A Network Management Architecture proposal for the GÉANT-NREN environment

Pavle Vuletić*, Afrodite Sevasti**

*University of Belgrade - Computer Centre / AMRES, Kumanovska bb, 11000 Belgrade, Serbia, pavle.vuletic@rcub.bg.ac.rs

**Grnet, 56, Mesogion Av. 11527, Athens, Greece sevasti@grnet.gr

Abstract: GÉANT-NREN network environment is an advanced communications infrastructure connecting end-institutions and end-users in different countries through several network layer organized in different legal entities. Seamless end-to-end service delivery in such multi-domain environment with the multitude of different technologies in use, operational procedures, network management subsystems and procedures is a significant challenge. It requires the design and deployment of Operations Support Systems, software components that facilitate all aspects of service operation. Many existing network management standards propose OSS design guidelines. However, it is not always possible to apply standard recommendations tailored typically for commercial service providers in such specific environment. This paper proposes a network management model for GÉANT end-to-end services that aims to identify the main entities, processes, actors and relationships involved in the multi-domain service operations and provide an architectural framework for the specification of present and future GÉANT services. It also tends to preserve mappings to existing network management standards, so that existing concepts can be reused and benefited from as much as possible. We also present a proposal for the migration path for the existing GN3 tools towards the modern and efficient componentized operations support system.

Keywords: Network Management, Services, Multi-domain management, Transport stratum, Service stratum

1 Introduction

GÉANT and the National Research and Education Networks (NRENs) compose an advanced communications' infrastructure serving research and education community in Europe. The infrastructure is organised in a multi-layer fashion, connecting research and education end-institutions and end-users. The network connection between two end-users in two end-institutions in different countries is provided through several networks. At least there are campus networks of end institutions, NRENs and the GÉANT backbone. One of the main aims within the GÉANT-NREN environment is the delivery of advanced connectivity, network support and access services for projects, institutions and end users. Seamless end-to-end service delivery in such multi-domain environment with multitude of different technologies in use, operational procedures, network management subsystems and procedures presents a significant challenge. It generally requires the design and deployment of Operations Support Systems (OSS), software components that facilitate all aspects of service operation. The design principles of such systems are a subject of constantly increasing research and standardization attention within the network management community in recent years. This interest in the OSS systems within the network management community instead of the interest in the network element management which is typically perceived as a network management activity by the majority of network operations engineers marks the network management paradigm shift that happened between 1990s and 2000s.

Network management has evolved along with network technologies and services development. After the first network management model defined, made more than two decades ago, the OSI Network Management model [1], many different standardization bodies and associations started to work on the specification of network management and OSS design principles. The OSI model is usually referred as FCAPS, according to the five general functional management areas of the model: Fault, Configuration, Accounting, Performance and Security. Two management standards emerged from it in the 90s: Simple Network Management Protocol (SNMP) and Common management information protocol (CMIP). Since that time when the device management perspective, device configuration and device monitoring were characteristic network management activities, network management has moved on to encompass a much wider set of activities that place greater emphasis on service provisioning and management [2][3][4]. Old-style network management is now only a part (or layer) of the overall activity. Activities in standardization bodies like TeleManagement Forum (TMF) [5], ITU-T [6], ITIL [7], ETSI [8], IETF [9], Distributed Management Task Force (DMTF) [10] and others cover different network management topics, from high level business view process decompositions down to particular protocols which interact with network elements and are used in specialized network technologies.

Despite the existence of many standardized approaches, the use of standardized management models is not always possible. Standards are typically written from the perspective of a single-enterprise for-profit commercial provider as these organizations present the majority of the users of such models and documents. It was recognized that the GÉANT-NREN environment differs from the typical commercial provider in several properties like: the non-commercial nature, nonexistence of a single enterprise that is responsible for all services, federated multi-domain nature, advanced network services aimed for special user groups, etc. However, establishing different services over a multi-domain network infrastructure, like that of GÉANT and the interconnected NRENs requires the same or largely similar processes as in the commercial world. This is why it is possible to reuse certain standard recommendations for single domain service management in the GÉANT-NREN environment, but some aspects need adjustments and/or extensions. The fact that not a single network management standard suite can be applied 'as-is' onto the GÉANT environment led us to the proposal that aims to:

- Identify the main entities, processes, actors and relationships involved in the multi-domain service operations.
- Provide an architectural framework for the specification of present and future GN3 services.
- Provide a common model and common terminology for management functions that are the building blocks of multi-domain services for wider use in the GN3 community.
- Preserve mappings to existing network management standards, so that existing concepts can be reused and benefited from as much as possible.

