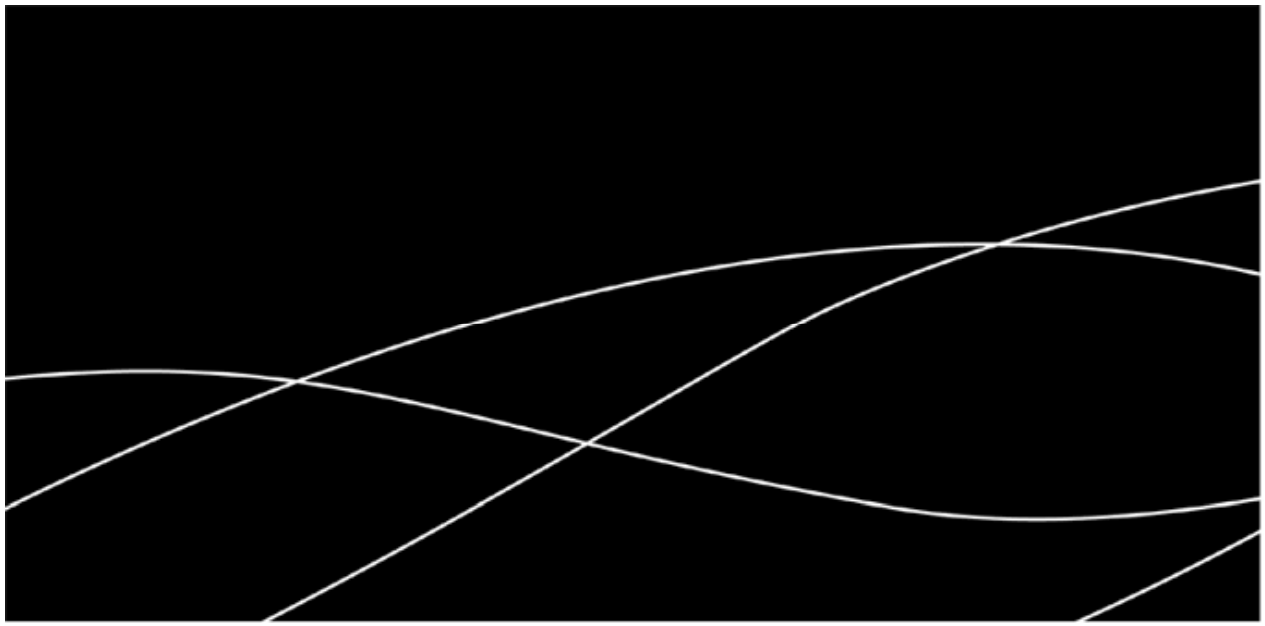

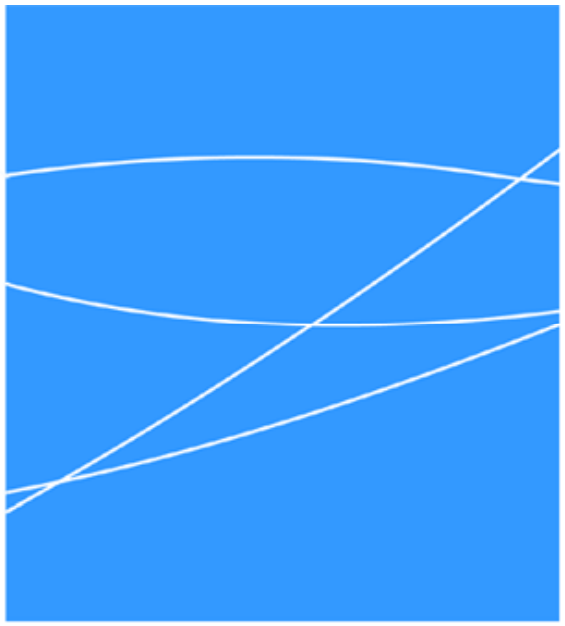

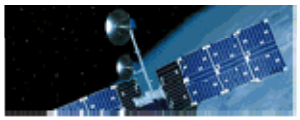

The Distribution of Precise Time over Packet Networks

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ITSF 2008

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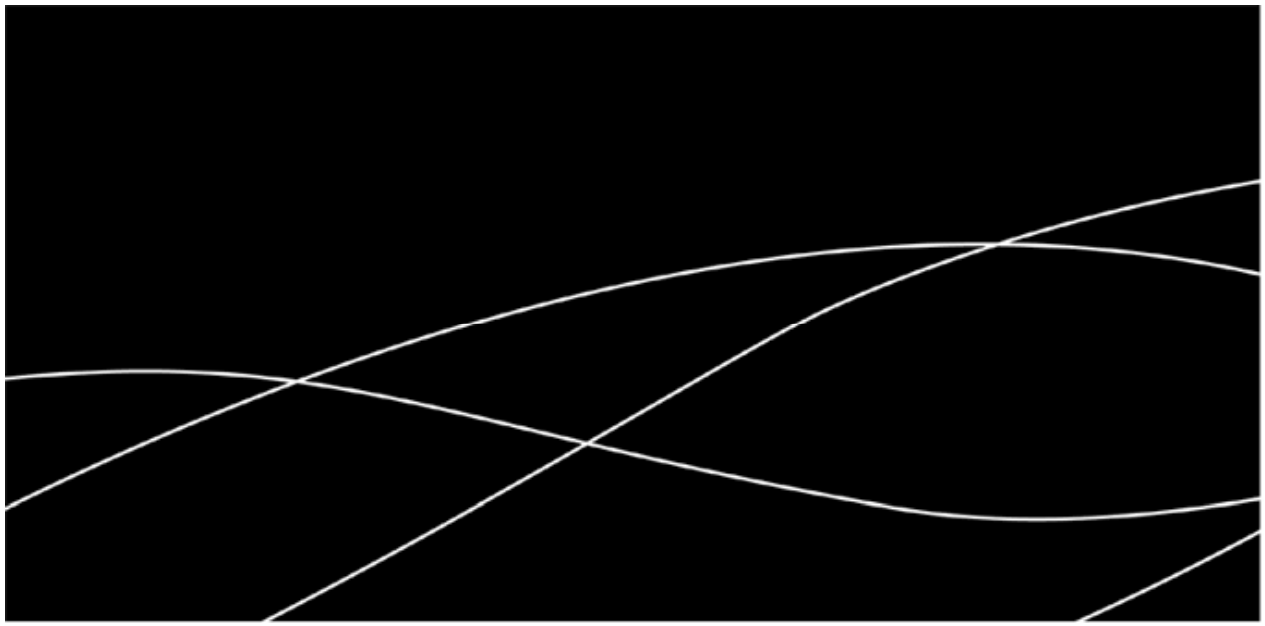
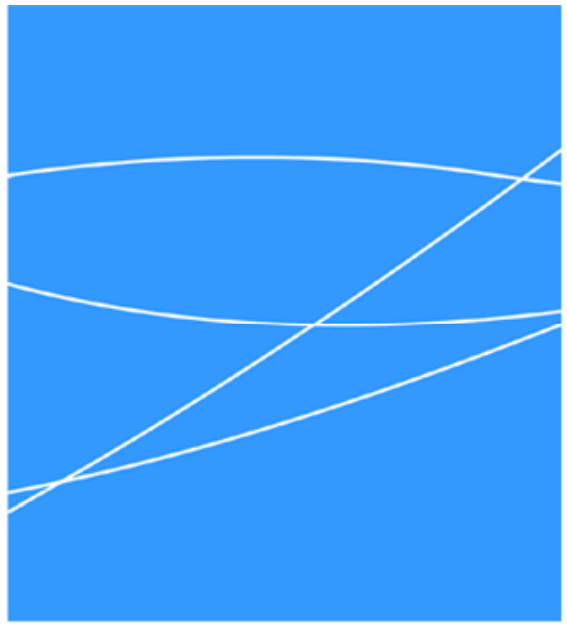
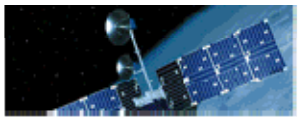
Contents

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







