High level decisions for 100 Gb/s over 80 km DWDM

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Introduction

This presentation provides proposals on some of the high level decisions required for the following objective:

Provide a physical layer specification supporting 100 Gb/s operation on a single wavelength capable of at least 80 km over a DWDM system.

At the previous meeting in Bangkok, November 2018, some suggested high level decision points were already provided in:
http://www.ieee802.org/3/cn/public/18_11/stassar_3cn_02a_1118.pdf

These are reproduced on the next slide.

High Level Decisions

- What is the reference model for the link?
  - Purely 80 km? Is it using the same model as in OIF for 400ZR?
  - Loss assumption? 0.25 dB/km? Amplified and unamplified?
- Number of channels and spacing?
  - 40 Channels? 75 GHz or 100GHz or both?
  - C-band, L-band or both?
- What is the modulation format?
  - DP-DQPSK for 100G? DP-16QAM for 400G?
- What are the frame assumptions?
  - 400G – Same as OIF? 400ZR frame, GMP, CFEC, 20ppm?
  - 100G – Similar choices to 400G? FEC?
- Then before being able to take decisions on OSNR values, we need to agree on a metric to specify the quality of the transmitter.

400G Motions & Straw polls, Bangkok, Nov 2018

- **Motion #8 passed:** “I support adopting DP-16QAM modulation format for the 400 GbE 80km objective”
- **Motion #9 passed:** “I support adopting the FEC proposal made in http://www.ieee802.org/3/cn/public/18_11/lyubomirsky_3cn_02a_1118.pdf (CFEC) for 400GbE 80km Objective”
- **Strawpoll #6 broad consensus:** “For the 400 GbE 80km objective - I would support the black link approach, noted in lyubomirsky_3cn_02a_1118 and defined in stassar_b10k_01_0318” Y:55, N:0, NMI:3, A:4
- **Strawpoll #7 broad consensus:** “For the 400 GbE – 80km objective I would support the following channel spacing (Chicago rules)”. 75 GHz: 0, 100 GHz:51, NMI:4, A:9
- **Strawpoll #11 broad consensus:** “I would support the frame assumptions made in lyubomirsky_3cn_02a_1118 (400ZR Frame, GMP, 20ppm, DSP Frame) for 400GbE 80km Objective” Y:38, N:0, NMI:7, A:9

400G Direction

The motions adopted and consensus on straw polls at the Bangkok meeting set a clear direction for defining baseline proposals for “400 Gb/s operation on a single wavelength capable of at least 80 km over a DWDM system”

Further considerations on 400 Gb/s were presented during the P802.3cn ad hoc calls since the Bangkok meeting.

100G Motions & Straw polls, Bangkok, Nov 2018

- **No Motions were made.**
- **Strawpoll #8 broad consensus:** “For 100 GbE 80km objectives I would support the following channel spacing (Chicago rules)”.

  50 GHz:6, 75 GHz:0, 100 GHz:37, NMI:11, A:9

- In order to make progress towards a baseline specification for “*100 Gb/s operation on a single wavelength capable of at least 80 km over a DWDM system*” similar high level decisions as for 400 Gb/s need to be made for 100 Gb/s. For instance on:
  - Modulation format
  - Support of black link approach
  - FEC
  - Logical architecture and frame

100G modulation format and methodology proposals

- **Adopt the DP-DQPSK modulation format (DP-QPSK with differential encoding) as in the recently approved ITU-T G.698.2.**

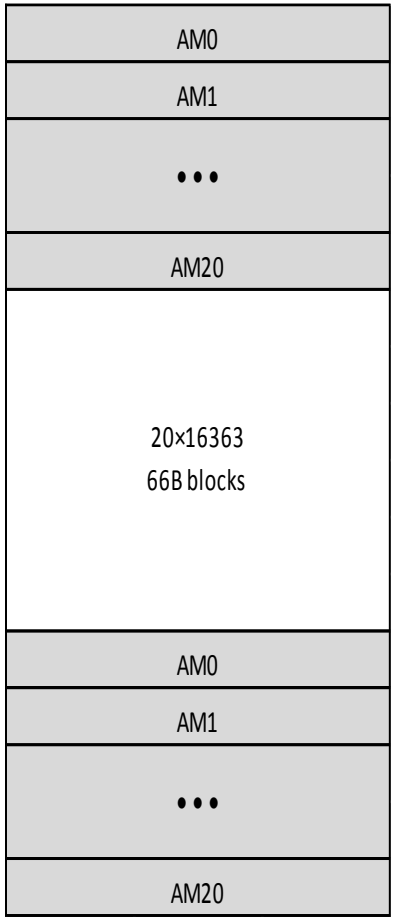
- **Adopt the black link methodology for 100 Gb/s as noted in** lyubomirsky_3cn_02a_1118 for 400 Gb/s and defined in stassar_b10k_01_0318”

