# Adding Probes and PHY Discovery to Upstream Transmissions

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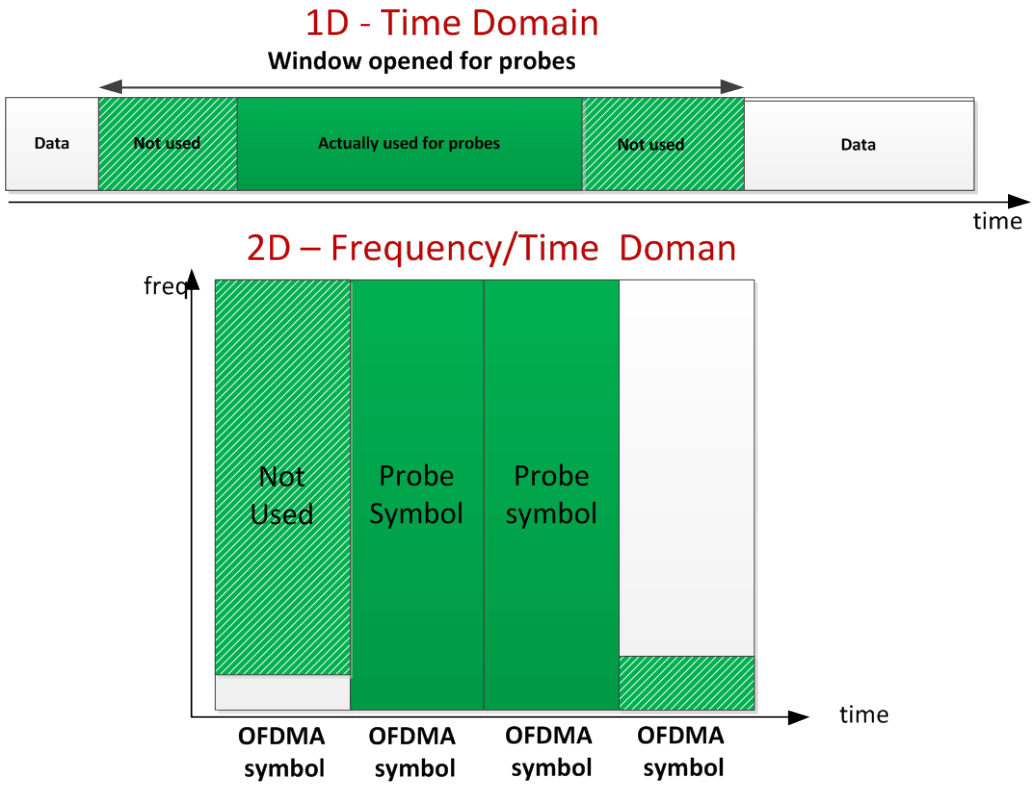
# Issue: Adding Probes and PHY Discovery to Upstream Transmissions

- Upstream probes and PHY Discovery signals ("PHY ranging") are required for the proper reception of data in the upstream direction
  - Probes are required to set and track pre-equalization coefficients and timing offset per CNU
  - PHY Discovery are required for initial roundtrip delay measurements and CNU timing alignments
- These signals consume a number of subcarriers too large to make them a part of the upstream PHY-link channel without a significant loss in the upstream capacity
- Probes and PHY Discovery can be added in MAC level or PHY level

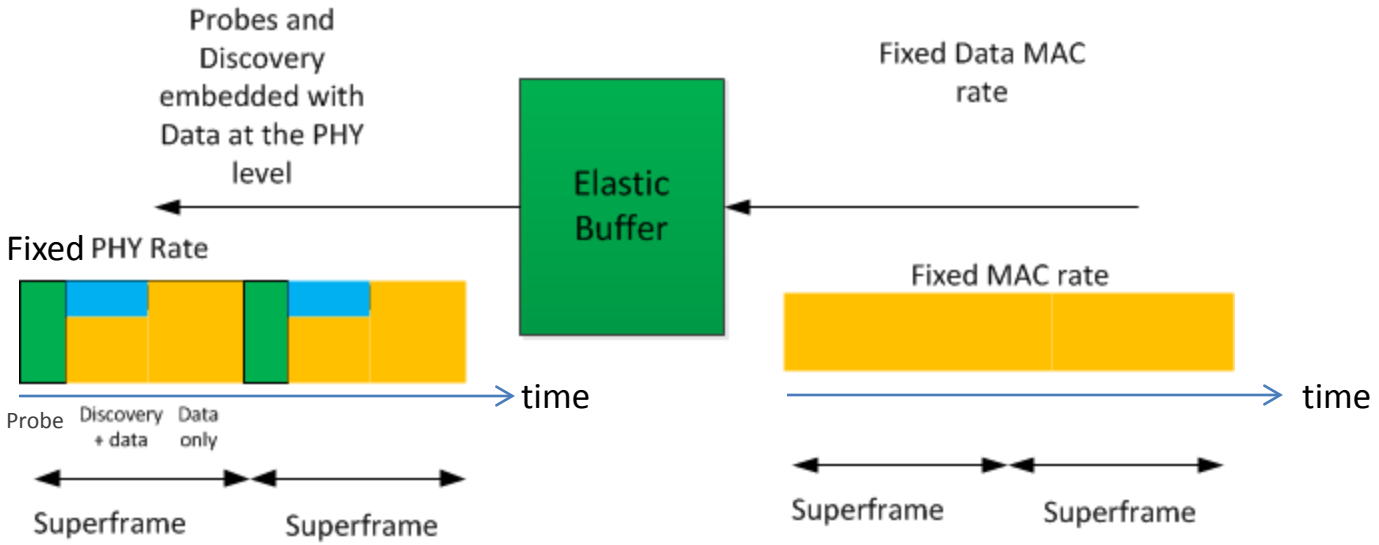
# Probes and PHY Discovery in Upstream Transmissions – Potential Solutions (1)

- At the MAC level
  - E.g. Use time slots that are used by EPON for discovery windows for probes and PHY discovery
  - Should new messages be created
  - As MAC window is not aligned with PHY frames, opened window should be by one symbol longer than the required for the probes



# Probes and PHY Discovery in Upstream Transmissions – Potential Solutions (2)

- At the PHY level
  - Define a framing structure over a longer than a single RB duration
  - MAC rate will be fixed
  - An elastic buffer used to compensate for the jitter iat the PHY level
- This presentation proposes a PHY super framing structure



# PHY Discovery Window and Probes

- PHY Discovery
  - Used for Initial Ranging and Fine Ranging signal intermittently
  - Can run in parallel with other CNUs on the same OFDMA frame
- Fine Ranging
  - Using 128 subcarriers over a single OFDMA frame (8 symbols)
- Initial Ranging
  - Uses 32 subcarriers but over a multiple OFDMA frames (32 symbols) 0r 64 subcarriers with 16 symbols

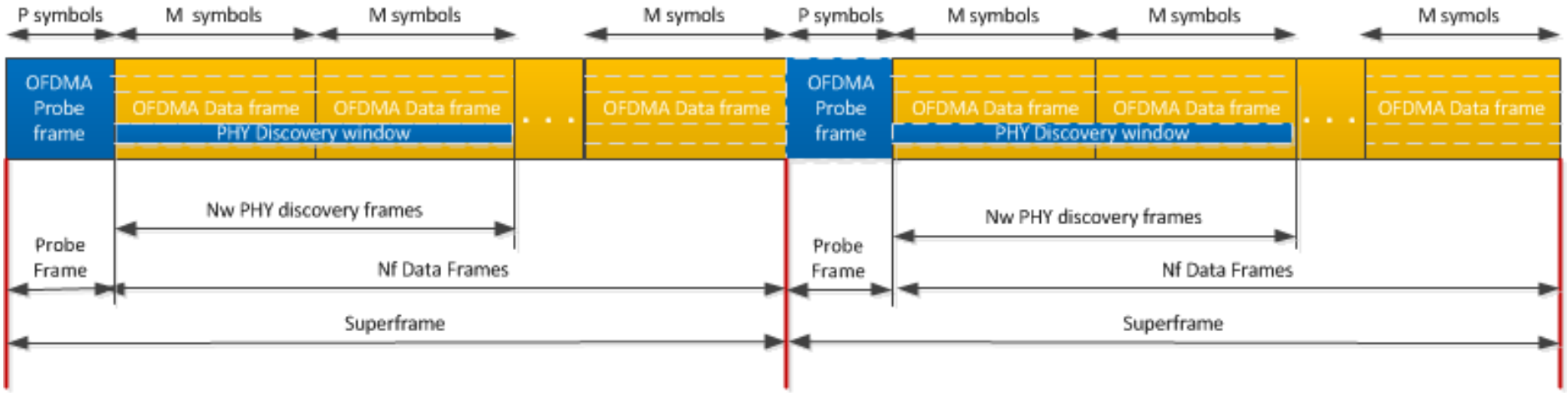
- Probes
  - Used for pre0equalizer coefficients and timing offset measurement
  - Use all subcarriers in a symbol
  - No data transmission during probes
  - Duration: 2 symbols
  - More symbols better upstream receiver performance

- Create a multiframe upstream structure with a fixed MAC overhead that include transmission opportunities for Probes and PHY Discovery window
- MAC overhead is

# Upstream Framing Structure

- Upstream Superframe
  - Could be aligned with PHY Link channel
  - A structure consisting of multiple OFDMA frames
    - Each OFDMA frames is a column of RBs (consists of M-symbols)
  - Each Superframe has a fixed number of data and probe symbols and include a PHY discovery window
    - Number of OFDMA frames times the number of subcarriers (inc. guardband) is fixed
- A Superframe can be configured by the PHY layer management via PLC but do not change during normal operation
- MAC data rate per Superframe is fixed

# Upstream Frame with PHY Discovery Window




- Figure shows two upstream superframes
- P probe symbols followed by Nw*M OFDMA symbols
  - M is the number of symbols in a RB
- Maintain a constant MAC data rate per upstream frame using padding (or zeroed valued RBs)

# Probes and PHY Discovery Window Examples

- Two probe symbols are required
- In this example a Superframe consists of 92 or 384 data symbols plus 2 probe symbols to create a frame length of 2.1–8.7 mSec
- Probe overhead is between 0.5-2 %
- PHY discovery overhead is between 0.65 % and 2.3 % for bandwidth of 85 MHz and 24 MHz
- Additional latency due to data buffering during probes is 45 uSec

| | | | | |
|---|---|---|---|---|
| Upstream bandwidth (MHz) | 85 | 85 | 24 | 24 |
| CP size | 2.5 | 2.5 | 2.5 | 2.5 |
| Number of CNUs | 64 | 64 | 64 | 64 |
| Number of subcarriers | 1700 | 1700 | 480 | 480 |
| Number of data symbols / frame | 384 | 92 | 384 | 92 |
| **Probes** | | | | |
| Number of probe symbols / frame | 2 | 2 | 2 | 2 |
| **PHY Discovery** | | | | |
| Subcarriers per PHY Discovery window | 32 | 128 | 32 | 128 |
| Number of symbols in PHY discovery window | 32 | 8 | 32 | 8 |
| **Overhead and duration** | | | | |
| Upstream frame duration (mSec) | 8.685 | 2.115 | 8.685 | 2.115 |
| Additional latency (uSec) | 45 | 45 | 45 | 45 |
| Fixed overhead per multiframe frame (probes) | 0.52% | 2.13% | 0.52% | 2.13% |
| Fixed overhead per multiframe (PHY discovery) | 0.16% | 0.65% | 0.56% | 2.32% |
| PHY discovery opportunity rate per CNU (Sec) | 0.56 | 0.14 | 0.56 | 0.14 |
| Probe opportunity rate per CNU (Sec) | 0.56 | 0.14 | 0.56 | 0.14 |

- This is an example, parameters can be changed to find the best trade off

# MAC Rate with Variable Bit Loading (1)

- Actual overhead due to PHY discovery may change with different allocations with variable bit loading
- Reduce the MAC rate to the minimal number of bits per upstream frame available with PHY Discovery
    - In this example it is 626 bits per superframe
  - Pad bits at the end of the superframe if required, 647-626 in the example

PHY Discovery REs example (yellow)

| subcarriers | Variable Bit Loading map | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 12 | 12 | 12 | 12 | 12 | 12 | 12 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |
| | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 6 | 6 | 6 | 6 | 6 | 6 | 6 | |
| Capacity | 85 | 85 | 85 | 98 | 98 | 98 | 98 | **647** |

Worst case allocation (yellow)

| subcarriers | Variable Bit Loading map | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 12 | 12 | 12 | 12 | 12 | 12 | 12 | |
| | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |
| | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |
| | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 6 | 6 | 6 | 6 | 6 | 6 | 6 | |
| Capacity | 78 | 78 | 78 | 98 | 98 | 98 | 98 | **626** |