Multiple Modulation Profiles in the Upstream?

An Examination of the Potential Benefits

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MMP in Upstream

Introduction:

- Many contributions have addressed the potential benefits and problems of MMP in the downstream
- No contributions have examined the need for MMP in the upstream, yet, some have assumed that MMP is a 'given' in the upstream

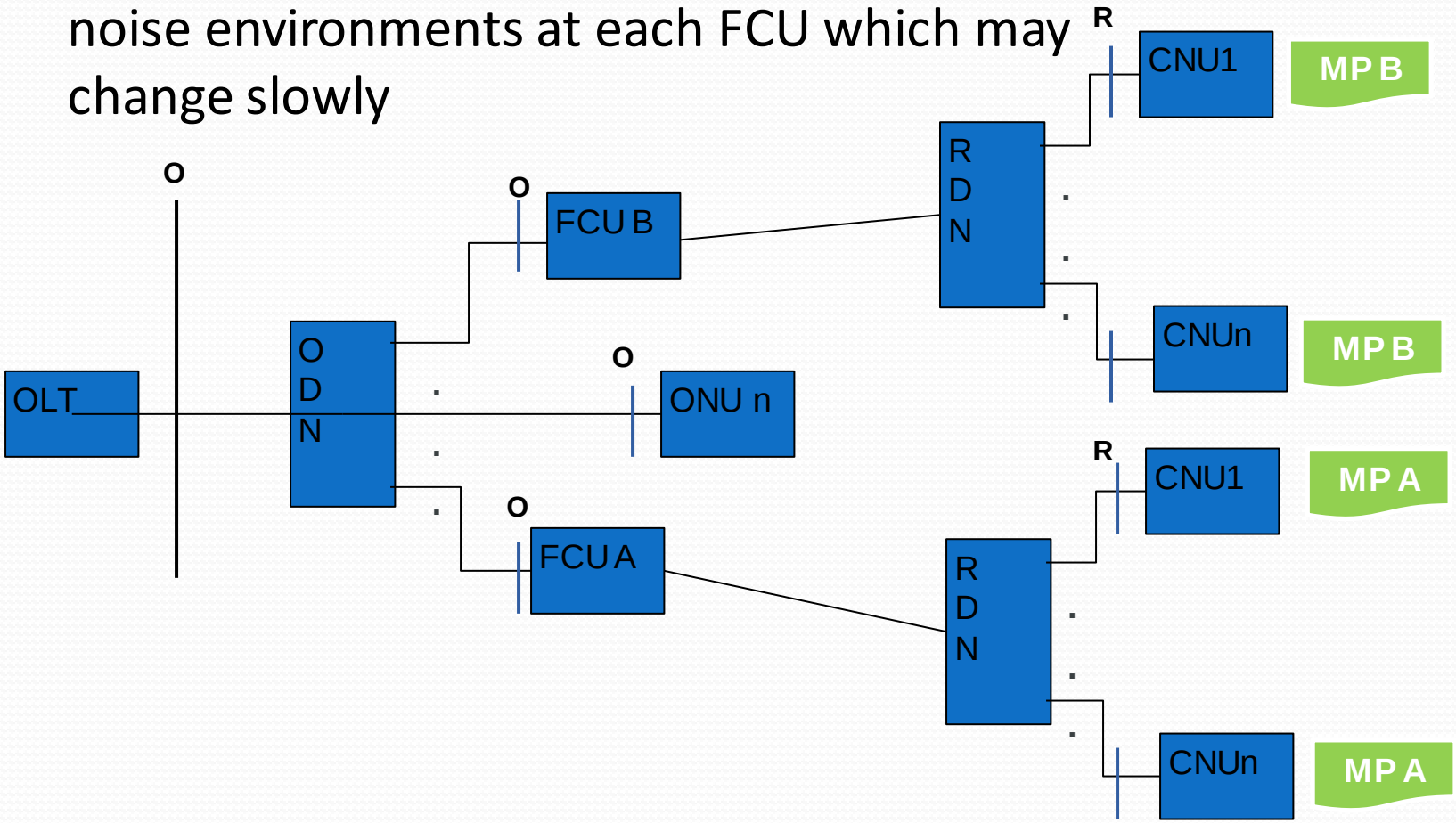
Scope:

- This contribution will *not* address the downstream, only the upstream
- This contribution will *not* address multiple modulation profiles across a PON, i.e. one MP per FCU. There are reasons for this and the complexity may be low
- This contribution *will* examine the potential benefits from MMP per FCU in the *upstream*.

