An Introduction To "Floor Population" & MAFE Packet Delay Variation Metrics

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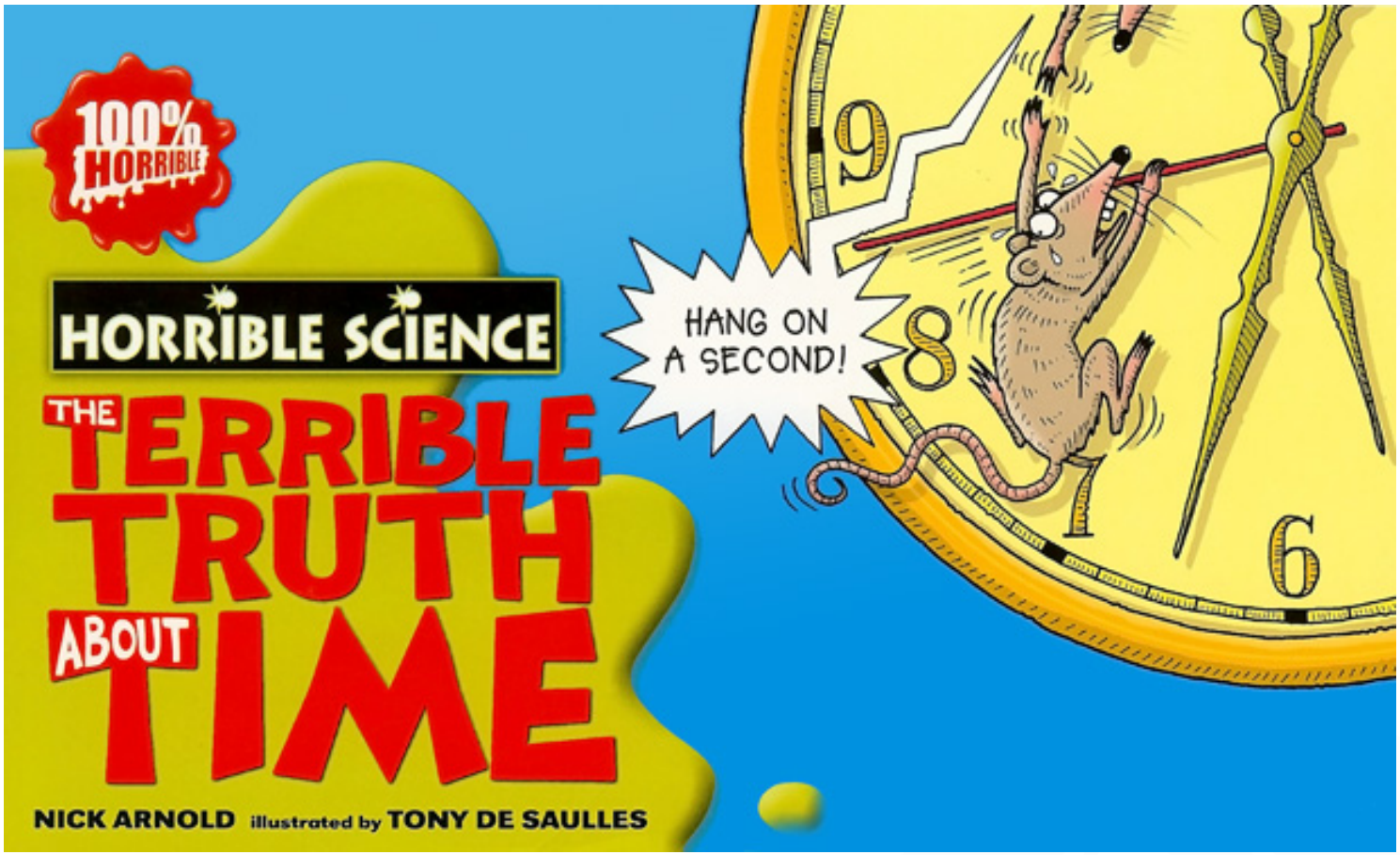
VP Technology

- **Introduction**
- Lucky Packets
- Floor Population
  - Definitions
  - Limits
  - Example Measurement
- MAFE
  - Definition
  - Example Measurement
- Conclusion

Introduction



Introduction

- What are the new metrics?
  - FP***C***, FP***P***, FP***R***:
  - MAFE
- Where are they used? New ITU Rec's
  - FPP & MAFE: Defined in G.8260
  - FPP: Network limit in G.8261.1 (1%)
  - FPP: Slave tolerance limit in G.8263 (1%)

What do they measure?

- Floor packet metrics measure:
  - How many packets go fast
  - Plotted versus time
    - It will tell you ***when*** a problem happened
- MAFE measures:
  - Peak frequency error implied by lucky packets
  - Helps estimate packet slave performance
  - Plotted versus observation interval (τ)

What are they used for?

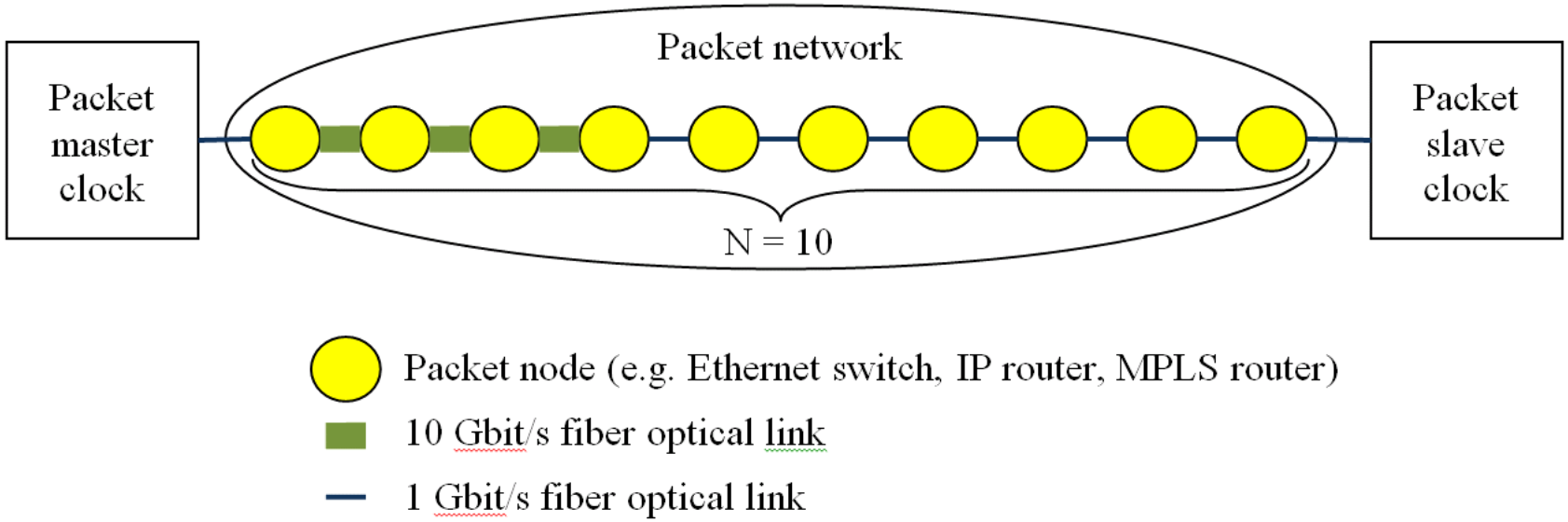
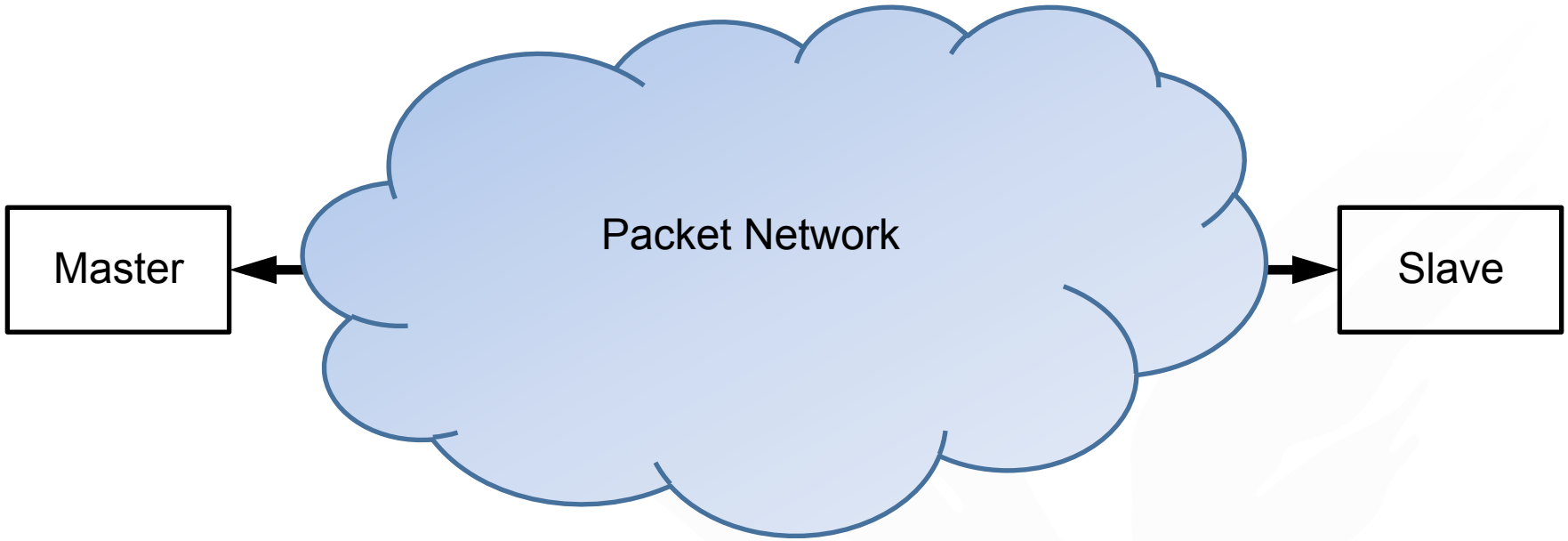


Figure 1/G.8261.1 - HRM-1 for Packet Delay Variation network limits

Packet Timing System



The Floor Population Metrics & MAFE are ways to characterize Packet Delay Variation (PDV) in this system

- Introduction
- **Lucky Packets**
- Floor Population
  - Definitions
  - Limits
  - Example Measurement
- MAFE
  - Definition
  - Example Measurement
- Conclusion

Quiz: Which of these shows Lucky Packets?

Lucky Packets

- Packets that experience near minimum delay are *Lucky*
  - They spend little or no time waiting in queues
  - They are fortunate to avoid congestion in the network
- KEY: PDV of lucky packets is relatively low
- Imagine driving home with all the traffic lights ***GREEN!***

Packet Selection

- Two ways:
  - Cluster range (e.g. within 150us of minimum)
  - Percentile range (e.g. 5% of fastest packets)
- Floor population metrics use cluster range
- We'll see MAFE with percentile range

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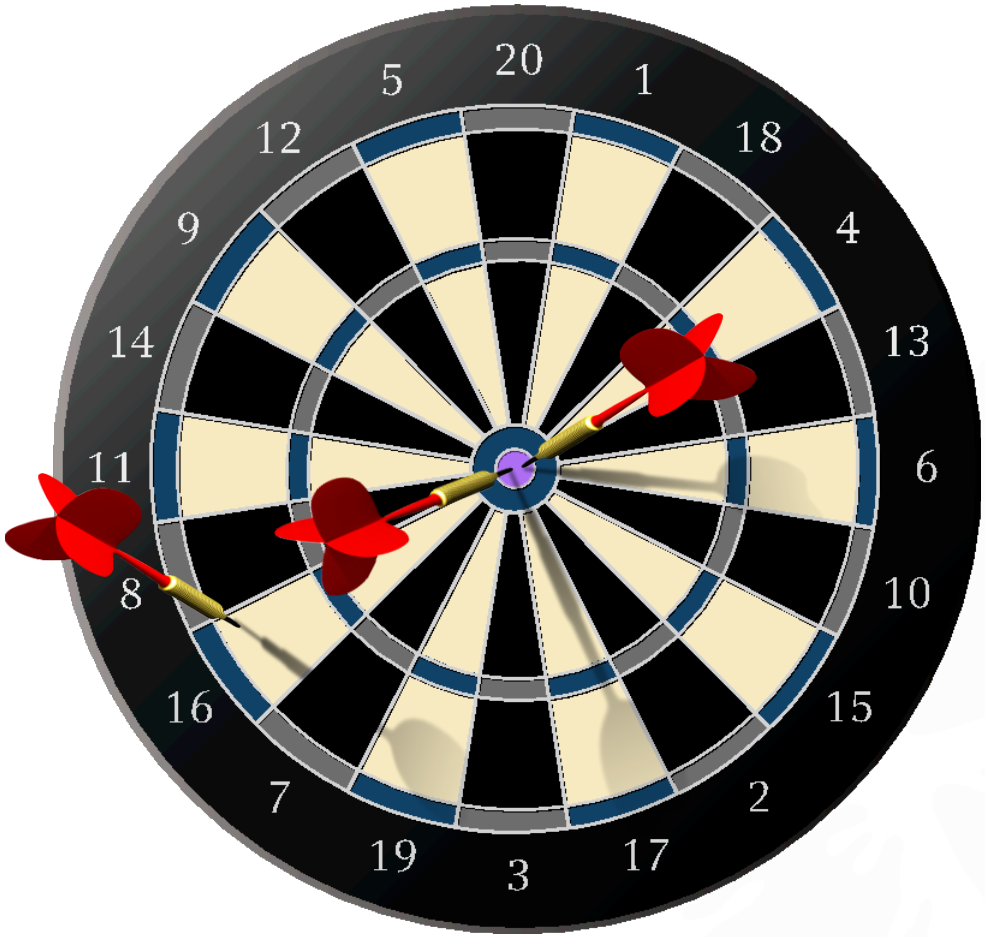
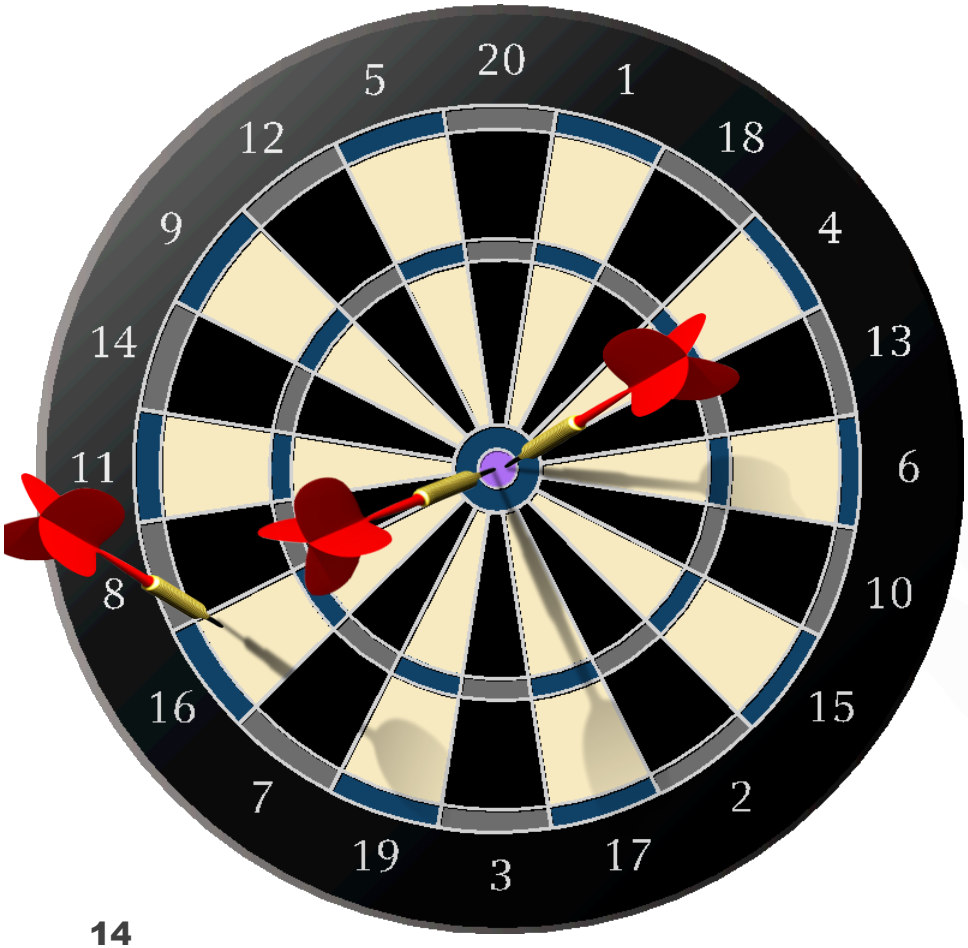
Cluster Selection Analogy



