Issues in the Integration of IN and TMN

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Abstract. Over recent years, the need to introduce rapidly new telecommunications services has led to the development of the Intelligent Network (IN). These services and the increasingly complex supporting network infrastructure need to be managed. The Telecommunications Management Network (TMN) provides the framework for their management. Now, it is becoming clear that future sophisticated services, diverging from the simple telephony call model, will need to be deployed, operated and managed in an integrated fashion. Target, long term architectures such as TINA are being developed to support these services. This paper considers the issues behind the co-existence of IN and TMN, contrasts their philosophies and architectures and explains the nature of operation in the control and management planes. It considers the use of the TMN to manage or even replace the IN and discusses issues for their integration in a unifying target framework such as TINA. The role of the supporting technologies is also examined.

Keywords: Control, Management, Service, IN, TMN, TINA, OSI, ODP

1. Introduction

Over the last few years, the increasing complexity and sophistication of telecommunication network infrastructures has led to the Telecommunication Management Network (TMN) [M3010] as the framework for their management. At the very same time, the need for sophisticated services based on the telephony call-model, such as Universal Personal Telecommunications (UPT), free-phone, Virtual Private Networks (VPN), etc. has led to the Intelligent Network (IN) framework [Q1200] in order to achieve their rapid introduction and operation. In the future, more sophisticated services breaking away from the simple call model, e.g. multi-media, multi-party conferencing etc., will need to be rapidly and efficiently introduced, deployed, operated and managed. Long term service architectures such as the Telecommunications Information Networking Architecture (TINA) [TINA] try to provide frameworks to make this possible.

Such service architectures address only the long term integration of the service creation, execution and management infrastructure. In the mean time, the traditional IN evolution is continuing while TMN systems have started being deployed. They both constitute substantial investment which cannot be neglected. In fact, new integrated architectures should provide for a smooth migration. What has certainly become clear is that the IN, sometimes also referred to as Advanced IN (AIN), adopts a functional, centralised approach while distributed object-oriented approaches would be more suitable. The modernisation of IN and its extension to support future sophisticated services is an important issue and this has led to the exploration of target integrated architectures. On the other hand, TMN principles should be used to manage the IN and, as TMN has a distributed object-oriented nature, there is the possibility of using TMN principles to realise IN services.

This paper considers the issues behind IN and TMN co-existence and integration and the evolution to target service architectures in the long term. As IN operates in the control while TMN in the management plane, this distinction is sometimes confused and the terms *control* and *management* are used in the wrong context. Here, similarities and differences between operation in the control and management planes are examined in detail while the current IN and TMN architectures are contrasted. The use of the TMN to manage the IN infrastructure in the medium term is considered while the possibility of using TMN object-oriented distributed principles to replace the IN by operating also in the control plane are discussed. The latter points to an eventual integration in a unifying framework using common underlying mechanisms e.g.a supporting Distributed Processing Environment (DPE) and bridging the gap between the computing and telecommunications worlds. The role of supporting technologies in this integration i.e. OSI Management / Directory [X701] [X500] and ODP / Object Management Group (OMG) Common Object Request Broker Architecture (CORBA) [X900] [CORBA] are considered.

2. Scope of IN and TMN in the Operation and Management of Communications Networks

The ITU-T have distinguished between the management and control planes in the operation of communications networks [I.320] [I.321] and introduced the TMN [M.3010] as a means of provisioning management systems.

IN addresses the separation of service control logic from core-network routing logic and has two aspects: the off-line service creation process and the service operation aspects in which new logic is used to intercept in the call establishment process and interpret/redirect it accordingly. The latter procedure takes place in the control (signalling) plane. Service creation is concerned with the initial generation of the logic involved while deployment procedures are used to plant it in the IN infrastructure, the process referred to in IN as “service management”. An interpreted scripting architecture is used so that existing compiled logic does not need to be updated.

