Managing Telecommunications Networks Using TMN Interface Standards

The standardization of TMN interfaces by the International Telecommunication Union has been expanded to cover all major telecommunication technologies and services and is today the foundation for TMN's global acceptance.

David J. Sidor

The concept of a Telecommunications Management Network (TMN), a product of the ITU-T (formerly the CCITT) standards environment, was first formally defined in 1988. During the 1989-1992 Study Period, the ITU-T completed an initial set of implementable TMN interface Recommendations (i.e., standards), and additions to this set are continuing. A major portion of this article is devoted to a discussion of completed, ongoing, and planned ITU-T activities.

During the last Study Period, the ITU-T also adopted OSI Management standards as a framework for TMN. OSI Management, which originated in the ISO and is now being progressed jointly by the ITU-T in its X.700 series of Recommendations and ISO/IEC in its International Standards, provides transaction-oriented capabilities to support TMN Operations, Administration, Maintenance, and Provisioning (OAM&P) functionality. Within OSI Management, and thus within TMN, these capabilities are defined using object-oriented techniques. The role of OSI Management currently and in the future in support of TMN is a major theme of this article.

The importance of TMN was recognized during the same Study Period by regional and national standards bodies, such as the European Technical Standards Institute (ETSI), Committee Telecommunications (CT) in the United States, and two Japanese groups. As a result, TMN is seen globally as the basis for the management of today's and tomorrow's telecommunications networks. A summary of these bodies' activities is also presented in this article.

The first section of this article presents the scope of TMN standards, identifies the role and importance of interface standards, and describes the key elements of a TMN interface. TMN activities within the ITU-T, from an organizational perspective, are summarized in the second section, which also presents a more detailed description of the ITU-T specifications, organized primarily by interface element categories. The third section examines the availability of TMN standards in support of Synchronous Digital Hierarchy (SDH) management. (In North America, SDH is known as the Synchronous Optical Network, or SONET.) The role of regional and national standards bodies in TMN is covered in the fourth section. Efforts to speed the availability of TMN implementations are briefly noted in the fifth section, while the sixth section describes major TMN challenges and new directions driving its evolution.

It should be noted that this article is not meant to be a tutorial on TMN, OSI Management, or object-oriented techniques, and it is assumed that readers have read the first article in this issue [1]. Readers are also encouraged to develop additional background by examining several ITU-T Recommendations: M.3000 [2] and M.3010 [3] for TMN, and X.701 [4] for OSI Management. X.701 also references Recommendations X.720 and X.722, which are useful regarding object-oriented techniques.

The Scope of TMN: Interfaces vs. Applications

As the ITU-T Recommendations explicitly state, TMN is first and foremost a communications concept. TMN standards define two types of telecommunications resources, which are the key entities in any TMN: managed systems, generally termed network elements (NE); and managing systems, of which the operation system (OS) is the most prominent. TMN standards also specify possible interconnection relationships between these resources in the form of interfaces, such as the OSI-NE (or Q3) interface, as described in [1]. Detailed interface specifications are the essence of TMN standardization.

TMN has, however, come to encompass more than two systems communicating in a specific manner across an interface. Typically, a TMN is seen to include the totality of the telecommunications, OAM&P applications residing in the NE and OS, involving both their communications and non-communications aspects. In other words, TMN standards are believed by many to include the specification of the information and means of information transfer across interfaces, and the processing of that...
information at both ends of the communications link. It should be made clear, however, that while this is a proper characterization of "real" TMN, current ITU-T work plans do not include the specification of the OAM&P information processing within the endpoints of the communications link.

The Role and Importance of TMN Interface Standards

The role and importance of TMN interface standards in telecommunications network management is well understood by examining the impact of competition and deregulation.

Most public network service providers (SP) purchase their NEs from multiple suppliers. And in many cases outside of North America, OSs have been bought from the NE suppliers to ensure operational compatibility with each NE type, regardless of the open nature of the interface. Now, in an increasingly deregulated marketplace, the benefits of a competitive OS multi-supplier environment are recognized as well. Common interface solutions based on TMN standards provide the foundation for suppliers to concentrate on innovative end-system applications to meet diverse customer operational environments.

