You Might Have a Screw Loose: Remote Detection of Thermal Imperfections

A technical paper prepared for presentation at SCTE TechExpo24

Matt Wichman
Director Network Operations, Access Networks
Comcast Cable
matthew_wichman@cable.comcast.com

Venk Mutalik, Fellow, Comcast Cable

Josh Cook, Engineer 4, Comcast Cable

Table of Contents

Title **Page Number**

List of Figures

Title **Page Number**

1. Introduction

Today's field hardware is becoming more advanced and can be impacted by environmental factors. Traditional node housings now contain a variety of advanced modules that have capabilities of delivering symmetrical gigabit speed to customers. To deliver reliable bandwidth, all components and modules in the node must be installed correctly. Incorrectly installed components can cause modules to overheat, causing reduced life of the module, reset, reboot or even complete sudden failure. With advanced analysis of telemetry, we can detect loose or improperly installed modules well ahead of customer impacting events. This new detection method will improve the customer experience, reduce outages, and extend the service life of field installed modules.

Advanced consistent telemetry of all temperature sensors in a node tells a complete story that one sensor alone can not reveal. Today's node modules are capable of reporting individual temperature readings and in some cases multiple temperatures from components, like small form pluggable's (SFP's) and chips. Individually we can tell if a module or component is overheating, but this leaves out the impact of external temperature the node housing is experiencing due to weather or the node location. When individual temperature readings are combined into a complete picture, we show in this paper how to remotely determine if the node is over heating due to external forces, or if individual modules and components are the cause of an overheated reading.

2. Impact of Overheated Node Modules

It is important for operators to monitor and maintain individual module temperatures. Adverse impacts can degrade or interrupt service that may not be easily identified. Each module can only be identified as a cause of the impact if they are monitored as part of a wholistic node environment logic.

Impacts of Overheat and Loose Modules

- SFP resets
- SFP frame errors
- Reduced signal quality
- Remote Phy (physical layer) device (RPD) reboots
- RPD offline, failure to bootup
- Shortened life span of components
- Sudden complete failure of the module

Without thermal information and logic, field teams have a hard time understanding the cause of a problem or why the repair fixes the service call. With the right information, not only can techs quickly resolve the issue, but also fix the problem before these conditions occur.

3. External Node Temperature

The external temperature of the node housing has an obvious impact to the temperature of the components in the node. It is important to quantify the normal temperature fluctuations a node and its modules experience in the outside plant. These expected changes can be observed by the equal impact to all modules in the node. The rise and fall of module temperatures is correlated with the cooling ability of the housing. Each module varies in exact temperature based on the thermal signature of the components, but all have been observed as being within 10 Celsius of each other as the over all temperature of the node changes.

External impact on temperature variation between module readings is much more precise than the difference between modules. When the external temperature rises the individual readings rise and fall together maintaining the temperature delta of the components within 3 Celsius (<3c). Using this expected behavior, we can identify when a node overheating due to an external factor.

When all sensors are reporting an overheating condition, we know the node housing itself is in a location impacted by external heat.

External Node Overheat Conditions

- All temperature readings within 10c Δ
- Component rate of rise/fall over time maintains < 3c uniformity

One or more node components exceed manufacture temperature specifications. External causes of overheat conditions can vary Identifying nodes overheating due to external conditions can help to fix the problem before the node modules are impacted. Node housings are designed to operate across large temperature variations while maintaining internal module temperatures within recommendations.

Typical Causes of External Overheat Conditions

- Node installed in a pedestal not rated for the heat output of the node
- Node installed in a pedestal over filled with fiber, cable, or additional actives
- Extreme weather conditions outside of the design of the node housing

Good construction practices and node placement can eliminate external temperature being a cause of an over heated node. All nodes must be placed in an environment suitable for the housing to dissipate the thermal load of the modules.

4. Node Module Heat Signature

Node modules exert a unique heat signature based on the thermal output of the device. Not all modules create the same amount of heat, so the internal temperatures vary based on the module type. Field observations show that radio frequency (RF) trays generally create about the same heat as a 1x1 RPD module, but a 2x4 RPD module runs about 4 Celsius hotter. The exact difference in nominal temperatures can be quantified based on the model of the module. Ethernet passive optical network (EPON) or remote switch (R-Switch) modules run slightly cooler than RPDs.

