Feasibility of Simple Superframe Structure for EPoC Upstream

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Problem in Focus

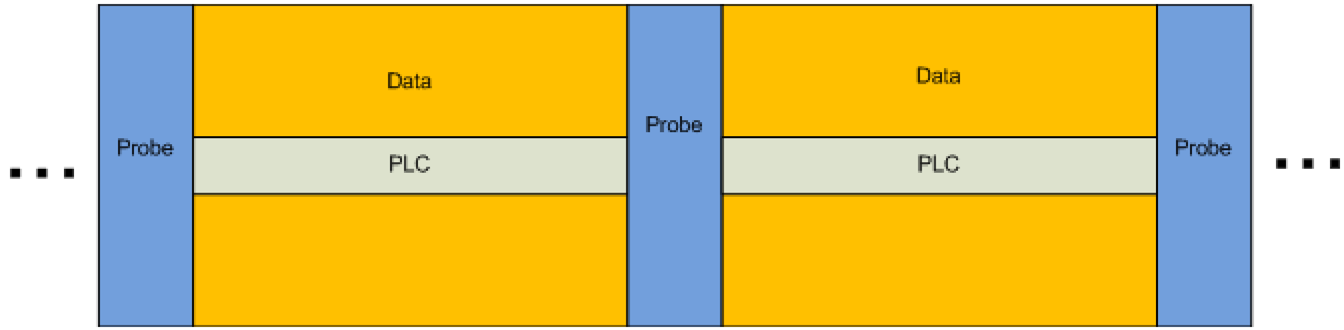
- Two proposals of superframe structure
  - Configurable superframe: varied for initial ranging, fine ranging. Varied data rate
  - One uniform superframe: constant data rate
- Two design philosophies
  - OFDM(A) technology
    - Dynamic rate adaptation
    - 2D resource allocation.
    - Optimize system capacity and utilization of resources
  - Ethernet (EPON)
    - Uni-directional layered structure, no handshaking between MAC and PHY
    - Data rate stays constant with infrequent reconfiguration
    - Extremely low jitter
- Our goal is Ethernet (EPON) MAC + OFDM(A) PHY
  - No cross-layer feedback.
  - Very limited rate adaptation and 1D channel allocation
  - Have to use more overhead to trade off flexibility

EPoC Design Methodology

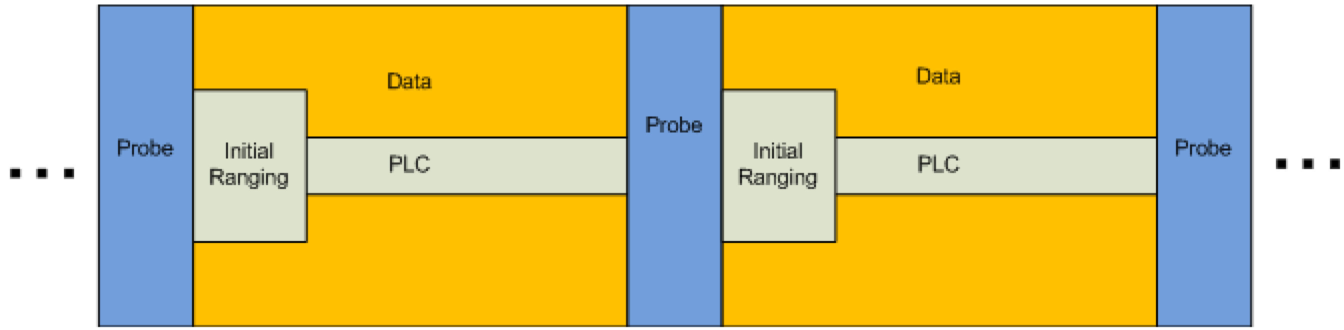
- The goal is to use EPON MAC + OFDM(A) PHY
- EPoC should adopt a hybrid design methodology
  - Static configuration for limited number of parameters.
  - Constant data rate when configuration is completed.
  - Zero or extremely low nominal jitter
- Therefore, EPoC Upstream superframe needs to deliver constant data rate
  - Static superframe structure is desired.

