Overhead Efficiency Analysis of Multi-Lane Alternatives

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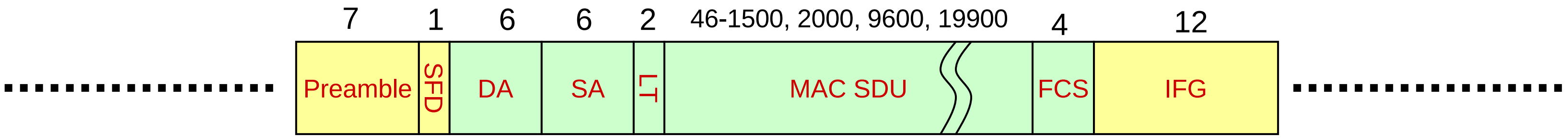
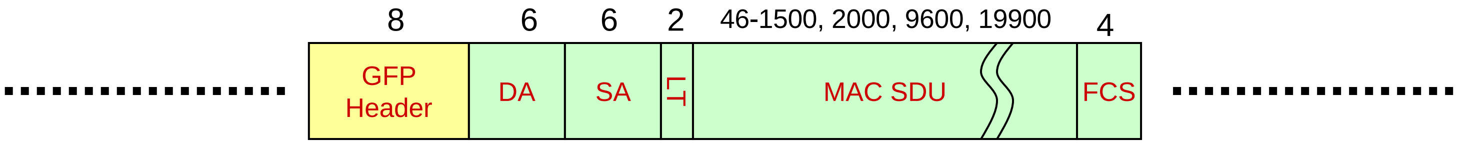
MAC Frame Format

Framing used in 10G Base-R, 10G Base W



Transport network framing used in PDH, SONET/SDH, OTN



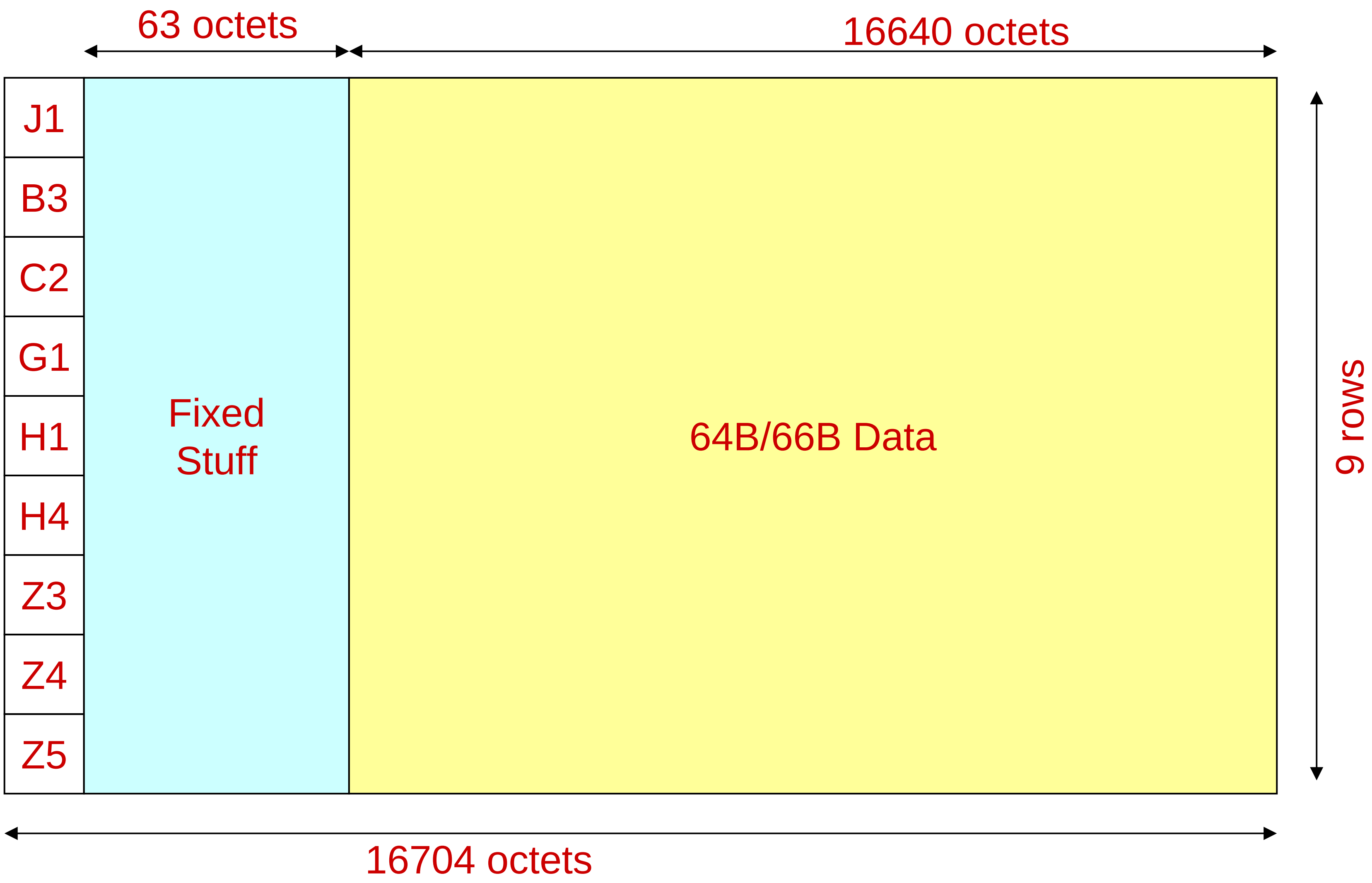
Note: The Characteristic Information is the Payload plus the necessary information to delimit, forward, and check for accurate reception of the Payload

