
# Synchronization of Television, Audio and Moving Pictures in a Digital Age

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# Contents

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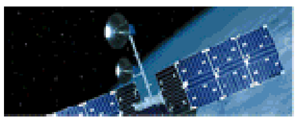
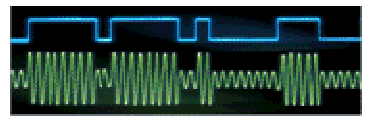
- Synchronization Requirements in a Digital TV Studio
- SMPTE/EBU Task Force Proposal
- Network Asymmetry and Time Distribution
- Achievable Performance
- Conclusions and Deployment Recommendations







# Synchronization Requirements in a Digital TV Studio

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# Existing Synchronization Solution

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- Synchronization split into two parts:
  - ***Time labelling*** – identifying and aligning media excerpts for editing and post-production
  - ***Signal alignment*** – for seamless video and audio mixing
- Time Labelling
  - Current solution is defined in SMPTE 12M timecode (30 years old)
  - Identifies individual frames
  - Doesn't support frame rates greater than 30Hz
  - Doesn't align well with other media (e.g. audio)
  - Only supports 24 hours of continuous operation
- Signal Alignment
  - Primarily based on a "black-burst" stream – a video stream containing solely the colour black
  - Supports alignment of analogue composite video to within 0.5ns, necessary to align phase of colour sub-carrier
  - Requires dedicated cabling infrastructure and careful equalization to achieve the required performance

# SMPTE/EBU Task Force

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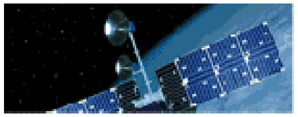
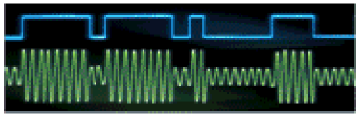
- SMPTE and EBU created a joint task force to design a new synchronization/labelling scheme for a digital studio
- Accuracy requirements:

| | |
|---|---|
| Timing accuracy (jitter and wander) between any two slave devices | ±1μs (±0.1μs preferred) |
| Frequency accuracy | ±0.225ppm |
| Frequency drift | ±0.0226ppm/s |

- Other goals:
  - Includes sufficient information to allow generation of any current (and future) video and audio signal, synchronized to the reference
  - Provides time-of-day and date information, including indication of local timezone and daylight savings time
  - Runs over the existing Ethernet network interface (i.e. no new cabling infrastructure required)
  - Slave implementation as simple and cheap as possible
  - Time/frequency acquisition to be within a few seconds




# Task Force Proposal

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# Schematic

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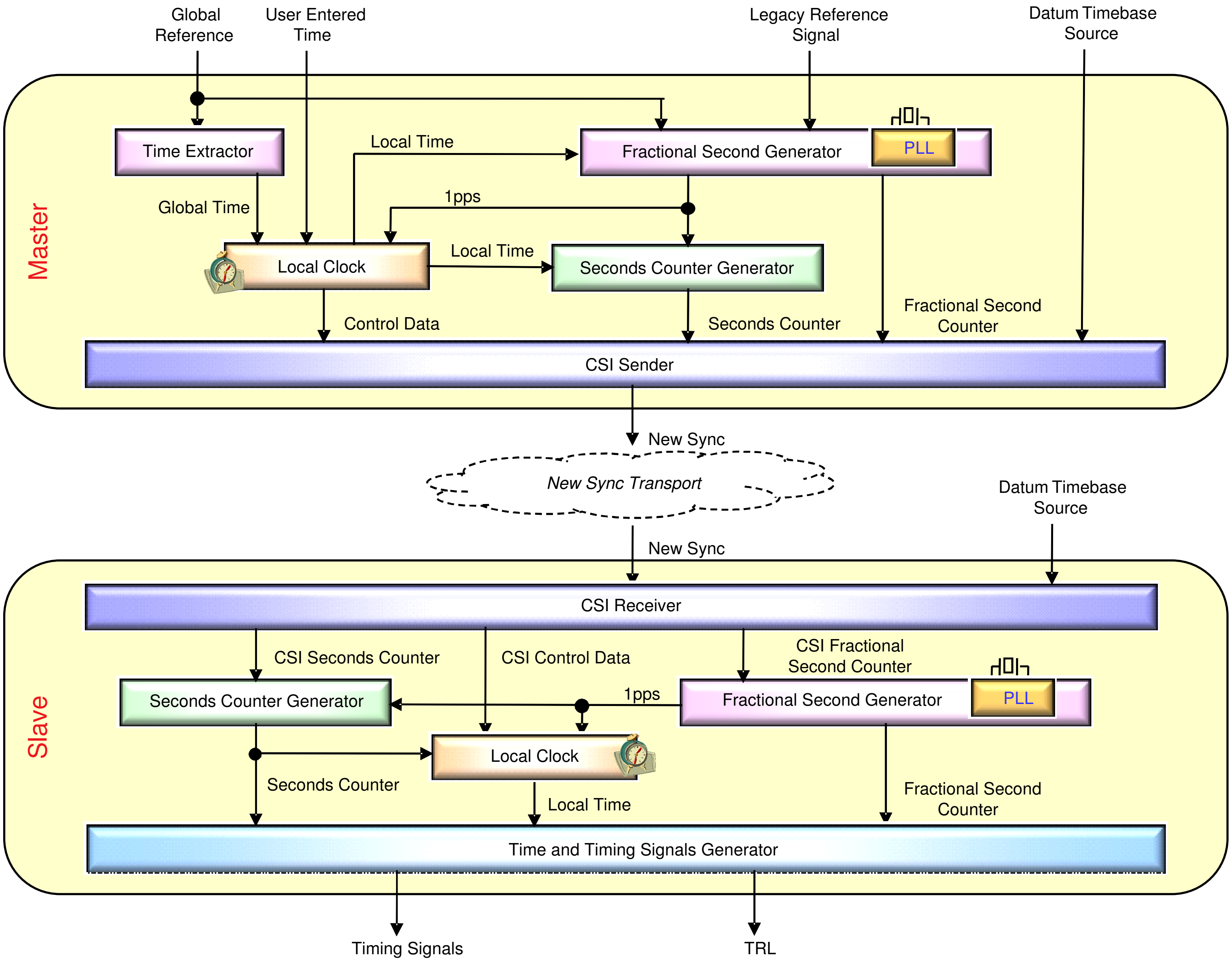