Example of Static Superframe Structures

Example 1: No dedicated area for ranging (Preferred superframe)



Example 2: Dedicated area for ranging



Key Elements for Superframe Structure

- Static overhead area
  - Probe symbols
  - PLC
- Initial and fine ranging areas are non-persistent.
- Can we fit initial and fine ranging into the persistent areas?

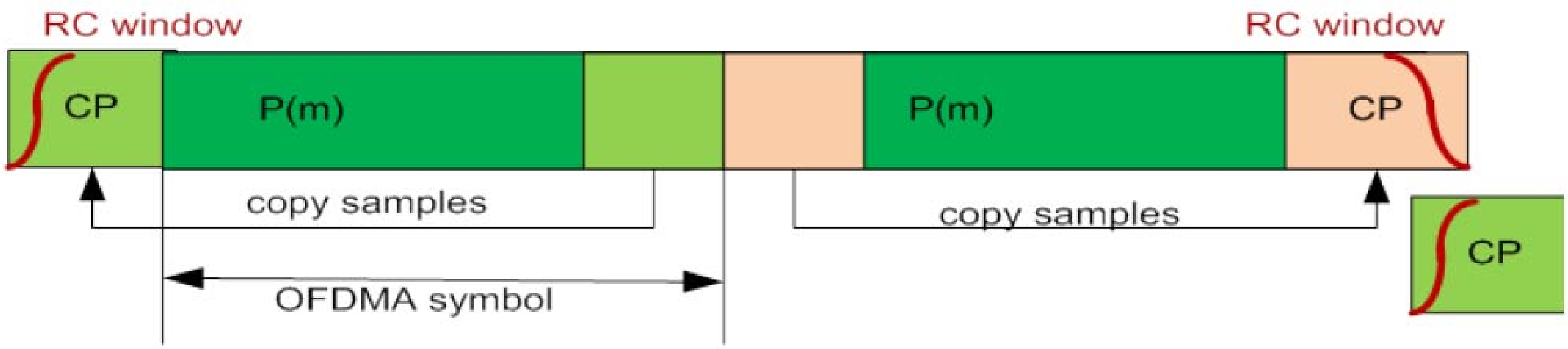
What does PHY Ranging Do?

- Adjust CNU transmit timing and power.
- Allow for basic information exchange
  - MAC address, CNU_ID
  - Channel bonding?
- Most PHY parameter exchange through PLC after ranging
- Registration of new CNU into network should be done through MAC discovery process
- We should keep the ranging message as short as possible.

Current Ranging Parameters

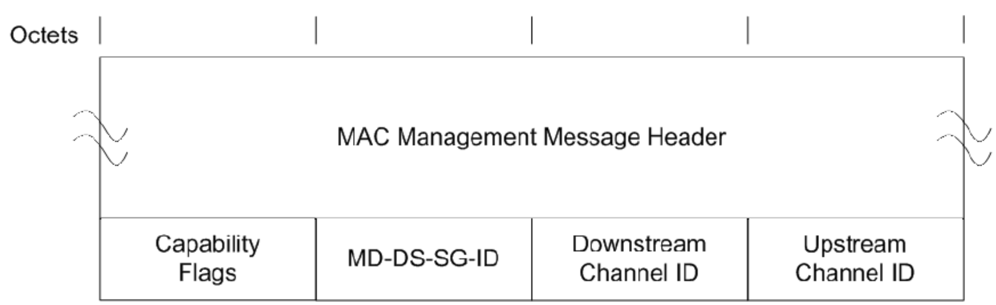
- Assume that CNUs has max RTT difference 200us.
- Initial ranging
  - 32 subcarriers: residual timing offset ~0.625us or 128 sample (worst case, actual implementation may have better numbers)
  - Preamble: 128 bit PRBS sequence, 4 slots or 8 symbols (A slot means an admission slot)
  - Payload:
    - MAC address: 48 bits
    - Channel ID: 1 byte???
      - For channel bonding? In D3.1, this is associated with both PHY and MAC. How do we use this in EPoC?
    - FEC: 24 bit CRC + (128,80) LDPC

Structure of Admission Slot



Current Ranging Parameters -- II

- Fine ranging
  - 128 subcarrier: residual timing offset ~0.156us
  - Preamble: 128 bit PRBS, 1 slot (2 symbols)
  - Payload:
    - 34 bytes??? This is the length of B-INIT-RNG-REQ MAC management message in D3.1.



