SCTE Smart Amplifier Project

Extend Proactive Network Maintenance to the Outside Plant

A Technical Paper prepared for SCTE by

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1. Introduction

A "smart amplifier" defines the information model needed to perform both remote configuration and the gathering of status information from RF amplifiers. At the time of this writing, the working group is actively completing its work based on the SCTE 1.8 GHz amplifier standard, [SCTE 279].

This proposed scope of the project is to define a standard information model using the Universal Modeling Language (UML) and then create the YANG data model for communications with broadband amplifiers used in hybrid fiber-coax (HFC) networks. The modeling can apply to all HFC networks including DOCSIS 4.0 applications and is intended to include all required monitoring and control communications with an amplifier, whether accessed over the HFC control plane or locally via direct wired or wireless connection.

The cable industry benefits from having a standardized information model that is used for amplifier configuration and status. A goal of this project is to create an information model that is applicable to both stand-alone distribution amplifiers and to launch amplifiers inside fiber nodes, leveraging existing CableLabs operations system work from the Distributed Access Architecture (DAA) project.

The smart amplifier features and capabilities can be leveraged to enable measurement and reporting of network conditions such that the system can be made more reliable. With this information cable network operations personnel can make modifications necessary to improve conditions and monitor network trends to detect when network improvements are needed.

2. Network Management Architecture

A smart amplifier extends the concept of proactive network maintenance (PNM) to the outside plant (OSP) elements including both the fiber node and amplifiers. PNM introduced data gathering and algorithms for DOCSIS components of the network that attached to the coaxial cable, these being the cable modem termination system (CMTS) and cable modem (CM).

Figure 1 show the DOCSIS CMTS and CMs sending telemetry data to a data store where algorithms can be performed on the information.

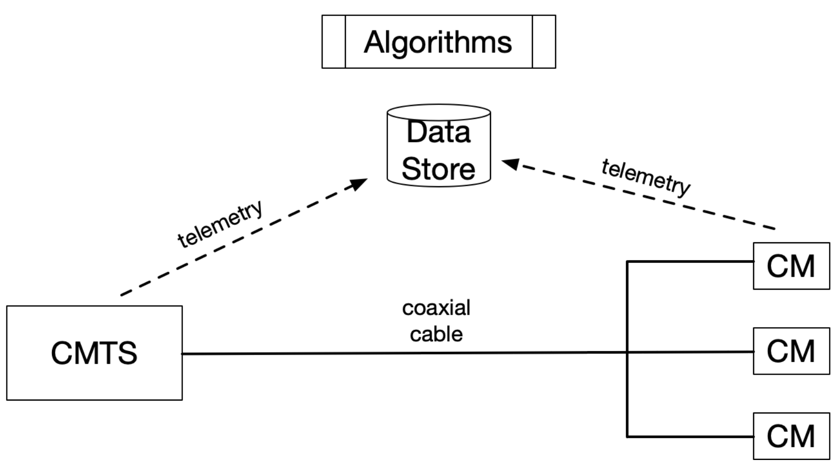

Figure 1 – DOCSIS PNM Architecture

Note that while the DOCSIS equipment directly connects to the coaxial cable network, the traditional elements making up the OSP, including the fiber node and amplifiers, are not sending information to that data store.

Figure 2 shows how the OSP, including both fiber node and amplifiers, can be included in the PNM solution.

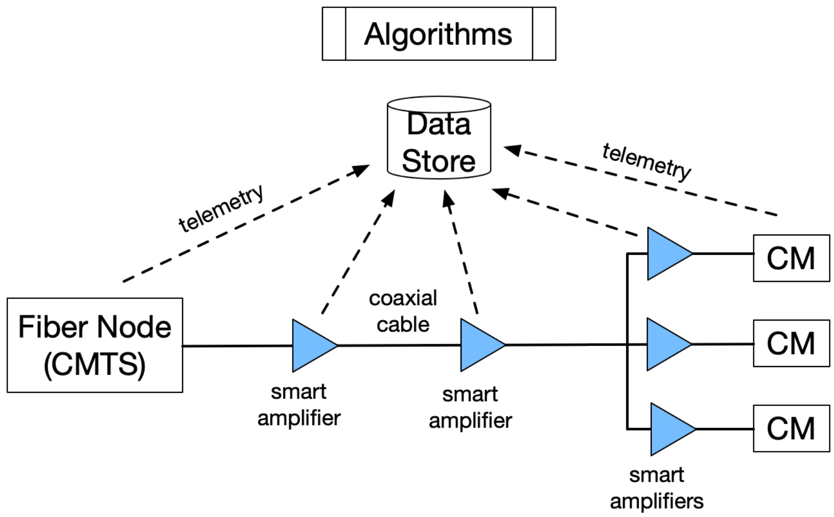

Figure 2 – Outside Plant PNM Architeture

The CableLabs DAA project has instrumented the fiber node so that data is available for the part of the CMTS in the node, as well as the RF launch amplifier in the node. The SCTE smart amplifier project is instrumenting the coaxial cable network amplifier, including both the downstream and upstream paths.