Cluster Selection Analogy



- Game lasted 1 minute
- Three darts thrown
- Two hit Bull's Eye
- 1 point for Bull's Eye

STATS

- Score=2
- Percent=67% (2/3)
- Rate=2/minute

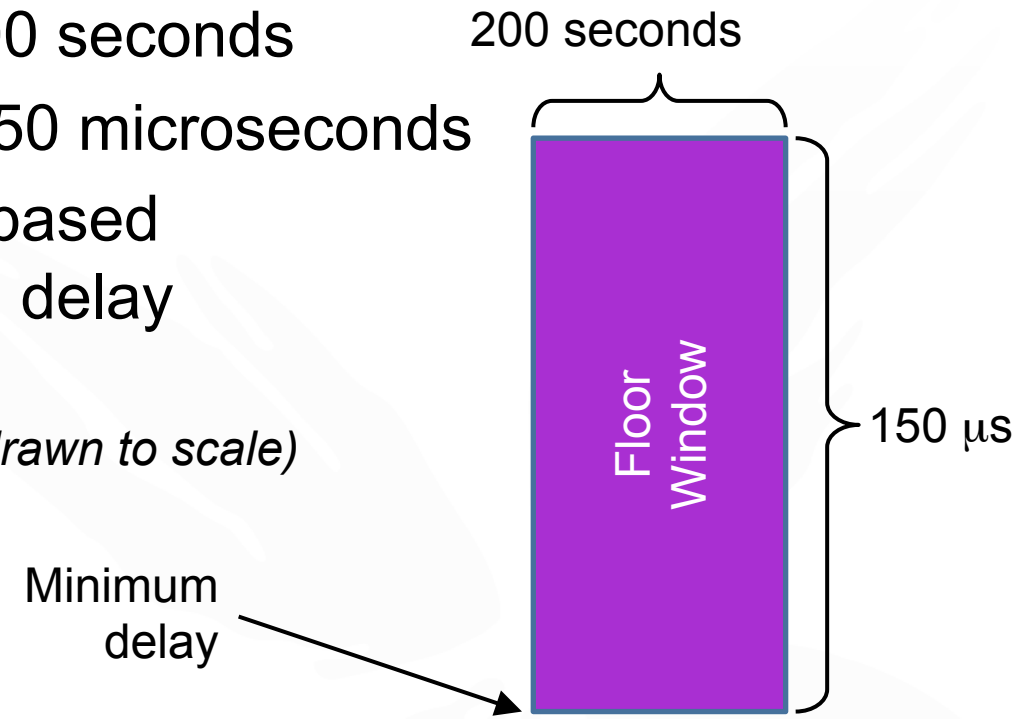
Metric Definitions via Dart Board Analogy

- Floor Packet Count (FPC)
  - The number of times a dart landed in the Bull's Eye
- Floor Packet Percentage (FPP)
  - The percentage of times a dart landed in the Bull's Eye
- Floor Packet Rate (FPR)
  - The rate that darts land in the Bull's Eye (e.g. per minute or hour)
- To apply to packet timing systems:
  - Replace "dart" with "timing packets"
  - Replace "land" with "have delay" (or "are delivered")
  - Replace "Bull's Eye" with "Floor Window"
    - (size of Bull's Eye is analogous to the "cluster range"

Note: Full mathematical definitions are in backup slides

The Floor Window
(a.k.a. the Bull's Eye)

- Window has width, height and vertical position
  - Width is defined as 200 seconds
  - Height is defined as 150 microseconds
  - Position of window is based on minimum observed delay



(NOTE: Not drawn to scale)

Network PDV Limit (G.8261.1)

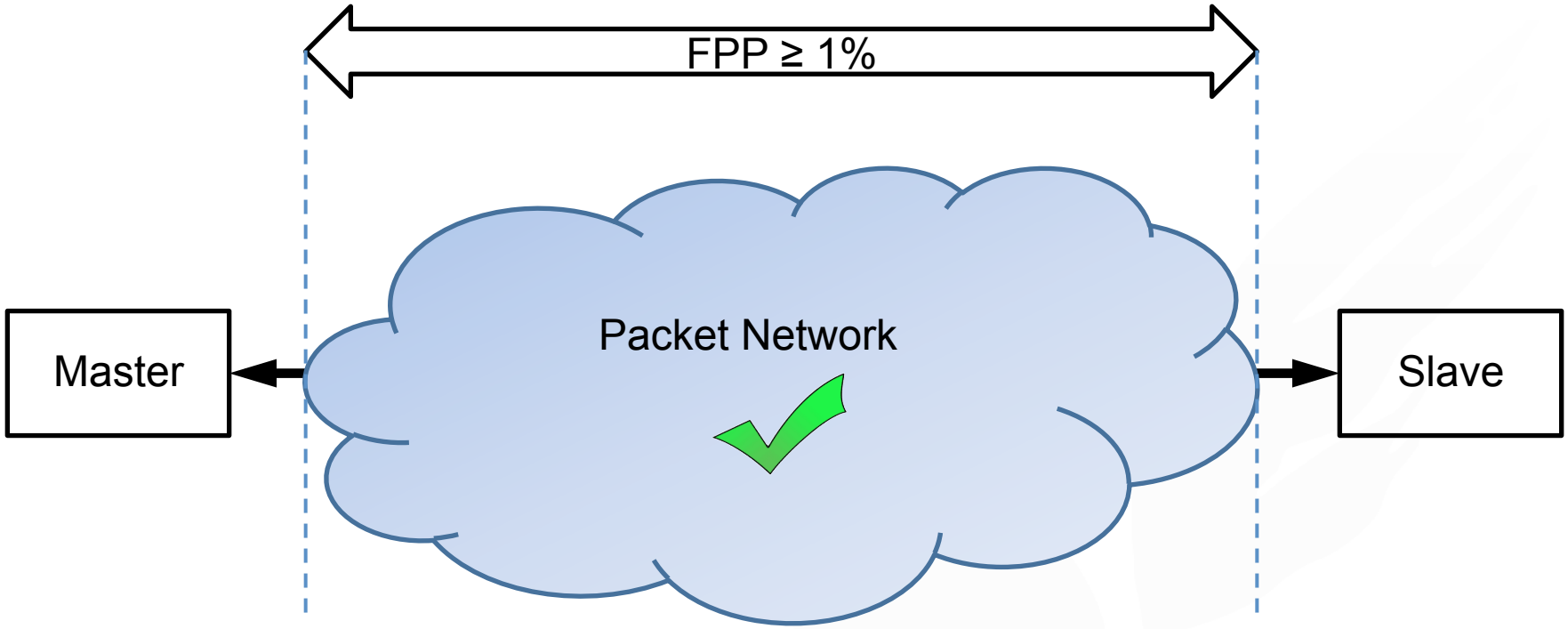
The Packet Delay Variation network limit at the point C of figure 3/G.8261.1 for the HRM-1 shown in figure 1/G.8261.1 is defined as follows:

With window interval $W = 200$s and fixed cluster range $\delta = 150\mu$s starting at the floor delay, the network transfer characteristic quantifying the proportion of delivered packets that meet the delay criterion should satisfy

$$\mathbf{FPP}\ (n, W, \delta) \geq 1\%$$

That is, the floor packet percentage must exceed 1%.

Network PDV Limit



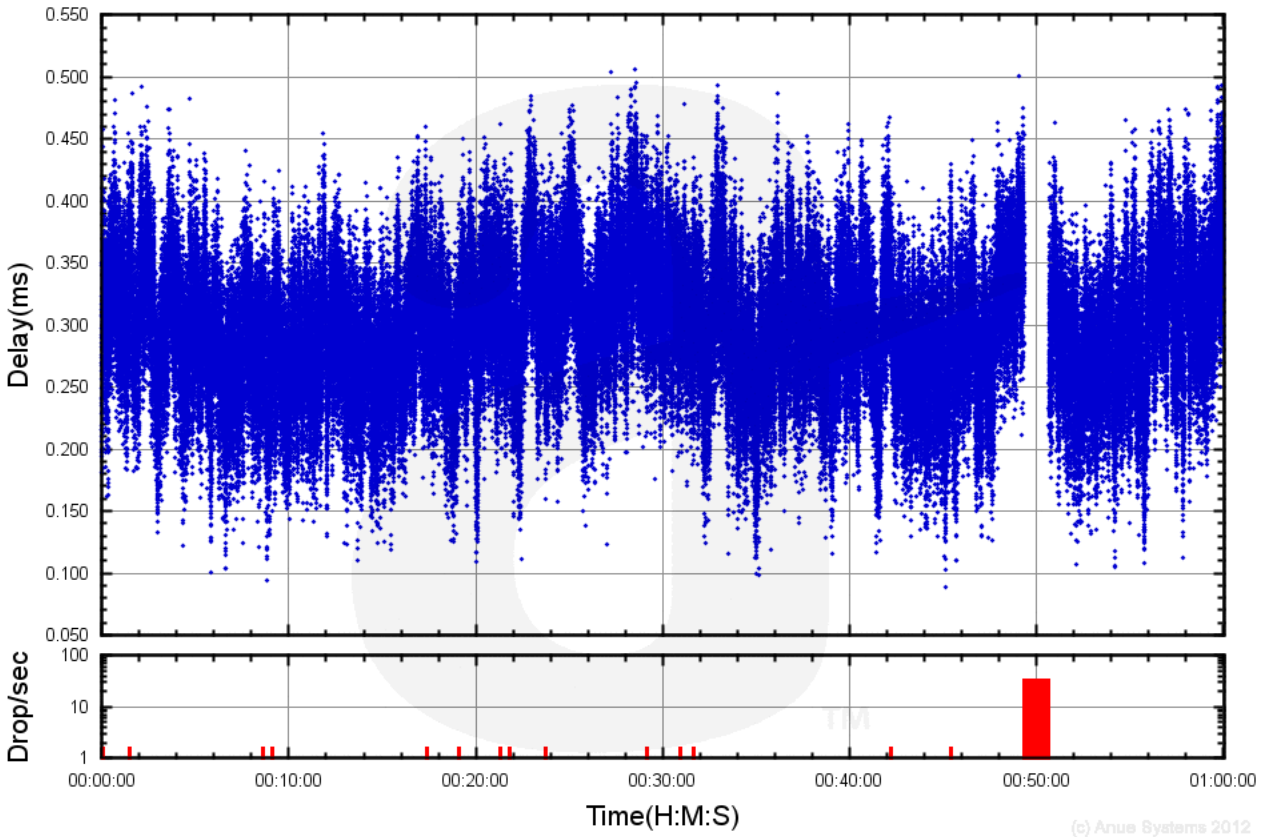
NOTE: This is a relative measurement
and doesn't depend on timing packet rate

