PAGETECH®

TMN

OTHER McGRAW-HILL TELECOMMUNICATION BOOKS OF INTEREST

Ali *Digital Switching Systems*
Ash *Dynamic Routing in Telecommunications Networks*
Benner *Fibre Channel*
Best *Phase-Locked Loops, Third Edition*
Clayton *McGraw-Hill Illustrated Telecom Dictionary*
Faynberg *Intelligent Network Standards*
Feit *TCP/IP, Second Edition*
Gallagher *Mobile Telecommunications Networking with IS-41*
Goralski *Introduction to ATM Networking*
Harte *Cellular and PCS: The Big Picture*
Harte *GSM Superphones*
Heldman *Information Telecommunications*
Heldman *Competitive Telecommunications*
Kessler *ISDN, Third Edition*
Kuruppilai *Wireless PCS*
Lachs *Fiber Optic Communications*
Lee *Mobile Cellular Telecommunications, Second Edition*
Lee *Mobile Communications Engineering, Second Edition*
Logson *Mobile Communication Satellites*
Macario *Cellular Radio, Second Edition*
Muller *Desktop Encyclopedia of Telecommunications*
Muller *Mobile Telecommunications Factbook*
Pecar *Telecommunications Factbook*
Richharia *Satellite Communications Systems, Second Edition*
Roddy *Satellite Communications, Second Edition*
Rohde et al. *Communications Receivers, Second Edition*
Russell *Signaling System #7, Second Edition*
Russell *Telecommunications Protocols*
Simon et al. *Spread Spectrum Communications Handbook*
Smith *Cellular Design and Optimization*
Smith *Practical Cellular and PCS Design*
Tsakalakis *PCS Network Deployment*
Turin *Digital Transmission Systems*
Winch *Telecommunication Transmission Systems, Second Edition*

TMN

Telecommunications Management Network

Divakara K. Udupa

McGraw-Hill
New York • San Francisco • Washington, D.C. • Auckland • Bogotá
Caracas • Lisbon • London • Madrid • Mexico City • Milan
Montreal • New Delhi • San Juan • Singapore
Sydney • Tokyo • Toronto

McGraw-Hill

A Division of The ***McGraw-Hill*** *Companies*

0-07-136943-0

The material in this eBook also appears in the print version of this title: 0-07-065815-3.

TERMS OF USE

DOI: 10.1036/0071369430

DEDICATION

To Father, Ramakrishna
Mother, Varija
Wife, Rajalakshmi
Brother, Dr. Sudhakara

This page intentionally left blank.

CONTENTS

This page intentionally left blank.

PREFACE

The telecommunications industry is intensively competitive because of liberalization and globalization of the telecommunications market. TMN is growing in importance as a means to provide a competitive edge for telecommunications service providers.

Although there is a large amount of material on TMN, unfortunately there is no good book that covers broadly most aspects of TMN. Lack of treatment of various topics of TMN in a single book motivated me to write this book.

This book focuses on how different standards relate to the TMN field. I have avoided the TMN work based on vendor-sponsored "standards" bodies and consortiums. Also, I have kept away from vendor-specific products that can quickly become obsolete. The alliances formed by leading vendors change frequently, and giving much importance to them is not appropriate while covering TMN in a general manner.

Objectives

To use this book, a certain amount of basic knowledge of computer networking and telecommunications is assumed, since there are many good books on these two topics. Here I would like to mention that a smooth and logical flow to many different TMN standards and protocols is maintained. I have also provided some insight into the issues of architecture, design, and implementation.

The rapid changes occurring in the computer and telecommunications industry are also having their impact on TMN. For this reason, I include discussions on some important topics such as CORBA, Java and the World Wide Web. For those interested in these developing areas, the discussions that center on these topics should lay the groundwork for further reading.

Comprehensive references are supplied at the end of each chapter. In addition, several chapters end with a list of further reading materials to enable the reader to further pursue a given topic. Also, Appendix A contains lists of important Web sites, and how to procure the pertinent standards. I have listed important and useful TMN standards in Appendix B.

This should be a useful reference material and pointer to those who wish to pursue further the subject matter covered in this book.

There are exercises for each chapter in Appendix C. Solving these should enable the reader to get a firm grip on the topics discussed here. Some exercises are complex and time consuming, suitable for independent study courses. My primary objective for including the exercises is to cultivate the spirit of innovation and to develop creative problem-solving skills.

Intended Audience

This is an introductory book with a wide range of TMN topics. It should serve to generate a keen interest and gain a good depth on the subject of TMN. This book is intended for the following audience:

- Telecommunications industry professionals interested in TMN.
- Architects, designers and implementors of TMN.
- Computer professionals interested in TMN.
- Undergraduate and graduate level TMN courses. TMN is sufficiently mature and should become a part of computer science, electrical and telecommunications courses.

How to Use the Book

This book has been logically organized. Those who know ASN.1, BER, GDMO, and M.3100 well may skip Chapters 5 and 6. Readers are encouraged to read Chapters 11 and 12 which cover many important and interesting topics. Basic material and different versions of SNMP are covered in Chapter 8. Those who are interested more in Internet Network Management should refer to the RFCs listed in the chapter references, or to other literature on Internet Network Management, found in the Further Reading section of Chapter 8.

How the Book Is Organized

TMN is a vast area. Therefore it is difficult to cover all the aspects of TMN in a single book. So I have focused on the important areas of TMN in order to provide a good insight into the subject. Those interested in specific details should consult the references listed at the end of each chapter and in Appendix B. With these points in mind, we will cover TMN concepts in Part 1, the TMN information model and TMN protocols in Part 2, and TMN applications in Part 3. See the following chart for an overview of the structure of the book.

Telecommunications Management Network

- Part 1: TMN Concepts
  - Chapter 1. TMN Overview
  - Chapter 2. TMN Architecture, Interfaces, OAM&P, and CNM
  - Chapter 3. TMN Management Services and TMN Functions
- Part 2: TMN Information Model and Protocols
  - Chapter 4. TMN Terms and Concepts
  - Chapter 5. Abstract Syntax and Transfer Syntax
  - Chapter 6. Structure of Management Information and TMN Information Model
  - Chapter 7. ACSE, ROSE, CMISE, and CMIP
  - Chapter 8. Internet Network Management: SNMPv1, SNMPv2, and SNMPv3
- Part 3: TMN Applications
  - Chapter 9. Network Management for Mobile Communications
  - Chapter 10. Broadband Network Management
  - Chapter 11. Recent Trends: Distributed Network Management, CORBA, Java, Web, and TMN
  - Chapter 12. Software Management Frameworks, TMN Challenges, and Trends
- Appendix A
  - How to Keep Up to Date and Procure the Latest TMN Standards
- Appendix B
  - Important TMN and Network Management Standards
- Appendix C
  - Suggested Exercises

Part 1: TMN concepts. Part 1 is primarily devoted to introducing to the topic of TMN. It forms the basis for understanding the other parts.

Chapter 1 contains an overview of basic TMN concepts. It begins by defining TMN and exploring the evolution of TMN. We furnish a brief overview of standards bodies and consortiums that have an impact on TMN, and introduce the concept of managers and agents right in the beginning, as it is an important concept in network management. Then we look into different ITU-T TMN layers such as business management, service management, network management, element management, and network elements.

Chapter 2 basically covers functional architecture, physical architecture, and information architecture. In this chapter, we look into TMN physical components such as the OS, DCN, MD, WS, NE, and QA; reference points such as q, f, x, g, and m; and interfaces such as Qx, Q3, X, and F. The ANSI-defined operations, administration, maintenance, and provisioning (OAM&P) category is useful as an insight into network management in telecommunications area. This chapter ends with a brief introduction to customer network management (CNM).

The topic of TMN management services and TMN functions is interestingly quite different from data communication network management and SMFAs. Chapter 3 is devoted to TMN management services and functions.

Part 2: TMN information model and TMN protocols. Part 2 covers how the equipment involved in resources in telecommunications networks can be modeled as managed object classes. Equipment, along with the managed objects that can be manipulated by managers, are modeled as network elements. The manipulation of managed objects in NEs are performed by managers using different management protocols. With these points as the basis for our discussions, we cover the important standards used for modeling and the management protocols such as CMIP and SNMP.

Chapter 4 discusses important TMN-related ITU-T terms such as management information hierarchies, object naming, scoping, filtering, MIBs, and directories.

Chapter 5 concerns explanations of ASN.1 and BER.

Chapter 6 is devoted to the structure of management information (GDMO, X.722). In this chapter, we discuss how to define managed object classes, and also TMN-specific M.3100, the Generic Network Information Model.

In Chapter 7, we discuss at length the ITU-T management protocol CMIP and ACSE.

In addition to the ITU-T management protocols, Internet management protocols such as SNMPv1, SNMPv2, and SNMPv3 are also used in the telecommunications industry. Chapter 8 is devoted to these protocols. This chapter ends with a discussion of comparison of the CMIP and SNMP.

Part 3: TMN applications. It is not enough to investigate information modeling and management protocols. It is also necessary to determine how these are being applied in real life. For this reason, we examine how different TMN standards are applied in mobile communications, SONET, SDH, and ATM. Part 3 also discusses the impact of CORBA, the World Wide Web (WWW), and Java on TMN. Also included are management frameworks used in building managers, agents, and TMN applications. No book on TMN would be complete without discussion of the challenges and trends in TMN.

Chapter 9 covers network management for mobile communications. ANSI and GSM standards for management are important aspects of the discussion.

Chapter 10 describes TMN for SDH, SONET, and ATM.

Recent advances in distributing network management are very appealing from the scalability aspect of network management solutions. So we devote a good amount of discussion to distributed network management, and to how we can incorporate CORBA in TMN solutions. Chapter 11 is devoted to some of these important topics. Also, TMN solutions are being influenced by advances in the Web and Java. These issues are covered in detail in this chapter.

The last chapter is devoted to TMN topics such as object-oriented toolkits and challenges in TMN. This chapter ends with a discussion of how TMN is going to evolve in future.

There are continuous changes and advances in the TMN area. It is essential to keep up to date. The amount of knowledge update required by professionals can be daunting. So there is a need for access to the latest material on TMN and other significant areas. This is the primary motivation for including this information in Appendix A.

Appendix B contains a list of important TMN documents for easy reference.

Appendix C provides suggested exercises for each chapter to aid in achieving a better understanding of the material presented in this book. There are also some challenging exercises that may be used for independent study courses on TMN.

This page intentionally left blank.

ACKNOWLEDGMENTS

I would like to warmly thank Steve Chapman, the editor of the book. He was very patient, understanding, and very encouraging despite my missing many deadlines. I also like to thank other staff members including the editorial board of the McGraw-Hill for giving me the opportunity to write the second book for them. Thanks also to copyeditor Stephanie S. Landis, paginator Lisa Kochel, and art director Patti Kahler, all of North Market Street Graphics, for doing an excellent job.

Notice that I have used of many standards developed by various standards bodies. These standards are the collective effort of many leaders in the industry who devoted much time, energy and effort to develop them. I have presented their work in this book in the best possible manner. While taking the blame for any mistakes, I would like to sincerely thank the vast number of original contributors to the standards.

As this book relies heavily on standards, I have made use of ITU-T, OSI, ETSI, ANSI, ATM Forum standards, and Internet RFCs. Wherever required I have acquired the necessary permission. I would like to thank the following organizations for granting permission to reproduce or adapt material from their copyrighted publications:

- The International Telecommunication Union (ITU) has granted permission to modify material for which they hold the copyright. The selection of material is my sole responsibility and can in no way be attributed to the ITU.
  - Figure 2-1 is modified from Figure 1, "General relationship of a TMN to a telecommunication network," of ITU-T Recommendation M.3010 (5/96), "Principles for a Telecommunications management network."
  - Figure 2-4 is modified from Figure 5, "Example of typical Functional Blocks containing Functional Components," of ITU-T Recommendation M.3010 (5/96), "Principles for a Telecommunications Management Network."
  - Figure 2-5 is modified from Figure 4, "Relative roles of MCF and DCF," of ITU-T Recommendation M.3010 (5/96), "Principles for a Telecommunications Management Network."
  - Figure 2-6 is taken from Figure 14, "An example of a simplified physical architecture for a TMN," of ITU-T Recommendation

M.3010 (5/96), "Principles for a Telecommunications management network."

- Figure 2-8 is modified from Figure 12, "Sharing management knowledge between systems," of ITU-T Recommendation M.3010 (5/96), "Principles for a Telecommunications management network."
- Figure 2-10 is taken from Figure 1, "Functional Architecture of Customer Network Management," of ITU-T Recommendation X.160 (10/96), "Architecture for customer network management service for public data networks."
- Figure 2-11 is taken from Figure 4, "Example 3 of Physical Architecture," of ITU-T Recommendation X.160 (10/96), "Architecture for customer network management service for public data networks."
- Figure 10-3 is modified from Figure 3-4, "TMN, SMN, SMS model," of ITU-T Recommendation G.784 (1/94), "Synchronous Digital Hierarchy (SDH) Management."
- Table 7-6 is modified from Table 4, "Correspondence between CMISE primitives and CMIP Operation," of ITU-T Recommendation X.711 (3/91), "Common management information service definition for CCITT applications."

- The Institute of Electrical and Electronic Engineers, Inc (IEEE) has granted permissions as related to the following figures.
  - Figure 2-2 is modified from Figure 3.2 (page 76), "TMN Function Blocks and Reference Points," of *Telecommunications Network Management into the 21st Century* (1994), edited by Salah Aidarous and Thomas Pleyvak.
  - Figure 2-9 is from Figure 10.1 (page 303), "OAM&P/OSI Functions," of *Telecommunications Network Management into the 21st Century* (1994), edited by Salah Aidarous and Thomas Pleyvak.
  - Figure 9-2 is taken from Figure 1 (page 122), "GSM Architecture," of *IEEE Communications Magazine* (vol. 35, no. 10, October 1997) "General Packet Radio Service in GSM," by Jian Cai and David J. Goodman.
  - Figure 12-1 is modified from Figure 3.4 (page 120), "Platform Components," of *Telecommunications Network Management Technologies and Implementations* (1998), edited by Salah Aidarous and Thomas Pleyvak.