Elements of a TMN Interface

To understand the degree of standardization that exists and is planned, it is useful to identify the elements of a TMN interface and then categorize the standards in terms of these elements. TMN interface specifications based on OSI Management consist of at least seven elements:

- An architectural definition of the communicating TMN entities, including their respective functional roles in the TMN and their interrelationships (e.g., the OS and NE in their roles as managing system and managed system, and their physical interconnection via a Q3 interface).
- The OAM&P functionality, which is planned to be supported by the communications (short-hand for functional requirements).
- Management application messages and information models to support the OAM&P functional requirements (short-hand for management application protocols and support objects, respectively).
- Resource information models, which provide abstraction of the telecommunication network resources to be managed in the form of generic or technology/service-specific managed objects.
- Communication protocols to transport the messages between TMN communicating entities.
- Profiles that assemble implementable and marketable packages of functionality from among the various mandatory and optional aspects of the standards.

It should be noted that current TMN standards require the use of information models only to support transaction-oriented applications, i.e., those based on OSI Management protocols as described later in the article.

Before providing a detailed description of the ITU-T specifications available and planned for each element of a TMN interface, it is also useful to describe the organization and responsibilities of the different groups within the ITU-T in terms of these interface elements.

**TMN Activities within the ITU-T**

TMN standardization activities in the ITU-T and in regional/national bodies generally fall into two categories: generic or technology/service-specific. Generic activities produce standards that are applicable to more than one technology or service and are the foundation for the wide application of TMN. The use of OSI Management standards, based on the object-oriented paradigm, is a major aspect of this foundation. However, TMN technology/service-specific standards, in many cases specializations of the generic standards, are ultimately the key specifications for TMN-based products.

**ITU-T Organizational Perspective**

The ITU-T standardization activities are divided among 15 Study Groups (SG) of which the four named in Table 1 have key TMN responsibilities. Each SG publishes the results of its standardization activities in documents known as ITU-T Recommendations, which are grouped into Recommendation series, e.g., the M-series. The Recommendation series in which TMN specifications are published for these four SGs are also identified in Table 1.

SG 4 is responsible for the overall TMN architecture and methodology, functional requirements in the form of TMN management services, generic information modeling of network resources, and specific characteristics of Q, X, and F interfaces. Architecture, functional requirements, messages, and support objects for the maintenance, configuration, and performance management of narrowband and broadband ISDN (N-ISDN and B-ISDN) are also handled as well as TMN requirements for circuit and Signaling System No. 7 (SS7) maintenance.

The primary role of SG 7 in TMN involves its OSI collaborative activities with ISO/IEC. These activities cover all interface aspects for OSI Management: communication protocols, messages, and support objects in the form of system management functions, architecture, and also information modeling methodology. All aspects of customer network management interfaces to public data networks are also its responsibility.

SG 11 addresses both categories of TMN activities. For generic use, it provides specifications of seven-layer protocol suites and also messages and support objects. Resource information...

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<th>Study Group (SG)</th>
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<tr>
<td>SG 4</td>
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<td>SG 11</td>
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<td>SG 15</td>
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**Table 1. Key ITU-T study groups involved in TMN.**

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A TMN management service can be viewed as the description of one aspect of the total management domain, e.g., switching management.

modeling and messages, and support objects specifically for switching, are also its responsibility. All aspects of TMN interfaces for SS7 networks are also generated, while aspects of asynchronous transfer mode (ATM) information modeling are shared with SG 15. Intelligent Network (IN) management is also centered in SG 11, which is working jointly with SG 4 to ensure the efficient application of TMN in support of IN's rapid service creation capabilities.

The initial application of TMN was to the management of SDH networks, a responsibility of SG 15. Currently, it is responsible for all aspects of TMN interfaces for transmission equipment, including SDH, physical-layer digital hierarchy (PDH), and relevant portions of ATM.