# Common Synchronization Interface

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- A common set of information, allowing:
  - Simple reconstruction of video and audio signals
  - Creation of acquisition timestamps for labelling
- Based on an "epoch", when all video and audio signals are deemed to have zero phase
- Includes:
  - Time since epoch (seconds and fractional seconds), allowing signals to be created with correct phase
  - Control data, e.g. flags, version, lock status, datum type
  - Leap seconds, timezone and DST information

# Datum Reference

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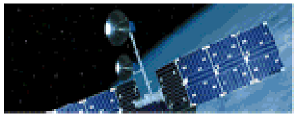
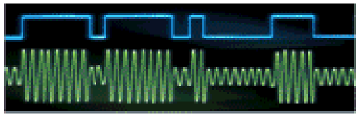
- CSI data is de-coupled from Datum reference
  - CSI is valid at a given datum point
    - Type 0: next second boundary of network time reference
    - Type 1: specified future time given by network time reference
    - Type 2: defined reference point in a black-burst reference signal
  - Not necessarily locked to time reference
  - Allows locking to legacy, free-running video references
  - Allows distribution of multiple independent references around the studio
- Datum reference is distributed independently to the CSI
  - Recommendation is to use IEEE1588 over the Ethernet control network, although other methods are allowed
  - Use of IEEE1588 means both datum and CSI can be distributed over same network infrastructure







