Integrated Management of IP over Optical Transport Networks

Lampros Raptis[1], Fotis Karayannis[2], Joan Serrat[3], Kostas Vaxevanakis[4], Alex Galis[5], Pablo Arozarena[6], Nikos Vardalachos[5], Giorgos Chatzilias[1], Dimitris Chronis[7], Roberto Garcia[3], Willem Romijn[8], Panos Philipopoulos[2], Yiorgos Patikis[1], Daniel Josef[9], Anat Schwartz[10], Theodore Zahariadis[4]

1 National Technical University of Athens, Athens, Greece, email: {lraptis, gchatzi, gpatikis}@telecom.ntua.gr
2 OTE Consulting, Athens, Greece, email: {fotisk, Philippopoulos}@oteconsult.gr
3 Universitat Politècnica de Catalunya, Barcelona, Spain, email: {serrat, rogarcia}@tsc.upc.es
4 Ellemedia Technologies, Athens, Greece, email: {vaxevana, zahariad}@ellemedia.com
5 University College London, London, U.K, email: {a.galis, n.vardalachos}@ee.ucl.ac.uk
6 Telefónica I+D, Madrid, Spain, email: {pabloa}@tid.es
7 Hellenic Telecommunications Organisation SA, Athens, Greece, email: {dichroni}@ote.gr
8 Lucent Technologies, Huizen, The Netherlands {romijn}@lucent.com
9 RAFAEL, Haifa, Israel, email: {djosef}@rafael.co.il
10 TTI Telecom, Haifa, Israel, email: {anatsch}@tti-telecom.com

Abstract

The exponential growth of Internet data has posed new demands to transport networks. As existing Time Division Multiplexing (TDM) transport networks cannot cope with this increase, WDM technology, which allows bit rates at the order of Gbits/sec, is being deployed by network operators. On the other hand, the forecast that data traffic will surpass the voice traffic in the near future force Network Operators for solutions that allow the convergence of the data and the voice transport networks. The IP directly over WDM approach is the most appealing solution and intensive research effort is spent into the integration of the IP and the WDM. Most approaches are based on the control plane as a mean for integrating the two technologies. A different approach is presented in this paper, where the integration of IP and WDM is based on the management plane. This approach has been adopted by WINMAN[1], an ongoing European research and development project, whose aim is to offer an open, flexible and scalable integrated network management solution for the provisioning and maintenance of IP over WDM end-to-end transport services derived from Service Level Agreements (SLAs). The management functional requirements are described as well as the corresponding WINMAN architecture. The description of a generic NMS framework, which is used to instantiate the different NMS, namely the Inter-Domain NMS (INMS), the IP-NMS and the WDM-NMS is also presented including as an example the instantiation of the IP-NMS.

Keywords: Integrated Network Management System (INMS), CORBA, TMN, Management, IP, MPLS, WDM, OTN

1 Introduction

The exponential growth of Internet data has posed new demands to transport networks. Deployed TDM transport networks have reached their limits and operators are seeking for solutions to relief the capacity exhaustion [1]. The emerging Wavelength Division Multiplexing (WDM) technology [2] is offering such a solution allowing the multiplexing of many optical signals into one fiber. Moreover, recent advance in the optical technology permits the deployment of optical transport networks (OTN), which has intelligent functionality leading to creation of an Automatic Switched Transport Networks (ASTN) [3].

In this context, the management of existing networks is becoming more complicated since one more transport technology is added to existing multi-technology networks. The challenge for the Network Operators/Transport Service Providers is to manage their complicated networks in a way, which allows the various technologies from the different vendors to inter-work in harmony and to

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make the differences in a heterogeneous network environment transparent to the customer. Moreover, in order to be competitive in this market they must have the capabilities to provide a broad range of services to the end-customers at a competitive price with a proven quality of service in the shortest possible time.
To surmount these challenges, service providers are asking for a solution to manage these diverse and large-scale networks, which are based on ATM, SDH, WDM and IP. Research efforts and solutions for managing every technology independently have already been reported even for the WDM ([4] and [5] and [6]), which is the newest of the four technologies. What is missing is an Integrated Network Management System that manages the network across the different technology/vendor domains. The advantages of such an Inter-Domain Management solution for service providers /network operators are greater flexibility, extendibility and cost control. WINMAN [7] aims at an integrated solution to the management of IP services deployed over an Optical Transport Network. This approach is based on management plane for integrating the IP and the WDM, instead of different proposals, which are based on the control plane for integrating the two technologies [8]. WDM networks are following the connection-oriented paradigm, something inherently opposite to the nature of IP networks. However, with the introduction of the MPLS framework, the IP layer resembles the connection-oriented nature of a WDM network, enabling the seamless integration of these two network technologies. The telecom style approach of management can be then extended and be applied in the IP-MPLS domain as well.

The structure of this paper is the following: next section presents an overview of the WINMAN Business model and the management functions that WINMAN covers are then described. The technical approach adopted by WINMAN is described in detail in section 3. Firstly, the high-level system architecture is presented and then the concept of the generic NMS framework and an example illustrating the IP-NMS architecture based on the generic NMS is given. Finally, a brief summary of the WINMAN activities (current and future) is presented in section 4

2 WINMAN Management Functions

The WINMAN solution is intended for two broad categories of customers namely network operators or Internet Service Providers (ISPs) and third parties, such as Value Added Service Providers (VASPs). These customers will make use of the system to increase revenues by offering improved and more efficient services to their clients by building and reselling sophisticated management solutions (i.e. Virtual Private Networks). Moreover, ISPs or third parties may want to manage by themselves the capacity that they hire from a transport network operator and/or provide value added services (e.g. extranets) to their clients. Both categories of customers have shaped the requirements of our system.
In the field of the services, two basic types are considered. The first type includes connectivity services that support real-time data transport over IP, like voice (VoIP) and multimedia (MoIP) applications. The second type embraces connectivity services for the establishment of Virtual Private Networks (VPNs). The objective is, however, to generalise the proposed solution to other services.

Following a formal process, the description of which is out of the scope of this paper, a detailed business model was identified [9] and the requirements of each player in the business model were captured. The actors of the Business Model pose their requirements as external actors to WINMAN solution, and then the WINMAN system requirements are derived from the needs of the WINMAN actors. Based on the WIINMAN system requirements the following management functions have been identified, covering three of the FCAPS (Fault, Configuration, Accounting, Performance and Security) management areas, namely Configuration, Fault and Performance.

Configuration Management

The Configuration Management application enables single point access to provisioning tasks and to end-to-end views of connections and their underlying infrastructure (down to the physical layer) and facilities, independently of domain. The main functions identified are:

- Discover the network resources and topology
- Maintain an inventory of all the network resources with their status and their hierarchical relationship
- Service requests from the Service Management for the configuration of the requested transport service
- Notify the Service Management about service state (pending, in-effect) changes
- Configure the end-to-end connections and services across the different technology domains, taking into account the inter-working between the routing on the IP and the WDM layers
- Support different service like VPN, point-to-multipoint services, etc
- Present an end-to-end view of the services giving the logical hierarchy of all

transmission sections constituting the end-to-end connection

- Provide updates to the Fault and Performance Applications reflecting the changes in the network configuration and new services

Fault Management

The Fault Management application collects faults across different technological domains and determines the root cause domain responsible for the fault. Topology information and user-defined rules (to be defined in the project) are applied to faults received form the domain fault managers. The main functions identified are:

- Maintain a fault topology database which contains the alarm status of the network resources and services
- Quick fault correlation between optical and client layers
- Quick fault localisation
- Design management rules for the multi-layer survivability aspects (avoidance of conflicting actions, protection and restoration, service differentiation)
- Service requests from Service Management system for the status of the connectivity services
- Interface with domain fault management systems and receive alarms depicting domain fault manager's view of the service affecting root cause
- Interface with the Inter-Domain topology database to obtain network topology information.
- Inventory of user-defined correlation rules

Performance Management

The Performance Management application collects data from the different technological domains and processes them in order to assess the performance and the usage of the network resources. Based on these assessments the operator is able to perform pro-active management of transport capacity across their multi-layer network and is able to perform pro-active management in order to prevent faults affecting the service in the network. The main functions identified are:

- Set threshold crossing alerts on the available route capacity between any two-service locations for all provided transport services/facilities,
- Set threshold crossing alerts on the equipment capacity,
- Be notified of capacity threshold crossings,
- Obtain periodic and on-demand reports of the monitored capacity (traffic load)
- Use the obtained traffic monitoring data for identifying hot-spots in the network and take measures to prevent network congestion
- Interface to the Configuration and Fault Management applications to learn about the actual status and state of the network resources and the services.

3 WINMAN System Architecture

3.1 Overview

The proposed management systems will be designed by applying mainly Open Distributed Processing (ODP) [10] principles taking also into consideration the TMN framework [11]. The TMN architecture structures the management complexity by layering the management applications, defining a common data model, enabling re-use of management data, and specifying system interfaces. ODP goes one step further, enabling the design of management applications that are independent of distribution, the underlying infrastructure and management protocols.

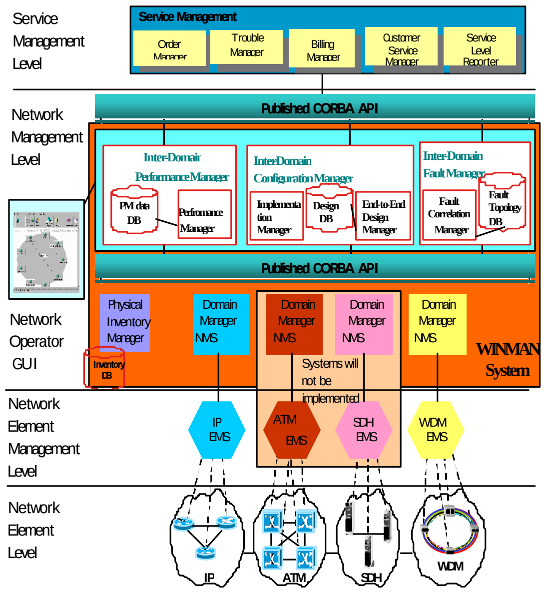

Figure 1: System Architecture

As it can be seen in Figure 1, the high level architecture of the WINMAN comprises three different network management systems, that is, the IP-NMS and the WDM-NMS at the technology dependent layer and the Inter Domain[2] NMS above them. The main focus will be the implementation of the INMS for Configuration, Fault and Performance Management with an open interface to the Service Management and the Network Management

[2] It should be noted that the term domain within this paper refers to technology domains and not administrative ones and there is no relationship with the X-type TMN interfaces.

Systems of the WDM and IP domains complemented with a GUI. Note that the architecture proposed hereafter could support multiple Service Management Systems (SMSs) over the Northbound Interfaces, multiple NMSs at the technology specific layer, and multiple EMSs under the Southbound Interfaces. Only the simplest option is depicted in Figure 1, with one single system per management layer.

The proposed architecture follows the three-tier concept, where the presentation layer contains the thin client GUI towards the operator, the business logic layer contains the core logic and management applications and finally, the persistency layer includes the system and management repository. The system architecture is constituted by several NMSs, each for the underlying managed technology and one acting as the integrated network management system that offers the supported services to the higher level.

A standard connection-oriented technology neutral interface supporting IP, WDM, ATM and SDH technologies will be defined, while only the IP and WDM will be implemented. The work done in this area by the Tele Management Forum (TMF) [12] will be used as a starting point and will be extended to support the IP technology. In case that vendor specific interfaces are provided by the IP and WDM NMS, then the proprietary or legacy non-compliant WDM or IP NMS have to be adapted to provide the open interfaces. Technology Object Adapter (TOA) should be developed in order to translate the requests and responses from the external interface protocol into the published CORBA API. This special case is not depicted in Figure 1. The IP and WDM NMS will also provide open interfaces towards vendor-specific WDM and IP EMSs. In case no particular IP EMS is shipped with the IP equipment, the IP NMS could interface directly towards the IP managed elements.

