Operating Fiber Access the Cable Way

Challenges for the Industry to Overcome

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Table of Contents

List of Figures

List of Tables

1. Introduction

Cable operators with the experience of DOCSIS® technology in their history will find passive optical network (PON) technology to be quite different when it comes to maintenance and operations. For example, while cable modems are instrumented with extensive test capabilities, the same cannot be assumed with the architecture equivalent PON optical network units (ONUs). Further, the operation of these different access networks presents distinct sets of problems, adding to the complexity of operations overall. And while operators of both DOCSIS and PON networks may say service impacting issues are fewer with PON architectures, that does not mean a transition is easy for all.

With these challenges in mind, CableLabs© started a working group and concerted effort to address these maintenance challenges: The Optical Operations and Maintenance (OOM) program and OOM working group (OOM-WG).

The objectives for the optical operations and maintenance program at CableLabs are to reduce troubleshooting and problem resolution time and costs while increasing network capacity and uptime. The effort includes proactive, reactive, and predictive repair; and includes work streams toward telemetry alignment, solution development, and more.

The OOM-WG is defining use cases that align to general architecture functions and network operations needs including fault and failure management and failure modes. This alignment extends through the use cases to the information needed, and telemetry requirements for the industry to help vendors and operators gain focus on requirements. The activity of this group also includes the identification of new potential capabilities to further reduce operations burdens.

2. DOCSIS Technology Contrasting with PON

There are several important differences when it comes to network operations and maintenance.

2.1. Use of Spectrum

DOCSIS technology utilizes a range of frequencies to carry its radio frequency (RF) signal. To help manage that spectrum, we have upstream and downstream spectrum capture for signal levels in bins, upstream and downstream RxMER per subcarrier for signal to noise ratio determination, and pre-equalization and channel estimation to characterize the network in the upstream and downstream frequency bands. Because a frequency impairment can affect the channel, we have modulation profiles to manage the impact. We monitor the spectrum range to make sure service is assured and use this information to proactively remove faults before they impact service.

With PON, however, we mostly use fiber to carry a single frequency band of optical (still RF energy) signal (in XGS-PON it is one band in each direction) and lack the instrumentation for the equivalent tests that we have in DOCSIS networks. The operator of a given PON segment may employ optical time domain reflectometry (OTDR) to characterize and locate faults in the fiber and may monitor for changes in transmit and receive power levels (Tx and Rx respectively) to indicate the presence of a fault; some network faults might be detectable from a frequency sweep capability that only appears as a small, ignorable power loss otherwise. Monitoring power levels to identify changes in the system provides little detail about the nature of the problem because no information about the location, failure mode, or cause is provided.

The spectrum used in DOCSIS technology over coax plant is smaller than used in PON in the optical domain. For example, we talk about 1.8GHz as a large amount of spectrum in the RF domain, yet a 1nm line width at 1300nm is equivalent to 177GHz, and most optical signals are 3nm and commonly as much as 20nm. While optical signals occupy more of the frequency for a single band, DOCSIS technology uses the RF spectrum to carry data more spectrally efficiently.

Figure 1 below shows how the spectrum used for PON is not so narrow, but due to the typical encoding, each band is used as a single frequency. Table 1 shows the numbers. In this chart, these PON protocols use intensity modulation and direct detection (IM/DD), a form of on-off keying (OOK), which uses the entire spectrum range for a single signal. DOCSIS data transmission relies on electronics that separate frequencies and decodes the RF signal in these individual frequency bins. PON has no such equivalent function. Without embedded electronics to separate frequencies for data transmission, there is little to build from if building any frequency-based analysis test such as full band spectrum capture.

