

As IP networks become more prevalent in professional broadcast environments, accurate synchronization using the Precision Time Protocol (PTP) is becoming a critical consideration. This paper provides background on PTP, and details on the SMPTE 'Broadcast' Profile.



SMPTE ST 2059-2:

Synchronizing Professional Broadcast Networks



PTP – Synchronization through Ethernet networks

Currently, several discrete applications are at various stages of implementing a shift from existing single-purpose (and often proprietary) systems to multi-functional Ethernet networks. Within the professional broadcast environment, potential benefits of moving to Ethernet from e.g. Serial Digital Interface (SDI) include provision for higher bandwidth, joint infrastructure for file-based and A/V signals, and access to advanced network management functions available for Ethernet.

Synchronization has always been required in the broadcast environment and is potentially becoming more important – for example with more prevalent (and complex) instances of live event broadcasting. Without the synchronization delivered through existing techniques such as black burst, there must be robust implementation of an Ethernet-based alternative.

Precision Time Protocol (PTP), as described in IEEE standard 1588-2008 is a widely adopted technique for synchronizing devices across Ethernet networks, for example as a fundamental part of the Time Sensitive Networking standards, as well as an integral part of International Telecommunication Union Standards for packet transport networks.

What is PTP?

PTP is a message-based time transfer protocol that is used for transferring time (phase) and/or frequency across a packet-based network. It ensures various points in the network are precisely synchronized to the reference (master) clock so that the network meets specific performance limits according to the network's application.

PTP timing messages are carried within the packet payload. The precise time a packet passes an ingress or egress point of a PTP-aware device is recorded using a timestamp. Because packets take different lengths of time to travel through the network – caused by queuing in switches and routers on the path – this results in Packet Delay Variation (PDV). To reduce the impact of PDV, Boundary Clocks (BCs) or Transparent Clocks (TCs) can be used to meet the target accuracy of the network.

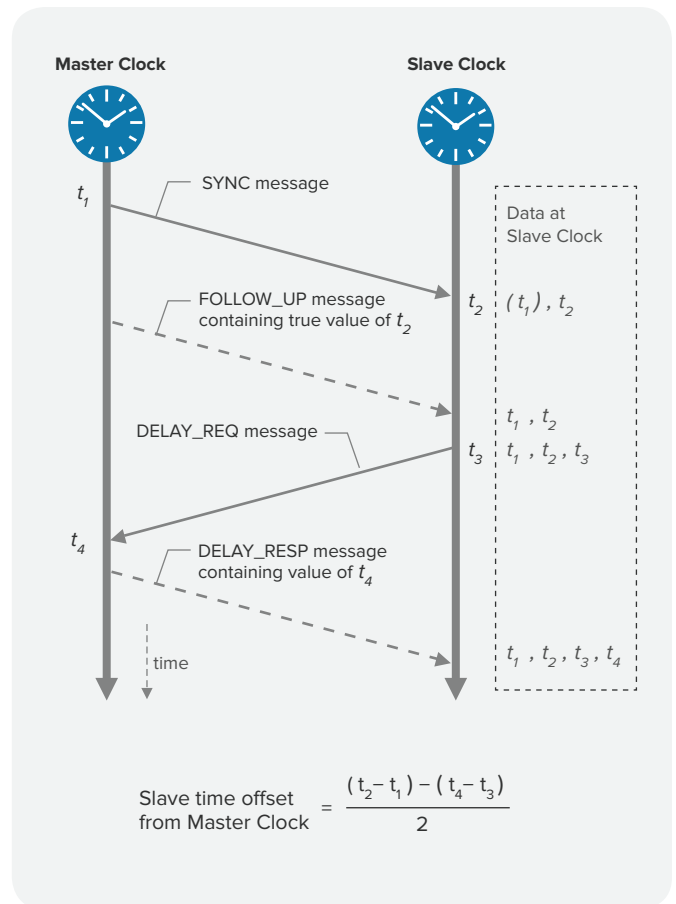
- BCs calibrate themselves by recovering and regenerating the PTP timing from the previous clock in the chain, thereby minimizing the PDV accumulation at the slave.
- If TCs are used, the PDV is written by each TC into a correction field within the packet. The end slave then has a record of the delay for each TC on the path.