FEC Proposal

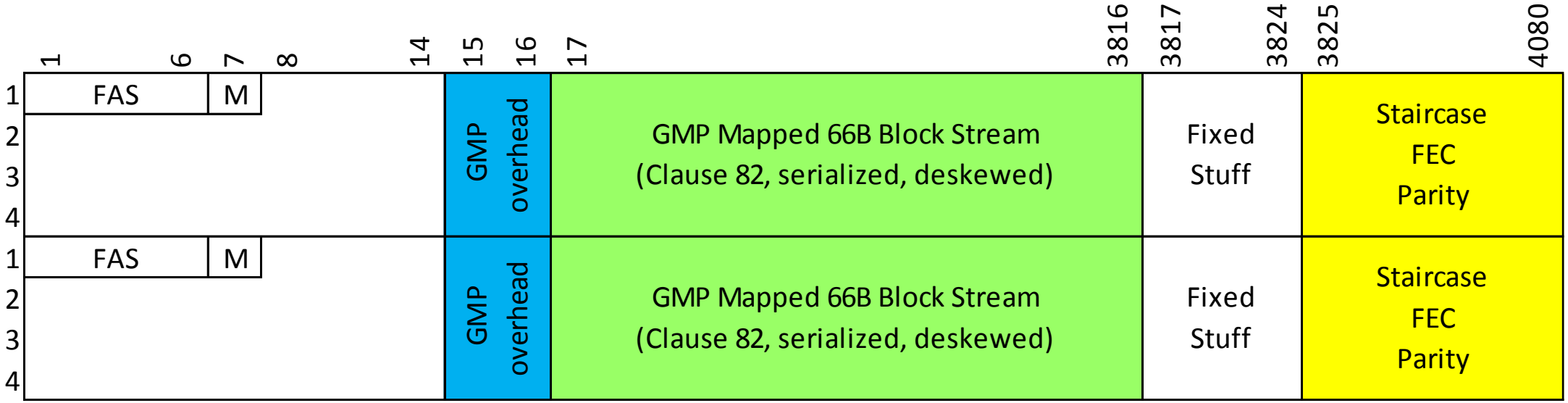
- Virtually all 100G multi-vendor interoperable metro line interfaces in the market (OpenROADM, Terastream, ITU-T G.709.2/709.3, CableLabs) use the same 6.7% overhead (255,239) hard-decision “Staircase” FEC code.
- This is exactly the same as the Hard decision outer code used for the OIF 400ZR and proposed for the P802.3cn 400GBASE-ZR Interface. The OIF 400ZR draft specifies this code through a normative reference to ITU-T G.709.2 Annex A
- Blockwise recursively encoded 512×510 staircase code, sandwiched between a 30592+2048 bit-wide optimized error decorrelator interleaver and error decorrelator de-interleaver
- **Propose** to adopt 6.7% overhead “Staircase” FEC for 100GBASE-ZR, as specified in ITU-T G.709.2 Annex A.

The OTN Mapper for 100GBASE-R behaves as a sort of extender sublayer

- Canonical form for OTN mapping is serialized and deskewed 66B blocks of the Clause 82 PCS
- FEC encoded signals are FEC corrected, trans-decoded back to 66B, and AMs remapped to clause 82 format
- No skew accumulation across “long haul” part of OTN link
- PCS lanes are re-distributed round-robin bit-muxing to physical lanes at OTN egress, as if it were a new PCS generated at the OTN demapper
- Since the frame is client independent, use robust 66B coding in the mapped signal to avoid the need for client-specific error marking (as would be required with 257B)



Frame Format Proposal – Use the same FEC frame as OTN uses for 100G DP-DQPSK links