Other SGs also play important roles for TMN. Such activities include the generation of traffic management requirements in SG 2, human-machine interface requirements in SG 10, transport network architectures in SG 13, and an information model for X-series modem management in SG 14. TMN concepts have also been extended to the work on the Future Public Land Mobile Telecommunications Service (FPLMTS) underway in the ITU-R.

Status of ITU-T TMN Recommendations

Provided below is a summary of approved, in-progress, and planned ITU-T Recommendations primarily organized by interface element. This summary covers the majority of known specifications, but is not meant to be exhaustive, especially regarding OSI documents. Approved ITU-T Recommendations are indicated via an asterisk (*) when first referenced. Other Recommendations noted are in preparation, but no guarantee of eventual publication can be made or should be assumed by the reader.

As noted earlier, TMN Recommendations are based on OSI Management and its object-oriented techniques. The reusability benefits of this decision impact each of the interface elements described above and are summarized below as well.

An overview of approved TMN Recommendations was recently released as M.3000*.

TMN Methodologies — Several methodologies play prominent roles for TMN. From OSI Management, guidelines are provided in X.720* on the "art" of information modeling and in X.722* on the specification via individual templates for each part of an information model, also known as Guidelines for the Definition of Managed Objects (GDMO).

An initial methodology for the specification of TMN interfaces is presented in M.3021* with a revision in progress. It also serves as a repository for TMN concepts and provides an understanding of the relationships among the different ITU-T activities driving TMN.

TMN Architecture — The TMN architecture in M.3010* is defined from three perspectives. It provides a physical architecture and information architecture based on the manager-agent concepts from OSI systems management (X.701*); the latter primarily supports transaction-oriented TMN applications. The TMN functional architecture introduces layers of TMN management functionality, about which more will be presented in a following section. The application of the TMN architecture to the management of various technologies is described in the following documents: SDH networks in G.784*, switching in Q.513*, SS7 networks in Q.750*, and ISDN in M.3600*. The TMN architecture is discussed in some detail in [1].

TMN Functional Requirements — Functional requirements for TMN are in many forms. A set of TMN management services was first described in M.3200*, and individual TMN management services are planned to be documented in the M.32xx series. A TMN management service can be viewed as the description of one aspect of the total management domain, e.g., switching management. In turn, each TMN management service may be recursively decomposed into smaller units of requirements until the smallest requirement unit, the TMN management function, is identified. A generic and comprehensive, but not necessarily exhaustive or final, set of TMN management functions organized by OSI Management functional areas is found in M.3400*. A detailed set of guidelines for preparing TMN management service Recommendations is planned to be included in M.3020. Currently planned and in-progress TMN management services include the following:

- M.3201: Traffic management.
- M.3202: Common channel signaling systems management.
- M.3203: User services management.
- M.3204: ISDN management.
- M.3205: B-ISDN management.
- M.32m: Intelligent Network management.

Revisions of M.3200 and M.3400 are also underway.

TMN management functions are also specified in many of the Recommendations described in the following section. A set of management capabilities for the F interface described in [1] are specified in M.3300*.

TMN Application Messages And Application Information Models — A TMN management function is essentially a cooperative activity involving two application processes, one in a managing system and the other in a managed system, but it is defined independently of the means of implementation. Similarly, OSI system management functions in the X.730-740 series define cooperative activity between a manager and agent, but their communications is predicated on the use of the OSI systems management services and protocol. It is the latter characteristic that is key to the usefulness and applicability of OSI Management to TMN. TMN management functions are mapped onto the OSI system management functions and associated OSI system management services, wherever possible, thereby allowing the latter to be used as the basis for TMN messages and support objects. Where there is a need for additional TMN application functionality beyond that provided by existing OSI Management standards, it is built on existing OSI capabilities provided by the OSI Common Management Information Service (CMIS; X.710*). Such system management services in turn are mapped onto associated application protocol data units defined in the
OSI Common Management Information Protocol (CMIP; X.717*) for transfer across TMN interfaces.

TMN application messages and information models are specified for generic alarm surveillance in Q.821* and for generic performance management in Q.822*. Specialization of the Q.822 messages and information model is available for SDH network management in G.774.01*, for ISDN layer management in M.3641*, and for switching traffic management in Q.823. To support switching service provisioning, Q.824 provides an information model applicable to both ISDN user-network and TMN Q3 interfaces.

