

Current Status of ST 2110 over 25 GbE

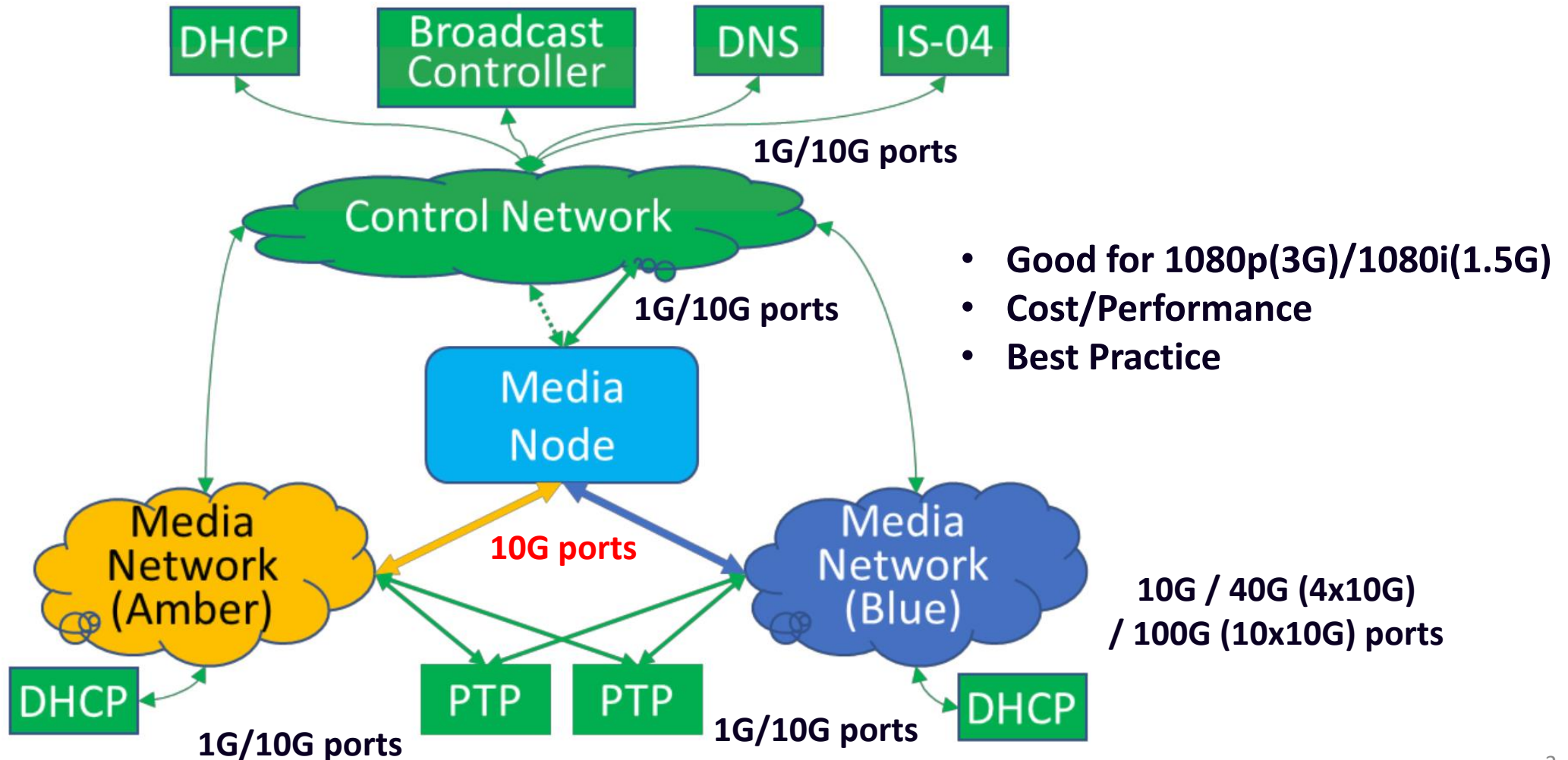
Koji Oyama, M3L Inc.

Who we are

- **M3L Inc.** (株式会社メディアリンクスエルエスアイラボ)
 - <http://www.m3l.co.jp/en/>
 - Found : April 1997
 - Capital : JPY 10M
 - President : Kenji Fukuda
 - Office : Kawasaki, Japan
 - Employees : 9
- **Independent IP-Core Design Company**
 - IP Core: Reusable logic design blocks ([See Wiki](#))
 - Mission: Speedy & High Quality
 - Vision: Pursue ideal IP cores
- Value: **15+ years Experience** with Professional Video Over IP technology
 - IP : Internet Protocol ([See Wiki](#)), Professional Video Over IP ([See Wiki](#))

Current 10 GbE-based System

- JT-NM TR-1001-1:2018 v1.0 shows the overview of broadcast IP network



What's next?

- Future:

- High resolution: 4K60P – 12Gb/s, 8K60P – 48Gb/s, 8K120P – 96G/s
- SDI → IP Network: More data to users
- Radio → Internet distribution: Less bandwidth restriction
- Mixed Broadcasting Live and PC world (VR/AR/360)

- Issue:

