An Expert Integrator for Communication Networks Management

Chi-Chun Lo
Institute of Information Management
National Chiao-Tung University
Hsinchu, Taiwan 30050
Republic of China

Abstract

Network management is a hard problem. How to manage the multi-vendor network efficiently and effectively has become a growing concern in the international communication networks community. OSI management [4] has defined a basic set of facilities (functional areas) that the network management should provide. In this paper, we propose an integrated architecture which allows the expert systems, one for each functional area, to work together in an organized way. An additional expert, namely the Integrator, will sit on top of the five functional experts. It forwards the triggering data received from the network components to the appropriate functional experts that understand a specific network problem. In this architecture, OSI network management protocols are used as the means of communications among experts. An object-oriented database and a generic user interface are presented.

Keywords:
Open System Interconnection
Network Management
Common Management Information Protocol
Common Management Information Service
Integrated Network Management System

1. Introduction

Networks continue to grow at a rapid pace and with greater complexity, with a variety of host-computers, workstations, personal computers, and terminals, etc. To have efficient network management tools become a critical part of any successful communication network.

The term "network management" is often used by different people to mean different things. In general, network management is expected to meet customer needs, in terms of availability, performance, and stability, business needs characterized by new applications, new customers, and requirements for greater access. Unified management of the physical and logical aspects of the network is the solution to these needs. Unified network management provides:
- the ability to manage the entire network, end-to-end, from a single point if so desired.
- the ability to control the network and its components.
- the ability to detect, isolate, and correct faults.
- the ability to measure the performance of the network, both in monitoring and analysis mode, in order to detect problems before they affect end users.
- the ability to support security and accounting, and facilitate capacity planning, on a network-wide scale.

However, the lack of a common network management protocol makes a unified network management impossible. The standards community must develop a common management architecture that supplies a common set of management functions which can support the requirements of a unified network management. Above all, this set of management functions should be implemented by each vendor independently. Along with this direction, OSI Network Management (OSI/NM) has defined five system management functional areas:
- Configuration Management:
- **Fault Management:**
  encompassing fault detection, isolation and the correction of abnormal operation of OSI environment.

- **Performance Management:**
  enabling the behavior of resources in OSI environment and the effectiveness of communication activities to be evaluated.

- **Security Management:**
  ensuring only secured and authorized access to the network management system and resources.

- **Accounting Management:**
  enabling charges to be established for the use of resources in OSI environment, and for costs to be identified for the use of those resources.

The introduction of expert systems is considered to be the next major evolutionary step in network management. By using expert systems, we can fully automate all management tasks. A number of expert systems, [11],[12],[13], with which a specific functional area is concerned, have been studied.

In this paper, we propose an integrated architecture which allows the expert systems, one for each functional area, to work together in an organized way. An additional expert, namely the Integrator, will sit on top of the five functional experts. It forwards the triggering data received from the network components to the appropriate functional experts that understand a specific network problem. These experts, in turn, may suggest possible hypotheses that might explain the triggering data. In this architecture, OSI network management protocols (CMIP/CMIS) are used as the means of communications among experts. An object-oriented database as well as a generic user interface are presented. Furthermore, the distributed nature of this architecture makes the future expansion possible.

2. **Expert Integrator Design Guidelines**

The Expert Integrator is designed with the following guidelines in mind:

- Provide intelligent assistance using knowledge of network experts.
- Comply with the international network management standards.
- Adopt the object-oriented paradigm.
- Support a generic user interface to the network operator.
- Allow future growth.
- Apply the concept of Integrated Network Management System (INMS).
- Minimize network management data flow.
- Provide fault-tolerant network management services.

1. **Provide intelligent assistance using experts knowledge**

Sophisticated knowledge of network experts is an essential aid in managing communication networks. By encoding expert knowledge into "expert" systems, we can reduce the required level of operator experience and increase the complexity with which problems can be addressed.

2. **Comply with the international standards [4]**

In order to manage multi-vendor networks in a unified manner, it is necessary to comply with the international standards such as OSI Network Management protocols. By using standard protocols, we can be sure of the interoperability among different networks and are able to provide a distributed network management system.

3. **Adopt the object-oriented paradigm [19],[20]**

Network management is a hard problem. Its technology is still evolving. To build a rapid changing system like the network management system, extensibility and reusability are of major concern. The network management system manages dispersed networks with diversified network resources. It is imperative to have a uniform way in representing network resources. Apparently, the object-oriented paradigm serves our needs very well. This paradigm supports important features such as the encapsulation, polymorphism, and inheritance. It allows us to construct network resources as objects and build the management system in a reusable and extensible way.
(4) Support a generic user interface

The generic user interface has to support user-friendly interactions with the network operator or analyst. It is the single point of contact for managing networks and should be designed to meet the user's expectation. Moreover, it should support both the graphical and textual modes of operation.

(5) Allow future growth

Network is grown by adding new network resources. New network comes to exist every day. Internetworking becomes more important than ever. All these requires us to design an architecture that is able to accommodate this growth.

(6) Apply the concept of INMS [14]

Heterogeneous is becoming a common term for describing today's network environment. Management of a multi-vendor environment is complicated by the fact that each vendor provides a different management system. To integrate these systems together is not an easy task. Integrated network management system is the final solution. We have to design the management system in a way that moves toward this ultimate goal.

(7) Minimize network management data flow

The exchange of network management information between the network management system and managed objects (network resources) should not add a large amounts of traffic to the network. In any circumstance, the management system should not degrade the network performance.

(8) Provide fault-tolerant network management services

Network management services should not be disrupted. They must be able to survive under component failures within the management system and within the underlying networks.

