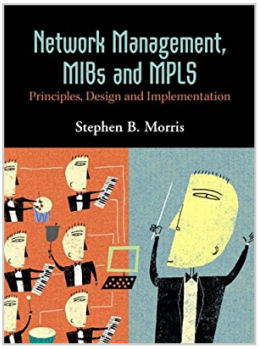

Network Management, MIBs and MPLS: Principles, Design and Implementation

By Stephen B. Morris

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Network Management, MIBs and MPLS: Principles, Design and Implementation is the definitive guide to managing and troubleshooting enterprise and service provider networks. This in-depth tutorial from networking expert Stephen Morris delivers clear and concise instruction on networking with MIBs, SNMP, MPLS, and much more. Coverage includes SNMPv3, network management software components, IP routing, HP Openview Network Node Manager, NMS software components, among other key techniques and tools for managing large network systems.

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Editorial Review

From the Back Cover

Network Management, MIBs and MPLS: Principles, Design and Implementation

Stephen Morris

- Efficiently manage large, complex, multi-service networks
- Proposes solutions to difficult network management problems
- Uses practical examples in Java and C++
- Covers both enterprise and service provider networks

Cost-efficiently manage and troubleshoot your MPLS network with SNMP!

In today's business world, it is crucial to be able to manage large, complex networks in an efficient and cost-effective manner. *Network Management, MIBs and MPLS: Principles, Design and Implementation* makes such management possible. Widely-experienced engineer and network management specialist Stephen Morris discusses how, the skillful use of MIBs (management information bases) and network management system (NMS) technology, can be used to help solve some of the management problems associated with running large footprint enterprise and service provider networks. These problems include issues of wide technology mix (ATM, FR, Ethernet, IP, MPLS etc.), the increasing need for real time IP traffic, the need for strong security, scalability (the latter is possibly the biggest single problem facing network managers).

With examples in both Java and C++, this book covers SNMPv3, network management software components, IP routing, MPLS and much more. Coverage includes:

- In-depth analysis of SNMP, the de facto network management standard
- Scalability solutions using special MIB features, NMS and MPLS
- HP's Openview Network Node Manager
- Network management server components
- NMS software components
- Case studies in MPLS network management using the IETF MPLS MIBs
- The theory and practice of network management
- Numerous reference appendices featuring over 20 pages of C++ and Java source code designed to clearly illustrate the rudimentary structure of an NMS

For networking professionals, network managers, MIB authors and anyone associated with programming for large-scale networks, *Network Management, MIBs and MPLS: Principles, Design and Implementation* is a vital handbook.

About the Author

STEPHEN MORRIS is an engineer and network management specialist at Marconi Communications, in Dublin, Ireland. For the last 15 years he has worked for some of the world's biggest networking companies on a wide range of software projects including: billing, porting/developing SNMP entities, NT and UNIX-

based management systems, and intelligent networking. He holds a master's degree (by research) in SNMP network management.

Preface

The last two decades have been dominated by distinct patterns of computer use. The 1980s saw wide-scale deployment of PC- and microprocessor-based technology. The 1990s saw this infrastructure becoming internetworked, connected to the Internet, and increasingly embracing client/server technology. Initially, clients were heavy duty (or fat) and communicated with local servers, but by the end of the 1990s clients had become thin and servers were increasingly distributed. The first decade of the 21st century may well be one of global system (as well as network) integration and management during which we will see previously disparate networks and systems interconnected for new purposes. Nowhere is this more apparent than in the area of telecommunications and data networking.

The relentless growth and extended reach of both enterprise and service provider (SP) networks have been accompanied by an increased demand for advanced vendor-independent network management software tools. This is particularly the case as enterprises leverage their network investments by deploying evermore advanced, mission-critical systems like voice-over-IP and desktop video conferencing applications ATM&IP2001. At the same time, service providers are consolidating and deploying Multiprotocol Label Switching (MPLS) cores and IP services, such as IP VPNs, as part of their migration path to an end-to-end packet-based infrastructure Alcatel2001.

In many ways the managers of enterprise networks face a daunting task because of the sheer diversity of network elements (NE) and systems--multi-vendor routers, switches, leased lines, WANs, VLANs, Storage Area Networks (SANs), mobile and desktop telephony, PABXs, soft switches Sweeney2001, databases, a wide range of software applications, NT/Windows 2000/Unix servers, minicomputers, mainframes, and so on. These systems are the data lifeblood of modern corporations, and their continuous availability is crucial. Unfortunately, most of these enterprise NEs have their own proprietary management tools, which have to be learned and maintained over time, adding to the cost of ownership. Proprietary systems (a bad thing) and centralized, automated management (a good thing) are, in general, mutually exclusive.

