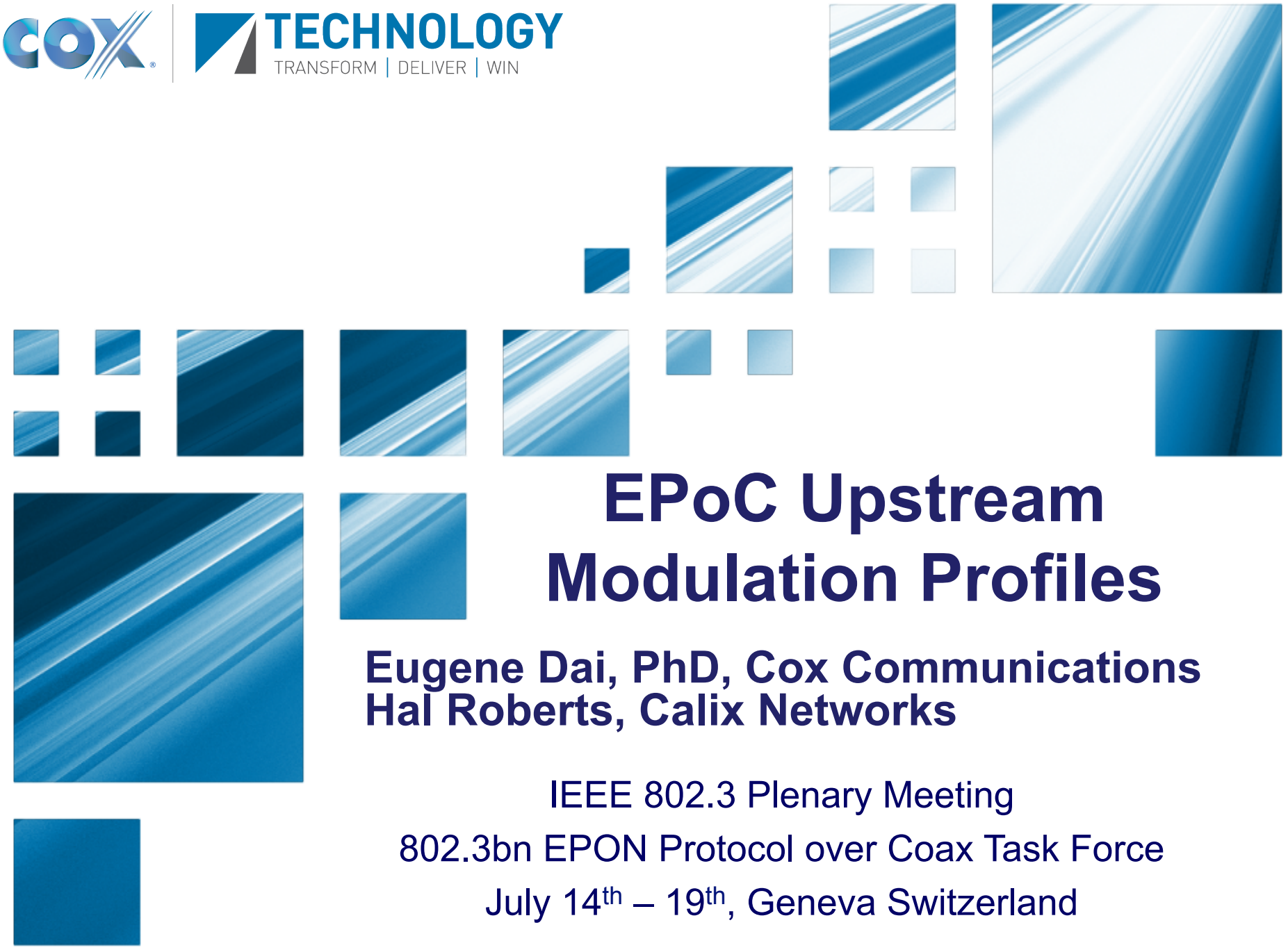

EPoC Upstream Modulation Profiles

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IEEE 802.3 Plenary Meeting

802.3bn EPON Protocol over Coax Task Force

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Outline

- Complexities of EPoC rate adaption
- Definition of modulation profiles
- Upstream Multiple Modulation Profiles use cases
- Characteristics of upstream impairments
- Slice of modulation profile
- Conclusions

