



Creating Infinite  
Possibilities.

# HFC Spectrum Efficiency and Quality Systematically Evolving Networks using PMA

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## Introduction

- During the Coronavirus pandemic, the surge of broadband bandwidth utilization grew 16% for downstream (DS) consumption while upstream (US) grew by 33%.
- The hybrid fiber-coaxial (HFC) network is complex. Every plant is unique and requires customization to address individual plant conditions.
- Techniques used to evaluate plant conditions.
- Techniques used to optimize PMA engine.
- Network initiatives requiring plant upgrades such as high-split and DOCSIS 4.0 are underway.
- PMA will defer the high cost of plant upgrades and improve capacity.
- How Charter's Autonomia is used to remediate them.

## Analyzing plant conditions

### Analyzing plant conditions

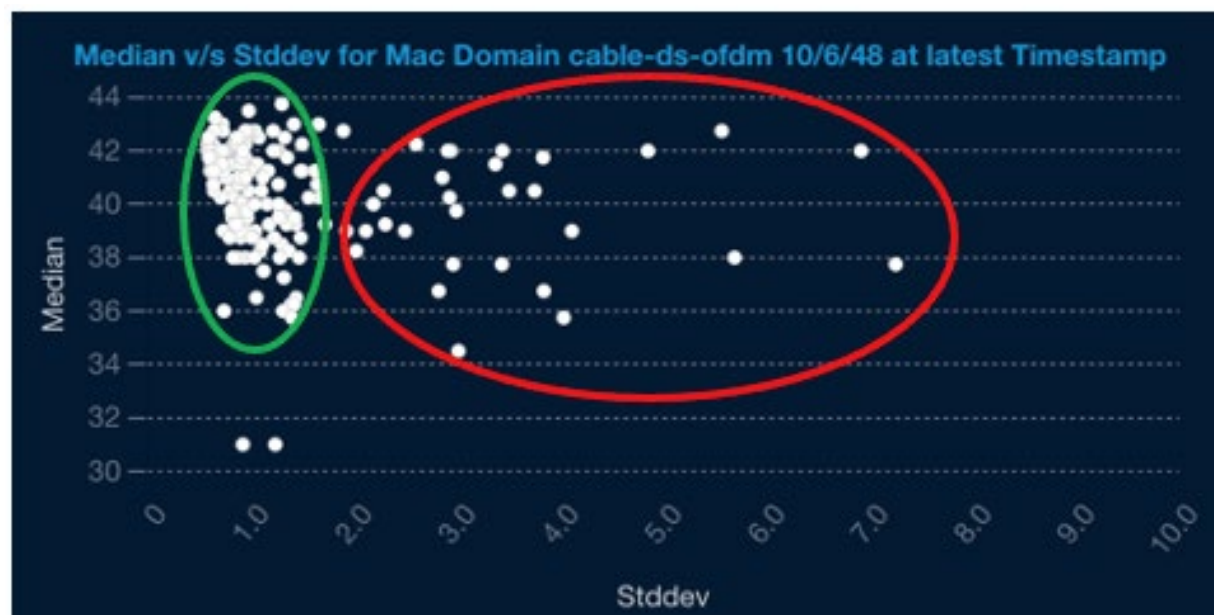


Figure 1 – Med Var plot of Mac Domain A

OFDM channel operating at ~680 – 772 MHz

- Telemetry data determines the state of the network and provides information that's not easily detectable. Subscribers may not be aware of network impairments. However, the network operator must be aware of impairments to:
  - Fix issues.
  - Ensure a quality experience.
  - Meet subscriber expectations.
- Proactive Network Management (PNM) data contains critical telemetry information for cable operators to proactively manage and mitigate plant issues.
- Receive modulation error ratio (RxMER) data provides the status of a subscriber's home network and describes the condition of a service group.

## Analyzing plant conditions

### Observations

Standard Deviation	Potential Cable Modem profile behavior
<1.0 dB	RxMER stable, cable modems (CMs) lock on the highest-profile the signal quality supports.
1.0 – 3.0 dB	Moderately-inconsistent RxMER values run across the channel. Cable modems may not lock on the highest profiles.
3.0 – 5.0 dB	Highly-inconsistent RxMER values run across the channel. Cable modems may not lock onto more than one profile.
> 5.0 dB	Extremely-high, inconsistent values run across the channel. Cable modems can't lock onto more than one profile and may be in partial service.