Applications

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Timing to cellular basestations

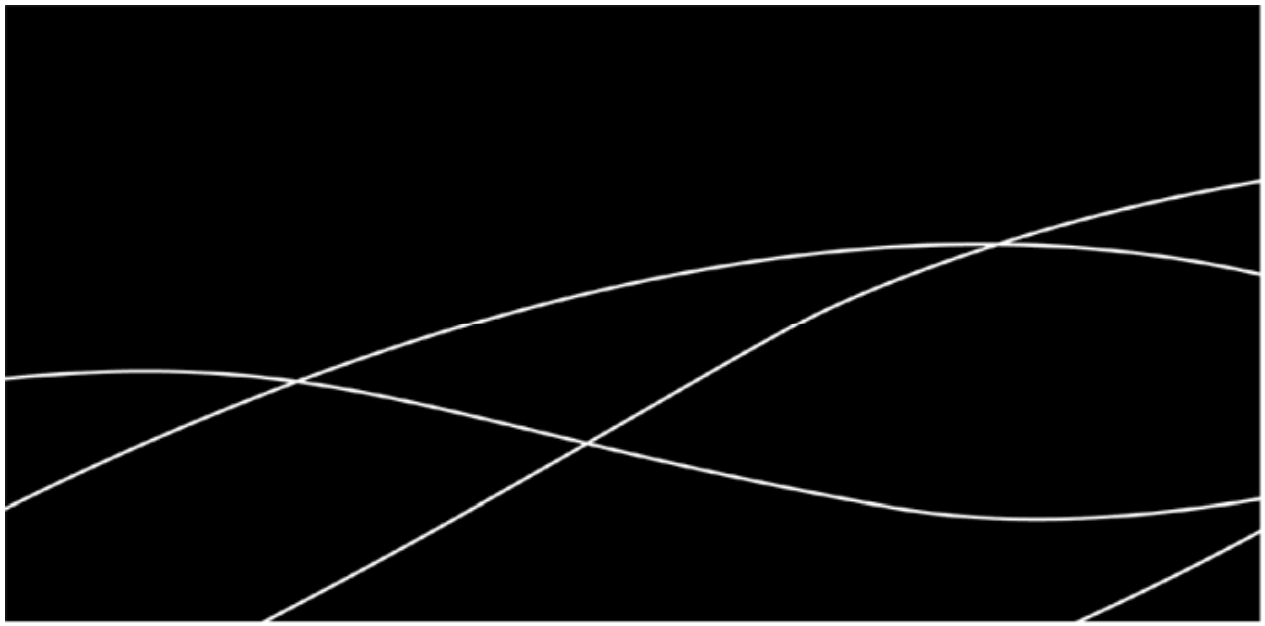
Application	Time/Phase Synchronization Requirement
GSM, UMTS-FDD	Fractional frequency accuracy requirement only (50 ppb)
UMTS-TDD	Phase alignment between basestations within ± 2.5µs
UMTS LTE	Not yet specified; likely to be around ± 5µs for MBMS
Mobile WiMAX	Phase alignment between basestations within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

