

PHY Control Channel and PHY Initialization Procedures

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Summary

- A PHY Control Channel (PCCH) is needed for
 - Aiding PHY initialization and CNU bring-up
 - Broadcasting information strictly necessary to enable the operation of the PHY layer (e.g., proper demodulation and decoding of data)
 - Collecting CNU-specific information (e.g., supported MCS in DS)
 - It does **not** convey MAC Control information (GATE/REPORT messages)
- In [boyd_01_0912], this has been termed “PHY Link”
 - “Frequency inserted”
 - Carried in every symbol
 - Enables a bi-directional protocol for PHY initialization (or “auto-negotiation”)
- This presentation introduces more details on the PCCH
 - Purpose (DS/US)
 - Information carried on the PCCH (DS/US)
 - PHY resources reserved for the PCCH (DS/US)
 - PHY initialization procedures related to the PCCH
- Assumption: MSC is adapted on a per-CNU (group) basis

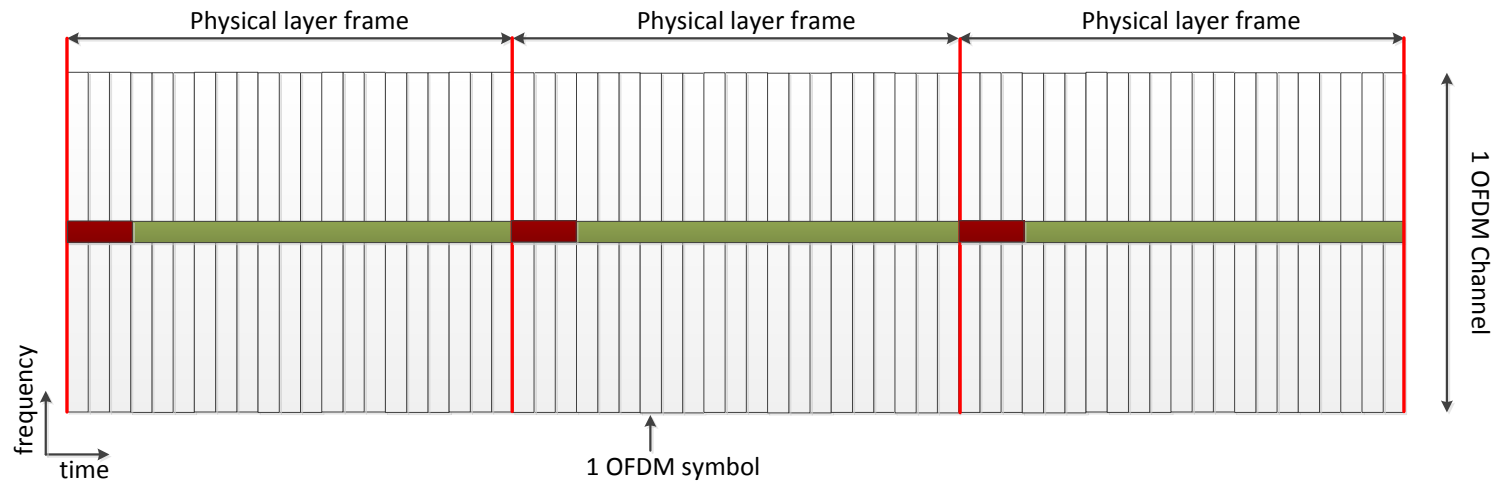
Purpose of PCCH - Downstream

- PCCH Reference Signal: Aids PHY acquisition
 - Carrier frequency recovery
 - PHY frame synchronization

 - PCCH Data: Broadcasts network information + CNU-specific information
 - OFDM channel ID
 - DS Bandwidth (Number of available sub-carriers in this OFDM channel)
 - Number of frequency notches
 - Start frequency of each notch
 - Bandwidth of each notch
 - Info regarding PHY frame structure
 - TDD split in terms of US/DS OFDM symbols and guard interval
 - FDD US information: carrier frequency, number of available subcarriers
 - Frequency Interleaving pattern (logical to physical subcarrier mapping)
 - Time Interleaving depth for DS
 - Active profiles (active MCS's)
 - **Timing advance information for specific CNU(s)**
 - **Assignment of specific CNU(s) to a given DS/US profile**
 - **Power control information for specific CNU(s)**
- } Needs definition of a PHY address

Resources Reserved for PCCH - Downstream

- A fixed number of subcarriers within all OFDM symbols (“frequency inserted”)