Table 2. Signal quality across OFDM channel

## Analyzing plant conditions

### We need dynamic bit modulation profile solution

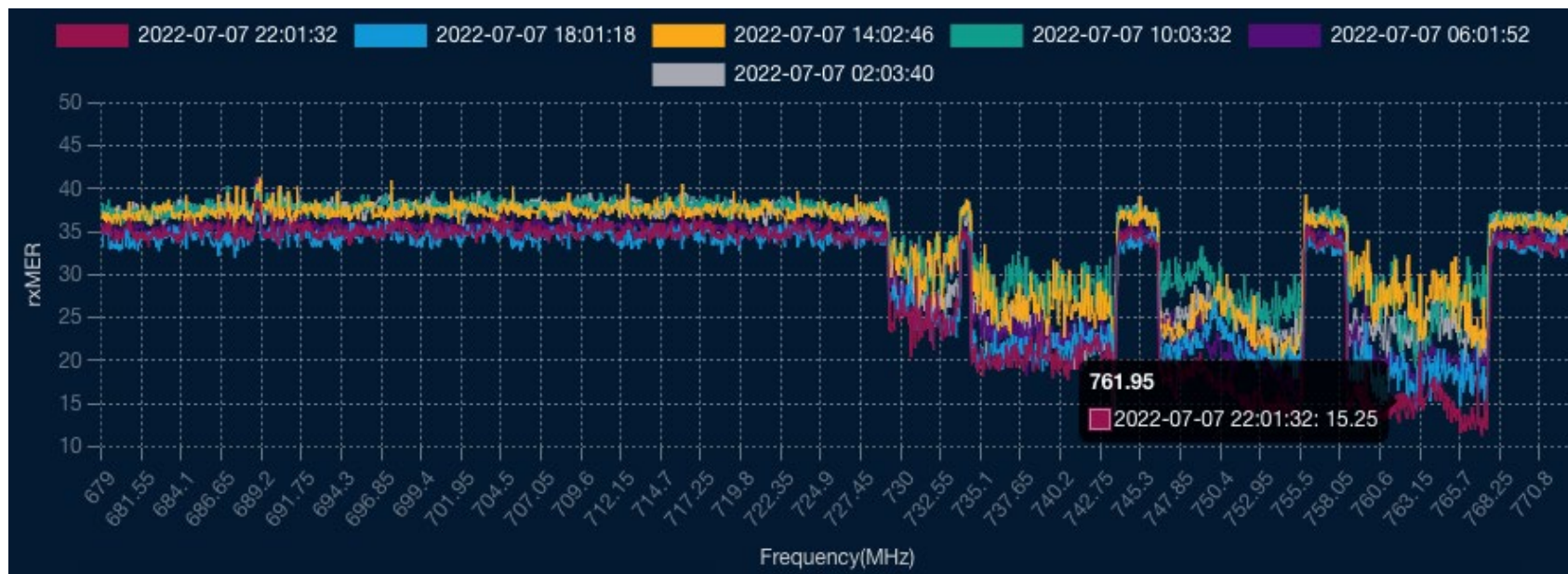


Figure 6  
A day in the life of an OFDM impaired cable modem.

- Dynamic profile solution is needed to take modems out of partial service and provide higher bit rates for modems.
- The number of CMs with impaired OFDM channels is 2% to 5%.
- The number of CMs operating on lower modulation schemes can increase by 20% during the day.

## Profile Management Application

- Automation programs that change the configuration of the CMTS multiple times a day should be vetted to ensure a minimal negative impact on the network.
- Low density parity check (LDPC) is highly effective in error correction. RxMER thresholds can be 5dB to 6dB below the specification in Table 1.
- Using RxMER readings and profile posture of a field device, triggering forward error correction (FEC) to optimize RxMER to QAM Level Mapping.

