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Time is Ripe for D3.0 Farming: Achieving Optimal Spectral Efficiency by Allocating D3.0 Spectrum to OFDM

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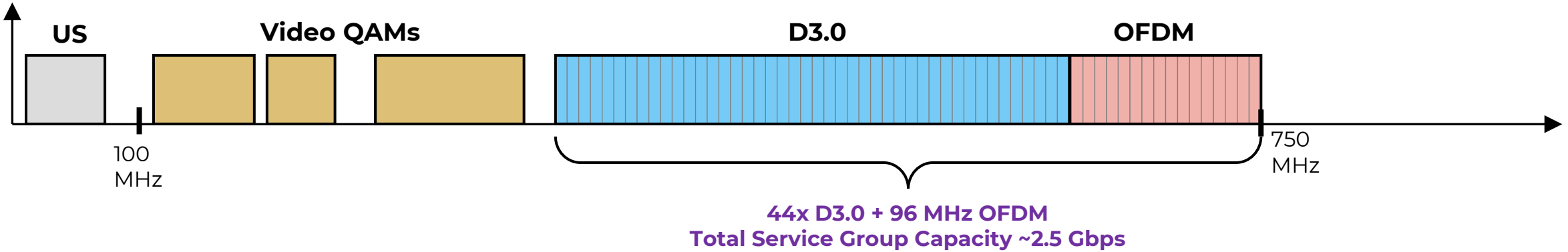
Outline

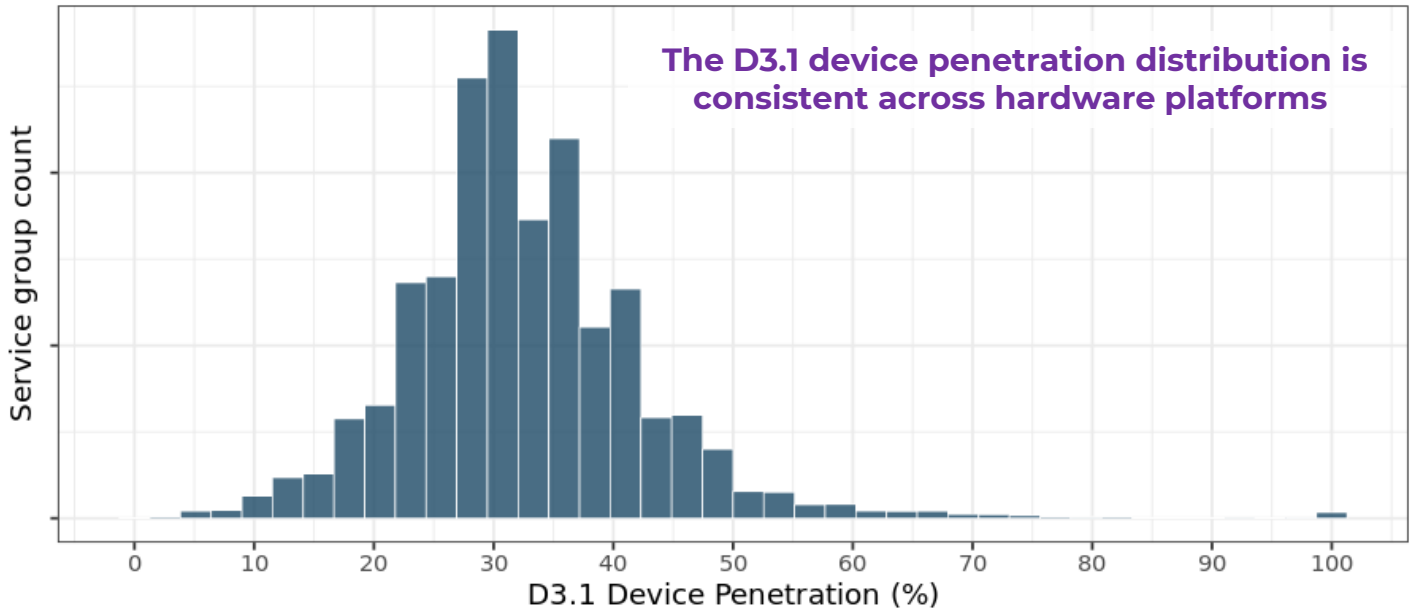
1. Motivation
2. How Downstream Spectrum is Utilized
3. D3.0 Spectrum Farming Approaches
4. View of the State of the Spectrum
5. 2G Speed Testing
6. Concluding Remarks

