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Network Operations Subcommittee

SCTE OPERATIONAL PRACTICE

SCTE 290 2024r1

Service and Network Reliability Measurements and Use Cases

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Document Tags

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☐ Test or Measurement	☒ Metric	☒ Access Network
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1. Introduction

1.1. Executive Summary

Broadband networks are continuously evolving to include the 10G Platform advancing the bandwidth and reliability available to our subscribers. There are four pillars that make up the 10G Platform, including: 1. Speed, 2. Latency, 3. Reliability, and 4. Security. With continuous innovation and expansion, industry service providers require new and advanced tools and measurement techniques to support the networks and services of today and tomorrow. What has emerged recently is the focus on customers' views of reliability. This position relates to service reliability, though network reliability remains a strong focus due to its impact on service. Ultimately the purpose of this operational practice is to aid broadband service providers and equipment vendors with a common reference for assuring the highest availability and reliability of network and service offerings.

1.2. Scope

The scope of this operational practice includes:

- measurement definitions,
- how the measurement definitions relate to service and network reliability,
- the importance of tracking and how to interpret statistics, and
- discussion about use cases aligning to the measurements for network and service reliability.

The focus of this document is on both service and networks as defined for the broadband industry. As such, it applies to the services provided and to the networks and technologies used to enable those services. Network performance is also in scope because service reliability is supported by network performance.

1.3. Benefits

The information in this operational practice can be used as a resource by the broadband industry to help achieve the highest network and service reliability. When the practices in this document are implemented, an operator has the visibility necessary to manage service and network reliability. A comprehensive solution will enable the operator to lower operations costs as they improve service and network reliability. Through measurement and then management of the key performance indicators defined in this practice, operators can improve their networks more methodically. By sharing practices across companies in the industry, the entire industry is more efficient on the path to continuous improvement of technology management and network and service operations.

1.4. Intended Audience

This operational practice is intended for operations and technical personnel from broadband operators and equipment vendors.

1.5. Areas for Further Investigation or to be Added in Future Versions

Future work may provide more detailed practices for how operators can collect data to support the use cases in this document. Building on the foundation of this document, the working group intends to develop specific guidelines and methods to support new architectures, technologies, and services. Future work directions planned for the group include software as a service, cloud services and architectures, and software reliability specifically.

2. Normative References

No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

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- [CableLabs 2023b] PNM Current Methods and Practices in HFC Networks (DOCSIS® 3.1), CM-GL-PNM-3.1-V05-230927, Cable Television Laboratories, Inc., 2023.

3.1. SCTE References

- [SCTE 186] ANSI/SCTE 186 2021, Product Physical, Environmental, Electrical, Sustainability, and Quality Requirements for Cable Telecommunications
- [SCTE 226] ANSI/SCTE 226 2015, Cable Facility Classification Definitions and Requirements
- [SCTE 270] ANSI/SCTE 270 2021, Mathematics of Cable
- [SCTE 280] ANSI/SCTE 280 2022, Understanding and Troubleshooting Cable RF Spectrum

3.2. Standards from Other Organizations

- [Handbook] TL 9000 MEASUREMENTS HANDBOOK
https://tl9000.org/handbooks/mh_outline.html - contains the measurements document's outline, and purchasable document.

- [Telcordia 1] Telcordia GR929 Core - RQMS - reliability and quality measurements for telecommunications systems - module of RQGR, FR-796 - contains basis for measurements used and applied to telco systems. See ToC for approach: total downtime performance measurement (DPM), partial DPM, total loss of capability, outage frequency measurement (OFM). Also software patches and updates. Also problem report, fix response, change notice, module returns, no trouble found measure (NTF). Objectives set for each, based on reliability allocation.
- [Telcordia 2] Telcordia SRQAC - software reliability and quality acceptance criteria - module of RQGR, FR-796 - contains software specifics. Quote from document:
- "The following Bellcore generic requirement documents provide related reliability and quality assurance requirements applicable to telecommunications systems. The SRQAC metrics used for software acceptance criteria are correlated with TR/TA-NWT- 000284,[3][4] Reliability and Quality Switching Systems Generic Requirements (RQSSGR), TR- NWT-000418,[5] Generic Reliability Assurance Requirements for Fiber Optic Transport Systems and TR-NWT-000179,[6] Quality System Generic Requirements for Software (SQPR)."
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- [OSI] ISO/IEC 7498-1 Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model – Part 1

3.3. Other Published Materials

No additional informative references are applicable.

