Upstream 10G Sync Pattern/Delimiter for reducing burst mode receiver sensitivity penalty

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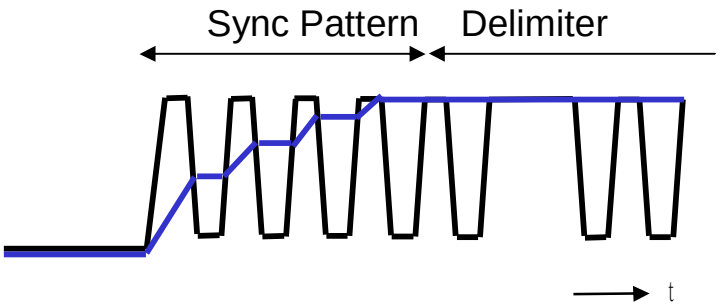
Back ground of Proposal

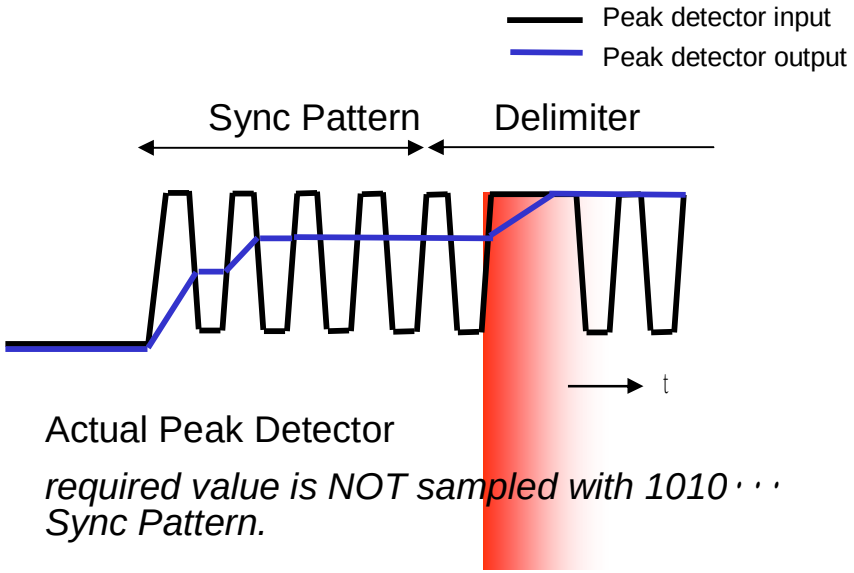
- Upstream 10G power/jitter budget is extremely tight.
- 1010 ···· Sync Pattern defined in D1.3 causes ”burst penalty” in receiver sensitivity/timing margin to affect power/jitter budget.
  - Error in peak detector
    - Employing peak detectors in TIA-AGC and LIM, instead of average detector or AC coupling, would be necessary in order to obtain less loose burst mode timing with $T_{receiver\_settling}$ of <400ns.
      - *Ex. of TIA,LIM architecture: 3av_0711_benamram_1.pdf, 3av_0803_nagahori_1.pdf*
    - Difference in detected/held peak value for Sync Pattern and other area causes “burst penalty”, that means receiver sensitivity degradation just after Sync Pattern.
    - This problem was revealed in early stage of G-PON at Upstream 1.2G. At G-PON, using Sync Pattern other than 1010, such as 1100, was one of the solution to solve the issue, because Sync Pattern is not defined ITU-T G.984 spec.
  - Phase error in burst-mode CDR
    - CLK phase with extracted from 1010 pattern is different from that from other data area, due to difference in group delay velocity for 1010 and random patterns at transmitter, optical fiber, receiver amplifier, and CDR itself.
    - This phase error reduces timing margin at the data just after Sync Pattern until CDR locks to appropriate phase to data area.

Effects on Peak Detector



Ideal Peak Detector

required value is sampled with 1010 · · · Sync Pattern.

