100G Ten Bit Interface Proposal

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Outline

• Considerations for the Interface
• Overview of the Interface
• Configuration Examples
• Alignment Options
• Open Issues
• Summary
Considerations for the interface

- Supports a single rate MAC speed (100G)
- Optical and electrical technologies requires a multi-channel/lane approach.
  - Channels will need to be bonded into one flow
  - Scheme needs to be robust to technology advances allowing future PMDs with reduced numbers of channels
- Minimize complexity of PMDs/Optical Modules
- Low overhead that is independent of packet size
- Enable small buffers
- Allow for differential delay due to wavelengths/fibers
- No auto-negotiation required between end points
Non-considerations for the interface

Certain features are not considered necessary

• Support for a scalable MAC
  • One MAC rate for the MAC Client is preferred

• Resiliency to single lane failures
  • Not considered necessary since a system level redundancy would be required anyway (e.g. Cable break, card power failure)
  • Working/protection links more than likely to be used
In IEEE Terminology

100GE Specific

100G MAC

Reconciliation

TBD

PCS (64B/66B, 8 byte distribution, alignment)

CTBI

PMA
(Muxing, alignment and SERDES)

PMD = n wavelengths

MDI

CTBI = 100G Ten Bit Interface
10 lanes at 10.3G (from XSBI)
100G Ten Bit Interface (CTBI) Overview

• 10 lanes @ 10.3G SERDES Interface to the PMA/PMD
• Uses 64B/66B encoding
• New 64B/66B encoded alignment mechanism
• Stripe data 8 bytes at a time across the lanes
  • It’s really 66 bits, 8 bytes plus 2 bits of encoding overhead
• Simple alignment and muxing is performed in the PMA
• The same alignment mechanism supports 2 stage alignment across the board electrical interface and PMD link if required.
Definition of CTBI allows simplified implementation of muxing function to enable support of many variants of PMDs that may be defined.
Example:
64B/66B based muxing (5 lanes of optics)

<table>
<thead>
<tr>
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<td>28</td>
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<td>30</td>
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</tbody>
</table>

8 bytes per CTBI Lane

CTBI0
CTBI1
CTBI2
CTBI3
CTBI4
CTBI5
CTBI6
CTBI7
CTBI8
CTBI9

80 bytes at PCS per row

PMD0
PMD0
PMD0
PMD0
PMD0

When the number of PMD channels are a factor of 10 (x1, x2, x5, x10), muxing is simple round robin

When the number of PMD channels are a factor of 10 (x1, x2, x5, x10), muxing is simple round robin

5 Fibers/Lambdas
Example: 64b/66B based muxing (4 lanes of optics)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>7</th>
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<td>28</td>
<td>29</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

80 bytes at PCS per row

CTB0

CTB1

CTB2

CTB3

CTB4

CTB5

CTB6

CTB7

CTB8

CTB9

8 bytes per CTBI Lane

PMD0

PMD1

PMD2

PMD3

4 Fibers/Lambdas

Pattern Repeats after 20 (LCM:20)

When the number of PMD channels are not a factor of 10 (x3, x4 x6, x8) gearbox is a simple pattern.
Encoded Packet Example – 4 Lane PMD

- The following is an example of how a frame is encoded, and how it is played out across the interfaces.
- The Frame can start on any CBTI lane.

<table>
<thead>
<tr>
<th>CBTI Lane</th>
<th>PMD Lane</th>
<th>Sync</th>
<th>Block Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0x78 Pr Pr Pr Pr Pr Pr SFD</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>01</td>
<td>DM DM DM DM DM DM SM SM</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>01</td>
<td>SM SM SM SM ET ET D0 D1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>01</td>
<td>D2 D3 D4 D5 D6 D7 D8 D9</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>01</td>
<td>D10 D11 D12 D13 D14 D15 D16 D17</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>01</td>
<td>D18 D19 D20 D21 D22 D23 D24 D25</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>01</td>
<td>D26 D27 D28 D29 D30 D31 D32 D33</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>01</td>
<td>D34 D35 D36 D37 D38 D39 D40 D41</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>01</td>
<td>D42 D43 D44 D45 CRC CRC CRC CRC</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>10</td>
<td>0x87 00 00 00 00 00 00 00</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>10</td>
<td>0x33 00 00 00 00 Pr Pr Pr</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>01</td>
<td>Pr Pr Pr SFD DM DM DM DM</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>01</td>
<td>DM DM SM SM SM SM SM SM</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>01</td>
<td>ET ET D0 D1 D2 D3 D4 D5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>01</td>
<td>D6 D7 D8 D9 D10 D11 D12 D13</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>01</td>
<td>D14 D15 D16 D17 D18 D19 D20 D21</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>01</td>
<td>D22 D23 D24 D25 D26 D27 D28 D29</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>01</td>
<td>D30 D31 D32 D33 D34 D35 D36 D37</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>01</td>
<td>D38 D39 D40 D41 D42 D43 D44 D45</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>10</td>
<td>0xcc CRC CRC CRC CRC 00 00 00</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0x87 00 00 00 00 00 00 00</td>
</tr>
</tbody>
</table>
Alignment schemes

Alignment of the channels is a key requirement

• Various schemes can be considered which require different levels of complexity in the PCS and PMA.
• One potential scheme is developed further in this presentation
How to do the alignment?