IEEE 802.3 MAC adds minimum 20 octets per packet to characteristic information
GFP Encapsulation of MAC frames adds minimum 8 octets per packet

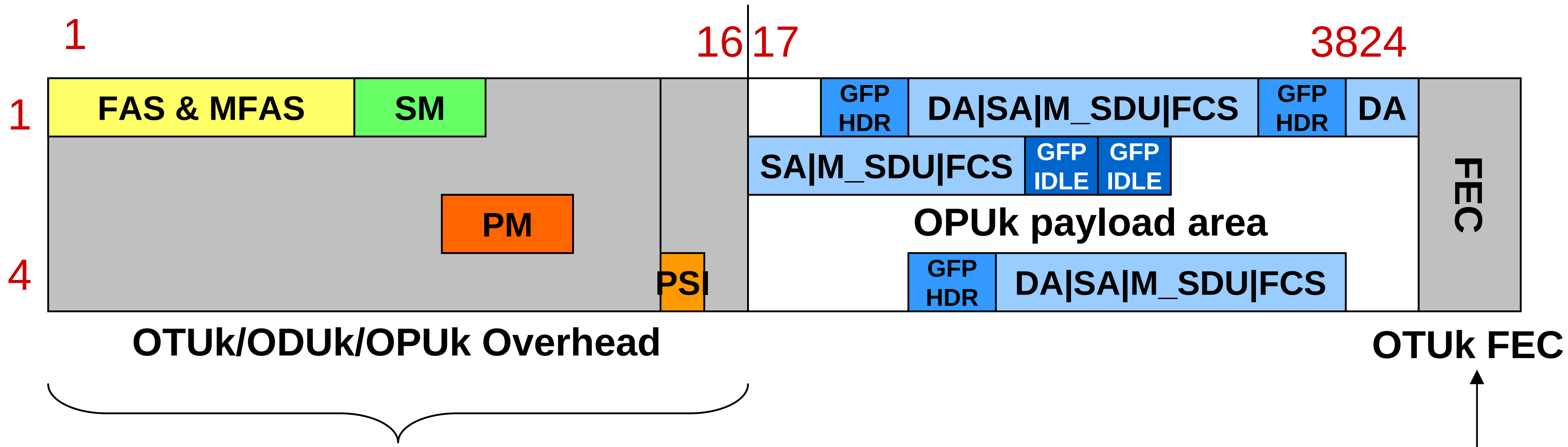
Where are we today? 10 Gbit/s Ethernet Transport

- Native Ethernet (10G Base-R) using 64B/66B PCS
- Longer Reach Alternatives compatible with Transport Networks
  - 10G Base-W – Encode 64B/66B data into VC-4-64c (OC-192c) carried via STM-64/OC-192
  - OTN OTU2 with GFP framing, with or without optional FEC