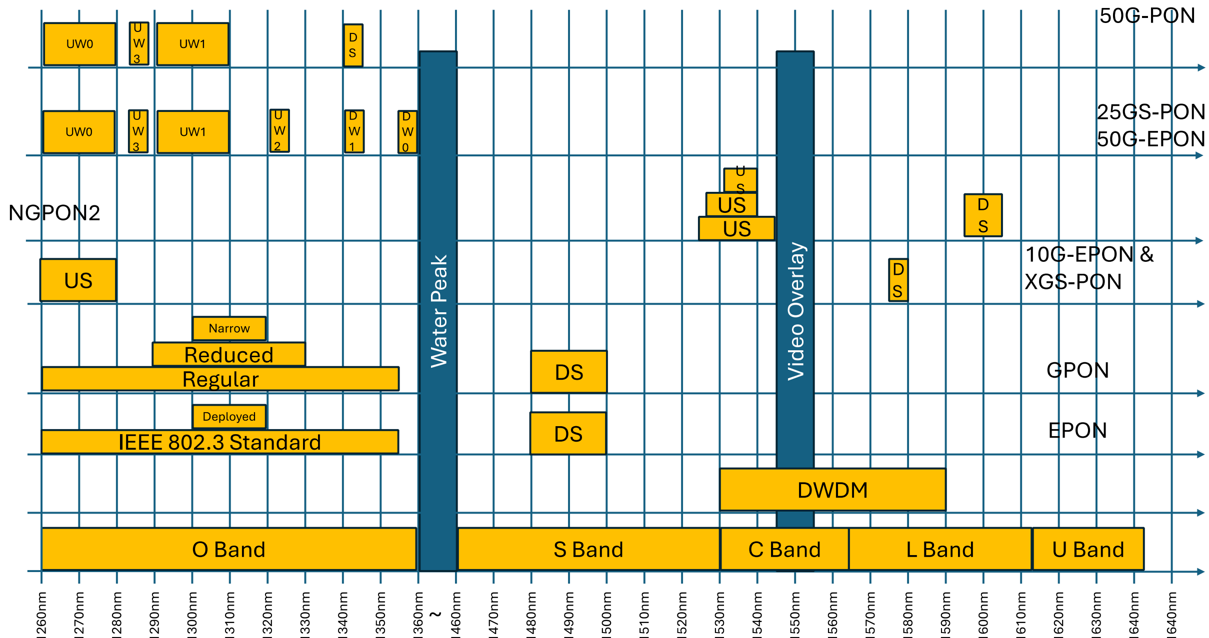

Figure 1 – Frequency plot of various PON technologies.

Table 1 – various versions of PON with the frequency use.

	Upstream Wavelength(s)	Downstream Wavelength(s)
GPON	1260nm-1360nm (regular) 1290nm-1300nm (reduced) 1300nm-1320nm (narrow)	1480nm-1500nm
XGS-PON	1260nm-1280nm	1575nm -1580nm
NGPON2	1524nm-1544nm (wideband option) 1528nm-1540nm (reduced) 1532nm-1540nm (narrow)	1596nm-1603nm
50G-PON	1260-1280 (UW0) 1290-1310 (UW1, wide) 1298-1302 (UW1, narrow, 25Gbps only) 1284-1288 (UW2)	1340nm-1344nm
25GS-PON	1260nm-1280nm (UW0) 1290nm-1310nm (UW1) 1310nm-1330nm (UW2) 1284-1288 (UW3)	1356nm-1360nm (DW0) 1340nm-1344nm (DW1)
EPON	1260nm-1360nm (defined in standard) 1300nm-1320nm (most widely deployed)	1480nm-1500nm
10G-EPON	1260nm-1280nm	1575nm -1580nm
25/50G-EPON	1260nm-1280nm (UW0) 1290nm-1310nm (UW1) 1310nm-1330nm (UW2)	1356nm-1360nm (DW0) 1340nm-1344nm (DW1)
Video Overlay		1550nm – 1560nm
ITU-T DWDM Grid	1530nm-1590nm	
Optical Bands	1260nm – 1360nm: O Band 1360nm – 1460nm: E Band (water peak region) 1460nm – 1530nm: S Band 1530nm – 1565nm: C Band 1565nm – 1625nm: L Band 1625nm – 1675nm: U Band	

2.2. Tests, Queries, and Status

DOCSIS equipment includes support for several active tests and queries, in addition to the usual status messages and measurements. A test is initiated when requested, and either adjusts the function of the system to facilitate the test or turns on data collection then provides statistics or averaging values as needed to answer the query.

PON has management entities or equivalent data elements, but these are not in support of system test functions; while tests are defined in G.988, they seem to be limited in specifics.

For example, in G.988:

"ONU-G (9.1.1) - Test the ONU. The test action can be used either to perform equipment diagnostics or to measure parameters such as received optical power, video output level, battery voltage, etc. Test and test result messages are defined in [G.988] Annex A.

Test results are reported via a test result message if the test is invoked by a test command from the OLT."

Another example from G.988:

"ANI-G (9.2.1) - Test the ANI-G. The test action can be used to perform optical line supervision tests. Refer to [G.988] Annex A."

2.3. Field Tools

In DOCSIS maintenance, field tools include spectrum analyzers, vector signal analyzers, field meters with embedded cable modems and tests, high impedance probes to prevent service disruption while connecting to the plant, leakage detection systems, and geographic information systems (GIS). With these tools, technicians can identify, localize, and remove faults effectively before they become failures or even impact service.

