PHY Link Up

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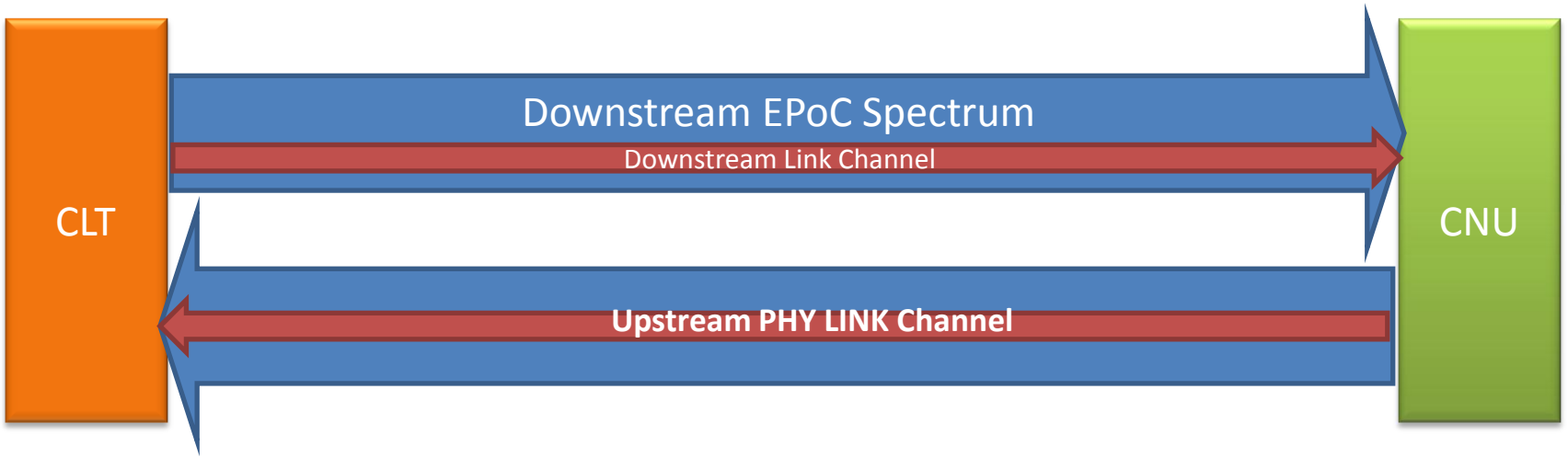
Overview