Use Cases 1 & 2: Single MP per FCU, MMP per PON

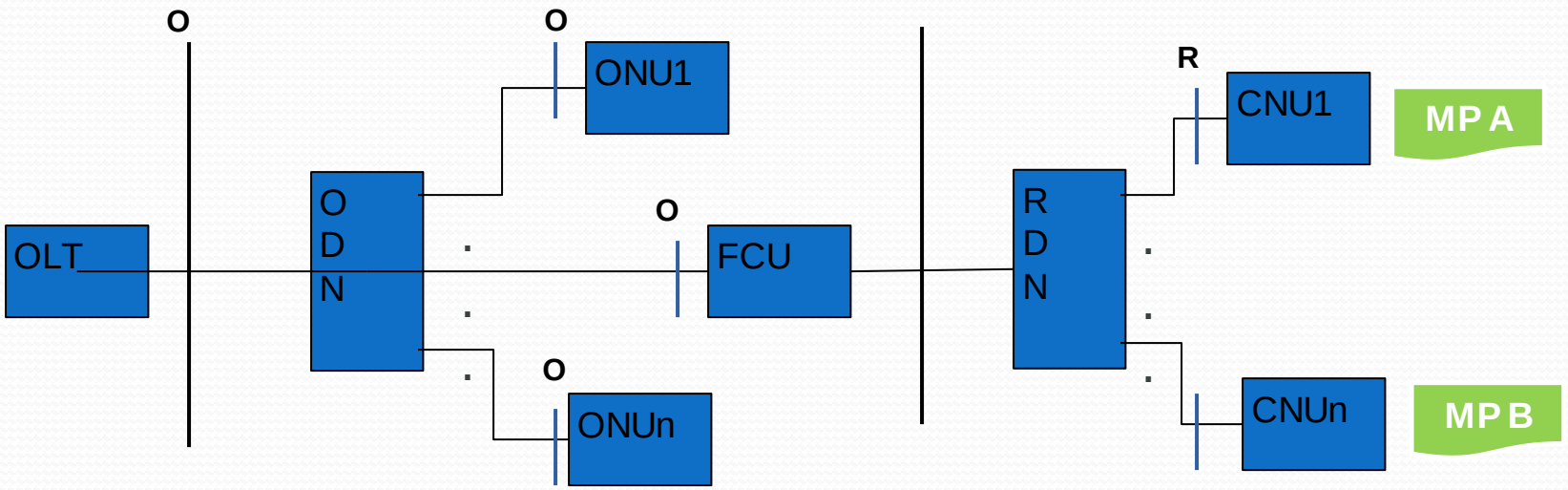
This contribution does not address this Use Case

- MMPs per PON are justified based on differing noise environments at each FCU which may change slowly