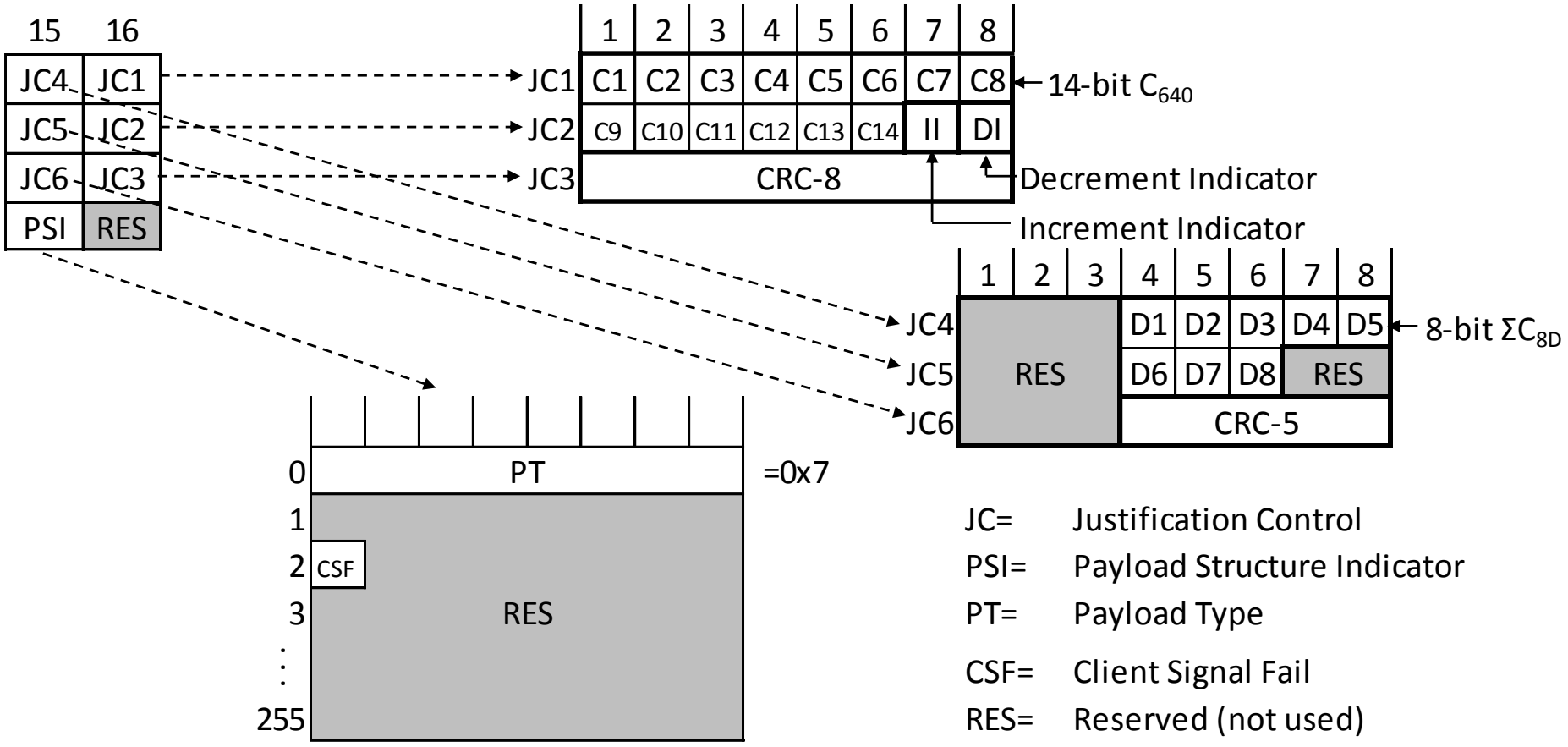
FAS= Frame Alignment Signal (fixed bit pattern, like an AM or CWM)

M= Multi-Frame Alignment Signal (1-byte counter 0-255 on successive frames)

Frame Signaling Rates

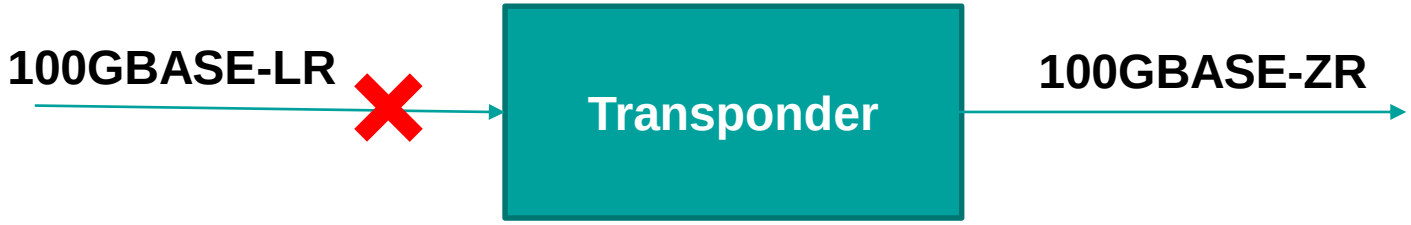
- Signaling Bit-rate = $\frac{255}{227} \times 99.5328\ Gb/s \pm 20ppm$
  (~111.8099736 Gb/s)
- Payload Area Bit-rate = $\frac{255}{227} \times \frac{3800}{4080} \times 99.5328\ Gb/s \pm 20ppm$
  (~104.1367401 Gb/s)
- Payload (Ethernet) Bit-rate = 103.125 Gb/s ±100ppm
- The payload is GMP mapped into the payload area based on dividing the payload area into 190 80-byte GMP words. 188 or 189 GMP words are filled into each 4-row frame