As a new concept, the proposed GN3 NMA is expected to provide a solid basis upon which the supporting network infrastructure will offer efficient service orchestration and an improved user experience for the pan-European research and education community.

This document focuses on high level views of process and functional decompositions of the overall multi-domain network management activity. Information and data models that support the model are the subject of current studies and our future work. The paper is organized as follows. Chapter 2 gives an overview of the related work in the standardization bodies and research community. Chapters 3 and 4 describe proposed GÉANT network architecture model, and main network management components respectively. Chapter 5 gives a proposal of the improvement of existing GÉANT tools and their migration towards the elements of an OSS system.

2 Related work

Network management literature is constantly growing and comprises of two tracks of the documents that describe network management principles and best practices: standard documents and research papers.

2.1 Network management standards

Network management in the modern sense assumes the design of complex software operations support systems. In order to capture all the important properties, such complex and distributed systems have to be described from different viewpoints, depending on a particular set of concerns. Viewpoints can describe: business processes that are covered by the OSS, functional modules that exist within the model and that perform subsets of management functions, information that is exchanged between them, technologies and protocols being used etc. Complex network management architectures that aim to provide a comprehensive set of viewpoints can be found in ITU-T, TMF and ETSI. Other standardization bodies that we analyzed typically address certain particular problems of the network management or one specific kind of communication technologies and thus contribute to the overall architecture, e.g. IETF focused its recent work on the configuration management (Netconf [11] and Yang [12]), Open Mobile Alliance (OMA) devoted a part of its work to the policy-based network management [13], DMTF designed its own CIM information model etc.

The three above mentioned standardized network management models and architectures although describing the same type of systems typically do not have the same sets of viewpoints. However some of the viewpoints are widely accepted in more than one network management model and can be treated as de facto standards and state of the art. Such common viewpoint is the view that describes business processes in the typical telecom service provider - TMF's Business Process Framework [14] also known as eTOM. Both ITU-T in its M series of recommendations and ETSI in its Telecoms and Internet converged Service and Protocols for Advanced Network (TISPAN) group fully adopted eTOM as the view that best describes all the processes that can be found in the typical ISP, from Strategy and Planning, through Operations to Enterprise Management processes. Further, it is widely accepted that OSS systems architecture should be based on the principles of the Service Oriented Architecture [16] [17] and [15]. TMF has defined Distributed Interface Oriented Architecture (DIOA) for OSSs, it is in essence SOA architecture following the same architectural requirements.

On the other side in the domain of information and data modelling, there is no consensus among standardization bodies on the single information model that should be reused and customized in the network management systems. The DMTF and TMF have each independently developed technology-neutral information/data models of physical and logical devices. TMF developed Information Framework or the SID [18] information and data model that is being gradually adopted by the ITU-T as the M.3190 recommendation On the other side DMTF developed both the Common Information Model (CIM) Specification and CIM Schema, and has positioned them as industry-wide standards for accessing and sharing network management data. As the existence of two models has been identified as a potential problem for vendors of managed equipment, a joint DMTF / TMF project team has been established to investigate the alignment of the DMTF CIM and the TMF SID models.

Other viewpoints that can be found in the literature are unique for particular standardization bodies. TMF developed the Application Framework (TAM) [19], a unique frame of reference for understanding the relationship between different OSS/BSS components and a common view of component applications. ITU-T and ETSI have Management Functional View and Functional/Information View respectively representing main functional blocks of the network management architectures designed by these bodies. However specializations/decompositions of functional blocks in functional views reflect the high level processes identified in eTOM and do not provide significant additional guidelines for the implementation of a network management system.

Significantly less emphasis is placed from the standardization bodies on the problem of federated network and service management. One of the groups that are working on it is the IPSphere group within TMF. In the IPSphere specifications, orchestrating services from different service providers assumes fully functional OSS/BSS systems [20], which is not the case in the GN3 environment, where NRENs typically only support partial OSS/BSS functions. Novel and advanced multi-domain services being developed within the GÉANT-NREN environment require OSS support built from scratch, complemented by federated network management functions. This is a focal point of our work presented here

2.2 Research papers

The research community has recently devoted significant effort to the development of self-managing, self-configuring, and self-regulating (or shortly self-* networks) network and communications infrastructures—collectively referred to as autonomic communications [21]. The main goal of autonomic communications is to simplify the management of complex communications structures and reduce the need for manual intervention and management. Among the activities that lead to the goal of self-* network the one that is related to the field of network management is the research on enriched information and data models, context-aware network management [25], semantics and ontologies [23] [24] and policy based network management [22]. Such research already has an impact on the Information view, especially SID information and data model that adopted some of the autonomic communication principles.