Example Measurement

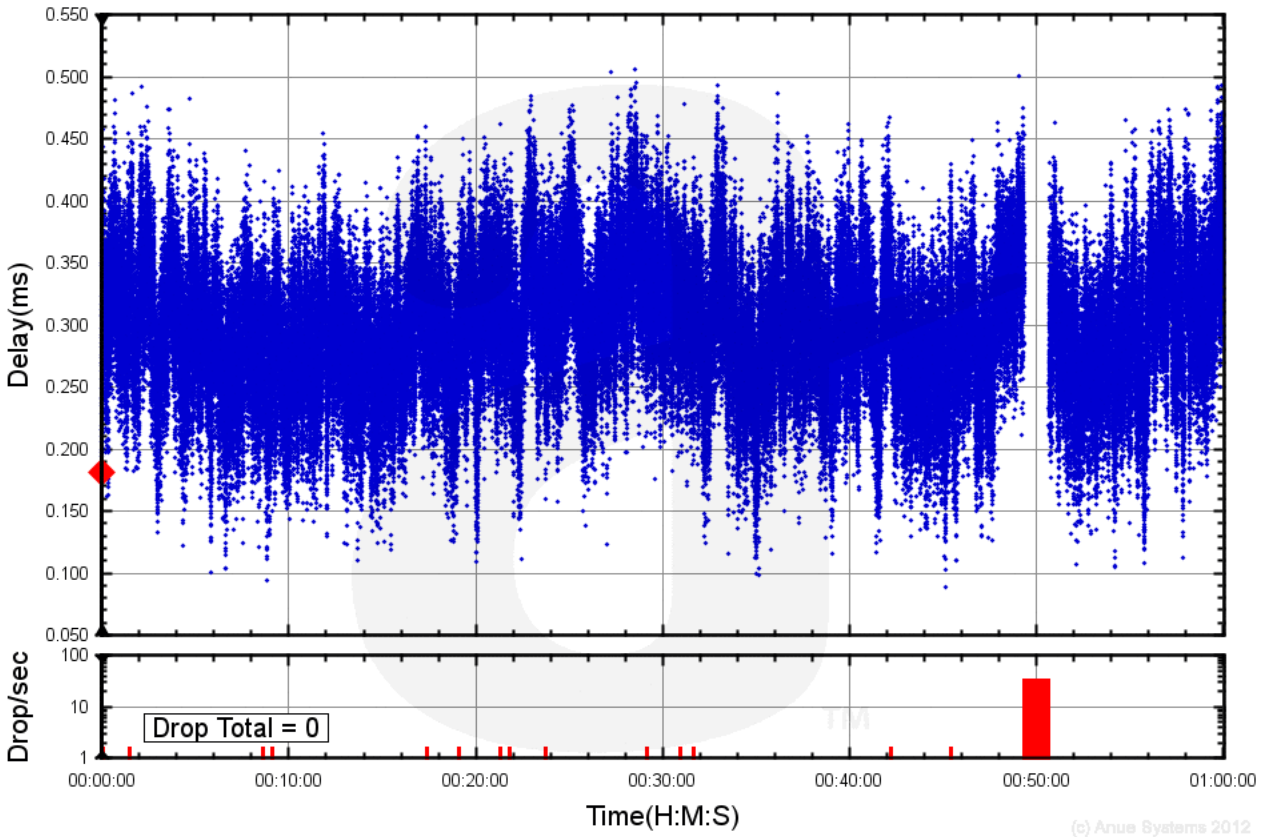
- Packet timing system operating at 32 packets per second
- Packet Delay Variation (PDV) based on flicker noise
- Low level of random packet loss (0.01%)
- Brief network outage (80 seconds)

- Steps for calculating FPC, FPP & FPR
  - Find minimum delay
  - Draw FPC graph, explain axes
  - Calculate with jumping window
  - Calculate with sliding window
  - Compare jumping and sliding

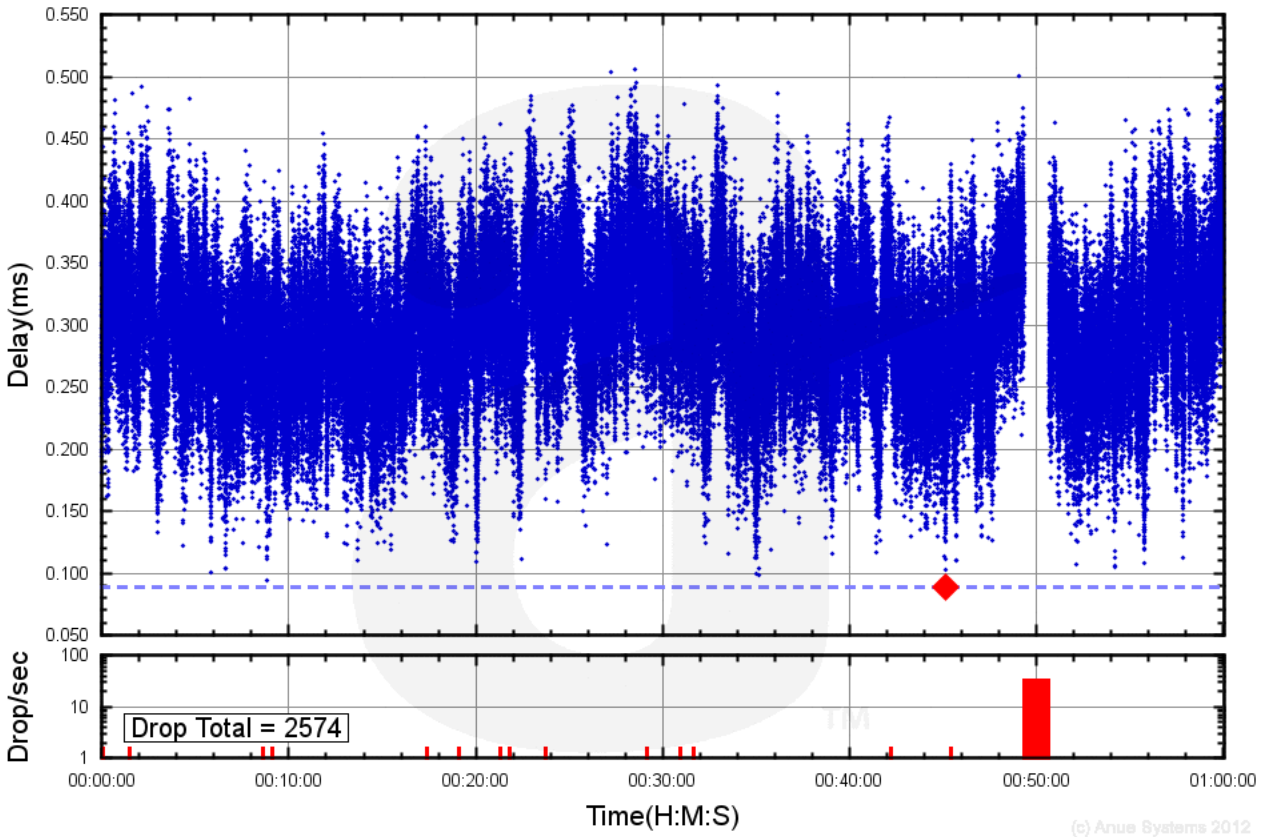
Example PDV with 0.01% Loss (@32 pkt/sec)