3. Expert Integrator Architecture

The expert integrator we propose is composed of eleven functional modules. Figure 1 illustrates the functional decomposition. Both the overall architecture and interactions among modules are presented. Each functional module executes its own set of functions. In the following paragraphs, we will discuss each module in details.

Figure 1. Expert Integrator Architecture

(1) Network Elements

Network elements are at the lowest level of the architecture. Each network element represents a particular type of network resource. Network element is hardware-dependent. By acting as the liaison between the network resource it represents and the management system, it communicates with the hardware component upon the request of the management system.

The advantages of isolating hardware-dependent information into one place (module) are three folds: First, the architecture is able to handle a variety of network configurations. Second, the architecture can grow without any modification to the underlying structure. For instance, after
installing a new resource into the network, we only need to add the corresponding network element (and object definition) into the management system. Third, proprietary information will be coherently included as extensions of common functionality.

(2) Object-Oriented Database Technology

Object-Oriented database technology provides a toolkit to the user of the Management Information Base (MIB), which is an Object-Oriented Database (OODB). With help from the toolkit, users are free from the complication of OODB. OODB technology establishes the foundation of the architectural design. By using the object-oriented concepts such as the class definition, property inheritance, and object instantiation, we can simplify the management system structure and achieve the purpose of declarative programming.

(3) Generic User Interface Utilities

Generic user interface utilities include basic user interface subroutines, such as window, graph, menu, icon, and scrollbar, etc. These utilities together provide a set of building blocks to a window-based, menu-driven, iconized, and graphical user interface design.

(4) Network Element Objects

Each network element and its associated functionalities and attributes are packaged as an object. It is the logical extension of the corresponding hardware component. To the management system, it manages network element objects instead of physical network resources. Network element objects are invoked via the message (request) from the management system. Certain operations, like create, delete, access, and modify, can act upon these objects.

(5) Generic User Interface Objects

We can package several generic user interface utilities, such as window, graph, etc., into one generic user interface object. Through the use of generic user interface objects, the user interface design can be simplified and accelerated.

(6) Network Management Objects

System management functions, being defined by OSI/NM, are modeled as objects. These functions include alarm reporting, log control, and event reporting, etc. Network management activities are carried out by the use of network management objects.

Routing is one major responsibility of this module. It determines where the requested network element object is. It can distinguish a local object from a foreign one. If the requested object resides on another node (or network), this module will redirect the request, using OSI CMIP/CMIS protocols, to the appropriate destination. In fact, by including OSI CMIP/CMIS protocols in this module, we have a distributed network management system.

(7) System Management Program Interface

This module provides application programmer interfaces (APIs) to network management experts. APIs are a set of parameter-driven subroutines. Each subroutine combines related messages together and presents a "self-contained" service to its user.

(8) System Management Interactive Interface

A set of interactive interfaces is introduced by combining generic user interface objects with the system management program interface.

(9) Network Management Experts

This module includes five functional experts. Each expert system is responsible for one of the five system management functional areas defined by OSI/NM. These experts are Configurator, Diagnostician, Performance Analyzer, Security Enforcer, and Accountant. Organizing network knowledge in multiple experts allows the most appropriate inference mechanism to be used in each expert, depending upon expert's problem domain.

(10) Expert Integrator

The expert integrator is the most critical part of the architectural design. It is a top-level expert. It acts as a scheduler, a coordinator,
and an event-handler.

As a scheduler, it provides a multitasking environment to the network operator. Multiple management requests can be entered into the system simultaneously. The expert integrator will schedule the requests based on a priority scheme. How to balance the system workload, maximize the throughput, and minimize the response time are of major concerns.

As a coordinator, it tries to reduce the management data traffic. It always finds out the best strategy in carrying out management requests. For example, after a faulty component is fixed, the performance analyzer can be started automatically to verify the impact on the system due to this fix.

As an event-handler, it forwards triggering data received from the network resources or generated by the network operator to the appropriate functional experts. It provides a single generic interface to its user. This interface can be operated in either the interactive or batch mode. The batch mode operation is supported by a script-like language.

(11) Network Management User Interface

This module provides a menu-driven, window-based, iconized, and graphical user interface. It interacts with both the expert integrator and generic user interface objects. By accessing generic user interface objects directly, this module can support new applications, such as the browser and monitor, very easily.

4. Implementation Issues

We have identified several issues which may merit thorough investigations before starting the implementation. These issues are as follows:

(1) How to choose the right platform - the platform for prototyping should be flexible and extensible.

(2) How to choose the right development tools - the development tools have to be state-of-the-art technologies and widely accepted.

(3) How to implement the system in parallel - for instance, we can develop the user interface, OODB, communication protocols, and expert systems at the same time.

(4) How to keep up with the evolving network management standards and reflect the changes in the management system as quickly as possible.

5. Conclusions

In this paper, we have described the architectural design of the expert integrator. The expert integrator we proposed has the following characteristics:

- It is modulized.
- It is flexible and extensible.
- It is a distributed network management system.
- It is fully adhered to the international network management standards.
- It applies the object-oriented methodology in both the database and user interface designs.
- It provides a single generic interface to its user.
- It outlines a generic network management system architecture which can be applied to various types of networks, such as the Wide Area Network(WAN), Local Area Network(LAN), and Integrated Service Digital Network(ISDN), etc.
- It is an automated network management system with assistance from several expert systems.

The architectural design is the first and most important step toward the complete implementation of an automated communication networks management system. The next phase of this research will focus on the detailed design and its implementation. We believe that we are on the right direction. However, in order to accomplish the final objective, more works need to be done.

References

(1) "Communication Networks Management," Kornel Terplan, Prentice_Hall.
(2) "Computer Network," 2nd, Andrew Tanenbaum, Prentice_Hall.