RIEDEL

Transparent versus Boundary Clocks (PTP) in Broadcast Environments

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Introduction

This document describes the difference between transparent clock and boundary clock, and explains why boundary clock scales better than transparent clock. The first section defines key terms, including precision time protocol (PTP) functionality, ST 2059-1 and ST 2059-2, transparent clock and boundary clock. The next section shows the IP broadcast center clocking scheme and relevant PTP standards.

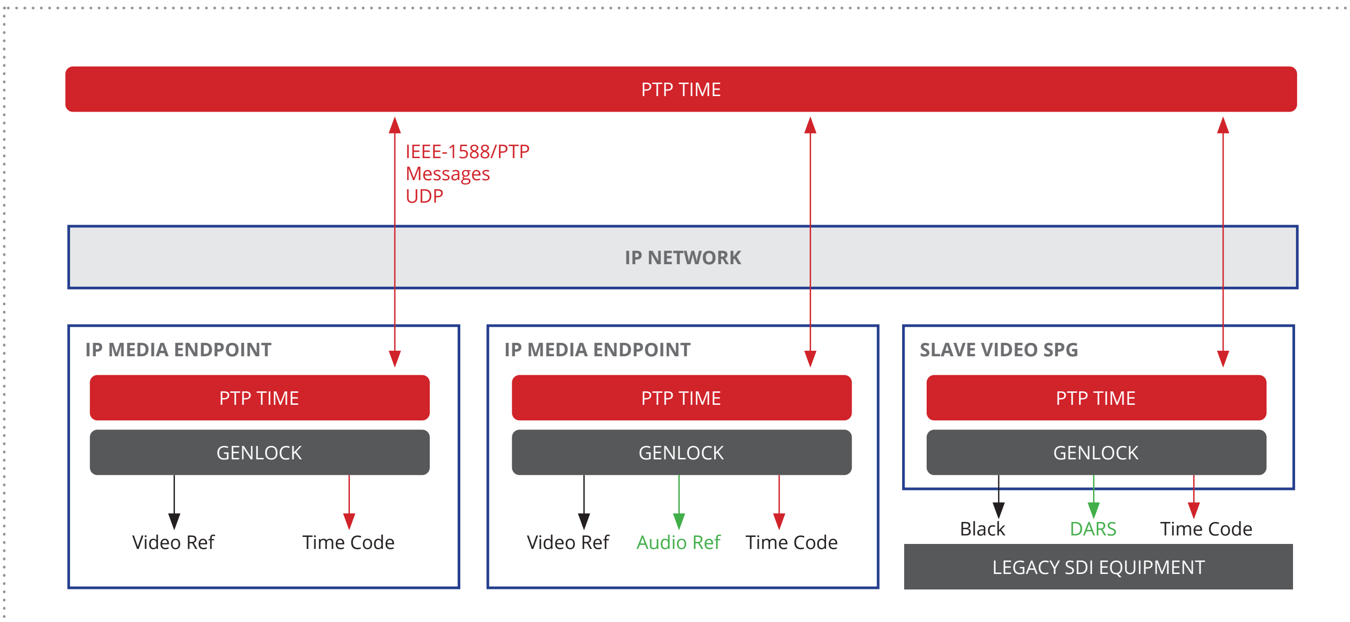

Figure 1. Video and Time Reference in an IP Media Facility (courtesy of Michel Proulx)

1. Definition

1.1 PTP functionality

The PTP is defined by the specification IEEE-1588. It is an algorithm that synchronizes the peripherals on the network with a common time reference. Before PTP, there was the network time protocol (NTP) which allowed systems to be synchronized within a few milliseconds of coordinated universal time (UTC). While the provided precision proved to be enough for basic transfer of time of day information, it is not enough for real-time applications such as audio and video. To improve accuracy, thus enabling real-time applications to utilize the Ethernet network, the Institute of Electrical and Electronics Engineers (IEEE) defined PTP.

The method is simple. A high precision clock, the master, will send out PTP sync messages using the User Datagram Protocol (UDP). Slaves will then receive the sync messages with the master time (t1). If hardware timestamping is not provided by the master, a Follow_Up message will be sent out to provide the time at which the initial sync message was sent out (t1). The slave stores the time at which it receives the Sync message (t2). After reception of the Sync message, the slave sends out a Delay_Request to the master clock (t3). The master finally answers with a Delay_Response message (t4).