Constellation/Bit Loading	CNR/MER(dB)
16 QAM	15.0 dB
64 QAM	21.0 dB
128 QAM	24.0 dB
256 QAM	27.0 dB
512 QAM	30.5 dB
1024 QAM	34.0 dB
2048 QAM	37.0 dB
4096 QAM	41.0 dB
8192 QAM	46.0 dB
16384 QAM	52.0 dB

Table 1. DS RxMER to QAM Level Mapping – Cable Labs

## Profile Management Application

- Maximize the gain on profiles by running as optimal as LDPC can handle.
- Conservative RxMER to QAM Level Mapping can lead to loss of capacity in plants with relatively clean conditions.
- Overly aggressive Level Mapping leads to profile flipping.

### Example Cable Modem.

- Median RxMER of 35.75 dB with a standard deviation of 1.43 dB.
- Profile changes from 12 to 10-bit flat profiles during the day and vice versa in the early morning hours.

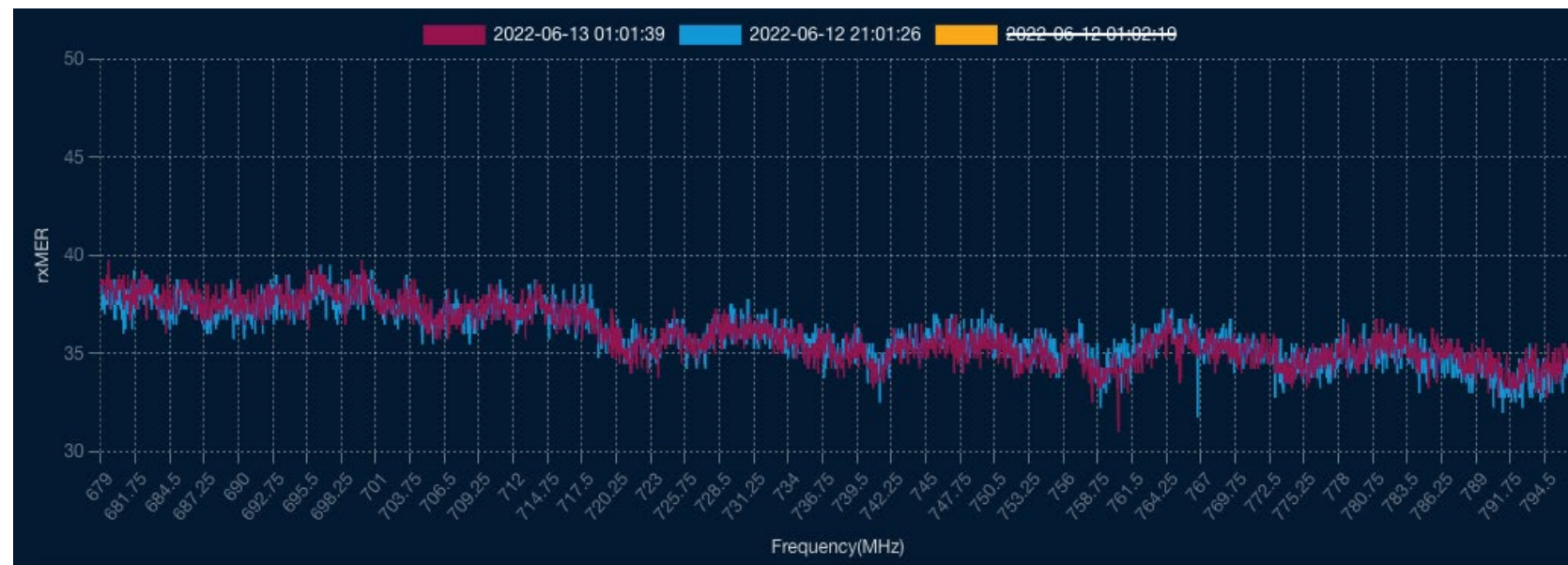


Figure 6 – CM Exhibit 1

## Profile Management Application

### Determining gains and losses

- PMA-generated profiles increased speed and capacity for impaired modems and modems running on lower fixed-modulation profiles.
- The best speed gains would be to take partial service modems out of partial service, recovering the OFDM channel.

