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Testing the PDV tolerance of PTPv2 slave clocks, an approach from an operator

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FT strategy for frequency sync in mobile networks

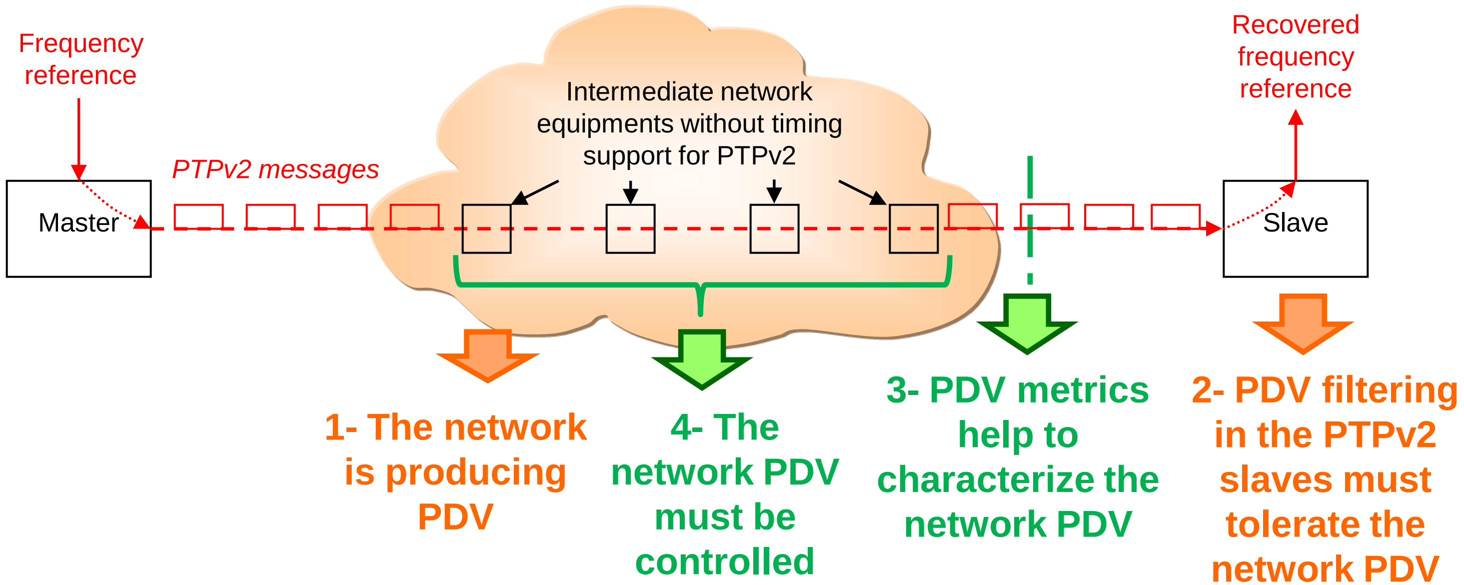
- Physical methods (Synchronous Ethernet) still recommended solution when possible
  - Straightforward integration in the existing synchronization networks
  - Excellent timing quality (no impact of PDV), strong support from the industry
  - Expected to support future stringent phase/time synchronization needs
- Packet based methods (IEEE1588v2 end-to-end) considered in some cases, when physical methods are not possible
  - Technology better understood now, about to be standardized for performance and network planning aspects, but…
  - Technology limited only to mobile applications, with loose requirements
  - PTPv2 slaves implementations not all mature => testing is very important
  - Commissioning and troubleshooting procedures not straightforward (not a plug and play solution) => the real challenge is now on the operational side

➢ This paper introduces possible approaches for anticipating the network Packet Delay Variation (PDV) accumulation based on the study of the PDV generated by network nodes such as routers, and for stressing a PTPv2 slave clock in order to ensure that it will tolerate the appropriate level of network PDV

understanding where and how PTPv2 slave clocks might be used

Picture: Treasurer's House, York

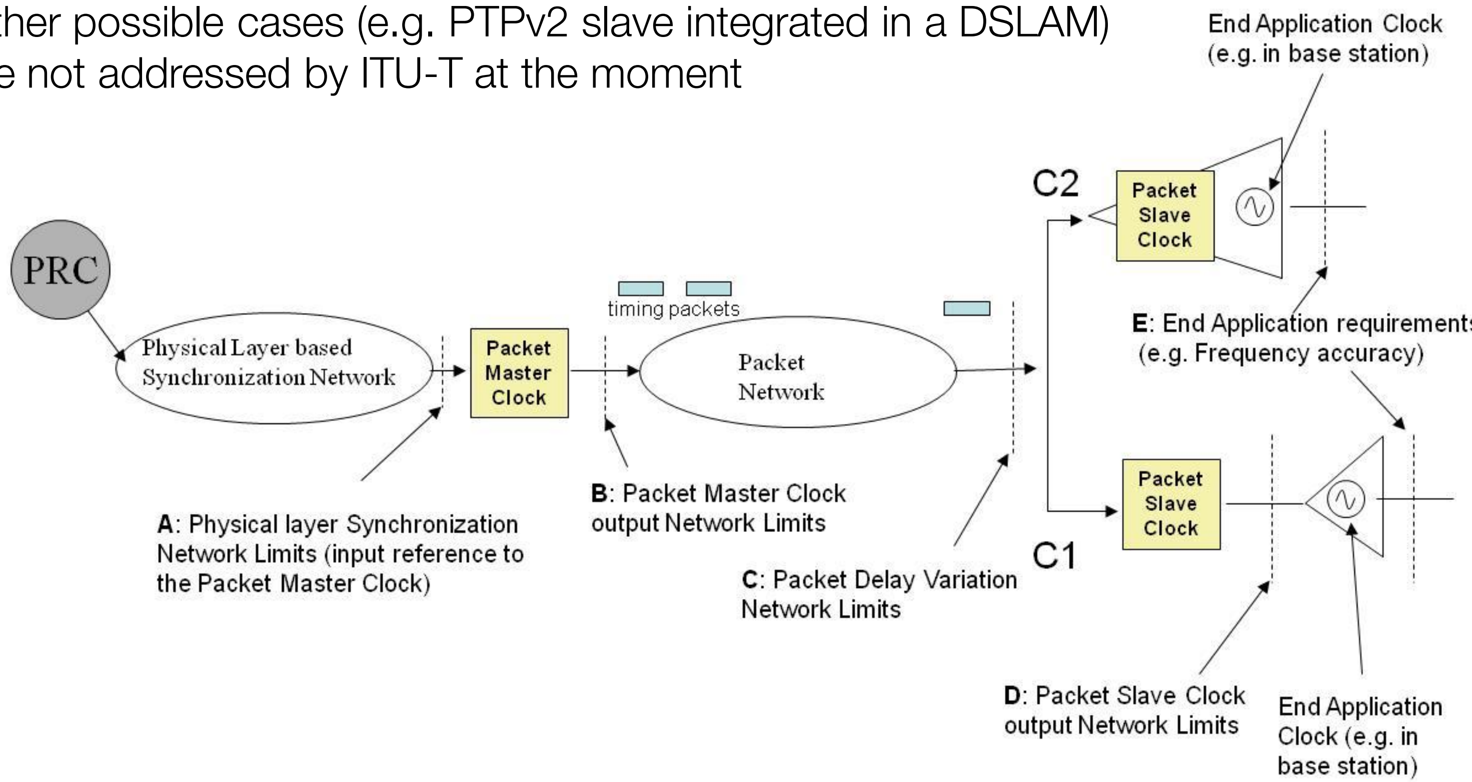
What are the challenges related to PDV?