This section has thus far focused on the transaction-oriented application capabilities, i.e., those supported by OSI Management. TMN standards for file transfer-oriented applications, such as accounting management, are also expected to be provided in the future.

TMN Resource Information Models — To ensure common solutions for the management of switching, transmission, and other technologies, ITU-T has initiated a Generic Network Information Model in M.3100*. Concurrently, ITU-T has defined an initial information model (G.774*) to support the management of SDH networks. Using the object-oriented concept of inheritance, which promotes the reusability of managed object class definitions, the SDH information model incorporates selected managed object classes from M.3100.

The development of the initial pair of information models led to the formulation of the concept that management information may be specified from several viewpoints, of which three are currently identified: NE level, which is concerned with information to manage an NE; network level, which is concerned with the information necessary for the network as a whole (including how NEs are related, topographically interconnected, and configured to provide end-to-end connectivity); and service level, which is concerned with information to manage customer services based on network resources. It is generally recognized that the initial M.3100 and G.774 Recommendations emphasize the NE-level viewpoint.

Additional SDH information models for the NE viewpoint have been approved or are in progress, including G.774.02* for configuration of the payload structure, G.774.03* for protection switching of multiplex sections based on a specialization of M.3100, and G.774.04* for protection switching of subnetwork connections as an extension of G.774.03. Extensions of M.3100 and G.774 to support the network-level viewpoint are also underway.

A network-level information model to support the management of SDH, PDH, and ATM transmission systems is also in progress. A catalog of TMN-related object classes defined in an approved Recommendations is presented in M.3100*, which will be updated on an ongoing basis.

TMN Communications Protocols — Specification of lower and upper layer protocols for TMN has been one of the easier tasks to accomplish, since a significant set of relevant OSI, ISDN, and SS7 communications protocols already exists. A set of seven full-stack protocol suites for any TMN Q3 interface is found in Q.811* and Q.812*, of which a subset has been identified as relevant to SDH management in G.784. Q.812 in particular supports two management application types: transaction-oriented via CMIP, and file transfer-oriented via ISO/IEC's File Transfer, Access, and Management (FTAM). Short-stack protocol suites for transmission NEs are also presented in G.774*, and a related set of protocol suites for intra-SDH network management are presented in G.784.

TMN Conformance Requirements and Testing — In order to maximize interoperability between communicating OSI-based implementations, the concept of conformance requirements and testing has been developed by ISO/IEC. Total conformance by an implementation is a necessary step toward the achievement of interoperability between implementations of different suppliers.

Conformance specifications exist for OSI communication protocols (including management application protocols), system management functions (messages), and information models (managed objects, both resource and support) standards. Most communication protocols adapted for TMN are accompanied by protocol implementation conformance statement (PICS) pro formas. And X.724* provides a methodology for the preparation of managed object conformance statement (MOCS) pro formas. The first application of X.724 to TMN is to prepare a MOCS pro forma for M.3100 (known as M.3101).

International Standardized Profiles for TMN — To speed the introduction of OSI-based protocol into the marketplace, the concept of International Standardized Profiles (ISPs) has been formulated jointly by ISO/IEC and the three regional OSI Regional Workshops: the Open Systems Environment Implementors Workshop (OWI) in North America, the European Workshop for Open Systems (EWOS), and the Asia-Pacific Oceania Workshop (AOW). As defined in ISO/IEC TR 10000*, an OSI profile is a set of OSI standards assembled to perform a particular task defined of value to the marketplace, while an ISP is an internationally recognized specification of one or more OSI profiles. ISPs are also an important basis for conformance testing.

Current TMN Recommendations in general are not based on ISPs, since they were progressed concurrently with several key ISPs. However, ISPs for many lower and upper layer profiles that are relevant for TMN are available now and are being examined for incorporation in TMN specifications. The migration of Q.811 and Q.812 protocols to ISPs is in progress. Two upper layer ISPs are most important, since they provide a comprehensive set of profiles for use over a multitude of lower layer profiles: ISP 1118* for CMIP-based transaction services and ISP 10607* for FTAM-based file transfer services. The use of ISP 12059 and ISP 12060 and the creation of ITU-T ISPs for TMN-specific application messages and information models is under study.