**XAUI** uses comma characters sent on all 4 lanes at once:

<table>
<thead>
<tr>
<th>XGMII</th>
<th></th>
<th>I</th>
<th>S</th>
<th>Dp</th>
<th>D</th>
<th>D</th>
<th>D</th>
<th>-</th>
<th>D</th>
<th>T</th>
<th>I</th>
<th>I</th>
<th>S</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXD[7:0]</td>
<td></td>
<td>I</td>
<td>Dp</td>
<td>Dp</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>Dp</td>
<td>Dp</td>
</tr>
<tr>
<td>TXD[15:8]</td>
<td></td>
<td>I</td>
<td>Dp</td>
<td>Dp</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>Dp</td>
<td>Dp</td>
</tr>
<tr>
<td>TXD[23:16]</td>
<td></td>
<td>I</td>
<td>Dp</td>
<td>Dp</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>Dp</td>
<td>Dp</td>
</tr>
<tr>
<td>TXD[31:24]</td>
<td></td>
<td>I</td>
<td>Dp</td>
<td>Ds</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>Dp</td>
<td>Ds</td>
</tr>
</tbody>
</table>

**XAUI**

<table>
<thead>
<tr>
<th>Lane 0</th>
<th></th>
<th>R</th>
<th>S</th>
<th>Dp</th>
<th>D</th>
<th>D</th>
<th>D</th>
<th>-</th>
<th>D</th>
<th>T</th>
<th>A</th>
<th>R</th>
<th>S</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td></td>
<td>R</td>
<td>Dp</td>
<td>Dp</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>K</td>
<td>A</td>
<td>R</td>
<td>Dp</td>
<td>Dp</td>
</tr>
<tr>
<td>Lane 2</td>
<td></td>
<td>R</td>
<td>Dp</td>
<td>Dp</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>K</td>
<td>A</td>
<td>R</td>
<td>Dp</td>
<td>Dp</td>
</tr>
<tr>
<td>Lane 3</td>
<td></td>
<td>R</td>
<td>Dp</td>
<td>Ds</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>-</td>
<td>D</td>
<td>K</td>
<td>A</td>
<td>R</td>
<td>Dp</td>
<td>Ds</td>
</tr>
</tbody>
</table>

We can do the same with 8 bytes at a time per lane.

Send 8 bytes on each lane every so often.

Frequency would depend on how much overhead is considered acceptable.
How to do the alignment?

Assume lanes are aligned out of the MAC

Send an 8 byte alignment word on each lane with some frequency (TBD).
Frequency depends on how much overhead is considered acceptable.
Alignment – 10 to 5 Lanes

When you send the alignment on the 10 lane CTBI, what does it look like on an optical interface with less lanes?

Can the same alignment words be re-used? Yes.

Note that each box is 8 bytes

<table>
<thead>
<tr>
<th>CGMII</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 0</td>
<td>n-9</td>
<td>A0</td>
<td>1</td>
<td>11</td>
<td>21</td>
<td>31</td>
<td>41</td>
<td>51</td>
</tr>
<tr>
<td>Lane 1</td>
<td>n-8</td>
<td>A1</td>
<td>2</td>
<td>12</td>
<td>22</td>
<td>32</td>
<td>42</td>
<td>52</td>
</tr>
<tr>
<td>Lane 2</td>
<td>n-7</td>
<td>A2</td>
<td>3</td>
<td>13</td>
<td>23</td>
<td>33</td>
<td>43</td>
<td>53</td>
</tr>
<tr>
<td>Lane 3</td>
<td>n-6</td>
<td>A3</td>
<td>4</td>
<td>14</td>
<td>24</td>
<td>34</td>
<td>44</td>
<td>54</td>
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<tr>
<td>Lane 4</td>
<td>n-5</td>
<td>A4</td>
<td>5</td>
<td>15</td>
<td>25</td>
<td>35</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Lane 5</td>
<td>n-4</td>
<td>A5</td>
<td>6</td>
<td>16</td>
<td>26</td>
<td>36</td>
<td>46</td>
<td>56</td>
</tr>
<tr>
<td>Lane 6</td>
<td>n-3</td>
<td>A6</td>
<td>7</td>
<td>17</td>
<td>27</td>
<td>37</td>
<td>47</td>
<td>57</td>
</tr>
<tr>
<td>Lane 7</td>
<td>n-2</td>
<td>A7</td>
<td>8</td>
<td>18</td>
<td>28</td>
<td>38</td>
<td>48</td>
<td>58</td>
</tr>
<tr>
<td>Lane 8</td>
<td>n-1</td>
<td>A8</td>
<td>9</td>
<td>19</td>
<td>29</td>
<td>39</td>
<td>49</td>
<td>59</td>
</tr>
<tr>
<td>Lane 9</td>
<td>n</td>
<td>A9</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