Quantifying the expected heat signature of each module model allows for more precise temperature delta measurements. The differences in temperature between modules becomes a static measurement that is used to identify when a module is running outside of an expected thermal delta.

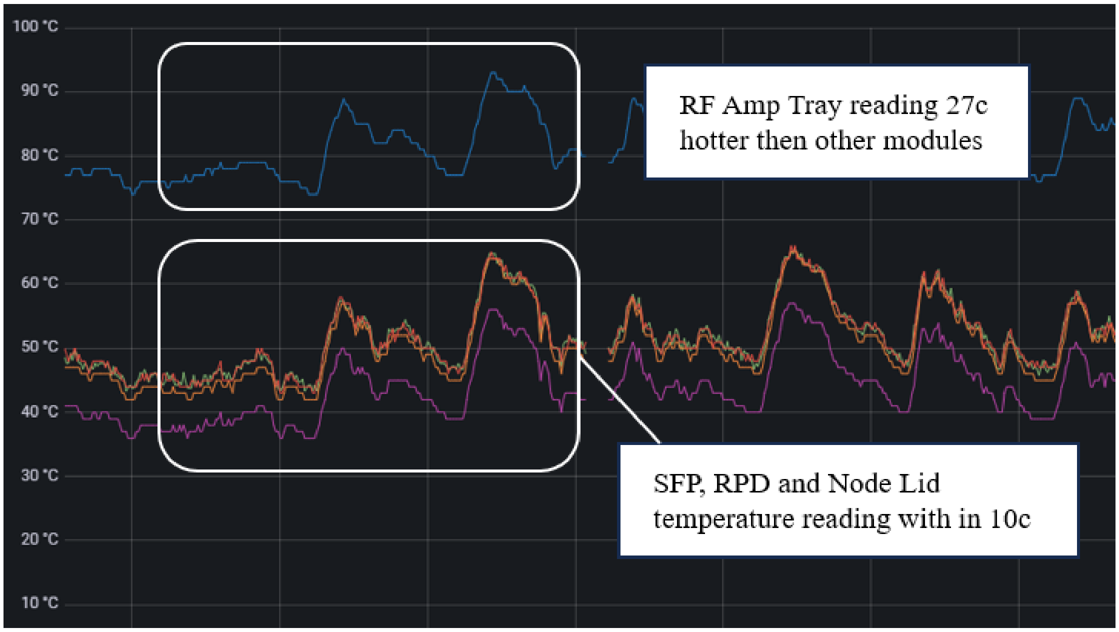

Figure 1 - Temperature readings indicating a loose amp tray signature.

Base temperature readings can be identified when nodes have a temperature sensor on a board directly screwed into the housing. Some nodes may have a lid mother board (LMB) that has little to no heat signature of its own, that other modules connect to. The LMB is lowest temperature reading due to its low thermal signature and being directly connected to the housing. In Figure 1, the lowest temperature reading is the LMB temperature as indicated by the purple line, while the blue line is the Amp Tray. The delta of these two modules indicates that the Amp Tray is loose or not installed properly.

5. Detecting Loose or Improperly Installed Modules

Loose or improperly installed modules have temperatures exceeding the nominal delta. This temperature increase is due to the module being not fully seated and making a good connection to the node housing. Detection is achieved by measuring the delta between modules and or the LMB temperature. It is possible to have multiple modules improperly installed, as indicated but the number of modules higher than the 10c delta or a more precise delta for the model of the module. Modules not capable of sending a temperature cannot be remotely identified and have a higher probability of going unnoticed before a failure occurs.

5.1. Loose RPD, EPON/R-Switch Modules

Network enabled modules with SFP's have multiple temperature readings to correspond to a loose module. The module and the SFP temperature will both be elevated above that of other sensors in the node. This improves the logic used to identify loose modules by having multiple readings to validate the delta is above the expected value of under 10c.