On the other hand, the TMN is a conceptual separate data network overlaid on the telecommunications infrastructure being managed. This monitors network/service resources through object-oriented abstractions and may perform intrusive actions to modify the way the network operates. The key difference to IN is that normal network operation (e.g. signalling procedures) are not affected at all as the whole operation takes place “outside” the managed network. The TMN should compliment and enhance the control plane functions by configuring operational parameters and, in general, it has less stringent requirements on real-time response

The two approaches have a lot of similarities and some important differences but are complementary in general and as such there is scope for their integration. Control affects the way the network operates and although the current IN architecture operates without the need to change the underlying signalling mechanisms, there are limits as to how far this approach may reach before such changes are necessary. On the other hand, the TMN operates outside the managed network and can be infinitely extended in functionality, as far as adequate provision for such functionality exists through abstractions of all the possible IN resources. The disadvantage of the management approach is potential lack high real-time reactions to conditions. However, this does not mean that the TMN approach is inferior in any way to the approach of IN, the management systems provided by the TMN are complimentary to the signalling plane and in general are not involved in real-time decision making processes to the same extent as the control plane features.

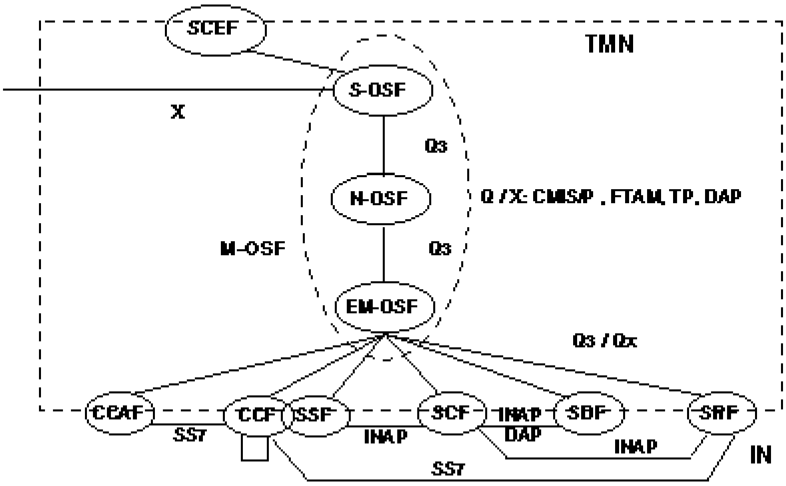

Fig. 1. Relationship between IN (control) and TMN (management)

The separation between control plane and management functionality is shown in Figure 1, which depicts the IN infrastructure operating in the control plane using signalling mechanisms and the TMN managing IN Functional Entities (FEs) operating as a logically different, overlaid management network. The Call Control Agent and Call Control Functions (CCAF / CCF) communicate over the standard signalling mechanisms while the Service Switching Function (SSF) intercepts in the call establishment process and communicates with other IN functions [Service Control Function (SCF), Specialised Resource Function (SRF)] using the IN Application Protocol (INAP) [INAP]. The TMN Operations System Functions (OSFs) manage the IN entities through q reference points (CMIS/P) [X710] in an object-oriented fashion. Note that currently the Service Creation Environment (SCE) does not yet communicate with IN FEs through the TMN. The various aspects of the IN and TMN architectures are presented in section 3.

3. Comparisons between the IN and TMN Architectures

Both the IN and TMN architectures follow logical hierarchical models and they both try to make physical (i.e. implementation specific) aspects independent of the logical/ functional aspects. A key concept in IN is its conceptual model which comprises four planes: the service plane, global functional plane, distributed functional plane and physical plane. The TMN comprises logical and physical architectures, while the management functionality is hierarchically decomposed into element, network, service and business management layers. The IN and TMN functional and logical layered architectures are shown in Figures 2 and 3 respectively.

