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Operational Transformation

How Network Topology Impacts RF Performance: A Study Powered By Graph Representation Of The Access Network

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2021 Fall Technical Forum
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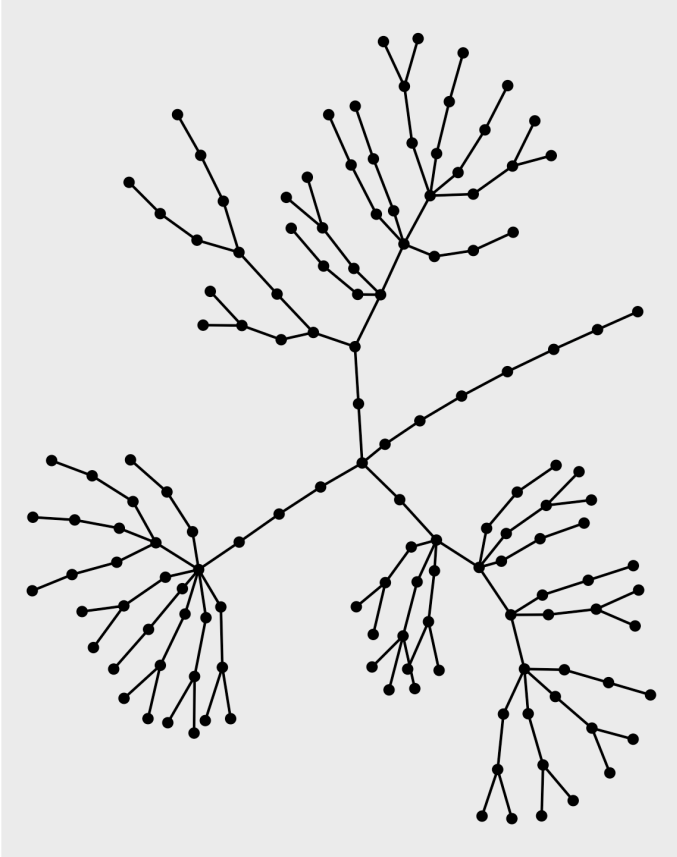
Overview

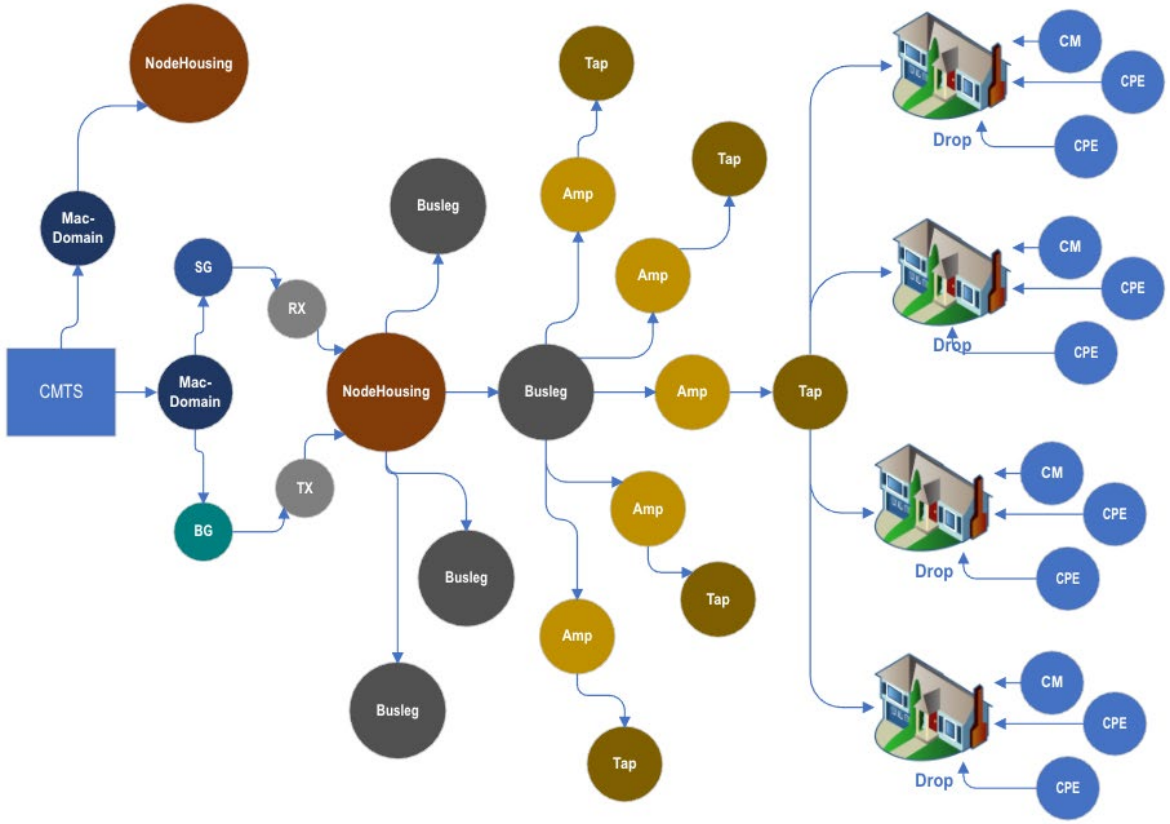
1. Graph Representation of the Access Network
2. Visualization Examples
3. Relationship between Amplifier Cascade Length and SNR
4. Conclusions

