TMN Standards: Satisfying Today's Needs While Preparing for Tomorrow

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ABSTRACT In response to telecom and computer industry forces, TMN standardization activities within the International Telecommunication Union have been consolidated and have been extended through complementary efforts in other fora and consortia. Efforts to widen the TMN technology choices, particularly in support of distributed management, have also been initiated with the support of these groups.

A concept first introduced in the mid-1980s, the telecommunication management network (TMN) has become the globally accepted framework for the management of public telecom networks. For the most part, this framework is described in International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) and other standards. However, while TMN is satisfying today's needs with existing technology, it is also preparing for tomorrow. This article is focused on describing, from a standards perspective, three characteristics — technical, organizational, and market — of today's and tomorrow's TMN.

TMN technical characteristics are primarily categorized by the standards bodies in terms of architecture, functional requirements, information models, protocols, conformance, profiles, and methodology. Although the technical foundation of today's TMN is still largely built on open systems interconnection (OSI) management, the need to move toward distributed management means emerging distributed processing technologies must be accommodated. The impact of this dual track standards approach, wherein today's needs are met with existing technologies while the needs of tomorrow are prepared for by recognizing emerging technologies, is a major theme in describing key TMN technical characteristics in this article.

From its origins in the ITU-T standards environment, TMN has been adopted as the basis for regional and national standards and has now spawned several fora and consortia focusing on TMN implementation agreements, and also in some cases, creating base standards in competition or partnership with the ITU-T. Concurrently, the ITU-T, in response to this and other standards challenges, has made procedural and structural changes, including the consolidation of most TMN activities in a single Study Group, SG 4. It has also begun a process of reaching out toward these bodies, realizing that the fragmentation of the TMN marketplace will only hurt the industry as a whole. Discussion of selected fora in relation to TMN standards, and of the ITU-T response, represents another theme of this article.

Lastly, marketplace interest in TMN, which is evident in support for specific TMN activities in the ITU-T and TMN-related fora, in industry conferences, and most importantly in deployment of TMN-based systems and standards, will briefly be discussed.

It should be noted that while this article does highlight selected TMN characteristics, it is not meant to be a tutorial on TMN or its supporting technologies. A description of OSI management is found in the previous article in this issue [1]. Readers are also encouraged to read ITU-T Recommendation M.3010 [2] and other references identified below.

TECHNICAL CHARACTERISTICS OF THE TMN

Following a standards classification scheme developed in an earlier paper [3], TMN characteristics may be split into at least seven categories:
- Architectural
- Functional requirements
- Information modeling
- Protocols
- Conformance
- Profiles
- Methodology

Perspectives regarding these technical characteristics are presented below.

TMN ARCHITECTURAL CHARACTERISTICS

The TMN architecture as defined in M.3010 [2] is concerned with defining TMN entities and the communications between them from three perspectives: functional, information, and physical. Though the TMN implementable specifications are most closely tied to the physical architecture, the architectural foundation is functional in nature.

The TMN functional architecture may be described at two levels: simple and extended. At its simplest (Fig. 1), the functional architecture describes two types of TMN communicating entities in the form of TMN function blocks, one of which focuses on the managed system:
- *NEF*: network element function block

and the other which focuses on the managing system:
- *MF*: mediation function block
- *OSF*: operation system function block
- *WSF*: workstation function block

By implication, all communications between the above function blocks is assumed to be standardized. To allow legacy functionality to participate in standardized TMN communications, the Q adaptor function block (QAF) has also been defined to serve as a legacy intermediary.

Another functional intermediary, the WSF, provides the means for human access to influence TMN activities. Recent M.3010 changes have clarified the distinctly independent role of the WSF within the functional architecture.

The communications between function blocks are defined in terms of the relationships between the function blocks, called *TMN reference points*, each of which is a "conceptual point of information exchange between non-overlapping management function blocks" [2]. In each case, a defined reference point has several instances but a common managing

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perspective (each instance involves the same function block):
- MF in the case of the qx reference point which is defined to be the boundary between an MF and NEF, QAF, or MF
- OSF in the case of the q3 reference point which is defined to be the boundary between an OSF and NEF, QAF, MF, or OSF
- OSF in the case of the x reference point which is defined to be the boundary between OSFs in different TMNs

To support human access, the WSF communicates with the OSF or MF via the f reference point.