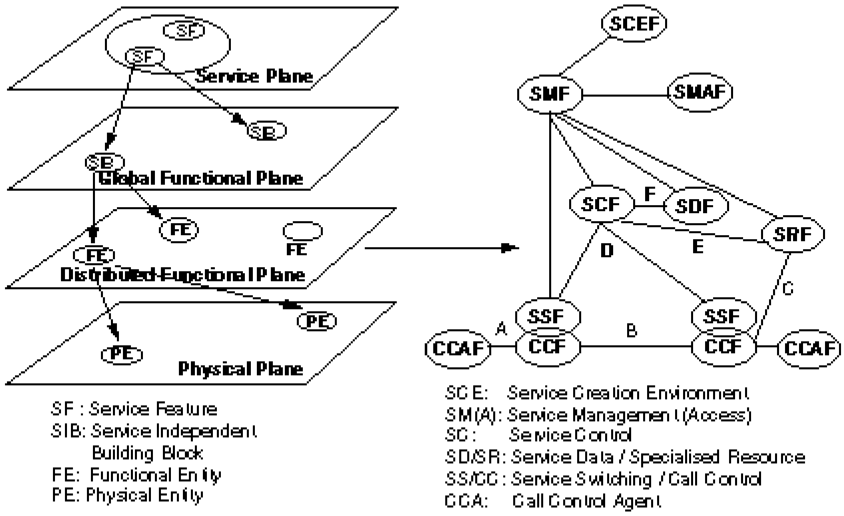

Fig. 2. The IN Layered and Functional Architecture

The TMN management services can be thought as analogous to IN services in the service plane as the latter represent an exclusively service oriented view. The global functional plane models the IN as a single entity and can also be considered to be analogous to the management services in the TMN as the management service definitions do not decompose the services into functional or physical components. The distributed functional plane and physical plane can be mapped onto the TMN logical and physical architectures.

An important distinction here is that the IN services are telecommunications services supplied to the end users or customers of the network operator. The management services provided by the TMN are primarily for the use of the operators and human managers of the telecommunications network. Despite that, it is possible to offer through the TMN services other than management e.g. international “leased” lines on demand (ATM-based VPN) etc. In principle though, the scope of the TMN and IN are different, however the comparison of their architectures is useful in the light of their long-term integration in a unifying framework

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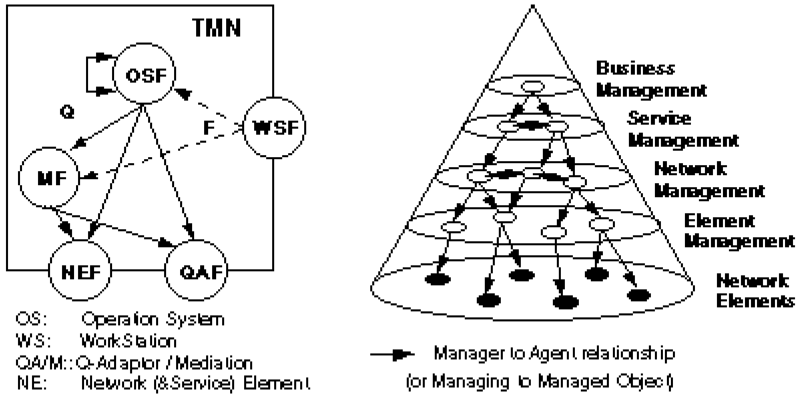

Fig. 3. The TMN Functional and Layered Architecture

Considering this difference in scope, one aspect of the service management layer of the TMN is service deployment and service provisioning. The deployment and provisioning of services must consider the issues related to co-existence of newly deployed services with those already existing and therefore involves the network layer functions of performance management to ensure that the degradation of network performance is minimised and that the QoS targets for new and existing services is not disrupted. The TMN approach, via the hierarchy of network and element management layers, ensures that performance management capabilities of the TMN are involved in the deployment of services via the configuration management facilities of the TMN.