Illustrative Spectrum Allocation in 750 MHz Plant



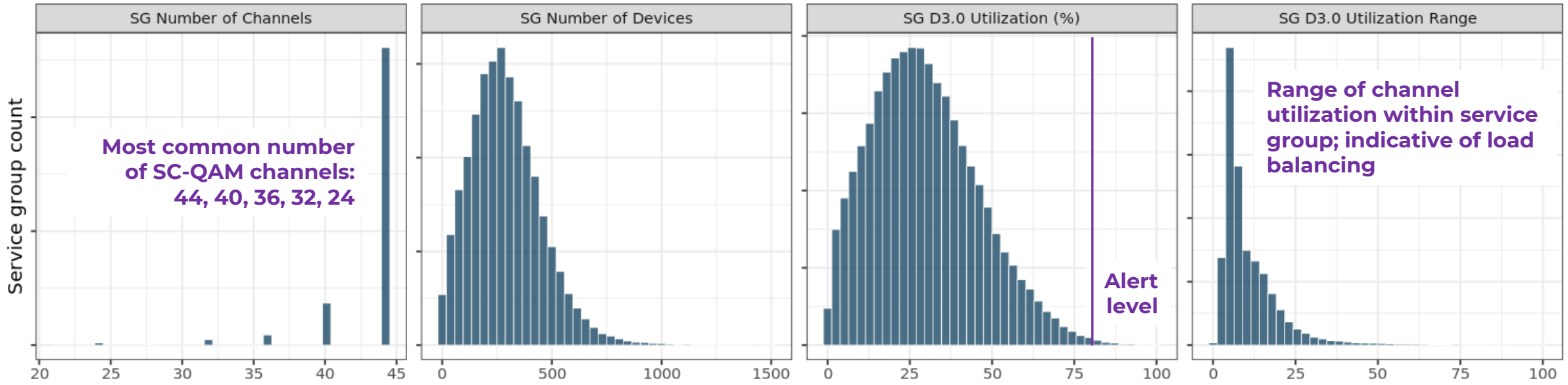
- Optimizing spectrum allocation serves multiple purposes:
  1. Increase service group capacity to support higher speed offerings
  2. Manage the D3.0 and OFDM balance to avoid congestion in either
- There's an inherent trade-off:
  - OFDM is more efficient, but significant portion of the device population is D3.0
  - Adding service group capacity by spectrum relocation may increase D3.0 utilization