Mapping of Ethernet MAC into VC-4-64c using 64B/66B coding



Mapping Payload Area into OTUk frame



Added overhead bytes
+0.42% of payload

Optional FEC
+6.72% of payload
Not included in this analysis as FEC is additional to any approach

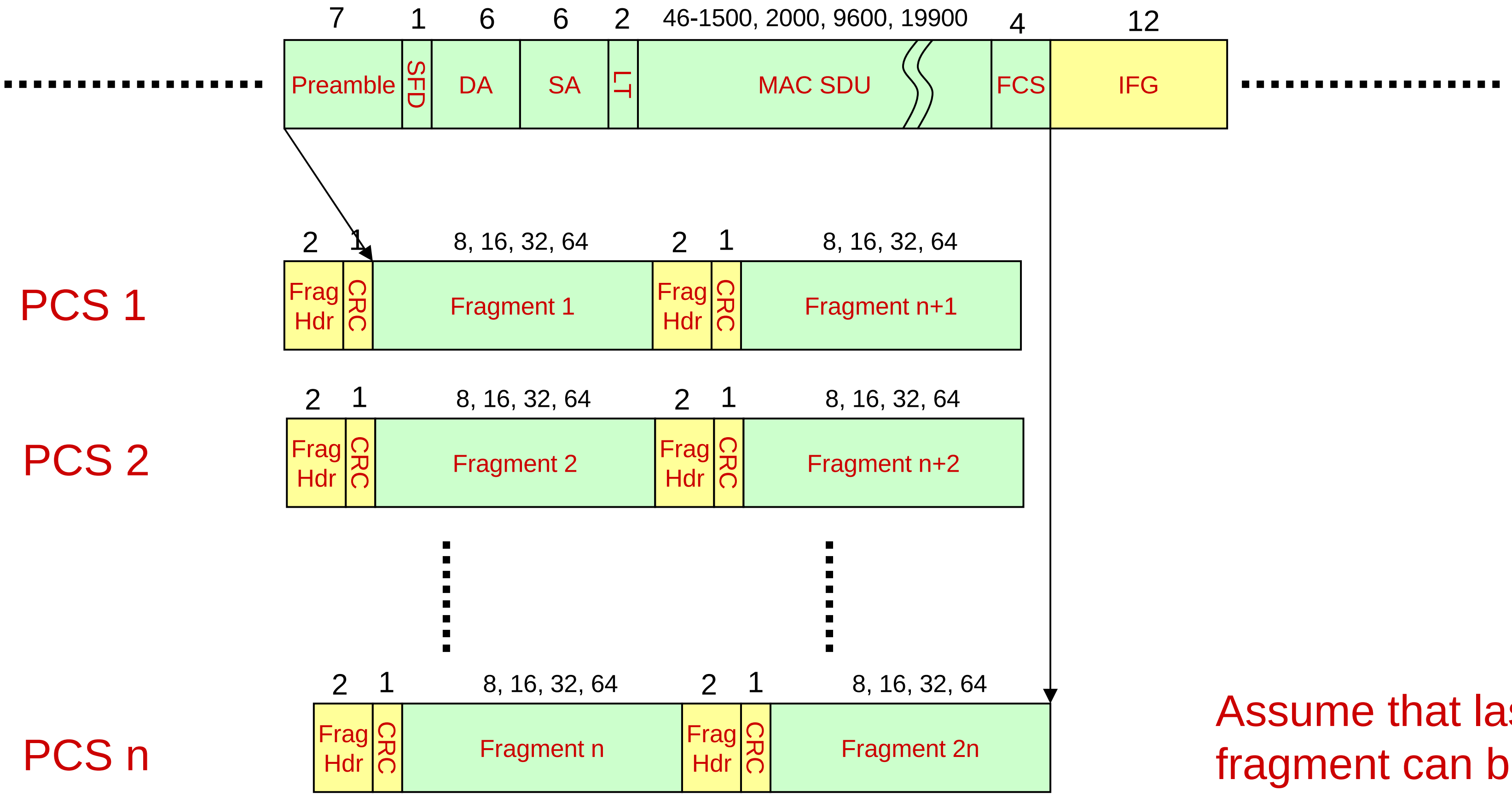
10 Gbit/s Ethernet – Frame Format Alternatives