One of the major strengths of the TMN approach to network operation and management is its hierarchical nature. First of all, the functions related to the day-to-day control of the network such as call set-up, switching and signalling are considered to be separate from those related to network management. This fundamental hierarchy distinguishes the real-time nature of the control plane from the management operations associated with the management plane and the TMN. Although a distinction exists between the two aspects of network control and network management, they are related. The TMN influences the way the control plane behaves by configuring operational parameters, such as routing table entries, according to management decisions. The TMN monitors the network, makes decisions based on network conditions and other information, such as management policy and knowledge of future events, and feeds back management actions to the control plane of the network to influence its future behaviour. This architecture allows the network to operate as intelligently as possible without burdening the network elements with sophisticated features.

The second aspect of the hierarchical nature of management is within the TMN itself. Management functionality is distributed over a number of components, both horizontally and vertically. In the horizontal direction different management components exist for different network elements or sub-networks; and for different management services operating on the same element, sub-network, network or service. However the important distribution is the vertical one. In this manner element level managers are themselves managed by sub-network level managers or network level managers, and so on. There are different object models at each layer of the hierarchy according to the level of concern and abstraction at that layer. Information flows move through the hierarchy in both directions via well defined object interactions. For monitoring, statistical analysis, billing, etc., elementary information retrieved from the Network Elements (NE) is transformed, in higher level objects, via higher abstraction and summarisation. In the reverse direction, management actions (e.g., a service deployment request at the service layer) can be decomposed according to the intelligence of the management components into lower level management actions until finally configuration changes are made in the NEs themselves. Cascading is achieved through an ordered sequence of management activity in the form of operations on managed objects at various management layers. In short, the TMN projects a hierarchical object-oriented model.

4. Use of the TMN to Manage or Replace the IN Infrastructure

4.1 Managing the IN by the TMN

The IN infrastructure needs to be managed in order to support the smooth operation of IN-based services. In addition, support to the service creation environment can be offered through the provision of deployment mechanisms that ensure the rapid and efficient deployment of IN services. Considering the **S**ervice Creation, **M**anagement and Execution **P**latform model (SMP) [Dic94], it is certainly beneficial if the interaction of the service creation and execution environments is through the management environment in order to maintain information related to IN services.

The main advantage of using the TMN for IN management has to do with a common management philosophy to other networks (e.g. ISDN, SDH). This will result in reusability of management functions and associated logic (management service components) and the unification of management processes.

In addition to the management services provided by the TMN for all network technologies the TMN can manage specifically the following aspects of IN:

- *service deployment:* the installation of service logic and data to the network and to the management systems associated with the management of that service
- *service provisioning:* the collection of service specific data and the installation of this data in subscriber and contact databases
- *service operation control:* software maintenance and information update
- *billing:* the collection and storage of usage records and tariffing
- *service monitoring:* the measurement, analysis and reporting of service usage and performance

To achieve management of the IN, its SSF, SRF, SDF and SCF functional entities have to be modelled as TMN NEFs, providing control of the associated resources through managed objects. The IN SMF functional entity will be modelled as a set of layered TMN OSFs, offering at the service level an interface to the Service Creation Environment Function (SCEF). Note that the various IN entities will still use the INA Service/Protocol across the IN reference points but they will also offer TMN q reference points. This architecture has been shown in Figure 1.

The important aspect of using the TMN to perform the above tasks is the existence of generic management functions that perform most of these tasks in their totality while they provide reusable generic capabilities to be specialised with respect to others. These generic management capabilities are offered through the OSI Systems Management Functions (SMFs[1]) and are used by TMN management service components and management functions [X701].

4.2 Replacing the IN in a TMN-based Framework

One of the features of the current IN is that it adopts a functional approach, identifying the capabilities required in the IN and allocating them to functional and physical entities. On the other hand the TMN is object oriented by nature while distribution is also an important aspect. Since the TMN will be used to manage the IN, the (co-)existence of its richer framework leads to the consideration of replacing IN functional entities by equivalent TMN object-oriented functional blocks, communicating with each other over the signalling plane e.g. using CMIS/P over a signalling protocol instead of INAP [Mag95]. This approach in fact integrates the mechanisms for control and management and is in line with the spirit of projected future service architectures such as TINA.