Idea for Ranging Parameters

- Initial ranging is to reduce the huge RTT difference (200us) down to a value that works for fine ranging.
- The final residual timing offset is determined by fine ranging.
- Fine ranging may also be divided in multiple steps.
- The payload message of fine ranging may need to be redefined and may be short.

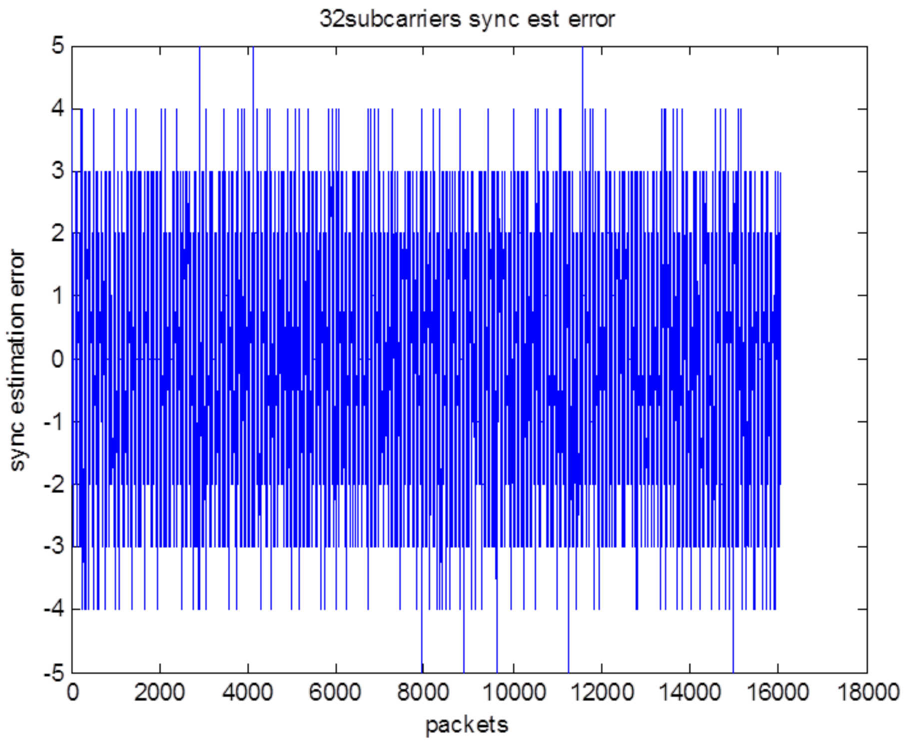
Example of Initial Ranging Parameters for Static Superframe