4. Compliance Notation

<i>shall</i>	This word or the adjective “ <i>required</i> ” means that the item is an absolute requirement of this document.
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5. Abbreviations and Definitions

5.1. Abbreviations

AHJ	Authority Having Jurisdiction
CEO	chief executive officer
CM	cable modem
CMTS	cable modem termination system
DOCSIS	Data-Over-Cable Service Interface Specifications
FCC	Federal Communications Commission
FEC	forward error correction
FMECA	failure mode, effect, and criticality analysis
FRACAS	failure reporting, analysis and corrective action system
HFC	hybrid fiber/coax
IT	information technology
LLD	low latency DOCSIS
LTE	long term evolution
MAC	media access control
MAUT	multi-attribute utility theory
MPLS	multiprotocol label switching
NOS WG8	[SCTE] Network Operations Subcommittee Working Group 8
OSI	Open Systems Interconnection ¹
OTN	optical transport networking
PNM	proactive network maintenance
QoE	quality of experience
QoS	quality of service
RCA	root cause analysis
RF	radio frequency
RMA	return merchandise authorization
SCTE	Society of Cable Telecommunications Engineers
SLA	service level agreement
SNR	signal-to-noise ratio
UPS	uninterruptable power supply

5.2. Definitions

Authority Having Jurisdiction	An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.
availability	Proportion of time that something is functioning over a long period of time, or a probability that something will be functioning at some far future time, beyond the time at which initial conditions matter.

¹ The standard's full name is "ISO/IEC 7498-1 Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model – Part 1".

cable network	A combination of interconnected facilities such as headends and hub sites, optical fiber equipment and cables, coaxial cables, power supplies, active and passive devices, and various hardware.
component	A non-repairable part of a system or network.
degradation	Degradation is defined as any condition in which one or more customers has one or more services operating at a diminished performance from design specification. This would include missing functionality of one or more features of a service.
domain	The set of possible inputs to a function.
failure	Lack of function.
failure rate, rate of occurrence of failures	The number of failure occurrences per unit of time over a very small interval of time, or when not a function of time or age.
fault	A defect, something that degrades performance.
feature	An add-on function of a service that depends on primary service functionality.
hazard rate	The failure rate for an item at a given age.
maintainability	The ease with which something can be maintained.
mean	Statistical average of a population or sample.
mean time between failures	The statistically expected amount of time between failures for a repairable component or system under defined conditions.
mean time to restore	The statistically expected time to restore a system to functioning.
median	The middle value of a population or sample, when the values of the set are ordered.
mode	The most frequent value in a population or sample.
network	More than one computer or communication device interconnected. A special case of a system.
outage	An outage is defined as any event in which one or more customers experiences loss of one or more services, regardless of the cause. Loss is defined as an interruption rather than a degradation of service.
outage time	Downtime; see repair time. The time between failure and restoration.
performability	A measurement of how well a system performs, usually over time and under the presence of faults and failures. The mathematical combination of performance and system or service state probabilities.
range	The difference between the highest value and lowest value in a set of numbers, when reported as a statistic. It may also refer to the maximum and minimum values possible for a value, when specified as an interval such as (y1,y2). For a function, it should be applied to the output of a function.
reliability	The probability that something functions as intended up to time $t > T$ given it works at time $T = 0$.
reliable	Works as intended.
repair rate	Inverse of the average repair time, the expected number of repairs per unit of time.
repair time	The amount of time it takes to complete a repair. Sometimes it is used as a synonym for downtime, but downtime consists of identification and localization time in addition to repair time.
repairability	How easily and quickly a component or system can be repaired, or the property of being repairable.
resiliency	The ability of an entity to limit the extent, severity, and-or duration of performance degradation following an event.