# Network Asymmetry and Time Distribution

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# Reminder: Asymmetry

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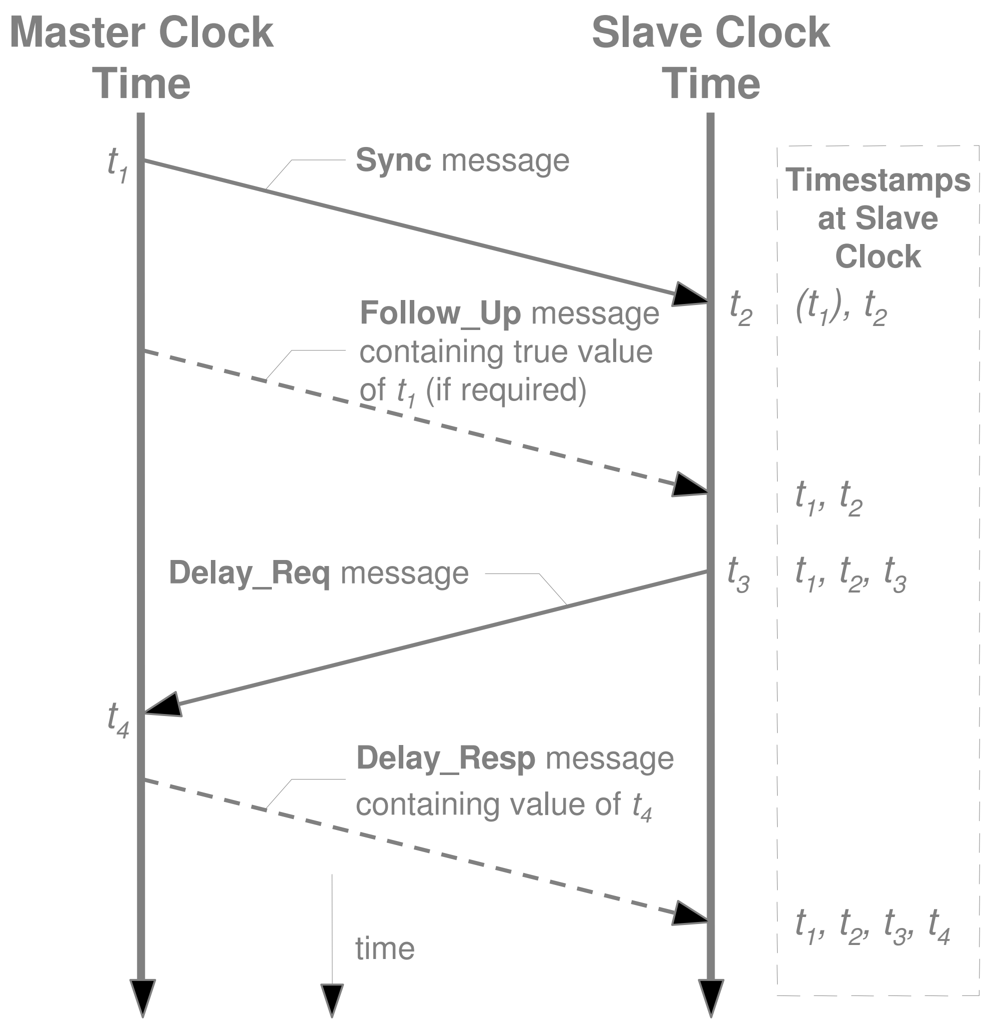


- Master frequency determined by comparison of timestamps
  - e.g. comparison of $t_1$ to $t_2$ over multiple ***sync*** messages, or $t_3$ to $t_4$ in ***delay_req*** messages
- Time offset calculation requires all four timestamps:
  - Slave time offset = $\frac{(t_2 - t_1) - (t_4 - t_3)}{2}$
  - assumes symmetrical delays *(i.e. the forward path delay is equal to the reverse path delay)*
- **Accurate time depends on a symmetrical network**
- **Time error =** $\frac{\textbf{fwd. delay} - \textbf{rev. delay}}{2}$