Having these four timestamps, the slave device can estimate the propagation delay and calculate its own offset from the master. The following formulas are used in the slave to establish the time at the master:

$$\text{Delay} = [(t_2 - t_1) + (t_4 - t_3)]/2$$
$$\text{Offset} = (t_2 - t_1) - \text{Delay}$$

Equation 1: PTP Delay and Offset calculation

The following image shows the low-level PTP algorithm

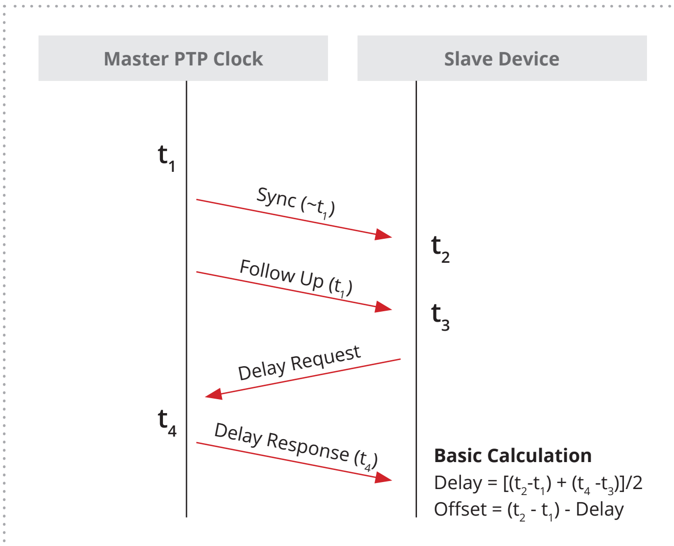

Figure 2: PTP Algorithm

1.2 Transparent Clock

The transparent clock will relay the master's PTP Sync, Follow_Up and Delay_Resp messages to all of the Riedel IP SFPs and will transfer PTP Request_Delay messages from all the SFPs to its master. The PTP master usually can answer to a limited number of slaves. When this number becomes too large, the master starts to be over solicited by the number of messages.

The network gets more congested, and packet scheduling across the network can add delays, which in turn cause inaccuracy in time synchronization (PTP messages have different delays that are not compensated for). The transparent clock adjusts the PTP messages to remove the delays of its own packet processing, and thus compensates delays in PTP messaging.

In a spine-leaf architecture, the top of rack switches can adjust the delay inside the PTP packets (by adding a correction field in PTP message) to ensure it is viewed as transparently as possible.

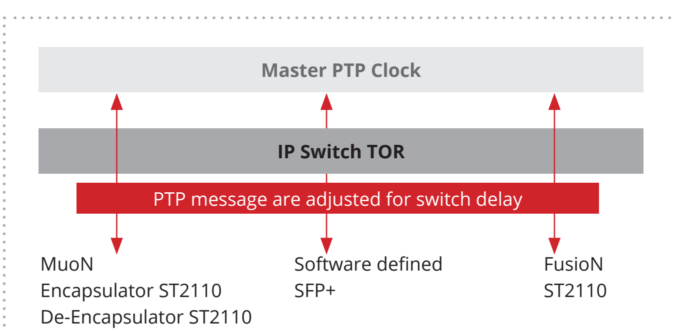

Figure 3. Transparent clock system

1.3 Boundary Clock

The boundary clock ready switches possess a built-in PTP master clock. The switch will be the master for the endpoint devices attached to it. For stability, the switch will be a slave to another PTP master clock. In this scenario, the PTP master in the switch will communicate to a limited number of slaves. This way the boundary clock method ensures that PTP masters are not over solicited, and this will greatly improve the accuracy of the PTP time and the system scalability. The following picture shows a boundary clock system.

