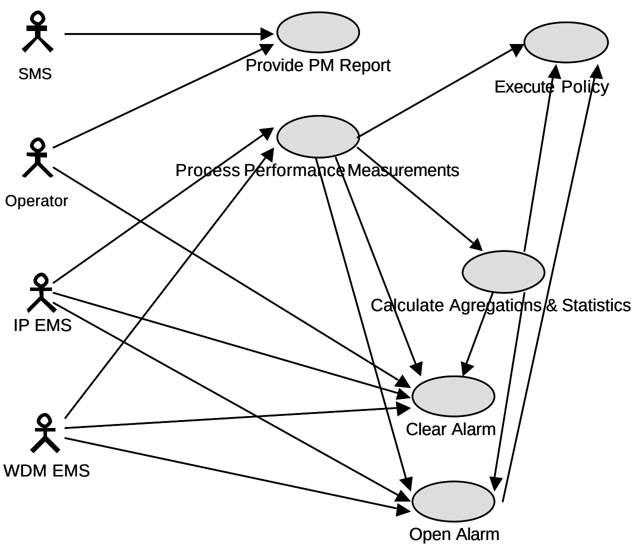

Fig.3: Network Data Management UCs

The following UC has been defined:

- Process Performance Measurements: It collects the counters according to a defined policy. If the thresholds are crossed, an alarm is triggered.
- Provide PM Report: It produces reports with an analysis of quality of the supported ICS.
- Calculate Aggregations & Statistics: It calculates aggregation of the counters for different periods of time; moreover calculates computed counters and statistics (compared to average and standard deviations) according to the customer's definitions. Calculates QoS counters for ICSs. If some thresholds were crossed by the calculated values, alarms are generated and sent to the fault management application.
- Clear Alarm: It clears an alarm and removes it from the list of active alarms
- Open Alarm: It handles alarms issued by the Element Management System (EMS), or by an internal application like the Performance Management.
- Execute Policies: The purpose of this Use Case is to carry out actions according to an instantiated policy. The policy conditions are checked and the relevant actions are executed.

It should be finally mentioned that although Clear Alarm and Open Alarm UCs belong to the Fault Management area and Execute Policy belongs to the Configuration Management area, they are strongly interrelated with the supported Performance Management operations.

3 Performance Management Functionality

3.1 Overview

The performance management functionality of the proposed system is to monitor, filter and report performance data. The INMS monitors the basic traffic and QoS network parameters of the LSPs and reports service degradations in case of performance gauges or counters threshold crossings. Secondary functions are the ones to set threshold crossing alerts on the available route capacity between any two-service locations for all provided transport services/facilities or on the equipment capacity, handle notifications of capacity threshold crossings, obtain periodic and on-demand reports of the monitored capacity (traffic load) and use the obtained traffic monitoring data for identifying possible problematic situations in the network and take actions to prevent network congestions.

Since the main objective of the provided PM functionality targets the insurance of the end-to-end quality of service, as perceived by the client, the system calculates results from appropriate measurements taken at the end-points of the service. Furthermore, since the service is IP/MPLS in nature, performance characteristics of the underlying optical domain can be abstracted. This is neither to say that the behaviour of the optical domain is of frivolous significance, nor is it left unmonitored. Management functionality of all functional areas surrounds all domains, but in this particular case the end result can and should be accumulated in merely the end-points.

The Performance Management application architecture is consisted by three key system components, namely the Quality of Service Manager, the Performance Collector and the Threshold Manager. The exact functionality of each component is described in section 3.3. These three components have instances running on both IP-NMS and WDM-NMS, as well as the INMS, following the notion of the Generalised NMS [2]. The Generalised NMS is a template NMS, where generic components has been defined for each management functional area. Those generic components have been appropriately adapted for each NMSs according to the specific needs of each technology.

3.2 Information model

This section contains a representation of the entities with which the performance management application needs to deal. The information model comprises all performance management related information that needs to be stored persistently in the system and visualised in the system Graphical User Interface (GUI).

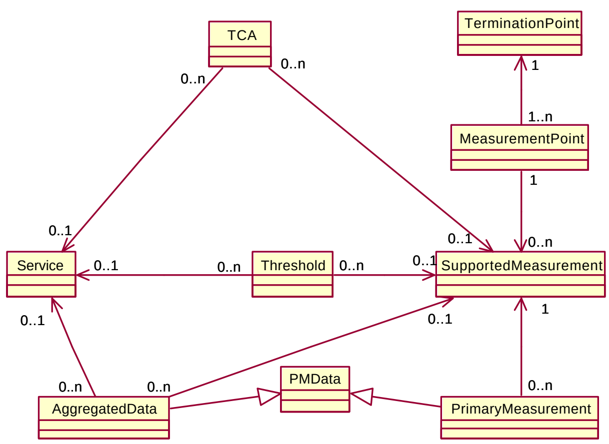

Fig. 4: Performance management information model

The basic model is system independent, and as such is valid for the IP-NMS, the WDM-NMS and the INMS. Considerations for each of these systems are out of the scope of this paper. Table 1 briefly explains each entity

Table 1: Entities Description

Entity Name	Description
PMData	Single chunk of performance management data. It is either a primary measurement or an aggregate. The data can refer to a termination point or to a service.
Primary Measurement	Basic measurement, retrieved from the IP or WDM NMS. A primary measurement is always associated to a measurement point, never with a service.
Aggregated Data	Performance data, obtained by means of processing primary measurements, alarm information and other data. Aggregated data can be associated either with measurement points or with services.
Measurement Point	Represents a specific layer rate within a termination point in which measurements can be done.
Service	It represents the service delivered by the MPLS or WDM network and managed by the system. The service is delivered either by the MPLS network meeting some QoS goals resembling a connection-oriented circuit or by the WDM network Services for PM purposes are the services as represented in both the Northbound Interface of the system, and at the Southbound Interface.
Threshold	Represents a threshold set for a supported measurement or for a service, the crossing of which will cause the IP-NMS or the WDM-NMS to issue a threshold crossing alert.
Termination point	A termination point is the logical abstraction of an endpoint (actual or potential) of a topological (physical) link, or a subnetwork connection.
Supported Measurement	Represents a type of measurement that can be taken at a measurement point
TCA	Represents a measurement whose value crosses, upwards or downwards, a defined threshold.