I thank McGraw-Hill for permitting me to use the materials in Chapters 3, 4, 5, 6, 8, and 10 from my book *Network Management Systems Essentials.* I have updated and revised a good amount of materials in these chapters.

I thank the reviewers of different chapters of the book. A good review is very essential to flush out technical mistakes and turn the book into a good one. I would like to thank Dr. Raymond Raud, Dr. Ingo Busse of GMD FOKUS, Ferenc Kocsic of Ericsson-Hewlett Packard Telecommunications, Tetsuya Yamamura of NTT Network Service Systems Laboratories, Dr. Dev Roy of Siemens Information and Communication Networks, and Dr. Ravi Shankar of Motorola for carefully reading and providing very good comments on the chapters they reviewed. Whatever mistakes remain in this book, I am responsible for them.

I would like to thank my managers Pedro Bello, and Joe McGhee of Siemens Information and Communication Networks, for extending me help in writing this book.

My thanks to readers of my first book, *Network Management Systems Essentials*, who quickly made it a success.

—DIVAKARA K. UDUPA

This page intentionally left blank.

PART 1

TMN Concepts

www.pcltools.com

www.pcltools.com

This page intentionally left blank.

www.pcltools.com

www.pcltools.com

CHAPTER 1

TMN Overview

1.1 Introduction

The telecommunications management network (TMN) concept has become vital to the survival of telecommunications service providers because of competitive pressures. In many nations, deregulation and globalization have dramatically changed how telecommunications service providers operate. Many service providers, who were protected with complex regulations, realize all of a sudden that they have to face competition for consistent and better service at a reduced cost.

In addition to the pressures of deregulation and globalization, demand for transfer of a variety of digital data including voice and video has increased bandwidth requirements. Also, the telecommunications networks have to integrate computer networks of different configurations. Internet services are also having their impact in the telecommunications arena. The days of video and Internet phones are almost here.

To meet these new requirements of being able to carry different kinds of data at a faster rate, new technologies and improvements to the existing technologies and protocols are being introduced. Examples of some of the new technologies are the different kinds of digital subscriber line (DSL) technologies. Though standards for synchronous optical network (SONET), synchronous digital hierarchy (SDH), and asynchronous transfer mode (ATM) are well established, implementations are at varying stages. So, in many cases, the migration from plain old telephone service (POTS) has to be realized quickly by telecommunications service providers.

Different services and technologies over diverse telecommunications and computer networks make the management problem a huge ordeal. As a result, TMN becomes very critical for the success of the operation of these telecommunications and computer services.

1.2 Evolution of TMN

TMN has an expanding role when telecommunications, computers, and television are merging. In addition, in the telecommunications arena itself, more and more services are being added to the traditional telephone services offered by telephone service providers. As a result, equipment involved in providing telecommunications services is expanding and is also becoming more complex. The ability to deliver voice, video, and data at higher speeds is also becoming a critical requirement.

In addition, fiber optics and wireless communications have added their own complexity and speeds quite different from that of POTS. These days, and in the future, telecommunication switches have to handle a variety of equipment and data instead of only voice.

This complex and diverse equipment makes controlling networks and resources quite a daunting task. So TMN has been gaining ground as a panacea to solve problems involved in carrying different kinds of data at different data rates with different levels of equipment sophistication.

In the early days, network management in the telecommunications industry was mostly proprietary. These proprietary solutions were good enough for the limited services and limited geographical coverage of telecommunications service providers. Because of the regulatory and protected environments, telecommunications service providers could afford to take their time in implementing new technologies. They could control the introduction and implementation of technological solutions. However, in many nations, led by the United States, deregulation has changed the scenario. This has introduced fierce competition among telecommunications service providers.

In addition, deregulation has also provided the impetus to major telecommunications service providers to expand their area of operations. This has led them to look beyond their own national borders. This tendency toward globalization has also increased competition. Competition is becoming fierce in the area of services provided. As an example, many telecommunications service providers are offering additional services such as Internet access in addition to telephone services. We are also witnessing a mushrooming of different services such as wireless and paging services.

These illustrations show that there has been a major paradigm shift in the telecommunications industry. Proprietary network management solutions are limited in their ability to meet the challenges of this paradigm shift. Proprietary network management cannot provide interoperability between diverse technologies and network management solutions. This has made the need for standard network management solutions vital and urgent. Some proprietary network management systems can also be grouped under the classification of *legacy systems*.

However, the legacy network management systems add another problem in providing network management solutions. A high degree of investment has been made in these legacy solutions. It is difficult to discard solutions that have been working and in which heavy investments were made. This necessitates that legacy systems coexist with the new standard network management solutions.

1.3 What Is TMN?

In the telecommunications industry, TMN is a loosely used term that covers all kinds of network management solutions. However, in the strict sense, TMN refers only to network management solutions that satisfy and conform to the network management standards of the International Telecommunications Union-Telephony (ITU-T).

TMN specifies a layered architecture for management of telecommunications networks. TMN is concerned with the monitoring, control, and coordination of resources in telecommunications networks. *Resources* are components of a system that provides services. These resources can be equipment, software, hardware, or customers. The telecommunications networks include the advanced intelligent networks (AIN) as well. Some of the TMN functions are:

- Remote management of system components and the different hardware and software involved in the transmission of voice, video, graphic images, Internet data, and others.
- Providing easy interface and easy interaction with customers to configure and request the required services. The interface with customers has to take into account the different skill levels of end users or customers.
- Providing increasing automation to rectify problems concerning the resources involved and end users. Automation also includes self-healing and self-correction in networks.
- Achieving seamless integration and management of legacy equipment and protocols in different networks with the new equipment and protocols. This is very vital in regards to the new vistas being continuously unfolded by the telecommunications industry.

Telecommunications network components encompass the whole range of equipment involved in our telephone lines. Some of the components are as follows:

- Remote digital terminals
- Public and private networks, including mobile networks
- Transmission terminals
- Transmission systems
- Operations systems and their peripherals
- Digital and analog exchanges

- Area networks
- Intelligent networks
- Circuit and packet-switched networks
- Signaling terminals and systems
- Bearer services and teleservices
- Switching equipment
- Routers and gateways

In addition to the hardware, software is used to enhance the functionality of telecommunications equipment. This software has also to be managed. In this category, we can also add software applications. TMN applications themselves also need to be managed to function properly. Services provided to users include resource and service provisioning.

The role of TMN is not static and is evolving to meet new customer requirements for services and the equipment used to provide these services. As an example, in the early days telephone services covered only the transmission of voice data and provision of telephone service. However, these days there is a need for the same telephone lines or wireless services to carry voice, digital data, video, and Internet and intranet data.

To cater to the requirements of faster data, there are established protocols such as ATM, SDH, and SONET, and different DSL technologies are emerging. So TMN has to cover these new protocols and technologies as well.

1.4 TMN Standards Bodies

Having stated that TMN solutions follow ITU-T standards, let us look into the standards bodies that have an impact on TMN.

The International Organization for Standardization (ISO) defines a standard this way: "Standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose."

There are different types of standards. When discussing industry standards, there are primarily two types. One is a *de facto industry standard* and the other is a *formal standard.* When a large segment of the user population accepts or a majority of vendors use the same technical specifications, then these technical specifications are termed *de facto industry* *standards.* These de facto industry standards are the result of prominent players in an industry forming cooperative bodies and introducing products that conform to the guidelines developed by the standards bodies.

Formal standards are the result of the work of international, regional, or national standards bodies. In many cases, there is a close cooperation between these standards bodies. Also, international and regional bodies are members of national standards bodies. This is done deliberately to foster cooperation between these bodies. The International Telecommunications Union (ITU) and the ISO are examples of international standards organizations. The American National Standards Institute (ANSI) is an example of a national standards organization.

The International Electrotechnical Commission (IEC) was founded in 1906. The IEC did some pioneering work in electrotechnical standardization and currently oversees electrical and electronic engineering standardization. The ISO came into existence in 1947 and comprises many international organizations and governmental and nongovernmental agencies. The ISO works closely with the IEC. A joint ISO/IEC technical committee, JTC1, addresses standardization related to the information technology field. In the systems management arena, the ISO and IEC have published many standards that are accepted in the computer and telecommunications industry.

The ITU has its headquarters in Geneva, Switzerland and has been a specialized branch of United Nations (UN) since 1947. Its telecommunications standardization sector, known as ITU-T, was previously called the International Telephone and Telegraph Consultative Committee (CCITT). The ITU-T publishes standards on global telecommunications networks and services. ITU-T recommendations are areas of primary interest in TMN.

TMN standards are broadly divided into generic and technology/service specific areas. *Generic standards* are applicable to more than one technology or service. These are covered by the ISO and IEC. These generic ISO/IEC standards are also accepted by the ITU-T. As an example, ISO/IEC 10165-4, Guidelines for the Definition of Managed Objects (GDMO), is also known as ITU-T X.722. However, there are many TMN-related specific standards and these are the result of ITU-T work on telecommunications standards.

The European Telecommunications Standards Institute (ETSI) is a European standards organization operating under a system of technical subcommittees. One of the subcommittees, NA4, is responsible for the network architecture, operations, and maintenance principles and performance. Another subcommittee, ETSI TM2, is active in traffic management. ETSI NA4 focuses on TMN standards activity and provides input to the ITU-T. ETSI's Global System for Mobile Communications (GSM) standards are widely accepted TMN standards for wireless communication and are followed in many European countries.

In the United States, the Telecommunications Industry Association (TIA) and the Electronic Industry Association (EIA) together develop telecommunications standards. Their standards are adapted by ANSI, the standards body in the United States. T1 is the ANSI-accredited committee for developing standards for the telecommunications industry. T1M1 is the subcommittee within T1 devoted to TMN standardization. T1M1 basically adopts the ITU-T standards wherever they are available. In areas where ITU-T standards are not available, T1M1 provides input to the ITU-T.

In Japan, telecommunications standardization activities are carried out by the Telecommunications Technology Council and the Telecommunications Technical Committee. The Telecommunications Technology Council has a TMN working group and provides input to the ITU-T. The Telecommunications Technical Committee is responsible for publishing Japanese telecommunications standards and has a working group that covers relevant TMN standards that are applicable to Japan.

In the Internet arena, the Internet Activities Board (IAB) broadly guides Internet standards activities. The Internet Engineering Task Force (IETF) is a subgroup of the IAB and is responsible for the development of protocols and standardization activities related to the Internet. From a network management perspective, the development of Simple Network Management Protocol Version 1 (SNMPv1). SNMPv2 and SNMPv3 management protocols is one of the important contributions of the IETF.

In addition to the national and international standards bodies just mentioned, there are many vendor-based consortiums. These consortiums also have significant impact on TMN. The TeleManagement Forum is one such body. The TeleManagement Forum is a global consortium of over 210 leading service providers and suppliers, with a prominent role in the implementation of OSI and TMN standards. The TeleManagement Forum has different OMNIPoint releases. Each OMNIPoint release is devoted to guiding the specific needs of network management implementations. Each release explains standards and includes software development tools and implementation and procurement guides.

The Object Management Group (OMG), a nonprofit organization founded in 1989, is another industrial consortium with over 800 members. The OMG's charter is to develop technically feasible, commercially viable, and vendor-independent specifications for the software industry. Its primary focus is on object-oriented software. One of its significant contributions has been the development of technical specifications for Common Object Request Broker Architecture (CORBA). The OMG is also very active in the object-oriented database field.

The ATM Forum is an international consortium with over 700 members. It is devoted to accelerating the implementation of ATM products and services by bringing out common ATM-related standards. Its specifications are quite popular in the ATM industry.

There are many other important consortiums such as the Desktop Management Task Force (DMTF). The DMTF is devoted to the development, support, and maintenance of management standards for desktop computers and products. It was started in 1992 by some of the PC industry leaders. Now the DMTF includes most of the computer industry leaders.

The Telecommunications Information Technology Networking Architecture Consortium (TINA-C) started its activities in 1992. TINA-C is composed of telecommunications network operators, telecommunications service providers, telecommunications hardware and software vendors, and telecommunications research organizations. NTT, Bellcore, and British Telecom are the founder members of TINA-C. The primary objective of TINA-C is to reduce the cost of introducing new telecommunications network information infrastructures and services in a multiplayer and multivendor environment.

In addition, there are organizations such as Bellcore that are actively involved in telecommunications standardization. Because of the history of Bellcore, many Bell companies in the United States follow Bellcore documents.

At this juncture, a note of caution and some explanation are appropriate. In addition to the standards bodies, consortiums, and industry groups just mentioned, there are many organizations, consortiums, and bodies that tout their work as standards-based. We will not cover the work done by these bodies. In many cases the work of some of the consortiums does not have much impact in the TMN arena in the long run. Besides, some industry-formed bodies and consortiums do not command much respect in the telecommunications industry due to the short span of their existence and shifting allegiances. In some cases, proprietary standards are also touted as "industry standards." Taking these factors into consideration, we prefer to exclude many such consortiums and bodies altogether. Where it is absolutely essential, we have made only passing references to them.

1.5 Network Management, Systems Management, and TMN

Even the terms used in network management are not uniform. Different vendors and standard bodies use different terms to refer to similar activities. In the Internet arena, the term *network management* is popularly used. The Institute of Electrical and Electronics Engineers (IEEE) uses *network management* liberally to apply to the standards it publishes on layer management. The OSI and IBM use the term *systems management* in these cases.