<table>
<tr><th>10G Base R</th><th>10G Base W</th><th>OTU2 (no FEC)
GFP Framing</th></tr>
<tr>
<td>IEEE 802.3 MAC framing
10.000 Gbit/s capacity for packet stream
64B/66B PCS
10.3125 Gbit/s physical layer</td>
<td>IEEE 802.3 MAC framing
9.58464 Gbit/s capacity for packet stream
64B/66B PCS carried in VC-4
9.95328 Gbit/s physical layer (STM-64/OC-192)</td>
<td>GFP framing
9.9953 Gbit/s capacity for packet stream
OTN scrambler rather than 64B/6B PCS
10.03727 Gbit/s physical layer (without FEC)</td>
</tr>
</table>

Payload (DA, SA, LT, MAC SDU, MAC FCS) Throughput for 10 Gbit/s Alternatives

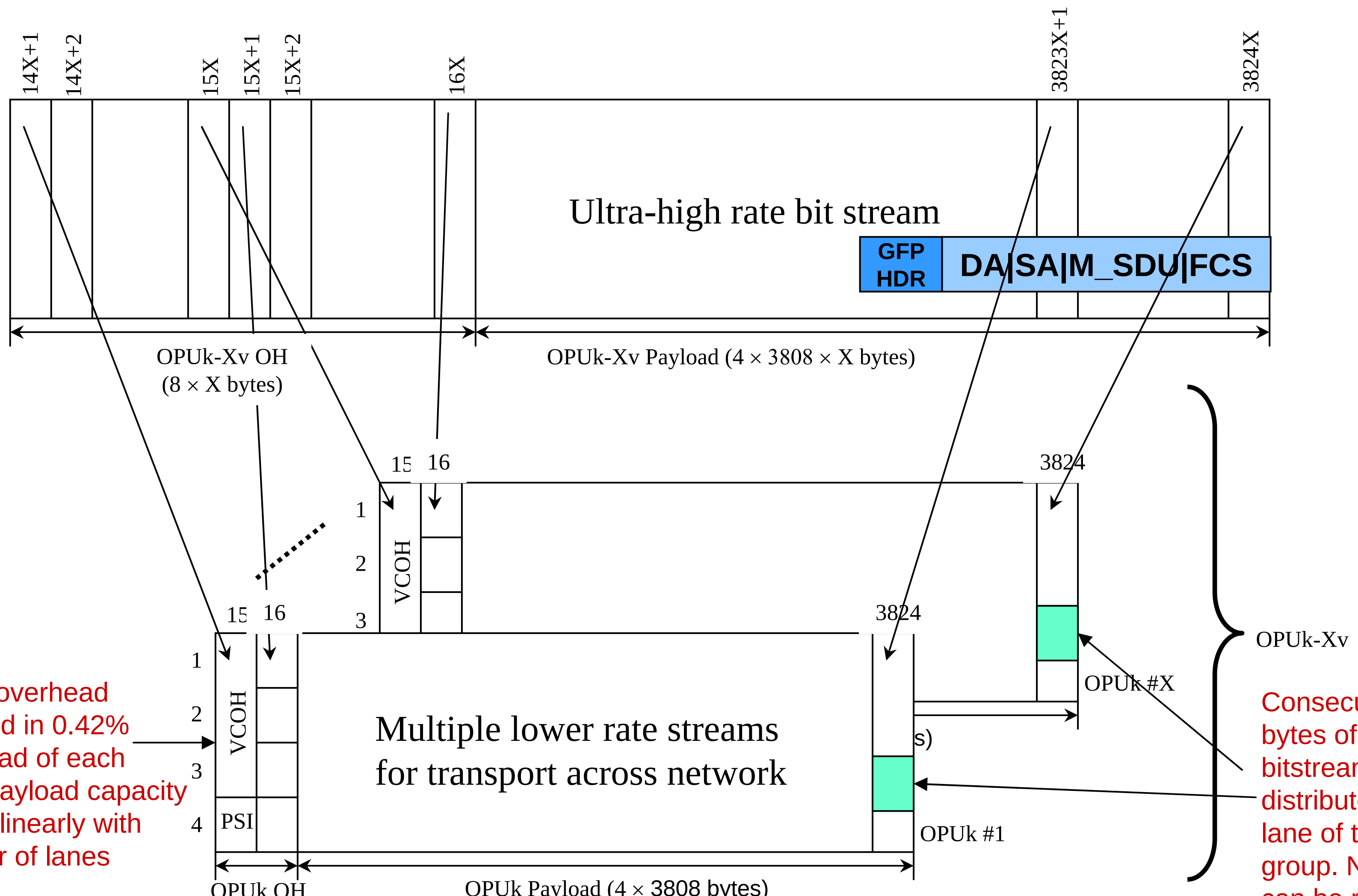
Packet Payload Size	**10G Base R Gbit/s**	**10G Base W Gbit/s**	**OTU2 (no FEC) GFP Framing Gbit/s**
46	7.619	7.303	8.885
100	8.551	8.196	9.361
500	9.628	9.228	9.843
1500	9.870	9.460	9.943
2000	9.902	9.491	9.956
9600	9.979	9.565	9.987
19900	9.990	9.575	9.991

