



The art of conforming to the SMPTE 2110-21 traffic model: part I

EBU

OPERATING EUROVISION AND EURORADIO

EBU

Media over IP Architect

Willem Vermost – vermost@ebu.ch

An aerial photograph of a city waterfront, likely Oslo, Norway. The foreground shows a dense urban area with various buildings, including a prominent white building with a dome. The middle ground features a large body of water with many sailboats and a long, narrow pier or bridge structure extending into the water. The background shows a range of mountains under a clear blue sky. A semi-transparent dark horizontal bar is overlaid across the middle of the image, containing the text.

part I: How to protect the network?



Well behaved traffic on a single lane



Bursty traffic

Packet Delay Variation

β ↑

AVERAGE SPEED

55

with average

Ideal Packet Spacing (IPS)

t

Ideal Traffic Shape on microscopic scale

t

Bursts

β ↑

Late packet

SPEED LIMIT

80

Actual Sender on microscopic scale





MULTIPLE LANES



REDUCED # LANES AHEAD





Spine

SPEED
LIMIT
40

Sa

Sb

OSPF
&
ECMP

Leaf

La

Lb

Lc

Ld

Le

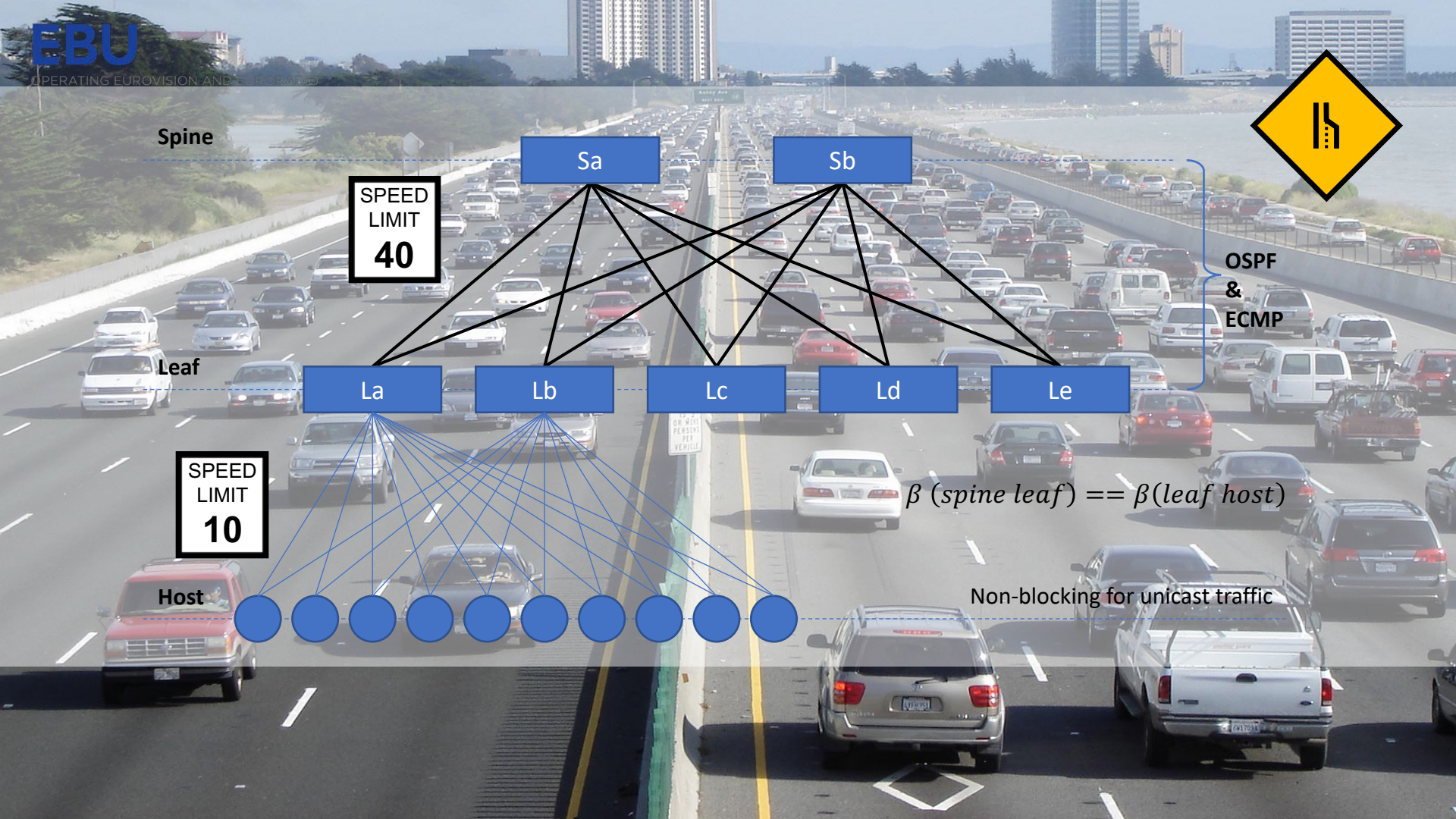
SPEED
LIMIT
10

$\beta(\text{spine leaf}) == \beta(\text{leaf host})$

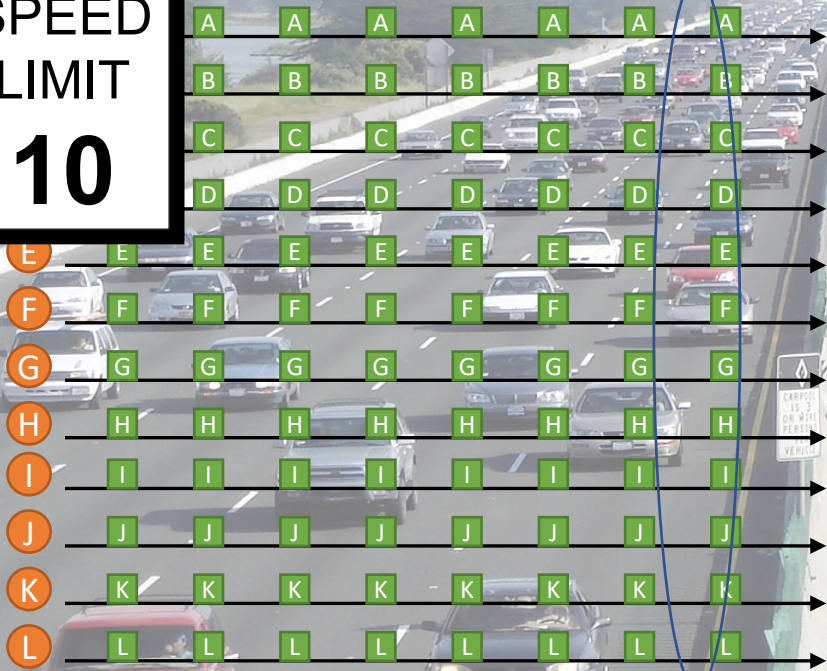
Host



Non-blocking for unicast traffic



SPEED
LIMIT
10



$12 \frac{1}{3} \beta$

12 packets arrive at linerate of 10 Gbps at the switch. Those packets will be serialised and put on the output port at 40 Gbps.

12

HGFEDCBA

32

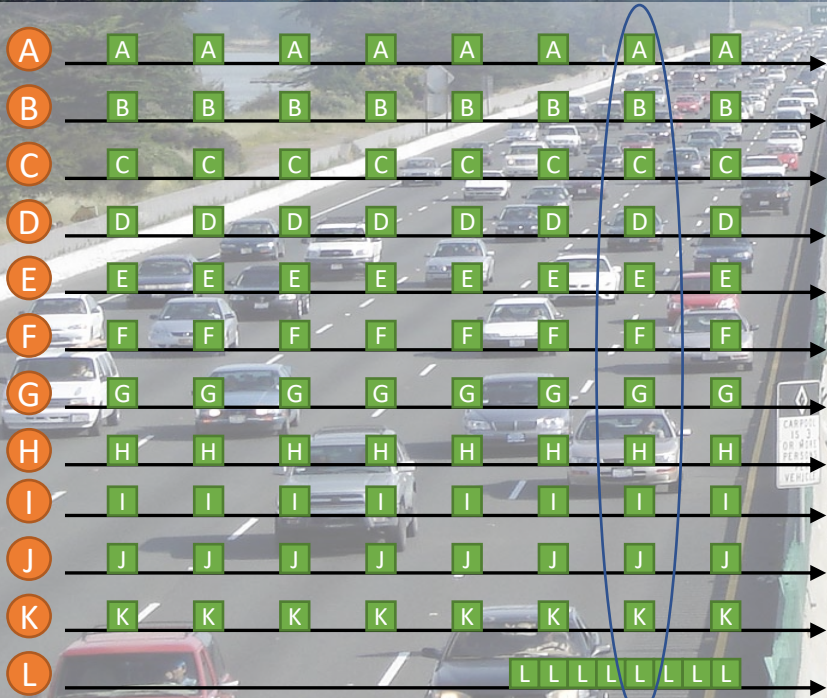
4β

LKJIHGFE

Buffer

SPEED
LIMIT
40

Packets arrive at line rate ... 12 x 10 Gbps pushed to 1 x 40 Gbps link



$$12 \frac{1}{3} \beta$$

Buffer will be used to store the bytes that don't fit the output due to speed limitations.