Many network management functions are covered in TMN. In one sense, network management and TMN both mean the management of networks and services. However, in the case of TMN the focus is on the telecommunications network, equipment, and services provided to customers. In addition, in the TMN world the standards bodies have more impact and the telephone carriers have to satisfy strict national and international regulations. So most of the TMN tools, by and large, follow one form of standards or other. We say "by and large" because in the vastly expanding mobile communications arena, many vendors in the United States have their own proprietary protocols. Some in the United States follow the Bellcore documents, whereas many European nations follow the GSM standards.

In the telecommunications industry, end user configurations and services are also included as a part of TMN. So we have terms such as *service and resource provisioning* that are not found in data communication network management. We will look into the details of provisioning in Chapter 3.

1.6 Systems Management Functional Areas

In the OSI systems management arena, *systems management functional areas* (SMFAs) is a very frequently used term. The overall systems management function is broken down into easily distinguishable smaller network management functions. This breakup of systems management functions into SMFAs is done by OSI. The SMFAs are configuration management, fault management, performance management, accounting management, and security management.

Let us look into what each of these SMFAs mean. *Configuration management* is used to locate resources, including failed ones, and also to keep track of the resources and their details. Primarily, configuration management provides the support services to keep the systems and resources operational. It is necessary to clarify what is meant by configuration management. Sometimes, this term is synonymous with configuring equipment. In the systems management and TMN sense, configuration management is not the same as configuring equipment. Configuration management covers areas such as view management, topology management, software management, inventory management, and provisioning.

Fault management primarily covers the detection, isolation by analysis, and correction of unusual operational behaviors of telecommunications network and its environment. These unusual operational behaviors include conditions such as deterioration of service or error situations. Effective fault management may require that errors be logged in a database. Broadly, fault management covers areas such as problem reporting and detection, problem diagnosis, problem correction, and problem tracking. Trouble ticket application is one of the popular applications for problem tracking.

Performance management covers performance data collection, analysis of performance data, reporting of problems, and display and formatting of performance data. Performance management is also concerned with the behavior and evaluation of the effectiveness of resources.

Accounting management covers the usage of resources, controlled collection of data, and charging for the usage of these resources. The process of charging for the usage of resources is also known as *billing*.

Security management functions cover areas such as detecting security violations; tracking and reporting security violations; and creating, deleting, and maintaining security-related services such as encryption, key management, and access control. Distributing passwords and secret keys to bring up systems is also a function of security management.

For more details on these SMFAs, refer to Reference 1.1.

1.7 Managed Object, Managed Object Class, and Management Information Model

Managed object (MO), *managed object class* (MOC), and *management information model* are commonly used terms in network management. So it is best to introduce these terms at the beginning to get a better understanding of topics we are going to discuss. We will revisit these terms in detail in Chapter 6.

1.7.1 Managed Object

The data communication or TMN resources provide services. A printer, digital cross-connect, PBX, or line card within a PBX is a *resource*. A resource may be physical or logical. A printer is an example of a *physical resource*; application programs, log files, and network services are examples of *logical resources*.

The conceptual view of a resource that can be managed is known as a *managed object*. In other words, in order for a resource to be managed, it must be represented as a managed object. Sometimes, a managed object is also referred to as a *managed object instance*. A resource may be physical, such as a card in a circuit pack, or logical, such as a cross-connection map. circuitPackCard1 is an example of a managed object.

There need not be one-to-one mapping between a resource and a managed object. A resource may be modeled by more than one managed object. In this case, each managed object represents a different abstract view of a managed object. A managed object may also represent a relationship between different resources, as in the case of a network.

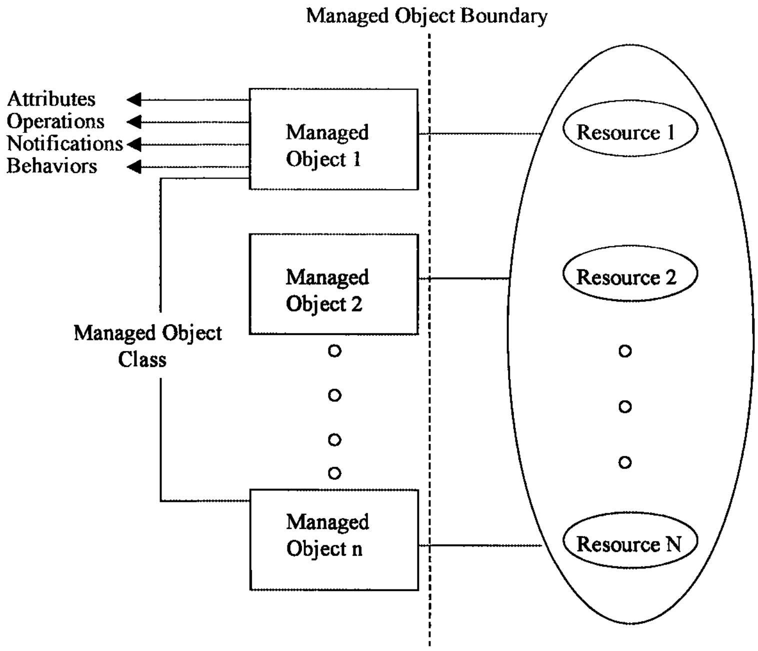
A managed object is defined by the following characteristics (Figure 1-1):

- *Attribute:* This refers to the properties of a managed object. A managed object can have one or more attributes. In the definition of a *network* managed object class (M.3100), networkId is an attribute. The type of printer—for example, dot matrix, laser jet, or laser printer—can be one of the properties; therefore, printerType is another example of an attribute. An attribute has one or more values.
- *Operation:* This is a set of activities performed on a managed object or one or more attributes to achieve a network management action. Create an object and Get an attribute value are operations. Get the value of networkId attribute of network managed object class is an example of an operation.
- *Notification:* This is an unsolicited message that contains details including why a notification has occurred, where it occurred, and for whom the notification is intended.
- *Behavior:* When the characteristics of a managed object such as attributes, operations, and notifications are defined, there must be a way to express their semantics and how they are related. This is done by behavior. Behavior is a text description.

Between a managed object and a resource, we perceive a conceptual boundary known as a *managed object boundary* (Figure 1.1). At this boundary, the characteristics of a managed object, such as attributes, operations,

www.pcltools.com
www.pcltools.com

Figure 1-1
Concepts of managed object and managed object class.



and notifications, are visible for management purposes. Items inside the managed object boundary pertaining to a resource are not needed for management purposes.

1.7.2 Managed Object Class

The common management characteristics of a group of managed objects are collected together in a managed object class. In TMN, the managed object classes are defined using principles involved in Management Information Model (X.720/ISO 10165-1), the templates provided in guidelines for the definition of managed objects (GDMO) (X.722/ISO 10165-4), and abstract syntax notation 1 (ASN.1) (X.208/ISO 8824). Separate chapters are devoted to ASN.1 (Chapter 5) and the GDMO and management information model (Chapter 6).

Of course, we have similar information models for Internet network management. However, we use the structure of management information (SMI) for defining the managed object classes. Notice that the information models for SNMPv2 and SNMPv3 extend the management information model for SNMPv1.

The process of creating a managed object according to rules is known as *instantiation*. As an example, if circuitPackCard is a managed object class, circuitPackCard1 is a managed object instance or a managed object of the circuitPackCard managed object class. A managed object class is defined in terms of attributes, notifications, operations, and behaviors. Each managed object has a unique name to identify it.

We will look in detail on the topic of managed object class in Chapter 6.

1.7.3 Information Model

A set of managed objects and the manner in which these managed objects are related to one another is known as an *information model*. The relationship between managed objects is depicted by inheritance hierarchy and containment hierarchy. We will look into what inheritance hierarchy and containment hierarchy mean in Chapter 4. Information models can be of two types:

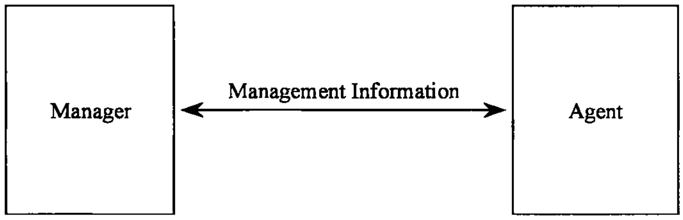
- *Generic Information Model:* The standard objects are gathered in this model. Of course, this model does not include all standard objects, only those required for a specific implementation.
- *Specific Information Model:* An interface definition includes a protocol stack (for example, an OSI seven-layer stack) and an information model supported by the interface. There are different types of interfaces depending upon the application. Q3 (Chapter 2, Section 2.3.3) is an example of an interface. The specific information model is a subset of the generic information model.

1.8 Manager, Agent, and Management Information

Managers and agents are very important basic concepts in network management and TMN. Because manager and agent concepts are important topics and are needed for discussion later on, we have introduced these terms in this introductory chapter. The interaction of managers and agents is shown in Figure 1-2.

A manager plays a key role in the monitoring and controlling of different agents in its span of control. Agents, in turn, interpret the commands sent from managers. Managers and agents communicate by exchanging management information as shown in Figure 1.2. The

Figure 1-2
Manager, agent, and management information.



exchange of management information between manager and agents can be done either by passing messages between them or by an object-oriented approach.

In the telecommunications industry, message-based exchange of management information uses Transaction Language 1 (TL1) developed by Bellcore in North America, or ITU-T Recommendation Z.300, Man Machine Language (MML). TL1 consists of ASCII string-based message sets for applications such as alarm reporting, performance monitoring, testing, and provisioning. TL1 has commands, responses to commands, and autonomous notifications for exchange of management information between manager and agents. As the TL1-based systems are slowly being replaced by the object-oriented approach, we will not deal with TL1 any further. The TL1-based systems are being relegated to the legacy systems. For more information on TL1, refer to Reference 1.2.

TMN and data communication networks use the object-oriented approach for representing resources and exchanging management information between managers and agents (Figure 1-3).

A manager may have different SMFAs. As an example, one manager may have a configuration management application and another may have a fault management application running. However, for these network management applications to run, data must be collected. To collect the data for, say, configuration management, a manager sends commands or operations to agent(s) to collect it. In return, the manager receives replies to its commands. In between, if something goes wrong in the agent, the manager may get notifications. Thus the managers interpret the management protocols and convert them into useful network management functions in SMFAs.

The commands sent from a manager are interpreted by agents and are sent to managed objects. These managed objects have the inherent intelligence to act on the basis of commands received. They send replies to agents, and the agents dispatch the replies to one or more appropriate managers.

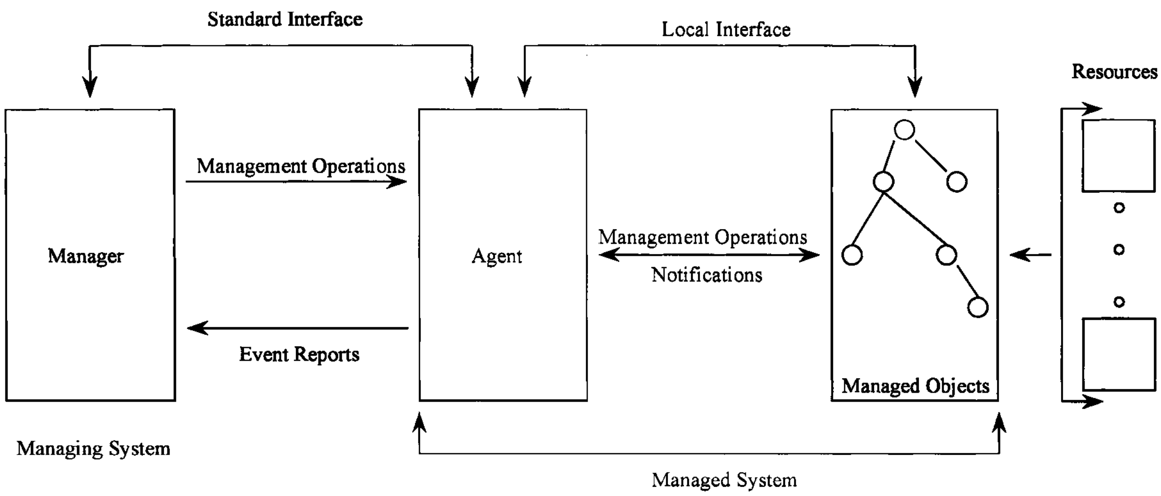


Figure 1-3
Manager and agent relationship.

Sometimes agents may receive notifications from managed objects. As an example, when a threshold has been crossed, one of the managed objects may send a notification to an agent. Then the agent sends notifications in the form of event reports to one or more managers. From this we see that a managed object emits notification and that this notification, when conveyed to external systems, becomes an event report.

A manager may be involved in exchanging management information with one or more agents. Similarly, an agent may also be involved in exchanging management information with one or more managers. An agent may deny operations from a manager for reasons such as security violations. So a manager must be able to handle negative responses from an agent.

Managers and agents communicate using *management protocols*. The network management protocols and applications are considered part of the application layer in the OSI seven-layer communication architecture. These management protocols can be common management information protocols (CMIP), SNMPv1, SNMPv2, SNMPv3, or proprietary protocols.

Between managers and agents are *standard interfaces*. The local interface between agents and managed objects is not covered by standardization. In OSI parlance, sometimes a manager is also known as a managing system (Reference 1.3). Similarly, an agent is known as a *managed system*. Note that the roles of managers and agents are not rigidly defined in OSI. As an example, a manager in one interaction may take up the role of an agent in another interaction.

Let us now examine the case of a cascaded environment (Reference 1.4), as this is one of the practices used to extend management capability in TMN. In a cascaded environment, a manager and an agent may be present in the same system (system B), as shown in Figure 1-4.