3 GEANT-NREN environment network management architecture

Our proposal for a Network Management Architecture (NMA) suitable for the GEANT-NREN environment specifies the main entities in the specific multi-domain service environment. Following the ITU-T Recommendation Y.2011 [10] to separate the service and transport functionality and combining the advantages of similar approaches (e.g. ITU-T NGN Architecture – Recommendation Y-2012 or ETSI TISPAN NGN Architecture [14]), the proposal for the GEANT-NREN environment network architecture distinguishes two basic layers: Service Stratum and Transport Stratum. Unlike the existing standardized models, It also distinguishes two main independent entities working in collaboration on service provisioning: GÉANT backbone and NREN network (see Figure 3-1).

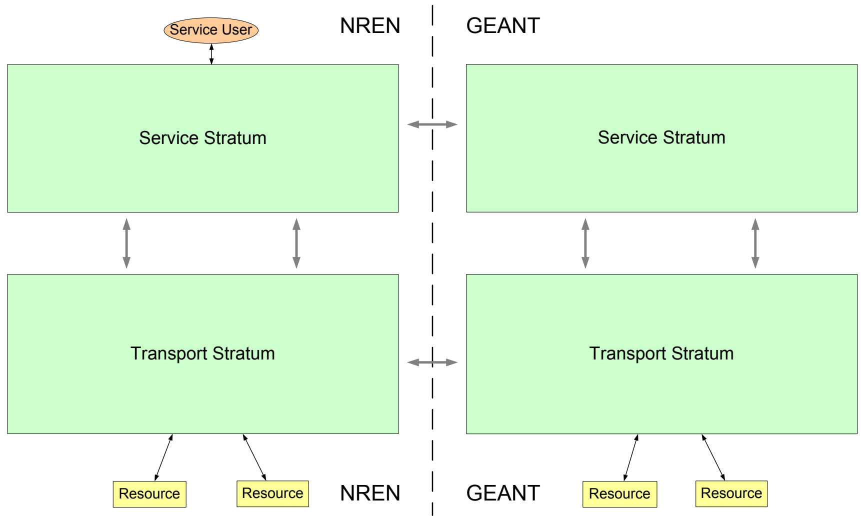

Figure 3-1 Overall view of proposed GEANT-NREN network architecture

The **Service Stratum** is responsible for the overall service coordination in the distributed networking environment, accommodating service-specific functions. The definition of the proposed NMA looks into the Service Stratum in order to provide recommendations for the existing services/tools (naming, addressing, messaging, concurrent access to underlying network resources, access to management functions at the Transport Stratum and more). The **Transport Stratum** is providing all the common network management functions required by services at the Service Stratum. The main focus of the work is on the Transport Stratum, as it has been identified that services and tools deployed over the GEANT-NREN environment up to now incorporate network management functions and operate upon a shared infrastructure with no consistency and this is an area where the NMA proposal can significantly improve interoperability and user experience. Also some services are unique in nature and thus require supporting tools that are being built on an ad-hoc basis, thus without being properly orchestrated in a consolidated management environment.

Although there are processes in both strata that look by their name similar or overlapping in functionality (Service trouble management vs. Resource trouble management, as it will be described later in the text), the separation on service and transport stratum processes is necessary for the efficient service operation. For example, resource trouble management processes captures, reports and analyzes any resource fault, while only a subset of the faults recorded affect one particular service. Service trouble management gathers information from resource trouble management and process it in the context of a particular service. Thus, different service instances can use the same resource trouble process. Similarly, any multi-domain service/tool at the Service Stratum can use the same Configuration Management principles and functions at the Transport Stratum.

The NMA proposal specifies also the Service Stratum (SS) to Transport Stratum (TS) interface within a single domain, as well as multi-domain specific TS-to-TS interfaces across neighbouring domains, wherever needed. Recommendations for SS-to-SS interfaces across neighbouring domains are also in scope of this work. Definition of these interfaces is a subject of further study.

