



Creating Infinite
Possibilities.

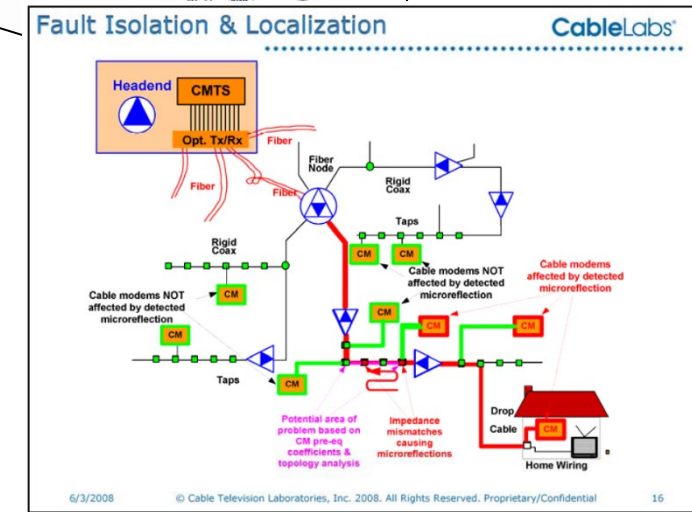
How Will Proactive Network Maintenance Change Under DOCSIS® 4.0?

Ron Hranac

rhranac@aol.com

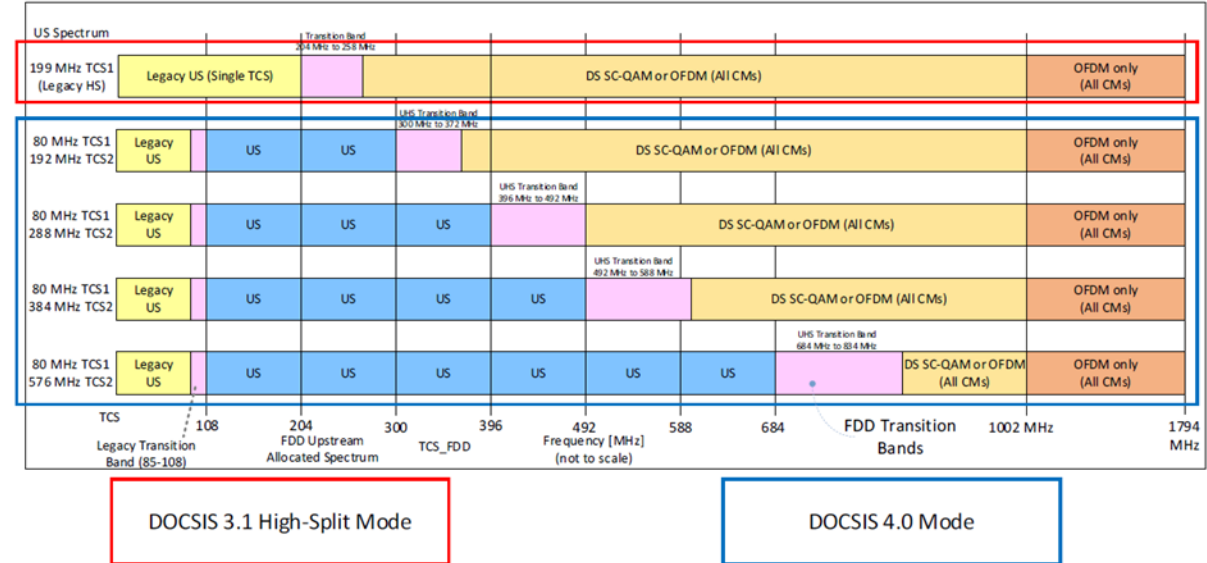
What is PNM?

- The concept of PNM was first proposed in a 2008 Cable-Tec Expo paper by CableLabs' Alberto Campos, Eduardo Cardona, and Lakshmi Raman.
 - The basic idea involved (1) deriving complex frequency response signatures from pre-equalization coefficients, (2) looking for responses indicative of the presence of linear distortions, and (3) overlaying CM location information from the cable company's customer database on a system topology display such as digitized outside plant maps.
- A PNM working group was formed to implement the 2008 paper's ideas, and the rest is history!
- Section 9 of the DOCSIS 3.1 Physical Layer Specifications includes PNM "hooks" and parameters.