With both DAA and smart amplifiers, the active elements of the OSP are instrumented and can provide data to the operator. With these new sources of data, new methods for managing both the OSP and the DOCSIS network can be developed. It is expected that new algorithms will use the combined data from both DOCSIS equipment and OSP equipment for proactively monitoring the cable broadband network.

A goal of the smart amplifier standard is to provide capabilities in the amplifier so monitoring can be performed remotely, for example in a network operations center (NOC), without having to dispatch a technician to the amplifier and open the lid to gather readings. The development of these use cases can be used to made future adjustments to the [SCTE 270] amplifier information model.

3. SCTE 1.8 GHz Amplifier Standard

[SCTE 279] was recently published and defines standard mechanical, environmental, and electrical characteristics for RF amplifiers that support DOCSIS 4.0 frequency division duplex (FDD) capabilities with downstream operation to frequencies up to 1794 MHz and upstream operation to frequencies up to 684 MHz.

The SCTE smart amplifier standard includes a management model for the [SCTE 279] amplifier to allow both remote configuration and status gathering from the amplifier. The same stanard tools used for the fiber node information modem in the DAA project are used to develop the amplifier information model and align with the fiber node work.

[SCTE 279] rounds out a group of SCTE standards tied to DOCSIS 4.0 technology that include:

Table 1 – SCTE Standards Supporting DOCSIS 4.0 Technology

Number	Title
[SCTE 264]	Broadband Radio Frequency Hardline Taps for Cable Systems
[SCTE 265]	Broadband Radio Frequency Hardline Passives for Cable Systems
[SCTE 273]	Generic Access Platform (GAP)
[SCTE 279]	1.8 GHz Broadband Radio Frequency Hardline Amplifiers for Cable Systems

In addition to the standards listed, numerous other SCTE standards have been updated for both 1.8 GHz and 3.0 GHz operation as part of the effort for the DOCSIS 4.0 specifications.

4. Smart Amplifier Model

4.1. Intoduction

[SCTE 38-10] was the first attempt to create standard instrumentation for an amplifier. The smart amplifier work both builds and extends this early work.

Figure 3 shows the smart amplifier modeled to include both a transponder and an embedded amplifier (eAMP). The eAMP includes amplifier functions defined in [SCTE 279] for both the downstream and upstream signal paths and is the focus of smart amplifier. The transponder is not defined in [SCTE 279] and the choice of transponder is left as a business choice by a cable operator. The transponder could be a DOCSIS modem or some other type of modem.

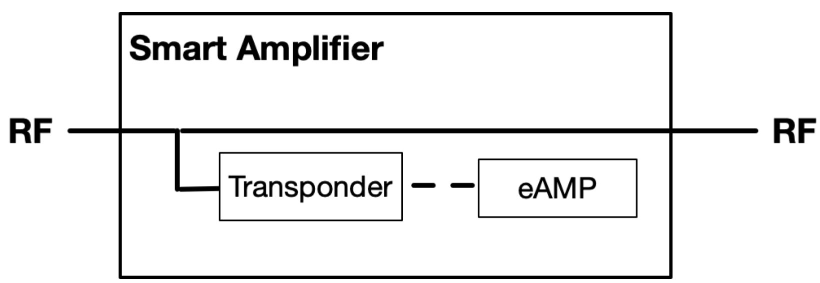

Figure 3 – Logical Model for Smart Amplifier

The choices of transponder and amplifier capabilities should be made carefully. The transponder and eAMP are separate logical entities and have separate information models. The smart amplifier work focuses on the eAMP logical entity and does not define the transponder.

To support the management model in the smart amplifier standard, it is recommended the transponder implement a high-speed IP connection that supports the types of networking used by the cable operator. Note that the DAA fiber node has direct digital fiber connection and does not use a cable modem as a transponder.

4.1.1. Embedded DOCSIS (eDOCSIS) Model

If the transponder is a DOCSIS modem, then the embedded DOCSIS (eDOCSIS) model is available to operators and suppliers. The eDOCSIS model has been updated in support of the smart amplifier and the relevant CableLabs specifications are listed in Table 2.