Service Users can be NRENs, end-institutions connected to NRENs or end-users in end-institutions, depending on the type of service being provided. In order to accommodate all these scenarios into a single model, a concept similar to the ITU-T M.3060 recommendation that provides the additional option of implementing services by recurring multiple service strata with each stratum responsible for operating on a different level of service abstraction. This model presents the way for the construction of more complex and advanced services by assembling miscellaneous types of services. For example, it is possible to develop three service strata as it is shown below. Stratum C is a community collaboration service which utilizes video conferencing service (Stratum B) and this middle service is above Stratum A for networking services (e.g. establishing e2e paths between peers). The end user of the top stratum does not have to be aware which network resources are involved or how the video conferencing service is established between other users. It is also important to mention that a high level Stratum is not limited to using only one low level Stratum but it is also available to utilize simultaneously multiple strata at lower layers. Each service stratum can have a complete set of Service stratum functionalities.

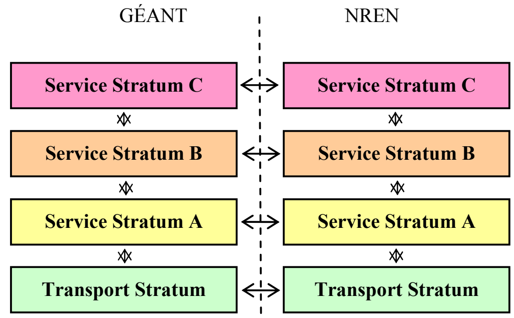

Figure 3-2 Recurring service stratum model

4 A closer look to the proposed NMA

As explained above, a significant set of business processes and related application modules described in existing network management standards are not applicable to the GÉANT-NREN environment. These include all the enterprise management processes, billing and revenue management and large parts of market and product management processes. Therefore the proposed NMA consists currently of two main viewpoints that describe the mapping of the minimal set of business processes and main application modules onto the GEANT-NREN environment. Furthermore, we propose the organization and orchestration of existing and future service supporting tools around the processes and described below and slight modification of the focus of some of the existing tools.

4.1 Processes

While network architectures such as in the GEANT-NREN case or the ITU-T NGN model represent system decomposition on some basic network entities or functions (e.g. in ITU-T NGN case: access, edge and core transport functions, resource and admission, service control, etc.), the business process framework represents a decomposition of the service provisioning and enterprise management activities onto more basic business processes. Apart from listing and reusing/extending existing standardized business processes [14] we have described the main interactions between them as a path towards the definition of necessary interfaces between software modules.

4.1.1 Service stratum decomposition

The proposed NMA Service Stratum is defined as a layer that is responsible for the overall service coordination in the distributed networking environment. It comprises four basic components:

- Service Configuration & Activation
- Service Quality Management
- Service Trouble Management
- Service Information Management

These processes support end users within the lifetime of the requested service. The layer handles end user requests, meeting their needs in particular by establishing and managing service instances across multiple domains according to user's privileges. Figure 4-1 shows all the main processes within the service and transport strata and their interactions.

Service Information Management is responsible for maintaining service specific data according to the Service Information model implemented in the Service Inventory database. The Service Inventory is an informational database of service data in the Service Stratum. It stores relevant information and maps service instances with particular users by providing a complete history of users' requests. Service Information Management creates request information entries in the Service Inventory with details like end user information, service type, service specific parameters, involved domains and resources, invocation time, and state of the service, etc. It also collects and aggregates relevant information about particular services from the Service Activation & Configuration, Service Trouble Management and Service Quality Management processes.

The main responsibility of Service Configuration & Activation is the configuration and activation of a multi-domain service instance within the local domain upon the arrival of an end user request or a request originating from another Service Stratum in the multi-domain environment. It should validate incoming request parameters and verify resource availability for service implementation in the local domain based on information from Resource Information Management process in the Transport Stratum. If resource allocation is required in the domain as a result of service activation, the Service Configuration & Activation block requests proper resources from the Resource Provisioning block of the Transport Stratum.

Service Configuration and Activation has to happen in coordination across the Service Strata of domains involved in provisioning of a specific service in order to track progress and jeopardy conditions, as a single request may invoke Service Configuration & Activation actions in other domains. After establishing the service instance, the Service Configuration and Activation block should be able to test and verify operations. Usually the home-domain Service Stratum collects these service instance activation results from all involved domains.

Updating the Service Information Management block in order to reflect that a specific service instance has been activated, modified or terminated is also part of the Service Configuration and Activation process functions.

The purpose of the Service Quality Management block is managing, tracking, monitoring and reporting on the performance of the specific services. This block receives performance information about utilized resources from the Resource Performance Management block in the Transport Stratum.

