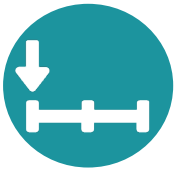
# DOCSIS 3.1 and the PNM Toolbox: The Future of Plant Maintenance is Here

A Technical Paper
Presented by ZCorum



## Introduction

This paper examines the Proactive Network Maintenance toolbox and it's functionality within the DOCSIS 3.1 standard. The approach with PNM in the new specifications is to include remote visibility into the operations of the cable plant and its equipment. Making PNM a requirement in DOCSIS 3.1 ensures manufacturer support of proactive troubleshooting and network maintenance.

## Laying the Groundwork

As cable networks transform, and services such as data, video, telephone, home monitoring and other services are going through them, the demand for exceptional reliability increases. To achieve such reliability the old break-fix routine also has to transform. Operators have to fix problems before they have an impact on service.

With this in mind, the goal of Proactive Network Maintenance (PNM) is to take all the information that can be gathered from devices already in the plant and use that information to determine what's happening and where in the plant the fault can be found. The net results being improved reliability and a drastic reduction in maintenance costs, significantly improving the provider's operational efficiencies.

DOCSIS devices are evolving, and elaborate monitoring tools such as full band spectrum analysis, are built in. This allows us on the downstream side to have the functionality of a spectrum analyzer implemented right in the software. We can now see tilt, ripple, ingress, nulls, etc remotely. In the upstream we can do triggered spectrum analysis that delivers a comparison of captured spectrum with transmitted signals.

DOCSIS 3.1 turns every single cable modem into a network probe that can be used to identify network impairments. By using the newly equipped devices as network probes, cable operators can easily collect device and network data. Analyzing this data alongside the plant topology and device locations, it is now possible to isolate the type of problem and the approximate location of that problem. The key benefit of the new DOCSIS requirements is the reduction of time in finding and resolving problems thereby reducing operational costs. With the capability to detect and resolve problems before they impact customer service, churn is reduced. Additionally, improvements in network reliability can lead to commercial services business and other advanced services thereby generating new revenue.

**Downstream PNM Requirements in DOCSIS 3.1**

**9.3.1 Downstream Symbol Capture:** Capture OFDM symbol at input and of plant, solve for response

**9.3.2 Wideband Spectrum Analysis:** Spectrum Analyzer in the CMs

**9.3.3 Noise Power Ratio NPR Measurement:** Notch reveals underlying methods

**9.3.4 Channel Estimate Coefficients:** Downstream equalizer

**9.3.5 Constellation Display:** QAM cluster variance

**9.3.6 Receive Modulation Error Ration (RxMER) Per Subcarrier:** SNR vs frequency, using pilots

**9.3.7 FEC Statistics:** Correctables, uncorrectables, etc.

**9.3.8 Histogram:** Signal distribution revealing nonlinearities

**9.3.9 Received Power:** Power received at CM

**Upstream PNM Requirements in DOCSIS 3.1**

**9.4.1 Capture for Active and Quiet Probe:** Capture known probe symbol (or empty slot) at output of plant, solve for response (or noise floor)

**9.4.2 Triggered Spectrum Analysis:** Spectrum Analyzer synchronized with upstream timeslots.

**9.4.3 Impulse Noise Statistics :** Burst/impulse noise level and duration

**9.4.4 Equalizer Coefficients:** Pre-and post-equalizer

**9.4.5 FEC Statistics:** Error-free, unreliable, corrected

**9.4.6 Histogram:** Signal distribution revealing nonlinearities

**9.4.7 Channel Power:** Power received at CMTS (ranging offset)

**9.4.8 Receive Mostulation Error Ration (RxMER):** SNR vs frequency

## Powerful Technology, Powerful Changes

PNM is now part of the DOCSIS standard and is a requirement in 3.1. This means that all modems and CMTS equipment, in order to be certified as DOCSIS 3.1, must include all of the PNM characteristics. This assures that all the devices will support PNM technology correctly and will enable the actual benefits accurately.

### CMTS Cache

In the upstream, CMTS equipment now must be capable of upstream capture. Part of the requirement in the new specification is the CMTS has to be able to take samples of the network. This gives the ability to actually see what is and is not ingress across the entire upstream.