ST

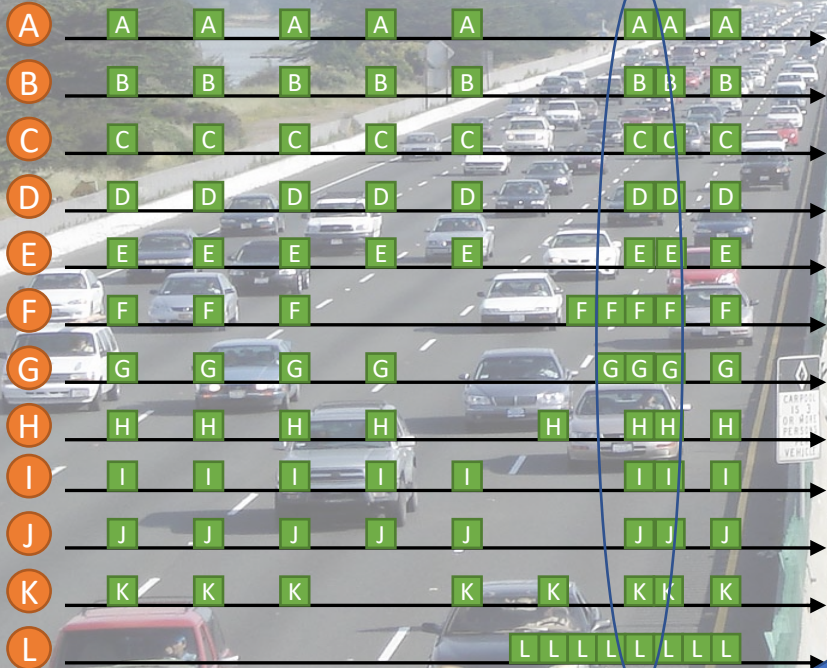
BALLLKJIHGFE DCBA

$$4\beta$$

SB

LKJIHGFE DCBA
LL

Buffer



$$12 \frac{1}{3} \beta$$

Packet will be dropped !

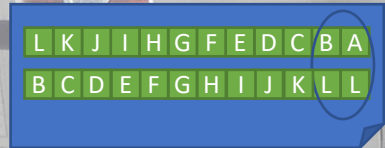
Buffer will be used to store the bytes that don't fit the output due to speed limitations.©