# Routing Variances

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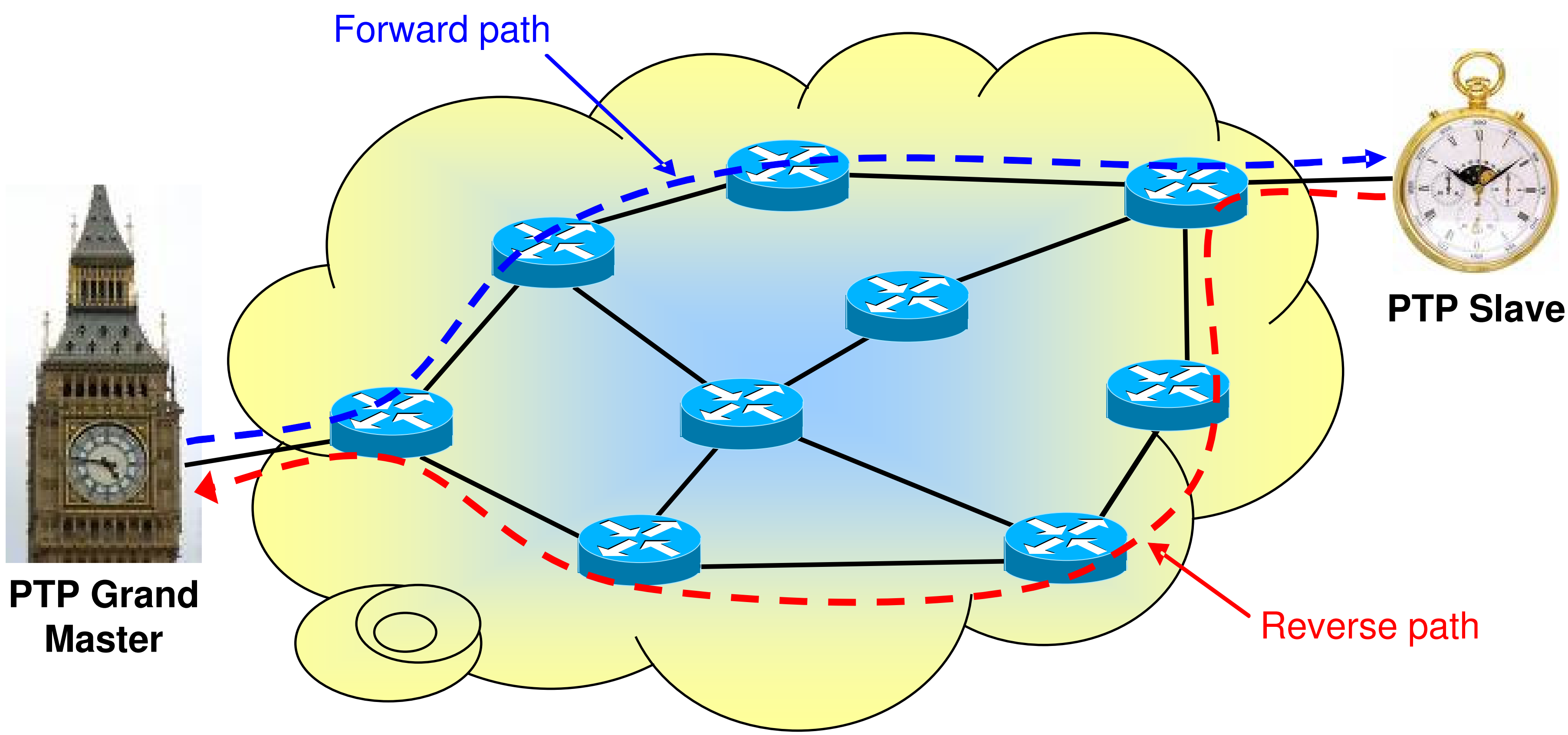
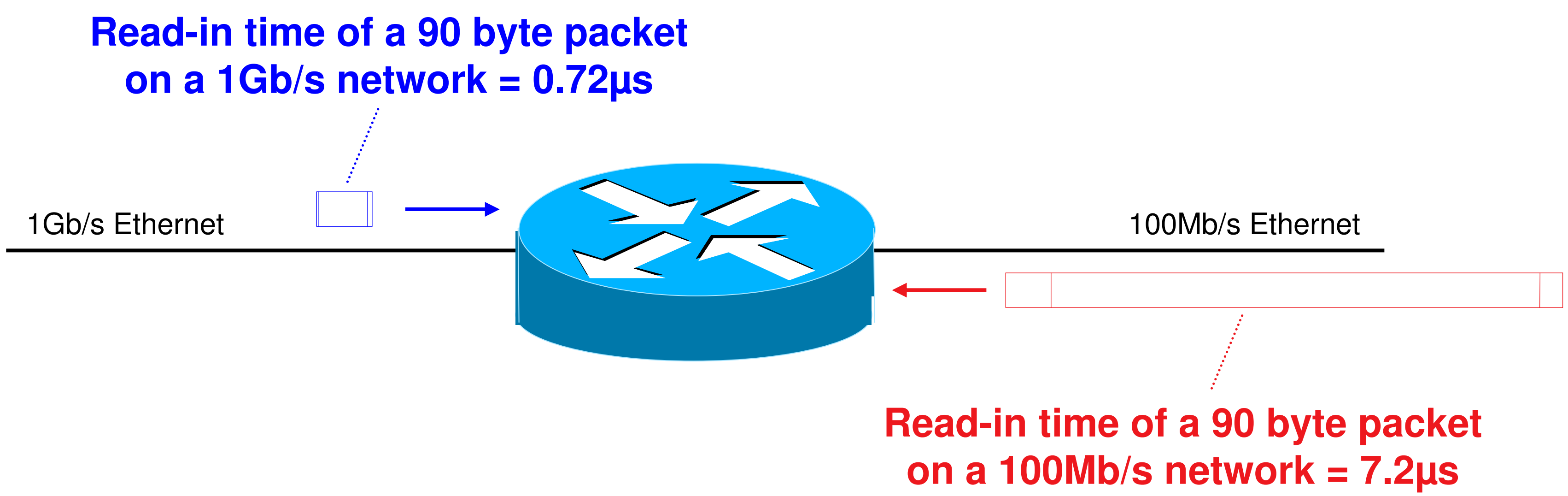



- Forward and reverse paths are routed independently in IP routing protocols, potentially causing asymmetry
- Potential for asymmetry worse in larger networks
- Use managed networks with symmetrical paths

# Data Rate Steps

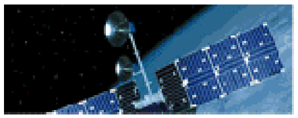
- Network elements (e.g. switches, routers) generally read in the entire packet before forwarding
  - Error check not complete until last bit received
- Takes longer on a slow link than on a fast link