service	A provided function; in telecommunications, it is the transfer, delivery, and security of data and information transfer.
standard deviation	A measure of the amount of variation a random variable has around its mean.
subsystem	A subset of things from a system, often which function together to deliver some subset of the tasks or purposes of the system.
survivability	The ability of a system or network to operate under attack or stresses and provide service in the presence of failures.
system	A set of things that function together.
unavailability	One minus the availability. Proportion of time that something is not functioning over a long period of time, or a probability that something will not be functioning at some far future time, beyond the time at which initial conditions matter.
variance	The expected value of the square of a random variable's deviation from the mean. The square of the standard deviation.

6. Goals for broadband network and service reliability

Network and service reliability are more important than ever to broadband operators. The industry has evolved from being the video delivery business of its early days to one that provides critical services such as digital telephony (including 911 access), home security, and more. People working or learning from home rely on operator-provided high-speed Internet access. The broadband industry is a major player in the commercial services arena, which usually mean quality of service (QoS) agreements and service level agreements (SLAs) are in place. Today's competitive marketplace adds to the list of reasons why reliability is top of mind. Subscribers are less willing to put up with network or service interruptions than in the past, even when it comes to entertainment services, whether operator-specific content or over-the-top streaming.

SCTE has developed guidance for the cable industry on network reliability and availability before, setting precedence for the work of this working group. By keeping these practices simple, and relying on established approaches, network reliability is supported historically in the cable industry.

ANSI/SCTE 186 provides high level requirements for the industry, specifying use of SR-332 reliability prediction methods, highly accelerated life testing, and service life prediction as part of the quality requirements for communication equipment. This standard places reliability requirements in the context of environmental sustainability.

ANSI/SCTE 226 presents a tiered classification structure to provide cable operators with a framework in which to categorize facilities and critical infrastructure, prioritize investment decisions, establish availability expectations, and to define performance levels for the cable industry. This standard defines classes of critical facilities along with expected performance availability across five classes of structures thus creating a common nomenclature for critical facilities.

The 10G initiative was introduced at the 2019 Consumer Electronic Show, and refers to the broadband industry's network technology platform of the future. The four pillars of the 10G Platform are speed, low latency, reliability, and security. The reliability pillar is the primary focus of this document; but when it comes to service reliability, all of these pillars become important. The 10G initiative represented a pivot point for the industry.

Of particular importance to the industry is understanding and measuring reliability from at least two perspectives: that of the broadband operator and the subscriber. Effective network and service

management necessitates comprehensive measurements that consider both the operator's perspective for operational efficiency and the subscriber's viewpoint of service usage. Simply assessing the performance of isolated network segments or the overall network is no longer adequate. Services are complex, involving new technologies and architectures which all require new performance measurements and approaches, using new telemetry methods too. What worked a decade ago does not directly translate to today.

The industry has understood this need for improvement, and has identified the need to focus on the customer experience. Customers express their view of reliability in terms of the services that operators provide to users, through the way customers use these services.

For these reasons, and to learn from the experience provided by preceding efforts including those of Bellcore-Telcordia and QuEST Forum, the broadband industry needs an improved approach that is specific to our operations, services, and architectures. That approach also should take advantage of new technology and our unique advantages.

The next section contains material largely from [Rupe 2022] which was written for this document.