Assessing the Time Error introduced by these devices is critical to determining network topology, suitability of equipment, and demonstrating network timing compliance.

How does PTP work?

PTP uses the exchange of timed messages to communicate time from a master clock to a number of slave clocks. The timed messages are SYNC, FOLLOW_UP, DELAY_REQ and DELAY_RESP as shown below.

These messages yield four timestamps (t_1 , t_2 , t_3 and t_4), from which it is possible to calculate the round-trip time for messages from the master to the slave, and back to the master (assuming that the slave clock is advancing at a similar rate to the master).



The time offset is then estimated using the assumption that the one-way network delay is half the round-trip delay and is used to correct the slave time base to align to the master.

Note that this assumes symmetry, that is, the forward and reverse paths are of equal length. If they are of different lengths, usually caused by queuing in switches and routers, this will introduce an error into the time offset estimate; this is asymmetry.

Alternative delay calculation methods using a 'peer-to-peer' mechanism are also supported by PTP – for more information please refer to the technical library at calnexsol.com

Ethernet + PTP = Synchronization for any network?

In principle, the answer to the above is yes. However, in the same way that various Ethernet networking techniques may or may not be used as required for an application, so IEEE-1588 allows for PTP 'profiles', allowing users to use optional elements of PTP differently as suits their needs:

"The purpose of a PTP profile is to allow organizations to specify specific selections of attribute values and optional features of PTP that, when using the same transport protocol, inter-work and achieve a performance that meets the requirements of a particular application."

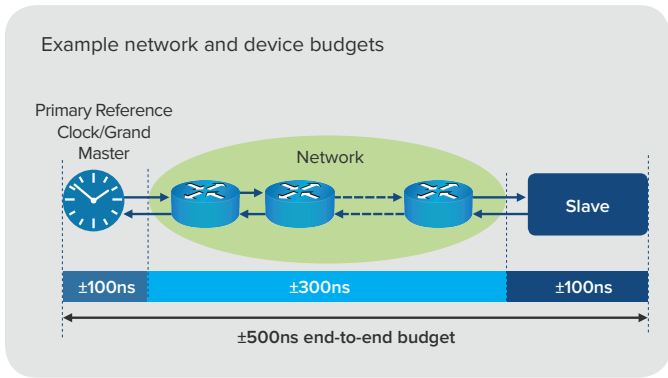
Many industries have leveraged this to create PTP profiles which give the performance and reliability they need.

(Note that the implication is that devices within these systems must apply the 'rules' of the determined PTP profile correctly, otherwise any features of the system which depend on timing (end applications or even other network protocols) will potentially fail to operate.)

Requirements for SMPTE ST 2059-2

The Society of Motion Picture and Television Engineers have defined the 2059-2 PTP profile to meet the needs of Professional Broadcast. Hence this is commonly referred to as the PTP Broadcast Profile.

Firstly, synchronization must meet a timing requirement of 1µs (±500ns) across the network. As long as this performance is met, most of the available options from the 1588 ‘default profile’ may be used: either end-to-end or peer-to-peer delay mechanism, IPv4/IPv6 encapsulation, multicast or unicast transmission, using ordinary, boundary or transparent clock devices.



The illustration above gives an example of how this specification can be broken down to provide equipment specifications for Grand Master devices, PTP aware network switches/routers (Boundary or Transparent Clocks), and slave functionality (possibly integrated into broadcast equipment). Dependent on the number of network hops between the end points of the network, BC and TC performance limits can vary by application and deployment. As per the illustration, 5 hops would give a per device limit of $\pm 300\text{ns} / 5 = 60\text{ns}$ per device.

Since the synchronization delivered by PTP is serving needs previously covered by an interface also capable of delivering other timing-related information (such as default frame rates) required for A/V systems, the Broadcast profile provisions for a Synchronization Metadata (SM) TLV – carried in PTP management messages – to carry this information through the Ethernet network.

Therefore, although not directly affecting the transmission of timing, correct generation and interpretation of the SM-TLV is critical to correct system performance.