Graph Representation of the Access Network

- A graph encompassing vertices and edges is naturally suited to represent the Access Network
- The graph includes all building blocks of the Access Network, their properties, and the relationships between them
- Both physical and logical elements are mapped within the graph
- The graph database reconciles data from different scattered data sources and serves as a single source of truth
- Paths traversed by the graph are the CMTS-to-CPE (downstream) and CPE-to-CMTS (upstream), including everything in between



Example of Mapped Elements



- Data schema defines elements and their properties
- Certain properties are common to all elements (e.g. every physical element has a latitude/longitude coordinates)
- Some elements are logical (service group, bonding group, billing address)
- Algorithms developed for associating physical address drops with billing accounts

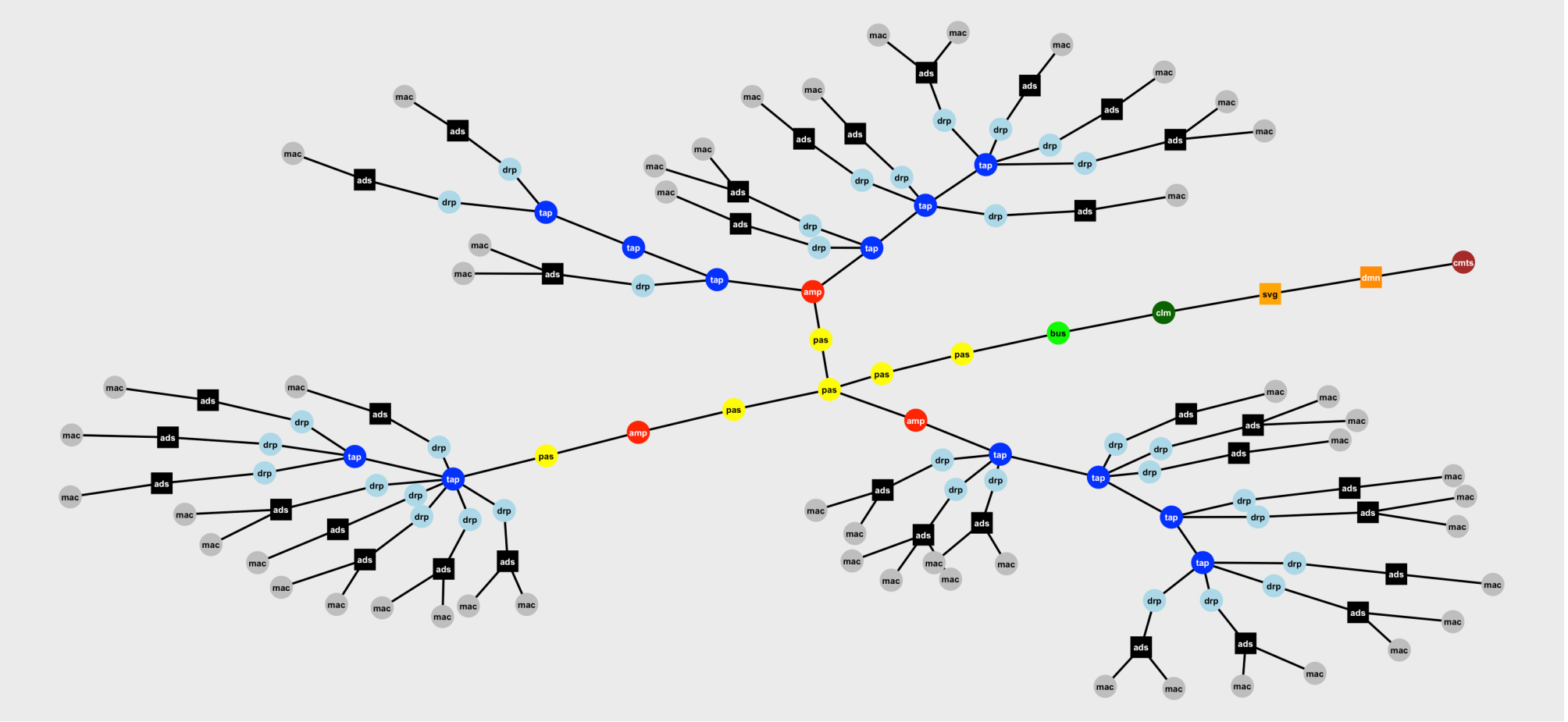
The Technology Platform

- Cloud-based solution for the construction and maintenance of the graph database
- The graph scales up to the size of Comcast's network (currently, ~20% of the network is fully mapped)
- The graph topology runs ~40 layers deep, yet it can be traversed in ~minutes for the entire Comcast network
- Querying the database is performed with Gremlin—an Apache graph traversal language