The relationships between TMN function blocks are also defined by the type of information passing across each reference point, although this aspect is much less definitive. For example, the information passing across the q3 reference point is assumed to be of a more processed nature than information passing across a qx, but the architecture is not specific as to how.

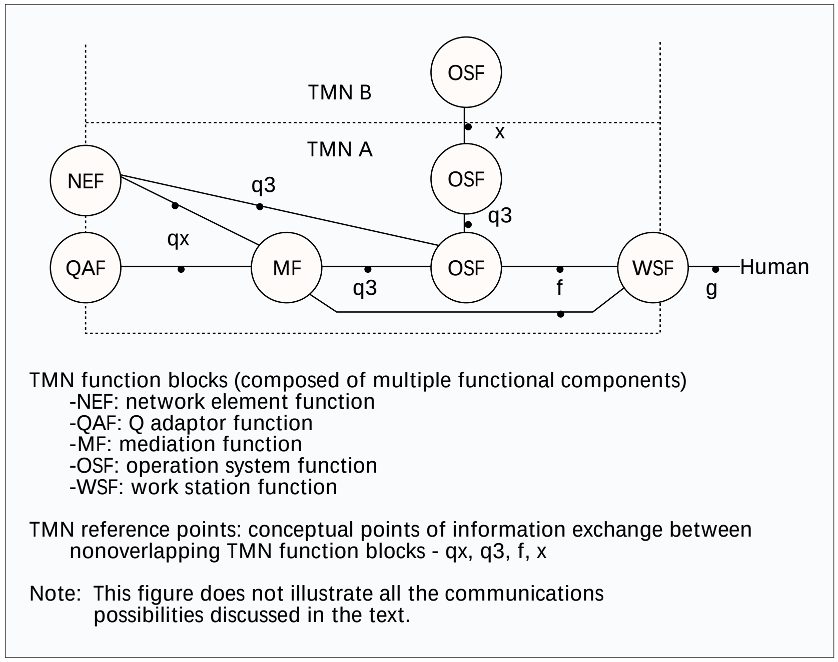


Figure 1. *TMN functional architecture — example.*

The actual information transfer between these function blocks is provided by the data communication function (DCF), which is assumed to support one or more information transport mechanisms, such as routing, relaying, and interworking.

The TMN physical architecture is completely based on these simple functional concepts:
- TMN physical blocks[1] are physical realizations of a combination of one or more of their functional counterparts. The name of each physical block is determined from the mandatory function block; for example, an operations system (OS) must be based on an OSF, but its realization may include other function blocks. Other physical blocks include network element (NE), mediation device (MD), workstation (WS), and Q adaptor (QA). Likewise, the data communication network is a physical realization of a DCF.
- TMN interfaces are physical realizations of reference points, thereby defining, by implication, relationships between communicating physical blocks. For example, the Q3 interface defines the relationship between an OS and an NE, an MD, a QA, or another OS. Other interfaces include Qx, X, and F.

A frequent misinterpretation of the physical architecture has in the past led some to define TMN interfaces in terms of protocols, with the Qx interface[2] defined by the use of short-stack protocols, while the Q3 interface is defined by full-stack protocols. This interpretation is, however, incorrect; more on this subject will be provided below.

The extended functional architecture is provided in two forms. The first form, the TMN reference model defines the functional components which comprise each TMN function block. Functional components have been defined to represent functionality involving security, directory system and access, work station and user interface support, data communication, information conversion, and management applications. Of these, the most interesting functional component is the latter, the management application function (MAF), which will be discussed later.

