20-11-13

# Deliverable D8.4 (DS4.3.1): End-to-end Management – Catalogue of Business Processes

**Deliverable D8.4 (DS4.3.1)**

| | |
|---|---|
| Contractual Date: | 30-09-2013 |
| Actual Date: | 20-11-2013 |
| Grant Agreement No.: | 605243 |
| Activity: | SA4 |
| Task Item: | T3 |
| Nature of Deliverable: | R |
| Dissemination Level: | PU |
| Lead Partner: | AMRES |
| Document Code: | GN3PLUS13-589-13 |
| **Authors:** | V. Bilicki (HUNGARNET), M. Dunmore (Janet), A. Gräter (DFN), I. Golub (CARNet), L. Hrboka (CARNet), B. Jakovljević (AMRES), F. Liu (DFN), V. Olifer (Janet), B. Schmidt, (CARNet), P. Vuletić (AMRES), M. Wolski (PSNC), M. Zdravković (AMRES) |

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7 2007–2013) under Grant Agreement No. 605243 (GN3plus).

Deliverable D8.4 (DS4.3.1):
End-to-end Management – Catalogue of Business Processes
Document Code: GN3PLUS13-589-13

# Table of Contents

# Table of Figures

# Table of Tables

# Abstract

This document describes the GÉANT business process catalogue, a set of business processes that are executed during all the phases of the operations of GÉANT3plus multi-domain services. It also describes the selection procedure for the most important business processes that will be analysed in subsequent phases of the project. The main process flows of the newly developed MDVPN service and the perfSONAR tool (which supports performance monitoring for the GÉANT community) were analysed. This revealed several places where existing manual procedures in the multi-domain service operations could be replaced by OSS components, making service operations significantly simpler. The analysis also highlighted some problems with the design and focus of the existing tools that require improvement.

# Executive Summary

The main aim of this document is to model the business process catalogue, a set of business processes that are executed during all the phases of the operations of GÉANT3plus multi-domain services (e.g. bandwidth on demand, multi-domain VPN and similar) and the selection of the most important business processes that will be analysed in the next phases of the project. It is a report of the first phase of the modelling and redesigning procedure for new and existing GÉANT OSS (Operation Support Systems) components.

The first two sections of this report describe standardisation in the field of network management and define the methodology for the analysis given in the remainder of the text and the criteria for the selection of the three processes. Because of the strict top-down structure of the task, defined through the set of milestones, the analysis will lead by the end of the project to significant improvements in the GÉANT OSS component. Since any kind of software development has to be properly justified, the analysis considered the information about available services, the need for particular OSS service components, the trends in the number of users, the tools and functionalities already provided, the availability within the market of similar tools and a cost/benefit analysis of some of the proposed changes.

The third section of this report presents the analysis of the typical process flows for the MDVPN service that is currently being developed in SA3 T3. These process flows describe typical end-to-end activities such as request-to-provisioning and problem reporting-to-resolution for newly designed services, and all processes that are currently executed by human administrators. Key conclusions of this section are that proper modelling of the Inter-domain service interaction is crucial for the efficient operations of the MDVPN (and any similar multi-domain) service. In addition, the existence of a service instance catalogue that stored domain service capabilities, a catalogue of installed service instances and service availability information, would significantly improve provisioning time for the service.

The final section of this report analyses perfSONAR, the tool that supports performance monitoring processes for the GÉANT community. The analysis revealed that different initiatives within the GÉANT community in the past made it difficult to define the main purpose and goal of perfSONAR. It is perceived among some groups in the community as a general multi-domain active network monitoring platform while others perceive it as a supporting tool for other GÉANT multi-domain services. These different views led in the past to the development of different modules that support one or the other view. The analysis shows that in both cases there are problems with perfSONAR which result in the relatively low rates of tool adoption and usage, but with a potential for these to be improved. perfSONAR as a general multi-domain active network monitoring platform, although performing similar types of network measurements, is handicapped compared to similar platforms by having a smaller number of measurement points, a smaller geographic range and a more complex installation procedure. On the other side, perfSONAR as a supporting tool for other multi-domain network services lacks the capabilities to process specific multi-domain service parameters (e.g. BoD reservations, VPN circuits, SLA parameters, warning thresholds, and so on). There is no correlation between network performance and service parameters in perfSONAR. The SA4 T3 task recommends revisiting the main goals of perfSONAR tool to define a sharper focus for the platform before proceeding with the tool improvements that would make it more desirable and competitive.

Based on the previous two analyses, the task decided to choose three process groupings for further analysis:

- Performance Management processes.
- Problem Management processes.
- Multi-domain Service Interaction.

The first group is supported by perfSONAR (though needing improvements) but the other two processes are unsupported in the current GÉANT OSS portfolio.

The document in the Appendix also contains a report on the integration of the two existing GÉANT tools (cNIS and AutoBAHN) using GEMBus, the GÉANT-developed Enterprise Service Bus (ESB) platform which is still in the pilot phase, and standard TM Forum's TIP Resource Alarm Management interface. OSS component integration using common communication vehicle (ESB, and in this case home developed solution) and standardised interfaces is the current network management best practice.

This report does not strictly belong to the business process analysis, but since the main goal of the task is the improvement of new and existing GÉANT tools, the improvement can be made also through better internal organisation and architecture (e.g. redesigning the tool from the software silo to SOA architecture or applying standardised interfaces for inter-OSS communication). The conclusion of this subtask is that the GEMBus platform is suitable for OSS component integration, and that this integration is easily achievable.

# 1 Introduction

## 1.1 Objective

The main objective of the Deliverable DS4.3.1 is to define the catalogue of network management business processes for the GÉANT-NREN multi-domain environment. This is a set of business processes that are executed during all the phases of the operations of GÉANT3plus multi-domain services (e.g. bandwidth-on-demand, multi-domain VPN and similar).

The first Milestone of the SA4 T3 task, which coincides with the due date of the DS4.3.1, is the selection from this catalogue of the three most important business processes which will be modeled in the next phases of the project and whose modeling will be eventually used for the redesign and refactoring of the existing tools that are being developed within the GN3plus project. Therefore this document will focus on the model of the business process catalogue and the selection of the most important business processes using the findings of GN3 JRA2T1 task which is a direct predecessor of GN3plus SA4 T3. It can be seen as a report of the first phase of the top-down approach to the modeling and/or redesign of the new/existing OSS (Operation Support Systems) components.

The document has a much wider scope than simply enlisting and briefly describing the set of business processes that are relevant to the GÉANT-NREN multi-domain environment. The selection of the most important business processes cannot be carried out by a purely abstract analysis of the business process frameworks: it needs to include an analysis of the particular services and tools that are in use or are being planned in GÉANT. In addition to focusing on processes whose automation could lead to significant service improvements, consideration must also be given to potential weaknesses and operational bottlenecks. Three Appendices have been included with this Deliverable in order to make the document self-sufficient. Some material is fairly readily accessible elsewhere (e.g. Ethernet performance monitoring standards) but other material is not (e.g. the Introduction to TM Forum specifications) and is included here for the convenience of the reader.

## 1.2 Document Outline

The document is organised as follows: Section 2 is a brief overview of the GÉANT business process catalogue modelled in GN3. Section 3 analyses MDVPN service operations and finds processes that could be candidates for the selection. Section 4 analyses the way Assurance business processes are currently supported in the GÉANT environment and Section 5 gives the conclusion to this report.

Appendix A is a brief introduction into TMF Business and Application Framework; Appendix B contains the report of the successful AutoBAHN-cNIS integration using GEMBus; Appendix C is an overview on the recently published standards for Ethernet performance monitoring.

## 1.3 GÉANT Multi-domain Services and Tools - Current Situation

The main aim of the SA4 T3 task is the redesign of the existing GN3plus monitoring and other tools supporting multi-domain network services. Existing GN3plus multi-domain services that are the potential subject of the SA4 T3 analysis are: Bandwidth on demand (developed by SA3T1), multi-domain VPN (SA3T3) and multi-domain wavelength service (SA3T2). These services are in different phases of service lifecycle. Bandwidth on demand (BoD) service is in a relatively mature stage, being developed throughout the GN3 project and supported by AutoBAHN tool for automatic service provisioning across multiple domains and cNIS as a repository of network topologies being used by AutoBAHN for service topology calculations. The design of the multi-domain VPN (MDVPN) service started with the beginning of the GN3plus project, and the service is now in the service design phase, where the main focus is on finding the best technical solution for the service, configuration, testing the service and on defining the service architecture, main actors, roles and functions. MDVPN service at the moment does not have any software supporting tools. Multi-domain wavelength service is not being actively developed as there is no sufficient demand for such service at the moment of writing this document.

Another tool that is being developed within the project and whose development and design matches the aim of the SA4 T3 task is perfSONAR multi-domain monitoring (MDM) (SA4T1). There is a slight ambiguity in the way perfSONAR is perceived within the GÉANT community that can be seen through the diverse subtasks and activities related to perfSONAR during the GN3 project and after it. Typically there are two different views:

- perfSONAR viewed as a service-agnostic[4] multi-domain monitoring platform, branded as a perfSONAR MDM product which NRENs can use in order to get the insight into the network performance parameters beyond the borders of their network and regardless of the services in use in the GÉANT environment
- perfSONAR viewed as a potential supporting service for other network services being offered in the environment (attempts and pilots to integrate perfSONAR and AutoBAHN in order to use perfSONAR as a monitoring platform for BoD service, circuit monitoring (CMON) module development, E2EMON and so on).

In the first case, perfSONAR users are NOC and PERT engineers from GÉANT-NREN environment and/or from supporting teams from multi-domain projects communities such as LHCONE or EGI. In the second case, perfSONAR users are other network services that would use perfSONAR features such as AutoBAHN, CMON, MDVPN, etc.

[4] perfSONAR is unaware of the underlying network services (e.g. GÉANT IP, BoD, wavelength), their service topologies, performance parameters and other service-specific details

One of the main challenges that SA4 T3 is facing during the GN3plus project is the decreased size of this part of the GÉANT service portfolio. Some services, like multi-domain wavelength service and tools like iSHARE and AMPS have now been withdrawn. The other challenge is a relatively low usage of other services and tools mentioned in this section. This fact makes it very difficult to create a real business case for the final goal of this task: the development of new or redesigned OSS components that would support service operations. This is because the cost of development could exceed the benefit of reducing manpower by automating certain supported processes, given the number of required service operations.

## 1.4 Background – Network Management Principles

Network management practice has evolved in recent decades from being mainly network device management to a much wider set of activities. Increased complexity of network technologies, inter-network relations and new services, the need to perform any service-related operations in the most efficient, reliable and quick way in order to provide the best possible customer experience has shifted the focus of modern network management towards the design and development of OSS components. One of the aims of network management is to replace manual procedures in service operations with software-supported processes wherever possible and suitable. The final goal is to create fully autonomic networks able to react without human intervention to various events inside or outside the network – though this goal is still at the research stage.

The shifting focus of network management towards OSS design and development led to the proposal of various specifications that summarize best practice in network management and define several standards. One of the leading bodies in the field that creates such specifications is TeleManagement Forum[5] (TMF). TMF specified the Frameworx, a set of documents that describe various topics in network management from different viewpoints (What do we have to do in order to provide a service? What do we want to manage? What kind of supporting tools can we create? How to model data for these tools? Which interfaces should we use in order to have interoperable OSS components?). The most well-known of the Frameworx specifications is the Business Process Framework (eTOM - enhanced Telecom Operations Map), which gives a description and decomposition of all business processes that could be found in a network service provider (it gives an answer to the question e.g. What has to be done in order to provide a service and by whom?, but not how you do that). The Business Process Framework is agreed as a common reference model and vocabulary for the business process description and is adopted by ITU-T[6] as M.3050 and by ETSI-TISPAN[7] as the best business process description for network service providers[8]. Other TMF specifications are the Application Framework (TAM – Telecom Application Map), which gives the functional description of an ideal set of OSS components in an ISP, and the Information Framework (SID – Shared Information and Data model) which describes the most complete existing information model that can be used for the design of OSS components. The scheme is being incrementally adopted by ITU-T as Recommendation M.3190. A significant part of the TMF work is the attempt to create standardised interfaces for

[5] http://www.tmforum.org/

[6] http://www.itu.int/en/ITU-T/Pages/default.aspx

[7] http://www.etsi.org/TISPAN/

[8] More details about the TMF Business and Application Framework, which are used extensively in this document, are given in Appendix A of this document. Additional details can be found in [GN3 DJ2.1.1]

the communication between OSS components. There have been several initiatives: MTNM, MTOSI, OSS/J, but the current effort is to gather all of these under the common umbrella of TIP (the TMF Interface Programme).

## 1.5 Catalogue of Business Processes

Various TMF specifications, although written in support of efficient and automated service operations in communication providers are not always fully compatible and their use is not always straightforward. For instance, business processes cannot be mapped one-to-one to TAM applications; it is not clear how and which parts of the SID model to use for the design of the tools supporting some process; the SID model is not always compatible with various TMF interface specifications, and so on. However, there is a general approach in TMF towards a top-down method in implementing their principles [GN921-R], as shown in Figure 1.1.

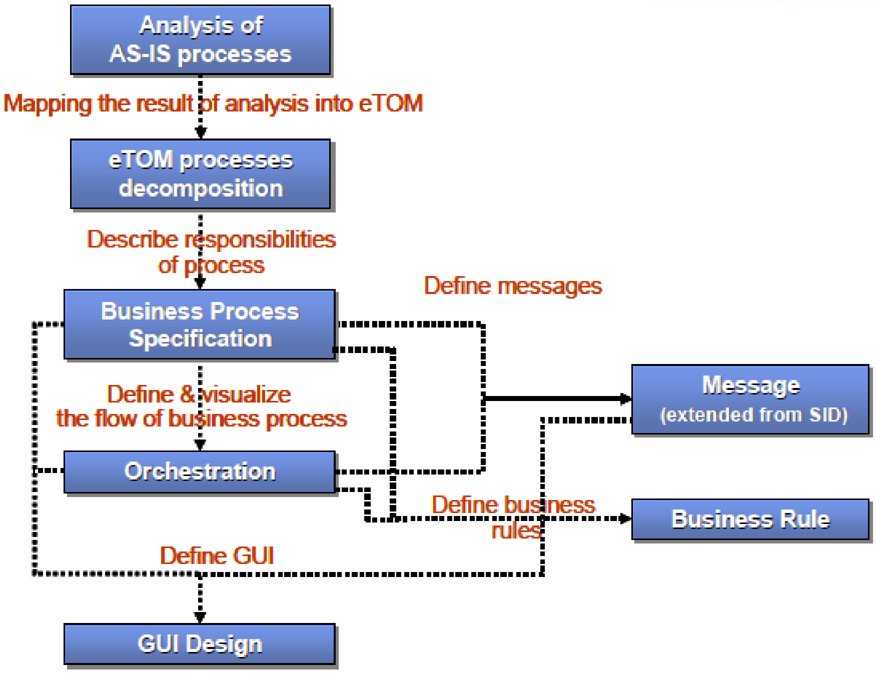

Analysis of AS-IS processes
Mapping the result of analysis into eTOM
eTOM processes decomposition
Describe responsibilities of process
Define messages
Business Process Specification
Message (extended from SID)
Define & visualize the flow of business process
Orchestration
Define business rules
Business Rule
Define GUI
GUI Design

Figure 1.1: Procedure for specifying and implementing business processes [GN921-R]

The approach may be summarised in the following steps:

- Choose a specific business processes whose automation could significantly improve service operations.
- Analyse that process thoroughly for the service which is being improved (the business processes as it is now executed).
- Decompose the process to technology-specific processes for modeling.
- Pick the correct information model for that particular problem from SID.
- Design an appropriate tool using TMF specific interfaces.

This approach is broadly in line with the GN3plus SA4 T3 task milestone schedule, according to which the task has to create the catalogue of business processes, then pick and model the three most important business processes before selecting one of the three processes and design the improvements to the existing GÉANT tools according to the model of this process.

This deliverable is a continuation of the work of the GN3 JRA2T1 task which applied TMF specifications to various network service management activities. Analyses were completed in order to find gaps and possibilities for improvement in the design of existing tools, to improve interoperability and later compatibility with other software tools in use, such as Network Management Systems. Many of the JRA2T1 recommendations turned out to be successful and are in production now, including the design of the DWDM plugin for the cNIS tool using SID artefacts and the integration of cNIS and AutoBAHN using TMF TIP interfaces.

The main findings of the GN3 JRA2T1 task were summarised in the Deliverable document [GN3 DJ2.1.1]. In addition to presenting a Business Process Architecture for the GÉANT-NREN environment, the report concluded that service operations in a multi-domain environment differ from the single domain case by the existence of a specific group of processes which define Inter-domain communication. This group of processes is called 'Multi-domain service Interaction' and is described in detail in [GN3 DJ2.1.1]. All other processes for the single-domain ISP case (and thoroughly described in the TMF Business Framework) are applicable to both single-domain and multi-domain environments. Therefore SA4 T3 (as GN3 JRA2T1) is of the opinion that there is little sense in creating a new static GÉANT-specific business process catalogue. Specifying a new business process catalogue would lead to either excessive duplication from the existing (and well proven) TMF Business Framework specification with the specific multi-domain extension already described in [GN3 DJ2.1.1]. The alternative would require the specification of a new proprietary model with the risk of errors and without the review from other independent sources and service providers. It is anticipated that only minor changes and refinements of the model will be made, if any, therefore **SA4 T3 will use Business Process Architecture [GN3 DJ2.1.1] as the business process catalogue for the GÉANT environment**.

## 1.6 Choosing the Most Important Business Processes

The first Milestone of the SA4 T3 task is to select the three most important business processes from the business process catalogue which will be modeled in the next phases of the project. The modeling will eventually be used for the redesign of the existing tools that are being developed within the GN3plus project. A few questions naturally arise from this procedure: How to measure the importance of the business processes? What are the measurable selection criteria? At what level of decomposition (in the sense of eTOM process decomposition) should the chosen process be?

Pure analysis of the business process framework cannot automatically give the right answer to these questions, as all business processes more or less equally contribute to a successful service delivery. For example, someone from a technical background might consider that efficient service provisioning is more important than service marketing or customer care, but this is not true. Even those services whose operations are organised in the most efficient and automated way, using the most advanced technologies can be completely unsuccessful if insufficient attention is devoted to capacity management, service marketing, relations to suppliers or other non-technical processes, so other criteria have to be found.

It was shown in the previous section that the methodology of the whole task is structured in a top-down manner where the selection of the important business processes will eventually feed into the design of the new or improved GÉANT tools according to the processes being modelled. The selection of the business processes in this phase therefore directly impacts the choice of the tool that will be developed or improved in the later phases of the project. Since the development or the significant change of the OSS component can be seen as the development of the new or changed IT service, such changes have to be properly justified. Justification for the development of some specific OSS components can then be used as a justification or a selection criterion for business processes that would be modelled later. Therefore the rigid top-down structure from choosing processes to the OSS redesign is not reasonable and has to be modified by taking into account the information about the available services, needs of services for particular OSS components, the number of users and trends in their change, existing tools, their set of functionalities, position within the market of similar tools, a cost-benefit analysis of some proposed changes, etc. Since the structure of the task assumes that in the later phase, one business process out of the three selected now will be used for the tool redesign, the justification in this stage does not have to be very detailed, but should just narrow down the scope to the set of business processes that appear to be the most often in the majority of typical multi-domain service operations. This will be done through the analysis of the service operations of MDVPN service and through the analysis of the business processes supported by the perfSONAR tool, its comparison to the standard models and similar existing tools.

The selected business processes are eTOM Level 2 process groupings that support some end-to-end activities (described in Section 3). It is better, for example, to analyse a Problem management vertical process grouping that includes both Resource Trouble Management and Service Problem Management L2 processes, than to single out one of these processes, because the process grouping contains all the processes from service problem report to problem resolution. In this way, the end-to-end activity will match the set of functionalities of the supporting tools.

Despite the earlier remark about the equal importance of the business processes of all process areas (strategy and product, operations and enterprise), the focus of the business process analysis in this document will remain on business processes from the operations area because the targeted recipients of the SA4 T3 recommendations are other SA tasks and activities whose objectives are to design and develop Operations Support Systems. Business processes, from strategy, product and enterprise process areas, typically belong to the NA tasks and activities of GN3plus, and their proper design and execution is of equal importance for the success of GÉANT services.

## 1.7 Business Process Analysis

Network management principles promoted by TMF were already applied to some tools and services in the GN3 project. Development teams of AutoBAHN and especially cNIS were exposed to the business process and functionality analysis. They adopted many features of the SID information model and the integration between the tools was developed using TMF TIP RAM (Resource Alarm Management) interfaces. The priority in this phase of the work will be on the analysis of the tools and services (i.e. perfSONAR and MDVPN) that did not have any contact with these principles and this style of assistance.

In order to assess the importance of business processes, the task analysed process flows for specific service related operations for the MDVPN service. Another result of the previous work of GN3 JRA2T1 are generic multi-domain process flows which describe the most common end-to-end process streams in the GÉANT-NREN environment such as request-to-service provisioning or service problem-to-resolution. Process flows are a powerful tool for process visualisation and were used to detect some of the components specific for the multi-domain environment which would significantly shorten the whole end-to-end activity. However, this approach was never applied to a particular service in our environment. Since the beginning of the GN3plus project, the SA3T3 task has been developing a Multi-domain VPN service (MDVPN). The design of this service from scratch gives a unique opportunity to test the top-down approach to the management of a service, and to potentially give recommendations for the service and OSS organisation before the development of the appropriate components actually begins. Therefore the first part of the Deliverable focuses on the detailed analysis of the actors and business process flows for the MDVPN service as a typical service in the GÉANT-NREN environment. This analysis will reveal business processes and process sub-flows whose automation would significantly shorten the complexity of the most common service operations procedures.

One of the main objectives of SA4 T3 is to improve the design of the existing GÉANT monitoring tools (e.g. perfSONAR). From the beginning of the GN3plus project, SA3T3 expressed the need to monitor the performance of the MDVPN service and was interested in the potential use of perfSONAR for service monitoring. perfSONAR is an infrastructure for network performance monitoring, and thus it could be said that it supports processes from the Assurance vertical process grouping, Performance Management vertical sub-group[9] in the GÉANT environment. Assurance business processes lie at the heart of service operations of any service, so we analysed the set of supported processes from that process grouping and the current status of perfSONAR platform.

Besides making the improvements of the existing tools through:

- The introduction of new features and processes supported by the tool.
- Functionality alignment with other similar tools.
- The introduction of standardised interfaces in order to improve the possibility to integrate the tool with other OSS components.
- The existing GÉANT tools can be improved by better internal organisation and architecture (e.g. redesigning the tool from software silo to SOA architecture or applying standardised interfaces for inter-OSS communication).

While the first three ways of tool improvement are covered by the top-down approach based on business process analysis mentioned above, the last one, the improvement of the internal architecture and organisation of the tools does not naturally come from the business process analysis. The SA4 T3 team used the Enterprise Service Bus (ESB) for tool integration, deploying cNIS-AutoBAHN integration using GEMBus and TMF TIP RAM interfaces.

GEMBus is a GÉANT-developed ESB platform which is still in the pilot phase, so practical experience of using ESB for tool integration should prove useful for the rest of the GÉANT community, The results of this analysis are available in Appendix B of this document since these results do not fall strictly into the overall objective of the document.

[9] Business process names are from the TMF Business Framework terminology. All business process names and descriptions throughout the text, unless stated otherwise, are going to be according to the TMF specifications.

# 2 Service Delivery Business Processes in the GÉANT-NREN Environment

As stressed in the introduction, Business process architecture for the GÉANT-NREN environment was already in use in the GN3 project. It is a combination of standard TMF Business framework specification and business processes specific for the multi-domain operations in the GÉANT-NREN environment. The main conclusions of that work will be briefly repeated in order to make an introduction to the reader and this deliverable as a stand-alone document. For details about the Business process architecture, process descriptions and other analyses please refer to [GN3 DJ2.1.1].

## 2.1 GÉANT-NREN as a Federated Environment

Federated environments are not unique to academic and research networks. Such environments exist also in the commercial provider's ecosystems (e.g. one can buy connectivity between Pittsburgh, PA and Dusseldorf, DE which spans networks of several service providers) or between military organisations in coalitions [MIL]. In the commercial case, one service provider has a contract with the customer and the underpinning contracts with other service providers which provide components needed to create the value chain for the whole service. The relationship between service providers in that case is typical consumer-provider, where the provider having a contract with the end user is a consumer of the services provided by other providers. These other providers are invisible for the end user.

GÉANT-NREN is also a federated environment. Multi-domain services in it are provided jointly by the participating NRENs and GÉANT network. Unlike the commercial case, there is no strict consumer-provider relationship between domains (NRENs). Service is composed by joining the effort of participating domains, and all domains have equal responsibility in the delivery of the service. In order to achieve the required quality of service, SLA and OLA for the services being provided exist. Domains participating in the delivery of services are autonomous in the control and management of the resources they own which makes this federated model a loosely coupled example.

## 2.2 GÉANT-NREN Business Process Catalogue

Domains in the GÉANT-NREN environment can be seen as independent service providers and business processes in them can be accurately described using the whole set of processes from the TMF Business Framework. What distinguishes GÉANT-NREN as a service delivery environment from similar commercial environments is the nature of the interaction between domains. There is no consumer-provider relation, but domains exchange technical data needed to deliver services and to react to various events. The process unique for this environment which models inter-domain interaction is called Multi-domain service interaction (see Figure 2.1, coloured orange) and is responsible for Federated Service topology discovery, allocation of service resources, coordination of Service Configuration and Activation, Service Problem Management and Service Quality Management across domain boundaries. Detailed description of the Multi-domain service interaction process is given in [GN3 DJ2.1.1]. This process is placed at the service functional area and it is important to stress that interactions over other functional areas are very unlikely. Interaction over resource area would mean that there is a signalling protocol which enables automatic device configuration from remote domains, which is violating the autonomy of the participating domains in controlling their own resources. Furthermore the interaction between the User Relationship Management functional areas is unlikely because of the language barriers between institutions in one country and other NRENs and contractual obligations between institutions and their NRENs. Also, each NREN has its own set of suppliers and partners.