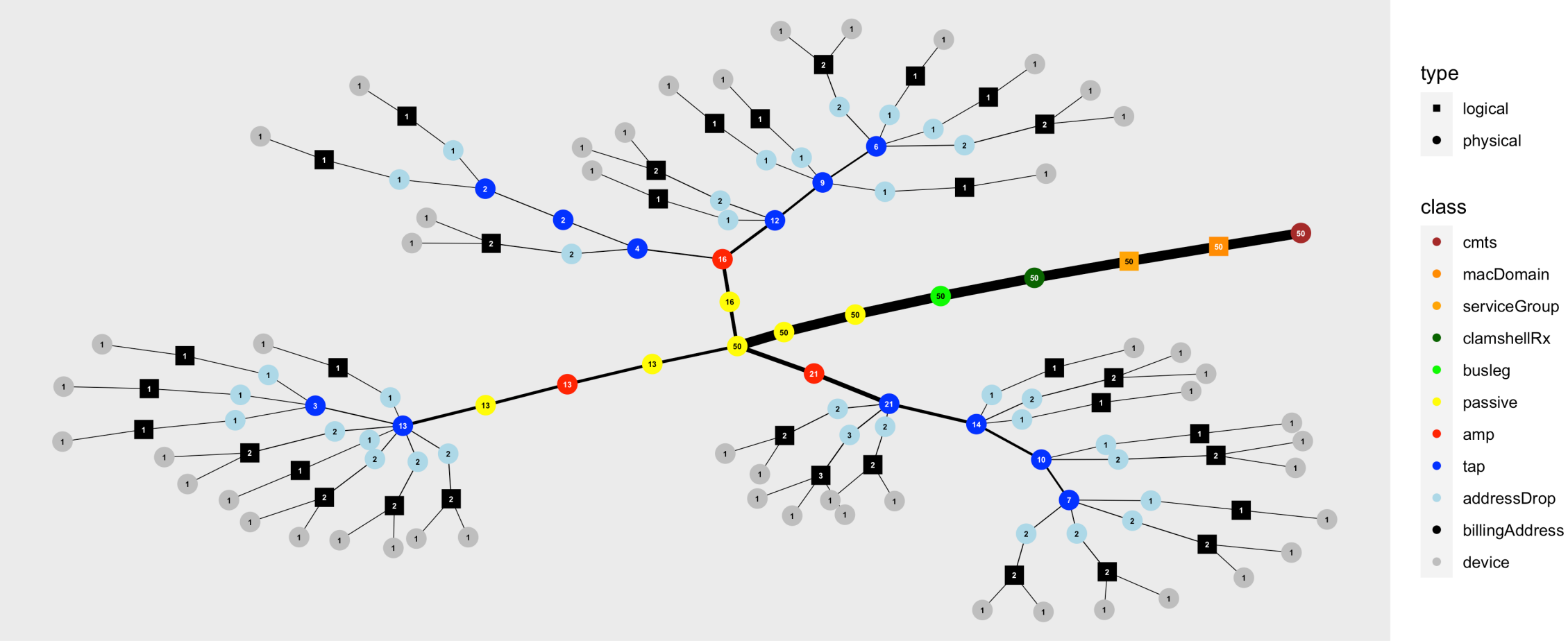
```
%%gremlin

g.V('acr01.wynkooplab.co.denver.comcast.net')
          .repeat(out('DS').simplePath())
          .until(hasLabel('device'))
          .path()
          .by(valueMap('className', 'id'))
```

