Test Processes in ITU-T Recommendation G.8261

Tim Frost,

Zarlink Semiconductor

tim.frost@zarlink.com

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Testing Synchronisation of CES using adaptive timing

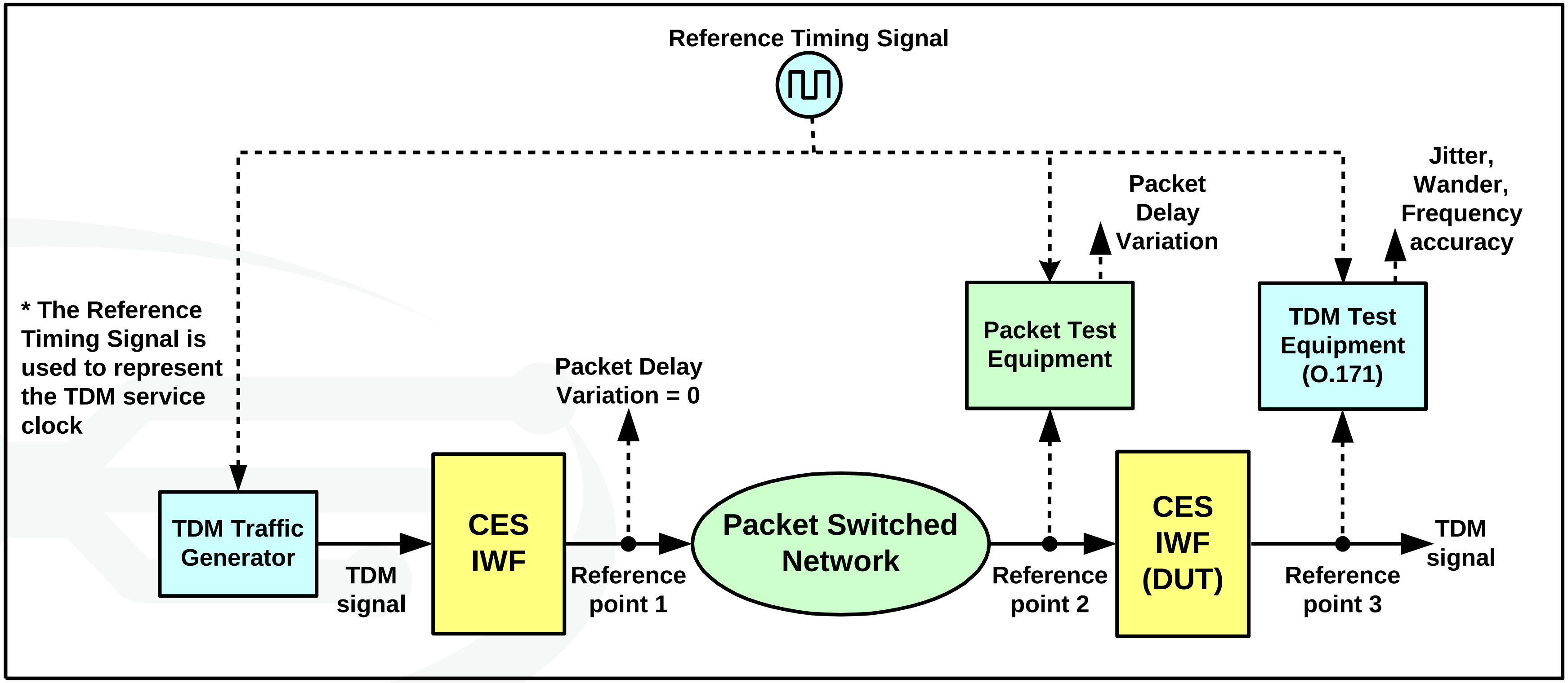


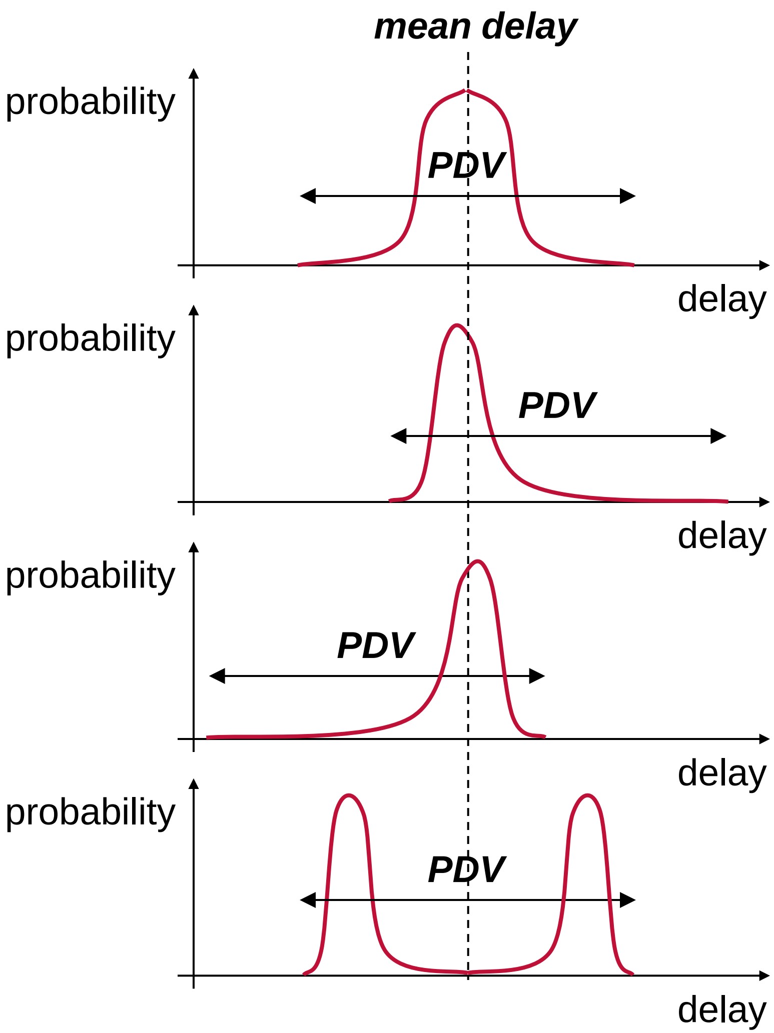
Figure VI.2, G.8261

Packet Network Impairments

- Packet Transfer Delay
  - Static delay is not a problem for recovery of clock frequency or phase
  - Delay is insignificant compared to typical filter bandwidths used
- Packet Delay Variation (PDV)
  - Appears as change in frequency or phase of the recovered clock
  - Multiple causes, including queuing delays, routing changes, congestion etc.
- Packet Loss
  - Not usually an issue for clock recovery, due to integration over several seconds of data
- Packet Error
  - Bit errors in packets cause packet loss due to discard of the packet
- Extended Packet Loss (Network Outages)
  - May cause clock recovery process to go into “holdover” from lack of information

PDV and Mean Packet Delay

- **PDV and Mean Delay figures are too abstract to be useful for predicting timing performance**
- **Example:**
  - **All four probability density functions on the right have same mean delay and PDV**
- **PDV and Mean Delay may vary with time**
- **PDV doesn't describe the correlation of delays between adjacent packets**



Causes of Network Impairments – 1

- Output queuing delays in network elements
  - Occurs due to queuing of timing packets behind other traffic waiting to be transmitted onto the same network link
  - Causes random variation in packet delay, correlated to the traffic load in the network
  - May be reduced by applying increased priority to timing packets
- Resource contention
  - Caused by contention for resources within network elements, e.g. forwarding engine, security processors
  - Causes random variation in packet delay, correlated to traffic load in the network
  - May be reduced by applying increased priority to timing packets

Causes of Network Impairments – 2

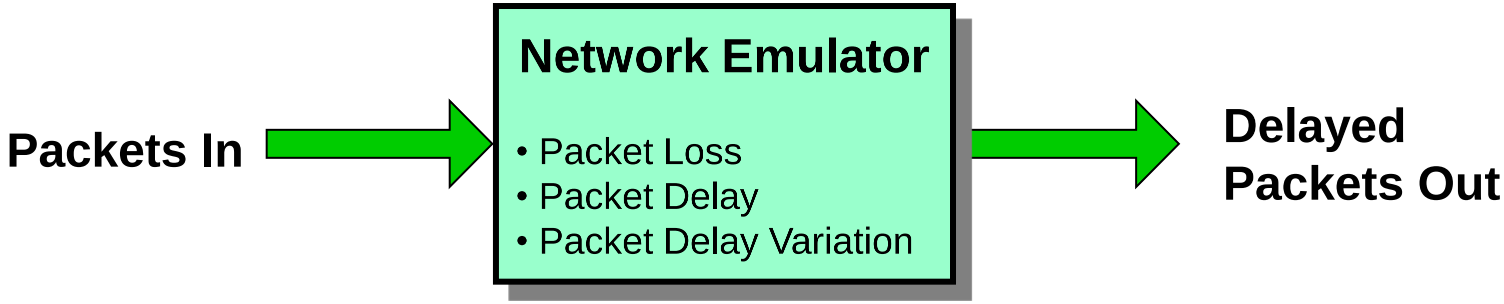
- Congestion Events
  - Caused by temporary increase in traffic load, leading to part of the network becoming "overloaded"
  - Causes packets to become severely delayed or dropped
  - Congestion events are usually of short duration, as network traffic (e.g. TCP flows) backs off to reduce traffic load
- Routing changes
  - Occur as a result of routing protocol behaviour, network re-configuration, traffic engineering, protection switching
  - Causes a step change in packet delay
- Conclusion: Primary cause of packet delay and packet delay variation is the traffic load in the network

Reproducing the Packet Network

Options:

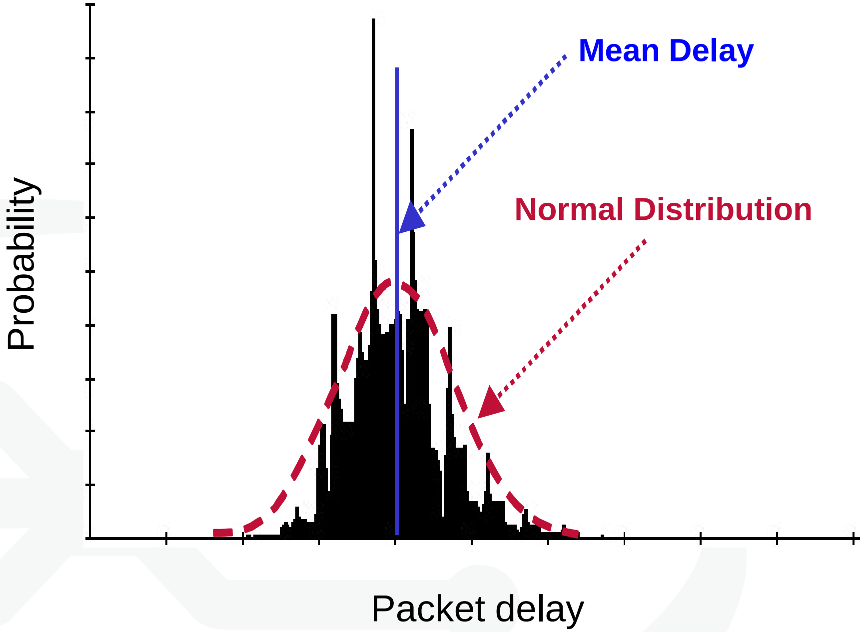
- **Use of network emulators**
- **Use of live networks**
- **Use of trace files collected from live networks**
- **Use of a controlled laboratory network**

Use of Network Emulators

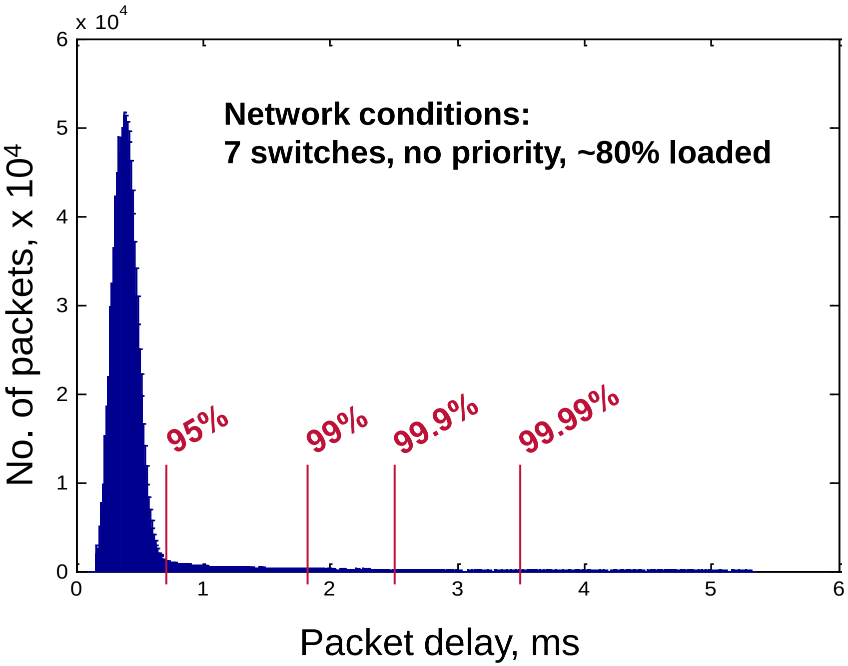


- Network emulator boxes simplify the experimental setup
  - Very attractive for performance evaluation
  - Offer the promise of repeatable, reliable results
- Do they work?
  - What are the delay distributions used?
  - What is the low frequency performance?
  - How accurately are the delays applied?
    - Can you recover clocks with microsecond MTIE performance from a network emulator that applies delays with millisecond accuracy?

Delay Distributions

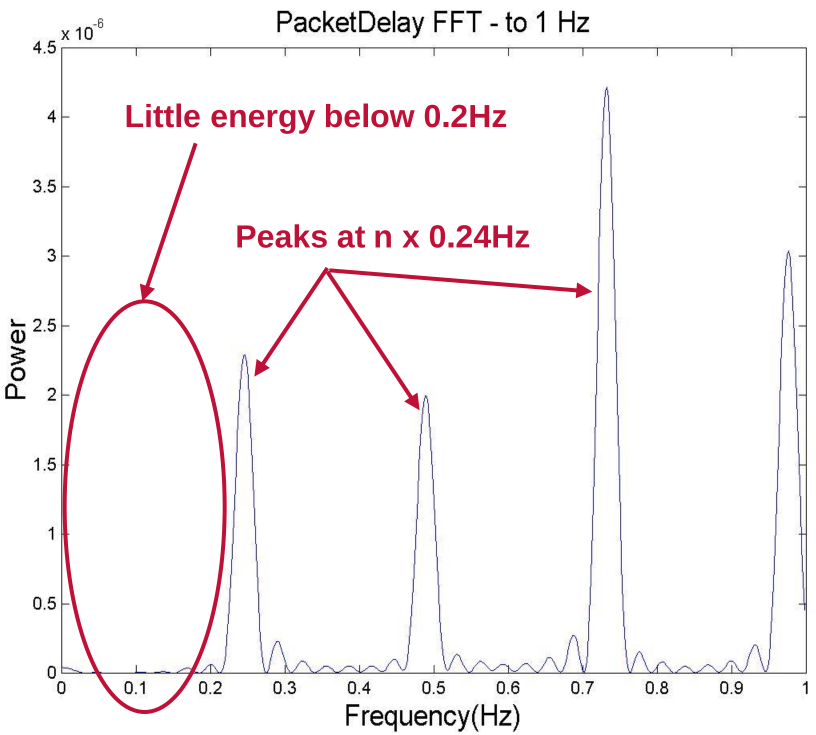


Delay distribution measured on NISTnet Network Emulator

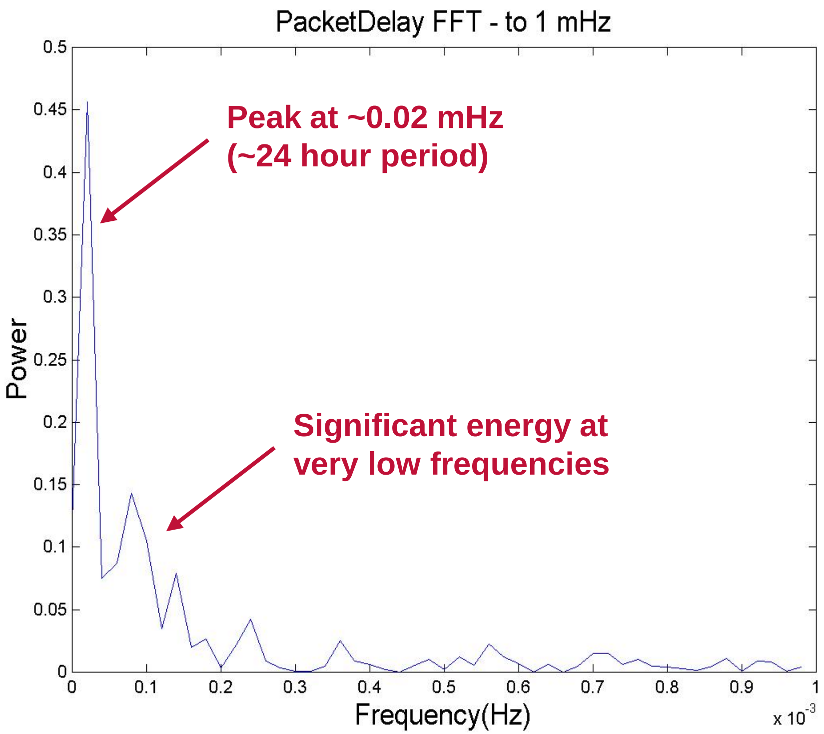


Delay distribution measured on Ethernet Switched Network

Low Frequency Packet Delay Variation



Frequency content of NISTnet model at frequencies below 1 Hz

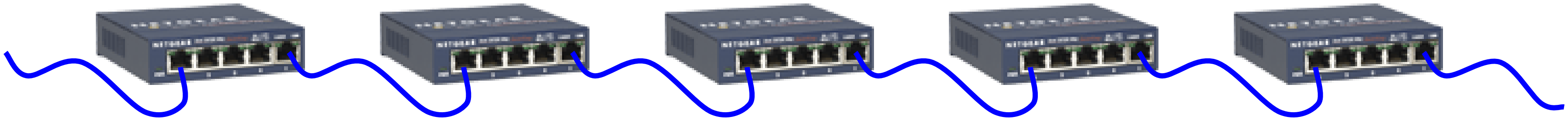


Frequency content of repetitive "ping" at frequencies below 1 mHz

Use of Live Networks

- Makes the results sound credible
  - *"Tested over service provider X's live network"*
- Who is to say that the traced network is representative?
  - What type of network is it?
  - What is the load on the network?
  - How many hops are there?
- Results are not repeatable
  - Conditions and usage change from day to day
- Network is not controllable
  - *"Please, Mr. Service Provider, can we just create a little congestion and a service outage in your live network?"*
- Can we use a trace file recovered from a real network?
  - Overcomes the repeatability issue
  - What equipment is there to apply trace files? Network Emulator?
  - How accurately can the delays be applied?

Use of a controlled, laboratory network



- Delays created by real network effects, not simulations
- Network is controllable and repeatable
  - Controls the primary parameter (*load*), rather than the secondary parameter (*PDV*)
- Allows particular conditions and events to be induced
  - e.g. congestion, outages, route changes
- Can be unwieldy and difficult to set up
- Performance may be dependent on the particular network elements used

G.8261 Test Network

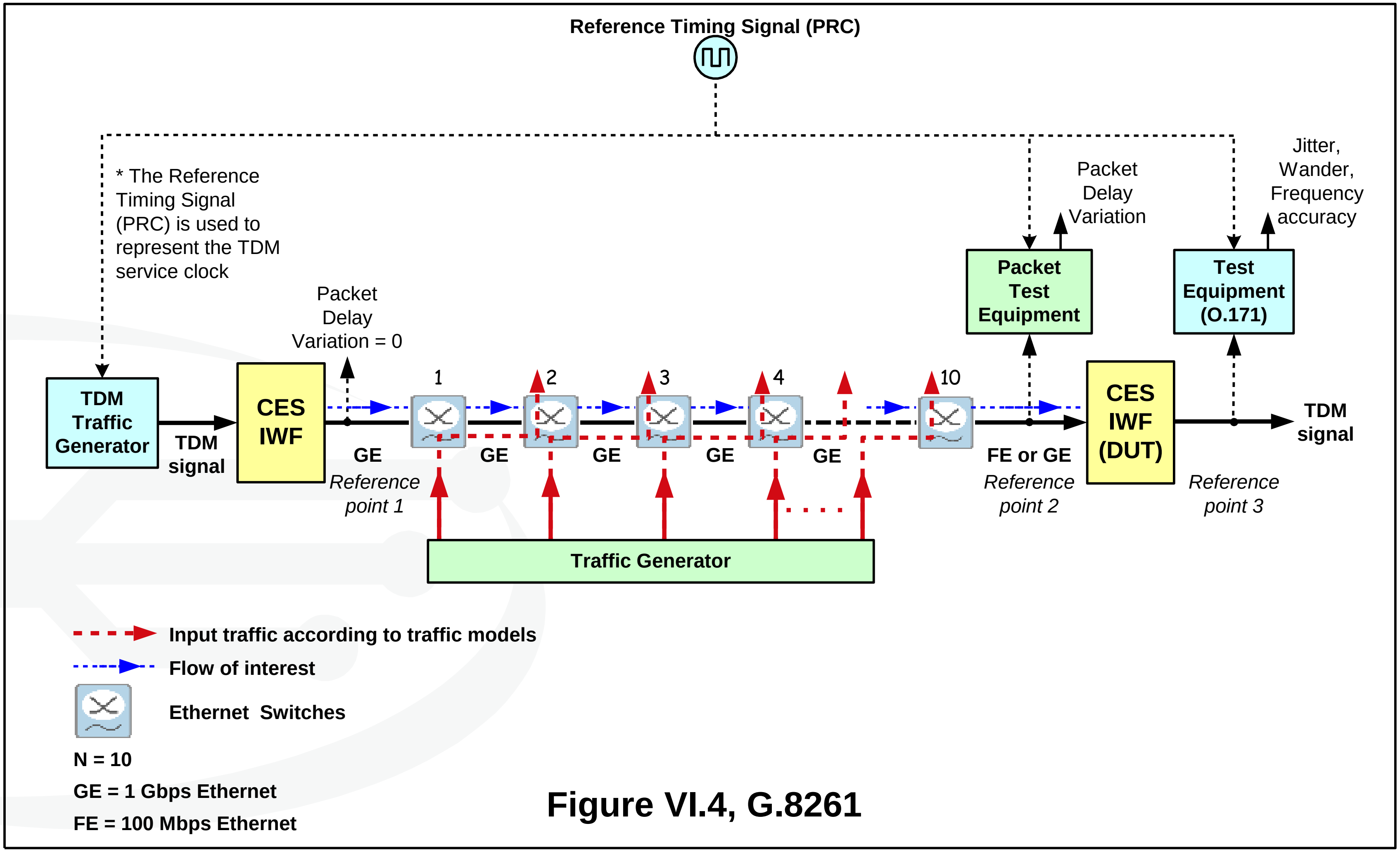
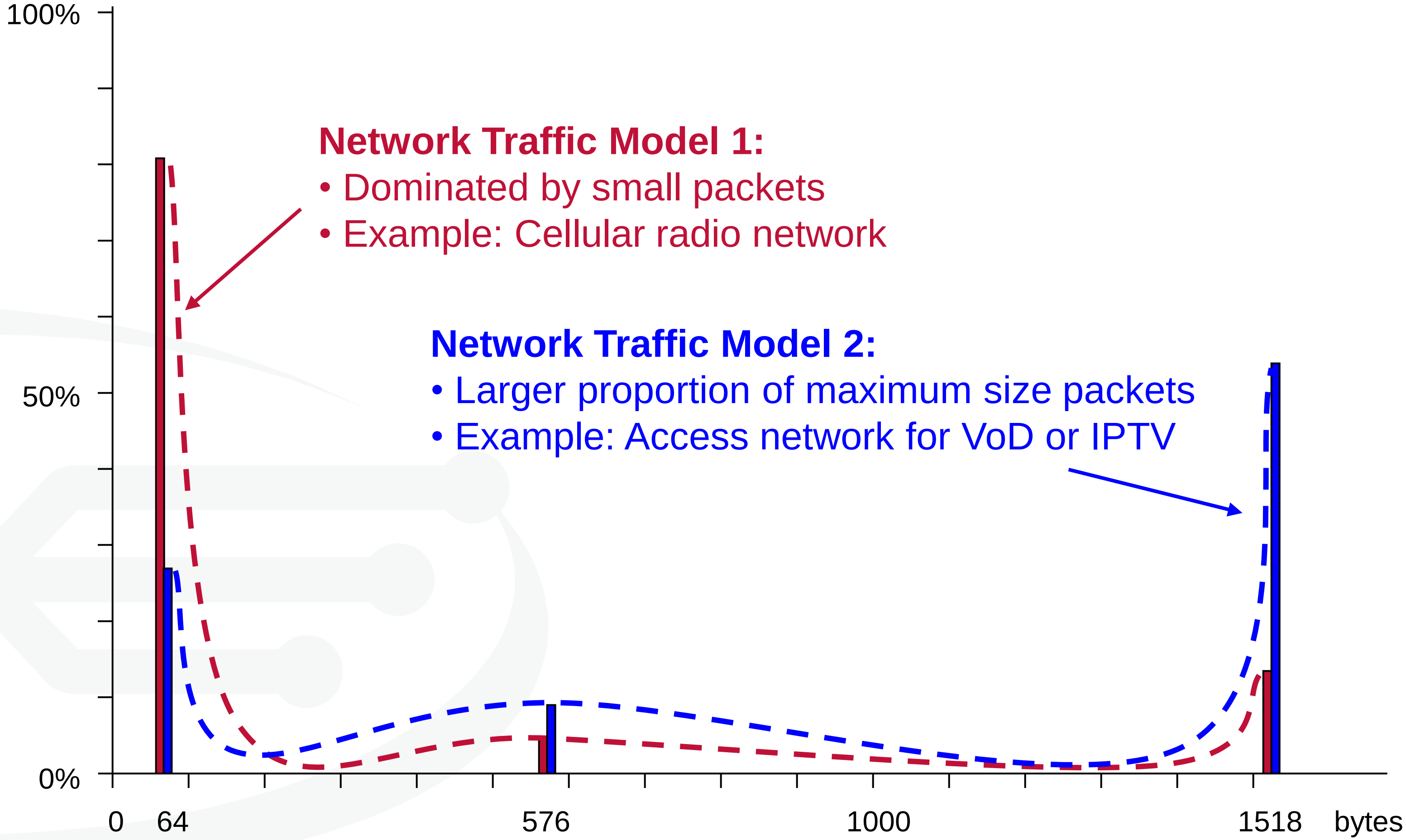


Figure VI.4, G.8261

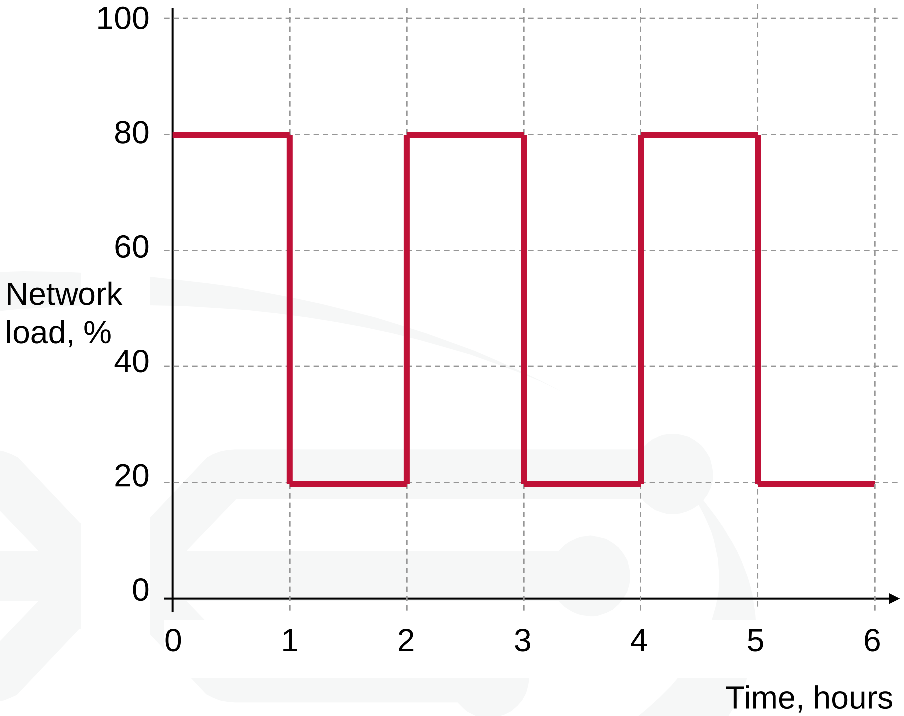
Traffic Size Models



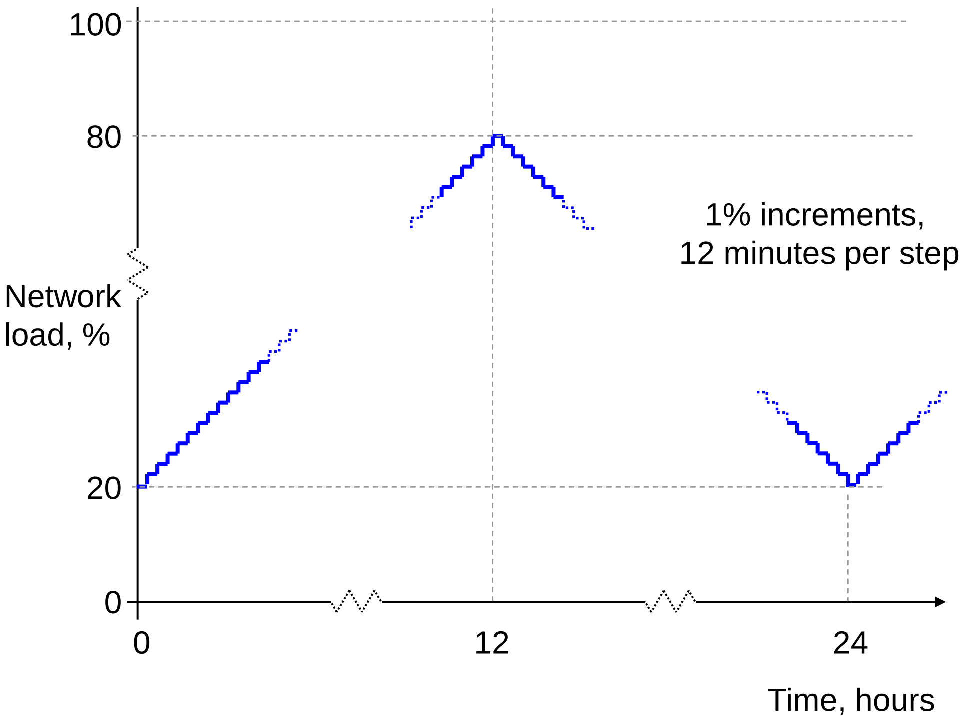
Test Cases Applied

- **Test Case 1:** **“Steady Load”**
  - Load each switch with a steady 80% traffic
  - Measure TIE and MTIE (or MRTIE) over duration of test (1 hour)
- **Traffic load modulation (e.g. periodic variations of traffic density)**
  - **Test Case 2:** On/off modulation
  - **Test Case 3:** Slow ramp in PDV over time
- **Disruptive Events**
  - **Test Case 4:** Network outages
  - **Test Case 5:** Network congestion
  - **Test Case 6:** Routing changes

Testing for Traffic Load Modulation



Test Case 2: Figure VI.5, G.8261
Sudden Traffic Load Modulation
Example: Large File Transfers



Test Case 3: Figure VI.6, G.8261
Slow Traffic Load Modulation
Example: Day/Night Variation

Testing for Disruptive Events

- **Test Case 4:** Network Outages
  - Disconnect DUT for 10s, then restore
  - Disconnect DUT for 100s, then restore
  - Simulates temporary network outages and restoration
- **Test Case 5:** Network Congestion
  - Apply 100% traffic load to all switches for 10s, then restore
  - Apply 100% traffic load to all switches for 100s, then restore
  - Induces severe delays and packet loss in the network for a period, simulating network congestion events
- **Test Case 6:** Routing Changes
  - Bypass one switch for a period, then restore
  - Bypass five switches for a period, then restore
  - Simulates re-routing events in the network

Future Work

- Define tests for differential clock recovery mechanisms
- Tests for alternative topologies
  - Aggregation points
  - Ring-based topologies
- Tests over network elements from different manufacturers
- Cover different network effects
  - Beating against other circuit emulation streams
  - Beating against network physical layer
  - Effect of QoS mechanisms

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