The second extended form of the functional architecture is termed the *logical layered architecture*. It essentially categorizes the OS management functionality into the following four layers (Fig. 2):
- *Element management*: concerned with managing a subset of NEs, individually or collectively as a subnetwork; also includes functionality mediating between NEs and the remainder of the TMN
- *Network management*: concerned with managing the network from end-to-end, that is, of all NEs and interconnecting links as a whole; also provides support of all services
- *Service management*: concerned with managing services to end customers or to other service providers, including handling service orders, complaints, and billing, and measuring the quality of services
- *Business management*: concerned with managing from an enterprise perspective, including finance, budgeting, goal setting, and product and human resource planning

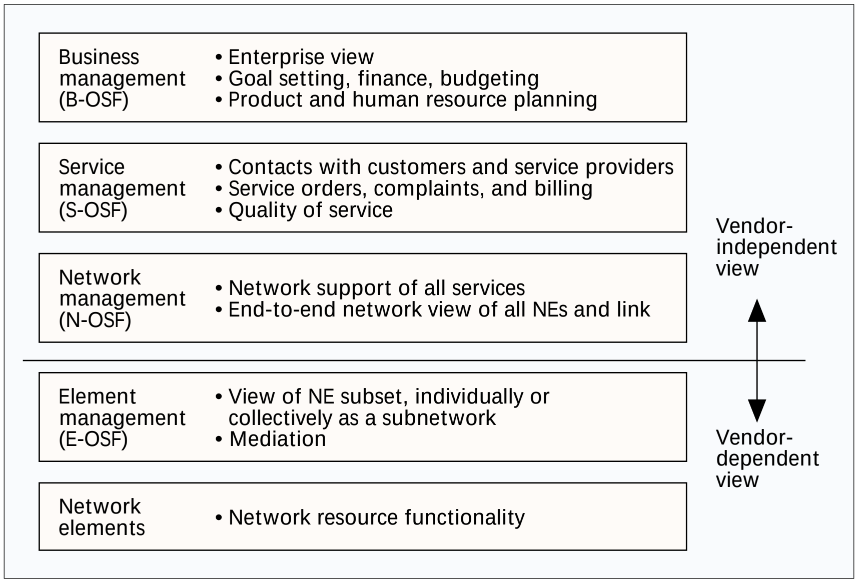
The use of the term *layer* recognizes an implied support hierarchy among the functionality (e.g., that service management is supported by network management). However, the architecture does allow communications between nonadjacent management layers. Also, higher layers are viewed as having a higher level of information abstraction compared to lower layers. From this perspective, network management functionality is viewed as more vendor-independent than element management, while service management functionality is viewed as more technology-independent than network management.

Although these layer definitions are clearly related to the functional architecture, it is recognized that physical realizations of such concepts are possible. Thus, for example, an OS which is primarily concerned with element management functionality may be termed an *element manager*.

The TMN information architecture provides the third architectural perspective, based currently on object-oriented concepts from OSI systems management. Under this approach, managed system and managing system exchange information modeled in terms of managed objects. The latter

[1] *While the current TMN physical architecture uses the term "TMN building block," SG 4 has tentatively agreed to replace it with a more meaningful term, "TMN physical block," and that is used herein.*

[2] *The continued need for the Qx interface is under study in SG 4.*



■ **Figure 2.** *TMN logical layered architecture.*

may represent one of three types of abstractions: the set of visible, manageable properties of a network resource, a relationship between network resources which is manageable, or support for a specific aspect of a management application. In TMN, sets of related managed objects are specified in the form of information models, such as the synchronous digital hierarchy (SDH) information model which represents the set of manageable logical and physical resources and properties of an SDH network, or a traffic management information model which represents the primarily logical constructs defined for managing traffic congestion control and related data collection.

It should be noted, however, that the object-oriented approach described thus far is focused on support of transaction-oriented information exchange; however, TMN is not limited to this approach.

Another characteristic of the information architecture is the defintion of two roles for information exchange:

- The manager role, which issues directives regarding the managed entity and receives information regarding that entity
- The agent role, which acts on the directives received from the manager and provides information about the managed entity to the manager

Two aspects concerning the current TMN information architecture are important to note. The first relates to the lack of full support for distributed management. Since TMN activities involve the exchange of information between cooperating processes in managed and managing entities, TMN may be said to define a distributed environment. However, it is recognized that the current information architecture is limiting in several ways. For example, communication in a location-transparent manner is not possible: the application process acting in a manger role must be aware of the location of the agent processes required to accomplish a task and establish a separate instance of communication to each.