DOCSIS 3.1 Device Penetration



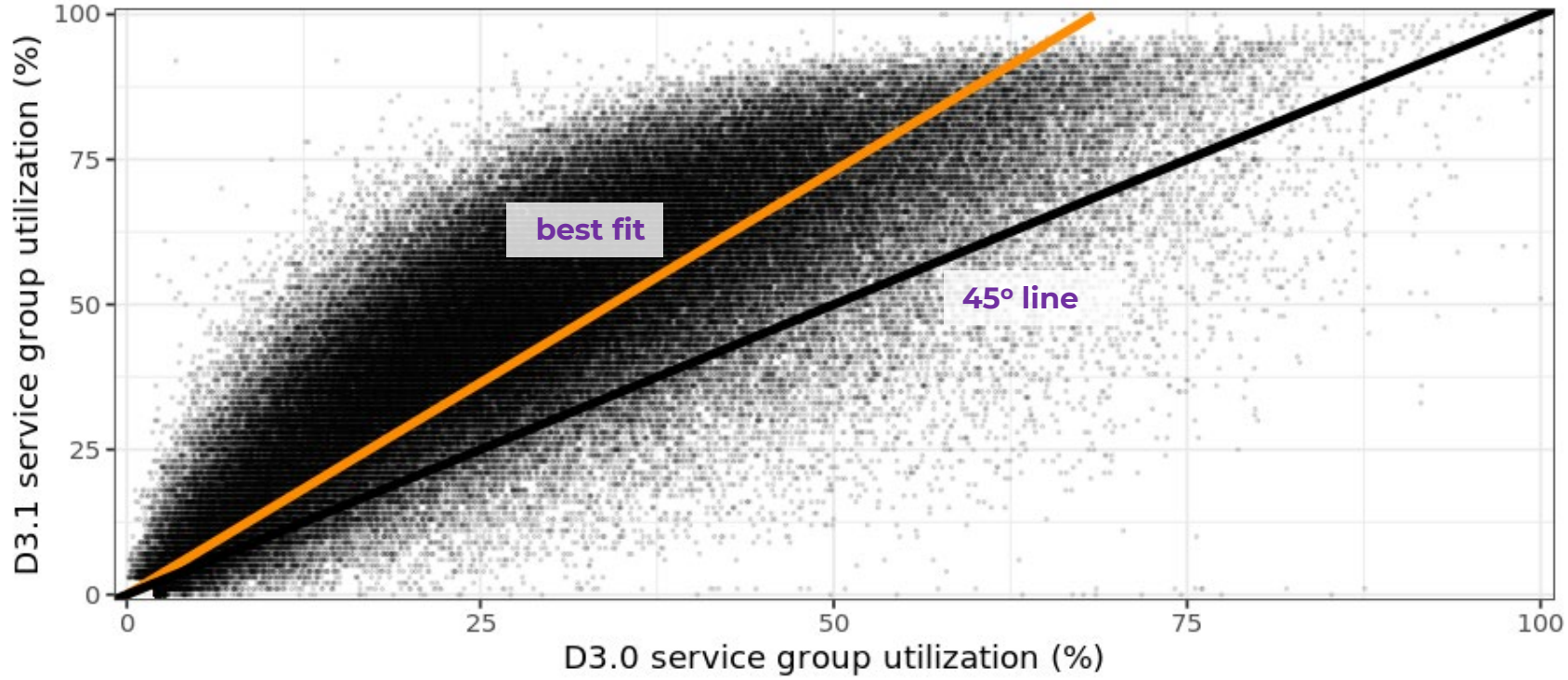
- D3.1 device penetration varies by service group
- With the penetration continuing to grow organically, rethinking the spectrum allocation between D3.0 and OFDM is due