Table 2 – CableLabs Embedded DOCSIS Specifications

Designation	Title
CANN	CableLabs Assigned Names and Numbers specification
CANN-DHCP-Reg	CableLabs DHCP Options Registry specification
eDOCSIS	Embedded DOCSIS specification

The eDOCSIS model has successfully been used for embedding modems for digital voice, set-top boxes, and other types of equipment. Cable operators are familiar with this model and have it in use.

Figure 4 shows the transponder being an embedded cable modem which is defined in [eDOCSIS].

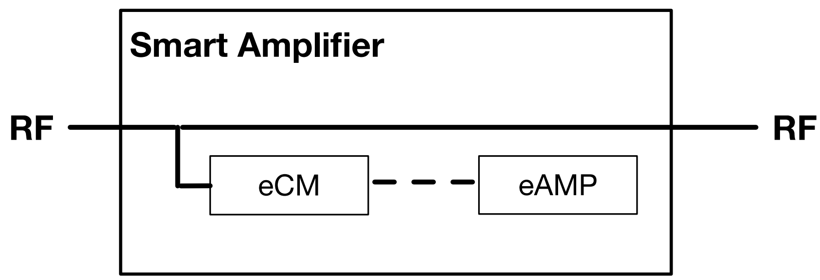

Figure 4 – eDOCSIS Model for Smart Amplifier

A short discussion on the DOCSIS version of the eCM transponder. As noted previously, the eCM and eAMP could have different capabilities. The amplifier defined in [SCTE 279] operates to 1794 MHz. A DOCSIS 3.0 eCM is required to operate to only 870 MHz (though many DOCSIS 3.0 modems operate to 1002 MHz) and is not required to have the PNM tools to report on OFDM and OFDMA carriers, which were introduced in the DOCSIS 3.1 specification. Even if the eCM is a DOCSIS 3.1 cable modem, it would be specified to operate to 1218 MHz and not to 1794 MHz.

[SCTE 279] discusses amplifier properties intended for a DOCSIS 4.0 network that include operation to 1794 MHz. [SCTE 279] does not discuss vector signal analyzer (VSA) functions such as OFDM symbol decoding or reporting RxMER on OFDM subcarriers, or other PNM functions that are associated with DOCSIS modems.

Hence the choice of DOCSIS transponder includes discussion on both the frequency range of that transponder as compared to the amplifier, and what if any DOCSIS PNM capabilities might be desirable in that transponder.

Additionally, while a DOCSIS CM supports various PNM capabilities, for these to come into play on each physical port of the amplifier, that CM would need to attach to those physical ports. This could entail a switch that could allow the CM to sample the RF at each port. Figure 3 does not identify a particular port the transponder is attached to and how the transponder may report is not specifically identified.

4.1.2. Other Transponders

The transponder does not have to be a DOCSIS CM; other transponders are possible. Note that the transponder should support a high-speed Internet Protocol (IP) connection.

One example is the SCTE Hybrid Management Subcommittee (HMS) working group specification of a transponder in [SCTE 25-1] and [SCTE 25-2]. The HMS transponder is in use for applications such as OSP power supplies and amplifiers.

Other types of transponders can be provided by suppliers; there are several deployed.

4.2. Embedded Amplifier (eAMP)

Looking again at Figure 3, the smart amplifier work defines an information model for the eAMP logical entity; smart amplifier does not define the transponder. There are no DOCSIS functions in the eAMP. The eAMP represents the [SCTE 279] amplifier functions including parameters such as RF test points, attenuators, and equalizers. From the standpoint of the eAMP, the transponder is simply a method to provide communications to the eAMP.

5. Semantics Around Modeling

5.1. Introduction

An information model is a way of representing and structuring information available from the device being modeled. An information model (as compared to a data model) is an abstraction and only provides a high-level view of relationships and things of interest (i.e., information). It aids in understanding the scope of functions of the device being modeled.

Data models usually specify items in more detail and include protocol specific constructs. The level of abstraction does not depend on the language being used (e.g., XML, IDL, YANG). Such languages allow modeling both at high and low (i.e., detailed) levels. The smart amplifier data model, using YANG, is planned to be available later this calendar year.

5.2. Information Model

The information model is designed using the unified modeling language (UML). A description of how to use UML can be found in [UML Guidelines].

Many network elements have an information model including CMTS, CM, Wi-Fi access points, servers, routers, and switches. This is how the network is managed, through interacting with the information models of these network elements. The DOCSIS CMTS and CM devices have had information models since the DOCSIS 1.0 specifications which have evolved as the DOCSIS specifications have evolved.