The ISP/profile work has received significant support from the Network Management Forum (NMF), which has also greatly stimulated the
availability of conformance tests and related services.

**Vertical Slice of TMN Functionality for SDH**

As stated above, the desire to meet real industry needs, specifically to support the introduction of SDH (SONET in North America), was the initial driving force in ITU-T, ETSI, and T1 to produce implementable TMN Recommendations. The period 1992-94 marked a watershed for ITU-T because a "vertical slice of functionality" for SDH was made available for implementation on a broad range of ITU-T Recommendations. This initial slice supports alarm surveillance and performance management and is specified in the Recommendations identified in Figure 1.

**The Role of Regional and National Standards Bodies in TMN**

Major regional and national standards bodies are strong supporters of ITU-T-based TMN. Most contributions to the ITU-T TMN activities originate in countries and companies that are members of these standards bodies. Equally important, many ITU-T TMN Recommendations are recognized explicitly or implicitly as local standards and as the basis for local extensions.

In ETSI, there are six key Sub-Technical Committees (STC) involved in TMN, as indicated in Table 2. NA 4 is the focus of TMN standards activity, while the other STCs emphasize technology/product-specific activities. In the United States, TMN activity is found primarily in three Committee T1 Technical Subcommittees (TSC) shown in Table 3. TIM1 is the counterpart to NA4 in the United States and thus is the focus of TMN activity there. SONET, the counterpart to SDH in North America, is covered by T1X1, while T1S1 is the focus of ATM TMN activity.

In Japan, TMN standardization activities are found in two organizations, The Telecommunication Technology Council, which is responsible for Japanese input to the ITU-T, has established a TMN Working Group to review proposed contributions and, if necessary, to prepare contributions. It also prepares the Japanese position on most JCG-TMN issues. The Telecommunication Technical Committee, which is responsible for publishing Japanese standards, also has a TMN Working Group that determines the relevant TMN aspects for Japan. These two groups work in parallel and cooperate with each other to avoid the proliferation of their activities.

**Efforts to Speed the Availability of TMN Implementations**

**Joint Coordination Group on TMN**

Several initiatives to speed the availability of TMN implementations are underway. One focuses on enhancing the TMN standards process to provide for faster output and for more effective use of available human resources. Because of the com-

![Figure 1. Vertical slice of TMN functionality for SDH.](image-url)
complexity involved in coordinating subject areas (such as TMN) which involve collaborative activities in many SGs. In 1993 the ITU created, on a trial basis, the concept of a Joint Coordination Group (JCG). The first such JCG authorized was for TMN. Meetings of the JCG-TMN bring together the working-level leaders of the key SGs in order to share information on TMN progress in their areas, to identify possible duplication of effort or the lack of needed activity, and to identify common issues and to recommend possible solutions. In the latter effort, the JCG-TMN’s role is advisory, serving only as an extension of the involved SGs whose responsibilities and authority remain pre-eminent.

Network Management Forum and TMN
As noted above, several organizations have and are continuing to play key global roles in the implementation of OSI management standards, namely, the NMF and the OSI Regional Workshops. In particular, the NMF has entered into a collaborative partnership with other groups to create the OMNIPoint program, with an emphasis on service management. This effort also has the support of the OSI Regional Workshops and several standards bodies. Each OMNIPoint release specifies a strategy and a comprehensive set of network management “components” sufficient to guide users with network management needs to prepare and evaluate responses to RFPs and to guide suppliers in implementing network management products. These “components” include, for example, standards, de facto standards, software development tools, and implementation and procurement guides.

Because of the natural synergy between TMN and OMNIPoint due to their mutual reliance on OSI Management specifications, the NMF and the ITU-T JCG-TMN are exploring how NMF work might complement the TMN work in the ITU-T. The current emphasis is on conformance, profiles, and ISPs. In addition, the NMF has developed an OMNIPoint program to speed TMN implementation.