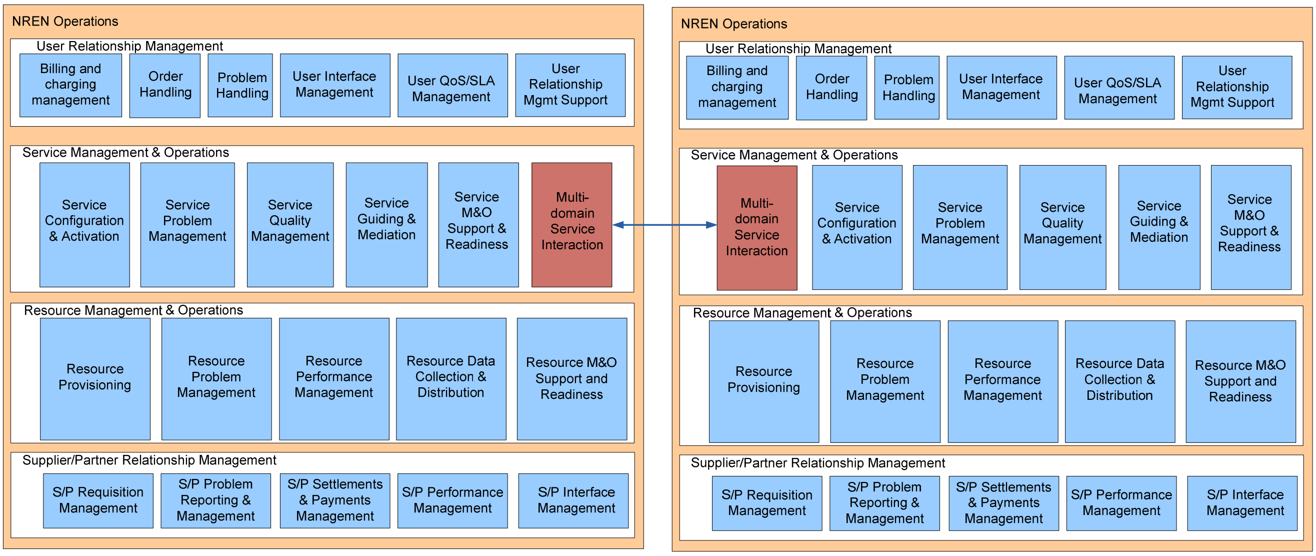

NREN Operations
User Relationship Management
Billing and charging management
Order Handling
Problem Handling
User Interface Management
User QoS/SLA Management
User Relationship Mgmt Support
Service Management & Operations
Service Configuration & Activation
Service Problem Management
Service Quality Management
Service Guiding & Mediation
Service M&O Support & Readiness
Multi-domain Service Interaction
Resource Management & Operations
Resource Provisioning
Resource Problem Management
Resource Performance Management
Resource Data Collection & Distribution
Resource M&O Support and Readiness
Supplier/Partner Relationship Management
S/P Requisition Management
S/P Problem Reporting & Management
S/P Settlements & Payments Management
S/P Performance Management
S/P Interface Management

Figure 2.1: Business process decomposition for NREN to NREN interaction [GN3 DJ2.1.1]

As the GÉANT-NREN environment is not a single enterprise, the whole Enterprise Process Area from the TMF Business Framework is hardly applicable as-is to the service operations in it and can be omitted from further consideration. Also since the main objective of the SA4 T3 task is the improvement of GÉANT OSS component design, business processes in the Strategy, Infrastructure and Product process area were omitted, while the focus was on the Operations process area. All TMF Level 2 business processes are depicted in Figure 1.1 and briefly described in the remainder of this section.

**User Relationship Management**

This process group defines processes responsible for development, maintenance and improvement of a relationship with the users. It includes processes which involve development of the support capability, contact management, accepting and issuing user orders, management of problems reported by customers, monitoring and management of service performance, billing, selling, charging and marketing.

### Service Management and Operations

This process group encompasses all the functionalities and processes necessary for the management and operation of services offered in the GÉANT environment. It includes processes which are responsible for the development of service capabilities, configuration and activation of services, service problems and quality management.

Beside standard Service Management and Operations processes, GÉANT Business Process Architecture also includes Multi-domain Service Interaction processes. These processes are needed for the establishment and operation of services in the multi-domain peer environment. Multi-Domain Service Interaction processes encompass the exchange of information between domains needed for the establishment, operation and maintenance of services delivered to end-users in the multi-domain environment where the domains are in the peer relationship. These processes enable the extension of the Service Management and Operations processes to the multi-domain environment.

### Resource Management and Operations

This is a group of functional processes which maintain resource information (application, computing and network infrastructures). This process group is also responsible for managing all resources (servers, routers, IT systems, networks, etc.) and ensuring that they deliver and support the services that are offered to the users.

Resource Management and Operations processes are also involved in collecting resource-related information from network elements or element management systems, and in integrating, correlating and summarising that information, either passing it on to the Service Management processes and systems, or executing appropriate actions on resources.

### Supplier/Partner Relationship Management

Supplier/Partner Relationship Management processes align closely with a supplier‘s or partner‘s Customer Relationship Management processes. These processes include issuing purchase orders and tracking them through to delivery. This involves the mediation of purchase orders to conform to external processes, handling problems, validating billing and authorising payments, and quality management of suppliers and partners. These processes cover the buying of Supplier/Partner products by the enterprise.

# 3 Business Processes in a typical End-to-End GÉANT service - MDVPN Service Process Flow Analysis

The design of the MDVPN service began at the start of the GN3plus project. Section 3.1 and 3.2 give a brief non-technical overview of the MDVPN service which defines the main actors and functions needed for proper service provisioning. For a detailed technical service description and service architecture, please refer to [DS3.3.1]. Section 3.3 explains process flows, their use and purpose, and describes process flows for some of the most common end-to-end process streams of the MDVPN service.

## 3.1 MDVPN Service – Overview

Multi-Domain Virtual Private Network (MDVPN) service is a core service[10] which provides its users connectivity between two or more institutions in various NRENs, using MPLS VPN technology. The MDVPN service will be offered collaboratively by GÉANT and participating European NRENs. GÉANT/Dante will provide the enabling service – Transport VPN service (Carrier Supports Carrier VPN solution) that is needed in order to deliver core MDVPN service. Transport VPN service that GÉANT provides to the NRENs will be invisible to the end users of MDVPN service. NRENs will provide core service – MDVPN service to the users across the Europe.

MDVPN is in the phase of service design. SA3T3 in this phase tries to establish the technological and technical procedures needed to establish a service and makes plans for the transition of the service to the operational phase. The MDVPN service currently has few service instances and service users seen as future customers (e.g. LHCone). However, because the service is very general and potentially useful to a wider set of users (e.g. various research projects can benefit from this kind of connectivity, access to common resources and so on), the potential number of service instances could be measured in hundreds in the near future. The amount of automation, the number and the set of OSS components that should support MDVPN service operations will depend on the actual uptake of the service.

[10] ITIL definition – Core services deliver the basic outcomes desired by the user

## 3.2 MDVPN Main Entities and Functions

To properly define the MDVPN business process architecture, it is important to clearly define the main entities/actors which will be included in the service delivery. Business processes are defined with respect to the particular Service provider that provides a well-defined set of Services to its Users using its subset of Network Resources. The provider can also have various relations to its Suppliers and Partners needed for the proper Service provision. The following entities will be included in the MDVPN business process architecture:

**Users** are those to whom the core MDVPN service is offered and are the focus of the business objectives. The following types of users could potentially use the service:

- **Campuses** and **Institutions**: Education and research campuses and/or other public institutions such as libraries and hospitals that have access to the GÉANT network through their NREN.
- **Projects**: Research and technology projects have specific networking requirements to facilitate their project‘s collaboration needs, and these are typically met by the project‘s host institutions (which are in turn connected to the local NREN and through that to GÉANT).

A **service provider** is an organisation supplying services to one or more users. The service provider of the MDVPN service is the set of NRENs participating in the VPN service. The MDVPN service will be listed in their service portfolios and offered along with the services local to the NREN. The MDVPN Service desk is a single point of contact for users on a day-to-day basis. It is responsible for dealing with a variety of service activities. It handles incidents, escalates incidents to problem management staff, manages users’ service and change request, handles communication with users, etc. Due to the MDVPN nature of the service provider, the service desk has to be decentralised and is typically a set of NOCs in those NRENs or their parts participating in the MDVPN service. Users group/project member institution will contact and communicate the local NREN service desk (first level NREN NOC) for every question or request regarding the MDVPN service. Higher level support will be decentralised and will be provided by members of participating NRENs NOCs (second and third level NREN NOCs), probably organised as a separate task within the future GÉANT projects.

**Suppliers** provide resources and other capabilities used by the service provider. NRENs have to be interconnected in order to provide the MDVPN service. This connectivity is provided by the GÉANT network through the Transport VPN service. In providing the MDVPN service, GÉANT will be one of the suppliers to the NRENs.

**Partners** are those with whom the service provider co-operates in a shared business area. In the context of the MDVPN service, Regional networks are partners in delivering of the service to the NRENs which have this complex architecture.

## 3.3 Business Process Flows and End-to-End Business Streams

Business process flows and streams are used to visualise the business, the main actors, the order of processes and potential scenarios in service-related operations [eTOM AddJ]. “End-to-end business streams” describe a high level view on the core activities within the service provider. Their name contains the start and end point of the core processes activity (e.g. Order-to-payment, Problem-to-resolution). End-to-end business streams do not include sub-processes and any more detailed description of the activity. On the other side, *process flows* include all sub-processes and activities in the sequence required to accomplish some particular goal. If the goal of the process flow is to accomplish the goal of the business stream, then such a process flow is called an *end-to-end business flow*.

It is important for process flows to be modelled as high-level, generic and technology independent, so that various services can be supported using the same flow. This is achieved through the top-down approach and with the level of decomposition of business processes up to eTOM Level 3. Further decomposition could lead into technology-specific solutions. Such an approach can be required when some specific actions have to be modelled in details for some particular service.

For process flow modelling described below we used TMF guidelines [eTOM AddK]. Process flows in the TMF documentation are described using a choice of notations [eTOM AddF]:

- TMF specific which is developed from the eTOM diagram, uses eTOM processes as boxes, and arrows between them designating communication and order.
- BPMN 2.0[11].

This document uses TMF-specific notation as in the authors' opinion it brings out more clearly which business processes are involved in the process flow. Converting from TMF-specific to BPMN 2.0 notation is, in any case, trivial.

The next sections describe two process flows:

- MDVPN service provisioning process flow
- MDVPN service problem resolution process flow

The task also analysed MDVPN performance problem resolution process flow. This process flow is very similar to the service problem resolution process flow. The only difference is in the different set of processes which are used within the same Assurance vertical process grouping (performance problem resolution uses Service Quality Management instead of Service Problem Management and Resource Performance Management instead of Resource Trouble Management). To avoid repetition this process flow has been omitted: in any case, Service Quality Management and Service Problem Management are described in Section 4 through the analysis of perfSONAR.

Process flows described in the next section are modelled using the following assumptions:

- The MDVPN service is in the design phase so there are only a few service instances and service users that are seen as future customers (e.g. LHCone), in addition the service has no supporting software tools. In such a case manual operations of almost all service operations processes can be justified. The situation

[11] http://www.bpmn.org/

at the time of writing is that there are no databases of services, service instances or domain capabilities that would be used to assist network operators in service operations to check whether the requested service instance is feasible and whether there are available resources for such service (section 3.4.2). However, with the increase of the number of service instances, designing and building such databases and components will become necessary; several steps in the process flow could then be skipped, resulting in the whole procedure becoming more efficient. Actually this reduction in the complexity of the process flow makes the perfect case for the design of various OSS components.

- Process flows described below are complex as they cover the whole end-to-end operations from service request via service provisioning and from service problem report to problem resolution. In these process flows an exception can occur in almost every step of the flow (e.g. a user may not be authorised to request the service, his/her request could be incomplete, there could be no available resources, or there could be a configuration error in some domain, etc.). All these exceptions create feedback loops to an earlier process and require further processing. Describing all possible feedback loops and appropriate actions after them would make the process flows, which are already quite complex, completely unreadable. Therefore only the process flows in a straightforward situation will be shown. Such process flows cannot be used for a thorough analysis of the behaviour of some actors and for the design of the appropriate OSS components, but it can show processes upon which service operations are very dependent and thus be used for our main goal – the decision of the business processes that will be further analysed during the course of the project.

## 3.4 End-to-End Service Configuration Process Flow

The Multi-Domain Service Provisioning process flow defined in [GN3 DJ2.1.1] illustrates business process interaction for general multi-domain service provisioning, regardless of the technologies used and the type of service provisioned. This model is used as a basis to describe MDVPN service provisioning workflow which shows the whole set of business processes required to complete end-to-end activity request-to-provision. This process flow is shown in Figure 3.1. It uses business processes from the Business process architecture described in Section 2, and where needed these processes are analysed up to the next level of decomposition. Note that standardised process names (as used in the diagram) are emboldened in this section of the text.

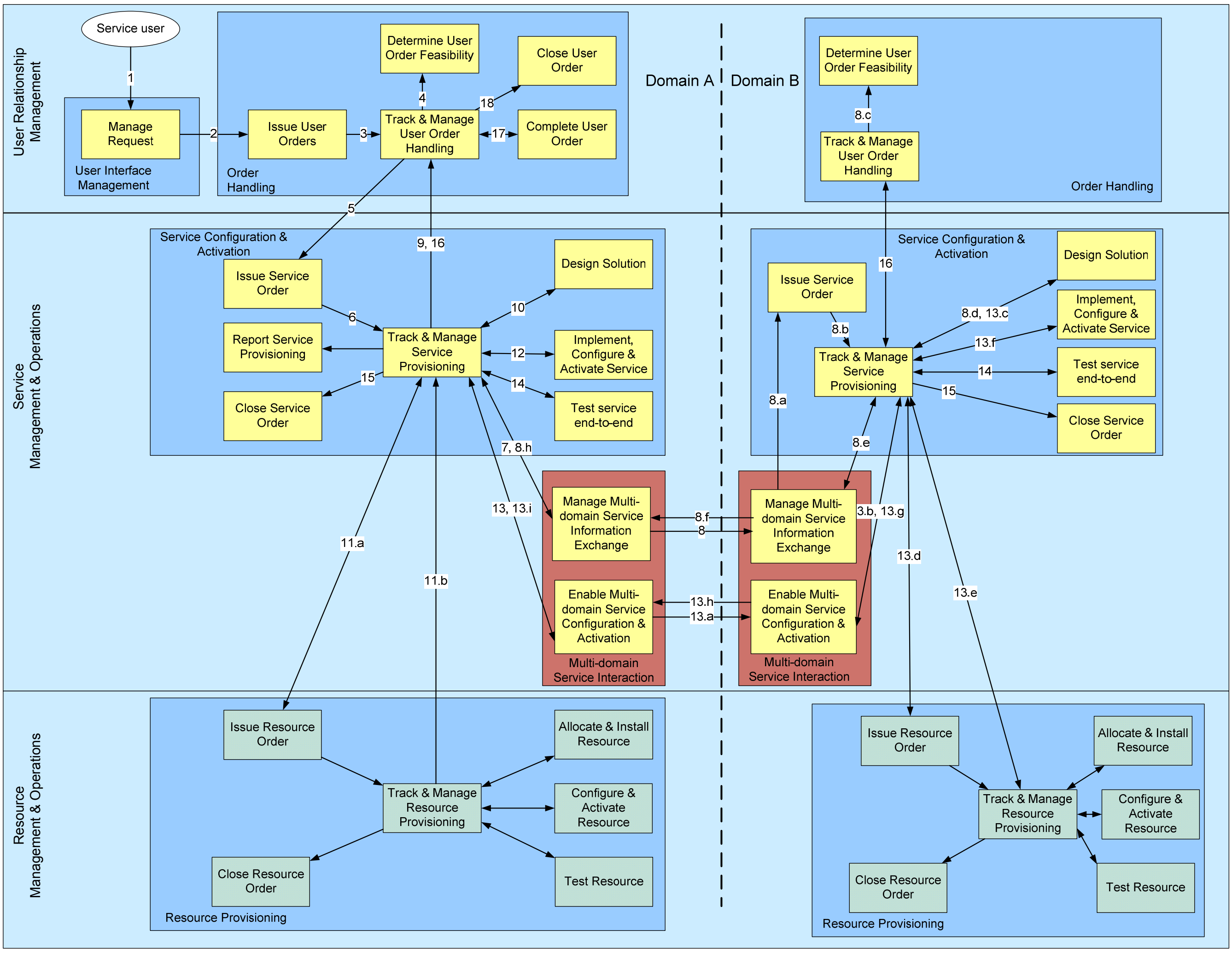

User Relationship Management
Service Management & Operations
Resource Management & Operations
Service user
1
Manage Request
User Interface Management
2
Issue User Orders
3
Track & Manage User Order Handling
Order Handling
4
Determine User Order Feasibility
18
Close User Order
17
Complete User Order
Domain A
Domain B
Determine User Order Feasibility
8.c
Track & Manage User Order Handling
Order Handling
5
9, 16
Service Configuration & Activation
Issue Service Order
Design Solution
10
6
Report Service Provisioning
Track & Manage Service Provisioning
12
Implement, Configure & Activate Service
15
14
Close Service Order
Test service end-to-end
7, 8.h
Service Configuration & Activation
16
Design Solution
Issue Service Order
8.d, 13.c
Implement, Configure & Activate Service
8.b
13.f
Track & Manage Service Provisioning
14
Test service end-to-end
8.a
15
Close Service Order
8.e
13, 13.i
Manage Multi-domain Service Information Exchange
8.f
8
Manage Multi-domain Service Information Exchange
3.b, 13.g
11.a
13.d
11.b
13.e
Enable Multi-domain Service Configuration & Activation
13.h
13.a
Enable Multi-domain Service Configuration & Activation
Multi-domain Service Interaction
Multi-domain Service Interaction
Issue Resource Order
Allocate & Install Resource
Track & Manage Resource Provisioning
Configure & Activate Resource
Close Resource Order
Test Resource
Resource Provisioning
Issue Resource Order
Allocate & Install Resource
Track & Manage Resource Provisioning
Configure & Activate Resource
Close Resource Order
Test Resource
Resource Provisioning

Figure 3.1: MDVPN Service provisioning process flow

## 3.4.1 User Request Management

The MDVPN Service Provisioning process flow starts when users group/project request for the new MDVPN service instance. The MDVPN service request in the name of the user group/project could submit any member institution that is authorised by the other partners in that user group (we will call it Authorised Member Institution - AMI). The AMI will submit MDVPN service request to the Service desk of local NREN to which AMI is connected providing all the necessary information for the user's service request.

- The **Manage Request** process inside local NREN receives the AMI service request for the new MDVPN service instance. This process is defined by the local NREN and will be performed according to the existing local NREN rules (e.g. phone call, service portal, email etc.) for their users. All necessary MDVPN service request details (e.g. user order description, service order end-point addresses, contact details, etc.) are captured and the status of the service request is managed.

- The **Manage Request** process transfers the AMI service request to the **Issue User Order** process which checks if the necessary information about the user group/project service order is provided.

### 3.4.2 Service Availability Check

The **Issue User Order** process will create a record of the relevant initiating request and the associated user order (e.g. ticket in ticketing system of local NREN, new request on the NREN service portal etc.) aimed for documentation purposes. The issued user order requires a feasibility assessment in all NREN domains that are listed in the initiating service request (whose users will participate in requested MDVPN service instance).

- Since the Issued User Order requires further handling and processing, it is passed to the **Track & Manage User Order Handling** process. The **Track & Manage User Order Handling** process is responsible for monitoring the service provisioning procedure, updating existing user order, modifying the user order status etc. The **Track & Manage User Order Handling** process tracks further progress of the user group/project service order. The local NREN who received the MDVPN service request from AMI will be responsible and accountable for further management of MDVPN service instance activation.
- The **Track & Manage User Order Handling** process requests from **Determine User Order Feasibility** process to check the availability and/or the feasibility of providing and supporting the MDVPN service to the AMI and all other members of the user group/project across the GÉANT Multi-domain Service Area (e.g. Are the member institutions authorised to use the MDVPN service inside their NREN domains? Does the NREN provide and support MDVPN service? Do they have enough resources to provide service to requesting institution?, etc.). The **Determine User Feasibility Order** process inside the local NREN domain checks if the AMI is authorised to use this particular service and in cooperation with the **Service Management and Operation** processes whether the technical conditions for access to service are met.

The **Track & Manage User Order Handling** process initiates communication with the **Service Configuration & Activation** processes in all participating NREN domains, whose users will participate in requested MDVPN service instance, to check the availability and/or the feasibility of providing and supporting the requested MDVPN service instance in their own domains. In the later stage of the development of the MDVPN service, checking the availability and/or feasibility of providing and supporting the MDVPN service can be automated through the use of the repository of service portfolios, service instances in use and domain capabilities – the Federated Service Inventory – FSI [GN3 DJ2.1.1]. In that case, steps 5 to 9 can be removed from this process flow and replaced by a single process – checking FSI.

- To be able to communicate with the **Service Configuration & Activation** processes in all participating NREN domains (and whose users have requested MDVPN service instance), the **Track & Manage User Order Handling** process needs to generate the Service Order through the **Issue Service Order** process. This will translate the User Order into a Service Order because user orders might have non-technical descriptions for marketing purposes. This could be done by completing a service order template document or web form on an MDVPN central repository location (e.g. a file server, web portal, MDSD knowledge base, etc.).
- Since the issued Service Order requires further handling and processing, it is passed to the **Track & Manage Service Provisioning** process. This tracks further progress and is responsible for scheduling,

assigning and coordinating service provisioning related activities, monitoring the service provisioning procedure, updating information in an existing service order, modifying service order status, etc.

- The **Track & Manage Service Provisioning** process transfers the issued Service Order to the **Service Configuration & Activation** processes in all NRENs domains whose users have requested an MDVPN service instance through the **Manage Multi-domain Service Information Exchange** process. The Service Order could be sent to the peer's domains by an email list or through the MDVPN central repository notification (e.g. web based portal, central ticketing system, etc.).
- The **Manage Multi-domain Service Information Exchange** process in all peer domains receives the service request and transfers it to **Issue Service Order** (8.a) and **Track & Manage Service Provisioning** processes (8.b). In this case, where the originating NREN domain (NOC) defines service request there should be no difference between the user and service orders in the remote domain. In this case, **Track and Manage User Order Handling** and **Track and Manage Service provisioning** processes might be supported jointly by the same local supporting tool and the difference between the processes may not be obvious.

The **Track and Manage Service provisioning** process needs to check the availability and/or the feasibility of providing and supporting the MDVPN service to member institutions in peer's domain. This is done through the activities in the **Determine User Feasibility Order** (8.c) and the **Design Solution** (8.d) processes. The **Determine User Feasibility Order** process checks if the local member institution is interested in providing MDVPN service, is it authorised by local the NREN to use an MDVPN service, etc. The **Design Solution** process will be invoked as part of a service feasibility assessment and will provide information about the fulfillment of technical requirements for access to an MDVPN service.

The **Track and Manage Service provisioning** process in every peer domains collect and send information to the originating NREN **Track & Manage Service Provisioning** process (8.h). This could be done by email list, a federated trouble-ticketing system or by updating an MDVPN central repository location (e.g. file server, web portal, MDSD knowledge base etc.). Information will be sent again through **Manage Multi-domain Service Information Exchange** process (8.f and 8.e).

- When the information from all peer domains about the availability and/or feasibility of providing and supporting the MDVPN service is received, the **Track & Manage Service Provisioning** process inside originating NREN will update the status of the Service Order record and transfer information to the **Track & Manage User Order Handling.**

The **Track & Manage User Order Handling** updates the status of User Order and informs the AMI about it. If all participating NRENs confirm the availability and/or the feasibility of providing and supporting the MDVPN service to all member institutions of user group/project, AMI is informed that the User Order is accepted and that request passes to the design, configuration and activation phase.

If all participating NRENs do not confirm availability and/or the feasibility of providing and supporting the MDVPN service to all member institutions of the user group/project, AMI is informed that the User Order is not accepted and that user group/project request has to be changed.

### 3.4.3 MDVPN Service Instance Design, configuration and activation

- When the User Order is confirmed the **Track and Manage Service provisioning** process requests the design of the solution for the MDVPN service instance. The **Design Solution** process uses information obtained through the **Service Order** process to develop end-to-end the MDVPN service instance design using design guidelines defined by SA3T3. The Service Instance Architect, typically a senior expert from the NOC of the originating NREN, could be consulted to define the technical and administrative parameters (Route Target, unique service instance identifier, etc.) needed for the functioning of the MDVPN service.
- The **Design Solution** process, depending on the MDVPN service topology, could request the installation of one or more new resources in the network. In that case, the **Track and Manage Service Provisioning** process will request one or more Resource Orders through the **Resource Provisioning** processes inside the local NREN domain. The local NREN (NOC) is responsible for the execution of these processes. When they complete activities, **Resource Provisioning** processes need to inform the resource order's requestor (i.e. the **Track & Manage Service Provisioning** process) that the resources are installed and configured according to the request.
- The **Track and Manage Service Provisioning** process forward the design solution to the local NREN **Implement, Configure and Activate Service** process for implementation, configuration and activation of the MDVPN service instance.
- Also, the MDVPN service instance activation is expected to begin in other participating NREN domains. According to the design of the MDVPN service instance, the **Track & Manage Service Provisioning** process triggers service activation in all other NREN peer domains via the **Enable Multi-domain Service Configuration & Activation** process (13.a).

The **Enable Multi-domain Service Activation & Configuration** process is responsible for the planning and deployment of the MDVPN service infrastructure, requesting MDVPN service configuration and activation from participating domains, processing service activation and configuration requests from other domains, and forwarding them to the local **Service Configuration and Activation** processes.

The **Enable Multi-Domain Service Configuration & Activation** process forwards the confirmed Issued Service Order to the peer domains' **Track & Manage Service Provisioning** process (13.b). This process forwards the confirmed service order and end-to-end MDVPN service instance design solution to the **Design Solution** process in the peer domain (13.c). The **Design Solution** process in the peer NREN domain designs only the intra-domain part of the MDVPN service instance (e.g. local IP address range, NREN PE – CPE routing protocol, etc.).

The **Design Solution** process, through the **Track & Manage Service Provisioning** process could trigger **Resource Provisioning** processes for the installation and configuration resources needed to activate the requested MDVPN service instance (13.d). After **Resource Provisioning** processes inform the **Track & Manage Service Provisioning** process that the resources are installed and configured (13.e), the **Track and Manage Service Provisioning** process forward the proposed design solution to the **Implement, Configure and Activate Service** process for service activation in the peer's domain (13.f).

After finishing the service provisioning activities, the peer domains inform the originating domain of the results.(13.g, 13.h, 13.i)

### 3.4.4 MDVPN Service Instance Testing, closing service request

- The **Track and Manage Service Provisioning** process of the originating NREN triggers the testing of the service across all participating NREN domains via the **Test Service End-to-End** process.
- If the testing of the requested MDVPN service instance is successful, the **Track & Manage Service Provisioning** process changes the status of the Service Order to activate and could initiate the **Close Service Order** process.
- The **Track & Manage Service Provisioning** process update the MDVPN service repository with the data about the installed service instances and informs the service order's requestor (i.e. the **Track & Manage User Order Handling** process) that the service is configured and activated according to the request. Also the **Track & Manage Service Provisioning** process in the peer's domain notifies the member institutions from their domains of the activation of the MDVPN service instance. This is done through the **Track & Manage User Order Handling** process in peers' domains.
- The **Track & Manage User Order Handling** process triggers the **Complete User Order** process to finalise the user order. Through activities in this process, the AMI is informed about the successful activation of the MDVPN service instance.
- Once the user order is finalised, the **Track & Manage User Order Handling** process triggers the user order to be closed.