- 1- If not controlled, the PDV generated by the network may lead to performance issues for the PTPv2 slave; it is very difficult to predict it without studying the network equipments
  - The PDV measured today is not necessarily the PDV that will occur tomorrow (e.g. traffic increase)
- 2- PTPv2 slaves must implement minimum common criteria to filter the network PDV
- 3- PDV metrics determine if the network PDV is acceptable for a slave in order to respect a certain performance objective
- 4- Appropriate methodology is required to build a network which meets the PDV tolerance of the filtering algorithms implemented in the PTPv2 slaves
  - Main question: how many nodes of different technologies can be cascaded?

2 deployment cases for PTPv2 slaves in ITU-T

- Case C1: the PTPv2 slave clock is external and co-located to the base station, and delivers an outgoing TDM timing reference (e.g. 2,048 MHz) to the base station
- Case C2: the PTPv2 slave clock is integrated to the base station
- Other possible cases (e.g. PTPv2 slave integrated in a DSLAM) are not addressed by ITU-T at the moment

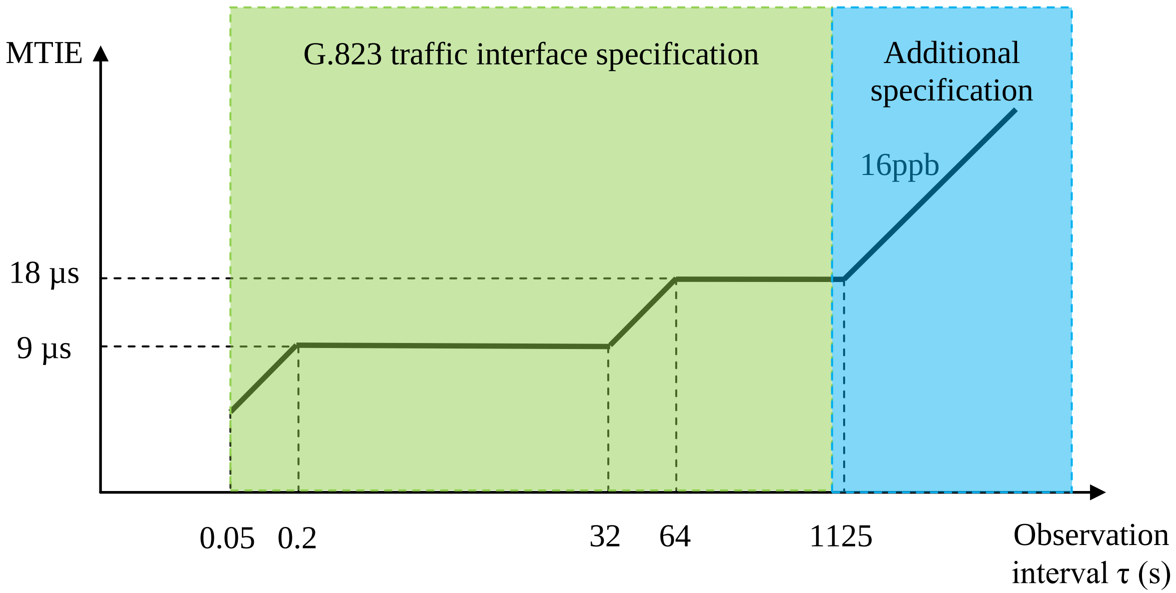


- The PDV network limits not to be exceeded at point C will be the same for the 2 cases.

Performance objective at the output of the slaves

- Case C1: the PTPv2 slave clock is external and co-located to the base station, and delivers an outgoing TDM timing reference (e.g. 2,048 MHz) to the base station

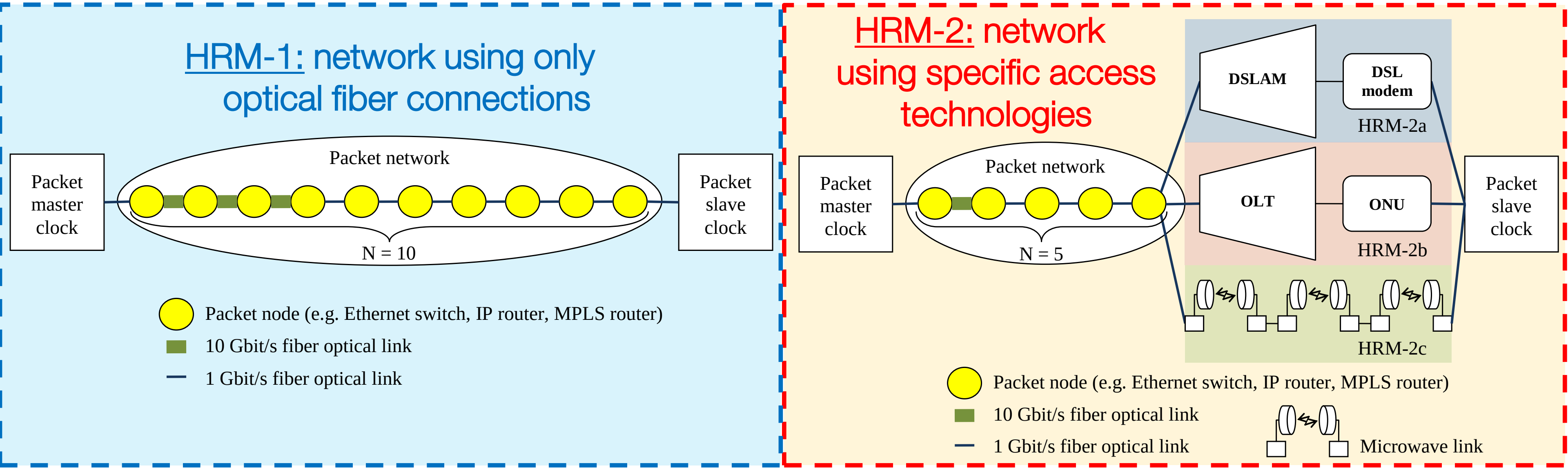
  => G.823 network limits for traffic interface + 16ppb long term slope (see next figure)



- Case C2: the PTPv2 slave clock is integrated to the base station

  => 50ppb over 0.667ms (and longer)