βT

BALL LKJIHG FEDCBA

$$4\beta$$

βS



Buffer

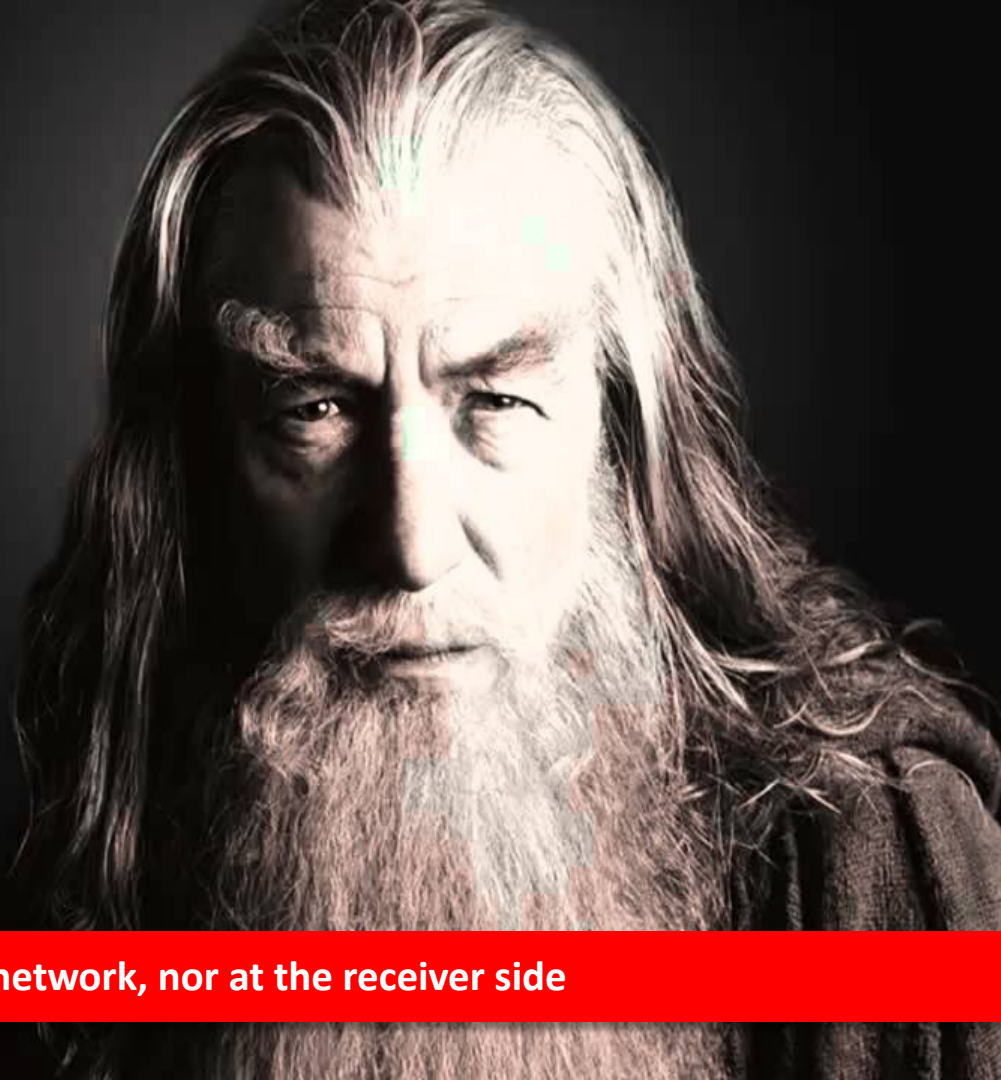


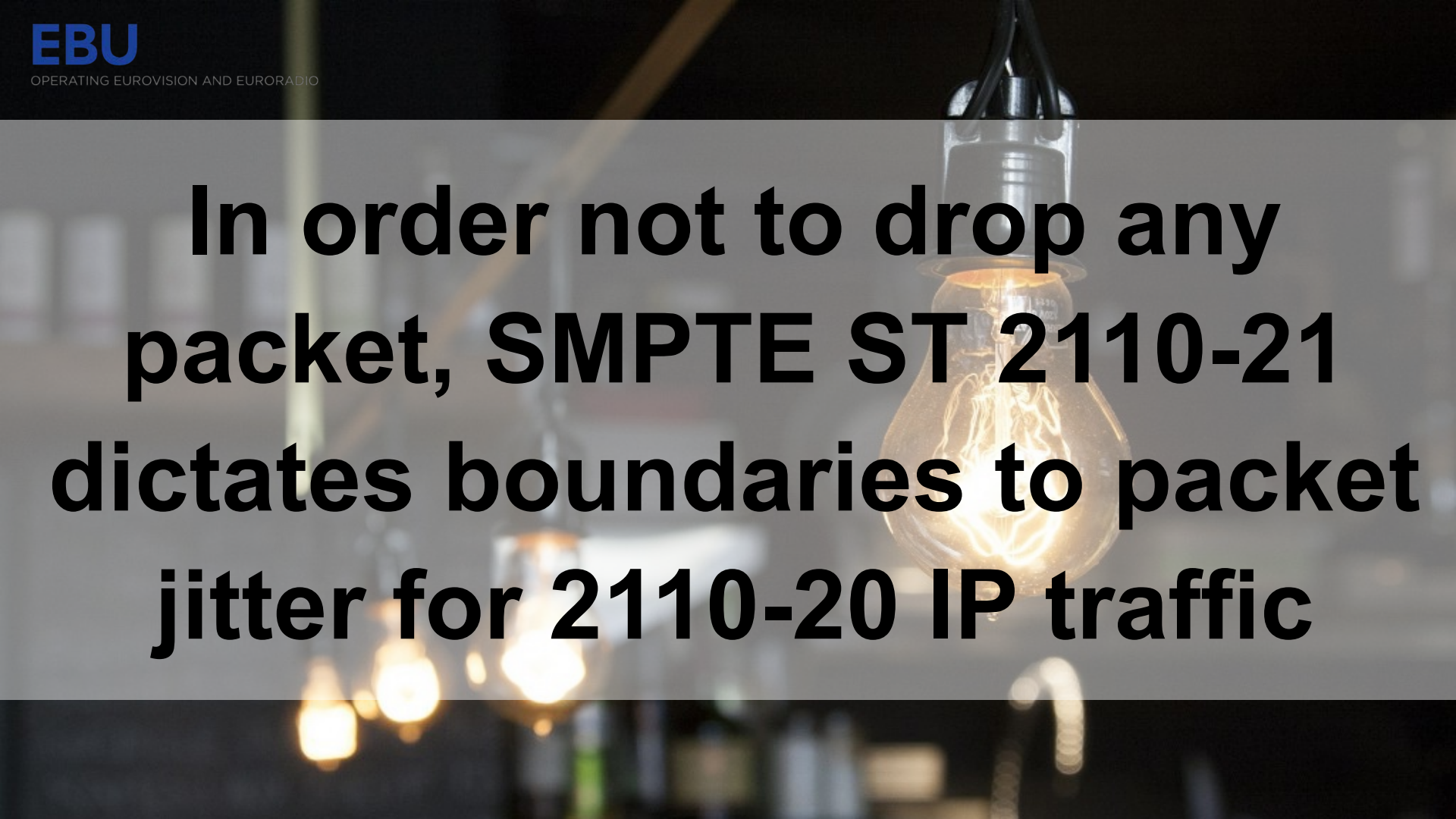


**Packet Delay Variation
results in:
Increased Latency
Dropped Packets**

**Thou shalt not
drop any packet**

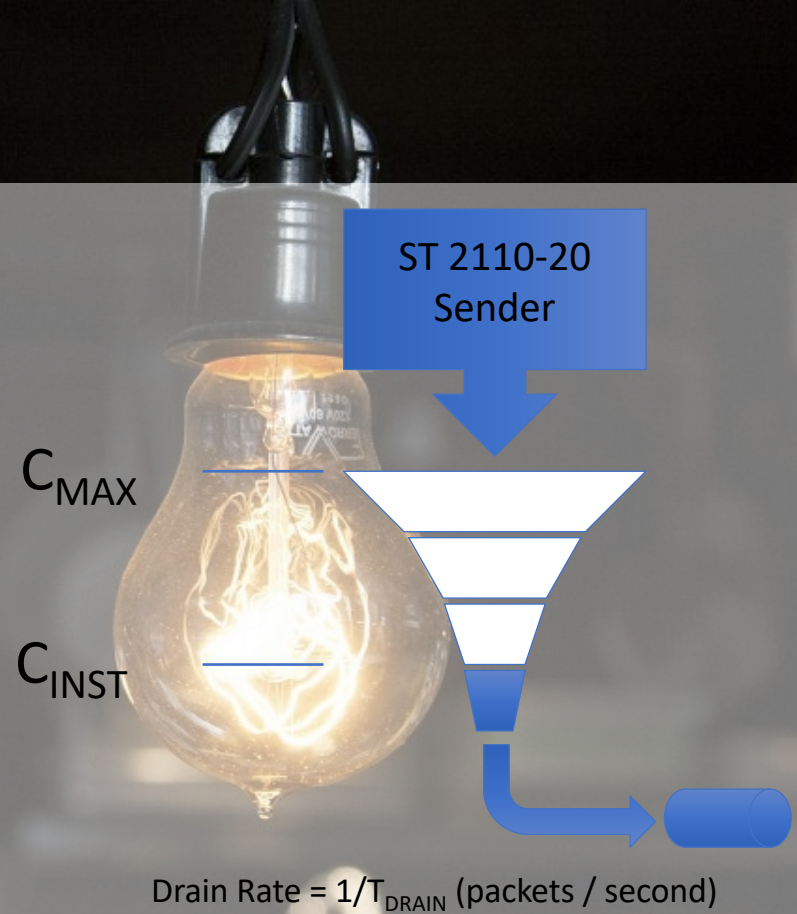
Nor at the sender, nor in the network, nor at the receiver side