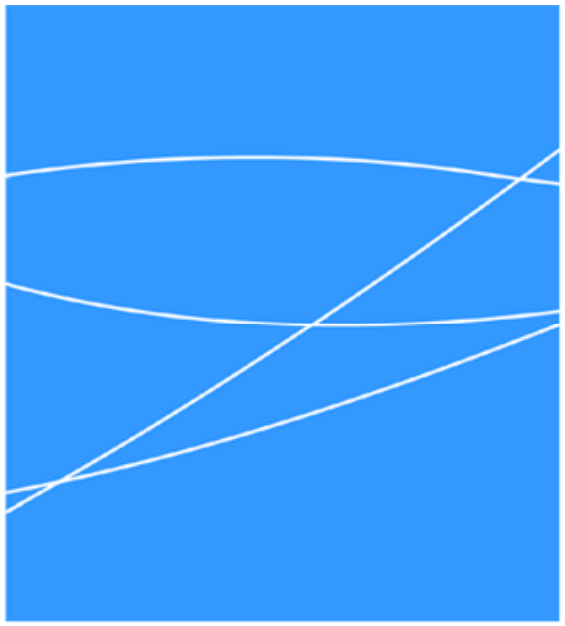
Other Applications

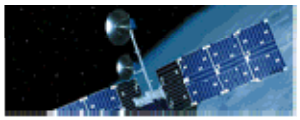
Application	Time/Phase Synchronization Requirement
Power Phase measurement	Time accuracy of < 1µs [1]
Printing industry	Phase alignment between operations within ± 1µs [1]
Audio/Visual	Phase alignment of audio/visual devices within ± 100ns [2]
Network SLA measurement	Time accuracy to be determined
Sensor Networks	Time accuracy to be determined

[1] draft-rodrigues-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

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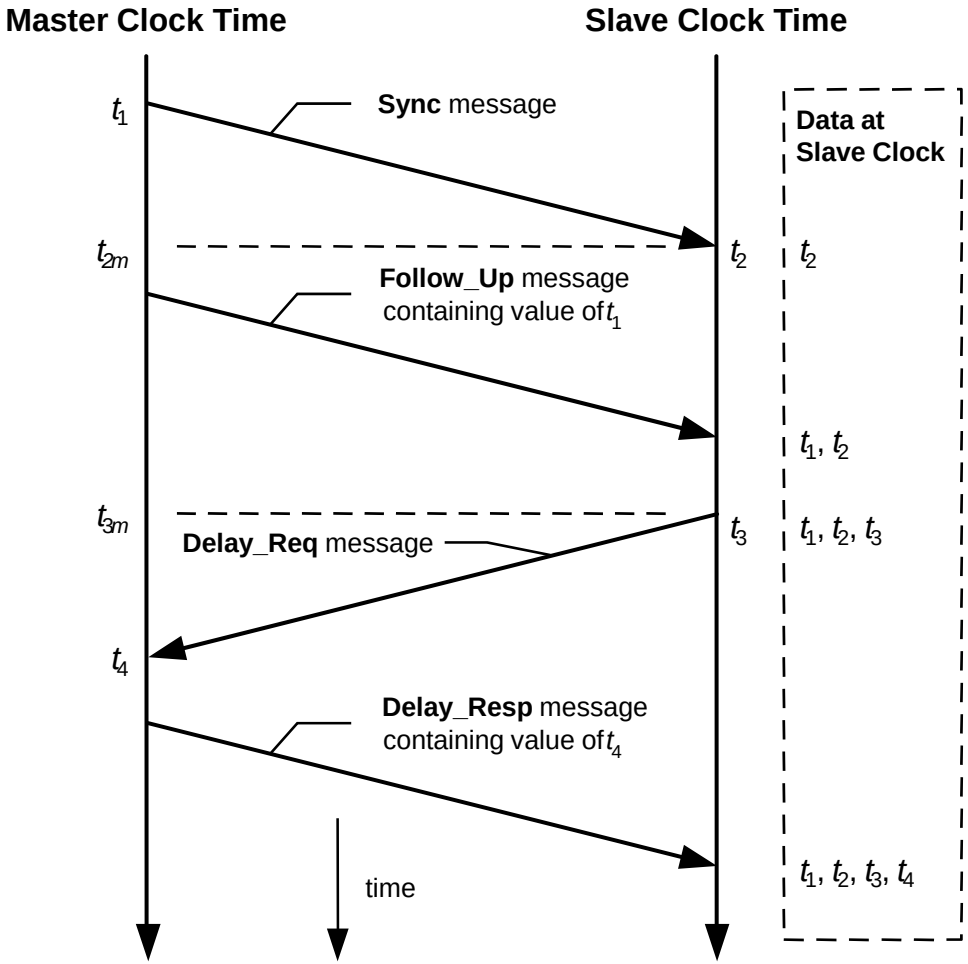
Asymmetry



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)