2 network reference models (HRM) studied at ITU-T

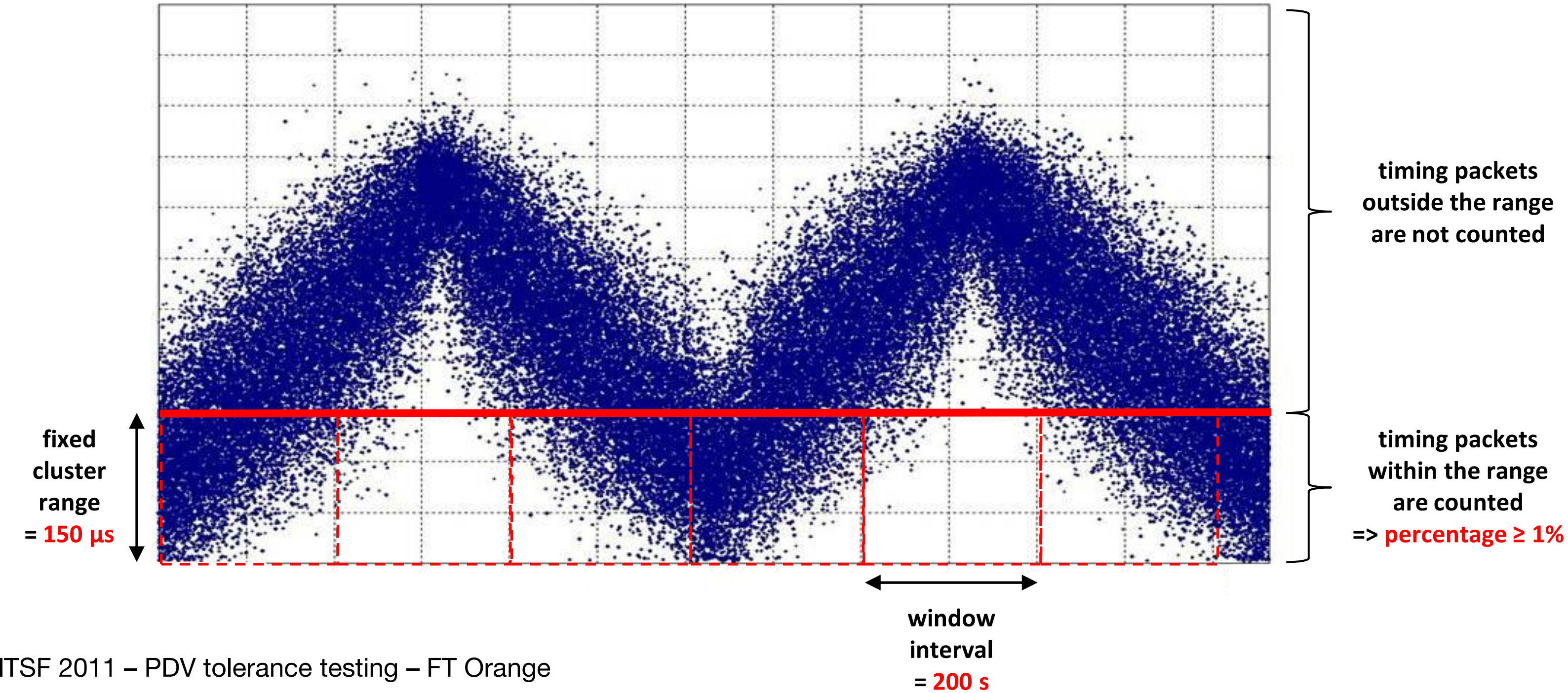


- The on-going studies at ITU-T (2011 time frame) address only the HRM-1.
- Some important limitations have to be noted (applicable to HRM-1 and HRM-2):
  - No 100Mb/s interface allowed for the HRM-1 between nodes carrying data traffic, only 1G or 10G
  - The links are in general allowed to be carried over transmission networks (e.g. OTN or SDH)
  - Jumbo frames are not allowed over the links carrying the PTPv2 packets (max size = 2000 bytes)
  - PTPv2 packets must have the highest priority and must be placed in a strict priority queue. This queue must either only contain PTPv2 packets, or the other data traffic packets going also in this queue must be small packets and the amount of data in the queue must be much smaller than the output interface capacity
  - The number of microwave hops in the HRM-2c is for further study

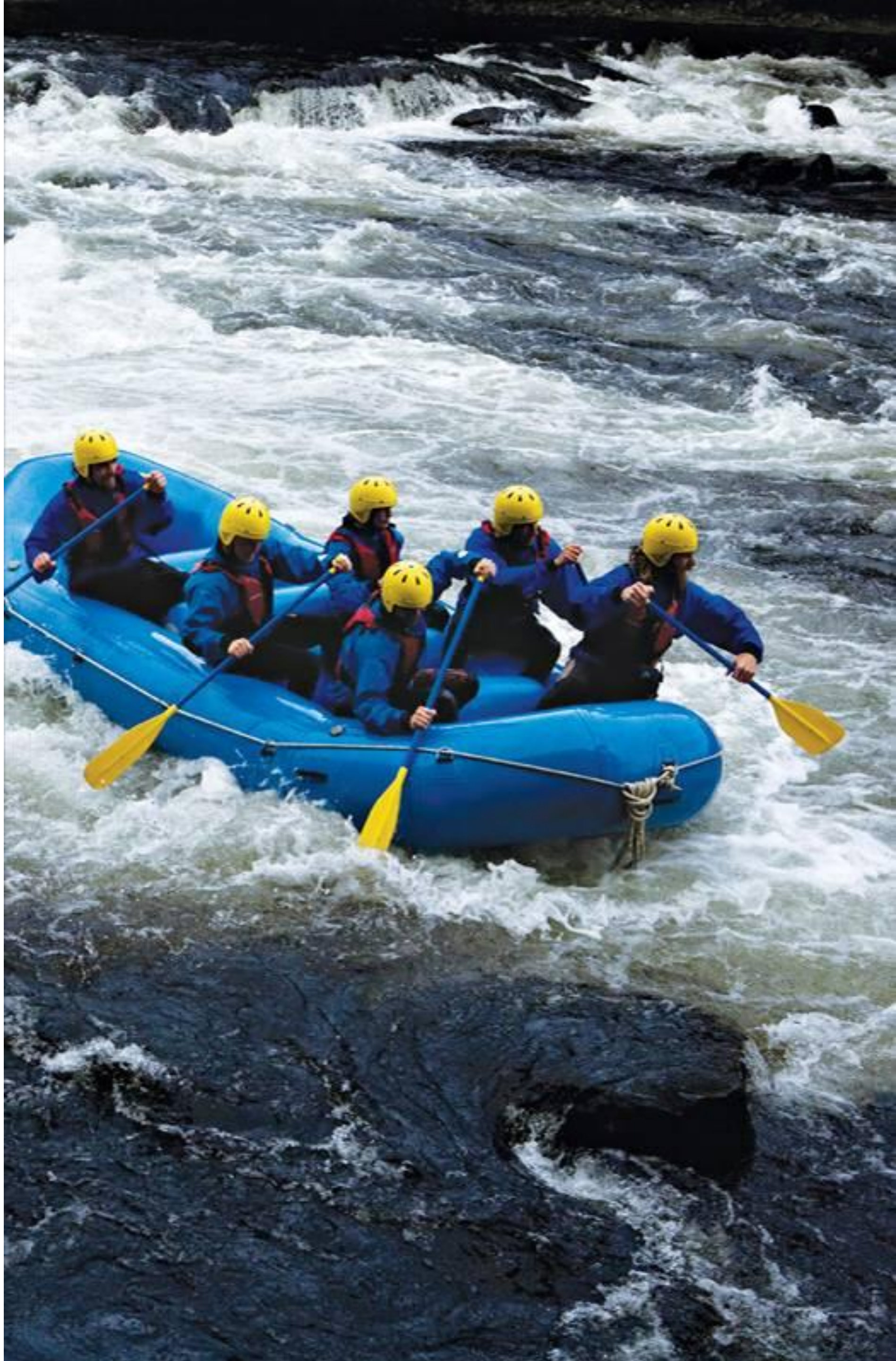
PDV network limits for the HRM-1

- Extract of G.8261.1 latest draft (the figure below is based on G.8260 latest draft):

"The Packet Delay Variation network limit for the HRM-1 (…) is defined as follows:
For any window interval of 200 seconds (jumping window), at least 1% of timing packets with a minimum of 2 timing packets must be observed within a fixed cluster, located at the observed floor delay, and having a range of 150 μs.
The fixed cluster range starts at the minimum delay of the entire PDV measurement, according to the definitions provided in G.8260, Appendix I, section I.5.
Note: other PDV metrics emulating the behaviour of a packet slave clock are currently under study and might be used in the future for specifying the PDV network limits in a less conservative way. Some information can be found in G.8260, Appendix I, section I.4."



the conquest of the engineering rules for PTPv2 deployments



Which engineering rules for PTPv2 deployments?

- Metrics called "Jitter Estimation by Statistical Study" (JESS and JESS-w) have been introduced to ITU-T in order to study the amount of PDV which can be generated by a single equipment, and to anticipate the level of PDV when several equipments are cascaded (under the assumption that the sources of noise are independent).