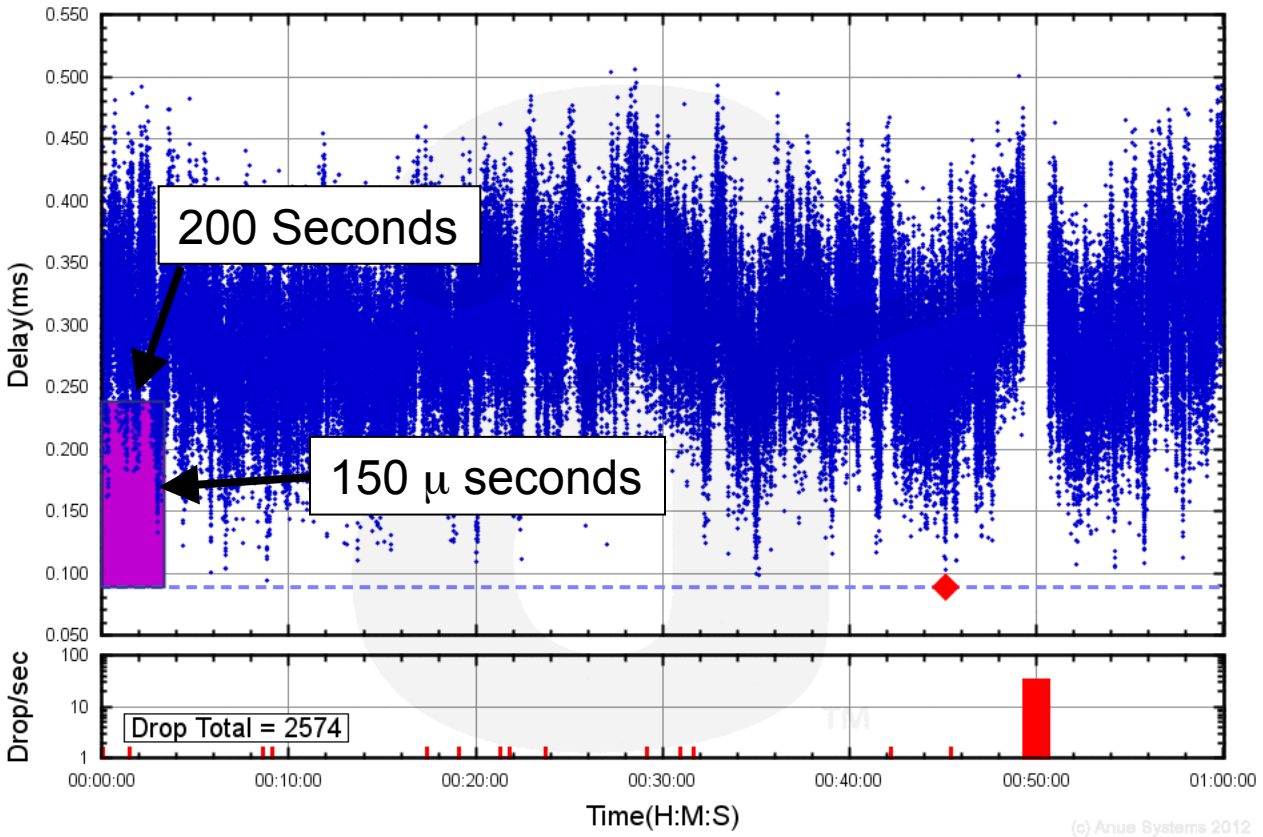
Search for minimum delay value



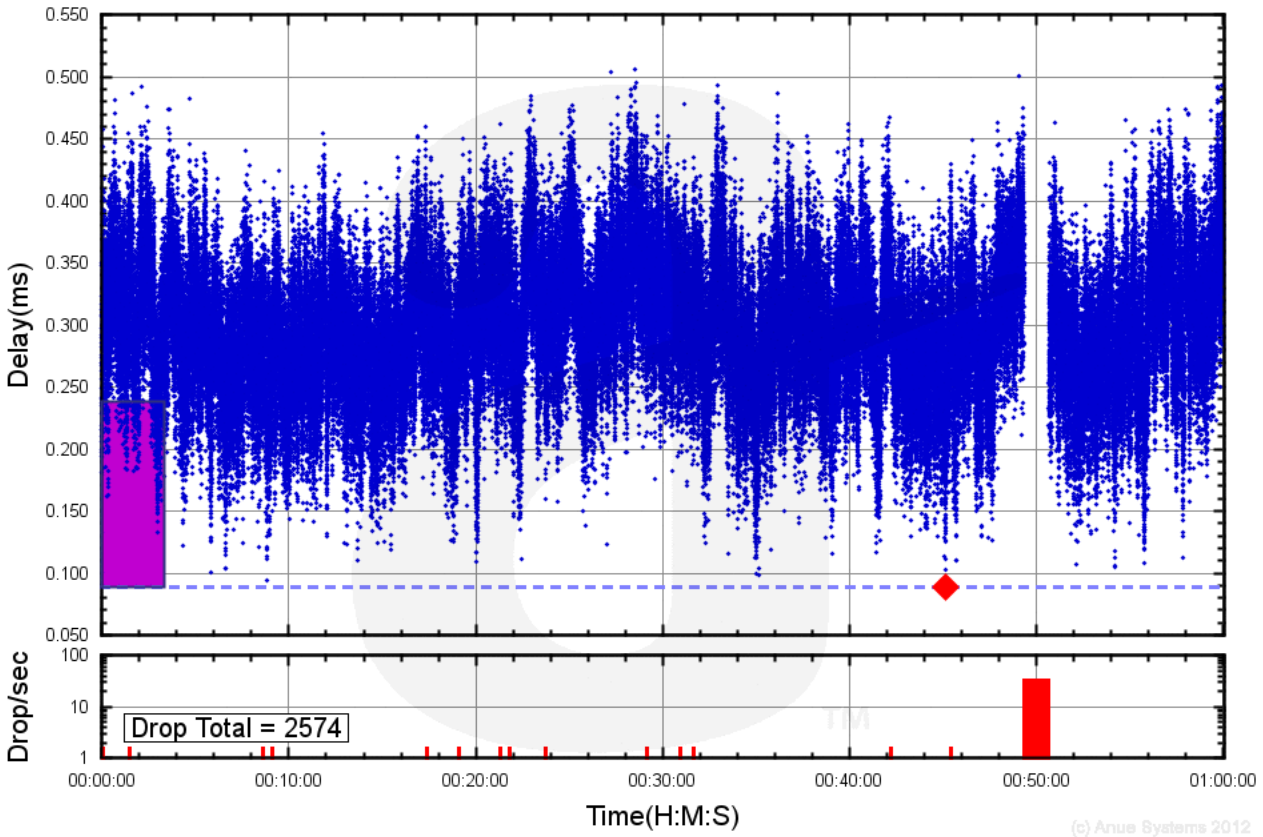
Draw horizontal line for minimum delay



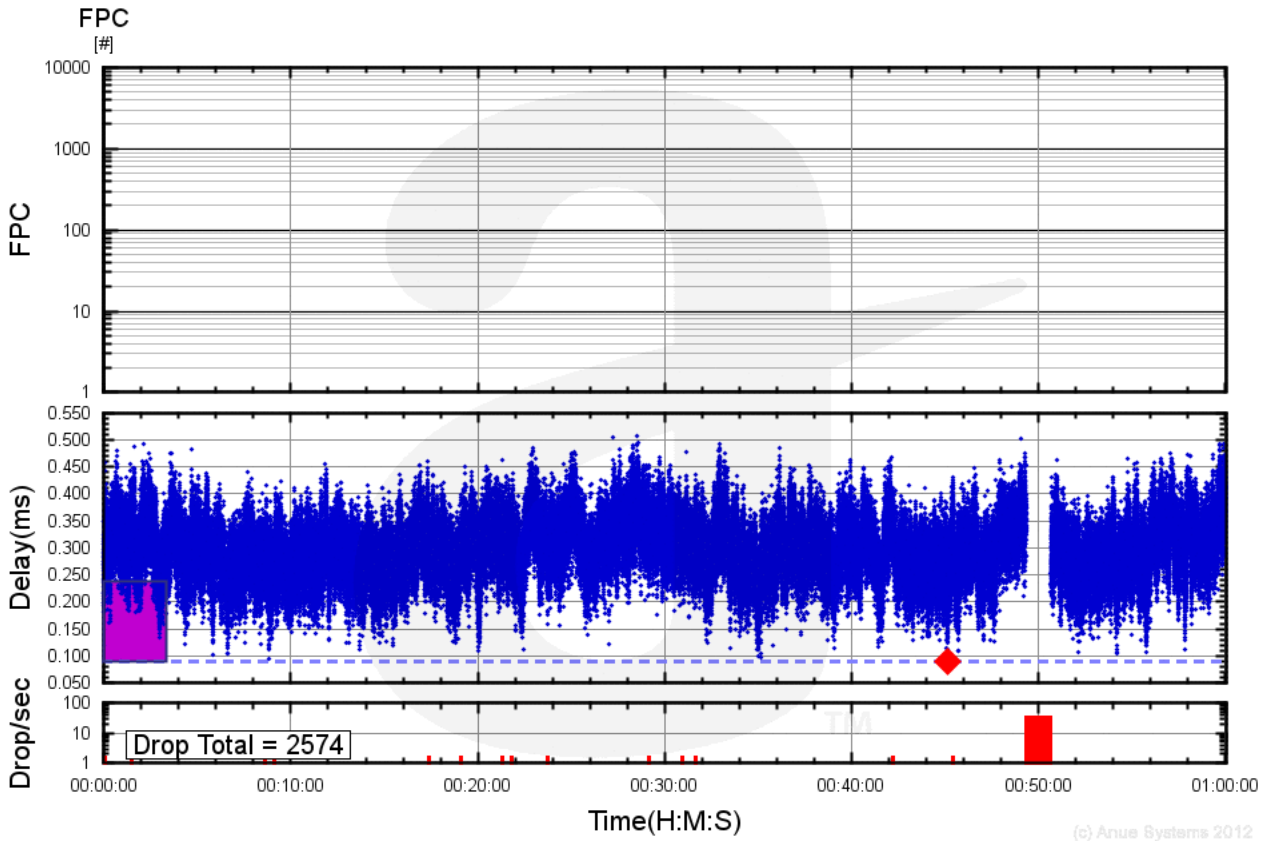
Draw the Floor Window



Add the FPC graph

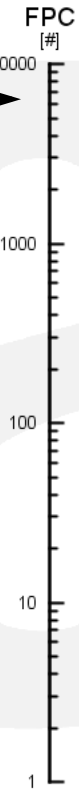


Look at just the FPC Axis



Look at just the FPC Axis

Largest possible value is 6400 pkt.
*(32pkt/sec * 200 sec)*

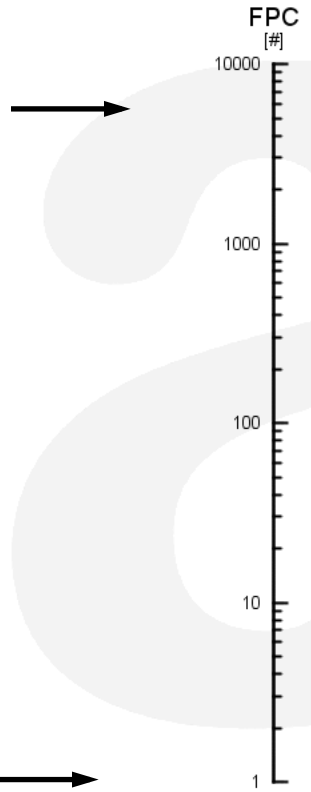


Axis has logarithmic scale

Smallest countable value is one packet

Compare FPC to FPP

Largest possible value is 6400 pkt. *(32pkt/sec * 200 sec)*



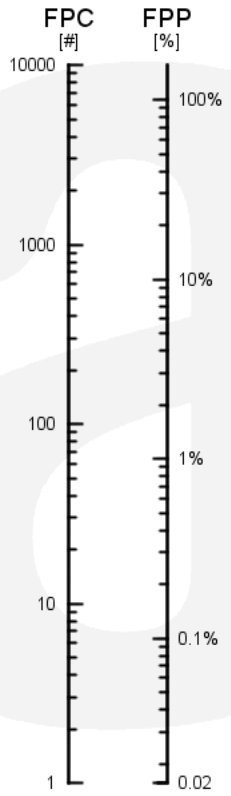
6400 pkt is 100%

64 pkt is 1%

Smallest countable value is one packet

Compare FPC and FPP to FPR

Largest possible value is 6400 pkt.
*(32pkt/sec * 200 sec)*

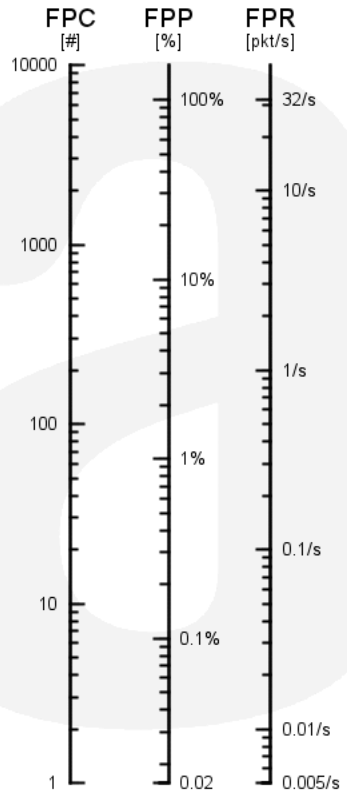


32 pkt/sec is max
(same as 100% FPP)

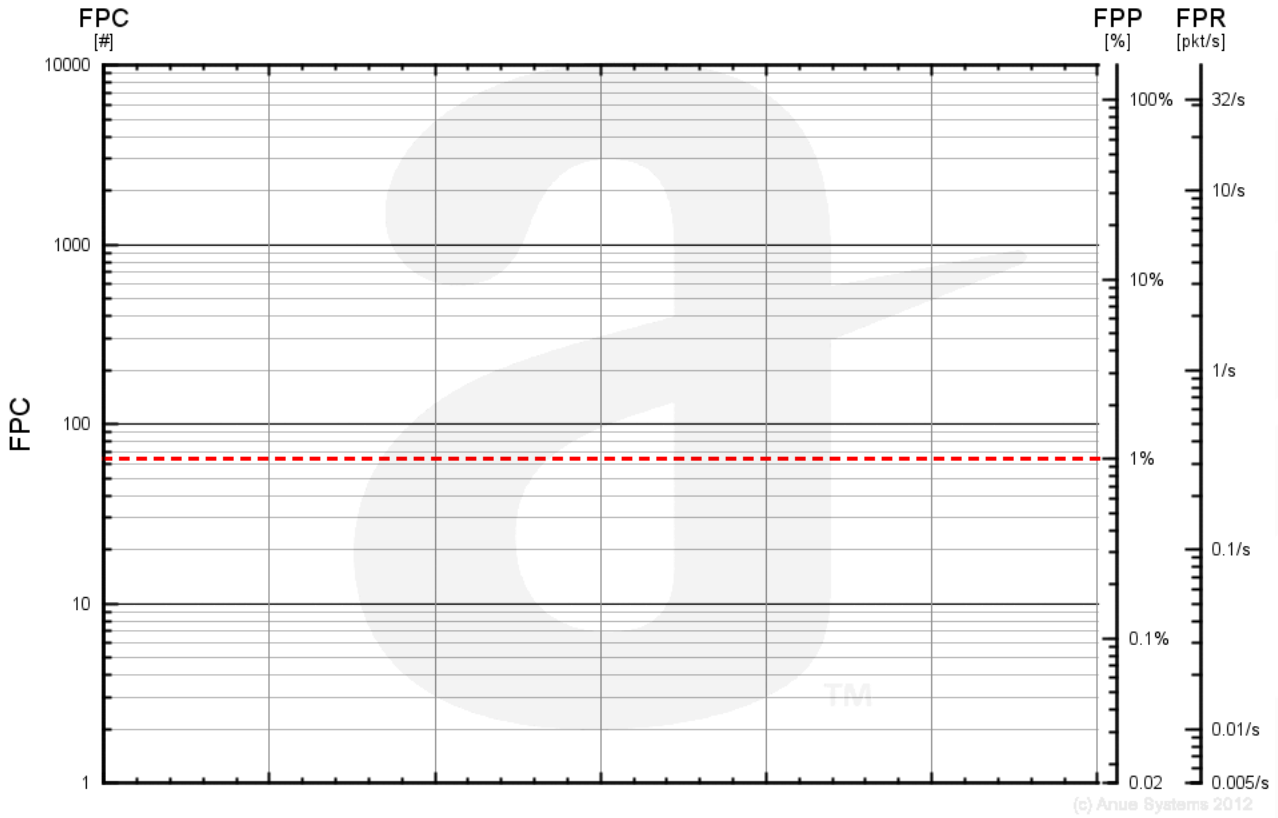
1% is 0.32pkt/sec
and is 64 pkt

Smallest countable value is one packet

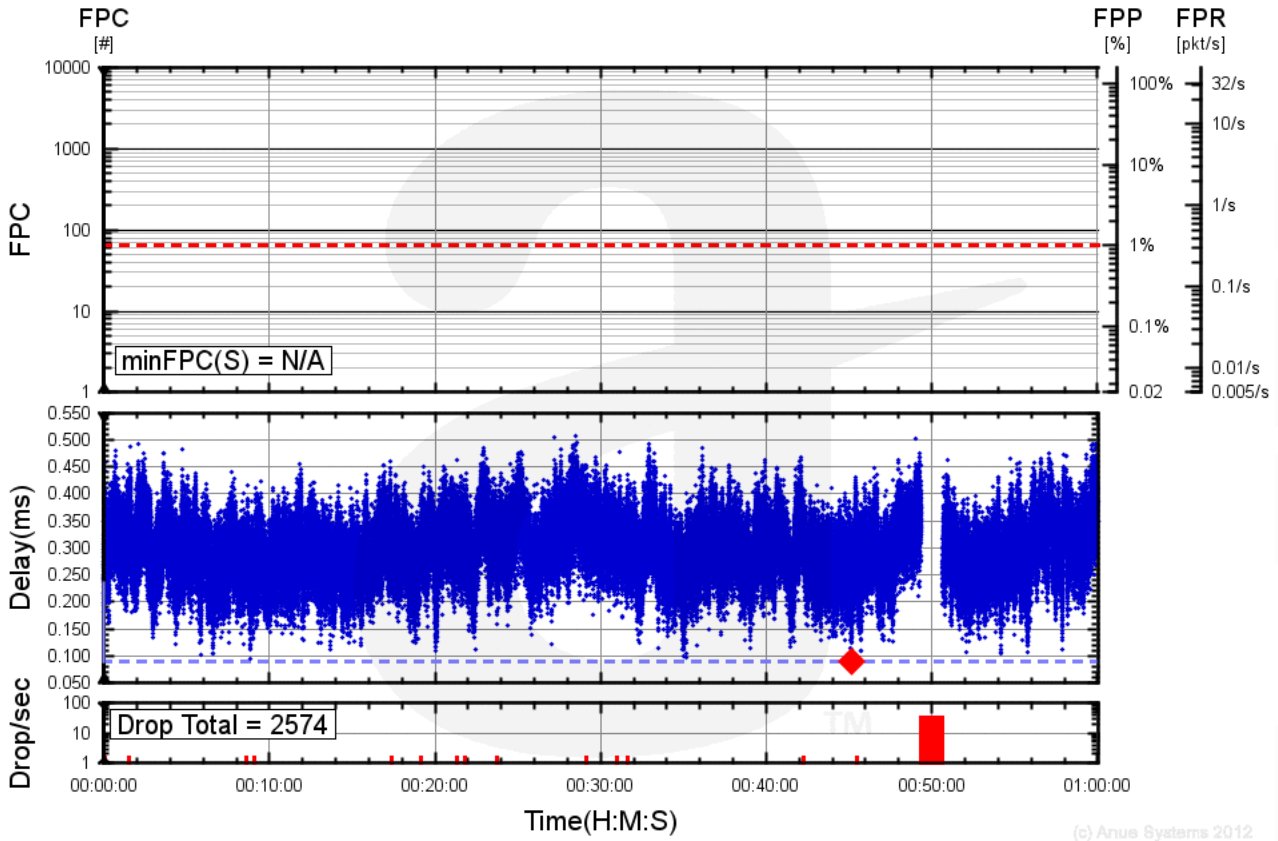
Draw the 1% FPP Limit Line



Draw the 1% FPP Limit Line



Calculate with Sliding Window



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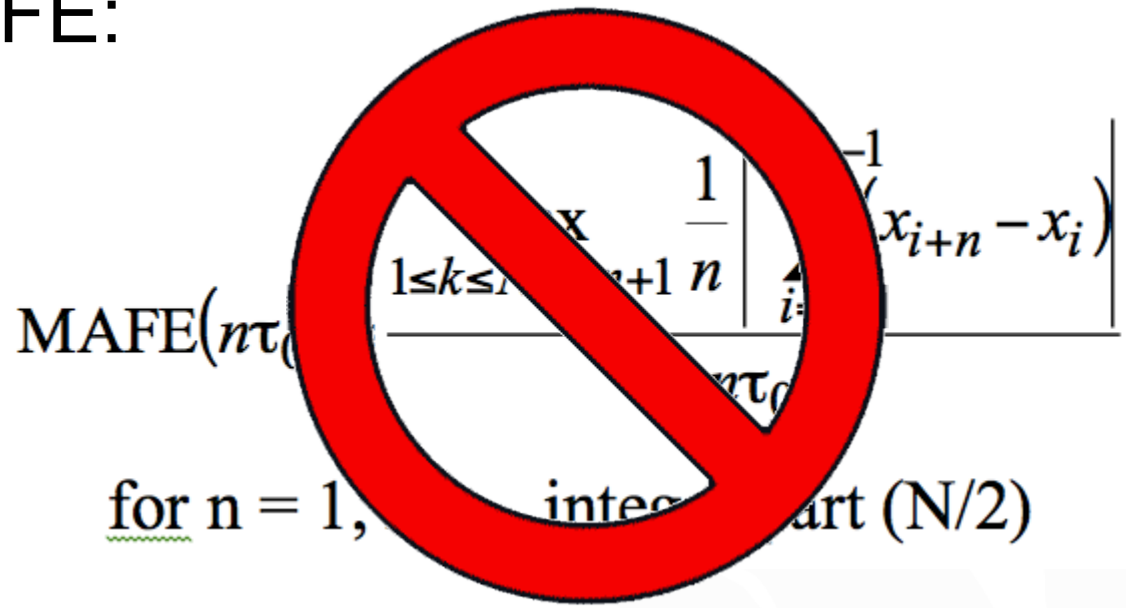
MAFE (in words)