A manager in system A can manage the agent in system B. The manager in system A sees and processes the information model of system B. Similarly, the manager in system B manages the agent in system C. Here, manager in system B uses the information model presented by the system C. In system B, the agent may forward some of the notifications received from system C to the manager in system A. Similarly, some operations from the manager in system A may be forwarded by the agent in system B to the agent in system C via the manager in system B. The management protocols between the agent and manager in system B are not standardized and are dependent upon the implementation.

The management protocols use a communication stack to communicate with the agents, using communication stacks such as the seven-layer OSI stack, Transmission Control Protocol (TCP)/Internet Protocol (IP) (TCP/IP), and Internet Packet Exchange (IPX)/Sequenced Packet Exchange (SPX) (IPX/SPX). Sometimes proprietary protocols are also used in the communication stacks.

The managers can be in workstations along with operating systems such as Sun's Solaris, HP-UX, Windows NT, Windows 95/98, or any other operating systems that provide processing functions required by managers. The recent trends are to have managers on Windows NT and agents

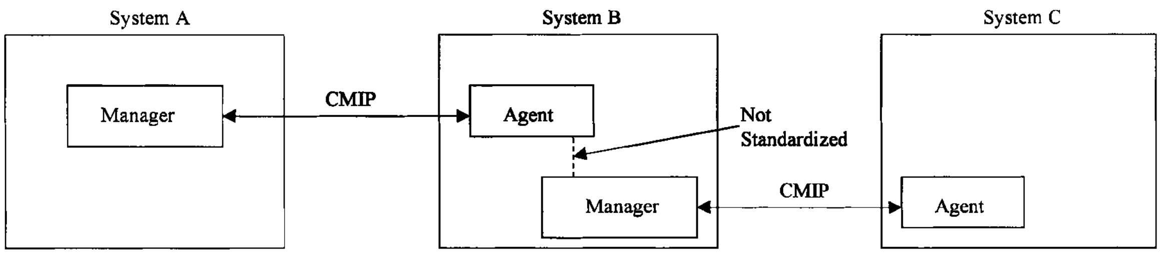


Figure 1-4
Managers and agents in a cascaded environment.

on Windows 95/98. The communication stacks are also available separately or as a part of the operating systems.

In large telecommunications or data communication networks it is a major problem to manage agents because a huge number of agents are involved. A large number of agents reporting to a manager can create performance bottlenecks. To overcome this problem, the concepts of management domains and distributed network management have evolved. A management domain may have one or more managers and zero or more agents. However, these managers are under one administrative control. Network management becomes difficult when we have to consider the coordination of these managers in different management domains.

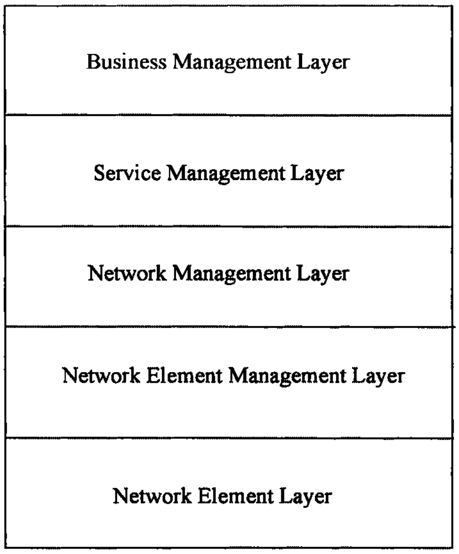
Manager and agents can be organized in different ways, such as the centralized model. In this model, one manager oversees many agents. SNMPv1 is one example. When the management of agents becomes unwieldy for one manager, a flat model can be used (Reference 1.5). As per this model, more than one manager manages the agents. Here, there is a need for manager-to-manager communication to coordinate different managers. In TMN, we use a hierarchical model where management activities are partitioned into different layers.

1.9 TMN Management Layers

When anything becomes complex, it is the normal practice to break down the functions. In computers and telecommunications, this is done by breaking into layers. The same principle is followed in TMN. Each layer has its own functions and roles as well as rules for interfacing with layers above and below. The scope of the layer above is broader than the one below. By this, it is apparent that the lower layers perform specific functions and the upper layers are progressively responsible for a broader set of functions. The different TMN layers are termed *management functional layers* and are explained in Reference 1.4. The TMN functional layers (Figure 1-5) are:

- Business management layer (BML)
- Service management layer (SML)
- Network management layer (NML)

Figure 1-5 Different TMN management layers.



- Network element management layer (NEML)
- Network element layer (NEL)

The breakdown of TMN functions just described facilitates easy step-by-step implementation. Let us examine the role and function of each layer in a top-down fashion.

The *business management layer* is concerned with the network planning, agreement between operators, and executive-level activities such as strategic planning. The BML is the topmost layer and, as a result, is responsible for management at the enterprise level. BML functions have more to do with setting and tracking the overall goals than with implementation of details. The BML has to interact with other TMN management layers to achieve BML layer functions.

The *service management layer* provides the customer interface. The SML performs functions such as service provisioning; opening new accounts; closing accounts; resolving customer complaints, including those related to billing; fault reporting; and maintaining data on quality of service (QOS). SML layer functions do not include the managment of physical entities.

The *network management layer* is concerned with the management of the whole network. It provides an end-to-end view of the network. The NML receives data from the lower NEML and synthesizes the data into meaningful total-network-level views. The NML communicates with other layers using standardized interfaces. This layer corresponds to the operations system (OS) functions. We will look into how OS functions in

Chapter 3. If we consider the NEML as corresponding to a manager, the NML layer can be viewed as a manager of a manager.

The *network element management layer* is used for managing a subnetwork—for example, a telecommunications network attached to a wire center. In this layer, data from network elements within the layer's span of control are analyzed and interpreted in a meaningful manner to monitor and control the subnetwork. As a subnetwork is a subset of the whole network, relevant data are passed on to the NML applications for integration of the views of the whole network. Sometimes the NEML is also referred to as the *element manager.*

The NEML is an intermediary layer between the NML and NEs. If a large number of network management functions are concentrated in the NEML, then the functionality required in the NML will be comparatively reduced. Therefore a judicious partition of network management functions is required between the NEML and the NML.

The *network element layer* (NEL) is the key to the TMN. It functions as an agent. This software or hardware component is present in physical entities that need to be managed. Some of the NEL functions are performance data collection, self-diagnostics, alarm monitoring and alarm data collection, traffic data collection, address translation, protocol conversion, data conversion, and data analysis.

Though the TMN functions are broken into the five layers just mentioned, implementations may not follow these textbook-style divisions. Also, with more and more emerging new demands on the telecommunications networks, new functions have to be aligned carefully and from a realistic implementation point of view.

1.10 Conventions Used in This Book

In view of the confusion in the network management terminology, it is a good idea to come to grips with what each term means. We refer to the network management based on ITU-T standards as *TMN.* In the context of the Internet, we use the term *network management.* In the case of OSI network management, we refer to *systems management.* Note that for IEEE-related management of resources and layer management, the IEEE uses *network management* (IEEE-related network management is not covered in this book).

Telecommunications companies can be broadly divided into different categories. Some companies only provide telephone and other telephone-related services—AT&T, BT, and MCI are a few examples. These companies are referred to as *telecommunications service providers.* Some other telecommunications companies manufacture telecommunications equipment and provide services to telecommunications service providers. Lucent, Nortel, and Siemens are examples of these telecommunications companies. These companies are referred to as *telecommunications vendors.*

1.11 Summary

This introductory chapter provides a baseline for the remainder of the book. Therefore we start with what TMN is and why TMN is an important part of the telecommunications industry. Since TMN is a loosely defined and used term in the telecommunications industry, we examine what TMN actually means and the scope of TMN. Then we look into the standards bodies involved in TMN. As some of the terms are frequently used in subsequent chapters, the topics of managed object, managed object class, management information model, manager, agents, and different TMN layers are introduced at the start.

1.12 References

1.1. Udupa, D. K., *Network Management Systems Essentials,* New York: McGraw-Hill, 1996.

1.2. TR-TSY-00831, *Operations Technology Generic Requirements (OTGR): Operations Application Messages—Language for Operations Applications Messages,* Issue 2, Bellcore, 1988.

1.3. ITU-T Recommendation X.701, Information Technology, Open Systems Interconnection, Systems Management Overview, 1992.

1.4. ITU-T Recommendation M.3010, Principles for a Telecommunications Management Network, 1996.

1.5. Pavlou, G., OSI Systems Management, Internet SNMP, and ODP/OMG CORBA as Technologies for Telecommunications Network Management. In *The Telecommunications Network Management, Technologies and Implementations,* Aidarous, S. and Plevyak, T. (eds.), New York: The Institute of Electrical and Electronics Engineers, Inc., pp. 63—110, 1998.

CHAPTER 2

TMN Architecture, Interfaces, OAM&P, and CNM

www.pcltools.com

www.pcltools.com

2.1 Introduction

We introduced the concept of TMN in Chapter 1. In this chapter we expand TMN concepts further. TMN is explained in different M-Series recommendations from ITU-T. ITU-T document M.3010 (Reference 2.1) lays the foundation for TMN architecture, discussed in this chapter. In TMN, terms such as *TMN function blocks, TMN functional components,* and *interfaces,* which are used to communicate management information between TMN components and also between TMN and non-TMN components, are quite common. At this stage it is necessary to introduce these terms and explain what they mean.

ANSI-based OAM&P is popular, at least in North America, so there is a need to look into this concept. OSI systems management functions are broadly used as yardsticks to explain other TMN functions. So, for understanding these concepts, it is prudent to explain how OAM&P is related to OSI systems management function. OAM&P explanations in this chapter are based on ANSI standard T1.210 (Reference 2.12).

In the telecommunications industry, ETSI standards are quite popular in European countries and some other nations around the world. ETSI uses operation, administration, and maintenance (OAM), which is slightly different from OAM&P. In ETSI standards, the provisioning function is part of the service and business areas. We will look into OAM in Chapter 9.

Customer network management (CNM) is a subset of the TMN functions exposed to customers. It is essential to standardize CNM so that customers experience a uniform look and feel. With this point in mind, we need to understand what CNM is all about.

Conformance is an important and vast topic. Conformance is very essential for interoperability. There are many ISO standards and ITU-T recommendations devoted to conformance. Also, conformance requirements are included in most of the protocol specification documents. In this chapter, we have only introduced the topic. For more details on conformance, refer to the standards documents. Also, there are some books that have detailed discussions of conformance (Reference 2.13).

2.2 TMN and Telecommunications Networks

Figure 2-1 shows the relationship between TMN and a telecommunications network, which TMN manages. TMN provides the management

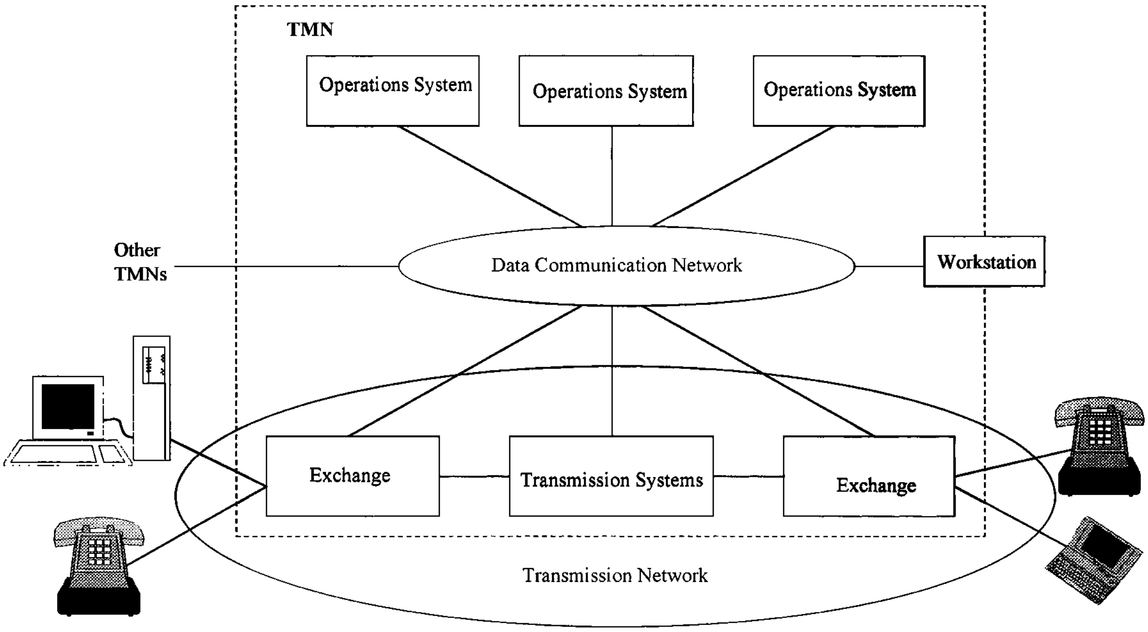


Figure 2-1
Relationship between TMN and telecommunications network.

support to plan, provision, install, maintain, operate, and administer telecommunications networks and services. The scope of TMN is broader than providing OSI SMFAs. TMN architecture can vary from simple to complex. As an example, there can be a single operations system (OS) managing a few pieces of equipment, or a number of OSs and a large, complex telecommunications network as in Figure 2-1. An OS is analogous to a manager; we will look into it in more detail.

A telecommunications network can include a variety of components such as equipment for analog, digital, or wireless transmission and support functions. This equipment can be switching systems, multiplexers, signaling terminals, front-end processors, cluster controllers, file servers, base stations, mainframes, and so on.