Let us define: $h_n = h \otimes h \otimes \ldots \otimes h \quad (n\ times)$ **(1)**

where $\otimes$ represent the convolution operator

Let us also define: $P_n = \int_0^w h_n(x)dx$ **(2)**

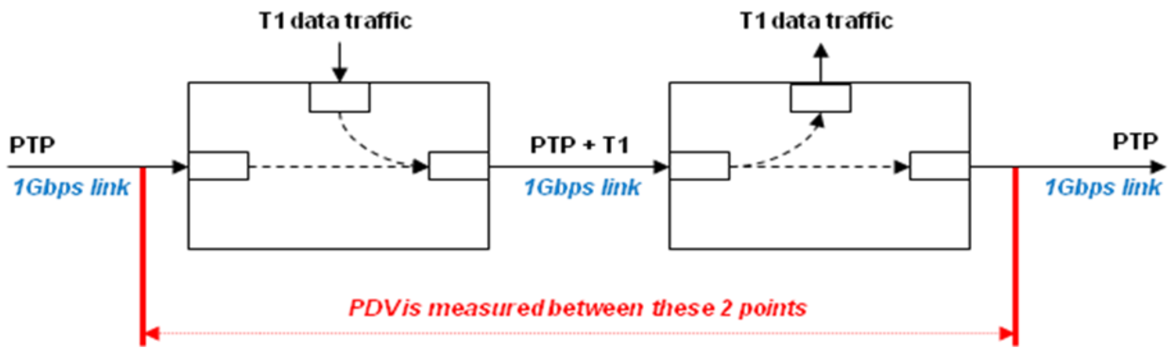
which is the probability that the relative delay suffered by a timing packet after n nodes lies within the floor delay window

JESS (h, w, p) is defined as the ***maximum value of n such that*** $P_n \geq p$ **(3)**

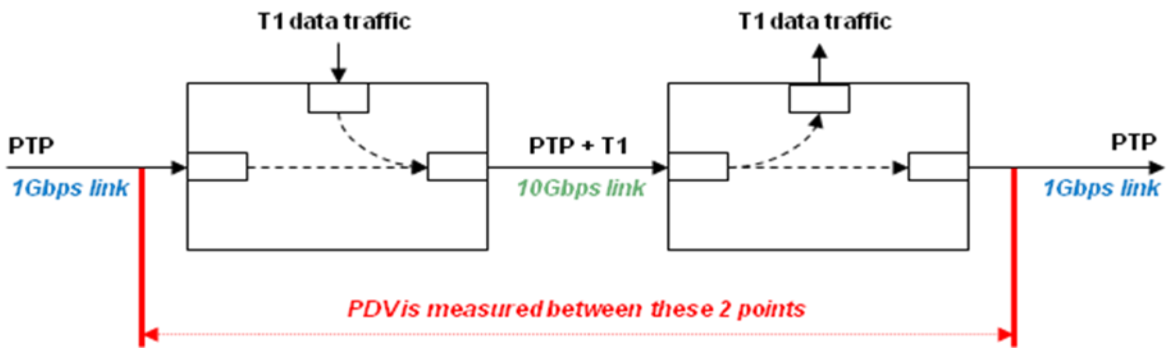
JESS-w (h, p) $= w_{min}$ ***such that*** $\int_0^{w_{min}} h(x)dx = p$ **(6)**

- These metrics can be useful for network planning purposes, together with network equipment PDV testing.
- The next few slides introduce estimations for routers (with 1G and 10G interfaces) and Microwave systems equipped with Adaptive Modulation Coding (AMC).

Configurations of the PDV generation testing



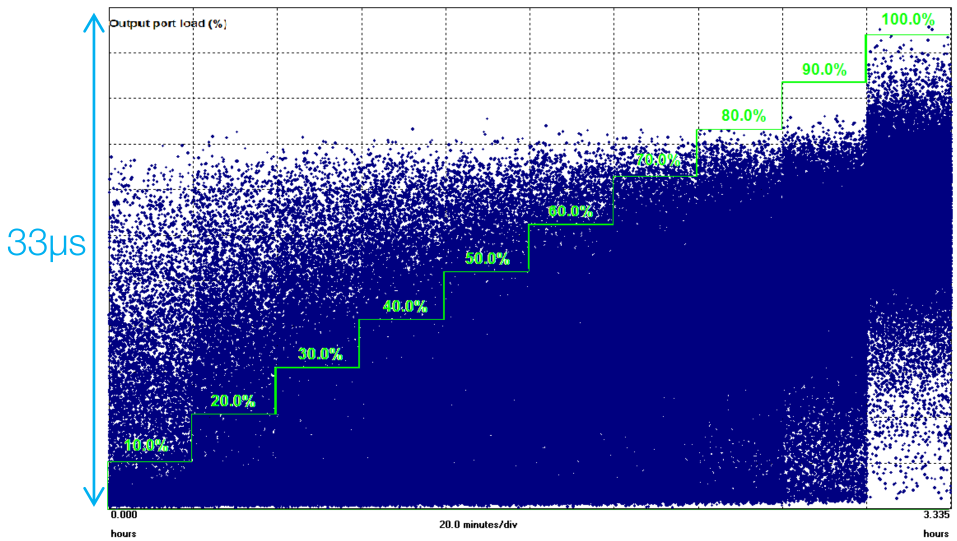
Configuration 1 with 1Gbps link



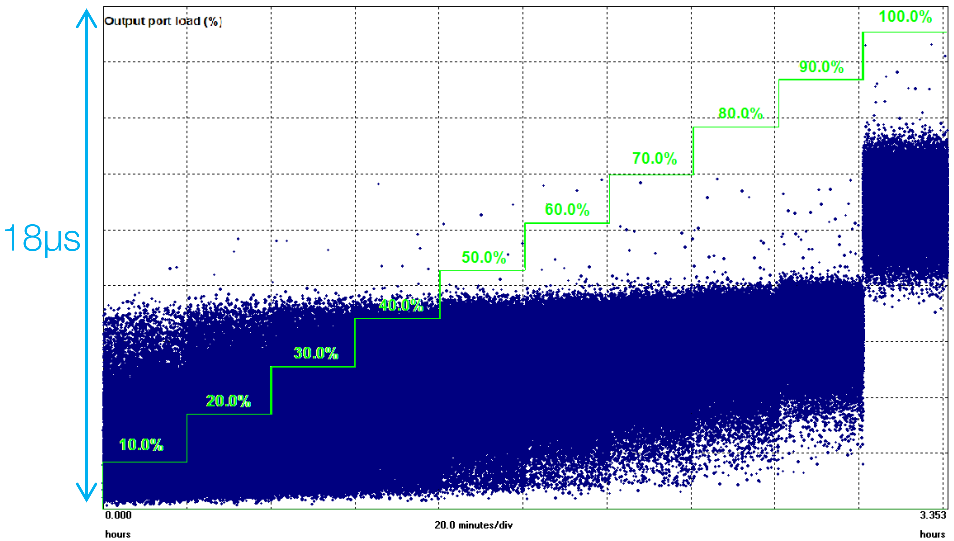
Configuration 2 with 10Gbps link

- In these tests: PTP traffic prioritized (EF), data traffic not prioritized (BE)
- 2 types of data traffic load considered (CBR in both cases):
  - All the data traffic packets have a 1518 bytes fixed size
  - The size of the data traffic packets is variable, from 64 bytes to 1518 bytes

Examples of raw PDV results (variable size case)