Enterprises have a lot of legacy systems and equipment, which must be depreciated over many years. Forklift upgrades (getting rid of all the old stuff and putting in the latest) are generally too expensive, so system and network management skill sets must be present throughout the lifecycle. This means that enterprises will continue to be a highly complex network management proposition for a long time to come. Complex management equates to high operational cost. This book proposes that all network-based systems produced for the enterprise market should:

- Provide MIB module files that describe the principal managed objects.
- Conform to or extend standard MIBs.
- Provide any proprietary MIBs in text file or downloadable form at the time of purchase.
- Guarantee as far as possible that the management facilities will be available during periods of high traffic or even congestion.
- Include high-performance agents that can issue useful notifications and execute both read and write operations against their MIBs.
- Deploy SNMPv3 agents (entities).
- Provide simple scripts for reading from and writing to their MIBs.

- Provide snap-in modules (Java/C++) to allow easy integration with existing network management systems.
- Support automation via SNMP of routine administrative tasks such as adding users to a VLAN or disks to a SAN.

Network managers should insist on these minimum requirements before making purchasing decisions. On the supply side of the industry, vendors should from day one build standards-based (SNMPv3) management facilities into their networking products. Many vendors leave the management infrastructure (agents, MIBs, etc.) development until quite late in the development cycle. This can result in poor-quality agents and MIBs, ultimately reducing the manageability of the NEs and the wider network.

Several equipment vendors have a large number of different element management systems (EMS) to manage just their own equipment. Since the EMS often forms the basis for the NMS, this multiplicity of different EMS can make NMS software harder to develop, particularly in multivendor networks. A single EMS across all NEs is a better proposition.

Another major theme of this book is the migration of networks toward a layer 3 model based on the IP protocol. This is a mega-trend affecting pretty much any industry involved in moving data from one networked location to another. Management systems for layer 3-converged (voice, video, and data) networks are an increasingly important issue. We use MPLS as a running example of how networks are evolving in terms of providing quality of service, traffic engineering, and so on.

Intended Audience

This book provides a practitioner's approach to understanding the area of network management. The only prerequisites are a reasonable understanding of network technology and a passing familiarity with SNMP. The book is suitable for:

- Network management software developers.
- Software developers considering a move into the area of network management system development.
- Network managers seeking a deeper insight into the area of network management.
- Network equipment vendors.
- Enterprise and SP networking professionals.
- Standards bodies producing MIBs for new technologies, such as the IETF, and industry-wide technology advancement groups such as the MPLS Forum (among others).
- Students taking courses in telecommunications, computer science, or network management.

Network Management, MIBs, & MPLS: Principles, Design, & Implementation provides much discussion of networks, MIBs, management software, and managed objects. Important points that are relevant to MIB authors are indicated by special sections entitled "MIB Notes."

We also include "Developer Note" sections that are of primary concern to software developers. Readers seeking an introductory overview can safely skip these few marked sections.

Purpose of This Book

This book is not a detailed description of the major versions of SNMP (1, 2c, and 3). Many other books do a good job of this. Our focus is on the use of SNMP technology for managing networks. It also attempts to tackle the complexities faced by the developers of NMS software products. MIBs are a crucial element of this for modeling the operation of large networks.

The field of network management is extremely broad with a vast range of products from many companies.

This book is intended primarily as a learning aid for hard-pressed engineers tasked with software development or development and maintenance of complex networks and management systems. The book is also a guide to adopting enhanced approaches to both NMS/MIB requirements definition and NMS/MIB development. It has no affiliation with any vendor or technical organization. Any mention of technologies--IP, MPLS, ATM, Frame Relay, VLANs, Ethernet, and so on--is intended purely as a teaching tool to illustrate network management principles and to place the latter in a modern and interesting context.

We use a big-picture approach and try to give a reasonable overall description of managed networks. In this context, network management should be seen as a type of abstraction; that is, it seeks to manage networks, not provide a comprehensive understanding of all the constituent technology (e.g., IP, ATM, and MPLS).

Using This Book

We hope our readers will gain a solid foundation for understanding the principles and practice of NMS use and development. The networking industry is highly dynamic, so referring to specific products tends to quite quickly date a book. Vendor devices and software management products come and go, but concepts tend to have a longer shelf life. For this reason, we focus mostly on principles and concepts with reference to important RFCs IETFWeb. The major exception to this is in chapter 5, "A Real NMS," where the highly successful HP OpenView Network Node Manager is described. Even in this case, however, we describe generic network management areas and then see how HP supports them. Also, some mention is made of SNMP software development tools. The book can be used to:

- Assist network managers in defining management requirements for their equipment and system suppliers.
- Gain a better understanding of the relationship between network management and cost of ownership.
- Bring network management needs to the top of the priority list for NE software and hardware development engineers.
- Encourage a sound approach to development on the part of management system vendors.
- Locate Internet resources on MIBs and network management.
- Learn how to build and extend a rudimentary SNMP-based management system.
- Get a good look inside big networks from a management perspective rather than to merely present the constituent technologies.