2.3 TMN Architecture

TMN architecture explains overall management of different telecommunications network components in a cooperative manner. For facilitating the ease of design and development of TMN, the management of a telecommunications network is subdivided into easily understandable and manageable components. These different TMN components are then combined into the total TMN functionality with proper coordination between the manageable TMN components. With this point in view, TMN architecture primarily consists of three different components: functional architecture, physical architecture, and information architecture. We will look into each in detail.

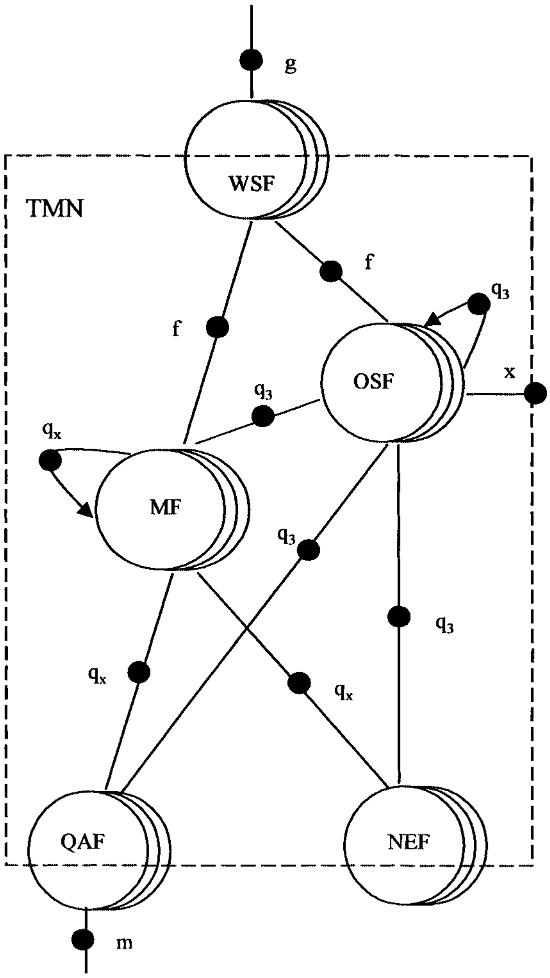
2.3.1 Functional Architecture

TMN functional architecture divides a TMN domain into different function blocks. Each function block in TMN functional architecture performs a specific TMN management function. Function blocks are similar to building blocks. By combining function blocks in different ways, we can derive TMN functionality of any complexity.

2.3.1.1 TMN Function Blocks. Some of the function blocks can be within and some outside the TMN boundary, as can be seen in Figure 2-2. The different types of function blocks are as follows:

- *Operations systems function (OSF):* Provides the management and planning functions for the telecommunications network and the TMN component itself. There are four OSF function blocks—namely element OSF, network OSF, service OSF, and business OSF—to support the element management layer, network management layer, service management layer, and business management layer functions, respectively (Figure 2-3). Here we may note that an OSF is separated by higher- and lower-level OSFs with a q_3 reference point. A peer OSF or OSFs in other domains are separated by x reference points. We will look into reference points in Section 2.3.1.3.
- *Network element function (NEF):* Monitored and controlled by TMN. Telecommunications network components are represented by one or more NEF function blocks for the purposes of management.
- *WorkStation function (WSF):* Enables management information to be viewed by human users. This involves translation of management data from F interface format to G interface format. F and G interfaces are explained in Section 2.3.3.
- *Mediation function (MF):* A sort of a gateway for exchanging management information when the function blocks have different reference

Figure 2-2
Functional architecture of TMN (© 1994 IEEE).



points. MF function blocks may store, convert, route, perform address mapping, filter, threshold, and condense management information.

- *Q adaptor function (QAF):* Used to translate management information between TMN reference and non-TMN reference points. Thus in Figure 2-2 a portion of QAF is outside the TMN boundary.

2.3.1.2 TMN Functional Components. Each function block contains functional components. The functional components are elementary building blocks. As an example, a NEF function block is obtained by grouping NEF-MAF, DSF, DAF, and SF (see the following list for explana-

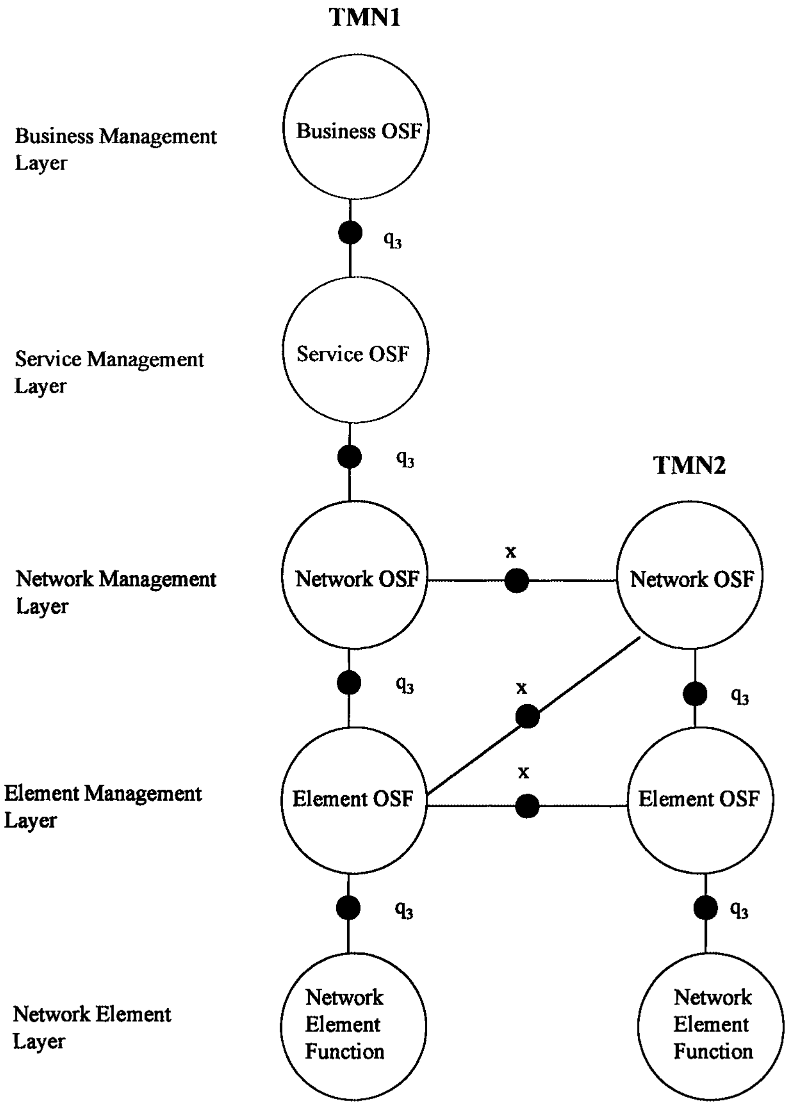
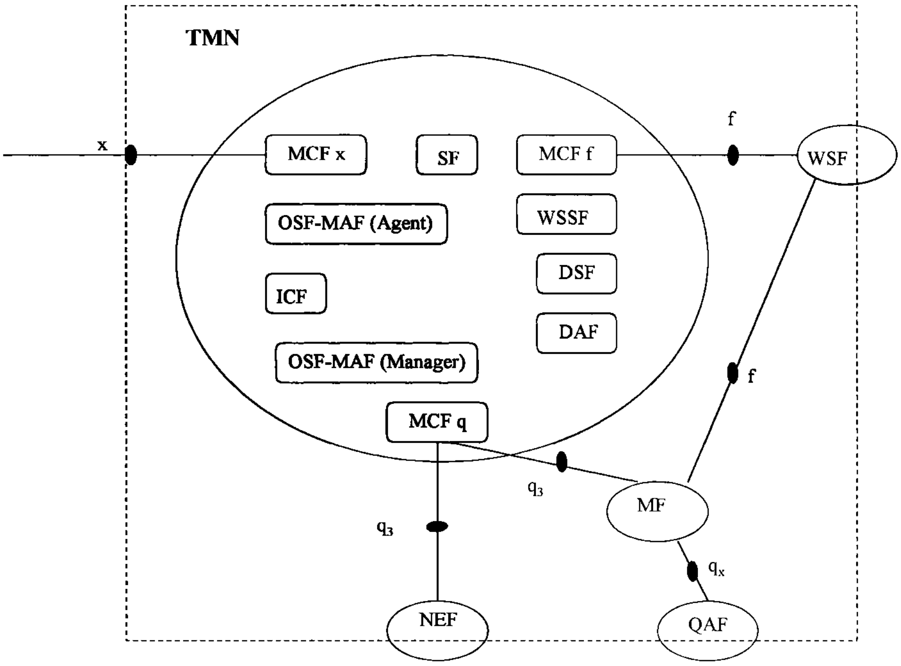


Figure 2-3
Different types of OSF function blocks.

tion of each term). Another example of an OSF function block with functional components is shown in Figure 2-4. The different functional components are as follows:

- *Management application function (MAF):* Provides functionality for one or more management services. Management services are explained in Chapter 3. MAF also includes the management information. When a MAF is included in other TMN function blocks to

Figure 2-4
Exploded view of OSF with functional components.



provide support for TMN function blocks such as MF, OSF, NEF, and QAF, these are referred to as MF-MAF, OSF-MAF, NEF-MAF, and QAF-MAF, respectively.

- *Mediation function—management application function (MF-MAF):* Present in an MF to support manager and agent roles of the MF.
- *Operations systems function—management application function (OSF-MAF):* Present to support simple to complex management functions. Some of the management functions in OSF-MAFs are alarm correlation, trouble tracking, statistics, performance analysis, and the like.
- *Network element function—management application function (NEF-MAF):* Present in an NEF to support the agent role.
- *Q adaptor function—management application function (QAF-MAF):* Present in a QAF to support manager and agent roles.
- *Information conversion function (ICF):* Provides a mechanism to convert information models from one form to another. ICF is required in MF and QAF as there is a need to transform information models.
- *WorkStation support function (WSSF):* Required for the realization of WSF management function.

- *User interface support function (UISF):* Translates user information to the TMN information model and vice versa, and makes the information in an information model available in a displayable format at the human-machine interface. The human-machine interface can be a workstation screen, a printer, or another device.
- *Message communication function (MCF):* Provides a means for exchanging management information between peers using a protocol stack (Figure 2-5). This protocol stack need not necessarily be an OSI seven-layer stack. MCF is necessary for all function blocks which need a physical interface. An MCF may be connected to a data communication function (DCF) as shown in Figure 2-5 and basically provides an information transport mechanism.
- *DCF:* may provide routing, relaying, and interworking functions. DCF provides OSI layers 1 to 3 or their equivalent. DCF capability can be point-to-point links, local area networks (LANs), wide area networks (WANs), and embedded operations channels (EOCs).
- *Directory system function (DSF):* Required for realizing directory support to the TMN. The directory used in TMN is based on the ITU-T X.500 directory document (Reference 210). Note that there are many ITU-T recommendations on different aspects of directory services. A directory contains information about systems with which associations can be made along with association details, application context details, security details, list of managed objects, managed object classes supported, and so on. Directories also include functions to manipulate directories, such as adding entries, deleting entries, searching entries, and modifying entries.
- *Directory access function (DAF):* Required for accessing directories. It is required for OSF and may also be required for WSF, MD, QAF, and NEF depending upon whether they use directories.
- *Security function (SF):* Required for providing security to function blocks. The security services are authentication, access control, data

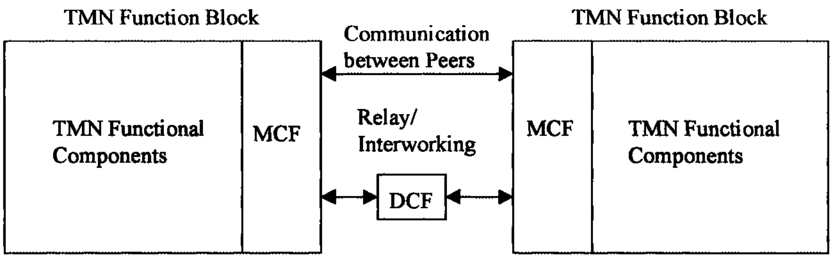


Figure 2-5
DCF functions.

confidentiality, data integrity, and nonrepudiation. The details of these security services are provided in ITU-T X.800 (Reference 2.11).

2.3.1.3 Reference Points. The function blocks are separated by conceptual boundaries known as reference points (Figure 2-2). As can be seen in Figure 2-2, there are q, f, x, g, and m reference points. There are two type q reference points, namely q_3 and q_x. g and m reference points delineate TMN and non-TMN boundaries.