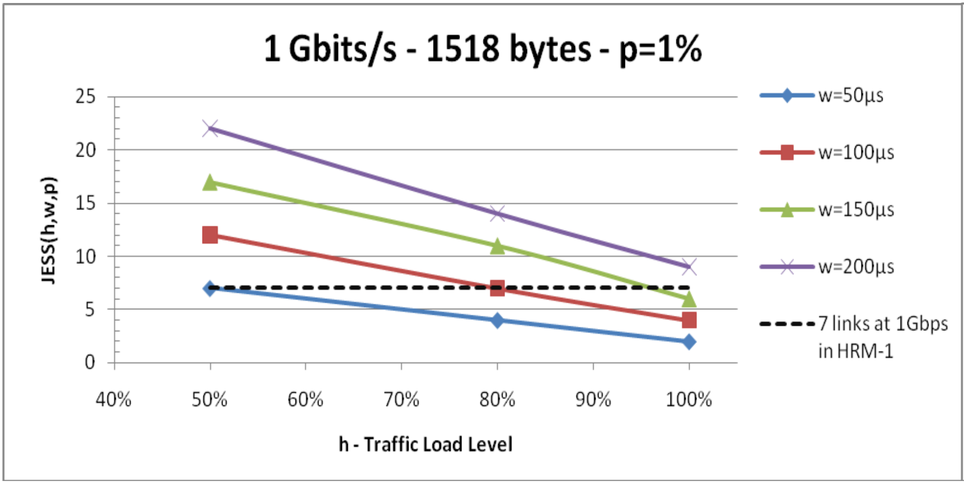
1Gb/s link

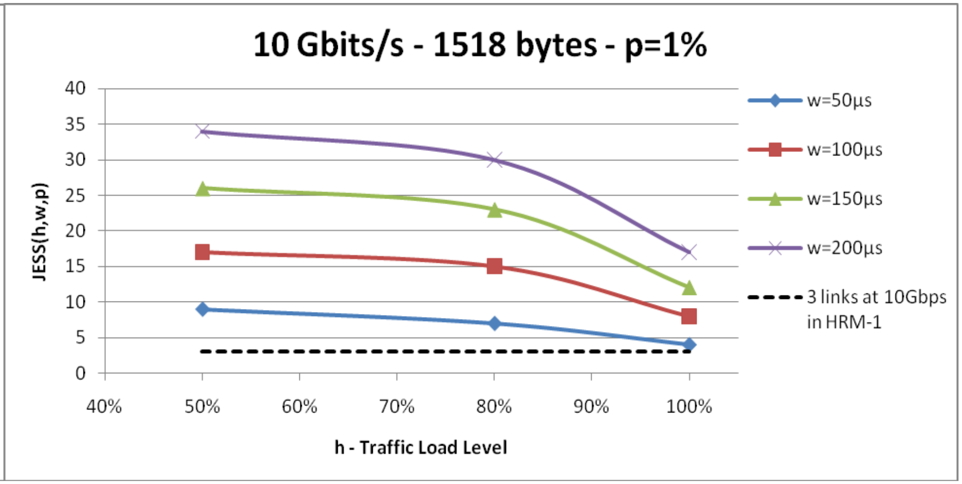


10Gb/s link

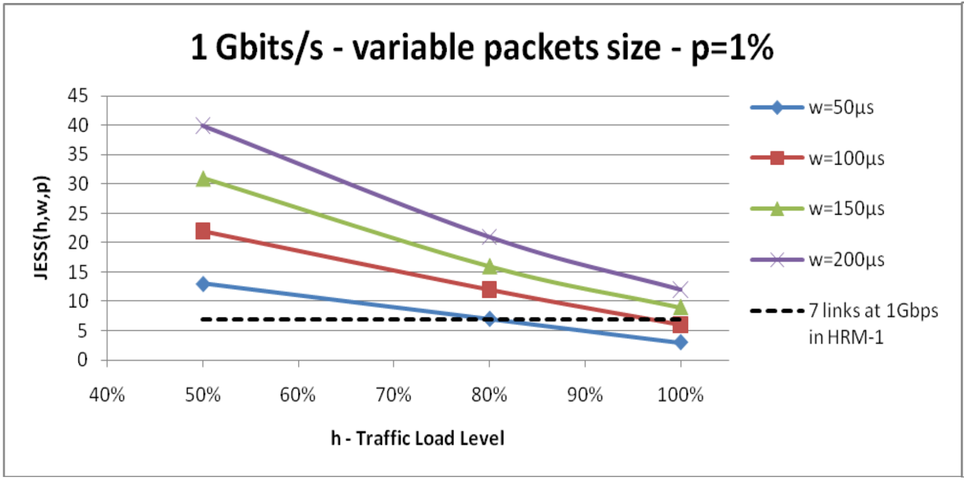
- The 10G link did not experience 10 times less noise as compared to the 1G link
  - Not only the effect of the output port accounts, other sources of PDV, such as the forwarding engine, have also to be considered => testing the PDV generation of equipments is important!
- Based on these results, metrics have been used to determine:
  - For JESS: the maximum number of nodes which can be cascaded between a master and a slave for fixed criteria (i.e. size of the floor delay window, minimum percentage of packets targeted)
  - For JESS-w: the amplitude of the noise of the 1% of fastest timing packets
- The estimations are given in the next slides (they are considered as conservative)

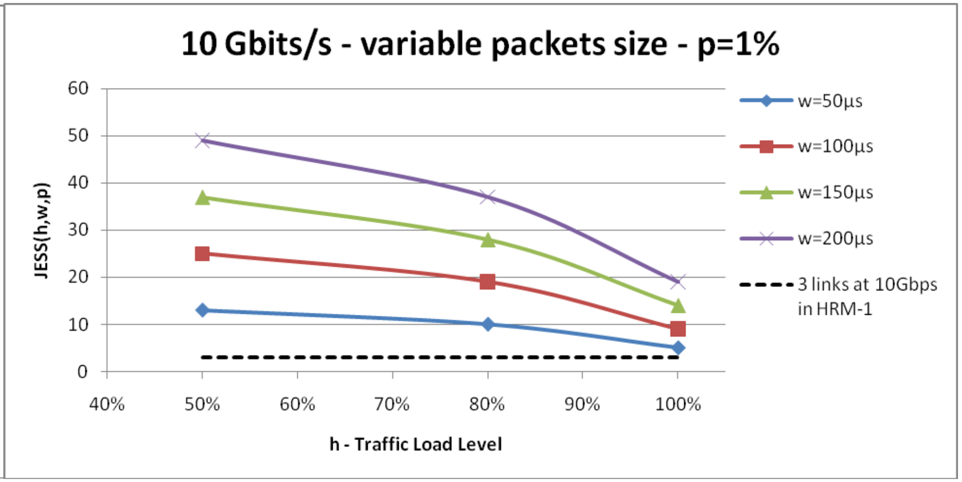
JESS estimations for 1Gbps and 10 Gbps links