6.1. Setting goals

In support of our industry's goals, operators have a lot of well-informed tasks to accomplish. Categorically, some of these tasks include:

- Assure service reliability primarily, which requires network and system reliability, availability, maintainability, and appropriate resiliency and survivability. But it also requires reliable processes, procedures, management, and more.
- Build a foundation of understanding, linking customer experience to system and network events, so operations, design, and upgrades all provide the best service possible.
- Design reliable network and service solutions, with degrees of freedom to manage service reliability, that are also reliable in executability, obtainability, etc.
- Select reliable, repairable solutions and components for given deployments.
- Create and maintain fault management that is reliable, inexpensive, and maintainable. That includes proactive network maintenance (PNM), which identifies and can be used to fix faults before customers are impacted.
- Develop operations tools that are inexpensive, reliable, understandable, and useful for proactive and reactive maintenance.
- Build intelligence to enable decisions for preventive maintenance, technology replacement, resiliency, and operations planning.

6.2. Measure to Manage

Service and network reliability require well-defined measures of performance that can enable management for effective results. This requires well understood service performance measures, network performance measures, and operations performance measures. When a customer experiences any service friction, that should be reflected in a key performance indicator. A key performance indicator is a quantifiable metric used to determine how components of the network are performing. Aligning the

measures to the customer experience is most important. It is not acceptable to answer a customer complaint with “everything looks fine” because that suggests either you are blind to an important aspect of service, your measurements are insufficient, or your customer is wrong. The latter option is not a helpful assumption. The other two tell you improvement in your operations is needed. High levels of “no trouble found” point to the need for improvement as much as repeat trouble tickets do.

Doing all of this well requires knowledge of the failure modes, effects on networks and service, and criticality of the failure modes. A useful tool for capturing and referencing this knowledge is a failure modes, effects and criticality analysis (FMECA). Considering fault management in networks and complex systems, faults should be included with failures.

To obtain and maintain this knowledge, effective collection of components and failure modes is required. This enables analysts to determine useful corporate knowledge including what manufacturer or lot of components are not performing to specifications, what parts are wearing out, and which failure modes need to be addressed quickly to defend service.

The most convenient example with direct application to our broadband industry can be found in the 2021 Cable-Tec Expo [Spaulding 2022] Fall Technical Forum paper on applying FMECA to cable faults. Also see the Appendix of this document for an example with explanation. This work is based on expert knowledge and is generalized for hybrid fiber/coax (HFC) networks.

But operator specific knowledge is necessary to support reliable services, so that problems specific to certain plant designs, aging or degradation, or even poorly performing components (hardware or software) can be found and addressed.

To use our industry’s strength of sharing knowledge and energy toward common goals, one could develop standard methods for coding repair tickets to capture failure mode and component details so operators can fully benefit from this knowledge, and apply it to assure service. But the implementation and use of the result will still be operator specific.

The industry could also benefit by standardizing how service and network reliability are measured. The working group should work to specify standard ways for measuring service and network reliability including:

- the measurement definitions,
- how they relate to service and network reliability,
- how to track statistics and interpret them, and
- how to set control limits, perhaps setting specification limits.

See the Appendix for a starting framework that could serve as the foundation; however, it is only a start. As you will see in the rest of this document, operators need equivalent, supportive measurements from all aspects of network operations to fully support service reliability.

6.3. Setting Service Level Agreements

Based on existing service performance information, SLAs for upper tier or business class subscribers can be set with confidence, and even rebates can be offered at net profit. When new technology is involved, models of the resulting performance may be needed, and appropriate SLAs should be set based on the

network providing the service. Fortunately, simple mathematical models are often sufficient for setting and designing services for SLAs.

SLAs should be based on customer use cases but translated to service and network measures of performance. Define the service missions and translate the measurements defined to the customer use cases. For example, consider the use case of watching a movie through video streaming, including pausing a few times, requiring several functions to work when needed for the duration; what is the resulting experience, and how does it vary by customer or network condition or resource utilization?

The SLAs need to be set rationally, so that they are achievable, and demonstrable. Achievability can be validated through a model, and the model fed with field data when available. Demonstrability can be achieved through data collection and translation to the customer experience. The translation again can be achieved through a use case model. For example, the movie use case just mentioned requires high availability from the network and supporting systems, and reliable performance of the network and functions for the duration of the use. If the network availability is 99.99% (equally 0.9999), and the probability of successfully delivering the movie and needed functions for the two-hour duration is 0.99999, then the overall probability of success for that mission is approximately $0.9999 * 0.99999 = 0.99989$. If a user has this use case once a week, then the probability of not experiencing a failed attempt to watch a movie in a year is approximately $0.99989^{52} = 0.9943$; there is a good chance (0.0057) that quite a few customers (more than two in a thousand) will not be able to watch a movie at least once a year, even with these seemingly high reliability and availability targets!