We hope that the book gives an integrated overview of network management issues. This includes an understanding of both management system technologies and trends in NEs. Much of the technology mentioned (MPLS, VLANs, etc.) is described in Andrew S. Tanenbaum's Computer Networks Tanenbaum2003, which also has much useful detail concerning the various standards organizations.

Linked Overviews

We introduce a four-step, fast-track technique in chapter 3, "The Network Management Problem," for gaining an overview of a given NE. Briefly, this technique is as follows:

- Review the NE technology.
- Use the device EMS.
- Learn the MIBs.
- Write some source code to manipulate the MIBs.

Clearly, software developers need all three steps, but steps 1 and 2 could also be useful for project managers, marketing executives, and others.

Source Code Location

In order to help solidify the concepts discussed, chapter 7, "Rudimentary NMS Software Components," includes the source code of two programs, one written in Visual C++ and the other in Java. The example source code is freely available from the Prentice Hall Web site, http://authors.phptr.com/morris.

The Four Ms

Many existing books do an excellent job of describing SNMP, MIBs, proxies, and other technologies. While this book describes SNMP (including version 3), its primary focus is more on what might be called the four ms:

- Manageability of NEs
- MIBs
- Multiservice devices
- MPLS

The manageability of NEs directly affects the cost attached to introducing them into large networks. The quality of the associated MIBs has an important bearing on the cost of introducing the NEs into existing and new management systems. Multitechnology NEs are increasingly the norm, supporting combinations of TCP/IP, MPLS, ATM, Frame Relay, Ethernet, SONET, DWDM, and so on. MPLS and GMPLS are now part of both the strategy and production environment of many service providers. MPLS is also finding its way into the WANs of some very large enterprises. MPLS is such an important technology that it forms a common thread throughout this book.

Outline of the Book

Chapter 1 presents a general overview of modern networks and introduces the area of management. Reference is made to sample enterprise and SP networks. VLAN technology and layer 3 are introduced, and the difference between ports and interfaces is described. The importance of network management is discussed and includes a brief explanation of the areas of network management. The network management pyramid is introduced to show the way different management system software layers can be deployed. Alternative techniques to SNMP are described. Aggregate network-resident objects are described, followed by the overall goal of an NMS. A closer look is taken at the elements of SNMP.

Chapter 2 describes some of the details of SNMPv3 message content. Some SNMPv3 message interactions are described with reference to an example network. Some of the problems associated with SNMP are described. The different versions of SNMP in common use are enumerated, followed by an introduction to the area of SNMP applications. A closer examination of a MIB is made to reveal the general structure of all MIBs. This is followed by a brief comparison between NMS software and more familiar applications. The generic structure of a network device is described, and an introductory section on MPLS is included.

Chapter 3 describes the fundamental operational problem in network management: scalability. The other major problem is a severe skills shortage among management system developers. The traditional approach to development of being able to specialize in application (high-level) development as opposed to system (low-level) development doesn't seem to fit the network management model. Developing management software requires a rarified mixture of skills, and some of these are enumerated and described. Likewise, operating and maintaining modern networks require a hard-to-find mixture of knowledge of layers 1, 2, and 3.

Chapter 4 presents some strategies for solving the network management problems identified in chapter 2.

This includes augmenting development skill sets, smarter management systems, smarter MIBs, smarter devices, good data models, distribution, policy, and directories. The distribution of management system servers is one possible approach to solving compute-intensive bottlenecks. The emerging area of policy-based techniques for network management is introduced, followed by a discussion of directory-enabled networking. IP Differentiated Services architecture model is introduced in the context of the ongoing MPLS discussion.

Chapter 5 presents a description of a widely used network management system. HP OpenView Network Node Manager is introduced in terms of its ability to discover networks and process notifications. Issues such as the bringing up and down of large networks are described, and the FCAPS areas are revisited. The important issue of visually depicting a network state is then described, followed by a discussion of client-side software.

Chapter 6 presents the internal software that makes up a network management system. This includes servers that talk to the network devices, clients that talk to the servers, MIBs, backend software, and database schema versus MIB content. Each of the FCAPS is described in the context of a software block description. The various databases employed in a managed network are described along with typical operations performed against them. Middleware is briefly described, and the trend toward using Java for developing network management systems is discussed.