5 Lanes of optics/lambda It can only align this way

<table>
<thead>
<tr>
<th>CGMII</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>n-4</td>
<td>A0</td>
<td>A5</td>
<td>1</td>
<td>6</td>
<td>11</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>Lane 1</td>
<td>n-3</td>
<td>A1</td>
<td>A6</td>
<td>2</td>
<td>7</td>
<td>12</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Lane 2</td>
<td>n-2</td>
<td>A2</td>
<td>A7</td>
<td>3</td>
<td>8</td>
<td>13</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>Lane 3</td>
<td>n-1</td>
<td>A3</td>
<td>A8</td>
<td>4</td>
<td>9</td>
<td>14</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td>Lane 4</td>
<td>n</td>
<td>A4</td>
<td>A9</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

Rx side can do its own alignment based on the above
Alignment - 10 to 4 Lanes

Same concept with 4 optical lanes. At receiver only two potential patterns exist (lanes can also be skewed of course). Align on those.

4 Lanes of optics/lambdas 2 ways the alignment can occur (if no restrictions are placed on the mapping)

<table>
<thead>
<tr>
<th>Lane 0</th>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-3</td>
<td>n-2</td>
<td>n-1</td>
<td>n</td>
</tr>
<tr>
<td>A0</td>
<td>A1</td>
<td>A2</td>
<td>A3</td>
</tr>
<tr>
<td>A4</td>
<td>A5</td>
<td>A6</td>
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<td>A8</td>
<td>A9</td>
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<tr>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

Rx side can always detect which of the two scenarios it received and do its own alignment based on that (2 vs. 3 word on which lane).

Examples not shown for other lanes counts. In all cases, a detectable set of scenarios exist.
How often to send the Alignment?

How often you send alignment will depend on the following:

• How much overhead you want to burden the interface with
  • Pushes toward slow repetition
• How much differential delay you want to be able to support
  • Pushes towards slow repetition
• How fast you want to be able to do alignment
  • Pushes towards fast repetition
How often to send the Alignment?

• How much bandwidth does the alignment take?
  • 80B at a minimum if it can interrupt a packet
  • Maximum of 159B if it can not interrupt a packet
• How to account for the bandwidth used by alignment?
  • Implement a deficit counter (similar to the XAUI Deficit Counter)
  • Delete IPG to keep average Idles + Alignment = 12 per packet
  • Delete 4 or 8 IPG Bytes per packet?
  • Range of Alignment Deficit Counter (ADC) is 0 to 80
• Potential triggers sending the alignment:
  • Idle plus ADC going to 80 (80 Bytes have been deleted)
  • Fixed interval
Alternative for Alignment

• Send alignment on a fixed time basis
• For example every 120usec (approximately 1000 x1500B packets)
• It interrupts packets on the CTBI
• Takes only 0.005% of the Bandwidth
• Accept the small loss in BW or speed up the CTBI a little bit
• Simpler solution than maintaining the ADC
A Note About Alignment - Egress

Where is alignment done?

- Lanes are sent aligned from the PCS
- Realigned on the PMA side of the CTBI (most of the time)
- Then distributed to the optics
- In some cases, whenever one lane of the CTBI is always sent on the same lane of the optics, the data does not need to be re-aligned in the PMA (x1,x2,x5,x10)
A Note About Alignment - Ingress

Where is alignment done?

• Before the CTBI, the data must be aligned. Sometimes this is trivial (2:10 for instance)

• If large skew is expected (say due to wavelength differential delay) then large buffers are in this function. Sometimes this alignment function is trivial such as a single optical interface…first alignment word must be sent on first lane of the CTBI.

• After the CTBI, the data must again be aligned to account for board level skew.
Open Issues

• Scrambling required to maintain sufficient transition density
• Optimal scrambling scheme to be investigated
• Scrambling options include
  • At the PCS aggregate level (before data is striped across lanes)
  • At the CTBI lane level
  • At optical lane level
• We probably can’t scramble the alignment word
• We are investigating ways to make the PMA simpler:
  • Sending multiple alignment words to allow all alignment in the PCS only
  • Performing bit level muxing only at the PMA, requires more complicated muxing in the PCS
Summary

• CTBI proposed as a potential interface for HSSG
• Enables lane bonding/aggregation at electrical and optical levels with a single alignment mechanism
• One PCS for many PMDs
• Low overhead which is independent of packet size
• Minimizes latency, minimizes buffer sizes