**In order not to drop any
packet, SMPTE ST 2110-21
dictates boundaries to packet
jitter for 2110-20 IP traffic**

- Leaky bucket to be measured at sender side.
- Packets are thrown in this virtual leaky bucket
- The bucket is drained at a certain drain rate
- Results in well behaved IP traffic
- There shall not be more packets in the leaky bucket as defined by C_{MAX}



	Egress total	3.2	Tbps		Cmax	4						
	Btotal	16	MB									
	Ractive	96%										
	Beta	1.1										
	1/Beta	Usage of Egress (1/Beta) and 100% of memory										
		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

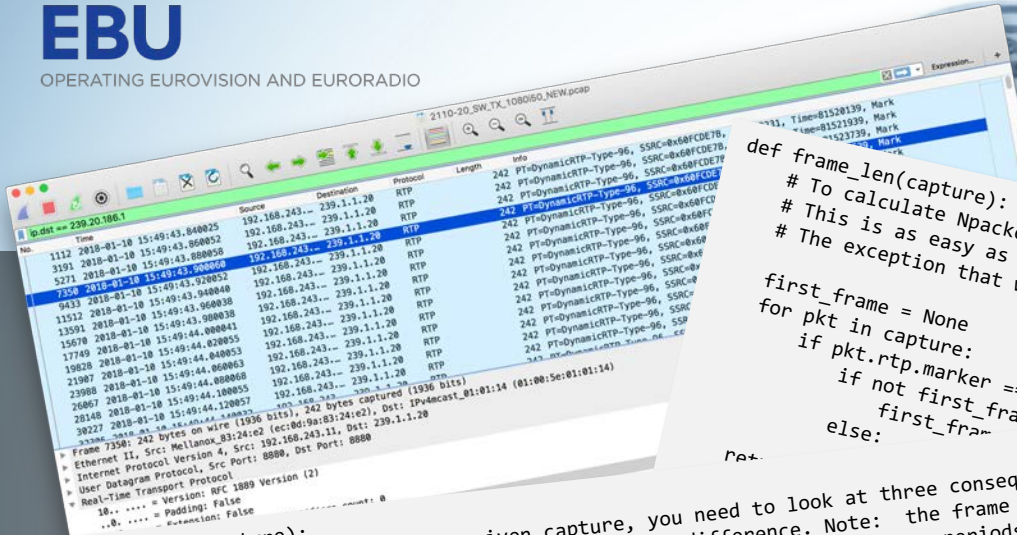
		Egress total	3.2 Tbps		Cmax	16						
		Btotal	16 MB									
		Ractive	96%									
		Beta	1.1									
			Usage of Egress (1/Beta) and 100% of memory									
		1/Beta		90%	80%	70%	60%	50%	40%	30%	20%	10%
				4.855E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	4.369E-04
				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	β_{gap}	#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

		Egress total	3.2 Tbps		Cmax	16						
		Btotal	64 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%	
			1.942E-04	2.185E-04	2.497E-04	2.913E-04	3.495E-04	4.369E-04	5.825E-04	8.738E-04	1.748E-03	
			5149.84	4577.64	4005.43	3433.23	2861.02	2288.82	1716.61	1144.41	572.20	
			C									
Resolution	Hz	Npackets	Packetrate									
720	50	1614	80700	15	17	20	23	28	35	47	70	141
720	60	1614	96840	18	21	24	28	33	42	56	84	169
1080	50	3631	181550	35	39	45	52	63	79	105	158	317
1080	60	3631	217860	42	47	54	63	76	95	126	190	380
2160	50	14522	726100	140	158	181	211	253	317	422	634	1268
2160	60	14522	871320	169	190	217	253	304	380	507	761	1522
2160	100	14522	1452200	281	317	362	422	507	634	845	1268	2537
2160	120	14522	1742640	338	380	435	507	609	761	1015	1522	3045
			#Streams									
Resolution	Hz	β	β gap									
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

How to measure C_{INST} ?

- Need an accurate timestamp in each Ethernet frame
- Need to Reconstruct the drain rate
- Calculate the instantaneous watermark

- Use Accurate Timestamp
- Drain rate = $1 / ((T_{frame} / N_{packets}) / \text{Beta})$



```
def frame_rate(capture):
    # To calculate the framerate of a given capture, you need to look at three consequent rtp time stamps [(t2-t1) +
    # (t3-t2)] / 2 will result in the average timestamp difference. Note: the frame periods (difference between 90
    # kHz timestamps) might not appear constant For example 60/1.001 Hz frame periods effectively alternate between
    # increments of 1501 and 1502 ticks of the 90 kHz clock.
    rtp_timestamp = []

    for pkt in capture:
        if pkt.rtp.marker == '1':
            if len(rtp_timestamp) < 3:
                rtp_timestamp.append(int(pkt.rtp.timestamp))
            else:
                frame_rate_c = Decimal(Constants.RTP_CLOCK /
                    (( rtp_timestamp[2] - rtp_timestamp[1]) % Constants.RTP_TIMESTAMP_BIT_DEPTH +
                     (rtp_timestamp[1] - rtp_timestamp[0]) % Constants.RTP_TIMESTAMP_BIT_DEPTH) / 2))
                return frame_rate_c
    return None
```

```
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 subtract 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 = pkt.rtp.sequence_number
            else:
                return pkt.rtp.sequence_number - first_frame
```