EPON Scheduling and EPoC PHY

- 10G EPON has a simple upstream scheduling mechanism based on TQ
- 10G EPON has a simple rate adaption mechanism based on “idle insertion & deletion”
  - MAC insert idles to reserve space for FEC at PCS
  - MAC know precisely how much idles to insert
- EPoC by default will use EPON/10G EPON scheduling mechanism
- 802.3bn TF passed a motion to adopt 10G EPON rate adaption mechanism for EPoC
  - MAC insert idles to reserve space for FEC at lower layer (PCS?)
  - Mac insert idles to adapt to lower coax rate
- Rete adaption in EPoC is much more complex than that of 10G EPON

Complexity of EPoC rate adaption

- EPoC rate adaption
  - MAC insert 1st kind idles to reserve space for FEC
  - MAC insert 2nd kind idles to adapt lower coax rate
- The insertion and deletion of 1st kind idles for FEC could be much more complex
  - If multiple code word sizes are used
    - MAC has to know in advance the combinations of code words PHY will use (MAC is not PHY aware)
  - For efficiency we may have no other choices
- The insertion and deletion of 2nd kind idles could be complicated if MMP are used for a CNU
  - MAC has to deal multiple PHY rate dynamically
- Double troubles – if both MMP (Multiple Modulation profiles) and Multiple code words are used

Double Troubles

- Double troubles – if both MMP and Multiple sizes of code words are used
- EPoC MAC need to know in advance the combination of code words and profiles
- FEC is globe – apply to all CNUs
- MP is local – apply to a given CNU or CNUs
- Combination of multiple sizes code-words is dynamic – determined by payload sizes at a give instance
- Simplify any of above will make EPoC simpler
- This contribution will focus on reduce the number of upstream modulation profiles
  - Why more MMP is needed in the upstream?

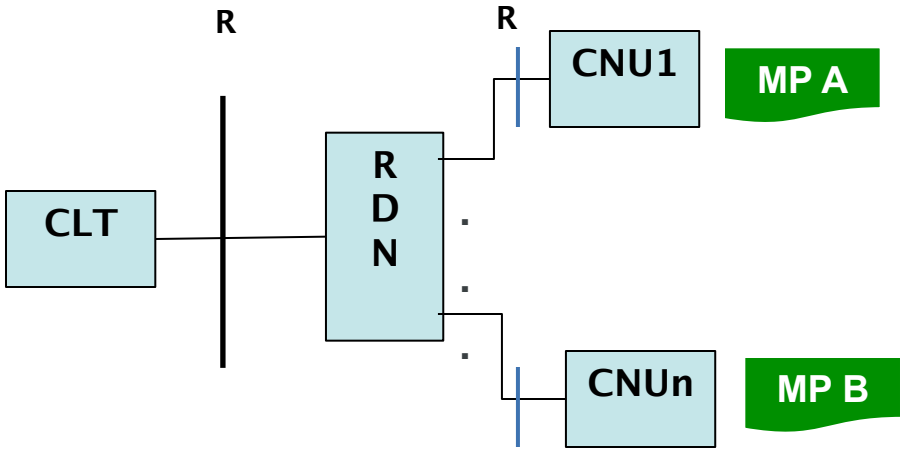
Modulation Profiles – a Clear Definition is needed

- Modulation profile is local to a CNU or a group of CNUs
  - Only local parameters should be included
- Global and local parameters
  - Global
    - FEC, Code-word size, CP, OFDM symbol size, OFDM frame, etc.
  - Local
    - Number of subcarriers assigned, bit loading per subcarrier or group, etc.
- A modulation profile includes:
  - Number of subcarriers or subcarrier groups
  - Bit loading per subcarrier or subcarrier groups
- Bandwidth capacity of a MP should be extracted and pass to MAC

