OTN-Compatible 40GbE and 100GbE interfaces/ 100GbE serial PHY considerations

Jörg-Peter Elbers, Neil Peers

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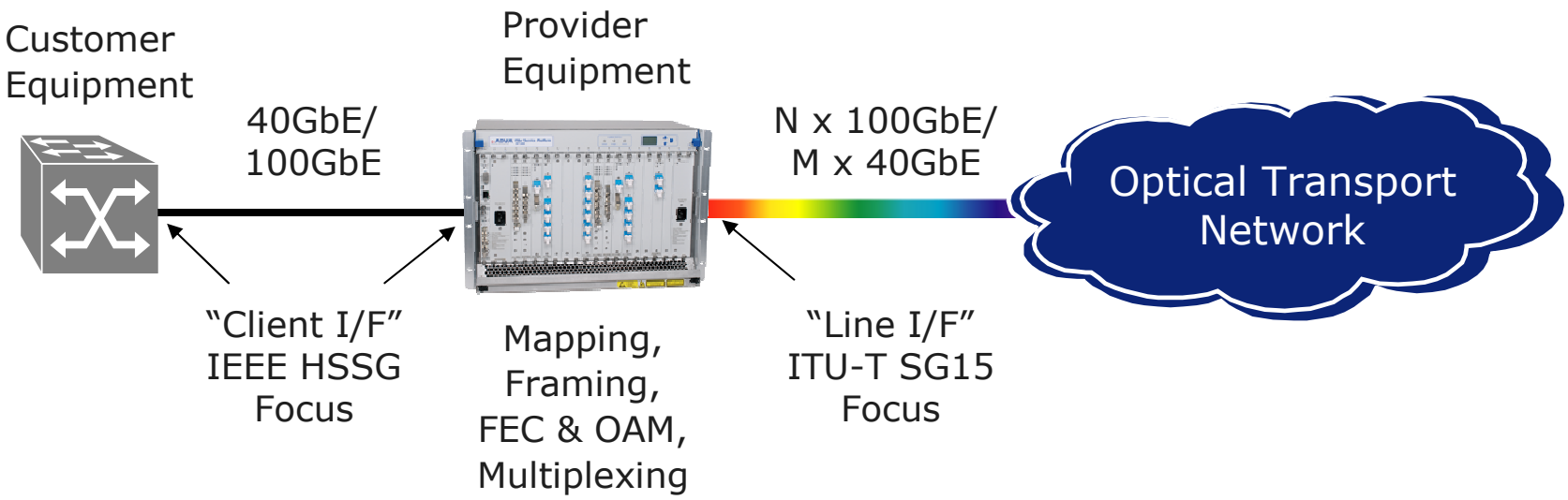
40GbE & 100GbE carrier transport



- Transparent transport of 40GbE & 100GbE services
- Reach and capacity extension (Mm, Tb/s)
- Inline optical amplification and dispersion compensation, DWDM, advanced modulation/coding