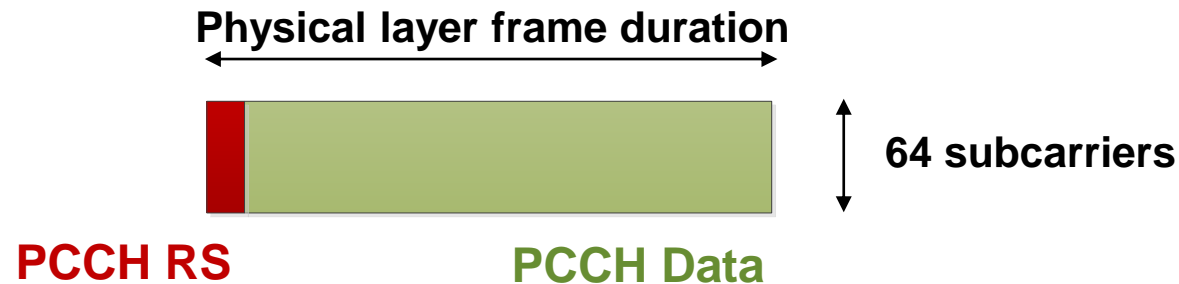


- It is also possible to have a frequency-hopping pattern [boyd_01_0912].
- PCCH includes reference signals (RS) for PHY acquisition and PCCH data (format TBD)



Resources Reserved for PCCH - Downstream

▪ Example



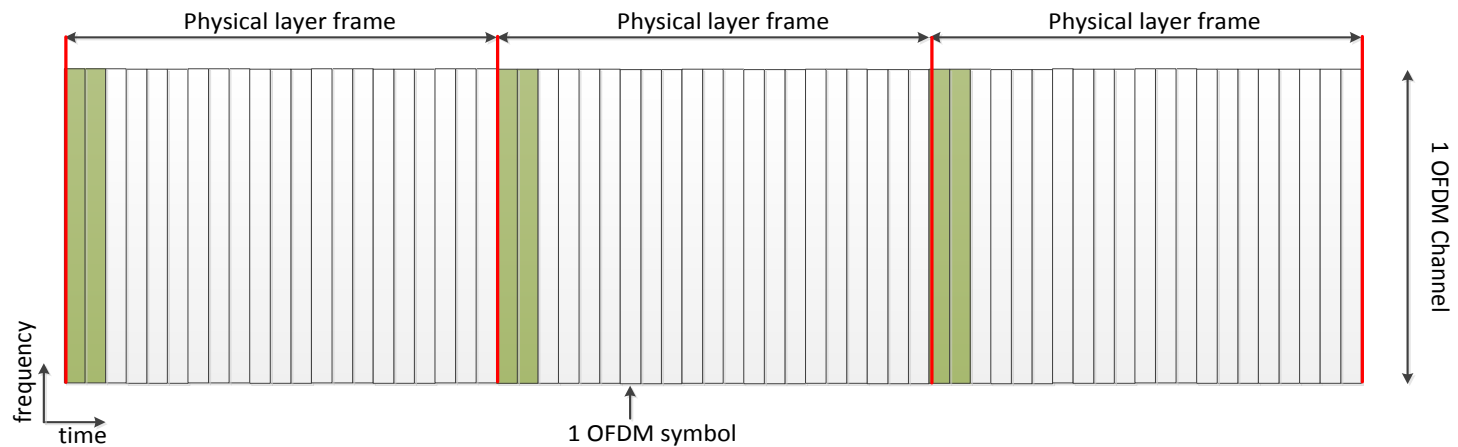
- Physical layer frame duration influences only the duration of the overall initialization phase
 - CNU has to first identify RS signal to obtain frame and frequency synchronization with respect to the CLT
- Data rate available for the PCCH and overall overhead (OH):
 - 64 subcarriers
 - 16-QAM modulation
 - 20us symbol duration (50kHz spacing)
 - 24 MHz available frequency resources (~512 sc)
- Excessive resource allocation for PCCH
 - Rate is much higher then strictly necessary
 - Overhead may be fairly large if not all frequency resources within one OFDM channel are used.

