Measuring and Visualizing Live IP traffic using LIST

Webinar – June 14th 2018

Willem Vermost - vermost@ebu.ch

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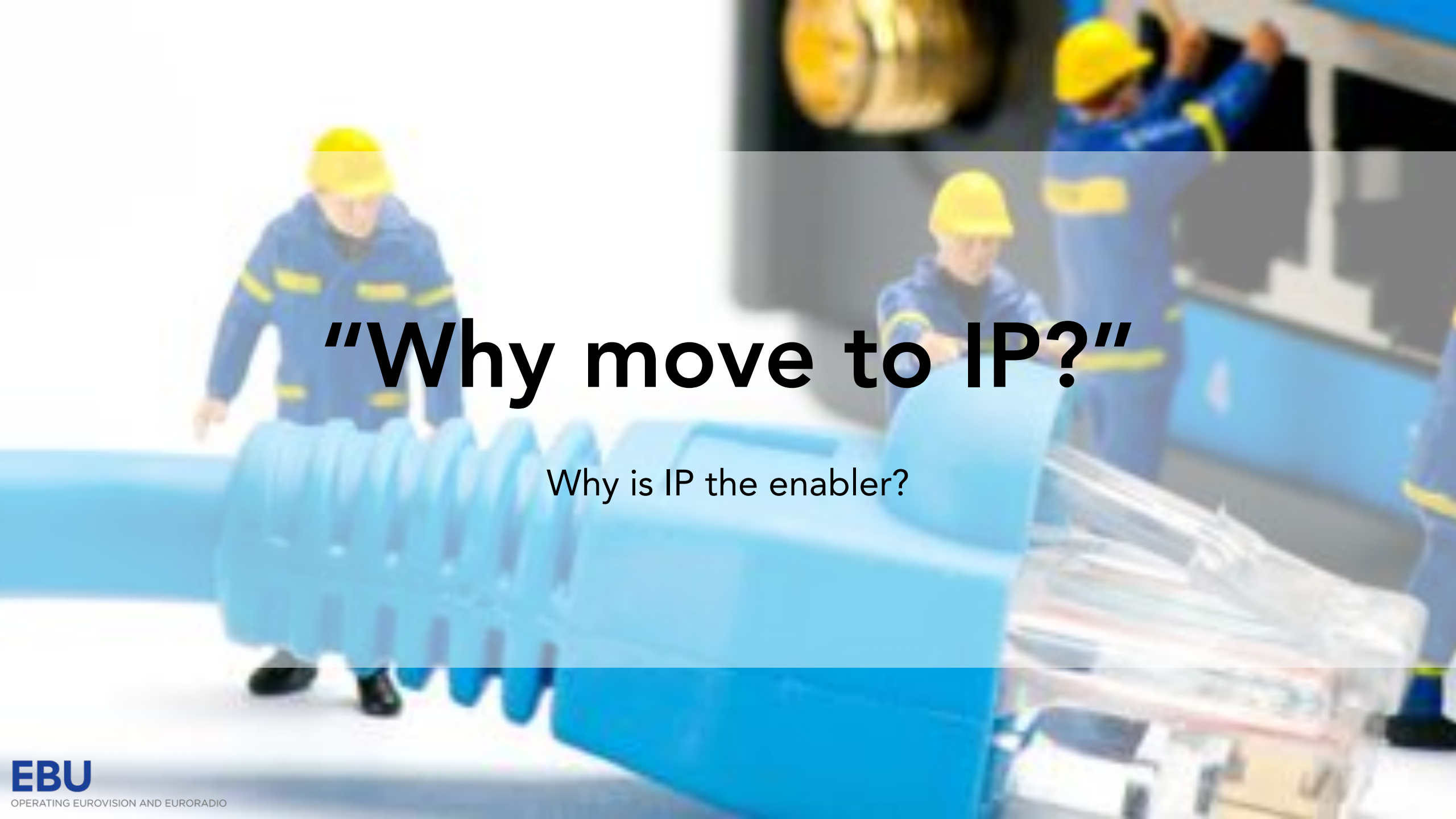
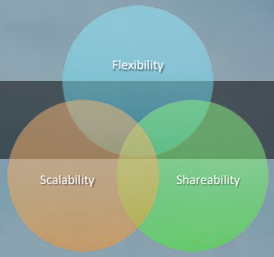
- Why we move to IP?
- The JT-NM Roadmap!
- In a nutshell… what is:
  - SMPTE ST 2110
  - SMPTE ST 2059
- Packet Delay Varation – why is this important?
- What is the Live IP Software Toolkit?
  - Why did we develop it?
  - What are its capabilities?



“Why move to IP?”

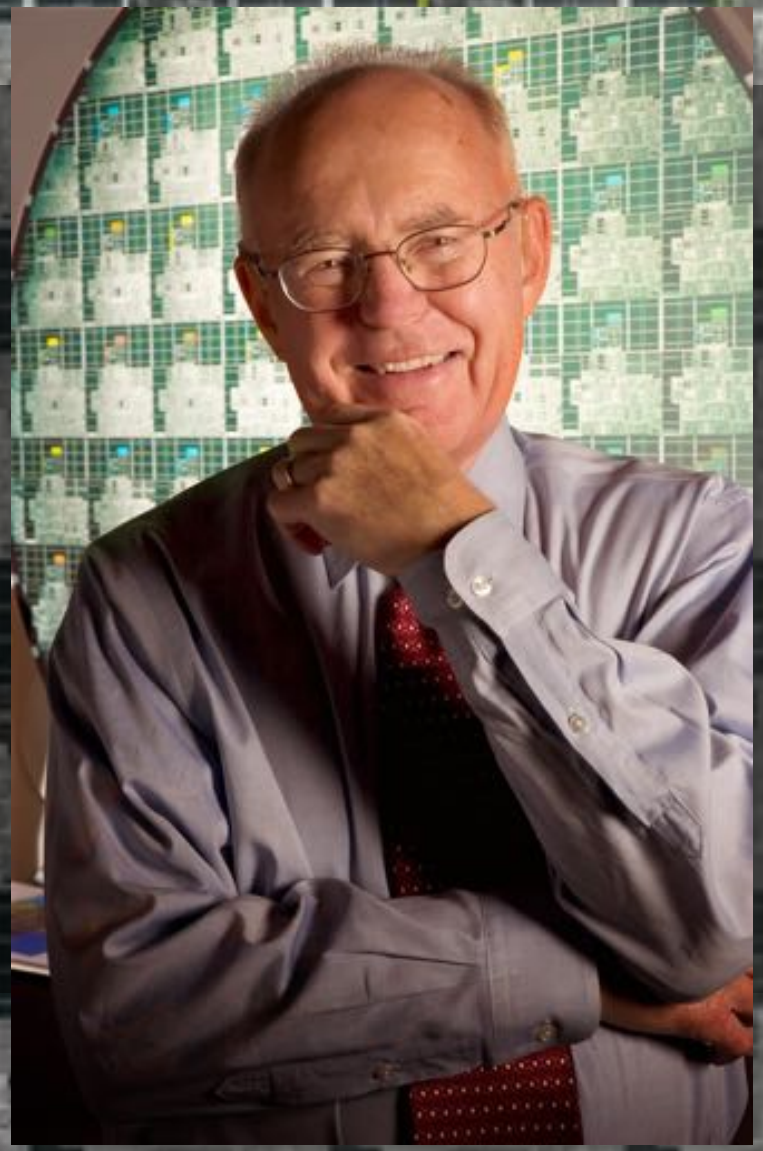
Why is IP the enabler?

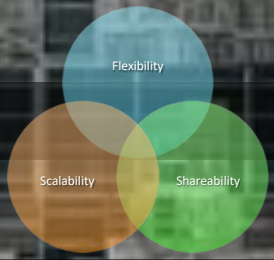
Flexibility



- To adopt new formats and use multiple formats (HD, UHD, HFR, HDR, VR, AR, …)
- To use right quality at the right time
- IP is agnostic to whatever it is transporting

