# Telecommunications Management Network (TMN)

## Definition

The telecommunications management network (TMN) provides a framework for achieving interconnectivity and communication across heterogeneous operating systems and telecommunications networks. TMN was developed by the International Telecommunications Union (ITU) as an infrastructure to support management and deployment of dynamic telecommunications services.

## Overview

The telecommunications industry is seeing rapid and ongoing change. With emerging technologies, deregulation, and increased consumer demand, companies are presented with a wide range of opportunities and challenges. As companies unify their networks and systems, they must merge new technologies and legacy systems. This is no small task, as a company's networks may encompass analog and digital systems, multiple vendor equipment, different types of subnetworks, and varied management protocols.

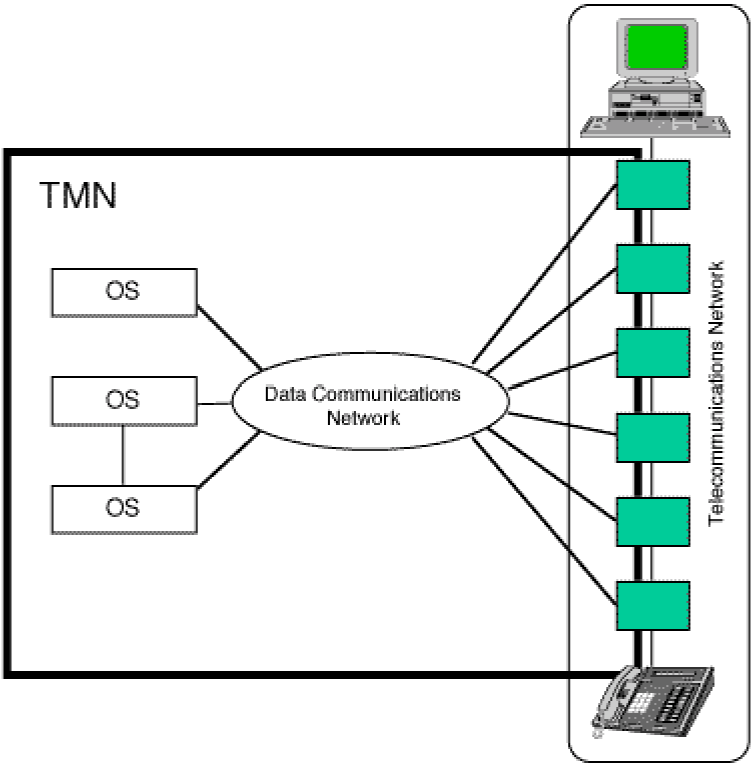
## Topics

# 1. TMN Framework

TMN provides a framework for networks that is flexible, scalable, reliable, inexpensive to run, and easy to enhance. TMN provides for more capable and efficient networks by defining standard ways of doing network-management tasks and communicating across networks. TMN allows processing to be distributed to appropriate levels for scalability, optimum performance, and communication efficiency.

TMN principles are incorporated into a telecommunications network to send and receive information and to manage its resources. A telecommunications network is comprised of switching systems, circuits, terminals, etc. In TMN terminology, these resources are referred to as network elements (NEs). TMN enables communication between operations support systems (OSS) and NEs.

**Figure 1. How the TMN Fits into a Telecommunications Network**



## The TMN Standard

TMN is defined in the International Telecommunications Union–Telecommunications Services Sector (ITU–T) (formerly known as the Comité Consultatif Internationale de Télégraphique et Téléphonique [CCITT]) M.3000 recommendation series. When telecommunications networks implement the TMN definitions, they become interoperable, even when interacting with the networks and equipment of other telecommunications service providers. Ultimately, interoperability can be achieved across all managed networks.

TMN uses object-oriented principles and standard interfaces to define communication between management entities in a network. The standard management interface for TMN is called the Q3 interface.