However, SLAs are not usually sufficient when assuring service. Customer use, needs, and perspectives can add a lot of variability between the service provided and the customer's view of service. That subject is addressed later in this document.

6.4. Service Assurance in Operations

Low friction, high reliability service is delivered through reliable networks and systems supported by reliable, efficient operations. From a network perspective, reactive, proactive, and predictive maintenance all play a role, along with fault management.

- *Reactive*: Fast restoration first then repair, prioritized by severity of impact.
- *Proactive*: Timely repair, cost efficient, prioritized by severity and opportunity, afforded due to resiliency, with no restoration needed. Also, proactive maintenance can be thought of as fault management, as it is a mechanism to manage faults before they become failures that must be reactively addressed.
- *Predictive*: Planned maintenance to address degradation before service is impacted in any way. Predictive maintenance occurs before a fault impacts network or service performance, so it can happen ahead of proactive maintenance. For example, detecting a trend in early degradation of a particular component type can lead an operator to predictively replace those components based on useful life prediction. Prognostics and Health Management is an emerging field of research which addresses this need. But predictive maintenance can also follow from proactive maintenance, such as when additional damage is observed in the proactive repair, leading to further maintenance planning. Well planned maintenance can minimize operations costs.

Standard methods for coding repair tickets to capture failure mode and component details for service and network assurance, as mentioned previously, would help operators gain full benefit from that knowledge for superior service assurance.

Note that reliable operations can play an important role when interacting with the customer, because operations usually faces the customer in response to service disruption or degradation. The first touch point for a customer when they experience friction is usually the call center; today that is supplemented with a software application. Behind these touch points resides all the network operations tools and back-office systems, all of which are a part of the service provided, and intended to reliably reduce friction for that customer. A poor experience is a failure in service, so needs to be addressed through rapid reactive repair. Likewise, service can be proactively and predictively repaired through early detection of risk (security, privacy, fault, and failure), and continuous improvement of systems and processes.

See Figure 1 for a depiction of the various types of repair cycles which complement and assure effective operations. Note that predictive management of services includes planning and engineering, including information technology (IT), functions that engineer reliability into the solutions that deliver service, as well as predictive maintenance to replace failed systems well before they have a chance to degrade other parts or impact network functions, far ahead of impacting service. If operators wait or fail to detect issues before they escalate into faults and failures, staying ahead of service disruptions is still possible through proactive management. This involves fault management, PNM, and other proactive measures. But if operators wait further, service is impacted because the faults and failures are felt by the customer through their service experience. Reactive management requires fast, and often expensive, restoration and repair; but sometimes the repair is not as fast as everyone wants because other resources, processes and systems are reactively taxed. Spare parts supply chains may extend the restoration and repair time, as might technician availability. When service is impacted, severity should determine the restoration priorities, and repair to follow. Note that with proactive and predictive maintenance, restoration is not necessary. Reactive repair requires more work, higher stress, higher cost, and results in decreased customer satisfaction.