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

PTP Transaction shown, but same principle applies to NTP

Causes of Asymmetry

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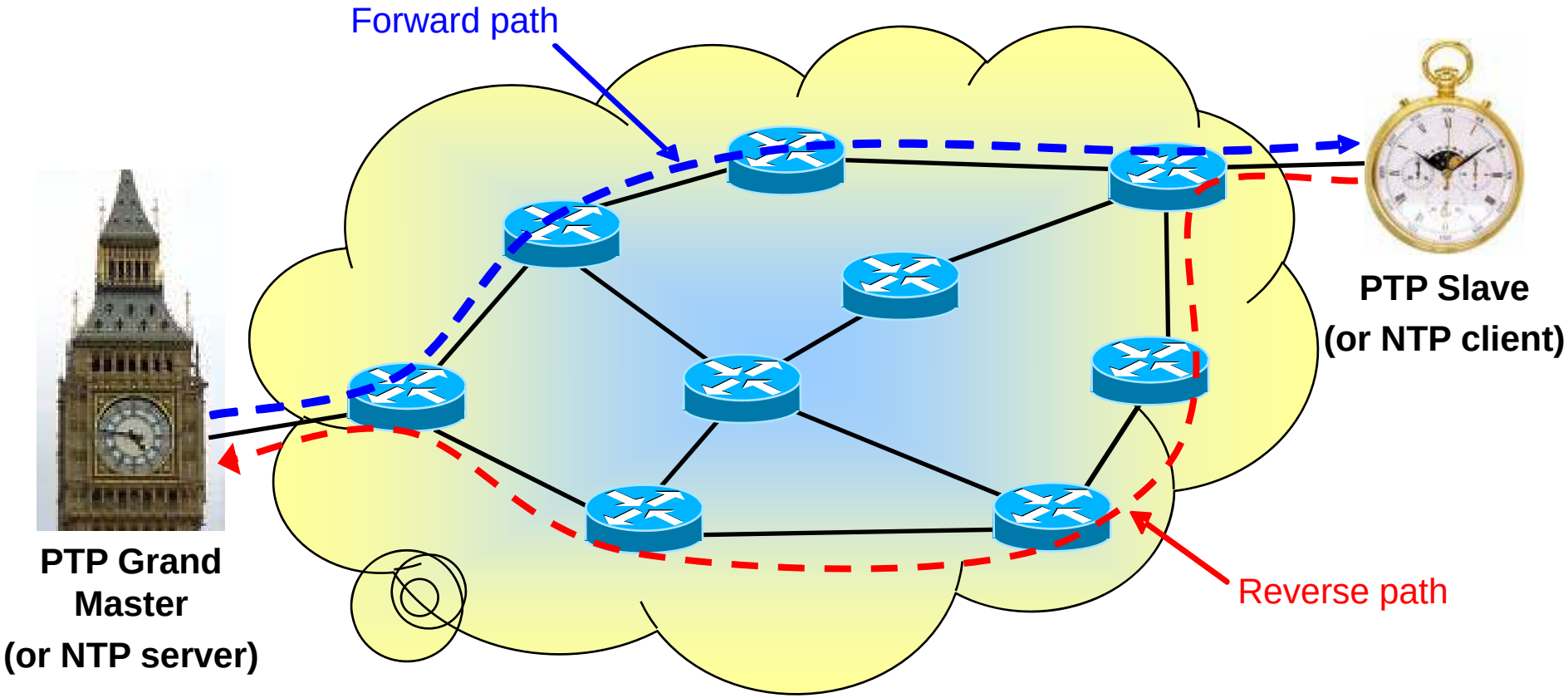
- Routing Variances
  - In a routed network, the forward and reverse paths may not necessarily take the same route
- Data Rate Steps
  - Data rate changes (e.g. from 1Gb/s to 100Mb/s) introduce asymmetrical forwarding delays
- Asymmetric networks
  - ADSL uses different data rates in the downstream and 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