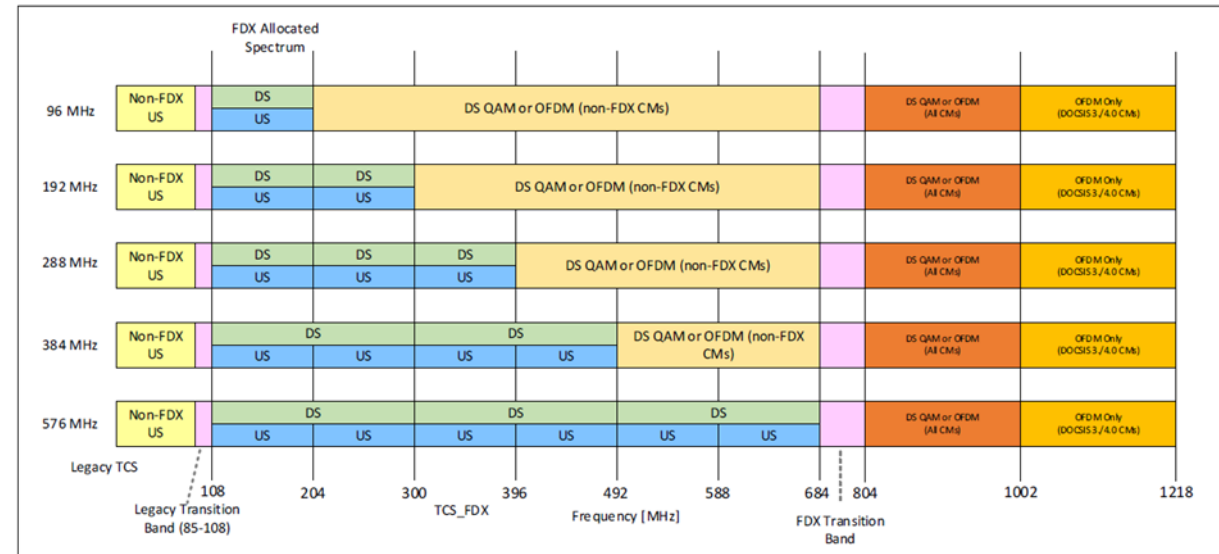


What is DOCSIS 4.0?

- DOCSIS 4.0 specifications, released in 2019, are the latest in the DOCSIS family.
- What's in the DOCSIS 4.0 specs?
 - **Frequency division duplex (FDD)** – sometimes called “extended spectrum DOCSIS” – supports legacy high-split and also provides extended splits up to 684 MHz, and expansion of usable downstream spectrum up to 1794 MHz (aka 1.8 GHz)
 - **Full duplex (FDX) DOCSIS** PHY layer technology to increase upstream capacity without significant loss of downstream capacity
 - **Support for PNM!**