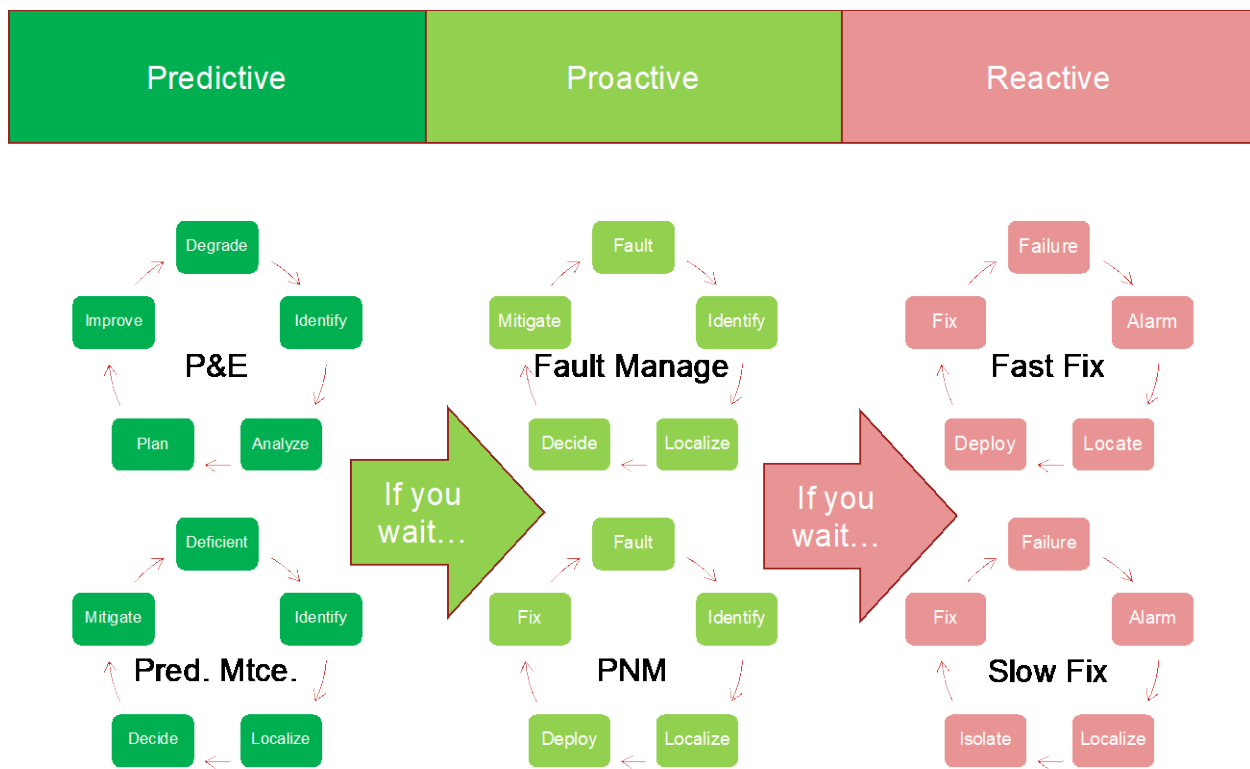


Figure 1 – Various types of repair cycles coexist in operations.

6.5. Fault Management

Knowing how a network can fail, the faults that lead to failures, and how those faults and failures are revealed in network performance can let an operator automate fault management and operate using PNM. Identifying the faults that impact service and where they come from is an important first step. How they relate to failures is also important. An important goal in fault management is to automate as much of the fault identification, localization, and isolation as possible; and to do so reliably, which includes low false positive and very low false negative occurrences.

Consider event frequency, effect on service, and ability to test or monitor, then set the policy based on established goals. Faults that are automatically mitigated can be ignored by repair technicians, but may need to be monitored by systems if faults are indicators of other problems. Faults that require intervention can be handled with the appropriate repair cycle. Efficient fault management, like repair, requires an effective way to translate telemetry into action, such as the ProOps framework available from CableLabs [Zhu 2020], [Rupe 2019], [Rupe 2020], which provides a framework to observe (collect telemetry and information), orient (add context, assess the information, and potentially collect more information to assess), decide (translate information into faults and failures, then identify and localize faults and failures), and act (take appropriate action based on the assessment and information, with consideration of resources, priorities, and schedules).

6.6. Repair and Supply Chain Optimization

With a strong handle on the priorities and planning for maintenance, operators can optimize their repair processes in many ways. Planning repairs on a longer schedule allows optimization of the travel time and distance required with maintenance, avoids unproductive technician time, and minimizes outage impact on service.