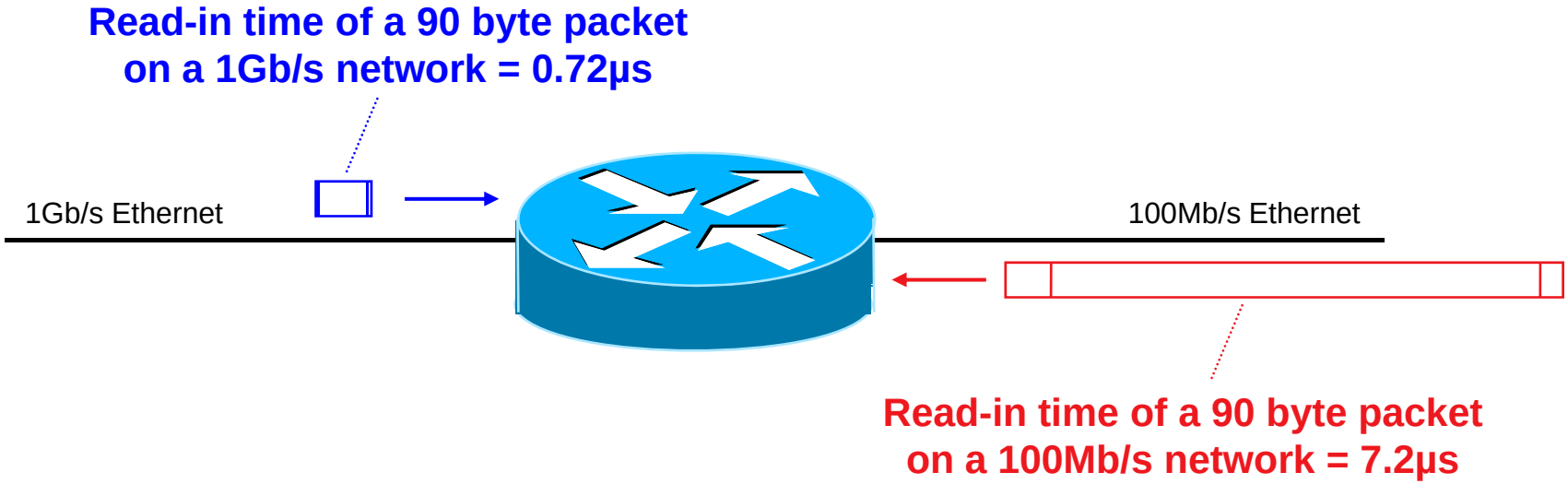
Routing Variances



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

Data Rate Steps

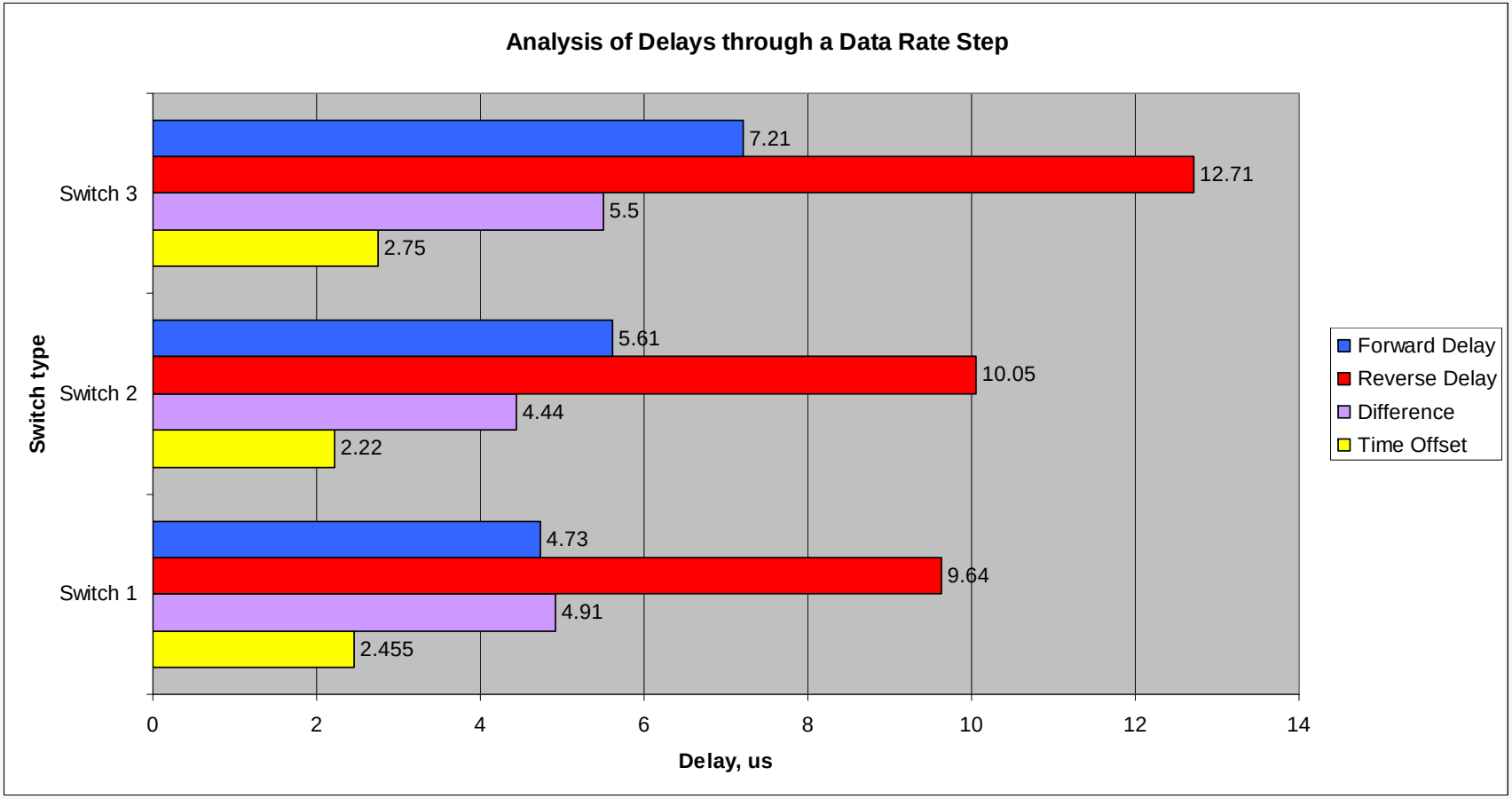
- Network elements (e.g. switches, routers) generally read in the entire packet before forwarding
  - Error check not complete until last bit received
- Takes longer on a slow link than on a fast link



- Delay difference on step from 1Gb/s to 100Mb/s = 6.48µs

Data Rate Steps

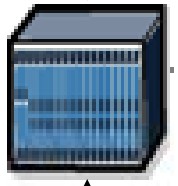
- Measured results on three different switches:



- Switches perform better than theory!
  - indicates forwarding delay is not the same on the two interfaces

Asymmetric Networks: ADSL

PTP Grand Master (or NTP Server)