TMN architecture and interfaces, defined in the ITU M.3000 recommendation series, build on existing open systems interconnection (OSI) standards. These standards include, but are not limited to:

- **common management information protocol (CMIP)**—defines management services exchanged between peer entities
- **guideline for definition of managed objects (GDMO)**—provides templates for classifying and describing managed resources
- **abstract syntax notation one (ASN.1)**—provides syntax rules for data types
- **open systems interconnect reference model**—defines the seven-layer OSI reference model

Since their publication, the TMN standards have been embraced and promulgated by other standards bodies, most notably by the Network Management Forum (NMF), Bellcore, and the European Telecommunications Standards Institute (ETSI). In general, the NMF and Bellcore efforts are directed toward accelerating implementation and providing a generic framework for establishing detailed requirements. At the same time, technology-centric forums such as the Synchronous Optical Network (SONET) Interoperability Forum (SIF) and the Asynchronous Transfer Mode Forum (ATMF) are specifying TMN–compliant management interfaces.

## TMN, OSI, and Management

TMN is based on the OSI management framework and uses an object-oriented approach, with managed information in network resources modeled as attributes in managed objects. Management functions are performed by operations comprised of common management information service (CMIS) primitives.

A network's managed information, as well as the rules by which that information is presented and managed, is referred to as the management information base (MIB). Processes that manage the information are called management entities. A management entity can take on one of two possible roles: manager or agent.

Manager and agent processes send and receive requests and notifications using the CMIP.

## TMN: Several Viewpoints

The benefits of TMN (multivendor, interoperable, extensible, scalable, and object-oriented) are important because they allow companies to manage complex and dynamic networks and services, and they allow those same companies to continue to expand services, maintain quality, and protect legacy investments. TMN describes telecom network management from several viewpoints: a logical or business model, a functional model, and a set of standard interfaces. Each of these is critically important and interdependent.

# 2. The TMN Functional Model

The TMN enables telecommunication service providers to achieve interconnectivity and communication across operating systems and telecommunications networks. Interconnectivity is achieved via standard interfaces that view all managed resources as objects.

## TMN Building Blocks

The TMN is represented by several building blocks that provide an overall embodiment of the management issues and functions of TMN. *Figure 2* illustrates the building blocks in TMN.

**Figure 2. TMN building blocks**

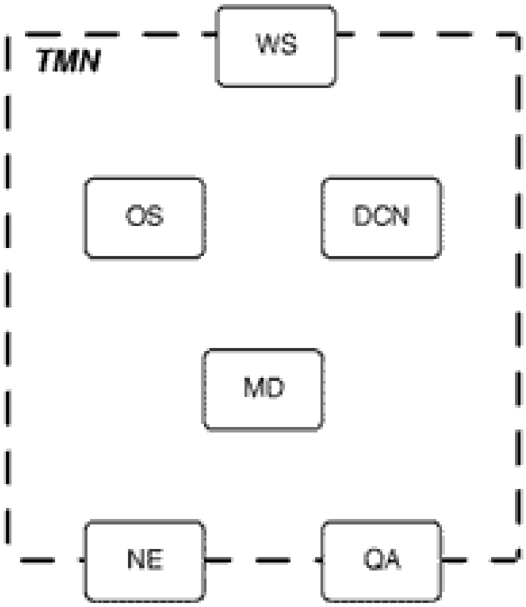


*Table 1* lists and describes each TMN component and the function that it performs. In some cases, functions may be performed within other system components. The mediation device (MD), for instance, may also provide some of the functions defined as operations systems (OSs), Q-adapters (QAs), and workstations (WSs). In addition, the OS may also provide some of the MDs, QAs, and WSs.