In PON, most of the devices are either simple continuity checking devices (shine the light and detect) or an OTDR function which is more expensive and only portable models are easy to transport. Most of the OTDR functions work on a narrow, single wavelength band only, so do not "sweep" the frequency response of the fiber. This means latent failures may remain undetected until they impact service. For example, a bend in the fiber that is moving in the wind may intermittently impact service but would be difficult to catch and locate. Further, many OTDRs function in band so will disrupt service, though there are options that work out of band and therefore does not disrupt user traffic.

Fortunately, the same GIS will serve both architectures.

2.4. Interoperation

In DOCSIS networks, we have interoperation between CMTS or nodes in the network with the cable modems or gateway end devices at the customer location. Most operators have integrated network operations center (NOC) tools that reduce the burden to monitor and troubleshoot in the NOC. A common collection framework (CCF) is a typical architecture, managing device polling to support tools without impacting the network's ability to serve, providing interoperation between tools and the network.

On PON, while it is improving, historically cross vendor optical line terminal (OLT) to ONU interoperation has been difficult to achieve. Functionality is predominantly vendor specific, requiring book ended solutions, and often tools that are specific to the vendor. It seems that in most PON deployments today, the operator is forced to use the OLT vendor's proprietary orchestrator/element-manager to manage the PON segments. This makes it challenging for the operator to build a single, common network management application that can talk to the OLTs of multiple vendors. Accepting the proprietary systems leads to NOC personnel having to "swivel chair" to monitor and troubleshoot networks, working with several different tools that do not integrate and require multiple screens and more difficulty to manage. The alternative is to build "shims" that integrate the data as best as possible and build applications to work on top of the shims. That's a lot of extra work.

Contrast this situation to DOCSIS deployments, where operators never were forced to use an element manager from the CMTS vendor, and the operator could build or purchase a single management tool that could talk to CMTSs from multiple vendors. While the current reality is not perfect here, it nonetheless is manageable, and the learnings extendable to PON technology.

2.5. Failure Modes: Same but Different

While it is obvious that different technology requires different hardware and software, leading to different ways in which the technologies can fail, their use environment is the same so there are some similarities worth mentioning.

Both coaxial cable (coax) and fiber cable can be cut to fail, or bent or crushed to impede function, for examples. A squirrel will chew on coax or fiber, and a backhoe will cut through coax or fiber with equal ease.

Fiber failure modes as listed by the OOM-WG are as follows. Some comparison to similar failure modes in coax cable are mentioned as well. Credit is due to the proactive network maintenance (PNM) working group at CableLabs for curating the initial list that informed the OOM work here.

- Water intrusion – while water in coax cable can lead to impedance problems when it gets into the dielectric, fiber has no conductor-shield pair to intrude. But still, water getting around the fiber strands can impede the signal, and at least become a vulnerability to the effect of freezing. Water intruding into the conduit shared by multiple fiber strands impacts all the fibers in the conduit, potentially. Even when a bundle is encased with gel filling, water can still do damage freezing around the bundle, and eventually erode the protection of the gel too.
- Cut – cables are often cut due to digging, but they can also be damaged from firearms, collisions, and sabotage. This failure mode applies to coax and fiber equally.
- Crush – there are many mechanical causes for fiber cable being crushed, leading to scattering, but an interesting one is when ice can crush the cable, from water entering the conduit or splice case, for examples. Crushing coax can create impedance mismatches that lead to reflections and impede transmission.
- Deformed – fiber can be squeezed in a similar manner to crushing, leading to different impacts to signals. Coax deformation can also lead to impedance problems.
- Microcracks – a microcrack often happens due to poor handling but can also occur due to movement in aerial cable. The parallel for coax can be shield integrity problems and related classifications.
- Broken – sometimes the cable is just broken due to being bent too severely or due to rubbing, for example. Pulling fiber through conduit improperly can lead to a tension break. This applies to fiber and coax both.
- Pulled – cable can be pulled from its connection point or even stretched or stressed to break. Again, this failure mode applies to both technologies.
- Abrasion – pulling fiber around a corner can damage the outside of the fiber. Movement in the wind or other forms of vibration or movement, while next to a poll or other object, can lead to abrasion of the fiber. A fiber bundle encased and protected will be robust to some amount of abrasion but when the jacket is damaged, elements can enter and do more damage. Repeated abrasion from wind and vibration can lead to eventual damage to the fiber strands too. Coax suffers from similar issues, but mostly jacket abrasion happens and leads to environmental degradation over time.
- Bend – a significant bend in fiber leads to higher loss. Coax can have impedance mismatches.
- Metallic strength member – when a strength member is metallic and electrified, the electricity through the strength member can lead to interference in the fiber signal. This is rare. There seems to be no coax equivalent.
- Strength member failed, broken – when the strength member breaks, fiber carries the weight and tension in the line, which it is not strong enough to do. This leads to pulling and breakage. There may be equivalent failures in coax.
- Fire damage – fire damages coax cable by melting the dielectric and burning the shield. Likewise, fire can damage the optical cable by damaging the cladding and even melting the glass. Fire damages coax as well, melting the dielectric and shielding, leading to impairments, then potentially worse.
- Lateral pressure – any lateral pressure of significance leads to light scattering. Coax seems to be much less sensitive.
- Burned from dirty connection and high-power density – high power light encountering a dirty fiber connection can actually burn the fiber. There seems to be no equivalent in coax.
- Lightning, vibration – lightning and at times vibration can lead to polarization issues in fiber. Coax is a conductor, so lightning can do serious damage to the system; vibration can show up by making an existing impairment better or worse over time, but vibration itself doesn't impact the signal.