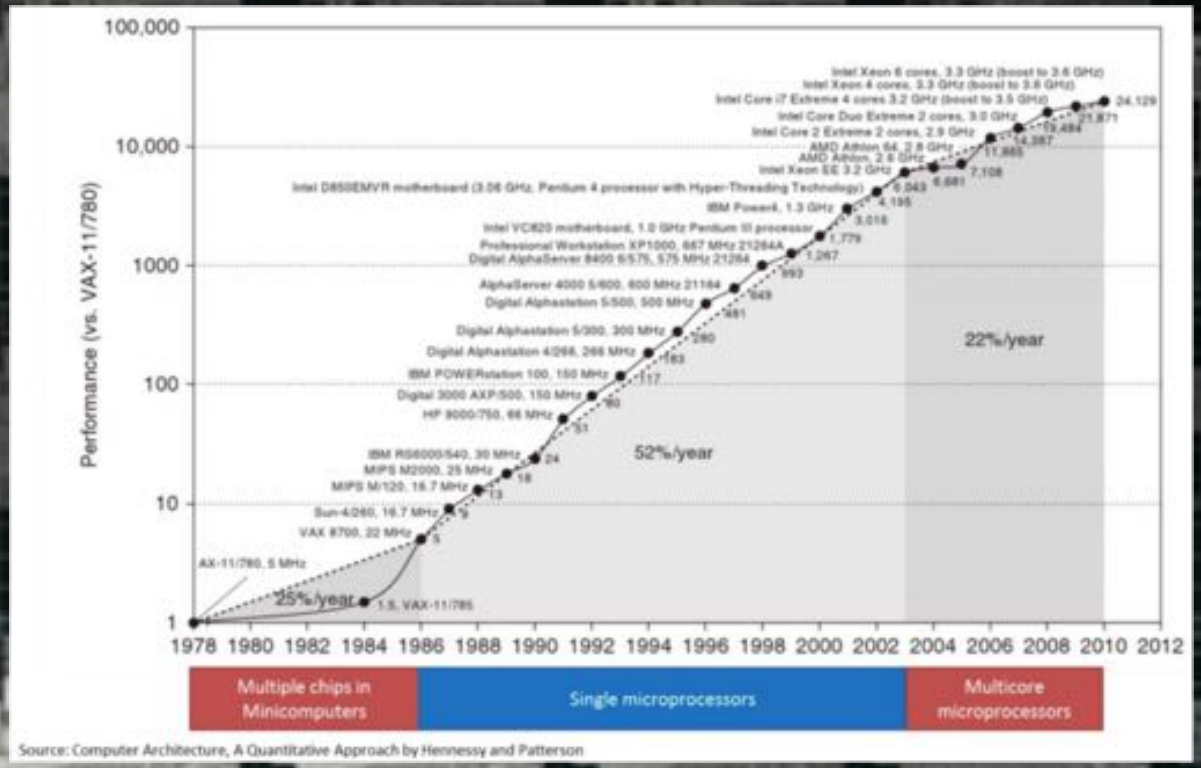
Scaleability



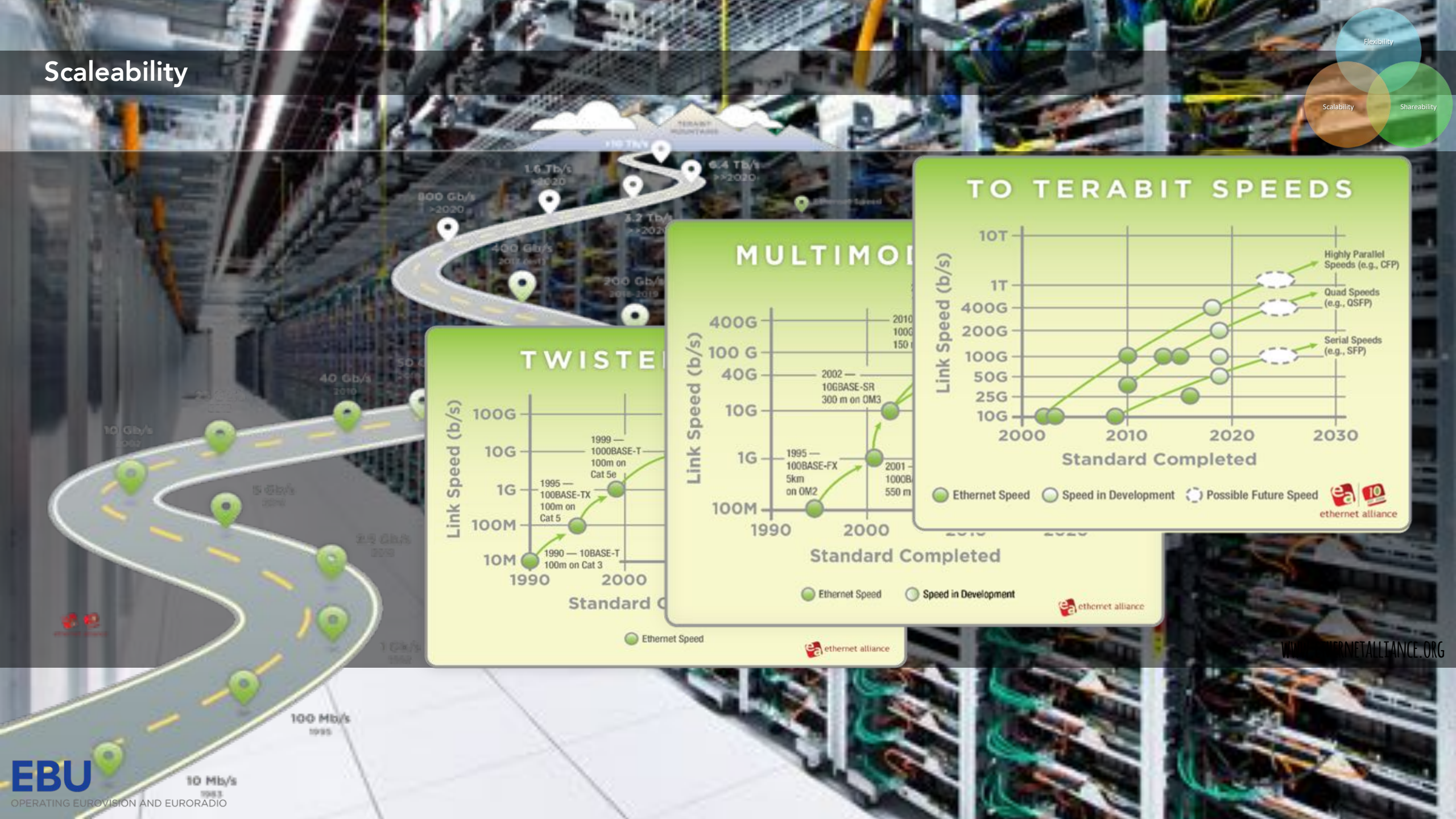


MOORE'S LAW

transistors per inch^2 **double every year**



Scaleability



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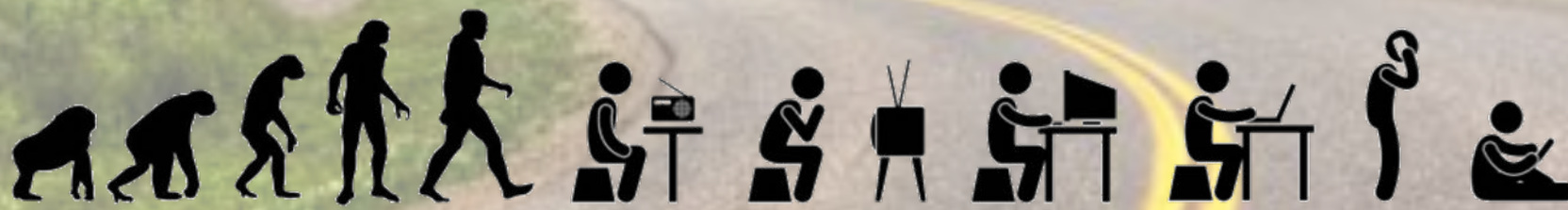
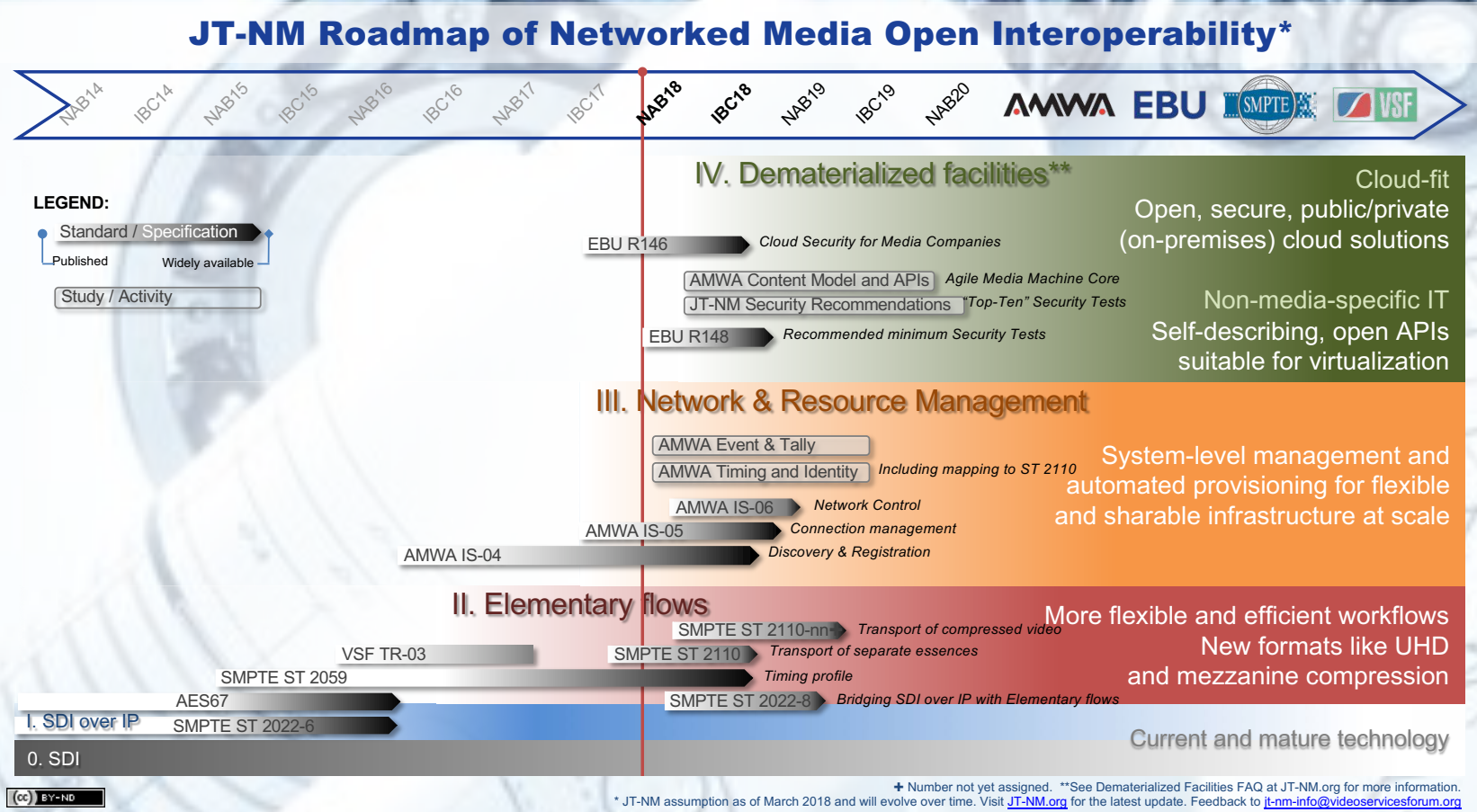
"Evolution Not Revolution!"



THE LONG WINDING ROAD...

Shareability



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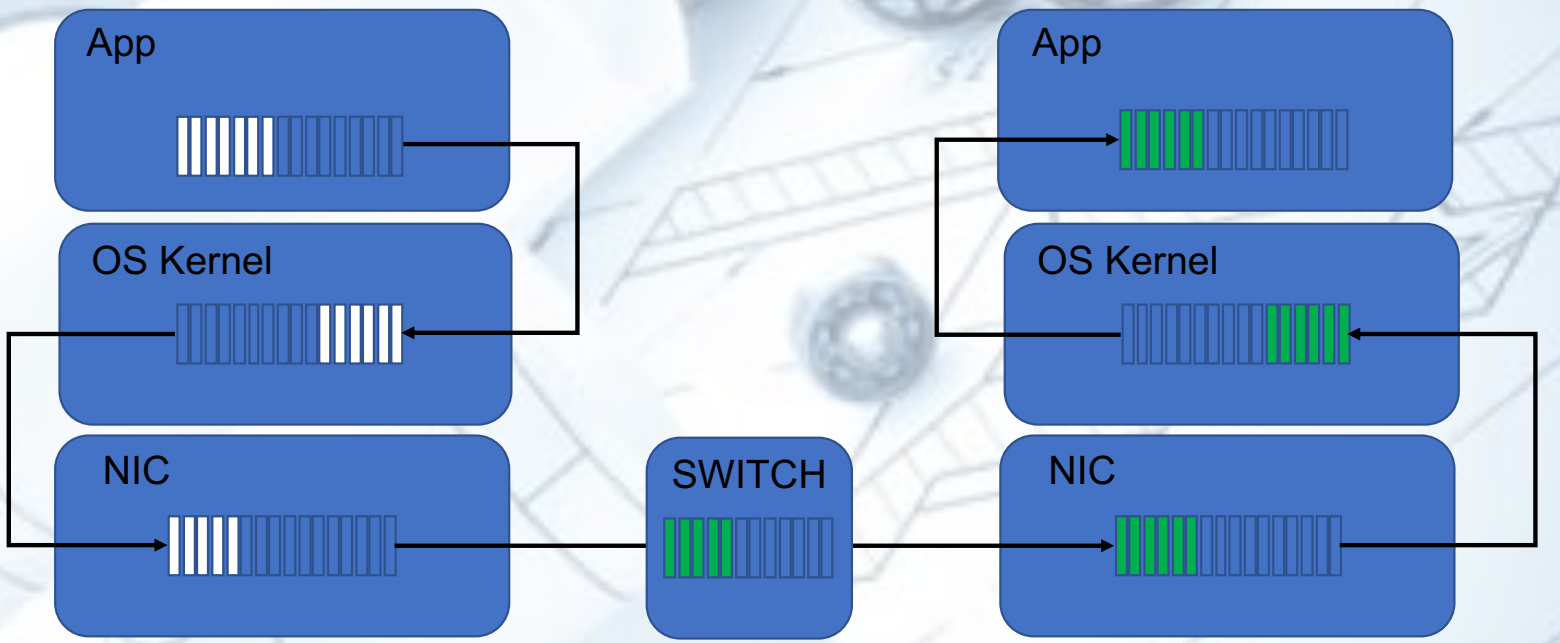
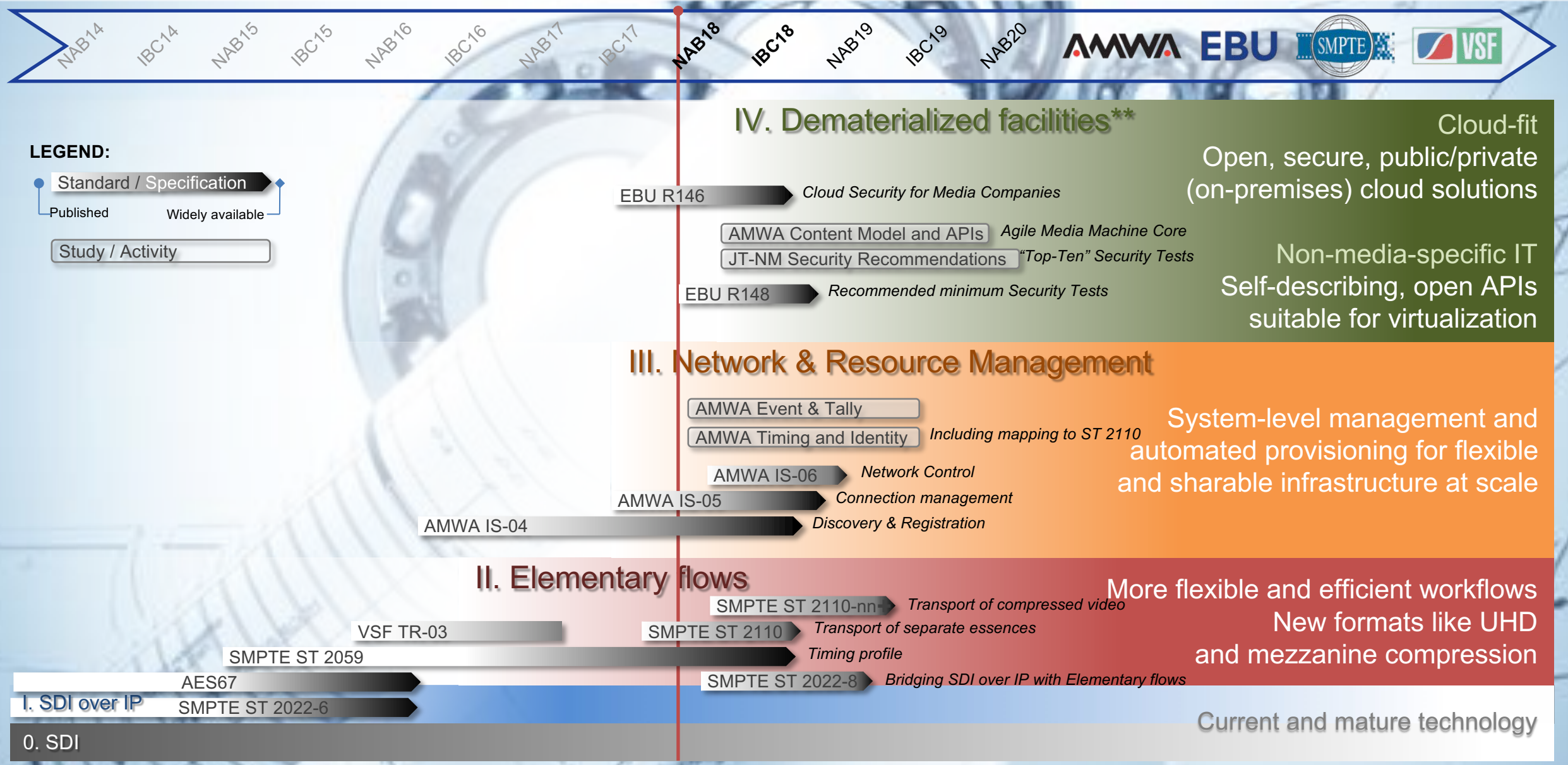
✚ Number not yet assigned. **See Dematerialized Facilities FAQ at JT-NM.org for more information.
* JT-NM assumption as of March 2018 and will evolve over time. Visit JT-NM.org for the latest update. Feedback to jt-nm-info@videoservicesforum.org

Shareability

- FPGA
- Software
- Virtual



JT-NM Roadmap of Networked Media Open Interoperability*



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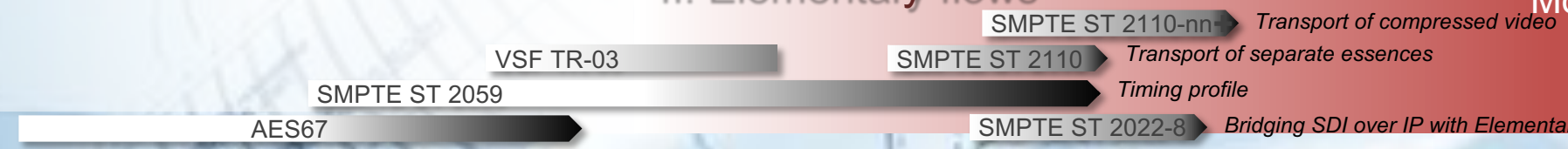
The focus of this presentation is measurement and visualization fundamentals of your Live IP facility SMPTE ST 2059 and SMPTE ST 2110

II. Elementary flows



More flexible and efficient workflows
New formats like UHD
and mezzanine compression

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What is SMPTE ST 2110?