SEQUENCE_BIT_DEPTH

The image displays several overlapping browser windows showcasing the EBU software toolkit interface. The windows are arranged in a layered fashion, showing different parts of the application:

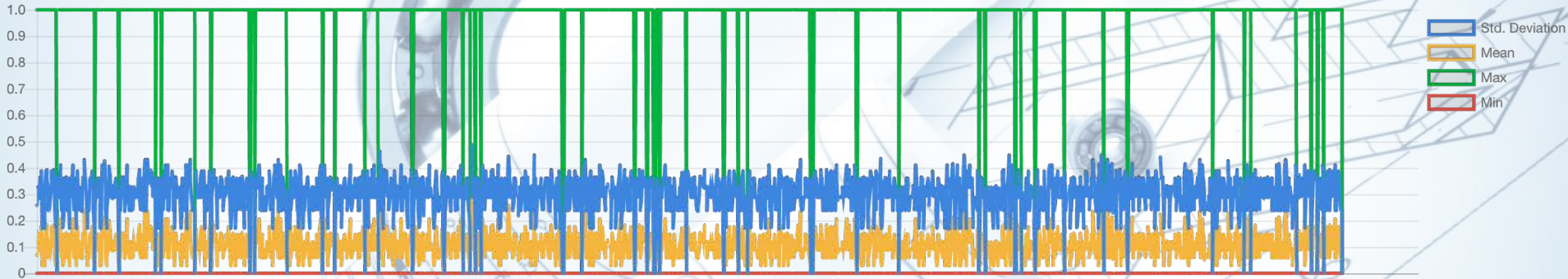
- Top Window:** Shows the 'Dashboard' with an 'Import PCAP files' section and a 'Last PCAPs' table. The table lists PCAP files with columns for 'PCAP' and 'Date'.

PCAP	Date
1	Apr 6, 2018 12:24 AM
2	Apr 5, 2018 11:56 PM
3	Apr 5, 2018 11:56 PM
4	Apr 5, 2018 11:56 PM
5	Apr 5, 2018 11:56 PM
6	Apr 5, 2018 11:35 PM
- Middle Window:** Shows the 'Streams' overview page with sections for 'PTP', 'Video', 'Audio', 'Ancillary Data', and 'Unknown'. It includes a 'Download SDP' button and a 'Back' button.
- Bottom-Middle Window:** Shows the 'Stream' configuration page with tabs for 'Information', 'Stream Explorer', 'Cinst', 'Vrx', 'RTP', and 'Per-frame'. It features a 'Configure Stream' button and a 'Back to Streams' button.
- Bottom-Left Window:** Shows the 'PTP Analysis' graph, plotting 'PTP Offset' on the y-axis (ranging from -30000 to 40000) against time. A green line represents the data, and a green box highlights a 'Value' at the end of the line.
- Bottom-Right Window:** Shows a detailed view of a stream with a bar chart and a legend for 'Std. Deviation' (blue), 'Mean' (orange), 'Max' (green), and 'Min' (red).

In the bottom right corner, a yellow starburst graphic contains the text: **EBU Live IP Software Toolkit**

Cpeak = 1

CInst



		Egros total	3.2 Tbps	CInst	1										
		16 MB													
		9%													
		1.1													
		Usage of Space (Physical and 100% of memory)													
1/Rate		90%	90%	70%	60%	50%	40%	30%	20%	10%	10%				
		4.835E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	3.369E-04	5.000E-04				
		20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64	2288.82					
Resolution	Hz	Streams	Packets	Packets	C										
720	50	1614	1614	80700	3	4	5	7	8	11	17	31			
720	60	1614	9680	4	5	6	7	8	10	14	21	43			
1080	50	3638	18150	8	9	11	13	15	19	26	39	75			
1080	60	3638	93800	10	11	13	15	19	23	31	47	93			
2160	50	14522	72600	39	41	47	53	63	79	105	158	313			
2160	60	14522	48120	43	47	54	63	76	95	125	190	380			
2160	100	48522	148200	70	79	90	105	126	158	211	317	634			
2160	120	14522	94240	86	95	109	126	153	190	253	380	763			
Resolution	Hz	B	Rate	Streams	Streams										
720	50	0.93	2987	2853	2323	1993	1693	1327	996	664	332				
720	60	1.11	2489	2232	1938	1659	1383	1106	830	553	277				
1080	50	2.00	2120	1880	1603	1351	1101	881	683	483	293	148			
1080	60	2.50	1760	1561	1331	1121	911	721	551	381	241	121			
2160	50	8.34	8.68	332	293	258	221	184	148	111	74	37			
2160	60	10.03	10.41	272	246	213	181	148	121	92	61	31			
2160	100	26.00	26.00	111	98	86	74	62	49	37	25	13			
2160	120	48.05	49.97	58	51	45	38	31	25	19	13	8			

Cpeak = 73
Out of -21
spec

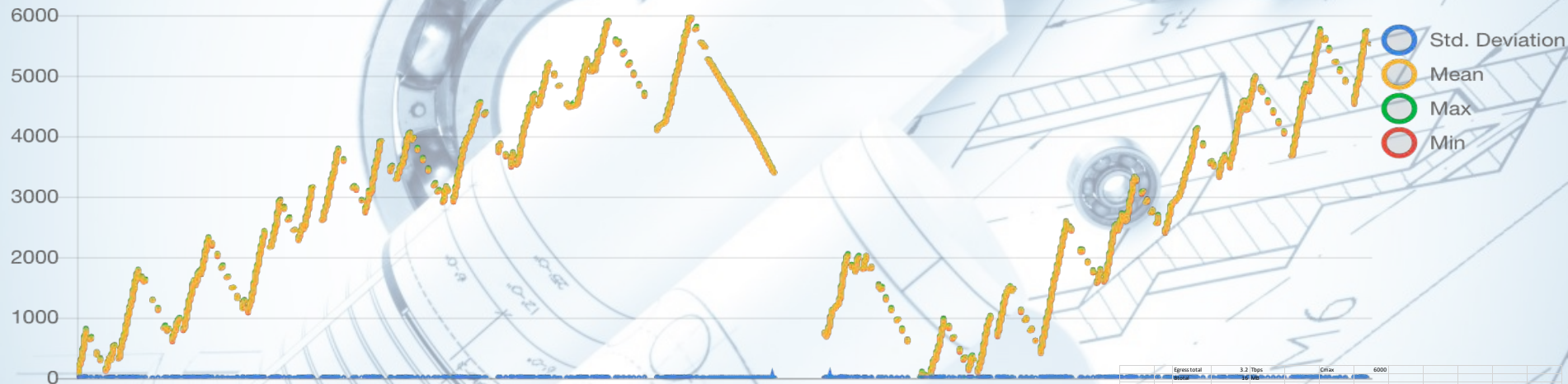


		Egros total	3.2 Tbps	Cmax	70											
		Brotan	16 MB													
		Beta	1.1													
		Range of Speed (Cdn) and 100% of memory														
		90%	90%	70%	60%	50%	40%	30%	20%	10%						
		4.835E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04	3.369E-04						
		20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64	2288.82						
		c														
Resolution	Hz	Hzpackets	Packets	1	2	3	4	5	6	7	8	9	10	11	12	13
720	50	1614	80700	4	1	1	1	1	1	1	1	1	1	1	1	1
720	60	1614	96840	4	1	1	1	1	1	1	1	1	1	1	1	1
1080	50	3638	181900	6	3	3	3	3	3	3	3	3	3	3	3	3
1080	60	3638	218280	6	3	3	3	3	3	3	3	3	3	3	3	3
2160	50	14522	726100	20	10	10	10	10	10	10	10	10	10	10	10	10
2160	60	14522	871320	20	10	10	10	10	10	10	10	10	10	10	10	10
2160	100	47632	2381600	70	35	35	35	35	35	35	35	35	35	35	35	35
2160	120	14522	726100	80	40	40	40	40	40	40	40	40	40	40	40	40

		B	Range	#Streams													
		0.93	0.96	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015
		1.11	1.15	2480	2522	2564	2606	2648	2690	2732	2774	2816	2858	2900	2942	2984	3026
		2.00	2.17	1120	1162	1204	1246	1288	1330	1372	1414	1456	1498	1540	1582	1624	1666
		2.50	2.60	1100	1142	1184	1226	1268	1310	1352	1394	1436	1478	1520	1562	1604	1646
		8.34	8.68	132	235	238	241	244	247	250	253	256	259	262	265	268	271
		10.00	10.41	250	400	404	408	412	416	420	424	428	432	436	440	444	448
		25.00	26.00	111	88	86	84	82	80	78	76	74	72	70	68	66	64
		40.00	49.97	58	53	48	43	38	33	28	23	18	13	8	3	0	0