$$R_{\text{PCCH}} = 12.8 \text{ Mbps}$$

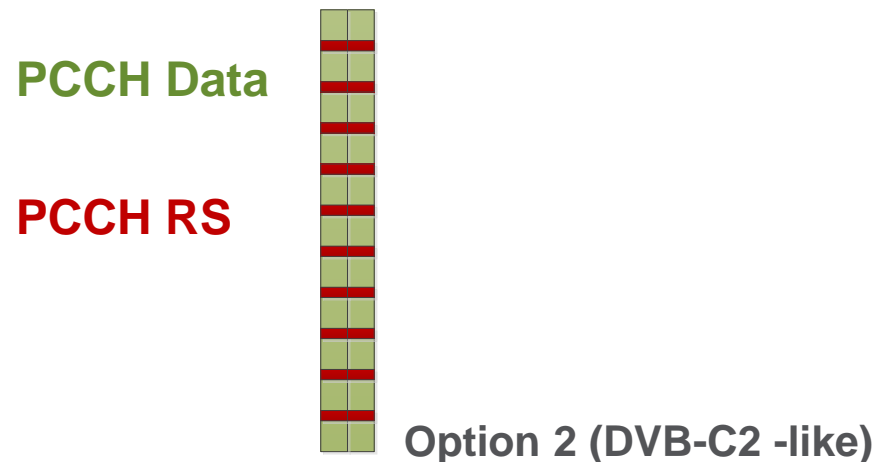
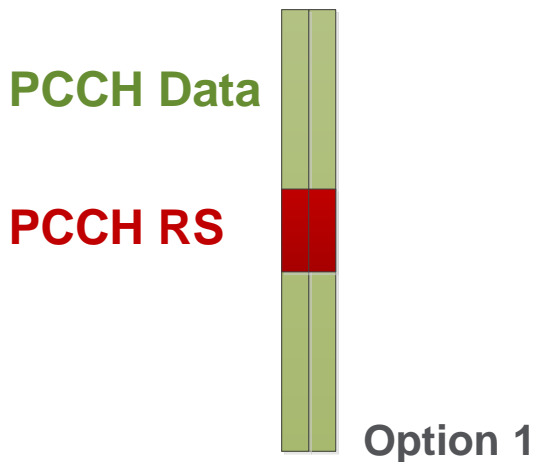
$$\text{OH}_{\text{PCCH}} \sim 12.5 \%$$

Resources Reserved for PCCH - Downstream

- A fixed number of OFDM symbols (“time inserted”)

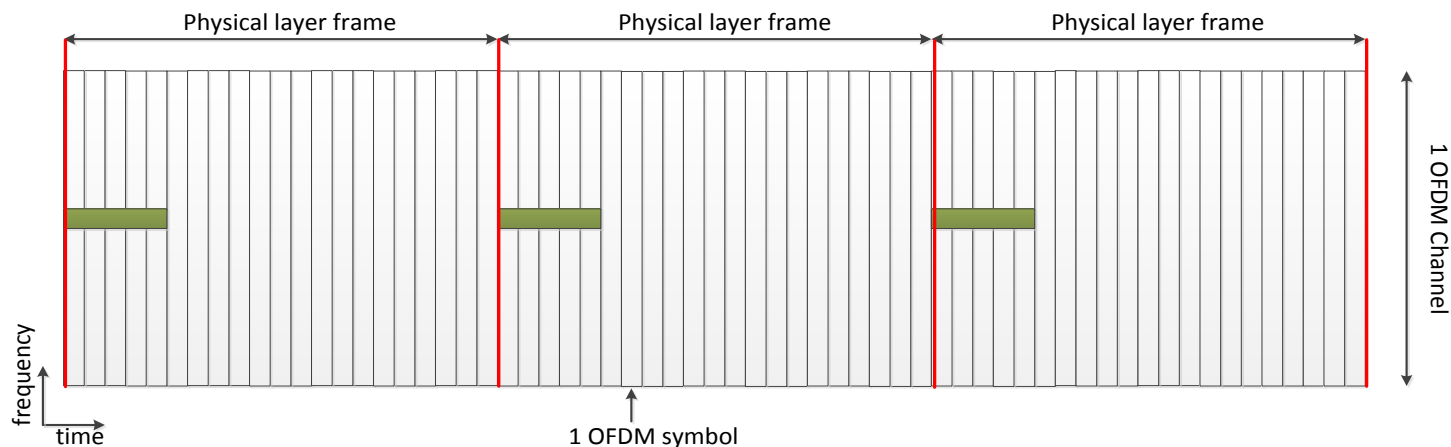


- Likely to reduce the overall overhead (similar to DVB-C2 approach)
- PCCH symbol includes reference signals (RS) for PHY acquisition and PCCH data