- Yellowing from aging – indeed, fiber has a limited lifetime. As it ages, it yellows, and will have higher attenuation and scattering. Coax cable ages but in different ways and doesn't require a fusion splice to reconnect.

The active components have typical hardware and software failure modes, with photonic integrated circuits (PICs) experiencing the failure modes of optical lasers and receivers. A complied list of failure modes for this part of the optical system are listed below.

- Transmit (Tx)/receive (Rx) internal defects
- Tx/Rx face or surface contamination
- Tx/Rx mechanical stress damage
- Tx/Rx electrical overload
- Laser diode jump mode or wavelength drift
- Rx reverse breakdown or leakage large
- Tx/Rx poor sealing
- Laser diode optical power too low
- Tx extinction ratio too low
- High return loss/high reflection
- Rx receiver sensitivity too low
- Hardware failure
- Overheating
- Optical connector failure - dirt, crack, misaligned
- Incompatibility Tx/Rx
- RF-electrical interference (optical hum, or o-hum)

These optical components have become highly reliable over the years, as have their equivalent RF components in DOCSIS networks. The failure modes differ at the subsystem level but are generally equivalent at the component level. The main differences are complexity, and the frequencies transmitted and received.

3. Operator Challenges

The challenges that operators face with operating both DOCSIS and PON or any optical network, are numerous, and can be burdensome. The technology differences have yet to be integrated for operations purposes.

3.1. Access Network Technology Choice Brings Challenge to Operations

Currently there is no real tool integration between coax and fiber FCAPS. Further, most fiber systems, particularly PON, require operations acceptance of the NMS that comes with the system. Neither of those conditions is acceptable in an efficient network operation with multiple architectures and technologies, as is the case for most cable companies. Without the ability to integrate networks at the tools level, there is a burden on people to learn and work with more tools, and deal with more complexity overall.

3.2. Choices and Variety

Interoperation allows choices in DOCSIS networks, but PON systems are bookended. Operator choice allows differentiation and the ability to better meet customer requirements.

3.3. Capacity Management

Capacity management has always been a critical part of managing a DOCSIS network. This was primarily due to larger service group sizes and very limited (sub-split) spectrum in the return path.

So far, capacity management on residential PON deployments has not been an urgent need. Many, but not all, systems provide ample downstream capacity and more upstream capacity than customers consume. This is changing in some cases and will become an issue in the future as demand continues to increase, and more customers are added to systems.

Operators will need to monitor PON service groups to assure they don't become capacity limited.

3.4. Optical PNM?

There is no proactive repair in optical systems aside from tracking the remaining useful life in lasers, and a few who are utilizing power consumption and cooling data to identify anomalies in components. Customer calls are not out of band telemetry. DOCSIS technology has tests and queries that provide insight into service and the network condition, allowing management of resiliency mechanisms, and identifying faults before they impact service. Operators need the ability to identify and fix faults before they affect customers. Operators depend on it, and customers expect it. PON is behind in this way.

3.5. Alignment of Key Performance Indicators (KPIs)

While there is no reason management KPIs can't be integrated between DOCSIS and PON technologies, there is not much progress here yet. Some of this is operator specific, but having some solid practice guidelines will be helpful.

Fortunately, a few of us started working on this gap. This year's Expo has another paper on the topic, to be presented in the same session as this paper. [1]

3.6. Customer Experience

Customers in the United States can purchase their own modems or gateways and expect them to work as advertised when connected to the service provider's network port. That's not generally expected or possible in PON networks.

4. Efforts at CableLabs and the OOM-WG

At the encouragement of operators, CableLabs started the optical operations and maintenance working group (OOM-WG) to address these challenges and create industry wide benefit.