### 3.4.5 Monitoring Service Provisioning Process Flow

The **Report Service Provisioning** process continuously monitors the status of service orders, provides notifications of any changes and provides management reports to the MDVPN Operational manager/ MDVPN Service Level Manager during the MDVPN Service Provisioning workflow. The activities inside **Report Service Provisioning** process could be implemented using an email list where the MDVPN Operational manager/MDVPN Service Level Manager is member, or through the “watcher” role inside Central MDVPN Ticketing system. Carrying out activities within this process ensures that all parties involved in the MDVPN Service Provisioning workflow take responsibility and adhere to the obligations defined in the OLA agreement.

## 3.5 End-to-End Service Problem Management Process Flow

MDVPN service user-reported problem management process flow is an instance of general Multi-Domain Service Problem Management process flow.

According to the procedures that are currently adopted by the SA3T3 task, we can assume that the user/member institutions of the MDVPN service instance will contact the local NREN service desk (part of the MDVPN Service Desk) to report problems in an MDVPN service instance they are currently using. It is assumed that every NREN will provide all necessary topological information relevant to MDVPN service instance delivery and problem management. Technical documentation related to the MDVPN service instance will be available at central MDVPN Service repository to all participating NRENs (e.g. MDVPN Knowledge Base integrated in the GÉANT MDSD Knowledge Base, MDVPN Wiki platform, MDVPN Web portal, etc.).

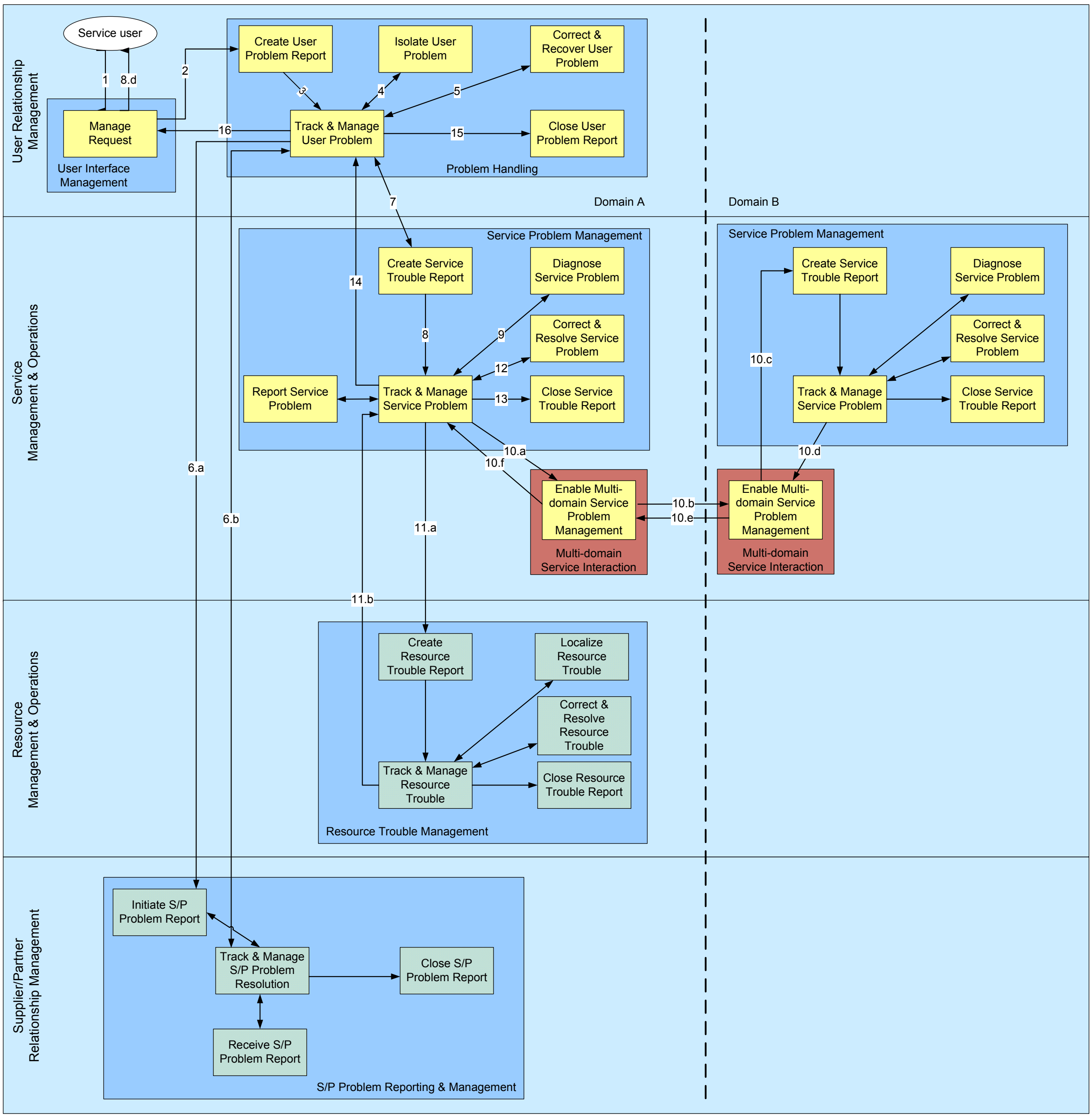

User Relationship Management
Service user
1
8.d
2
Manage Request
User Interface Management
16
Create User Problem Report
Isolate User Problem
Correct & Recover User Problem
3
4
5
Track & Manage User Problem
15
Close User Problem Report
Problem Handling
7
Domain A
Domain B
Service Management & Operations
Service Problem Management
Create Service Trouble Report
Diagnose Service Problem
14
8
9
Correct & Resolve Service Problem
12
Report Service Problem
Track & Manage Service Problem
13
Close Service Trouble Report
10.a
10.f
6.a
6.b
11.a
Enable Multi-domain Service Problem Management
Multi-domain Service Interaction
10.b
10.e
Service Problem Management
Create Service Trouble Report
Diagnose Service Problem
10.c
Correct & Resolve Service Problem
Track & Manage Service Problem
Close Service Trouble Report
10.d
Enable Multi-domain Service Problem Management
Multi-domain Service Interaction
11.b
Resource Management & Operations
Create Resource Trouble Report
Localize Resource Trouble
Correct & Resolve Resource Trouble
Track & Manage Resource Trouble
Close Resource Trouble Report
Resource Trouble Management
Supplier/Partner Relationship Management
Initiate S/P Problem Report
Track & Manage S/P Problem Resolution
Close S/P Problem Report
Receive S/P Problem Report
S/P Problem Reporting & Management

Figure 3.2: MDVPN User reported problem resolution process flow

### 3.5.1 Problem Reporting

- The MDVPN Service User-reported Problem Management workflow starts when a user reports a problem through the **Manage Request** process. Every participating institution of the MDVPN service instance could report a problem in delivery of service and will have to request resolution from the local NREN Service Desk. The **Manage Request** process inside a local NREN is responsible for collecting all required problem-related data (e.g. user problem description, MDVPN service instance ID, contact details, authentication information, etc.). This process is defined by the local NREN and is performed (by phone call, service portal, email, etc.) according to the existing local NREN rules for their users.

- The **Manage Request** process extracts and transfers information from the User Problem request to the **Create User Problem Report** process to create a User Problem Report for later problem solving (e.g. a trouble ticket in a local NREN ticketing system).
- Because the User Problem Report needs further processing, the **Create User Problem Report** process informs the **Track & Manage User Problem** process of the creation of a new problem report which then assigns and coordinates any recovery, repair and restoration activities delegated to other processes, tracking their execution progress and modifying the User Problem Report status.

### 3.5.2 Problem Isolation and Recovery

- The **Track & Manage User Problem** process triggers the **Isolate User Problem** process, which isolates the user problem and identifies its root cause (e.g. is the problem in the service domain of the MDVPN service, or is it caused by the improper use of the MDVPN service by the user, or is it caused by a problem linked to the underlying services?). The **Isolate Customer Problem** processes updates the status of open User Problem Report during the assessment, and when the root cause has been identified.

After successful identifying the root cause of a problem, the local NREN Service Desk must inform Service Desks of other participating NRENs. This MDVPN service problem notification will improve efficiency in resolving issues inside the MDVPN service instance and will inform participating NREN domains about the existence of problems in the functioning of a service. Notification could be sent by the email list of the **MDVPN operational group**. The information which needs to be included in a message will be defined by the **MDVPN Technical group**.

- Once the user problem is isolated, the **Track & Manage User Problem** process triggers correction activities via the **Correct & Recover User Problem** process. Depending on the cause of the problem, activities inside of the **Correct & Recover User Problem** process may include educational interaction with users to ensure correct usage of the MDVPN service, identifying restoration activities inside the **Service Management & Operation** processes, or initiating request to enabling services Supplier for restoration and recovery. NREN Service Desks will perform activities within these **User Relationship Management** processes.
- The MDVPN service is provided in a specific and complex GÉANT Service Area environment where Transport VPN service (the enabling service for the core MDVPN service) is managed by GÉANT/DANTE. If the **Correct & Recover User Problem** process indicates that the user problem is caused by problem linked to the Transport VPN service, the **Track & Manage User Problem** process becomes responsible for initiating requests through **S/P Problem Reporting & Management** processes for restoration and recovery of the Transport VPN service (6.a). This process coordinates, tracks and manages GÉANT /DANTE problem resolution activities. In this case GÉANT/DANTE will inform all NREN domains about the cause of the problem and provide an estimated time for resolution through the GÉANT MDSD function. The **Track & Manage S/P Problem Resolution** process informs the **Track & Manage User Problem** process about results of activities done by the **S/P Problem Reporting & Management** processes (6.b).

### 3.5.3 Service Problem Diagnostics and Resolution

- If the **Correct & Recover User Problem** process indicates that the user problem is caused by the specific MDVPN service problem, the **Track & Manage User Problem** process triggers the creation of one or more Service Problem Reports.
- The **Create Service Trouble Report** process creates a Service Problem/Trouble Report (e.g. change trouble ticket owner from Service Desk to NREN NOC, open trouble ticket on Central MDVPN Ticketing system or create new item on Central MDVPN Service Repository etc.) and notifies the **Track & Manage Service Problem** process to continue to monitor the progress of the MDVPN service instance problem resolution. The **Track & Manage Service Problem** process is responsible for co-ordinating the necessary activities in order to guarantee that all tasks are finished in the appropriate time and sequence.
- The **Track & Manage Service Problem** process triggers the necessary diagnostic actions. The **Diagnose Service Problem** process performs diagnostics, tests and various audits against specific MDVPN service instances in order to detect the cause of the service problem. During diagnosis, the **Diagnose Service Problem** process uses MDVPN Service Instance documentations (maintained centrally on MDVPN Service repository or maintained locally by every participated NREN.) that contain topology information, participating domains, IP addressing and MDVPN general monitoring tools. The **Diagnose Service Problem** process updates the Service Problem Report during and after the cause has been identified. After a diagnosis of the service problem, all participating NRENs are informed about the cause of the problem and the status of the Service Problem Report.

The service problem can be caused by a problem in some of the underlying services. In this case, the **Diagnose Service Problem** process initiates the creation of appropriate trouble reports for the underlying services and the **Track & Manage Service Problem** process continues to monitor the progress of their resolution.

- If the **Diagnose Service Problem** process shows that the problem is located in other domains, the **Track & Manage Service Problem** requests the **Enable Multi-Domain Problem Management** process (10.a) to create a Service Trouble Report in the other domains involved in the provisioning of the service instance (e.g. an email notification, an email notification to the peer NREN domain, a trouble ticket in a Central MDVPN ticketing system). The **Enable Multi-Domain Problem Management** process (10.b) in the peer domain will trigger instances of a Service Problem Report using the **Create Service Trouble Report** process (10.c).

The **Track & Manage Service Problem** process in peer domains coordinates actions for resolving the service problem in the remote domains. These processes can also trigger **Resource Trouble Management** processes or **S/P Problem Reporting & Management** processes in their own domain. Once the problem is solved in the peer domain, the **Track & Manage Service Problem** process informs **Track & Manage Service Problem** in the originating domain of the result via the **Enable Multi-Domain Problem Management** process (10.d, 10.e, 10.f).

- If the **Diagnose Service Problem** process shows that the problem is caused by resource trouble within the local NREN domain, the **Track & Manage Service Problem** process request one or more Resource Trouble Reports to be created inside **Resource Trouble Management** processes (11.a). The objectives of these processes are to efficiently and effectively manage reported resource trouble, isolate the cause and act to resolve the resource trouble. When the resource troubles are resolved, **Resource Trouble**

**Management** processes inform the **Track & Manage Service Problem** process of the successful resource trouble-solving actions (11.b).

### 3.5.4 Closing User Problem Report

- Regardless of the nature of the MDVPN service failure, the **Track & Manage Service Problem** process is ultimately informed about a successful resolution. This triggers the **Correct & Resolve Service Problem** process to restore the service to a normal operational state.
- After the successful resolution of the service problem, **Track & Manage Service Problem** triggers the **Close Service Trouble Report** process (it updates the status of open trouble ticket at Central MDVPN Ticketing system, notifies peer NRENs regarding the resolution, etc.).
- The **Track & Manage Service Problem** process notifies the **Track & Manage User Problem** process of the successful resolution of the service problem.
- The **Track & Manage User Problem** process initiates the closing of the User Problem Report (e.g. close trouble ticket in local NREN Ticketing system, etc.).
- The **Manage Request** process informs the user of the successful restoration of the service.

### 3.5.5 Monitoring Problem Management Process Flow

The Report Service Problem process continuously monitors the status of service trouble report, provides notifications of any changes and provides management reports to the MDVPN Operational manager/MDVPN Service Level Manager during the MDVPN Service Problem Management workflow. The activities inside Report Service Problem process could be implemented using an email list where the MDVPN Operational manager/MDVPN Service Level Manager is member, or through the “watcher” role inside the Central MDVPN Ticketing system, etc. Carrying out activities within this process ensures that all parties involved in Problem Management workflow take responsibility and adhere to the obligations defined in the OLA agreement.

## 3.6 MDVPN Service Conclusions

Business process flows given in previous sections describe the main procedures in some of the most common operational business flows in MDVPN service. These process flows assumed completely manual operations and did not analyse various error feedback loops. However, even such simplified description allows several conclusions to be drawn:

- The set of business processes in both process flows described in this section show one important property: the main processes in the end-to-end activities belong to the same vertical process grouping (in the first case, the set of processes belong to Fulfilment and in the second to Assurance process groupings). Therefore in order to properly define some of the key end-to-end operations procedures it is more important to start with the analysis of the vertical process groupings than with the single processes at some level of decomposition.

- User/customer-level procedures are performed independently in all domains, typically because of the language barriers and contractual obligations between NRENs and the institutions that are their customers.
- Resource-level procedures are performed independently in all domains, as all domains have full control over the resources they own. Resource-level procedures for MDVPN service are the same as for all other services operated in each of the domain.
- Inter-domain service interaction is crucial for successful operations of the MDVPN service. It appears in various phases of the service operations: capability exchange, request exchange, problem and performance reports exchange, problem correlation and resolution information exchanges, and so on. Without automation, operations teams in different domains communicate using emails or phone calls. Such communication is typically difficult to track and manage and prone to inefficient processing. Therefore MDVPN service operations could benefit from some sort of automation for inter-domain service communication.
- The exchange of service capability information can be automated through the existence of inter-domain service catalogues that are populated by the participating domains. The existence of a service instance catalogue where at least domain service capabilities, a catalogue of installed service instances, service availability information is stored would significantly shorten provisioning time, as all business processes described in section 3.4.2 can be executed in the background and replaced with a single process of checking the service catalogue for service availability and feasibility.
- The exchange of service configuration requests can be implemented either by developing a system like AutoBAHN that automatically configures devices in several domains, or by the Federated Trouble Ticketing System (which allows the exchange of ticketing information between TTS in use in different domains). Both systems can track and manage configuration requests but also allow for manual intervention. The choice of the system depends on the organisational model that exists between participating domains.
- Service problem reports, as well as service performance issues can also be tracked and managed using the Federated Trouble Ticketing System [FTTS].

# 4 Support for Performance Management in the GÉANT environment

Assurance is vertical process grouping of the eTOM Operations Process Area responsible for the execution of proactive and reactive maintenance activities. The main purpose of those activities is to ensure that the services provided to customers are continuously available and conform to the agreed SLA or QoS performance levels. The Assurance vertical process grouping is divided into four horizontal process groupings: Customer Relationship Management, Service Management and Operations, Resource Management and Operations and Supplier/Partner Relationship Management, and can be divided into two vertical subgroupings:

- **Problem Management processes** which are responsible for the management of various incident, failure and problem resolution processes that can occur during the service operations.
- **Performance Management processes** (shown in Figure 4.1) which are responsible for the management of service performance level in order to assure that contracted service levels are met.

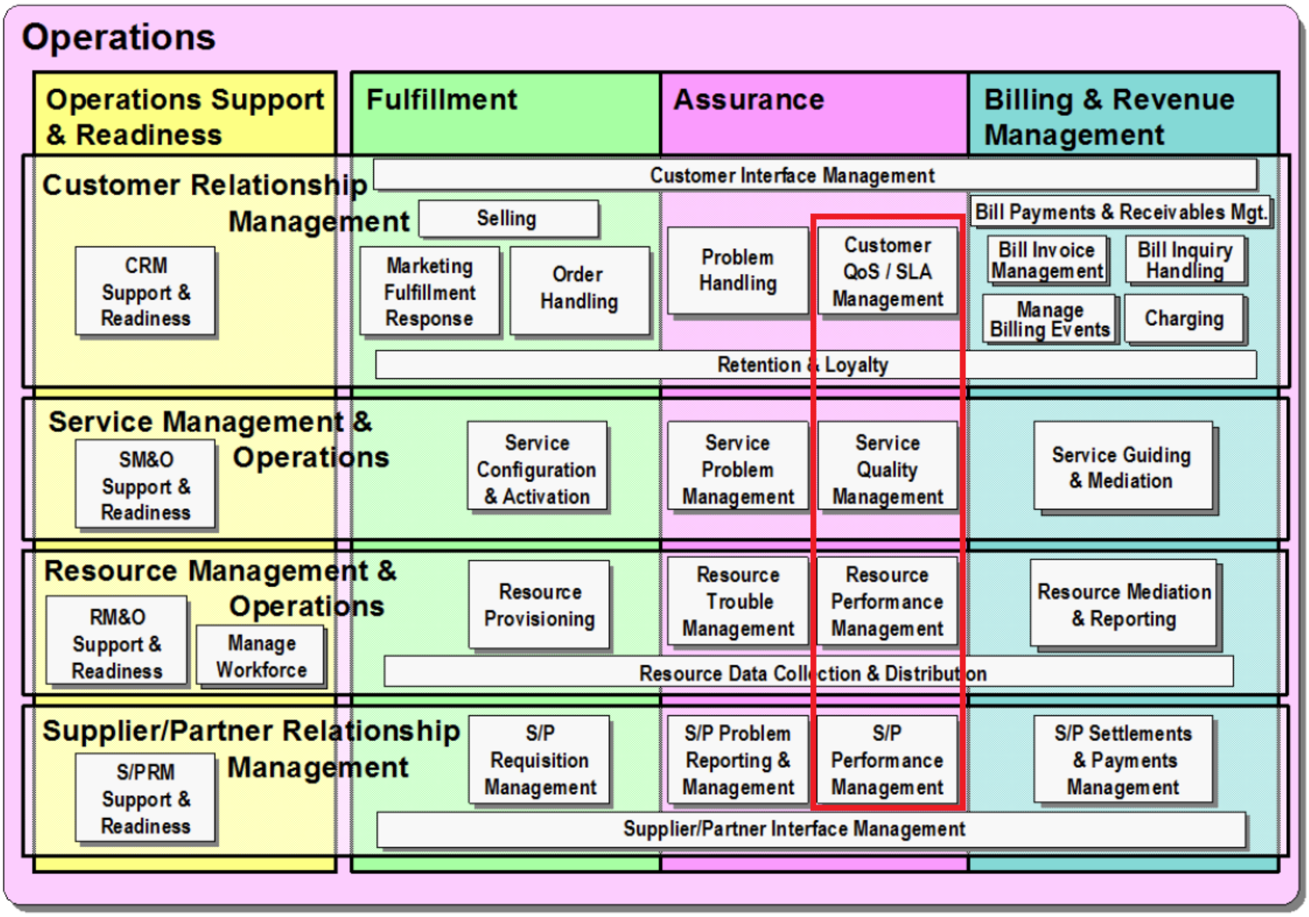

Operations
Operations Support & Readiness
Fulfillment
Assurance
Billing & Revenue Management
Customer Relationship Management
Customer Interface Management
Selling
Bill Payments & Receivables Mgt.
CRM Support & Readiness
Marketing Fulfillment Response
Order Handling
Problem Handling
Customer QoS / SLA Management
Bill Invoice Management
Bill Inquiry Handling
Manage Billing Events
Charging
Retention & Loyalty
Service Management & Operations
SM&O Support & Readiness
Service Configuration & Activation
Service Problem Management
Service Quality Management
Service Guiding & Mediation
Resource Management & Operations
RM&O Support & Readiness
Manage Workforce
Resource Provisioning
Resource Trouble Management
Resource Performance Management
Resource Mediation & Reporting
Resource Data Collection & Distribution
Supplier/Partner Relationship Management
S/PRM Support & Readiness
S/P Requisition Management
S/P Problem Reporting & Management
S/P Performance Management
S/P Settlements & Payments Management
Supplier/Partner Interface Management

Figure 4.1: Performance Management process subgrouping

Monitoring resource and service performance is one of the essential processes in the service assurance, and typically one of the first that are designed when a service is being planned. The GÉANT environment developed the perfSONAR tool for multi-domain performance monitoring. perfSONAR supports Performance Management processes (see section 4.1), and especially those processes related to Resource Management and Operations and Service Management and Operations:

- Service Quality Management (SQM) is a Layer 2 business process belonging to the Service Management and Operations horizontal and Assurance vertical process grouping. This process element manages, tracks, monitors, analyses, improves and reports on the performance of specific services.
- Resource Performance Management (RPM) is a Layer 2 business process belonging to the Resource Management and Operations horizontal and the same Assurance end to end process grouping. This process element manages, tracks, monitors, analyses, improves and reports performance of resources participating in the operations of specific services.

This section will assess the extent of the support for the Performance Management processes in perfSONAR by analysing the set of Layer 3 business processes supported by perfSONAR and assessing its position in the OSS portfolio and its feature set compared to the TAM framework. These analyses will enable an understanding of perfSONAR's position within the service operations and will show potential gaps and possibilities for improvement. Further, the task analysed similar existing multi-domain performance monitoring platforms; these are a subject of recent research and standardisation activities (IETF LMAP working group) in order to enable strategic positioning of the tool and to resolve the ambiguous viewpoints on perfSONAR mentioned in section 1.3. In section 4.5 (Trends in Network Performance Management) some novel methods for performance data gathering that could be potentially included in perfSONAR are analysed.

## 4.1 perfSONAR - Brief Overview

perfSONAR is a multi-domain tool that provides performance monitoring and diagnostics for NOC and PERT engineers in different NRENs or NREN-associated institutions. According to the official perfSONAR documentation [perfSONAR], perfSONAR supports the following set of features grouped under the following headings:

perfSONAR active measurements:

- Available Bandwidth.
- One Way Delay.
- Jitter (One Way Delay variation).
- Route Tracing - Traceroute.
- One Way Packet Loss.

perfSONAR passive measurements:

- Link utilisation.
- Input errors.
- Packet drops.

perfSONAR central functionalities:

- Archiving.
- Visualisation.
- User interface.

perfSONAR is built according to the principles of the Service Oriented Architecture with the following sub-services [perfSONAR-MDM][perfSONAR Services]:

- Measurement Point (MP), i.e. performing network parameter measurements.
- Measurement Archive (MA), i.e. storing measurement data.
- Lookup Service, allowing user to discover other services like MA/MP, Authentications Service.
- Authentication and Authorisation controlling access to monitoring data.

- Topology Service, i.e. making network topology information available.
- Resource Protection Service, i.e. arbitrating consumption of limited resources such as bandwidth.
- Transformation Service, i.e. enabling data modification between perfSONAR components (e.g. data producer and data consumer.

## 4.2 perfSONAR – Business Process Analysis

The main purpose of this section is to map the set of business processes supported by the current perfSONAR toolset onto selected business processes defined by enhanced Telecommunication Operation Map (eTOM) standardised by TM Forum. The ultimate goal of this effort is to provide a clear overview of the perfSONAR toolset in the context of a standardised business process framework, so that stakeholders of perfSONAR in GÉANT community could better position this toolset into their holistic business process management landscape. Note that this section intends to serve as a referential proposal for stakeholders of GÉANT, such as NRENS, to map perfSONAR onto standardised business processes.

### 4.2.1 Methodology and Analysis Context of perfSONAR

This section gives an overview on the methodology and context that is applied for the analysis of the perfSONAR tool. The analysis context includes premise and settings that are made for the analysis and roles we defined in the context of perfSONAR. The actual analysis process follows top-down approach which starts with top level process groupings in different areas. The refinement of the business process and the final placement of functionalities of perfSONAR are presented in this section.

#### 4.2.1.1 *Premise and Settings for Analysis*

Section 1.2 showed that perfSONAR is perceived in the GÉANT community in two different ways. The key difference between the two is the definition of the user of perfSONAR. When perfSONAR is used as a multi-domain monitoring platform, perfSONAR users are NOC teams in DANTE and NRENs. When perfSONAR is used as a supporting tool for other multi-domain network services, the users of perfSONAR can then be either OSS components supporting these services, or administrators performing manual service operations. However in both cases the underlying perfSONAR architecture remains the same, as well as the set of network parameters monitored and perfSONAR components used (except the interface towards the user). Therefore, the set of business processes supported by the tool will largely be the same with only few differences. In our analysis we will focus on the second case, when perfSONAR is used as a supporting tool for other multi-domain network services; the key differences from the first scenario will be indicated where appropriate.

#### 4.2.1.2 *Definition on Terms & Roles*

Based on the premise made, in order to conduct analysis and mapping operations, it is necessary to clarify roles that may involve in the analysis to ensure conceptual consistency.

The eTOM scheme defines roles whose interactions are described in the form of business processes.

