Simple Link Protocol (SLP) Delineation Performance

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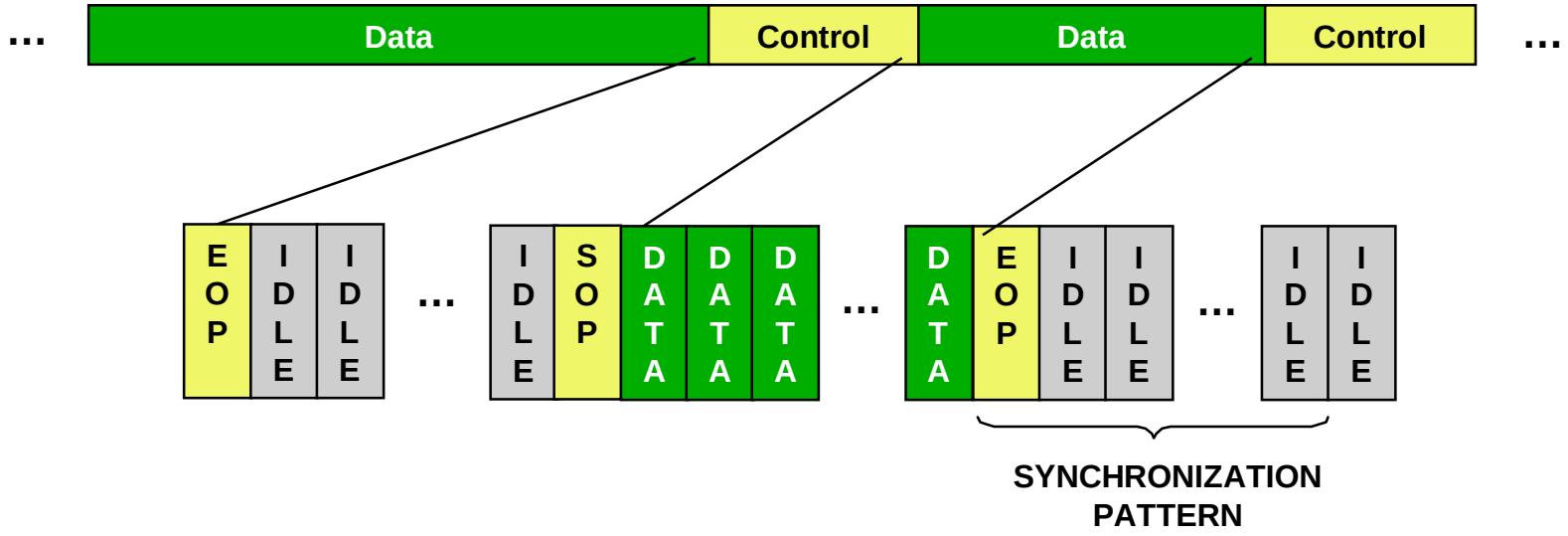
OUTLINE

- Simple Link Protocol (SLP) Delineation Overview
  - Key concept for SLP (refer to “Simple Link Protocol” presentation for details)
  - 10G LAN PHY delineation using SLP
- 10G LAN PHY Delineation Performance
  - Delineation performance parameters
    - Probability of Packet Loss (PPL) & Mean Time To Packet Loss (MTTPL)
    - Probability of False Packet (PFP)
    - Probability of Link Synchronization Loss (PLSL)
    - Mean Time To Synchronization (MTTS)
- Comparison with 8B10B delineation performance

Analysis is similar to “10GE WAN PHY Delineation Performance” by Bijan Raahemi, David Martin, et. Al., Jan 18-20, 2000, Dallas meeting.

