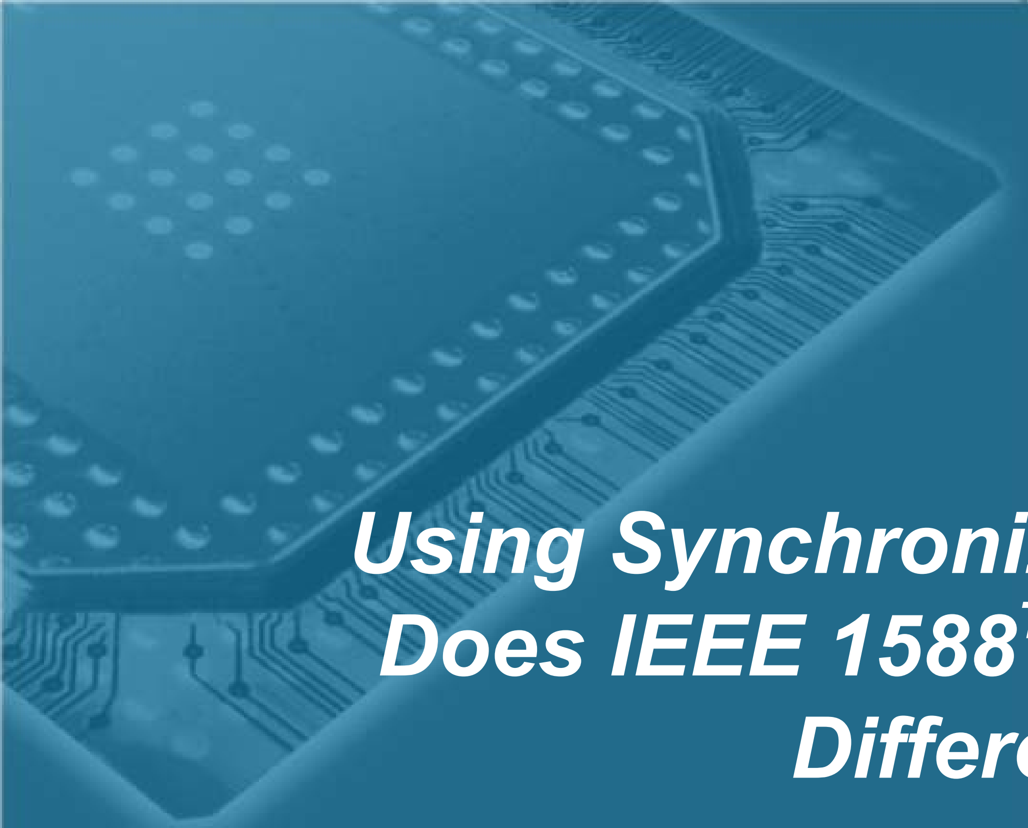

Using Synchronization over PSN: Does IEEE 1588^{TM} Really Make a Difference?

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Special thanks to Alon Geva
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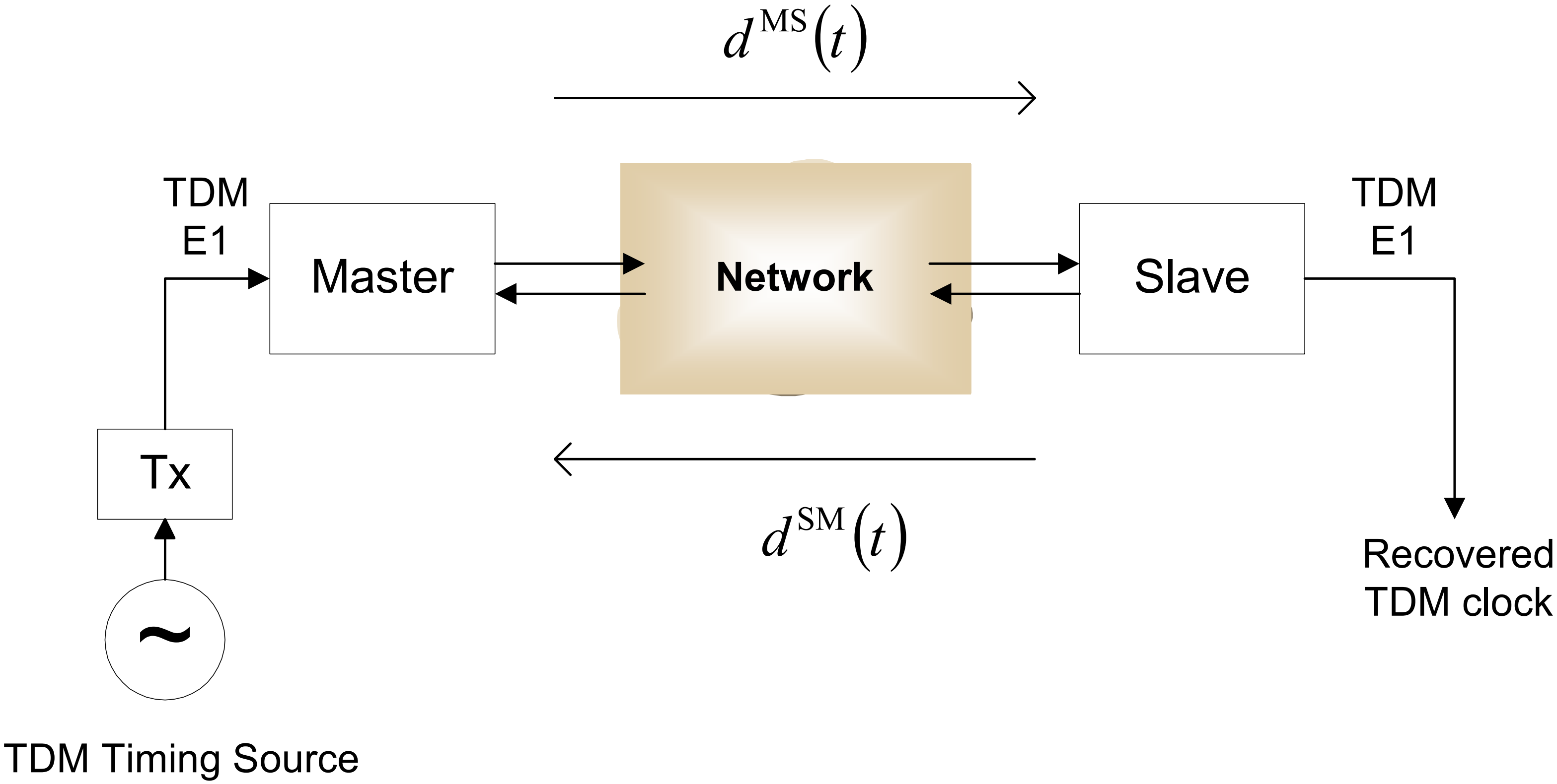
Basic system diagram



$d^{MS}(t)$

TDM
E1

Master

Network

Slave

TDM
E1

Tx

$d^{SM}(t)$

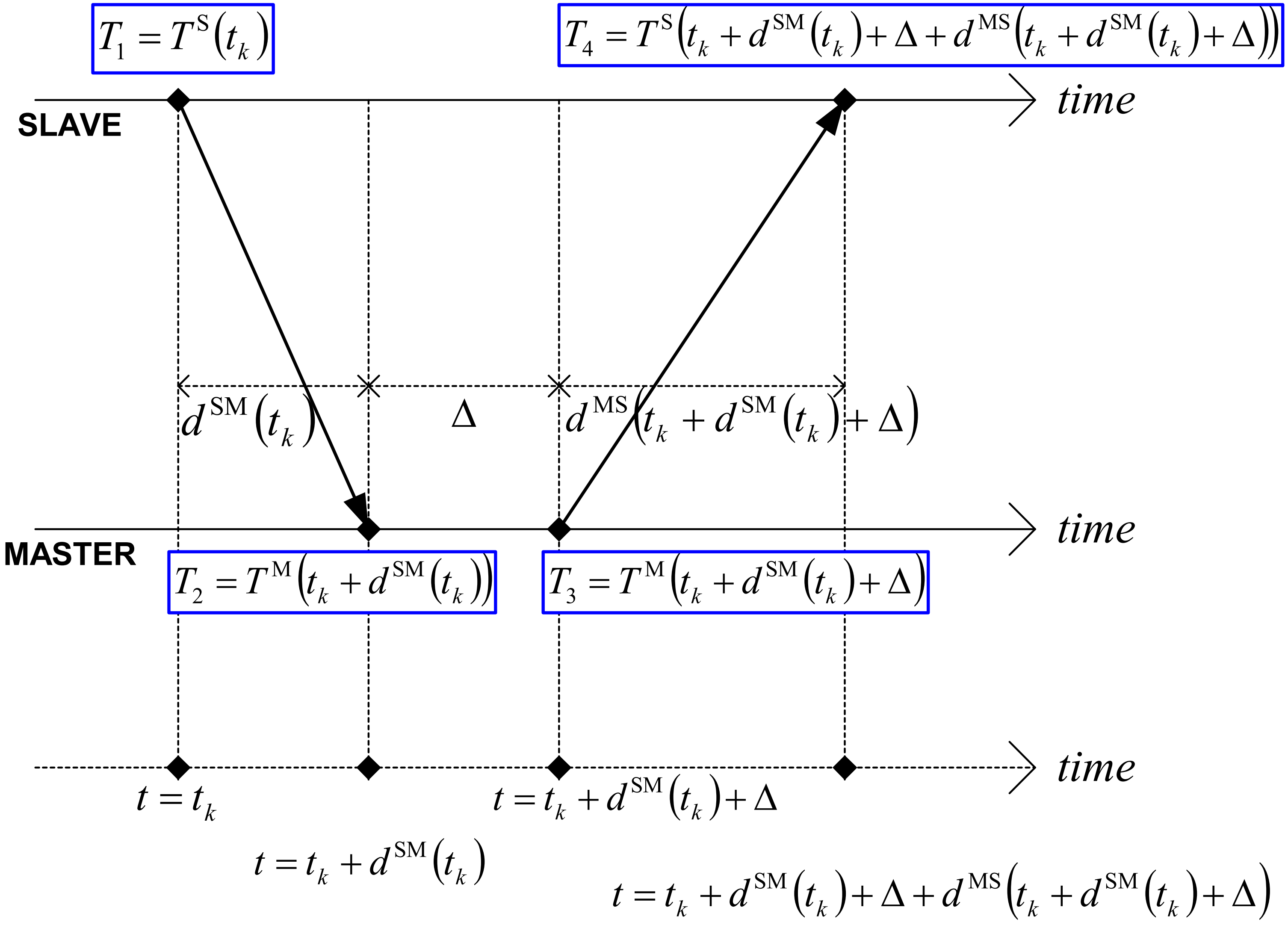
Recovered
TDM clock

~

TDM Timing Source

Figure 1

IEEE 1588 Timestamp Exchange



$T_1 = T^{\mathrm{S}}(t_k)$

$T_4 = T^{\mathrm{S}}\left(t_k + d^{\mathrm{SM}}(t_k) + \Delta + d^{\mathrm{MS}}\left(t_k + d^{\mathrm{SM}}(t_k) + \Delta\right)\right)$

SLAVE

time

$d^{\mathrm{SM}}(t_k)$

Δ

$d^{\mathrm{MS}}\left(t_k + d^{\mathrm{SM}}(t_k) + \Delta\right)$

MASTER

time

$T_2 = T^{\mathrm{M}}\left(t_k + d^{\mathrm{SM}}(t_k)\right)$

$T_3 = T^{\mathrm{M}}\left(t_k + d^{\mathrm{SM}}(t_k) + \Delta\right)$

time

$t = t_k$

$t = t_k + d^{\mathrm{SM}}(t_k) + \Delta$

$t = t_k + d^{\mathrm{SM}}(t_k)$

$t = t_k + d^{\mathrm{SM}}(t_k) + \Delta + d^{\mathrm{MS}}\left(t_k + d^{\mathrm{SM}}(t_k) + \Delta\right)$

Figure 2

$T^{\mathrm{M}}(t) \cong t$

Simplifying Assumptions

- **The slave's PLL has achieved lock so there is a (almost) zero frequency error between the master and the slave. Hence, the relationship between the local time representation of the slave and that of the master is** $T^{\mathrm{S}}(t) = T^{\mathrm{M}}(t + \varepsilon)$**, where** ε **is a constant uncompensated phase (time) error between the master and the slave.**

- **The master's clock is locked to a primary reference clock (PRC or Stratum 1 clock). Hence the time representation of the master can be simplified to:** $T^{\mathrm{M}}(t) \cong t$

Simplifying Assumptions

- **Given the above assumptions we can rewrite the four timestamps of Figure 2 in a simpler manner (where *k* is the packet's sequence number):**

$$T_1(k) = t_k + \varepsilon$$

$$T_2(k) = t_k + d^{\mathrm{SM}}(k)$$

$$T_3(k) = t_k + d^{\mathrm{SM}}(k) + \Delta$$

$$T_4(k) = t_k + d^{\mathrm{SM}}(k) + \Delta + d^{\mathrm{MS}}(k) + \varepsilon$$

Slave's Delay Calculation

- **Bidirectional:**

$$\tilde{d}_{2\mathrm{way}}^{\mathrm{MS}}(k) = \frac{T_4(k) - T_3(k) + T_2(k) - T_1(k)}{2} = \frac{d^{\mathrm{SM}}(k) + d^{\mathrm{MS}}(k)}{2}$$

- **Unidirectional:**

$$\tilde{d}_{1\mathrm{way}}^{\mathrm{MS}}(k) = T_4(k) - T_3(k) = d^{\mathrm{MS}}(k) + \varepsilon$$

Signal to Noise Comparison

$d^{\mathrm{SM}}(k), d^{\mathrm{MS}}(k)$ are uncorrelated stochastic processes having the following means and standard deviations:

$$\mu^{\mathrm{SM}} = E\left[d^{\mathrm{SM}}(k)\right]$$

$$\sigma^{\mathrm{SM}} = \sqrt{E\left[\left(d^{\mathrm{SM}}(k)\right)^2\right] - \left(\mu^{\mathrm{SM}}\right)^2}$$

$$\mu^{\mathrm{MS}} = E\left[d^{\mathrm{MS}}(k)\right]$$

$$\sigma^{\mathrm{MS}} = \sqrt{E\left[\left(d^{\mathrm{MS}}(k)\right)^2\right] - \left(\mu^{\mathrm{MS}}\right)^2}$$

- **Total noise power of bidirectional method:**

$$\tilde{d}^{\mathrm{MS}}_{\mathrm{2way}}(k) = (\sigma^{\mathrm{SM}\,2} + \sigma^{\mathrm{MS}\,2})/2$$

- **Total noise power of unidirectional method:**

$$\tilde{d}^{\mathrm{MS}}_{\mathrm{1way}}(k) = \sigma^{\mathrm{MS}\,2}$$

Signal to Noise Comparison

- **Suppose that only $d^{\mathrm{MS}}(k)$ has changed (CDC) by d_0 seconds...**
- **Then the SNRs at the CDC detection circuit inputs will be**

$$SNR_{1way} = d_0 \Big/ \left(\sigma^{\mathrm{MS}^2}\right)$$

$$SNR_{2way} = (d_0 / 2) \Big/ \left((\sigma^{\mathrm{SM}^2} + \sigma^{\mathrm{MS}^2}) / 2\right)$$

$$= d_0 \Big/ \left(\sigma^{\mathrm{SM}^2} + \sigma^{\mathrm{MS}^2}\right)$$

G.8261 "Disruptive Events"

- Cause sudden changes in the “constant delay” component of a PSN’s performance

- May be permanent or temporary

- Include:
  - Routing changes
  - Sudden changes in network loading
  - Temporary network overload
  - Temporary loss of service

Some G.8261 Test Cases

- **Test Case 1 (VI.2.2.2/G.8261)**
  - Static network disturbance load (baseline)
  - Maintained at 80% for one hour assuming that the clock recovery is in a stable condition

- **Test Case 2 (VI.2.2.3/G.8261)**
  - Sudden large and persistent changes in network load (i.e. CDCs)
  - It tests stability under sudden changes in network conditions, and wander performance in the presence of low frequency PDV
  - Load alternates between 80% for an hour and 20% for an hour

- **Test Case 3 (VI.2.2.4/G.8261)**
  - Slow change in network load over an extremely long timescale. It tests stability under very slow changes in network conditions, and wander performance in the presence of extremely low frequency PDV
  - Load varies smoothly from 20% to 80% and back over 24 hours

G.8261 Traffic Model 1

- **Packet size profile:**
  - **80% of the load is minimum size packets (64 octets)**
  - **15% of the load is maximum size packets (1518 octets)**
  - **5% of the load is medium size packets (576 octets)**

- **Maximum size packets occur in bursts lasting between 0.1 sec and 3 sec**

Test Setup

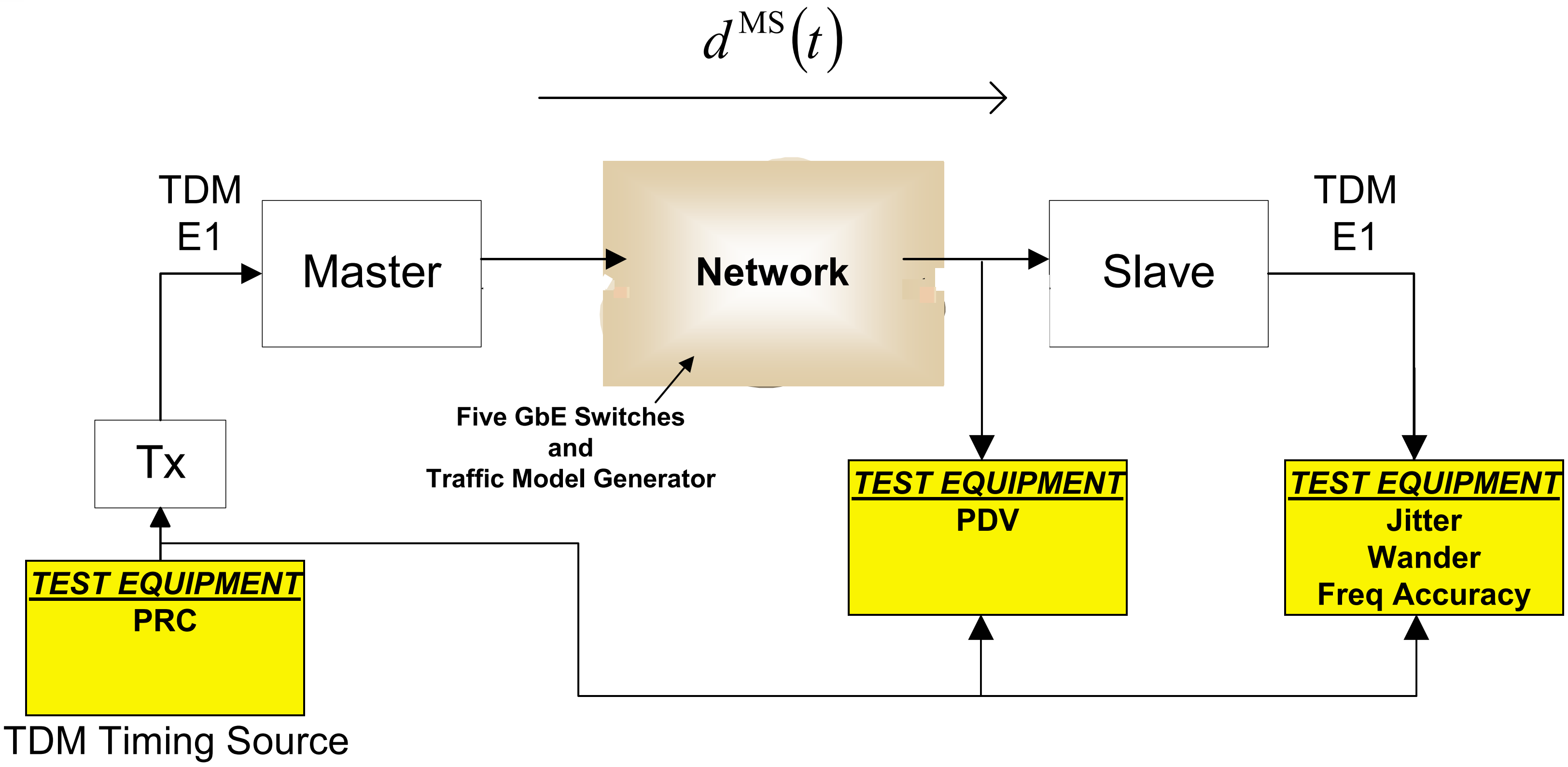
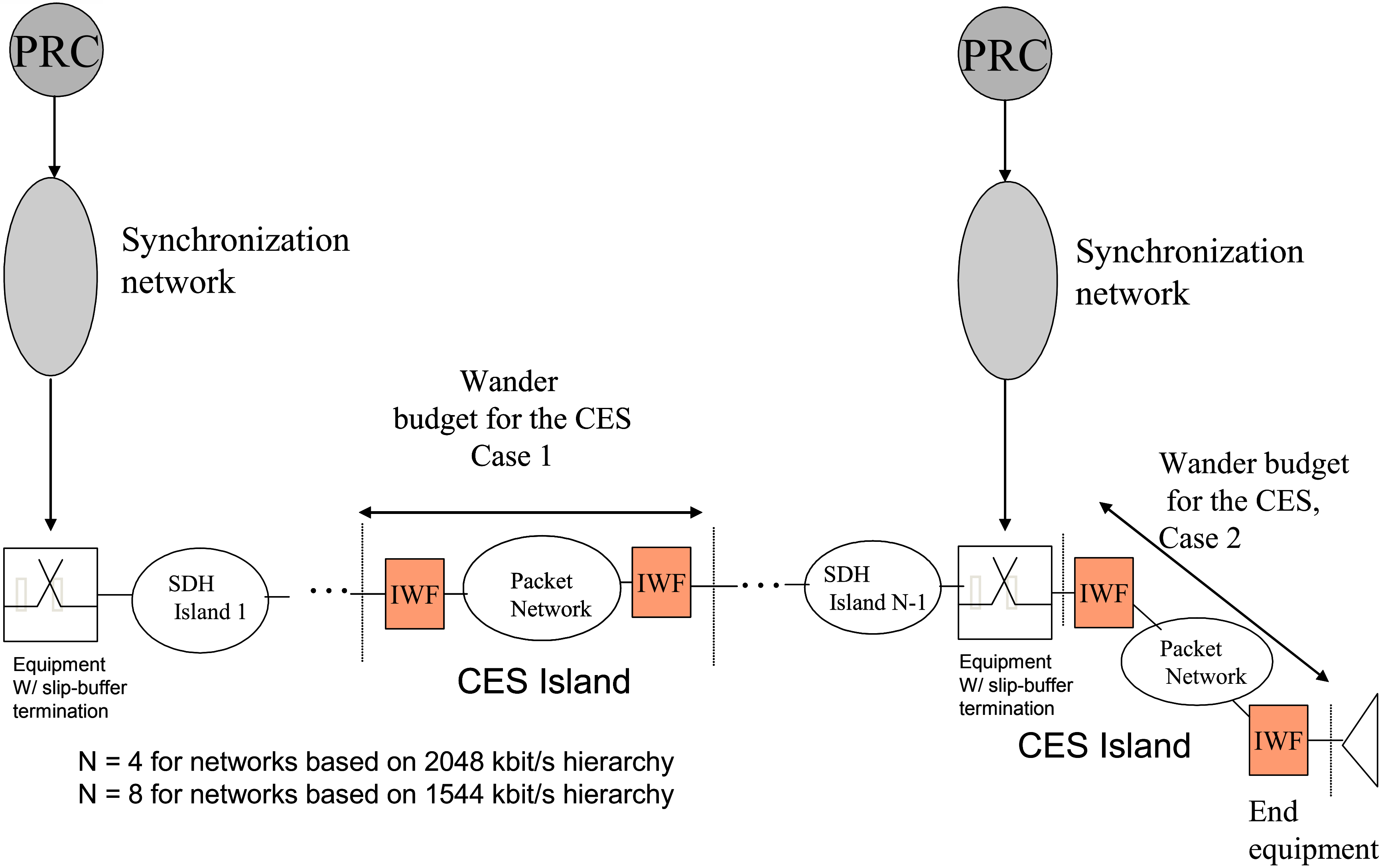


Figure 3

G.8261 Deployment Cases 1 and 2A



PRC

Synchronization network

PRC

Synchronization network

Wander budget for the CES Case 1

Wander budget for the CES, Case 2

SDH Island 1

IWF

Packet Network

IWF

SDH Island N-1

IWF

Packet Network

IWF

Equipment W/ slip-buffer termination

CES Island

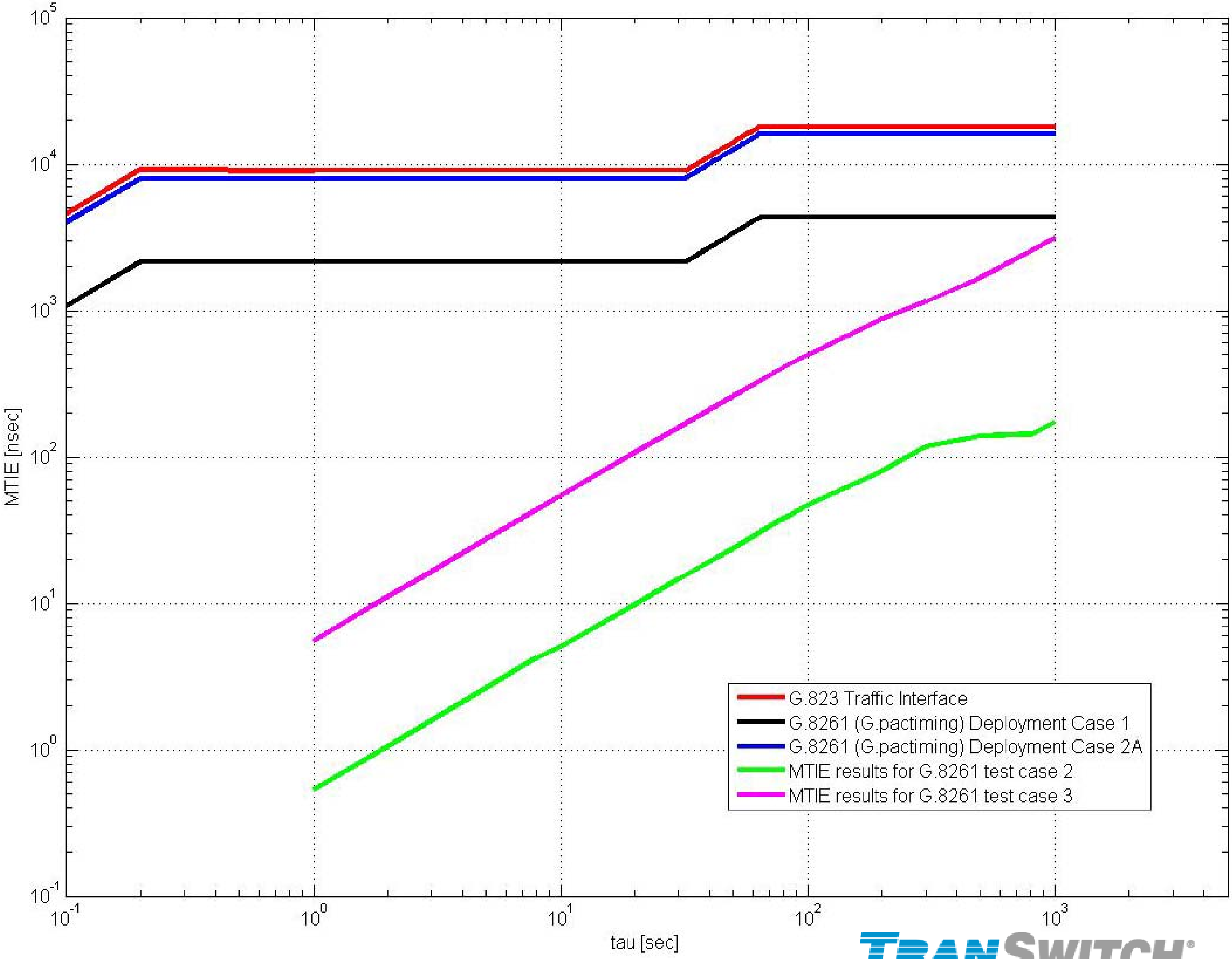
Equipment W/ slip-buffer termination

CES Island

End equipment

N = 4 for networks based on 2048 kbit/s hierarchy
N = 8 for networks based on 1544 kbit/s hierarchy

Test Results



Conclusion

- Bidirectional protocols are inherently noisier than unidirectional protocols, thus less well-suited for detecting disruptive events which cause CDCs

- Unidirectional protocols for circuit emulation services (CES) like TDMoIP, SAToP, and CESoPSN are demonstrably more than sufficient for delivering sync over a PSN