- Enterprise/Service Provider: MDVPN service providers of perfSONAR are like the providers of multi-domain network services in GÉANT environment: jointly NRENs and DANTE.
- Customers. The users of perfSONAR in the chosen scenario are - depending on the level of automation of these services - either OSS components supporting multi-domain network services (e.g. BoD or MDVPN), or administrators performing manual service operations.
- Product/Service. The main product of perfSONAR is monitoring the performance of diverse network parameters. Monitoring data acquired by perfSONAR is intended to support and reinforce operations of the network. It will be easier to describe the product after this analysis, because the way performance data is presented (e.g. whether the tool provides only raw measurement data or the data is put in the context of some service related parameters like SLA, QoS parameters, performance thresholds, etc.) will affect these conclusions.
- Resources. In this document, resources refer to devices such as routers or switches that enable the networking services required and servers needed to establish the perfSONAR measurement architecture.

### 4.2.2 eTOM Analysis of perfSONAR

Analysis and mappings of perfSONAR on eTOM business process follow a top-down approach. They start with top level process groupings both vertical and horizontal, followed by process decomposition operations in which details of mappings are revealed.

At the highest level of eTOM view, perfSONAR can be mapped to the process area of *Operations* as shown in Figure 4.2. This eTOM process area covers all operation processes that support customer operations and management. The following analysis is focused on this area.

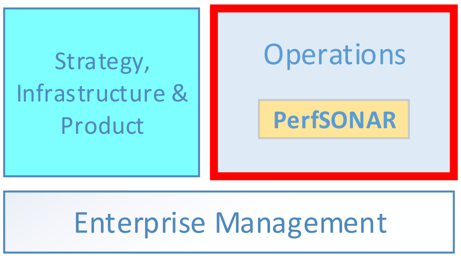


Figure 4.2: eTOM High Level Mapping

#### 4.2.2.1 *Generic Process Groups for the Operations Process Area*

This section organizes perfSONAR into horizontal as well vertical end-to-end process groups. Figure 4.3 illustrates the mapping of perfSONAR on an eTOM level 1 view.

a) *Vertical Process Groupings*. perfSONAR can be located in the *Assurance* process group which is responsible to collect and provide customers with correct monitoring and other performance data on the target network in a near-realtime manner.

b) *Horizontal Functional Process Groupings*. perfSONAR can be mapped across three different functional process groups:

- Customer Relationship Management (CRM). This process group maintains fundamental knowledge of customers' needs and all functionalities for interacting with them. perfSONAR subservice mapped in this process group
  - Authentication and Authorisation Service
- Service Management & Operations (SM&R). This process group is responsible for maintaining knowledge of services and functionalities that are necessary for operation and management of information service to customers, for example status reports of network operation. perfSONAR has following sub-services to support SM&O:
  - Measurement Point (MP)
  - Measurement Archive (MA)
  - Lookup Service
  - Topology Service
- Resource Management & Operations (RM&O) focus on obtaining knowledge about underlying resources that support main services as well as management of them.
  - Resource Protection Service
  - Measurement Point (MP)
  - Measurement Archive (MA)
  - Transformation Service

Note that MP/MA have been included in both service management and resource management operations since they can be part of the RM&O by collecting and distributing resource information, as well as supporting the SM&R process group by revealing monitoring information on networking services, e.g. collecting resource information from multiple distributed MP/MA. However, it should be emphasised that the support for SM&R in perfSONAR is weak, as perfSONAR is not aware of the service-related parameters (SLA parameters, threshold values, etc.) and that support for other services is only possible if there is a logical layer between perfSONAR and the service user able to compare measurement results to these parameters.

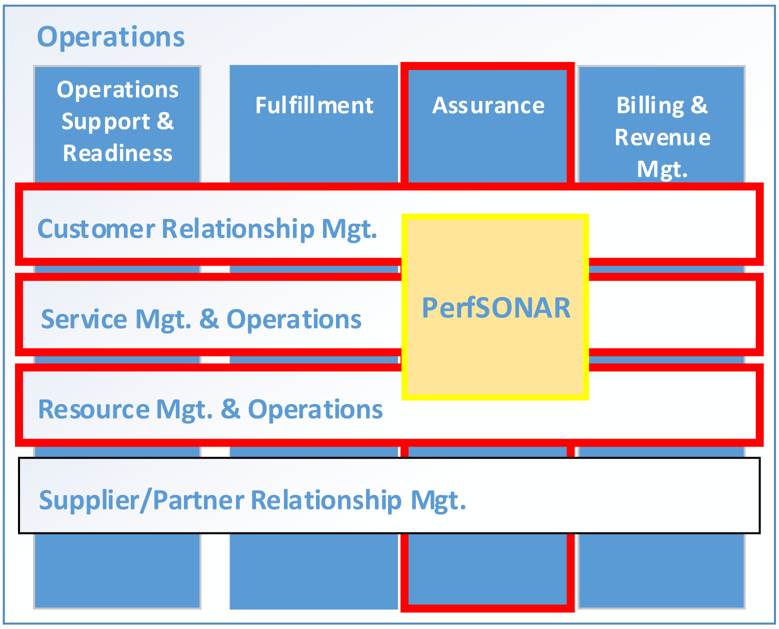

Operations
Operations Support & Readiness
Fulfillment
Assurance
Billing & Revenue Mgt.
Customer Relationship Mgt.
Service Mgt. & Operations
Resource Mgt. & Operations
Supplier/Partner Relationship Mgt.
PerfSONAR

Figure 4.3: Mapping of perfSONAR on Vertical and Horizontal Process Groups

### 4.2.2.2 *Decomposition and Mapping of perfSONAR on eTOM Level 2*

In the previous section, we narrow down the mapping of perfSONAR on the level 1 of eTOM. This mapping allocated perfSONAR across multiple process areas, in both vertical and horizontal groupings. perfSONAR is further decomposed into eTOM level 2 processes as shown in Figure 4.4.

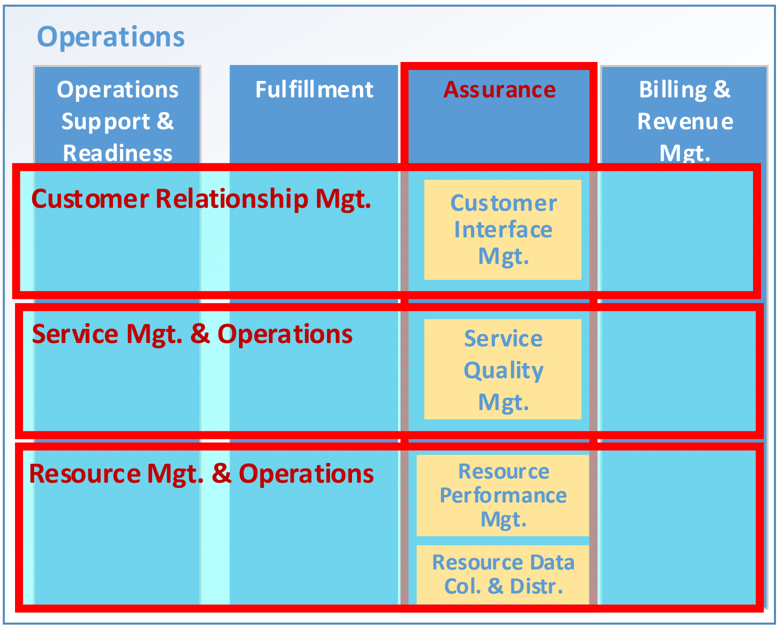

Operations
Operations Support & Readiness
Fulfillment
Assurance
Billing & Revenue Mgt.
Customer Relationship Mgt.
Customer Interface Mgt.
Service Mgt. & Operations
Service Quality Mgt.
Resource Mgt. & Operations
Resource Performance Mgt.
Resource Data Col. & Distr.

Figure 4.4: Mapping of perfSONAR to eTOM Level 2 Process

The mapping of perfSONAR on Level 2 process groups produces the following:

- The **Customer Interface Management** process group include the perfSONAR Authentication and Authorisation subservice, with authenticates and authorises the use of certain perfSONAR subservices.
- The **Service Quality Management** process group is mainly responsible for tracking, managing and analysing service quality and performance. perfSONAR supports service quality management process by providing access to distributed monitoring data on the performance data of targeted network services provided by the NOC.
- The **Resource Performance Management** process group has the responsibility to monitor, track, analyse, control and report performance of resources.
- The **Resource Data Collection & Distribution** process group records or distributes management information and data records. It is also responsible for processing collected data and information.

### 4.2.2.3 *Decomposition and Mapping of perfSONAR on eTOM Level 3*

This section shows how the level 2 processes can be mapped to eTOM level 3 processes:

#### Customer Interface Management

The AA subservice from perfSONAR allows customer access control to the monitoring data, so it can be mapped onto **Manage Contact and Manage Request** of the CIM process at level 3. The first level 3 process manages all contacts/requests between customers and enterprises, while the latter manages all requests made by them.

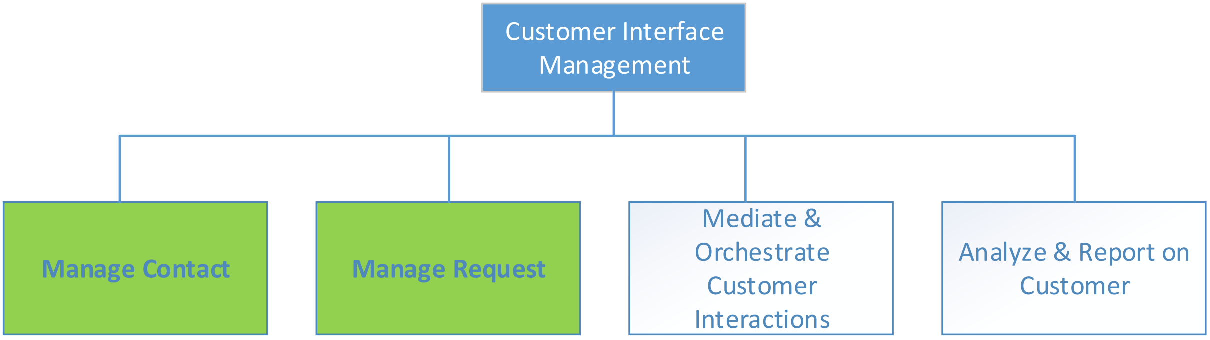

Customer Interface Management
Manage Contact
Manage Request
Mediate & Orchestrate Customer Interactions
Analyze & Report on Customer

Figure 4.5: Mapping of perfSONAR on level 3 Customer Interface Management process according to eTOM

## Service Quality Management

perfSONAR provides means to monitor network service quality by collecting and storing performance data on the network resources thus can be mapped onto **Monitor Service Quality** as level 3 process under Service Quality Management process.

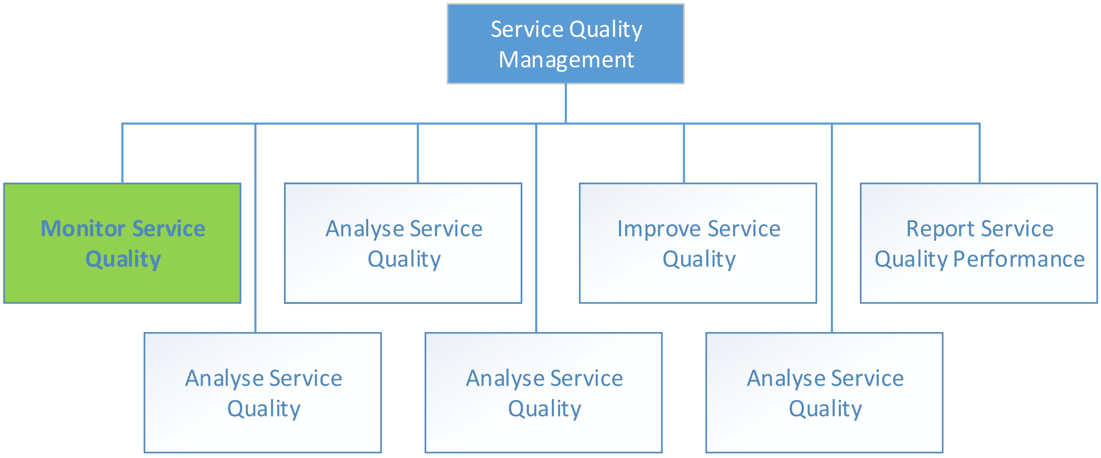


Figure 4.6: Mapping of perfSONAR on level 3 Service Quality Management process according to eTOM

## Resource Performance Management

perfSONAR contributes to Resources Performance Management processes by providing monitoring and measurement data on network infrastructure. It can be further be mapped onto **Monitor Resource Performance** and **Control Resource Performance** (e.g., resource protector) at level 3 process level.

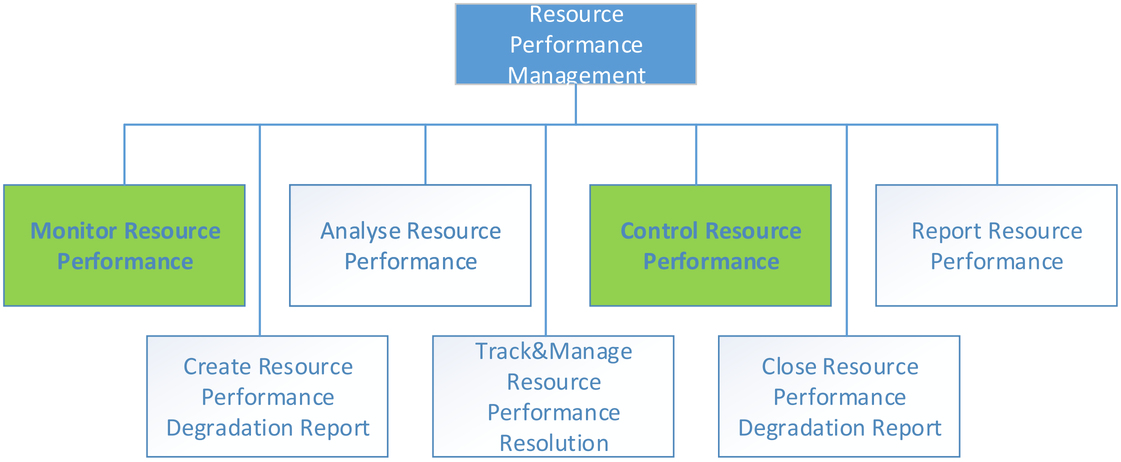

Resource Performance Management
Monitor Resource Performance
Analyse Resource Performance
Control Resource Performance
Report Resource Performance
Create Resource Performance Degradation Report
Track&Manage Resource Performance Resolution
Close Resource Performance Degradation Report

Figure 4.7: Mapping of perfSONAR on level 3 Resource Performance Management process according to eTOM

### Resource Data Collection & Distribution

perfSONAR allows the collection and distribution of monitoring and performance data through its MP and MA, with the transformation subservice enabling conversion and processing of monitoring and measurement data between various components. These lead to the mapping of perfSONAR onto **Collect Management & Data**, **Process Management Information & Data** and **Distribute Management Information & Data** level 3 processes respectively.

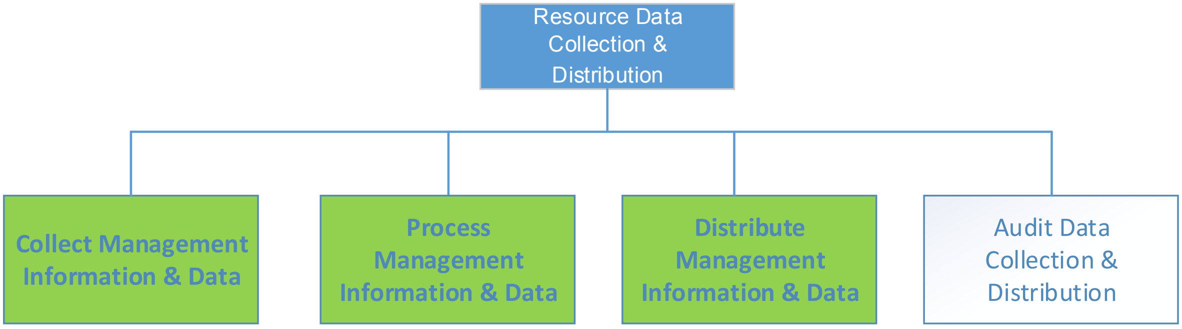

Resource Data Collection & Distribution
Collect Management Information & Data
Process Management Information & Data
Distribute Management Information & Data
Audit Data Collection & Distribution

Figure 4.8: Mapping of perfSONAR on level 3 Resource Data Collection & Distribution Management process according to eTOM

## 4.3 perfSONAR – Features Analysis

As in section 4.2, for the purpose of this feature analysis, perfSONAR is primarily perceived as a multi-domain tool that supports other services in the GÉANT environment. From that perspective, perfSONAR is analysed as a product (application) supporting services like GÉANT IP, GÉANT Plus, GÉANT Lambda, GÉANT BoD (Bandwidth on Demand), etc. Users of perfSONAR are NOC and PERT engineers in different NRENs or NREN associated institutions. Their use of perfSONAR can be accomplished either through a perfSONAR UI web service or through some other third-party application that is integrated with the perfSONAR API (Application

Programming Interface). For example, AutoBahn (the bandwidth-on-demand provisioning tool) used in the GÉANT BoD service would be considered as an integrated application that presents perfSONAR features to its users (NOC and PERT engineers) indirectly, through the perfSONAR API.

### 4.3.1 perfSONAR Supported TAM Features

Figure 4.9. shows TAM level 1 categories that are implemented in current multi-domain perfSONAR implementation:

- Customer Information Management.
- Service Performance Management.
- Service Test Management.
- Resource Performance Management.
- Resource Fault Management.
- Resource Test Management.

Dark orange colours represent TAM applications that are more aligned/ significant for the current implementation. Those are Service and Resource Test Management categories, in accordance with the explanations given later in this section. It should be emphasised that Service Management Domain decomposition is only observed from the perspective of a basic IP connectivity service in current perfSONAR deployment (e.g. the GÉANT IP service).

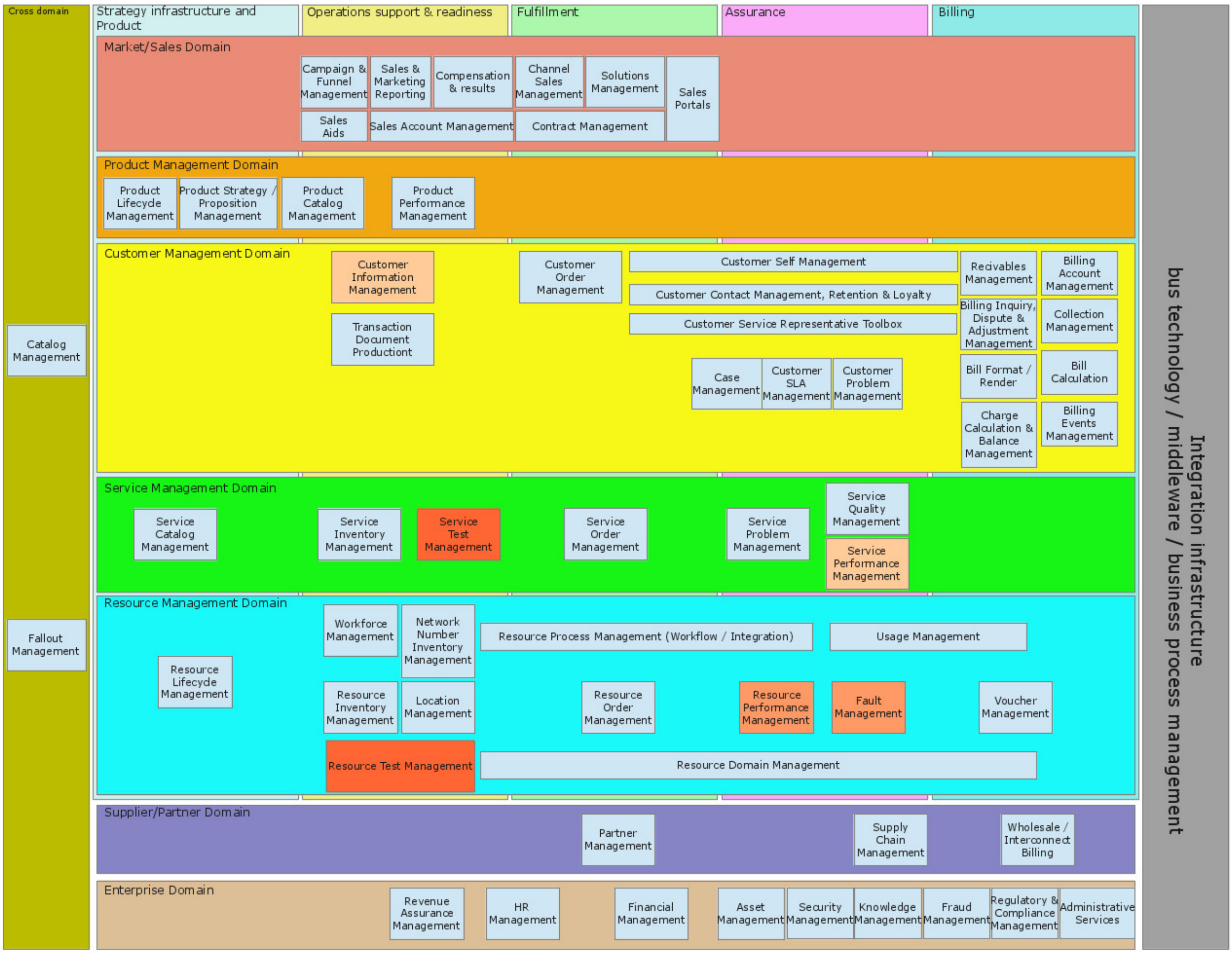

Cross domain
Strategy infrastructure and Product
Operations support & readiness
Fulfillment
Assurance
Billing
Market/Sales Domain
Campaign & Funnel Management
Sales & Marketing Reporting
Compensation & results
Channel Sales Management
Solutions Management
Sales Portals
Sales Aids
Sales Account Management
Contract Management
Product Management Domain
Product Lifecycle Management
Product Strategy / Proposition Management
Product Catalog Management
Product Performance Management
Customer Management Domain
Customer Information Management
Transaction Document Production
Customer Order Management
Customer Self Management
Customer Contact Management, Retention & Loyalty
Customer Service Representative Toolbox
Case Management
Customer SLA Management
Customer Problem Management
Recivables Management
Billing Account Management
Billing Inquiry, Dispute & Adjustment Management
Collection Management
Bill Format / Render
Bill Calculation
Charge Calculation & Balance Management
Billing Events Management
Catalog Management
Service Management Domain
Service Catalog Management
Service Inventory Management
Service Test Management
Service Order Management
Service Problem Management
Service Quality Management
Service Performance Management
Resource Management Domain
Resource Lifecycle Management
Workforce Management
Network Number Inventory Management
Resource Process Management (Workflow / Integration)
Usage Management
Resource Inventory Management
Location Management
Resource Order Management
Resource Performance Management
Fault Management
Voucher Management
Resource Test Management
Resource Domain Management
Fallout Management
Supplier/Partner Domain
Partner Management
Supply Chain Management
Wholesale / Interconnect Billing
Enterprise Domain
Revenue Assurance Management
HR Management
Financial Management
Asset Management
Security Management
Knowledge Management
Fraud Management
Regulatory & Compliance Management
Administrative Services
Integration infrastructure bus technology / middleware / business process management

Figure 4.9: Overlap of TAM and current perfSONAR implementation

In the following sections, perfSONAR and its features are analysed through three horizontal domains: Customer Management Domain, Service Management Domain and Resource Management Domain. The analysis uses the TAM framework model.

## 4.3.2 Customer Management Domain Analysis

### Customer Information Management

Authentication and authorisation for secure access in current perfSONAR implementation is realised through static single end-user credentials. Other authentication mechanisms that exist in GÉANT, such as GÉANT AAI, eduGAIN, or static intranet accounts, are not used for perfSONAR.

### 4.3.3 Service Management Domain Analysis

perfSONAR is basically a service-agnostic tool (i.e. it is not aware of service-specific topologies, changes, configurations, performance parameters, etc.). Therefore this section of TAM analysis looks at how perfSONAR supports GÉANT IP service and associated simple IP connectivity monitoring and testing.

#### Service Performance Management

perfSONAR features enable monitoring and analysing the end-to-end service in the GÉANT multi-domain environment (GÉANT IP service). Real-time measurements can be initiated to ensure that service is working correctly. Historical data can be provided using measurement archives. This application includes the following TAM category:

- The Service Performance Monitoring application provides functionality to support performance monitoring of the service (active and passive measurements) and data collection (measurement archives).

The TAM categories that are related to the current perfSONAR implementation are shown in Figure 4.10.(coloured orange).

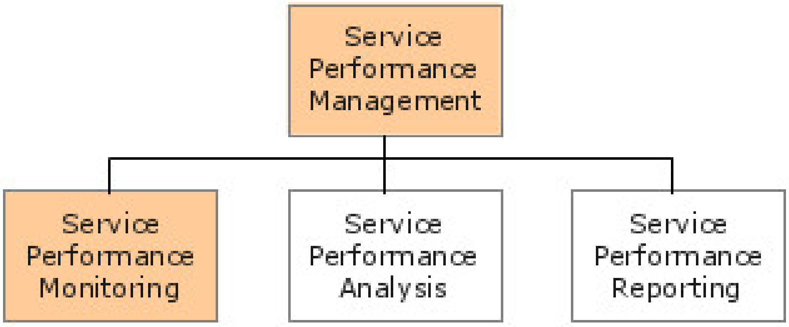

Service Performance Management
Service Performance Monitoring
Service Performance Analysis
Service Performance Reporting

Figure 4.10: Service Performance Management

Service Performance Management Applications are built on the Resource Performance data (physical infrastructure elements in the GÉANT network): they are basic inputs to determine the Quality of Service.

In the scope of Service Performance Management section, perfSONAR measurements can be made on-demand or at scheduled intervals.

#### Service Test Management

The Service Test Management Application, as part of both the fulfillment and the assurance process is responsible for:

- Ensuring that the assigned service works as designed using scheduled measurements.

- Service trouble/problem isolation using on-demand measurements.

Regarding active measurements in perfSONAR (both scheduled and on-demand), it contains following entities:

- The Service Test Strategy and Policy Management application provides functionality to manage the rules that define the strategies for conducting various service tests.
- The Service Test Lifecycle Management application manages the end-to-end lifecycle of a test of a service. This primarily refers to scheduling active measurements, setting up the test configurations and test executions.
- The Service Test Command and Control application accesses, commands and controls the devices required for service testing (perfSONAR Measurement Points).
- The Service Test Services application accesses the testing capabilities. For the current perfSONAR implementation, this TAM category primarily refers to a user interface (perfSONAR UI) for performing manual (on-demand) or automated (scheduled) real-time service testing.