\*\* Flat Profiles 0 = 6 bits, 1 = 8 bits, 2 = 10 bits, 3 = 12 bits

\*\* PMA Profiles 0 = 6.26 bits, 1 = 10.76 bits, 2 = 10.38 bits, 3 = 7.63 bits

Cable Modems	Non-impaired Flat		Impaired Flat		Impaired PMA	
	Profiles**	Speed	Profiles **	Speed	Profiles ***	Speed
CM1	0,1,2,3	907	0,1,(2),(3)	665	0,1,2,3	836
CM2	0,1,2,3	907	(CH)0,1,2,3	175	0,(1),(2),3	665
CM3	0,1,2,3	907	0,1,(2),(3)	665	0,1,2,3	836
CM4	0,1,2,3	907	(CH)0,1,2,3	175	0,(1),(2),3	665
CM5	0,1,2,3	907	0,1,(2),(3)	665	0,1,2,3	836
CM6	0,1,2,3	907	0,1,(2),(3)	665	0,(1),2,3	811
CM7	0,1,2,3	907	0,1,(2),(3)	665	0,(1),2,3	811
CM8	0,1,2,3	907	0,1,(2),(3)	665	0,(1),2,3	811
CM9	0,1,2,3	907	(CH)0,1,2,3	175	0,(1),(2),3	665
CM10	0,1,2,3	907	0,1,(2),(3)	665	0,(1),2,3	811
CM 11	0,1,2,3	907	0,1,(2),(3)	665	0,1,2,3	836
CM 12	0,1,2,3	907	0,1,(2),(3)	665	0,1,2,3	836

Table 2. DS RxMER to QAM Level Mapping – Cable Labs

## Profile Management Application

### Potential gain from a live port

Cable Modems (206 Total)					
Flat Profile Configuration		Non FEC PMA Profile Configuration		FEC PMA Configuration	
Bit Load (bits per hertz)	# CM	Bit Load (bits per hertz)	# CM	Bit Load (bits per hertz)	# CM
12	182 (88.3%)	10.4	182 (88.3 %)	12	182 (88.3%)
10	14 (6.7%)	10.0	2 (0.9%)	11.6	8 (3.8%)
8	5 (2.4%)	7.8	18 (8.7%)	10.4	10. (4.8%)
		5.5	4 (1.9 %)	7.1	6 (2.9%)
0	5 (2.4%)	0	0	0	0

Table 3. Potential Gain/Loss comparison using profiles with non-FEC and FEC adjustments

- The PMA can remove CMs from an impaired OFDM state.
- FEC is needed in the PMA engine to ensure CMs adopt the highest bit loads.

## High-split Rolloff

### Initial Feedback

- Deploying new technology in cable plants is challenging and requires a natural progression as cable networks evolve.
- Figure 7 illustrates challenges to a high split network with OFDM on 1.0 GHz to 1.2 GHz.
- Setup five amplifier cascades, with 32 passive taps (1.0 GHz), with 20 devices on five taps.
- The most salient pattern is three distinct clusters seen in Figure 7.