4.1. OOM, a Partner to CPMP

As a larger part of the optical effort, CableLabs launched an FTTP program that will include several work efforts. In addition to the OOM working group, CableLabs also started the common provisioning and management of PON (CPMP) working group. The work in this group, while a complementary effort to OOM, is focused on simplifying the PON integration for cable networks and removing barriers to full ONU interoperability. Additionally, near-term attention is being given to ITU-T PON technologies, including XGS-PON and 25GS-PON. At this Expo, there is a related paper being presented that outlines the work on the CPMP-WG. [2]

The primary objective of removing ONU interoperability barriers will be handled through two major work items. The first goal is to leverage the existing DOCSIS back-office systems to support the provisioning and management of the PON system. The second goal is to create a cable OpenOMCI profile that will complete the ability for interoperability in the in cable-specific PON deployment.

The CPMP and OOM working groups have aligned due to common goals, and for efficiency. Once the initial work on PON completes, OOM intends to look further toward the core for more opportunities to align operations and reduce technology burdens. CPMP's work on provisioning and a cable OpenOMCI profile help OOM streamline and align on telemetry for its use cases too.

4.1.1. DOCSIS Provisioning of ITU-T PON

While CableLabs has had a history of developing DOCSIS provisioning solutions for PON implementations, typically included a set of specifications. However, this is not the current route that is planned for this effort. The plan is to develop a process that can be quickly implemented, tested, and deployed. This process consists of:

1. Develop a set of use cases with the help of operators and vendors.
2. Generate DOCSIS cable modem configuration files based on the use case.
3. Run the cable modem configuration files through a DOCSIS adaption layer that converts the files into a configuration the PON system can process.
4. Send the PON configuration to the ONU.

Today in the cable PON ecosystem, the equipment suppliers that have a DOCSIS adaptation function in their product portfolio are likely the only vendors that will plan to have one going forward. Mentioned in step 3 above, this DOCSIS adaption layer is a function that converts DOCSIS configuration parameters (TLVs) into a PON configuration (OMCI MEs, managed entities). This is a key function in the ability for a DOCSIS system to support PON configuration.

Given that some PON vendors have already developed a DOCSIS adaptation layer, it would be counterproductive to create new specifications and require vendors to significantly modify their current features. Therefore, the plan is to allow the vendors to use their current products with only minimally changing their feature set. This will allow CableLabs to create a technical report that describes the process, rather than developing detailed requirements. This technical report will also include the set of use cases that will be used to develop the cable modem configuration files. Lastly, this document will also describe what OMCI is and how it used in this scenario. While OMCI is described in the technical report, there will be a specification created to support the mapping of DOCSIS TLVs to OMCI MEs. Future work within the FTTP program will include the development of next-generation provisioning and management methodologies. This could include, but not be limited to software defined networking (SDN)-based solutions and virtualized PON networks.

4.1.2. Cable OpenOMCI Profile

Within the ITU-T PON standards there is a study group 15 assigned to develop the ONU Management and Configuration Interface. This has become the G.988 standard. The OMCI is the way to manage ONU equipment via the OLT within the ITU-T. OMCI supports ONU configuration, fault reporting, performance monitoring, and security. This is done through managed entities (ME). These MEs define a message set and message exchanges for all OMCI functions.

The specification being developed by CableLabs with support from vendor partners and member operators will create a specific cable OpenOMCI with a set of MEs that will support the use cases defined in the technical report. This specification will map the list of DOCSIS TLVs to the equivalent OMCI MEs that will be used to configure and manage ONUs.

This cable OpenOMCI profile is the glue that will support the interoperability of ONUs within a cable access network, regardless of the provisioning methodology. Therefore, it can be leveraged with a DOCSIS back-office implementation or a next-gen SDN-based deployment.

4.2. Architecture Through Use Cases to Telemetry and Beyond

See Figure 2 below for how we align architecture to the telemetry through use cases. The CPMP and OOM working groups have aligned on this architecture for consistency. OOM extends this alignment further for its needs: Alignment of network operations tools requires alignment of telemetry. The OOM-WG is focused on identifying the best and sufficient telemetry to address the needed use cases. The use cases must address the operators' needs including monitoring for faults and failures, so it is important to identify the failure modes, effects, and criticality (FMECA) for the system. The architecture elements and their functions must also be monitored for performance to assure reliable service, so we have generalized the PON architecture. The architecture, components, functions, faults, and failures all drive the operator use cases, and there are other use cases driven by how the network and services are provided. All these connections assure traceability of the requirements to the telemetry chosen. For example, operators use Tx and Rx levels for a number of purposes, but some use cases may need the data in a particular delivery manner, with a specific tolerance, or at a cadence that some platforms may not support. Traceability assures we can define the needed telemetry that will be sufficient and meet the needs of the operators.