SMPTE ST 2059-2 protocol interoperability

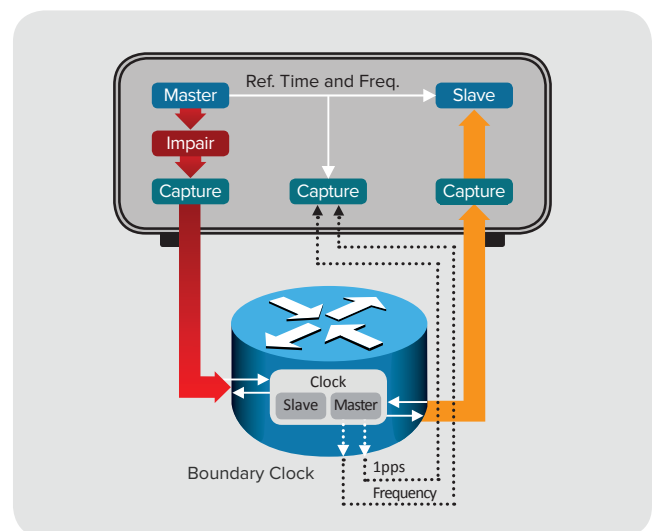
Often overlooked, a key item in deploying robust PTP networks is ensuring all devices apply the same PTP profile correctly and consistently. As mentioned above, the specific SM-TLV makes this a particularly important matter for broadcast environments.

Initial ‘on-boarding’ and evaluation should include validation of PTP message fields.

The screenshot shows a PTP analysis tool interface. At the top, it displays 'Ruleset File: G.8275.1 Phase Profile.xml' and 'View Rules'. Below this is a table of PTP messages with columns for Direction, Packet #, Arrival Time, messageType (t), reservedField, sourcePort/destinationPort, sequenceId, logMessageInterval (t), and PTP Body Fields (t). The table lists 21 packets, including SYNC, DEL.RESP, and DEL.REQ messages. At the bottom, there is a summary section with 'Average Message Rate (msg/sec)' for SYNC (33.75), FOLLOW-UP (0.00), ANNOUNCE (0.00), DEL.RESP (12.5), DEL.REQ (6.20), and SIGNALING (1.30). It also shows 'Total Counts' for Packets (302) and Errored Packets (10), with a 'FAIL' status and 'Total Pass Rate: 96.69%'.

To prove the PTP performance of network equipment:

1. It must be shown that the equipment can connect and engage in a PTP session correctly. It is recommended to use test equipment that can generate and control PTP message exchanges to avoid, for example, ‘masking’ of interoperability issues (a common problem when using commercial network equipment for test purposes).
2. ‘Steady state’ timing accuracy should be measured either directly on PTP messages, or on external timing outputs if present. It is essential that test equipment validating performance should have measurement accuracy an order of magnitude better than the device performance spec (note: this should cover the entire stimulus to measurement setup, which must be time aligned to confirm, for example, time traceability).
3. Response to likely negative conditions (protocol errors, timing offsets, etc.) should also be tested and measured i.e. ‘worst-case performance’. Both long-term gradual timing offsets and short-term jumps in timing should be applied to check robustness of equipment. Again, this should be possible without affecting simultaneous timing accuracy measurements.



Related Products



Calnex Paragon-One Broadcast

- Focussed one-box test solution for SMPTE ST 2059-2
- Master and Slave Emulation for fully controllable protocol and timing test
- Automatic protocol configuration for SMPTE ST 2059-2, including SM-TLV generation and control
- Full timing analysis of all PTP timing metrics and parameters
- Report generation capability – prove performance
- Unrivalled test accuracy



Calnex PFV

- PTP Field Verifier – decode and view multiple PTP fields in an easy-to-use table format
- Check transmitted PTP messages for compliance with IEEE, IEC, ITU-T and user-defined standards and rules
- Analyze all key fields simultaneously, with individual Pass/Fail indications, plus report generation



Calnex Sentinel

- PTP, NTP, SyncE and TDM in one portable box
- Measure ALL parameters at the SAME time
- Test networks for Frequency and Phase
- Test networks with Boundary Clocks and Transparent Clocks
- Standard industry masks and packet metrics, with built-in Pass/Fail limits when measuring the network
- Measurement reports in pdf format
- Embedded GPS receiver and Rubidium (Rb)



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