Example of retrieving all paths from a given CMTS to every CPE underneath

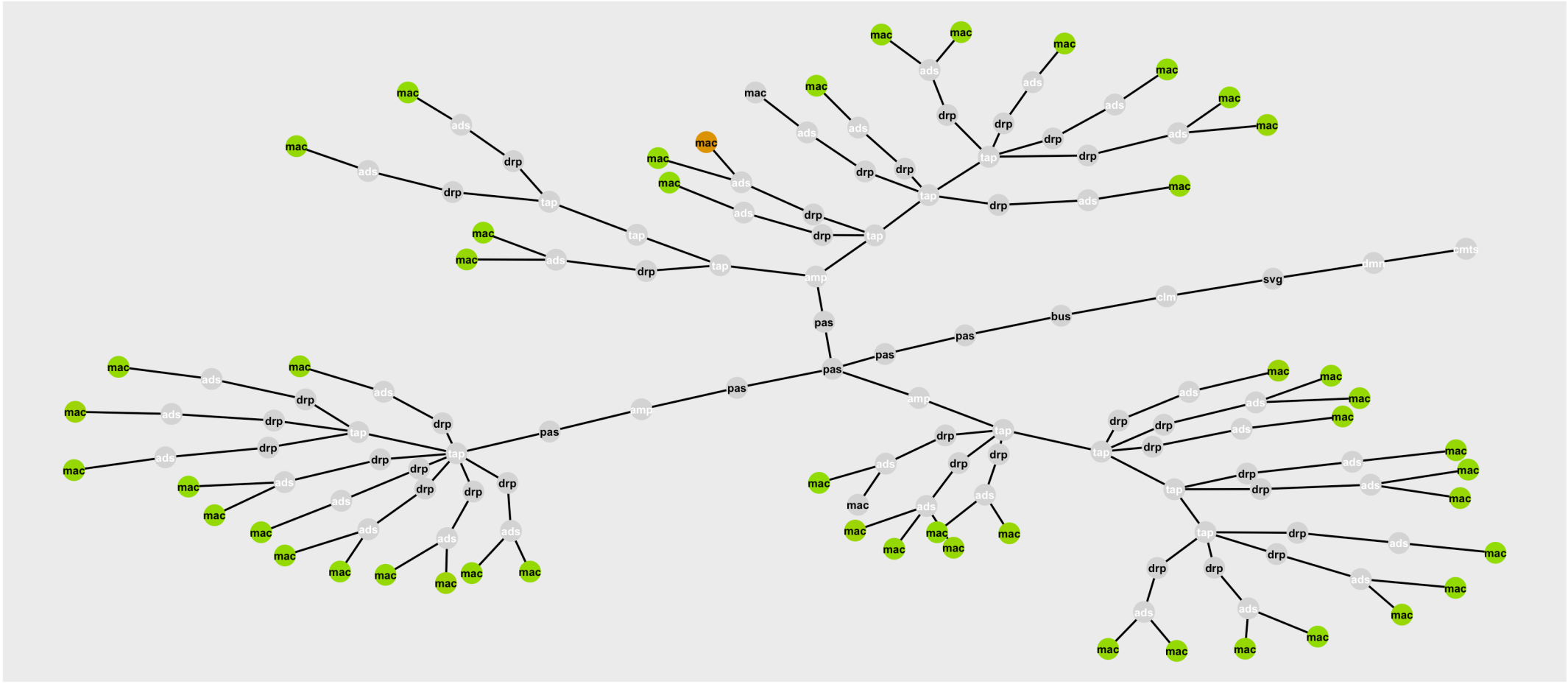
Example of a Mapped Node: Basic View



Example of a Mapped Node: Traffic Highlight



Example of a Mapped Node: Telemetry Highlight

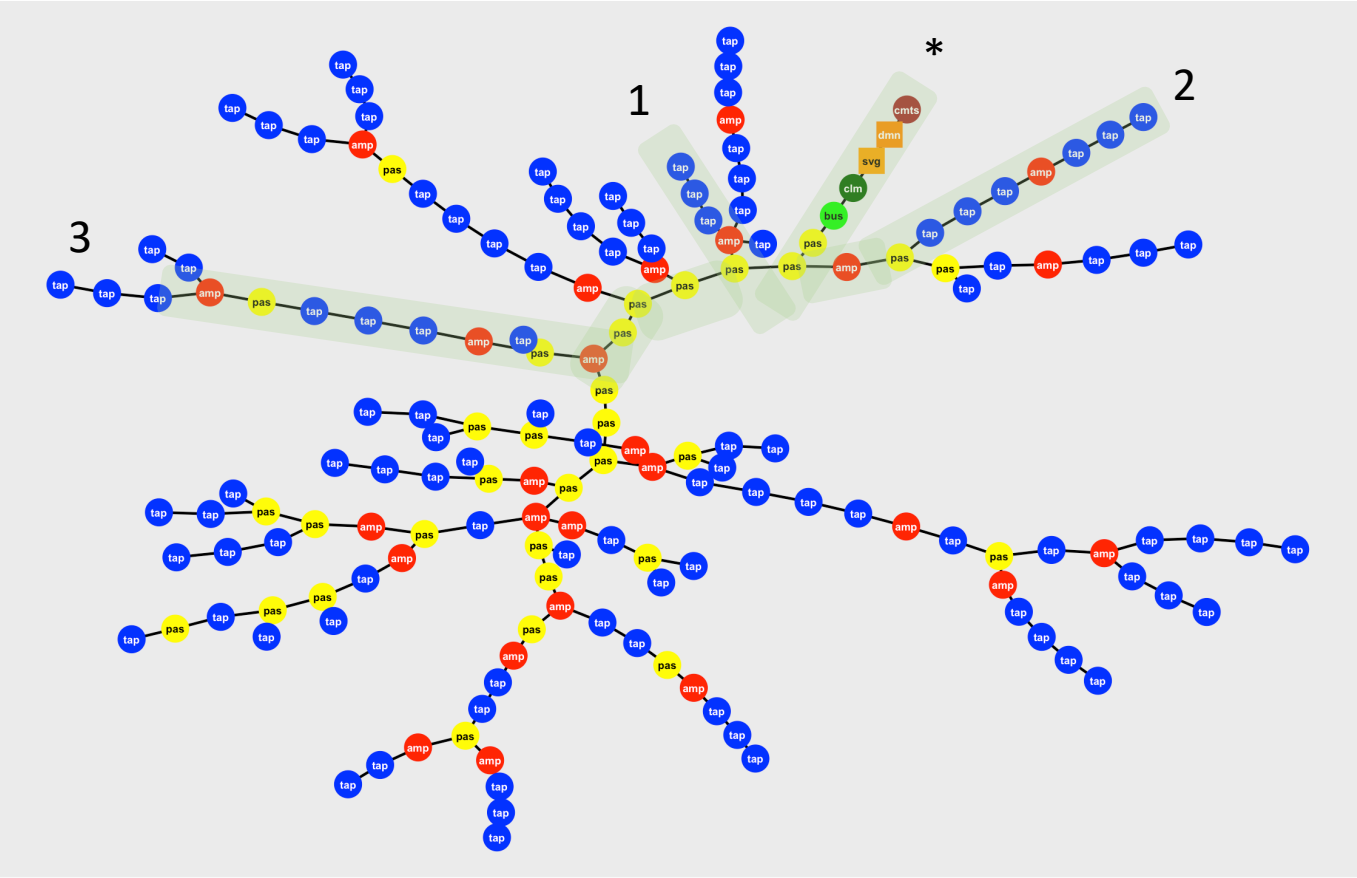


Use case: Impact of Amplifier Cascade on RF Performance

- **Big Question**: Amplifiers introduce distortions, but do they cause 'measurable' impact on customer experience?