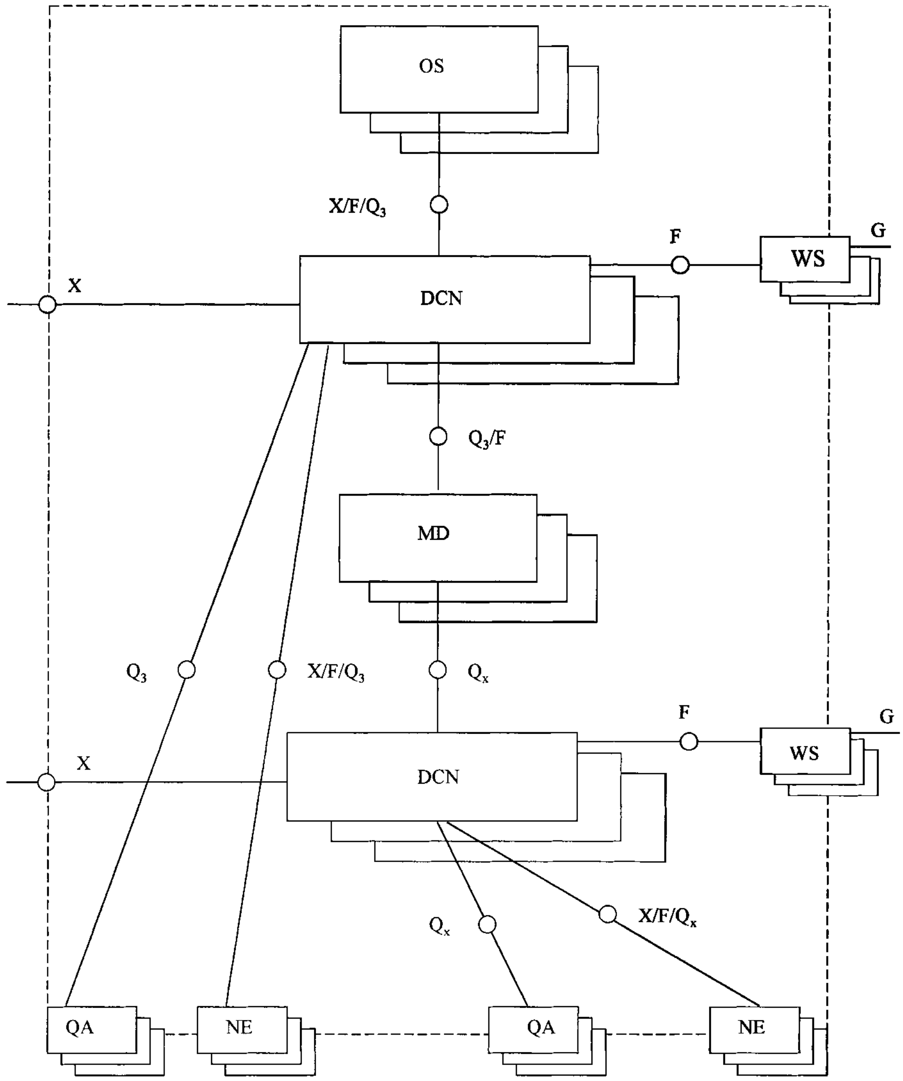
2.3.2 Physical Architecture

Physical architecture explains the implementation of function blocks on physical systems and the interfaces between them. Implementations of function blocks on physical systems can be treated as building blocks from which complex TMN systems can be developed. For exchange of management information between building blocks, these building blocks must be connected by a communication path and each building block must have a similar interface with the communication path.

The components of physical architecture (Figure 2-6) are as follows:

- *Operations system (OS):* Supports information processing related to operations, administration, maintenance, and provisioning of telecommunications networks. Operation systems are analogous to managers. In Figure 2-6 there is only one OS. It is not necessary that there be only one OS within a TMN boundary: there can be more than one OS interconnected. As a matter of fact, when the TMN workload is heavy for a large telecommunications network, distributed architecture is required. This will lead to more than one OS, as in Figure 2-1.
- *Data communication network (DCN):* Has routing and transport capabilities used to exchange management information between OS and OS, OS and NE, WS and OS, and WS and NE. The DCN supports the DCF functional component and provides support for only one to three OSI layers. ANSI T.210 (Reference 2.12) defines a gateway network element (GNE) as a DCN. A GNE also has routing and relaying capabilities. Here, relaying means forwarding of data from one network to another. There is no data format conversion involved. Relays can be bridges, routers, or network relays based on the layer of support of the OSI protocol stack. As an example, repeaters provide connectivity and relays at the OSI physical layer.

Figure 2-6
Physical architecture for TMN.



- *Mediation device (MD):* Has a relay or gateway function. An MD includes many functions such as protocol conversion, message conversion, signal conversion, address translation, and routing. An MD also may be required to perform information processing functions such as execution of functions, information processing, storing data, and filtering data.
- *Workstation (WS):* The entry or exit point that permits human users such as operators of a system to access management data. These sys-

tems are normally data processing systems such as mainframes, Unix-based workstations, or Intel PCs using Windows NT. Human users need to interpret management data received from MDs and OSs and are presented data on the computer screens and by means of reports.

- *Network element (NE):* Has intelligence. An item, a group of items, or a piece of telecommunications equipment that is part of a telecommunications network and performs NEF functions is known as an NE. An NE is similar to an agent and has a NEF function block and support for a Q interface. We will look into Q interfaces in the next section. An NE also may have optional support for F and X interfaces. NE functionality is realized by microprocessors and software. Legacy NEs, which may not support TMN standards, are connected to the TMN environment using Q adaptors.
- *Q Adaptor (QA):* Converts the non-TMN data to the TMN data format and vice versa. As an example, the non-TMN data may be TL1 messages from nonstandard devices. These TL1 messages are converted to CMIP data and transmitted to the DCN. A similar but reverse conversion of CMIP data from OS to TL1 messages suited for the non-TMN environment is also performed.

2.3.3 Interfaces

We have looked into reference points in functional architecture. When these reference points are implemented in physical systems, they become interfaces. For management information to be exchanged between two or more building blocks, there has to be a communication path between the building blocks and similar interfaces. An interface consists of a protocol suite and messages carried over the protocol. These messages are a mechanism to convey information to manage objects defined in an information model.

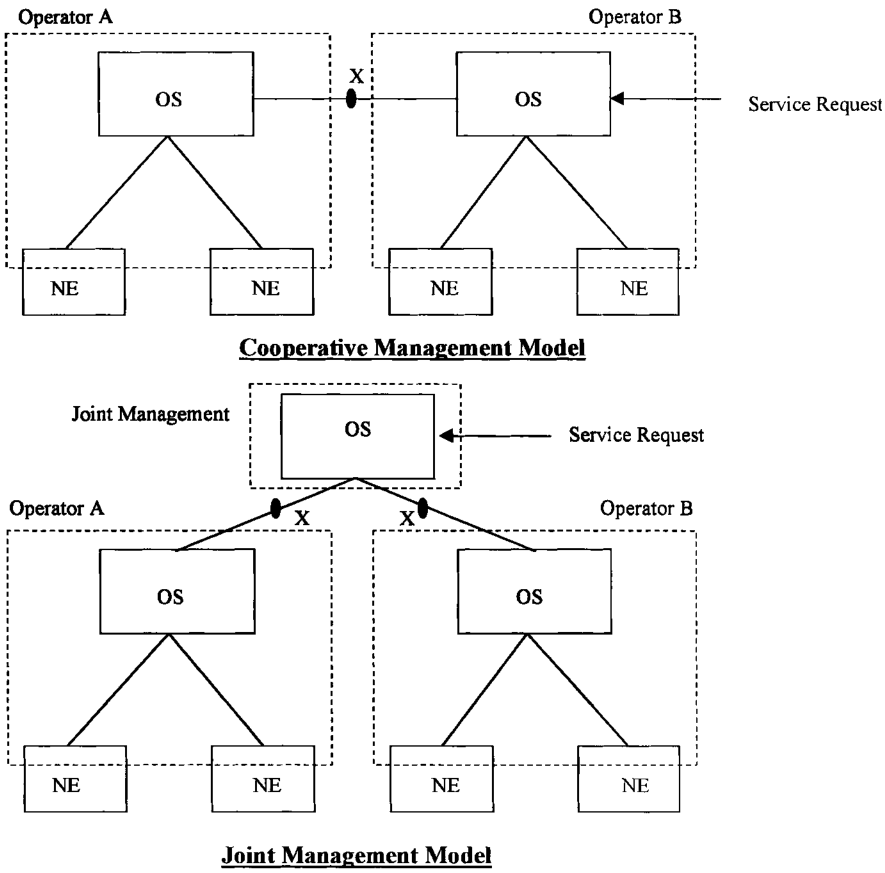
2.3.3.1 Q Interface. A Q interface is used at a q reference point. However, a Q interface can be either a Q3 interface or a Qx interface.

Q3 INTERFACE. The Q3 interface is a very popular interface in the TMN world. It uses a full OSI seven-layer stack. It refers to the interfaces provided by ITU-T recommendations Q811 (Reference 2.2) and Q812 (Reference 2.3). Q811 provides the details of the physical interfaces, the data communication layer, and the networking layer, while Q812 defines standards to the upper layers of the OSI stack.

Qx INTERFACE. In many cases it is not necessary to have the full OSI seven-layer stack. There is a lot of overhead involved in supporting a full OSI seven-layer stack. To overcome this lacuna, the Qx interface is quite useful. So, when NEs need to use less than the full seven OSI layers, the Qx interface is sufficient. As we have seen, the Q3 interface uses the full seven OSI layers.

2.3.3.2 X Interface. The X interface is used to interconnect OSs in different TMNs or to connect a TMN to other network management systems with TMN-like interfaces. OSs can be connected using different configurations. The X interface can be used to connect OSs in a peer-to-peer relationship, as in the case of the cooperative management model shown in Figure 2-7. There can also be a manager-to-agent relationship between OSs, as shown in the joint management model shown in Figure 2-7. The X interface needs security requirements in addition to the proto-

Figure 2-7
X interface examples.



col stacks as management information is exchanged with other TMNs. For more details on the X interface, refer to Reference 2.4.

2.3.3.3 F Interface. The F interface supports functions to interconnect workstation OSF and MF using data communication networks. Users access TMN data via the F interface (Reference 2.5).

2.3.3.4 M Interface. The M interface corresponds to the m reference point. It is located outside the TMN boundary. The M interface provides connection between QAF and non-TMN managed entities or managed entities that do not conform to TMN standards.

2.3.3.5 G Interface. The G interface corresponds to the g reference point. The G interface is not considered part of TMN. The G interface provides access to the human user interface in a workstation. A human user can access TMN information via the G interface.

2.3.4 Information Architecture

Information architecture explains how OSI systems management and X.500 principles can be applied to TMN. Information architecture describes the resources that have to be managed by TMN using the guidelines for the definition of managed objects (GDMO) and abstract syntax notation one (ASN.1). Separate chapters are devoted to ASN.1 (Chapter 5) and GDMO (Chapter 6). Information architecture uses object-oriented approach in providing TMN solutions.

We looked into manager and agent concepts in Chapter 1. Managers and agents exchange management information about the resources controlled by agents using management protocols. These protocols in TMN are based on CMIP. However, in some cases, the exchange of management information can be done using file transfer, access, and management (FTAM) protocols.

There are two aspects of management information. One is what constitutes management information. The resources to be managed and the management operations that can be performed on the resources are contained in a management information model. These are application-level activities. Another important aspect of management information is how this management information is transferred. The transfer of management information is done using communication stacks involving DCFs and MCFs.

2.3.4.1 Shared Management Knowledge. *Management knowledge* refers to the management information required by an open system to associate and perform management operations on another open system. For a manager and agent to communicate, manager and agent must share a common body of management knowledge. This common management knowledge is known as *shared management knowledge* (SMK). This is analogous to the ability of two people to communicate with each other: For this to occur, there have to be some commonalties such as languages or interests. The shared management knowledge includes the following:

- Protocol knowledge such as application context
- Function knowledge such as TMN function blocks
- Managed object knowledge such as managed object classes and available managed object instances
- Constraints on functions supported and the relationships between those functions and managed objects
- Similar name bindings

SMK must be established before transfer of management information between two systems. Sometimes, this may require negotiation between the two communicating systems. SMK between interdependent systems can be different (Figure 2-8). As an example, while there can be one type of SMK between the manager in system A and the agent in system B, SMK between the manager in system B and the agent in system C can be of an entirely different type. However, communication protocols between the agent and manager in system B are an internal matter.

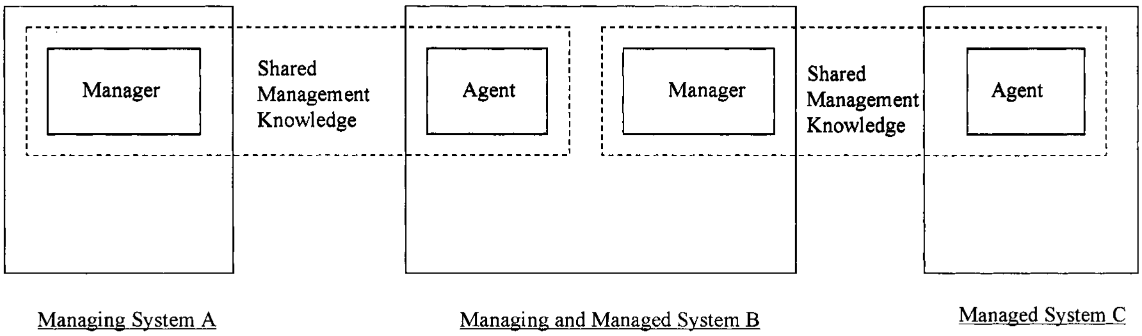


Figure 2-8
Shared management knowledge between different systems (© 1994 IEEE).

2.4 OAM&P

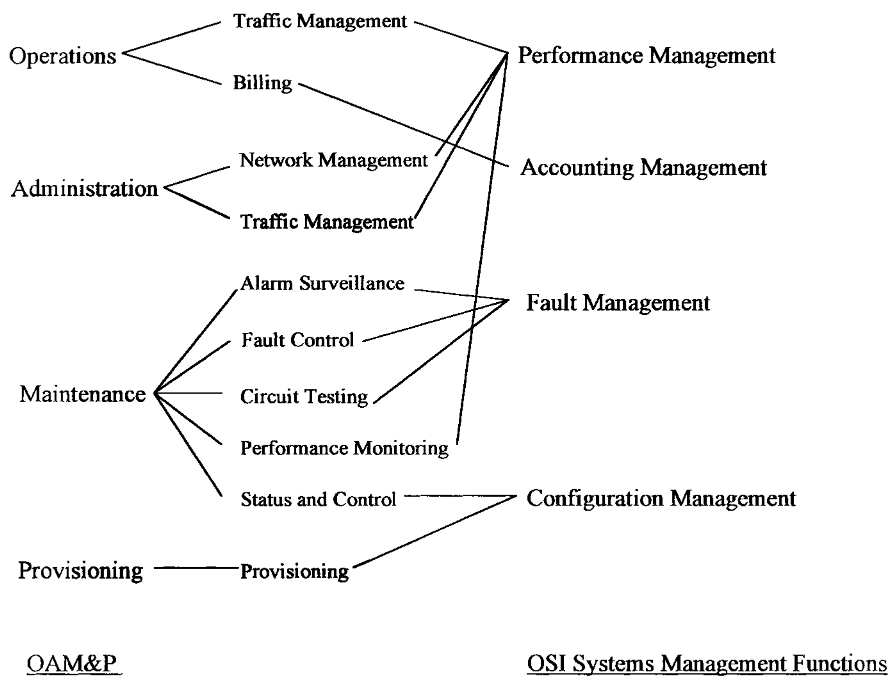
OAM&P is explained in Reference 2.12. OAM&P categories are shown in Figure 2-9. For a better understanding of OAM&P, OAM&P is mapped to OSI systems management functions (Figure 2-9). We will now look into each of the OAM&P categories.