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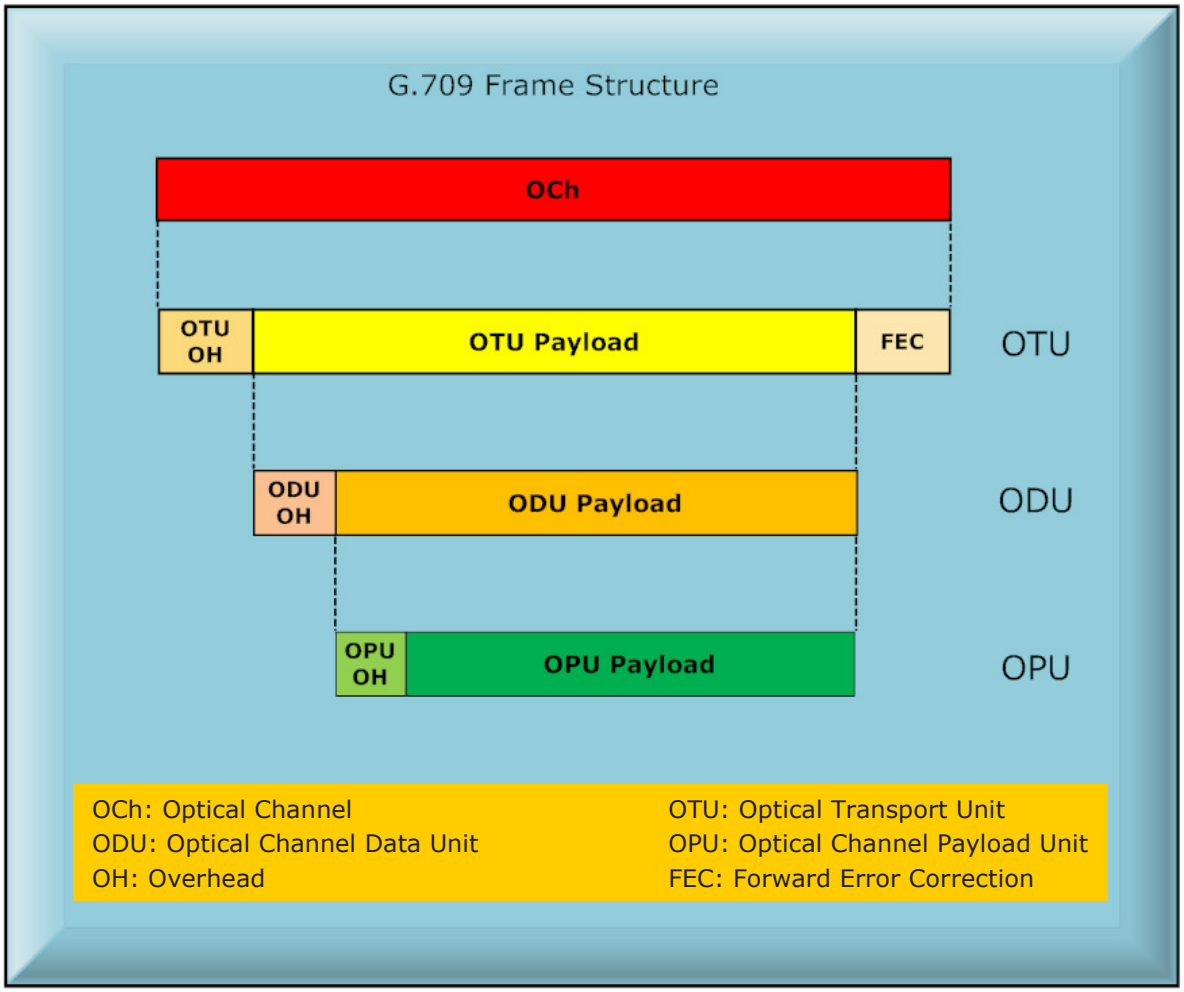
ITU-T G.709 OTN framing



OPU			
Nominal Payload Bit Rate (Gbps)			
OPU1	2.488	x1	= 2.488
OPU2	9.953	x 238/237	= 9.995
OPU3	39.813	x 238/236	= 40.150

ODU			
Nominal Bit Rate (Gbps)			
ODU1	2.488	x 239/238	= 2.499
ODU2	9.953	x 239/237	= 10.037
ODU3	39.813	x 239/236	= 40.319

OTU			
Nominal Bit Rate (Gbps)			
OTU1	2.488	x 255/238	= 2.666
OTU2	9.953	x 255/237	= 10.709
OTU3	39.813	x 255/236	= 43.018

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Motivation & recapitulation

- OTN compatibility is key for transport of 40GbE & 100GbE services
- *Appropriate OTN support* is clear objective of the IEEE HSSG
- *Which support is appropriate* is an important discussion point
- Bad timing & conflicting requirements with 10GbE lead to
  - 7 different OTU2 mappings for 10GBASE-R/W clients
  - Proprietary implementations and incompatibilities
  - Interoperability problems for operators, equipment vendors & component suppliers
- This story should not repeat with 40GbE and 100GbE