- Analysis:
  - Graph database allows extracting node features related to amplifier cascades in the access network
  - When crossed with device telemetry, correlations between node features and telemetry can be highlighted
  - Strong correlations are further explored through the appropriate statistical model

Features Related to RF Amplifiers



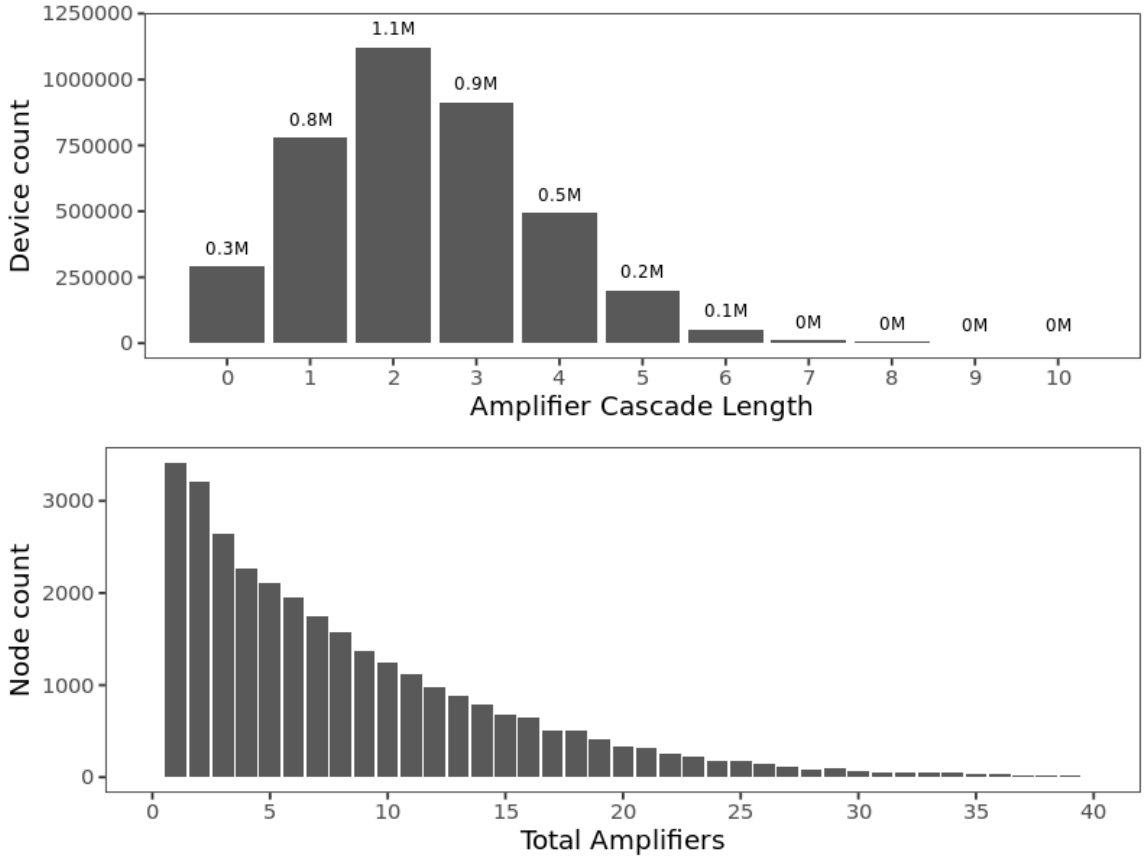
class
- cmts
- macDomain
- serviceGroup
- clamshellRx
- busleg
- passive
- amp
- tap