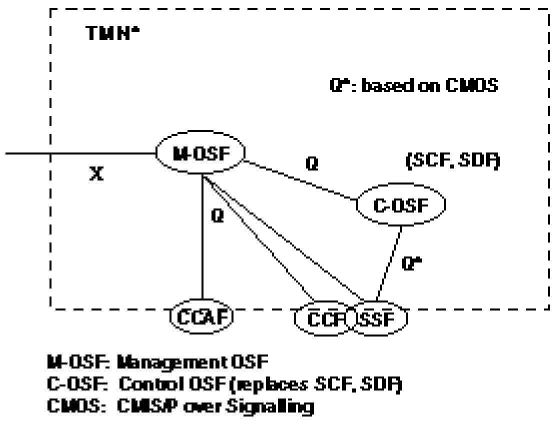

Fig. 4. Realising the IN through the Enhanced TMN (TMN*)

1. To avoid confusion with the IN SMFs, the acronym SMF will be prefixed by IN or OSI to refer to Service Management Functions and Systems Management Functions respectively.

In this approach, the SSF will have to be modelled as a lightweight TMN OSF or NEF. It will offer managed objects to be configured and managed while it will access other OSFs modelling the Service Control and Data Functions (SCF/SDF). This access may be peer OSF to OSF or as a subordinate NEF to OSF, as in Figure 4. In the latter case, an event to the control OSF will trigger the normal IN procedures with the call proceeding after a subsequent operation to the SSF, passing the necessary information.

In order to achieve this, efficient implementations of CMIS/P over lightweight transport mechanisms and efficient OSF Management Information Base (MIB) implementations are required. Research in investigating such mappings is under progress [Pav95b]. The overall architecture for such a TMN-based IN realisation is shown in Figure 4. Note that there are different OSFs for management and control. The former will have to configure the latter with the necessary customer profile information etc. over a standard Q interface while the communication between the latter and the SSF NEF will take place over Q^* using CMIS/P Over Signalling (CMOS). Note also that the TMN is now referred to as TMN^* as it is extended to perform both the standard management but also control functions using the same object-oriented (CMIS/P, GDMO) hierarchical architecture.

5. IN and TMN Integration in a Target Long Term Architecture

The traditional IN uses a centralised service control and service data model. This centralisation together with the relative simplicity of the SCF causes problems when considering services breaking away from the simple call model. An example of such a service is multi-media, multi-party conferencing which requires significant connection and session control and management.

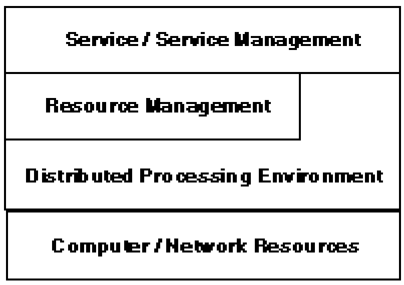

Fig. 5. The TINA Layered Architecture

One of the driving forces behind the TINA initiative was to modernise the IN and the traditional control plane functions. The TINA approach for the future IN resolves both the above issues, by adopting object oriented techniques, the ODP modelling approach and making use of a Distributed Processing Environment as a ubiquitous supporting infrastructure which encapsulates the transport network. The TINA approach has similarities with the approach presented in section 4.2 for replacing IN with a TMN-based framework but it does the opposite: it creates a new framework for the future IN and applies it also to the management of the services, network and supporting resource infrastructure. A simplified view of the TINA proposed layered architecture is shown in Figure 5

An important consideration in the long term integration of IN and TMN is that the advantages of the hierarchical TMN approach are retained. Components related to real-time, on line decisions should be made as lightweight as possible and located near to the network elements, and at the other extreme, management components involved in sophisticated decision making activities over a longer time scale should be allowed to work in an off-line mode without burdening the network elements or the time-critical control and management functions. This principle holds whether a pure TMN approach based on OSI systems management, the TINA approach based on CORBA and DPE, or a hybrid approach is taken.