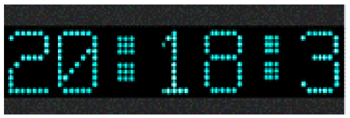



- Delay difference on step from 1Gb/s to 100Mb/s = 6.48µs
- Avoid data rate steps where possible, or explicitly correct for known data rate steps

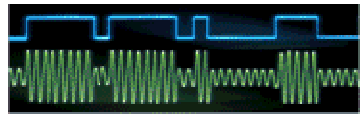
# Link Asymmetry

- Asymmetric link technology
  - e.g. xDSL, GPON, WiFi
  - Downstream delay usually shorter than upstream delay
- PHY Layer Component Forwarding Delays
  - Component delays (e.g. PHY devices) may not be the same in the forward and reverse direction
  - This may be true particularly in cases where equipment or components come from different vendors
- Differential Cable Delays
  - In twisted pair cables, each pair can be a different length
  - Delay skew between pairs can be as much as 50ns/100m
  - Use matched cables for controlled delay skew
- Asymmetric link delays are not solved by peer-to-peer transparent clocks









# Achievable Performance

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# Test Network Diagram

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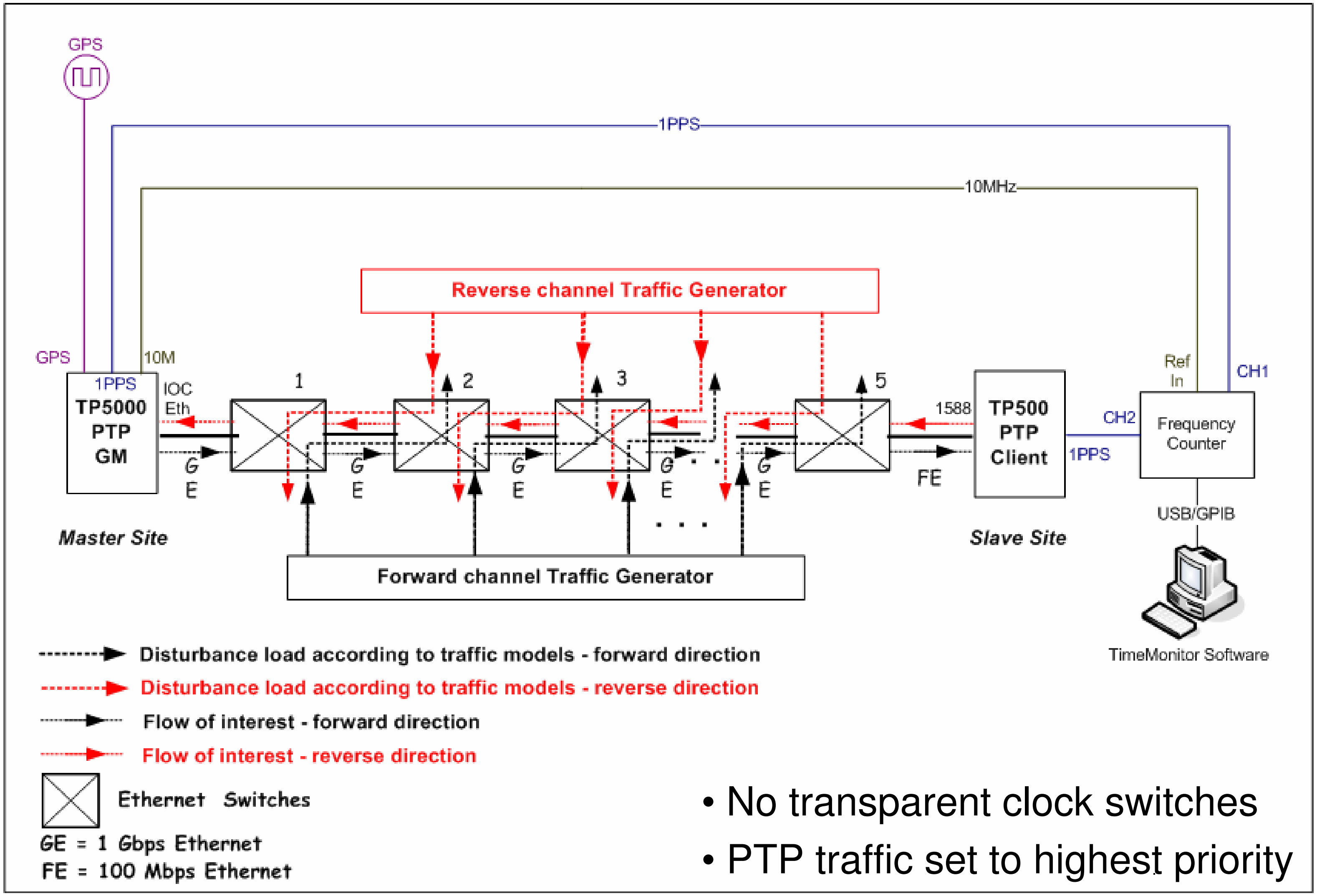


- No transparent clock switches
- PTP traffic set to highest priority

# Baseline Test: ITU-T G.8261 Test Case 13 Test Description Continued

| Total FW Load | Forward 64B | Forward 1518B | Forward 576B |
|---|---|---|---|
| 80% | 24% | 48% | 8% |
| 20% | 6% | 12% | 2% |

| Total RV Load | Reverse 64B | Reverse 1518B | Reverse 576B |
|---|---|---|---|
| 50% | 15% | 30% | 5% |
| 10% | 3% | 6% | 1% |

**Table - Individual Flow Rate for Disturbance Traffic on Forward and Reverse direction**

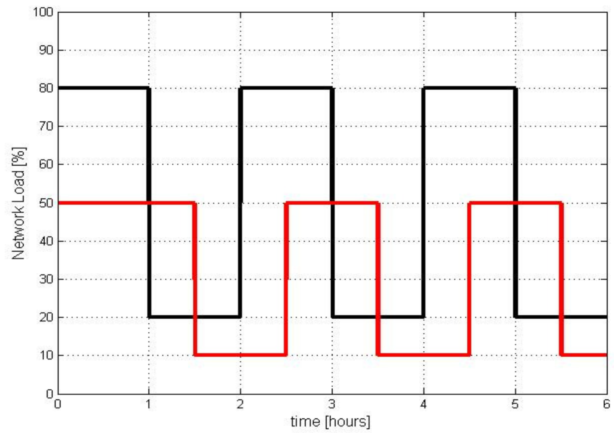


**Figure VI.11/G.8261 - Sudden Network disturbance load Modulation for 2-way**

- Measurement:
  - Compare phase error between 1pps output of slave, and 1pps output of master

# Test Results: Phase Deviation

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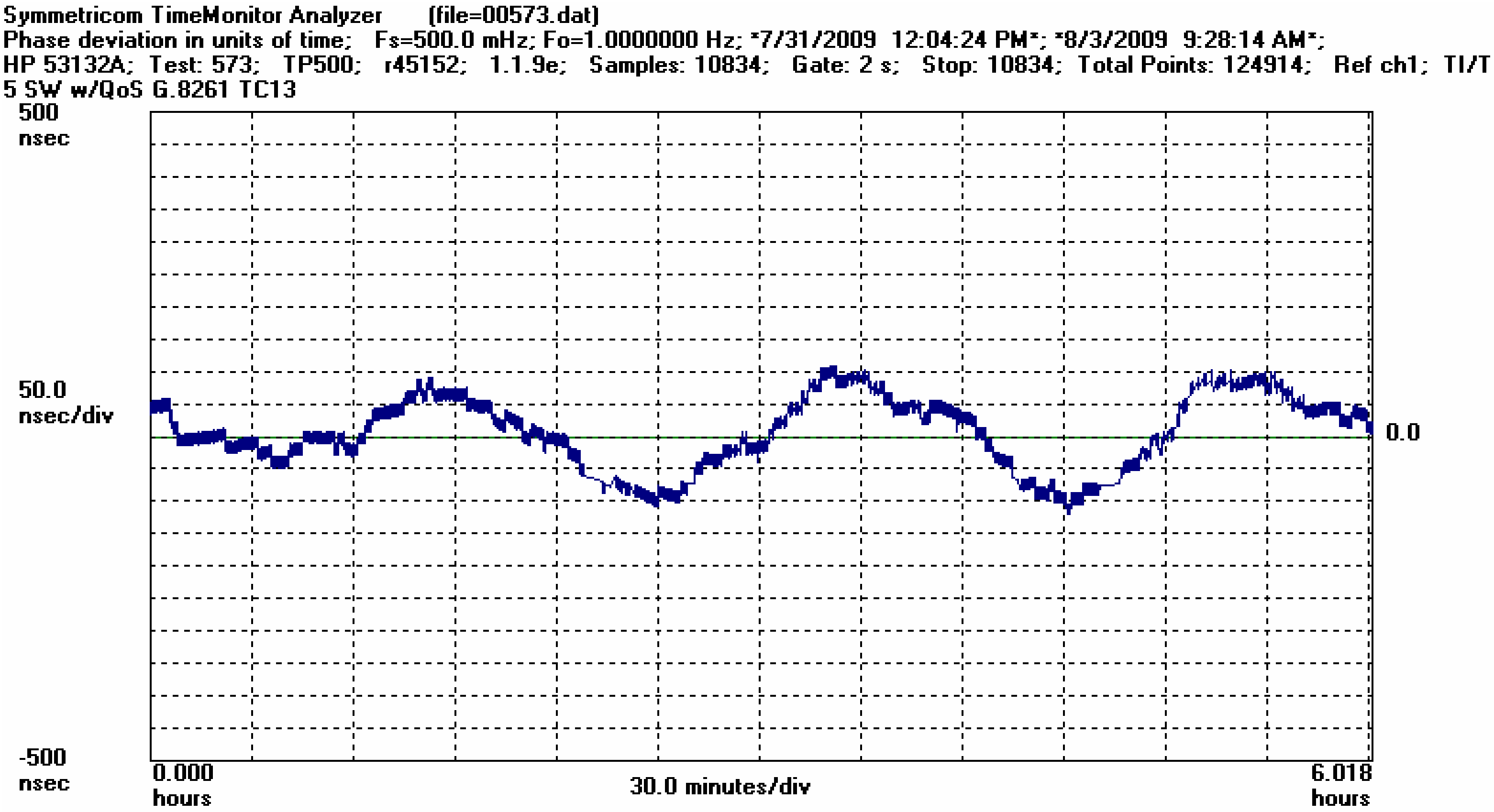
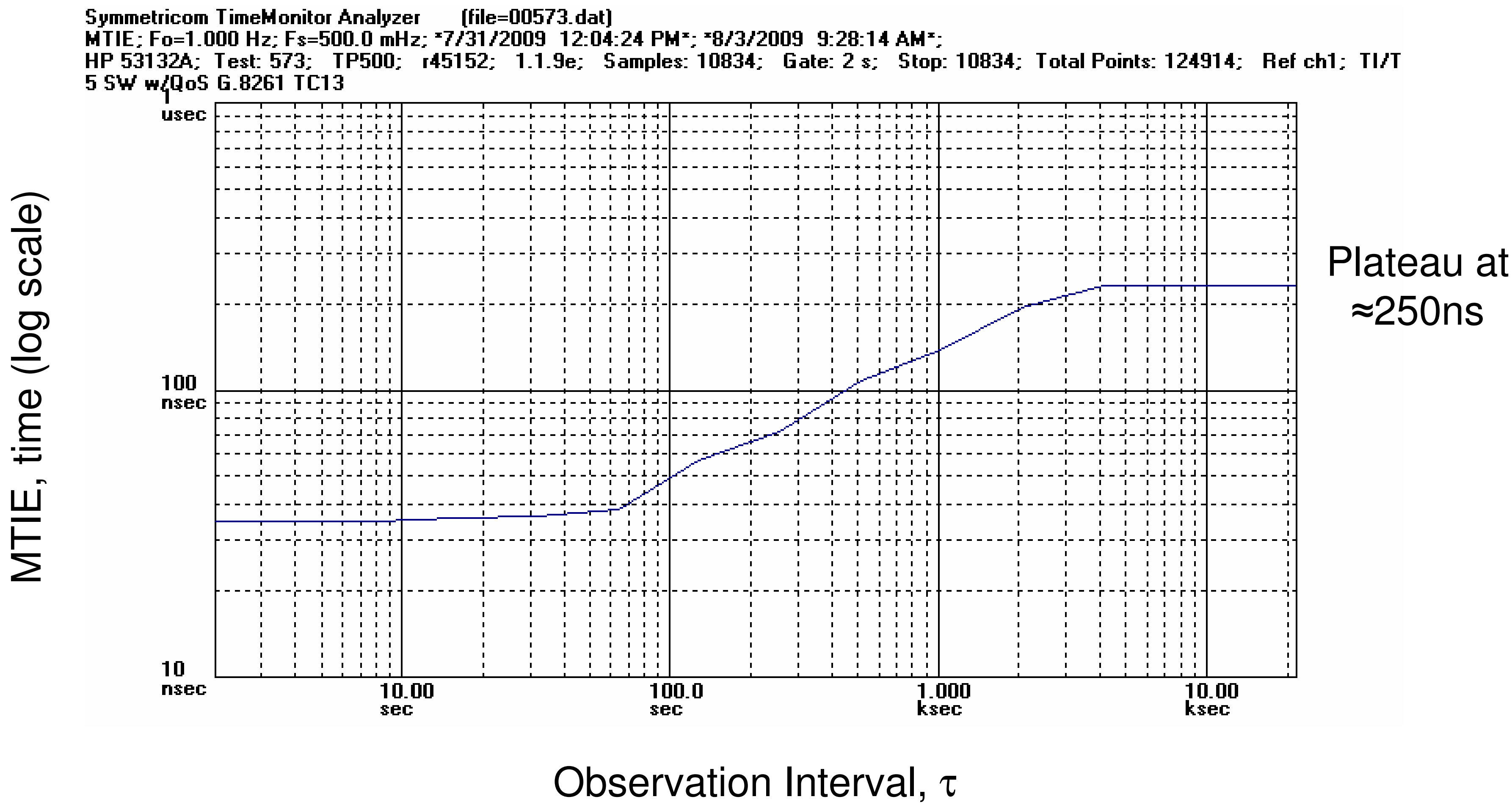
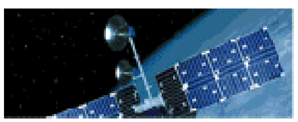



Phase deviation, 50ns/division

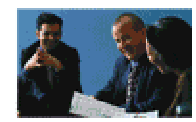
Time, 30 minutes/division

# Test Results: MTIE









# Conclusions and Deployment Recommendations

# Conclusions

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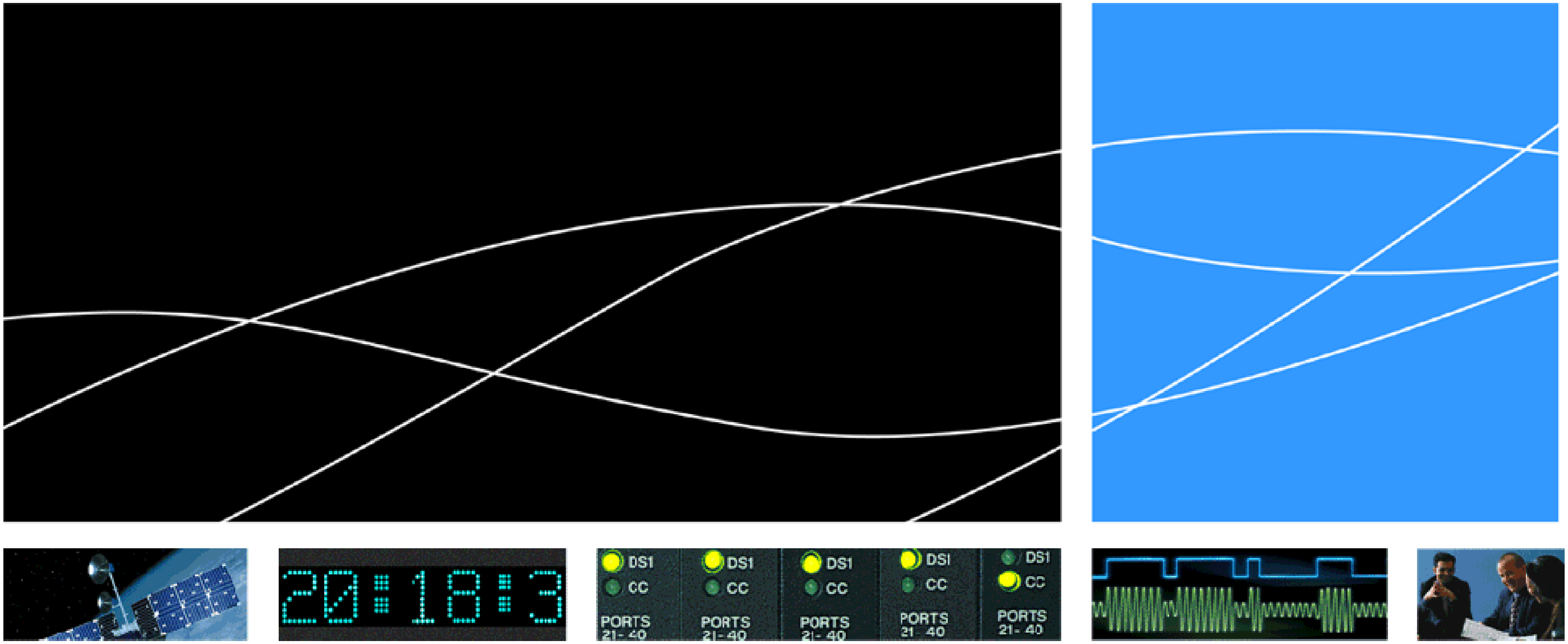
- ±250ns time accuracy is achievable
- Avoid data-rate steps
  - e.g. use all 1Gbit/s or 10Gbit/s networks
  - For accurate timing, faster is better!
- Manage the network for symmetrical paths
- Avoid inherently asymmetric link technology
  - e.g. ADSL, potentially some wireless technology
  - Native Ethernet links are good
- Avoid mixing switch types to minimise component asymmetry
- Keep cables short to avoid differential cable delays
  - Use matched cables if available
- Transparent clocks may aid performance in large networks
  - Don’t solve the problem of asymmetric link delays




# Thank you for listening!
# Any questions?