5.3. Data Model

A data model is a specific implementation of an information model using a specific set of protocols. For example, the early DOCSIS specifications had data models for the CMTS and CM devices using structure of managed information (SMI) and simple network management protocol (SNMP) which were early network management protocols, designed in the 1990s and were included in DOCSIS 1.0 technology and are still available with the DOCSIS 4.0 specifications.

SMI provides the rules for structuring the information, these structures are commonly referred to as a management information base (MIB), and these MIBs were managed using SNMP. While MIBs and SNMP were used in the past, the migration is toward YANG models and RESTCONF for the future.

YANG and RESTCONF are modern, web scale protocols which were included with DOCSIS 3.0 technology for more saleable network management. YANG is a method of representing the data model and RESTCONF is a protocol based on HTTP (hyper-text transfer protocol) that has proven to be very scalable for use in large networks and includes its own security model.

5.4. FCAPS Modelling

The FCAPS model is a widely used framework that organizes management functions into the categories of fault, configuration, accounting, performance, and security management. Telecommunications operators, including cable operators, commonly use the FCAPS model to manage large networks of devices. This specification uses these management categories to organize the requirements for the configuration and management of the smart amplifier.

- Fault management seeks to identify, isolate, correct, and record system faults.
- Configuration management modifies system configuration variables and collects configuration information.
- Accounting management collects usage statistics for subscribers, sets usage quotas, and bills users according to their use of the system.
- Performance management focuses on the collection of performance metrics, analysis of these metrics and the setting of thresholds and rate limits.
- Security management encompasses identification and authorization of users and equipment, provides audit logs and alerting functions, as well as providing vulnerability assessment.

Each of these management categories is discussed in more detail in the following sections.

5.4.1. *Fault Management*

Fault management is a proactive and on-demand network management function that allows non-standard/abnormal operation on the network to be detected, diagnosed, and corrected. A typical use case involves network elements detecting service-impacting abnormalities; when detected, an autonomous event (often referred to as an alarm notification) is sent to the NOC to alert the operator of a possible fault condition in the network affecting a customer's service. Once the operator receives the event notification, further troubleshooting and diagnostics can be performed by the operator to correct the fault condition and restore the service to proper operation.

5.4.2. *Configuration Management*

Configuration management enables system configuration building and instantiating, installation and system turn up, network and device provisioning, auto-discovery, backup and restore, software download, status, and control (e.g., checking or changing the service state of an interface).

Configuration management is primarily concerned with network control via modifying operating parameters on network elements such as the smart amplifier. Configuration parameters could include both physical resources (for example, a gain stage) and logical objects (for example, a description of the amplifier).

5.4.3. *Accounting Management*

Accounting management allows operators to measure the use of network services by subscribers for the purposes of cost estimation and subscriber billing. No Accounting management has been defined for the smart amplifier at this time.

5.4.4. *Performance Management*

Performance management is a proactive function to gather and analyze data for the purpose of monitoring and correcting the behavior and effectiveness of the network, network equipment, or other equipment and to aid in planning, provisioning, maintenance, and the measurement of quality. A Performance management use case might include the NOC performing periodic (15 min, for example) collections of output level measurements from each port on the amplifier to perform monitoring and identification of any potential performance issues. With the historical data that has been collected, trending analysis can be performed to identify issues that may be related to certain times of day or other corollary events.

Additional performance management functions include monitoring the amplifier power supply or managing an ingress detection mechanism enabled by the amplifier.

5.4.5. Security Management

Security management provides for network and operator security, as well as providing an umbrella of security for the telecommunications management network functions. Security management functions include authentication, access control, data confidentiality, data integrity, event detection, and reporting. For example, [SCTE 279] requires the amplifier to have a USB port for configuration, and while outside the scope of this work, that USB port needs to be secured from tampering. A sensor is required to provide notification when the amplifier enclosure is opened and closed.

5.5. RESTCONF / YANG

Interfaces to the smart amplifier are defined using YANG-based data models. To manage that data model, RESTCONF is expected to be chosen as the protocol for creating, reading, updating, and deleting instances of YANG objects in the smart amplifier. The YANG models are not yet defined and will be available in the smart amplifier standard.

6. The Smart Amplifier Information Model

6.1. Background

The information model diagrams shown were still under development when this paper was written. While they are substantially complete, changes may occur as the SCTE smart amplifier standard is completed.