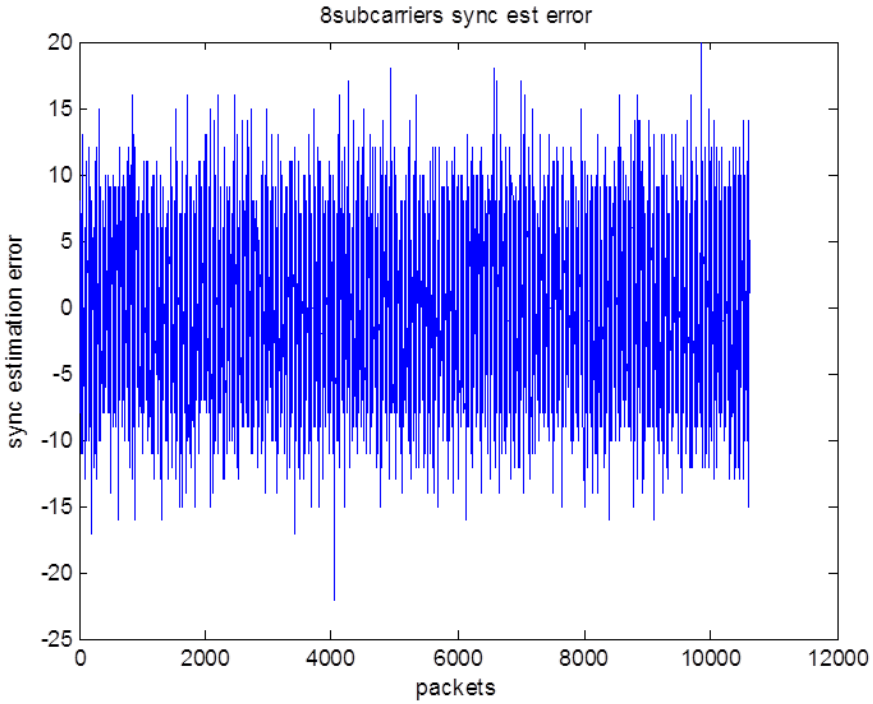
- Initial ranging:
  - 8 subcarriers as PLC, residual RTT timing offset 2.5us or 512 samples.
  - Preamble: 32 bits PRBS sequence, 4 slots (8 symbols)
    - Only need 1e^-3 detection error rate for SNR=2dB
  - Payload: 128 bits, 16 slots (32 symbols)
  - Total length: 40 OFDM Symbols
- Fine ranging parameters need to cover 2.5us RTT ambiguity as well as fine ranging payload.
  - 128 subcarriers, residual RTT timing
  - Preamble: 128 bits PRBS sequence, 1 slot (2 symbols)
  - Payload: 128 bits BPSK, 1 slot (2 symbols)
  - Total 4 OFDM symbols fit into a 5 OFDM symbol probing area

Simulation On Initial Ranging Band

- Assume cross-correlation in time domain
  - Ideal receiver, used as a performance bound for actual implementation
- Simulation settings:
  - No micro reflection channel
  - SNR = 7dB
  - Initial ranging band: 32 carriers vs 8 carriers