Operations are related to the activities for providing telecommunications services to end users or subscribers. Operations include traffic management and billing. Note that accounting management includes functions beyond billing. Similarly, performance management includes more functions beyond traffic management.

Administration refers to the functions involved in providing efficient services to customers or subscribers and meeting the quality of service requirements. Administration includes traffic management and network management. As can be seen in Figure 2-8, traffic management and network management are part of OSI performance management.

Maintenance activities include detection of faults, location of faults, and restoration of a unit to a specific state by repairing the faults. Maintenance is further subdivided into *corrective maintenance* and *preventive*

Figure 2-9
OAM&P functions and mapping between OAM&P and OSI systems management functions.



maintenance. Corrective maintenance covers procedures to restore normal operations after a failure has occurred. Instead, the preventive maintenance procedures are used to track and correct possible failures before the occurrence of failures. The objective of preventive maintenance is to minimize the failures. Despite preventive maintenance, failures are unavoidable and this is where the corrective maintenance comes into the picture. Maintenance includes the functions shown in Figure 2-9.

Provisioning refers to the management activity that makes different telecommunications resources available to telecommunications services. Provisioning includes *resource provisioning* and *service provisioning.* Resource provisioning refers to the deployment of resources to satisfy service demands of end users. Service provisioning is related to the activities involved in providing timely services and features to end users.

2.5 CNM

External users of a telecommunications network may need to be provided with limited control and view of the network. This facility is provided by customer network management (CNM). With the globalization of telecommunications services, customer interfaces with service providers have to be uniform from the point of view of cost and ease of use by customers. It is also important that these common customer interfaces be required within nations and across national boundaries. Hence, it is necessary to focus on the standards available in CNM. Internationally, there is no substitute for ITU-T standards.

With this important point in focus, we look into ITU-T standards as related to CNM. However, note that the ITU-T standards on CNM X.160 (Reference 2.6), X.161 (Reference 2.7), X.162 (Reference 2.8), and X.163 (Reference 2.9) are specifically defined for public data networks (PDNs). Still, these standards are generic enough to be applicable to other network technologies with slight modifications. The CNM domain is in the non-TMN environment and it is a vast topic. So we restrict the discussion of CNM to an overview. To complement the ITU-T description of CNM, we also look to ANSI standards on CNM at a high level.

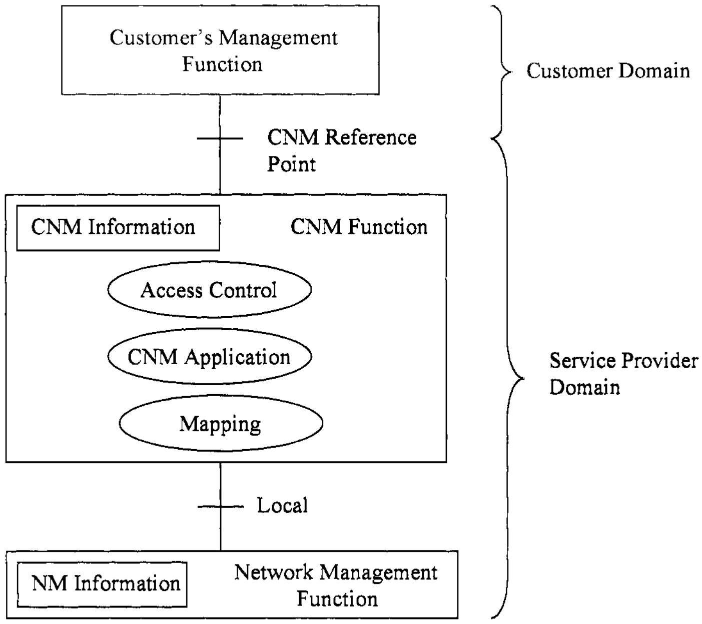
CNM is used for the exchange of management information relating to the services provided between customers and network service providers. These customers can be subscribers of network services or private network administrators who manage a portion of the public networks. The management information used in CNM is more restricted than the normal management information used by service providers to manage their networks. The CNM information provided to customers is more related to service provisioning.

2.5.1 CNM Functional Architecture

CNM functional architecture is shown in Figure 2-10. The boundary between CNM function and the customer's management function is the CNM reference point. The CNM reference point can be mapped to the X reference point. We have discussed the X reference point earlier in this chapter. CNM function is analogous to the function of an OS. CNM function contains the following function blocks:

- *CNM information:* Contains service management-related information and provides a customer's view of network services.
- *Access control:* Used to restrict access to the services provided by the network to authorized customers.
- *CNM application:* Acts in the agent role and implements the CNM services.

Figure 2-10
CNM functional architecture.



- *Mapping:* Provides customer-related management information. As already mentioned, customer-related management information is a subset of the management information used by a service provider.

2.5.2 CNM Physical Architecture and Interfaces

Figure 2-11 explains the CNM physical architecture. As shown in the figure, between the customer's management system and the service provider's CNM system, either a customer network management using CMIP (CNMc) interface or a customer network management using EDI (CNMe) interface can be employed.

The CNMc interface uses CMIP protocols and is useful for supporting interactive and real-time monitoring applications. The CNMc interface provides real-time/asynchronous notification, object-oriented support, and the ability to pick and choose OSI systems management software. For

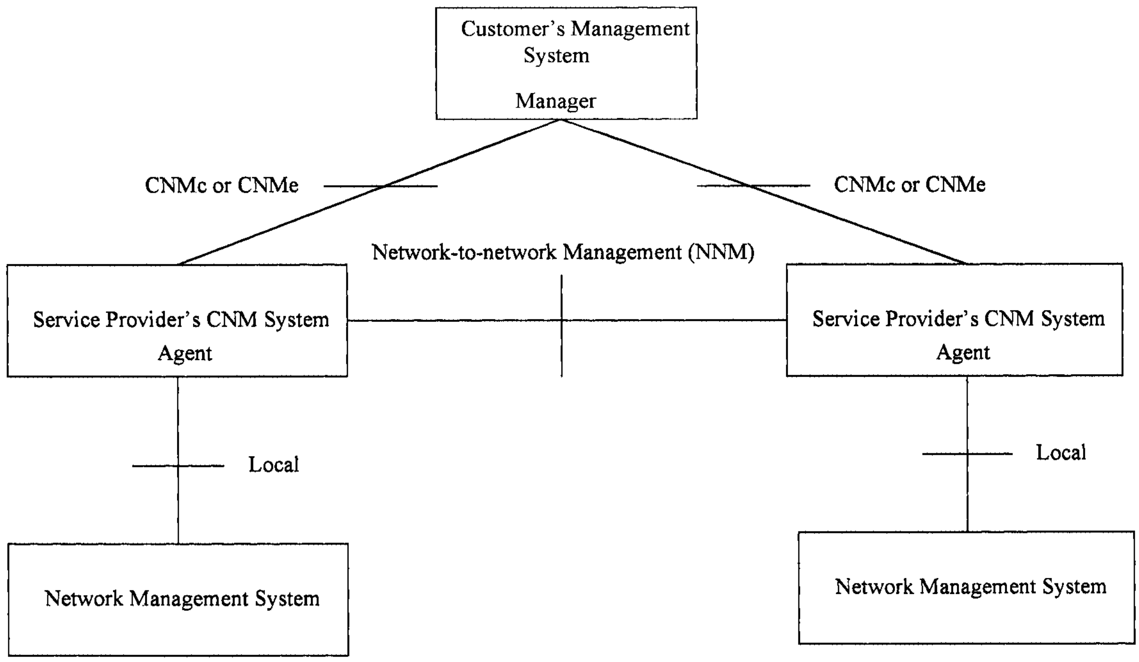


Figure 2-11
CNM physical architecture and interfaces.

more information, including management information on the CNMc interface, refer to Reference 2.8.

The CNMe interface uses electronic data interchange (EDI) messages with message handling services (MHS) as the supporting protocol. The CNMe interface is useful for supporting cases where there is a need for auditing data exchanged between a customer and service provider, such as in contractual obligations.

EDI messages are explained in ISO 9735, Electronic Data Interchange for Administration, Commerce, and Transport (EDIFACT)—Application Level Syntax Rules. MHS is defined in ITU-T Recommendation F.400/X.400, Message Handling Services: Message Handling System and Service Overview. The CNMe interface uses storing and forwarding of information for communication between the customer's management system and the service provider's CNM system. The CNMe interface permits buffering of messages, use of mailboxes, and protection against communication failures. The advantage of using mailboxes is that there is no need to form an association between the CNM customer and the service provider. For more details on the CNMe interface, refer to X.163 (Reference 2.9). Management information flowing across the CNMe interface is also defined in X.163.

Between service providers, the interface for exchange of management information is network-to-network management (NNM). The NNM interface is not standardized. Service providers can choose their own protocols for the exchange of management information across the NNM interface.

In Figure 2-11, two CNM service providers service the customer's management system. Typically, one customer's management system uses the services of a CNM service provider. The motivation for including two service providers is to explain the NNM interface.

In Figure 2-11, the customer's management system provides manager role activities and is located on the customer premises. The service provider's CNM system supports the agent role. Note that there can be one or more associations between a manager and an agent. The topic of association between manager and agent is discussed in detail in Chapter 7.

2.5.3 CNM Management Services

CNM management services are provided to customers by service providers across CNM interfaces. CNM management services are a subset of TMN management services (Chapter 3). As we have seen, CNM interfaces can be CNMc or CNMe. CNM management services are divided into the following groups:

- *Fault management:* Includes alarm notification service, fault history service, trouble report service, loop setup service, test host service, and protocol monitoring service.
- *Accounting management:* Includes billing service, detailed accounting service, quota control service, and real-time charging information service.
- *Configuration management:* Subdivided into configuration inquiry service, reconfiguration service, ordering service, cancellation service, systematic call redirection service, and inventory inquiry service.
- *Performance management:* Includes traffic information service, quality of service information service, and network statistics service.
- *Security management:* Concerned with password change service and access rights definition service.
- *CNM supporting services:* Provides service request function. The service request function enables a customer's management system to request service provisioning or usage from a service provider.

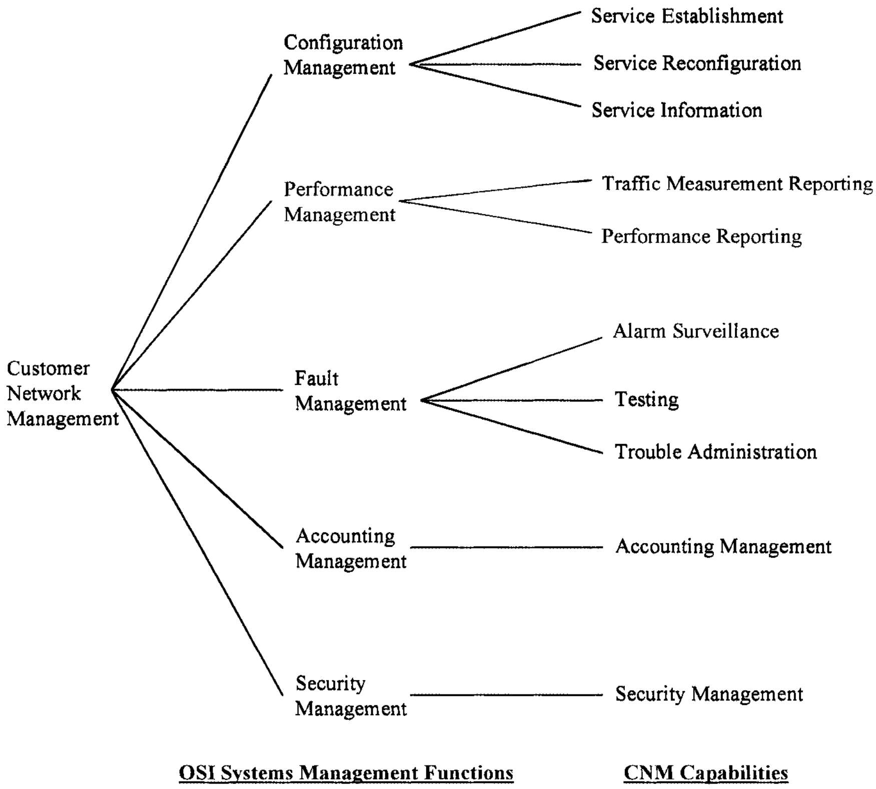
We have briefly looked into different CNM management services; for more details on this subject, refer to X.161 (Reference 2.7).