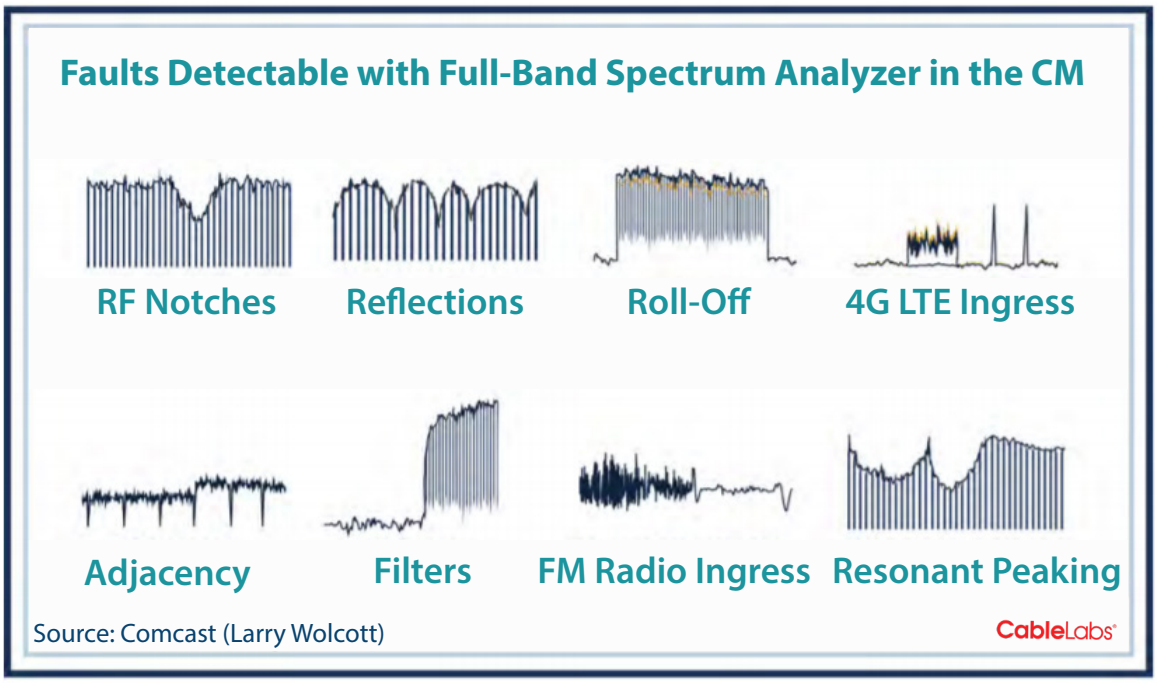
### Full Band Capture

On the downstream side new modems have spectrum analyzers inside and a picture of the entire forward spectrum. In essence, the CPE becomes a remotely controlled spectrum analyzer. Modems are also required to support the powerful technology of FBC. The Full Band Capture ability in the CMTS will detect faults such as reflections, resonant peaking, 4G LTE Ingress, Roll-off, RF Notches, FM Radio Ingress and others.

### New OFDM Carrier

Also on the downstream side there's a new data carrying symbol. This means the CMTS will have the ability to send a known symbol and have the cable modem capture that same symbol and send it back to the CMTS. By examining the differences in a symbol sent by the CMTS and what the cable modem sends back we can determine what's going on in the plant as it's passing through. The ability to collect this intelligence is accomplished by examining the unique attributes of the components.

Each type of modem has individual characteristics with specific signatures unique to each different modem. Types of impairments also have individual characteristics that can be identified. After extensive analysis of these signatures, CableLabs realized that there are common problems that particular types of cable modems have to deal with.




By correlating this data from groups of cable modems, we can see if cable modems in a group are exhibiting common impairment characteristics, such as micro-reflections or group delay. The clustering of the CM signature responses can be sorted out into different categories to see the various faults that are occurring.

If the cable modems in a group exhibit common problems, such as micro-reflection or group delay, the estimated distance to the impedance mismatch causing the micro-reflection can be determined by using powerful algorithms. By measuring this distance between the taps and then correlating with known equipment out in the plant, pinpointing the almost exact location of the impairment is possible, thus dramatically reducing the typical troubleshooting repair time.