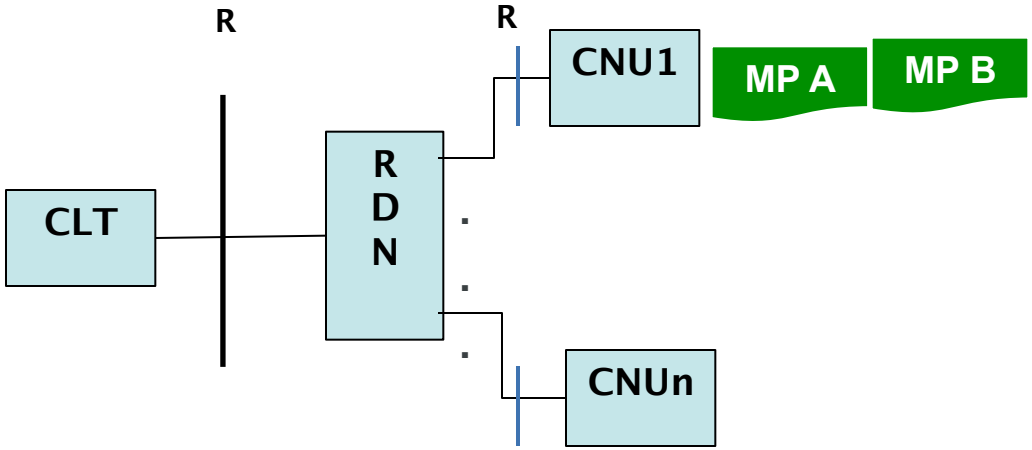
Upstream Multiple MP Use Cases

Upstream MMP: MP changed dynamically for a given CNU or among CNUs

Use case A: MPs change among CNUs



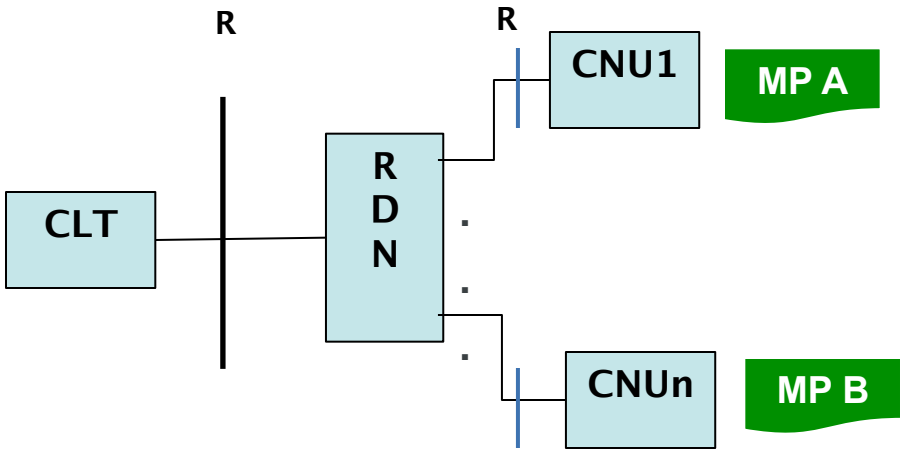
Use case B: MPs change per CNU over time



MP –Modulation Profile
MMP- Multiple Modulation Profiles
RDN – RF Distribution Network