type
- logical
- physical

Features

- Total number of amplifiers per node
- Amplifier cascade length = number of amplifiers traversed in a CMTS-to-CPE path

Distribution of Amplifier-based Features



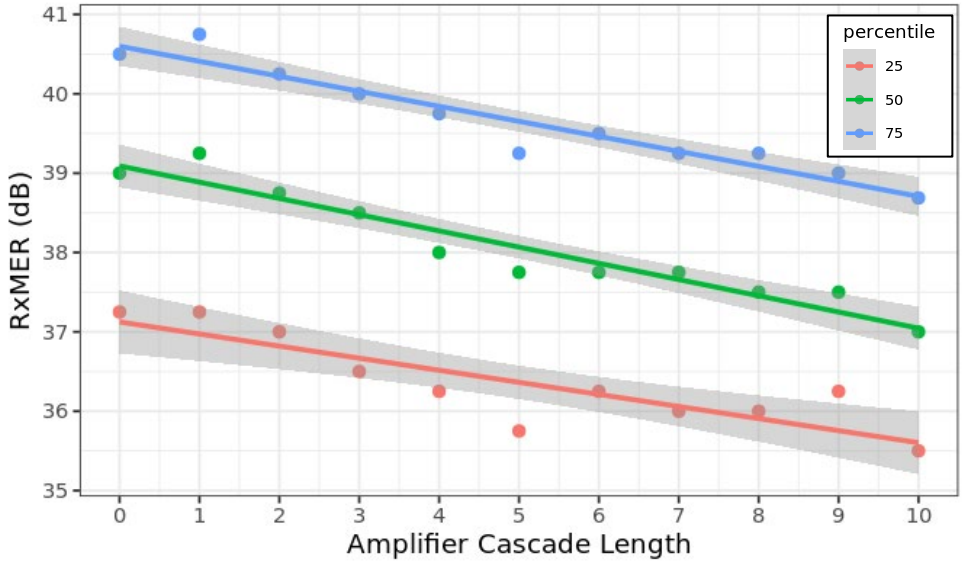
Amplifier Cascade Length

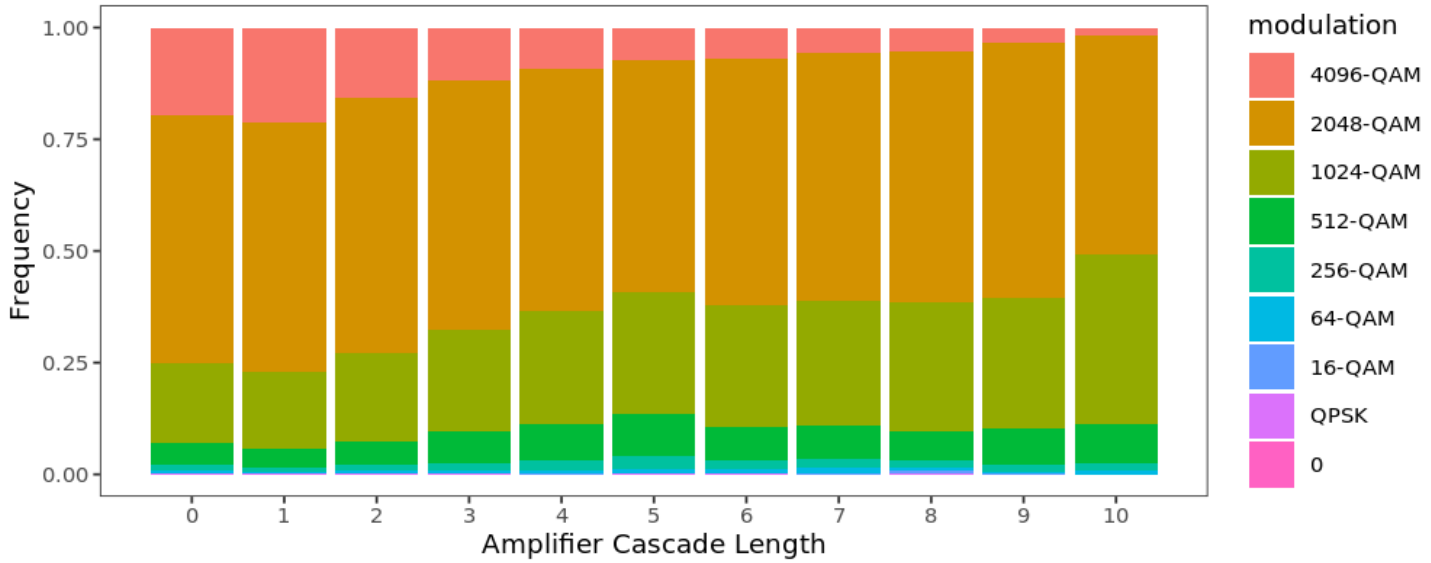
- Most devices connect to the CMTS through a cascade of 2 amplifiers
- Distribution cut off at 10; however, there exist outliers with cascade length > 10