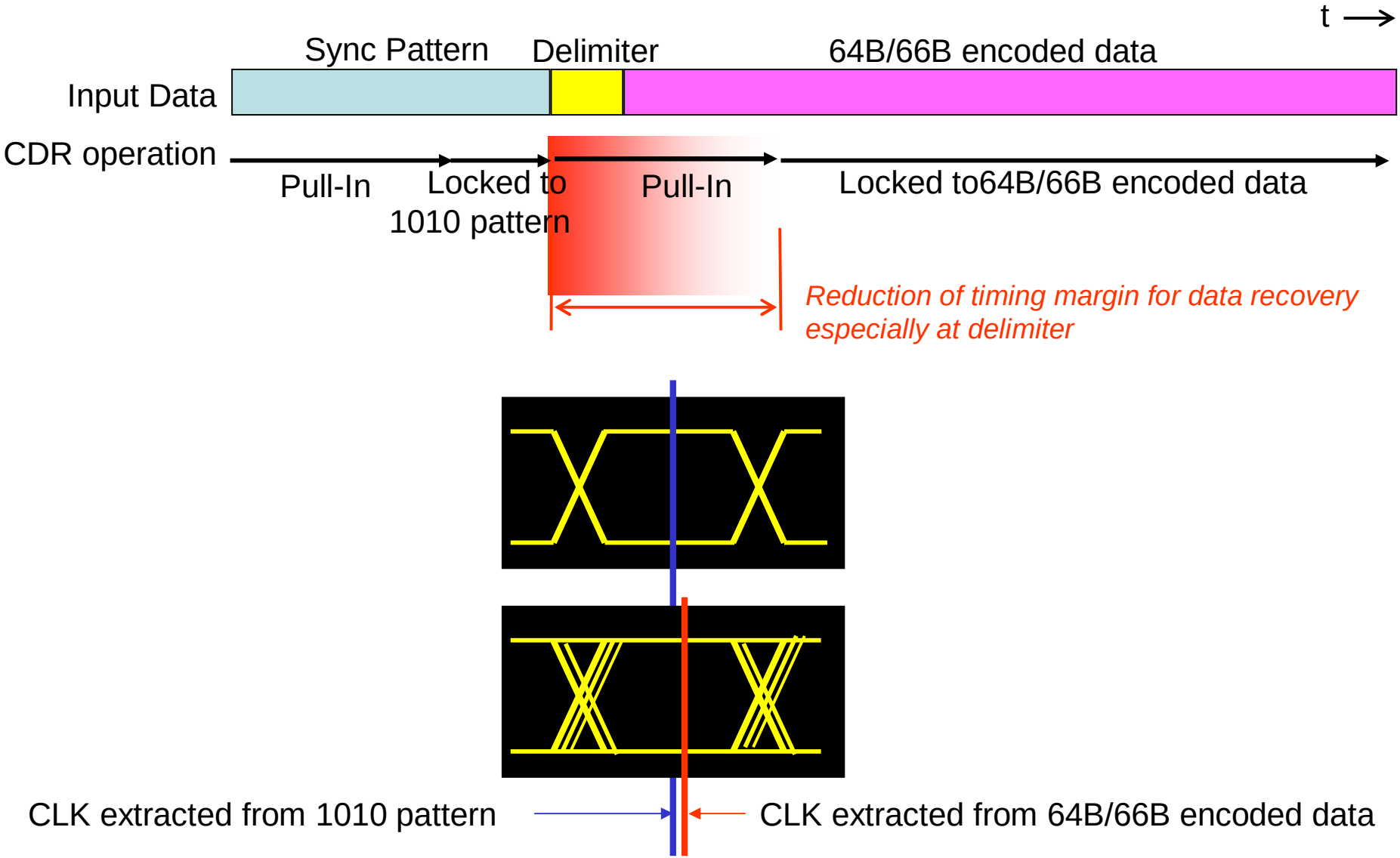


Actual Peak Detector

required value is NOT sampled with 1010 · · · Sync Pattern.

Degradation in receiver sensitivity especially at Delimiter

Effects on CDR



Requirement for Sync Pattern

- Including 010, 101, and CID with its length of larger than several bits.
- Not to affect $T_{receiver\_settling}$ and T_{cdr}.
- DC balance of 1/1.
- Easy to implement.
  - Repetition of fixed pattern with its length that equals to a divisor of 66 is preferable, if we consider easy implementation with 64B/66B encoder/decoder.
- If FEC codeword synchronization performance cannot be maintained with a combination of a proposed Sync Pattern and a Delimiter defined in D1.3, other delimiter may be applied.

Proposal 1: Sync Pattern

D1.3	Binary	1 0101010101 0101010101 0	(at 22bits)
Proposed	Binary	1 0011111010 1100000101 0	(22bit unit interval)
	Hex	4 BE 06 95 AF 41 E5 6B 50	(3 x 22bits)

	D1.3	Proposed
Maximum CID(1)	1	5
DC Balance	33/33(1/0)	33/33(1/0)
Number of rise/fall edge in 400ns(2)(3)	4000	2200

(1)Requirement for bandwidth of Peak Detector

Relaxed to 1/5 compared with D1.3 Sync Pattern.