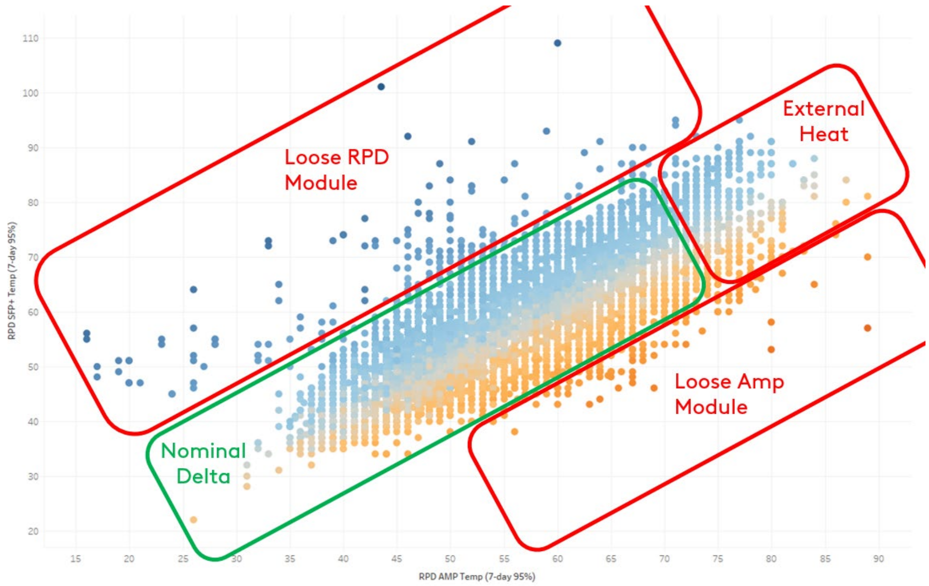

Figure 2 - SFP to RF Tray Deltas, and likely conclusions.

We can observe the differences in temperature readings for an SFP versus the RF Tray (figure 2) by plotting them on the X and Y axis. The readings showing a hotter SFP indicate a loose module, whereas readings showing the RF Tray hotting indicate that the RF tray is loose. Readings where multiple temperature sensors are within nominal range indicate that the node is impacted by the external environment.

External temperatures impact on loose module detection has not been detected. We observed loose modules in the seasons, making the detection method using module temperature deltas consistent though out the year. This means that a loose module can be detected at any time, day, night, summer, or winter. This is ideal for filed team dispatching because although temperature can vary wildly, we can always identify if the problem exists and if it has been fixed.

Additional module types can easily be added to existing loose module detection, by measuring the nominal operating temperature delta to existing components. In this way future modules and node housings can be folded into field events by identifying the underlying thermal characteristics.

6. Field Trials and Fixing Loose Modules

Initial field trials indicate that loose module logic for the remote detection of loose modules to be accurate and actionable. In the past it was not known if a module was loose or if it was the cause of customer impact, techs would reseat or replace the module with no attributable cause of the failure. Field teams initially reported about 80% accuracy in loose module, by simply checking the module screws for manufacture recommended torque settings. The 20% not identified as a problem were revisited and attributed to loose guide pins, improper torque sequence or tech training.

With training and tuning the loose module logic is now near 100% effective in identifying a node problem with additional refinements to specific modules possible.

6.1. Improper Torque Sequence

Node modules must be torqued down in the proper sequence for the module to be seated evenly in the node housing. When modules are not torqued properly (figure 3), one side of the module may exhibit a gap between the module and housing. Improper torque sequence causes heat buildup in the module.

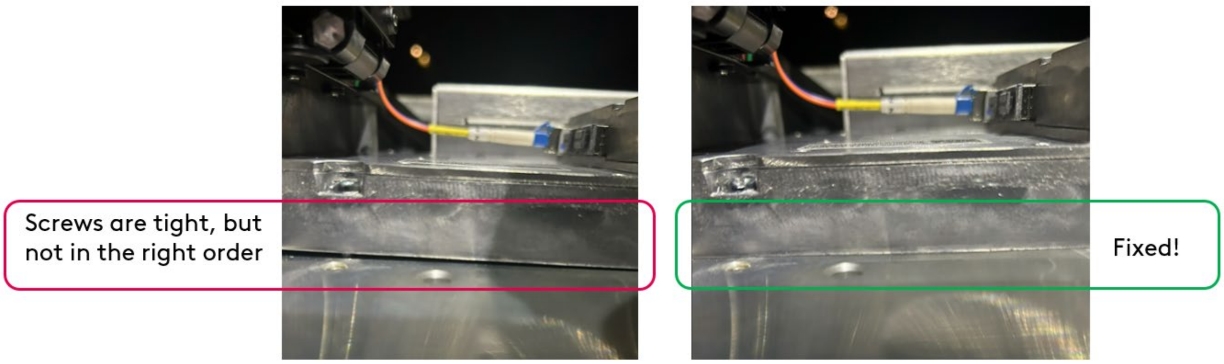

Figure 3 - Improper torque sequence

6.2. Loose Guide Pins

A potential problem identified for overheated modules is loose guide pins. Guide pins are needed to center the module in the node so that it makes a positive connection with the LMB pins. When these guide pins are not seated all the way in the module, their overall length is greater than the intended mounting hole, bottoming out. When a guide pin bottoms out, it prevents the module from resting directly on the node housing surface. Loose guide pins cause heat buildup in the module.