Distributions of Interest



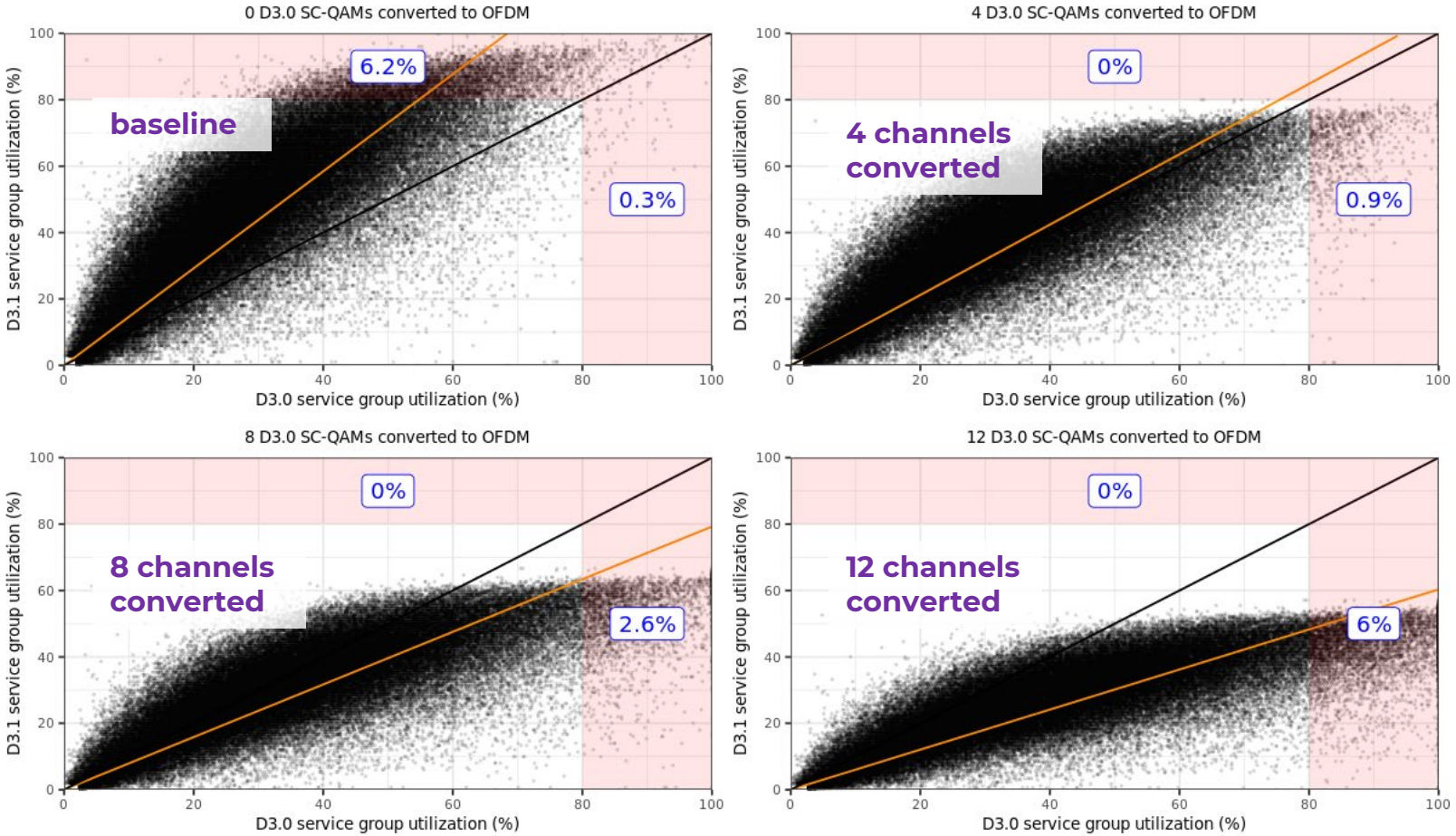
- Service group utilization is calculated as the 98th percentile of 30-day period sampled at 5-min resolution
- Very few service groups have high (>80%) utilization (<1% in the tail)
- Data suggests that the D3.0 spectrum is under-utilized

Joint D3.0 and OFDM Utilization Distribution



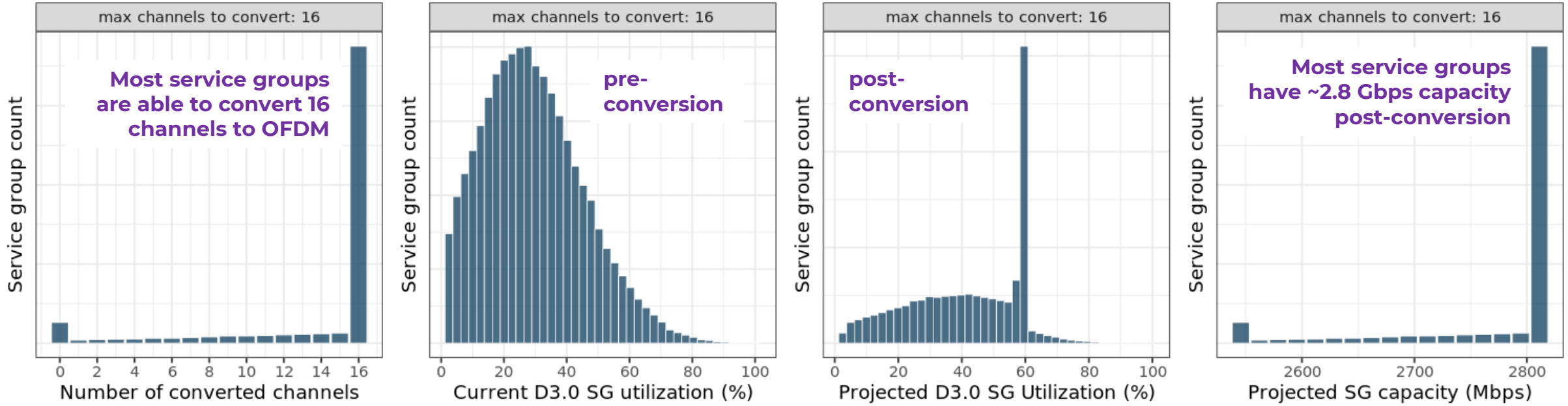
- Heavily used service groups are driven largely by the OFDM component of the utilization
- The joint distribution will continue to rotate counterclockwise as the D3.1 device penetration grows organically