The Service Quality Management block initializes, modifies and cancels continuation of performance data collection scheduled in coordination with the Control Resource Performance block in the Transport Stratum. When performance quality thresholds are violated, the Service Trouble Management block is notified about a service failure and should determine the root causes of the service performance degradation. Additionally early warnings of potential issues in the future should be issued.

Service Quality Management blocks across domains may exchange information about a service instance's perceived performance. This allows the Service Quality Management block of the request origination domain's Service Stratum to compile overall service quality information from all involved domains.

The Service Trouble Management block is managing the faults associated with service instances. The objectives here are to respond immediately to reported service problems or failures in order to minimize their effect on the users' perceived quality, and to invoke the restoration of a service instance, or provide an alternative one.

Service Trouble Management is mainly focused on detecting, analyzing, managing and reporting on service alarm event notifications raised by the Service Performance Management block (of the local or a remote domain) or by the Resource Trouble Management block of the Transport Stratum. It performs problem localization analysis which is used for further resolving service issues. It manages necessary service restoration activities in coordination with the Service Configuration & Activation process. If a failure affects other domains, the required service restoration actions are coordinated with Service Trouble Management blocks of the same service in other domains. This block reports all service trouble events to the Service Information Management one which collects information and recovery actions taken for this service.

4.1.2 Transport Stratum decomposition

The proposed Transport Stratum is defined as the entity responsible for federated management of transport resources between the user end points. The basic components of the GN3 Transport Stratum are:

- Resource Management.
- Resource Data Collection and Distribution.
- Resource Performance Management.
- Resource Trouble Management
- Resource Provisioning

The basic function of the Resource Management is to assemble information about the network resources (Physical, Logical, and Compound), integrate and correlate that data to pass on the relevant information to Service Stratum, or to take action upon appropriate resources.

Resource Performance and Trouble management blocks are tightly tied in the overall network management architecture. Resource Performance Management generally refers to the functions of monitoring and measuring relevant metrics to assess resource performance. Collected metrics from specific resources can indicate that the resource is up and running with particular performance parameters, or that the resource is demonstrating errors or malfunction issues. Resource Performance Management can also compare performance metrics and statistics with defined thresholds, the violation of which can be interpreted as faults. Collecting relevant metrics from resources in performance management is usually achieved as polling specific metrics in regular time periods. This two-way communication between the management system and resources is implemented though query and response operations.

Resource Trouble management generally refers to the set of functions that detect, isolate, and correct malfunctions of resources. These functions can include maintaining and examining alerts, accepting and acting on threshold violation notifications from Resource Performance Management, tracing and identifying faults, carrying out sequences of diagnostic tests, correcting faults, and reporting on error conditions. The process of collecting alerts is usually implemented a one-way communication from a resource to the network management system, which is triggered by a fault condition on a specific resource. Many NRENs are using legacy management systems for resource trouble management but the integration of the functionality offered with the operations of multi-domain services in the GEANT-NREN environment is currently ad-hoc or lose if any at all.

Both Resource Performance and Trouble Management blocks' operations are based on the communication with resources. Therefore, this communication can be implemented as a separate block that will be used by both blocks and potentially other ones, for example Resource Provisioning and Resource Management. This block has to implement different protocols and data models that are supported by resources. This is particularly useful when the Resource Performance and Trouble management communication protocols used in real life are often the same. This separate block is identified by the TMF recommendations in the eTOM model as Resource Data Collection & Distribution. Figure 4-1 shows a proposed architecture of the Transport Stratum's relevant blocks and their communication with the Service Stratum ones.