After telemetry requirements are defined, we intend to go shopping. There are several standards and specifications available which will potentially meet the needs we identify. That is idea, because we can then simply reference the standard or specification that outlines the specific telemetry and accompanying details. In cases where we require something close to a specified telemetry element, say via a streaming protocol instead of the defined SNMP response, then we can reference the defined element and provide modification notes. In cases where there is no telemetry, we can find that meets the needs or even close, then we will define new telemetry and provide the specific requirements and rationale for it.

All of this will be outlined in our technical report to be released in the future. We can use the result to represent the cable industry requirements and points of view on maintenance, and consider contributions to other standards bodies as well.

Alignment of KPIs follows from this too. The telemetry, in support of service and network assurance, can be translated into performance measures through translation functions. These performance measures can be combined to form overall measures of effectiveness too, which will also be KPIs. Other KPIs will use the performance measures in combination with other information, and may need additional transformation functions such as normalization, for example. More about the KPI alignment can be found in [1].

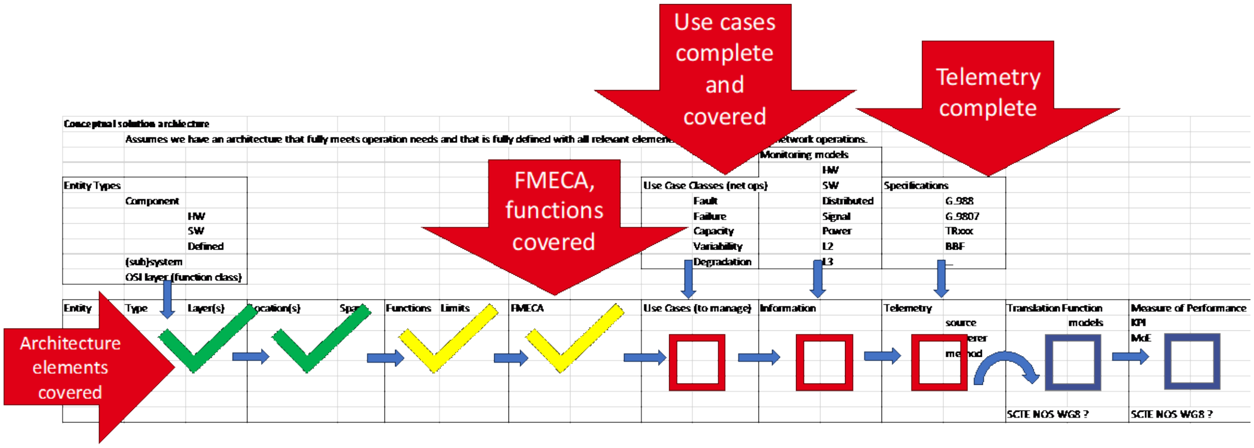

Figure 2 – A depiction of traceability from architecture to telemetry and beyond.

5. A Vision for Network Operations

To streamline network operations, cable operators will have to partner with vendors to help DOCSIS and PON technologies make friends. The operational stack, which must be integrated throughout, consists of the network at the base, through telemetry and data collection and information about the network and services, supporting tools that help operators to manage faults and failures and assure service, up through supporting repair and troubleshooting, all the way to decision support, planning, engineering, and strategy. Some of this is depicted in Figure 3 below, which is the ProOps model of observe, orient, decide, and act for network operations. [3] Alignment throughout the entire stack will be needed.

