The TRUMPET Service Management Architecture

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Abstract

This paper describes the service-level management architecture, developed to support the aims of the TRUMPET project: to investigate secure, high integrity interactions between administratively separate bodies concerned with the provisioning of broad-band telecommunications services. To allow these issues to be fully investigated a system was designed that included a number of bodies, or organisations, interacting over a mixture of technologies - specifically Java, CMIP and CORBA. These technologies were deployed so as to implement the technology-independent interface information models developed by the consortium, following the TMN recommendations. These models were developed using the ODP Viewpoint methodology enhanced with UML notation schemes. The service architecture provides ATM Virtual Path connections, within specified Quality of Service parameters, across two or more Public Network Operators offering service to a Values Added Service Provider; who in turn is offering the full end-to-end or 'One Stop Shopping' service to a number of customers.

1. Introduction

This paper presents the service level architecture designed for the TRUMPET consortium. This architecture is intended to be used to explore integrity and security of open network management and service provisioning in the liberalised market. To this end, the design described here takes into consideration a number of factors seen as being important in the future. Each of the players in the model - the customer, the 3rd party retailer and the network provider - has a fully active management element under its control with a full featured interface with the other appropriate players. Consideration is given to security, correct functionality and performance issues across each of these interfaces. Technologically, a mixture of systems has been used to enable us to explore many aspects of the emerging distributed processing environments being deployed. Principle amongst these aspects is the development of a fully distributed managed object model in Java™ compatible with the TMN philosophy.

2. Background

The progressive liberalisation of the telecommunications market has placed high demands for technical innovation on both service providers and vendors. On one hand new regulation forces incumbent operators to provide access to their systems to new operators. On the other hand new kinds of operators are emerging, those who may be selling part solutions such as trunk routing or may not be network operators at all, but may be involved in retail sales of network services. The open market drives the needs for providing interconnection of bearer services between operators; this in turn drives the need for open network management platforms.

The context of the TRUMPET project is interconnection of service level management systems between network operators, customers and third party service retailers. The architecture described below has two such interconnection points. The first one is between a customer premises network management system and a third party retailer (Value Added Service Provider). The second interconnection point is between the third party retailer and several network service providers. For these interconnection points, the project is concerned in particular with issues relating to the integrity of these interconnections. The issues of integrity concern the correct and proper operation of the management systems when they are interconnected. This correct and proper operation can be jeopardised either through systematic faults in the operation of the applications and communications systems implemented or through intentional external attack. For the former problem area, careful design and thorough testing is required prior to the assumption of a full working system. For the latter issue, security measures need to be in place. The appropriate security issues are only touched on below, the full details of the TRUMPET security architecture can be found in [i].

Another consequence of the liberalised market is that new operators are looking at alternative technologies for supporting their network and service management tasks. Two principle demands have emerged; price and versatility. For the first part, as reliance on network provisioning - particularly data networks - becomes more pervasive for all market sectors, entrants into the market, as both consumers and providers, may be smaller and less willing to invest in large scale high end platforms. For the second part, with more competitors in the market, product differentiation becomes critical to a companies survival. To maintain a differentiated product, it is necessary for a company to be able to implement new services quickly. Until recently the assumption was that the appropriate technology for open network management provisioning should be based on OSI facilities and CMIP. However alternative technologies are being explored by the industry. Examples of these alternatives are Java and CORBA - these are included in the architecture described below. Another aspect of a companies' ability to differentiate itself is in its support of the customer.

For this reason, TRUMPET has put a great emphasis on the customer interface within the service level architecture. In the architecture described here, the combination of easily available and versatile software being made available to the customer enables the customer to smoothly incorporate the externally purchased network facilities into both its private network and to its business processes as a whole at the service management level.

2.1 The TRUMPET trials

The above sets the scene for the work of the TRUMPET consortium. The concepts developed here will, however, be tested in real operational environments. Three trial contexts have been developed. The first, based at EPFL Lausanne, provides broadband connectivity between a number of medical sites, using the EXPERT testbed located in Basel. Provisioning and control of connectivity, such as developed by TRUMPET, for the medical community is seen as very important. When transmitting mission critical information upon which good diagnostics - and a person's life - depend, the network connectivity becomes an important link in the information chain. The second trial scenario concerns the provisioning, through the third-party retailer, of virtual semi-permanent connections between end-users across the network of an established provider - Scottish Telecommunications. The last trial takes place within the "Network Society" event in the Eurescom premises in Sophia Antipolis. Each trial requires that ATM virtual paths are established with specified quality of service parameters between the host sites, through which the user applications may establish Virtual Connections. These three scenarios give a spread of quality of service parameters and configuration requirements to test the system with.