Commonly, non-service affecting events have a much longer MTTR than service affecting events. Most of the time, non-service affecting events involve redundant hardware or functions, placing the system in a single point of failure state. Functional block diagrams are useful for describing the network's intended use, but a reliability block diagram will depict the redundancy and degraded network states more clearly, and therefore highlight the reduced urgency of stocking redundant components. This approach guides the requirements for service and non-service affecting components as they differ in impact to service availability and reliability.

In addition, spare parts can be optimized to reduce held inventory and assure spare parts are on hand when and where needed to never adversely impact service, and never require expensive expedited shipping of parts (see section 11.10). Critical parts necessary to correct critical failures should be readily available. Well-designed spare parts inventories can be created with lowest cost and appropriate spare parts availability. There are many applicable mathematical models available that can help operators set optimal inventory levels and policies for given targets of delivery time and probability of shortage.

6.7. Removing Degraded or Poor Quality Components

Technicians who deal with the plant all day know that some components wear out sooner than others, and some have specific faults in their design or manufacture that result in failure modes that emerge earlier or uniquely to these components. Sometimes environment has a strong influence on the early emergence of these failure modes. Temperature cycling, humidity, exposure to water, and even dry climates can impact

network components differently. But even in controlled environments, poorly designed, selected, or built components can exhibit early failures which need to be addressed predictively. Early warnings from a few components can foretell the emergence of failures in the rest. As a result, tracking failure events by component type, manufacturer, age, location, and other factors can allow the operator to predict early issues and address them with predictive maintenance programs, instead of waiting for one-by-one replacement at failure. It is far cheaper to replace soon-to-fail components while doing other maintenance, to save on truck rolls and unproductive time. If such a program is required earlier than expected, a vendor management issue may need to follow, including perhaps warranty assisted replacement.

6.8. Vendor and Contract Management

Once an operator sets their goals for service and can articulate how the network and its components translate to meeting those goals, they can align their contracts toward the goals, and even manage vendors to meet their contribution to the goals.

Component and system testing assures functionality, which reduces friction in the user experience. Testing for design and features is well established in our industry. Testing for basic features and functionality is a necessary foundation. Testing for capabilities necessary to provide specific services and features is important, too. Because long duration testing of hardware-software integrated systems is not feasible in most cases, it is important to test software well, life test hardware, and design-in system health monitoring and management capabilities for what can't be assured otherwise. Measuring early and useful life performance of components and system parts allows prediction of problems and validation of vendor performance. [SCTE 186] and [SCTE 203] provide good examples of guidance for such activities.

When reliability data for purchased hardware doesn't exist, the operator could ask the vendor to perform a reliability demonstration test. This test should be done on production hardware and be designed to confirm desired or better reliability with defined confidence levels during a specified period of time.

To ensure hardware performance and reliability, and minimize risk related to premature functionality loss, vendors should perform service assurance tests. Most of the time this test is automated and conducted at typical use case temperatures. Service providers and vendors should coordinate testing and perform statistical analysis of the measurement results.

6.9. Network Design

Networks should be built with performance goals in mind, and that performance should include reliability concerns as well. Doing this requires modeling of service and network behavior, including protection and restoration and resiliency mechanisms, for hardware, software, systems, and even people.

Network architecture will dictate allocations of service and network reliability to provide a given level of service based on the measurements specified. How much friction-degradation and/or downtime can be allowed at, say, an optical backbone link as compared to the cable modem termination system (CMTS), cable modem (CM), or access network? Operators who are targeting service and network reliability will be collecting information and modeling to assure good decisions get made at the point of system and network design. This purposeful design enables management of network sections and knowing where to focus resources for network and service health.

Network operational cost-benefit modeling is an important component of this ability. Start with a framework for modeling the needed tradeoffs and making decisions around improvements.

This work can apply to operations design. Should a technician be sent to fix a fault today, or should they wait a week in case there are more issues that can be solved with the same truck roll? If an operator is not