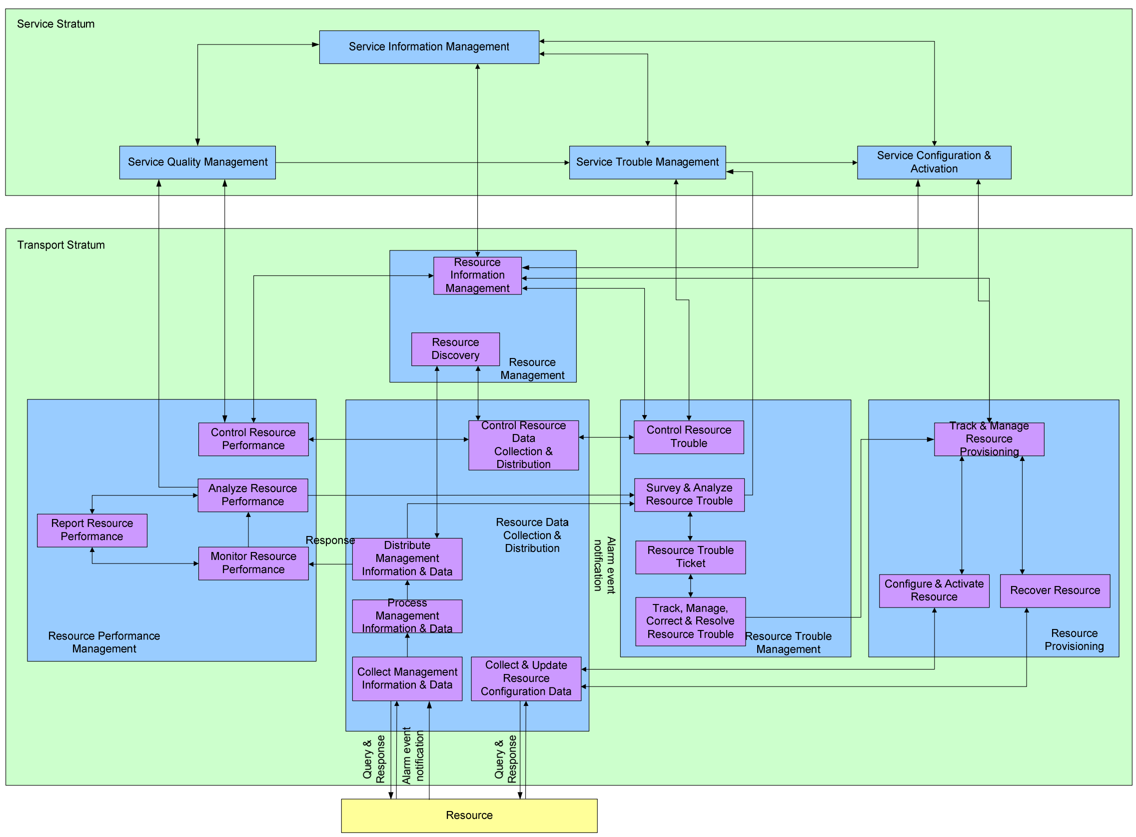

Figure 4-1 The proposed business process architecture of the Service and Transport Stratum and their interaction

4.2 Applications

Standardized framework that defines the main entities of an ideal OSS system is TMF's TAM [19] which describes main software components of the system. Applications that correspond to the ones in the transport and service strata of the GN3 Network Architecture model, roughly also correspond to the processes defined in the previous section. Service stratum applications include: service configuration and activation management, Service problem management, Service quality and SLA management and Service performance management, but also some applications that correspond to Service Information management like Service order validation, tracking and management. Other applications are in the domain of processes that do not exist in the GN3 framework, as described previously. Similarly transport stratum applications include data collection, configuration, fault monitoring, traffic analysis, problem and performance monitoring, and other. Therefore, GN3 service support systems can be organized according to the process boundaries defined and described in the Chapter 4.1. Previously defined processes can be seen also as main functional blocks or software components of the management system.

4.3 Software architecture

By defining main software components in the Chapter 4.2 we implicitly accepted main of the SOA architectural requirements defined in [15] that the software architecture has to be inherently distributed, componentised and that it uses interfaces to communicate. Other requirements defined in the same document, listed here for the reference are: the separation of business processes from component implementation (Business processes should be realized through a flow of execution between component instances), the architecture is security-enabled, the architecture is policy-enabled, the architecture should use common information and data models, the architecture uses a common repository of all OSS components, the architecture uses a common communication vehicle (information exchange infrastructure).

5 Applying the NMA principles to the GEANT-NREN environment

Analysis conducted by comparing existing tools currently used in the GÉANT-NREN environment with the TMF Business Process and Application Frameworks revealed some overlapping in functionality between existing tools. For example all: AutoBAHN [26], AMPS [27] and cNIS [28] have components that cover Service Order Management processes or Resource Data Collection and Distribution processes [29]. Such overlapping is a sign of the practice of designing software tools as independent silos that have the same functionalities in order to be fully functional stand-alone applications that support services.

However, the previous definition of the minimum set of business processes needed for the successful service support and the analysis of existing tools shows one possible path towards the componentization of existing tools, more accurate definition of the processes covered by them and more efficient OSS design. This path does not necessarily mean abandoning previous development of existing tools or significantly changing their functionality, but rather adding new functionalities and interfaces that will enable existing tools to be used as components in complex service support systems.

