MANAGEMENT ASPECTS OF A HYBRID FIBER COAXIAL (HFC) NETWORK

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Abstract

This paper addresses Network Management aspects of a Hybrid Fiber Coaxial Full Service Network (FSN) [i] *delivering services such as video, voice, and data. Spectrum Allocation and Bandwidth Management structured around an Open System Architecture are some of the focal points of this paper.*

Illustrated in the paper is a design approach describing an example of the Network Management Architecture. It is based on an Open System Architecture for the new management platform because it promotes connectivity to existing Management Systems (Operation Support Systems). In addition, this platform makes it possible to incorporate a more intuitive, standard Graphical User Interface (GUI) in a windowing motif.

Also addressed is the selection of off-the-shelf solution tools for presentation, communication and the storage of the distributed information.

Use of Artificial Intelligence (AI) techniques in decision-making tasks for a distributed network environment is suggested as a logical extension to the HFC network management.

HFC Network Overview

CATV networks of today are evolving into two-way switching and distribution systems carrying both analog and digital services that are now referred to as FSN. As fiber gets closer to the home (Figure 1), networks are able to offer more services (such as video, voice, high and low speed data, and telemetry). As a result,

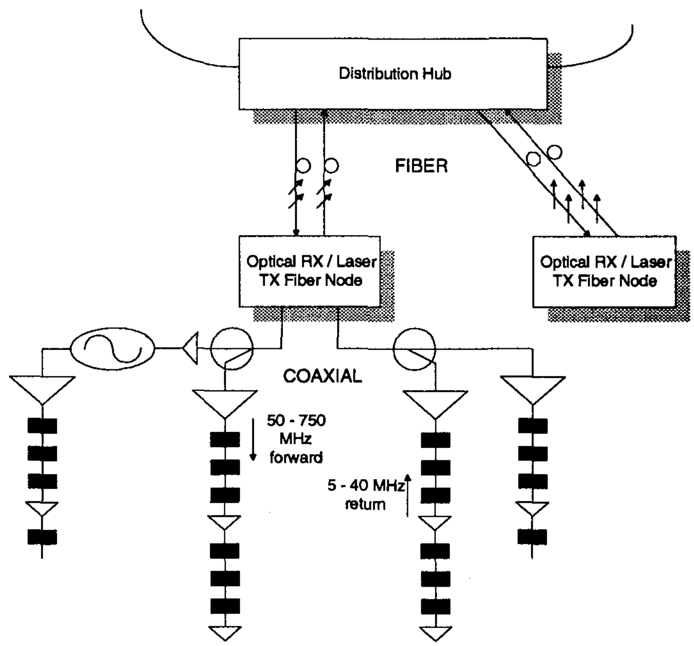

Figure 1 Fiber to the Node HFC Architecture

today's Network Management Systems (NMS) must provide management features never before required in the older one-way video broadcast system.

Managing HFC networks is complicated by the fact that these networks asymmetrical and were built without attention to many management aspects. Further use of equipment from various vendors with proprietary protocols increases the complexity in the implementation of a standards based system. The complexity of mapping many different services to the HFC's asymmetrical bandwidth dictates the use of a centralized Spectrum Management entity.

Network Management Paradigm Overview

A NMS consists of three main elements: a manager, agents, and managed objects. The manager is the console through which the network administrator performs network management functions. Agents are the entities that interface with the actual devices being managed. Optical hubs, trunk amplifiers, and Premise Interface Devices (PIDs) are examples of managed devices that contain managed objects. Examples of managed objects might be Automatic Gain Control (AGC) signal, provisioning information for the PID, or anything else that directly relates with the particular device.

The Managed Objects are described in a structured way using Abstract Syntax Notation 1 (ASN.1). As the name implies, ASN.1 is the formal notation used to describe managed information in a formal and unambiguous way. All managed objects are structured using a framework called the Structure of Managed Information (SMI). A Management Information Base (MIB) defines managed objects and is written using ASN.1.

There are several protocols used for network management. Among the most popular ones is Simple Network Management Protocol (SNMP) which uses ASN.1 as a tool to describe its MIB. SNMP is a "light weight" protocol and imposes minimal overhead for implementation. It is an accepted standard in the Internet community and appears to be a preferred protocol for HFC network management by the industry. For interoperability requirements, vendors with proprietary protocols can encode data using Bit Encoding Rule (BER) which is available under SNMP.