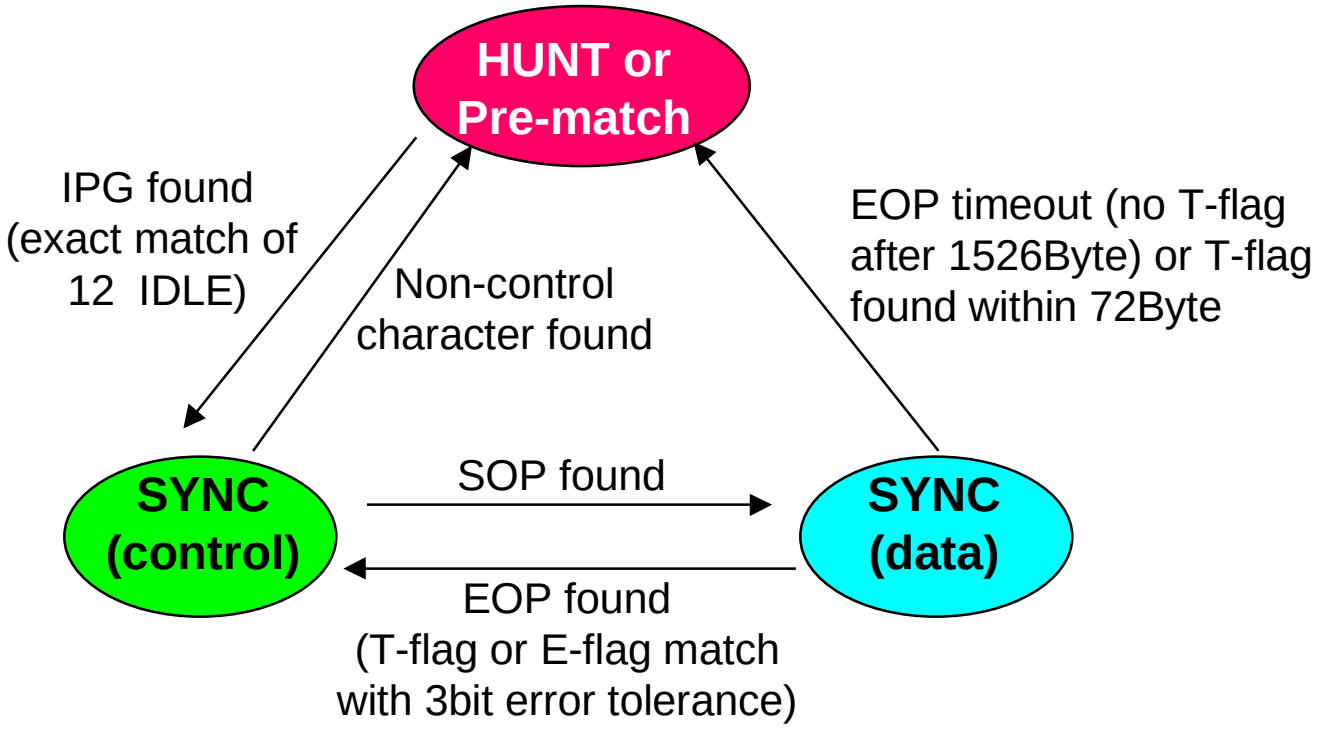
Key Concepts for SLP

- Encoding: zero-overhead
  - Data payload is scrambled bit serialization of Ethernet packets
  - Control characters: Use DC-balanced Hamming code or EMI-reducing scrambling
- Control characters are embedded in Inter-Packet Gap (IPG)
  - Synchronization is based on an exact match of the end-of-packet flag (the T-flag) sitting between successive packets. The T-flag contains 1 EOP character and 11 IDLE characters.



10G LAN PHY Delineation using SLP

- Hunt for the 12 IDLE (I-flag) to gain sync and enter the control mode
- In control mode, search for SOP character for start of packet
- In data mode, search for T-flag consisting of EOP character and 11 IDLE to terminate the current packet



Probability of Packet Loss

- Probability of packet loss due to delineation error
  - A packet is accepted when an exact match of the SOP byte (after 1-bit error correction) is found at the start of the packet and a match of the T-flag (end-of-packet flag, 12Byte long) with 3-bit error tolerance is found at the end of the packet. Hence, a packet is accepted when there are no more than one-bit errors in the SOP byte and no more than 3-bit errors in the T-flag. Otherwise, the packet is rejected.
  - PPL $= 1 - \{ [(1-BER)^8 + 8 \cdot BER \cdot (1-BER)^7] *$

$$[(1-BER)^{96} + \binom{96}{1} \cdot BER \cdot (1-BER)^{95}$$

$$+ \binom{96}{2} \cdot BER^2 \cdot (1-BER)^{94} + \binom{96}{3} \cdot BER^3 \cdot (1-BER)^{93}] \}$$

$$\approx 28 \cdot BER^2$$

Probability of False Packet (1)

- Probability of accepting a false packet due to delineation error
  - A packet is accepted when an exact match of the SOP byte is found at the start of the packet and a match of the T-flag (end-of-packet flag, 12Byte long) with 3-bit error tolerance is found at the end of the packet.
  - Note that
    -- The Hamming distance between different control characters is 4
    -- No12Byte sequence with less than 4 bit Hamming distance from either a 12Byte IPG sequence or the 12Byte T-flag is allowed in the payload
  - False packet could be due to false match of either or both cases :
    -- CASE 1: start-of-packet (SOP) character
    -- CASE 2: end-of-packet flag (T-flag)

Probability of False Packet (2)

- CASE 1: False packet due to false match of SOP character
  - (1) In control mode, some other control character is corrupted by noise and causes a match of SOP. This is possible only when 3-bit or more errors occurred.
  - $$P11 \approx C_1 * \binom{8}{3} \cdot BER^3 \cdot (1-BER)^3 * (1/2)^4$$
    $$\approx 3.5 \cdot C_1 * BER^3$$
  - (2) Failed to detect the right SOP (when more than 1-bit error occurred to it) and find a match of SOP in the payload

$$P12 \le [1-(1-BER)^8 - 8 \cdot BER \cdot (1-BER)^7] * (1/2)^8$$
$$\approx 0.11 * BER^2$$

Probability of False Packet (3)

- CASE 2: False packet due to false match of T-flag
  - (1) Find a match of T-flag inside payload. This is possible when more than 3-bit error occurred in a 96-bit pattern in payload.