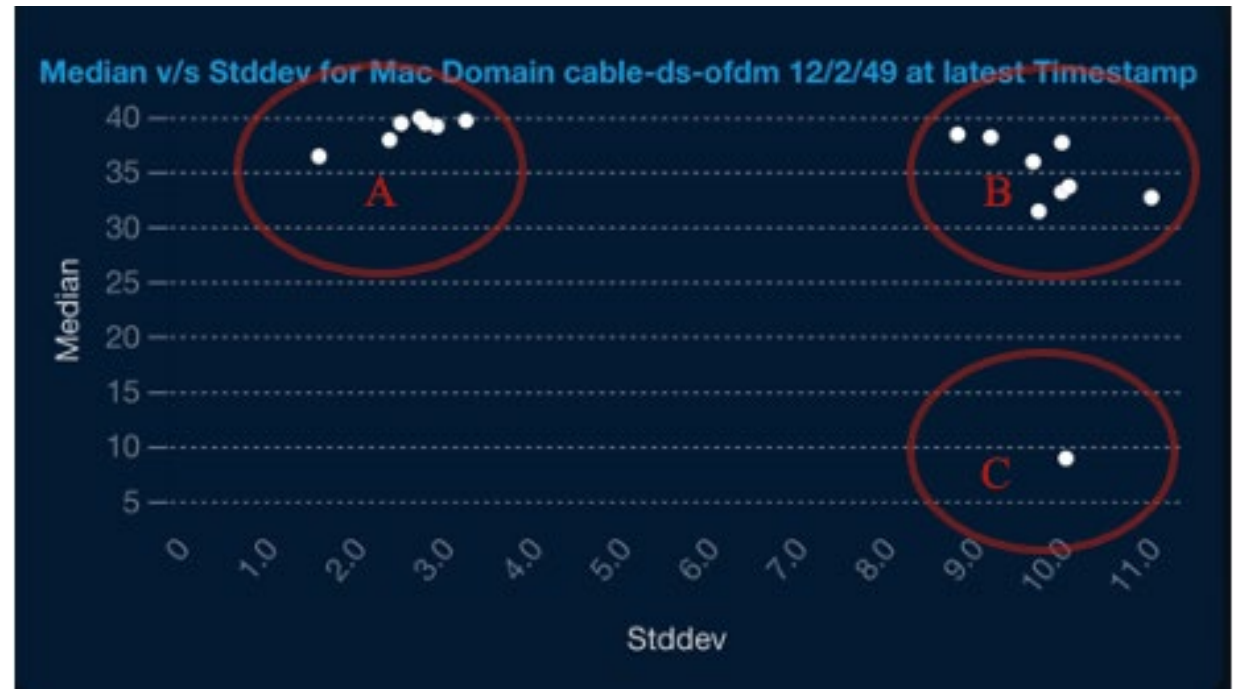


Figure 7 – 1.0GHz to 1.2 GHz Spectrum

## High-split Roll-off

Utilizing OFDM channel on a high -split deployment

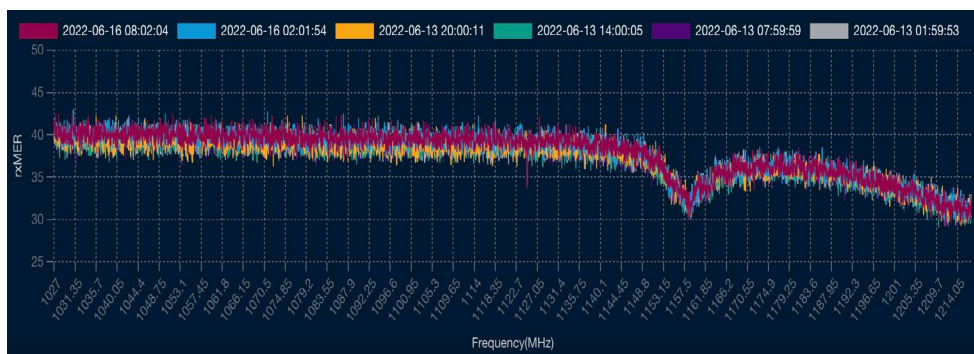


Figure 8 – (Lab) Sample CM from Cluster A

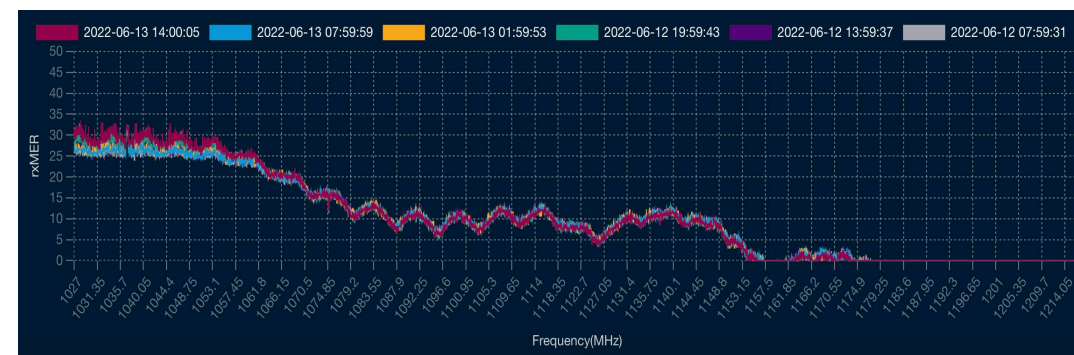


Figure 10 – (Lab) Sample CM from Cluster C

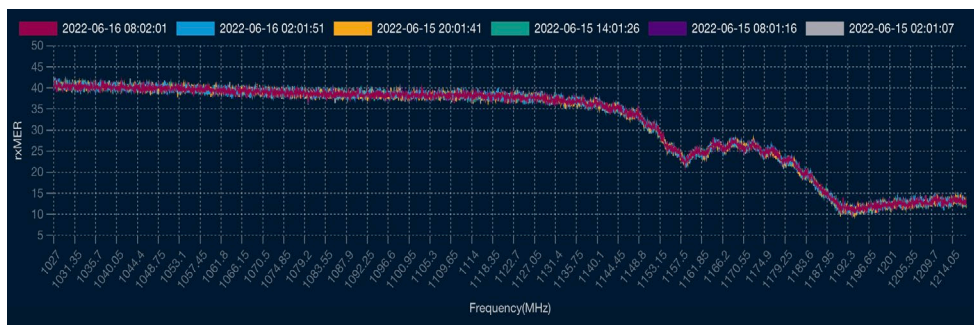


Figure 9 – (Lab) Sample CM from Cluster B

- Flat profiles don't work where the roll-off region renders higher parts of the spectrum unusable for most cable modems.
- PMA profiles must operate at 1.0 GHz to 1.2 GHz to adjust for the roll-off region.
- Operators can incrementally upgrade plant components such as taps using PMA profiles.

## High-split Roll-off

### Utilizing OFDM channel on a high -split deployment

- Replacement of taps in the plant is required to mitigate the roll-off region entirely for an OFDM channel running on 1.0 GHz to 1.2 GHz.
- Use PMA to defer initial costs of plant upgrades.
- Using telemetry to systematically upgrade the cable plant by deferring upgrades on the most efficient sections of the plant.
- Reduce the cost of deployment and simultaneously boost capacity until upgrades are necessary.

## Autonoma Platform

- Data has become prominent in architecting modern networks.
- Autonoma Platform focuses on Data Ops, by building fast and reliable data pipelines, feeding Model Ops, by turning data into action.
- It's not practical to use traditional simple network management protocol (SNMP) or command-line interface (CLI) methodologies to acquire data.
- A cost is associated with supplementing and accommodating polling capability for D4.0 network, from a D3.1 network.
- It's impossible to control multi-data-polling agents, polling disparate management information bases (MIBs) at disparate frequencies during various times of the day.

## Autonoma Platform

### Data Ops

- Alternatives to polling methods like push-based data acquisition are becoming more relevant as real-time data becomes more critical.
- Two classes of network data:
  - **Bulk data** – Telemetry data collected at predefined frequencies from all devices on the network.
  - **Real-time polling** – Data collected from devices, on an ad hoc basis, that identifies the devices' condition at a particular moment.