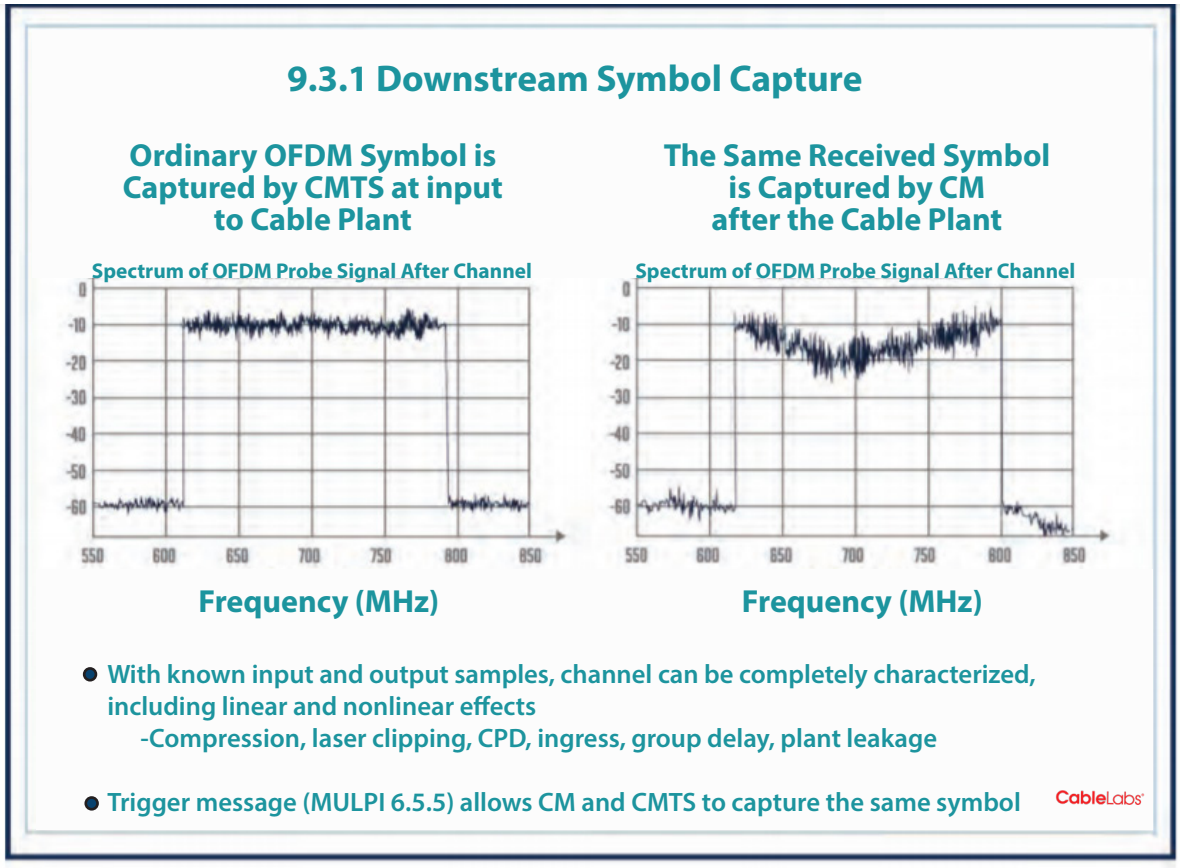
## Granularity

Better granularity enables the ability to create correlated groups. DOCSIS 3.0 is a time based tap platform but the change in 3.1 is the taps will be frequency based. Basically each carrier will be its own tap which means there will be a much wider band in which to isolate problems. The wider the band the easier to see more symbols being compared. This makes the entire process of analysis and deduction of impairments much more accurate.

## The Exceptions

The new DOCSIS 3.1 cable modem chipsets are so superior at taking advantage of this monitoring capability, it's giving MSOs even greater incentive to move 3.1 modems into the field as quickly as possible. However, it should be noted that some of the functions remain available without a 3.1 modem. With a 3.1 CMTS, all of the pure CMTS features such as seeing ingress will still happen.

Without the 3.1 modems though the new capture functions of the OFDM, the synchronized downstream captures and other valuable functionality will not be available.