2.5.4 ANSI-Based CNM

Customers of CNM are the network managers of a telecommunications service. Mapping of CNM to OSI systems management functions is shown in Figure 2-12, and CNM components are as given here:

- *Configuration management:* Applies to the networks and equipment used in providing telecommunications services. Configuration management includes following categories of functions:
  - *Service establishment:* Deals with service order—related activities such as receiving a service order, initiating a service order, checking service order status, modifying a service order, canceling a service order, and cross-referencing related service orders.
  - *Service reconfiguration:* Relates to changing and rearranging assignments, for example adding or deleting a directory number hunt group (DHNG) member in Centrex.
  - *Service information:* Has to do with listing of circuits and telephone numbers with the services offered. In addition, it also provides the capability to obtain information for planning purposes such as availability of network resources, capacity of resources, compatibility of resources, and so on.

Figure 2-12
CNM management services and mapping to OSI systems management functions.



- *Performance management:* Consists of the following:
  - *Traffic measurement reporting capability:* Relates to the ability to create, delete, and modify schedules and reports.
  - *Performance monitoring capability:* Refers to the ability to obtain and evaluate the conditions of network resources. Performance monitoring capability may also include real-time performance monitoring and modifying the criteria for real-time performance monitoring, logging performance data, retrieving performance data and modifying performance data logging criteria.
- *Fault management:* Includes the following:
  - *Alarm surveillance:* Concerned with alarm reporting, logging of alarms, retrieving of alarms logged, modifying alarm logging criteria, and other activities related to performance degradation.
  - *Testing:* Includes a whole range of activities related to the testing of resources and isolating faults. Some of the activities are scheduling

of tests, modifying the parameters related to testing of resources, cancellation of tests, and getting reports on tests.
- *Trouble administration:* Includes activities connected with trouble tickets. These activities include entering trouble, tracking trouble status, canceling trouble information, and getting different kinds of trouble reports.

- *Accounting management:* Concerned with billing information, billing payment, usage data, and reconciling billing differences and other billing-related activities.
- *Security management:* Relates to management of security audit trials and alarms, access security, and recovery from intrusion.

2.6 Conformance

Conformance is very important to interoperability. For interoperability, the protocols, formatting of data, and application environments must be similar so that applications developed on different platforms can work together. An application developed by one vendor must work with a similar application from another vendor. For example, two electronic mail systems must work together regardless of which vendors developed the systems.

By and large, standards do not go into the details of implementation; also, standards are either not available or incomplete in some areas. As a result, during implementation some assumptions are made. However, these assumptions may result in incompatible implementations. To overcome this problem, a set of guidelines should be clearly stated for checking whether an implementation has adhered to the standards.

Checking whether an implementation really matches the protocol specifications mentioned in standards such as ITU-T recommendations is done by conformance testing. One of the key aspects of conformance testing is to model the implementation as a set of states and transitions to these states; thus, protocol specifications and implementations are modeled as finite state machines (FSMs).

There are many ITU-T recommendations on how conformance testing is to be done. In addition, most protocol specifications also have portions solely devoted to conformance. So, when interoperability is a key issue, it is important to perform rigorous conformance testing. Conformance is a very vast topic. There are many standards documents and books that have separate chapters devoted to conformance. Refer to these for more details.

2.7 Summary

This chapter explains the basic concepts of TMN. We have examined different types of TMN architecture, namely functional architecture, physical architecture, and information architecture. Detailed explanations are also furnished on interfaces and the closely related topic of reference points.

We also describe different components of OAM&P. This explanation is primarily based on ANSI standards. It is very important to examine the user interfaces to TMN. From this point of view, there is a limited discussion on customer network management (CNM). Though CNM as treated in this chapter is related to public data networks, it can be extended to telecommunications networks based on protocols such as SDH, ISDN, and ATM. From an interoperability standpoint, conformance is an important topic. Therefore we have included a brief description of conformance.

2.8 References

2.1. ITU-T Recommendation M.3010, Principles for a Telecommunications Management Network, 1996.

2.2. ITU-T Recommendation Q.811, Lower Layer Protocol Profiles for the Q3 and X Interfaces, 1997.

2.3. ITU-T Recommendation Q.812, Upper Layer Protocol Profiles for the Q3 and X Interfaces, 1997.

2.4. ITU-T Recommendation M.3320, Management Requirements Framework for the TMN X-Interface, 1997.

2.5. ITU-T Recommendation M.3300, TMN Management Capabilities Presented at the F Interface, 1992.

2.6. ITU-T Recommendation X.160, Architecture for Customer Network Management Service for Public Data Networks, 1996.

2.7. ITU-T Recommendation X.161, Definition of Customer Network Management Services for Public Data Networks, 1997.

2.8. ITU-T Recommendation X.162, Definition of Customer Network Management Service for Public Data Networks to be used with CNMc Interface, 1997.

2.9. ITU-T Recommendation X.163, Definition of Customer Network Management Services for Public Data Networks to be used with CNMe Interface, 1995.

2.10. ITU-T Recommendation X.500, The Directory: Overview of Concepts, Models and Services, 1993.

2.11. ITU-T Recommendation X.800, Security Architecture for Open Systems Interconnection for CCITT Applications, 1991.

2.12. ANSI T1.210, *Telecommunications—Operations, Administration, Maintenance, and Provisioning (OAM&P)—Principles of Functions, Architectures, and Protocols for Telecommunications Management Network (TMN) Interfaces,* New York: American National Standards Institute, 1993.

2.13. Udupa, D. K., *Network Management Systems Essentials,* New York: McGraw-Hill, 1996.

2.14. Sen Subhabrata, B., Network Performance Management. In *Telecommunications Network Management into the 21st Century,* Aidarous, S. and Plevyak, T. (eds.), New York: The Institute of Electrical and Electronics Engineers, Inc., pp. 302—336, 1994.

2.15. Sahin, V., Telecommunications Management Network, Principles, Models, and Applications. In *Telecommunications Network Management into the 21st Century,* Aidarous, S. and Plevyak, T. (eds.), New York: The Institute of Electrical and Electronics Engineers, Inc., pp. 72—121, 1994.

CHAPTER 3

TMN Management Services and TMN Functions

3.1 Introduction

There are some basic differences in network management for data communications and telecommunications. The scope of network management in telecommunications is broader and slightly different. Some of the major areas of differences are related to user activities in provisioning, alarm surveillance, and traffic management. This is partly due to the more stringent regulatory environments in the telecommunications industry. As a result, in TMN more network management functionality has to be covered.

The basic TMN documents are M.3000-series documents. These documents define different TMN architectures, interfaces, management services, and functions. In Chapter 2 we discussed TMN architecture and interfaces; in this chapter we will discuss different TMN management services and TMN functions.

From a TMN standards point of view, telecommunications management network management services (TMN-MSs) are described in ITU-T Recommendation M.3200 (Reference 3.1). TMN management functions are described in ITU-T Recommendation M.3400 (Reference 3.2). The overall structure of how the TMN management services and TMN management functions are related is explained in ITU-T Recommendation M.3020 (Reference 3.3). In addition, M.3020 ties together the concepts of TMN users, management services, management functions, operations, attributes, notifications, and managed object classes.

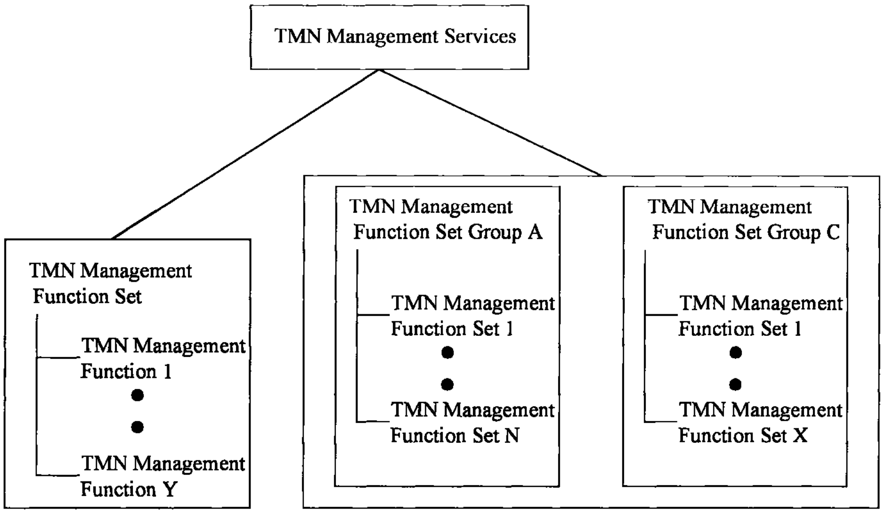
3.2 TMN Management Services

TMN-MSs are modeled from a user perspective. They provide the operations, administration, maintenance, and provisioning (OAM&P) support for a telecommunications network. A TMN-MS can reside in different systems and is not part of standardization.

The hierarchy of TMN-MSs is shown in Figure 3-1. The TMN-MS is partitioned into TMN management function set groups, which are further subdivided into TMN management function sets. A TMN function set includes two or more TMN management functions. In the hierarchy of relationships between TMN-MSs and TMN functions, a TMN function is the smallest functional part of a TMN-MS and the TMN function is at the lowest level of the hierarchy.

By combining elementary building blocks such as TMN management functions, we can form simple to complex TMN applications in a modu-

Figure 3-1
Hierarchy of management services and management functions.



lar manner. This is analogous to building simple to complex and sophisticated houses or building complexes with the elementary bricks or concrete slabs with gluing and supporting materials.

Let us look into another specific example of a TMN management function set group. Alarm surveillance consists of an alarm reporting function set, an alarm summary function set, an alarm event criteria function set, an alarm indication management function set, and a log control function set. The alarm reporting function set, in turn, includes a report alarm function, an inhibit/allow alarm reporting function, a request alarm report route function, a condition alarm reporting function, and a route alarm report function.

A TMN-MS can be provided by one or more TMN management functions. TMN management functions are mapped to TMN systems management (SM) services and these TMN SM services exchange management information with the managed objects as shown in Figure 3-2. The exchange of management information between TMN SM services is done by a series of operations and notifications on one or more managed object instances using CMIS services.

TMN management functions such as performance monitoring usually reside in a manager or an OS. The data related to these management functions are collected from the agents or NEs by an exchange of messages between the NEs and the OS. This exchange of messages is done by using management protocols. Usually, in TMN, the management protocol

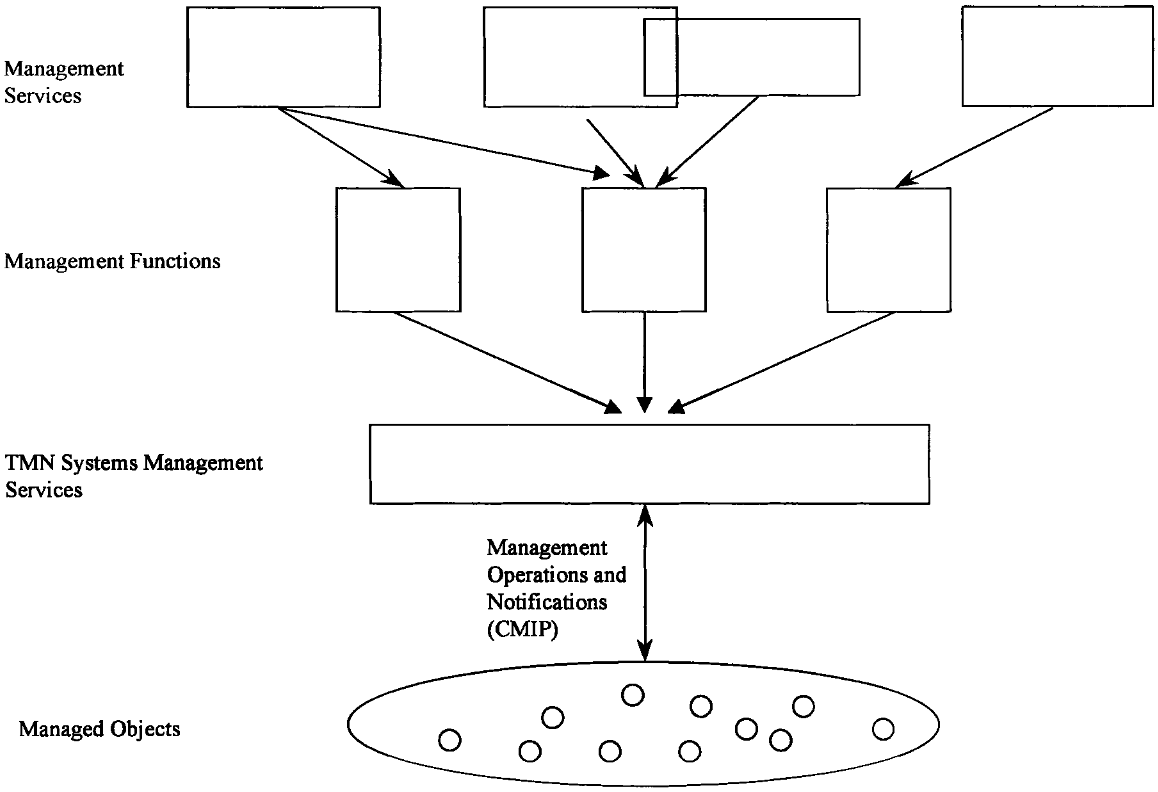


Figure 3.2
TMN systems management services.

is CMIP. CMISE services are M-GET, M-CANCEL-GET, M-SET, M-ACTON, M-CREATE, M-DELETE, and M-EVENT-REPORT. We will look in detail at CMISE services in Chapter 7. Note that the exchange of messages between managers and agents can also be done by FTAM as an alternative to the use of CMIP.

TMN SM services (Figure 3-3) are provided by one or more OSI systems management functions such as log control functions, event report management functions, security audit trail functions, and so on. The OSI specification documents of interest to us are the 10164 series.

In this section, only a summary of management services is provided. For more details refer to Reference 3.1. Also, M.3400 Appendix has detailed flows on each of the management services.

The details of the management services are as follows: