A COMPREHENSIVE MANAGEMENT APPROACH FOR HFC NETWORKS

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Abstract

Deployment of interactive data services over HFC networks demands a comprehensive approach to network management. Advanced customer terminals, such as standards-based cable modems and intelligent set top boxes, are increasingly talked about as the ideal vehicle for the collection and storage of information regarding the state of the physical HFC network. The support for standard management protocols in these new advanced terminals greatly increases the appeal of this approach: It makes the process of collecting and analyzing network data platform and vendor-independent, and also facilitates the task of integrating multiple platforms and systems.

HFC network management is thus evolving away from the more traditional approach based on the deployment of proprietary systems and protocols to poll and collect status information from active network elements. However, this does not imply the demise of this type of monitoring system. Advanced customer terminals provide operators with indicators regarding the health of the HFC network but they do not provide data on the operational status of active network elements such as power supplies, fiber nodes, and amplifiers. Thus, the data collected using advanced terminals complements rather than replaces the monitoring of active HFC devices.

This paper discusses a management framework for HFC networks predicated on the deployment of standards-based platforms. In such a framework, there is still a strong requirement for systems that monitor active HFC network elements. It is discussed how data from these systems can assist in the more detailed diagnostics and troubleshooting process following the detection of threshold alarms and early warnings generated by advanced terminal devices. To achieve this goal it is imperative that management platforms intended to monitor active HFC elements move away from proprietary protocols and support the same standard protocols as emerging management platforms for advanced terminal devices. The ultimate objective is to have open-standards based systems to facilitate not only integration with other management platforms but also to allow components from multiple vendors to operate together over the same HFC network. This paper concludes with an update on the progress of standards-development activities currently taking place within the cable industry to help achieve this objective.

INTRODUCTION

The impending deployment of advanced cable modem systems based on the DOCSIS standard as well as future deployment of OpenCable™ set top boxes has already begun to change the way HFC networks are managed.

These new advanced terminals will support the Simple Network Management Protocol (SNMP) and standard SNMP Management Information Base (MIB) definitions containing a number of variables and counters that will enable collection of system and HFC network information at various levels. These standard MIBs will support collection of data such as customer terminal RF input and output level variation, RF channel frequency response, number of transmitted and received data packets, packet transmission errors and collisions, and packet retransmission rates.

HFC network operators already realize the value derived out of SNMP MIB data analysis and the powerful insights that are gained into the performance of their physical networks and systems. A particularly powerful tool is the historical trend analysis made possible by the periodic collection of SNMP MIB counter information. Such analysis enables the continuous tracking of HFC network changes to identify non-critical chronic network problems, and to trigger preventative network maintenance activities. Early detection of service-affecting problems is also possible since periodic measurements help the operator determine when specific impairment levels exceed pre-defined thresholds.

Focus is shifting steadily out of proprietary element management systems and into standards-based systems and management platforms. In parallel with this process, there is also a migration towards adoption of a Telecommunications Network Management (TMN) or similar model for the planning, deployment and management of the evolving HFC telecommunications network. The five constituent layers in the TMN model are illustrated in Figure 1. Adoption of such models is expected to facilitate the collection, analysis and correlation of status information from multiple subsystems that are not necessarily supplied by a single vendor. These functions are performed within the three bottom layers in the TMN model: the Network Element Layer (NEL), the Element Management Layer (EML), and the Network Management Layer (NML). The available status information is then used to support higher-level network functions such as customer service provisioning, usage reporting and billing, and service expansion planning, functions that reside within the top two TMN layers: Service Management Layer (SML) and Business Management Layer (BML).

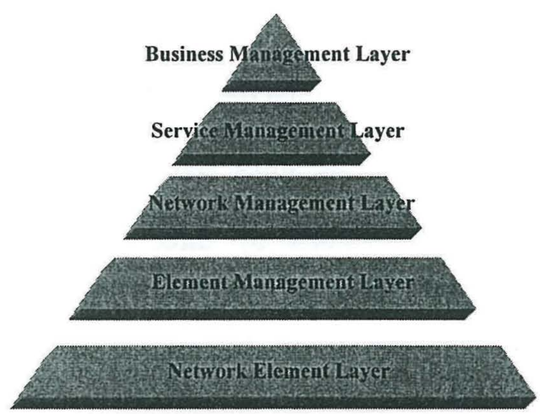

Figure 1. The TMN Model

To support these new network management models, operators must make significant investments in standard management platforms and systems. Deployment of advanced customer terminals and other network elements that support standard management protocols help justify these investments: the ability to address network elements from multiple vendors and correlate data from multiple sources is too big of an advantage to ignore.

Deployment of more traditional platforms based on proprietary protocols to poll and retrieve status information from active network elements such as fiber nodes, power supplies and amplifiers is sometimes perceived as providing only marginal benefits. Moreover, the proprietary nature of these systems makes them difficult to integrate into a standard platform without a significant development effort, which makes them a somewhat less attractive management tool. This notion is further reinforced by the belief that advanced terminals can provide all the necessary data for effective monitoring and troubleshooting of network and service problems.

Although it is true that advanced set top boxes and next-generation cable modems can act as repositories of HFC network health indicators and can provide early warning of system-wide problems, additional data is still required to assist the management systems in determining the most likely cause of those problems. This additional data can only be obtained by directly polling critical active transmission elements in the physical network. Therefore there is still significant value in providing selected active elements with the necessary intelligence to allow management platforms to retrieve data on their operational status. This supplementary data can then be correlated with data retrieved out of customer terminal devices and used to pinpoint the most likely cause of a system-wide failure or a degradation in the quality of the delivered services.

This paper describes a proposed approach for integration of various element management systems found in a typical HFC network. This approach is based on a TMN network management model. The end objective is to facilitate the gathering and correlation of status monitoring information from multiple platforms, and the effective utilization of this data to provision, deploy, monitor, and manage HFC networks. The benefits derived from cross vendor platform integration in the areas of monitoring, diagnosing and troubleshooting are discussed. The reasons for demanding compliance with open standards as a condition to allow integration of new platforms and systems into this proposed HFC network management platform are discussed. The impact this has on poll-based systems for monitoring of active network transmission elements is discussed. Finally, a brief update is presented on the current efforts to develop physical and MAC layer standards to facilitate integration of these systems with other standard-based element managers deployed in HFC networks.

HFC NETWORK MANAGEMENT PLATFORM

Figure 2 is a layered representation of a typical HFC service network and its various constituent elements. It shows a subset of the various services that are supported and the various elements involved in the provisioning, delivery and management of those services. Figure 2 attempts to depict the various network layers within the context of the TMN model. Following is a more detailed description of each of those layers and how they relate to that model.

HFC Physical Layers – TMN Network Element Layer (NEL)

These are typically the two-way RF broadband communications channels between an HFC network primary hub or headend and the end customer. In general, multiple HFC segments consisting of a set of downstream and upstream RF channels are allocated to support each of the distinct services supported by the network. Figure 2 illustrates the elements involved in supporting a subset of those services: standard broadcast as well as interactive video services, internet access services, and telephony services to name just a few.

Also included in this layer are the physical LAN and WAN that provide connectivity between various service support systems within a primary hub or headend, and the higher-level connectivity between individual headends and the central HFC management location.

HFC MAC Layers

Multiple MAC layers are supported within the HFC physical layers to implement communications protocols between the various service controllers at the primary hub or headend and the various terminal devices in the customer premises and any other active elements deployed within the various physical segments. In Figure 2, the various MAC layers arbitrate element access to the allocated HFC channel bandwidth.

The HFC physical layer is where network elements operate to handle the transmission of telecommunications data and to provide end customers access to the various network services. Collection of status monitoring information and data regarding the health of the physical network is collected within this layer. These two functions also reside within the Network Element Layer in the TMN model.

HFC Primary Hubs and Headends – TMN Element Management Layer (EML)

The primary hubs and headends are where all service processing and gateway equipment resides. This equipment performs a number of functions including: implementation of appropriate MAC and access protocols to arbitrate access to the physical HFC network, support for initial service provisioning and activation, and collection of network statistics and other health indicators for the physical plant. The latter function may involve polling of active network elements or periodic collection of stored data out of customer terminals. In general, all alarm information concerning specific services and elements is collected at this layer where some data pre-processing or data reduction may take place as well. These are the same functions that reside within the Element Management Layer in the TMN model.

Some of the service processing equipment and independent element managers within the element management layer includes the following:

Telephony Service Controllers

These are the devices used to provision and manage telephony customer network interface units (NIU). These devices may also collect data on service performance metrics such as bit error rates, dropped calls, etc. They may also provide indicators on the state of the physical RF channels allocated from the headend to the NIU.

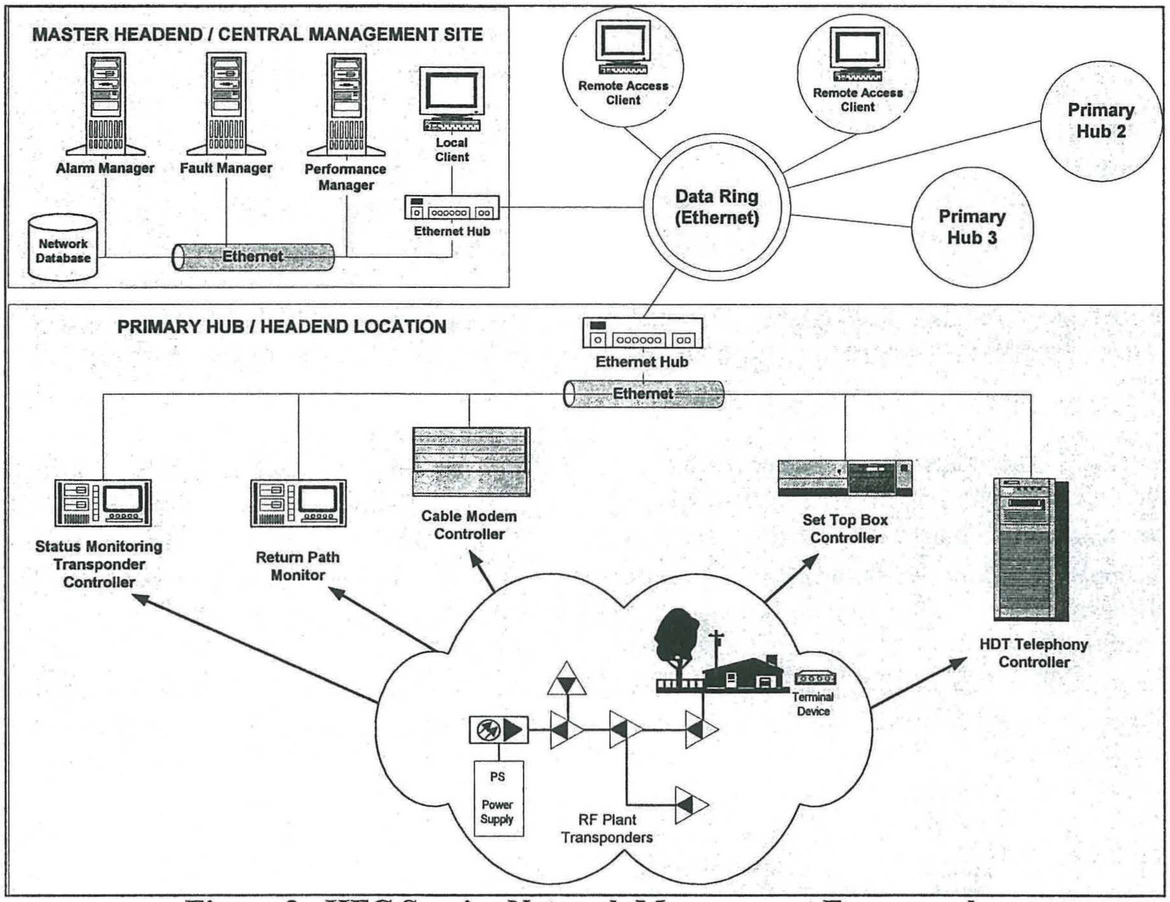

Figure 2. HFC Service Network Management Framework

Set Top Box Controllers

These devices support the provisioning and management of traditional and advanced video services through standard video set top boxes. Traditionally, set top boxes have not supported enough intelligence to support monitoring of the HFC physical transport network. However, this began to change with the deployment of advanced analog and digital set top boxes. These new terminals can provide operators with information related not only to the usage of specific services, but also related to the health of the overall transport and delivery network. The advent of OpenCable™ set top boxes will increase these capabilities while at the same time supporting standard management protocols such as SNMP.

Cable Modem Controllers

These devices manage communications with cable modems in customer premises and support the provisioning and delivery of Internet access services. Cable modems and associated control systems have supported the SNMP management protocol and related MIB definitions from early implementations. These systems allow the collection and storage of data about the status of the physical HFC network. The also provide powerful insights on parameters such as the severity of HFC RF channel impairments, the efficiency of the underlying MAC protocols that arbitrate end user access to available service bandwidth, and the efficiency of the higher IP and TCP network and transport layer protocols respectively. Cable modems and systems based on the DOCSIS standard will further advance these capabilities and will support standard MIB definitions to greatly facilitate integration of systems from different vendors.

Controllers for Status Monitoring Transponders

These allow for polling and collection of telemetry data from status monitoring transponders deployed within selected active elements in the physical distribution network. Traditionally, these systems have been based on proprietary protocol implementations that prevent efficient integration into standard management platforms as well as interoperability of products from multiple vendors. In addition, transponder deployment very often results in the gathering of a vast amount of information of limited value when analyzed in isolation. These systems are also difficult to access from higher-level management platforms.

Return Path Monitoring Systems

These are specialized monitoring systems that are used to collect information related to the severity of specific RF impairments, i.e.: impulse noise and ingress that affect the HFC return path channel availability. Impairments on any of the distribution legs in the upstream path of HFC networks will affect customers in an entire distribution area because of the funneling effect of the return paths at the system headend. Therefore, dedicated systems that can track the severity of return path RF impairments at any time become a necessity. These systems must operate independently of other systems that collect performance information for network layers above the physical HFC layer. These systems must also facilitate integration into a single management platform which makes support for standard management protocols a critical requirement.

HFC Central Management Site – TMN Network Management Layer (NML)

In Figure 2, this is the location that supports all servers and higher-layer network management platforms. The various servers support communications with service controllers distributed across multiple primary hub and headend locations. All control activities for the network originate from the central management site. This layer supports specialized servers to perform five basic network management functions that also reside within the Network Management Layer in the TMN model: performance, fault, configuration, accounting, and security management. The first two functions are particularly critical to network operators as they directly impact the quality of the services delivered over the HFC network.

Performance Management

This involves continuous communication with all element management systems deployed throughout the network to collect and store all status information about the state of the physical HFC layer as well as information on the performance at the MAC, network and transport layers.

The process of collecting performance information may rely on pre-processing of data done at the element management layer. If this is the case, care must be taken to ensure this function is not duplicated between the element management and the network management layers. If data pre-processing is not done at the element management layer, the network management layer must support data reduction functions.

Furthermore, the role of performance management also demands standard ways to access all deployed element management systems and the ability to correlate performance data from multiple platforms. Referring back to Figure 2, this is accomplished through the requirement for support of standard communications protocols and formats such as SNMP and TL 1.