Simulation Results

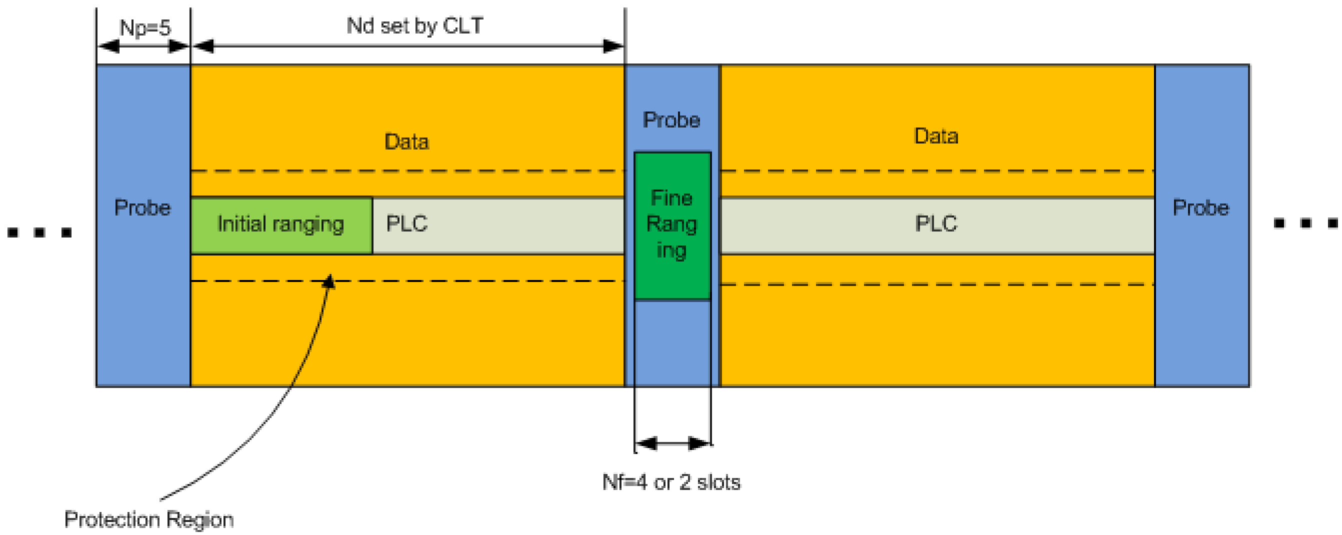




32 subcarriers ranging band
Max timing error 5 samples

8 subcarriers ranging band
Max timing error 20 samples

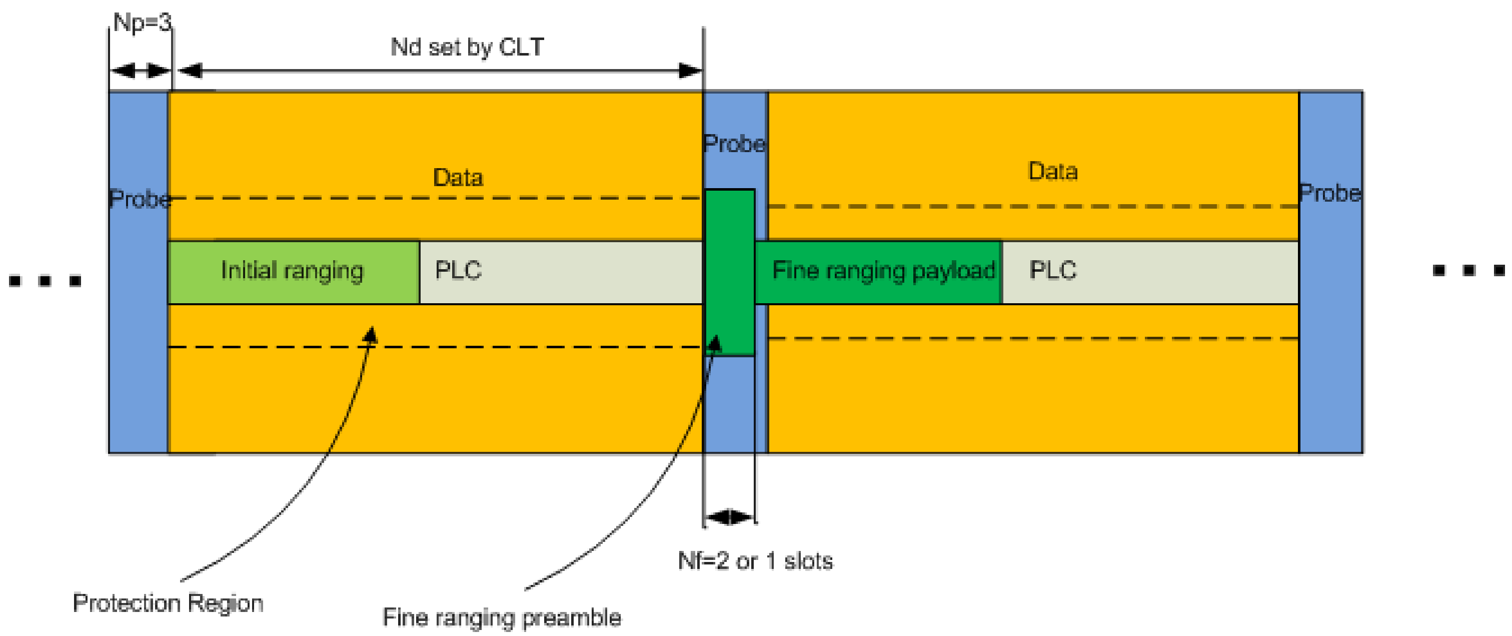
Example of Ranging Area for Static Superframe Structure



Another Example of Placement of Fine Ranging

- Fine ranging payload does not need to cover all the frequencies as for preamble
- Fine ranging payload can use PLC just like initial ranging.
  - Preamble: 128 subcarriers, 128 bit PRBS, 1 slot or 2 OFDM symbols
  - Payload: 8 subcarriers, 128 bit, 16 slots or 32 OFDM symbols
  - 2-symbol Preamble can fit in 3 symbol probe area.