For the sake of brevity, not all the UML diagrams will be presented. The intent is to introduce the concepts of an information model and show the applicability to an RF amplifier. The complete UML with text descriptions will be available in the SCTE smart amplifier standard when that becomes available.

Aspects of the information model have been borrowed from the CableLabs Distributed Access Architecture (DAA) project which is defining “Smart Fiber Nodes” for the next generation HFC network. The intent is to have active elements of the OSP, including both fiber nodes and amplifiers, be managed using common systems.

6.2. Introduction

As shown in Figure 5, the smart amplifier information model is organized around three areas:

- SystemGrp, which is system group information including model number and software version
- RfGRP, which is RF Group information and settings for the RF functions on the eAMP
- NetworkingGrp, which provides networking information known to the eAMP

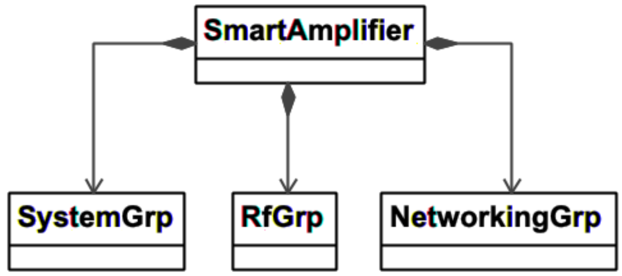

Figure 5 – Smart Amplifier Top-Level Information Model

Each of the three areas will be described in more detail later in this document.

6.2.1. Status and Configuration Modules

The UML diagrams are separated into status models, which provide read-only information, and configuration models which provide read-write information and support configuration of the eAMP.

Status is about reading data information from the eAMP. Status diagrams can show both capabilities of the amplifier and the actual status of components of the eAMP, for example, RF test points on a physical port, the diplex filter in use, as well as any other information described in the UML diagrams and [SCTE 279]. Another example is the amplifier power supply provides status information, to check the input voltage to the power supply, as well as get information on the power rails used inside the amplifier.

Capabilities depend on the specific amplifier and will vary from supplier to supplier. These are capabilities the amplifier can provide.

Configuration allows the amplifier to be set-up or simply adjusted from a remote operations system. This includes changing the output settings of the amplifier or configuring an upstream ingress attenuator, and any other settings specified in [SCTE 279].

Looking back at Figure 5, both the system group and RF group support both status and configuration information. The network group supports just status information as the information is configured during the eAMP DHCP process and is not directly configurable.

6.2.2. Initial Setup

[SCTE 279] requires the amplifier to use a USB port for configuration via an application provided by the supplier. Initial setup is expected to be performed by a technician at the site where the amplifier is installed. Parameters set during this initial configuration will be reflected in the data model of the eAMP that then can be remotely accessed, either to verify the configuration by reading status objects or by adjusting the configuration of the eAMP by setting configuration objects.

6.3. System Group Information

6.3.1. System Status Information

System status information is read-only, and these items are not configurable by the operator.

Figure 6 shows the system group UML diagram and under SystemGrp there are two branches. To the left are system capabilities and beneath are system status information.

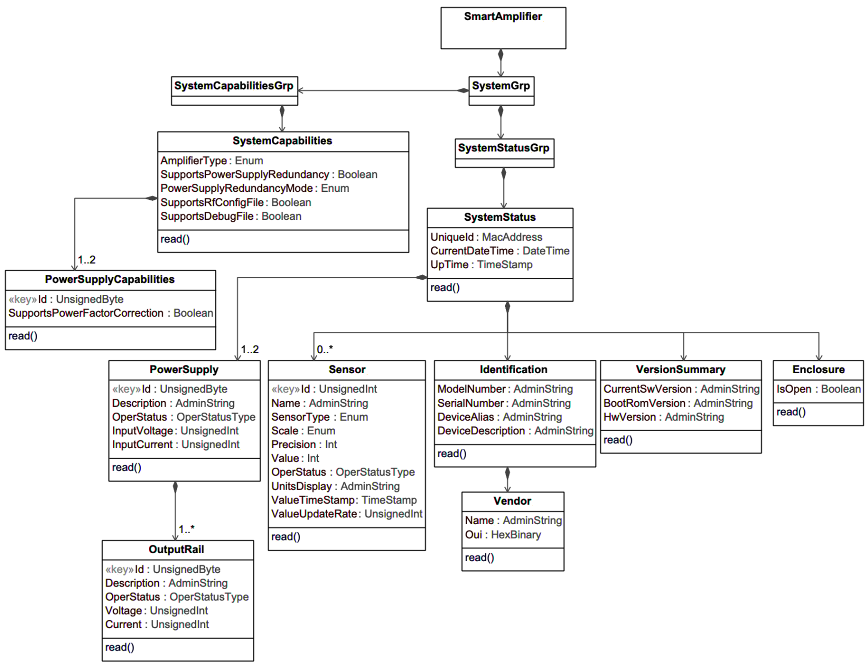

Figure 6 – System Status UML Diagram

System capabilities are what is designed into the amplifier and are not changeable by the operator. This information includes the type of amplifier, which is set at manufacture and cannot be changed. [SCTE 279] lists four types of amplifiers including:

- Multiport amplifier which could be a trunk or bridger amplifier.
- Line extender amplifier which typically has one or two outputs.
- Booster amplifier which typically has one output with lower gain and power consumption.
- Compact amplifier can be mounted in a cabinet and can have one or multiple outputs.

System status information includes supplier-provided information about the amplifier including model number and serial number, as well as software and hardware versions running in that amplifier. Information on the power supply is also available, including monitoring the input voltage as well as the output voltages of the various power rails available inside the amplifier.

Unique to smart amplifier is the capability of having sensors in the amplifier that the operator can get status data from. There is a defined lid sensor, to indicate if the housing is open or closed. And there can be additional sensors that could include a temperature or moisture sensor.

6.3.2. System Configuration Information

System configuration information is read-write and can be configured either at the amplifier location or remotely, for example, from a NOC. Figure 7 shows the system configuration UML diagram.

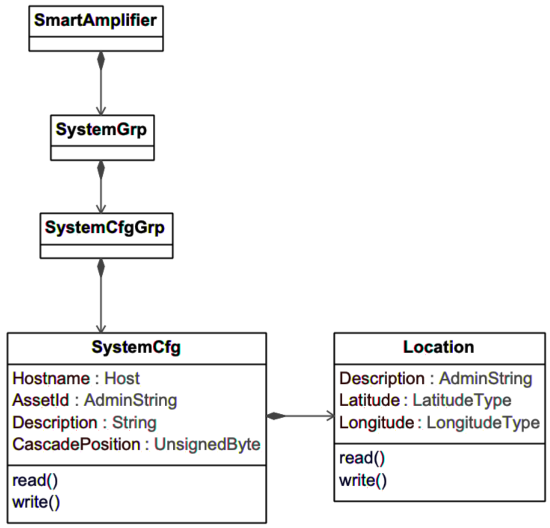

Figure 7 – System Configuration UML Diagram

Items that are writeable include identifying information that can be unique to the operator naming conventions such as hostname, asset identifier and a description of the amplifier. Additionally, the location of the amplifier and its position in the cascade can be written to that amplifier.

6.4. RF Group Information

The RF group contains the details for managing the RF capabilities of the eAMP including RF signal processing functions such as attenuators, equalizers, tilt control, and diplex filters, as well as diagnostic circuitry.

Within the RF UML diagrams, each physical port on the amplifier has logical ports including:

- Downstream logical port
- Upstream logical port
- Bi-directional logical port

This classification exists in both the RF status and configuration UML diagrams.

6.4.1. RF Status Information

Figure 8 shows the RF status UML diagram and under RfGrp there are two branches. The RF status information provides a view of how the amplifier is operating. To the right side are RF capabilities and beneath is RF status information.

The RF capabilities include what the amplifier is capable of in terms of downstream, upstream, and diplex filters. These are physical capabilities of the amplifier, including

- the operating frequency ranges
- available diplex filters
- upstream and downstream attenuation and equalization capabilities. Since the [SCTE 279] amplifier is electronically controlled, there are no plug-ins.
- downstream automatic gain control (AGC) capabilities
- upstream ingress attenuator capabilities, i.e., a “wink” switch

- downstream AGC settings
- upstream level control settings

The RF capabilities information is read-only because it is built into the amplifier by the supplier.