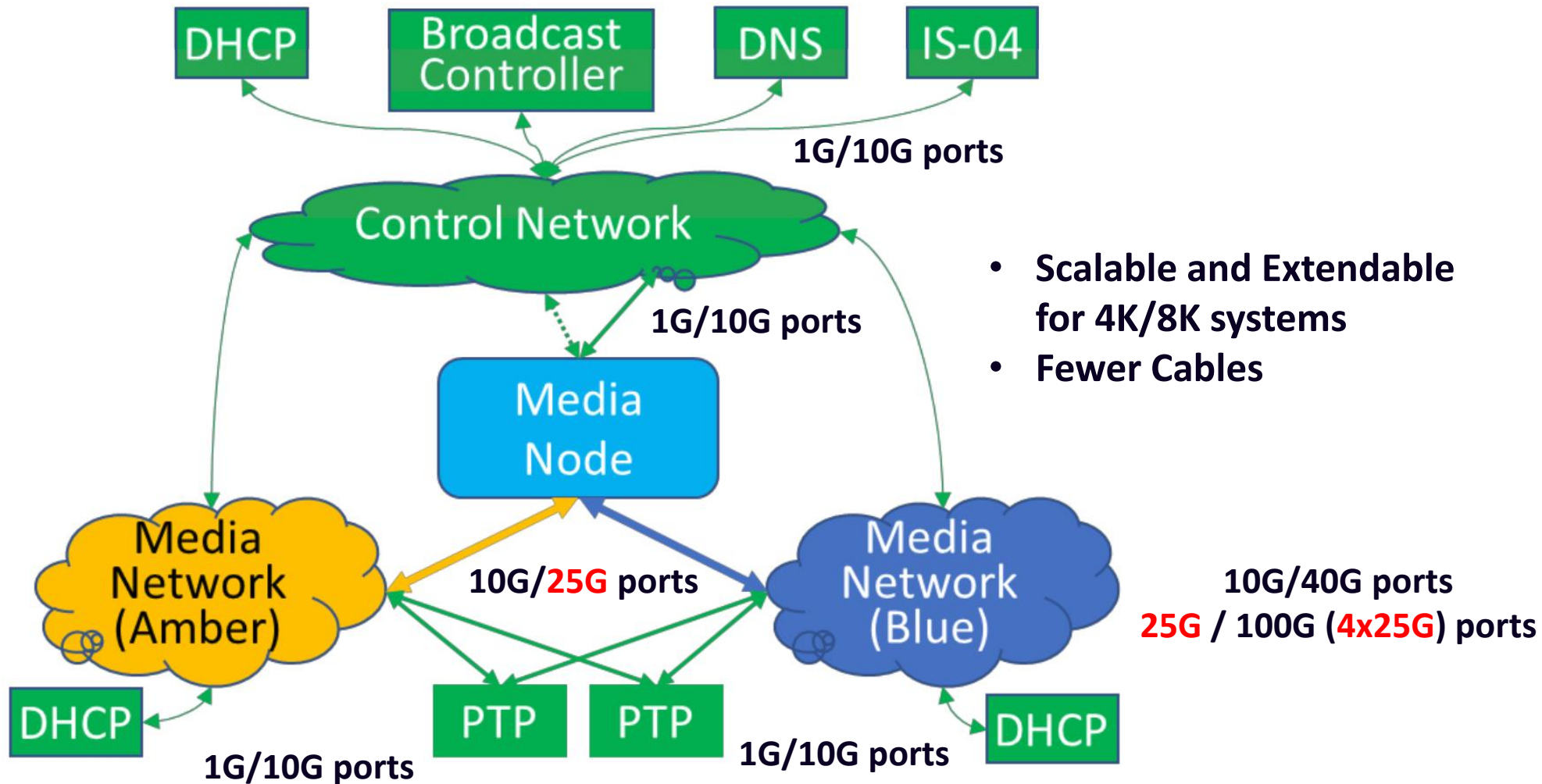
- Need for Higher Bandwidth of Network

- Solution

1. Higher Bandwidth per Lane → 25 GbE, 50 GbE
2. Multiple Lines in Parallel → 40 GbE (4 x 10 GbE), 100 GbE (10 x 10 GbE)
3. 1 & 2 → 50 GbE (2 x 25 GbE), 100 GbE (4 x 25 GbE)
4. Compressed Streams → J2K-ULL, TICO, JPEG-XS

Next System: 25 GbE-based

- Uncompressed or Light-Compressed = Simpler and Less Latency



What's 25 GbE?

- Specified as IEEE 802.3by and cc

- <http://www.ieee802.org/3/by/index.html>
- <http://www.ieee802.org/3/cc/index.html>
- https://en.wikipedia.org/wiki/25_Gigabit_Ethernet

25 GbE - (Data rate: 25 Gbit/s - Line code: 64b/66b with **RS-FEC(528,514)** × NRZ - Line rate: 25.7813 GBd - Full-Duplex)

Name	Standard	Media	OFC or RFC	Transceiver Module	Reach in km	# of Media	Lanes
25GBASE-CR <i>Direct Attach</i>	802.3by-2016 (CL110)	twinaxial balanced	SFP28 (SFF-8402)	SFP28	0.005	2	1
25GBASE-CR-S <i>Direct Attach</i>	802.3by-2016 (CL110)	twinaxial balanced	SFP28 (SFF-8402)	SFP28	0.003	1	1
25GBASE-KR	802.3by-2016 (CL111)	Cu-Backplane	N/A	N/A	0.001	1	2
25GBASE-KR-S	802.3by-2016 (CL111)	Cu-Backplane	N/A	N/A	0.001	1	1
25GAUI	802.3by-2016 (CL109A/B)	Cu-Backplane	N/A	N/A	0.00025	2	1
25GBASE-SR	802.3by-2016 (CL112)	Fiber 850 nm	LC	SFP28	OM3: 0.07	2	1
					OM4: 0.1		
25GBASE-LR	802.3cc-2017 (CL114)	Fiber 1295 – 1325 nm	LC	SFP28	OS2: 10	2	1
25GBASE-ER	802.3cc-2017 (CL114)	Fiber 1550 nm	LC	SFP28	OS2: 40	2	1

c.f.) 10 GbE - (Data rate: 10 Gbit/s - Line code: 64b/66b × NRZ - Line rate: 10.3125 GBd - Full-Duplex)

10GBASE-SR	802.3ae-2002 (CL49/52)	Fiber 850 nm	SC LC	SFP+ XENPAK, X2 XPAK, XFP	OM1: 0.033	2	1
					OM2: 0.082		
					OM3: 0.3		
					OM4: 0.4		
10GBASE-LR	802.3ae-2002 (CL49/52)	Fiber 1310 nm	SC LC	SFP+ XENPAK, X2 XPAK, XFP	OS2: 10	2	1



Quoted from https://en.wikipedia.org/wiki/25_Gigabit_Ethernet
https://en.wikipedia.org/wiki/10_Gigabit_Ethernet

What's 25 GbE? (cont'd)

- 25 GbE technology have been used in 100 GbE since 2010

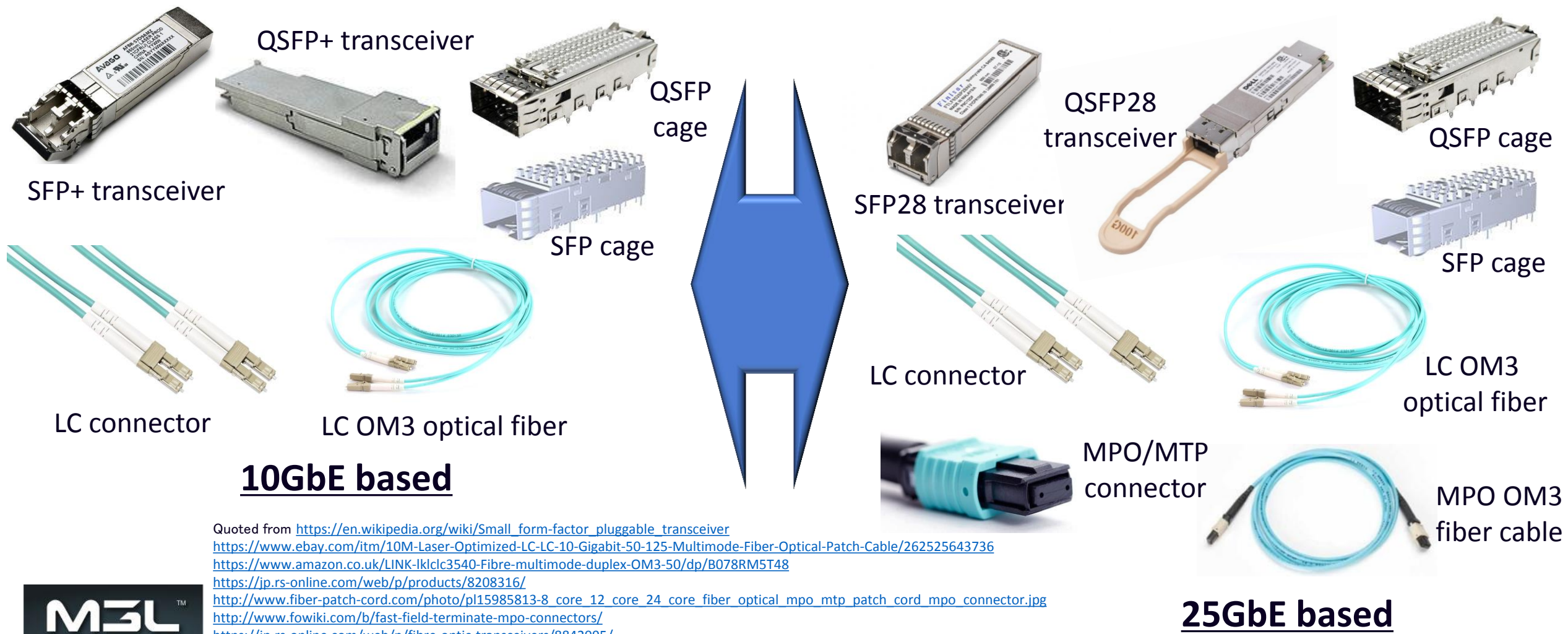
100 GbE (25GbE-based) - Data rate: 100 Gbit/s - Line code: 256b/257b × RS-FEC(528,514) × NRZ - Line rate: 4x 25.78125 GBd - Full-Duplex							
Name	Standard	Media	OFC or RFC	Transceiver Module	Reach in km	# of Media	Lanes
100GBASE-CO4 Direct Attach	802.3bj-2010 (CL92)	twinaxial balanced	QSFP28, (SFF-8665) CFP2, CFP4	QSFP28 CFP2, CFP4	0.005	4	4
100GBASE-KO4	802.3bj-2014 (CL93)	Cu-Backplane	N/A	N/A	0.001	1	4
100GBASE-KM4	802.3bj-2014 (CL94)	Cu-Backplane	N/A	N/A	0.001	1	4
100GBASE-SR4	802.3bm-2015 (CL95)	Fiber 850 nm	MPO/MTP (MPO-12)	QSFP28 CFP2, CFP4, CPAK	OM3: 0.07 OM4: 0.1	2	4
100GBASE-LR4	802.3ba-2010 (CL88)	Fiber 1295.56 nm, 1300.05 nm 1304.59 nm, 1309.14 nm	LC	QSFP28 CFP, CFP2 CFP4, CPAK	OSx: 10	2	4
100GBASE-ER4	802.3ba-2010 (CL88)	Fiber 1295.56 nm, 1300.05 nm 1304.59 nm, 1309.14 nm	LC	QSFP28 CFP, CFP2	OSx: 40	2	4