Farming the Same Number of Channels Across Network



- As number of SC-QAM channels allocated to OFDM increases, the joint distribution rotates clockwise
- At 4 channels, heavily used service groups are reduced significantly while ~66 Mbps of capacity is added to each service group
- At 12 channels, heavily used service groups are at the same current level but driven by D3.0 spectrum while ~200 Mbps of capacity is added to each service group

Farming Custom Number of Channels per Service Group



- Under this approach, we require that projected service group utilization does not exceed 60% post reallocation of D3.0 spectrum to OFDM
- We also require that a service group should maintain at least 24 SC-QAM channels
- Analysis shows that most service groups are able to yield 16 SC-QAM channels

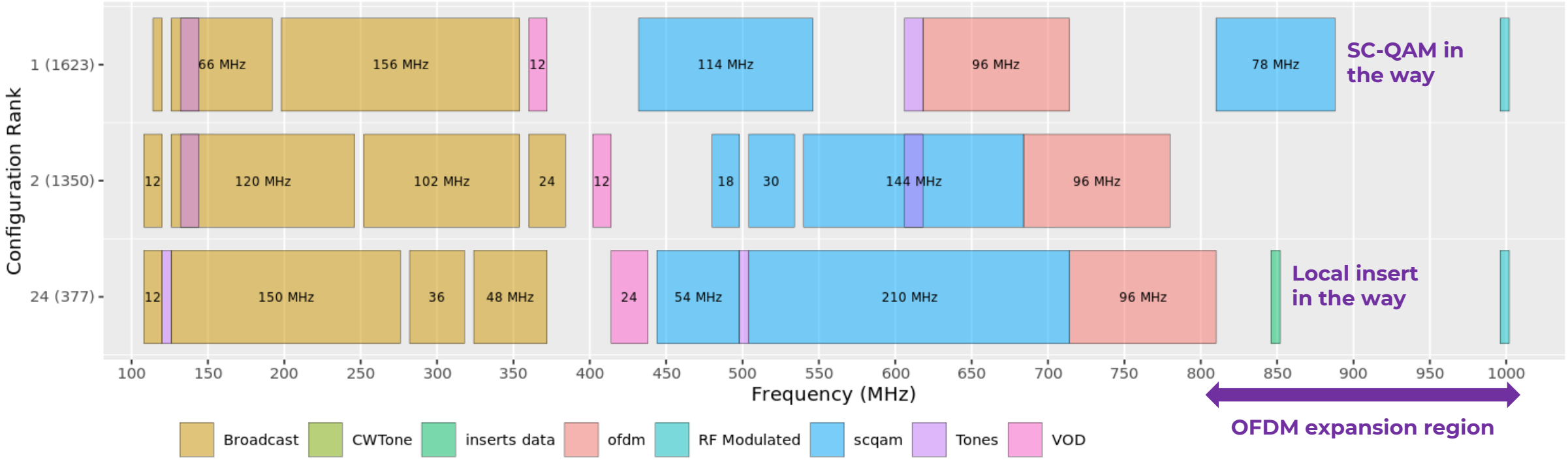
The Motivation for Developing an Automation Tool

1. Optimizing capacity in HFC network segments with limited spectrum by converting D3.0 channels to OFDM
   - Performed on a per service group basis
   - Dynamic in nature; considers service group utilization, D3.1 device penetration, speed offerings

2. Freeing up contiguous chunks of spectrum to deploy OFDM where plant configuration allows it; i.e., a “housekeeping” exercise

