Consideration of FLR in TSN for Fronthaul

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FLR vs BER in IEEE 802.3

- Frame loss ratio is related to frame size and BER.
- 802.3 standard defines BER objective and ensures realistic FLR is better than $6.2 \times 10^{-x}$, $x$ is according to specific Clause of “IEEE Standard for Ethernet”. When link quality is poorer than expected, Ethernet can disconnect by loss of sync.
  
  - For 64-Octet frames with minimum inter packet gap
  
  - FLR is slightly different over 10/25/50/100/200GbE and 400GbE

<table>
<thead>
<tr>
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<th>BER Objective</th>
<th>FLR Guarantee (64 Octet)</th>
<th>FLR Guarantee (1000 Octet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/25/50/100/200GbE</td>
<td>1E-12</td>
<td>6.2E-10</td>
<td>6.6E-8</td>
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<tr>
<td>400GbE</td>
<td>1E-13</td>
<td>6.2E-11</td>
<td>6.6E-9</td>
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</table>
Burst Error Impacts to BER/FLR

- From physical link perspective, burst errors are inevitable and already counted in overall BER objective of 802.3 standard.
- High speed Ethernet, e.g. 25/50/100/ 200/ 400GbE, has mandatory Reed Solomon FEC to resist burst errors.
- 802.1CM does not have to worry about burst errors in particular physical link.
There were discussion of FLR measurement in D0.4 comments.

Refer to Equation 9-11 from ITU-T G.Sup39 for required number of error free bits in test with a corresponding confidence level.

\[ n = \frac{\log(1 - C)}{\log(1 - P_E)} \]

Where:
- \( n \) is the required number of error free bits
- \( C \) is the confidence level (e.g., 0.95 for 95% confidence)
- \( P_E \) is the BER requirement (e.g., \( 10^{-12} \))

To verify BER of 1E-12@100GbE, test time is at least 30 seconds; and for BER of 1E-13@400GbE, need to test at least 75 seconds.

No need to define measure time in 802.1CM document.
Comment in D0.4 of Target FLR

FLR will be impacted by

- BER of physical link
- Congestion
- Re-transmission

It is assumed that in fronthaul network in D0.4, no frame is lost due to congestion and late delivery.

- But how to ensure no congestion in fronthaul network?
Impact to FLR from Bridged Network

- Congestion
  - Use buffering to avoid frame loss, at expense of latency as in Annex C.1
  - 802.1CM project allows background flow conflicting and corresponding delay to CPRI, but provides no specification on its priority and behavior. Need more study and analysis on the influence of background traffic.

- Re-Transmission
  - 802.3 Ethernet will corrupt/drop data if too many errors happen in transmission, this protection behavior may cause more bandwidth cost in retransmission from application level;
  - No re-transmission in Bridged Network for CPRI application, so we think this is not in scope of 802.1CM
End-to-End FLR

Refer to FLR analysis in [cm-varga-CPRI-packetloss-considerations-0116-v02],

- Optical transport (dark fiber or lambda):
  - Errors: bit errors
  - Characterized by BER
- Switched Ethernet transport
  - Errors:
    - loss of frames caused by congestion, failures, etc.
    - out-of-order delivery caused by multiple paths, rerouting, etc.
      note: late delivery also causes loss for CPRI
    - Note: can be also treated as loss if no re-ordering function at receiver
  - Characterized by FLR

- Factors affecting End-to-End FLR (over Bridged Ethernet Network)
  - What is the typical packet length? 1000 bytes or 1500 byte? Or in a range?
  - What is the FLR over multi-hop PTP-link?
    - Sum of FLR on each PTP links which is characterized by BER from physical link
    - What is the estimation of number of hops: N=6~8? Or in a range?
  - What is the behavior in network device?
    - Congestion: Assumed no congestion in 802.1cm D0.4. But how ensure that in bridged network?
    - Out of order in multi-path scenario: Assumed no multi-path scenario in 802.1cm, options? Shall we clearly state it in draft?
Suggestions

- End-to-End FLR requirement from CPRI TWG are different to the definition of single-link 802.3 Ethernet FLR capability, and we think Bridge Ethernet Network can satisfy the demand in general, but some issues exist and need clarify.

- Decouple FLR in 802.1CM from CPRI TWG requirement can avoid the risk of changes from CPRI TWG for future scenarios or emerging technologies. So we suggest to define FLR in 802.1CM according the FLR capability of Ethernet physical link and bridged network.

- Based on analysis, FLR equation will be as follows, with the assumptions of ideal network.

  \[ BER \times packet\_length \times number\_of\_hops \]

  //use up\_limit for pkt\_length and hop\_number
Further Questions

- Then the questions leads to the assumptions, how to ensure them in Bridged Ethernet Network in reliable solutions.

- Figure out how to prevent frame loss from traffic congestion.
  - By use light traffic load and enough queue buffering? How to quantify?
  - How to provide specific guidance to implementation based on 802.1CM?

- Figure out the effect of multi-path and fast re-routing on FLR, will this affect FLR? Or we can clearly state that no multi-path in TSN for Fronthual.
Thank You
Reference