PTP PRIMER

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

Calnex
Insight and Innovation

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, for example, Serial Digital Interface (SDI) include provision for higher bandwidth, joint infrastructure for file-based and A/V signals, and access to advanced Ethernet network management functions.

Synchronization has always been required in the broadcast environment and is becoming ever more important – for example with the increasing prevalence and complexity 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 the standard IEEE 1588-2008 is a widely adopted technique for synchronizing devices across Ethernet networks, for example, as a fundamental part of Time Sensitive Networking and 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 (leader) 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.

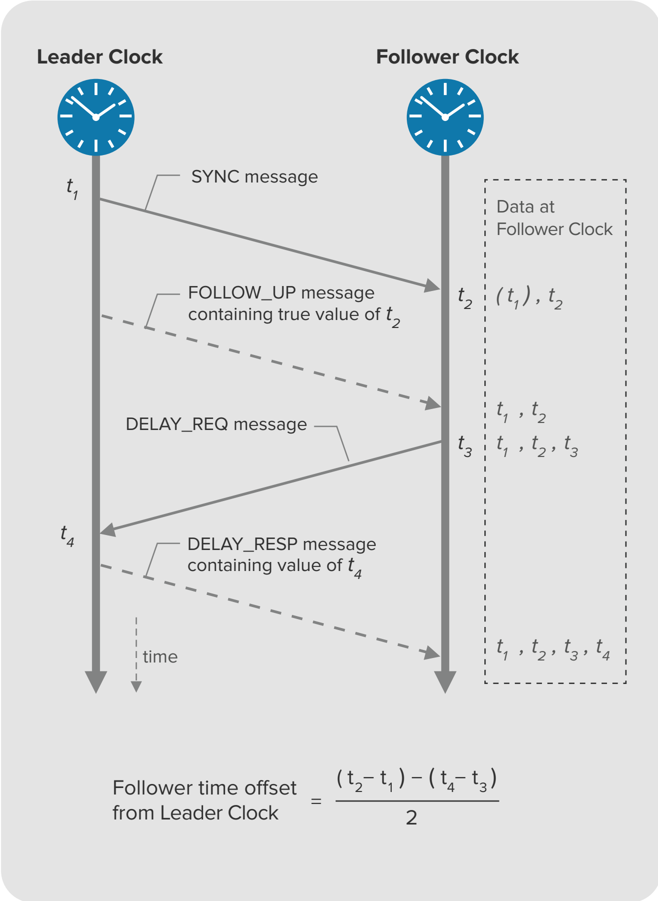
- BCs calibrate themselves by recovering and regenerating the PTP timing from the previous clock in the chain, thereby minimizing the PDV accumulation at the follower.
- If TCs are used, the measured link delay and residence time is written by each TC into a correction field within the packet. The end follower 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 and suitability of equipment, and demonstrating network timing compliance.

How does PTP work?

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

These messages yield four timestamps (t1, t2, t3 and t4), from which it is possible to calculate the round-trip time for messages between the leader and the follower (assuming that the follower clock is advancing at a similar rate to the leader).



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 follower time base to align to the leader.

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 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', enabling 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."

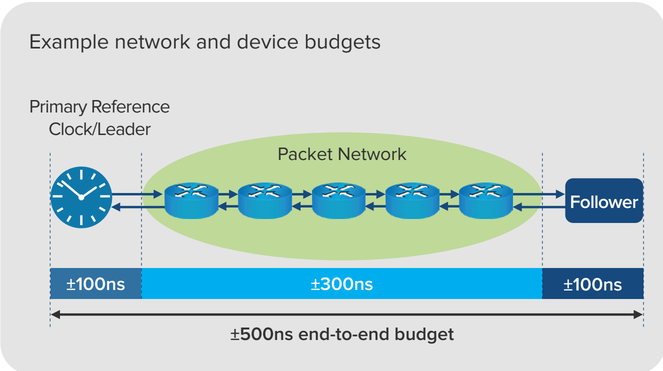
Many industries have leveraged this to create PTP profiles which give the performance and reliability they need.

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. SMPTE ST 2059-2 is therefore 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: end-to-end or peer-to-peer delay mechanism, IPv4/IPv6 encapsulation, multicast or unicast transmission, using ordinary, BC or TC devices.



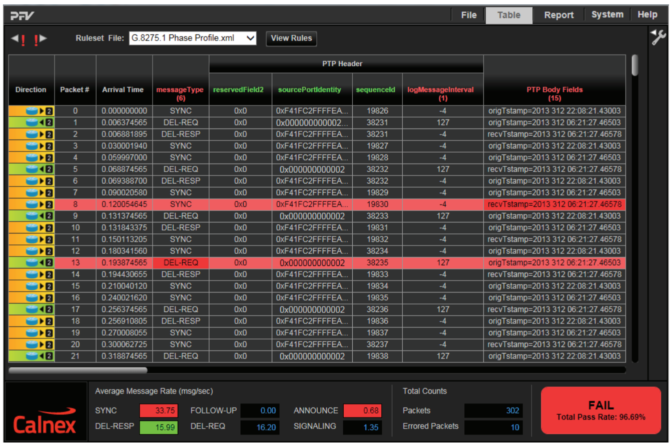
The illustration above gives an example of how this specification can be broken down to provide equipment specifications for Leader devices, PTP aware network switches/routers (BCs or TCs), and follower functionality (possibly integrated into broadcast equipment). Dependent on the number of network hops 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 ±300ns / 5 = 60ns 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 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.

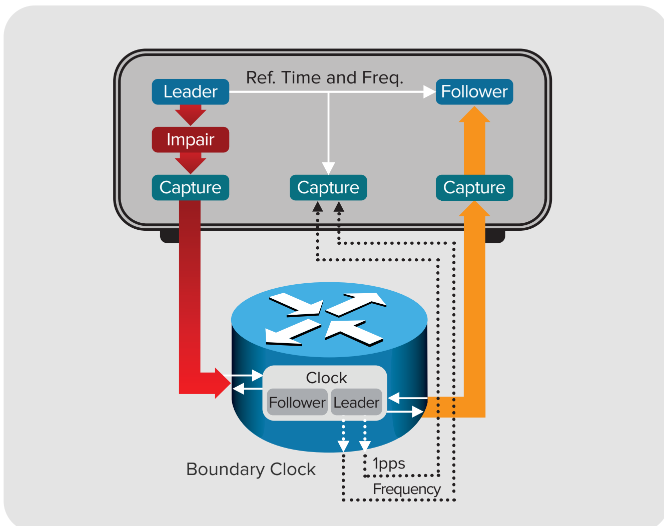


To prove the PTP performance of network equipment:

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 specification. 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
- Leader and Follower 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
- Embedded GPS receiver and Rubidium (Rb)
- 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

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