10GBASE-W/R mapping into OPU2

Type	#	OPU Mapping	OTU2 compliance	Data rate	Throughput	Preamble Transport	PCS Transport	Transparency
10GBASE-W (WAN-PHY)	**1**	CBR → OPU2 (G.709/17.1.2)	Yes OTU2	10.7Gb/s ± 20ppm	100% (WIS rate reduction)	Yes	Yes	Yes
10GBASE-R (LAN-PHY)	**2**	CBR → OPU2e (G.709/17.1.2)	No OTU2e	11.1Gb/s ± 100ppm	100%	Yes	Yes	Yes
	3	CBR → OPU1e (G.709/17.1.1)	No OTU1e	11.0 Gb/s ± 100ppm	100%	Yes	Yes	Yes
	4	PCS termination → GFP-F → VC4-Xv → OPU2 (G.709/17.1.2)	Yes OTU2	10.7Gb/s ± 20ppm	96% VC4-64v 99% VC4-66v	No	No	No
	5	PCS termination → GFP-F → OPU2 (G.709/17.3)	Yes OTU2	10.7Gb/s ± 20ppm	100%	No	No	No
	6	PCS recoding with 4/8 idle blocks removal → CBR → OPU2 (G.709/17.1.2)	Yes OTU2	10.7Gb/s ± 20ppm	97% PAUSE for rate reduction	Yes	Yes, optional including unknown PCS blocks	Partial
	7	PCS decoding → user data & ordered sets in proprietary GFP-F → OPU2 (G.709/17.1.2)	Yes, OTU2 prop. use of M&CS OPU OH, OPU PT & GFP-F UPI	10.7Gb/s ± 20ppm	100%	Optional	No, Ordered Sets only	Partial

[c.f. also ITU-T G.sup43 for a similar comparison]

Lessons learnt from 10GbE

- 10GBASE-W as dedicated WAN-PHY interface did not pick up
- 10GBASE-R (LAN-PHY) is dominant client interface to transport equipment
- Frame-based mapping (GFP-F) of 10GBASE-R did prove not to be sufficient
- Bit-transparent 10GBASE-R mapping (CBR) is requested for various reasons, e.g.
  - Preservation of proprietary information (preamble, PCS codes)
  - Throughput (albeit mostly a marketing argument)
  - Security/zero-touch
- Pragmatic approach is required for both 40GbE and 100GbE
  - Bit-transparent CBR mapping of 40GbE/100GbE PHY signals in OPU3/OPU4
  - Only one aggregate data rate for 40GBASE-x and one for 100GBASE-x PHYs
  - Method without intermediate adaptation steps (e.g. transcoding, WIS) preferred
  - No 40GbE/100GbE WAN PHY!

40GbE situation

- Initial 40GbE focus is on computing/server interfaces
- 40GbE networking interfaces may/will follow
- OTN-based 40GbE transport is required in any case
  (reach extension/inter-connection)
- 40G transport market is established:
  - IP core routers with 40G PoS (CBR40G) interfaces are in service
  - 40G OTN equipment is deployed world-wide (CBR40G clients)
  - Mature 40G component base exists
    (optical components/subsystems, serialisers/deserialisers, G.709 OTU3 framers)
  - 40G SMF interface standards (ITU-T G.693/G.959.1) and modules
    (e.g. 2km-SMF intra-office interface VSR2000-3R2/3/5) exist
- 40GbE should leverage installed 40G transport base & technology

40GbE proposal

- 40GbE PHY to adopt OPU3 CBR40G interface characteristics
- PHY bitrate: 39 813 120 kbit/s ±20ppm
- Nominal MAC bitrate depending on PCS coding
- MAC rate: 38 606 661 kbit/s (assuming 64B/66B coding)
- Allows OPU3 standard mapping according to ITU-T G.709 clause 17.1

- Benefits: It is all there…
  - Accelerates 40GbE standardization and adoption
  - Complements HSSG 40GbE focus (Cu/MMF) with SMF interfaces
  - Jointly drives existing 40G economies of scale
  - Can directly be carried over today's transport equipment

[c.f. option 1 in trowbridge_01_0907.pdf]

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100G situation

- Initial 100GbE focus is on networking interfaces
- 100GbE computing/server interfaces may/will follow
- OTN-based 100GbE transport required in any case (reach extension/inter-connection)
- 100G transport market is not yet established:
  - Initial feasibility studies of 100G metro/LH transport
  - Discussions on system concepts, modulation formats, …
  - Discussions on OTU4/ODU4/OPU4 frame format and data rates
- Co-operation between ITU-T and IEEE to align ITU-T OTU4 format and IEEE 100GbE definition