Upstream MMP use case A

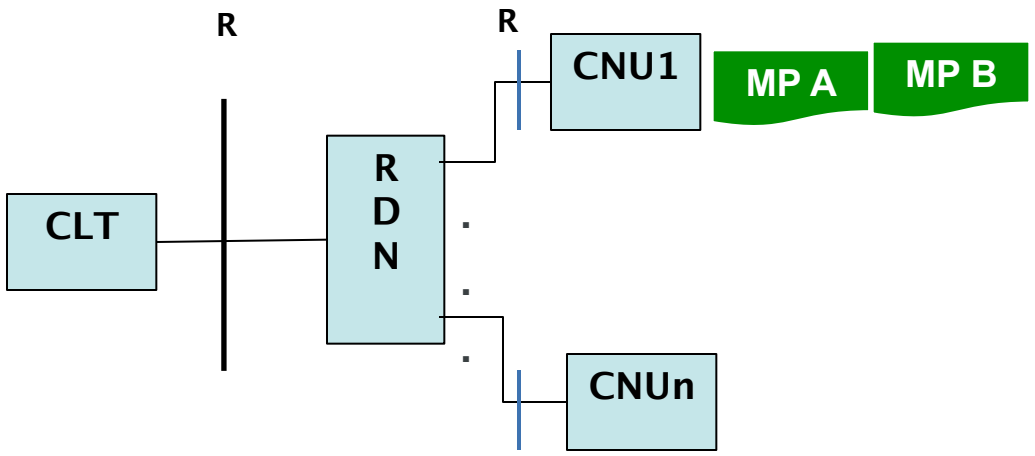
Use case A: MPs change between CMs



- **MP for a given CNU does not change overtime**
- **MP among CNUs could be different**
- **MMP in space (OFDMA)**

Upstream MMP use case B

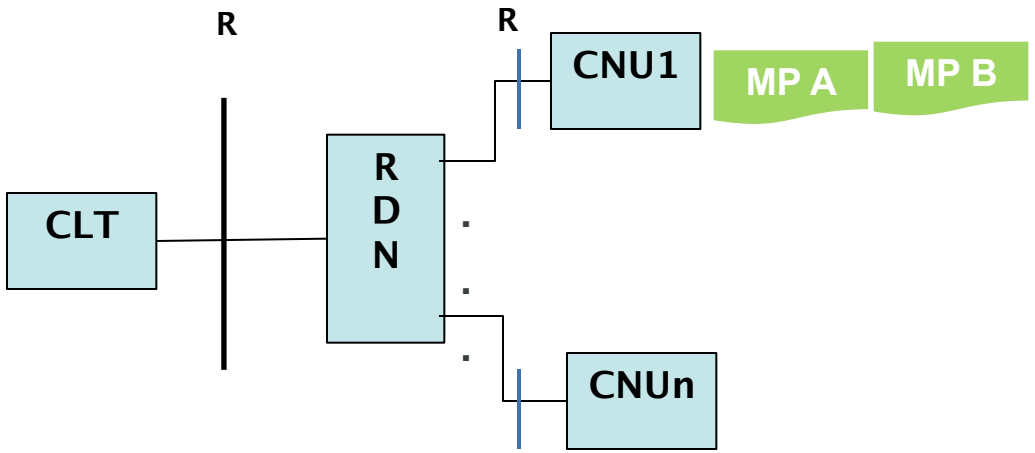
Use case B: MPs change over time for a CNU



- MP for a given CNU change overtime (MMP in time)
- The change is slow, in the time scale of many hours
  - For example MP A is for day time and MP B is for night time
- MP among CNUs could also be different (covered in use case A)

Upstream MMP use case C

Use case C: MPs change over time (shorter scale) for a CNU



- MP for a given CNU change overtime
- The change is fast, the time scale could be as short as sub-second
  - For example like bit map change in ADSL
- Only dynamic bit loading, like bit swap in ADSL, could keep up with this kind of dynamic change
- It is believed (or hope?) in coax environment this use case can be avoided (we are not going to discuss case c further in this contribution)

What are the arguments for more profiles?

- The noises experienced among CNUs are different
- The distortion among CNUs are different
  - Different multipath
  - Different group delay
- The attenuation for CNUs are different
  - Could result non-uniform signal strength at CLT receiver
- Long cascaded RF amplifier depths are different per CNU
  - Diplex filter roll-off effect will be worse in cascaded amplifier chain