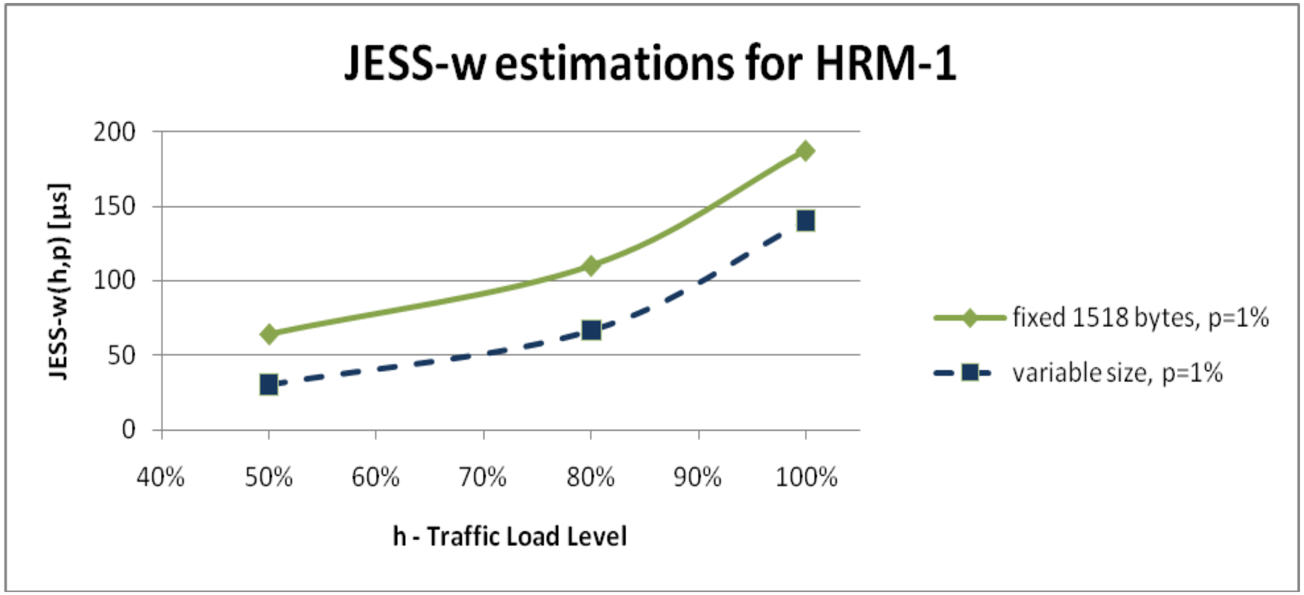
Cases of data traffic with fixed 1518 bytes packet size





Cases of data traffic with variable packet size

JESS-w estimation for the HRM-1 of G.8261.1



- In this case, histograms representative of the HRM-1 have been calculated for different values L of levels of load as follows, based on the initial PDV measurements:

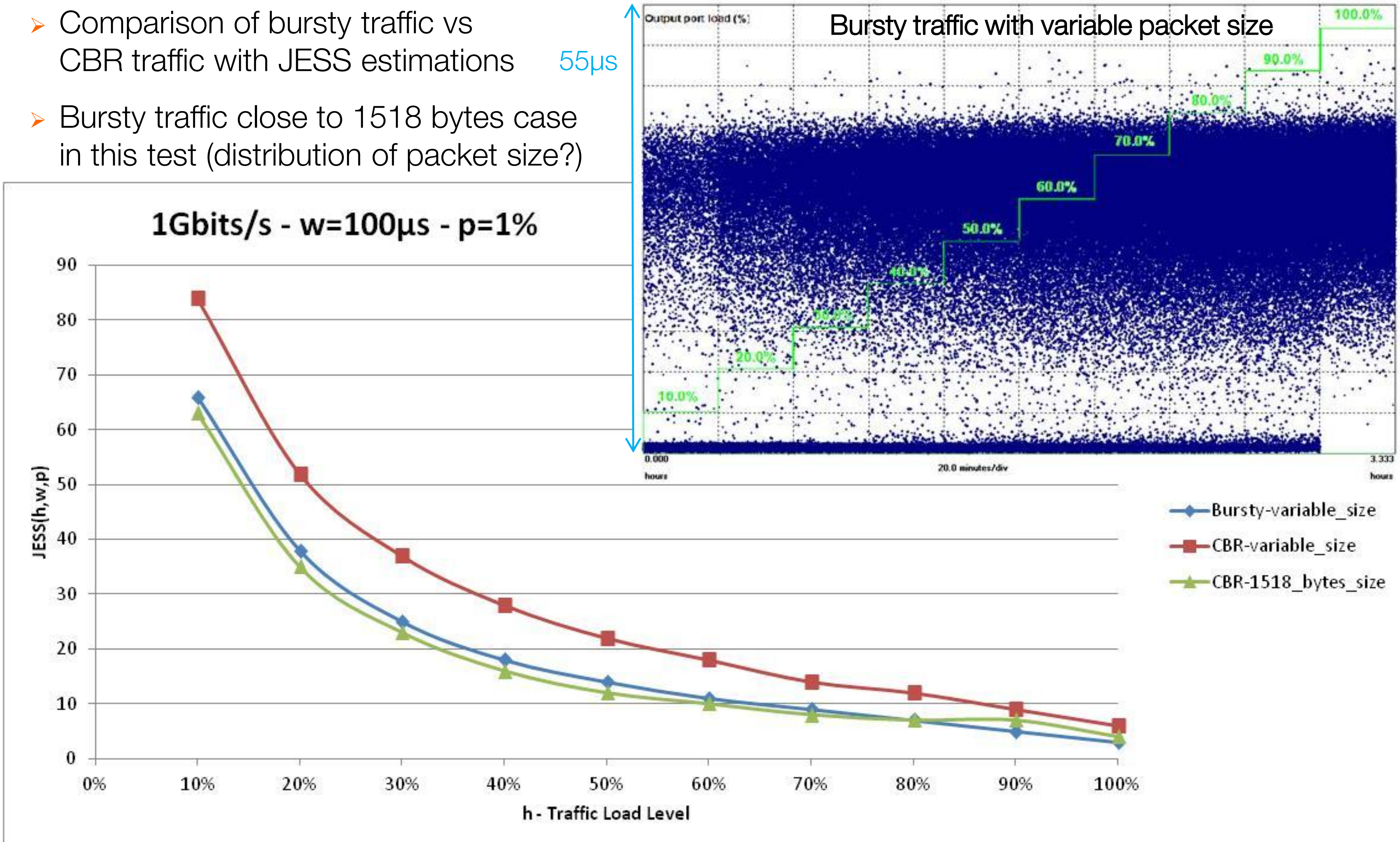
$$h[HRM\text{-}1,L] = h_7[1Gbps,L] \ \text{x} \ h_3[10Gbps,L]$$

where ‘h_n’ represents h convolved with itself to the power n, and ‘x’ the convolution operator

- These results have been presented to ITU-T to specify the PDV network limits (i.e. the 150µs floor delay window size presented before)

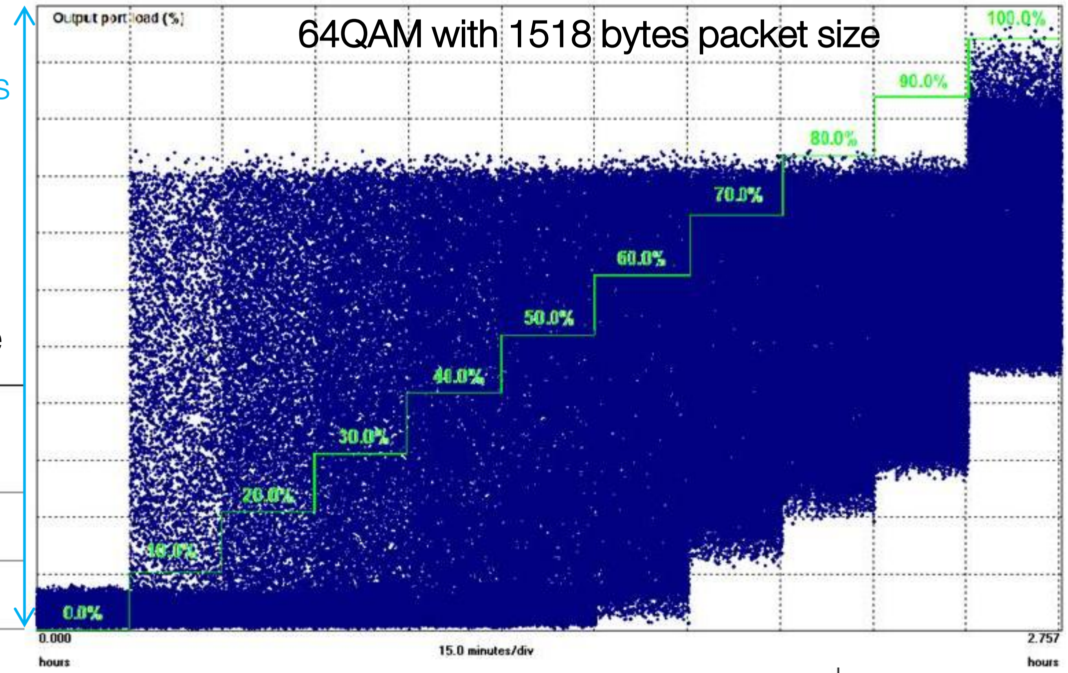
JESS estimation for bursty traffic over 1Gbps link