Total Amplifiers

- Distribution cut off at ~40

Correlation Between Amplifier Cascade Length & RxMER

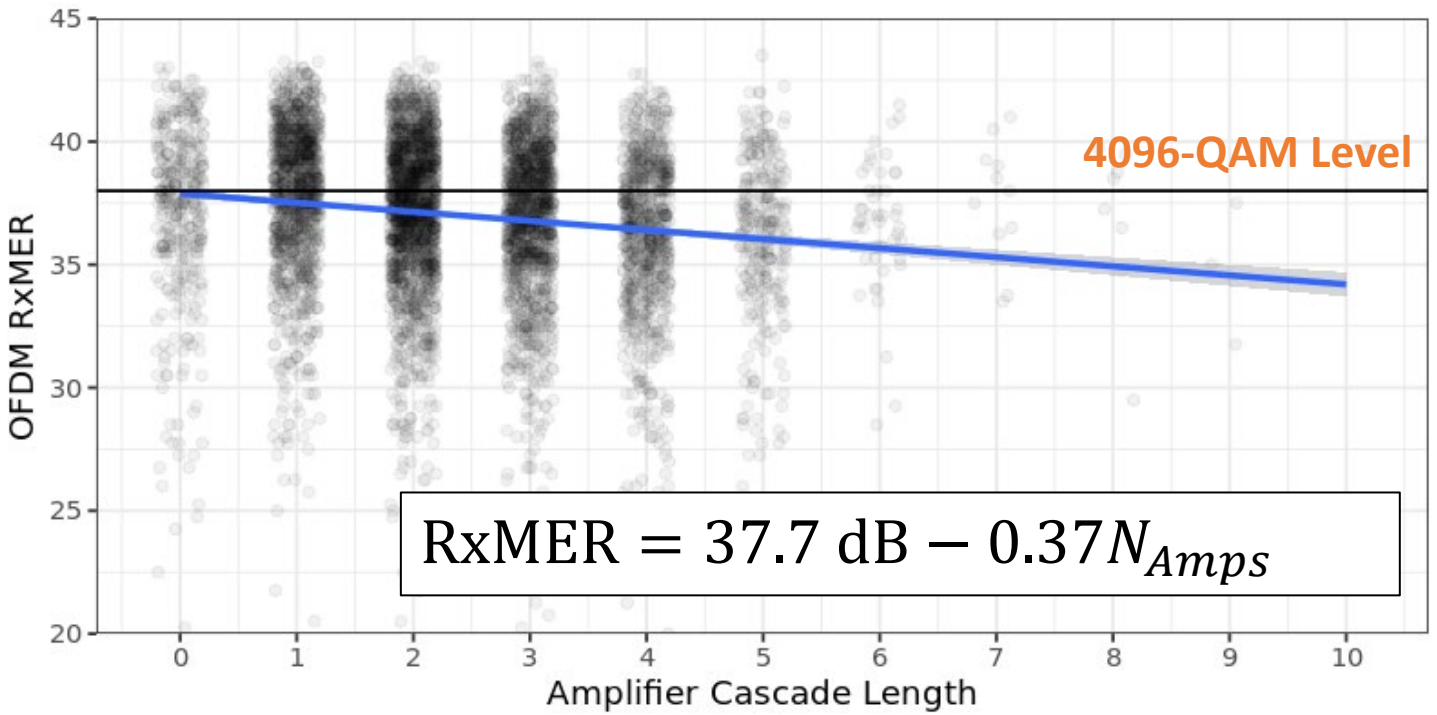




- Plots show a trend of decreasing OFDM RF performance with increasing amplifier cascade length
- This's manifested on lower RxMER and lower ratio of 4096-QAM modulation