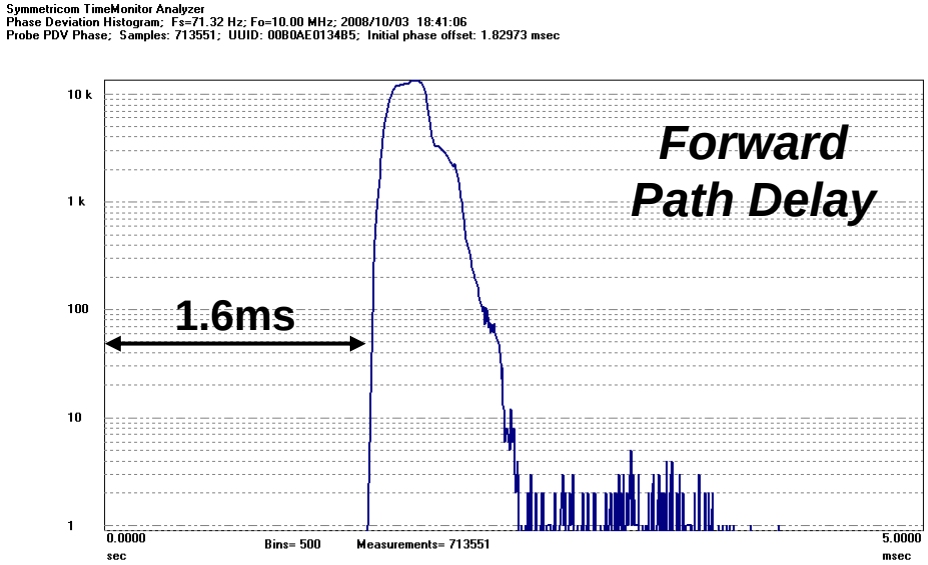


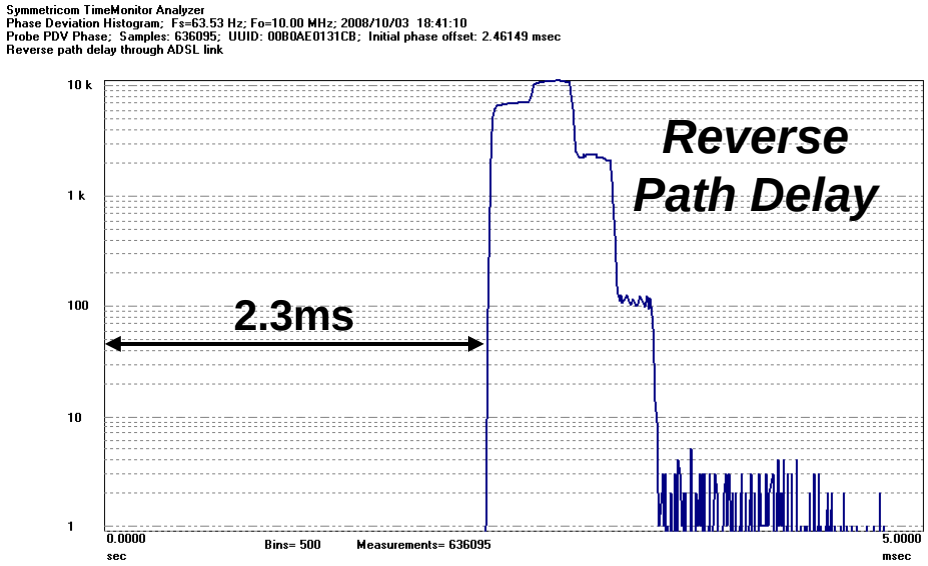
IP DSLAM

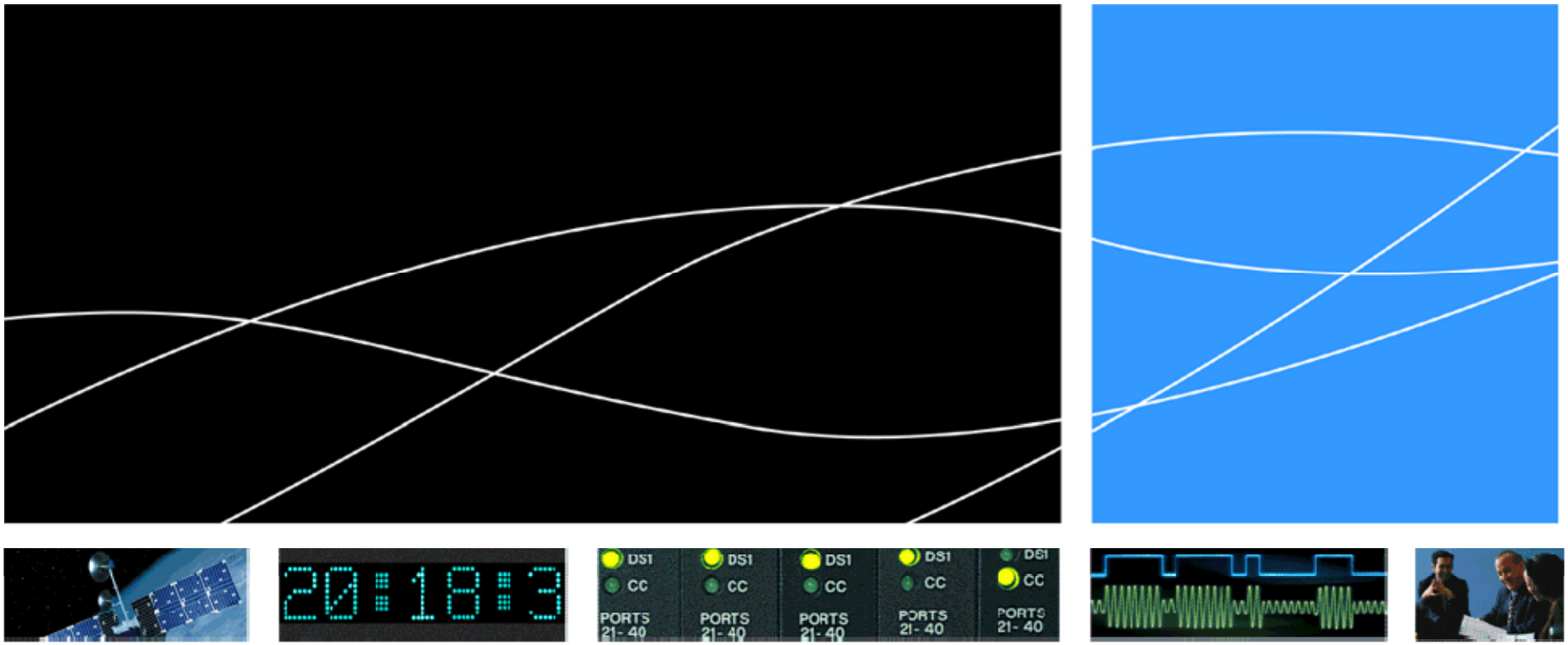
ADSL 2+ Link

ADSL 2+ Modem

PTP Slave (or NTP Client)