In a nutshell

- SMPTE ST 2110-10 System Timing and Definitions
- SMPTE ST 2110-20 Uncompressed Active Video
- SMPTE ST 2110-21 Traffic Shaping and Delivery Timing for video
- SMPTE ST 2110-30 PCM Digital Audio
- SMPTE ST 2110-40 SMPTE ST 291-1 Ancillary Data

SMPTE ST 2110-10 System Timing and Definitions

- Specifies how SMPTE ST 2059 PTP timing is used for SMPTE ST 2110
- Specifies how the RTP timestamps are calculated for Video, Audio, and ANC signals
- Specifies general requirements of the IP streams (UDP, Multicast)
- Specifies using the Session Description Protocol (SDP)
- The actual stream formats are in the other parts of the standard

SMPTE ST 2110-20 Uncompressed Active Video

- Only the “Active” image area is sent – no blanking
- Supports:
  - Image sizes up to 32k x 32k
  - Y’Cb’Cr’, RGB, XYZ, I’Ct’Cp’
  - 4:2:2, 4:2:2, 4:4:4, and more
  - Bit depth: 10, 12, 16
  - HDR

SMPTE ST 2110-21 Traffic Shaping and Delivery Timing for video

- Constrains the packet delay variation of a sender
- Describes a virtual test for the network ($\mathbf{C_{MAX}}$)
  - Narrow senders
  - Wide senders
- Describes a virtual test for the receive buffer ($\mathbf{VRX_{FULL}}$)
  - Narrow receivers (not capable of receiving wide senders)
  - Wide receivers (universal)

- Built On AES67 -- PCM Audio (only)
- Many things allowed but only a few required
  - 48kHz sampling is required for all devices
  - 1ms packet time is required for all devices
  - 1..8 channels per stream is required for all devices
  - 16 & 24 bit depth required for all devices
- Outside the required, must read specs carefully!

SMPTE ST 2110-40 SMPTE ST 291-1 Ancillary Data

- Over the years, lots of things have been put into the SDI "Ancillary Data" system
  - Some are tightly related to the video signal
  - Some are really separate essence
  - Some are just along for the ride
- Audio is handled a better way – don't use this method for audio
- IETF RFC 8331 RTP Payload for SMPTE 291-1 Ancillary Data
- SMPTE ST 2110-40 says how to use this RFC with SMPTE ST 2110

- What is SMPTE ST 2110?
  - It is a Suite of documents
  - It is about elementary streams
  - It is leveraging IT standards: PTP, IP, UDP / Multicast, RTP, …
- Based upon RFC 4175, AES 67
- References SMPTE ST 2059

Packet Delay Variation

SMPTE ST 2110-21: The network compatibility model - C_{MAX}

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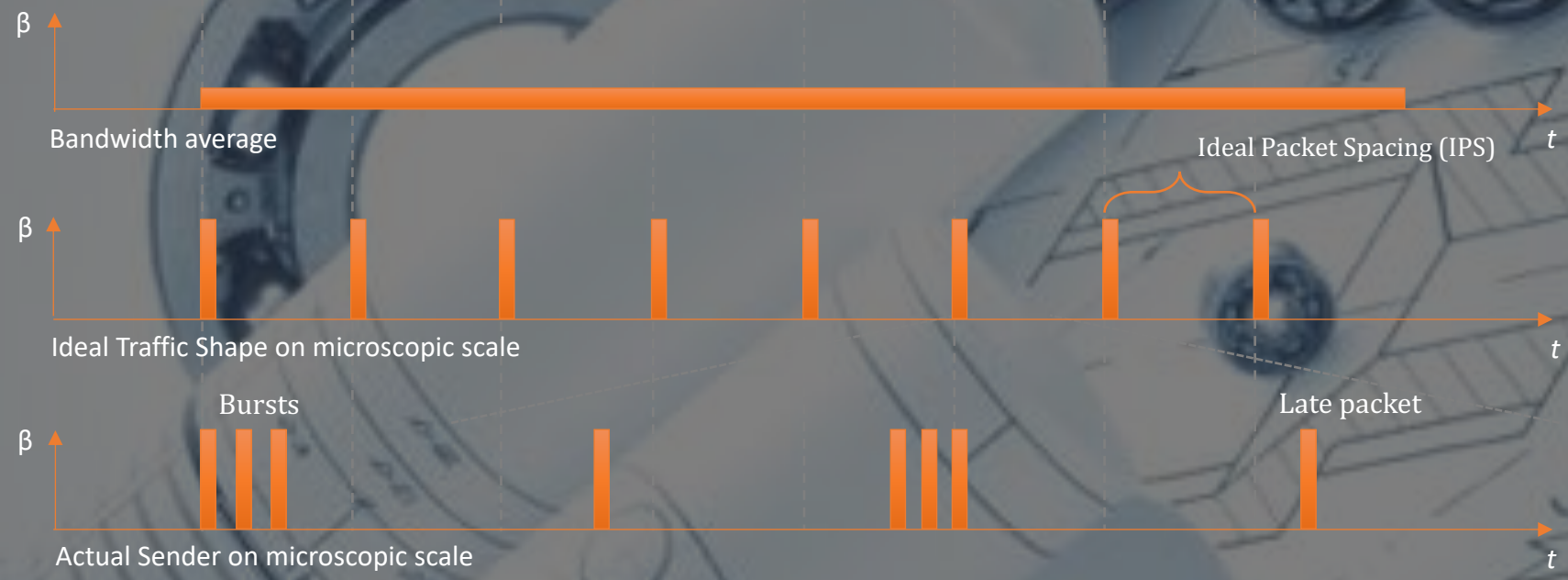
Well behaved traffic on a single lane

Bursty traffic

AVERAGE SPEED

55



SPEED LIMIT

80

☺
MULTIPLE LANES

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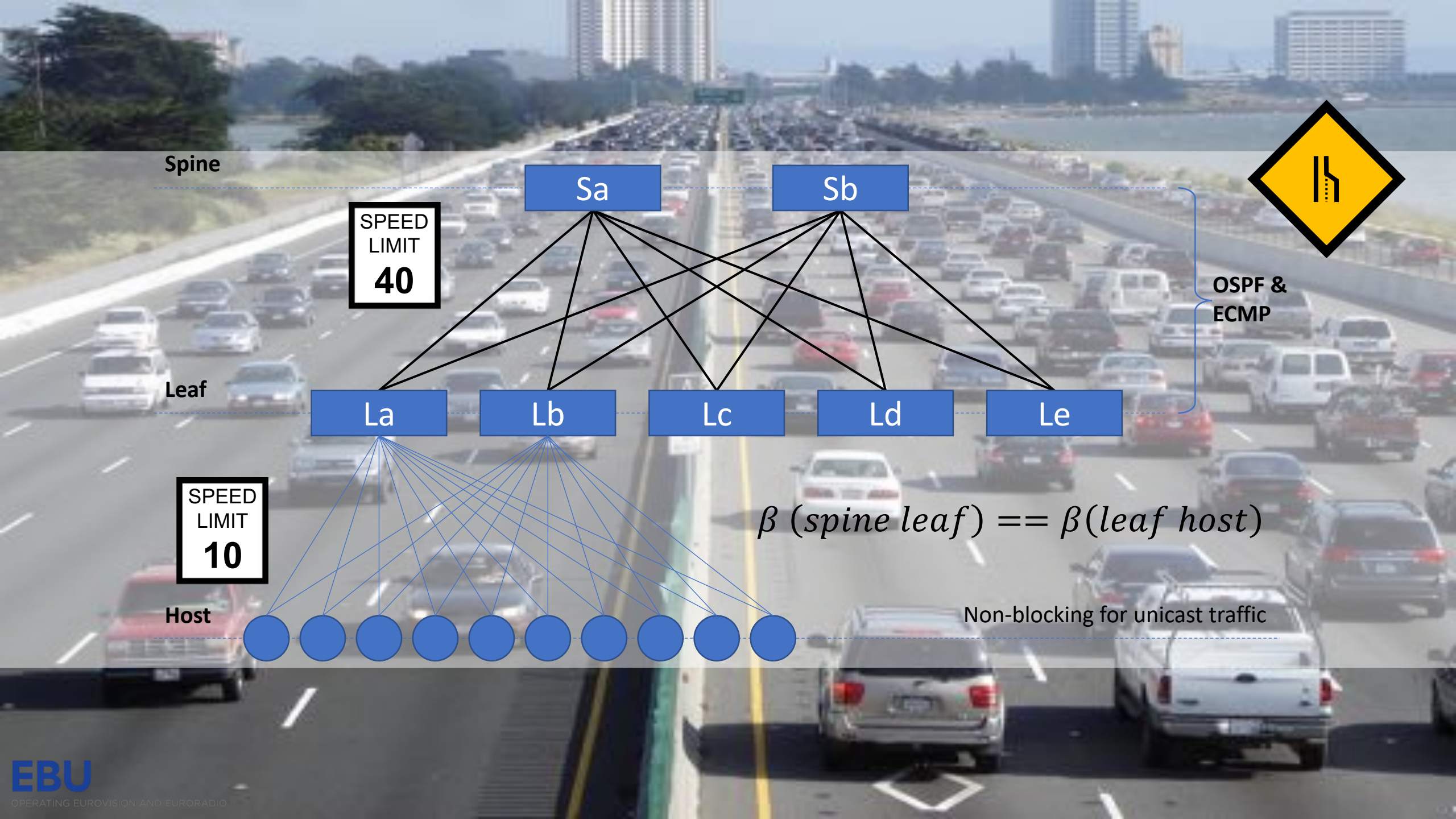

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SPEED LIMIT 10
12 packets arrive at linerate of 10 Gbps at the switch. Those packets willl be serialised and put on the output port at 40 Gbps.
La
Sa
4β
Buffer
$12\ \frac{1}{3}\beta$
SPEED LIMIT 40
Packets arrive at line rate … 12 x 10 Gbps pushed to 1 x 40 Gbps link
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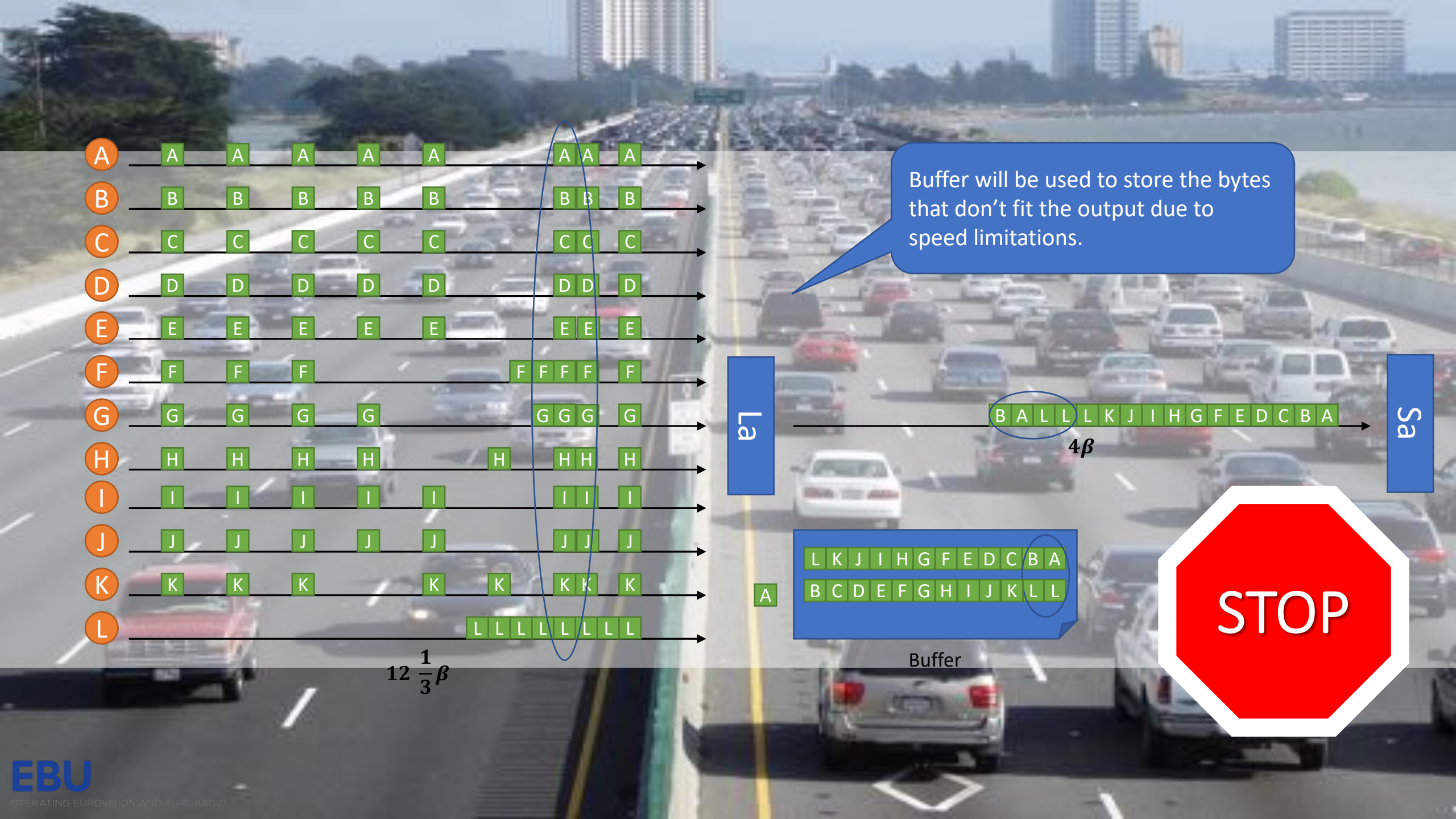
A
B
C
D
E
F
G
H
I
J
K
L
$12\frac{1}{3}\beta$
La
Sa
Buffer will be used to store the bytes that don't fit the output due to speed limitations.
B A L L L K J I H G F E D C B A
4β
A
L K J I H G F E D C B A
B C D E F G H I J K L L
Buffer
STOP
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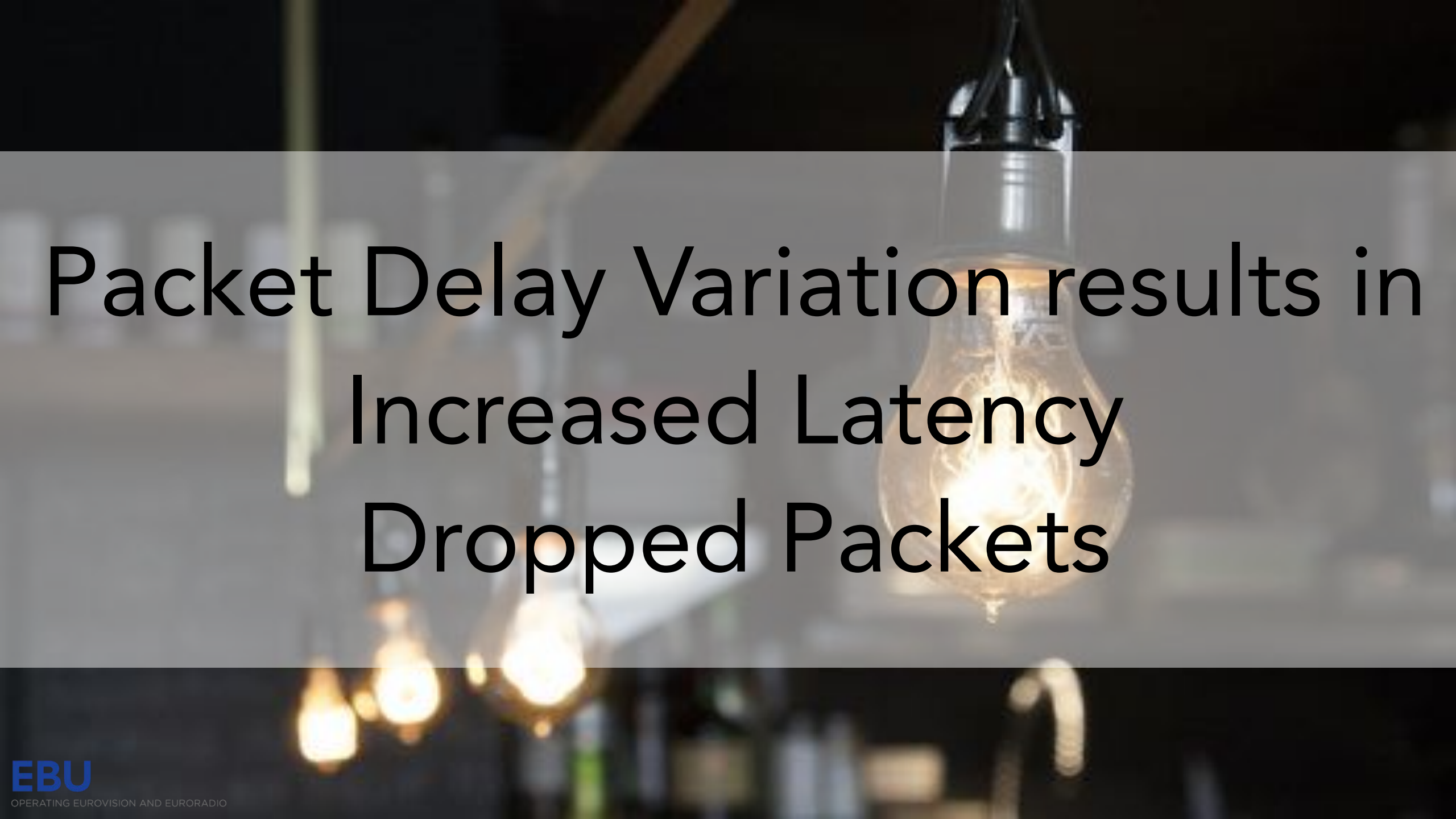
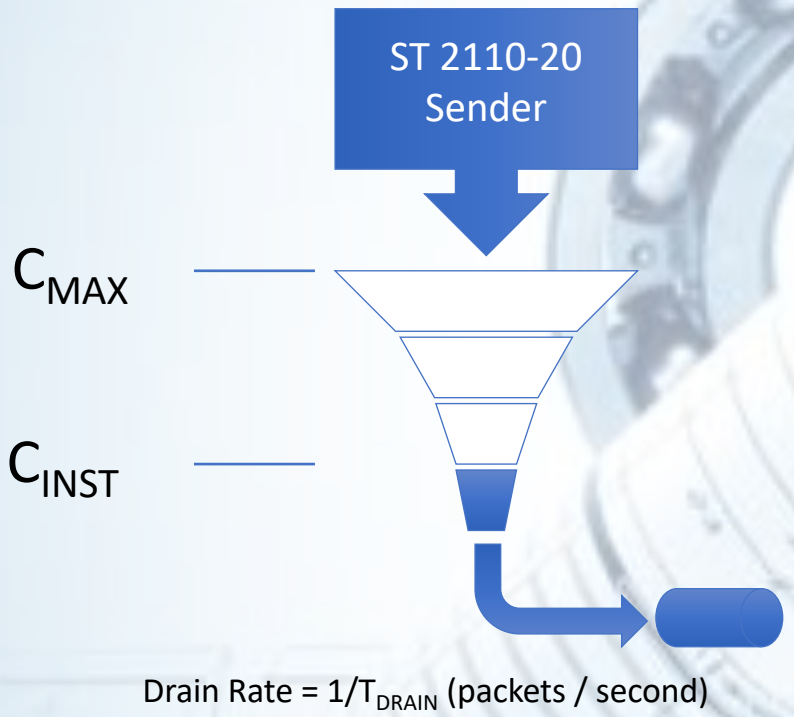


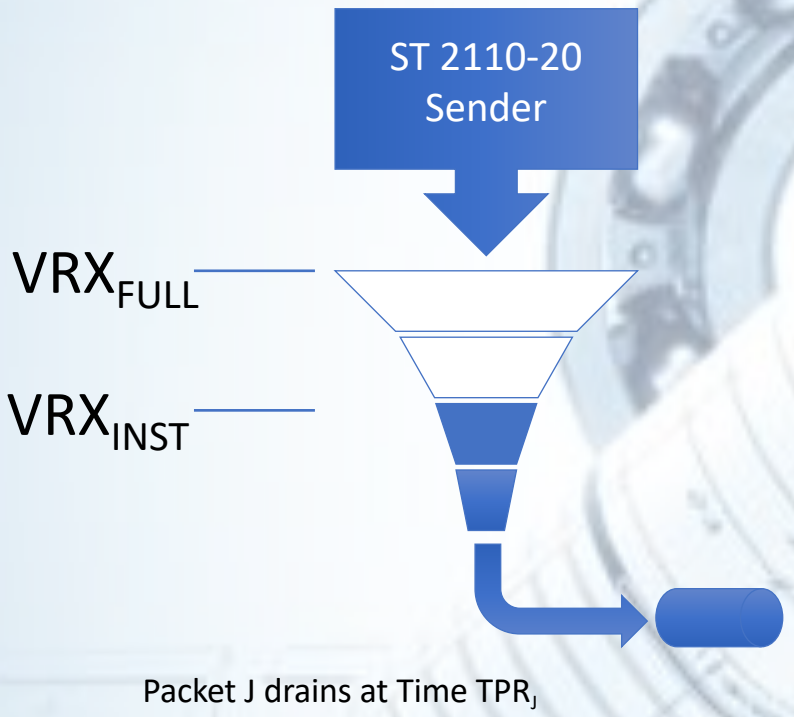
Packet Delay Variation results in Increased Latency Dropped Packets

SMPTE ST 2110-21 – Network Compatibility Model



- Tested at the output of the sender
- Measures PDV introduced by a sender
- C_{MAX} is the maximum amount of packets allowed in the “leaky bucket”
- If $C_{INST} > C_{MAX}$ -> packet might get dropped in the network

SMPTE ST 2110-21 – Virtual Receive Buffer VRX



- Tested at the output of the sender
- The VRX buffer is drained as a function of the clock
- VRX_{FULL} is the maximum amount of packets allowed in the “leaky bucket”
- If $VRX_{INST} > VRX_{FULL}$ -> packet might get dropped at receiving end

What is SMPTE ST 2059?

In a nutshell

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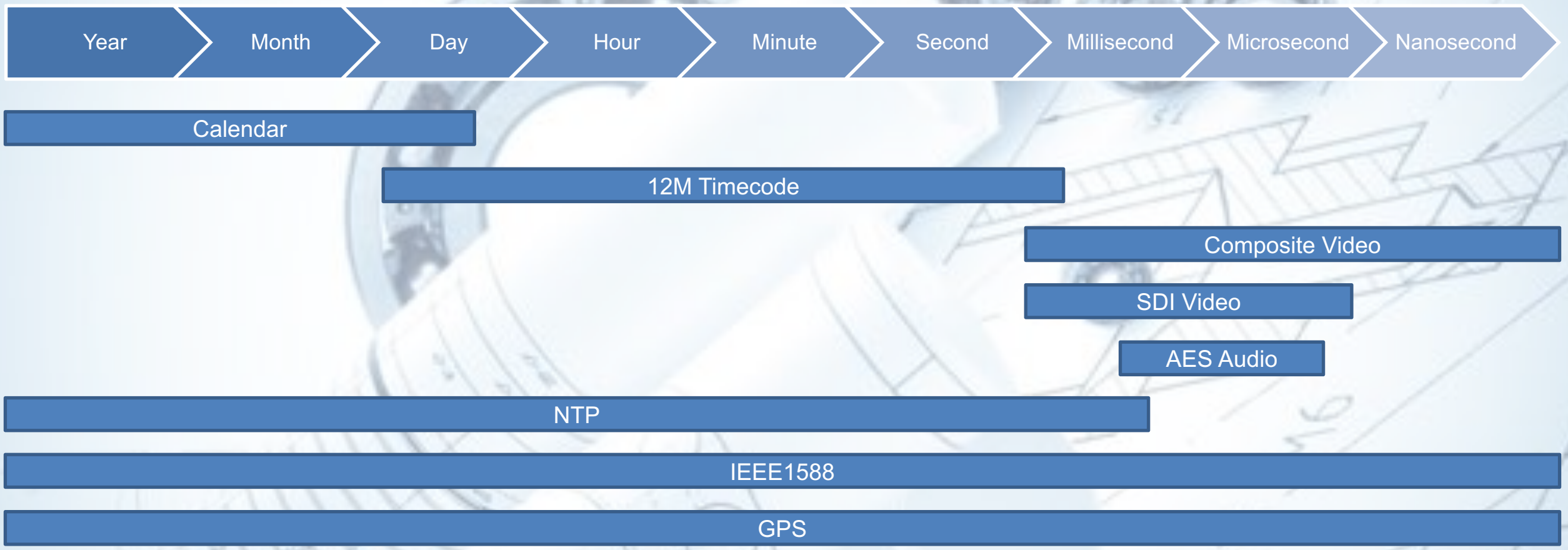
- SMPTE ST 2059-1
  - Generation and Alignment of Interface Signals to the **SMPTE Epoch**
- SMPTE ST 2059-2
  - SMPTE **Profile** for Use of **IEEE-1588** Precision Time Protocol in Professional Broadcast Applications

Range And Granularity



SMPTE 2059-2 Profile

Attributes	AES67-2015 profile	SMPTE ST 2059-2:2015 profile
defaultDS.domainNumber	default value: 0 configurable range: 0 to 255	default value: 127 configurable range: 0 to 127
portDS.logSyncInterval	default value: -3. configurable range: -4 to +1.	default value: -3 configurable range: -7 to -1
portDS.logAnnounceInterval	default value: 1 configurable range: 0 to 4.	default value: -2 configurable range: -3 to +1
portDS.logMinDelayReqInterval	default value: 0. configurable range: -3 to 5 or portDS.logSyncInterval to portDS.logSyncInterval +5, whichever is more restrictive.	default value: portDS.logSyncInterval configurable range: portDS.logSyncInterval to portDS.logSyncInterval+5
portDS.announceReceptTimeout	default value: 3 configurable range: 2 to 10	default value: 3 configurable range: 2 to 10

A PTP profile is a constrained set of values / ranges of IEEE 1588

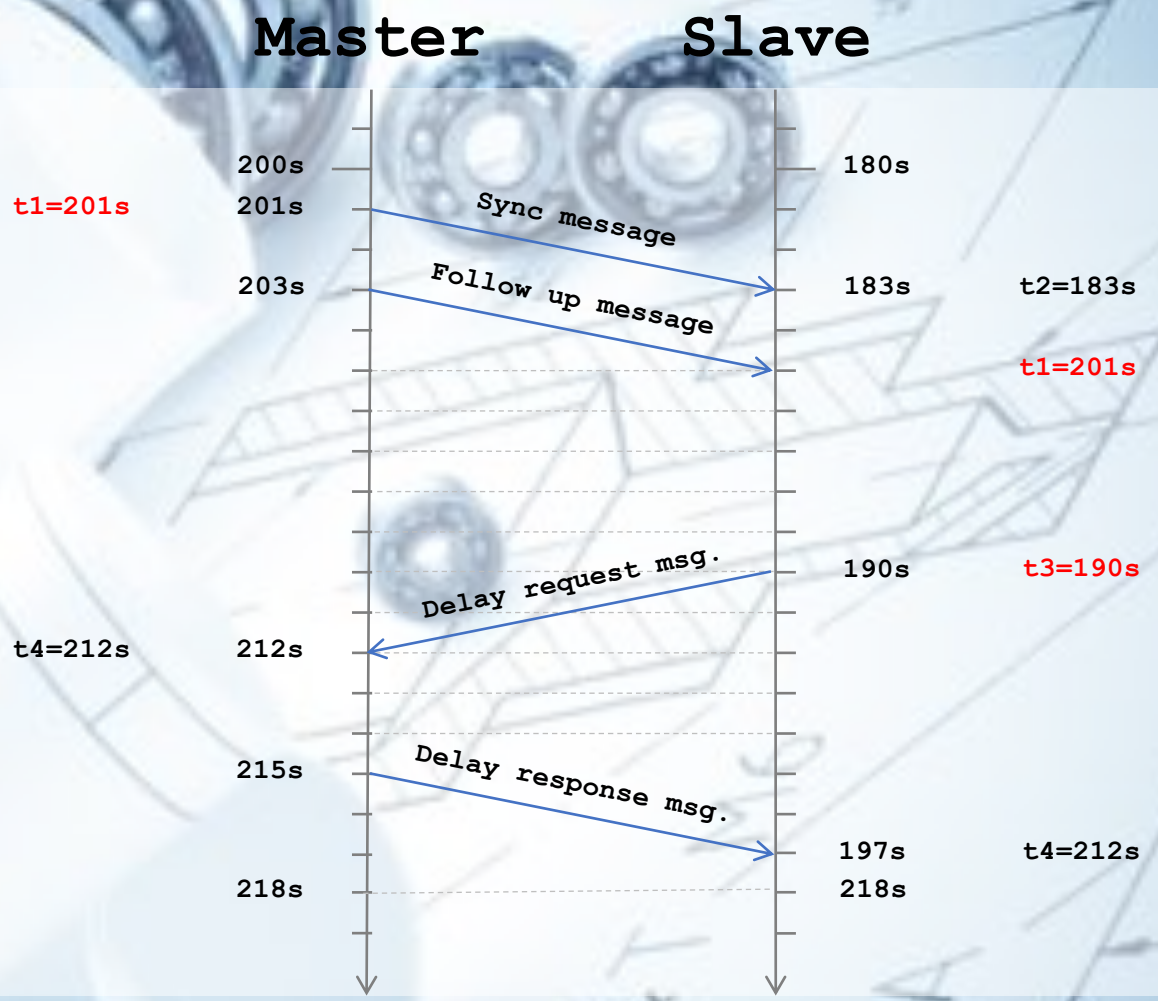
Synchronizing the slave

In order to synchronize the slave time with the exact time of the master, 4 messages are exchanged:

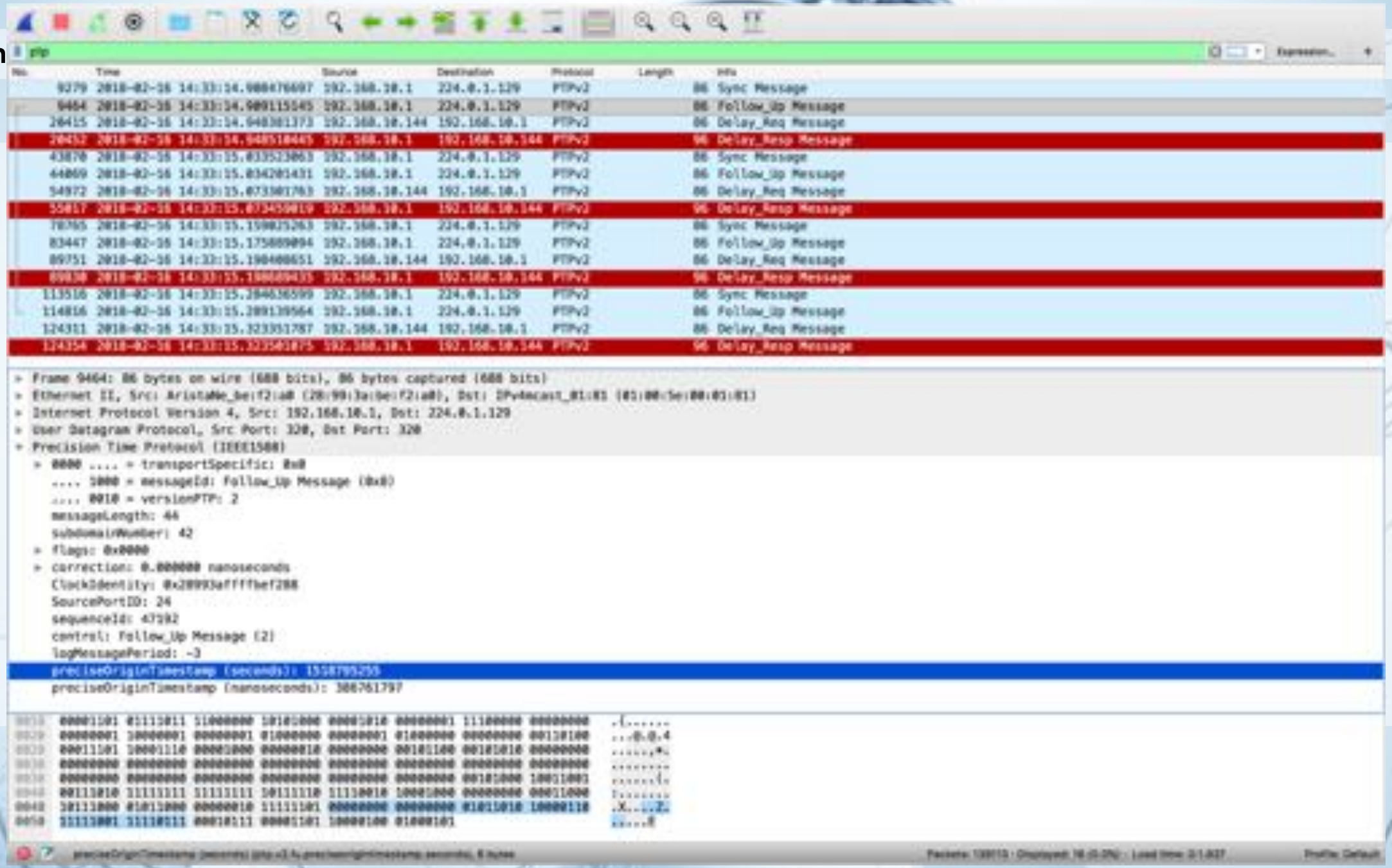
- Sync Message
- Follow up Message
- Delay Request Message
- Delay Response Message

This synchronization is done on a regular basis, defined in the PTP Profile as logSyncInterval.

- The default value is -3



Synch

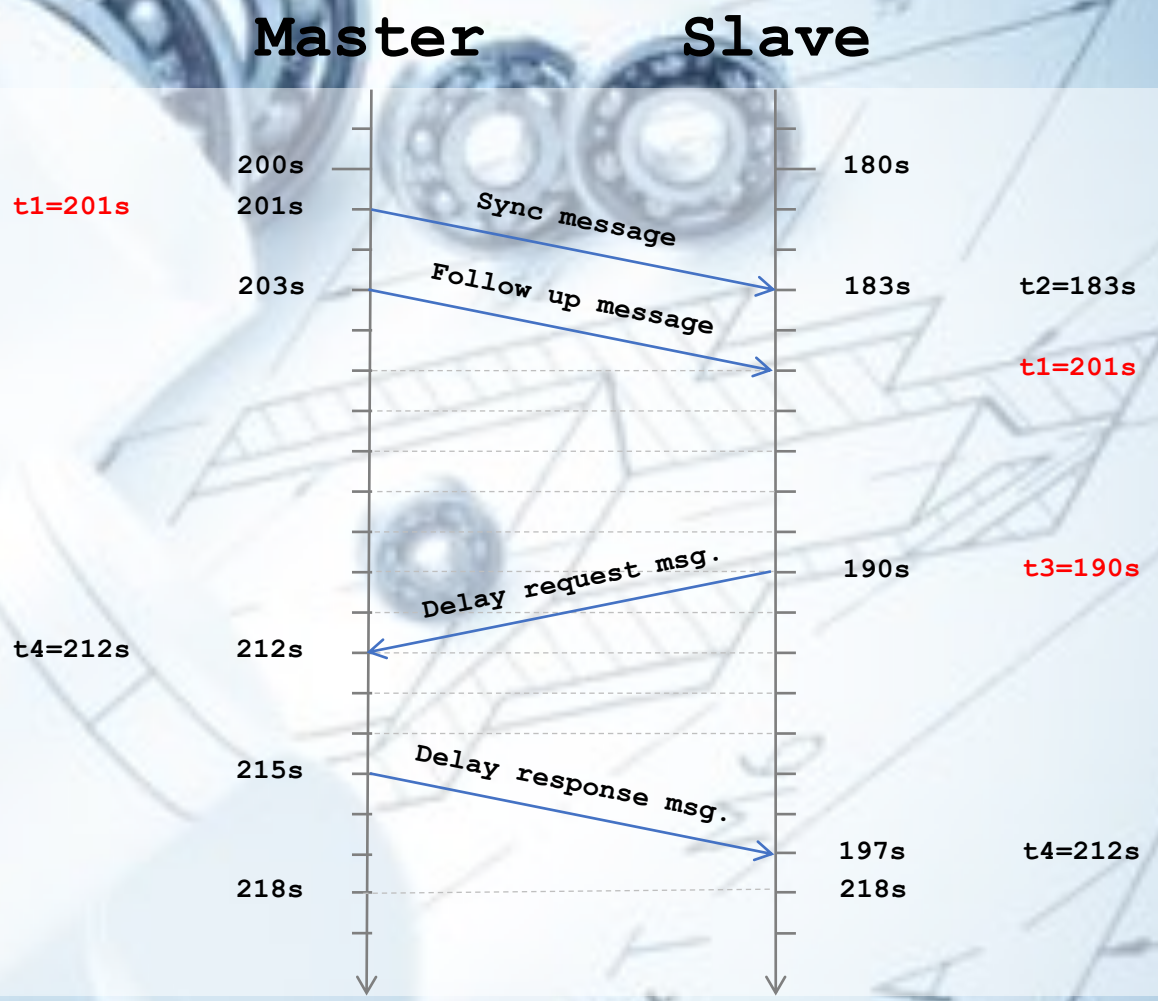

ptp
No. Time Source Destination Protocol Length Info
9279 2018-02-16 14:33:14.988476697 192.168.10.1 224.0.1.129 PTPv2 86 Sync Message
9464 2018-02-16 14:33:14.989115545 192.168.10.1 224.0.1.129 PTPv2 86 Follow_Up Message
20415 2018-02-16 14:33:14.948301373 192.168.10.144 192.168.10.1 PTPv2 86 Delay_Req Message
20432 2018-02-16 14:33:14.948518445 192.168.10.1 192.168.10.144 PTPv2 96 Delay_Resp Message
43870 2018-02-16 14:33:15.033523863 192.168.10.1 224.0.1.129 PTPv2 86 Sync Message
44069 2018-02-16 14:33:15.034201431 192.168.10.1 224.0.1.129 PTPv2 86 Follow_Up Message
54972 2018-02-16 14:33:15.073301763 192.168.10.144 192.168.10.1 PTPv2 86 Delay_Req Message
55017 2018-02-16 14:33:15.073459819 192.168.10.1 192.168.10.144 PTPv2 96 Delay_Resp Message
78765 2018-02-16 14:33:15.159825263 192.168.10.1 224.0.1.129 PTPv2 86 Sync Message
83447 2018-02-16 14:33:15.175889894 192.168.10.1 224.0.1.129 PTPv2 86 Follow_Up Message
89751 2018-02-16 14:33:15.198400651 192.168.10.144 192.168.10.1 PTPv2 86 Delay_Req Message
89838 2018-02-16 14:33:15.198889433 192.168.10.1 192.168.10.144 PTPv2 96 Delay_Resp Message
113516 2018-02-16 14:33:15.284636599 192.168.10.1 224.0.1.129 PTPv2 86 Sync Message
114816 2018-02-16 14:33:15.289139564 192.168.10.1 224.0.1.129 PTPv2 86 Follow_Up Message
124311 2018-02-16 14:33:15.323351787 192.168.10.144 192.168.10.1 PTPv2 86 Delay_Req Message
124354 2018-02-16 14:33:15.323501875 192.168.10.1 192.168.10.144 PTPv2 96 Delay_Resp Message
Frame 9464: 86 bytes on wire (688 bits), 86 bytes captured (688 bits)
Ethernet II, Src: AristaNe_be:f2:a0 (28:99:3a:be:f2:a0), Dst: IPv4mcast_01:81 (01:00:5e:00:01:81)
Internet Protocol Version 4, Src: 192.168.10.1, Dst: 224.0.1.129
User Datagram Protocol, Src Port: 320, Dst Port: 320
Precision Time Protocol (IEEE1588)
0000 .... = transportSpecific: 0x0
.... 1000 = messageId: Follow_Up Message (0x8)
.... 0010 = versionPTP: 2
messageLength: 44
subdomainNumber: 42
flags: 0x0000
correction: 0.000000 nanoseconds
ClockIdentity: 0x2899 3aff ffbe f2a0
SourcePortID: 24
sequenceId: 47592
control: Follow_Up Message (2)
logMessagePeriod: -3
preciseOriginTimestamp (seconds): 1518795255
preciseOriginTimestamp (nanoseconds): 388761797

Accuracy

The highest accuracy is achieved by the use hardware timestamping as close the physical layer as possible.

Do not just capture with your PC and assume accurate values!

“PTP can use the hardware assistance capability provided by a compatible NIC to improve the clock synchronization accuracy”



URL's of interest

- EBU Tech Review: Using PTP for Time & Frequency
- It's About Time – SMPTE ST 2059
- Synchronization and the IP evolution
- What Are All Of These IEEE 1588 Clock Types?
- PTP Track hound

Live IP Software Toolkit

TO GO IP OR NOT GO IP? IT'S NOT A QUESTION ANYMORE!

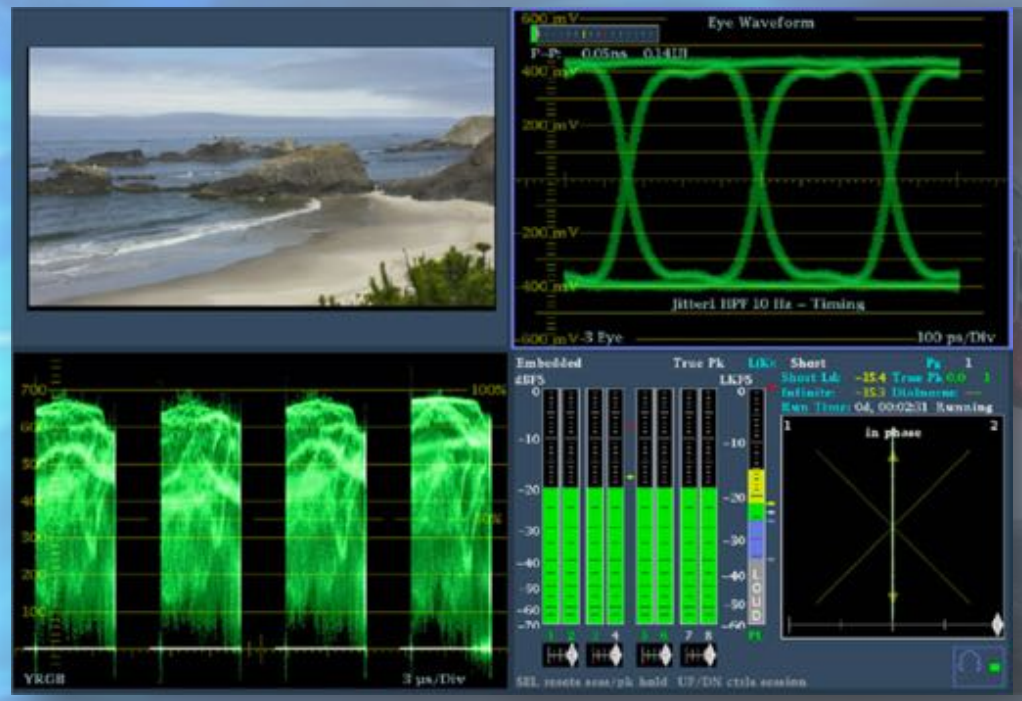
WHAT TO MEASURE?

- How many streams are available?
- What type of streams are available?
- Is there a clock available?
  - How stable is the clock?
- Is there any video available?
  - Does the video comply with the specifications? C_{MAX}, VRX_{FULL}, …
  - Is it a wide or narrow sender?
  - Is it locked to PTP?
- Is there any audio available?
  - How many channels per stream?
  - What sampling rate? What is the bit depth?

- What skillset do we need?
  - Broadcast Engineer?
  - Network Engineer?
  - Software Engineer?
- One cable is no longer one signal
  - “If it works it is great, if it doesn’t: how can we visualize what’s going on?” (quote VRT Live IP PoC)
  - “We need different tools to monitor and check our facility” (Quote RTL City)

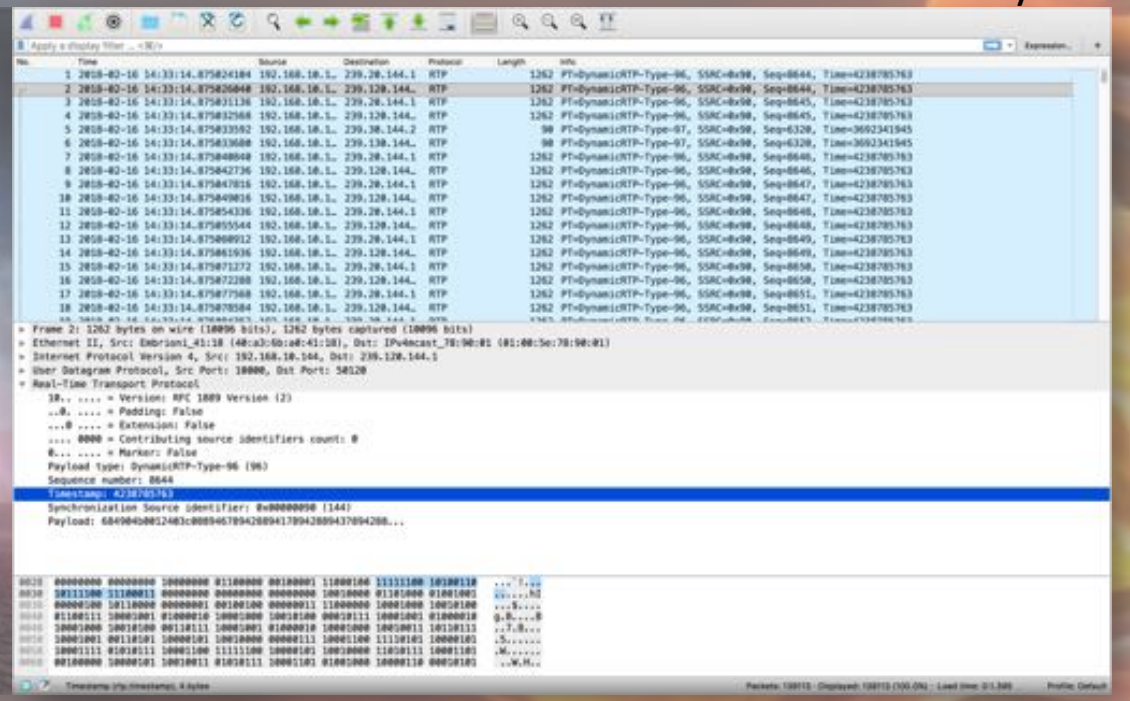
SKILLSET – Bringing people together

Waveform Monitor



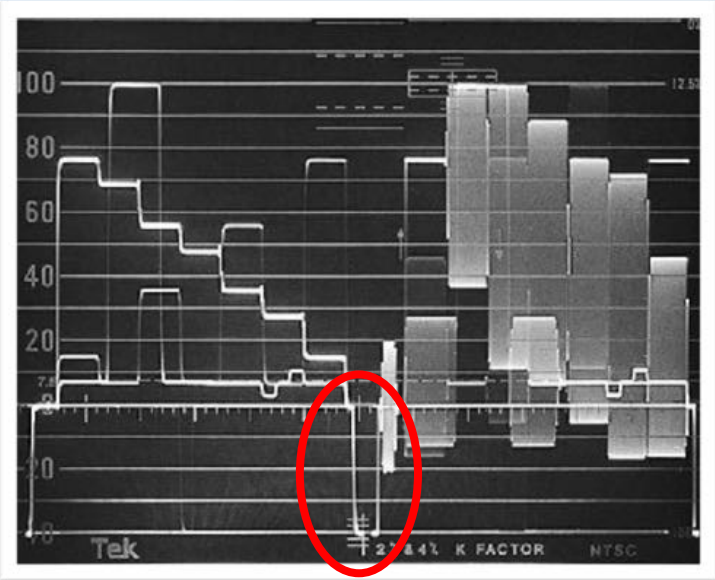
Broadcast Engineer

Packet Analyser



Network Engineer

Waveform Monitor



Broadcast Engineer

Python Snippet

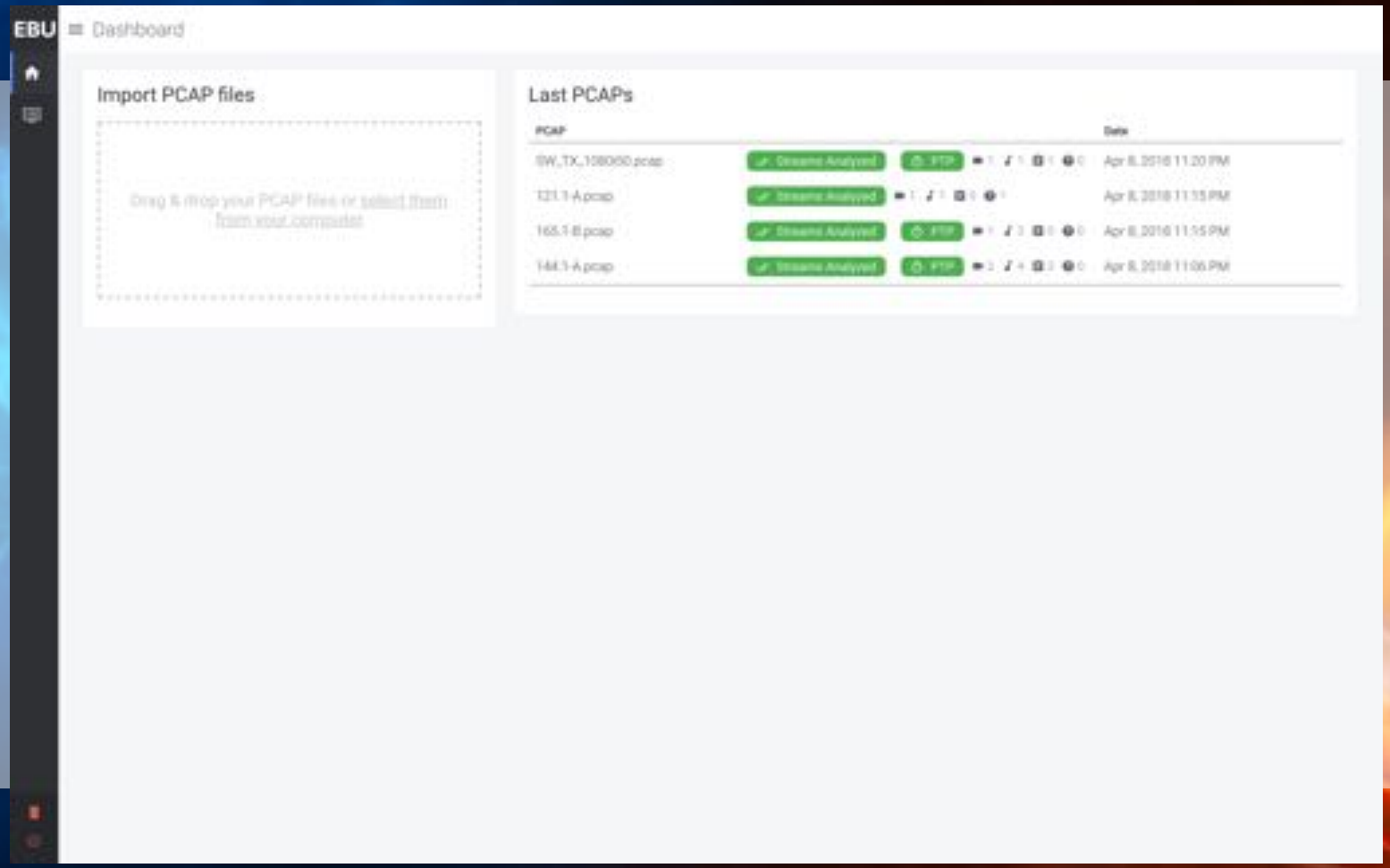
```python
class Constants:
    PKT_SEQUENCE_BIT_DEPTH  = pow(2,16) # The RTP packet sequence number is defined as a 16 bit number.
    RTP_TIMESTAMP_BIT_DEPTH = pow(2,32) # The RTP timestamp value is defined as a 32 bit number.
    RTP_CLOCK = 90000                   # RTP clock frequency is defined at 90kHz.

def frame_len(capture):
    # To calculate Npackets, you need to count the amount of packets between two rtp.marker == 1 flags.
    # This is as easy as looking to 2 rtp.marker == 1 packets and substract the rtp.sequence number.
    # The exception that will occurs is that the packet sequence number rotates. Modulo is your friend!

    first_frame = None
    for pkt in capture:
        if pkt.rtp.marker == '1':
            if not first_frame:
                first_frame = int(pkt.rtp.seq)
            else:
                return (int(pkt.rtp.seq) - first_frame) % Constants.PKT_SEQUENCE_BIT_DEPTH
    return None
```

Software Engineer

Draft ST 2110 → Interop Tests → Evaluate → Debugging → Continuous Deployment

Excel try-out → Python prototype → C++ optimized

Dashboard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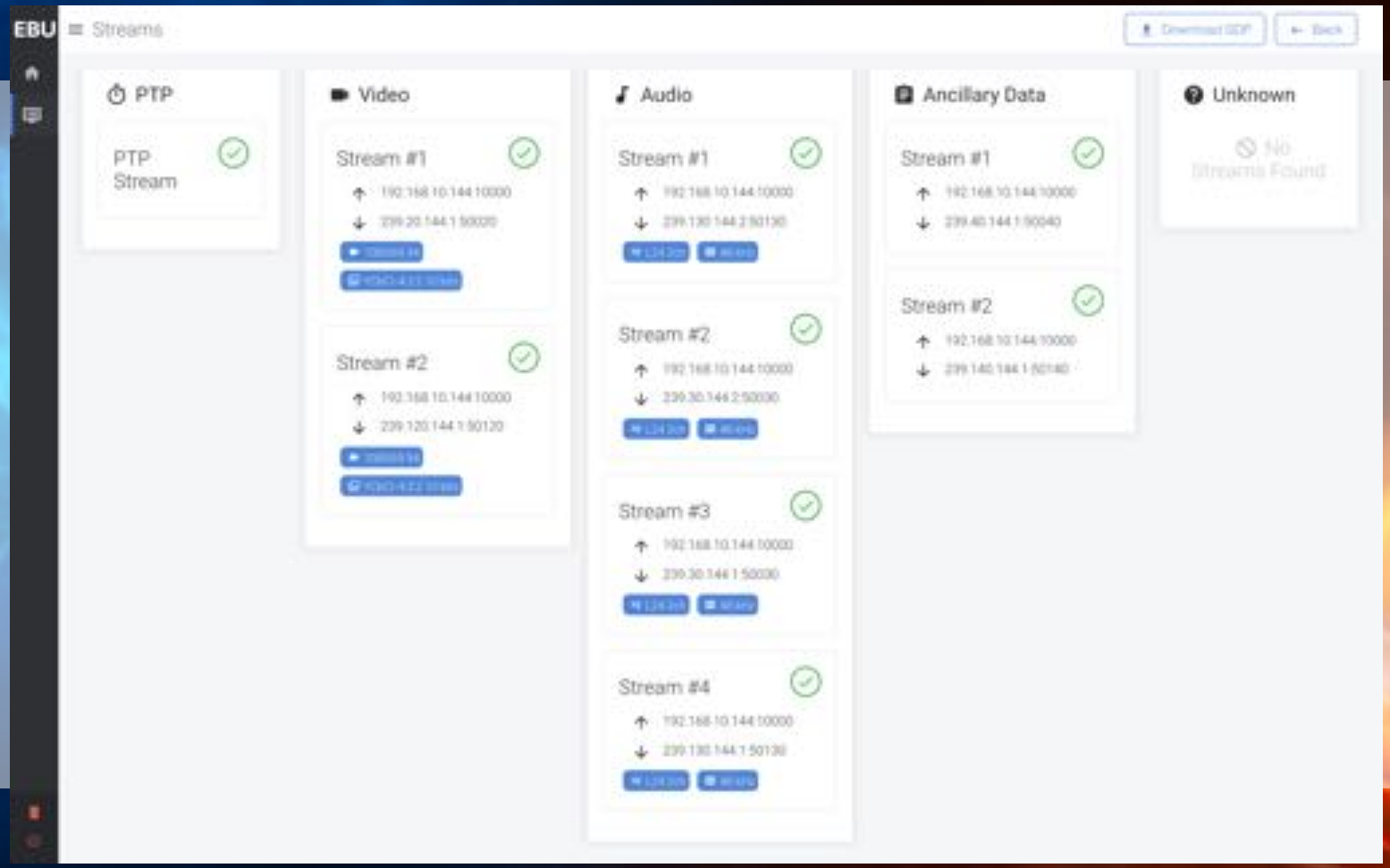
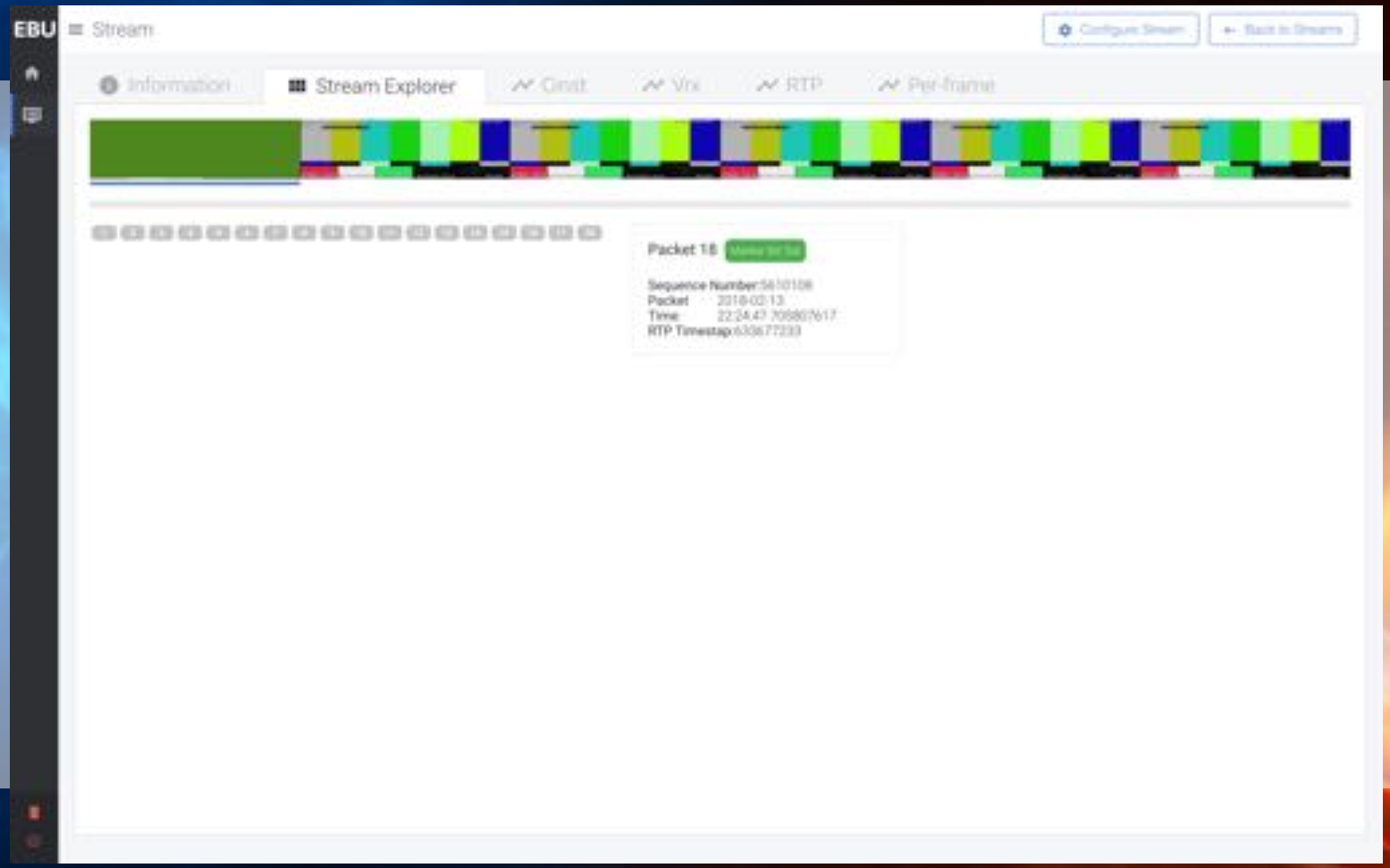
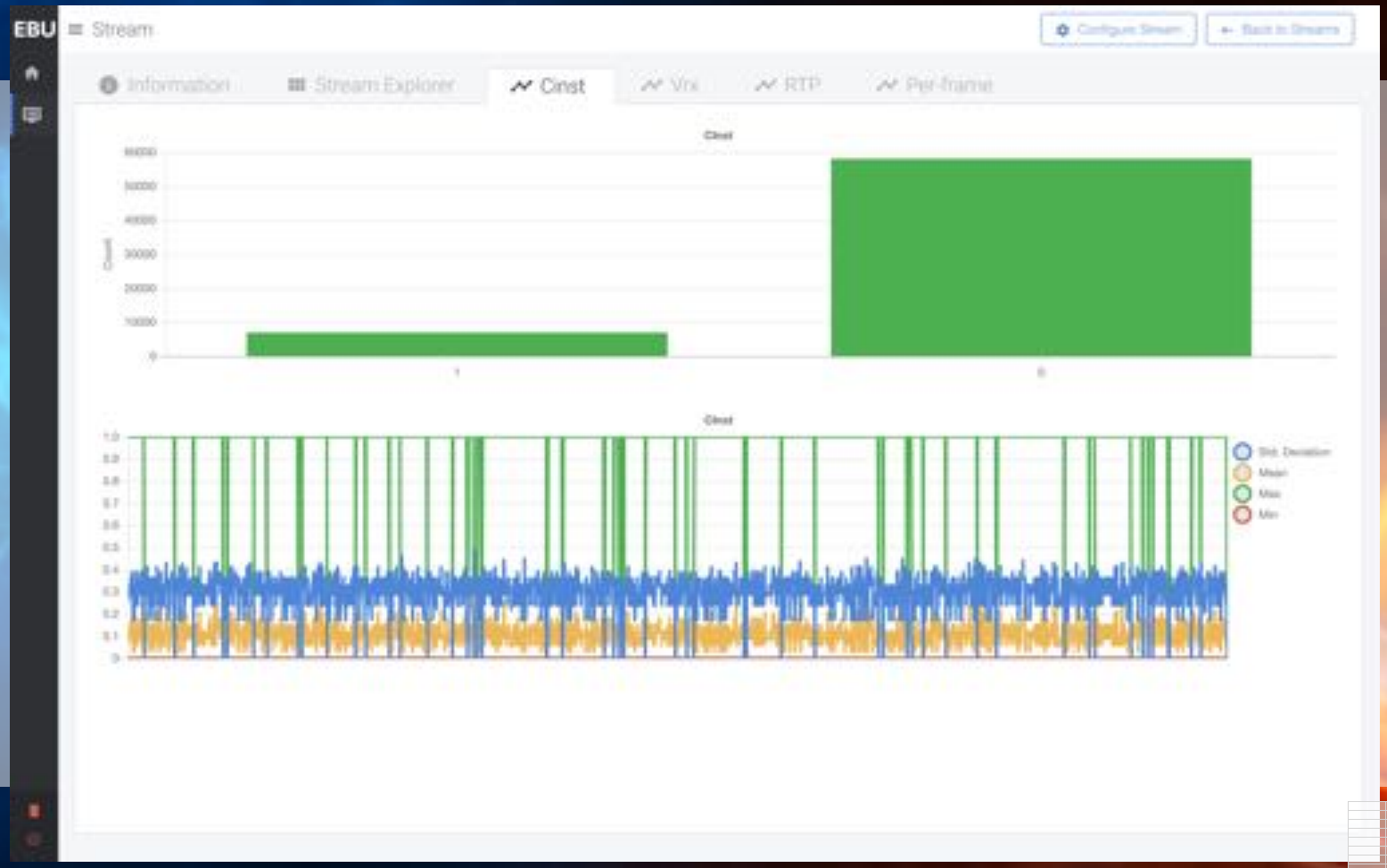
Dashboard
Import PCAP files
Drag & drop your PCAP files or select them from your computer
Last PCAPs
PCAP
Date
SW_TX_1080i50.pcap
Streams Analysed
RTP
Apr 8, 2016 11:20 PM
121.1-A.pcap
Streams Analysed
Apr 8, 2016 11:15 PM
165.1-B.pcap
Streams Analysed
RTP
Apr 8, 2016 11:15 PM
144.1-A.pcap
Streams Analysed
RTP
Apr 8, 2016 11:06 PM