c.f.) 100 GbE (10GbE-based) - Data rate: 100 Gbit/s - Line code: 64b/66b × NRZ - Line rate: 10x 10.3125 GBd = 103.125 GBd - Full-Duplex							
100GBASE-SR10	802.3ba-2010 (CL82/86)	Fiber 850 nm	MPO/MTP (MPO-24)	CXP, CFP, CFP2 CFP4, CPAK	OM3: 0.1 OM4: 0.15	2	10

c.f.) 40 GbE - Data rate: 40 Gbit/s - Line code: 64b/66b × NRZ - Line rate: 4x 10.3125 GBd = 41.25 GBd - Full-Duplex							
40GBASE-SQ4	802.3ba-2010 (CL82/86)	Fiber 850 nm	MPO/MTP (MPO-12)	CFP, QSFP+	OM3: 0.1 OM4: 0.15	1	4
40GBASE-LR4	802.3ba-2010 (CL82/87)	Fiber 1264.5 – 1277.5 nm, 1284.5 – 1297.5 nm 1304.5 – 1317.5 nm	LC	CFP QSFP+	OSx: 10	2	4
40GBASE-ER4	802.3bm-2015 (CL82/87)			QSFP+	OSx: 40		
40GBASE-FR	802.3bg-2011 (CL82/89)	Fiber 1550 nm	LC	CFP	OSx: 2	2	1

Mechanical Interface

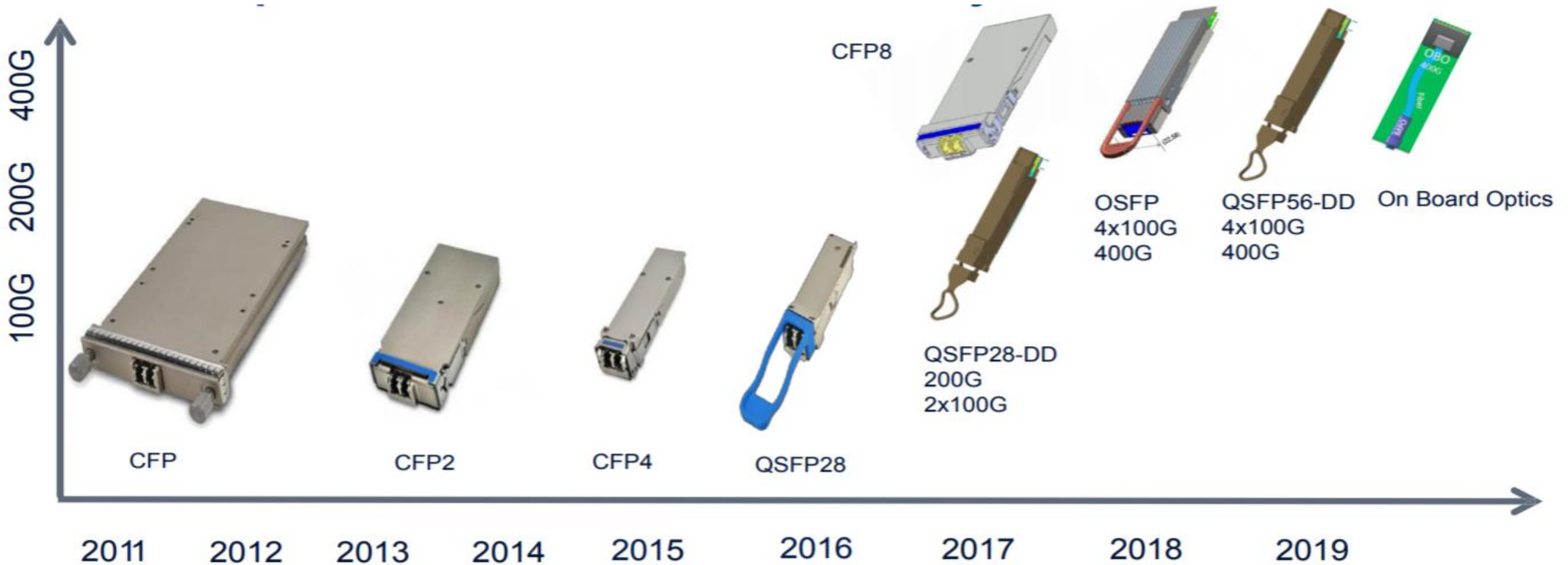
- Almost the same interface between 10GbE-based and 25GbE-based system



Quoted from https://en.wikipedia.org/wiki/Small_form-factor_pluggable_transceiver
<https://www.ebay.com/itm/10M-Laser-Optimized-LC-LC-10-Gigabit-50-125-Multimode-Fiber-Optical-Patch-Cable/262525643736>
<https://www.amazon.co.uk/LINK-1klcl3540-Fibre-multimode-duplex-OM3-50/dp/B078RM5T48>
<https://jp.rs-online.com/web/p/products/8208316/>
http://www.fiber-patch-cord.com/photo/pl15985813-8_core_12_core_24_core_fiber_optical_mpo_mtp_patch_cord_mpo_connector.jpg
<http://www.fowiki.com/b/fast-field-terminate-mpo-connectors/>
<https://jp.rs-online.com/web/p/fibre-optic-transceivers/8842095/>
<https://www.finisar.com/optical-transceivers/ftlf8538p4bcl>
<https://www.ebay.ie/itm/382208186498>

100 GbE transceivers

- CFP → QSFP28 : the same cage for QSFP+ (40GbE)



Challenge to 25 GbE-based System

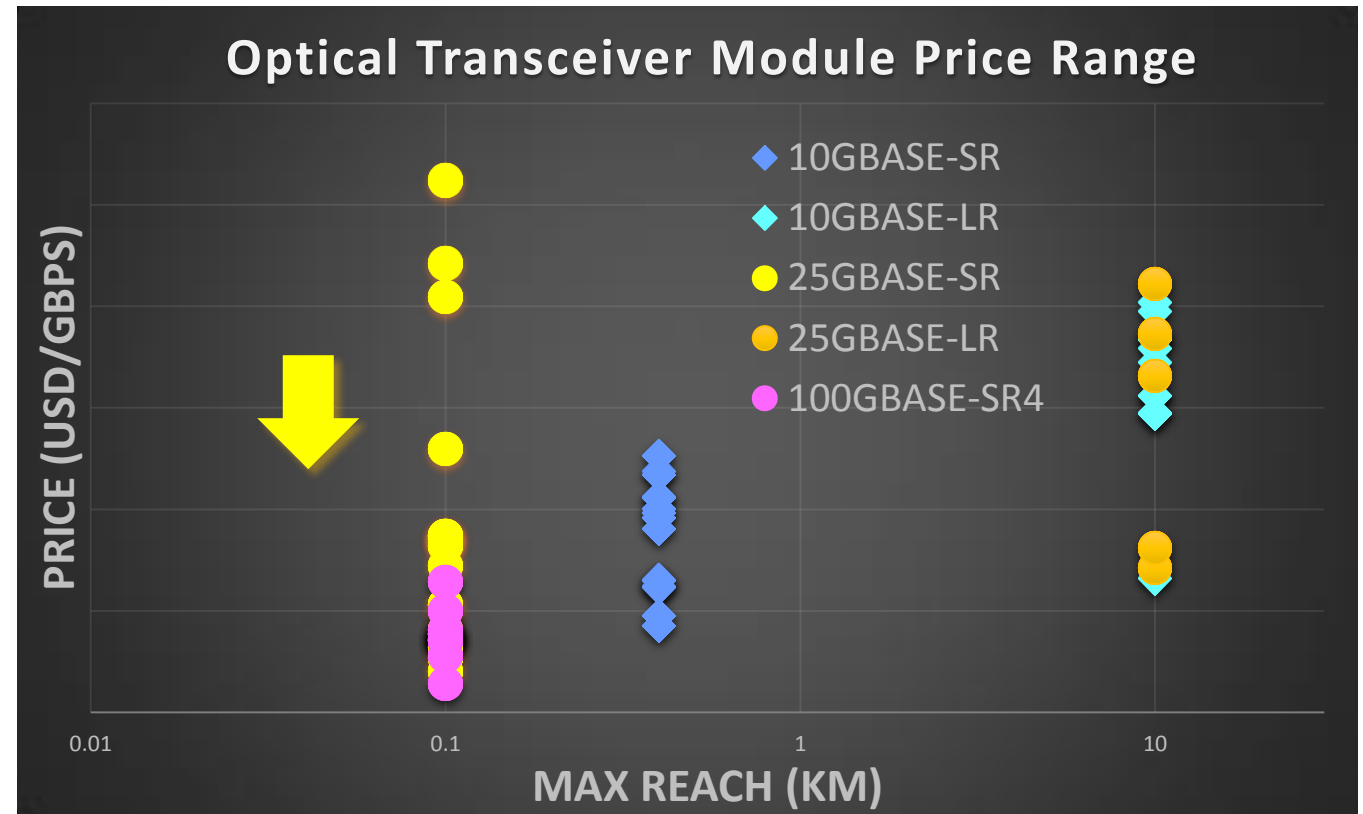
- Criteria
 1. Cost
 2. Reliability
 3. Number of Products
 - ...

Cost of 25 GbE-based products



- L3 Switches: Sub-\$10K @ 2 – 4Tb/s throughput
 - Non-Blocking, Spine/Leaf, Low Latency
 - Major SWes recently have 10 & 25GbE dual-purpose ports
 - Cisco, Arista, Mellanox, etc.

- Optical Modules: \$100 – \$1K
 - 10 GbE based: SFP+/QSFP
 - 25 GbE based: SFP28/QSFP28
 - Price difference
 - Compatibility
 - Reach : SR, LR
 - Bandwidth : 10G, 25G, 40G, 100G
 - Warranty : 1 year, lifetime
 - Env Substances : RoHS, non-RoHS



Affordable Chip and Board

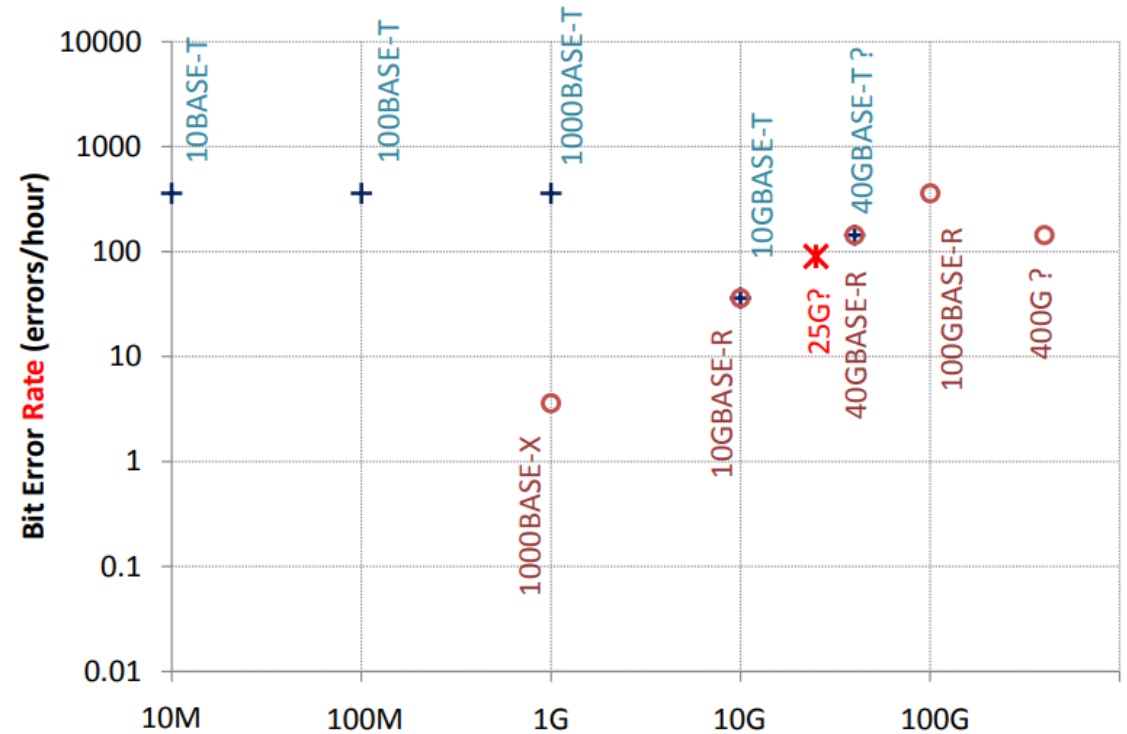
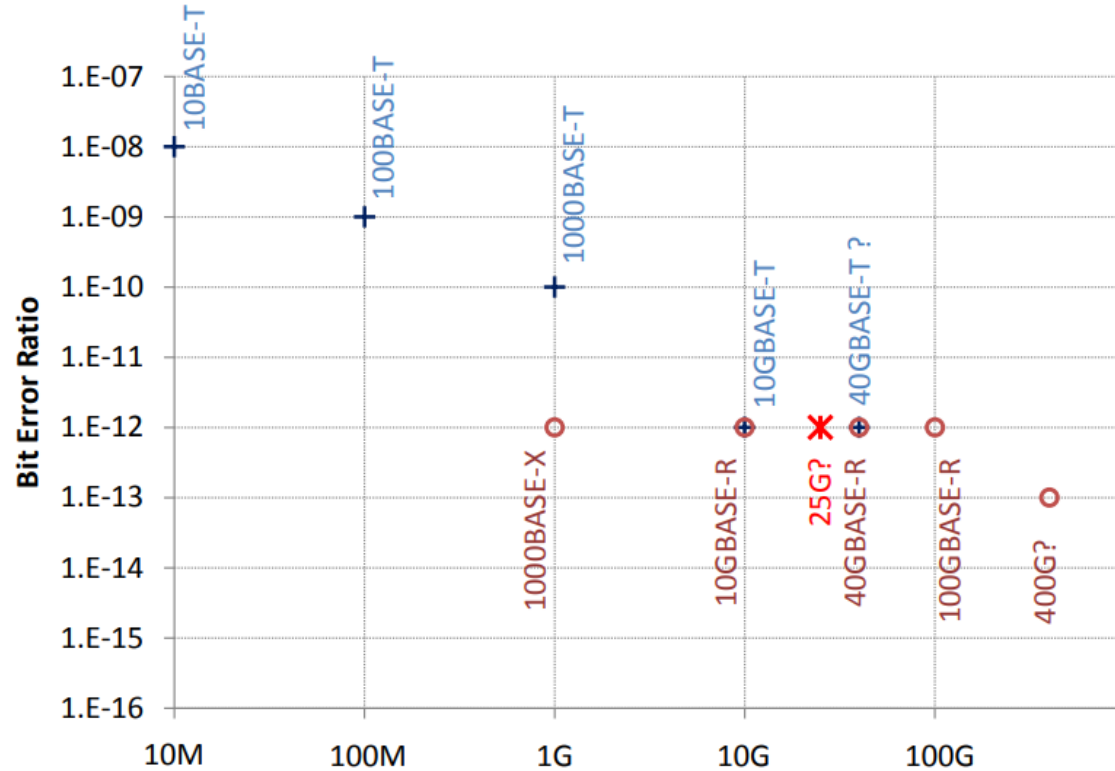
- Latest mid-range FPGA:
 - Multiple 12G-SDI and 25GbE ports on a chip
 - Reasonable chip price range
 - Multiple DDR4 memory interface
- Integrated FPGA modules:
 - Faster to market
 - Easier development by just putting it on a customer's carrier board
 - Less design effort for signal integrity and power integrity of a high-speed and high-density board
 - Very small size
 - Good price: Sub-\$1000