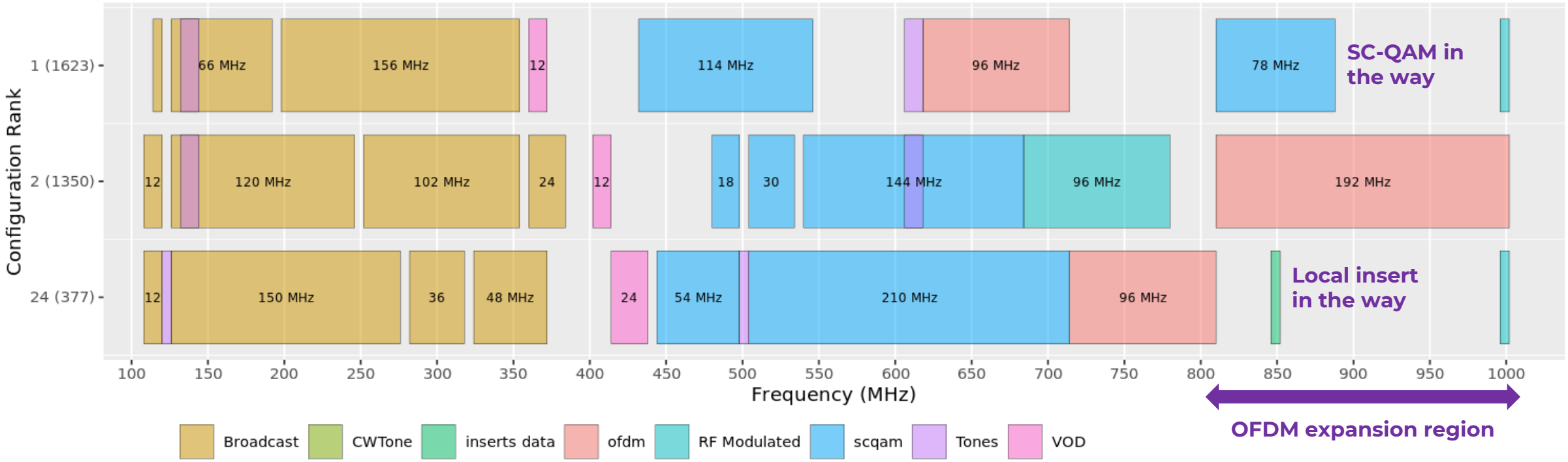
3. Relocating specific channels in order to move towards a steady state with a few standardized configurations across the network
   - Simplifies day-to-day operations
   - Supports deployment of future technologies (e.g., FDX, high split)

Example of Common Downstream Configurations



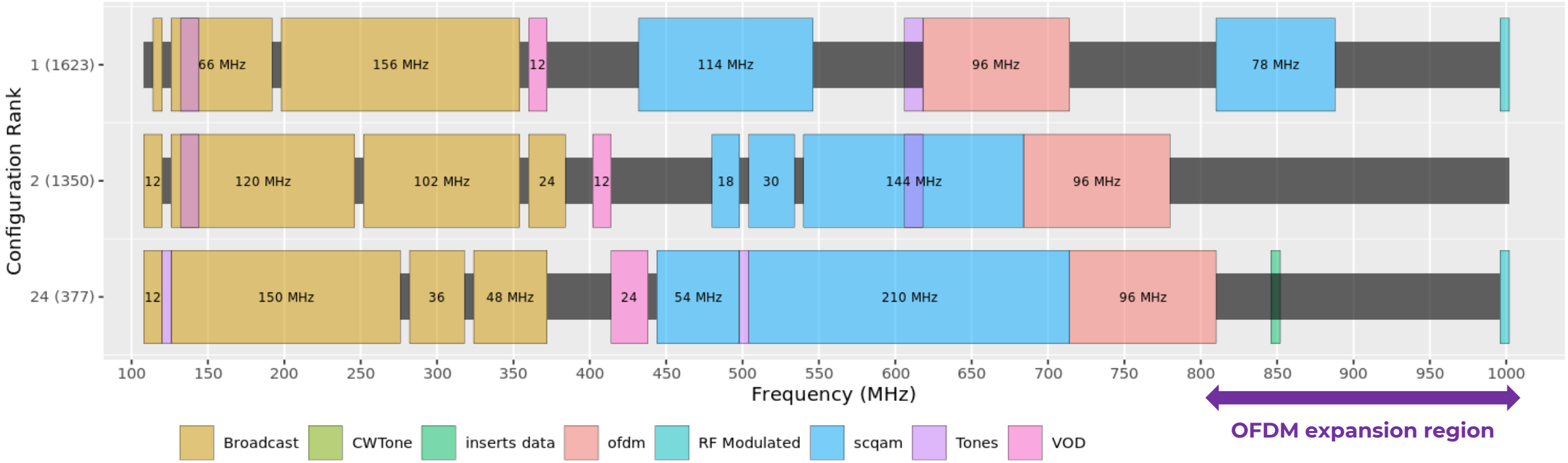
- Examples of common configurations reveal that the configuration vary across plant
- Current uses occupying the 810-1002 MHz region present a challenge for OFDM expansion