The need to gain the full benefits of distributed management has been recognized, and several ITU-T efforts are underway to incorporate such concepts into TMN. One effort involves the separation of the TMN principles and architecture into two documents: one specifying the basic, communication-technology-independent characteristics, and the other the technology-dependent characteristics. Basic characteristics should be independent of today's and tomorrow's technologies. For example, the OSI management architecture which, as noted above, forms the current basis for the TMN information architecture, is not viewed as basic in the sense that it constrains communication technology choices. In addition, other perspectives based on emerging distributed processing technologies need to be accommodated.

A second effort involves the creation of a technology-independent open distributed management architecture (ODMA) [4] defined in terms of open distributed processing (ODP) concepts [5]. The TMN itself may be viewed as an ODP system. Initial standards include the ODMA framework and OSI management support for ODMA, while others are in progress or planned, including an ODP interface definition language (equivalent to CORBA IDL) support for ODMA. The latter standard will be based on the work of the Object Management Group (OMG), which is discussed further below.

Another aspect of the information architecture is a defining characteristic of today's TMN: TMN standards define information for exchange, but do not constrain the internal implementation of the associated communicating TMN entities.

Characteristics of TMN Functional Requirements

As noted in [3], a TMN management function, the most elementary form of TMN functional requirements, may be viewed as a cooperative activity involving two application processes, one in a managing system and the other in the managed system. In the architectural terms defined above, each application process may be equated to a management application function (MAF) in a TMN function block. However, since the current TMN standards are focused on the specification of the information to be exchanged by these processes rather than the processes themselves, it is appropriate to state that these MAFs are only indirectly defined. This is in keeping with the earlier assertion that TMN standards are currently concerned with defining a communication process, not with the information processing occurring within the communicating TMN entities.

In retrospect, it may be asserted that the initial sets of TMN management functions, specified in M.3400, focused on element management. Subsequent to the adoption of the logical layered architecture however, M.3400 was substantially expanded to include descriptions of what are termed *function sets* in support of network, service, and business management. These function set descriptions are categorized according to configuration, fault, performance, accounting, and security management, a schema introduced by OSI systems management, but populated with functional descriptions that mirror the traditional division of telecom management functionality into operations, administration, maintenance, and provisioning.

Ultimately, the value of TMN standards comes from addressing specific management problems, such as the provisioning of a leased circuit. In TMN these problems are specified in the form of TMN management services for a specific managed area. Each management service standard consists of one or more TMN function sets.

CHARACTERISTICS OF TMN INFORMATION MODELING

Information models are the essence of TMN standards and are categorized by the following characteristics:

- Whether they are specific to the management of one type of telecom technology (e.g., SDH), or may be applied to manage more than one
- Whether they represent abstractions of network resources (physical or logical), or of specific aspects of management applications
- Whether they are concerned with either element, network, service, or business management, or are applicable to more than one type of management

For example, M.3100 specifies a generic network resource information model from which technology-specific information models may be derived, such as G.774 for SDH, and which is generally considered to be most supportive of element management.

TMN information modeling has been extended to cover switching, transport (PDH, SDH, ATM), and wireless network resources, primarily from an element and network management perspective, while applications include configuration, fault, performance, and accounting management. This expansion of functionality has been accomplished partly through the creation of TMN activities in national, regional, and international bodies beyond the ITU-T, which are discussed below.

In keeping with the guidelines of the current TMN information architecture, the initial TMN information models were specified using only the GDMO (Guidelines for the Definition of Managed Objects) templates (X.722) associated with OSI systems management. As the need for using distributed management techniques was recognized, initially to support transport-network-level information modeling, the search for a technique which would allow ITU-T information models to be used with multiple communication technologies led to ODP and its viewpoint concepts. This search also highlighted the importance of defining the most critical TMN standards, those specifying the management information, in a reusable, protocol-neutral fashion. In the case of transport-network-level modeling the resultant ODP-based methodology (G.851.1) essentially provides two techniques: one for developing a protocol-neutral model in terms of ODP enterprise, information, and computational viewpoints, and another for deriving one or more protocol-dependent models from the protocol-neutral model. Initial protocol-dependent models will be specified using GDMO, but it has also been shown that this process can be used to develop models using CORBA IDL, standardized by ISO as ODP IDL [6].