Three of the main goals of performance management are:

1. Identification of underlying network problems that may not immediately result in critical service disruptions,

2. Assisting in scheduling of preventative network maintenance activities as required, and

3. Uncovering and tracking trends in resource usage. This data is handed to the higher service and business management layers where it is used to determine when to expand and add services

Fault Management

This involves collection of alarm information from all element management systems. This function must also support alarm reduction and correlation of alarms generated from multiple element management platforms. The most critical goals of fault management are:

1. Fast identification, reporting and filtering of critical and non-critical alarms,

2. Cross-platform alarm correlation and fault isolation,

3. Assist in the diagnostic and troubleshooting of network problems, and

4. Expedite problem resolution

Implementing the two network management functions just described, as well as support for the remaining three functions, requires deployment of network management platforms that can enable communication and sharing of network performance information across the various element managers and service controllers depicted in Figure 2. Some of these element managers already support standard management protocols such as SNMP for OpenCable™ set top boxes and DOCSIS cable modems and TL-1 for telephony service controllers. This greatly facilitates the migration to a TMN model for the management of the HFC network. It also enables quicker integration of equipment from multiple vendors to support additional network services.

INTEGRATION OF PHYSICAL PLANT STATUS MONITORING SYSTEMS INTO HFC NETWORK MANAGEMENT PLATFORMS

As the adoption of TMN models of network management progresses, it becomes increasingly critical to ensure that any new network elements and devices added to the HFC network management platform support open management standards. Element management systems for addressing and controlling status monitoring transponders deployed in active transmission elements in the HFC network have a very important role to fill in the areas of performance and fault management. These systems can provide valuable data on the operational status of selected active transmission elements such as power supplies, fiber nodes and distribution amplifiers. As such they complement the role of terminal devices: while the latter are able to track changes in service degradation and generate warning alarms as performance thresholds are violated, the status data on active elements assists in accurately pinpointing the exact location of a network fault.

Most transponder management systems commercially available today, however, offer limited support for standard protocols. In addition, these systems do not support standards at the physical or MAC layers which makes interoperability between platforms extremely difficult if not impossible to achieve. Furthermore, retrieving of this information by a high-level management platform requires extensive development of customized data interfaces.

The critical requirement for these systems to conform to open standards has prompted renewed efforts to define standards for both physical layer (PHY) and media access control layer (MAC) operation as well as message layer specifications. The Hybrid Management Sub-Layer (HMS) subcommittee, newly created under the SCTE Engineering Committee, is currently leading these efforts with help from both network operators and equipment vendors.

For the physical layer, the proposed standard is expected to define a minimal set of specifications for operation of headend controllers and field transponders. These include RF output transmission ranges, frequencies of operation, tuning ranges, maximum levels of spurious outputs, and data transmission rates.

At the MAC layer, the draft documents currently under discussion define the format of protocol packets, addressing functionality, MAC message lengths, synchronization procedures, initialization of network elements, algorithms to arbitrate access to the transmission channel bandwidth, and mechanisms for contention resolution.

The draft documents for the message layer specification define proposed MAC message types and their formats for communications between field transponders and headend controllers over the forward and return RF transmission channels. This also includes an effort to define standard MIBs for communications with the most commonly deployed active network elements, i.e.: power supplies, headend controllers, and fiber nodes.

To date, this standardization effort has the support of various HFC network operators as well as members of the vendor community. It is expected that throughout the remainder of 1999 consensus will be achieved among all participants to enable publication of interim specifications. Once these are published, early product implementations conforming to the proposed specifications are expected early in the year 2000.

CONCLUSIONS

This paper has described a management approach for HFC networks based on migration to a TMN model. Such migration demands the adoption of element management systems and platforms that are based on open standards. Implementation of standards-based systems has already begun with the deployment of DOCSIS cable modem systems and OpenCable™ set top boxes. However, these devices by themselves will not provide all the data required to support the monitoring, troubleshooting and management of advanced HFC networks. It is also necessary to integrate information on the status of active network transmission elements before a management platform for HFC networks can be considered complete.

The support for the monitoring of active network transmission elements, although existing today, is based on proprietary vendor implementations. This prevents proper integration with other enterprise element management systems and the sharing of network performance data. A definition of proper standards to facilitate this integration is therefore a critical task that has been undertaken by HFC network operators and the vendor community. Completion of this effort is critical to the success of network operators as new advanced services demanding ever-increasing levels of network reliability are deployed.

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