OFDM Channel Expansion & Relocation to 810-1002 MHz



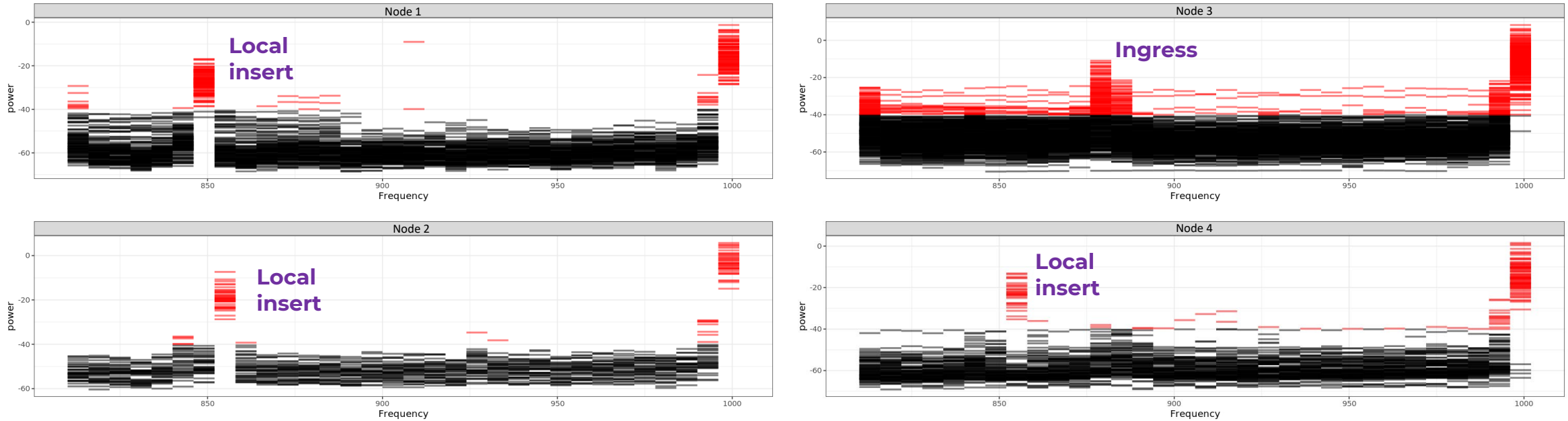
- The middle configuration is able to accommodate positioning of the OFDM channel in the 810-1002 MHz range of the spectrum
- The bottom configuration requires validating the local insert at 855 MHz

Validating the Configuration against Full Band Spectrum



- The validation is based on inferring spectral occupancy from device full band capture
- Statistics of the power at the suspected channel are used to trace the insert to specific nodes