Use Case 3: Multiple Profiles per FCU, one per CNU

This contribution addresses Use Case #3 where MMP are used per FCU dynamically

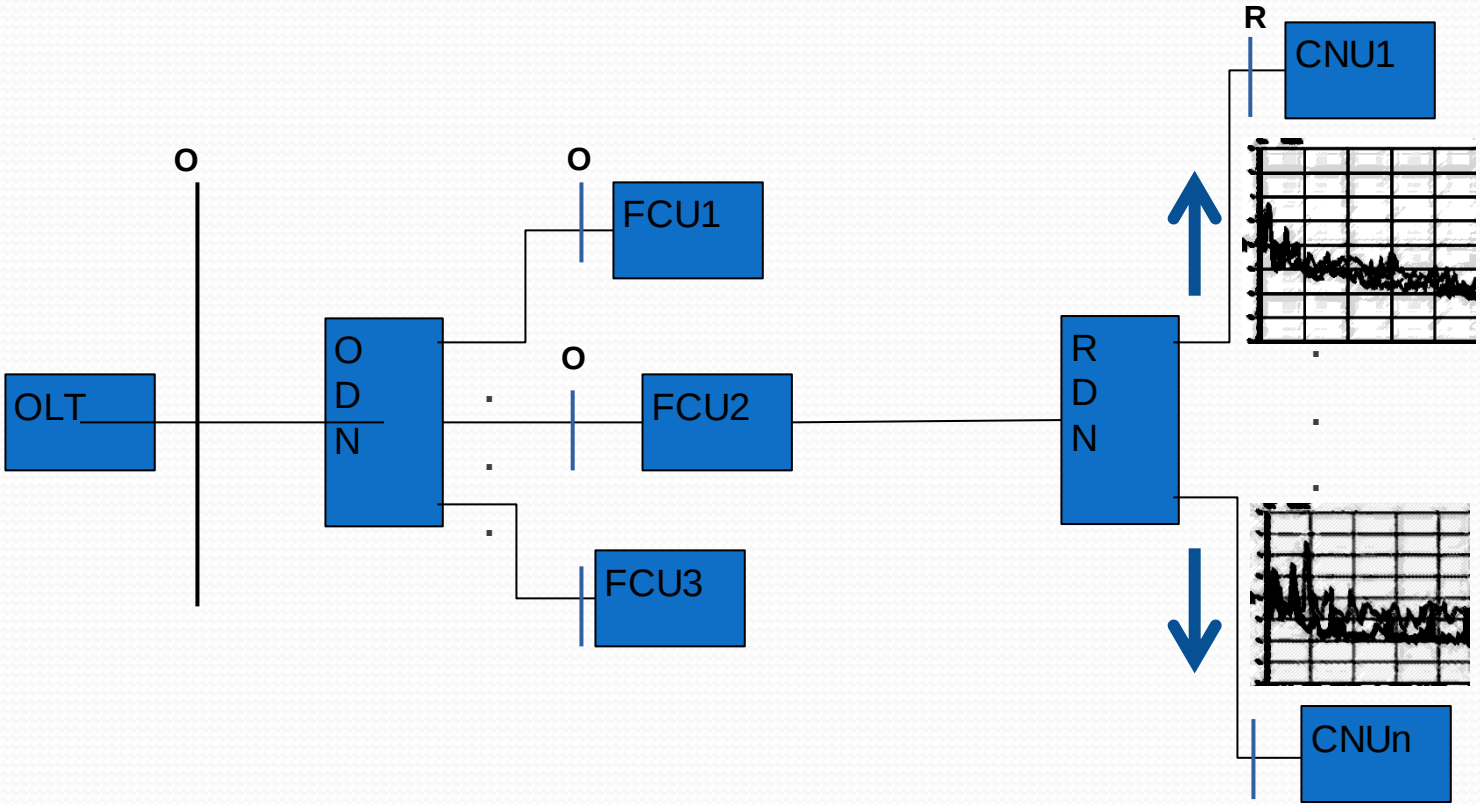


The Difference between Upstream and Downstream Impairments

Downstream: Multiple receivers, one per CNU, each with different Impairment Environments

- Distortions from FCU to CNU are different per CNU, such as multipath and group delay (i.e. parameters from Prodan model)
- Noise from FCU to CNU is different per CNU, such as SNR, CSO, CTB, impulse/burst noise and narrowband ingress
- Signal strength is different from FCU to CNU

Downstream Impairments Diagram



Downstream Impairments

Downstream noise generally enters in the coax drop or in the in-home network

- Therefore the noise signatures vary from CNU to CNU
- In addition, the power levels cannot be compensated via feedback from the CNU to the FCU, each CNU sees a different power level from the FCU.
- Subcarrier levels cannot be equalized, if using multicast or broadcast (in theory, unicast bursts could have equalized levels on subcarriers, but this is complex).