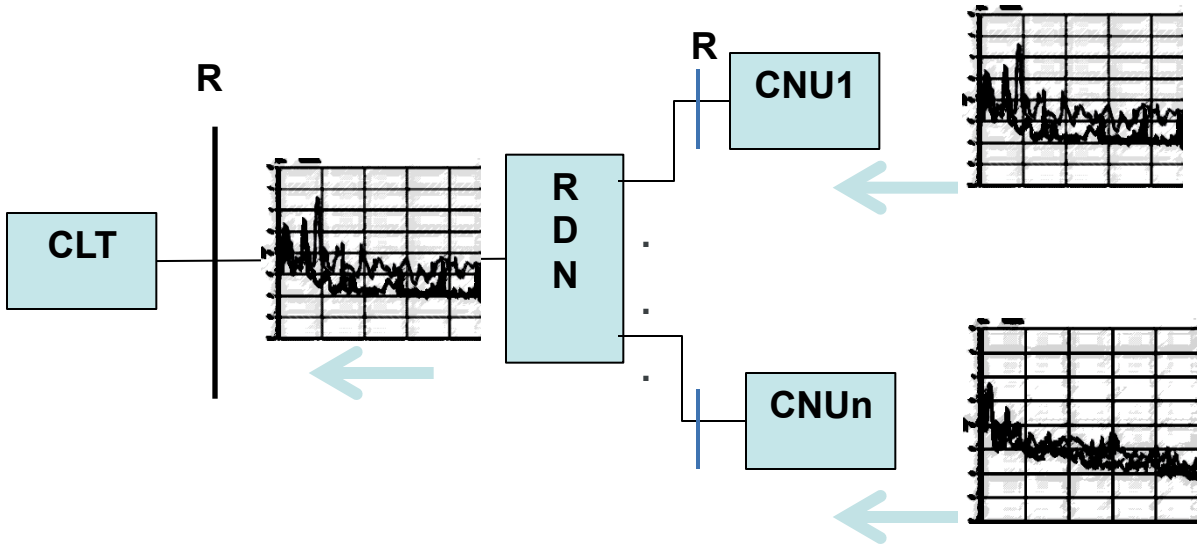
Characteristics of Upstream Impairments

In the upstream there is a single receiver at CLT, therefore we should expect:

- **Same Noise spectrum (Funneling effort): noises from CNUs to CLT are the same, such as SNR, CSO, CTB, impulse/burst noise and narrowband ingress etc.**
- **Same signal strength: signal strength should be the same at CLT upstream receiver from CNUs via ranging and sub-carrier equalization in normal situations**
- **Different distortions: distortions from CNUs to CLT could be different, such as multipath and group delay, etc.**

Noise funneling effect

- In the upstream direction all noises, no matter where it comes from, have the same impact on a CLT receiver
- Equivalency: All CNUs transmit in the same noise environment - a *Single Noise Signature*



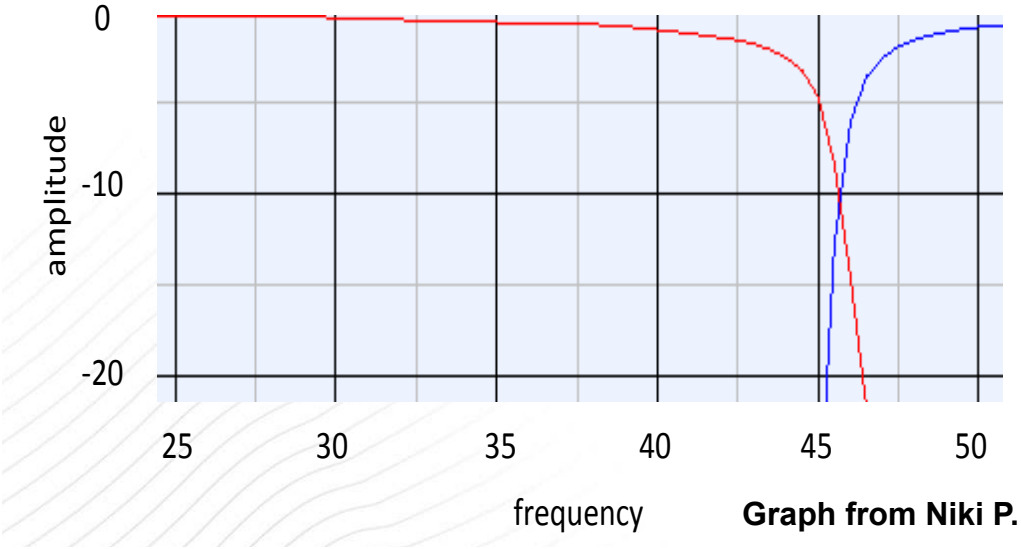
Close Look at Upstream Impairments

In spite of noise funneling effect, there still could be difference between CNU transmission powers (arguments for more profiles):