To accommodate devices that cannot contain a full standard compliant agent, the concept of "proxy" is used. In this scheme, a standard compliant agent, typically a software entity residing on a PC in the Network, acts as a proxy for one or more other devices. This is commonly used whenever there is a need to interface a proprietary protocol with a standard protocol.

Spectrum Allocation And Bandwidth Management

The main focus of bandwidth management is to address the bottlenecks in the coaxial plant, specifically in the return direction where the bandwidth is limited. Network management must pay close attention to this area so as to distribute two-way services in an efficient manner. Overall though, the bandwidth management encompasses the entire HFC from the Distribution Hub/Fiber Node and the rest of the coaxial cable to the Subscriber Premises.

The basic spectrum allocation operation would fit in Network Management in the following way:

The entire spectrum would be managed from the Spectrum Management Application (SMA) which would reside in the primary Headend or Distribution Hub as a part of the NMS.

On request from the SMA, the spectrum allocation operation would be carried out by the Spectrum Allocation Proxy Agent (SAPA) which would reside in the Distribution Hub.

Between the Distribution Hub/Fiber Node and the rest of the coaxial network, it is typical to have a proprietary transport protocol in order to carry out spectrum allocation. That would involve using a separate, maybe out-of-band, management channel.

The whole decision making intelligence that determines spectrum allocation to different services would reside in the SMA.

To be able to address spectrum allocation and bandwidth management, it is necessary to identify all Spectrum Management Objects (SMOb) and to describe them in a rigorous way in order to avoid misinterpretation.

From the Spectrum Management point of view, the HFC can be viewed as several abstract networks layered over each other. Due to the predominantly asymmetrical architecture of the HFC network and the diversity of services on it, the abstract layers may be unidirectional. The SMObs are implemented on the physical devices. They can be categorized in several groups: Abstract Network Layers Objects, Service Objects, Channel Objects, Modulation Objects, Power Level Objects and so on. These objects are interrelated in a structured and behavioral way. The best way would be to describe the system by describing the MIB using ASN.1. However, that would go beyond the scope of this paper.

From the implementation point of view, the managed objects would be distributed over the network and the communication /control of them would be done through a combination of standard and proprietary protocols (Figure 2).

The ultimate goal of spectrum management is to simply provision a service and the management application and dynamically allocate spectrum for the service through automatic provisioning of the network devices involved. This can be accomplished through autodiscovery and enough intelligence for the software to reprovision devices for the most efficient use of all resources. Then together with the fault management application, both will monitor and reprovision the system to meet the set requirements of operation (Figure 2).

Off-the-shelf Solution Tools

Our assumption is that the HFC will be built based on cost/performance criteria. That implies using distribution/switching equipment from various vendors. We want to consider the development tools that will meet the accepted standards for interfaces in this system.

The network management development tools can be subdivided in several groups: Core Management Platform, Communication, and Database. We will address each group separately.