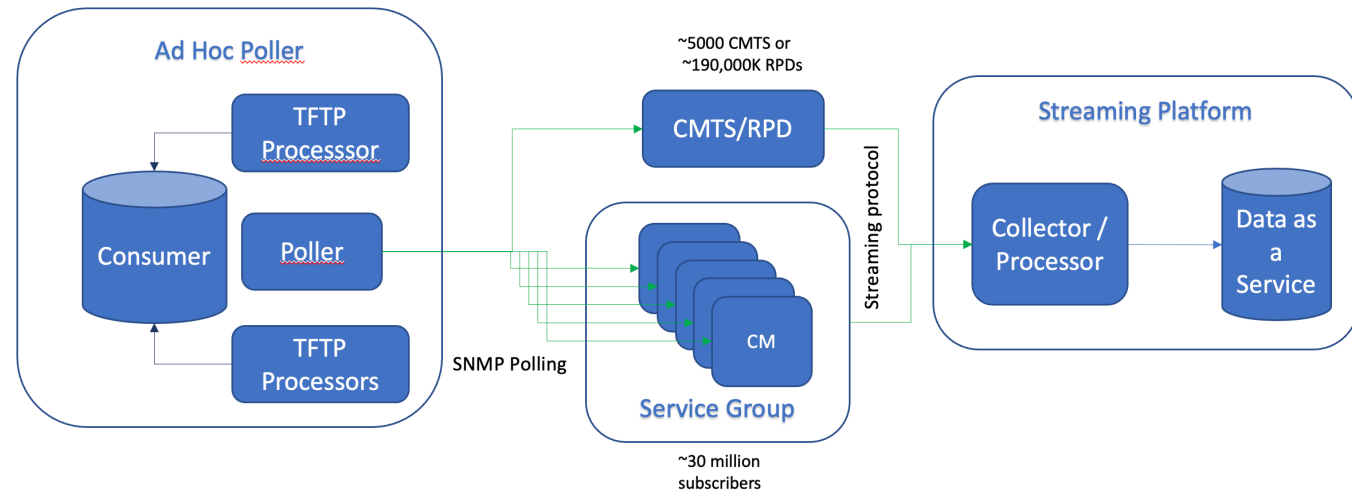


Figure 12 – Modern Streaming Telemetry Data Architecture

## Autonoma Platform

### Model Ops

Signal-to-noise ratio, is one of the most helpful signals for diagnosing the condition of individual modems on the Charter network.

We can determine the quality of the signal subscribers receive, including a range of potential impairments that can impact service experience, by analyzing the data level, shape, and spread. Impairment Types include -

- **Amplitude Ripple**: Caused by improper network alignment, micro-reflections, or missing end-of-line terminators.
- **Suckout**: Caused by unterminated cable, smashed cable, or repeating divets.
- **LTE Ingress**: Caused by signal leakage (the passage of an outside signal into a coax cable), which can be remediated using Exclusion Bands.
- **Rolloff**: A result of improper balancing, bad amplifiers, or exceeding amplifier specification.
- **Standing Wave**: Can be used to determine the distance to a fault and is the initial premise behind PNM.

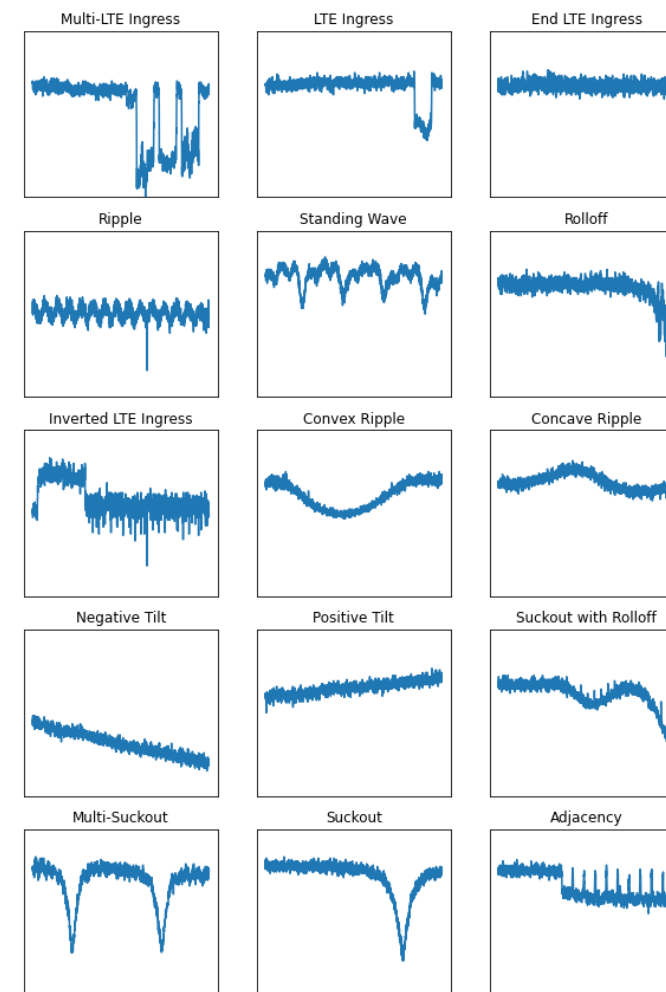


Figure 13 – Example impairment classes

## Autonoma Platform

### Model Ops

- Impairments can help identify potential network faults with known solutions.
- Using the data patterns, we can score and rank-order potential candidates to resolve issues in the field.
- The challenge is these patterns aren't self-evident, and manually reviewing the available data can be difficult and time-consuming.
- Using ML, we can monitor data signals 24x7x365, automatically identifying and classifying various impairment types.
- We can also detect if several modems are displaying the same impairment—a clear indication of an outside plant (OSP) issue—to isolate the impact in homes versus OSPs using clustering and nearest-neighbor modeling.