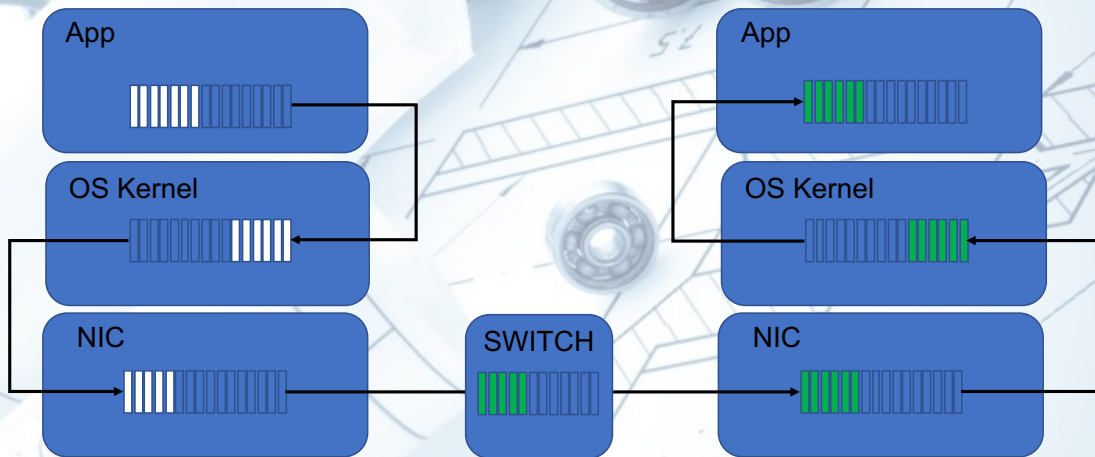
CInst



- Std. Deviation
- Mean
- Max
- Min

		Egros total	3.2 Tbps	CInst		6000			
		Active	95%	95%	95%	95%	95%	95%	95%
		Beta	1.1						
		Range of Speeds (100% of memory)							
		90%	90%	70%	60%	50%	40%	30%	10%
		4.835E-05	5.461E-05	6.242E-05	7.282E-05	8.738E-05	1.092E-04	1.456E-04	2.185E-04
		20599.37	18310.55	16021.73	13732.91	11444.09	9155.27	6866.46	4577.64
		c							
Resolution	Hz	Packets	Packets	Packets	Packets	Packets	Packets	Packets	Packets
720	50	1614	1614	80700	4	4	4	4	4
720	60	1614	1614	96840	4	4	4	4	4
1080	50	3636	3636	181800	4	4	4	4	4
1080	60	3636	3636	218160	4	4	4	4	4
2160	50	14532	14532	726600	4	4	4	4	4
2160	60	14532	14532	871920	4	4	4	4	4
2160	100	48572	48572	2428560	4	4	4	4	4
2160	120	14532	14532	726600	4	4	4	4	4
		#Streams							
Resolution	Hz	B	Bps	Bps	Bps	Bps	Bps	Bps	Bps
720	50	0.93	2.16	2062	2403	2323	1913	1327	994
720	60	1.11	1.16	2489	2323	1936	1623	1109	830
1080	50	2.60	2.17	1126	1659	1603	1303	960	641
1080	60	2.50	2.50	1026	1661	1651	1316	916	664
2160	50	8.34	8.68	337	235	228	213	184	141
2160	60	10.03	10.41	276	166	161	144	124	92
2160	100	26.00	26.00	111	88	86	74	62	49
2160	120	48.05	49.97	50	63	61	53	45	34

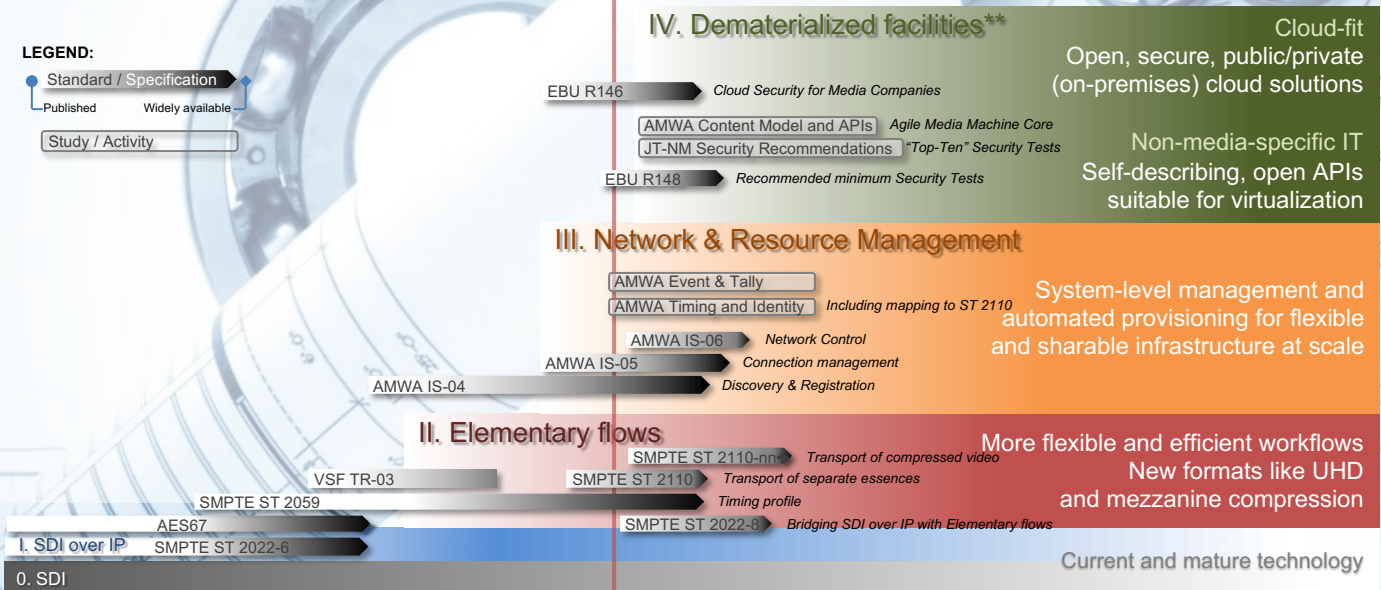
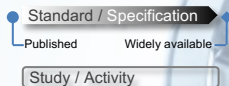
- **FPGA**
- **Software**
- **Virtual**



JT-NM Roadmap of Networked Media Open Interoperability*



LEGEND:



* 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@videncore.com.