By integrating the methods for the control and management of INs into a single framework, the interactions between the control and management planes are simplified. Common components can be used, in particular the data used by the management components (OSFs, etc.) can be integrated with the data used by the IN components (SDFs). This will aid the manipulation of, for example, customer data records, by the service management layers. No longer will specific adaptors (QAFs) or mediators (MFs) be needed, as the control plane functions will be integrated into the same DPE as the management components.

The base technologies for TMN have been the OSI management and directory [X701] [X500], supported by file transfer and transaction processing. On the other hand, technologies for the future IN will be ODP-based [X901]. For example, OMG CORBA [CORBA] forms the basis of the TINA Distributed Processing Environment. As there are analogies and complementary aspects between IN and TMN, the same is true for the supporting technologies. OSI management is object-oriented technology and the impact of the emerging ODP-RM is currently under study, the result being the Open Distributed Management Architecture (ODMA). On the other hand, the management aspects of the TINA DPE use the OSI management operational model with managed objects specified in GDMO/GRM from an information viewpoint while they become CORBA IDL computational objects.

An open-minded view to the current TMN architectures and supporting technologies shows many similarities to the ODP-influenced approaches for the future IN. The TMN functional, information and physical architectures map directly onto the ODP computational, information and engineering viewpoints. OSI management projects an object-oriented model which could be supported by ODP-based technologies such as CORBA in the future. The necessary additions are object clustering; bulk data retrieval capabilities based on sophisticated queries that enable to traverse object relationships; and fine-grained notification capabilities based on sophisticated assertions. The OSI system management power should be maintained in order to support the efficient management of sophisticated future telecommunications infrastructures. In essence, this means transposing the OSI management model over the ODP-RM to become (part of) the latter's management framework. There have been fully object-oriented realisations of OSI management providing distribution and other transparencies [Pav94] [Pav95a], showing the power and benefits of the OSI management *cluster* or *ensemble* model and its applicability in management environments where engineering issues such as the amount of management traffic, timely response to events and early suppression of unnecessary notifications are of paramount importance.

One possibility for retaining the current TMN investment in advanced future long-term service architectures is to accept the existing TMN infrastructure as the means to manage network aspects of broadband infrastructures and provide adaptation to the ODP mechanisms used for service execution and management in those architectures. Recent research suggests this is possible and there are ongoing activities between the NMF and X/Open to define generic mappings between OMG CORBA and OSI management [XoJIDM]. In addition, the TMN itself may eventually migrate to the use of ODP-based technologies by retaining its information aspects but using ODP-based distribution and transport mechanisms as described above.

6. Discussion

As presented in the previous sections, IN and TMN are two important aspects of modern telecommunications networks and services, covering different aspects of their operation and management: IN is more closely related to the control plane, while TMN is concerned with the management plane. Although they are complimentary, there are areas of overlap, particularly from the point of view that IN networks need to be managed in the same way as any other network technology. The other major area of overlap is in the IN Service Creation and Management Functions. The SCEF in general lies outside of the scope of the TMN, but it provides an important input to the management functions in the form of service specifications. However, the IN SMFs directly overlap with the TMN. Whereas a significant amount of work has been performed in the TMN and management area, the exact capabilities of the IN SMFs are largely unspecified or untested through prototypes and experimentation. Because of the maturity of the TMN work, and the fact that the TMN approach to management has been proved through numerous research initiatives, prototypes, and now commercial developments, *we propose that the TMN is the best possible choice for implementing the IN SMF features*.

As argued in the previous sections, harmonising the approaches of IN and TMN is beneficial from a number of viewpoints: interactions between the two are needed anyway as the IN needs to be managed, and management decisions are based on data retrieved from the IN; data needs to be shared between the management and control planes; the dividing line between the latter is not completely fixed; and there is no need to provide a completely different framework for IN SMFs when the TMN framework exists.