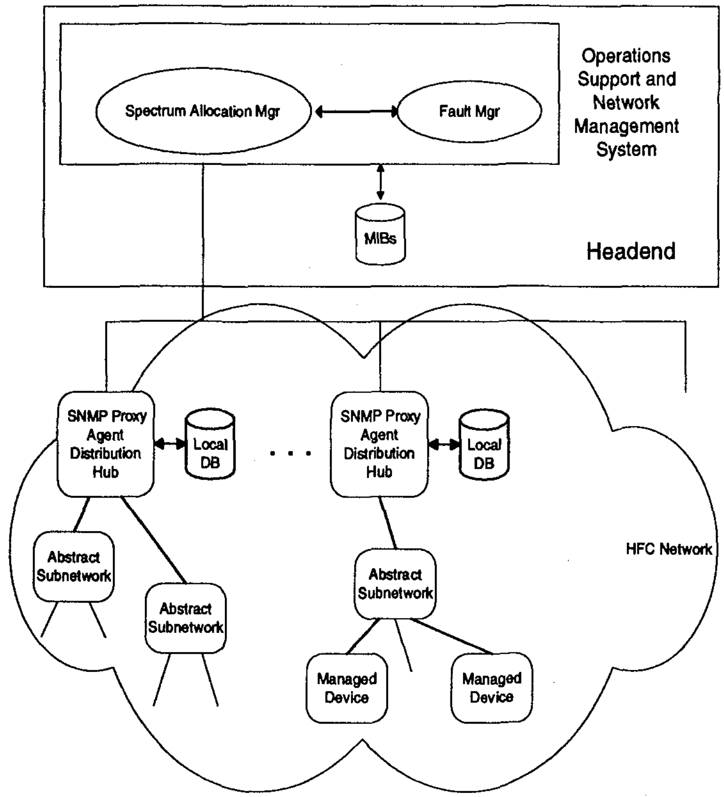

Figure 2 Intelligent HFC Network Management

<u>Core Management Platform (CMP)</u>

In general, Core Management Platform provides an integrated environment for displaying information from several different applications at the same time. It does this by combining device and status information from each application. All applications run in the background. CMP controls exchanging of the information between the platform and the applications and updates the graphical user interface accordingly. It usually provides the hierarchical graphical map with interconnected device icons and the mechanism to create and edit the map. Among other things, it provides a way to handle the alarms as well as "autodiscovery" and "layout" of the network. In this context, autodiscovery is a mode of operation where the management system "discovers" the managed devices and draws the icon based map of them in the layout mode.

Several major companies provide the CMPs. The key element in Core Management Platform is scalability. It is important to select a platform that can be applied to smaller networks but leave the possibility to grow to virtually limitless size. Very often you may need to manage a small network using a PC based development platform, but you want to integrate it with some other more powerful workstation based platforms. One such CMP is HP OpenView (HPOV). It is based on an international OSI management framework and models. In particular, it derives three essential elements from the OSI standard: a network management framework, a well-defined mechanism for describing managed objects, and a set of services and protocol for communication. At the same time it supports the SNMP concepts.

Communication

Exchanging the management information between the Managed Objects and the managing station requires some information exchange infrastructure. This infrastructure is usually different from the infrastructure that the network uses to communicate the payload information like voice, data, and video. For example, in HFC networks it may be convenient to use an out-of-band channel to provide the communication for management information.

As mentioned earlier, there are several standards for managing networks being used in industry. Besides the syntax to describe the MIB, the standard defines the transport protocol to communicate information. This paper stresses SNMP as the most feasible choice. SNMP defines how to communicate the information between the management entity and the managed object. One of the transport protocols used in SNMP is User Datagram Protocol/Internet Protocol (UDP/IP).

There are some other proprietary transport protocols such as Sequenced Packet Exchange/Inter-network Pack Exchange (SPX/IPX) used by Novell. CMPs usually support both, although UDP/IP is the more dominant.

CMPs such as HPOV support SNMP and SNMP implementation tools from other sources. Some implementation tools comply with additional standards, and we will mention some of them used in the PC environment. For example, the WinSNMP standard defines a set of Application Program Interface (API) links to provide SNMP services. Also, WinSock provides a similar set of interfaces to perform TCP/IP communication.

Database

From the point of the Database Management Tools, a HFC network can be perceived as a Distributed Database. We need to manage a set of objects that are grouped in various network elements and distributed in a geographical area. The CMP offers some database capabilities. These are usually some Internet Protocol (IP) queries and some Alarm Database capabilities such as reporting of acknowledged alarms. The general idea is to build on these capabilities. As far as the database tools are concerned, three alternatives available are: 1) use relational database technology, 2) use Object Oriented technology, and 3) use a combination of the two. The network management as described by various Bellcore standards using Transaction Language 1 (TL 1) does not support object oriented technology. Most of the standards, including SNMP, are at least somewhat based on object oriented technology as it relates the protocol to the database.

There are two other important points. The database development tool would need to support Object Data Base Connectivity (ODBC). That is necessary to interface with the database modules provided on the CMP. The other aspect is to be able to let your product be flexible and independent from the particular vendor. It is important to select database development tools that support some type of GUI; this provides an integrated solution in representing physical entities as database elements. There is more than one database development tool on the market that supports all these requirements.