One such proposal is depicted in Figure 5-1. As an example, web-service interfaces might be added to Perfsonar so that it can be used by any existing and future service as a part of more complex monitored multi-domain services. Also, cNIS which now covers almost all Resource Data Collection and Distribution processes can be further strengthened to be used also for the collection and update of resource configuration data and as such used by other service components. iSHARE is at the moment built as a tool that mainly issues, tracks manages and closes work orders and has some sub-processes of service inventory management. It can be improved as a service that will be able to perform other Resource provisioning processes and allocate resources, prepare resource configurations and activate them, as well as to test or recover resources through Resource Data Collection and Distribution. For that purpose web service interfaces facing other service support components should be added along to the existing user interfaces.

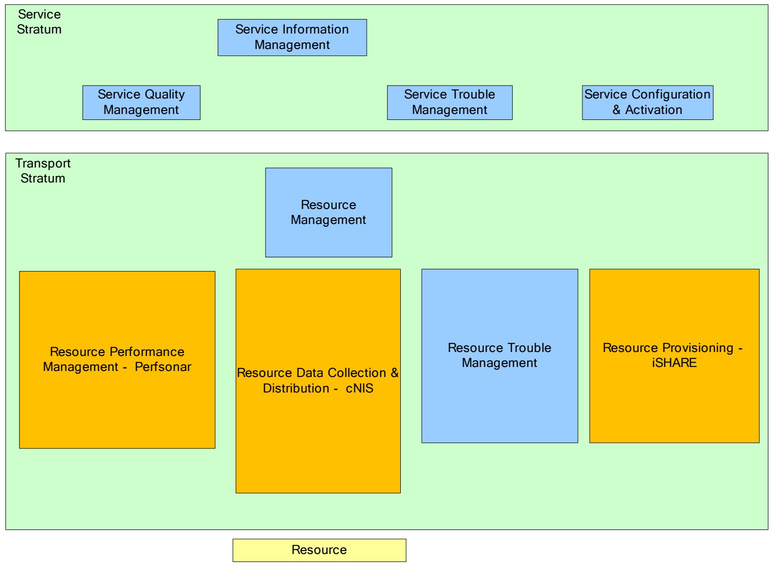

Figure 5-1 – A possible migration path for some of the GN3 service supporting tools

Other GÉANT service supporting tools like AutoBAHN or AMPS are perceived to belong to the Service Stratum and should use mentioned transport stratum services in the context of the service being supported by them.

6 Conclusion

Business process network management view gives an answer to the question about 'what' has to be done in order to have network services operational. On the other side application or functional views give an answer on the question about 'who' or which element will support some of the business processes defined in the business view. Described GÉANT network management architecture tries to give the answers to these questions through the use of a minimal set of existing standardized processes and corresponding application modules modified and customized in such way to propose a framework for the successful service operation in a specific multi-domain environment. It also shows a possible migration path for the existing GÉANT service supporting tools towards the modern designed operations support system.

What is left is to describe in more details is 'how' all these things have to be done and one part of the answer to this question is obtained through the analysis and recommendations of information models that support described entities and business processes. Orchestration of various software modules that reside in different domains and operate under the administration of different legal entities, require the implementation of strict and sound policy schemes. Policy rules determine how network devices deliver services to users or other software components and enable the lifecycle of network services and resources to be better and more efficiently managed. The analysis of policy models and the possibility of the introduction of the policy continuum concept into the GEANT network management model is a subject of current studies within the project along with the studies on enriched information models that eventually lead to the autonomic networking operations.

Acknowledgements: This work was supported by GN3 project, financed by the EC (Grant Agreement No. 238875). Also, all GN3 Joint Research Activity Task 1 members contributed in different phases of the work on this paper.

7 References

[1] ISO/IEC 7498-4: "Information processing systems – Open Systems Interconnection – Basic Reference Model – Part 4: Management framework", 15.11.1989

[2] L. Bernstein: "Network management isn't dying, it's just fading away", Journal of Network and Systems Management (2007) 15, pp. 419-424, DOI 10.1007/s10922-007-9080-y

[3] A. Gupta: "Network Management: Current Trends and Future Perspectives", Journal of Network and Systems Management (2006) 14, pp. 483-491, DOI 10.1007/s10922-006-9044-7

[4] Blum, Magedanz, Schreiner, Wahle, "From IMS Management to SOA based Management", Journal of Network and Systems Management (2009) 17, pp. 33-52