Another Example of Placement of Fine Ranging



What is the max RTT difference?

- CNUs located on different sides of HFC networks
  - In HFC network, delay from cable is less than 3%
  - The max one-way delay for fiber is determined by an effective index of reflection, e.g 1.5 for single mode fiber.
  - DOCSIS specifies 161km for max fiber run, amounts to about 0.8ms one-way delay.
  - Previously the TF assumes a 1ms one-way delay for CNUs on both ends of HFC networks, which is sufficient for the case
- The use case that EPoC CLT needs to manage CNUs on both ends of HFC networks is not justified by MSOs.

What is the max RTT difference?-II

- CNUs located on the far end of HFC networks
  - Only need to consider coaxial network delay
  - The max one-way delay for coaxial cable is determined by the relative dielectric constant, which further determines the propagation velocity w.r.t. c (light speed)
  - The table in the Appendix shows a worst case about 65.9% of c.
  - The propagation delay for above cable is 1.54ns/ft
  - A total of 20km amounts to 101us.
  - The assumption of 200us RTT difference in this presentation has 100% margin. Maybe a 30% margin is enough.

Guard Band for the Ranging

- During Ranging process, the asynchronous ranging message will generate interference to normal data.
- We need to study how much interference there is and how to design the guard band.

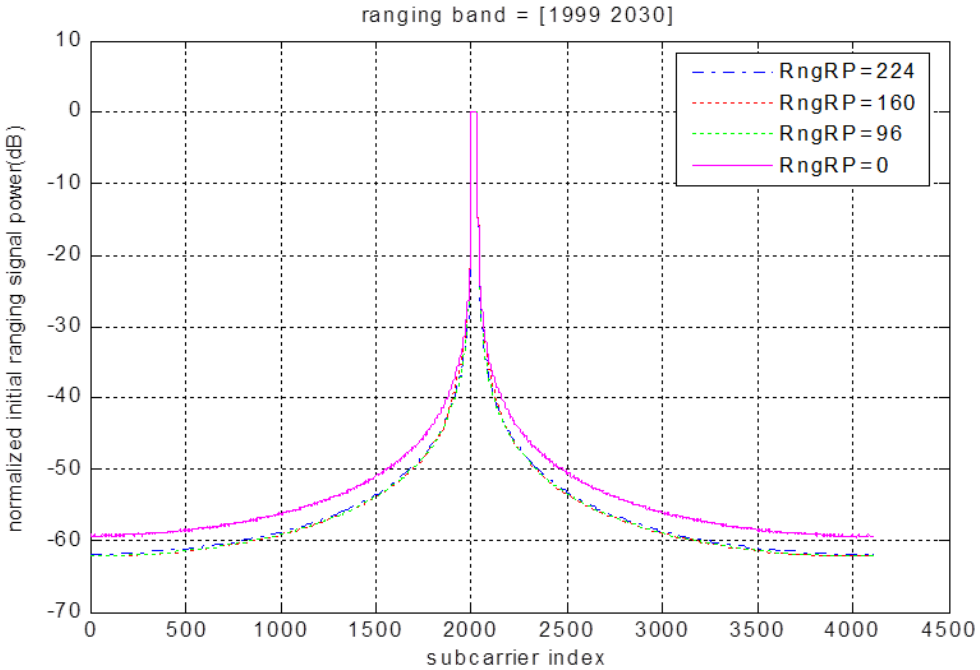
Inter-carrier Interference (ICI) Due to Ranging Message

- ICI is affected by the Roll-off Samples Nrp.