The TAM categories that are related to the current perfSONAR implementation are shown in Figure 4.11.(coloured orange).

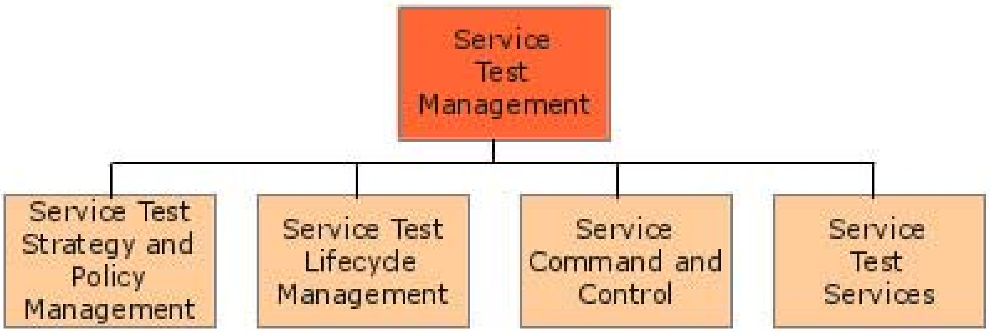

Service Test Management
Service Test Strategy and Policy Management
Service Test Lifecycle Management
Service Command and Control
Service Test Services

Figure 4.11: Service Test Management

## 4.3.4 Resource Management Domain Analysis

### Resource Performance Management

perfSONAR features enable monitoring and analysing performance of the resources in GÉANT multi-domain environment (key infrastructure elements for GÉANT Service Performance Management). This application includes the following TAM categories:

- The Resource Performance Monitoring application provides functionality to support performance monitoring of the resources (active and passive measurements) and data collection (measurement archives).

- The Resource Performance Analysis application provides functionality to analyse the performance data received from Resource Performance Monitoring, and to determine the root cause of resource performance degradation (e.g. perfSONAR Analyse path segment feature).

The TAM categories that are related to the current perfSONAR implementation are shown in Figure 4.12.(coloured orange).

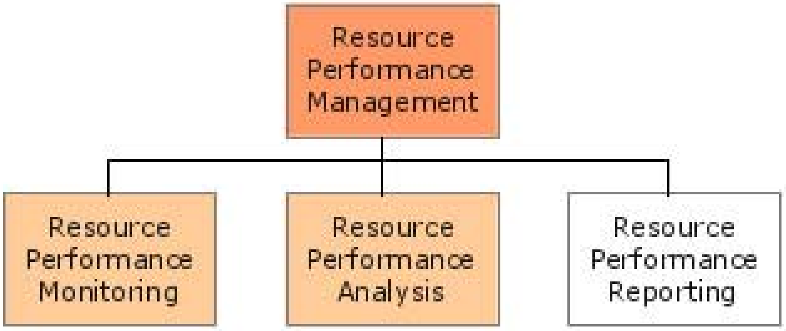

Resource Performance Management
Resource Performance Monitoring
Resource Performance Analysis
Resource Performance Reporting

Figure 4.12: Resource Performance Management

## Resource Fault Management

perfSONAR features enable troubles associated with resources in the GÉANT multi-domain environment to be managed. This application includes the following TAM categories:

- The Fault Monitoring (Surveillance) application provides functionality to monitor the operational status of resources.
- The Fault Root Cause Analysis application provides functionality to determine the root cause of a problem in the network (eg. perfSONAR Analyse path segment feature).

The respective TAM categories are shown in Figure 4.13 (coloured orange).

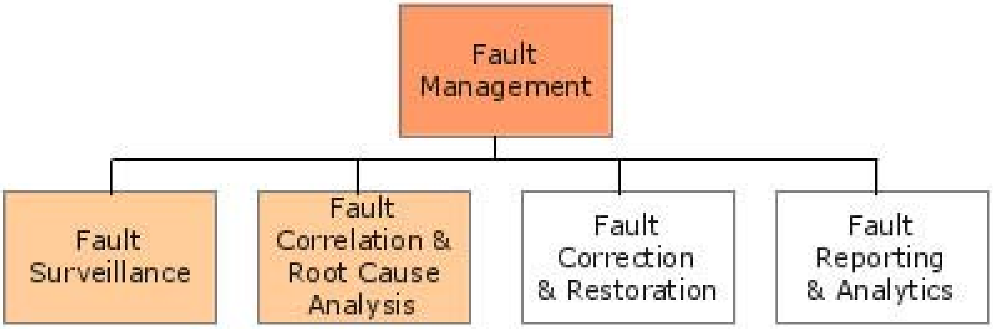

Fault Management
Fault Surveillance
Fault Correlation & Root Cause Analysis
Fault Correction & Restoration
Fault Reporting & Analytics

Figure 4.13: Resource Fault Management

## Resource Test Management

perfSONAR Resource Test Management features ensure that the various resources in the GÉANT network are working properly: they are part of both the fulfillment and the assurance process. A resource test in the fulfillment process ensures that the assigned resources work as designed, while in the assurance process these application ensure fault isolation.

Resource Test Management could be considered as the primary or most important TAM category in the perfSONAR feature analysis. Regarding active measurements in perfSONAR (both scheduled and on-demand), it contains following entities:

- The Resource Test Strategy and Policy Management application provides functionality to manage the rules that define the strategies for conducting various resource tests.
- The Resource Test Lifecycle Management application provides functionality to manage the end-to-end lifecycle of a resource test. This primarily refers to scheduling active measurements, setting up the test configurations and test executions.
- The Resource Test Command and Control application provides functionality to access, command and control the devices required for resource testing (perfSONAR Measurement Points).
- The Resource Test Services application provides functionality to access the testing capabilities. Regarding the current perfSONAR implementation, this TAM category refers to a user interface (perfSONAR UI) for performing manual (on-demand) or automated (scheduled) real-time resource testing.

The respective TAM categories that are related to the current perfSONAR implementation are shown in Figure 4.14.(coloured orange).

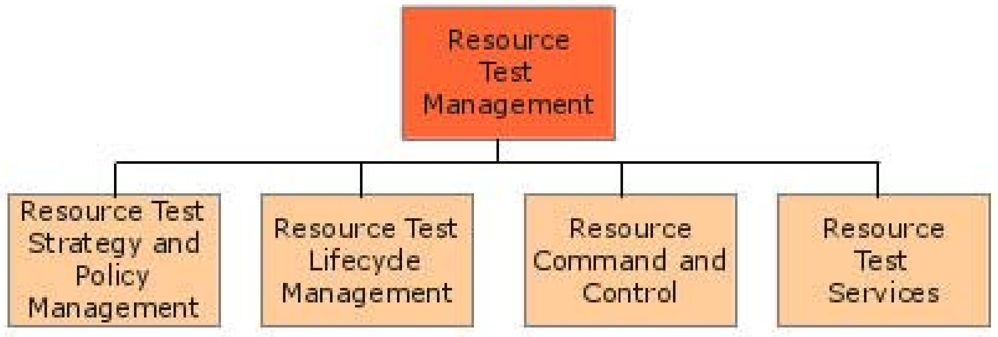

Resource Test Management
Resource Test Strategy and Policy Management
Resource Test Lifecycle Management
Resource Command and Control
Resource Test Services

Figure 4.14: Resource Test Management

## 4.4 Multi-domain Network Performance Management – Current Status

This section gives an overview of several multi-domain active measurement platforms more or less similar to perfSONAR in the set of provided functionalities. These platforms are briefly described in order to assess the current research and industry trend in the domain of active network monitoring, as well as to position perfSONAR among these similar tools. A quick overview of the recent LMAP (Large-Scale Measurement of Broadband Performance) IETF working group which aims to standardise methods for active measurement of ISP access links is given. This IETF effort has partially emerged from the efforts of the SamKnows and the Grenouille platform described below.

### 4.4.1 M-Lab

Measurement Lab (M-Lab)[12] is an open, distributed server platform for active end-to-end performance measurement and detection of other characteristics of broadband connections. It was founded by a group of researchers from several Universities in the USA and Europe, New America Foundations' Open Technology Initiative (OTI), the PlanetLab consortium and Google (which provided servers and purchased network connectivity for the platform). The aim of M-Lab is to carry out research in the area of large scale Internet measurement and to offer to the public useful information about their broadband connections. Currently there are 33 M-Lab servers worldwide[13].

The tools that make up the M-Lab platform are created by researchers, not M-Lab itself. M-Lab supports active network tests on user demand (from a web browser or from the stand-alone application, or a special probe in the case of the BISmark test). Measurements capture basic operational characteristics (e.g., TCP throughput, available bandwidth), advanced host diagnostics (e.g., misconfigurations, small socket buffer sizes), and ISP traffic management practices (e.g., BitTorrent blocking, traffic shaping). The set of tools that make the M-Lab platform is gathered from various supporting research projects like BISmark (Georgia Tech), DONAR (Princeton University), Glasnost (Max Planck Institute), Mobiperf (University of Michigan), NDT (Internet 2), etc. At the time of writing, M-Lab supports the following set of tools [M-Lab1]:

- Network Diagnostic Tool (NDT) is a web-based or command-line TCP client-server application for testing upstream- and downstream-TCP throughput. NDT measurements results can support the detection of congestions, upload/download impairments and infrastructure failures.
- NPAD (Network Path & Application Diagnostics) – is also web-based or command-line diagnostic tool designed to diagnose network performance problems in the end-system (the machine your browser is running on) or the network between it and your nearest NPAD server.
- Neubot is a tool that periodically creates BitTorrent, HTTP and raw TCP transmissions in order to check network neutrality (the non-existence of any preferential treatment/classification towards any kind of traffic).
- ShaperProbe is an application which checks whether ISP uses traffic shaping mechanism.
- Glasnost is a web-based set of tools that allows one to check whether there are application-specific traffic-shaping mechanism installed on the network between client doing the test and M-Lab servers. Supported protocols are: BitTorrent, eMule, Gnutella, POP4, IMAP4, HTTP, SSH, Usenet and Flash video

[12] http://www.measurementlab.net/

[13] http://measurementlab.net/mlab_sites

transmission. Glasnost tests are the longest tests in the M-Lab set of tools which last about 500 seconds per tested protocol.

- MobiPerf is an Android application for measuring throughput and latency of the mobile platform Internet connection.
- Reverse traceroute measures reverse paths from arbitrary destinations back to the user. Similar to looking glass in functionality, but unlike that tool, it does not require access to the destination host. The method relies on the fact that there are numerous M-Lab servers, uses record route and timestamp IP options and assumes that ISPs along the route will allow address spoofing (the weakest point of the method).
- Paris-traceroute: ordinary traceroute can lead to the discovery of inaccurate and incomplete paths in the presence of routers that employ load balancing; Paris-traceroute controls the probe packet header fields in a manner that allows all packets towards a destination to follow the same path in the presence of per-flow load balancing. All M-lab tools collect Paris-traceroute traces for every TCP connection they use.
- BISmark is an OpenWRT-based platform similar to SamKnows described in the next section. Unlike SamKnows Whitebox probes, BISmark devices have a web interface that allows for monitoring performance in a LAN network, the graphical display of measurement results, QoS configuration, etc.
- SideStream - collects statistics about the TCP connections used by the measurement tools running on the M-Lab platform.

NTD, NPAD, Neubot and SideStream use Linux servers with Web100 extensions for gathering an extended set of statistical data about TCP connections (RFC 4898).

All data collected by M-Lab tools is intended to be made publicly available under a Creative Commons Zero license. Measurement results can be accessed as raw data on Google Storage or by sending SQL queries to BigQuery (Google's RESTful web service that enables the analysis of massively large datasets in conjunction with Google storage). Raw data is kept in tar format under the name that includes the testing date, the name of the M-Lab server, the tool used and a serial number. Google Storage provides two different ways to access the raw data: the gsutils command line tool and a web based interface.

A user-friendly way of showing M-Lab data is through Google Public Data Explorer which is shown in Figure 4.15.

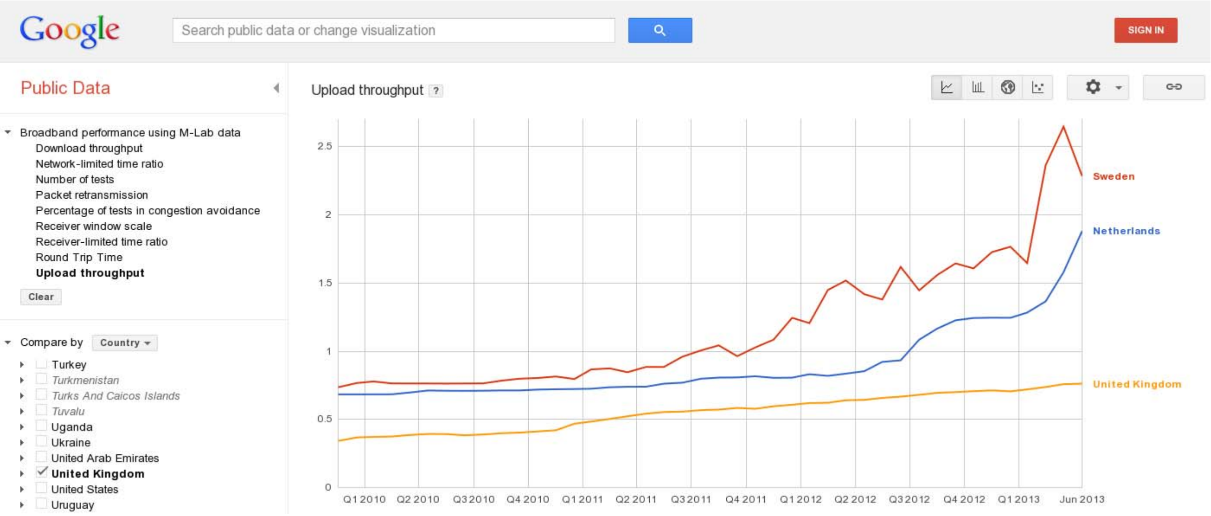


Figure 4.15: M-Lab performance measurement results presented through Google Public Data Explorer

Researchers and organisations wishing to access the part of the server resources can do that after accepting and fulfilling the conditions defined in [M-Lab2]. Resource allocation policies are designed to avoid contention between different tools.

### 4.4.2 SamKnows

SamKnows[14] is an active measurement platform for large scale testing of ISP access link characteristics created by UK software developer Sam Crawford in 2009. Sam Crawford is currently actively involved in the IETF LMAP (Large Scale Measurement of Broadband Performance) working group.

The SamKnows platform is comprised of more than 300 servers worldwide [SamK1], and more than 40 000 *Whitebox probe*s [SamK2]. Whitebox probes are CPE devices installed at the user end of fixed or mobile broadband connections. SamKnows developed probes based on TP-Link access routers and an adapted version of the OpenWRT operating system. The custom firmware is flashed at the factory and is not directly upgradeable by the user hosting the Whitebox, but the firmware is remotely upgradeable by SamKnows. Probes do not have a web or other kind of GUI that would allow the users to access the devices. However SamKnows software is free and open-source under the GPLv2 license. No measurement data is stored on test servers. All results recorded by the Whiteboxes are transmitted to SamKnows.

SamKnows supports the following set of tests typically oriented toward the end user of the Internet connection:

- Web browsing – Measuring time to get the web content from some of the well-known publicly available sites. Measurement includes DNS resolution time.
- Video streaming – Measuring time to get and buffer shared video from the sites like (YouTube, Metacafe).

[14] http://www.samknows.com/broadband/index.php

- Voice over IP – Measuring throughput, delay, jitter and packet loss using UDP probes in both directions.
- Availability test – this test is started during the startup of the Whitebox and remains active in the background. Whitebox establishes three long-term TCP connections with SamKnows servers. When a server stops responding to Whitebox requests, the TCP connection is re-attempted. If all three connections are not able to be established, Internet connectivity is considered to be down. Traceroute is then executed in order to find the place of the outage.
- UDP latency and packet loss – this test is a UDP ping which measures round-trip time (RTT) and UDP packet loss between the client and the SamKnows server.
- Data usage tests – passive monitoring of the amount of incoming- and outgoing-user traffic during one hour. SamKnows guarantees that the user's privacy will not be compromised.
- Speed tests – uplink and downlink throughput measurement using HTTP GET and POST Requests.
- ICMP latency and packet loss - ICMP ping. The minimum, maximum and standard deviation of successful results are measured.
- ICMP latency under load - ICMP ping executed during speed test;
- DNS resolution – the time for ISP's DNS servers to resolve names of some of popular web sites.
- Peer-to-Peer – this test emulates BitTorrent 10MB file transfer. Measured metrics:
    - The average and peak throughput during the transfer.
    - The number of connections established to peers.
    - The total number of pieces transferred.
    - The number of TCP connections that were reset during transfer.
- FTP transfer – measuring FTP upload and download throughput.
- Email relaying – measures the time that an ISP's SMTP server needs to send an email to a SamKnows email server.

All times are measured in milliseconds. Whitebox probes have threshold managers installed which can delay measurement execution if the user traffic is over certain limit. When a testing cycle has completed, the results are encrypted and transmitted over SSL to a hosted backend infrastructure for processing and presentation through a web interface to each SamKnows user and other interested parties. The Whitebox then sends the results to secure SamKnows reporting servers which then present the results back to the user either via the SamKnows web reporting site, a smartphone app or a monthly personalised ISP report card. ISPs that sign the Code of Conduct are given access to anonymised and aggregated performance results on their network so they can pro-actively deal with any network problems. Figure 4.16 shows a sample set of measurement results obtained by the SamKnows system.

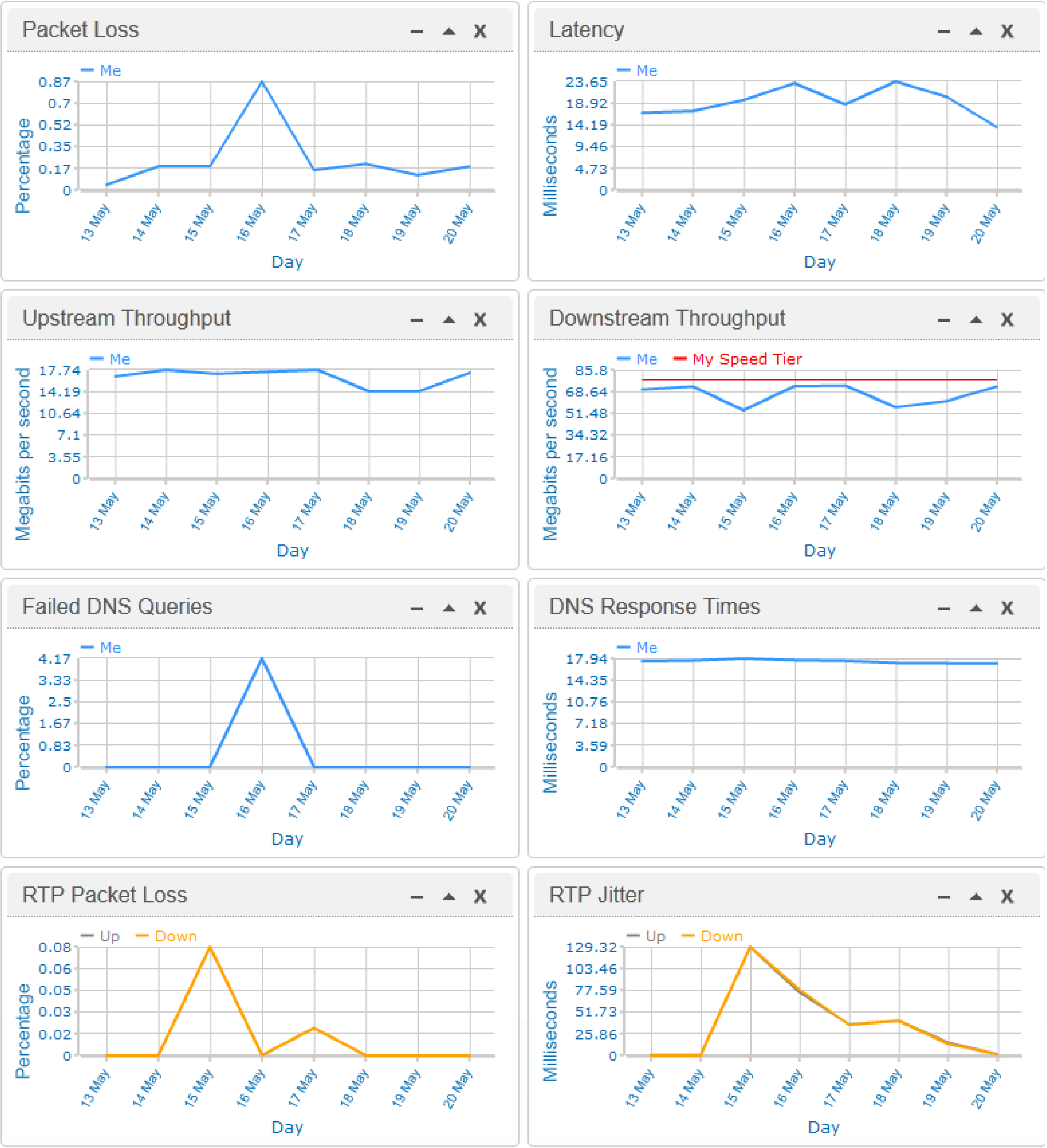


Figure 4.16: An example of SamKnows measurement results

SamKnows offers two types of probes: for fixed and mobile broadband connections and these can be ordered from the official site together with a free application with a subset of tests that can be executed. The placement of the Whitebox probe for the fixed access connection can be seen in Figure 4.17. The Whitebox probe behaves like an Ethernet switch and has an antenna used for passive monitoring of the strongest access point in the surrounding area.

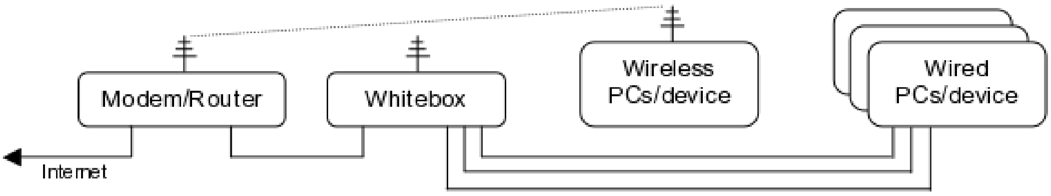


Figure 4.17: SamKnows Whitebox probe placement

Unlike the Whitebox probe for fixed connections, the mobile probe does not share Internet connectivity with the end-user, but is used exclusively for testing. The mobile probe is connected to USB SIM adapters, and has GPS and WiFi triangulation capabilities installed, so the exact location can be sent together with the measurement results.

Apart from smaller number of tests, the free SamKnows application has lower measurement reliability because it does not have exclusive access to the network medium, but it shares it with other applications on the end-user device.

### 4.4.3 Grenouille

Grenouille[15], developed in France, is an active measurement platform for testing broadband access connections between subscribers and their ISPs. The aim of the platform is similar to that of SamKnows; the difference is that Grenouille uses a client software application developed under GPL and AGPL licenses and not dedicated hardware. Grenouille performs the following measurements:

- Upload and download speeds using FTP transfers of a file large around 500KB. The system is able to detect if there is other user traffic that could interfere with the FTP test and to defer the execution of the test.
- Ping to test the response and round trip time.

The client application sends measurement results every 30 minutes to the central servers where these results are stored and from which they can be seen. Daily data is stored for several weeks, and monthly data for much longer periods of time. Measurement data is not publicly available, but is password protected for each user. According to the report from 2011 [Gr1], Grenouille had more than 20 000 users.

[15] http://www.grenouille.com/

### 4.4.4 RIPE TTM and Atlas

The RIPE NCC began the development of RIPE Atlas[16] in late 2010 with the goal of creating a global measurement network for monitoring critical operational and performance aspects of the Internet infrastructure. Atlas is a continuation of the older RIPE Test Traffic Measurement (TTM)[17] service which is shortly to be decommissioned. Both platforms are active end-to-end measurement platforms.

TTM is measuring:

- One-way delay.
- One-way packet loss.
- Round-trip time.
- Jitter.
- Bandwidth.
- Root and TLD DNS server availability.

Participants of the TTM project had to provide rack space for the installation of the TTM test-box servers. Servers also had GPS antenna and receiver which was used for the time synchronisation necessary for one-way measurements, as shown in Figure 4.18. TTM boxes could have been used as stratum 1 NTP servers with a time accuracy of 10ms.

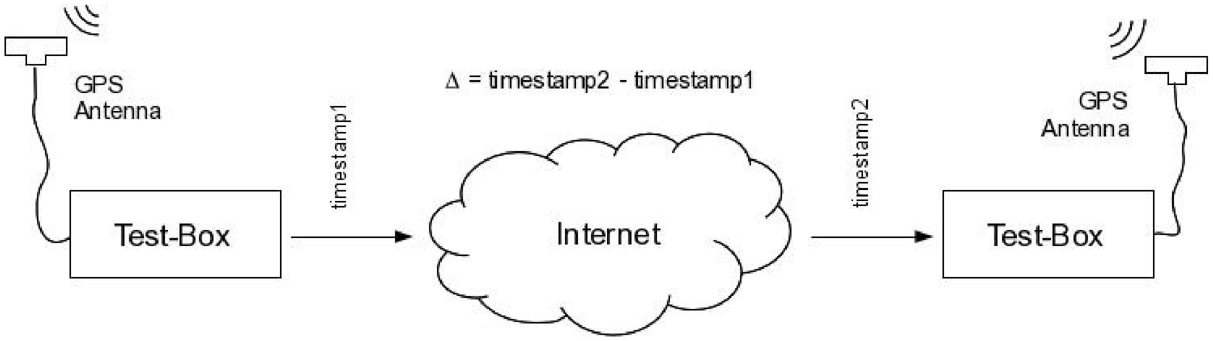


Figure 4.18: RIPE TTM measurement architecture

Users were not able to configure the system. All upgrades and configurations were done remotely by RIPE NCC administrators through the SSH.

There were three ways in which a TTM box host could access the measurement results:

- Follow in real time the network interface of the TTM test-box server.

[16] https://atlas.ripe.net/

[17] http://www.ripe.net/data-tools/stats/ttm/test-traffic-measurement-service

- RIPE NCC FTP site – raw data.
- RIPE NCC website – user friendly data presentation with summaries and graphical diagrams.

Data at the web site was available with some restrictions to those who did not participate in the TTM programme.

TTM had only around one hundred servers in European Autonomous Systems (AS). One of the reasons for this low adoption was the relatively high price of a test-box [RIPE1]. For some major AS, Internet exchange points or places near root DNS servers, RIPE sponsored expenses. Sponsored hosts had to commit to support the node for a minimum of three years.

Unlike TTM, Atlas is designed to be economically acceptable to the majority of ASs, and designed to be scalable deployed. Test-box servers were replaced with thumb-sized Lantronix Xport Pro probes (Figure 4.19) which are freely given to all the participants in the project. The number of active probes is 3923 at the time of writing.