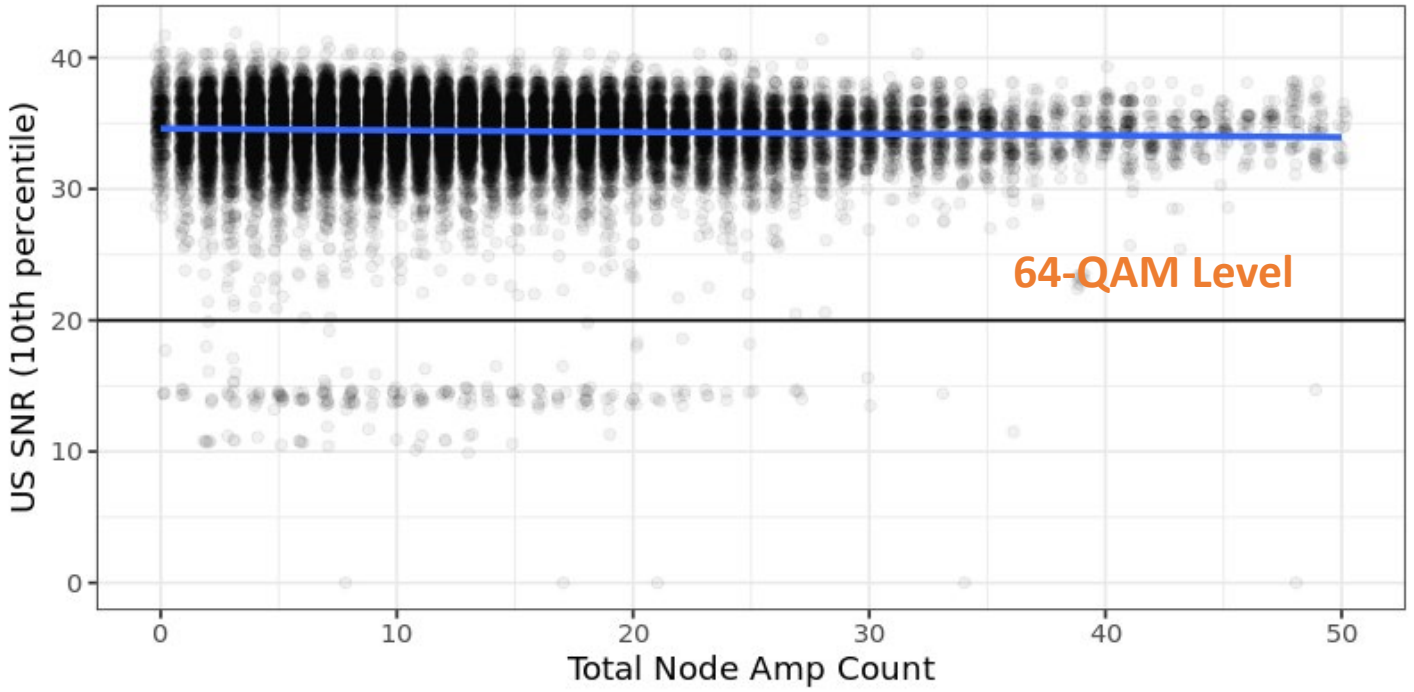
Linear Fit to the RxMER-Amplifier cascade length relation

- Statistically significant relationship (p-value $< 2 \times 10^{-16}$)
- Translates into RxMER reduction by 3.7 dB on average for every 10 amplifiers in the cascade
- With PMA running on OFDM, we're operating close to the Shannon limit
- From Shannon's law, $C \approx 0.332 \cdot B \cdot \mathrm{SNR(dB)}$, we estimate ~100 Mbps reduction in capacity of 96 MHz channel for for every 10 amplifiers in the cascade



Linear Fit to the SNR-Total number of amplifiers relation

- Statistically significant relationship (p-value $< 2 \times 10^{-16}$)
- However, D3.0 operates with a large safety net (maximum possible modulation is 64-QAM)
- With such a safety net, the impact on customers is negligible
- Analysis is more relevant for OFDMA



Findings

- The graph database makes a powerful platform for execution of traversal queries to extract network views of interest
- As a first use case, we detected a negative correlation between amplifier cascade length and OFDM RxMER
- Even though the effect is measurable, it is found not to be service impacting for cascade lengths <10 amplifiers

Future Work

- Scaling up the graph to cover the full network
- Building algorithms for root cause analysis/noise triangulation

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Thank You!

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