GMP Overhead 80-byte GMP words, 8-bit timing information



Client Signal Fail

- Likely not used for 100GBASE-ZR implemented in a pluggable module, where Tx failures more likely send continuous LF or switch off the Tx depending on where the failure occurs in the stack
- 100GBASE-ZR could also be implemented in a transponder

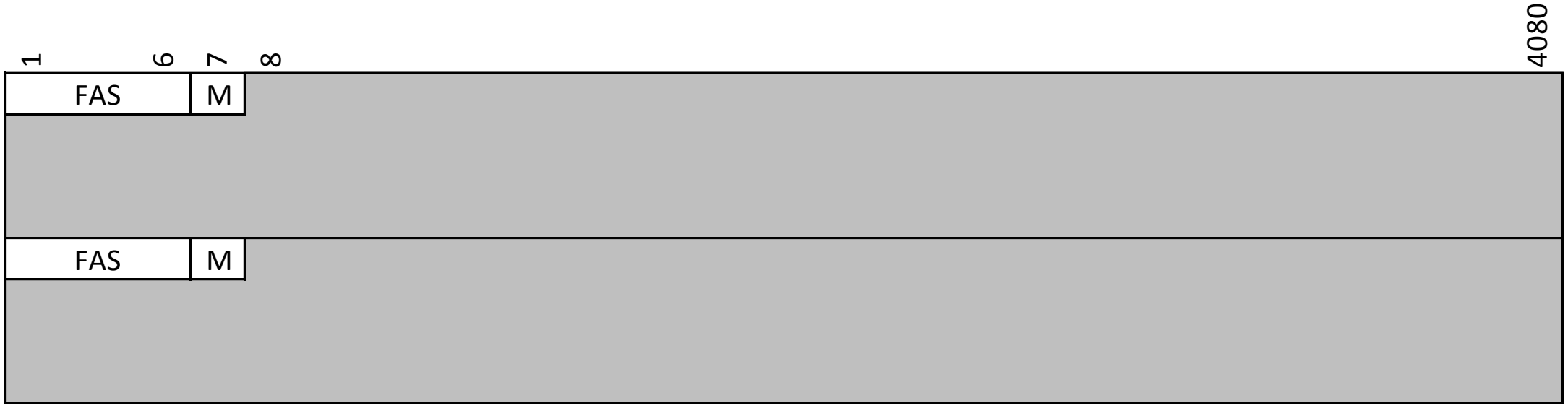


- If the system keeps the line interface alive when the client signal fails, CSF allows the 100GBASE-ZR Tx to signal to the Rx that there is no Ethernet signal inside the frame

FEC Computation and Insertion into Frame

- Two four-row frames are completed by inserting the blockwise recursively encoded 512×510 staircase code
- 2×4×4080×8 = 512×520 = 261120 bits
- Adds 16384 systematic FEC parity bits to 244736 payload bits

Scrambling – After FEC insertion, everything but the frame alignment bits are scrambled with a frame-synchronous scrambler



Frame synchronous scrambler $1+x+x^{3}+x^{12}+x^{16}$

What are the trade-offs to consider regarding using an Ethernet optimized frame rather than a generic frame?

- Pro – you could reduce the bit-rate slightly

Overhead Locations	0.34%
Fixed Stuff	0.20%
Extra space in payload area to support multiservice	0.96%
No 257B Transcoding	2.65%
Approximate Bit-rate reduction opportunity with Ethernet Customized Frame	4.15%

- Note, however, that the same FEC is used with slightly different optical parameters for up to 450km over a metro ROADM network using a 50GHz grid. So this shouldn't be a challenging link budget for 80km with no ROADMs
- Con – By choosing a different frame format, you would sacrifice the additional broad market potential that would arise from the ability to interconnect 100GBASE-ZR with many other 100G line interfaces in the market designed for multi-vendor interoperability. Recommendation is to maximize the broad market potential

Framing Proposal

- Propose to use the FEC frame specified in G.709.2 for 100GBASE-ZR
- Only the overhead required for frame alignment is used
- The GMP mapping of 100GBASE-R into the frame is as specified in G.709 clause 17.7.5

Further options for 100 Gb/s 80 km DWDM

- **Considering that it is the only 100G coherent DWDM specification available with adequate quality metrics for the 100 Gb/s coherent transmitter, it is proposed to leverage the optical specification methodology, parameter definitions, and values from draft revised Recommendation ITU-T G.698.2 (11/18), G.698.2 liaison attachment and presentation outlining specification methods stassar_3cn_03a_1118**

- **The specification for application code DW100U-8A2(C)F, for 100 Gb/s applications appropriate for 80 km distances (not excluding 120 km) with 100 GHz channel spacing, in revised G.698.2 is proposed as the baseline for the Optical Tx/Rx and link parameters for 100GBASE-ZR.**

Thanks!