A fundamental part of the architecture is the information repository or database of all the physical and logical network configuration data needed to manage the network. This database can be viewed as a large directory with open, standard interfaces. In the INMS architecture, each application building block will provide well-defined functionality via open interfaces encapsulating the different network elements, thereby logically decoupling the high level applications from the physical infrastructure. Thus GDMO, CMIP, and SNMP interfaces will be transparent to the building blocks.

3.2 Generic NMS architecture

This section describes the architecture of a common framework for all NMSs (INMS, IP-NMS and WDM –NMS) that altogether form the WINMAN system. The particularities that belong to each of the WINMAN sub-systems (INMS, WDM-NMS and IP-NMS) and are not covered by the Generic NMS functionality are out of the scope of this paper. This generic NMS is based on a 3-tier architecture and there are mainly two categories of sub-systems, the application sub-systems and the supporting sub-systems. The application sub-systems perform management operations that are relevant with the problem under solution, whereas the supporting sub-systems perform auxiliary operations, which support and are needed for the smooth operation of the application sub-systems.

The subsystems of the generic NMS, shown in Figure 2, are derived from the management functions described in the previous section. Some arrows (those related to the Policy Manager and the Supporting Subsystems) have not been included in order to simplify the figure. The functionality of each subsystem is described in Table 1.

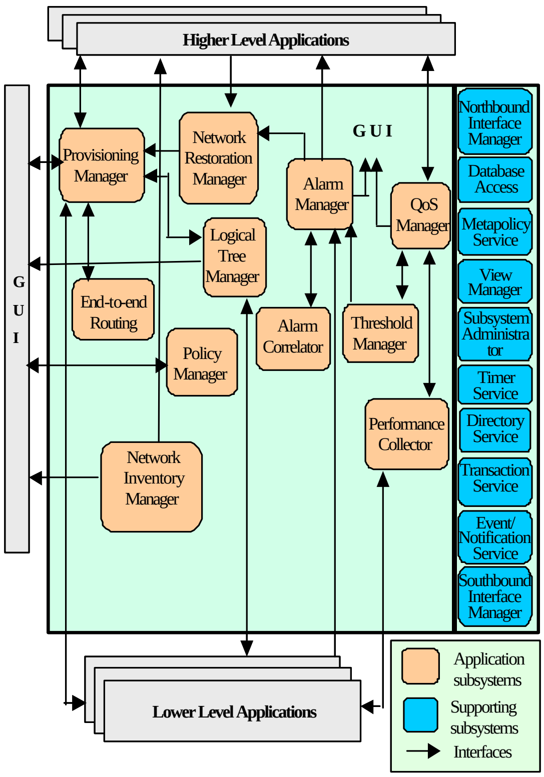

Figure 2: Reference architecture building blocks

Table 1: Description of sub-systems' functionality

Sub-System	Functionality
Provisioning manager	It is in charge of provisioning the IP Connectivity Service (ICS) that users – the SMS or WINMAN operators - request through the Northbound Interface or the GUI,

	respectively. It manages the provisioning process, including scheduling.
End-to-end routing	It performs the design of the end-to-end connections inside its own network, taking into account QoS constraints and routing policies
Network inventory manager	It is responsible to store, update, maintain and provide information about the data that WINMAN uses related to network physical resources, according to the information received from the network element layer and the GUI system. The other subsystems will use these data.
Logical tree manager	It updates, maintains and provides logical information of the network, like connectivity or capacity, according to the information received from the Provisioning Manager and from lower level applications.
Network restoration manager	It is responsible for the network restoration actions taken in order to prevent the degradation of the provided connectivity services. These actions are taken when alarms from the Al arm Manager arrive to the Network Restoration Manager subsystem.
Policy manager	It is responsible of managing and providing policies, necessary to make decisions in a variety of actions. For instance, it checks a provision request against the correspondent policies. Alarm and performance mechanisms can be policy oriented. The routing and the restoration mechanisms can also be controlled by policies.
Alarm manager	It receives alarms from the Lower Level Application, triggers alarm correlation, stores alarm data and distributes alarms to other systems and subsystems.
Alarm correlator	It filters, correlates and evaluates the alarms to find out their root cause and generate new alarms, sending the results to the alarm manager
QoS manager	It monitors and analyses the QoS data of the paths provisioned in the network and sent by the Lower Level Applications. It also provides performance data to the GUI and the Higher Level Applications.
Threshold manager	It check counters against the defined thresholds in order to generate alarms and reports if the thresholds are passed.
Performance collector	It collects performance data from the Lower Level Applications.