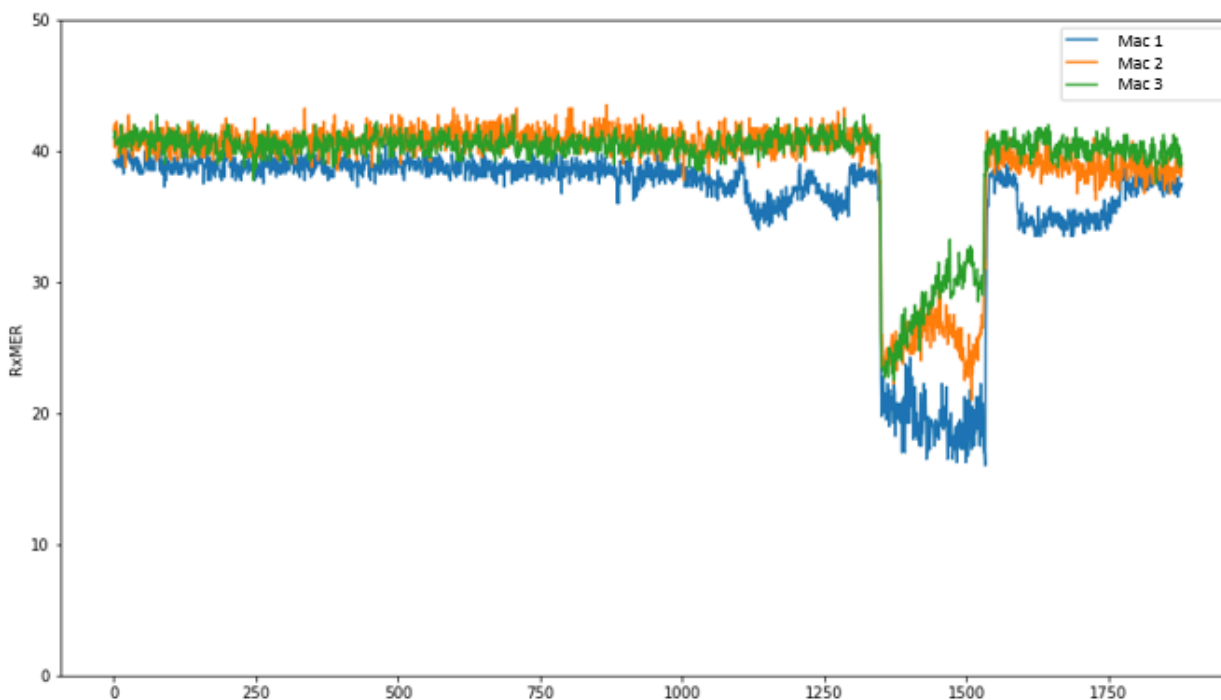


Figure 14 – Clustering and nearest neighbor modelling

## Conclusion

- Every plant is unique and requires customization to address individual plant conditions.
- Software solutions (such as PMA), are cost-effective ways to troubleshoot and address impairment issues in the plant.
- When using PMA, adjustments to the RxMER and QAM level mappings, using FEC is important to:
  - Not lose capacity and maximum capacity gain on the plant, while maintaining or improving customer experience.
  - Remove cable modems from partial service.
- PMA can be used to systematically enable 1.0 GHz – 1.2 GHz spectrum, and systematically defer the costs of plant upgrades.
- Evolution of a modern network requires machine learning.
  - Classification of impairments can identify potential network faults.
  - Use clustering techniques such as nearest neighbor to determine fault locality.



# Creating Infinite Possibilities.

## Thank You!

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