Cyclic Prefix Samples (N_{cp})	Roll-Off Samples (N_{rp})
96	96
128	128
160	160
192	192
224	224
256	224
288	224
320	224
384	224
512	224
640	224

ICI Due to Ranging Message

- The ICI simulation setting:
  - Ranging CP samples=512; RngRP= Ranging roll off period samples
  - Random RTT delay=[0,6500], larger than one symbol
  - Normalization method: per-carrier power/average(ranging band power)

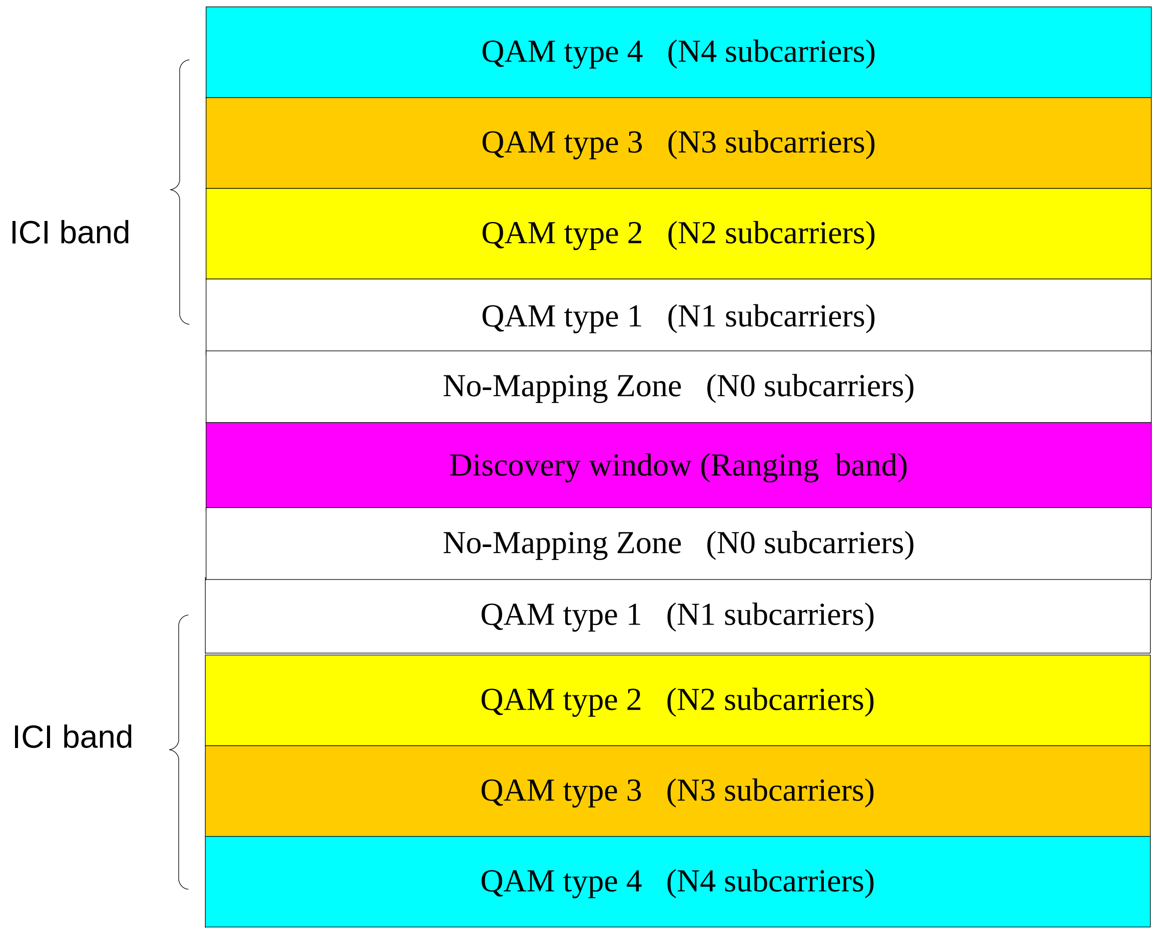


ICI Due to Ranging Message

- The ICI attenuation (dB) of different roll off samples

Carrier offset	1	2	3	4	5	6	7	8	9	10
Rp=0	-9.9	-14.0	-16.3	-17.8	-19.0	-20.0	-20.9	-21.6	-22.2	-22.9
Rp=224	-9.9	-14.3	-16.8	-18.6	-20.0	-21.2	-22.3	-23.2	-24.0	-24.8
Carrier offset	11	12	13	14	15	16	17	18	19	20
Rp=0	-23.4	-23.9	-24.3	-24.8	-25.2	-25.6	-25.9	-26.3	-26.6	-26.9
Rp=224	-25.5	-26.1	-26.7	-27.3	-27.8	-28.2	-28.7	-29.1	-29.4	-29.8
Carrier offset	21	22	23	24	25	26	27	28	29	30
Rp=0	-27.2	-27.5	-27.8	-28.1	-28.3	-28.5	-28.8	-29.0	-29.3	-29.5
Rp=224	-30.1	-30.4	-30.7	-31.0	-31.2	-31.5	-31.7	-32.0	-32.2	-32.4
Carrier offset	31	32	33	34	35	36	37	38	39	40
Rp=0	-29.7	-29.9	-30.1	-30.3	-30.5	-30.7	-30.9	-31.0	-31.2	-31.4
Rp=224	-32.6	-32.8	-33.0	-33.2	-33.4	-33.6	-33.8	-34.0	-34.2	-34.3
Carrier offset	41	42	43	44	45	46	47	48	49	50
Rp=0	-31.6	-31.7	-31.9	-32.1	-32.2	-32.4	-32.5	-32.7	-32.8	-33.0
Rp=224	-34.5	-34.7	-34.8	-35.0	-35.1	-35.3	-35.4	-35.6	-35.7	-35.9

Guard Band Design



Example of Guard Band Design

- The guard band bit loading mask
  - N0=5; No mapping
  - N1=5; highest order modulation:32QAM
  - N2=5; highest order modulation:128QAM