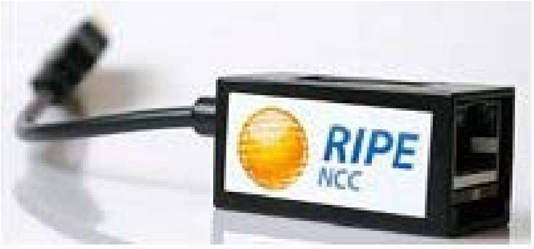
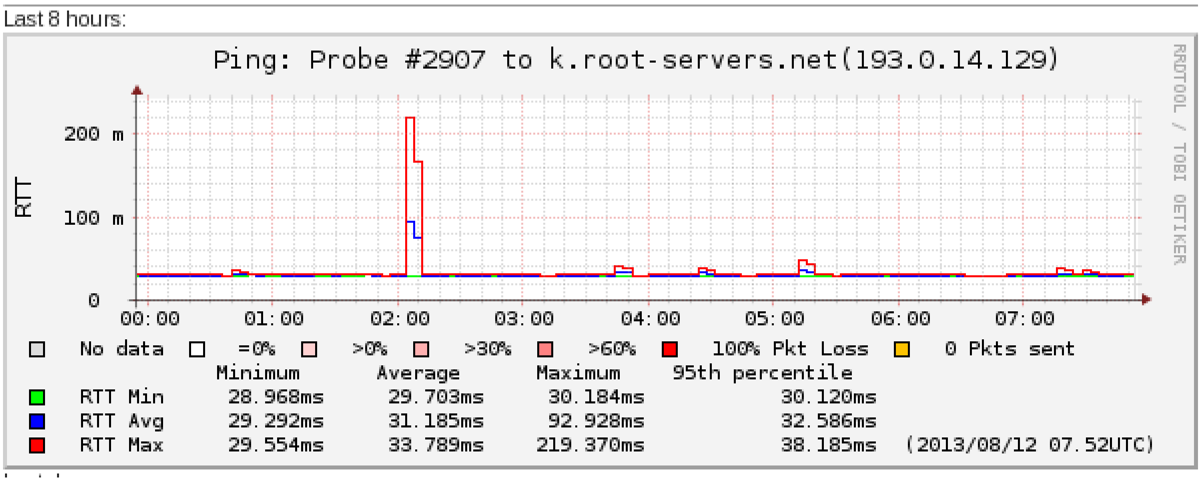


Figure 4.19: RIPE ATLAS probe

The Atlas probe needs a USB connection for the power supply and a network connection with DHCP enabled. Probes do not have any other interface through which they can be accessed - Atlas project participants require an account on the RIPE Atlas web site (https://atlas.ripe.net).

RIPE Atlas is can perform the following measurements and tests:

- RTT to the first and second hops.
- Ping and Traceroute to a number of predetermined destinations. One such result is shown in Figure 4.20.
- DNS queries to root DNS servers.
- SSL queries to a number of predetermined destinations.
- Probe current uptime, total uptime and uptime history.
- User-defined measurements (UDM) [RIPE2].



□ No data □ =0% □ >0% □ >30% □ >60% 🟥 100% Pkt Loss 🟨 0 Pkts sent

| | | Minimum | Average | Maximum | 95th percentile | |
|---|---|---|---|---|---|---|
| 🟩 | RTT Min | 28.968ms | 29.703ms | 30.184ms | 30.120ms | |
| 🟦 | RTT Avg | 29.292ms | 31.185ms | 92.928ms | 32.586ms | |
| 🟥 | RTT Max | 29.554ms | 33.789ms | 219.370ms | 38.185ms | (2013/08/12 07.52UTC) |

Figure 4.20: RIPE ATLAS measurement results

Atlas probe does not have GPS receiver, so one-way measurements are not possible. User-defined measurements are customised tests the hosts can run against the entire RIPE Atlas network in addition to the tests performed by default. The Atlas web portal allows the user to set appropriate user-defined measurements (UDM) parameters:

- Measurement type - Ping, Traceroute, DNS resolution, SSLCert or HTTP.
- Target – destination IP address or FQDN name. For DNS measurements, the target refers to the resolver which will be used, not the host the resolver will attempt to resolve.
- Origin – a set of probes that will be included in the measurement. Various criteria can be set, such as: geographic area (West, North-Central, South-central, World-wide, etc.), country, AS, IP prefix or probe ID.
- Time – test start and end time (UTC); start can be defined as "ASAP" (as soon as possible), and the end as "Never" (host manually ends the test).

Each type of measurement allows the specification of additional settings like packet size for ping, the number of alternative paths for Paris Traceroute, type of DNS request, etc. The UDM can be defined as private or public: the portal keeps the history of user defined measurements.

Each user-defined measurement requires resources from the network of involved probes, as well as from the RIPE Atlas infrastructure itself, so to keep the load of the Atlas system under control, RIPE developed a credit system [RIPE3] which limits the number of user-defined tests. Credit is increased with every minute the probe is active, and is decreased when user-defined tests are run. UDM can be run only if there is sufficient credit.

### 4.4.5 Summary

Table 4.1 summarises the main features of the multi-domain measurement platforms described in previous sections.

| | SamKnows | M-Lab | Grenouille | RIPE Atlas | perfSONAR GÉANT version |
|---|---|---|---|---|---|
| Test ISP access connections | Yes | Yes | Yes | Yes | No |
| Test inter-AS connections | No | Yes | No | Yes | Yes |
| Test mobile connections | Yes | Yes | No | No | No |
| Hardware- or software-based platforms? | Hardware. Whitebox probes free application with restricted set of functions | Software. BISmark requires access router to be purchased | Software | Hardware | Software |
| Paid for service? | No | No | No | No | No |
| Pay for hardware? | Yes | Yes. Only for BISmark | N/A | No | N/A |
| Physical size of hardware | Home access router | Home access router for BISmark | N/A | Slightly bigger than a typical flash drive | N/A |
| Number of measurement points (31/07/13) | 300 servers; 40k Whitebox probes; 3 data collection server sites. | 34 servers in USA, Eurpoe, Australia, Africa, China and Japan. Users' PCs used to execute measurements. | Over 20k users. | 3619 probes worldwide | Less than 20 European NRENs |
| Available bandwidth measurement? | Yes | Yes | Yes | No | Yes |
| Traffic-shaping detection? | Yes | Yes | No | No | No |
| Network neutrality check? | No | Yes | No | No | No |
| One-way measurement? | No | No | No | No | Yes |
| Ping? | Yes | Yes | Yes | Yes | Yes |

| | SamKnows | M-Lab | Grenouille | RIPE Atlas | perfSONAR GÉANT version |
|---|---|---|---|---|---|
| Traceroute? | No. Only for the location of the closest SamKnows server. | Yes.<br>Paris and reverse traceroute. | No | Yes.<br>Paris traceroute. | Yes |
| BitTorrent and other protocols? | Yes | Yes | No | No | No |
| HTTP and FTP tests? | Yes | Yes | No | No | No |
| DNS resolution tests? | Yes | No | No | Yes | No |
| SSL Cert tests? | No | No | No | Yes | No |
| Flash video streaming? | Yes | Yes | No | No | No |
| VoIP? | Yes | No | No | No | No |
| User-customised measurement? | No | Yes | No | Yes | Yes |

Table 4.1: Comparison of the main multi-domain measurement platforms

### 4.4.6 LMAP

LMAP (Large scale Measurement of Broadband Performance)[18] is a new workgroup within the IETF which started in 2013. It aims to standardise the LMAP measurement system for performance measurements of broadband access devices such as home and enterprise edge routers, personal computers, mobile devices, set top boxes, etc. Workgroup gathers participants from network equipment vendors (Cisco, Avaya, Huawei), service providers (BT, NTT), similar systems already deployed (SamKnows) and research institutions. Since the group has just started, there are no Request for Comments (RFC) yet.

The goal of the group is to specify an information model, the associated data models, and select/extend one or more protocols for secure communication:

- A Control Protocol, from a Controller to instruct a large number of Measurement Agents on the Internet what performance metrics to measure, when to measure them, how/when to report the measurement results to a Collector,

[18] http://datatracker.ietf.org/wg/lmap/charter/

- A Report Protocol, for a Measurement Agent to report the results to the Collector.

A key assumption constraining the initial work is that the measurement system is under the control of a single organisation: however, the use of the system in different domains is not forbidden.

## 4.5 Trends in Network Performance Management

### 4.5.1 Trends

Two recent trends in network performance monitoring are becoming important for NREN monitoring and management practices:

- The emergence of network devices (routers, switches) with embedded performance monitoring agents.
- The growing importance of performance monitoring of Ethernet services.

Until recently all the perfSONAR measurement services worked at the IP layer and most of these used software-based agents such as Iperf or HADES MP Perl script. Now perfSONAR functionality could benefit from these new opportunities.

#### 4.5.1.1 *Embedded agents*

Currently there are network boxes from different vendors, which have embedded agents for carrying out performance monitoring at Ethernet, IP and application layers.

The principal difference between software-based performance measurement tools like BWCTL hosts[19] or hardware-based RIPE TTM probes and embedded agents is that hardware-based probes do not require the installation of extra servers or devices in a network. Instead, to measure performance parameters between two points in the network one needs only to configure and activate two embedded performance agents on the respective routers or switches.

An embedded Ethernet performance agent is a relatively new feature of network devices; its emergence reflects the transformation of Ethernet into a carrier-grade transport technology, i.e. ‘Carrier Ethernet’. However, many vendors, for example Cisco, Juniper, Extreme, Alcatel-Lucent and Ciena, already have models of routers and switches with such embedded agents.

Embedded agents that are capable of measuring and monitoring performance at the IP and upper layers have the longer history, being available on commercial routers for years.

[19] Used for perfSONAR measurements as well

For example, Cisco IOS has an agent called IP SLA [IPSLA]. The agent supports a wide spectrum of active performance measurements from UDP-based one-way and two-way delays, jitter and packet loss ones for measuring DNS, DHCP and HTTP reaction times. Juniper Junos also has an agent with similar functionality called RPM (Real-Time Performance Monitoring) [RPM]. Both Cisco and Junos agents are proprietary implementations and they do not support open protocols like OWAMP.

It is not clear why the academic community hasn’t used the functionality of embedded performance monitoring agents in network devices more widely so far. However, at least one case of such a use is known: in 2004, the Janet QoS Development Project participants built a performance-monitoring system based on Cisco 1700 IP SLA agents. The system was used for measuring round-trip delays of IP/UDP traffic over the project lifecycle.

#### 4.5.1.2 *Performance monitoring of Ethernet services*

It is understandable that the performance monitoring of IP/UDP/TCP and applications traffic has been and still is the focus of the customer and network administrator’s interest.

However, the performance monitoring of wide-area Ethernet services and connections is becoming more important because of the growing use of Ethernet (or more precisely – Carrier Ethernet) as the carrier transport technology.

Wide-area (also referred to as ‘Carrier’, or ‘Metro’) Ethernet services play an important role for the UK and European academic users. Examples of wide-area Ethernet services are the GÉANT Plus service and the Janet Lightpath service. Both of these represent point-to-point connections with Ethernet User Network Interface (UNI); some segments of these connections are also Ethernet (along with SDH or OTN/DWDM ones).

Such services connect organisations which have particular data transfer requirements, e.g. large research centres like CERN and RAL that transfer vast amounts of data and need bandwidth guarantees and isolation from other network users. The specific requirements vary between customers but generally consist of one or more of the usual metrics: bandwidth guarantees, high availability, low latency and low loss. The main point here is that, whichever customer requirements are necessary, the network service is presented as a wide-area Ethernet service instead of plain IP connectivity.

In addition to customer-facing services, NRENs also use wide-area Ethernet services themselves to underpin their other network services such as IP transport. These internal Ethernet services and their particular implementation, status and performance are only visible to NOC staff.

The problem with wide-area Ethernet connections is that they are mostly unmonitored, which creates a potential conflict: on the one hand customers of such services expect to have better services than plain IP ones (better in different aspects: predictability, availability or guaranteed bandwidth). On the other hand, providers of these services have to rely blindly on a proper design and configuration of their network and its nodes in the absence of measuring the real performance characteristics of the connections they provide. In fact, in the area of service verification, we rely on the immaculate provisioning of a service by NOC engineers. In the area of service monitoring, we mostly delegate this problem to our users (except for monitoring network interfaces of the core routers) and wait until somebody reports a problem.

At the same time, Ethernet performance monitoring standards have been developed and ratified and vendors have implemented them in their equipment[20]. Hence, the prerequisites of adding Ethernet monitoring to our tools and systems including perfSONAR are in place, but some effort is still needed to convert them into real functionality.

## 4.5.2 Results of the joint GN3 JRA1/JRA2 Ethernet OAM activity

To test the new features which could be used for performance monitoring of Ethernet services the joint GÉANT 3 Year 4 JRA1/JRA2 activity was established. The activity consisted of two sub-activities:

- Testing embedded Ethernet OAM functionality of modern network equipment. For this a wide-area multi-NREN testbed was created.
- Developing a perfSONAR extension capable to obtain, store and visualise the Ethernet performance monitoring data from network equipment.

The results of both sub-activities were mostly positive.

### First sub-activity

Cisco, Juniper, Ciena, Brocade, Accedian and Overture equipment was tested for support of Connectivity Fault Management (CFM) and Y.1731 functions. CFM functions of boxes under test allowed the real-time monitoring of status for single-segment and multi-segment Ethernet connections. For some connections, robust and plausible two-way delay and delay variation data were obtained (but not one-way data because of some bugs in the equipment software).

### Second sub-activity

The perfSONAR sub-activity developed the Ethernet OAM Application with Web GUI. The architecture of the application is shown in Figure 4.21:

[20] A brief overview of Ethernet performance monitoring standards is given in Appendix C of this document. It is an excerpt from the GN3 JRA1 T1/JRA2 T3 report.

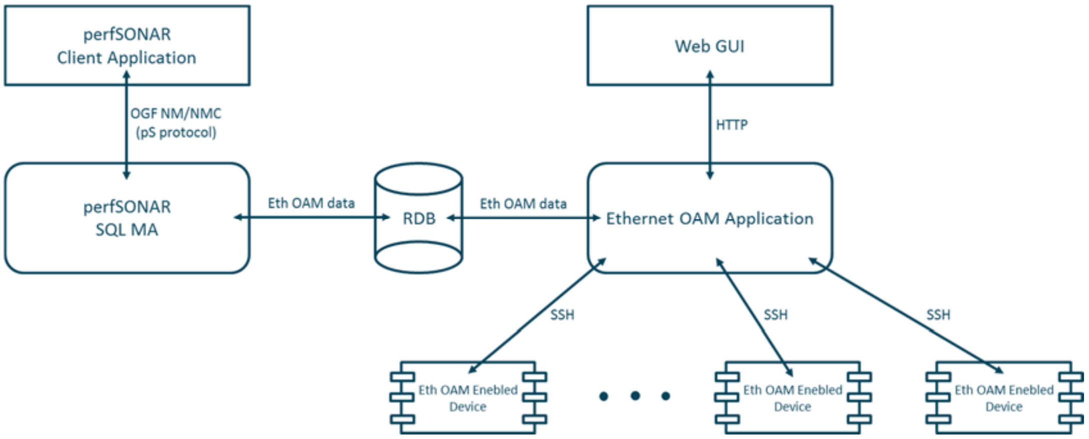


Figure 4.21: perfSONAR extension architecture

The Ethernet OAM Application polls embedded Ethernet CFM agents using Secure Shell (ssh) protocol and stores data about the status of Ethernet services in the Relational database (RDB). The application is able to poll three types of devices: Juniper MX80, Brocade MLX-8, and Overture ISG24.

The Web GUI allows users to control the Ethernet OAM Application as well as visualise the Ethernet OAM settings and measurement data.

In order to use perfSONAR SQL MA service to access historical Ethernet status data in the RDB, several extensions have been developed: Table 4.2 shows the main ones.

| Library/Service | Description | Extensions |
|---|---|---|
| nmwg | The library containing the implementation of the perfSONAR protocol elements (OGF NM/MNC). | New metadata describing the OAM configuration and a new metric – the Ethernet CCM status. |
| perfSONAR_base | The library that includes common functionalities of perfSONAR GN3 services. | New query generator for fetching the Ethernet CCM status. |
| perfSONAR-java-sql-ma | This service is used to publish the monitoring data stored in the relational database. | Fetching the Ethernet CCM status from the relational database. |

Table 4.2: perfSONAR extensions needed to access Ethernet measurement data

The developed software and perfSONAR extensions were an attempt to show how embedded Ethernet performance agents could be used by perfSONAR instead of incorporating new Ethernet metrics and sources of performance data into perfSONAR itself.

The obvious limitations of the developed software are that:

- It support only one metric (a service status 'Up/Down' which is an instant indicator of availability and could be used for its calculation) of the Ethernet performance metric set described in Y.1563 and MEF 10.2&10.2.1 (i.e. no support of delay/loss metrics)
- It doesn't support service assurance measurements (analogous to Iperf measurements) according to the Y.1564 recommendation.
- It is not fully integrated with perfSONAR services and components: e.g. with the perfSONAR UI, authentication service.

### 4.5.3 Incorporation of Embedded Ethernet Performance Agents into perfSONAR

A systematic and full-scale solution might include the following elements:

*The full support of the all Ethernet performance metrics, tools and agents*

- These metrics and tools are described in respective standards (IEEE 802.1ag CFM, ITU-T Y.1731, Y.1563, Y.1564, MEF 10.2&10.2.1). The positive thing here is that there are standards that describe Ethernet performance monitoring procedures and metrics in detail, and that all leading vendors follow these standards and implement them in a similar way, making cross-vendor hardware much easier to support. Software agents do not have this problem as one can use the same software on different platforms so such a solution is uniform by design.
- Support of Connectivity Fault Management (CFM) agents to monitor Ethernet services status (Up/Down). Historical sequences of this type of data allows the availability of a service to be calculated, one of the Ethernet performance metrics described in Y.1563. Support of this Ethernet performance metric means.
  - Ability to manage configuration parameters of CFM MEPs.
  - Ability to start and stop monitoring sessions between CFM MEPs (Maintenance End Points).
  - Including the MEP configuration parameters, and status/availability metrics into a respective database scheme.
  - Support of topology maps with MEPs.
- Support of Y.1731 agents to monitor frame latency (one-way and two-way) and loss metrics of Ethernet services. The aspects of this support are similar to the CFM support described above.
- Support of Y.1564 agents to test the bandwidth limits (CIR, EIR, policing limit) of Ethernet services.
- Support of troubleshooting tools of CFM agents: loopback (a ping-like tool) and linktrace (a traceroute-like tool): this should be similar to how perfSONAR uses ping and traceroute for testing reachability.

*The support of different ways of obtaining measurement data from embedded agents*

- Despite the fact that all vendors follow the same standards and their agents supply the same set of metrics to a monitoring software system like perfSONAR, the methods of obtaining these data vary from vendor to vendor. The following methods of obtaining performance data from network devices could be used:
- SNMP MIB poll. This could be an excellent method if standard Management Information Bases (MIBs) existed for all Ethernet performance monitoring metrics and configuration parameters and all vendors

implemented them. Unfortunately this is not the case, at present. IEEE 8021 CFM MIB is standard for CFM but not all major vendors have implemented it: for example, Cisco have but Juniper haven't. There is no standard Y.1731 MIB, so all MIBs for latency/loss metrics are proprietary if they exist. However, this is not a major problem as most Network Management Systems (NMSs) can use a proprietary MIB if its description is written according to "Structure of Management Information Version 2 (SMIv2)" RFC 2538.

- Secure Shell (SSH) access to a device. This is the most powerful method as allows data to be obtained from any box supporting a Command Line Interpreter (CLI) although CLIs differ between each vendor.
- Syslog messages could be used for status monitoring as it is 'Up/Down' type of messages and vendors usually allow logging them. However, latency/loss data are not of that type and hence can't be taken from Syslog.
- File Transfer Protocol (FTP) or Session Control Protocol (SCP) push. Some vendors support an FTP- or SCP-push method where a box regularly sends performance data to a specified server using FTP or SCP protocols.

- In the absence of a single method of obtaining performance data from embedded agents, an implementation might use a set of per-vendor or per-method add-ons similar to the Technology Proxies approach of Autobahn.
-

*Incorporation into the perfSONAR architecture*

- A way in which support of embedded Ethernet CFM/Y.1731 agents could be incorporated into perfSONAR architecture could be similar to adding OWAMPs and HADES modules to the sets of IPPM and Ethernet latency/loss metrics. The difference is that an embedded agent can't be wrapped by Multilink Protocol (MP) software working on the same node as in OWAMP or HADES cases. So, an MP should work on separate server and access several embedded agents. A distributed architecture of MPs also could be used for a multi-domain scenario.
- Y.1564 agents might be used by perfSONAR in a similar way to the BWCTL MP agents in the existing perfSONAR modules.
-
- For all types of embedded agents (e.g. for CFM, Y.1731, and Y.1564) either extensions for the existing perfSONAR modules should be developed or new modules have to be written. Extension might be developed for:
- perfSONAR UI to provide a single point of management and visualisation of all perfSONAR functions.
- SQL MA for storing configuration parameters of MEPs and historical performance data.
- Authentication service (e.g. eduGAIN).
- Topology service, probably using the GN3 cNIS service for the intra-domain topology. (The GN3 inter-domain topology service does not exist as a separate service but an Autobahn implementation of it could be used for developing one).

## 4.6 Conclusions of the perfSONAR Analysis

Previous high-level analysis of the current GÉANT version of perfSONAR (perfSONAR MDM) reveals the following main perfSONAR properties:

- perfSONAR is a service-agnostic multi-domain performance monitoring platform. It monitors and measures general network parameters like latency, jitter, round-trip-time, network path topologies, and is unaware of the specific properties of the multi-domain services (e.g. BoD reservations, VPN circuits, SLA parameters, warning thresholds and so on). There is no correlation between network performance and service parameters in perfSONAR. However, with the proper placement of the Measurement Points, current version of perfSONAR can be used as a service performance monitoring platform that assists human operators in detecting specific service performance issues. It is also possible to integrate perfSONAR components and the tools supporting specific network services which would allow these tools to gather performance data and to react to specific changes in performance parameters. Such attempts have so far been experimental.
- The set of business processes that perfSONAR supports matches the best RPM layer 2 business process. Similarly the Resource Test Management (in the Resource Management Domain) set of TAM functionalities is the closest match to the set of perfSONAR functionalities.
- Due to its service-agnostic nature it can be said that currently perfSONAR partially supports the SQM business process only for the simplest network services such as IP connectivity.
- perfSONAR is not the only multi-domain network performance monitoring platform that exists and is being developed nowadays. Other platforms have either a similar goal as perfSONAR (M-Lab, ATLAS) or are targeting the performance measurement of access broadband links (SamKnows, Grenouille). The latter is the subject of the standardisation work in the IETF LMAP working group established recently. Due to its larger footprint and complex and lengthy installation, the current version of perfSONAR is not dedicated for access link performance measurements.
- perfSONAR is capable of supporting a similar set of performance measurements to other tools. Adding additional measurements should not be problem, as even the present measurements are performed by the third party tools (bwctl[21]).
- perfSONAR is not a plug-and play platform like ATLAS, SamKnows or Grenouille
- perfSONAR has a smaller number of measurement points than similar platforms (M-Lab, ATLAS) with a smaller geographic range covered (only European NRENs create perfSONAR MDM performance monitoring area). Platforms like Grenouille and SamKnows have a significantly higher number of measurement points.
- perfSONAR has a larger footprint than similar monitoring platforms and does not allow for performance checks by individual users. Unlike, for example, M-Lab, there are no client applications or web access that would allow performance checks between a user machine and a measurement point.
- There are other measurement methods that could be executed by network elements which could be used as a source of performance data (e.g. network elements monitoring specific service parameters and

[21] http://www.internet2.edu/performance/bwctl/

exporting them to the MPs). Such measurements are currently not supported by other multi-domain measurement platforms.

# Conclusions

This document presents process flows of one of the typical multi-domain services and analyses in depth functionalities of perfSONAR tool developed within our community. Based on these analyses, the SA4 T3 task concluded the following:

- Inter-domain service interaction is a crucial business process for successful operations of any multi-domain service. It appears in various phases of the service operations: capability exchange, request exchange, problem and performance reports exchange, problem correlation and resolution information exchanges, and so on. Automation, efficient execution and organisation of these processes is extremely important since without it, operations teams in different domains have to communicate using emails or phone calls. Such communication is typically difficult to track and manage and prone to inefficient processing.
- perfSONAR analysis revealed that perfSONAR-MDM is lagging behind the other multi-domain monitoring platforms in terms of the number of measurement points and their placement, footprint size ease-of-installation and user experience. On the other side, perfSONAR as a support to multi-domain services is incomplete and does not support entirely Service Quality Management business processes; it requires manual interventions in order to correlate measured data with the service-related information. Various ideas and initiatives about the use of perfSONAR that exist in the GÉANT community (multi-domain monitoring platform vs. performance support for multi-domain tools) create a challenging environment for the perfSONAR team to focus on. The future direction of perfSONAR development should be established as soon as possible to avoid abandoning further development. There is a high risk that perfSONAR as it is now will soon become an obsolete and unattractive platform.
- The other half of the Assurance vertical business process grouping – Problem Management – is not supported by any of the existing GÉANT tools. This business process grouping was not analysed in detail in previous GÉANT community projects using the principles of Network Management Architecture. Multi-domain root cause analysis and multi-domain troubleshooting could be a challenging and time-consuming task as the necessary information (errors, events, warnings produced by active devices) are in most cases stored in separate information silos. Even inside a single entity (NREN) it is rare to have a unified intelligent event/error handling facility. In the case of multi-domain services like MDVPN the investigation of the feasibility of using multi-domain root cause analysis and multi-domain troubleshooting supporting tools should be considered. Analysing this process grouping will make the analysis of main service operations process groupings complete (as with the GN3 project's analysis of AutoBAHN, cNIS and iSHARE tools).

As explained in the Introduction in the second phase of the work, SA4 T3 will analyse three different process groupings:

- Performance Management process subgroup
- Problem Management process subgroup
- Multi-domain Service Interaction

According to the Business Process Framework, the Performance Management process subgroup includes, but is not limited to, Service Quality Management and Resource Performance Management; the Problem Management process subgroup includes Service Problem Management and Resource Trouble Management. Multi-domain Service Interaction falls in the Service Management and Operations, according to the Business process decomposition for NREN-to-NREN interaction [GN3 DJ2.1.1] shown in Figure 2.1. All of those selected processes and process subgroups are in the domain of Operations, which is the primary concern of the Network Support Services - SA4 - Activity. In addition, all the GÉANT3plus products described in this document belong in the same area, thus representing the potential field of interest for the future work of SA4 T3, including milestones and deliverables. With the selection of the three processes that will be the basis for the future work of SA4 T3, the team has also achieved the first Milestone - MS4.3.1. the "Definition of business processes and selection of three business processes for modelling".