Reliability of 25 GbE network

- RS-FEC in 25 GbE PHY/PCS for Bit Errors
- Jitter and Wander of Video/Audio streams: 10 GbE vs 25 GbE
- ...

Bit Error Rate



- 10 bit error @25 Gb/s

BER	Time
1E-12	6.7 minutes
1E-13	1.1 hours
1E-15	4.6 days

ST 2110 = UDP transmission
 → No error allows

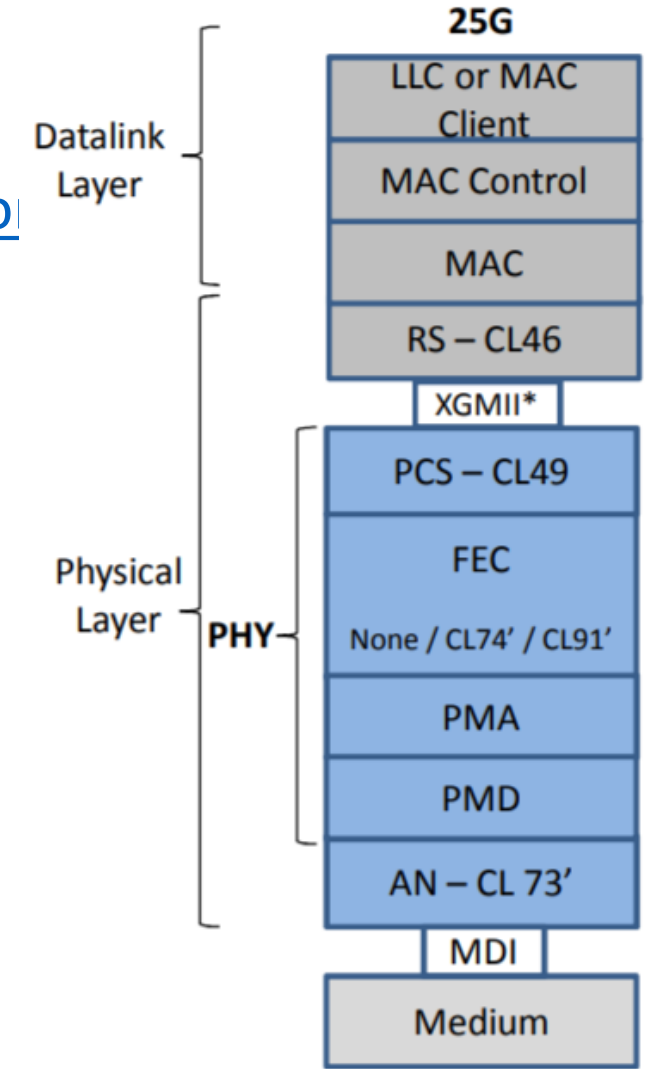
How complements bit errors
 → **RS-FEC** on PCS

- 95 % confidence

BER	Time
1E-12	2 minutes
1E-13	20 minutes
1E-15	1.4 days

RS-FEC in 25GbE PHY

- RS: Reed Solomon, FEC: Forward Error Correction
 - c.f.) <https://en.wikipedia.org/wiki/Reed%E2%80%93Solomon>
- 25GbE: RS-FEC, BASE-R FEC, no FEC
 - **CL91: RS-FEC**: Reed-Solomon – Latency: **250nS** (5280 bits)
 - CL74: BASE-R FEC: Firecode – Latency: 82nS (2112 bits)
- Criteria:
 - up to 5m: RS-FEC
 - up to 3m, lower loss: RS-FEC or BASE-R FEC
 - up to 3m, even lower loss: RS-FEC, BASE-R FEC, or no FEC
- **RS-FEC(528,514)**
 - Total symbols: $n = 528$, Message symbols: $k = 514$
 - Bits per symbol: $m = 10$, Correctable symbols: $t = 7$



ST 2110 with PTP Synchronization

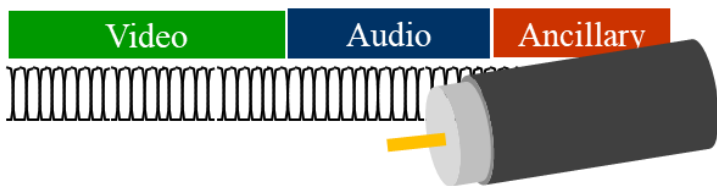
Key Factor of Reliability: **clock recovery** @ receivers