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

[6] http://www.itu.int/ITU-T/

[7] http://www.itil-officialsite.com

[8] http://www.etsi.org/tispan/

[9] http://www.ietf.org/

[10] http://www.dmtf.org/

[11] Enns, “NETCONF Configuration Protocol”, RFC 4741, http://datatracker.ietf.org/doc/rfc4741/

[12] Bjorklund, “YANG – A data modeling language for NETCONF“, draft-ietf-netmod-yang-12, http://datatracker.ietf.org/doc/draft-ietf-netmod-yang/

[13] “Policy Evaluation, Enforcement and Management Architecture”, Candidate Version 1.0, Open Mobile Aliance, 5.August 2008.,

[14] GB921 “Business Process Framework (eTOM) Concepts and Principles”, Release 8.0, Version 8.1

[15] “The NGOSS Technology Neutral Architecture”, Release 6.0, TMF053, Member evaluation, version 5.3, November 2005.

[16] ITU-T M.3060/Y.2401 Principles of the management of the Next Generation Networks, 03/2006

[17] ETSI TS 188 001 v1.2.1 “NGN management; Operations Support Systems Architecture”, 03/2006.

[18] “TMF, Shared Information/Data (SID) Model - Business View Concepts, Principles, and Domains. GB922, Ed. NGOSS R6.1, Document Version 6.1, November, 2005.

[19] GB929 “Telecom Application Map, The BSS/OSS Systems Landscape”, Release 3.1, TMForum Approve Version 3.5, June 2009

[20] “IPSphere Technical Framework (Release 1)”, IPSphere Forum, June 2007.

[21] Dobson, Denazis, Fernandez, Gaiti, Gelenbe, Massacci, Nixon, Saffre, Schmidt, Zambonelli, "A Survey of autonomic systems", ACM Transactions on Autonomous and Adaptive Systems, Vol. 1, No.2 December 2006, P 223-259.

[22] Verma, "Simplifying Network Administration using Policy based Management", IEEE Network Magazine, March 2002, vol 16, Number 2, pp 20-26

[23] De Vergara, Guererro, Villagra, Berrocal, "Ontology-based Network Management: Study Cases and Lessons Learned", Journal of Network and Systems Management (2009) Vol. 17, Number 3, pp. 235-254, DOI 10.1007/s10922-007 -009-9129-1

[24] De Vergara, Villagra, Asensio, Berrocal, "Ontologies: Giving Semantics to Network management Models", IEEE Network, May-June 2003, **Volume:** 17 Issue: 3, pp 15-21

[25] Strassner, van der Meer, O'Sullivan, Dobson, "The Use of Context-Aware Policies and Ontologies to Facilitate Business-Aware Network Management”, Journal of Network and Systems Management (2009) Vol. 17, Number 3, pp. 255-284, DOI 10.1007/s10922-009-9126-4

[26] Bandwidth on Demand with AutoBAHN, http://www.geant2.net/server/show/ConWebDoc.2544

[27] Advanced Multi-domain Provisioning System – AMPS, http://www.geant2.net/server/show/nav.00d008009002

[28] Common Network Information Service – cNIS, http://cnis.psnc.pl/

[29] GN3 JRA2T1 “Definition of a multi-domain Control and Management Architecture”, http://wiki.GÉANT .net/pub/JRA2/T1Sandbox/MJ2.1.1_Definition_of_a_multi-domain_control_and_management_architecture_v1.0-final.doc

8 Biographies

Pavle Vuletic is a Senior Networking Engineer in University of Belgrade, Computing Centre (AMRES). Education: BSEE, MSEE University of Belgrade in Computer Systems and Network Architecture and Organization, Career/Employment: Institute Mihajlo Pupin, Belgrade University Computing Centre: 1998- , Senior network engineer. Currently GN3 JRA2T1 task leader. Previous projects: task leader in SEEFIRE project, AMRES team member in SEEREN, SEEREN2 projects. Independent consultant in several EC funded projects in Serbia. Specialization and areas of interest: Network management, network performance and traffic characteristics, network design, implementation and security, AMRES NOC member.

Dr. Afrodite Sevasti holds the position of Services & Infrastructure Development Coordinator at the Greek Research and Technology Network (GRNET) S.A. She is also a GN3 project Activity Leader, coordinating the research activity on multi-domain services. She has participated in a number of R&D projects including FEDERICA project (EU-RI FP7). Afrodite received her PhD in the field of QoS enhancements on IP-based networks from the Computer Engineering and Informatics Department, Engineering School of Patras University (Greece). She also holds an MSc degree in Information Networking from Carnegie Mellon University. She has published 30 papers in refereed conferences and journals