# Appendix A TM Forum eTOM and TAM Specifications

## A.1 TMF Business Framework (eTOM)

The enhanced Telecommunication Operation Map (eTOM) initiated by TM Forum intends to deliver a business process model and framework for service providers in telecommunication as well as IT service providers. It is included in the TM Forum's Frameworx architecture which as is described in Section 1 appears to be the industry's most comprehensive integrated business architecture.

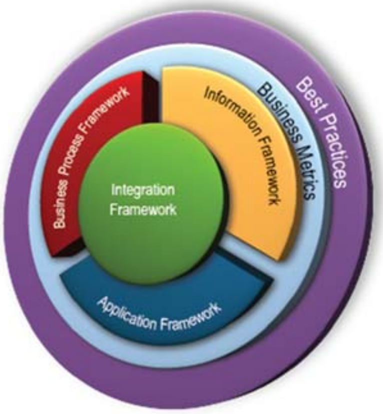


Figure A.1: Frameworx Components [tmforum.org]

Figure A.1 shows the components included in the Frameworx architecture, in which the business process framework (eTOM), the information framework (SID) and the application framework (TAM) is brought together by the integration framework (TNA). Whereas each framework describes a particular perspective of enterprise management, in this section the focus is given to the business process framework – eTOM.

As defined by the TM Forum, the business process framework or eTOM predefines a decomposition hierarchy of the tasks that an enterprise needs to consider. A TM Forum document [eTOM-C&P] describes it as: "*… a reference framework for categorizing all the business activities used by an enterprise involved in delivering on-line information, communications and entertainment services. This is done through definition of each area of* *business activity, in the form of process components or process elements that can be decomposed to expose progressive details."*

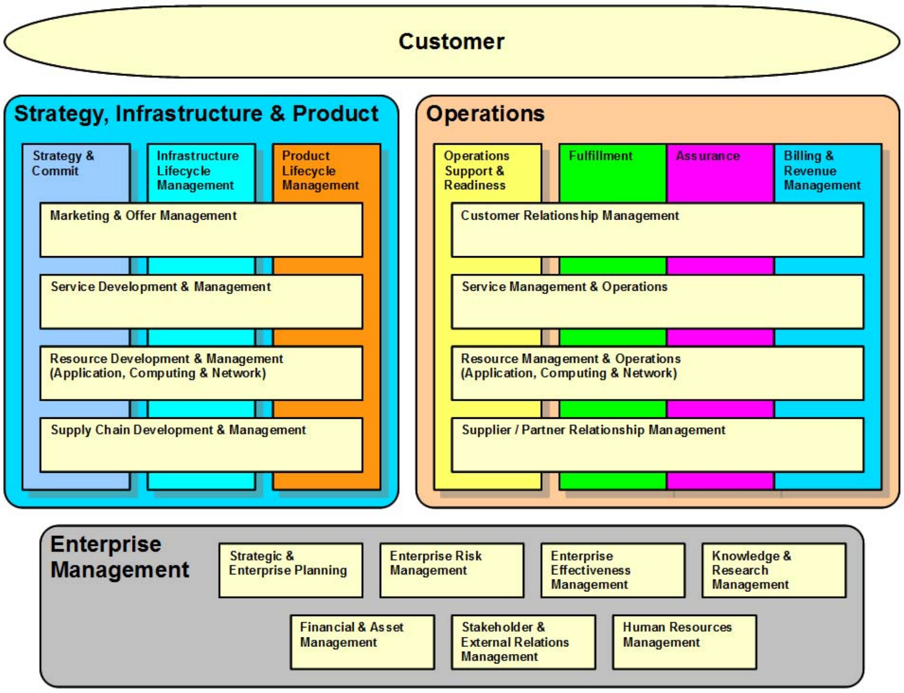

Customer
Strategy, Infrastructure & Product
Strategy & Commit
Infrastructure Lifecycle Management
Product Lifecycle Management
Marketing & Offer Management
Service Development & Management
Resource Development & Management (Application, Computing & Network)
Supply Chain Development & Management
Operations
Operations Support & Readiness
Fulfillment
Assurance
Billing & Revenue Management
Customer Relationship Management
Service Management & Operations
Resource Management & Operations (Application, Computing & Network)
Supplier / Partner Relationship Management
Enterprise Management
Strategic & Enterprise Planning
Enterprise Risk Management
Enterprise Effectiveness Management
Knowledge & Research Management
Financial & Asset Management
Stakeholder & External Relations Management
Human Resources Management

Figure A.2: eTOM Level 1 View

Business processes are organised in different detail levels in eTOM, which forms a hierarchical structure. The level 0 view defines three process areas: Strategy, Infrastructure & Product (SIP), Operations and Enterprise management. In level 1 view are illustrated in Figure A.2, more detailed vertical and horizontal process groupings are added. Vertical groupings are end-to-end processes that are required to support customers and to manage the business, whereas horizontal process grouping documents functional processes across an organisation. Each higher level process can be decomposed into lower level processes, with which business processes are refined into a more detailed view.

eTOM records the decomposition hierarchy, with which progressive details of the processes and elements are revealed. Note that the purpose of eTOM is more of reference nature than a set of mandatory rules, which means enterprises are not required to completely adopt business processes as defined in eTOM, rather they can select processes which are suitable to the current structures and characteristics of their businesses. Due to this flexibility, eTOM is also frequently applied by enterprises to map and analyse their current business processes according to eTOM. This is also the focus of this section.

## A.2 TMF Application Framework (TAM)

TAM (The Application Framework) is intended to be an industry set of standard application requirements to support a more modular approach in application development.[TAM] It has been designed for both operator and suppliers communities worldwide to have a common frame of reference in describing their current and future needs and intentions. TAM can be applied on the entire communication software value chain, as shown in Figure A.3.

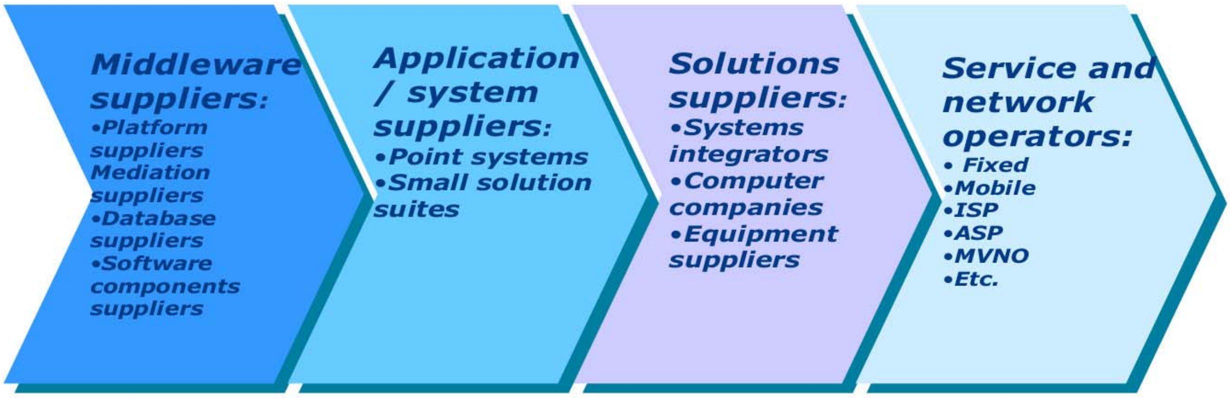


Figure A.3: Communication software value chain [TAM]

As part of the TM Forum's Frameworx program, the Application Framework is built on the common process and information models (Business Process Framework and Information Framework). Level 1 Application Framework categories are shown in Figure A.4. The Application Framework categories are organised vertically using Business Process Framework level 1 areas and horizontally aligned with the layering Information Framework domains.

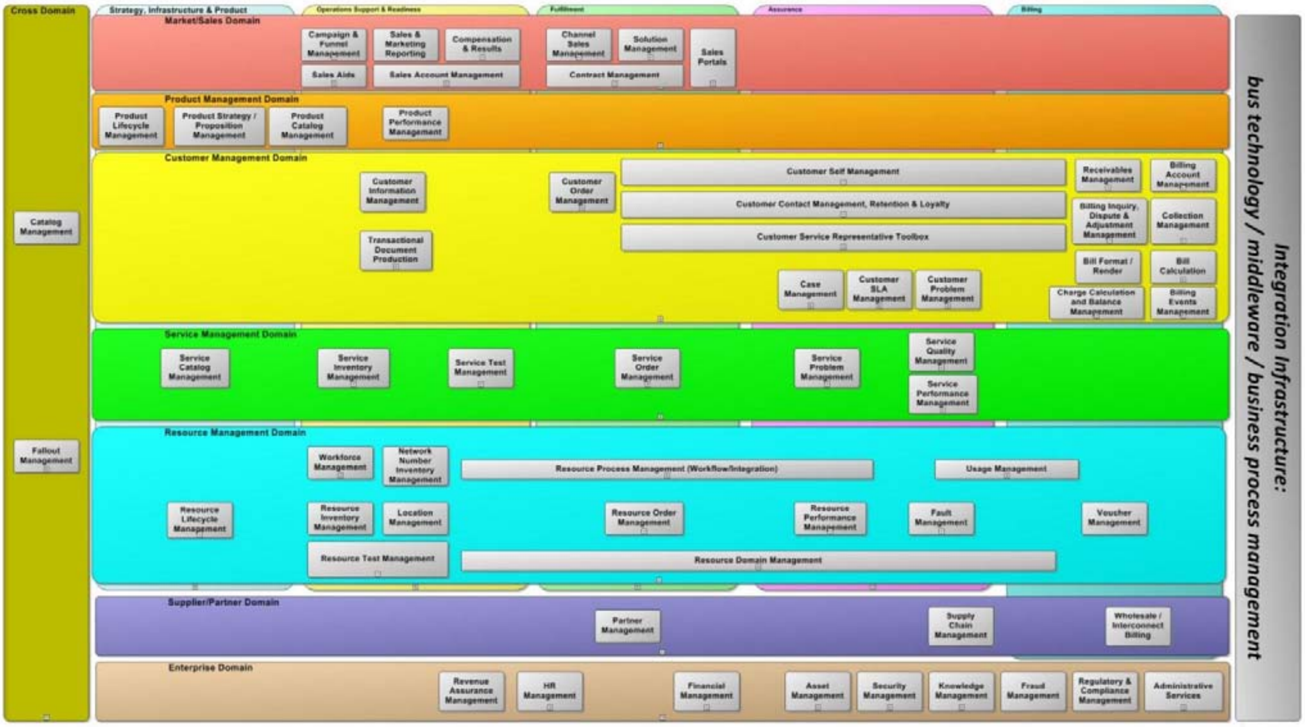

Cross Domain
Strategy, Infrastructure & Product
Operations Support & Readiness
Fulfillment
Assurance
Billing
Market/Sales Domain
Campaign & Funnel Management
Sales & Marketing Reporting
Compensation & Results
Channel Sales Management
Solution Management
Sales Portals
Sales Aids
Sales Account Management
Contract Management
Product Management Domain
Product Lifecycle Management
Product Strategy / Proposition Management
Product Catalog Management
Product Performance Management
Customer Management Domain
Catalog Management
Customer Information Management
Customer Order Management
Customer Self Management
Customer Contact Management, Retention & Loyalty
Customer Service Representative Toolbox
Transactional Document Production
Case Management
Customer SLA Management
Customer Problem Management
Receivables Management
Billing Account Management
Billing Inquiry, Dispute & Adjustment Management
Collection Management
Bill Format / Render
Bill Calculation
Charge Calculation and Balance Management
Billing Events Management
Service Management Domain
Service Catalog Management
Service Inventory Management
Service Test Management
Service Order Management
Service Problem Management
Service Quality Management
Service Performance Management
Resource Management Domain
Fallout Management
Workforce Management
Network Number Inventory Management
Resource Process Management (Workflow/Integration)
Usage Management
Resource Lifecycle Management
Resource Inventory Management
Location Management
Resource Order Management
Resource Performance Management
Fault Management
Voucher Management
Resource Test Management
Resource Domain Management
Supplier/Partner Domain
Partner Management
Supply Chain Management
Wholesale / Interconnect Billing
Enterprise Domain
Revenue Assurance Management
HR Management
Financial Management
Asset Management
Security Management
Knowledge Management
Fraud Management
Regulatory & Compliance Management
Administrative Services
Integration Infrastructure:
bus technology / middleware / business process management

Figure A.4: The Application Framework

# Appendix B GEMBus and TMF TIP Interfaces

## B.1 Introduction

This sub-activity is a continuation of the work of GN3 JRA2 T1. In GN3, cNIS and AutoBAHN were integrated using the TIP RAM notification schema for topology changes. The last step was to evaluate the possibilities of introducing the Enterprise Service Bus (ESB) into that scenario. Modern network management principles, summarised in [NGOSS TNA] assume the use of a common communication vehicle (ESB) for the OSS component integration in complex OSS architectures. In this activity ESB acts as a Notification Service.

- The objectives of the activities covered in this document are to build knowledge, experience and know-how on a standardised interface implementation in real-life applications. cNIS and AutoBAHN, as the supporting tools for the delivery of the m-domain Bandwidth on Demand service, have been chosen as the target application suite. The work explained in this Appendix is based on the existing TIP RAM notification schema for topology changes in cNIS and AutoBAHN, with the aim of evaluating the introduction of ESB into that scenario. The opportunities of using ESB were determined by the SWOT analyse for GEMBus [ESB-SWOT]. GEMBus is a GÉANT ESB implementation combining and leveraging both SOA and ESB features.
- The scope of the work within the sub-activity included the following activities:
- Designing the TIP-RAM notification service with the use of GEMBus following the WS-Notification specification. The existing TIP RAM notification interface which was built upon the OASIS WS Notification specification will be used.
- Building and configuring the testbed.
- Implementing the service and deploying it for evaluation purposes.

## B.2 TM Forum Standardised Interfaces

As for other types of TM Forum interface, work is being done within the TM Forum to bring together the previous work done on OSSJ/FM [FaultMgmtAPI] and MTOSI RTM [MTOSI-rtmba] and to some extent the 3GPP Alarm IRP. The aim is to harmonise the achievements and benefits of these previous efforts and align them under a single alarm management interface, which should provide a simple solution for use in simple alarm reporting scenarios but also have the flexibility to accommodate more complex scenarios.

This work is being done under the auspices of the TM Forum Interface Program (TIP) team. Part of their work is focused on the development of interfaces for resource and service assurance. This group has focused on Resource Alarm Management as it is a key interface where such alignment is needed, and such a harmonised solution is high on the wish-list of Service Providers. From [MTOSI-rmidba]: *"The long term plan (which is already well under progress) is to migrate the various input work to a single harmonized suite of interfaces."*

The actual list of the TIP interface families is given here:

- Service Problem Management:
  - Service Problem Management
- Inventory:
  - Basic Resource Inventory
  - Generic Query
- Security:
  - Enterprise Identity Management – Operator User Management
  - Enterprise Identity Management – Single Sign On
  - Security Compliance Audit
- Fault Management:
  - Resource Alarm Management
  - Service Problem Management
  - Maintenance, Protection and Alarm Control
- Policy Management:
  - Policy Information Exchange
- Performance Management
- Expedited Interfaces

These standardised interfaces, processes and application demarcation points contain in-depth knowledge in a given domain, although the SOA-specific implementation of the TM Forum interfaces is an open question. One can implement it as a so called "spaghetti integration" without using any integration facility/platform. From the Total Cost of Ownership (TCO) point-of-view, this is the simplest and cheapest route in the short term, but in the long term the TCO of this approach could become higher compared to an open standard SOA implementation using ESB or API management facilities. The following is an overview of the "pros and cons" of using an ESB as a platform for a Service Oriented Architecture.

## B.3 ESB as a Platform for SOA

The Enterprise Service Bus (ESB) is an abstraction layer on top of an Enterprise Messaging System. This section presents the ESB capabilities as a platform for SOA and it outlines the motivation and rationale for using ESB for cNIS and AutoBAHN integration.

ESB is meant to deliver reliable communication between a producer and consumer according to the given rules and ensuring message integrity. From the application perspective, ESB can be seen as a synchronous or asynchronous system for messages exchange, which enables secure communication between applications with the use of XML, Web Services or any other supported protocol.

GEMBus (GÉANT Multi domain Bus) is the federated multi-domain service-oriented infrastructure developed in the GN3 project [GEMBus]. It is founded on a Composable Service Architecture (CSA), based on a general framework for composite services, and on the industry adopted Enterprise Service Bus (ESB), extended to support dynamically reconfigurable virtualised services.

### B.3.1 Background

ESB is a flexible software architecture construct based on service orientation, the many capabilities of which include provisions for [IBM10]:

- Communications.
- Service interactions.
- Integration.
- Quality of services.
- Security.
- Service level.
- Message processing.
- Management and autonomic services.
- Modelling.
- Infrastructure intelligence.

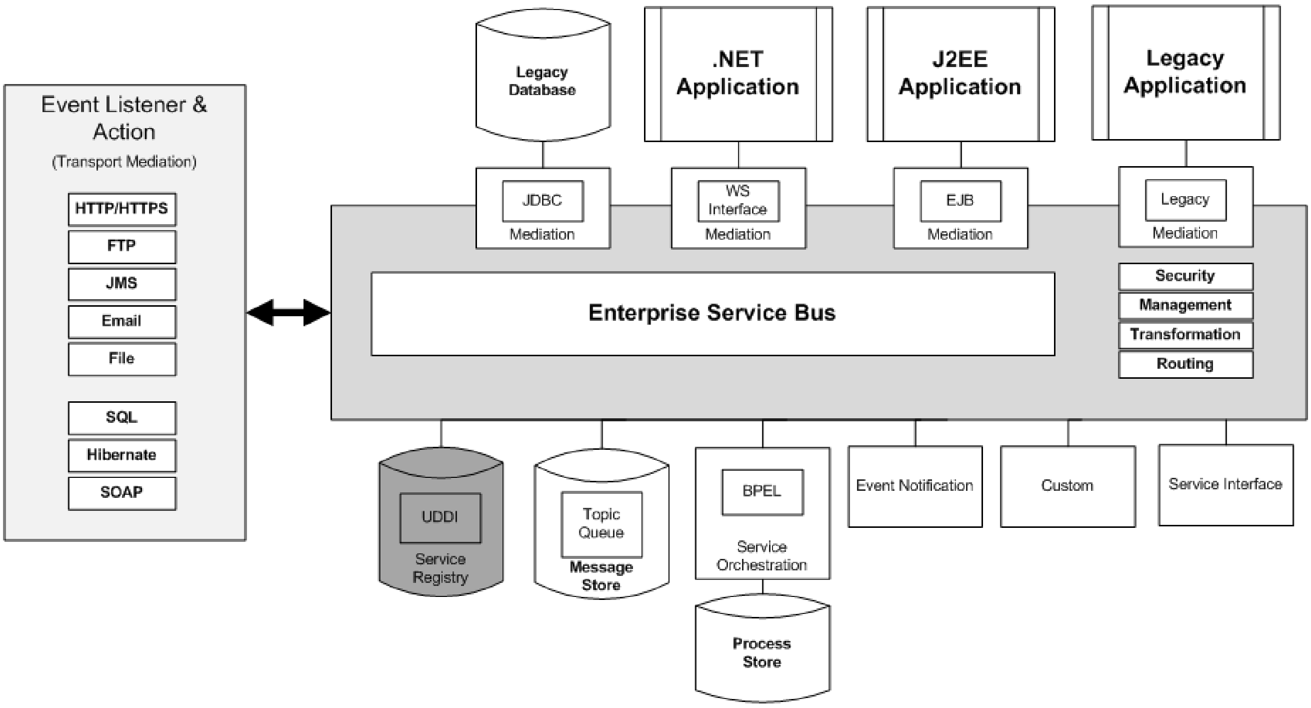


Figure B.1: Enterprise Service Bus (reference architecture)

Service Oriented Architecture (SOA) is characterised by its properties of loose coupling, reusability, discoverability and interoperability. The principles of service-orientation have been outlined as [Fan2010]:

- Loose coupling - the underlying logic of a service can be changed with little or no impact on the other services within the same system.
- Contract - documents describing how a service can be programmatically accessed.
- Abstraction - services expose only the logic defined in the service contract and hide implementation from the end user.
- Autonomy - services have to control only the logic and functionality, which they encapsulate.
- Reusability - services can be reused more than once and from multiple clients.
- Composition - services can be grouped in composite service, which coordinate the data exchange between composite services.
- Statelessness - services cannot save the state of activity.
- Interoperability - services are platform- and implementation-independent.
- Discoverability - services are discoverable; there has to be a standard mechanism, which allow services to be discovered.

### B.3.2 Focus

The SWOT chart for ESB [ESB-SWOT] provides the detailed analysis for using this architectural solution in the GÉANT application area. The identified opportunities of ESB are the following:

- Creation of global application collaborations ('global' in the sense that its participating applications could potentially be anywhere on the Net, running on any platform). It means bringing the GÉANT app ecosystem closer with other Future Internet initiatives, environments and applications.
- Reliable messaging layer for BoD and other network tools. By introducing ESB and replacing the point-to-point integration with a common messaging layer we would potentially enhance the interoperability between BoD systems (AutoBAHN, OSCARS, OpenNSI, OpenDrac) and other GÉANT applications. We might also enhance the reliability of the transport layer to avoid information loss.

The SOA architecture is also recommended by standard network management bodies. ITU-T and ETSI recommend that OSS systems should be built according to the Organisation for the Advancement of Structured Information Standards (OASIS) SOA principles, laid out in their OSS design specification documents. TM Forum's NGOSS [NGOSS TNA] extended the SOA architecture for their purpose and named it Distributed Interface Oriented Architecture (DIOA) [DJ2-1-1]

The architectural concepts within NGOSS provide guidelines for designing and building the OSS according to the list of requirements detailed in the previous section. The concepts are mainly related to SOA software design practices. An NGOSS system is characterised by the existence of a *communications service* (e.g., a "communications bus") [NGOSS TNA] or some other form of common communication, which is used by all software entities to communicate with each other. Each communications service offers one or more different transport mechanisms. There may be more than one such communications service within a given system implementation, and these services may represent different technology-specific mappings

.

## B.4 Autobahn TIP RAM-based cNIS Integration without ESB

This section outlines the TIP RAM based integration for cNIS and AutoBAHN. The results of this work have been inherited from the previous project, GN3, which was a joint effort of SA2 T5 and JRA2 T1.

An example TIP RAM based integration was focused within the "Alarm Service" effort for BoD tools – cNIS and AutoBAHN. Attention was placed on producing something that was useful in the GÉANT BoD service area (i.e. topology update notification) and "in line with" relevant standards (i.e. TIM RAM). The outcome of the GN3 project has now been expanded towards Resource Alarm Management and further beneficial standardisations.

### B.4.1 Context

The TM Forum Interface Programme's Resource Alarm Management Business Agreement [TIP-RAM] documents the business problem description, supported scenarios, requirements and use-cases for the management of alarms. Three Alarm Profiles are defined:

- Simple Alarm Reporting Profile.
- Standard Alarm Profile.
- Enhanced Alarm Profile.

The Simple Alarm Reporting was chosen to be the reference for the implementation.

The SimpleAlarmReportingProfile includes the following notifications:

- NewAlarm, mandatory.
- ClearedAlarm, mandatory.
- ChangedAlarm, optional.
- HeartbeatNotification, optional.

The first three notifications (NewAlarm, ClearedAlarm, ChangedAlarm) are applied on the ResourceAlarm object. Their actual TIP implementations will contain a sourceTime and an objectType and Id, referring to the ResourceAlarm.

The SimpleAlarmReportingProfile includes only one operation: getResourceAlarms

### B.4.2 Focus

The focus of the Resource Alarm Management interface implementation was narrowed for a simple small subset of the Information Framework as applied to RAM for cNIS and AutoBAHN. The Information Framework provides a couple of entities of interest here: a Resource and a Resource Alarm

This translated into the requirement: *for AutoBAHN to be made aware by means of a notification via a standards-based TM Forum notification interface of an event on cNIS (phase 1)*. An "event" in this context is the occurrence of a "Relevant Topology Update". Furthermore, we defined the cNIS's Relevant Topology Update Monitor to determine a "Resource". The Resource creates a new alarm, a "Resource Alarm", to indicate that a relevant topology update has occurred

For the purposes of the next phase of this implementation (i.e. Phase 2), this was translated into the requirement: *for AutoBAHN to be made aware by means of an object creation event via a standard TM Forum RAM interface of a new Resource Alarm on cNIS.*

### B.4.3 Implementaton

The implementation effort for the TIP RAM integration has been divided into three phases [RAM-cNIS]

- Phase 0: Preparations to ensure that TIP RAM-originated WebService skeletal code could be accommodated on both cNIS and AutoBAHN to allow external clients to retrieve resource alarms.
- Phase 1: Integration of standards-based WS-Notifications between cNIS and AutoBAHN.
- Phase 2: Integration, bringing the capability beyond simple notification towards supporting standards-originated alarms for SID-originated managed objects. This would be starting from a single Resource Alarm for a single cNIS resource managed object and ending with full Resource Alarm Management and further standardisations.

**Phase 1** was accomplished with the implementation of the TM Forum Interface Program (TIP) Resource Alarm Management (RAM) interface between cNIS and AutoBAHN, with the aim of cNIS being able to notify AutoBAHN of updates in topology in the form of a standardised RAM alarm.

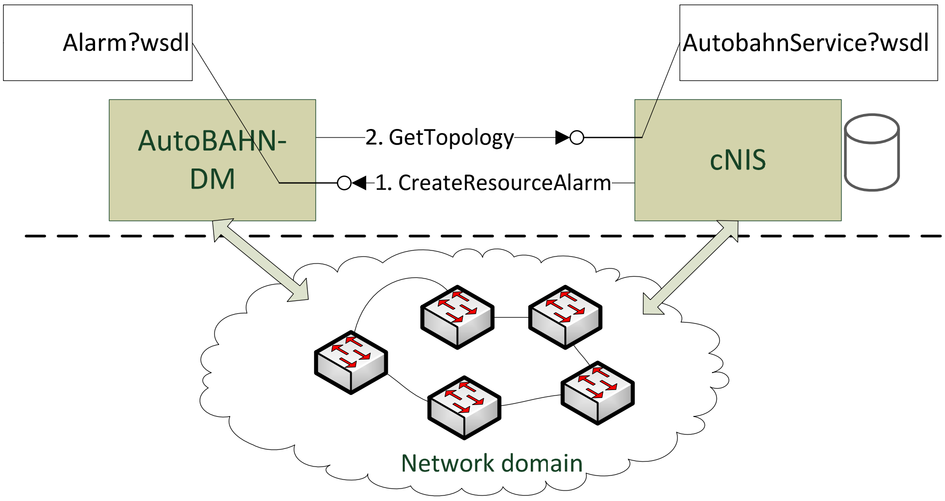


Figure B.2: TIP RAM implementation for cNIS and AutoBAHN (Phase 1)

Figure B.2 describes a basic scenario for the SimpleResourceAlarm profile - newAlarm notification:

1. cNIS invokes createResourceAlarm action. The event is generated when:
   - cNIS operator confirms that a change in the network topology has occurred (send Alarm button available in cNIS Management Application)
   - cNIS software detects a change in the network topology
2. AutoBAHN accepts the request and retrieves the network topology from cNIS.