The Difference between Upstream and Downstream Impairments

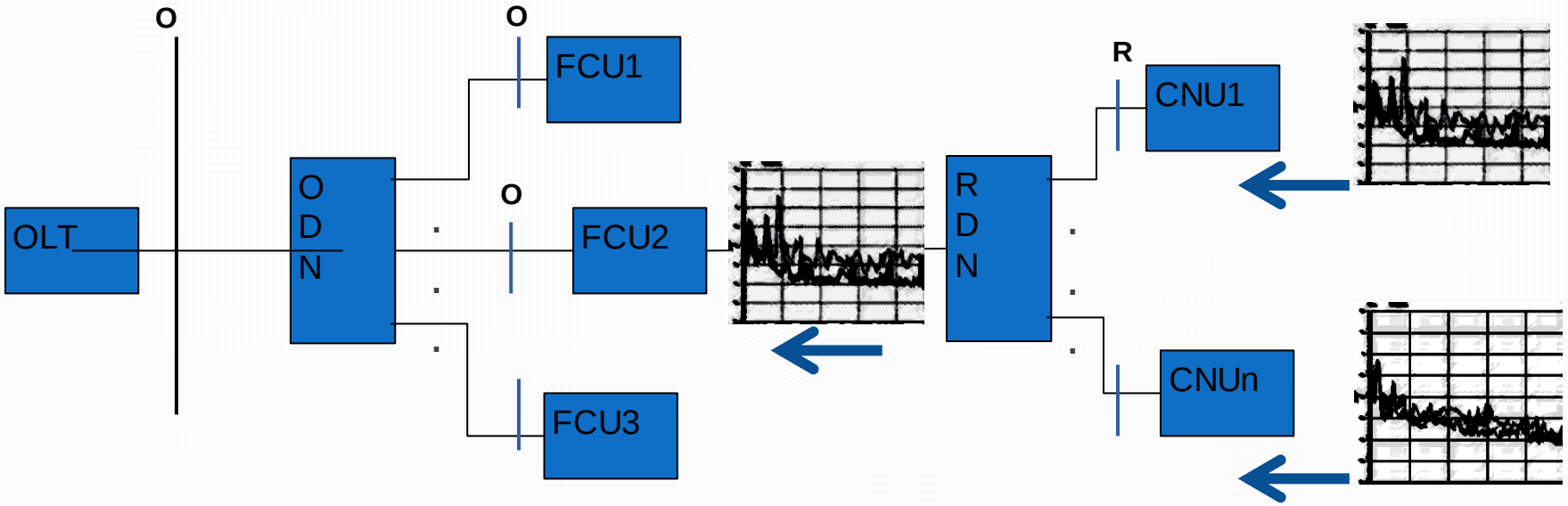
Upstream: Single receiver at FCU

- Distortions from CNUs to FCU are different per CNU, such as multipath and group delay (i.e. parameters from Prodan model)
- Noise from CNUs to FCU is the same per CNT, such as SNR, CSO, CTB, impulse/burst noise and narrowband ingress, due to the well-known Upstream Funneling effect
- Signal strength should be the same at FCU from CNU via ranging and sub-carrier equalization

Upstream Impairments Diagram

Noise funneling effect

- In the upstream all noise, no matter where it comes from, impacts the FCU receiver
- As such, all CNUs transmit in the same noise environment, i.e. a *Single Noise Signature*



If all Upstream Noise is Funneled, are there any Differences between CNU Transmissions?

Multipath Distortion is different from CNU A vs. CNU B

- **Why this doesn't matter**: Cyclic prefix is designed to withstand worst case multipath and group delay. This works in the wireless environment with much worse impairments than HFC.

Upstream Power Differences due to In-home Losses

- **Why this doesn't matter**: Upstream ranging will allow CNU to compensate for upstream losses. OFDM allows per sub-carrier equalization so each sub-carrier arrives at FCU at the ideal power level

What if CNU doesn't have the capability to transmit enough power per SC?

- **Why this doesn't** matter: This indicates CNU was not specified adequately or drop or home network needs fixing
- Even in this case, OFDMA allows sub-channelization (next slide) to boost power density at the expense of CNU maximum throughput

OFDMA Sub-Channelization (used in LTE)

How to overcome high in-home or drop attenuation…

If OFDMA is used in the Upstream

- And the plant loss is too high from a given CNU to FCU, the FCU assigns a maximum subset of OFDM sub-channels within the 192 MHz band
- Limiting CNU to ½ of sub-channels provides a 3dB boost, ¼ of the sub-channels a 6dB boost
- *At a proportional loss in CNU peak throughput*
- **HFC Systems should not need Sub-Channelization, losses should be more contained than in wireless**

Conclusions

- There are no compelling reasons for MMP in the upstream
  - All CNU transmissions will experience the same noise at the FCU as long as they can transmit at adequate power levels.
- There could be multiple predefined or dynamic modulations profiles to address the change in outside plant conditions in upstream, but at a given instance only one is active
- While MMP “might” be simpler in the upstream, it should not be implemented unless there is a benefit.
  - *Just because we ‘can’ doesn’t mean we ‘should’*