Example of Nodes that Show Local Insert Signature



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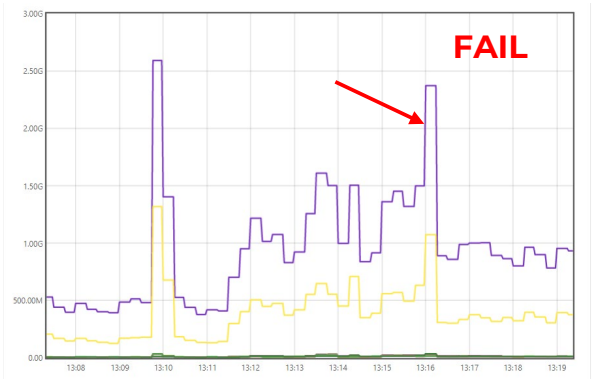
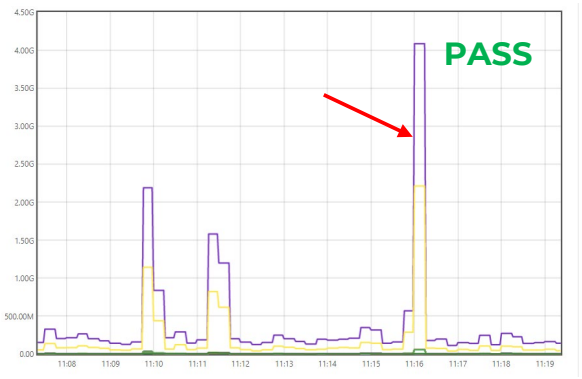
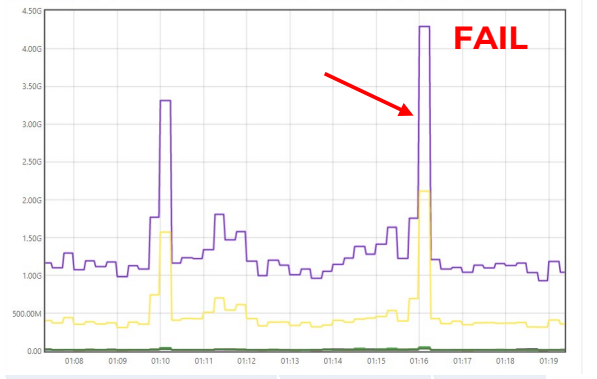
Speed Test Results



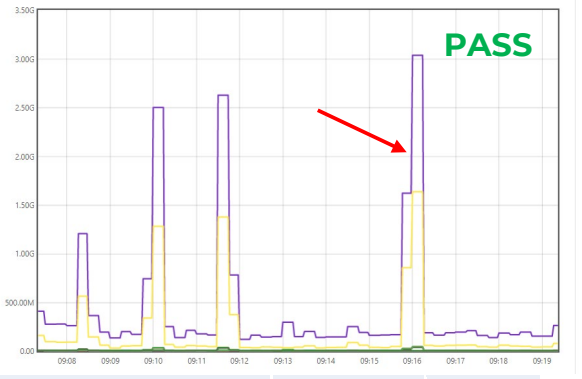
2022-05-18T13:15 857333.6 kbps



2022-05-18T11:15 1995333.4 kbps



2022-05-18T01:15 1742566.1 kbps



2022-05-18T09:15 2082374.1 kbps

- Experimented with lab setup in which 192 MHz OFDM channel is configured alongside 24/44 SC-QAMs
- Cable modem can reach ~2.4 Gbps throughput with absence of RF noise and low utilization on service group
- However, speed test outcome is sensitive to the baseline traffic on service group, as shown in the graphs
- This highlights the importance of further increasing the service group capacity by farming D3.0 spectrum and/or adding a second OFDM channel

Concluding Remarks

- The growth in D3.1 device penetration has now reached a level where reconsidering how downstream spectrum is allocated between D3.0 and OFDM is a must
- The objective is twofold: increase service group capacity to enable higher speed offering and provide relief to a currently highly utilized OFDM spectrum
- To this end, two approaches were presented: a one-size fits all farming of D3.0 channels, vs. a customized recommendation that considers service group characteristics
- The latter, due to its dynamic nature, requires building a spectrum management tool; a cornerstone of such a tool is building a unified source of truth for current state of the spectrum configuration
- Such a tool also feeds into additional spectrum housekeeping efforts that are targeted towards freeing up space for expanded OFDM region in support of enabling 2 Gbps downstream speeds

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Thank You!

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