Resources Reserved for PCCH - Downstream

- A fixed number of subcarriers within the first few symbols of a PHY frame



- Minimizes the overhead
- Rate adaptation is performed according to the net PHY rate (accounting for all overheads)
 - » MAC is aware of the net PHY rate (accounting for all overheads).
- Moderate increase of buffering requirements at the PHY
 - » No interleaving (worst case): proportional to the PCCH overhead and PHY frame duration in symbols (N_{FRAME})

$$\text{Buffer increase \%} = \text{OH}_{PCCH} \times N_{FRAME} \times 100$$

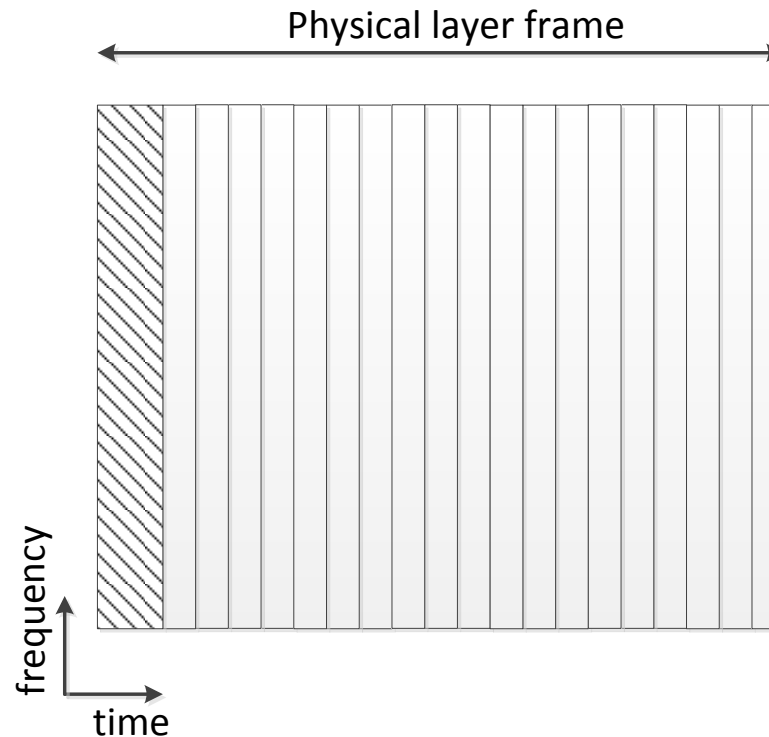
Purpose of PCCH - Upstream

- PCCH Reference Signal: Aids PHY procedures
 - Timing advance estimation for the CNU which is transmitting
 - Assignment of the CNU to a specific US profile (evaluation of US MCS)

- PCCH Data: CNU-specific information
 - PHY address identifying this CNU
 - Supported MCS for DS for this CNU (needed to assign CNU to a specific DS profile)
 - Unusable sub-carriers in DS for this CNU (needed by CLT to determine notches in DS)