Physical Layer Aggregation via Fragmentation – Option 1 – Preamble as payload



Assume that last fragment can be shortened

Inverse Multiplexing for ODUk Virtual Concatenation (VCAT)



VCAT overhead included in 0.42% overhead of each lane. Payload capacity scales linearly with number of lanes

Consecutive bytes of original bitstream are distributed to each lane of the VCAT group. No packet can be retrieved from only one lane.

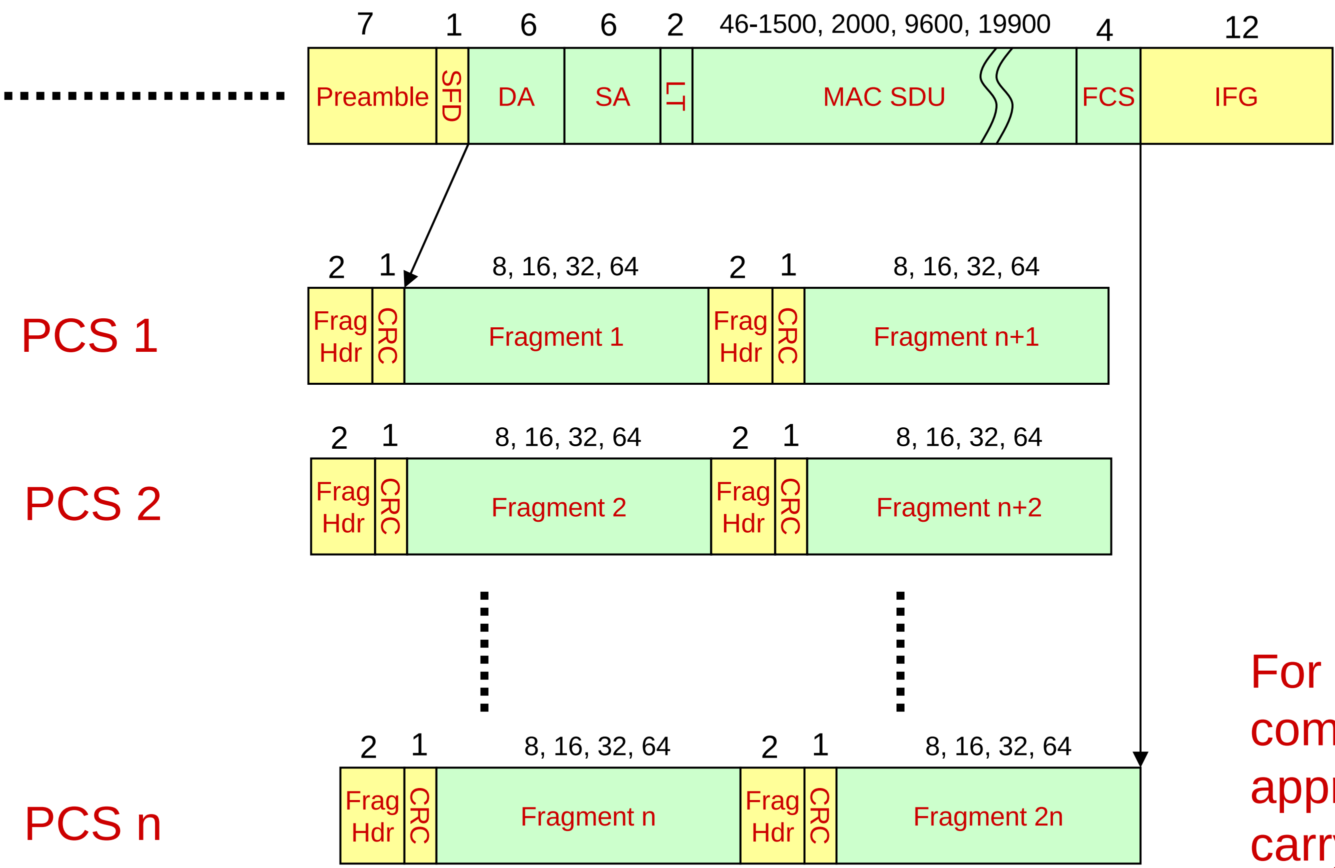
Option 1 – Physical Layer Aggregation, Carry Preamble, 64B/66B PCS for lanes – OH percentage