$$P21 = C_3 * (1/2)^{96} * [1 - (1 - BER)^{96} - \binom{96}{1} \cdot BER \cdot (1 - BER)^{95} - \binom{96}{2} \cdot BER^2 \cdot (1 - BER)^{94} - \binom{96}{3} \cdot BER^3 \cdot (1 - BER)^{93}]$$

$$\approx 4.2 \cdot 10^{-23} \cdot C_3 * BER^4$$

  - (2) Failed to detect the right T-flag (when more than 3-bit error occurred to it) and find a match of T-flag later ...

$$P22 = C_4 * [1 - (1 - BER)^{96} - \binom{96}{1} \cdot BER \cdot (1 - BER)^{95} - \binom{96}{2} \cdot BER^2 \cdot (1 - BER)^{94} - \binom{96}{3} \cdot BER^3 \cdot (1 - BER)^{93}] * [1 - (1 - BER)^{96}] \cdot (1/2)^{96}$$

$$\approx 4.03 \cdot 10^{-21} \cdot C_4 * BER^5$$

Probability of False Packet (4)

- Probability of false packet due to delineation error
  - Prob(FP) = Prob(CASE1 U CASE 2)
    = (P11+P12) + (P21+P22) - (P11+P12)*(P21+P22)
    $\approx \max(C * BER^3, 0.11 * BER^2)$
  - For BER = 10^{-12} , PFP < 10^{-25}
    ~ once every billion years !
  - C_1, C_3 and C_4 *are number of occurrence of 1Byte or 12Byte patterns inside a maximum length packet*
  - $C = \max(C_1, C_3, C_4) < 10^4$

Link Synchronization Loss (1)

- Probability of link synchronization loss
  - There are two possibilities to lose sync and return to HUNT mode
    - -- CASE 1: In control mode, find non-control character
    - -- CASE 2: In data mode, fail to detect T-flag after (1518+12)Byte when more than 3-bit error occurred in the T-flag; or detect the T-flag within (63+12)Byte due to data corrupted by noise (negligible)
  - PLSL(CASE 1)

$$P1 = 1 - [(1 - BER)^8 + 8 \cdot BER \cdot (1 - BER)^7]$$
$$\approx 28 \cdot BER^2$$

Link Synchronization Loss (2)

- Probability of link synchronization loss

  - PLSL(CASE 2)

$$P2 = \{\ 1-(1-BER)^{96} - \binom{96}{1}\cdot BER\cdot(1-BER)^{95}$$

$$-\binom{96}{2}\cdot BER^{2}\cdot(1-BER)^{94} - \binom{96}{3}\cdot BER^{3}\cdot(1-BER)^{93}\ \}$$

$$*\{\ 1+(1/2)^{96}\cdot[\binom{96}{0}+\binom{96}{1}+\binom{96}{2}+\binom{96}{3}]\ \}$$

$$\approx 3321960\cdot BER^{4}$$

  - PLSL(total) = P1 + P2 $\approx 28\cdot BER^{2} + 3321960\cdot BER^{4}$

Re-Synchronization Delay

- Mean Time To Synchronization (MTTS)
  - When lose sync, go back to HUNT mode and search for the exact match of 12 IDLE (I-flag)
  - The average time (in terms of number of packets) it takes to regain sync equals

    0*Prob(being in control mode and find the I-flag)

    + 1*Prob (exact match in the 1st I-flag encountered)

    + 2*Prob (fail to match the 1st I-flag and exact match in the 2nd I-flag)

    + 3*Prob (no match in first 2 I-flags and exact match in the 3rd I-flag) + ……
  - MTTS (# of packets)

$$
\begin{aligned}
&= 1*(1-BER)^{96} \\
&+ 2*[1-(1-BER)^{96}]\cdot(1-BER)^{96} \\
&+ 3*[1-(1-BER)^{96}]^2\cdot(1-BER)^{96} + ... \\
&\approx 1+96\cdot BER \approx 1 \text{ packet delay}
\end{aligned}
$$

Comparison with 8B10B Delineation

- Simple Link Protocol (SLP)
  - PPL
    2.8×10^{-23}
  - MTTPL
    21.5 million years
  - PFP
    10^{-25}
  - PLSL
    2.8×10^{-23}
  - MTTS
    1.22 us

- 8B10B
  - PPL
    2×10^{-11}
  - MTTPL
    4.5 hours
  - PFP
  - PLSL
    NA
  - MTTS
    1.2 us

BER=10^{-12} SLP LAN PHY link rate = 10 Gbps
8B10B link rate = 12.5 Gbps Average packet size = 500Byte

Summary

- SLP LAN PHY delineation using control characters with 1-bit error correction capability is as robust as 8B/10B, without the 25% overhead penalty
  - Probability of Packet Loss
    - -- Prob (SLP) = $2.8 \times BER^2$
    - -- Prob (8B10B) = $20 \times BER$
  - Probability of False Packet (both schemes) < $0.1\ BER^2$
  - Mean Time To Synchronization is around 1.2us for both schemes