These contexts form the base of the TRUMPET trials. Once the system is proven in these contexts, the overall implementation is expected to be extended to join sites in the UK, Switzerland, Sophia (France) and other trials developed by the MISA (DGXIIIB ACTS project AC080) collaboration. These extended trials will prove many aspects of inter-working such as accessibility by the customer to management functionality as well as bearer services and the secured and integral inter-working between various kinds of service providers.

This diverse and incrementally more complex scenario will allow us not only to demonstrate that high integrity and highly secure interconnection of management systems may be achieved, but will afford us an opportunity of actually measuring the performance and robustness of such systems. For this reason, some emphasis is being given to developing test software based on TTCN [ii] to automate these measurements.

3. The service architecture

The TRUMPET service architecture ranges over three principle players. There are service level components in the Customer Premises Network (CPN), in the Public Network Operator (PNO) and in a third party, the network retailer - the Value Added Service Provider (VASP), as illustrated in Fig. 2. The objective is to hide detail as appropriate (illustrated in Fig. 1).

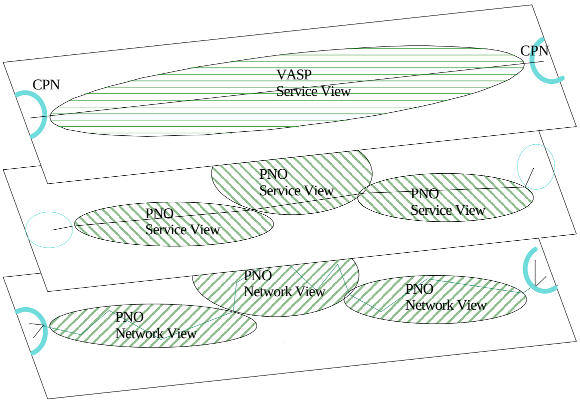

Fig. 1. TRUMPET service layers

Thus a customer of the VASP only needs to know about connectivity between his various CPNs; he is presented with the VASP Service view of the network. The VASP provides services from many independent Public Network Operators. As such, the PNOs present the VASP with their respective service views. These represent end to end connections between ports on their networks. Naturally, the PNOs have a detailed view of their underlying networks and it is the job of their network layer OSes to provide connectivity as offered by their service layers to the VASP.

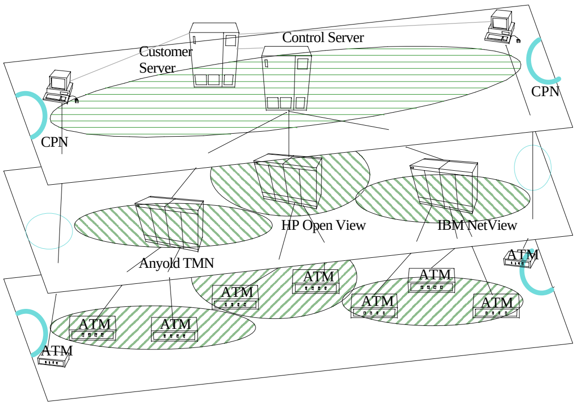

Fig. 2. TRUMPET service points

In TRUMPET the network layer support is taken as being provided by the host (trial) sites of the project and is not a development of the project. In practice an implementation of the ATM-Forum M4 [iii] interface for ATM network management has been deployed.

The CPN is thus the customer of - one or more - VASP, who in turn is a customer of the PNOs. In this model, the VASP is a role completely separate from that of the PNOs. Alternative models would have the VASP as a role played by one or other PNO [iv]. The architecture described here was chosen for a number of reasons. On one hand, the VASP as an independent third party is becoming an increasingly popular model as legislation in the US and Europe facilitates the open market. The role of the VASP is already appearing as ‘Bandwidth Arbitrage’ - although not automated. Thus the architecture presented here represents a possible technology to allow an automation of this market. A second motivation for this architecture can be found when compared with alternatives which require that the CPN supports the same technology as used by the PNO (in this case, a CMIP based TMN architecture, described in more detail below).

Although CMIP is the established network management protocol technology, evolving requirements for alternatives led by the smaller operators drives requirements that alternative communications technologies are explored. The interface between the CPN and the VASP has been developed using Java based communications technology. On the other hand, the interface between the VASP and PNOs is CMIP based. With this mixture of technologies, it was also proven necessary that a CORBA gateway between the Java and the CMIP worlds should be deployed. This gives us a variety of interfaces and requirements to explore for the various research aspects of the TRUMPET consortium; *viz.* security, integrity and service management.

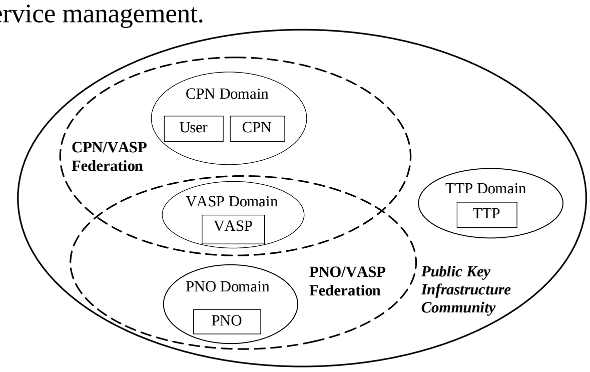

Fig. 3. Enterprise domains

Each of the players in the model is located within a policy domain as shown in the enterprise diagram in Fig. 3. These define domains in which certain administrative or interface policies hold. Principle amongst these for TRUMPET are the security policies. Each of the zone thus covers a particular policy for security levels of inter-domain service management interactions. Other contractual agreements may be agreed within these zones. In the figure it can be seen that the VASP participated in two interaction agreements; each of which may have different policies. Overall, the players participate in one domain which covers wide scope agreements. The overall domain includes all the players, and a common Trusted Third Party authority which they all use for certification and possibly non-repudiation.

3.1 Designing the TRUMPET architecture

The TRUMPET architecture [v] was designed using a combination of three methodologies or guidelines: the Telecommunications Management Network architecture (TMN) [vi] models, the Open Distributed Processing (ODP) concepts [vii] and techniques, and the Unified Modelling Language (UML) [viii] analysis and design notation schemes. The consideration of TMN is essential as much of the system is targeted at the world of large scale commercial public network management. TMN presents both a considered model of the components and functionality of the entities found within data and telecommunications networks and network management systems; and an engineering concepts of how management functions should be supported across distributed systems. The ODP framework provides a highly structured framework in which to design distributed systems. Above all, ODP requires that a system be decomposed into several divisions: the Enterprise, Information, Computation, Engineering and Technology viewpoints. One major problem with the analysis of a model built in this way is that there is often no clear mapping between elements occurring in each view point. The outcome of this is that it can be difficult to 'prove' the system for consistency and completeness. The UML language presents a coherent way of expressing a software engineering design using Object Oriented techniques. Models are included for class inheritance and inter-class relationship definitions, for describing the states of classes and for defining how classes interact. There are, thus, notation schemes in UML which fit well into the ODP viewpoints of information and computational modelling. The detailed mapping between UML diagram semantics and the ODP viewpoints is discussed in [ix]. This applies in particular to the Enterprise, Information and Computational models.

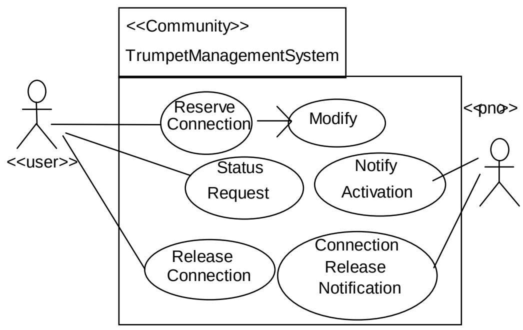

Fig. 4. The use-case diagram

For illustration, an example of the kind of diagram used for the enterprise model is shown in Fig. 4. Here the desired functionality of the system is described in the form of the UML use-case diagrams depicting the scenarios of the system's use.

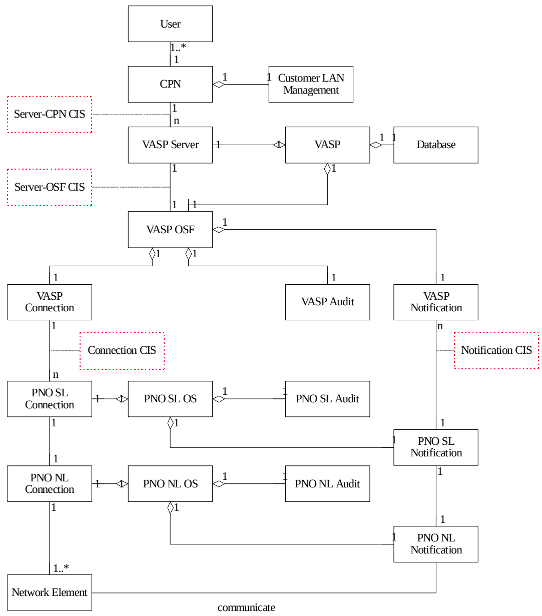

Fig. 5. High level information viewpoint

For the Information viewpoint, the UML static structure diagram shown in Fig. 5 shows the high level information objects in the TRUMPET architecture. Lower level diagrams further detail the low level design of the information model.

The Computational viewpoint is principally modelled using component diagrams, showing organisation of computational objects, and collaboration diagrams showing interactions between these objects. Collaboration diagrams were built for each role in the model (CPN, VASP, PNO).

3.2 The customer premises network interface

The conceptual model for the Customer Premises equipment developed in TRUMPET is one of a 'glue centre'. The idea is that the interface is provided through which the Customer may interface to the VASP and also which may be used to automate interactions between the VASP and other elements within the Customers premises - the examples being local network management; local data base management of accounts or usage or local bespoke applications which might require close control of broadband network management. The motivation for this is that in realistic situations a customer network manager may have to manage many hundreds of connections and it is more than likely that this would be done through a data base system rather than a custom Graphical User Interface (GUI). Thus this architecture leaves all the possibilities open. The UML static structure diagram for the computational objects necessary to support this is shown in Fig. 6.

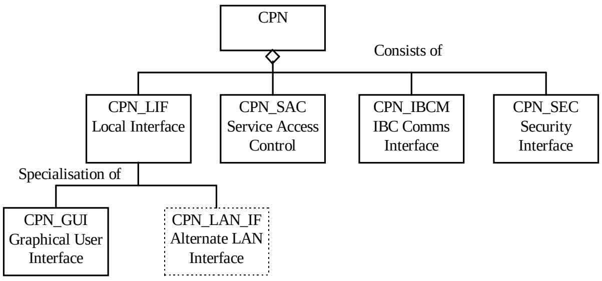

Fig. 6. The overall static structure of the CPN

Two popular technologies exist which may support this: CORBA and Java. Both are viable and have their own advantages. An interface based on CORBA is platform independent due to the fact that CORBA provides a platform independent transport mechanism - as does CMIP. Java achieves the same results by defining a platform within a platform; *i.e.* the Java Virtual Machine (JVM). The Java platform was selected for the CPN technology as it provides three critical facilities: LAN management interfaces (SNMP) (some aspects discussed in [x]), distributed data transport and versatile user interface capabilities using its built-in GUI libraries or the WWW - the latter being suitable for distributed interfacing.

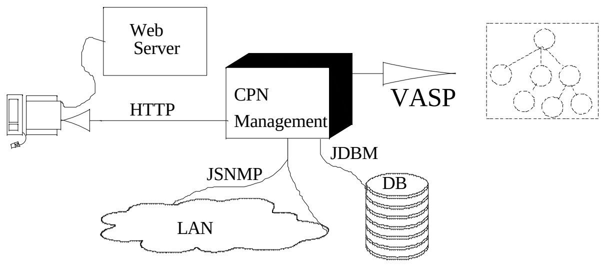

Fig. 7. The CPN technology model

Thus the CPN equipment (Fig. 7) consists of a JVM containing an interface with the VASP and local displays for user interfaces and for displaying events generated at the service level from the VASP and of relevance to the particular customer. The local displays can use the Java windowing libraries (*e.g.* JSNMP for SNMP management and JDBM for relational data base interfaces) or be driven through a Web Browser to achieve distributed access.

3.3 The Value Added Service Provider platform

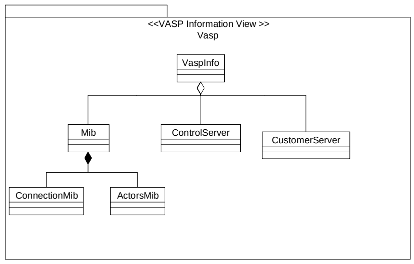

Fig. 8. The overall static structure of the VASP

The VASP supports two roles: that of the service provider to the Customer and that of a consumer to the Public Network Operators (PNOs). The requirements on the VASP equipment are that it supports connections from many customers through Java-based communications. This is achieved by dividing the VASP into three principle parts, as shown in Fig. 8. These three basic parts are: the Customer Server, for customer access to the Value Added Service Provider; the Control Server - for interfacing the Value Added Service Provider with the Public Network Operators, and a MIB-like system for supporting the required data models.

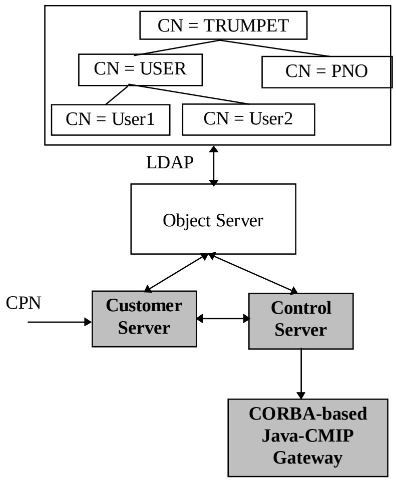

Fig. 9. The VASP elements

Internally it is required to support an information model that is both convenient to the customer and which works harmoniously with that of the PNO (which is taken to be TMN based). To meet these requirements a managed object system was constructed in Java. This provides a standard interface both to the PNOs and the CPN as well as giving a uniform information model across several players.

The interface to the VASP was designed to be closely related to the requirements set out by TMN, based on distributed managed objects and supporting a Managed Information Base (MIB). The manager (principally the CPN, but this can be also used internally to the VASP) can perform an association with managed objects in the VASP agent OSF using scoping and filtering based on X.400 (Lightweight Directory Access Protocol, LDAP [xi]) as illustrated in Fig. 9. Having built the association, operations (GET, SET, DELETE, INVOKE) may be performed on the objects selected. Thus this interface not only allows the CPN manager to both work from a GUI in order to query and manipulate individual network connections, but allows bulk operations to be performed on all the connections owned by that customer - possibly driven from a database application.

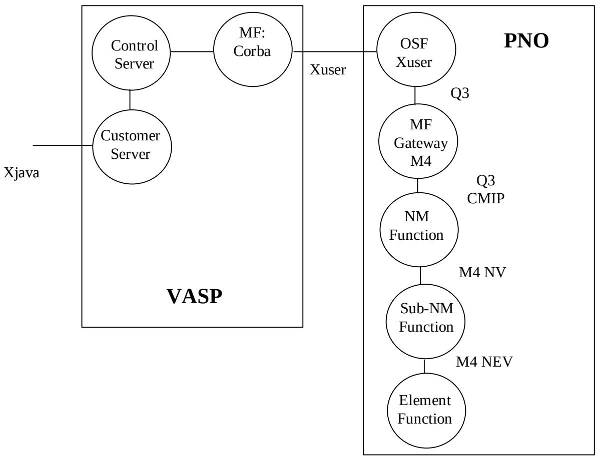

Fig. 10. The VASP / PNO OSes & interfaces

The fourth component of the VASP interfaces the Control Server to CMIP through a CORBA gateway - since CMIP can be considered to be a distinct platform. The TMN model of the service elements (down to the NE functionality) and each of the interfaces is illustrated in Fig. 10. The full manager-agent chain thus consists of the Customer Server - Control Server - CORBA Gateway - Xuser OSF - M4 Gateway - NM Function - Sub-NM Function - Element Function.

3.4 The CPN-VASP Java interface

Particularly important in the architecture is the distributed information model presented by the VASP. The design of this, has been done so as to facilitate the recommendations of TMN. This in turn places requirements both on the communication protocol and on the ability of the system to handle distributed managed objects, and in turn on the ability to make these Managed Objects persistent. There are predominantly two technologies that are used to help facilitate these aims: ObjectSpace’s Voyager ORB package and the use of an LDAP Directory Server.

The Customer Server Management Information Base contains Managed Objects that contain all the information about the resources that need to be managed. It has the facility for sophisticated selection of Managed Objects based on their properties and ensures that these Objects are persistent. Selection of Managed Objects is provided for by having the structure of the TMN-like MIB reflected by a Directory structure stored in an LDAP Directory Server. The LDAP entries hold the Distinguished Names of the managed objects they represent, as well possibly holding attributes for use in filtering and scoping operations, and a variable called a Voyager Object Name that allows for the selection and invoking of operations on the corresponding Managed Object instance.

The class Customer extends ManagedObject and instances of it contain all the necessary information on each Customer that connects to the VASP. Instances of VASPVPConnection are created to represent an end to end Connection between two Customer Premises Networks. Attributes contained represent connection information such as bandwidth, schedule and Quality of Service.

Communication between the elements of the Distributed Information model employed is achieved via the use of ObjectSpace’s Voyager ORB technology. Communication is achieved by calling methods on the CustomerService Object (the reference to which is obtained as the result of the associate() call which gives the reference to this remote object to the CPN) such as get( ) and set( ).

Communication between the members of the MIB themselves is achieved by employing a Distributed Database and a Federated Naming Service. Objects can get a reference to the Voyager enabled Directory (within Federated Naming Service) and thus get a reference to other Managed Objects and then call operations on them. All instances of ManagedObject and the classes that extend it are Serializable and are saved in this central Database, hence providing the stipulated persistence.

Thus by using the TMN interoperability concept, based on manager agent inter-operation and MIB concept, coupled with ORB and LDAP technology we are able to provide integration and flexibility between the customer (CPN) and VASP domains.

3.5 The Public Network Operator domain

The PNO Service Layer is interfaced from the VASP CORBA gateway through the Xuser interface initially defined by the MISA collaboration [iv] and derived from EURESCOM group P408. The implementation of the Xuser interface follows that of MISA very closely so as to allow inter-working of the two systems. The actual functionality of the Xuser is provided by an implementation of the ATM-Forum M4 interface providing network and element functionality at each PNO site.

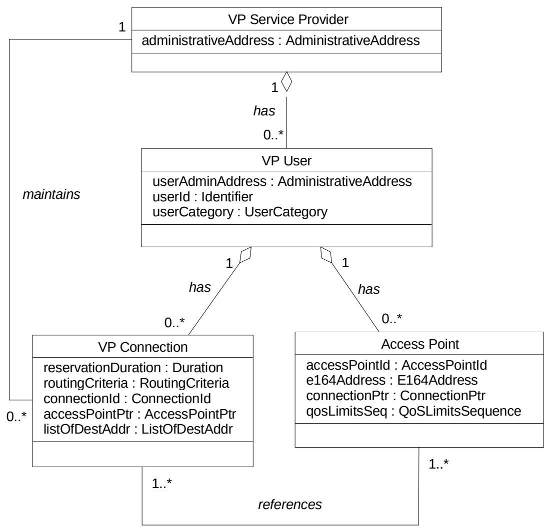

Fig. 11. PNO information model

The information model supported at each PNO site is shown in Fig. 11 for the Virtual Path (VP) connection management.

The VP Service Provider presents the entity within the PNO domain which is responsible for the provisioning of the VP connectivity service. The service may be provided to many customers represented by instances of class VP User. Within the TRUMPET management system the role of the VP User is taken by the VASP on behalf of its customers. A VP User may be associated with many access points representing network access points of the public network providing interfaces to adjacent network domains. Each VP user may have many VP connections which have been established by the VP Service Provider upon user's request.

4. Testing

As mentioned before, the TRUMPET project is concerned with two basic issues related to the interconnection points between open service management platforms : security and integrity. Security refers to secure, authenticated, etc. data exchange between two players in different domains, while integrity refers to the ability of interconnected management systems to retain their specified attributes in terms of performance and functionality. The focal point of the testing phase is the Xuser interface between the VASP and the PNO service management systems. The supporting CMIS-based communications mechanism was expanded with the addition of the security features [i]. Thus, the first aim of the testing phase is to demonstrate the correct operation of the support management communications mechanism both with and without security features, in terms of sequencing of operations, timing of operations, liveness and data integrity. This phase aims not only to prove that the integrity of inter-domain communications is preserved when expanding the functionality by adding security, but also to measure the time-related performance of the communications mechanism both with and without security deployed. This is to be done by developing the test-software based on the standardised test-language TTCN, which offers the possibility to verify correctness and measure time-related performance issues. For more detail on testing refer to [xii].

The possibility of expanding these basic test-cases so as to make them applicable over Java, as well as over the CORBA interface is being considered. This would result in a set of generic test-cases that would have the power to both verify the correct operation of a wide range of management communications mechanisms deployed in TRUMPET, and to measure performance of these mechanisms, both "stand-alone" and expanded with security features.

5. Conclusion

This paper focused on the presentation of the service-level management architecture developed by the TRUMPET consortium. The architecture spans not just over a number of autonomous players in the telecommunications market - Customer (and its local networks), Value Added Service Provider (third party retailer) and Public Network Operator, but also over a number of technologies: the established CMIP standard, the emerging CORBA, and Java technologies. This scenario allowed the investigation of the issues of open network management platforms, flexible customer access to service provisioning, and highly integral interoperability between autonomous systems. These issues are not only investigated during design and implementation stages (discussed in this paper), but also in three distinctive operational trial environments.

Basic issue in the open network management and provisioning in the emerging market is that of the integration of the legacy TMN-based protocols and models with the emerging distributed object techniques which are aiming at flexible service provisioning. The future is more likely to see the customers moving from the heavy-weight TMN solutions to the more accessible CORBA and Java approaches. On the other hand, the major players will not be willing to discard their existing TMN systems. The TRUMPET consortium thus designed and implemented an architecture which allows the flexible customer access to the PNO CMIS-based management services via the third-party retailer (VASP). The customer has access to the services provided by the VASP through the managed object model developed in Java, which is compatible with the TMN architecture. In turn, VASP accesses the CMIS-based PNO service management systems via the CORBA-based gateway. The network layer support is taken as provided by the trial sites (M4 interface providing ATM management access). Thus, the customer is presented by the end-to-end ATM connectivity over one or more network operators.

The design of the TRUMPET system thus considered the criteria for the convergence (an overview can be found in [xiii]) of TMN-based and distributed object models and methodologies, and this resulted in the "three dimensional" approach, which took into account: the TMN models, the Open Distributed Processing Viewpoint methodology, and UML notation schemes. Each of the ODP Viewpoints was modelled using different UML diagrams. This unifying notation scheme [ix] ensured high ODP viewpoint consistency and eased traceability between system components, resulting in the highly coherent design, which also had the power to embrace some TMN concepts.

Furthermore, the trial sites provided an opportunity to validate the architecture in real operational environments. The first trial offered a platform for initial top-down system integration, and the TRUMPET service management system successfully provided a broadband connectivity between a number of medical sites, using the EXPERT test-bed in Basel. The second trial is in progress, allowing the deployment of the high-end public network access system on the real operator - the Scottish Telecom. The operator is expected to produce the assessment of the TRUMPET system. Some experiments also offered an opportunity to integrate the open interface of the TRUMPET VASP with a non-TRUMPET PNO, that developed by the MISA consortium [iv].

The final issue investigated within the TRUMPET project is that of that ability of interconnected systems to retain their attributes in terms of performance and functionality: referred to as integrity. The project has developed a set of security policies that ensure that interconnected systems can avoid intentional external attack. A complementary integrity issue is to ensure that systematic faults in interworking between autonomous systems and the supporting management infrastructure and communications mechanisms are avoided. This is envisaged to be done by applying thorough tests over the various communications mechanisms deployed in the project. These test focus on both functionality (sequence, data integrity, liveness) and performance (time-related) issues. The tests are envisaged to be applied on the remaining two trial sites.

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