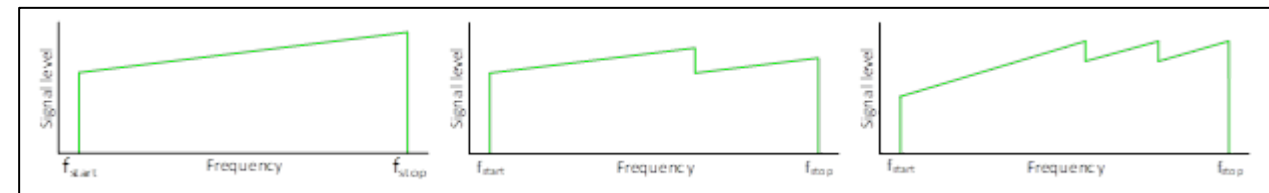
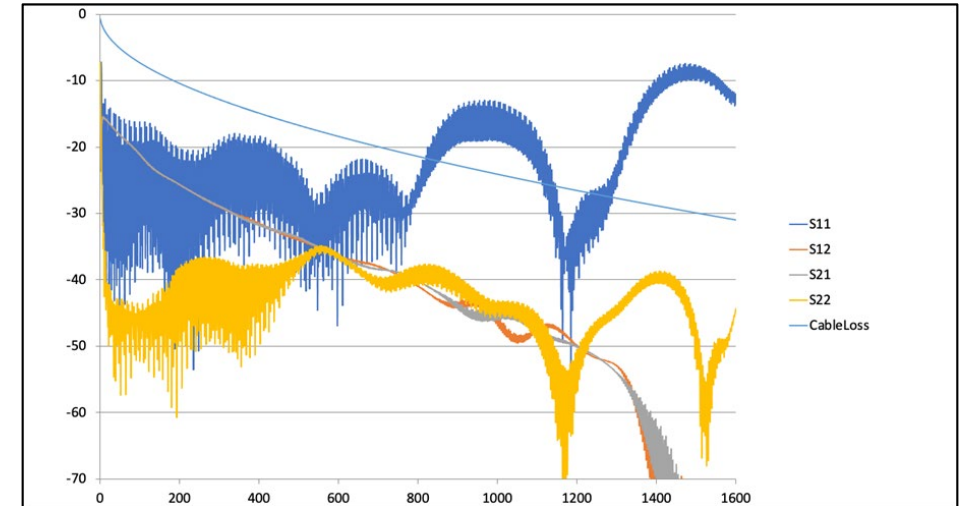
FDD frequency maps



FDX frequency maps

Plant Preparation and Transition Path

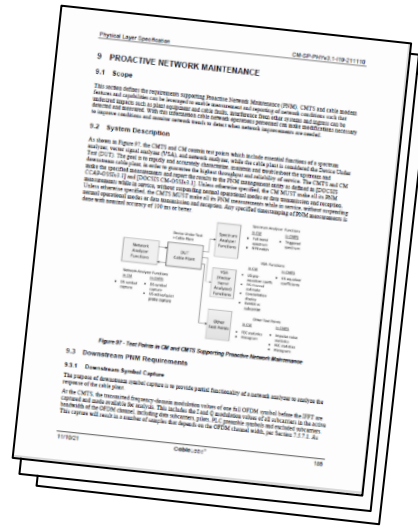
- The best PNM is that which happens when the network is being prepared for DOCSIS 4.0 technology, well before an impairment occurs.
- Potential gotchas
 - Legacy passives: performance at higher frequencies
 - Drops: Poor quality, passive intermodulation
 - Leakage and ingress at higher frequencies, ingress in FDX bands, leakage management in upstream spectrum that overlaps aeronautical bands (OUDP)
 - Total composite power
- Opportunities for PNM to shine!



How will PNM Change Under DOCSIS 4.0?

DOCSIS 3.1 PNM

- Section 9 in the DOCSIS 3.1 PHY specification comprises 11 pages of PNM measurements and tests.
- Several cable operators and third party vendors have developed DOCSIS 3.1-based PNM tools.



DOCSIS 4.0 PNM

- PNM will have to change to accommodate DOCSIS 4.0 operation.
 - More data: telemetry requirements will increase.
 - PNM features such as FBC will have to operate over the wider upstream and downstream frequency ranges supported by DOCSIS 4.0 technology.
- FDX does add some complexity to PNM.
- Smart amplifiers, FDX-capable amplifiers, echo cancellation, and other DOCSIS 4.0 features provide great opportunities to expand the PNM toolkit.

How will PNM Change Under DOCSIS 4.0?