The communication process between cNIS and AutoBAHN is asynchronous, which means that step 2 can be postponed or even the alarm might be ignored in exceptional cases. Phase 2 ended with the prototype implementation of TIP RAM Notification Server, service consumer and service producer.

# B.5 Autobahn TIP RAM-based cNIS Integration with ESB

This section describes the results of the Proof of Concept (PoC) project conducted in order to validate the effectiveness and the availability of the GEMBus-based SOA oriented example integration of BOD tools. Based on the results of the second phase, where the web-service-based integration was demonstrated, a plan was elaborated for ESB-based integration.

## B.5.1 Setup

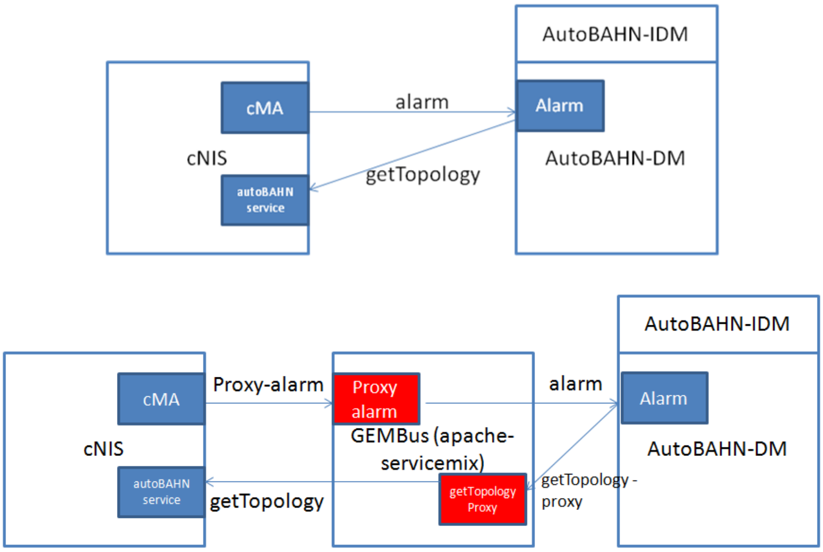


Figure B.3: Pure WS based vs. ESB based SOA implementation

Figure B.3 shows a comparison of the pure WS and the ESB based integration. The two application are in a same virtual machine which runs an Ubuntu server operating system. The cNIS Management Application (CMA) can send an alarm to AutoBAHN-IDM (Inter Domain Management), that the current topology changed. And in that case the AutoBAHN can call the getTopology web service to get the actual topology from cNIS.

## B.5.2 Role of the ESB, role of the proxy modules

In order to be able to use an ESB proxy, modules are needed. Figure B.4:  shows the location and role of these proxy modules.

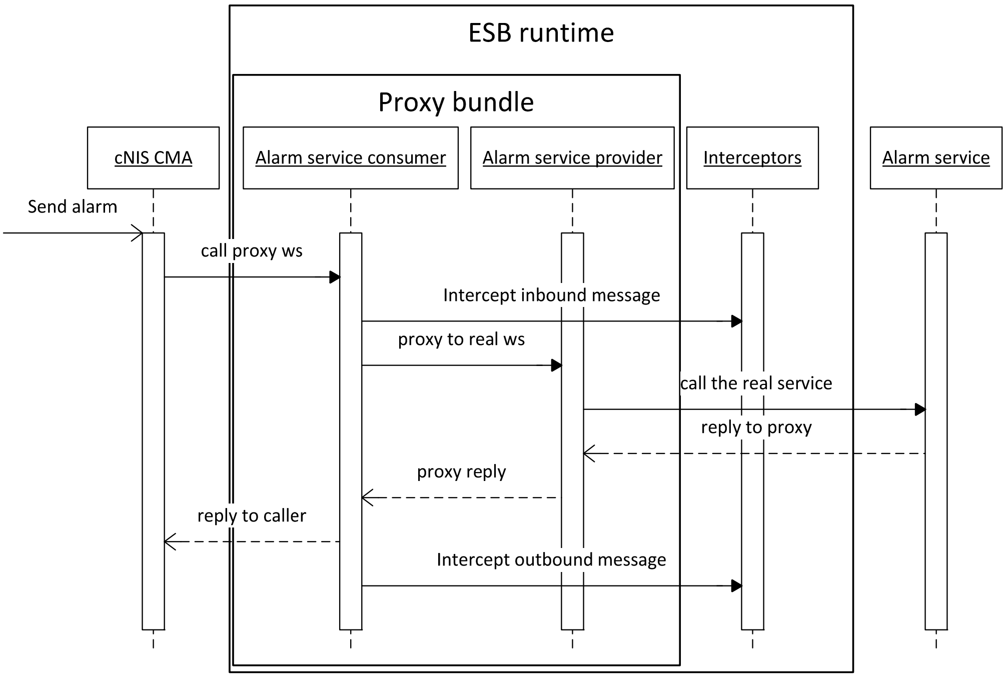


Figure B.4: Alarm service call sequence

If the cNIS CMA gets a Send Alarm request, it will call the AutoBAHN's Alarm web service. First the call goes to the consumer proxy, where inbound interceptors (in the ESB runtime) are called, for logging the incoming message. There are three interceptor (both have also outbound type):

- SAAJInterceptor – an interceptor for using the Soap with Attached API for Java.
- AccountingInInterceptor – an interceptor for GEMBus Accounting.
- LoggingInInterceptor – an Apache ServiceMix logger Interceptor.

The consumer passes the message to the provider and the provider calls the real web service. The response goes to the provider, which passes the response to the consumer. The consumer sends the reply back to cNIS.

The AutoBAHN web service works in the same way:

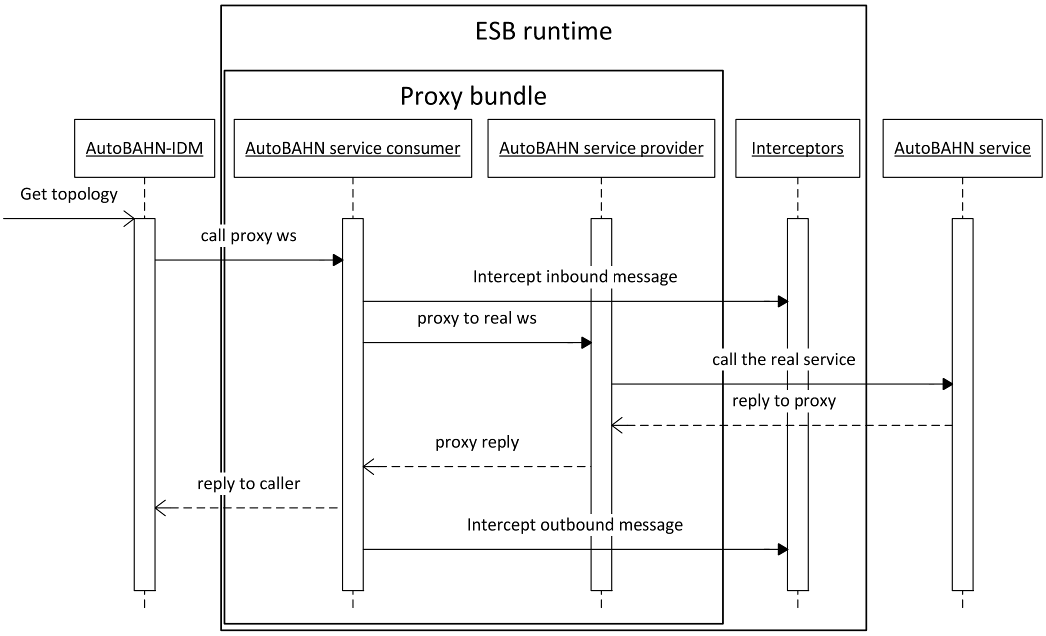


Figure B.5: AutoBAHN service call sequence

## B.5.3 Short Summary of the Work Done

For the proxies, a new OSGi bundle was created that acts as a proxy for these two web services and adds the GEMBus Accounting interceptor for them. The proxies are created from the two web service wsdl file. Both will be duplicated, one will be the consumer (the new proxy web service interface), and the other will be the provider (that will communicate with the original web service). In the consumer wsdl files, the soap addresses is changed to the new address and port. The address can be the same, but in that case the post must be changed.

The main part of the bundle is in the beans.xml file. There are two cxfbc:consumer-cxfbc:provider pairs for the two web services. These interconnect the consumer and provider wsdl files and adds the interceptors (e.g. the GEMBus Accounting Interceptors) for them. The following code line provides that the new customers (proxy web services) will be available through the specified new address (URLs):

```
<bean class="org.apache.servicemix.common.osgi.EndpointExporter"/>
```

When the proxy OSGi bundle is ready, it will be compiled and added to GEMBus repository.

The ESB runtime is the opensource apache-servicemix 4.4.1-fuse. It can be downloaded from the fusesource repository to the virtual machine. The downloaded archive should be extracted. It can be started with the following command to access the ServiceMix console:

```
apache-servicemix-4.4.1-fuse-08-15/bin/servicemix
```

In the servicemix console, the compiled accounting module is installed:

```
osgi:install file:/home/GEMBus/GEMBus/accounting/target/accounting-0.0.1-
SNAPSHOT.jar
```

The added GEMBus Accounting module logs all inbound and outbound web service calls and made available in the following URL:

```
http://<machine_ip_address_or_dns_name>:8283/AccountingService?wsdl
```

For installing bundles from OSGi Bundle Repository such as the GEMBus Repository, we should install it first also from ServiceMix console:

```
features:install obr
```

The URL of the repository where the bundles are available (it can be also a file path of repository.xml) is then added:

```
obr:addurl file:/home/GEMBus/GEMBus/repository/repository.xml
```

Now the proxy bundle can be installed:

```
obr:deploy GEMBus-proxy
```

After a successful deployment it can be started:

```
start <bundle_id>
```

Now the proxies are available in the setted addresses. The ServiceMix should be stopped, and started in server mode. In server mode it won't stop after ssh session is over or if ServiceMix console is closed. Running the ServiceMix in server mode:

```
apache-servicemix-4.4.1-fuse-08-15/bin/start server &
```

## B.6 Conclusions

This section summarises the work on standardised interfaces and confirms that the use of standardised interfaces takes only small additional effort and that it enables the integration of the TM Forum conformant OSS solutions. We have also seen two approaches for integration, both using standardised interfaces:

- The so called “spaghetti integration” where the implementation of the SOA is done in a point-to-point way. Here the monitoring, security, management could be very painful if the system grows from two integrated systems to ten or more (if we consider the full mesh and the point-to-point monitoring/debugging) The maintenance of a value chain implemented in a P2P way could be very resource intensive task.

- The ESB based integration paradigm was also benchmarked. In a simple situation where there is no need for message transformation or unification, the development process was found to be no longer compared to the point-to-point integration. In a real world case when there is a mismatch between two WS endpoints, more resources would be needed in order to elaborate the normalised messages and the WS transformation endpoints (although the same work must be done in the case of simple point-to-point integration too).

Using an API monitor solution as a framework for the SOA could be also on option. The API management approach simplifies the publishing, promotion and overseeing of application programming interfaces (APIs) in a secure and scalable environment. The growing interest in API management can be observed recently as it is seen as the missing link for SOA success. In addition, API management makes sense running in a cloud, as opposed to on-site in the operator's data center. On the contrary, ESB cannot be easily moved to the cloud. There are some examples of ESB deployed in the cloud (typically known as Cloud Service Bus, Cloud Hub or Enterprise Service Cloud) however the debate whether ESBs can be a legit part of clouds is still opened.

The API monitor solutions are also popular in the field of network management. For example, Alcatel-Lucent has introduced an open source and cloud-based API management platform called apiGrove.

Using the ESB or API management solution offers the following benefits:

- Connections between different applications can be automated and controlled.
- Version control for integration.
- Traffic monitoring, anomalies checked, etc.
- A performance boost with different caching solutions
- A wide range of AAA capabilities

Moving the communication to ESB runtime makes the whole system an enterprise grade system, with communication potentially supervised centrally. All incoming and outgoing web service calls are logged, with the log available through web services for third-party systems. The ESB also ensures remote management, so the proxy bundle can be stopped/started/restarted if is necessary. In the GEMBus Repository multiple proxy bundles can be stored with multiple web service addresses, so they can be changed immediately. If one AutoBAHN-IDM fails, the system can be restored by changing the proxy, making maintenances easier too. There are also several features of Apache ServiceMix that make the manageability easier for administrators and more transparent for leaders.

The TIP RAM implementation described in this document applies not only for BoD tools – it can be seen as standard even for alarm notification mechanisms to convey a signal from one system to another. The standardised approach can be also applied to the multi-domain interaction.

# Appendix C Standards of Ethernet Performance Monitoring

## C.1.1 Standards of Ethernet Performance Monitoring

Ethernet Operation, Administration and Maintenance (OAM) functionality includes those capabilities that allow a service provider to create, monitor and troubleshoot Ethernet links and services in a standardised fashion. It helps service providers offer end-to-end service assurance across the IP/MPLS core, the Ethernet Metro, and to the customer premises. Ethernet OAM standards can be divided into three groups, which correspond to three stages of network maintenance:

- Service Assurance.
- Service Monitoring.
- Service Troubleshooting.

The standards in each group are described below.

## C.1.2 Service Definitions Standards

Service Definitions Standards describe:

- A service type, e.g. point-to-point or point-to-multipoint.
- A service bandwidth profile, which includes such parameters as Committed Information Rate (CIR) and Excess Information Rate (EIR) for several classes of service.
- Service performance parameters such as availability, frame delay (one- and two-way), jitter, and loss.

Service Definitions standards are of great importance as their absence can easily lead to confusion: for example, CIR might be measured for User Datagram Protocol (UDP) payload rate or for Ethernet frame rate and the results will be very different for the same service.

There are three major standards in this area – MEF 10.2 [MEF 10.2] and MEF 10.2.1 [MEF 10.2.1] from the Metro Ethernet Forum (MEF) and G.8011 and Y.1563 [ITU-T G.8011] from the ITU-T. All these give precise formal definitions of Ethernet service types and parameters. These standards are aligned with each other and give similar and non-contradictory definitions of Ethernet services.

### C.1.2.1 *Service Assurance Standards*

Ethernet OAM standards of this type describe how to check whether a provisioned Ethernet service complies with its SLD parameters. Until recently there were no standards in this area that took into account Ethernet-specific services; the most popular standard among tester vendors, RFC 2544, is an IP-centric standard and its use for Ethernet services could lead to ambiguous results. Fortunately, in spring 2011, the ITU-T approved the Y.1564 recommendation “Ethernet service activation test methodology” [ITU-T Y.1564], which bridges this gap.

Figure C.1 illustrates a simple disruptive on-demand procedure described in Y.1564 which tests connectivity and throughput up to CIR and EIR and policing limits by injecting traffic into an Ethernet connection. Traffic rate and performance parameters are measured according to the definitions in Y.1563 “Ethernet frame transfer and availability performance” [ITU-T Y.1563].

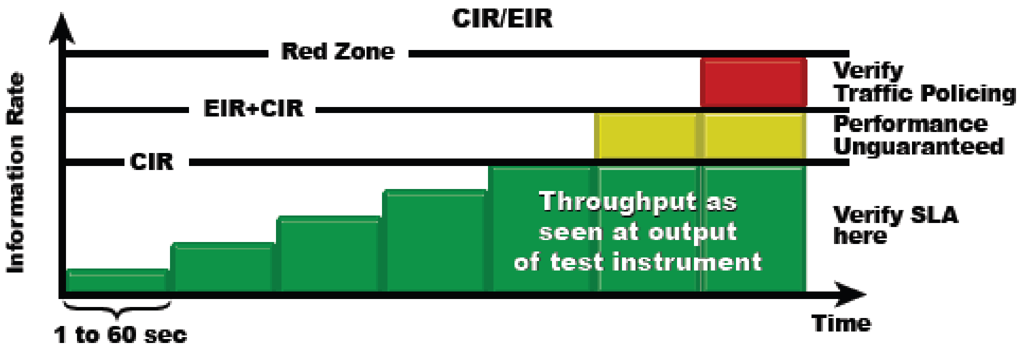


Figure C.1: Throughput test according to the ITU-T Y.1564 recommendation

This standard corresponds to measurements which iperf/BWCTL carries out in UDP mode, with the difference that iperf tests the one throughput specified by a user, while Y.1564 tests includes several steps up to the actual service bandwidth limits.

There is no Y.1564 mode which corresponds to iperf TCP mode as Ethernet is a connectionless transport.

### C.1.2.2 *Service Monitoring Standards*

Two major standards have been developed for this area:

- IEEE 802.1ag: “Connectivity Fault Management” (CFM) [IEEE 802.1ag].
- ITU-T Y.1731: “OAM functions and mechanisms for Ethernet based networks” [ITU-T Y.1731].

For the purpose of monitoring Ethernet services, IEEE 802.1ag defines a hierarchy of maintenance sessions which allows independent monitoring for different segments of the same service by different entities, such as a customer, a service provider or an operator (Figure C.2).

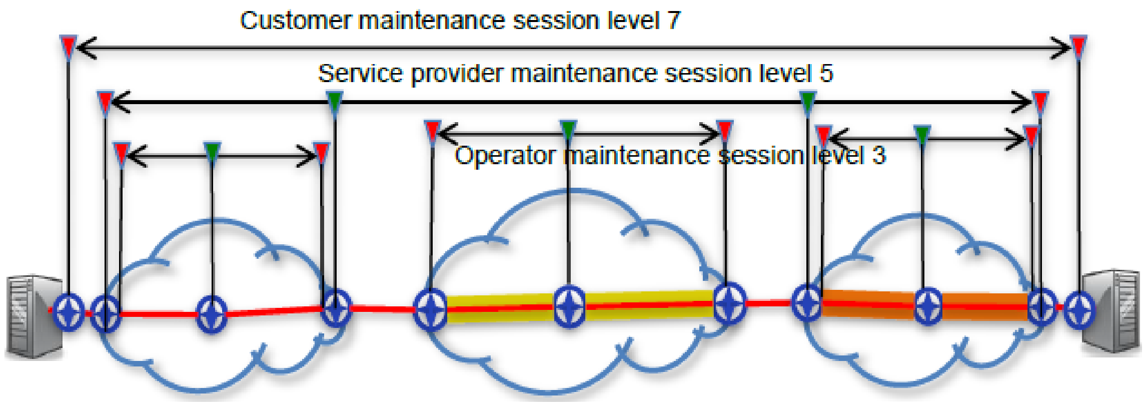

Customer maintenance session level 7
Service provider maintenance session level 5
Operator maintenance session level 3

Figure C.2: A hierarchy of maintenance sessions according to IEEE 802.1ag specification

Each maintenance session uses a separate sequence of “heartbeat” messages called Continuity Check Messages (CCMs) to monitor the health of a service.

The Y.1731 recommendation extends the IEEE 802.1ag specification and includes the description of the CFM CCM function (called ETH-CC in Y.1731), adding several performance monitoring functions:

- Loss Measurement (LM).
- Delay Measurement (DM).

These functions allow active measurements of delay, delay variation and loss between connection end or intermediate points to be carried out.

**Note:** As Y.1731 covers all IEEE 802.1ag functionality and adds some extra functions, the name Y.1731 will be used in this chapter to refer to the IEEE 802.1ag / Y.1731 combined functionality when appropriate.

### C.1.2.3 *Service Troubleshooting Standards*

Both the IEEE 802.1ag and Y.1731 standards describe two protocols (“functions” in Y.1731 terminology) that may be used for service troubleshooting:

- Linktrace Protocol – allows a path to be traced in an IP traceroute manner and can report on passing intermediate maintenance points along a service path.
- Loopback Protocol – allows connectivity to be checked with connection end and intermediate maintenance points in an IP ping manner.

# References

[DJ2-1-1] Deliverable D.J2.1.1: Information Schemas and Workflows for Multi-Domain Control and Management Functions, https://intranet.GÉANT.net/sites/Research/JRA2/Deliverables/DJ211/Documents/GN3-11-072_DJ2-1-1_Information_Schemas_and_Workflows_for_Multi-Domain_Control_and_Management_Functions.pdf

[DS3.3.1] First deliverable of SA3T3

[ESB-SWOT] M. Wolski, GEMBus (ESB) – SWOT Chart, https://GÉANT3-intranet.archive.GÉANT.net/sites/Services/SA2/T5/Documents/ESB_SWOT.docx

[eTOM AddF] Process Flow Examples, TMF GB921, Addendum F, Version 12.0, June 2012.

[eTOM AddJ] Joining the Business Process Framework through to Process Flows, TMF GB921 Addendum J, Version 11.2, October 2011

[eTOM AddK] Construction Guidelines for Process Flows, TMF GB921, Addendum K, Version 12.3, October 2012.

[eTOM-C&P] eTOM Concepts and Principles, Release 9.0, April 2011

[Fan2010] L. Fan, B. N. Jagdish, A. Senthil Kumar, S. Anbuselvan, S. Bok, “Collaborative Fixture Design and Analysis Using Service Oriented Architecture”, 2010

[FaultMgmtAPI] Fault Management API Overview, Version 1.0, OSS Through Java Initiative

[FTTS] Integrated Trouble Ticket System – installation instructions, https://geant3-intranet.archive.geant.net/sites/Research/JRA2/T1/Documents/Trouble%20Ticket%20System%20integration/Integrated_trouble_ticket_system_installation_instructions.pdf

[GEMBus] Deliverable DJ3.3.2 Composable Network Services Framework and General Architecture: GEMBus, https://GÉANT3-intranet.archive.GÉANT.net/sites/Research/JRA3/T3/Documents/Deliverables/GN3-11-002%20Composable%20Network%20Services%20Framework%20and%20Architecture%20(GEMBus)%20DJ3.3.2.pdf

[GN3 DJ2.1.1] DJ2.1.1 Information Schemas and Workflows for Multi-Domain Control and Management Functions

[GN921-R] NGOSS Real World Use Case, How to realise NGOSS principles? June 2009

[Gr1] Feamster N., Sundaresan S., de Donato W., Teixeira R. The Case for Measurements from Home Network Gateways, CAIDA AIMS-3: Workshop on Active Internet Measurements. 2011 http://www.caida.org/workshops/isma/1102/slides/aims1102_nfeamster.pdf

[IBM10] www.ibm.com/developerworks/webservices/library/ws-esbscen/

[IPSLA] http://www.cisco.com/en/US/technologies/tk648/tk362/tk920/technologies_white_paper0900aecd8017531d_ps6602_Products_White_Paper.html

[MIL] Federated Service Management for Defence (Catalyst) - Blueprint, TMF 866, TM Forum Approved, Version 1.2, (2012)

[M-Lab1] Measurement tools running on M-Lab, http://measurementlab.net/measurement-lab-tools

[M-Lab2] M-Lab, Procedure for approval of new experiments and allocation of slices, http://measurementlab.net/sites/default/files/SubmissionguidelinesforM-Labexperiments.pdf

[MTOSI-mridba] TM Forum MTOSI Manage Resource Inventory DDP Business Agreement, Version 1.2, September 2011

[MTOSI-rtmba] TM Forum MTOSI Resource Trouble Management Business Agreement, TMF518_RTM, Version 1.2, September 2011

[NGOSS TNA] The NGOSS Technology Neutral Architecture‖, Release 6.0, TMF053, Member evaluation, version 5.3, November 2005

[perfSONAR] http://GÉANT3.archive.GÉANT.net/service/perfSONAR /Resources/Pages/home.aspx

[perfSONAR-MDM] perfSONAR Services Listing: http://geant3.archive.geant.net/service/perfSONAR /About_perfSONAR/How%20perfSONAR_MDM_works/Pages/perfSONAR_MDM_service_components.aspx

[perfSONAR-Services] perfSONAR Service Descriptions: http://www.perfsonar.net/services.html

[RAM-cNIS] Resource Alarm Management Integration for cNIS and AutoBAHN, P.Wright, JRA2T1, https://GÉANT3-intranet.archive.GÉANT.net/sites/Research/JRA2/T1/Documents/Resource_Alarm_Management/RAM_Integration_for_cNIS_AutoBAHN.docx

[RIPE1] RIPE TTM - Request Test Traffic Measurement Services, http://www.ripe.net/data-tools/stats/ttm/sign-up

[RIPE2] RIPE Atlas - User-Defined Measurements, https://atlas.ripe.net/doc/udm

[RIPE3] RIPE Atlas - The Credit System, https://atlas.ripe.net/doc/credits

[RPM] http://www.juniper.net/us/en/local/pdf/app-notes/3500145-en.pdf

[SamK1] Test Node Briefing Note, Technical information relating to the SamKnows test nodes, April 2012, http://www.samknows.com/broadband/uploads/methodology/SQ302-001-EN-Test-Node-Briefing-D01.pdf

[SamK2] http://www.ietf.org/proceedings/85/slides/slides-85-iesg-opsandtech-7.pdf

[TAM] TM Forum: The Application Framework (TAM) GB929, Version 4.7. April, 2012.

[TIP-RAM] TM Forum Resource Alarm Management Business Agreement, TMF524, Version 1.8, September 2011

# Glossary

| | |
|---|---|
| **AS** | Autonomous System |
| **BoD** | Bandwidth on Demand |
| **BPMN** | Business Process Model and Notation |
| **ESB** | Enterprise Service Bus |
| **eTOM** | enhanced Telecom Operations Map |
| **ETSI** | European Telecommunications Standard Institute |
| **ITU-T** | International Telecommunications Union – Telecommunication Standardisation Sector |
| **MDVPN** | Multi-Domain Virtual Private Network |
| **MTNM** | Multi-Technology Network Management |
| **MTOSI** | Multi-Technology Operations System Interface |
| **NREN** | National Research and Education Network |
| **OSS** | Operation Support System |
| **RPM** | Resource Performance Management |
| **SOA** | Service Oriented Architecture |
| **SQM** | Service Quality Management |
| **TAM** | Telecom Applications Map |
| **TISPAN** | (ETSI) Telecommunications and Internet converged Services and Protocols for Advanced Networking |
| **TMF** | TeleManagement Forum |
| **UDM** | User-defined Measurements |