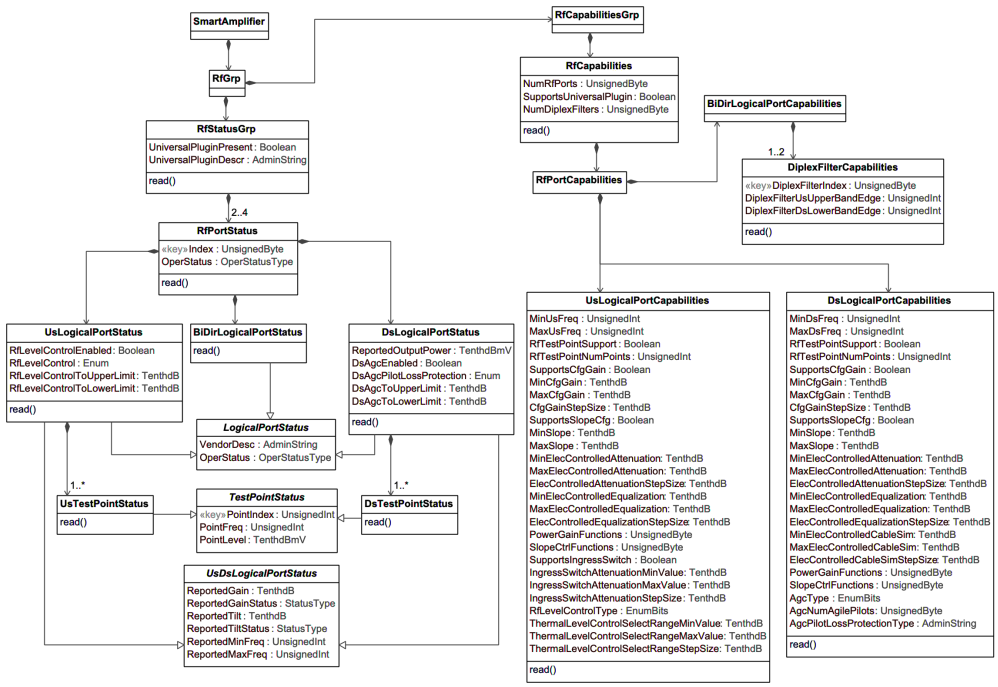

Figure 8 – RF Status UML Diagram

Under the RF status group, available information includes the amount of headroom left in the downstream automatic gain control (AGC) and upstream level control, to allow the operator to learn how the station is performing. Additionally, the upstream and downstream RF test points can be remotely read to give the operator a picture of the output on each port without having to send a tech to that location.

6.4.2. RF Configuration Information

Figure 9 shows the RF configuration information model. These items are described in [SCTE 279] and are read-write to allow remote configuration of the amplifier. For each physical port, common downstream and upstream parameters include adjusting attenuation, and equalization.

Additionally level control is available including downstream AGC including the location of the pilots, and upstream level control. There is also a setting to mute either (or both) the downstream or upstream signals associated with a physical port.

If there is a switchable diplex filter, this is where that choice of diplex filter would be made.

And finally, on the upstream an attenuator can be switched in or out of any upstream path to support locating ingress.

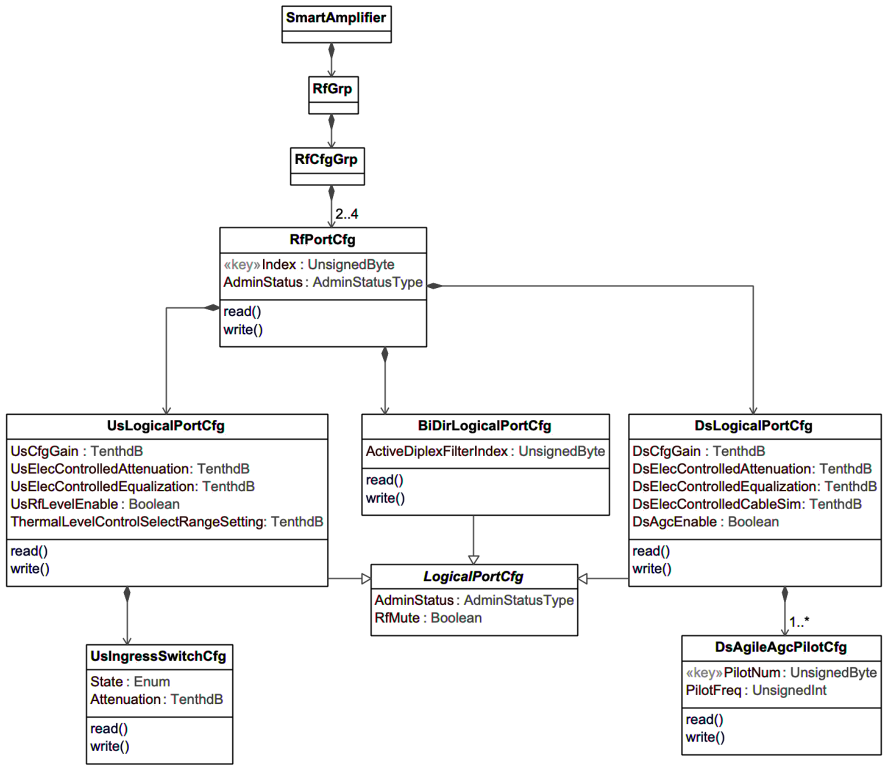

Figure 9 – RF Configuration UML Diagram

These configuration objects allow the eAMP to be adjusted to perform its functions.