3.3 Example of the IP NMS architecture

The IP policy-based network management system (IP-PBNMS) carries out the management of the IP network layer and offers a technology independent management view of the IP network. The architecture of the IP NMS described hereafter is aligned with the generic architecture that has been selected to drive the architecture of all the WINMAN NMSs. This means that we made use of the same functional blocks and we adopt their basic interrelationships.

In order to present a readable model three views are needed, the configuration view, the performance view and the fault view. Each view contains the subsystems relevant to the corresponding management area. We can say that in case that we were interested to implement only the configuration management functionality, only the elements appearing in the configuration management view would be needed and so on. The main configuration management functions are:

- Design of connections inside the IP subnetworks
- Establishment and maintenance of end-to-end QoS connectivity services, including the setting up of MPLS Label Switched Path (LSPs)

The configuration view is depicted in Figure 3, as an example.

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This architecture is also compliant with the IETF policy-based management model ([13] and [14]). It identifies a Policy Manager, which is functionally equivalent for the three views and three Policy Enforcement Points (PEPs). The PEPS are in fact the aggregation of other functional blocks. More specifically we identified:

- Provisioning Manager and Network Restoration Manager as PEP-1 in the configuration management view
- Qos Manager, Threshold Manager and Performance Collector as PEP-2 in the performance management view
- Alarm Manager and Alarm Correlator as PEP-3 in the fault management view

This points out that in WINMAN we understand the Policy Based Management concept not as an additional management function but as the same management functions (or part of them) of conventional systems under the control of policies.

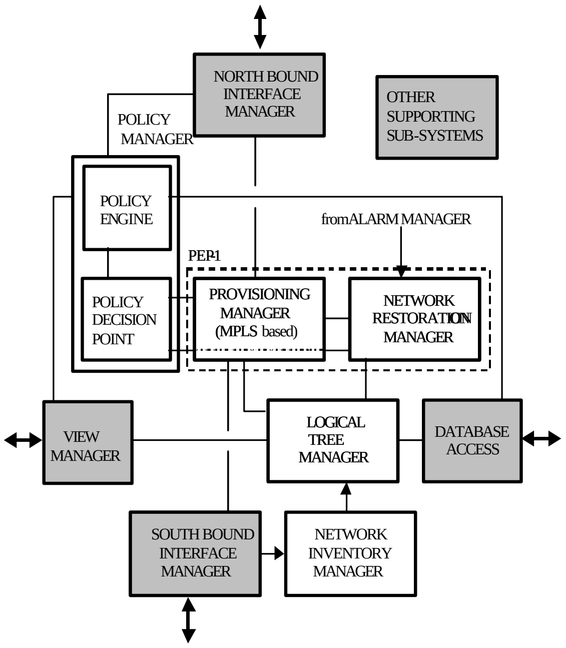

Figure 3: The IP-NMS configuration management view

4 Summary

In this paper, we have proposed an approach for providing IP connectivity services over the Optical Transport Network. This approach is based on the telecom-style network management in both the IP and WDM layer in an integrated way. With the introduction of the MPLS Internet packet switching protocol, the IP layer resembles a connection-oriented network. This approach has been adopted and is being carried out in WINMAN, an ongoing European research and development project, whose aim is to offer an integrated network management solution for the provisioning of end-to-end IP connectivity services, embedding the most promising management paradigms like policy-based network management. WINMAN consists of an open, distributed, and scalable management architecture supporting multi-vendor, multi-technology environments. The project will contribute to the establishment and operation of worldwide IP over WDM networks. The trials envisaged in the project would demonstrate inter-connectivity across a worldwide network management infrastructure.

The proposed system architecture eases the development, provision and validation of a novel Integrated Network Management architecture for future IP networks.

5 Acknowledgements

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