3.3 Performance Parameters and Procedures

The next logical step is to define the network performance parameters that are of interest in order to substantiate the rather abstract notion of QoS. The list of parameters that are supported by the system are the one-way delay, the IP packet delay variation (jitter), the one-way packet loss and the “abstract measurement” of service availability (i.e. its calculation is based on the previous “primitive” performance measurements)

All information is requested from the underlying EMS that manage the network element (e.g. router) that accommodate the relevant terminating point (e.g. IP port). In case of bi-directional services the system acquires information for both end points, resulting in an up-link and down-link performance data record. Communication with the EMSs as well as raw data gathering, rudimental processing and storing are under the responsibility of the Performance Collector component, which functions as a mediator between the NMS (specifically the Quality of Service Manager component) and the EMSs. From the perspective of the NMS, the Performance Collector component serves as the network performance database.

Sequentially data are further processed and brought to a more useful format in the Quality of Service Manager component. This is where the assessment of measurement results that are either complex (availability) or involve more parameters (time window, historic data) take place.

The component responsible for the performance monitoring of any of the established services is the Threshold Manager. Performance data are accessed through the Quality of Service Manager. Its functionality – configuration is based on two types of parameters:

- Thresholds that are linked to a certain connection – performance parameter couple. There can be more than one threshold value for each couple, resulting in a quantization in the provided service level.

- Time parameters that pertain to both the time window of the measurement and the frequency of sample measurements. Thus, the Threshold Manager in effect configures the other two performance related components.

These parameters are set by either policies or the network operator directly, with the former being the most expected scenario since:

- On one hand policies provide for a generic, easily manageable and comprehensive way for the network operator to intervene to the overall network performance.

- On the other hand policies are what SLAs with potential clients are expected to be translated into.

Threshold crossings result in the issue of a Threshold Crossing Alert (TCA) which in turn is propagated to the corresponding system components of the Fault functional area. TCAs originated from performance degradation result in new alarms and are handled by the Fault management procedures accordingly, whereas TCAs originated from performance recovery affect the corresponding previously issued alarms.

4 Adaptation to the Testbed

The described system has been validated on a trial infrastructure, equipped with appropriately interconnected Network Elements (NEs), their corresponding management platforms and the appropriate Data Communication Networks (DCNs). The WDM subnetwork was based on the commercial DWDM ring of OTE in Attica whereas the IP sub-network was based on 4 IP/MPLS routers.

For the communication of the proposed NMS with the network element an adaptation layer was needed. The adaptation of the IP-NMS and WDM-NMS to the respective EMSs was based on the TMF MTNM interface. Due to the existence of the commercial WDM-EMS of Marconi, there is no need to develop a WDM-EMS from scratch and the adaptation of the WDM-EMS was much simpler since only a mapping between the Marconi proprietary interfaces and MTNM interface was needed. The main functions of the WDM adaptation layer as far as performance management is concerned was the mapping of the proprietary performance data structure to a MTNM compliant and the mapping of the proprietary methods' calls to the MTNM calls in order to establish and manage the session between the WDM-NMS and the WDM-EMS. The transfer of any performance bulky history data retrieval is based on the FTP protocol.

In the case of the IP-EMS, due to the lack of an IP-EMS, it was decided to develop from scratch a CORBA component, which was responsible for the direct interactions of the IP-NMS with the network elements. With respect to performance management functionality, the access to the IP-EMS was achieved through file transfers using the FTP protocol for bulky history data retrieval, and native CORBA-based interface that implements the mapping between the MTNM interface and the IP-EMS proprietary. The communication between the IP-EMS and the network elements (the IP routers) is achieved through the use of SNMP for reading the

different counters' values and through CLI for configuring the requested monitoring points.
Lastly, but most importantly, the access privileges and policy as set by the network operator was a crucial factor to be taken into account.

5 Conclusions

Performance Management, one of the 5 functional management areas of FCAPS (Fault, Configuration, Accounting, Performance and Security), has drawn significant attention the last years due to the increase of customer requests for services with guarantee QoS parameters. The latter is a result of the fierce competition between network and service providers to increase their market share through the differentiation of their offered services. Thus more and more providers are offering services with guarantee QoS parameters as complement of their basic best effort service. This paper presents the latest developments regarding the performance monitoring of IP connectivity service (ICS) based on a hybrid IP/MPLS over WDM network. The proposed system is part of a larger system that allows not only the provisioning of ICS with guarantee QoS but also supports the fault monitoring and restoration of them. The proof of concept of the proposed functionality has been evaluated through an in-field trial. It is within the intention of the authors to study further the close relation between the performance degradation of the provided services and the triggering of the recovery mechanisms.

6 Acknowledgements

The authors would like to thank all the WINMAN [6] project colleagues who have contributed to the ideas presented here. The views presented in this paper reflect the authors' opinion.

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