Impact of FDD and FDX on DOCSIS 4.0 PNM Tests

| DOCSIS PNM Test | FDD Impact | FDX Impact |
|---------------------------------------|----------------------|---|
| DS Symbol Capture (CM and CCAP) | None | RBA configured for DS, testing required – investigation required |
| DsOfdmNoisePowerRatio (CCAP/Spectrum) | None | RBA for sub-band used on target DS – investigation required |
| Spectrum Analysis Full Band Capture | More bins, more data | Dual direction, more bins, more data, more complexity, filters in modems may differ by vendor – investigation required |
| CmDsOfdmChanEstimateCoef | None | Only possible when RBA for TG is set in DS direction, other dependencies involved |
| CmDsConstDispMeas | None | Uncertain. There may be an ability to capture I and Q values in two directions – investigation required |

Impact of FDD and FDX on DOCSIS 4.0 PNM Tests (cont'd)

| DOCSIS PNM Test | FDD Impact | FDX Impact |
|-----------------------|------------|---|
| ModulationOrderOffset | None | None expected |
| CmDsOfdmRxMer | None | None Expected |
| CmDsOfdmMerMargin | None | None Expected |
| CmDsOfdmFecSummary | None | Test runs for several minutes which may be impacted based on RBA scheduling – investigation required |
| CmDsHist | None | Undetermined what happens with this test when in FDX operation – investigation required |

Impact of FDD and FDX on DOCSIS 4.0 PNM Tests (cont'd)

| DOCSIS PNM Test | FDD Impact | FDX Impact |
|---------------------------------|------------|--|
| Upstream Histogram | None | Uncertain how to measure the FDX band from 108 MHz to 684 MHz and how to account for any co-channel interference and echo cancellation |
| Us Impulse Noise | None | Recommend that this test does not apply to the FDX band |
| Us OFDMA Active and Quiet Probe | None | Multiple issues to address such as configuring all RBAs for the TG and configuring active probes – investigation required |
| Us OFDMA Rx Power | None | None expected |

Impact of FDD and FDX on DOCSIS 4.0 PNM Tests (cont'd)

| DOCSIS PNM Test | FDD Impact | FDX Impact |
|-------------------------------|--------------------------------------|--|
| Us OFDMA RxMER per Subcarrier | None | If other transmission groups are operating in a DS direction, the RxMER values for the tested OFDMA channel could be lower – investigation required |
| Us Triggered Spectrum Capture | Wider spectrum, more bins, more data | Wider spectrum, more bins, more data, in addition, for SID filtering all TGs and channels must be sync'd to same TG to get a valid measurement |

Challenges

- ✓ Vendors of PNM tools must adapt some of the testing to accommodate FDD and FDX impacts, and the implementation of smart amplifiers that are added to the plant.
- ✓ Cable company operations and back-office teams have to deal with the increased amount of data coming from devices in the field.
- ✓ Scheduling of testing for FDX channels.
- ✓ Compliance of FDD- and FDX-capable CMTSs and CMs with the DOCSIS 4.0 specifications
- ✓ Interoperability among vendors' products (CMTSs, nodes, CMs, etc.) with both FDD and FDX
- ✓ Clearly defined FDD and FDX PNM test and query specifications from the standards and specifications development organizations
- ✓ Adoption of FDD and FDX PNM test and query DOCSIS specifications by vendors
- ✓ Standards and specifications development groups exploring further the usage of FDX sounding data for PNM testing; the addition of test capabilities in smart amplifiers and other plant equipment is an area ripe for study and requirements creation that will likely see more activity as more FDX plant and modems become available.

Challenges

In order to address the challenges identified on the previous slide, the following groups will need to collaborate, as has historically been done in specifications development:

- ✓ Chipset vendors
- ✓ CMTS vendors
- ✓ CM vendors
- ✓ PNM tool vendors
- ✓ Standards and specifications development organizations
- ✓ Cable operators

Conclusions

Call to action

- DOCSIS 4.0 PNM tools and applications must work over the wider frequency ranges stated in the specification
- DOCSIS 4.0 PNM tools and applications must work with FDD and FDX technology
- Operators and vendors must work together to define priorities
- This is our path to deploying the 10G Platform, supporting higher speeds, improved reliability, security, and lower latency





Creating Infinite Possibilities.

Thank You!

Ron Hranac

rhranac@aol.com

A sincere thanks to the coauthors of the paper and presentation material:

- Jason Rupe, Ph.D., CableLabs
- Dan Torbet, CommScope
- Brady Volpe, The Volpe Firm