Telecommunication Industry Use of TMN — Selected Examples
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. Initial TMN studies have focused on the economics and other factors of several organizational strategies. TMN interface standards published by ETSI and ITU-T and other specifications have been identified for use and complementarily activities necessary for a complete TMN implementation initiated, with an emphasis on network and service management.

Belcore (an R & D arm of seven major U.S. SPS) has been a major force in global and U.S. standards bodies and has also established de facto standards for its owners. In keeping with its leading role, Belcore has specified the use of key TMN Recommendations, such as M.3100, G.774, and G.821, in its specifications for SONET management, and planned their availability on its SONET management system. Belcore has also participated in interoperability demonstrations of TMN-based implementations [5].

Major TMN Challenges and New Directions
TMN Management Layers
As noted above, the current TMN architecture in M.3010 contains an example of layering of TMN management functionality, specifically identifying layers for business, service, network, and element management as shown in Fig. 2. Primarily as a result of the application of TMN to SDH/SONET and ATM subnetwork management, the importance and role of element management is under intensive study both in and out of standards bodies [6], and the so-called “example” has achieved significant high-level, global acceptance while the details and role of each layer remain under discussion. One conclusion drawn thus far by some as a result of this discussion is that the focus of TMN information modeling in the future should be to support network and service layer management functionality.

SNMP/CMP Interworking for ATM Management
Because end users will expect seamless, end-to-end management of their ATM-based services, it is recognized that the interworking of CMP with the Simple Network Management Protocol (SNMP), the other significant open systems protocol for management, is essential. Such interworking is especially relevant for communications between the public network TMN and private network management systems. A generic need for this interworking was recognized early by the NMF and is addressed by several OMNIPoint specifications. And the NMF is also in the process of applying these specifications to the problem of ATM management.

Several organizations have and are continuing to play key global roles in the implementation of OSI Management standards, namely, the NMF and the OSI Regional Workshops.
Open Distributed Management

Currently, TMN, as based on the OSI Systems Management architecture in X.701, supports communication between a single manager and a single agent. While this is initially sufficient for TMN, an architecture and supporting infrastructure based on open distributed management concepts and techniques that supports communication among multiple managers and multiple agents is more powerful. This would allow, e.g., one manager to invoke an atomic operation across several agents. Related architectural and protocol activities are in progress in ISO/IEC and SG 7.

The application of Open Distributed Processing (ODP) to OSI Management and TMN is expected to have a major impact as well, but the full extent of this impact remains to be determined. SG 15 is already studying the use of ODP as a specification tool for network level information modeling of SDH networks.

Conclusion

The implementation of uniform interfaces based upon ITU-T TMN Recommendations is an essential step toward addressing the telecommunications OAM&P needs of the 1990s, and industry demonstrations have shown that they are a reality today for one new technology: SDH/SONET.

OSI Management currently provides the framework for TMN, and with its evolution toward open distributed management, it will be well placed to continue that role. However, technology is advancing rapidly toward support of broadband and personal communications. Concurrently, the needs of the primary users of TMN standards, public network telecommunication SPs, are rapidly evolving in a deregulated marketplace as their customers demand seamless public/private telecommunication management. Consequently, the TMN interface standardization process must remain open to new directions and ideas, while at the same time the current TMN work program is progressed at a greater pace than before.

References

The following references provide a bibliography of resources which are themselves good sources of other TMN-related references:


Biography

Dave L. Seck is a manager, OAM Standards, at BNR (the R & D arm of Northern Telecom, Inc.), Research Triangle Park, North Carolina, where he has the responsibility for TMN standards planning. He has participated in the formulation of TMN standards in the ITU-T and TMF since 1986. Within the ITU-T, he is currently chair of the TMN Working Party in SG 4 and of the Joint Coordination Group on TMN. Prior to joining BNR in 1989, he was with AT&T, where he established requirements for switching systems and for several switching operations systems, and also participated in TMN and Multi-Protocol Language standards. He received B.S. and M.S. degrees in electrical engineering from Michigan State University and New York University, respectively, and is a member of Tau Beta Pi.