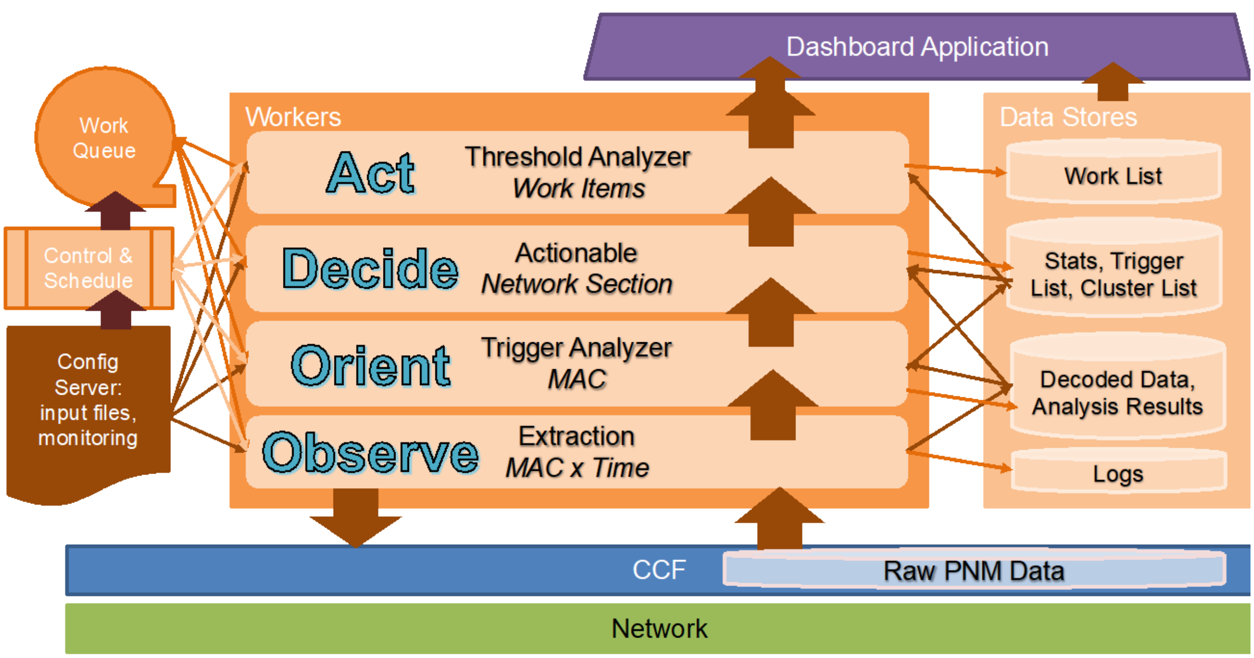

Figure 3 – ProOps model of data to action for network operations.

Telemetry collection must be reliable, and a single platform that supports all networks and all tools is ideal. A RESTful API is a good option for serving tools and all operations purposes in a unified way while also protecting the network from unmanaged and uncoordinated data requests. For this to work, avoiding a host of translation shims for proprietary telemetry, unified telemetry which supports the use cases and enable fault and performance management are required.

Tools that can work with any vendor platform reduce the need to learn multiple tools that do essentially the same task, reducing swivel chair, and simplifying operations overall. Modular functions can be effective as they facilitate continuous improvement and alignment of network operations including automation and decision support.

Network operations is won by appropriate action: knowing when to not act can be as important as knowing when to act; but also important are knowing what to do, where to do it, and who to alert to do it. Developing better automation, including more accurate identification and localization of faults and failures, will always be the goal. But accountable decisions end with appropriate actions well executed, which can't all be automated. Some of this goal can only be achieved through greater capabilities that we have to research and develop together. This is where the DOCSIS model can provide a model for PON.

Aside from unification through the dashboards and tools used to conduct network operations, there remains the need to compare and assess performance in unified ways across networks, for the purpose of customer service assurance. Measures of performance can be unified through normalization, common statistical models and sampling, and combining into like measures of effectiveness. Capacity can be managed on multiple dimensions; some services may need sessions, flows, connections to applications, etc., all of which may be limited in capacity. Some of these are common across access technologies, while others are not. But capacity can be normalized to percent units to track utilization in uniform ways. This type of translation can ease the burden of managing resources. Likewise, there are ways to develop functions that help translate faults and alarms, as well as facilitate troubleshooting and repair.

This way, from a network operations perspective, DOCSIS and PON management can make friends.

5.1. An Evolution Path for Optical PNM

The value of PNM has come from its demonstrated ability to find and fix faults in the coax network before any impact to customers. Sometimes service is impacted but the customer doesn't notice yet, and that still is a good outcome.

With PON, we can start with analyzing what we have today, demonstrating value, and incrementally evolving optical PNM. We can also start from DOCSIS PNM as an informative model, but not something to copy.

We propose several activities for the industry to focus around, in parallel with or once the current goals of the OOM-WG are met:

1) Research and unify on prognostics and health management (PHM) models for photonics, plug in cards, and all electrical field replaceable units. Identify the existing telemetry to monitor and develop models toward sufficiently accurate solutions.
2) Study available telemetry over time to develop models to identify faults and accelerated failure risks in PON fiber. The industry may need to share knowledge to achieve this goal. As we achieve what can be done with available telemetry and knowledge, we develop cost effective solutions to increase our proactivity on optical systems.
3) With consideration of the previous two activities, identify gaps in the knowledge and develop solutions to close on the needs. For example, we may find that intermittent faults that lead to poor

service are often caused by fiber bends in various parts of the network. By mitigating the bends where possible, we can improve service. But we may find a need to monitor for these problems directly, and a cost-effective way to do that would be a necessary innovation.