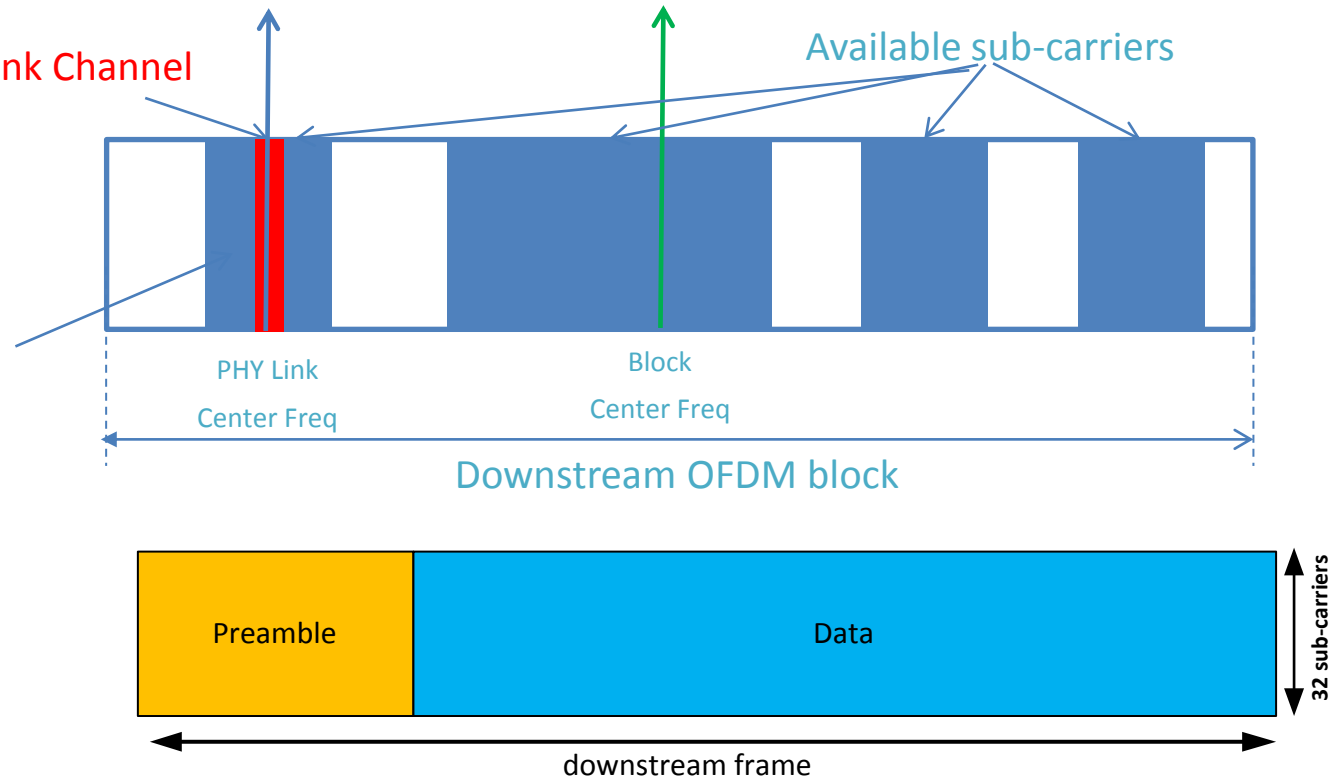
- This presentation provides a baseline proposal for the PHY Link up procedure for EPoC
- It is a continuation of presentations from the 2012 Geneva meeting
  - *EPoC PHY Link and Auto-Negotiation / Ed Boyd et al. Geneva. Sept 2012*
  - *Baseline Proposal for EPoC PHY Layer / Avi Kliger at al. Geneva Sep 2012*
- The PHY Link Up procedure is transparent to the EPON MAC

PHY Link Channel (PLC)



- In-band PHY control channel not visible to MAC
  - Downstream and Upstream
- Purpose
  - PHY link up procedure transparent to MAC
  - PHY link control and management of linked CNUs transparent to MAC
- Link up procedure on PHY level until PHY link is established
- Once link is established MAC starts running messages and data

Downstream PHY Link Channel



- Use 32 subcarriers for the Link Channel
  - < 1% of the 192 MHz OFDM channel
- Aligned to a 6/8 MHz legacy channels
- Uses fixed constellation with own FEC

- A periodic Preamble followed by a block of data
- Preamble can be used as a marker of a Downstream Frame
- Preamble period could be 2.5-5 mSec

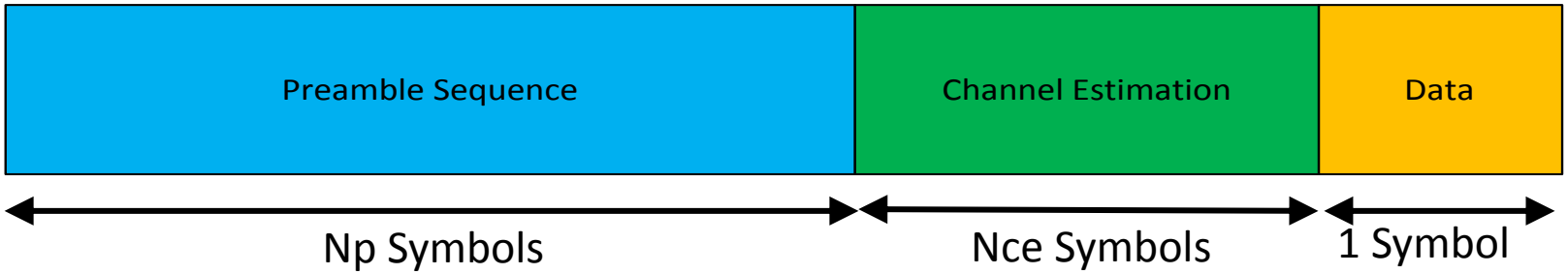
Protection of the PLC in the Downstream

- Narrow band signal is more susceptible to ingress noise or notch in the frequency domain
- Use a single frequency for the PLC
  - Lower modulation order than the lowest allowed for data to improve robustness
    - With this additional protection It is unlikely that a failure will occur in the downstream
  - CLT PHY has the capability to change the
- Alternatively: PLC hops between two frequencies
  - Add frequency diversity
  - May double time of PLC search

Upstream PHY Link Channel

- Use a fixed number of sub-carriers on each upstream OFDMA frame (e.g. 32 sub-carriers)
- A CNU PHY transmits upstream in response to a downstream PHY Link message from the CLT PHY
  - One transmitter per OFDMA frame
  - CLT can specify different sub-carriers for PHY Link response
  - CLT can specify different bit loading for PHY Link response
    - Minimal constellation is QPSK
- Used for upstream signaling and messaging
  - Coarse and fine adjusting upstream symbol alignment
  - Periodic EVM probes
  - Status information from the CNU e.g. EVM per sub-carriers, errors, …
  - Power management related settings

Upstream PHY Discovery Signal ("Broadcast Link Response")



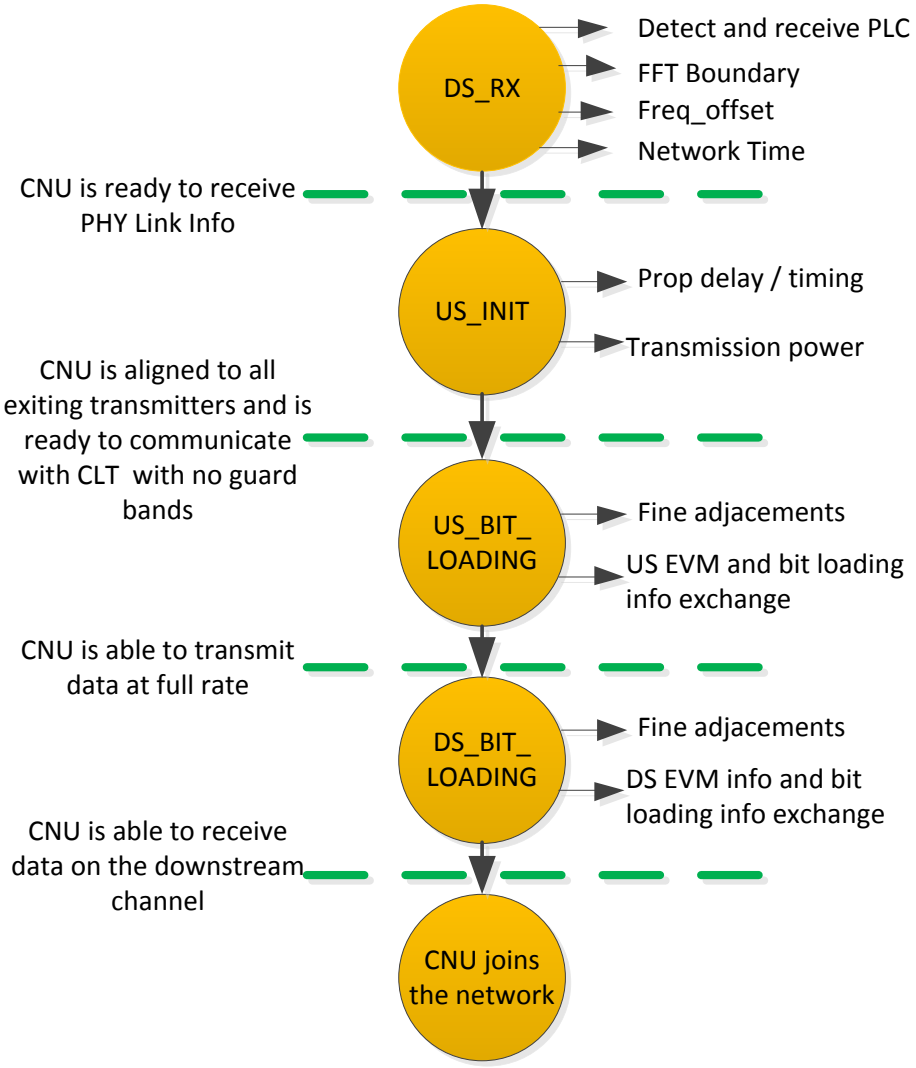
- Used by the CNU to identify itself for initial link process including symbol time alignment and transmit power adjustment
- All upstream transmissions must arrive at the CLT PHY aligned to the same OFDMA time reference and received power

- Uses 32 sub-carriers (1.6 MHz)
- Embedded in the OFDMA Frame
- Sub-carriers are dynamically set by the CLT PHY
- A Preamble is followed by data
  - PHY ID
- Length of Preamble depends on the max propagation delay supported
- May exceed one OFDMA frame

Initial Link Procedure

- Link process has four states
  - Downstream PLC receive
  - Initial upstream alignment
  - Bit loading in the upstream
  - Bit loading in the downstream

  - With multi-profiling Profile
    - Ranging uses the Broadcast (Baseline) Profile
    - Additional profile settings can be done once the CNU is in the network



Initial Link Up State
Receive Downstream PLC

- CNU search for the PHY Link Channel
  - Scan over all possible PLC center frequencies (~ 150 frequencies in a 900 MHz range)
  - A Preamble is sent every downstream frame , assume every ~ 2.5 or 5 mSec
    - one scan over all frequencies 400 to 800 mSec
  - Once a Preamble is detected the CNU can find CP size, FFT boundaries, frequency offset …
- Acquire timing and carrier frequencies
- CNU adjusts its transmit OFDM sampling frequency and carrier frequency to the downstream

Link Up State
Initial Upstream Alignment (Part 1)

- CNU waits for PHY Discovery Opportunity
- CNU transmits Broadcast Link Response
- Wait for acknowledge on the PLC with corresponding PHY ID
- If acknowledge arrives before Time Out the CLT and the CNU can start exchanging alignment commands and responses
- If acknowledge didn’t arrive before Time Out, the CNU will continue sending Broadcast Link Respond signals with back off and power adjustments
- Transmission power is set according to the Initial Transmission Power Control protocol

Link Up State
Initial Upstream Alignment (Part 2)

- Once the CLT PHY is able to receive the Broadcast Link Response it initiates fine tuning protocol using the Node ID
- The CLT PHY sends commands with the corresponding PHY ID over the PLC
  - Fine time alignments times and transmission power setting
- CNU set transmission times and transmission power and responds with an acknowledge message
- CLT continues until it is satisfied with the received performance
- At the end of this state the CNU can send data in the OFDMA frame without using the Broadcast Link Response

Link Up State
Upstream Bit Loading

- For upstream SNR estimations
  - CLT PHY schedules transmission opportunities for the CNU to send Probe Signals over the Upstream PHY Channel
  - Scans all available sub-carriers
  - Once settled CLT PHY exchanges bit loading information with the new CNU over the downstream PLC
- Once CLT PHY is satisfied with the performance of the new CNU it terminates the Upstream SNR Probing state
- At the end of this state the CNU can send data at high throughput

Link Up State
Downstream Bit Loading

- CNU receive PHY information
  - PLC carries all information required to properly receive the downstream transmission over all OFDM channels
- CNU Measures SNR over all sub-carriers
  - Can use pilots and / or data to assess the SNR per sub-carriers
  - Should we specify Probes in the downstream?
  - CNU verifies ability to reliably receive the downstream broadcast profile
- CNU sends SNR information on all sub-carriers
- At the end of this state the CNU is able to receive downstream data in the Broadcast Profile

Adaptation to Multi-Profiling

- This propose Link Up process can work with multi profiling
- Use the Broadcast (baseline) Profile for the Link Up
- PLC carries the Broadcast Profile information
- Other profiling assignments and bit loading updates could be determined when the new CNU is on the network

Probing Signals Considerations

- Downstream
  - SNR per sub-carrier can be measured by averaging slicer SNR over time on data or pilots
  - Do we need special Probe Signals from the Downstream?
    - Rotated Pilots?
    - How would they be transmitted? Rotating PLC?
    - MAC messaging? OAM?
- Upstream
  - CLT scheduled rotating probes over some of the sub-carriers
  - Periodically and when required
  - Bit loading information can be delivered on the PLC? Management messages?

Ranging Requirements Considerations

- Essential to define the Broadcast Link Response and initial alignment
- Maximal round trip time (RTT)
  - For Node+5 1.5 km distance may be enough -> 12 uSec
  - Is this good enough?
- Number of CNUs
- How many may admit simultaneous
  - Would one in a time be sufficient?
- Total time required for a single CNU to join the network
  - First time, after drop or power failure