The need for a common, broadly accepted approach has been recognized in the ITU-T, and an effort has been initiated to reach agreement. When completed, the resultant method is expected to be applied across ITU-T information modeling activities.

It should be noted that the Network Management Forum (NMF) has concurrently also identified the need for protocol-neutral information modeling and has contracted with a modeling tool vendor to support their activities. To encourage industry convergence, the NMF experience has been shared with the ITU-T.

In support of interoperability in a multiple-protocol environment, the X/Open consortium and the NMF formed the Joint Inter Domain Management (JIDM) group to specify algorithms for performing static and dynamic translations among CORBA IDL, GDMO, and SNMP management information bases (MIBs). A set of static translation specifications have been completed, and work on specifications for dynamic translations is in progress.

TMN PROTOCOL CHARACTERISTICS

From the beginning, TMN communication protocols have come in a variety of packages to support the diverse needs of its users categorized from two perspectives: either on the basis of the data network type employed or by the application. Currently support is provided for X.25 packet, 802.3 LAN, ISDN, Signaling System No. 7, and TCP/IP-based networks. Application protocol types supported include transaction class using CMIP, file transfer class using FTAM, and directory service class using X.500. Although guidelines for protocol selections are based on the OSI reference model, the inclusion of Signaling System No. 7 and TCP/IP protocols indicates a pragmatic selection process based on market needs. Protocols in support of distributed management technologies remain to be determined, although the acceptance of TCP/IP is an important first step.

TMN CONFORMANCE AND PROFILES

As noted earlier [3], the specification of conformance requirements and profiles is an important element in achieving interoperability between TMN products. While such specifications exist for many TMN protocols and are referenced, only three conformance documents (M.3101, X.790, and Q.823.1) and one profile (X.790) for GDMO-based TMN information models have been advanced by the ITU-T.

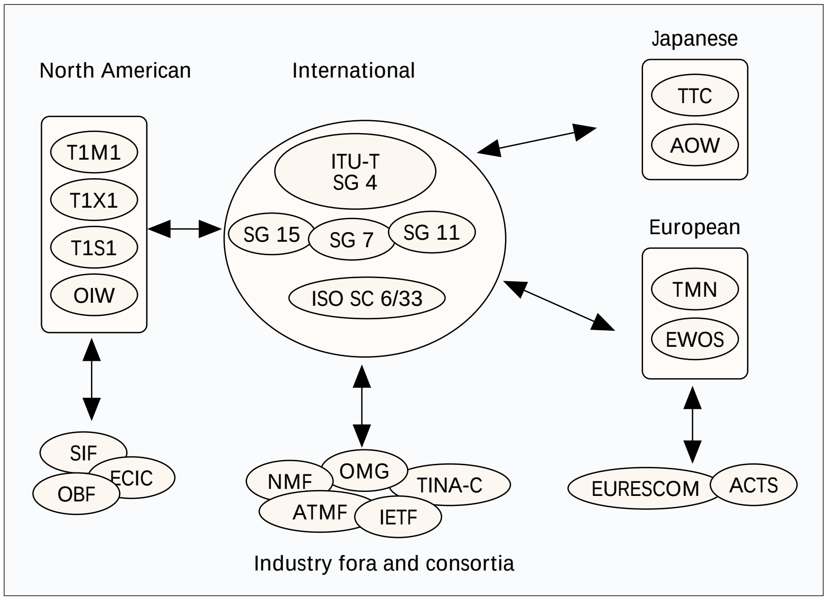
One of the deficiencies of current TMN standards is the lack of conformance guidelines to support the existing conformance specifications. In response to this recognized market need, an initial set of guidelines for TMN interface protocol conformance and TMN interface information conformance has been proposed. In addition, guidelines for specifying compliance to TMN interface functional requirements have also been suggested.

CHARACTERISTICS OF THE ORGANIZATIONS SUPPORTING TMN

As noted above, the concept of a TMN was initially a product of the ITU-T standards environment, supported by associated regional and national standards bodies in Europe (ETSI), the United States (T1), and Japan (TTC). Until recently, most TMN standards were the result of activities in these bodies. However, for various reasons to be discussed below, other fora and consortia have been spawned by the telecom and related industries, and have led to the creation of additional TMN and TMN-related standards. Since the existence of these bodies is expected to be critical to the future of TMN, a discussion of their impact and the reaction of the ITU-T to them is provided below. A nonexhaustive set of major standards organizations impacting TMN is shown in Fig. 3; however not all organizations shown are discussed below.