Apart from the standardised INAP protocol specifications, IN platforms are in general proprietary and network operators have their own solutions for developing IN functionality. There are obvious benefits in moving towards a common technology with well defined generic protocols and APIs. In the TMN world, GDMO and CMIS/P provide the object-oriented framework while sophisticated software platforms have been developed and a number of initiatives are aiming at standardising high-level APIs for TMN developments. Furthermore, the TINA initiative has adopted a CORBA-based approach for its DPE, with well-defined APIs and IDL to specify object interfaces.

The TINA approach seems promising for the long term integration of IN and TMN. Though the main driving force behind it was the modernisation of IN, it does address, to a certain degree, the incorporation of network and service management. However, we believe that TINA still has some way to go before it can fully address the management issues which are currently resolved in the TMN. Currently, TINA incorporates the majority of what is known in the TMN world as network management into its "resource management" architecture. We feel that this is an over-simplification, and more importantly, many of the features identified in TINA as "management" (such as session management and connection coordination) are mainly involved in the on-line creation, maintenance and termination of user connections and calls, issues more related to the control rather than the management plane. However, it is recognised that the TINA work will progress, to address more directly issues related to the management plane such as fault, performance and QoS, routing, bandwidth management, etc.

Furthermore, the TMN has many essential features which are invaluable in the design and operation of management systems:

- *hierarchical layering* which allows for object-oriented abstractions at different levels, supporting system encapsulation and making possible to express different viewpoints and concerns (element, network, service, business management)
- *control and management plane functionality distinction*, which is closely related to the performance aspects of the TMN hierarchy
- *use of OSI systems management* to structure and cluster management information in an object-oriented fashion and to provide generic management features through the OSI SMFs

These features of the TMN have been proved indispensable, particularly when designing and implementing large TMN systems with sophisticated functionality [Gri95]. Although it is possible that TINA will adopt these facilities in the future, *we propose that the most efficient way of integrating TMN and IN in the medium term is through the TMN infrastructure and procedures*.

The medium term solution proposes that IN based networks are managed in the same way as other networks (ISDN, B-ISDN, etc.), by considering the IN physical entities as network elements providing management access through Qx or Q3 interfaces. The second aspect of the medium term solution is that the IN SMFs are implemented in the TMN itself as OSFs at the service management layer, using the existing TMN methodologies for management service decomposition [M.3020], design and implementation; using OSI systems management concepts for object-oriented information modelling; using the OSI SMFs for providing generic management capabilities; and using existing TMN platforms for APIs and other generic functionality.

As the IN SMFs will be implemented in the TMN framework, they can fully interact with other OSs in the TMN which provide the other TMN management services e.g. performance and QoS management, routing, bandwidth, fault, configuration management, etc. The relationship, dependencies and interactions required between the IN SMFs and the other management services of the TMN is an important consideration. IN SMFs cannot exist in isolation, and by bringing them into the TMN itself, such necessary interactions are more easily accommodated.

Finally it is proposed that the TMN takes on part of the control plane burden itself by implementing the SCFs and the SDFs in Control OSFs within the TMN*. To do this, it is proposed that a more lightweight version of Qx or Q3 is used, with CMIP mapped onto existing signalling protocols such as SS7. This is to ensure that the interactions between the SSFs in the network elements and the SCFs in the C-OSFs in the TMN* is as fast and efficient as possible. The advantages of this are numerous: there can be a common object oriented framework for both management and control; mapping between object oriented views is much easier than mapping between procedural and object-oriented approaches; the integration of the more intelligent part of the control plane with the TMN allows management and control to interact more easily within a common framework; the distinction between management and control no longer needs to have a clear dividing line; the capabilities of the control plane are no longer bounded by the capacities of the IN PEs as in the TMN framework, the SCFs and SDFs may be distributed (as opposed to centralised in traditional IN) and intelligence may be added as required through interaction with other components in the TMN*.