4) Extend what we achieve on PON systems toward the core. Coherent systems have additional telemetry that can make proactivity easier. CableLabs has demonstrated some solutions to grow from. See Figure 4 below for a screen shot of an Optical PNM tool for coherent optics, built by CableLabs, which demonstrates several performance measures worth tracking for potential anomalies. Work to align these to physical issues in the network should be a focus for the industry so that this information can be used to identify, localize, and remove faults.
5) Continue the work started in SCTE Network Operations Subcommittee WG8, Network and Service Reliability, to develop industry practices for assuring network and service reliability on optical networks and the optical portions of cable networks.

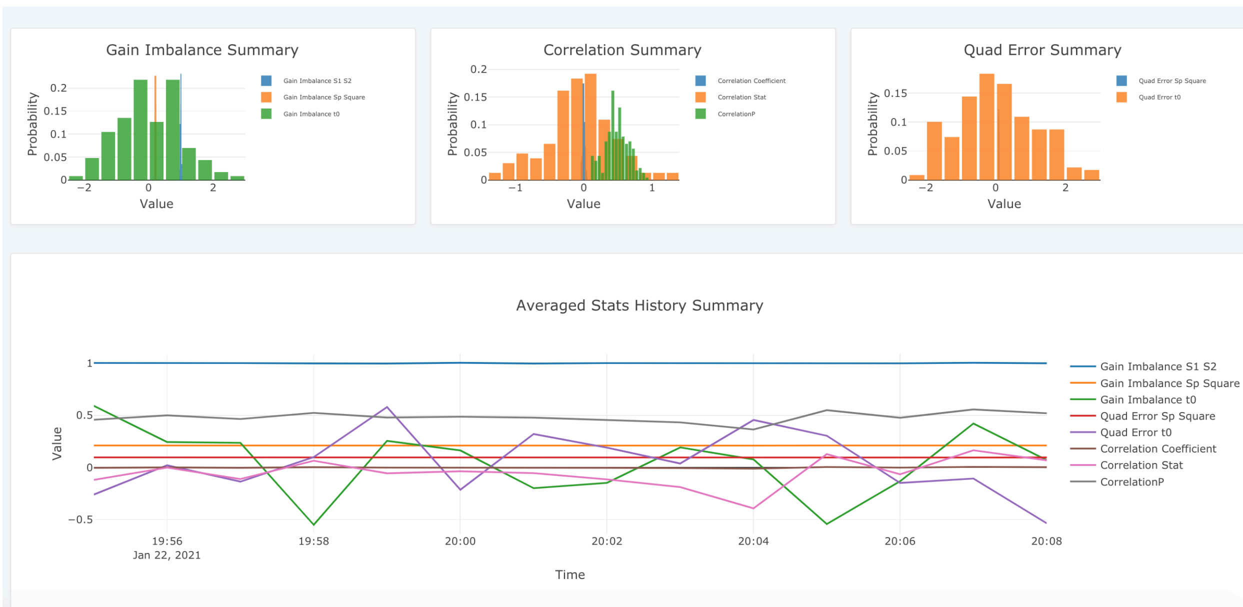

Figure 4 – CableLabs' Optical PNM Tool.

6. Conclusion

For cable operators to make the transition from hybrid fiber-coaxial to PON, operations efficiencies are needed. These start with industry wide alignment of telemetry, obtained through documenting needs reflected in use cases. A common architecture to identify the faults, failures, and components that need to be managed is also needed. As the OOM-WG develops this common set of requirements for cable operators to manage PON networks on par with DOCSIS networks, we lay a foundation for thoughtful innovation, taking PON technology to the next level of providing service by identifying opportunities, furthering technology, and creating new solutions to enable optical PNM. All cable operators and vendor friends are welcome to join the party!

Abbreviations

CCF	common collection framework
CMTS	cable modem termination system
CPMP	common provisioning and maintenance of PON
DOCSIS	data over cable service interface specification
GIS	geographical information system
IM/DD	intensity modulation and direct detection
KPI	key performance indicator
ME	managed entity
NMS	network management system
NOC	network operations center
OLT	optical line terminal
ONU	optical network unit
OOK	on-off keying
OOM	optical operations and maintenance
OTDR	optical time domain reflectometer
PHM	prognostics and health management
PIC	photonic integrated circuit
PNM	proactive network maintenance
PON	passive optical network
RF	radio frequency
SDN	software defined networking
TLV	type, length, value (in reference to provisioning parameters)
Tx	transmission
Rx	receive

Bibliography & References

[1] Robert-Jan van M., Jason R., “The Fiber Folding Ruler,” SCTE TechExpo24 2024.

[2] Jon S., John B., “Navigating Interoperability Hurdles for XGS-PON Within the Cable Access Network,” SCTE TechExpo24, 2024.

[3] CableLabs “Proactive Operations Platform, Application User Guide and Technical Report,” CL-TR-ProOps-V01-190925, 2019.