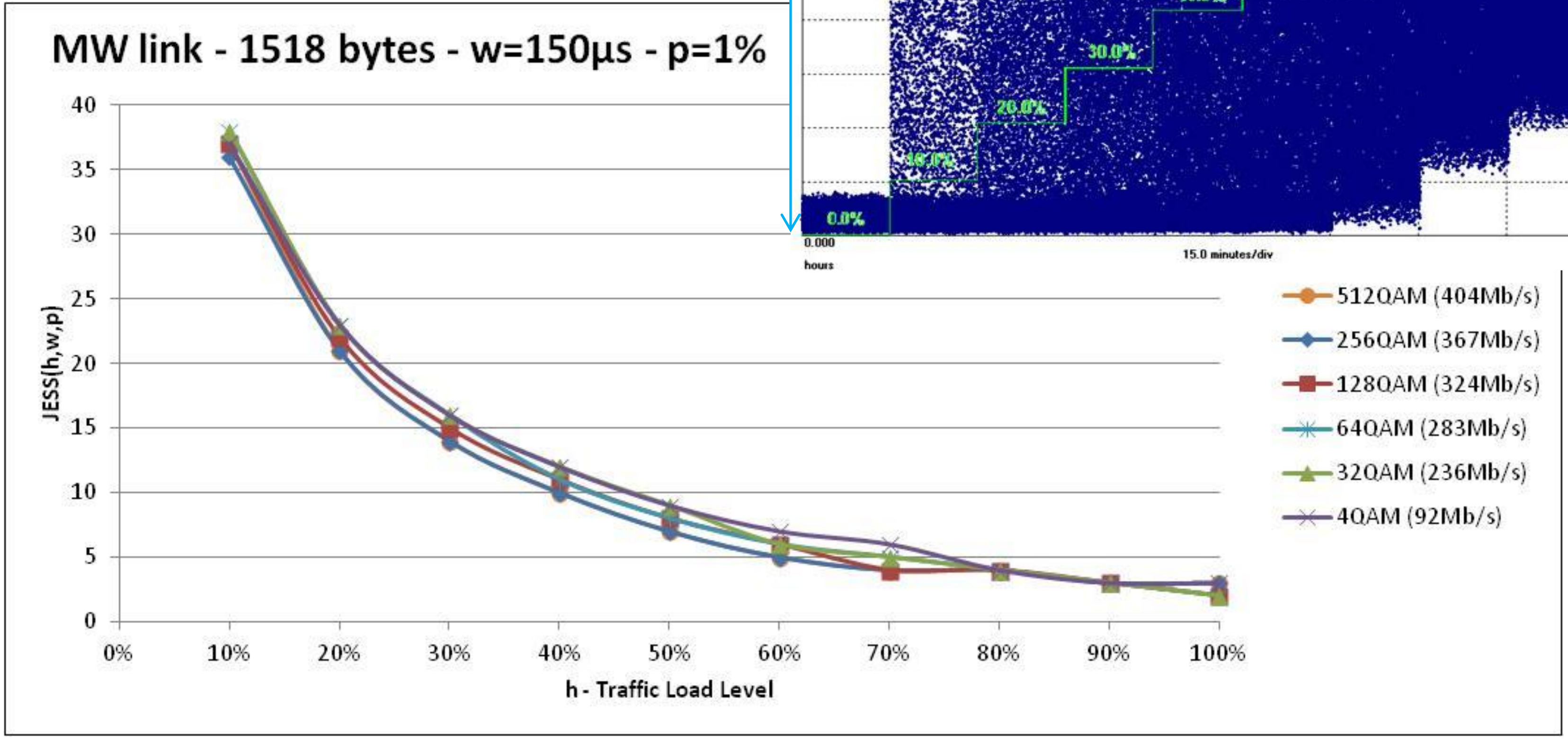
- Comparison of bursty traffic vs CBR traffic with JESS estimations
- Bursty traffic close to 1518 bytes case in this test (distribution of packet size?)



JESS estimation for Microwave links with AMC

- Quite good MW system here (packet fragmentation probably helps?)
- 3 to 4 MW hops seems achievable for w=150µs (HRM-1 limit) with this system
- Delay steps (not shown) when changing modulation must be handled by the slave





testing the PDV tolerance of PTPv2 slave clocks

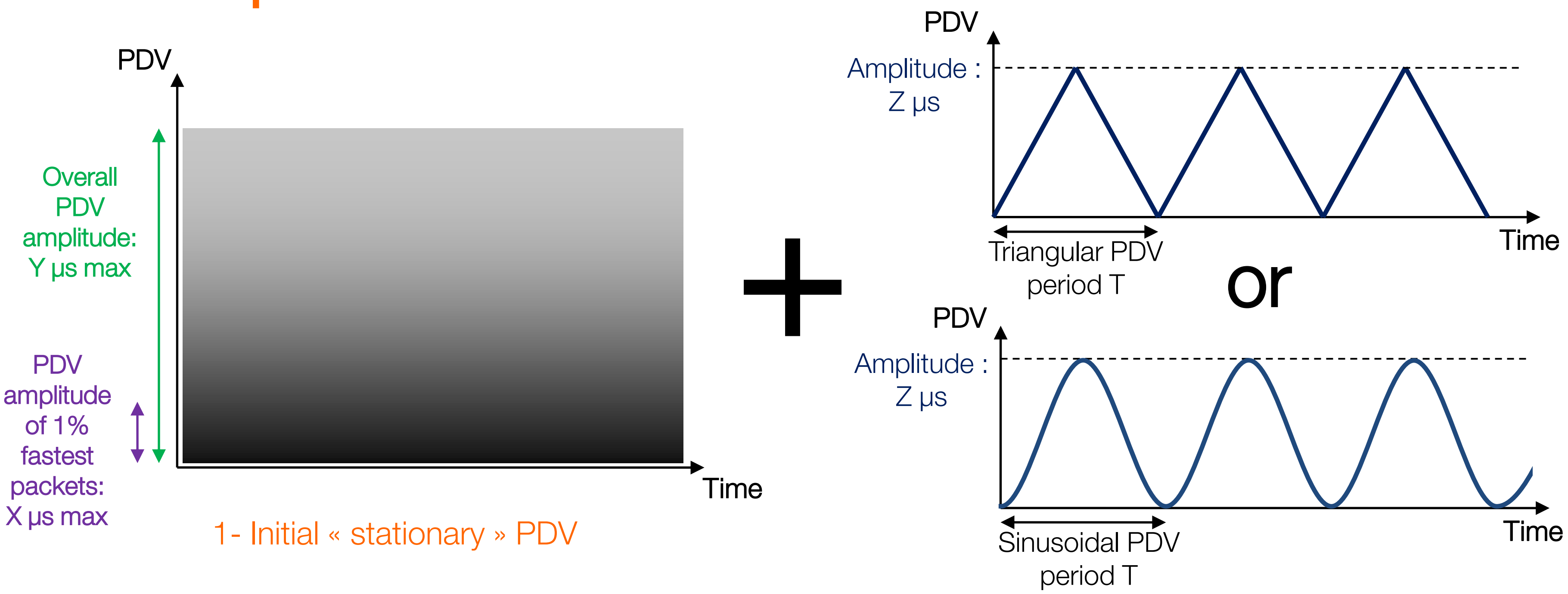
Simulations of minimum time constant in PTPv2 slaves (performed with Tellabs)