An Example of Network Management Architecture

In our example, the devices in the network either will be SNMP compliant (contain an SNMP agent) or will be proxied by some other entity. Encompassing these two approaches in the Spectrum Management architecture will allow for a low cost solution, vendor independence, and compatibility with legacy devices upon which the newer HFC is evolving.

The Proxy Agent (Figure 3) is a Vendor Supplied Application which uses an SNMP interface between itself and the NMS. This approach can be implemented on a single controller platform (PC with MS Windows®™) that realizes an inter-application message passing operation through SNMP. The main function of the Proxy Agent will then be to translate the SNMP messages into a Vendor Dependent Protocol (VDP). The physical interface for the Proxy Agent on the vendor device side may be RS485, RS232, 802.3. which will connect to a RF Mux/Mod device that facilitates the communication with non SNMP managed objects/devices. This gives the industry a low cost solution of integrating the existing equipment that is not SNMP compliant into a single integrated open NMS. Typically, these RF Mux/Mod devices are non SNMP managed objects themselves and communicate over the HFC through a low data rate out-of-band channel.

The second approach is to include an SNMP agent into the new managed objects/devices of the evolving networks. And incorporating this functionality into the devices allows the cable

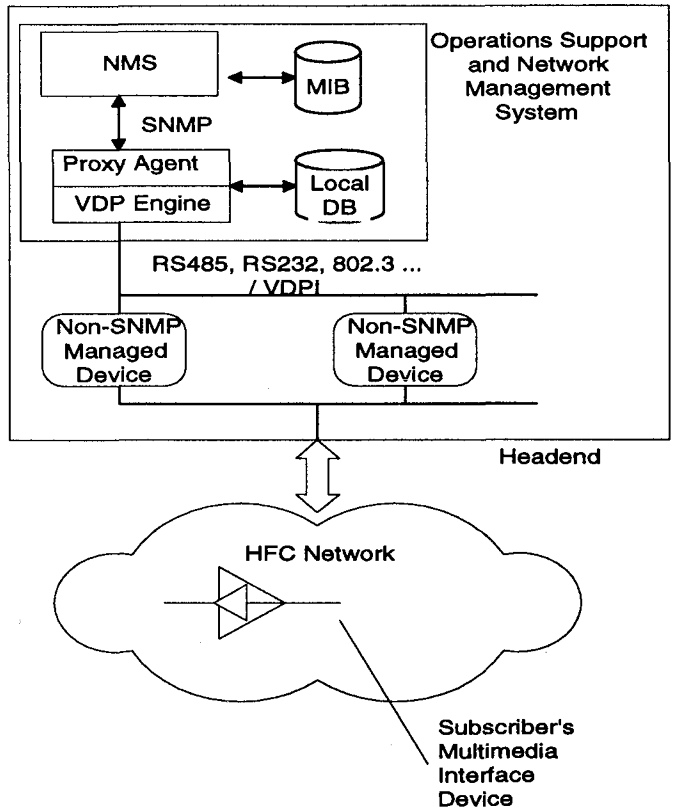

Figure 3 SNMP Proxy Agent

operator to build a vendor independent system. With this approach, the NMS can physically connect to the SNMP managed objects (typically the service specific Mux/Mod) at the headend via an 802.3 interface (Figure 4). However, for the NMS to manage the remote managed objects (SNMP or non-SNMP compliant) it must use a hierarchical approach. This is accomplished by first communicating with the service Mux/Mods, and then the service Mux/Mods will communicate with the remote managed objects units via the HFC.

Future Directions

So far we have addressed the current technology that is being deployed for management of the HFC networks.

Traditional algorithmic approaches for network management have been successful for managing the networks of current complexity. As the networks evolve in complexity, the more powerful heuristic approaches such as Artificial Intelligence (AI) may be necessary.