SDI Network

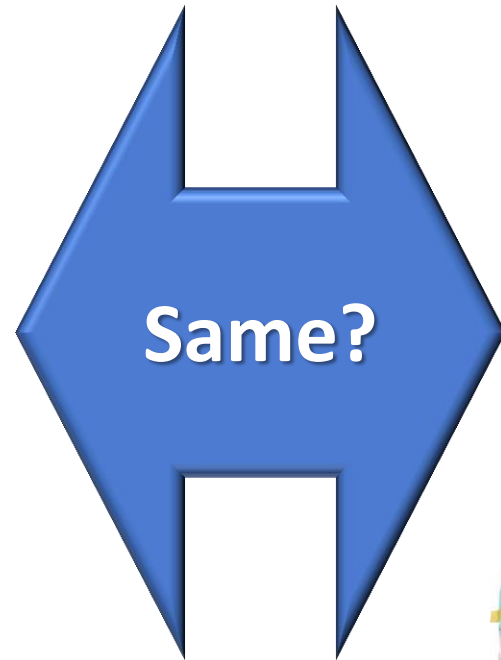
Timing Jitter Requirement

3G-SDI < 2UI

12G-SDI < 2UI

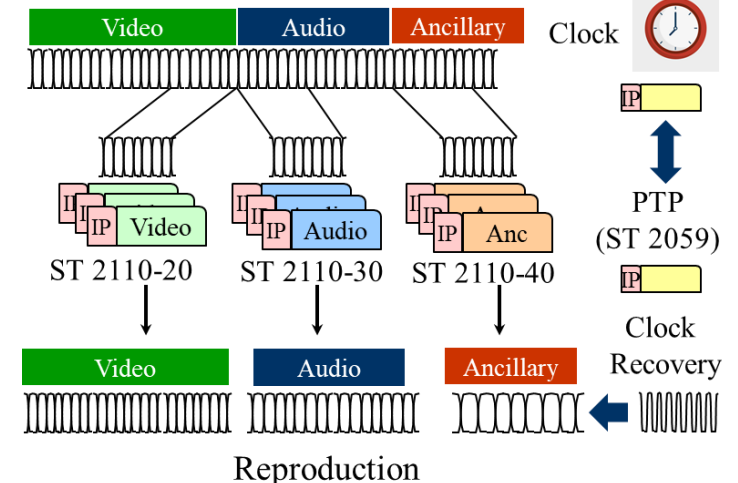


UI := minimum time interval between condition changes of a data transmission signal
 UI = 0.333 ns / baud @ 3Gb/s (3G-SDI)
 UI = 0.083 ns / baud @ 12Gb/s (12G-SDI)



IP Network

Lock-time Requirement
 5 sec with 1 uS PTP offset



Low Latency

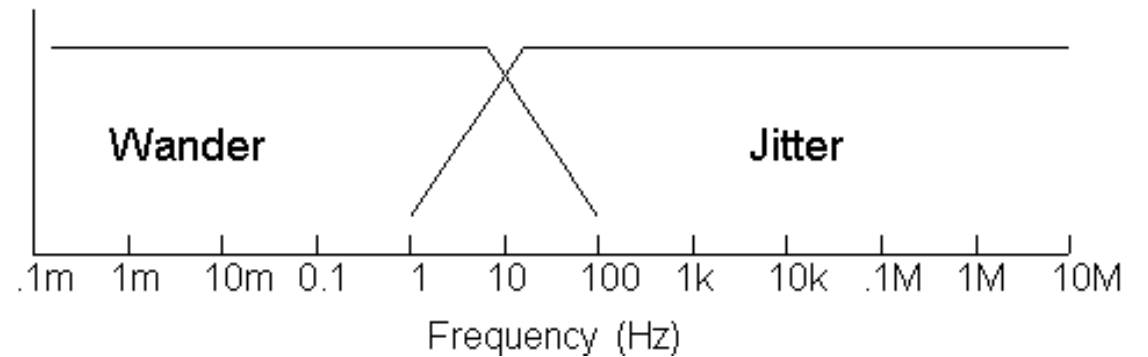
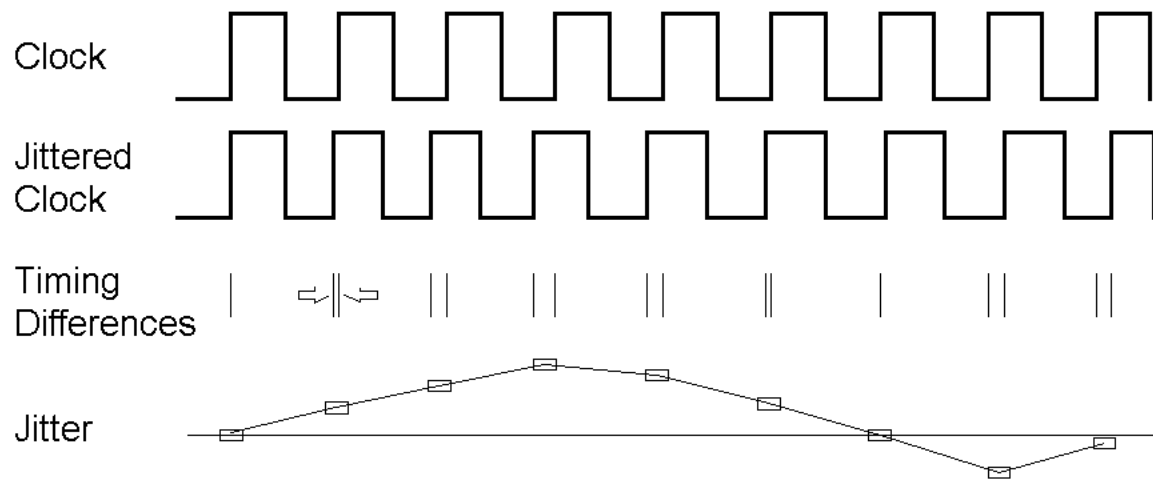
↓↑ **tradeoff**

Buffer Size (overflow/underflow)

... clock recovery performance

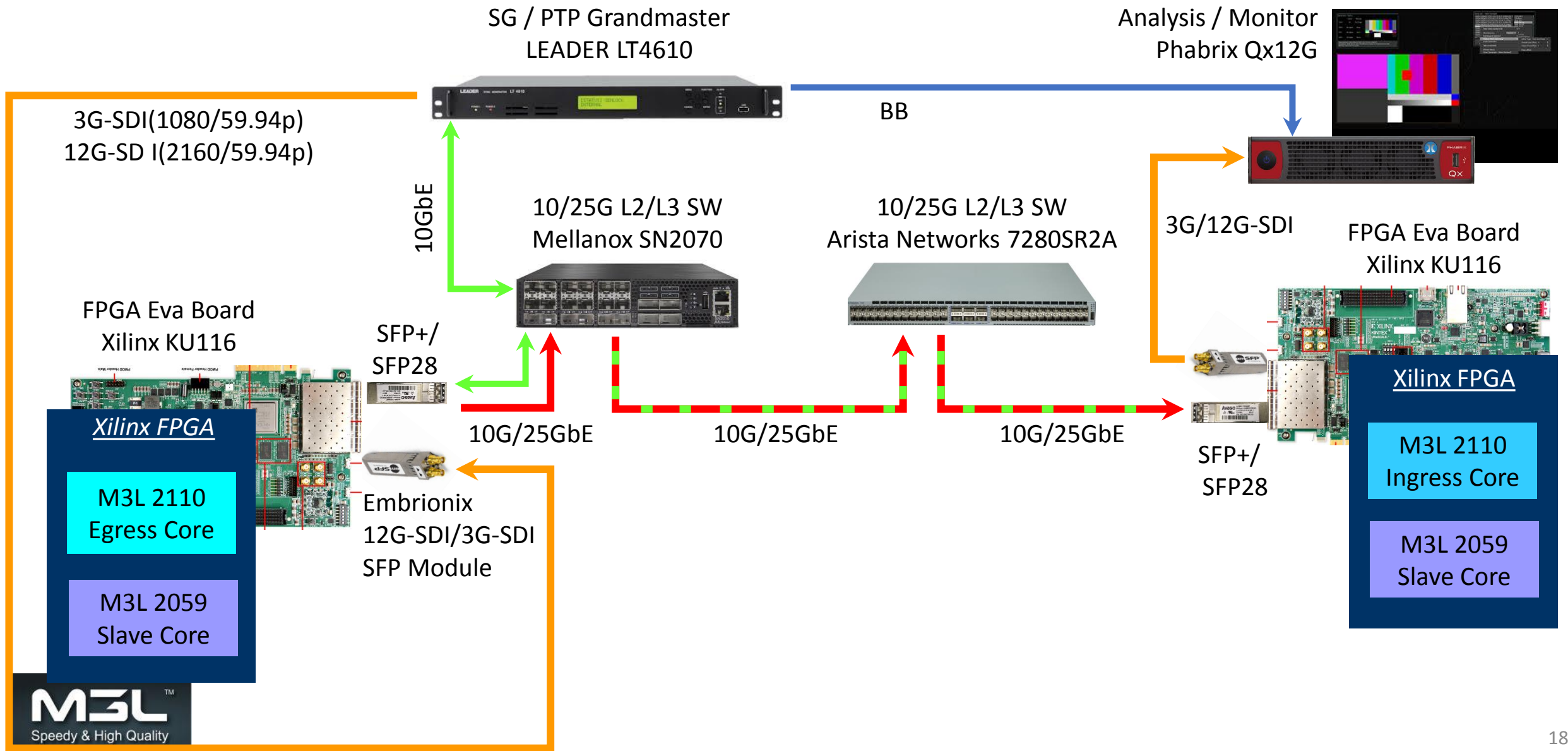
Jitter and Wander Evaluation for ST 2110

- Jitter and Wander of reproduced SDI signals
 - What’s Jitter/Wander ?
 - “the *short-term (jitter)* and the *long-term (wander)* variations of the significant instants of a digital signal from their ideal positions in time”



The figures are quoted from the site above.

25 GbE vs 10 GbE Evaluation



FPGA Eva Board
Xilinx KU116

Xilinx FPGA

M3L 2110
Egress Core

M3L 2059
Slave Core

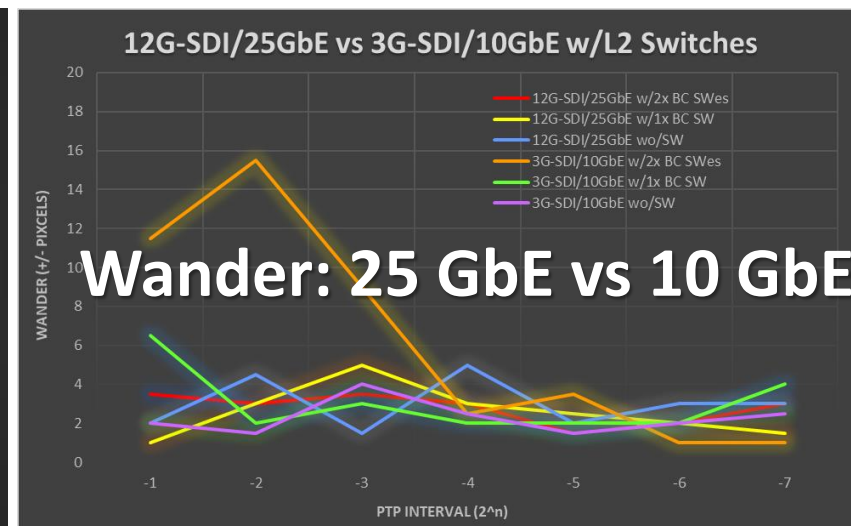
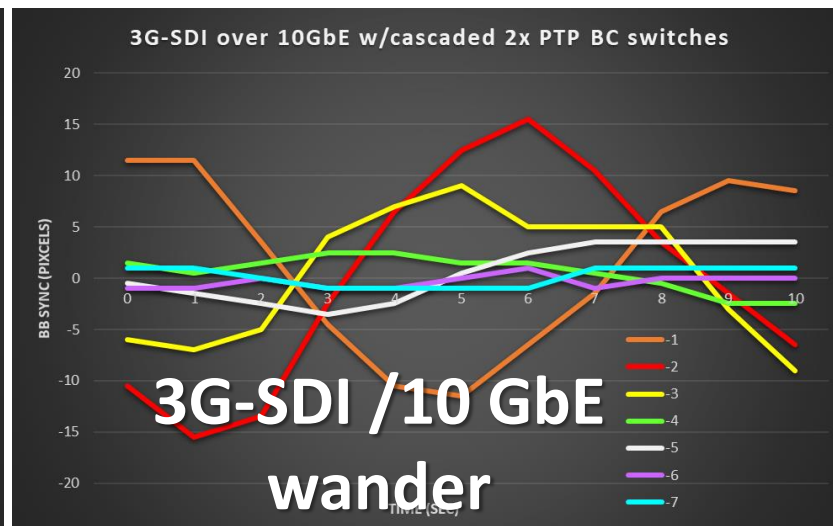
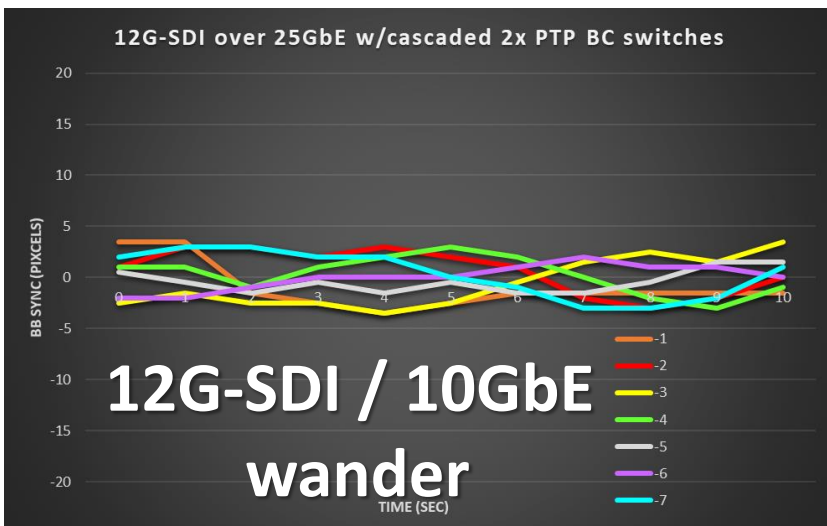
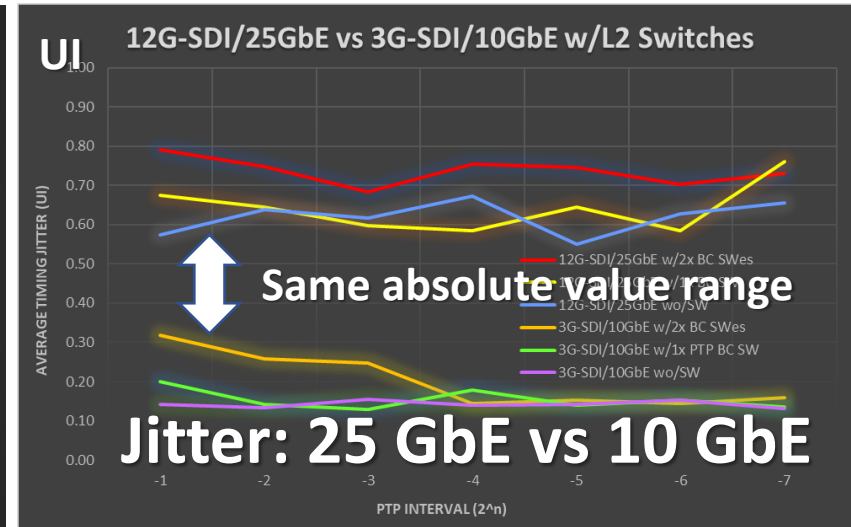
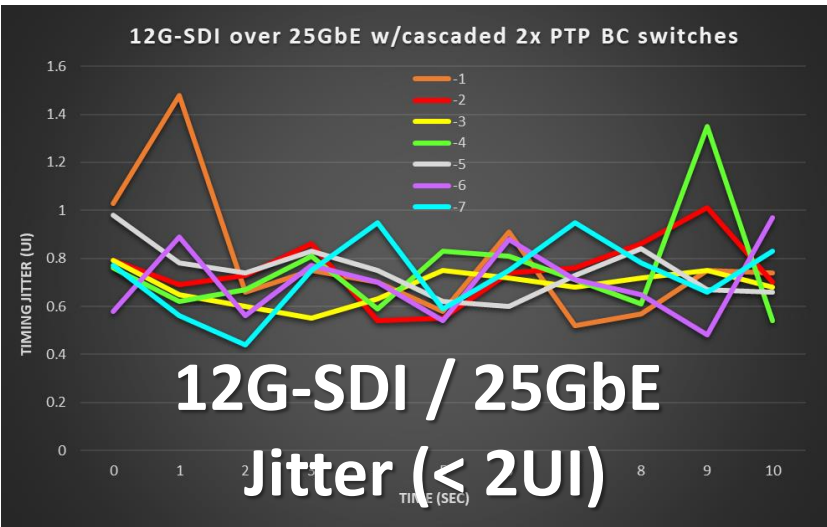
Xilinx FPGA

M3L 2110
Ingress Core

M3L 2059
Slave Core

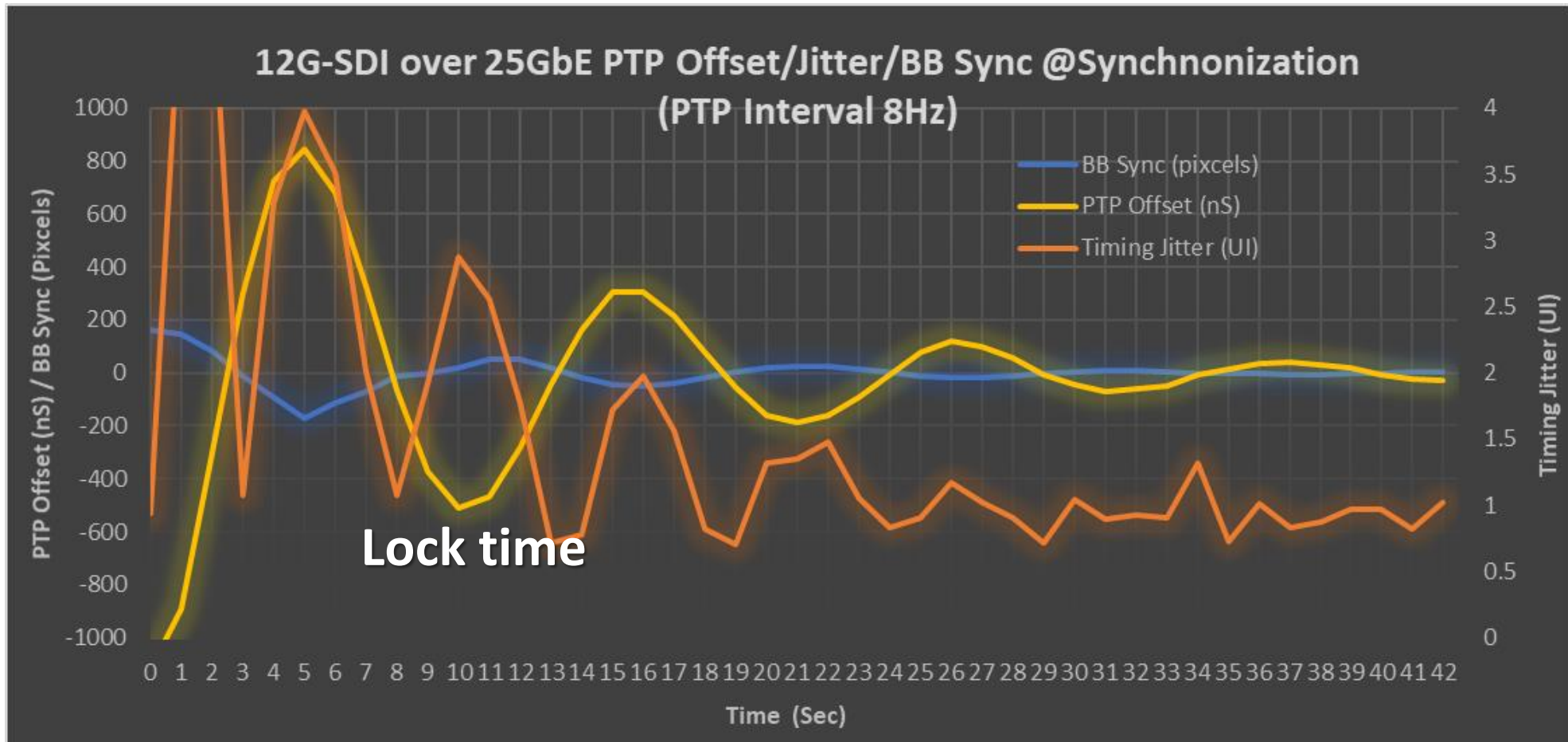
Evaluation Result: Jitter and Wander

- Received video data on 25 GbE has the similar quality as on 10 GbE



Evaluation Result: Lock time

- Working to make it faster convergence
 - Even though we met the ST 2059 requirements : PTP offset = 1 uS within 5 sec



Number of 25 GbE-based Products

- Let's take a look lots of 25GbE-based products in NAB Show this year

- Ikegami @C7925 : [4K Camera Control Unit](#)
- FOR-A @C5016 : [4K Video Switcher](#) *
- LEADER @C8508 : [4K Wave Form Monitor, Rasterizer](#)
- Matrox @SL3808 : [Network Card](#)
- Grass Valley @SL106 : [Universal Optional Card](#)
- AJA @SL2416 :
- Embrionix @N2508 :
- Imagine Communications @SL1516 :
- EVERTZ @N1503 : [Media Gateway](#)
- Tektronix @SU5006 : [Media Monitor/Analyzer](#)
- Cisco Systems @SU8510 : [L3 switches](#)
- Arista Networks @N3008 : [L3 switches](#)
- Mellanox Technologies @SL6025 : [L3 switches](#)
- Nextera Video @SL10230 : [FPGA IP Cores](#)
- Image Matters @C8826 : [FPGA Modules](#)
- ... etc

25GbE Advantage

- Compact
 - 200 Gb/s in 1 slot (8 ports x 25 Gb/s)
- Multiple streams per port
 - 16 in / 16 out x 1080i (1.5G)
 - 8 in / 8 out x 1080p (3G)
 - 2 in / 2 out x 2160p (4K)
- Configurable per port
 - More flexible compared with 40/100 GbE
 - ST 2110 or ST 2022-6 per port
 - 25 GbE or 10 GbE per port
 - Different type of configured multiple streams can be trunked



* prototype

FOR.A®

SFP+ポート



* prototype

Conclusion

- 25 GbE-based production system is almost ready in production
 - Already reasonable cost range
 - Similar network quality with 10 GbE
 - More new equipment supported 25 GbE seems to be launched this year
- Historically users want as high bandwidth network as possible if it's at the similar cost
- Let's find 25 GbE-based solutions in NAB Show!
- Let's start using 25 GbE !!

Thank You :)

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