6.5. Networking Group Information

Figure 10 shows the networking information model for the eAMP. These items are read-only and are intended to be set during the DHCP exchanges the eAMP has with operator-managed configuration servers.

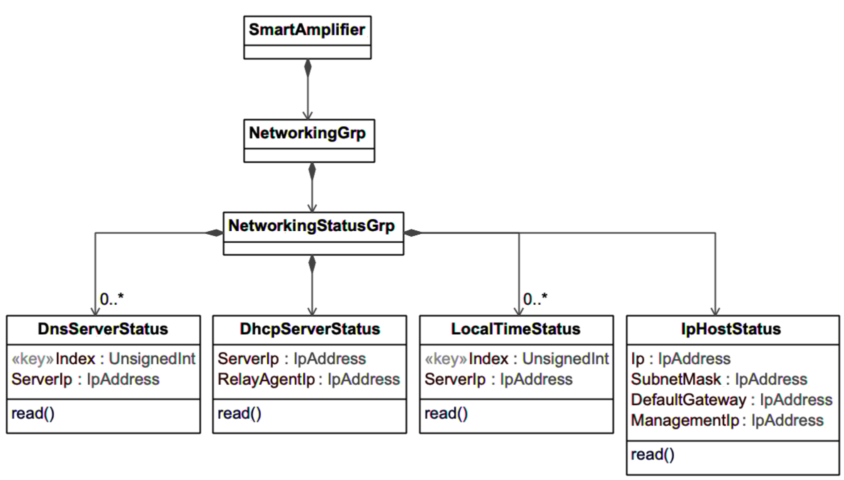

Figure 10 – Network Status UML Diagram

The network status UML diagram shows both internet information for the eAMP and servers the eAMP interacts with, including:

- the IP address of the eAMP
- the DHCP server that provided the IP address to the eAMP
- the IP address of an amplifier management server
- a DNS server that the eAMP uses to resolve IP addresses.
- a server where time is distributed

This information can be useful in debugging network connectivity issues and verifying the eAMP is using the correct servers to send and receive information.

6.6. Additional Information Model Areas

6.6.1. Reset

The information model includes capabilities to remotely reboot the amplifier.

6.6.2. Events

The information model includes capabilities for a local event log, and for the amplifier to send events to the cloud including a syslog server or using other protocols. Additionally, standard events have been defined for the amplifier.

6.6.3. File Management

The amplifier has the capabilities to create two types of files that could be remotely accessed by the operator.

1. A debug file in case the amplifier unexpectedly reboots or has a fault. This file would contain information to allow debugging what caused the issue.
2. A configuration file that provides supplier-specific details on the actual internals of the amplifier and how they are configured.

The information model provides a means to learn which files are on the amplifier, and fetch, rename or delete them.

7. Conclusion

The smart amplifier project provides a method to remotely gather status and configure the amplifier defined in [SCTE 279]. The model is designed to both provide standard management functions and provide room for suppliers to innovate on new products and services.

The smart amplifier work aligns with the CableLabs DAA project so that both fiber nodes and amplifiers have a common management framework. Combined with DOCSIS PNM capabilities, new methods can be developed to increase the reliability of the HFC network.

Abbreviations

AGC	automatic gain control
CM	cable modem
CMTS	cable modem termination system
DAA	distributed access architecture
DHCP	dynamic host configuration protocol
DNS	domain name service
DOCSIS	data over cable service interface specifications
eAMP	embedded amplifier
eCM	embedded cable modem
eDOCSIS	embedded DOCSIS
FCAPS	fault, configuration, accounting, performance, and security
FDD	frequency division duplex
GAP	generic access platform
HFC	hybrid fiber-coax
HMS	hybrid management subcommittee
HTTP	hyper-text transfer protocol
IP	Internet protocol
MHz	megahertz
MIB	management information base
NOC	network operations center
OFDM	orthogonal frequency division multiplexing
OFDMA	orthogonal frequency division multiple access
OSP	outside plant
PNM	proactive network maintenance
RESTCONF	representational state transfer configuration protocol
RF	radio frequency
RxMER	received modulation error ratio
SCTE	Society of Cable Telecommunications Engineers
SMI	structure of managed information
SNMP	simple network management protocol
UML	unified modeling language
VSA	vector signal analyzer
YANG	yet another next generation

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