Chapter 7 describes how to build some basic network management system components using Visual C++ and Java. Typical SNMP operations are illustrated with screenshots. A scheme for extending these rudimentary components is enumerated.In Chapter 8, the MPLS management case study is introduced with a description of the principal components of this forwarding technology. The MPLS MIB content of interest is then introduced, and detailed directions on how to create an LSP and a tunnel are provided. The merits of using signaling for the creation of MPLS tunnels are briefly described followed by a discussion of adding new entries into MIB tables. The role of the standards process is then described.

Chapter 9 brings together all of the threads running through the book and reiterates the overriding importance of MIB structure and design for successful network management system development. There is a strong need for thin, well-separated software layers in network management systems. Scalability is also a major issue in network management, the more so given the emerging generation of dense, multitechnology NEs. The latter provide a compelling argument for pushing more decision-making into the network. We illustrate a trend in this direction with the MPLS FTN MIB. As far as possible, technology-specific code in the network management system should be minimized. Security is high on the agenda of network operators, as is the need for solutions (rather than just technology). Economic downturns may diminish operator appetite for purchasing consultancy services--this can put more pressure on vendors to produce generic overall solutions. The need for solution mindsets has an important bearing on the roles of QA, IT, and software developers.

A Note About Abbreviations

The field of network management features an enormous and ever-growing array of abbreviations and acronyms. Since this book is aimed at practitioners, we chose not to expand all abbreviations inline (though many are). Instead, there is a detailed glossary at the end of the book containing descriptions and short definitions of many of the abbreviations. Readers less familiar with the abbreviated terms will hopefully find the glossary useful. There is also a list of abbreviations at the start of the book.

Additional Resources

One of the big problems attached to working in the network management area lies in knowing where to locate good sources of information. Below are some additional resources (in alphabetical order) for further reading.www.etsi.org/ European Telecommunications Standards Institute--details on standards for mobile telephony, signaling, and so on.www.ietf.org/ Internet Engineering Task Force--RFCs, MIBs, and many other useful documents. This site provides lots of interesting reading written by industry experts. Some IETF documents are a little impenetrable at first but are usually well worth the effort of reading in full.www.itu.int/home/index.html International Telecommunications Union--general telecommunications.www.metroethernetforum.org/about.htm Metro Ethernet Forum--dedicated to accelerating the adoption of Optical Ethernet in metropolitan networks worldwide.www.mplsforum.org/ The MPLS Forum serves two important functions. First, it produces Implementation Agreements (IAs) in the areas that are not covered elsewhere and/or are related to a combination of technologies. Examples are IAs on voice-over-MPLS and MPLS PVC UNI. Second, it works with major interoperability labs, such as the ones in the University of New Hampshire and at the technical university of Berlin (EANTC), on defining interoperability requirements for various MPLS protocols and then organizing testing events. The MPLS Forum also has an MPLS educational function, and in this role it develops and presents tutorials related to advanced and emerging areas of MPLS and provides speakers to major conferences. The MPLS Forum actively works with other organizations, such as the ATM Forum and the Frame Relay Forum, and many members of the MPLS Forum are active participants in the IETF, particularly in the PWE3 group.

- www.mplsrc.com/ The MPLS Resource Center--lots of information about MPLS.
- www.protocols.com/pbook/ Protocol directory--details on various protocols.
- www.simple-times.org/ Historical introduction to SNMP.
- standards.ieee.org/catalog/olis/ IEEE--standards and many other technical topics.
- www.simpleweb.org/ietf/mibs/ IETF Web site dedicated to MIBs.
- www.telecoms-mag.com/ Telecommunications Online Magazine--good topical coverage.
- www.telcordia.com/ Telcordia--excellent site on general telecommunications issues, current research and ideas on algorithms, management, and so on.
- www.telelogic.com/ Telelogic--producers of development tools for telecommunications. Its impressive Tau product has SDL and UML interfaces and provides code-generation technology based on formal methods.

Any of the Internet search engines can provide further information if required.

Users Review

From reader reviews:

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Diana Chung:

Playing with family within a park, coming to see the water world or hanging out with close friends is thing that usually you have done when you have spare time, subsequently why you don't try matter that really opposite from that. 1 activity that make you not sense tired but still relaxing, trilling like on roller coaster you have been ride on and with addition of knowledge. Even you love Network Management, MIBs and MPLS: Principles, Design and Implementation, it is possible to enjoy both. It is good combination right, you still want to miss it? What kind of hangout type is it? Oh seriously its mind hangout fellas. What? Still don't obtain it, oh come on its called reading friends.

Elizabeth Blake:

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