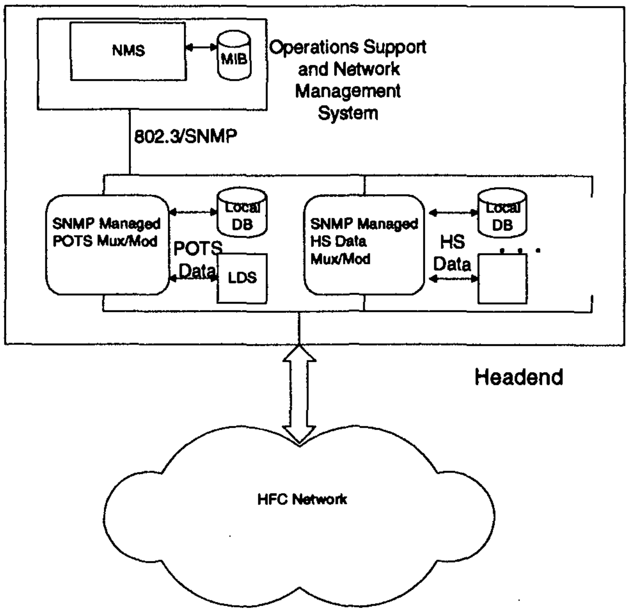

Figure 4 SNMP Managed Devices

AI is a very broad discipline and we will not go into it in any depth. Among other things, AI is a set of programming methodologies that focuses on the techniques used to solve problems by generating new strategies and plans. Expert systems are a subset of the AI disipline. The name is based on the term used in daily language for somebody who acquired experience that allowed him to solve problems. The programs that capture their problem solving strategies and selectively apply them under specific circumstances are called expert systems.

Many expert systems have been deployed in telecommunication industry in the past. Unfortunately, most of them were designed to solve local and constrained problems without addressing the needs of the distributed networks. That is changing, and today there are several laboratory expert systems that address the network management.

To illustrate how expert systems can be used to address the needs of HFC network management we will identify the functional tasks and corresponding modules to do them.

The modules/tasks can be categorized as follows (Figure 5):

1. HFC Distributed Network Model which represents the network configuration in terms of number of subscribers, traffic characteristics, managed devices and their attributes.

2. Optimal Resource Allocation Module which feeds its decisions to Knowledge base and Self-learning module.

3. Self-learning module which processes optimal solutions, makes proper changes in HFC network model and communicates it to the Knowledge database.

4. Knowledge Database stores the clauses that characterize the normal and abnormal operations of the HFC network.

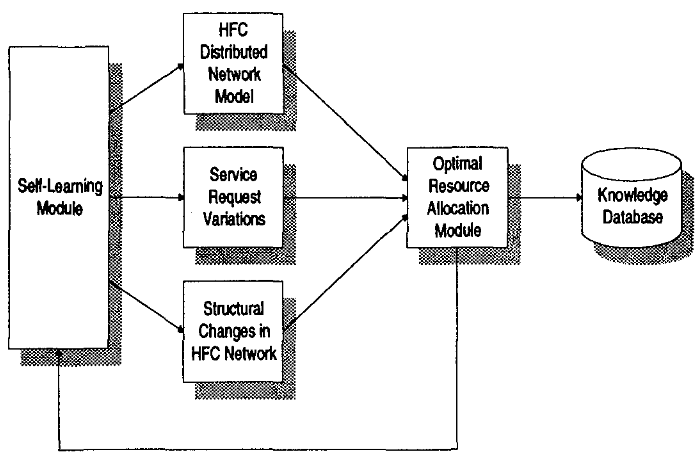

Figure 5 HFC AI Self-Learning System

Although the AI and expert systems of the future may be addressing needs that are hard to predict today, one application that is needed today may be the interoperabilty and communication among the equipment from different vendors. The expert systems would go through a learning process before they acquire knowledge of how to communicate with different pieces of equipment.

Summary

After reviewing basic HFC network architecture, we introduced general network management terminology in order to be able to address the needs of the HFC network management. Then we addressed the off-the-shelf tools and building blocks in such a way as to be able to develop a sound Standard compliant HFC Network Management System which would be able to manage the equipment from various vendors. Since the Spectrum Management of the HFC network represents a very important issue of the bandwidth utilization we addressed some basic aspects of it. At the end we illustrated our analysis by presenting a sample architecture of the Network Management System. The general philosophy emphasizes multivendors and standard compliance, while maintaining simplicity. Also, using off-the-shelf building blocks as much as possible improves speed-to-market of the product.

References

[i] Aravanan Gurusami, Jeffrey Cox, and Mark Chapman, "Multimedia Delivery Device for Fiber/Coaxial Hybrid Networks", 1994 NCTA Technical Papers