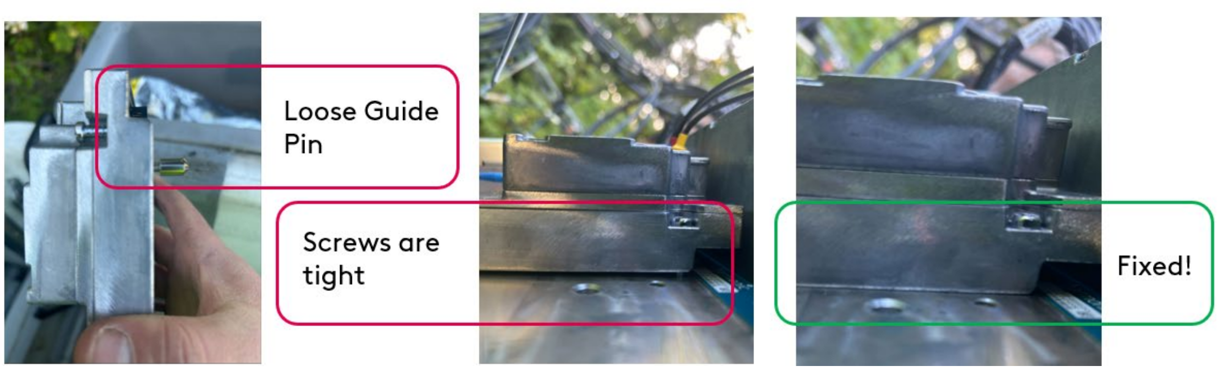

Figure 4 - Loose guide pins

7. Future Work and Data Science

Using the methodology and field trial results, this new way of detecting potential reliability problems can be further refined with AI and ML algorithms. Further studies into the impact can improve detection also adding a level of criticality to alarms, based on variables outside of those described in this paper.

The access network continues to evolve with the addition of Coherent Muxponders (CMP), full duplex DOCSIS® (FDX) amps, and additional new devices. Future devices can be folded into existing ways of identifying multi-metric-based impairments. Building on algorithms that evaluate the overall health of a field device reveal problems only trained technicians can identify now. Heat, power, light levels and the measured bias of these measurements will provide future visibility into our network that is beyond current expectations for reliability.

8. Conclusion

Today's networks demand consistent monitoring of multiple metrics like temperature to deliver tomorrows reliability. Overheated module and temperature-based module installation problem detection is a key component to improving the reliability of digital networks.

Some of the benefits advanced thermal monitoring provides:

- Node Construction validation identified and fixed before construction ends.
- Post maintenance validation after modules have been swapped.
- Future heat related problems can be avoided before the summer.
- Reduce time spent troubleshooting high heat issues in a node.
- Persistent monitoring ensures longevity of the network.

Long lasting, reliable networks require telemetry from all devices. Manufactures can ensure that operators have the most reliable equipment by providing temperature data on a per removable module basis. If a module can be removed, it can be installed incorrectly. This impacts the failure rate and reliability of equipment.

Intelligent alarming and eventing to avoid outages and improve reliability requires operators to seriously consider the advantages of adding thermal based alarms, events, and ticketing to their Preventative Network Maintenance range of metrics for field teams.

Abbreviations

C	celsius
CMP	coherent muxponder
DOCSIS	data over cable service interface specification
EPON	ethernet passive optical network
FDX	full duplex DOCSIS
LMB	lid mother board
Phy	physical layer
R-Switch	remote switch
RF	radio frequency
RPD	remote Phy device
SFP	small form pluggable

References

Mutalik, V., Viera, A., Wood, S., Rice, D., Gaydos, B. (2024). *If You love Coherent, Set it Free.* SCTE TechExpo24 Papers, (all)