- MAFE measures:
  - Peak frequency error implied by lucky packets
  - Helps estimate packet slave performance
- Helps answer questions like:
  - With a 1 hour averaging period, what is the worst-case frequency offset that will be seen?
- Closely related to MATIE
  - Max. Abs. Time Interval Error

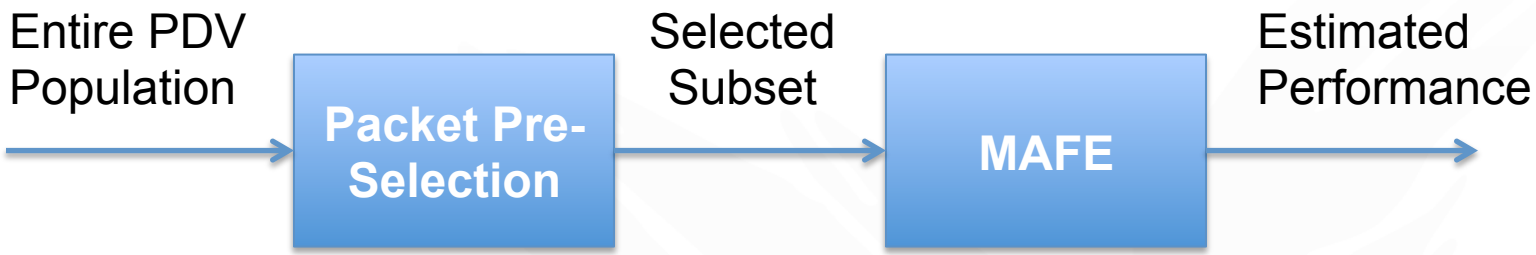
MAFE (in equations)

- MAFE:

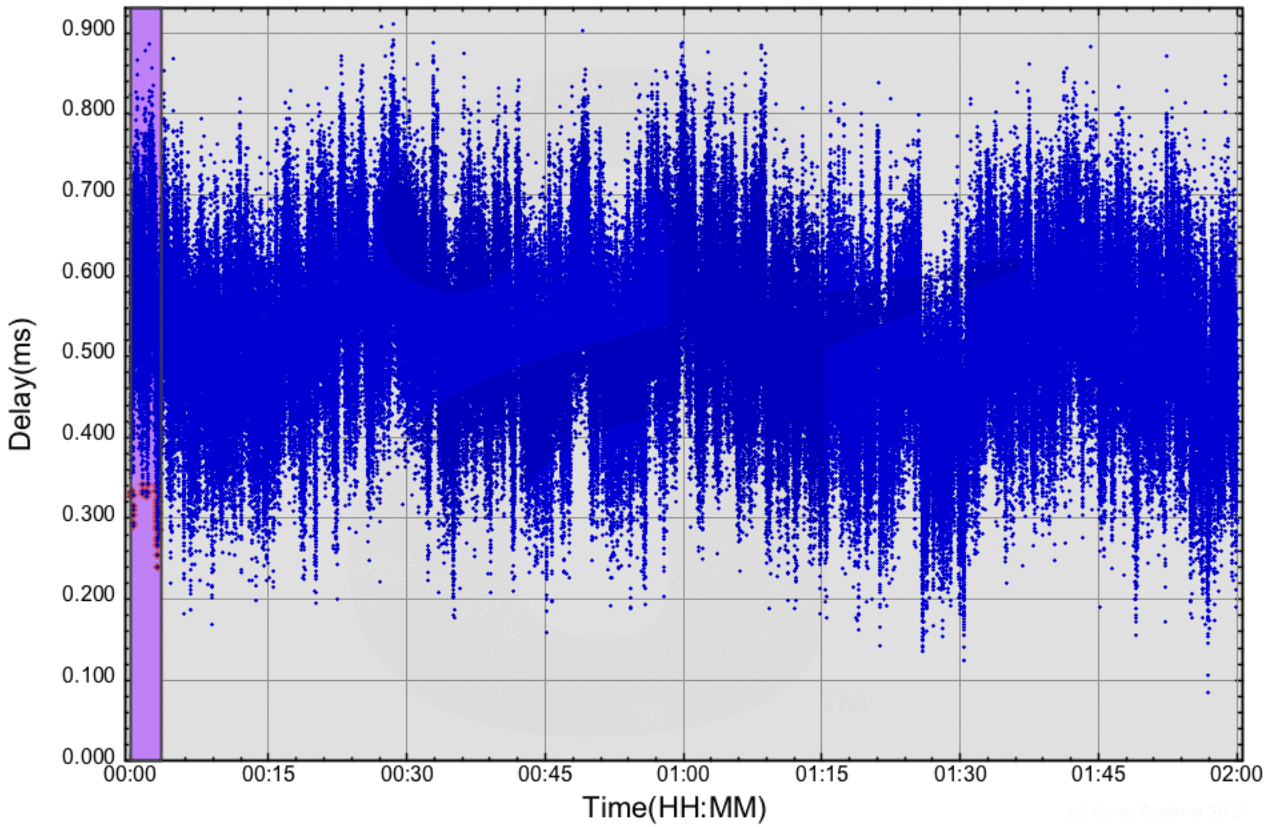


(Note: this is the MAFE estimator formula from G.8260, eq. I-21)