- **Distortions could be different, but the difference in multipath and group delays could be covered by choose proper Cyclic Prefix.**
- **Ununiformed signal strength between CNUs beyond the compensation of ranging could happen, but it can be solved with:**
  - **OFDMA subcarrier equalization**
  - **Limiting CNU subcarrier space:**
    - **a CM to ½ of sub-channels provides a 3dB boost, ¼ of the sub-channels a 6dB boost (at the expense of throughput)**
  - **Tighten outside plants and in-home networks**

Diplex filter roll-off efforts – another argument for upstream MMP

- Diplex filter normally cut off near 42 MHz
- It was argued that the roll-off effect could has impact when amplifiers are cascaded.
- Pre-equalization may not has enough power to correct in cascaded amplifier situation.

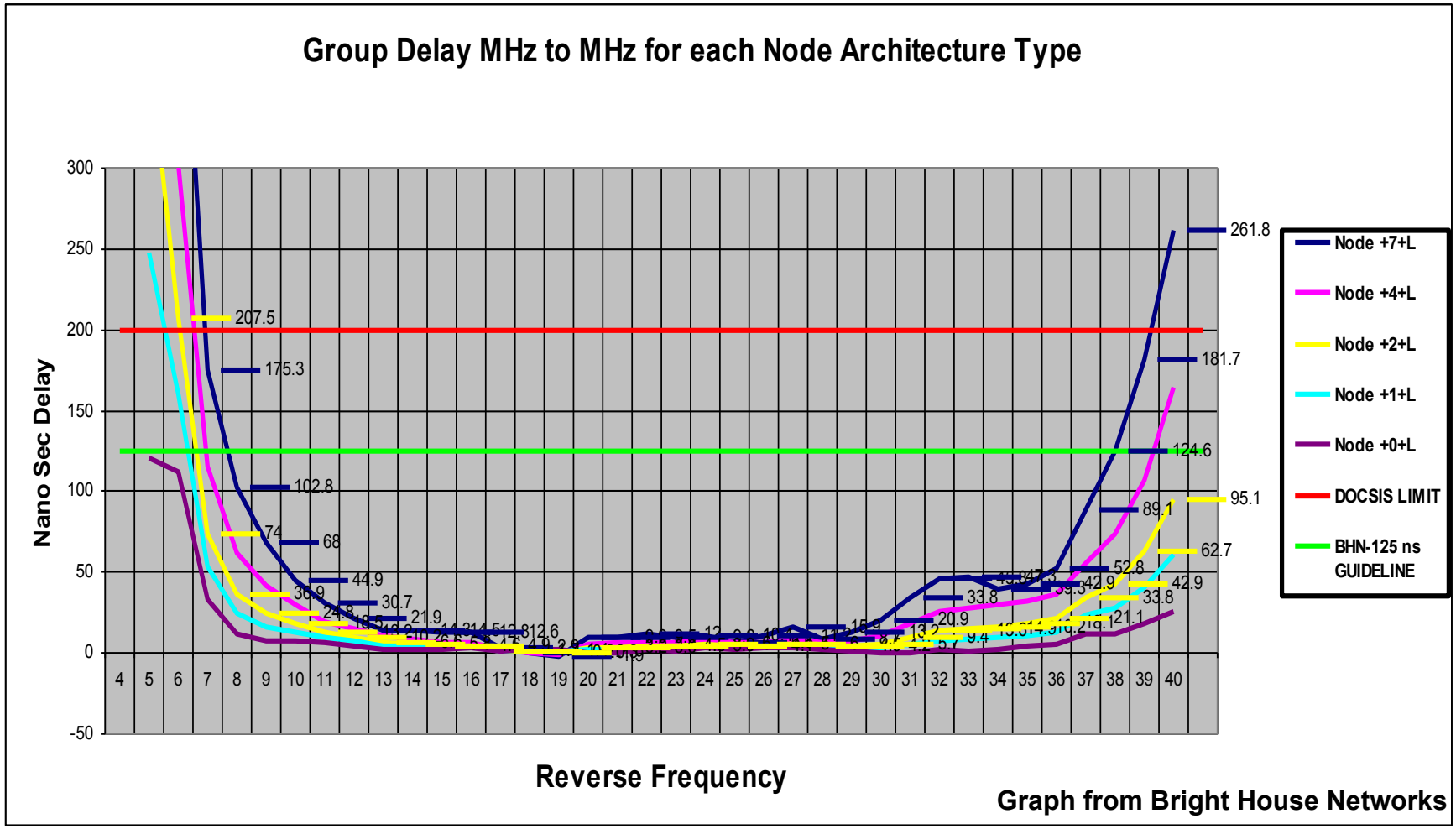


Graph from Niki P.