Amplitude of PDV noise (1% fastest packets)	Minimum time constant required to maintain output FFO < 16ppb (triangular PDV pattern)	Minimum time constant required to maintain output FFO < 16ppb (sinusoidal PDV pattern)
100µs	3000 s (53µHz BW*)	6000 s (26µHz BW*)
150µs (HRM-1 limit)	5000 s (33µHz BW*)	10 000 s (16µHz BW*)
200µs	6400 s (25µHz BW*)	13 000 s (12µHz BW*)
500µs	16 000 s (10µHz BW*)	32 000 s (5µHz BW*)

- These simulations show that a long time constant is required to filter the network PDV
- Simulations performed without noise generation effects of the internal oscillator due to temperature variations for now (additional simulations are planned for end of 2011)
  - Temperature effects may lead to performance issues in case of poor oscillator choice in the PTPv2 slave => OCXO/Stratum 3E should be OK, TCXO may raise problems
- PLL simulations only, not FLL (some implementations are FLL based)
- Similar methodology considered to test the PDV noise tolerance of a PTPv2 slave clock

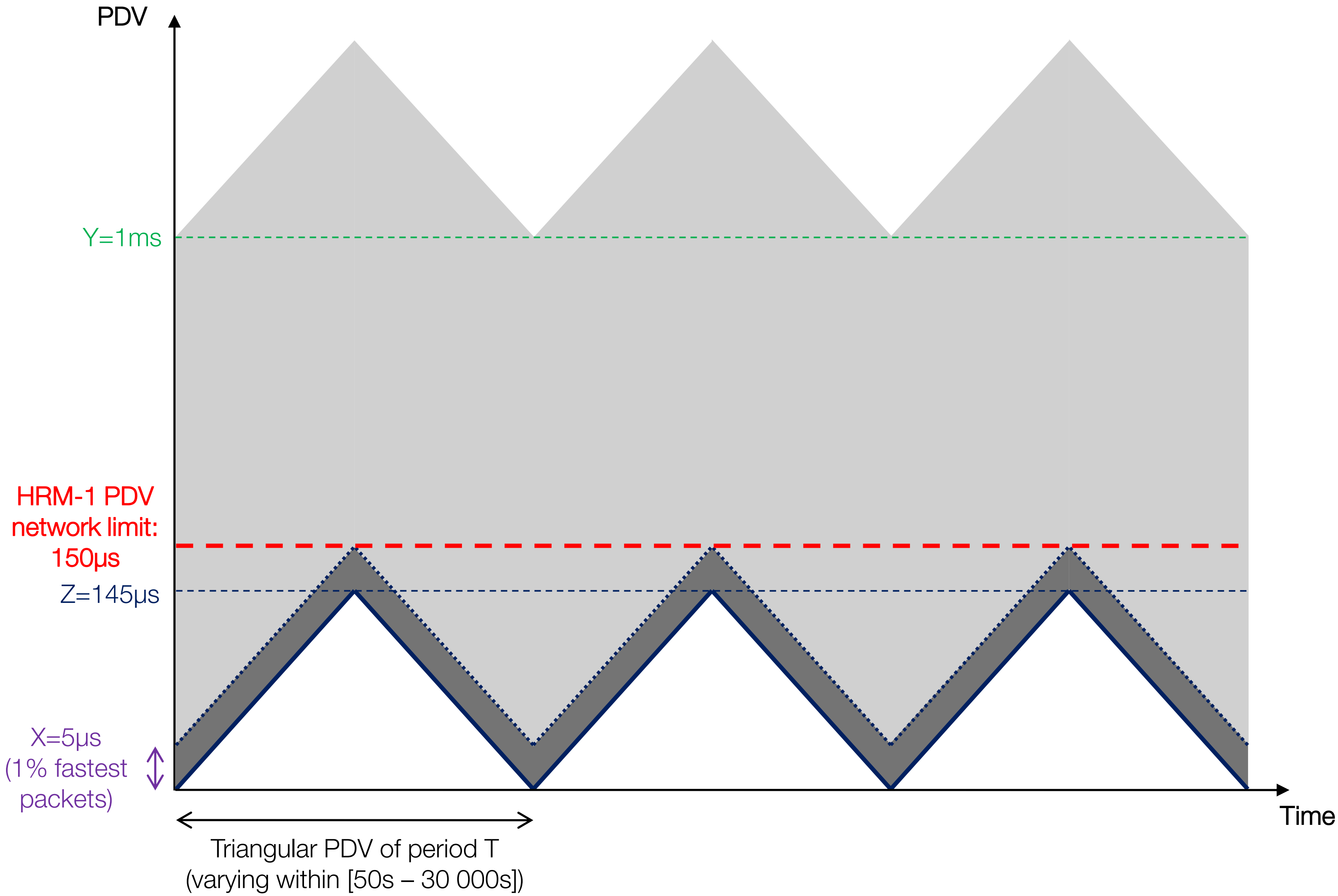
* time constant = 1 / (2 x Pi x BW)

How to generate suitable PDV patterns to stress the packet slave clock?



- Suitable PDV test signals that check conformance to the PDV network limits that will be specified in G.8261.1 can be generated as shown above
- E.g. for 150µs network limits: {Y=1ms; X=50µs; Z=100µs} or {Y=1ms; X=5µs; Z=145µs} …
- The period T can be chosen around the expected time constant of the packet slave clock
  - e.g. several periods for T can be chosen within [50s – 30 000s]

Example of resulting PDV pattern for HRM-1



Benefits of this testing method (proposed for G.8263)

- Much simpler testing compared to G.8261 Appendix VI (repeatability, …)
- In line with traditional noise tolerance testing of clocks with sinusoidal test signals of varying periods (e.g. G.813, G.8262, …)
- Directly connected to the PDV network limits specification (minimum of 1% of packets within a floor delay window of 150µs)
- Much stressful for the PTPv2 slaves, especially for small values of X/large values of Z => a slave clock complying to this testing is expected to work in all G.8261.1 HRM-1 deployment scenarios, even the worst ones (under the assumption that the PDV network limits are respected)
- Enables stressing both packet selection and filtering capacity/oscillator quality of the packet slave clock
- Note: the value X could be defined as parametric, such that the PDV pattern generated would exactly meet the PDV network limits, i.e. all the time, only 1% of packets and not more would be within the floor delay window of 150µs (it is not the case with the current approach, where more than 1% of timing packet will very likely be observed when the triangular/sinusoidal pattern is close to zero => this methodology can be improved)

conclusion

Key elements required for safe PTPv2 deployments for frequency synchronization in mobile networks

1- standardized PDV metrics and network limits (G.8260 / G.8261.1)

2- standardized telecom profile (G.8265.1) and packet slave clock performance (G.8263)

3- suitable methodology for engineering rules and network planning

PTPv2 end-to-end deployments for frequency sync in mobile networks

4- commissioning and troubleshooting procedures

5- PDV generation testing of network nodes

6- packet master and slave clocks testing (protocol and performance)

R&D → Operational


thank you
any question?
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