(2)Effect on $T_{receiver\_settling}$

No impact on $T_{receiver\_settling}$, because it is determined by acquisition time of capacitor in peak detectors, integrators, or AC coupling, that is not affected by the number of edge.

(3)Effect on T_{cdr}

Reduced number of edge by a factor of 0.55 enlarges pull-in time, but there are 8 times larger number of edge compared with that for 802.3ah. There is still enough number of edge.

Effects on Delimiter Performance

	Sync Pattern	Delimiter	Minimum Humming Distance
(1)	D1.3 (1010)	D1.3	32
(2)	Proposed	D1.3	21
(3)	Proposed	Complement of Delimiter 3 and 5 in 3av_0711_leung_1.pdf	27

- Performance on FEC codeword synchronization is not maintained with a combination of the proposed Sync Pattern and a Delimiter defined in D1.3 or in 3av_0711_leung_1.pdf.
- Another Delimiter should be applied.

Proposal 2: Delimiter

Delimiter 1

Binary **10 1111 0111 0000 1000 0001 0100 0011 0011 1001 1011 1110 0001 1011 0101 0110 0101**

Hex **4 EF 10 28 CC D9 87 AD A6**

Minimum Hamming Distance = 30

Distribution of Hamming Distance

$A_{30} = 17$ $A_{31} = 10$ $A_{32} = 14$ $A_{33} = 8$ $A_{34} = 12$
$A_{35} = 5$ $A_{36} = 15$ $A_{37} = 1$ $A_{38} = 4$ $A_{39} = 1$ $A_{40} = 1$

Maximum run length = 6 DC Balance = 33/33 (1/0)

Delimiter 2

Binary **10 0111 1101 1010 0110 1100 0100 0010 0111 0000 0101 1111 1001 0101 0001 1001 1100**

Hex **4 BE 65 23 E4 A0 9F 8A 39**

Minimum Hamming Distance = 30

Distribution of Hamming Distance

$A_{30} = 18$ $A_{31} = 8$ $A_{32} = 18$ $A_{33} = 5$ $A_{34} = 17$
$A_{35} = 3$ $A_{36} = 8$ $A_{37} = 5$ $A_{38} = 3$ $A_{39} = 3$

Maximum run length = 6 DC Balance = 33/33 (1/0)

Proposal 2: Delimiter (Cont'd)

Delimiter 3

Binary **10 0111 0101 0011 0001 0101 0000 1101 0111 0011 1101 1111 0000 0011 1010 0110 0100**

Hex **4 AE 8C 0A EB BC 0F 5C 26**

Minimum Hamming Distance = 30

Distribution of Hamming Distance

$A_{30} = 9$ $A_{31} = 14$ $A_{32} = 15$ $A_{33} = 12$ $A_{34} = 14$

$A_{35} = 8$ $A_{36} = 8$ $A_{37} = 3$ $A_{38} = 5$

Maximum run length = 6 DC Balance = 33/33 (1/0)

- Minimum Hamming Distance of 30 between the proposed Sync Pattern and Delimiter is obtained.
- Although this value is slightly smaller than the value of 32 between D1.3, there is few impacts on practical usage, considering probability of lost burst or false lock at input BER = 10^-3

Summary

- Upstream 10G Sync Pattern/Delimiter in order to reduce burst mode receiver sensitivity/timing margin penalty is proposed.

  – Sync Pattern

    4 BE 06 95 AF 41 E5 6B 50 (Hex)

  – Delimiter

    1. 4 EF 10 28 CC D9 87 AD A6 (Hex)
    2. 4 BE 65 23 E4 A0 9F 8A 39 (Hex)
    3. 4 AE 8C 0A EB BC 0F 5C 26 (Hex)

Straw Poll 1

- Considering burst mode penalty, Sync Pattern for Upstream 10G should be

  a. Repetition of 1010 ···· .
  b. Repetition of fixed pattern including 010, 101, and CID with its length of several bits.
  c. Others.
  d. No Opinion.

Straw Poll 2

- Sync Pattern and Delimiter for Upstream 10G should be the pattern that of

  a. determined in D1.3.
  b. proposed in 3av_0805_nagahori_1.pdf.
  c. Others.
  d. No Opinion.