EBU
Streams
PTP
PTP Stream
Video
Stream #1
Stream #2
Audio
Stream #1
Stream #2
Stream #3
Stream #4
Ancillary Data
Stream #1
Stream #2
Unknown

Stream Explorer



C_{INST} – Network Compatibility Test

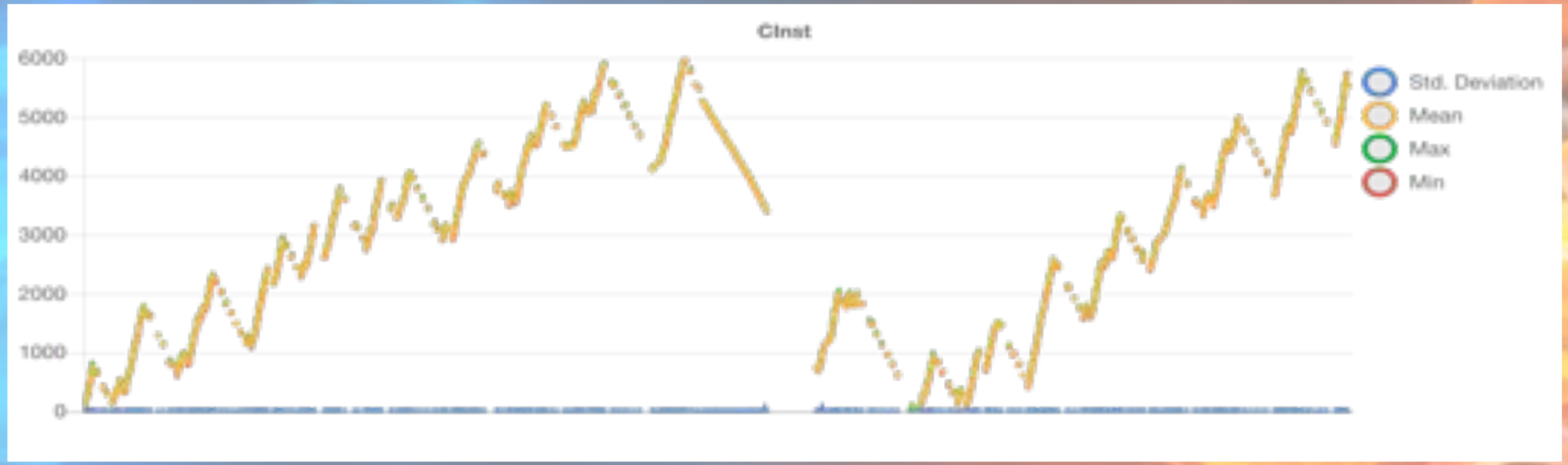


		Egress total	3.2	Tbps		Cmax	1				
		Bfotal	16	MB							
		Ractive	96%								
		Beta	1.1								
					Usage of Egress (1/Beta) and 100% of memory						
		1/Beta			90%	80%	70%	60%	50%	40%	30%	20%	10%
					4.855E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	4.369E-04
					20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64	2288.82
Resolution	Hz	Npackets	Packetrate		C								
720	50	1614	80700		3	4	5	6	7	8	11	17	35
720	60	1614	96840		4	5	6	7	8	10	14	21	42
1080	50	3631	181550		8	9	11	13	15	19	26	39	79
1080	60	3631	217860		10	11	13	15	19	23	31	47	95
2160	50	14522	726100		35	39	45	52	63	79	105	158	317
2160	60	14522	871320		42	47	54	63	76	95	126	190	380
2160	100	14522	1452200		70	79	90	105	126	158	211	317	634
2160	120	14522	1742640		84	95	108	126	152	190	253	380	761
Resolution	Hz	β	βgap		#Streams								
720	50	0.93	0.96		2987	2655	2323	1991	1659	1327	996	664	332
720	60	1.11	1.16		2489	2212	1936	1659	1383	1106	830	553	277
1080	50	2.09	2.17		1328	1180	1033	885	738	590	443	295	148
1080	60	2.50	2.60		1106	983	861	738	615	492	369	246	123
2160	50	8.34	8.68		332	295	258	221	184	148	111	74	37
2160	60	10.01	10.41		277	246	215	184	154	123	92	61	31
2160	100	25.00	26.00		111	98	86	74	62	49	37	25	12
2160	120	48.05	49.97		58	51	45	38	32	26	19	13	6

C_{INST} – Network Compatibility Test

			Egress total	3.2	Tbps		Cmax	70					
			Bbotal	16	MB								
			Ractive	96%									
			Beta	1.1									
						Usage of Egress (1/Beta) and 100% of memory							
			1/Beta			90%	80%	70%	60%	50%	40%	30%	20%	10%
						4.855E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	4.369E-04
						20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64	2288.82
Resolution	Hz	Npackets	Packetrate			C								
720	50	1614	80700	3	4	5	5	7	9	11	17	25		
720	60	1614	96840	4	5	6	7	8	10	14	21	42		
1080	50	3631	181550	8	9	11	13	15	19	26	39	79		
1080	60	3631	217860	10	11	13	15	19	23	31	47	95		
2160	50	14522	726100	35	39	45	52	63	79	105	158	317		
2160	60	14522	871320	42	47	54	63	76	95	126	190	380		
2160	100	14522	1452200	70	79	90	105	126	158	211	317	634		
2160	120	14522	1742640	84	95	108	126	152	190	253	380	761		
Resolution	Hz	β	βgap			#Streams								
720	50	0.93	0.96	2987	2655	2323	1991	1659	1327	996	664	332		
720	60	1.11	1.16	2483	2212	1920	1660	1383	1106	830	553	277		
1080	50	2.09	2.17	1329	1180	1033	885	738	590	443	295	148		
1080	60	2.50	2.60	1106	983	861	738	615	492	369	246	123		
2160	50	8.34	8.68	332	295	258	221	184	148	111	74	37		
2160	60	10.01	10.41	277	246	215	184	154	123	92	61	31		
2160	100	25.06	26.00	111	98	86	74	62	49	37	25	12		
2160	120	48.05	49.97	58	51	45	38	32	26	19	13	6		

VRX – Virtual Receive Buffer

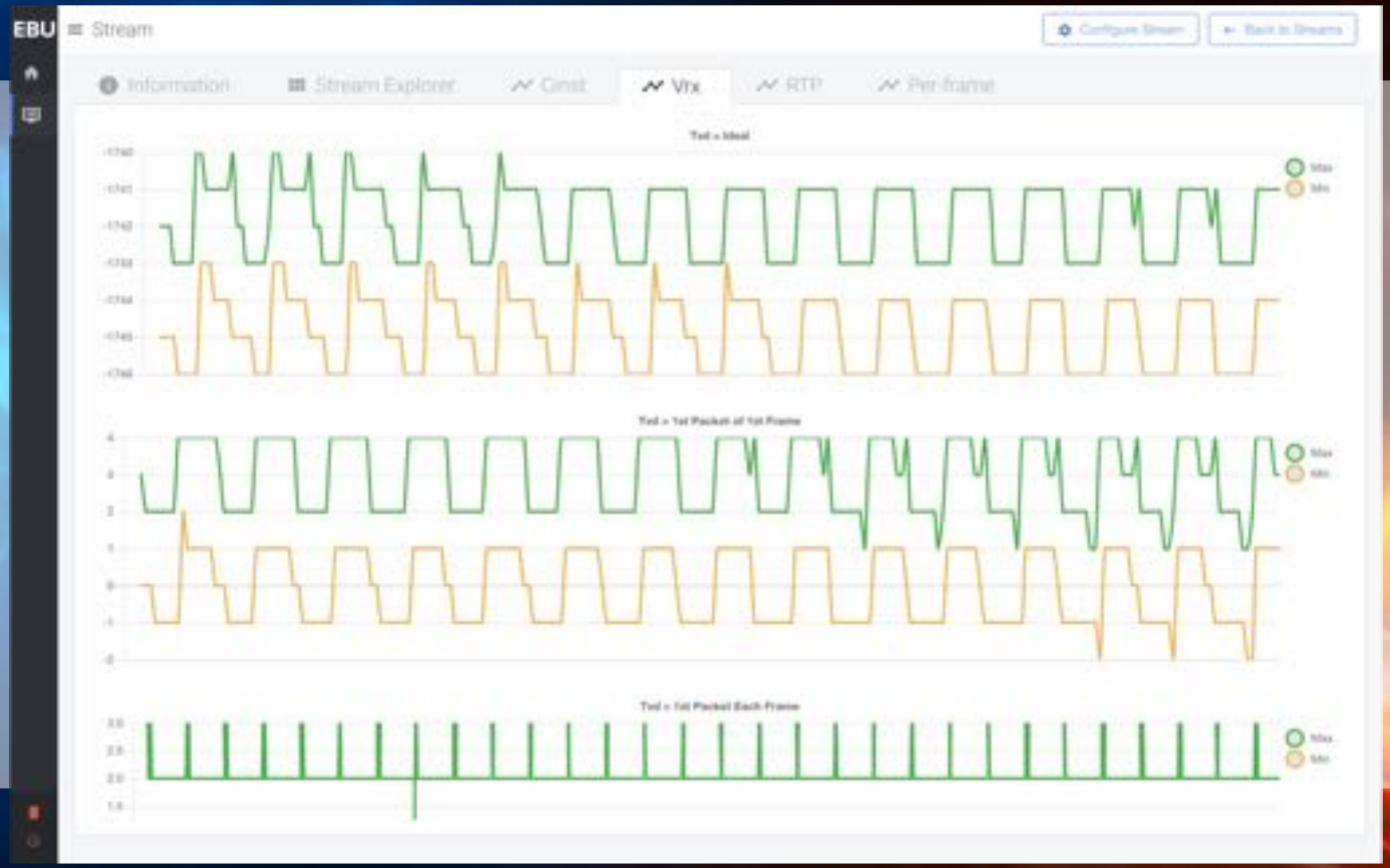


		Egress total	3.2	Tbps		Cmax	6000						
		Btotal	16	MB									
		Ractive	96%										
		Beta	1.1										
					Usage of Egress (1/Beta) and 100% of memory								
		1/Beta			90%	80%	70%	60%	50%	40%	30%	20%	10%
					4.855E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	4.369E-04
					20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64	2288.82
Resolution	Hz	Npackets	Packetrate		C								
720	50	1614	80700		3	4	5	5	7	9	11	17	35
720	60	1614	96840		4	5	6	7	8	10	14	22	42
1080	50	3631	181550		8	9	11	13	15	19	26	39	79
1080	60	3631	217860		10	11	13	15	19	23	31	47	95
2160	50	14522	726100		35	39	45	52	63	79	105	158	317
2160	60	14522	871320		42	47	54	63	76	95	126	190	380
2160	100	14522	1452200		70	79	90	105	126	158	211	317	634
2160	120	14522	1742640		84	95	108	126	152	190	253	380	761
Resolution	Hz	β	βgap		#Streams								
720	50	0.93	0.96		2987	2655	2323	1991	1659	1327	996	664	332
720	60	1.11	1.16		2483	2212	1910	1659	1383	1106	830	553	277
1080	50	2.09	2.17		1329	1180	1033	885	738	590	443	295	148
1080	60	2.50	2.60		1106	983	861	738	615	492	369	246	123
2160	50	8.34	8.68		332	295	258	221	184	148	111	74	37
2160	60	10.01	10.41		277	246	215	184	154	123	92	62	31
2160	100	25.00	26.00		111	98	86	74	62	49	37	25	12
2160	120	48.05	49.97		58	51	45	38	32	26	19	13	6

		Egress total	3.2	Tbps		Cmax	6000					
		Btotal	16	MB								
		Ractive	96%									
		Beta	1.1									
				Usage of Egress (1/Beta) and 100% of memory								
		1/Beta		90%	80%	70%	60%	50%	40%	30%	20%	10%
				4.855E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	4.369E-04
				20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64	2288.82

Resolution	Hz	Npackets	Packetrate	C								
720	50	1614	80700	3	4	5	5	7	8	11	17	35
720	60	1614	96840	4	5	6	7	8	10	14	21	42
1080	50	3631	181550	8	9	11	13	15	19	26	39	79
1080	60	3631	217860	10	11	13	15	19	23	31	47	95
2160	50	14522	726100	35	39	45	52	63	79	105	158	317
2160	60	14522	871320	42	47	54	63	76	95	126	190	380
2160	100	14522	1452200	70	79	90	105	126	158	211	317	634
2160	120	14522	1742640	84	95	108	126	152	190	253	380	761

Resolution	Hz	β	βgap	#Streams								
720	50	0.93	0.96	2987	2655	2323	1991	1659	1327	996	664	332
720	60	1.11	1.16	2489	2212	1936	1659	1383	1106	830	553	277
1080	50	2.09	2.17	1328	1180	1033	885	738	590	443	295	148
1080	60	2.50	2.60	1106	983	861	738	615	492	369	246	123
2160	50	8.34	8.68	332	295	258	221	184	148	111	74	37
2160	60	10.01	10.41	277	246	215	184	154	123	92	61	31
2160	100	25.00	26.00	111	98	86	74	62	49	37	25	12
2160	120	48.05	49.97	58	51	45	38	32	26	19	13	6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Any Questions?
Thank you!