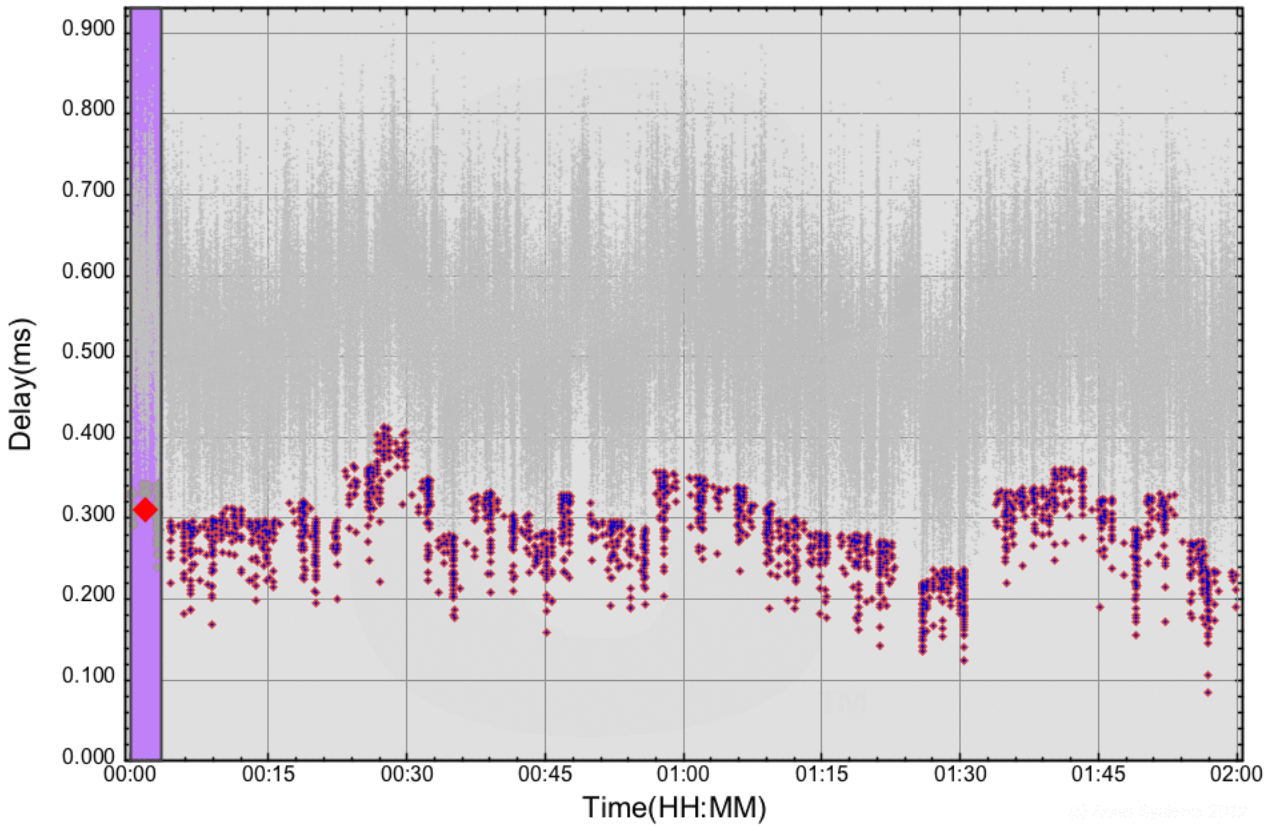
MAFE Overview



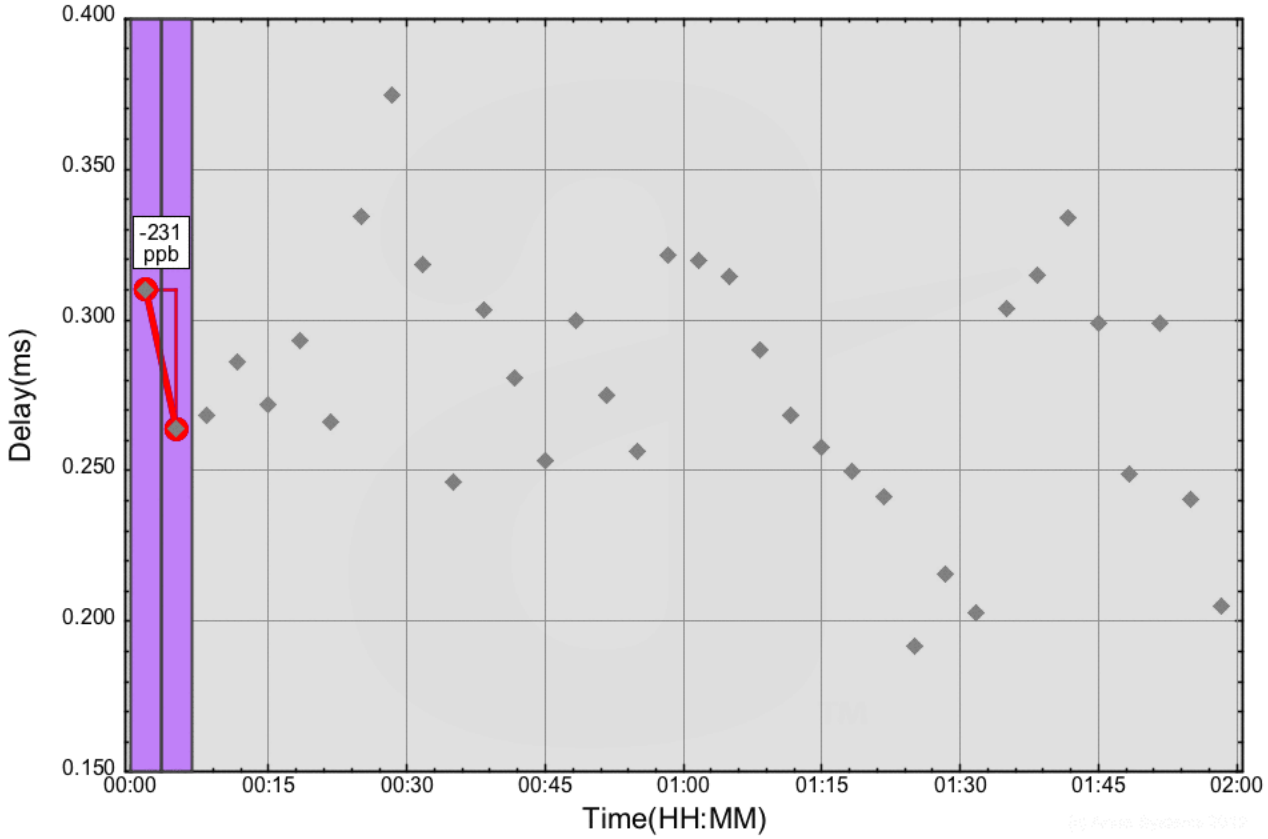
Packet Pre-Selection



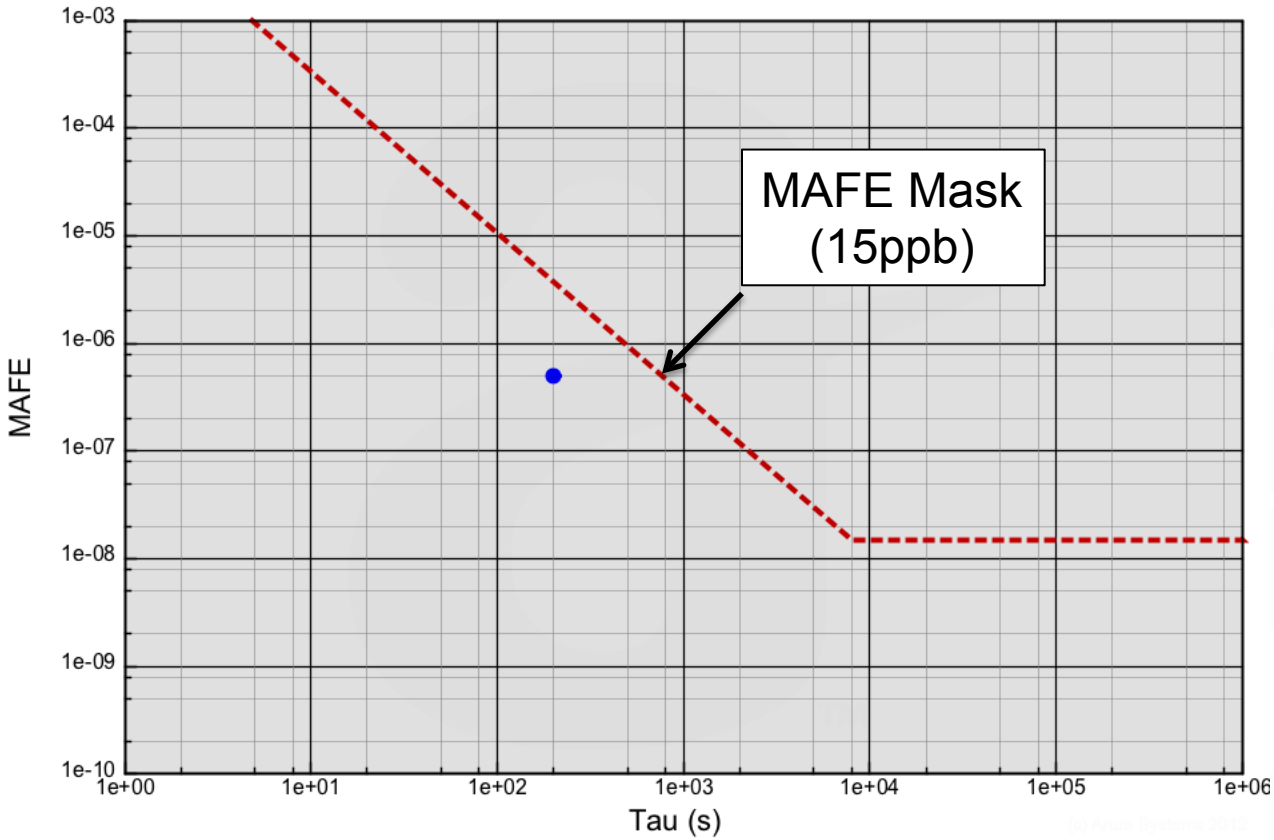
Packet Pre-Selection



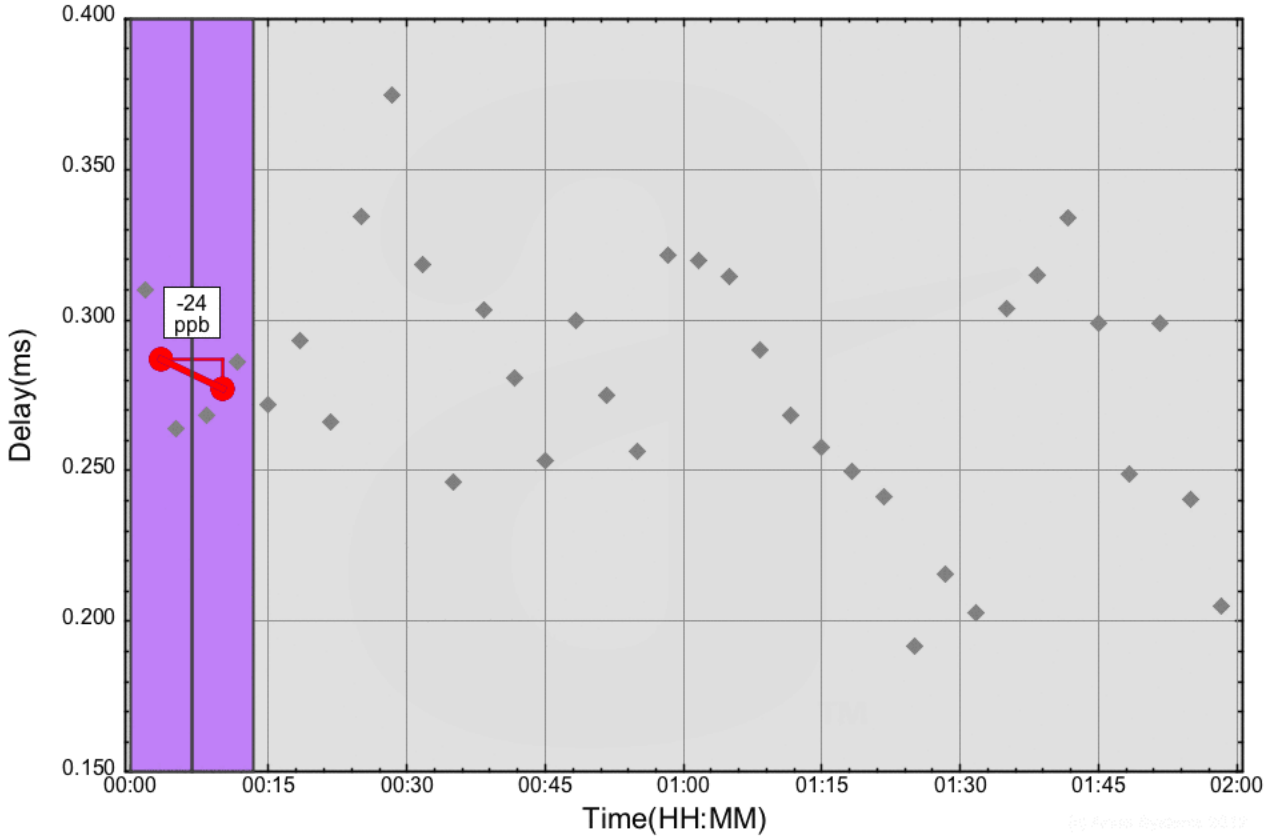
MAFE Computation (Tau=200s)



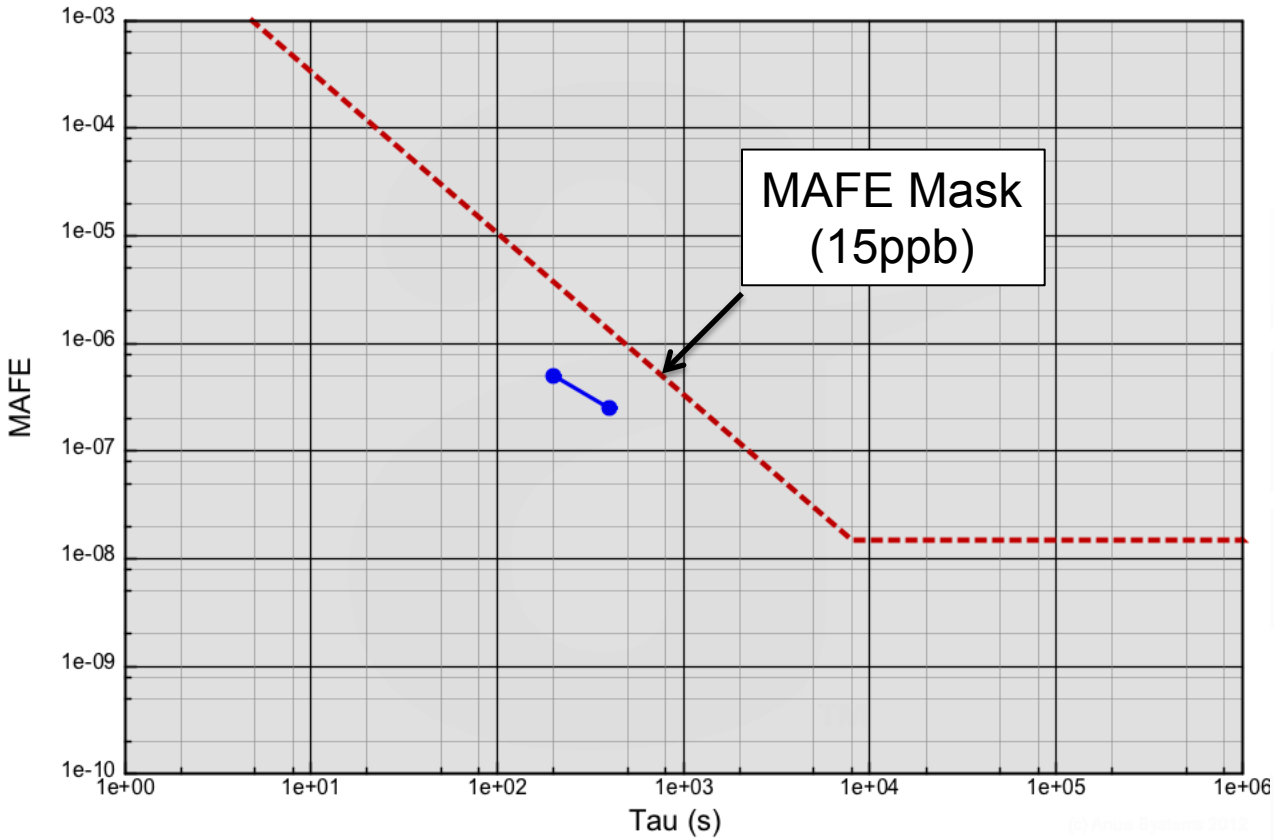
MAFE Plot


MAFE Mask
(15ppb)
MAFE
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06
Tau (s)

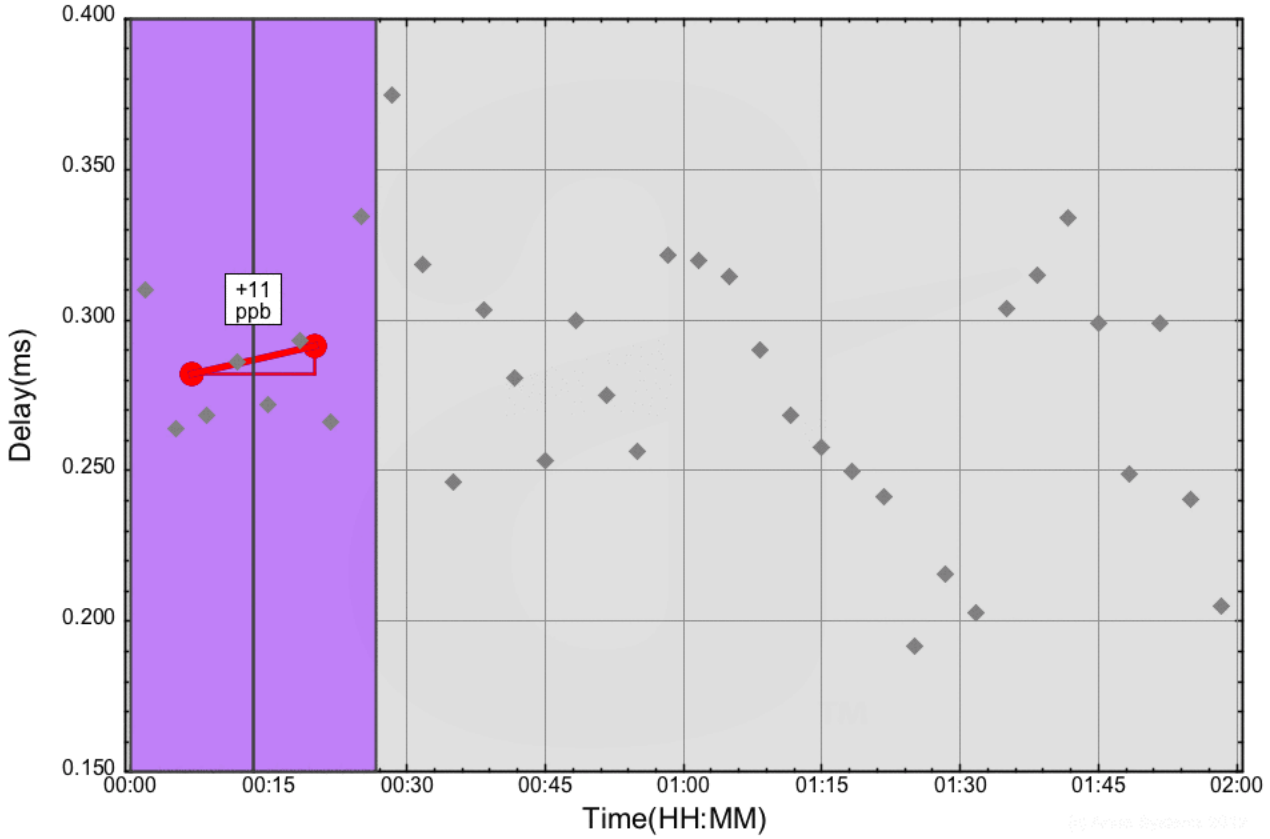
MAFE Computation (Tau=400s)



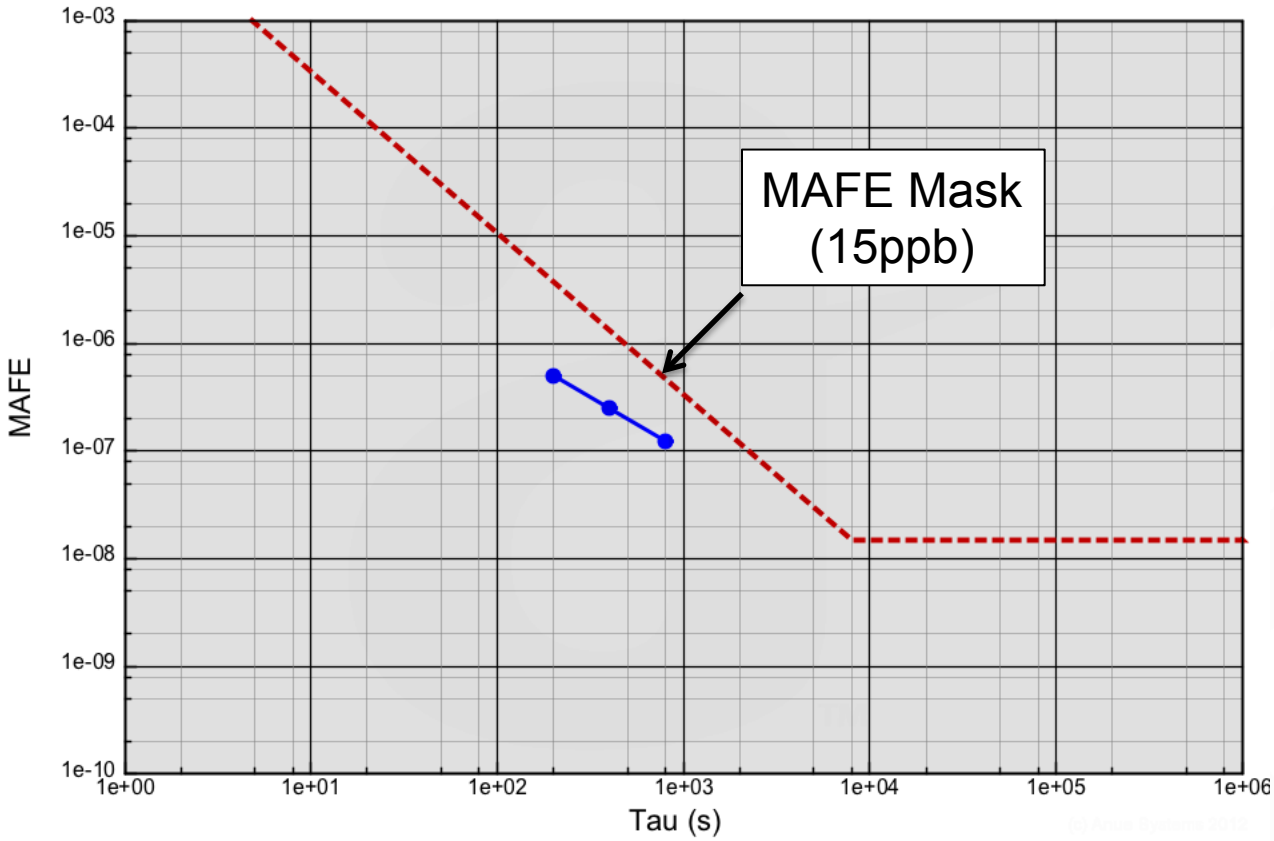
MAFE Plot


MAFE Mask
(15ppb)
MAFE
Tau (s)
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06

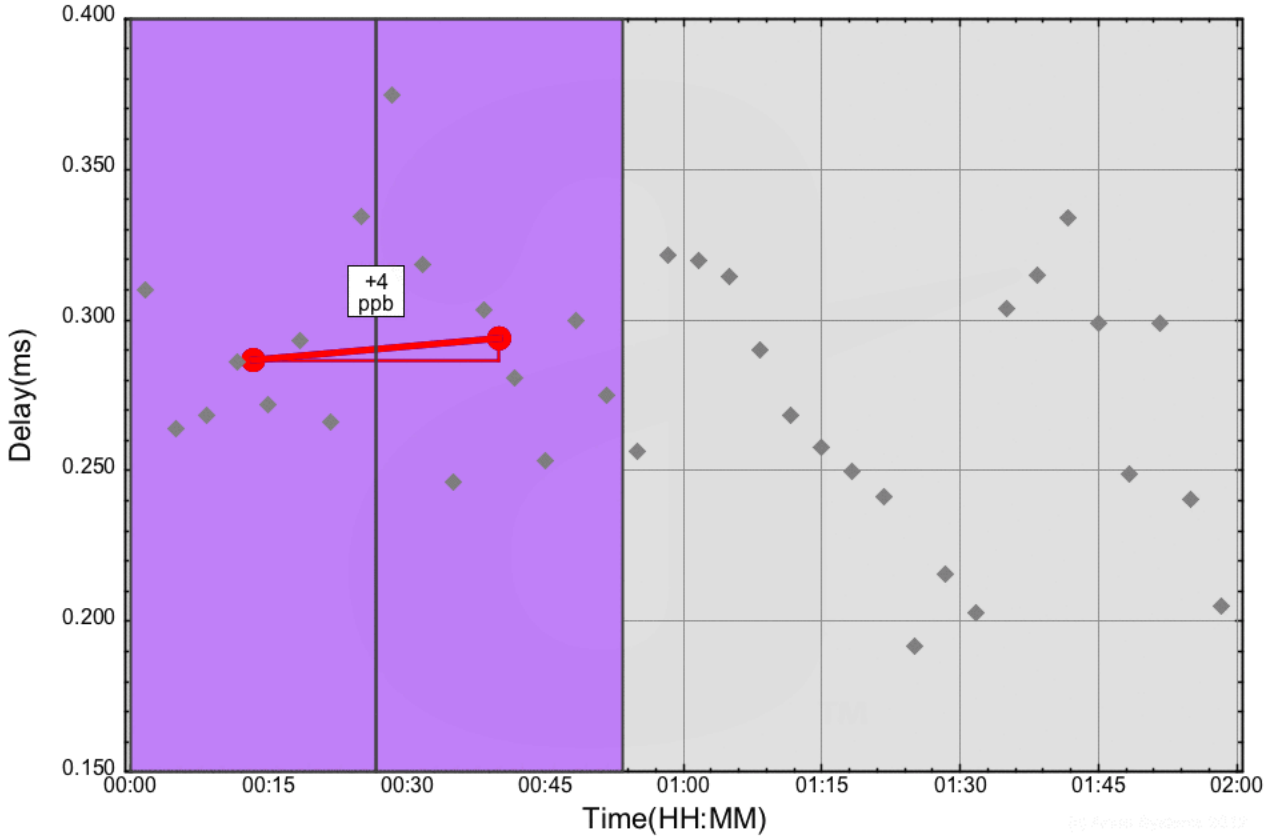
MAFE Computation (Tau=800s)



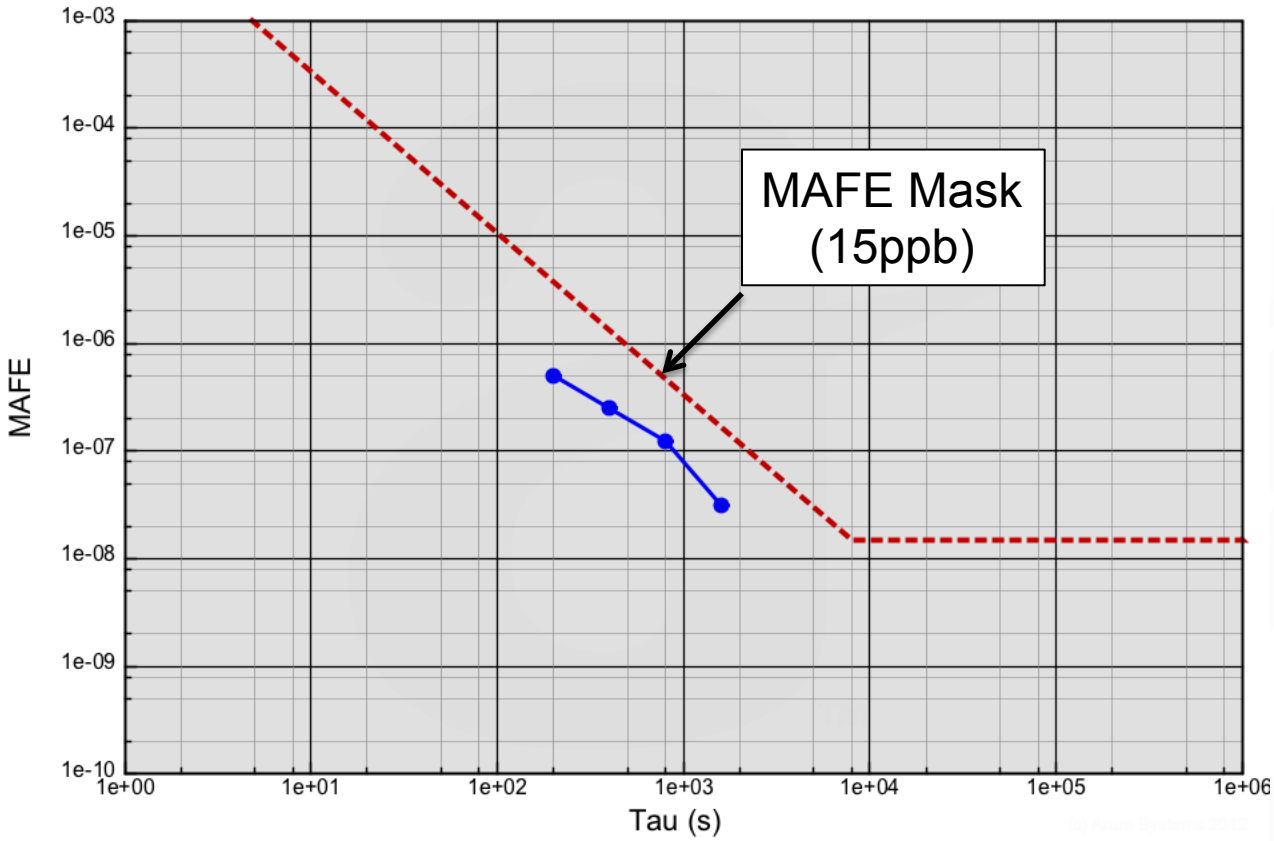
MAFE Plot


MAFE Mask
(15ppb)
MAFE
Tau (s)
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06

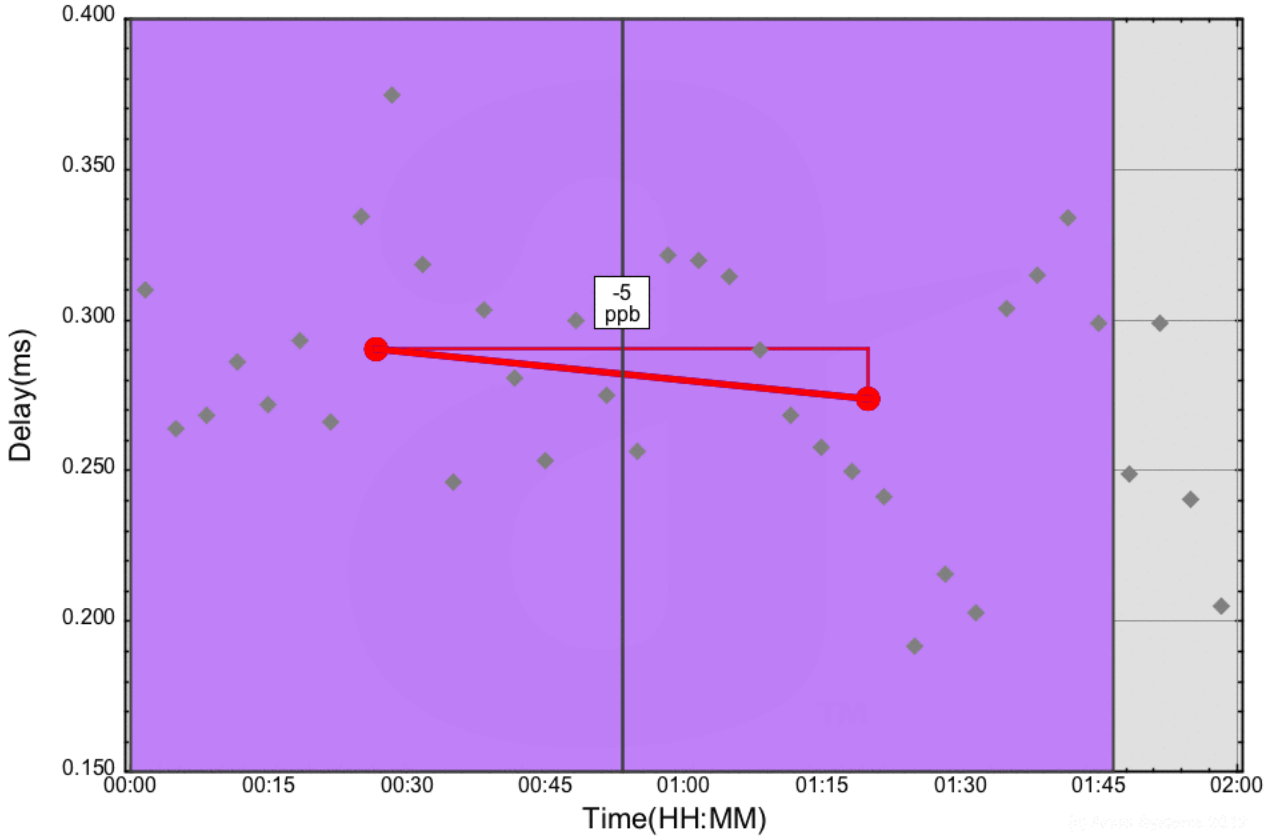
MAFE Computation (Tau=1600s)



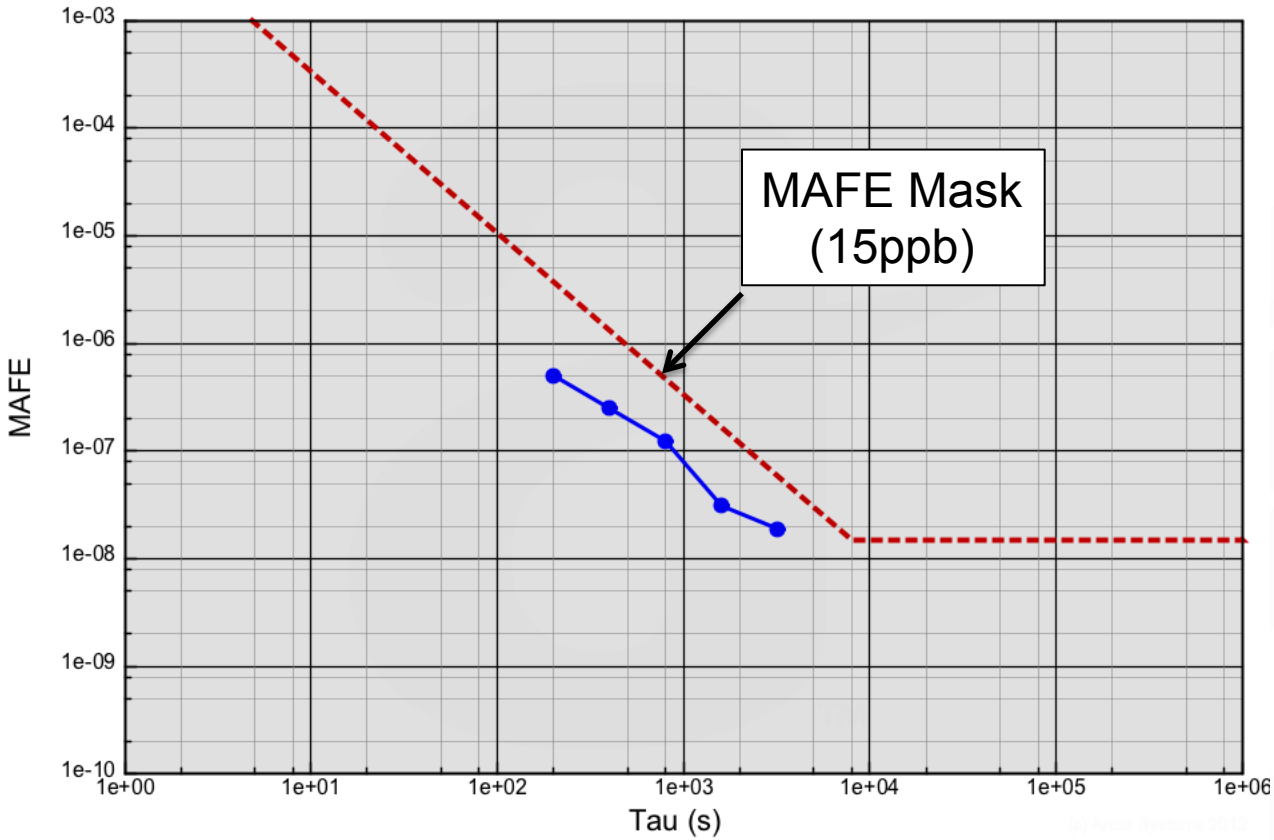
MAFE Plot


MAFE Mask
(15ppb)
MAFE
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06
Tau (s)

MAFE Computation (Tau=3200s)



MAFE Plot


MAFE Mask
(15ppb)
MAFE
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
1e-09
1e-10
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
1e+06
Tau (s)

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Floor Population Metrics: In a nutshell

MAFE: In a nutshell

Thank You! Questions?

About the Presenter

About Ixia

Ixia provides the industry's most comprehensive converged IP network validation and network visibility solutions.
Equipment manufacturers, service providers, enterprises, and government agencies use Ixia's solutions to design, verify, and monitor a broad range of wired, Wi-Fi, and 3G/LTE equipment and networks. Ixia's test solutions emulate realistic media-rich traffic and network conditions so that customers can optimize and validate the design, performance, and security of their pre-deployment networks. Ixia's intelligent network visibility platforms provide clarity into physical and virtual production networks for improved performance, security, resiliency, and application delivery of cloud, data center, andservice provider networks.

For more information, visit www.ixiacom.com.

About Chip

Chip is VP, Technology at Ixia, after its acquisition of Anue Systems, where he was co-founder and CTO. He has 20+ years of experience in the design of high-speed networking products. Prior to founding Anue Systems, Chip was a Distinguished Member of Technical Staff at Bell Laboratories. Chip received a Master's degree in Electrical Engineering from Columbia University, and a Bachelor's degree, with honors, from RPI. He has been awarded 14+ patents.

BACKUP SLIDES

Formal Mathematical Definition

- $x[i]$ is the measured latency of timing packet i,
  - $0 \leq i < N$. (i.e. there are N packets in the data set
- τ_P is the nominal time between timing packets
- δ is the cluster range (vertical window height)
- W represent the window interval (horizontal window width)
  - It can also be expressed as K samples, $K = W/\tau_P$.

Note: It is assumed that the packet rate of the timing flow is nominally constant. The case for a variable rate of packet transmission is for further study.

Mathematical Definition of the Metrics

- Step 1: Find the minimum delay packet

$$d_{\min} = \min_{0 \le i < N} x[i]$$

- Step 2: Calculate the indicator function

$$\phi_F(i,\delta) = \begin{cases} 1; & \text{if } x[i] \le d_{\min} + \delta \\ 0; & \text{otherwise} \end{cases} \qquad \text{for } 0 \le i < N$$

Mathematical Definition of the Metrics (cont.)

- Step 3: Count the packets in the window (FPC)

$$FPC(n,W,\delta) = \sum_{j=n-(K-1)}^{n} \phi_F(j,\delta)$$

- Step 4: Express this result as a packet rate (FPR)

$$FPR(n,W,\delta) = \frac{FPC(n,W,\delta)}{W}$$

- Step 5: Also express as a percentage (FPP):

$$FPP(n,W,\delta) = \left(\frac{\tau_P}{W}\right) \times FPC(n,W,\delta) \times 100\,\%$$

Absolute and Relative Metrics

- FPP is a relative metric
  - Calculation does not depend on packet rate
  - Relative means that the metric tells us what has changed between reference planes.
- FPC and FPR are absolute metrics
  - Calculation depends on the rate at which timing packets are sent

- Network performance is best measured as a relative limit
  - FPP compares the network output relative to its input
  - Since the network doesn't create the packets, can't be absolute
- Slave performance is best measured with an absolute limit
  - FPC or FPR
  - But G.8263 refers to G.8261.1 limit at a given packet rate (still absolute)

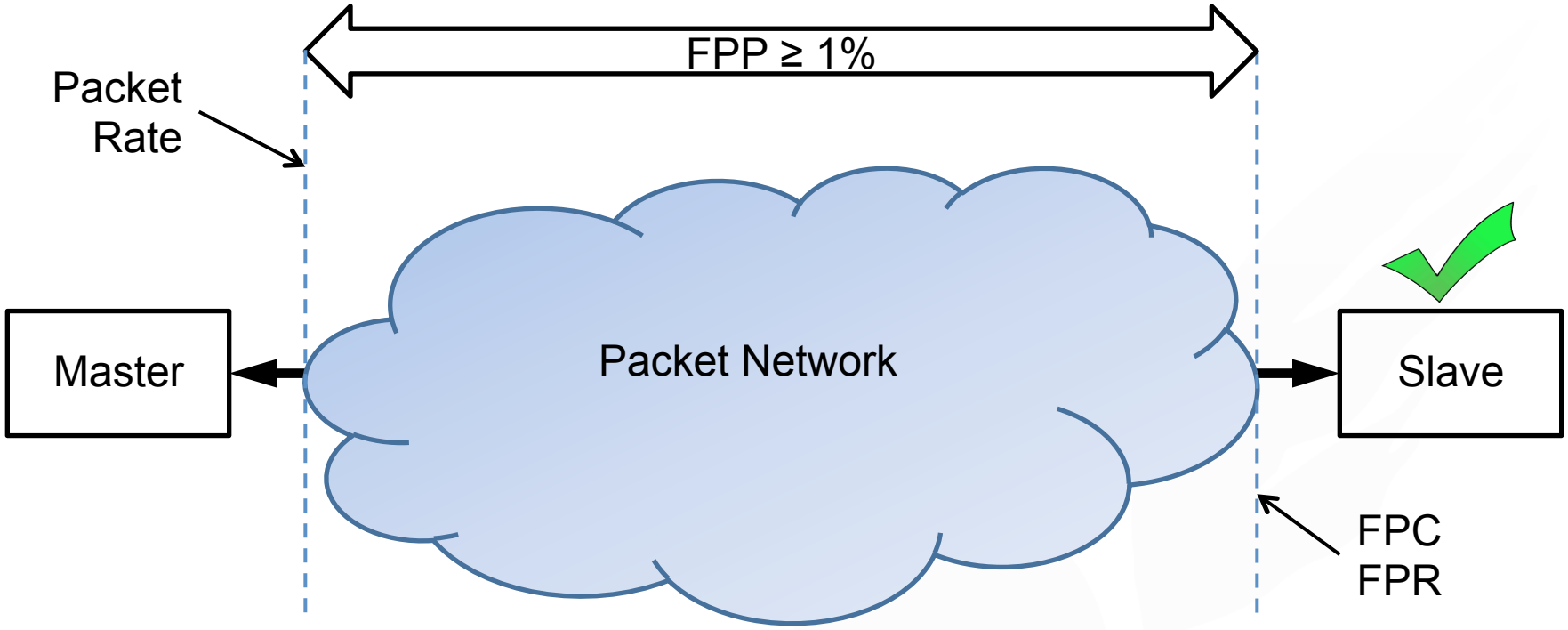
Slave PDV Tolerance (from G.8263)

The PEC-S-F must tolerate the noise at the limits specified in Recommendation G.8261.1, clause 8 (PDV network limits at point C).

[…]

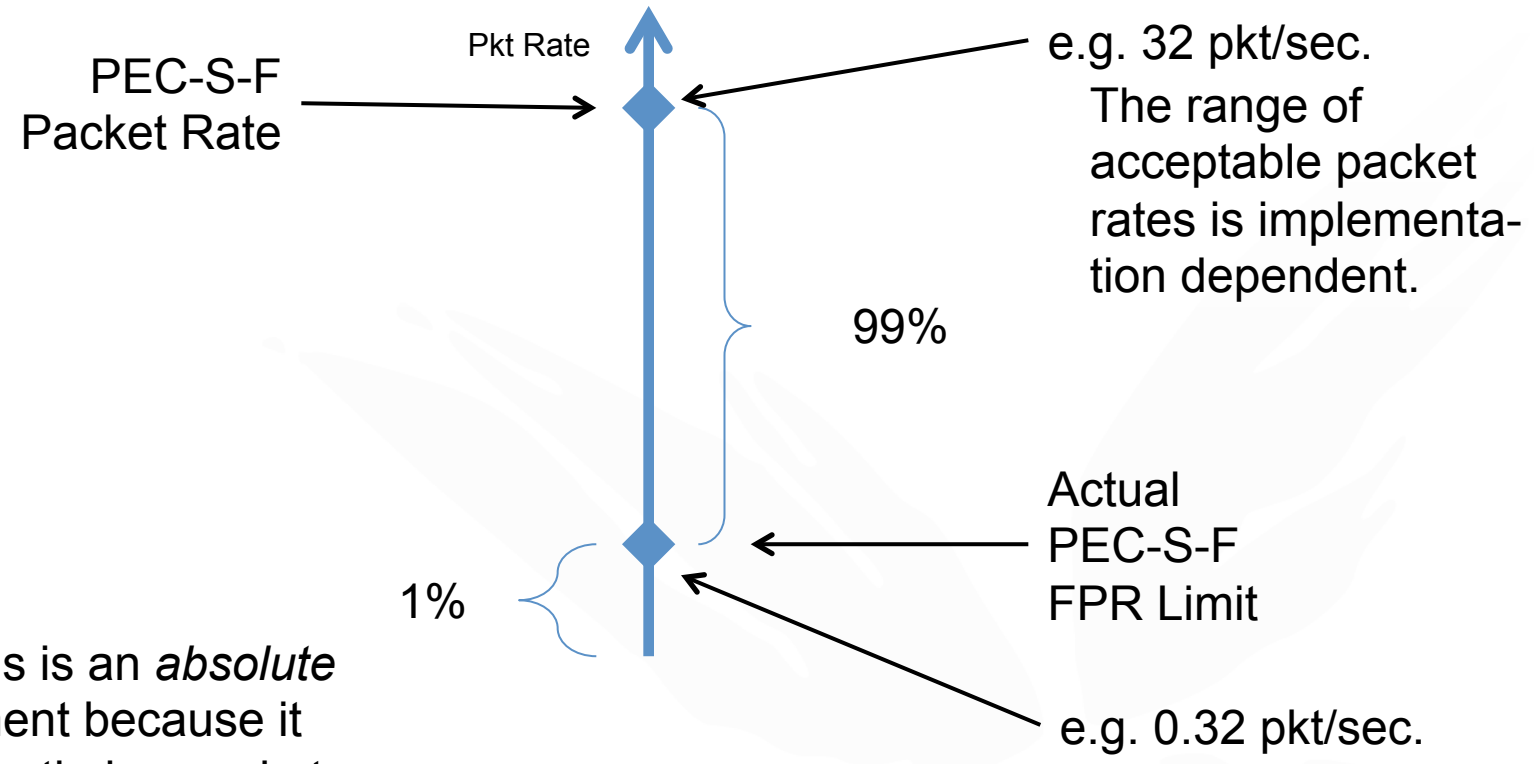
Note: ***For the particular packet rate used by an actual PEC-S-F implementation***, within the range specified in Recommendation G.8265.1, the PEC-S-F clock must therefore tolerate the PDV generated by the network as specified in G.8261.1. More specifically, for the HRM-1 of G.8261.1, the PEC-S-F must meet the output performance specification for its particular packet rate when only 1% of the timing packets sent by the packet master remain in the 150µs fixed cluster range starting at the floor delay in every observation window of 200s.

Slave PDV Tolerance



NOTE: This is an absolute measurement
that depends on timing packet rate

Slave PDV Tolerance Limit is absolute



NOTE: This is an *absolute* measurement because it depends on timing packet rate.

NOTE: But it allows different PEC-S-F implementations to have different limits.