Although the TMN is in general not considered to be a real-time system, the TMN* can meet the constraints of both the control and management plane functions. By using lightweight versions of Qx or Q3 interfaces over existing signalling protocols, and by ensuring that strict engineering view constraints are considered in the design of the TMN*, these restrictions can be overcome. Signalling systems in the control plane of existing networks have been designed with performance in mind, signalling messages and decisions must be made quickly, within an acceptable time for the service user to wait between dialing the called number and receiving ringing tone. These performance considerations must be applied rigorously to the control parts of the TMN*, without unduly burdening the remainder of the TMN* (the original management functions and the new IN SMFs) when they are not necessary.

7. Conclusions

In this paper, we presented the issues behind the nature of operation of IN (service control) and TMN (service and network management) and explained their complimentary but also overlapping aspects. Given the fact that IN service management is largely as yet unspecified, we propose the use of the TMN for implementing the IN SMF features by modeling IN entities as TMN NEFs (Figure 1). Given also the distributed object-oriented nature of the TMN, the current understanding of relevant methodologies and modelling principles and the existing investment, we propose the integration of TMN and IN in the medium term through the TMN infrastructure and procedures (Figure 4). Finally, we envisage a target long-term architecture for their integration based on ODP principles, assuming the presented strengths of the current TMN approach are retained. An evolution of the relevant ODP-influenced base technologies such as OMG CORBA is necessary to support a powerful hybrid control and management DPE.

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References

[Q1200] ITU-T Q.1200 series, Intelligent Networks

[M3010] ITU-T M.3010, Principles for a Telecommunications Management Network

[M3020] ITU-T M.3020, TMN Interface Specification Methodology

[I320] ITU-T I.320, ISDN Protocol Reference Model

[I321] ITU-T I.321, B-ISDN Protocol Reference Model and its Application

[INAP] ETSI, Intelligent Network Application Protocol, Version 8, 1993

[X701] ITU-T X.701, Information Technology - Open Systems Interconnection - Systems Management Overview

[X710] ITU-T X.710 / X.711, Information Technology - Open Systems Interconnection - Common Management Information Service/Protocol, Version 2

[X500] ITU-T X.500, Information Processing - Open Systems Interconnection - The Directory: Overview of Concepts, Models and Service, 1988

[X901] ITU-T X.900, Information Processing - Open Distributed Processing - Basic Reference Model of ODP - Part 1: Overview and guide to use

[CORBA] Object Management Group, The Common Object Request Broker Architecture and Specification (CORBA), 1991

[TINA] Mulder, H., J. Pavon, Telecommunications Information Networking Architecture, Tutorial presented at the 4th IFIP/IEEE International Symposium on Integrated Network Management, May 1995, Santa Barbara

[XoJIDM] XOpen / NM Forum Joint Inter Domain Management, Comparison and Interworking of OSI Management, OMG and Internet Management

[Mag95] Magedanz, T., Modelling IN-based Service Control Capabilities as part of TMN-based Service Management, in Integrated Network Management IV, pp. 386-397, Chapman & Hall, 1995

[Pav94] Pavlou, G., T. Tin, A. Carr, High-level APIs in the OSIMIS TMN Platform: Harnessing and Hiding, in Towards a Pan-European Telecommunication Service Infrastructure - IS&N '94, pp. 219-230, Springer-Verlag, 1994

[Pav95a] Pavlou, G., K. McCarthy, S. Bhatti, G. Knight, The OSIMIS Platform: Making OSI Management Simple, in Integrated Network Management IV, pp. 480-493, Chapman & Hall, 1995

[Pav95b] Pavlou, G., LCMIP: A Lightweight Protocol Architecture for Data and Telecommunication Network Management and Control, Research Note, Department of Computer Science, UCL, 1995

[Gri95] Griffin, D., P. Georgatsos, A TMN System for VPC and Routing Management in ATM Networks, in Integrated Network Management IV, pp. 356-369, Chapman & Hall, 1995.

[Dic94] Dickerson, K., J. Chester, Standards for Integrated Services and Networks, in Towards a Pan-European Telecommunication Service Infrastructure - IS&N '94, pp. 5-16, Springer-Verlag, 1994