Questions:

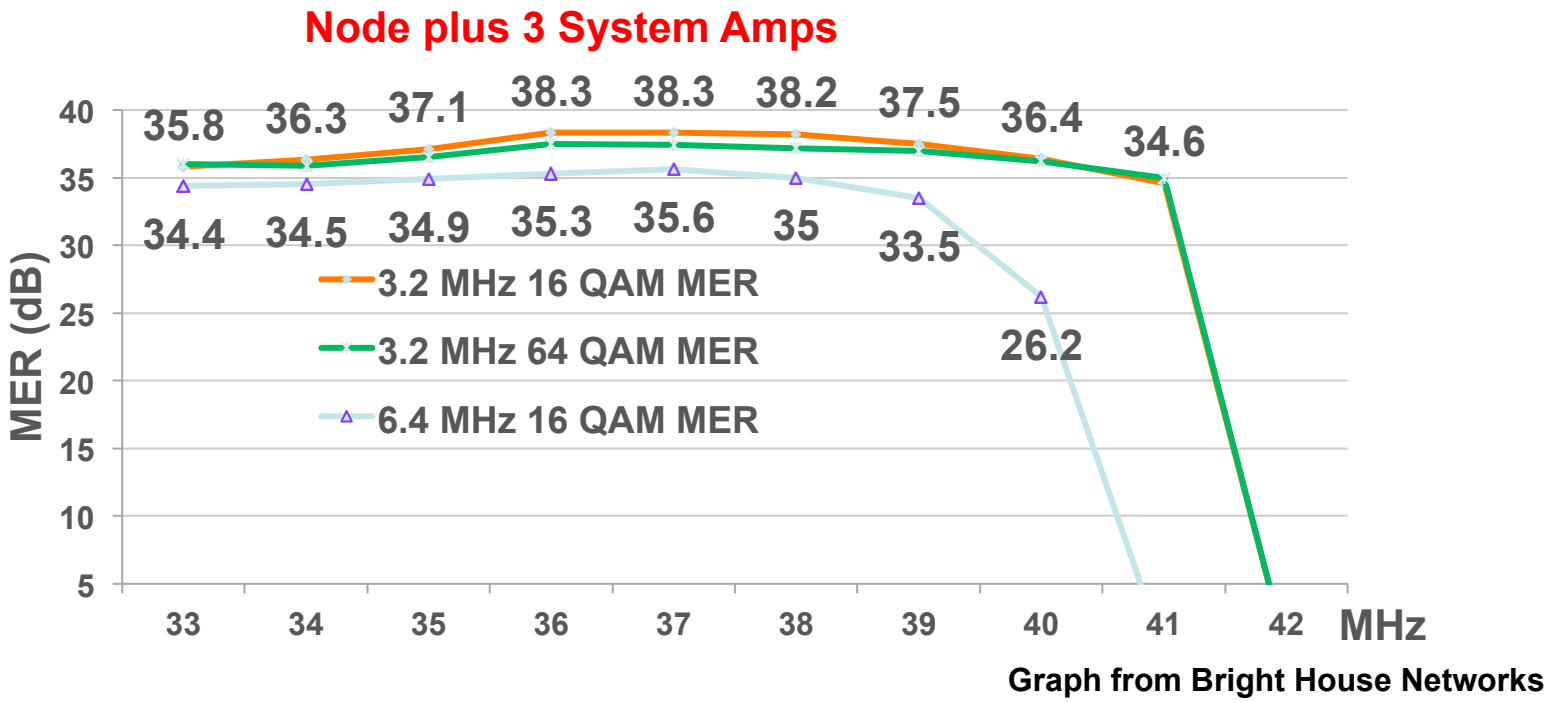
- What is the impact of roll-off on frequency response and group delay in cascaded amplifier chain?
- How good (or bad) is the roll-off region (start at 35MHz)?

