Adding Probes and PHY Discovery to Upstream Transmissions
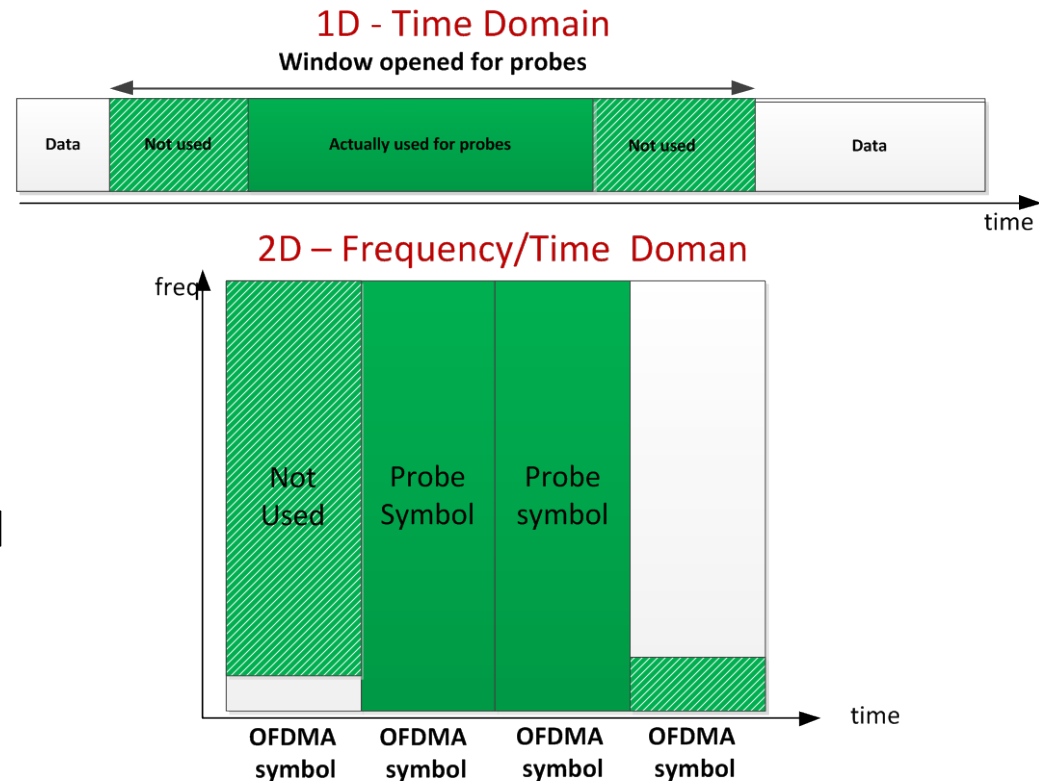
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Issue: Adding Probes and PHY Discovery to Upstream Transmissions

- 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

1D - Time Domain
Window opened for probes

| Data | Not used | Actually used for probes | Not used | Data |

time

2D – Frequency/Time Doman

freq

| Not Used | Probe Symbol | Probe symbol | |

OFDMA symbol | OFDMA symbol | OFDMA symbol | OFDMA symbol

time

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 at the PHY level
- This presentation proposes a PHY super framing structure
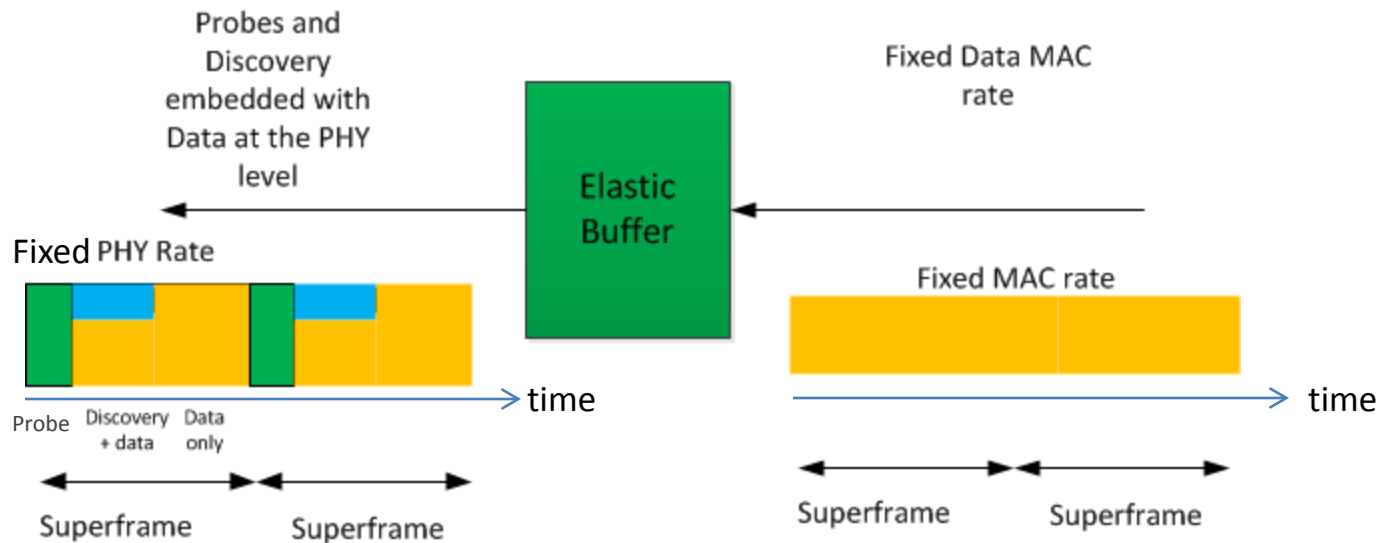
PHY Discovery Window and Probes

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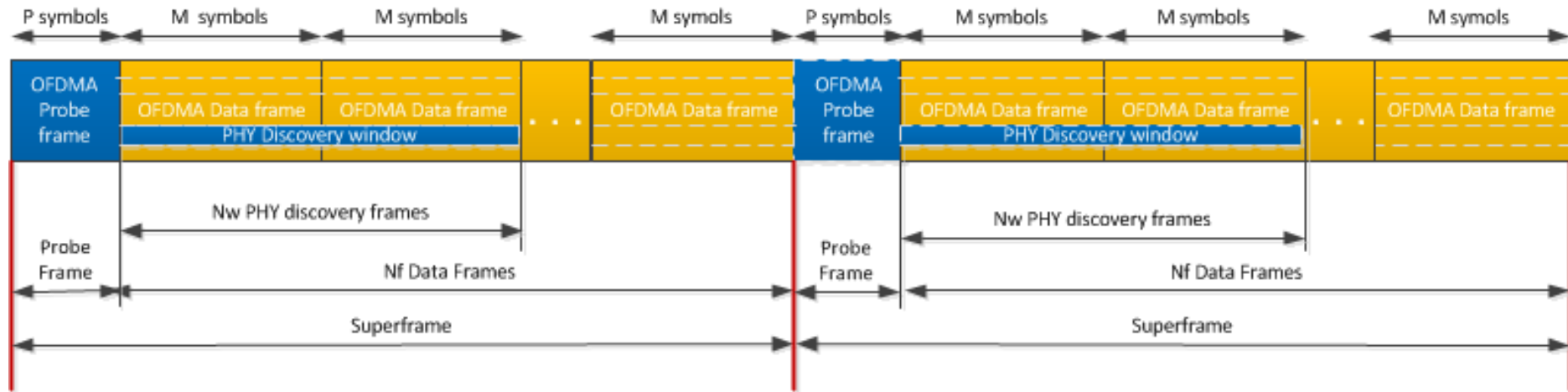
- Figure shows two upstream superframes
- P probe symbols followed by Nw*M OFDMA symbols
  - M is the number of symbols in a RB
- Maintain a constant MAC data rate per upstream frame using padding (or zeroed valued RBs)

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)

	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)

	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**