**Table 1. Functional Components**

| System Component | Description |
|---|---|
| OS | performs operations system functions, including operations monitoring and controlling telecommunications-management functions; the OS can also provide some of the mediation, q-adaption, and WS functions. |
| MD | performs mediation between local TMN interfaces and the OS information model; mediation function may be needed to ensure that the information, scope, and functionality are presented in the exact way that the OS expects. Mediation functions can be implemented across hierarchies of cascaded MDs. |
| QA | The QA enables the TMN to manage NEs that have non–TMN interfaces. The QA translates between TMN and non–TMN interfaces. A TL1 Q-adapter, for example, translates between a TL1 ASCII message-based protocol and the CMIP, the TMN interface protocol; likewise, simple network management protocol (SNMP) Q-adapter translates between SNMP and CMIP. |
| NE | In the scope of TMN, an NE contains manageable information that is monitored and controlled by an OS. In order to be managed within the scope of TMN, an NE must have a standard TMN interface. If an NE does not have a standard interface, the NE can still be managed via a Q-adapter. The NE provides the OS with a representation of its manageable information and functionality (i.e., the MIB). Note that the NE contains NE functionality—that is, the functions required in order to be managed by an OS. As a building block, the actual NE can also contain its own OS function, as well as QA function, MD function, etc. |

| | |
|---|---|
| WS | The WS performs workstation functions. WSs translate information between TMN format and a displayable format for the user. |
| data communication network (DCN) | The DCN is the communication network within a TMN. The DCN represents OSI layers 1 to 3. |

# Distribution Of TMN Management Functions

One type of management activity can be broken into a series of nested functional domains, each of which can exist in the same or separate logical layers. Each functional domain is under the control of an OS. Because management can be divided among OSs within the TMN environment, distributed management tasks can occur. One user transaction might encompass several management tasks. The logical layers enable that transaction to be processed across several OSs in a tree-like but nested hierarchy. Note that functional domains are nested within one another, and OS functional blocks communicate with each other. The layers may be distributed to recursive subordinate OSs within one TMN environment.

# OSI Functionality in TMN

## Stack Support

TMN defines a message communication function (MCF). All building blocks with physical interfaces need to have an MCF. An MCF provides the protocol layers necessary to connect a block to a DCN (i.e., Layers 4 to 7). An MCF can provide all seven OSI layers, and it can provide protocol convergence functions for interfaces that use some other layer configurations (e.g., a short stack).

## Manager and Agent Roles

TMN function blocks can act in the role of a manager and/or agent. The manager/agent concepts are the same as those used for CMIP and OSI management. In other words, a manager process issues directives and receives notifications, and an agent process carries out directives, sends responses, and emits events and alarms. As shown below, a building block may be viewed as a manager to one peer, even though it is viewed as an agent to another peer.

# 3. The Standard Interfaces

In the TMN model, specific interfaces between two TMN components communicate with one another. The TMN interfaces are as follows:

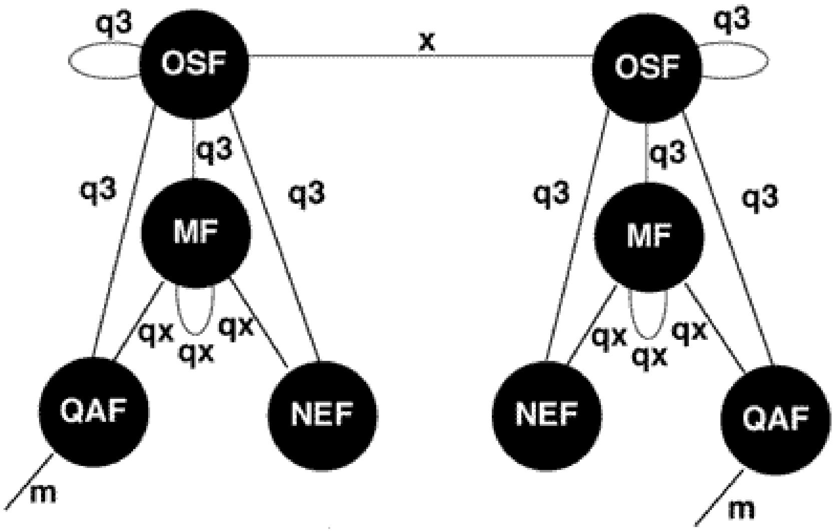
**Table 2. TMN Interfaces**

| | |
|---|---|
| **Q** | The Q interface exists between two TMN–conformant functional blocks that are within the same TMN domain. The Qx carries information that is shared between the MD and the NEs that it supports.<br>The Qx interface exists between the NE and MD; QA and MD; and MD and MD. The Q3 interface is the OS= interface. Any functional component that interfaces directly to the OS uses the Q3 interface. In other words, the Q3 interface is between the NE and OS; QA and OS; MD and OS; and OS and OS |
| **F** | The F interface exists between a WS and OS, and between a WS and MD |
| **X** | The X interface exists between two TMN–conformant OSs in two separate domains, or between a TMN–conformant OS and another OS in a non–TMN network. |

Two other reference points, g and m, are outside the scope of TMN. They are between non–TMN entities and the non–TMN portion of the WSF and QAF, respectively.

In *Figure 3*, each line represents an interface between two TMN components.

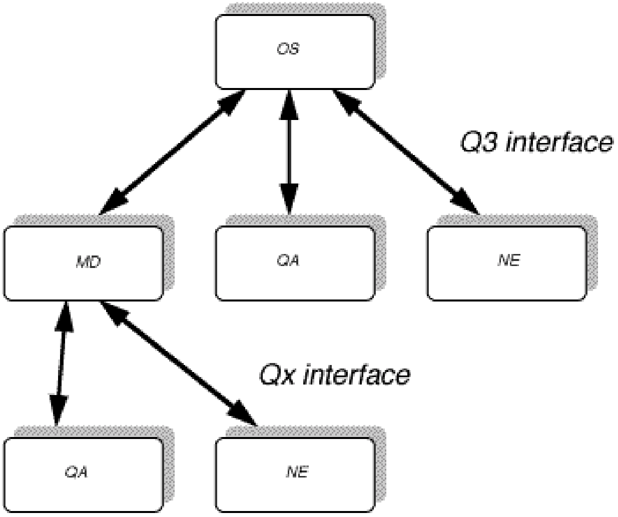
**Figure 3. Standard Interfaces Between TMN Components**



## More About the Q Interfaces

There are two classes of Q interfaces: Q3 and Qx. *Figure 4* illustrates which function blocks can communicate via which Q interface.

**Figure 4. Q Interfaces**



### Q3 Interface

The Q3 interface is the lifeline to the operations system—Q3 is the only interface that QAs, MDs, or NEs may use to communicate directly with the OS. If a QA or NE does not use the Q3 interface, it cannot communicate directly with the OS; instead, it must communicate via an MD.

### Qx Interface

The Qx interface always operates with a MD. It never takes the place of a Q3 interface. The MD can interpret between local management information provided by a Qx interface and the OS information provided by a Q3 interface.

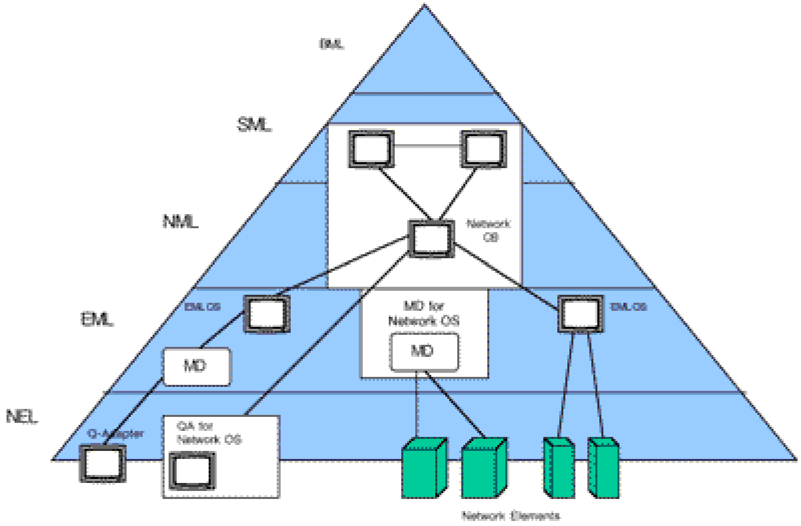
# 4. The TMN Logical Model

TMN supplies a model of logical layers that define or suggest the management level for specific functionality. The same type of functions can be implemented at many levels, from the highest level, which manages corporate or enterprise goals, to a lower level, which is defined by a network or network resource. Starting with the bottom level, these hierarchy layers include NEs, element-management layer (EML), network-management layer (NML), service-management layer (SML), and business-management layer (BML). Once management is defined at the lower layers, additional management applications can be built on this foundation.

**Table 3. Logical Layers**

| Layer | Concerned with |
|---|---|
| BML | high-level planning, budgeting, goal setting, executive decisions, business-level agreements (BLAs), etc. |
| SML | uses information presented by NML to manage contracted service to existing and potential customers; this is the basic point of contact with customers for provisioning, accounts, quality of service, and fault management. The SML is also the key point for interaction with service providers and with other administrative domains. It maintains statistical data to support quality of service, etc. OSs in the SML interface with OSs in the SML of other administrative domains via the X interface. OSs in the SML interface with OSs in the BML via the Q3 interface. |
| NML | The NML has visibility of the entire network, based on the NE information presented by the EML OSs. The NML manages individual NEs and all NEs as a group. In other words, the NML has the first managed view of the network. The NML coordinates all network activities and supports the demands of the SML. OSs in the NML interface with OSs in the SML via the Q3 interface. |
| EML | manages each network element; the EML has element managers, or OSs, each of which are responsible for the TMN–manageable information in certain NEs. In general, an element manager is responsible for a subset of the NEs. An element manager manages network element data, logs, activity, etc. Logically, MDs are in the EML, even when they are physically located in some other logical layer, such as the NML or SML. An MD communicates with an EML OS via the Q3 interface. In addition, an EML OS presents its management information from a subset of the NEs to an OS in the NML through the Q3 interface. |
| network-element layer (NEL) | The NEL presents the TMN–manageable information in an individual NE. Both the Q-adapter, which adapts between TMN and non–TMN information, and the NE are located in the NEL. In other words, the NEL interfaces between the proprietary manageable information and the TMN infrastructure. |

**Figure 5. Example: TMN Components Across the Logical Layers**



# 5. TMN Solutions

The key challenge for service providers, original equipment manufacturers (OEMs), software vendors, and integrators is to develop TMN–conformant, robust applications that can perform varied network management operations in a changing, multivendor, multiplatform network. Service providers and independent software vendors need to deploy solutions that:

1. reduce time to market
2. reduce cost
3. support increasing demands for higher quality
4. incorporate legacy systems and are future-proof
5. conform to industry standards for TMN

## Integrating Legacy Equipment

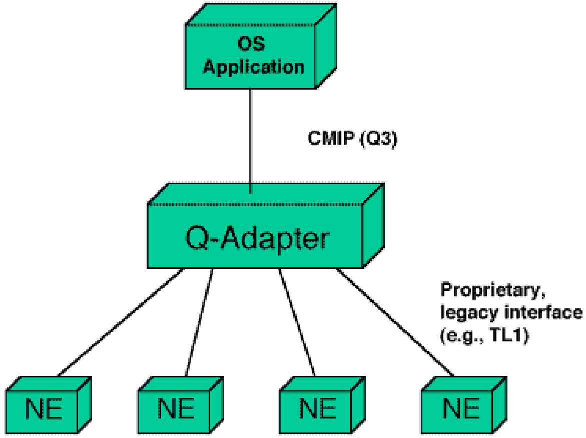
Legacy network equipment and systems, which are generally not TMN–conformant, understand ASCII messages, not TMN–conformant operations. The ASCII messages are often proprietary to a specific vendor or platform. TMN's standard interfaces provide for a machine-readable, programmatic interface to an NE's ASCII message-based or bitstream, informally-defined information model.

By defining standard interfaces, TMN does not mandate that network elements themselves be replaced with CMIP–conformant hardware or management messages. By allowing for intelligent mediation components, Q-adapters, and MDs, TMN enables companies to bring all systems and equipment into a distributed, scalable, and interoperable managed solution.

A Q-adapter can impose a machine-readable, object-oriented structure on a flat proprietary or legacy information model. An example of an NE with an informal, flat information model would be an NE that is managed by ASCII–based TL1 messages. These messages are human-readable, but are formally defined only as hard-copy message definitions.

By using a Q-adapter to derive information from messages, and then interpreting between that information and an object-oriented, machine-readable form, a systems developer can expose a machine-manageable interface to the OS.

**Figure 6. A Q-adapter Translates Between CMIP/Q3 and Proprietary Interfaces**



Another use for a Q-adapter would be the integration of a legacy enterprise network into the TMN infrastructure. Most enterprise networks manage resources by using the SNMP services. By adapting between SNMP and CMIP, the legacy network can be brought into the TMN realm.

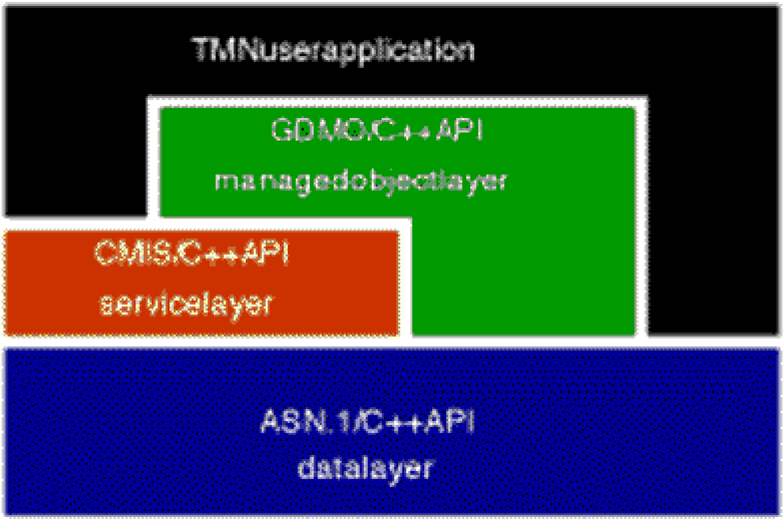
Sometimes Q-adaption is all that is needed to convert an NE's interface to one that an OS can use. Often, however, further refinement is needed. A MD can further reconstitute or impose structure on this interface so that it matches the OS application's expected format.

## Standardized, Object-Oriented Programmatic Interface

The recently introduced TMN/C++ application-programming interface (API) is being promoted by NMF and is referred to as the NMF API. The NMF API offers a standardized, object-oriented API for telecommunications management applications. The architecture comprises three modular, layered APIs.

- A managed object interface (the GDMO/C++ API) provides a framework for accessing and implementing managed objects in a hierarchical, tree-like model.
- A service interface (the CMIS/C++ API) provides for the basic management information model services, which include:
  - the sending and receiving of requests and responses that create and delete objects, as well as get and set their attributes
  - the reporting of events that occur in the network
- A data interface (the ASN.1/C++ API) defines a role-independent interface to the data itself and to its encoding.

**Figure 7. NMF's TMN/C++ High-Level API**



Prior to the NMF API, there were already some widely accepted standard APIs for TMN applications. The most common was XMP/XOM, which provided a C-language API for managing objects. The utility of XMP/XOM as an API in the TMN domain, however, was hampered by its high degree of abstraction. It was and is generally perceived as difficult to use, and most TMN platforms that boast XMP/XOM compliance also offer more easy-to-use API layers to hide it.

The NMF API overcomes the difficulties of this previous API, and provides a more natural development language (C++), straightforward interfaces, and platform-independent exposed interfaces. The NMF API provides the following advantages:

- The NMF API's platform-independent API has reusable C++ classes, so interface codes can be reused across diverse applications from built-in NE agents to large applications for SML platforms. This reduces time to market, lowers development costs, and shortens the learning curve for a development team.

The NMF API also supports two distinct application types: specific and generic. Specific applications implement a static information model. Generic applications provide for changing management information and dynamically interpret network changes into the information model.

- Ease of use mandates that the programming language be the most natural for expressing the nature of managed resources as objects, so the NMF API uses the C++ language. C++, with its compartmentalized class representation, exposes the network's information model but hides its complexities behind the public methods and data types of specific classes.

- The NMF API provides for complete representation of the TMN model GDMO, common management-information service element (CMISE), and ASN.1. Development efforts do not need to restrict functionality or to impose unnecessary limitations based on some subset of the information model.

## Tools to Automate TMN–Conformant Application Building

Tools are available that automate the task of building TMN–conformant agent or manager applications. TMN agent and manager toolkits can be implemented and customized to match your company's GDMO/ASN.1 MIB representations. These products should have the following features in order to maximize the advantages of TMN and to most productively support a TMN infrastructure:

- **dynamic information modeling**—the ability to add or change the network configuration or functionality without reinstalling or recompiling applications and implementations

- **automated prototyping**—tools that can compile GDMO/ASN.1 information models and produce model-specific exposed C++ interfaces and other required reports and data formats

- **system-management functions (SMFs)**—generate, filter, forward, and log incoming events and alarms

- **platform-independent interfaces and tools**—testing and simulation tools that focus on the behavior of a manager or agent, not on its implementation; these tools should be able to act in the role of agent, manager, or both. MIB–building tools that help the developer to construct a GDMO/ASN.1–conformant information model for any managed network.

- **Q-adaption capability or compatibility**—the ability to interface to and thus integrate legacy NEs (such as TL1 message-based equipment types) as well as enterprise network systems (SNMP–based information)

- **conformance to all TMN standards**—implementation of service, data, and managed object layers of the NMF API, and support for specific and generic application types

# 6. Conclusion

Companies need to continue to operate at the cutting edge of today's industry and to gain footholds in emerging technologies. By understanding TMN concepts, implementing TMN management applications, and building a TMN infrastructure, companies can maximize the value of current systems and equipment and be ready for the future.

# Self-Test

1. In TMN terminology, the switching systems, circuits, terminals, etc., which comprise a telecommunications network, are known as __________.

   a. OSS

   b. NEs

   c. MDs

   d. Q adapter

2. A network's managed information and the rules by which that information is presented and managed is referred to as __________.

   a. MIB

   b. CMIP

   c. GDMO

d. ASN.1

3. What TMN functional block can impose a machine-readable, object-oriented structure to an NE's proprietary or legacy information model?

   a. NE

   b. OSs

   c. Q-adapter

   d. WS

4. How many OSI layers are there in a TMN network?

   a. three

   b. six

   c. eleven

   d. seven

5. Most TMN function blocks can function as both managers and agents.

   a. true

   b. false

6. The Q3 interface is the only interface that the QAs, MDs, or NEs may use to communicate directly with the OS.

   a. true

   b. false

# Correct Answers

1. In TMN terminology, the switching systems, circuits, terminals, etc., which comprise a telecommunications network, are known as __________.

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# Glossary

**ASN.1**
abstract syntax notation one

**API**
application-programming interface

**ATM**
asynchronous transfer mode

**ATMF**
Asynchronous Transfer Mode Forum

**BLA**
business-level agreements

**BML**
business-management layer

**CCITT**
Comité Consultatif Internationale de Télégraphique et Téléphonique

**CMIP**
common management information protocol

**CMIS**
common management-information service

**CMISE**
common management-information service element

**DCN**
data communication network

**EML**
element-management layer

**ETSI**
European Telecommunication Standards Institute

**GDMO**
Guideline for Definition of Managed Objects

**ITU**
International Telecommunications Union

**ITU–T**
International Telecommunications Union–Telecommunications Services Sector

**MCF**
message communication system

**MD**
mediation device

**MIB**
management information base

**NE**
network element

**NEL**
network-element layer

**NMF**
Network Management Forum

**NML**
network-management layer

**OEM**
original equipment manufacturer

**OS**
operations system

**OSS**
operations support system

**OSI**
open systems interconnection

**QA**
Q adapter

**SIF**
Synchronous Optical Network (SONET) Interoperability Forum

**SML**
service-management layer

**SNMP**
signaling network management protocol

**TMN**
telecommunications managed network

**WS**
workstation