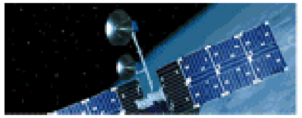


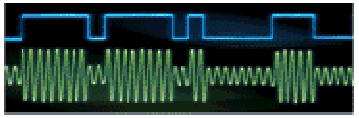


Deployment Considerations for IEEE1588 in Telecommunication Networks

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ITSF 2007

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- Establishing a Synchronization Budget
- Quantifying Packet Network Behaviour
- Deployment Guidelines
  - Engineering Aspects
  - Operational Aspects
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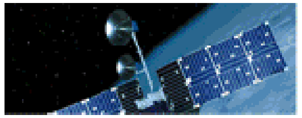
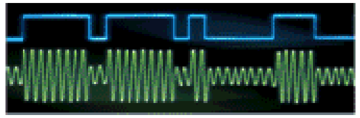
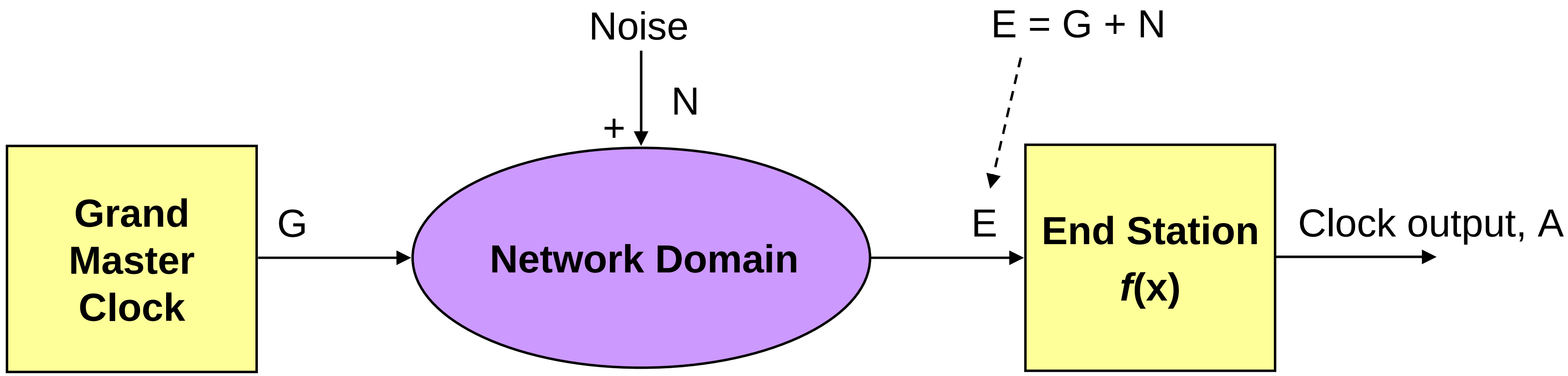



Synchronization Budgets

Network Domain Budget

- A metric or series of metrics on a “domain” that shows whether the synchronization (frequency or time) delivered by the network will meet the application requirements
- Determines the maximum noise budget of the network



Clock output must meet application requirement, A

Measure E to determine if network is delivering packets to the required specification in order to allow the end station to recover the application clock to the required quality level

Budget at E = upper bound on packet noise level = $f^{-1}(A)$
If E < budget metric, then clock output will meet service requirement, A

Noise Budget Calculation

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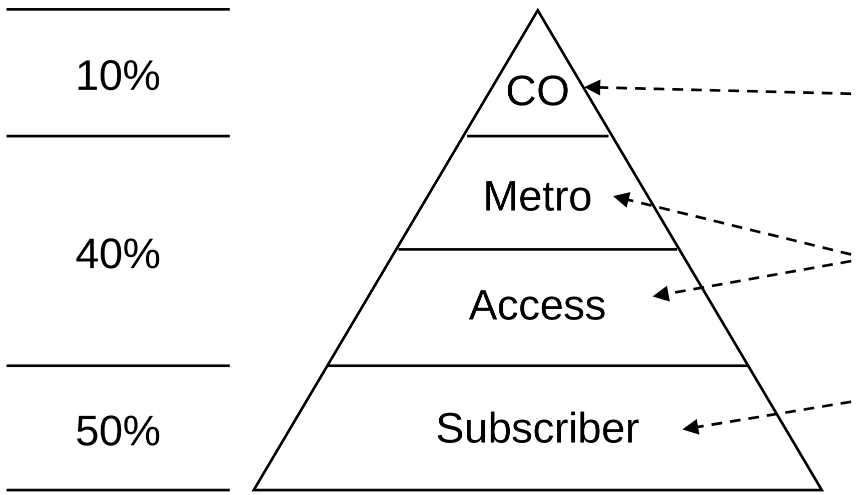
- Packet timing is statistical, so need to first derate the application requirement by at least 3-sigma
  - e.g. MTIE for CES is 4.5µs => target requirement of 1.5µs
- Then use a pyramid structure to calculate noise budget for a given network domain:

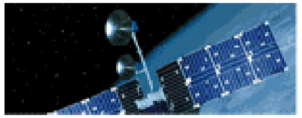


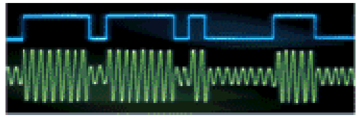
CO is constrained to minimal allocation consistent with established cost effective performance levels

Metro / Access given maximum sensible allocation to support real-world edge networks

Majority of budget is reserved for subscriber domain to permit low cost design

Example: *Budget for CES application over Metro/Access domains*
= 40% of 1.5µs
= 0.6µs





Quantifying Packet Network Behaviour

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PDV and Mean Packet Delay

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- PDV and Mean Delay metrics are too abstract to predict timing performance
- PDV doesn't describe:
  - distribution of delays
  - correlation of delays between adjacent packets
- PDV and Mean Delay may vary with time
- Without a time reference at each end, they can't be measured

Empirical Behaviour

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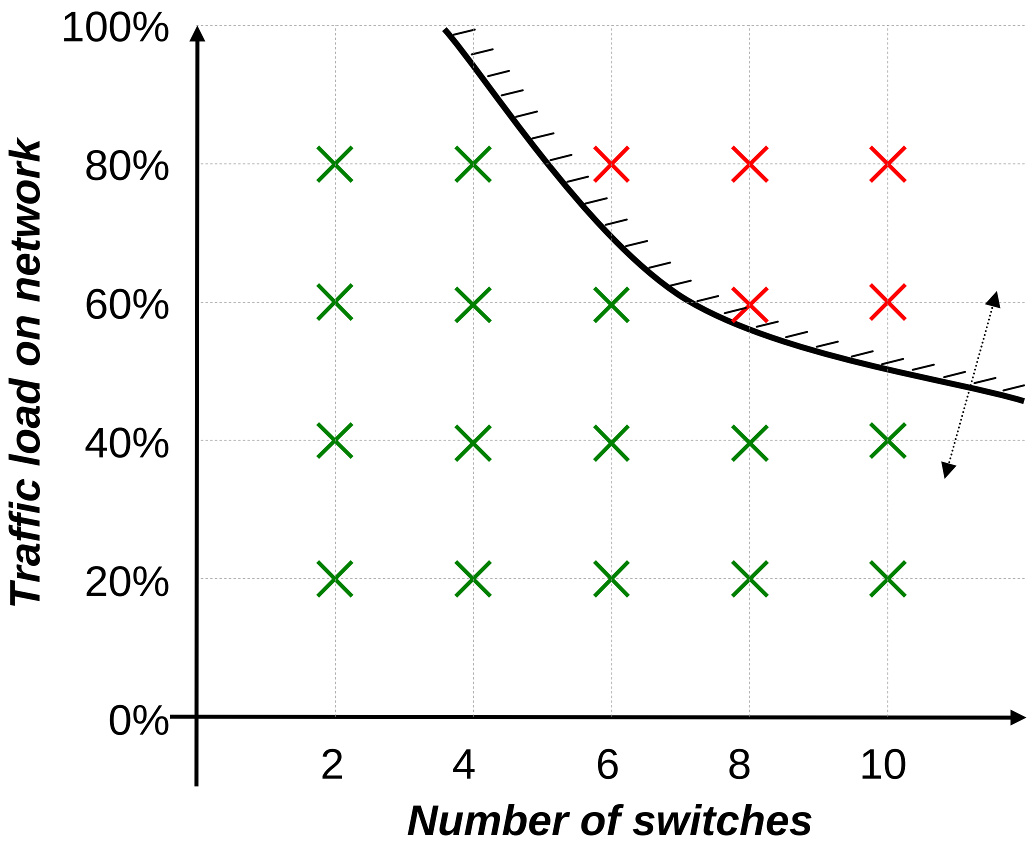

clock stability compliant with application

clock stability non-compliant with application

Limit of operational area

Varies with:

- *Application requirements*
- *Type of switches*
- *Traffic loading patterns*
- *Client performance*
- *Local oscillator stability, e.g. TCXO or OCXO*

Packet Network Characterization

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- PDV metric and Mean Delay figures are too abstract to be useful for predicting timing performance
  - No indication of distribution or correlation of delays
- Characterization by load and number of hops is better, but:
  - Still need to know distribution and correlation of load flows
  - Different switches have varying delays and behavior under load
- Need a metric that is:
  - Independent of the number or type of switches
  - Independent of loading patterns in the network
  - Dependent on the network characteristics used by the clock servo algorithms
  - Able to predict clock servo performance

Packet Network Properties

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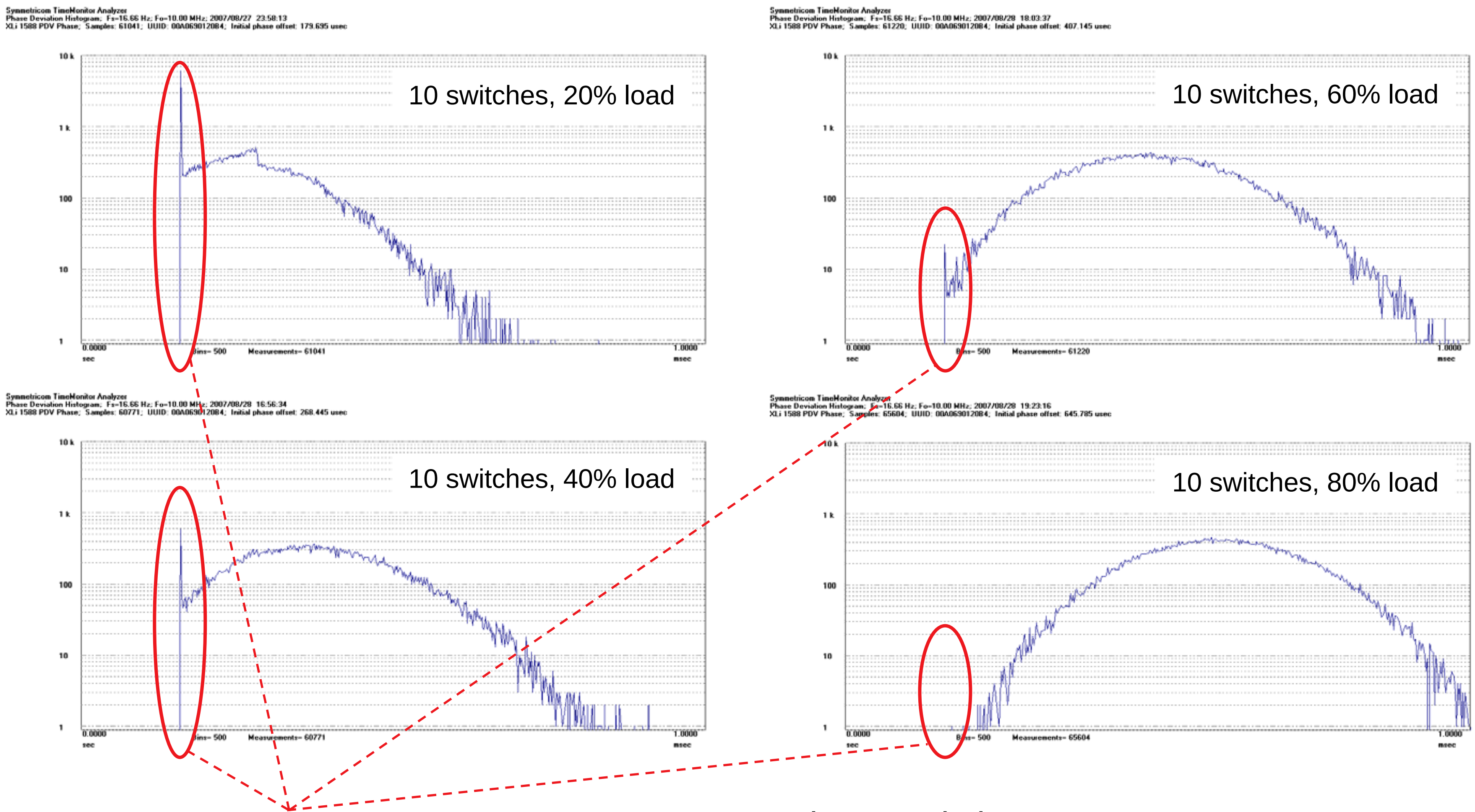
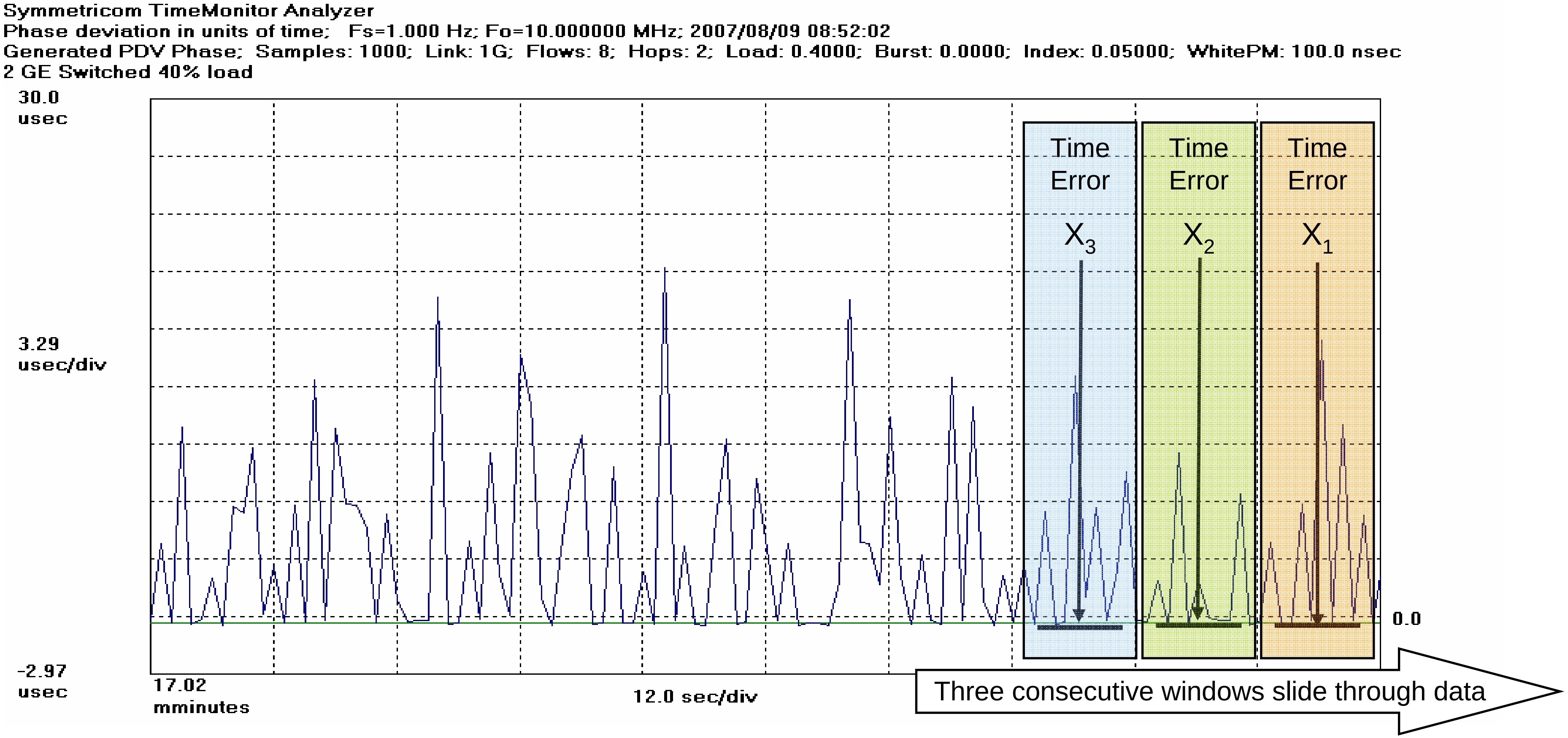


Packets experiencing minimum delay

Key characteristics:

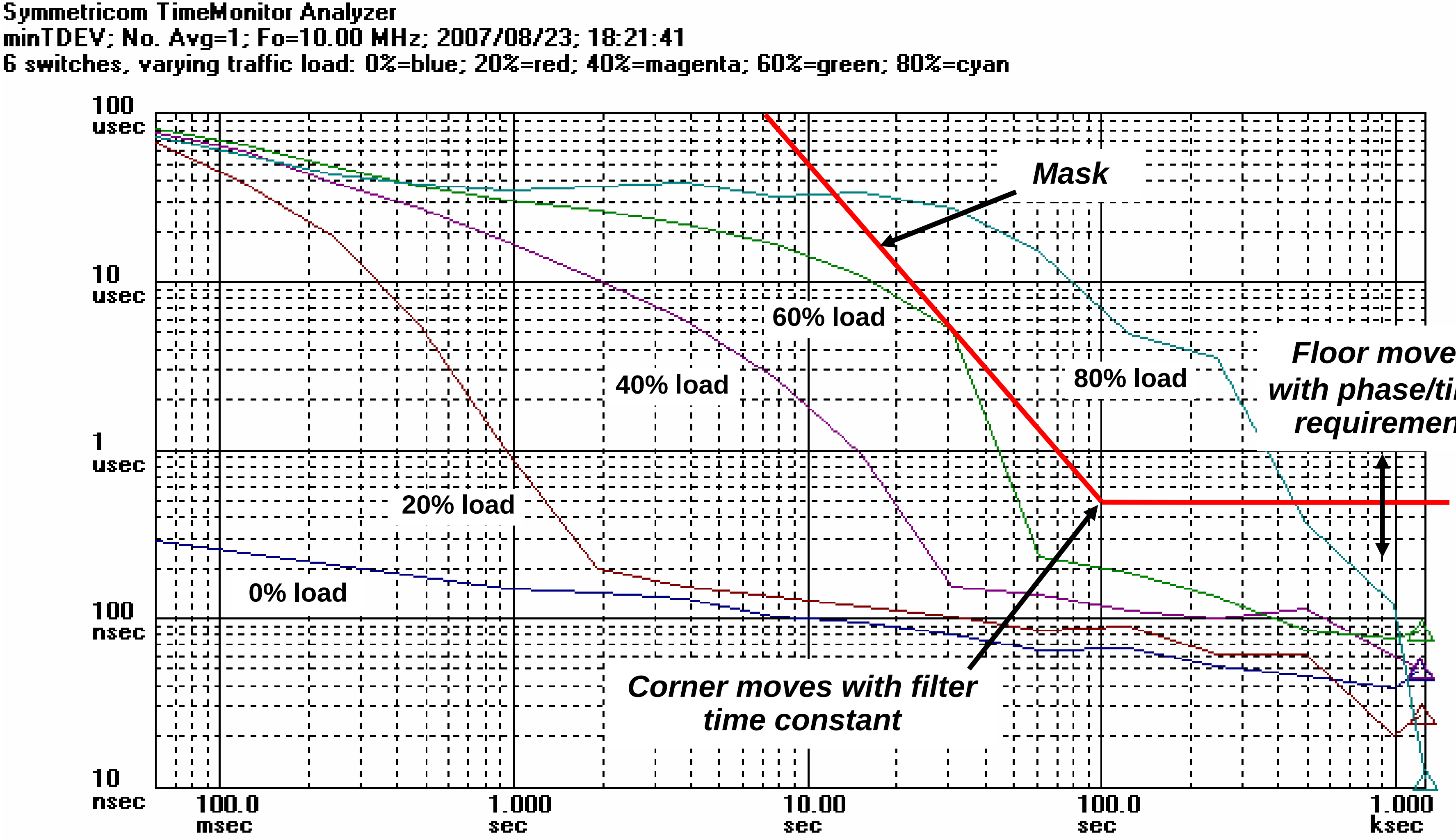
- variance of minimum delay
- frequency of packets with minimum delay

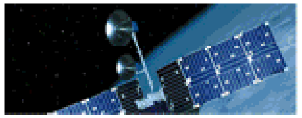
Minimum Time Deviation

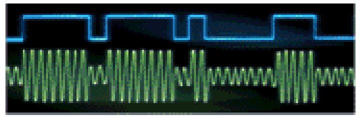


- Slide three windows through the data set, selecting the minimum delay value in each window *(N.B. Allan variance selects the first value, TDEV selects the mean value)*
- Calculate the second difference at each point = $(X_3 – X_2) – (X_2 – X_1) = X_3 – 2X_2 + X_1$
- Calculate the variance on the set of second differences
- Repeat for different window sizes, plotting the variance for each window size on the plot

MinTDEV Mask






Packet Timing Deployment Guidelines

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Engineering and Operational Aspects

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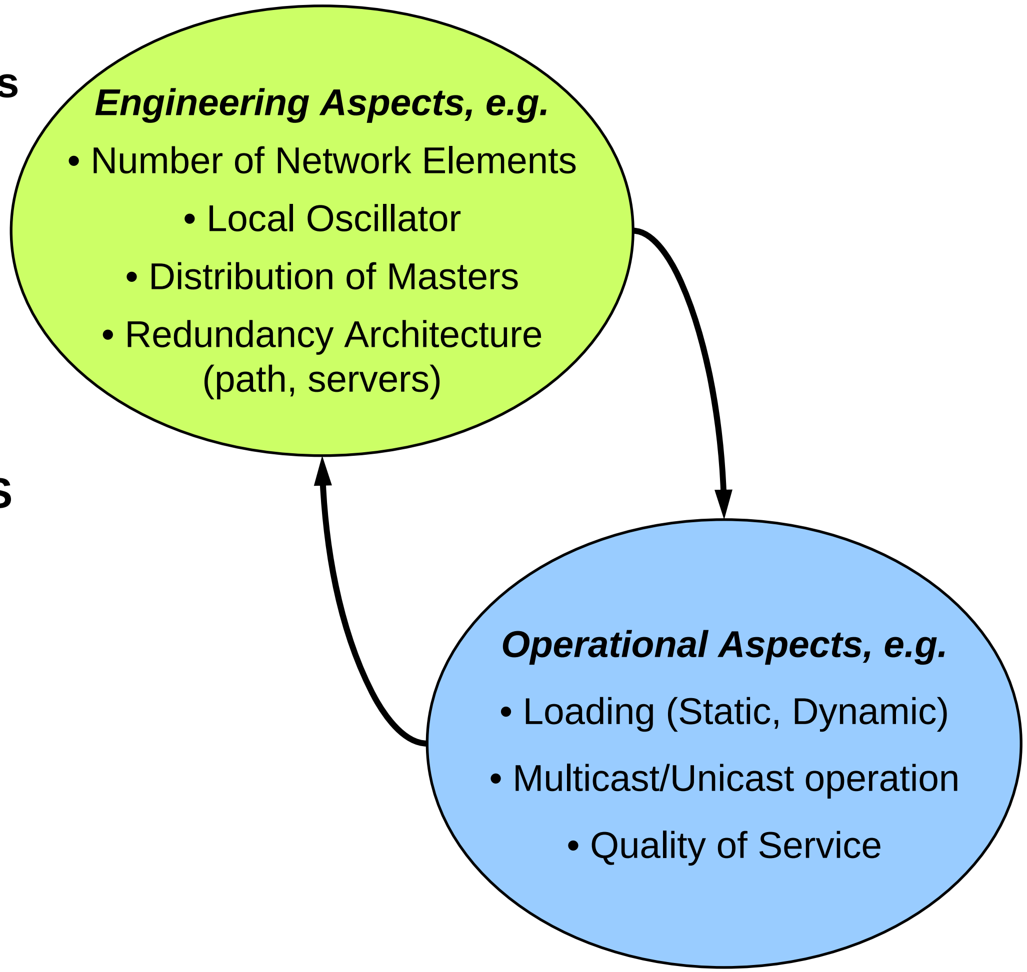
- **Successful delivery of synchronization services depends on workable deployment guidelines**
- ***Engineering Guidelines*** **address static network considerations, such as the maximum number of elements**
- ***Operational Guidelines*** **address dynamic network attributes such as loading and QoS**
- **The *engineering guidelines* establish a framework for procurement and deployment of a network that can operate successfully if the *operational guidelines* are also observed.**



Engineering Considerations - 1

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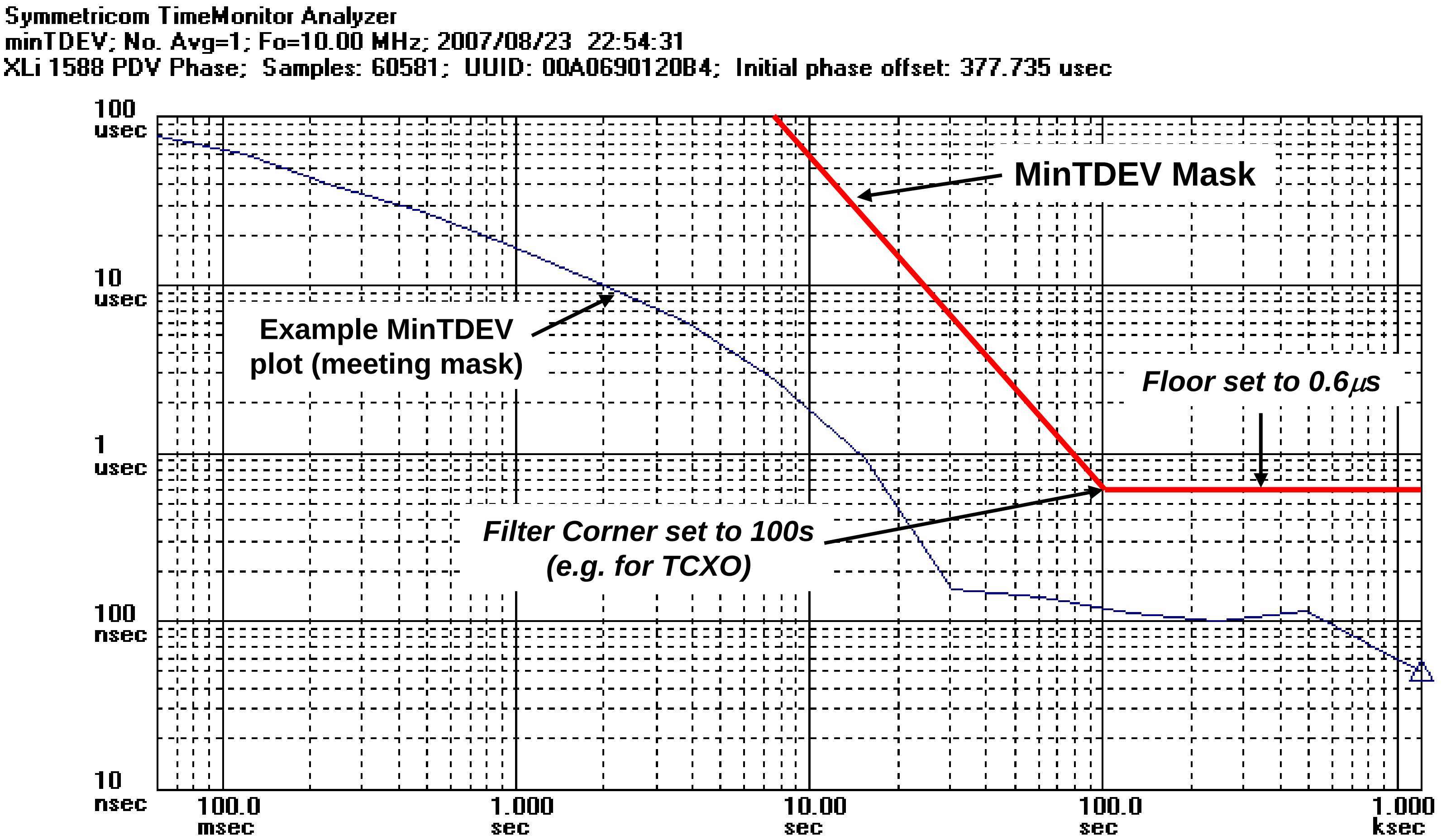
- Network Constraints
  - *Previously:* establish a maximum traffic load for the number of hops in a given network
  - *Now:* establish a MinTDEV mask for the application
    - Make MinTDEV part of the SLA with the network operator
- Local Oscillator
  - Stability of local oscillator affects the ability to filter network noise
  - More stable the oscillator, the better the noise filtering
  - Balance between oscillator cost, network size and application requirements

Example: MinTDEV mask for CES



Mask floor calculation:

- MTIE Requirement from G.8261, Deployment Case 1, is 4.5µs
- Using 3-sigma approach leaves 1.5µs
- Apply 40% budget for Metro/Access domain leaves 0.6µs

Engineering Considerations - 2

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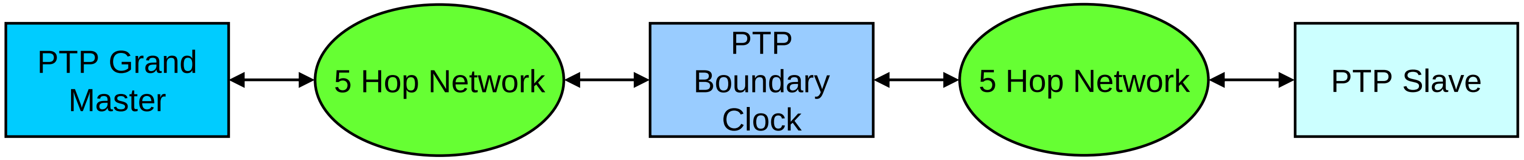
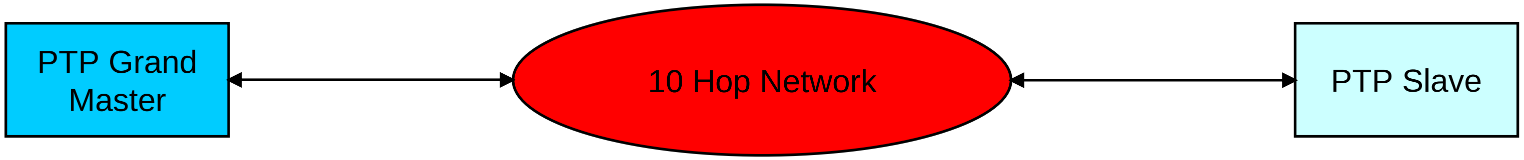
- Distributed Masters
  - Place a boundary clock as near as possible to the end stations, for example:



is better than:



- Redundancy Strategy
  - Separate Grand Masters, or separate blades?
  - Best Master Clock Algorithm, or manual configuration?

Operational Considerations - 1

- **Multicast vs. Unicast Operation**
  - Multicast requires packet replication at each network element
  - Multicast often treated at low priority, or may not propagate at all in some networks
- **Quality of Service (QoS)**
  - In general, switches/routers optimized for maximum throughput with minimum intervention
  - In other words, adding QoS features slows the switch/router down
- **Frequency of Timing Packets**
  - Increasing number of timing packets gives only logarithmic increase in performance

Operational Considerations - 2

- Monitoring the Packet Network
  - Operators need to be able to monitor any SLA metrics they may be measured on, e.g. MinTDEV
  - Need some kind of probe device to continuously measure the network performance
- Managing Network Loads
  - What does the operator do when the MinTDEV metric starts to go out of specification?
  - Limiting network load to reduce MinTDEV
    - Connection Admission Control
    - Priority Application

      … but these are QoS techniques which may damage timing!!

Conclusions

- Every application for packet timing is different
  - Need to establish a budget for each application
- Metrics for quantifying network behaviour must be:
  - Independent of the network elements
  - Independent of traffic loading patterns
  - **Minimum Time Deviation *(MinTDEV)*** appears to satisfy these criteria
- Deployment considerations include:
  - ***Engineering aspects***, i.e. up-front planning considerations
  - ***Operational aspects***, i.e. on-going management considerations

Thank you for listening!

I · T · S · F

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