Roll-off effect - Group delays in N+x



- **Will OFDM break the group delay limit from SC QAM data?**
  - **Yes!**

MER Near Roll-off Region



Graph from Bright House Networks

Surprising results:

- **MER actually slightly increasing when approach roll-off region before cut-off.**
- **Upper portions of the return frequency spectrum are more available to use than we believed.**
- **Why?**

Discussions of Roll-off effect

- Roll-off effect has significant impacts on frequency response – it is understandable
- Roll-off effect has apparent impacts on group delay – it is manageable in OFDM (with properly choose of CP)
- In SC QAM measurement, the roll-off region actually show slightly increase in MER – surprising but understandable
  - Equalization at CMTS receiver
  - Upper portion of upstream spectrum has less noise than that of lower portion
- OFDM can handle the roll-off region better (than SC QAM)
  - Per-subcarrier equalization
  - Choose worse case CP
- Characteristics of 85MHz and 200MHz diplex filters need further study

How many MPs is enough?

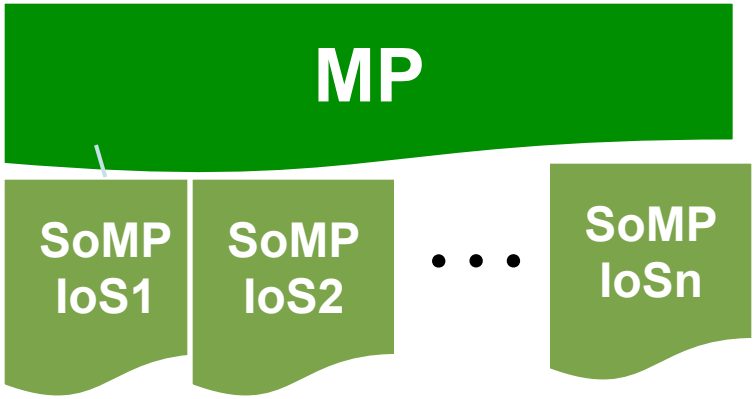
- As far as noise difference is concerned, due to the funneling effect there is no need for MMP in upstream
- In use case A:
  - For OFDM, one universal profile should be sufficient (for CLT and CNUs)
  - For OFDMA, one profile for each CNU, multiple profiles for CLT.
- In use case B, there could be more than one MPs per CNU in order to address the slow changes in outside plant conditions in upstream, such as “day profile” and “night profile”, but at a given instance only one should be active
  - But the need for such slow change profiles is not clear

How many MPs is enough? (continue)

- Single MP per CUN significant simplify rate adaption in the upstream direction
- CLT still has to handle different MPs from CNUs
  - Large look up table and processing power
- Can we further simplify ?

Slice of Modulation Profile

- A CLT maintain one large modulation profile cover entire frequency block
- A CNU assign a slice of block or slice of MP; other parameters are not changed
- A CLT only needs to maintain one look up table with an Index of Slices (IoS)



Conclusions

- Due to noise funneling effect, there is no need for Multiple upstream MPs per CNU just because of noise difference.
- MER measurements on SC QAM in filter "roll-off" region do support additional upstream profiles just because of "roll-off" effect.
- OFDMA with per-subcarrier equalization could handle transmission power difference and "roll-off" effect better (than SC QAM)
- Therefore, each CNU needs only one upstream MP. CLT may need to maintain multiple MPs
- With the concept of "Slice of MP", an CLT only need to maintain one MP; each CNU get a Slice of MP (SoMP)

References

1. Hal R. and Eugene D.“Multiple Modulation Profiles in the Upstream?”, IEEE 802.3bn Phoenix meeting, January 2013
2. Niki P. “WHAT IS AN UPSTREAM PROFILE, WHY DO WE NEED UPSTREAM PROFILES (IF AT ALL), AND HOW MANY UPSTREAM PROFILES DO WE NEED (IF MORE THAN ONE)? CableLabs MAC WG, June 2013
3. Bright House Networks, “DOCSIS Upstream Frequency Testing”, workshop at Tampa, May 2012

Thanks