## Remaining Challenges

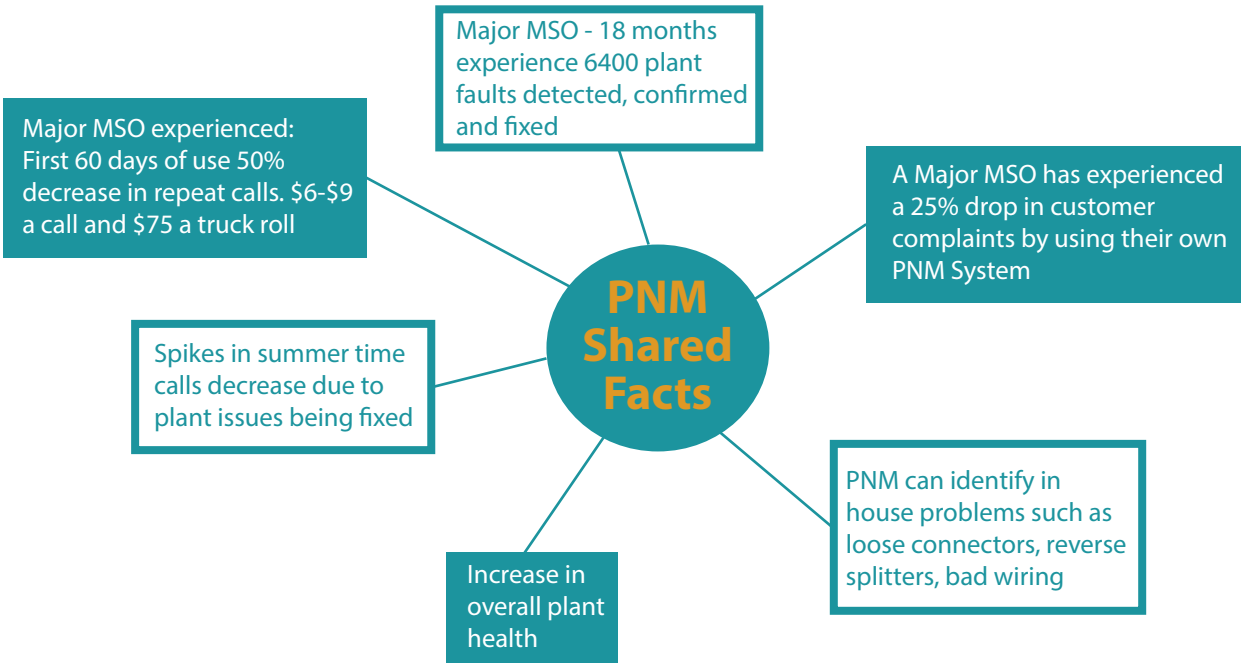
The remaining challenges in the near term include the development of installation and maintenance tools, and training for cable engineers and technical staff. Unlike with DOCSIS 3.0, DOCSIS 3.1 means that new cable modems will no longer operate at a fixed modulation. Some cable modems in a
service group could be using 1024 QAM, while others could be running on 4096 QAM. New tools must be able to identify which modulation profiles work best where and understand how to manage the modulation diversity.

Vendors designing new DOCSIS 3.1 test and measurement tools will need to develop all new algorithms to test entire channels while automatically identifying subcarriers that have MER, BER or ingress issues. But existing techniques are being modified to provide technicians with simple, intuitive test procedures that don't require a steep learning curve.

## Future Applications

Cable's flexibility gives it a vast amount of tools at its disposal without needing to invest in costly FTTH solutions any time soon. It might even be questioned whether cable will have to go all fiber at all. Even though FTTH is widely regarded as future-proof, thanks to DOCSIS 3.1 technology, cable will offer average customer broadband speeds of 10 Gbps in downstream and 1 Gbps in the upstream.

Capacity modeling, based on continued aggressive video and data growth scenarios, has shown that there is plenty of life left in HFC, and certainly more than ten years.




"We do not see a cliff emerging where operators will have no choice but to go to FTTP," suggests John Ulm, Engineering Fellow at Arris. In fact, he points out that FTTP is a complimentary aspect of a company's HFC portfolio.

"I think that cable will always have a choice. Cable operators will be competitive with the telcos for a long time and always have that advantage that they have a choice as opposed to being forced to go one way or another," agrees John Chapman, engineering fellow and CTO of Cisco System's Cable Access Business Unit.

## Conclusion

Cable is once again opening up its toolkit in order to fulfil requirements of future services and increasing demand for more capacity. The real key to getting the most out of PNM is to have a good understanding of what's in the toolkit, how it reduces capital and operational expenses and how it significantly improves the subscriber experience. With this knowledge a roadmap for implementation can be created and cable operators will stay ahead of the telco FTTH deployments for (at least) the next decade.

> **"Cable service providers, in addition to being able to provide richer experiences to their customers, will have an easier time maintaining their networks due to the Proactive Network Maintenance functionalities embedded into DOCSIS 3.1; thus being able to provide a more consistent and reliable experience to their customers"**
>
> *- Belal Hamzeh, Director of Broadband Evolution at CableLabs*

## Bibliography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## Abbreviations

BER..... Bit error ratio
CM..... Cable Modem
CMTS..... Cable modem termination system
DOCSIS..... Data over cable service interface specification
DS..... Downstream
FEC..... Foreward error correction
HFC..... Hybrid fiber coaxial
MER..... Modulation error ratio
(C)OFDM..... (Coded) orthagonal frequency division multiplex
QAM..... Quadrature amplitude modulation
RS..... Reed-Solomon
US..... Upstream

## Additional Resources

**Whitepaper:** Using the CMTS to Find Return Path Ingress in DOCSIS Cable Plants

**Whitepaper:** Correlation Groups and vTDR Using DOCSIS Proactive Network Maintenance (PNM)

**Webinar:** Remote Return Path Analysis

**For more information about PreEqualization Analyzer, ZCorum's DOCSIS PNM application, visit our website, or read the product sheet.**

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