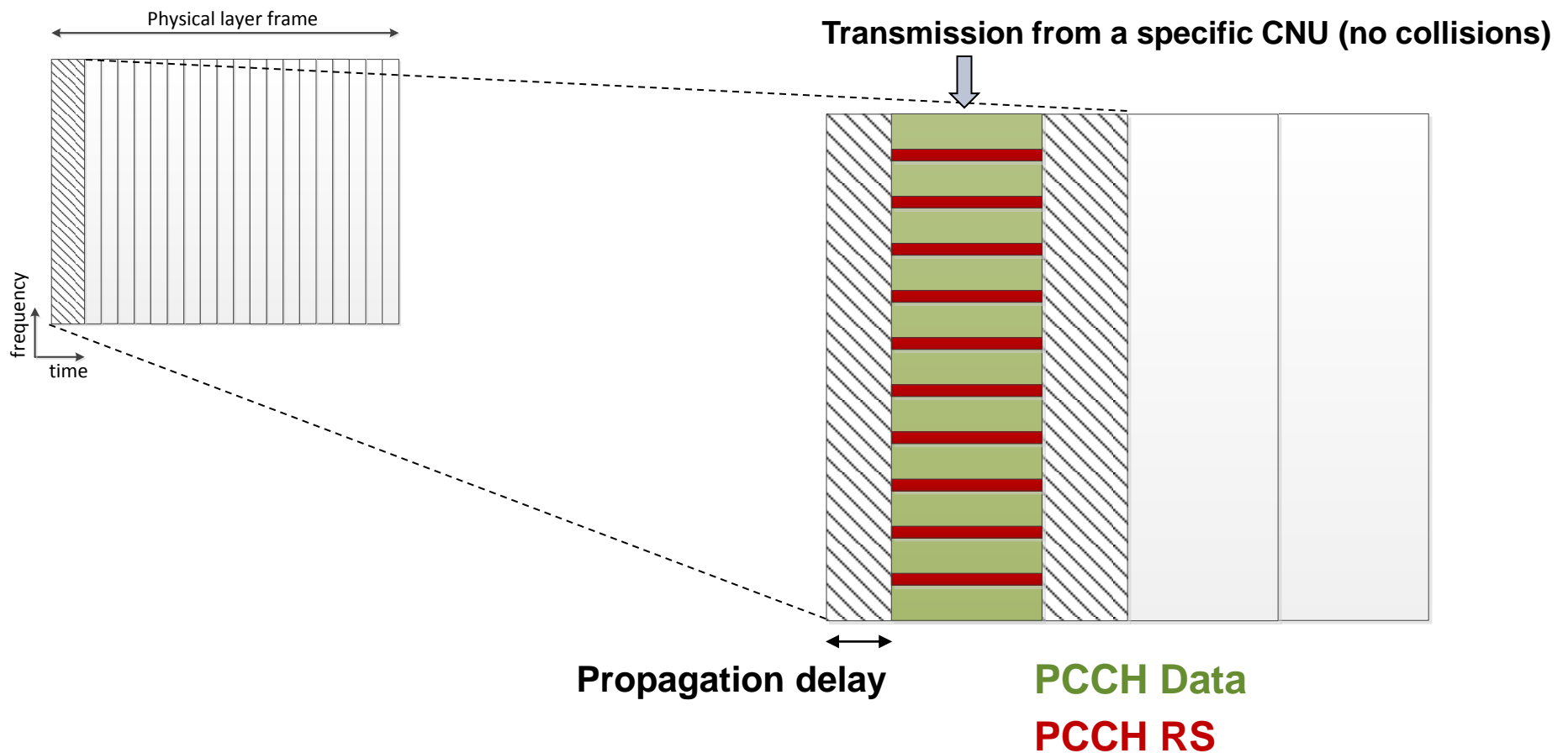
Resources Reserved for PCCH - Upstream

- The upstream PCCH is accessed with a **contention-based protocol**
- Resources need to be reserved for the PCCH in upstream
 - Same options as for Downstream
 - A particularly convenient solution is to reserve a number of OFDM symbols



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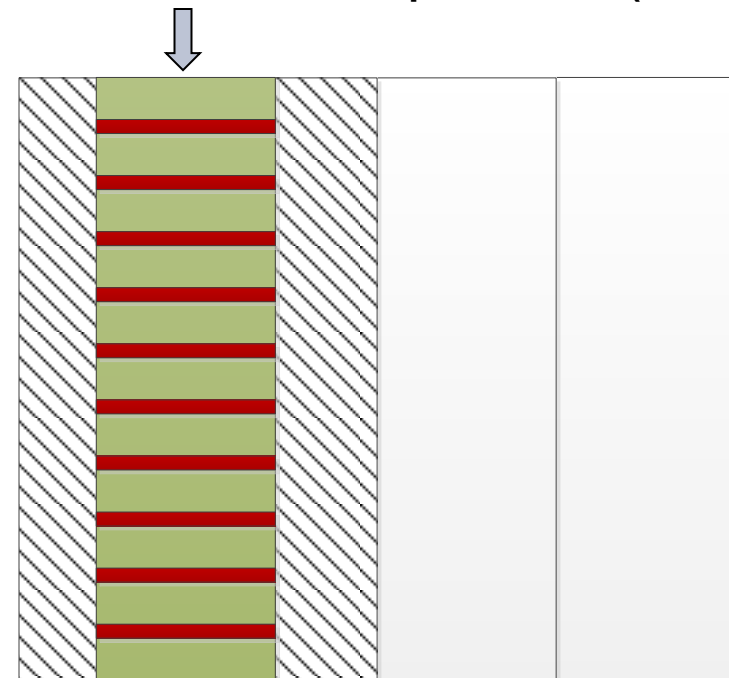
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Features:

- CLT estimates full channel for the user and assigns US profile
- CLT estimates timing advance (to compensate propagation delay)
- CLT estimates optimal power control settings
- CNU is identified after decoding PCCH Data

Transmission from a specific CNU (no collisions)

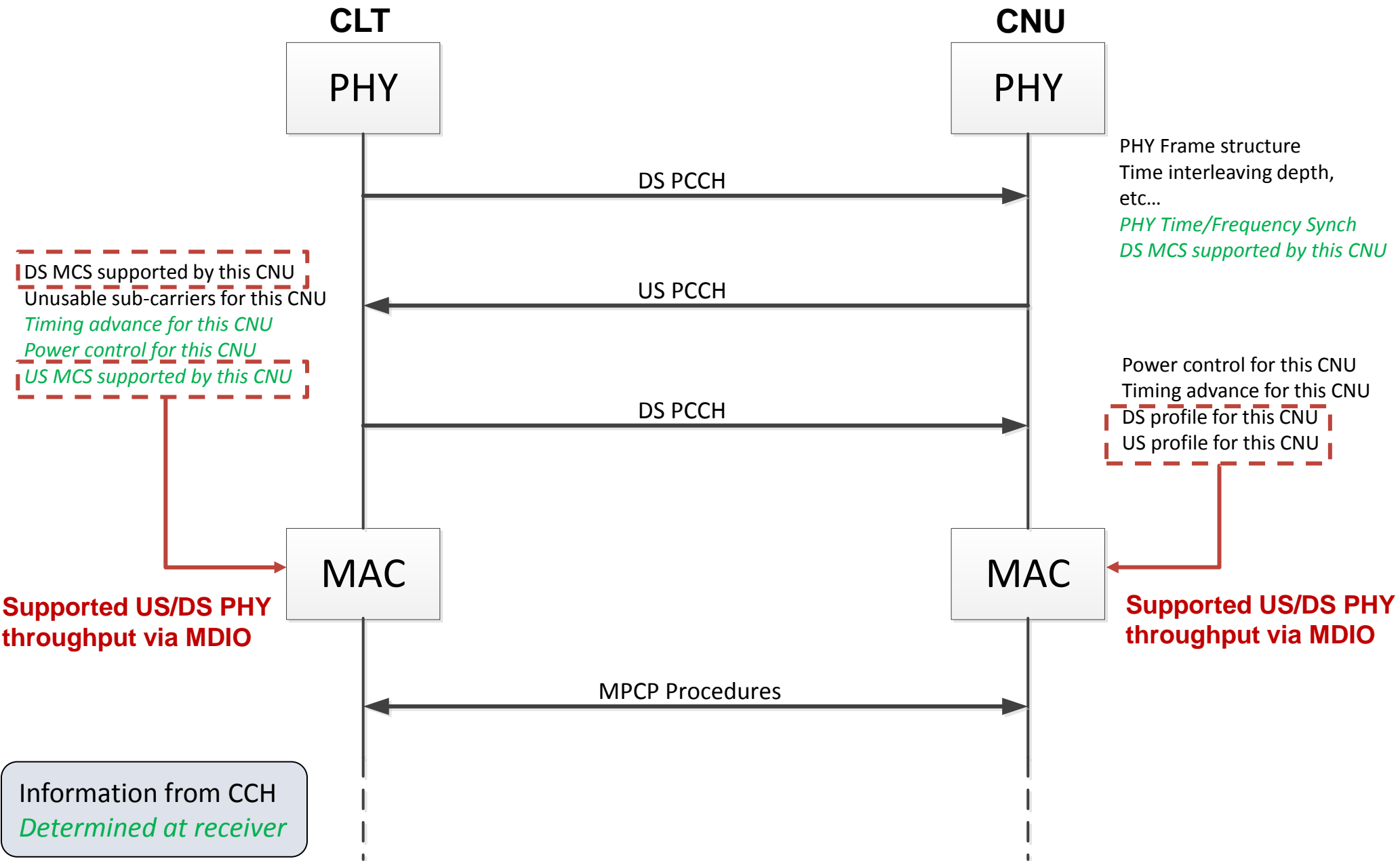


Propagation delay

PCCH Data

PCCH RS

Timeline of PHY Initialization Procedure



Notes on PHY Initialization Procedures

- US and DS PCCH use the lowest MCS
 - e.g., 16 or 64-QAM with strong FEC and time interleaving
 - Further details on PCCH data structure TBD
- DS PCCH has its own time/frequency interleaving

- There is no need for a complex protocol for exchanging information over the PCCH
 - Simple three-way exchange

- DS PCCH is a broadcast channel
 - i.e., information on the PCCH can be decoded by all CNU's
 - It contains both broadcast (network info) and unicast (CNU-specific) information

Proposals

- PCCH is carried only in selected few OFDM symbols within a PHY frame
- Simple PHY initialization procedure (Slide 11)