Potential Solutions

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Engineer the network

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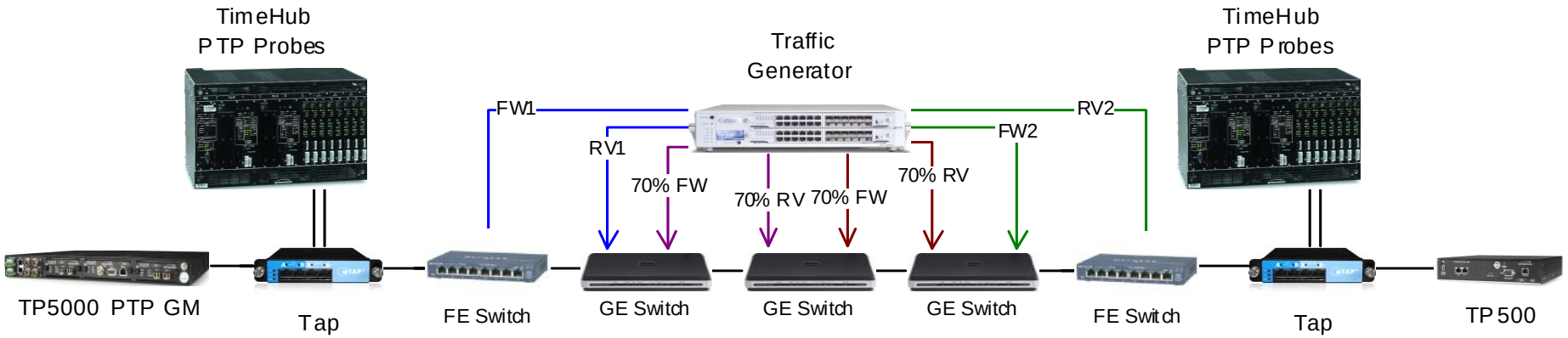
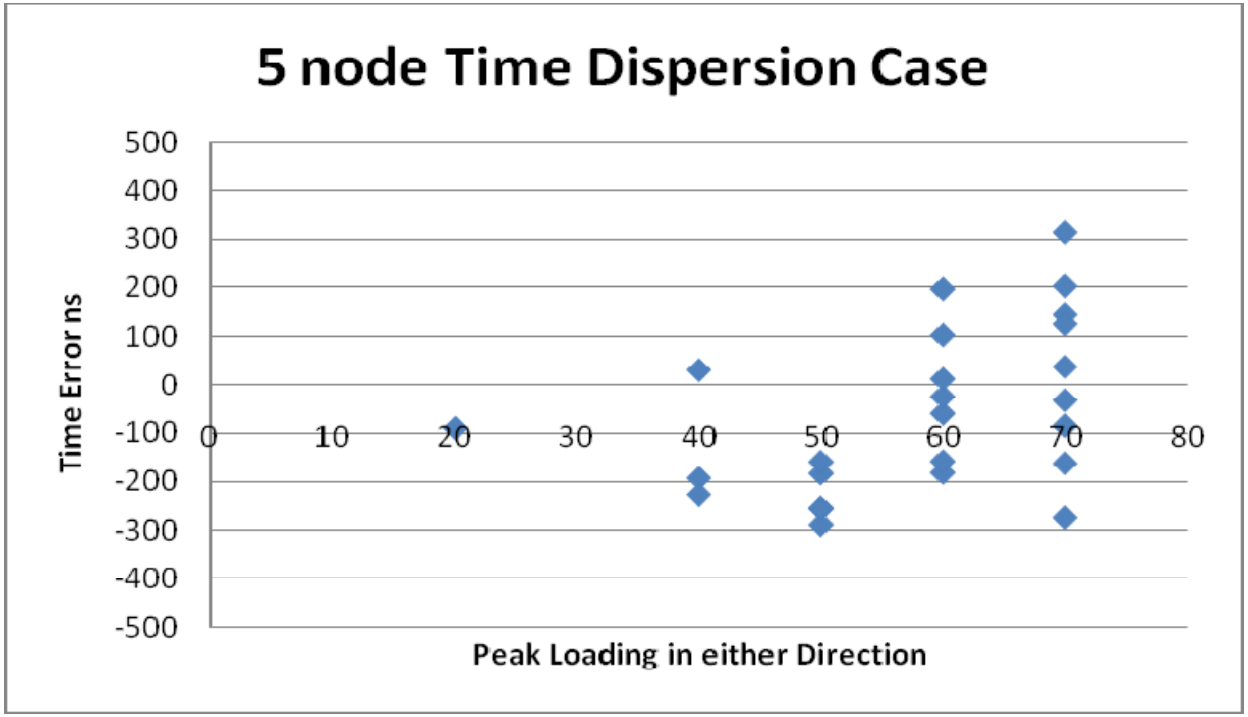
- Eliminate causes of asymmetry:
  - Avoid speed steps, or use “book-ending” (reverse step)
  - Ensure single bi-directional route
  - Avoid asymmetric physical layers (e.g. ADSL)
- Place the time server as close as possible to the client
  - e.g. in the closest point-of-presence to the destination

Example LAN Performance





Other Potential Solutions

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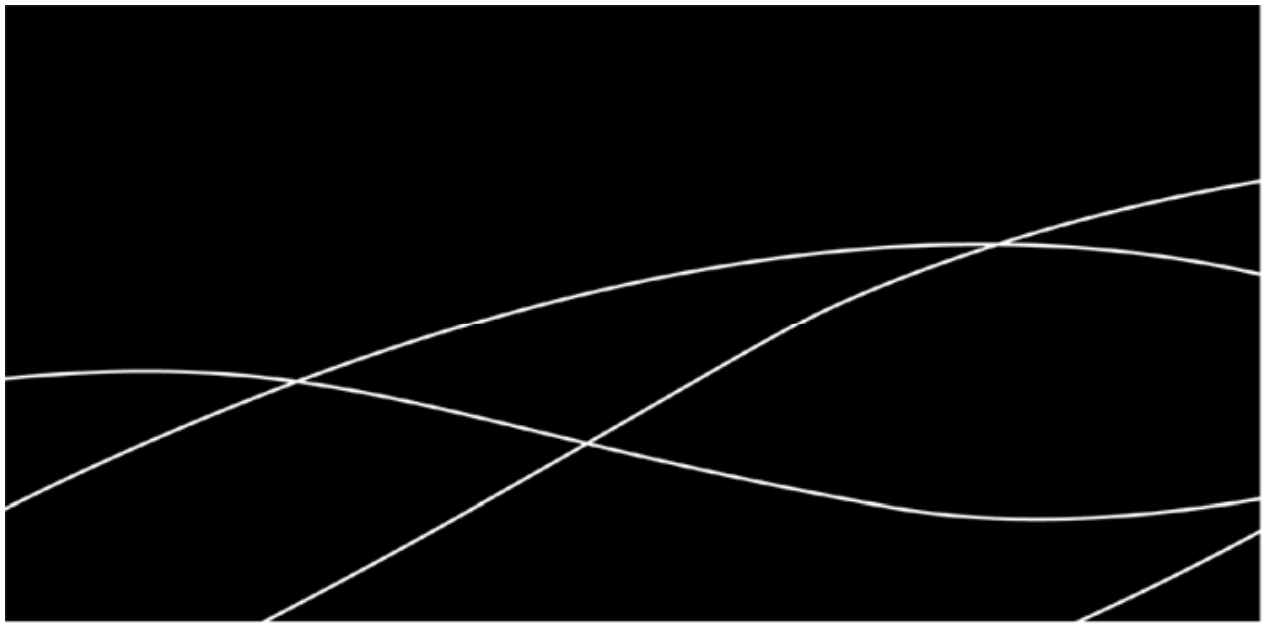
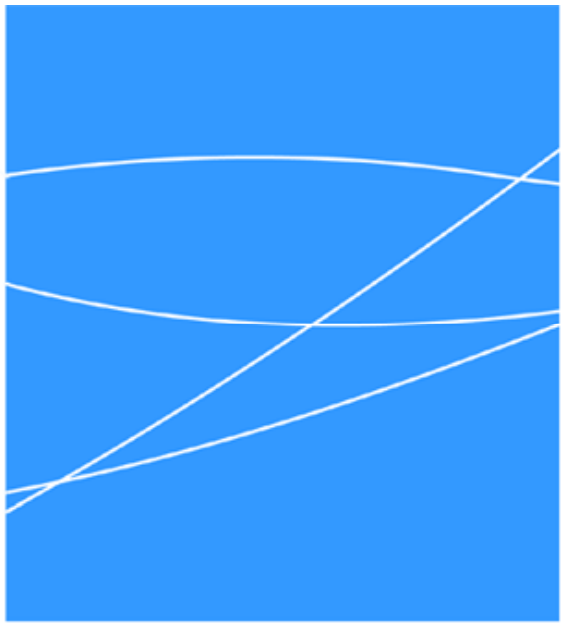
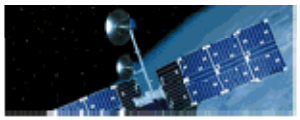
- On-path support
  - Use of transparent clocks to calibrate path delay
  - Use of strategically located boundary clocks
- Standards-based advances
  - Define new routing protocols to deliver symmetrical paths, or transparent clock paths (e.g. in IETF TICTOC group[1])
  - PTP Profiles and Packet Network 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

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Conclusions

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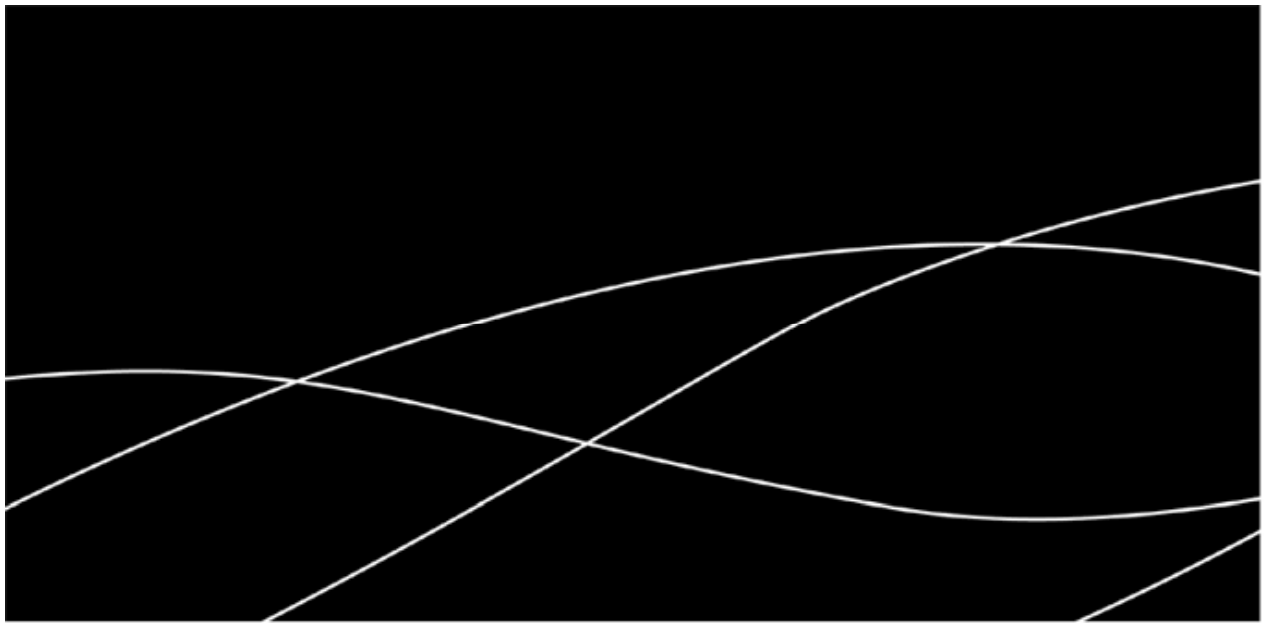
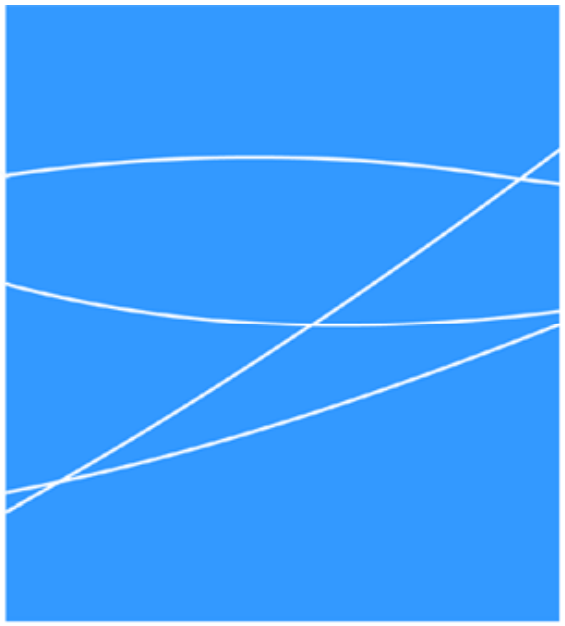
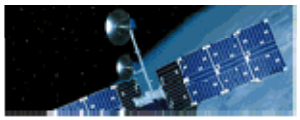
- Time is harder than frequency!
- Accurate time over a LAN or a controlled Metro Ethernet environment is feasible
- Over more general networks, several challenges remain to be solved
- Solutions will need to consider a combination of approaches to deliver accurate time
- Explicit network knowledge may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



Thank you for listening!

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