100G position

- OPU4 CBR100G to match 100GbE PHY characteristics
- Boundary conditions for OTU4/ODU4/OPU4:
  - Stay with architecture & principles of G.709 OTN standard
  - Support bit-transparent mapping of full 100GbE PHY signal (CBR100G)
  - Support bit-transparent mapping of 10x10GBASE-R signals (CBR10G3)
  - Keep OTU4 rate close to CBR100G rate to avoid physical layer problems with serial transmission (50GHz/100GHz optical filters, TX/RX component bandwidths)
- Possible outcome for CBR100G: 103 125 000 kbit/s ±100ppm
- Nominal MAC bitrate depending on PCS coding
- MAC rate: 100 000 000 kbit/s (assuming 64B/66B coding)
- Benefits:
  - Is clean solution for universal 100GbE and 10GbE transport at OTU4 rate
  - Shares component/technologies and economies of scale with 25GBd (40GBd)
  - Accelerates implementation of 100G transport solutions

Some remarks on 100G serial PHYs

- For metro/regional transport, serial PHY is expected to win over parallel
  - C.f. history with 10G & 40G
  - Fiber capacity/spectral efficiency needs to keep pace with bandwidth growth
  - Single wavelength easier to manage than 4-12…
  - Technology is rapidly progressing (e.g. DSP/EDC techniques)
- Serial PHYs should also be investigated for very short reach (VSR) applications
  - Less piece parts (manufacturability, reliability)
  - Single fiber (compared to MMF-ribbon)
  - Potentially more compact
  - Potentially less expensive
- Possible interface classes 300m and 2km SMF
  - Simple TX/RX (binary modulation, direct detection)
  - No optical dispersion compensation
  - Interest for these reaches has been expressed before
- Possible realizations (1.3µm)
  - 100G NRZ over 300m SMF
  - 100G ODB over 2km SMF
  - 100G NRZ PolMux (2x50G) over 2km Panda Fiber

Summary

- Pragmatic approach for OTN-compliant 40GbE and 100GbE
  - Only one aggregate data rate for 40GBASE-x and one for 100GBASE-x PHYs
  - Bit-transparent CBR mapping of 40GbE/100GbE PHY signals in OPU3/OPU4
  - 40GbE PHY to adopt OPU3 CBR40G bitrate: 39 813 120 kbit/s ±20ppm
  - OPU4 CBR100G to match 100GbE PHY bitrate: e.g. 103 125 000 kbit/s ±100ppm

- Serial PHYs should also be investigated for VSR applications
  - Possible interface classes 300m and 2km SMF
  - Simple and compact TX/RX
  - No optical dispersion compensation

Thank You

jelbers@advaoptical.com

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Acronyms

CBR	Constant Bit Rate
Cu	Copper
DWDM	Dense Wavelength Division Multiplex
FEC	Forward Error Correction
GFP-F	Frame mapped according to the Generic Framing Procedure (ITU-T G.7041)
I/F	Interface
MAC	Media Access Controller
Mm	Mega meter (1000 km)
MMF	Multi mode fiber
M&CS OH	Mapping & Concatenation Specific Overhead (here bytes 1,2, 3 of col. 15 and all of col. 16 of OPU)
NRZ	None Return Zero
OAM	Operations, Administrations And Management
ODB	Optical Duo-Binary
ODU	Optical Channel Data Unit
OPU	Optical Channel Payload Unit
OPU1e, OPU2e	over-clocked OPU for bit-transparent 10GbE mapping
OTN	Optical Transport Network
OTU	Optical Channel Transport Unit
OTU1e, OTU2e	over-clocked OTU for bit-transparent 10GbE mapping
Panda Fiber (aka Bow-Tie fiber)	Polarization Maintaining Fiber
PCS	Physical Coding Sublayer
PolMux	Polarization Multiplexing
PoS	Packet over SONET
PT	OPU Payload Type (part of the OPU OH)
TX/RX	Transmitter/Receiver
UPI	(GFP-F) User Payload Identifier
VC	SDH Virtual Container
VSR	Very Short Reach
WIS	WAN Interface Sub-layer

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