SELECTED FORA AND CONSORTIA IN SUPPORT OF TMN

The 1990s have seen a proliferation of international, regional, and national fora and consortia concerning the technical areas of most relevance to TMN: information technology, data communications, and telecommunications. However, the revolution actually began earlier, first with the formation with the Internet Engineering Task Force which publishes data communications standards to support the Internet. Then, in 1988, the Network Management Forum (NMF) was formed to cre-



■ **Figure 3.** *Major standards organization impacting TMN.*

ate "intercept" specifications (preliminary versions of planned standards) and to complement ISO/ITU base standards with implementation specifications. The NMF's initial emphasis was on communications of Service Management information between jurisdictions, e.g., between two private and/or public companies (across the X interface in TMN parlance). A key differentiator of the NMF was (and still is) that it brought together representatives of the telecom service providers and equipment suppliers with equivalents from the computer hardware and software vendors, a primary result of the NMF's focus on implementation and procurement needs.

Since then, while the specifics of the NMF program have evolved, the NMF has generally focused on complementing and extending the work of traditional standards bodies (e.g., via their OMNIPoint program). And over the years, the NMF technical program has evolved more and more toward support of the TMN. The major role of the TMN in the NMF was marked in 1994 by the publications of two guides on implementing TMN, one focused on the business case for TMN [7], the other on TMN technical aspects [8]. Packages of service management capabilities called *solution sets* have been progressed for order processing, trouble ticketing, performance reporting, and billing. Infrastructure packages called *components sets* have also been specified, including one focused on TMN protocol profiles. The work activities related to protocol-neutral information modeling and support for multiple-protocol environment was also discussed above. Recently, the NMF reorganized into a three-part structure directed at specifying solutions for service management, network management, and management platforms and technologies.

Other fora which followed, including the ATM Forum (ATMF), had a similar mission to complete and extend base standards, but in many cases it must be recognized that the creation of a new forum, as opposed to expanding the role of an existing standards body, was motivated by the perceived deficiencies of the accredited standards process: a bureaucratic, consensus-driven process which produced specifications too late and too "rich" for the market. Not surprisingly, it was not long before such fora entered the business of creating base standards as well.

Other than the NMF, these fora typically address management as one aspect of a total product specification. The ATMF is probably the best example of such a body, impacting TMN via what might be termed an informal partnership with the ITU-T. To manage ATM equipment used in public and private networks, the ATMF developed a TMN-like physical architecture identifying the ATM network elements, management systems, and related interfaces (several equivalent to Q3 and X, and others for NE-NE). Initial TMN-related work focused on the development of M4 (Q3-equivalent) interface information models based partly on existing ITU-T information models. Because of participant interest in utilizing the models in two application protocol environments, CMIP and SNMP, the creation of protocol-neutral models was seen as a necessary first step, followed then by a protocol-dependent model. Following the completion of the initial ATMF work on an NE-level information model using GDMO, it was submitted to the ITU-T, which approved it with minor changes (I.751). This activity was followed by work on a network-level information model.

Other fora related to the information technology industry are also expected to utilize and influence TMN. One could argue that the OS is the heart of TMN; from that perspective, the computer hardware and software industry provides the product foundation of TMN. Thus, it is critical to TMN interests to understand and follow, where appropriate, this industry's direction. A major force in this industry today is CORBA and its creator, the OMG, with over 700 members, including telecom equipment suppliers and service providers. CORBA is a set of specifications for developing heterogeneous, distributed, object-oriented computing systems. As noted in [9], the essence of CORBA is an object request broker, "which facilitates communication between local and remote objects." It relies on the same object-oriented principles embodied currently in TMN, but its scope is broader in that it is a distributed processing platform for both computing and communications. Thus, CORBA is a candidate for implementing TMN OSs (and associated OSFs), and the communications between them as well. To encourage the identification of telecom needs, the OMG established a Telecom Domain Task Force whose output includes a position paper on CORBA-based TMN and several specifications supportive of TMN needs, such as the notification and topology services.

Telecommunication-oriented fora related to TMN have also been created. EURESCOM, a consortium of most European public network operators, was established to advance pan-European telecommunications services, primarily based on broadband and intelligent networks and their management via TMN. TMN activities include organizational models, OS platforms, and specifications for management services and ATM/SDH networks, based on ETSI and ITU-T standards. A TMN laboratory consisting of interconnected, member-owned OSs geographically distributed across western Europe has been used to field test communications across the X interface. The results of some activities [10] have been used to drive ETSI ATM management standards.

In the United States, a cooperative arrangement among T1M1 and two other bodies of the Alliance for Telecommunications Industry Solutions (ATIS), the Order and Billing Forum (OBF) and the Electronic Communications Implementation Committee (ECIC), has driven the development of T1M1 standards for "electronic bonding," another instance of X interface applications [11]. Such standards include information models for trouble ticketing, primary interexchange carrier identification, and ordering of interexchange carrier access lines, the latter two unique to the United States. As an example of the informal partnerships on TMN, the T1M1 trouble ticketing information model was extended by the NMF and submitted to the ITU-T, where it was approved as X.790.

As suggested above, some of the electronic bonding applications were necessitated by the unique characteristics of the U.S. telecom regulations which differentiate between interchange carriers and local exchange carriers. The U.S. telecom environment is now in total flux as a result of the U.S. Telecom Act of 1996 which significantly extended the deregulation of the U.S. telecom industry. A key element of this Act is a requirement on existing local exchange carriers to "unbundle" selected management functions (preordering, ordering, provisioning, maintenance, and repair) in their OSs, making them accessible to any new service provider. The role of TMN standards in such an environment remains to be determined; equally unclear is the impact of this environment on TMN standards. European deregulation scheduled for 1998 will probably have a similar undefined impact.

In summary, the organizational foundation for the development of TMN standards has changed. Fora and consortia focused on telecom, data communications, and computers have joined the ITU-T in influencing the direction of TMN. And what has been the ITU-T's response to these changes?

ITU-T Response to Fora and Consortia

The ITU is a treaty-based organization, a specialized agency of the United Nations, and, as such, its formal members are governmental bodies. Outside of the ITU regulatory activities, most of its standards, including those for TMN, are created largely by the efforts of representatives of telecom service providers and equipment suppliers recognized by each member state. Being a treaty-based organization is both its strength and weakness. It is a strength in that ITU standards are recognized as comprehensive, high-quality products created by representatives of some of the world's leading telecom corporations. It is a weakness in that in the past ITU procedures and structures have not supported the rapid change required in a deregulated telecom marketplace.

Beginning in 1992, the ITU began to reinvent itself, recognizing that it had to respond more quickly to telecom market needs and open its doors to all potential interested parties. The previous constraint of standards approval only once every four years was supplemented with a process allowing approval to be initiated whenever the specification was ready. To facilitate continual review and evolution of the ITU-T, the Telecommunications Standards Advisory Group (TSAG) was created. Its initial work has led to an even shorter standards approval process, now down to about nine months once a specification is stable, and to a trial of a new concept in flexible working methods allowing the creation of Focus Groups operating outside normal ITU procedures. Focus Groups are designed to be project-oriented, of short duration, self-financing, and open to any interested person or organization. Procedures for establishing a formal communication process between an ITU-T Study Group and a forum or consortium, such as those discussed above, and for referencing a forum's specifications have also been implemented.

More specifically regarding TMN, a TSAG proposal to consolidate most ITU-T TMN standards activities in Study Group 4 was approved in October 1996. This action brought together the TMN work on architecture, functional requirements, protocols, and common, switching, and network-level transport information modeling with the TMN infrastructure work on OSI systems management and ODMA. Some equipment-specific information modeling activities, however, remain in other SGs. This reorganization was facilitated by the mixed results (quite successful regarding technical issues and less so regarding administrative ones) of the Joint Coordination Group (JCG) on TMN over the previous four years. These activities made clear that ITU-T TMN standards deserved to be managed as a project and that consolidation in a single SG was the proper vehicle. The ITU-T has long had an informal relationship with several fora related to its TMN activities and based on the new procedural flexibility discussed above, SG 4 has established formal relationships with the NMF, the ATMF, and the OMG.

(It might be noted that during a major reorganization of its activities, ETSI followed the ITU-T lead and consolidated most of its TMN activities in one body, TC-TMN.)

The ITU is continuing to streamline its processes, particularly regarding standardization. It is generally recognized that the creation of standards to meet rapidly moving market needs is of most interest to ITU-T's private (nongovernmental) members and of less interest to ITU member states. The challenge remaining is to translate that recognition into changes of the ITU structure and procedures. In the interim, the changes already approved have significantly improved the ITU-T's effectiveness and flexibility.

Characteristics of the Marketplace Interest in TMN

The marketplace interest in TMN is evident in several ways: via support for specific TMN activities in the ITU-T and TMN-related fora and consortia, via industry conferences, and most importantly via deployment of TMN-based systems and standards. Earlier, it was reported [3] that initial ITU-T TMN standards focused on the management of SDH (or synchronous optical network, SONET, in the United States) network equipment. Concurrently, a major series of ETSI TMN standards were issued for the management of GSM equipment, a digital wireless technology. Subsequently, the ATMF and the ITU-T informally collaborated on initial TMN standards for ATM management. In retrospect and not surprisingly, it can be seen that the focus was on the management of new rather than legacy technology. This emphasis on support of new telecom technology remains a basic driving force regarding TMN.

But were these standards implemented on those products and then deployed in service provider networks? The answer appears to be yes where legacy interfaces do not exist (e.g., for GSM and ATM). However, where legacy interfaces exist (e.g., TL1 for SONET in the United States), there is still reluctance on the part of service providers to replace such legacy interfaces with TMN interfaces. Market deregulation, which by definition is meant to increase the number of providers and thus the need for standard interfaces, may have a major impact on such usage.

Another gauge of the market-driven interest in TMN is evident at industry conferences. Internationally, the premier telecom network management conference is the IEEE Network Operations and Management Symposium, also known as NOMS, held in every even year. At the last NOMS held in April 1996, a majority of sessions either directly or indirectly referenced TMN concepts or capabilities. And the TMN logical layered architecture was easily the most popular organizing principle for sessions and papers.

Conferences focused on TMN are also becoming very popular. Examples include the Global TMN Summit held in San Diego in February 1997 which drew 450 participants to hear telecom service providers and equipment suppliers, and computer software and hardware vendors. A similar three-day conference in London in March 1997 addressed "Achieving Competitive Advantage Through TMN Integration." The most distinguishing characteristic of latter conferences is the prominent role played by software vendors, who are not only supplying development tools and protocol stacks, but also contracting with individual service providers to develop custom TMN applications.

CONCLUSION

The strength of TMN most likely lies in one simple fact: in this day of rapid technological and regulatory change, a unifying management framework is essential. As a result of this need, it has been recognized that TMN standards have a difficult task ahead in ensuring the technical characteristics involving TMN architecture, functional requirements, information modeling, and protocols satisfy the market needs of today while preparing for those of tomorrow. Such a TMN will likely possess the following characteristics:

- A "future-proof" architecture supportive of distributed management and independent of any particular communications technology
- Protocol-neutral information models supportive of an interoperable, multiprotocol environment
- Accommodation of concepts and implementation technologies strongly supported by the computer industry

And while the ITU-T led the way in the past, it is clear that the success of TMN will also be significantly impacted by the activities of regional and national standards bodies, fora, and consortia. Partnerships among these organizations already exist today and are essential for the TMN of tomorrow.

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BIOGRAPHY

DAVID J. SIDOR is a manager, OAM Standards, at Nortel (Northern Telecom), Inc., where he has the responsibility for TMN standards planning. He has participated in the formulation of TMN standards in the ITU-T and T1M1 since 1986. Within the ITU-T, he is the former chairman of the Joint Coordination Group on TMN and current chairman of TMN SG 4. Prior to joining Nortel in 1991, he was with AT&T where he established requirements for the management of switching systems and for several switching operations systems. He received a B.S. and M.S. in electrical engineering from Michigan State University and New York University, respectively, and is a member of Tau Beta Pi.