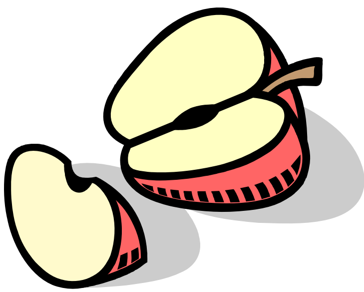
		Fragment Size				ODU2 VCAT
		8	16	32	64	
Packet Payload Size	46	45.31%	26.56%	17.19%	12.50%	12.97%
	100	43.80%	23.46%	13.29%	8.21%	7.23%
	500	41.35%	22.24%	12.97%	8.34%	1.97%
	1500	40.87%	22.10%	12.61%	7.87%	0.95%
	2000	40.89%	22.01%	12.64%	7.88%	0.82%
	9600	40.68%	21.90%	12.51%	7.83%	0.50%
	19900	40.64%	21.89%	12.51%	7.82%	0.46%

Option 1 – Physical Layer Aggregation, Carry Preamble, 64B/66B PCS for lanes –10x10G Lane Throughput

		10x10G Base-R Fragment Size				10x ODU2 VCAT
		8	16	32	64	
Packet Payload Size	46	70.968	81.481	88.000	91.667	88.847
	100	71.713	83.526	91.024	95.301	93.607
	500	72.958	84.365	91.285	95.189	98.433
	1500	73.205	84.461	91.576	95.603	99.429
	2000	73.198	84.525	91.553	95.590	99.558
	9600	73.305	84.596	91.656	95.632	99.870
	19900	73.324	84.604	91.660	95.642	99.913

Physical Layer Aggregation via Fragmentation – Option 2 – do not transmit preamble





For "apples to apples" comparison with other approaches that do not carry preamble

Note that clause 61 PME aggregation does not carry the preamble

Option 2 – Physical Layer Aggregation, Do not transmit Preamble, 64B/66B PCS for lanes – OH percentage

		Fragment Size				ODU2 VCAT
		8	16	32	64	
Packet Payload Size	46	40.63%	21.88%	12.50%	7.81%	12.97%
	100	41.26%	23.46%	13.29%	8.21%	7.23%
	500	40.77%	22.24%	12.97%	8.34%	1.97%
	1500	40.67%	21.90%	12.61%	7.87%	0.95%
	2000	40.74%	22.01%	12.64%	7.88%	0.82%
	9600	40.65%	21.90%	12.51%	7.83%	0.50%
	19900	40.63%	21.88%	12.51%	7.82%	0.46%

Option 2 – Physical Layer Aggregation, Do not transmit Preamble, 64B/66B PCS for lanes – 10x10G Lane Throughput

		10x10G Base-R - Fragment Size				10x ODU2 VCAT
		8	16	32	64	
Packet Payload Size	46	73.333	84.615	91.667	95.652	88.847
	100	73.003	83.526	91.024	95.301	93.607
	500	73.258	84.365	91.285	95.189	98.433
	1500	73.308	84.598	91.576	95.603	99.429
	2000	73.275	84.525	91.553	95.590	99.558
	9600	73.321	84.596	91.656	95.632	99.870
	19900	73.331	84.614	91.660	95.642	99.913

Conclusions/Follow on work

- Physical Layer Aggregation based on Clause 61 most efficient for small packets using large fragments
- OTN/GFP framing has some attractive features over traditional MAC
  - Lightweight, minimal overhead approach
  - Built-in VCAT capability to build flexible multi-lane groups with linear capacity scaling
  - Option for FEC which is likely required for longer reach interfaces
  - Seamless interoperability with transport networks
- Is it time to consider dropping the inter-frame gap for full-duplex interfaces?