  - N3=5; highest order modulation:256QAM
  - N4=10; highest order modulation:512QAM
  - Others, any order modulation
- EPoC needs to specify MDIO registers to program the guard band bit loading mask.

Summary

- A constant number of bits in a superframe is key to maintain a constant rate between PMA and PCS.
- Without constant bit rate, the jitter of gate and report message in MPCP will be out of control and violate the principle of MPCP.
- It is feasible to achieve a constant number of bits within superframe.
- The main purpose of this talk is to show the feasibility. The particular values of examples are not final.

Appendix

Dielectric Material	Time Delay (ns/ft)	Propagation Velocity (% of c)	Propagation Velocity (formula needs single value) (% of c)	Time Delay ns/ft Worst case	Speed of light in free space
Solid Polyethylene (PE)	1.54	65.9	65.9	1.5417E-09	1.016E-09
Solid Teflon (ST)	1.46	69.4	69.4	1.4640E-09	
Foam Polyethylene (FE)	1.27	80	80	1.2700E-09	
Air Space Polyethylene (ASP)	1.15-1.21	84-88	84	1.2095E-09	
Air Space Teflon (AST)	1.13-1.20	85-90	85	1.1953E 09	
Foam Polystyrene (FS)	1.12	91	91	1.1165E-09	

Reference: http://www.gpssource.com/files/Cable-Delay-FAQ.pdf

Straw Poll #1

- The EPoC upstream shall have initial ranging message sent within the PLC band and have fine ranging preamble sent within probe regions.

Yes:

No:

Abstain:

Straw Poll #2

The EPoC shall specify MDIO registers to program the bit loading mask, which is used to protect data transmission from interference during initial ranging process.

Yes:

No:

Abstain: