

The Distribution of Precise Time over Packet Networks

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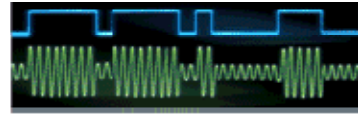
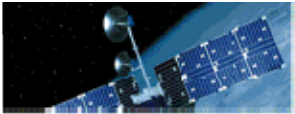
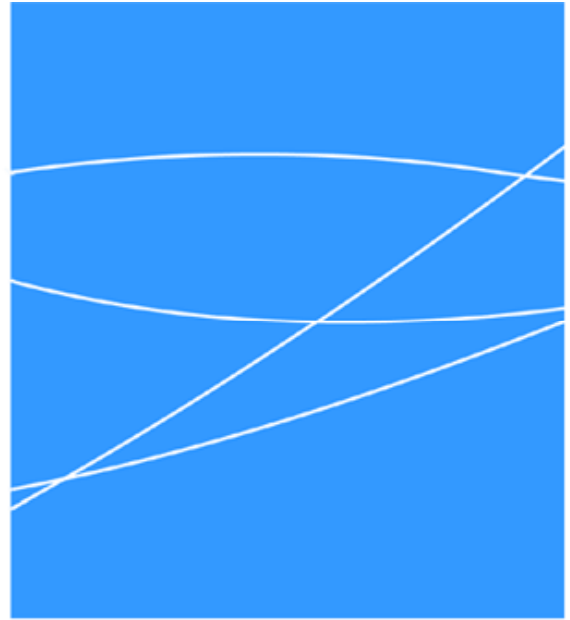
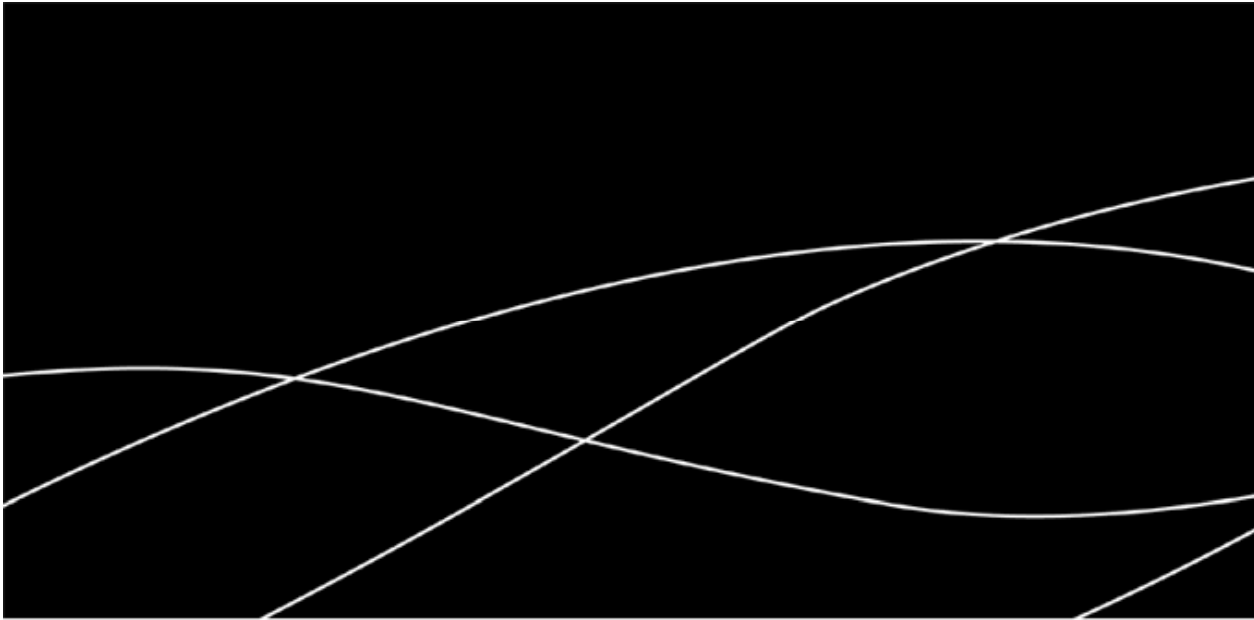
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ITSF 2008



- ▶ Applications for Precise Time over Packet Networks
- ▶ Issues with Distribution of Time
- ▶ Potential Solutions
- ▶ Conclusions





Applications



Timing to cellular basestations



Application	Time/Phase Synchronization Requirement
GSM, UMTS-FDD	Fractional frequency accuracy requirement only (50 ppb)
UMTS-TDD	Phase alignment between basestations within $\pm 2.5\mu\text{s}$
UMTS LTE	Not yet specified; likely to be around $\pm 5\mu\text{s}$ for MBMS
Mobile WiMAX	Phase alignment between basestations within $\pm 1\mu\text{s}$
CDMA2000	Time alignment of basestations within $\pm 10\mu\text{s}$ ($\pm 3\mu\text{s}$ preferred)
TD-SCDMA	Phase alignment between basestations within $\pm 3\mu\text{s}$



Other Applications

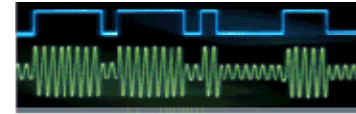
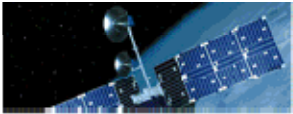
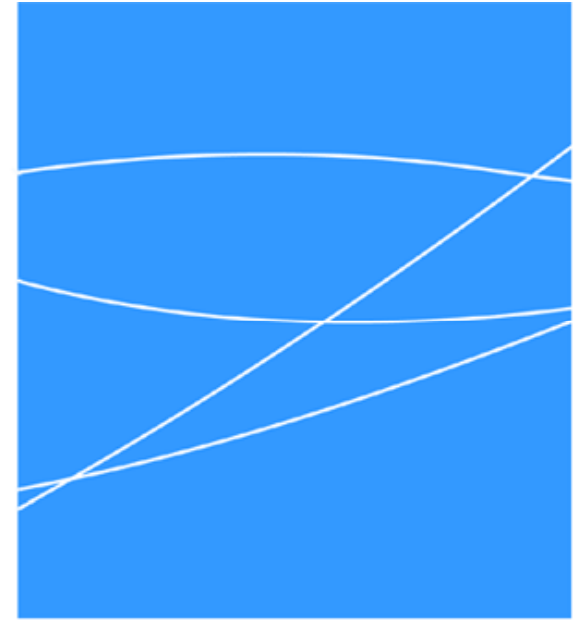
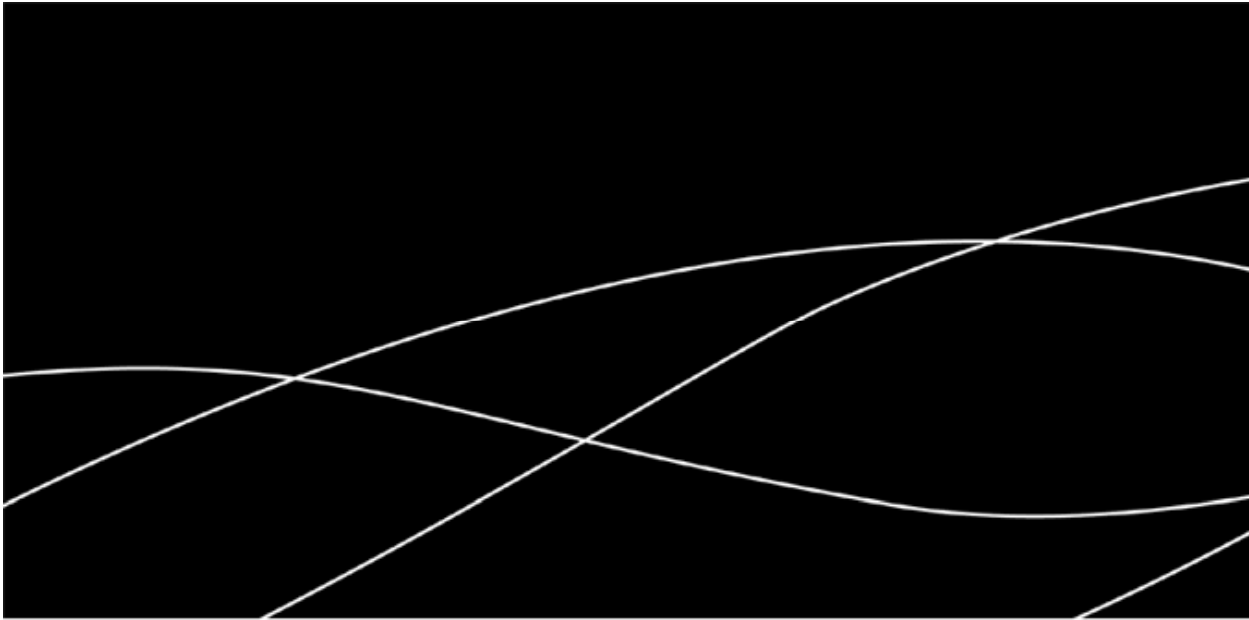


Application	Time/Phase Synchronization Requirement
Power Phase measurement	Time accuracy of $< 1\mu\text{s}$ ¹
Printing industry	Phase alignment between operations within $\pm 1\mu\text{s}$ ¹
Audio/Visual	Phase alignment of audio/visual devices within $\pm 100\text{ns}$ ²
Network SLA measurement	Time accuracy to be determined
Sensor Networks	Time accuracy to be determined



¹ draft-rodriques-lindqvist-tictoc-req-01.txt (IETF, November 2008)

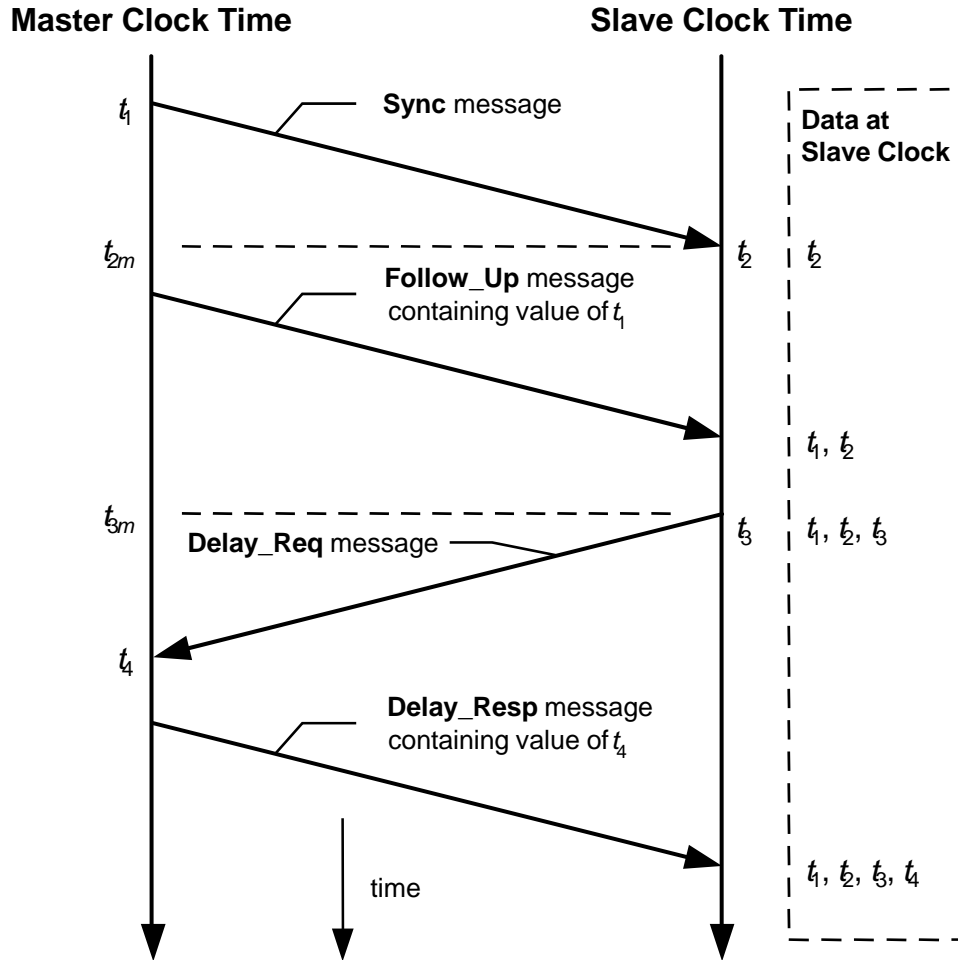
² Joint EBU-SMPTE Task Force on Time Labelling and Synchronization, TFTS_RFT270208



Issues with Time Distribution



Asymmetry



$$\text{Client time offset} = \frac{(t_1 - t_2) + (t_4 - t_3)}{2}$$

Assumes symmetrical delays
(i.e. the forward path delay is equal to the reverse path delay)

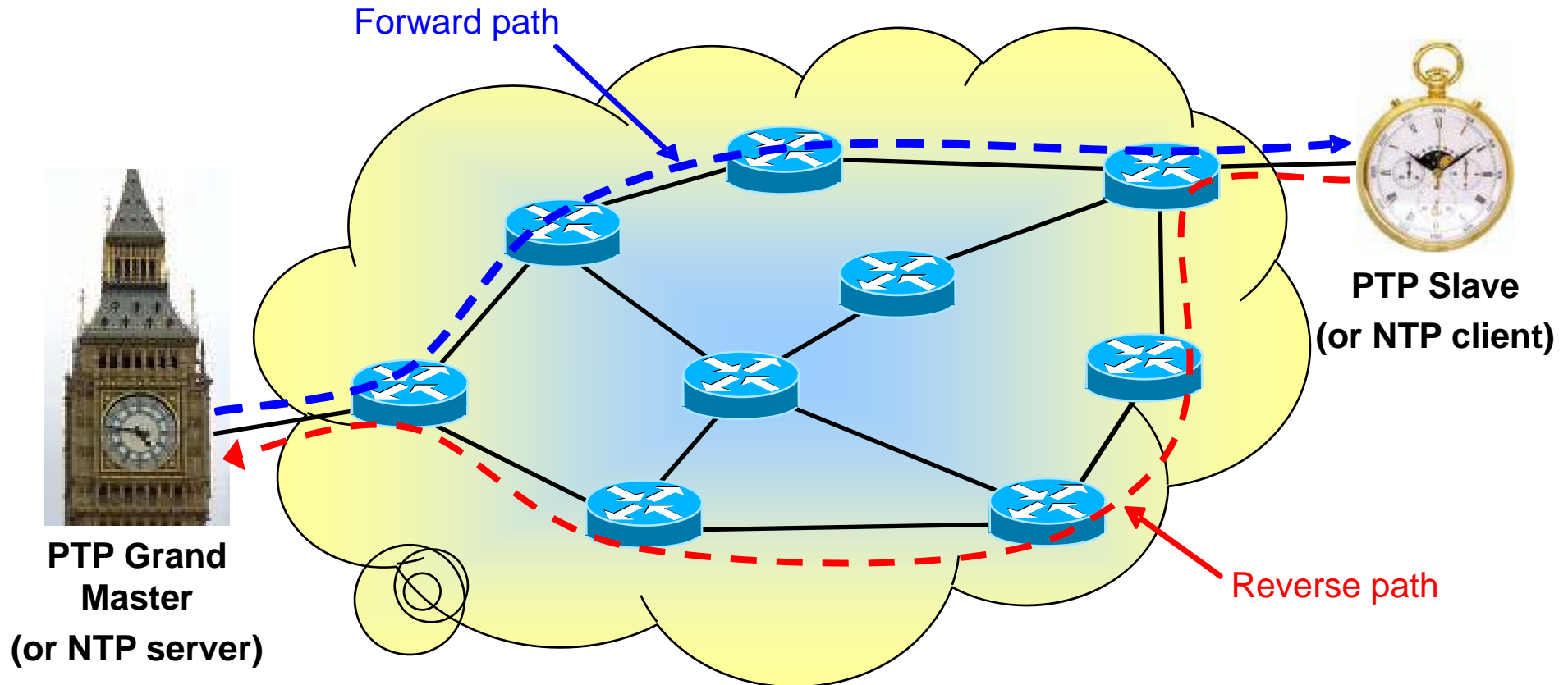
$$\text{Time offset error} = \frac{\text{fwd. delay} - \text{rev. delay}}{2}$$

PTP Transaction shown, but same principle applies to NTP



- ▶ **Routing Variances**
 - In a routed network, the forward and reverse paths may not necessarily take the same route
- ▶ **Data Rate Steps**
 - Data rate changes (e.g. from 1Gb/s to 100Mb/s) introduce asymmetrical forwarding delays
- ▶ **Asymmetric networks**
 - ADSL uses different data rates in the downstream and upstream directions
- ▶ **Network Element and Component Forwarding Delays**
 - Depending on network element design, forwarding delays may not be the same in the forward and reverse direction
 - Component delays (e.g. PHY devices) may not be the same in the forward and reverse direction
- ▶ **Different Cable Delays**
 - e.g. in twisted pair cables, each pair can be a different length
 - Delay skew between pairs can be as much as 50ns/100m

Routing Variances

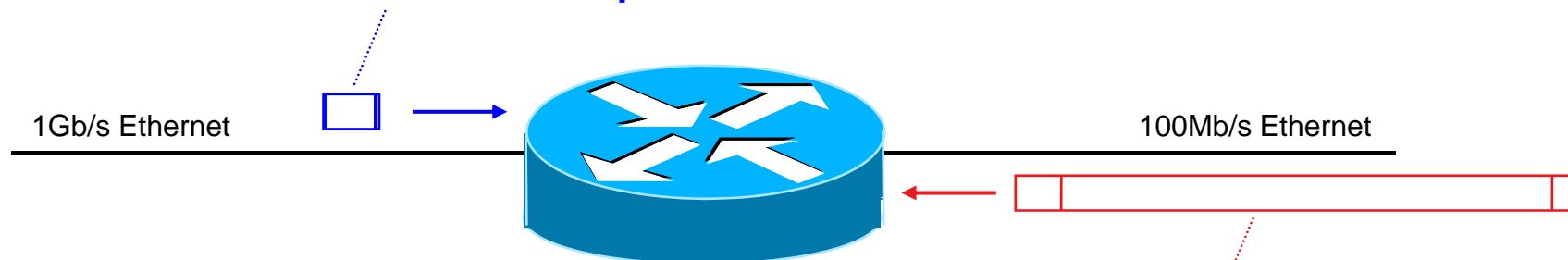


- ▶ Forward and reverse paths are routed independently in current routing protocols
- ▶ Symmetry is not part of the current considerations



- ▶ Network elements (e.g. switches, routers) generally read in the entire packet before forwarding
 - Error check not complete until last bit received
- ▶ Takes longer on a slow link than on a fast link

Read-in time of a 90 byte packet
on a 1Gb/s network = $0.72\mu\text{s}$



Read-in time of a 90 byte packet
on a 100Mb/s network = $7.2\mu\text{s}$

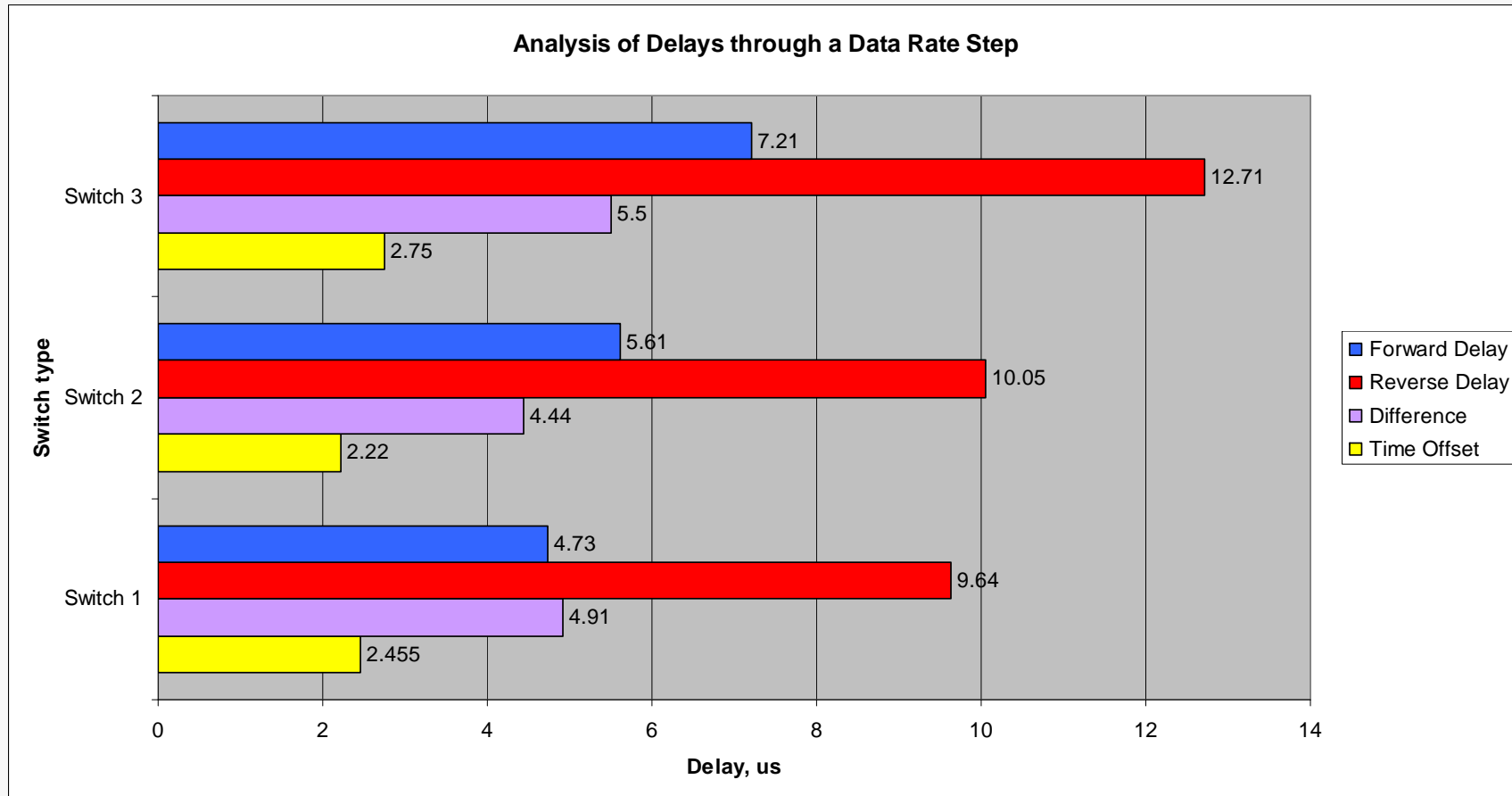
- ▶ Delay difference on step from 1Gb/s to 100Mb/s = $6.48\mu\text{s}$



Data Rate Steps



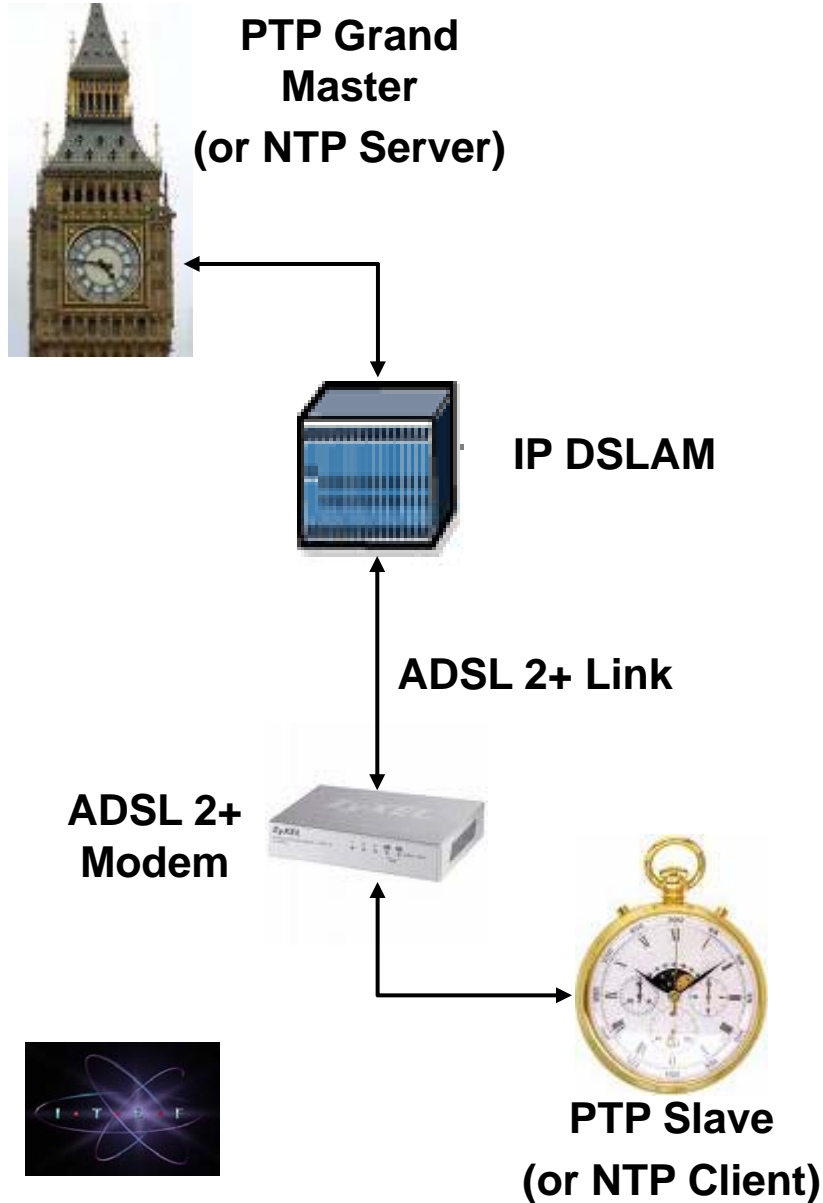
► Measured results on three different switches:



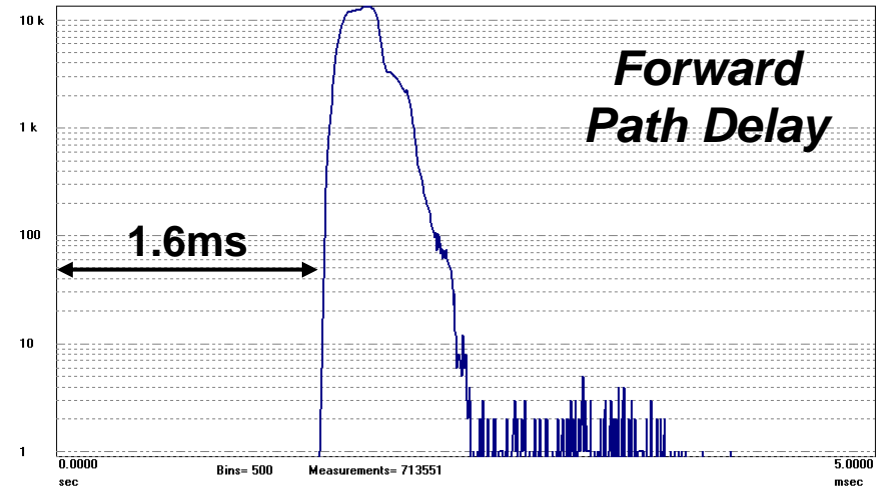
► Switches perform better than theory!

- indicates forwarding delay is not the same on the two interfaces

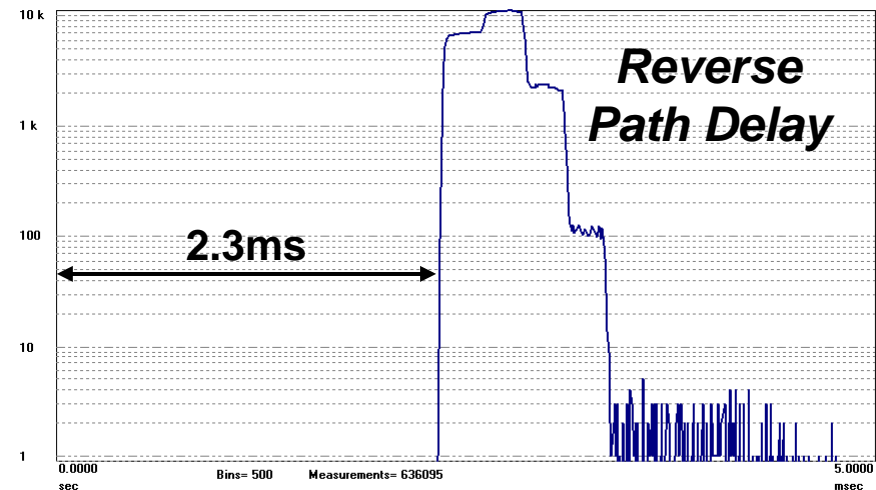
Asymmetric Networks: ADSL

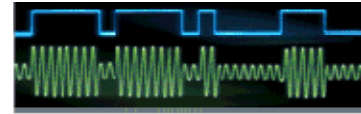
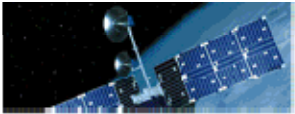
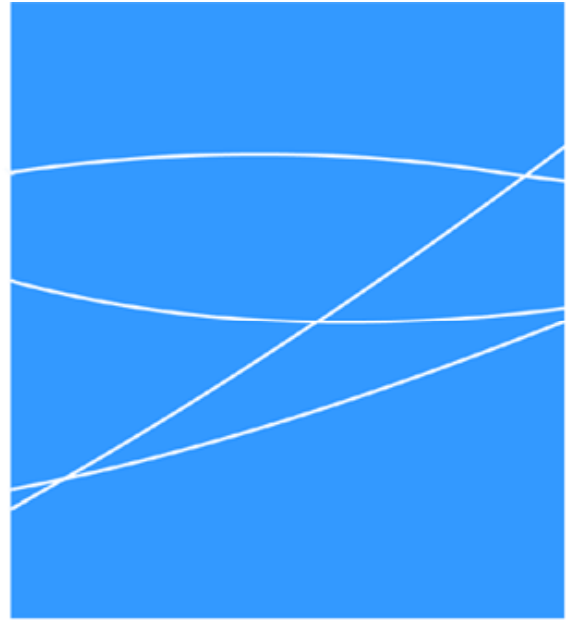
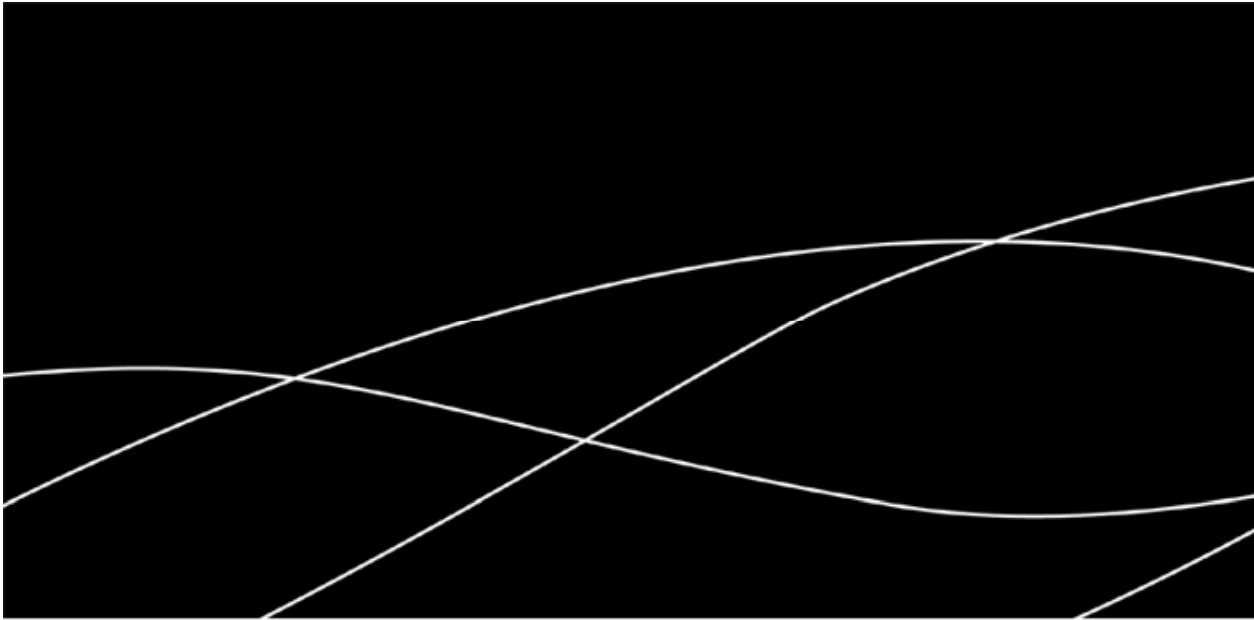


Symmetricom TimeMonitor Analyzer
Phase Deviation Histogram: Fs=71.32 Hz; Fo=10.00 MHz; 2008/10/03 18:41:06
Probe PDV Phase; Samples: 713551; UUID: 00B0AE0134B5; Initial phase offset: 1.82973 msec



Symmetricom TimeMonitor Analyzer
Phase Deviation Histogram: Fs=63.695 Hz; Fo=10.00 MHz; 2008/10/03 18:41:10
Probe PDV Phase; Samples: 636095; UUID: 00B0AE0131CB; Initial phase offset: 2.46149 msec
Reverse path delay through ADSL link





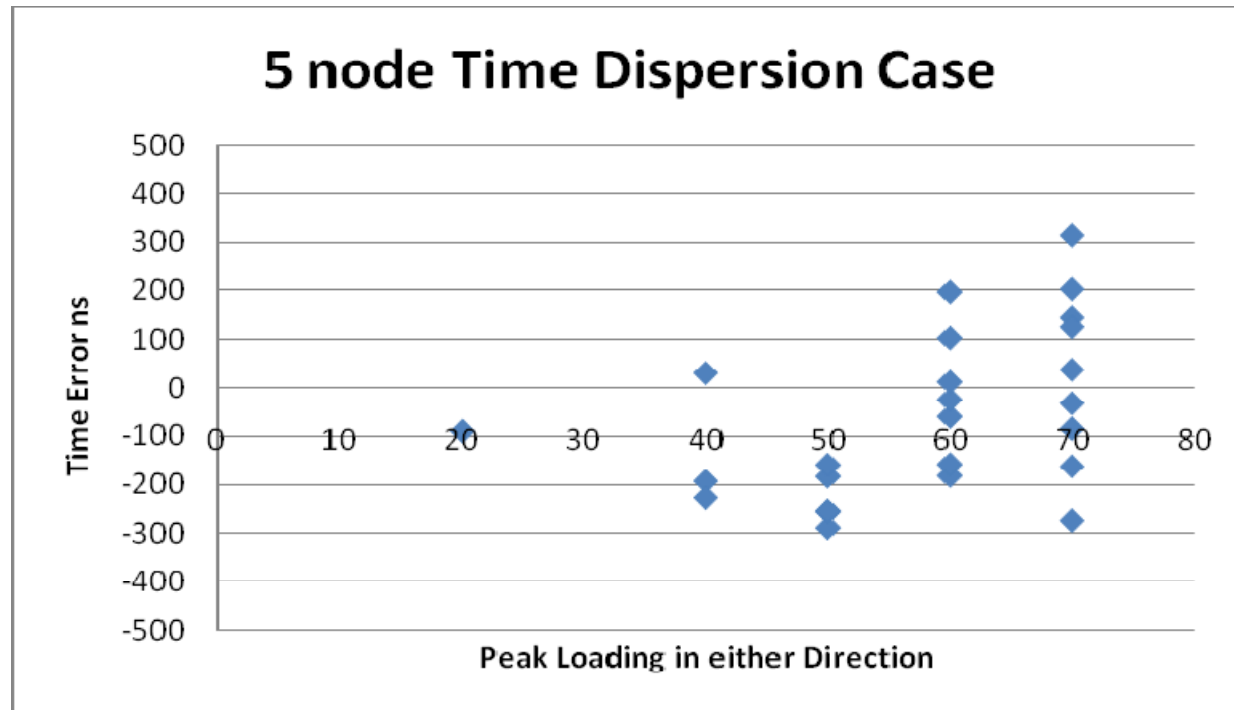
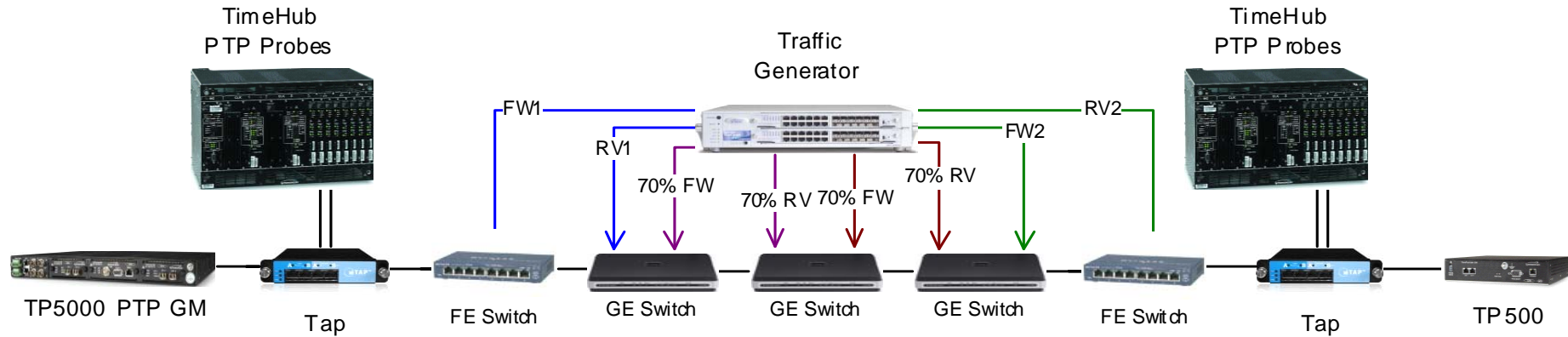
Potential Solutions



- ▶ Eliminate causes of asymmetry:
 - Avoid speed steps, or use “book-ending” (reverse step)
 - Ensure single bi-directional route
 - Avoid asymmetric physical layers (e.g. ADSL)
- ▶ Place the time server as close as possible to the client
 - e.g. in the closest point-of-presence to the destination

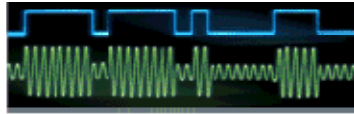
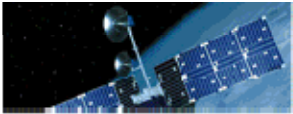
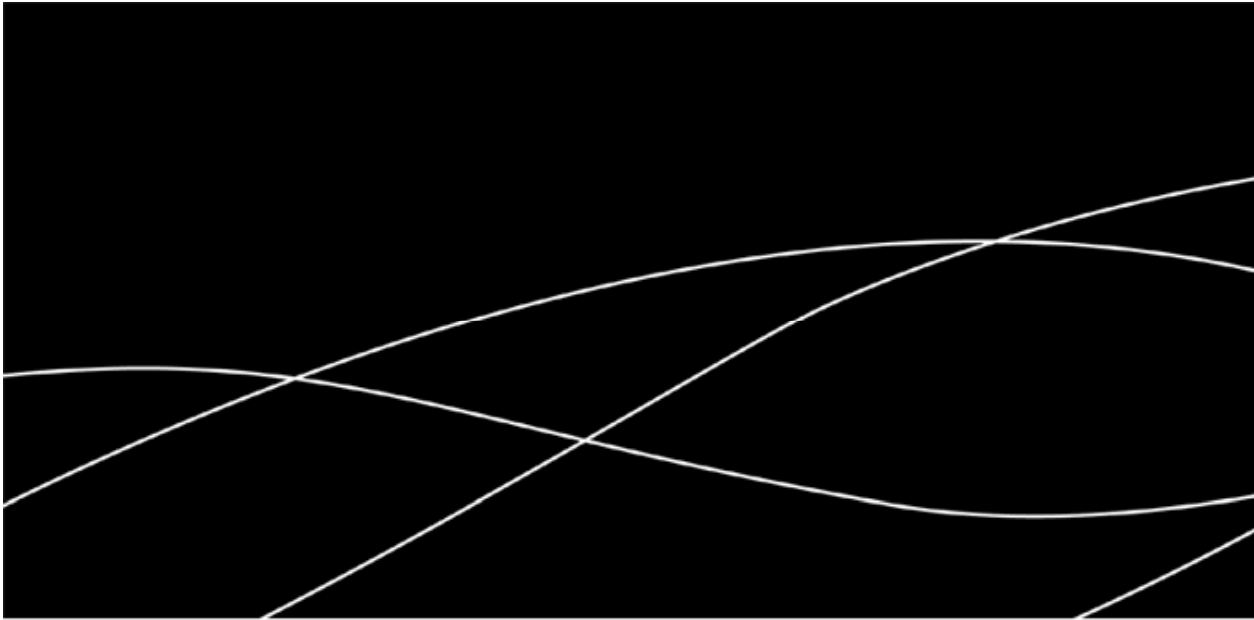


Example LAN Performance



- ▶ On-path support
 - Use of transparent clocks to calibrate path delay
 - Use of strategically located boundary clocks
- ▶ Standards-based advances
 - Define new routing protocols to deliver symmetrical paths, or transparent clock paths (e.g. in IETF TICTOC group¹)
 - PTP Profiles and Packet Network limits (e.g. in ITU)
- ▶ Explicit knowledge
 - “dial in” known asymmetry into the algorithm (e.g. differential delay for ADSL)
- ▶ Implicit knowledge
 - Inferences from observing other packets (e.g. RTP packets)

¹ draft-stein-tictoc-modules-03.txt (IETF, November 2008)

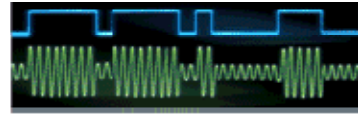
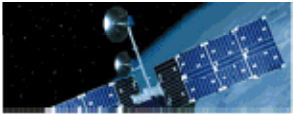
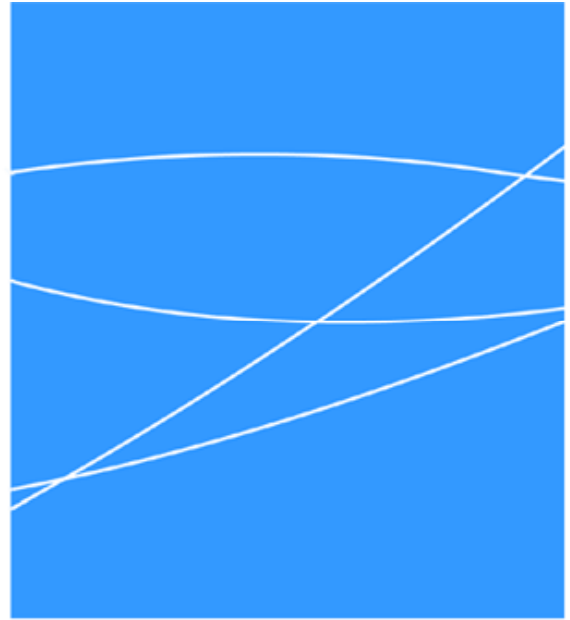
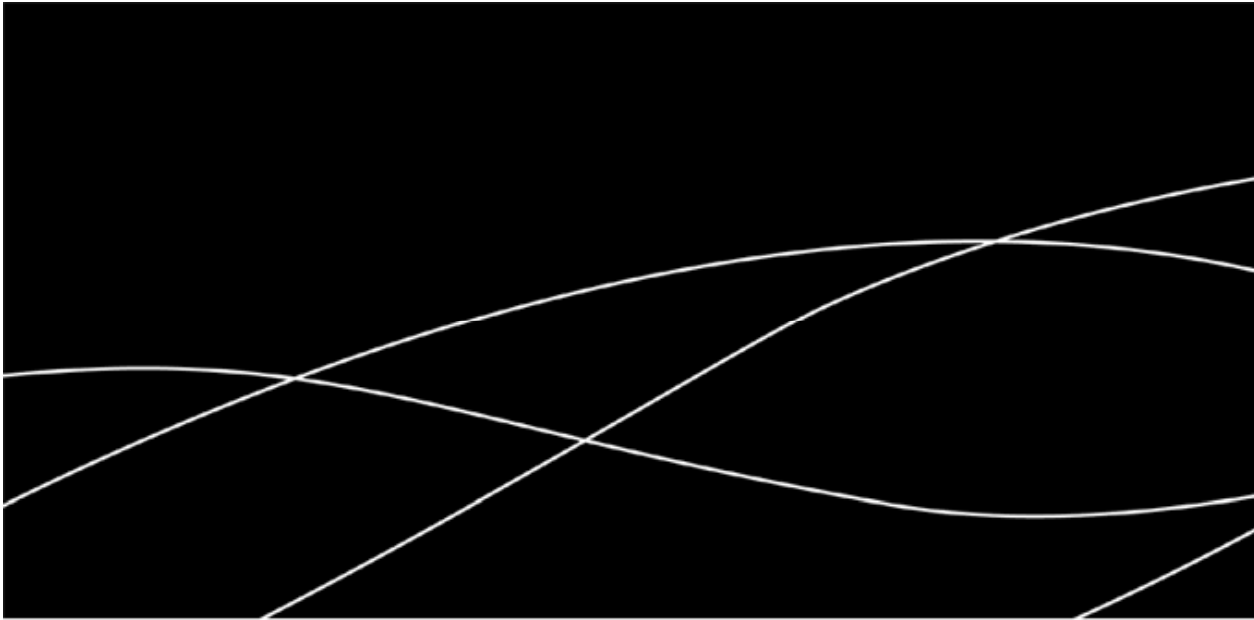


Conclusions



- ▶ Time is harder than frequency!
- ▶ Accurate time over a LAN or a controlled Metro Ethernet environment is feasible
- ▶ Over more general networks, several challenges remain to be solved
- ▶ Solutions will need to consider a combination of approaches to deliver accurate time
- ▶ Explicit network knowledge may be required





Thank you for listening!



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