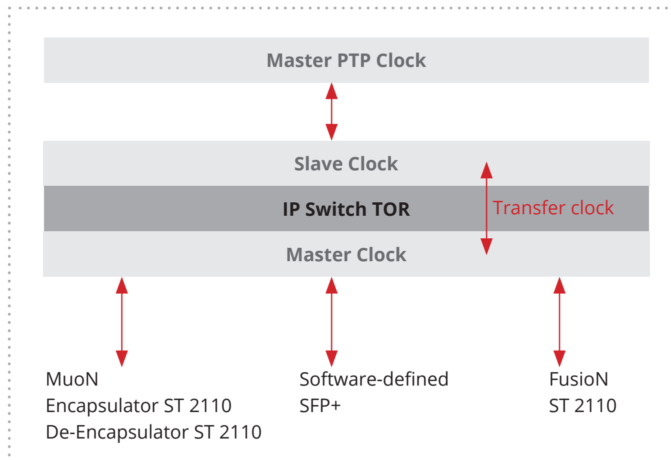

Figure 4. Boundary clock system

1.4 Timing Signal Generation in IP Media

Once the slave has iteratively computed its time difference with its master, it is synchronized within sub-microsecond accuracy of UTC. But time synchronization is just the first step. The second step is to use precise time to derive the timing reference signals needed by ST 2110 audio/video devices.

The Society of Motion Picture and Television Engineers (SMPTE) decided to create the ST 2059-1 and ST 2059-2 standards. The ST 2059-1 defined a method of deriving phase aligned audio and video sync from PTP. The ST 2059-2 defined a profile of IEEE-1588 suitable to audio and video requirements.

From the PTP ticks count, slaves accurately find the vertical and the horizontal pulses and align its video to the video reference. It is also possible to extract the audio clocks and finally to generate the Digital Audio Reference (DARS) if required. The following image shows the process of re-creating the clock for synchronization of signals.

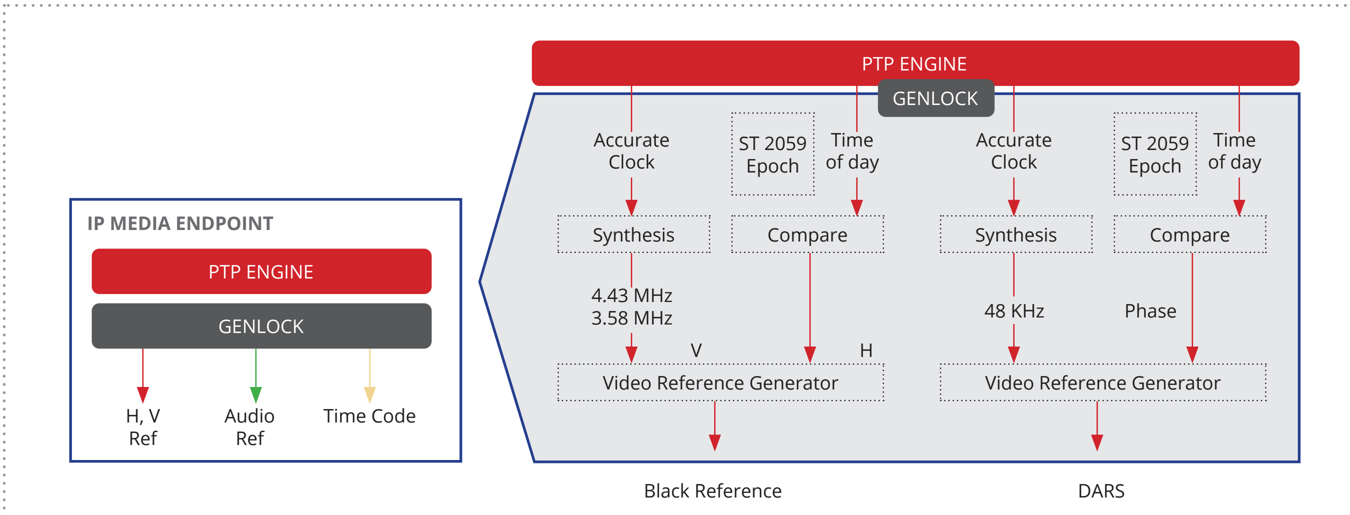

Figure 5. Timing signals generation in IP Media devices (courtesy of Michel Proulx)

2. IP Broadcast Environment Clocking

In an SDI broadcast environment, timing is crucial. It is no different in an IP broadcast environment; timing is important to synchronize endpoints. PTP was already used by various industries, so it was an obvious choice to be reused for broadcast.
From our industry's perspective, PTP is mandatory and therefore is now defined in the ST 2110-10 standard for audio, video and metadata transport. To be compliant, ST 2110 endpoint (devices) should be PTP / ST 2059-1 and ST 2059-2 compliant.

3. Conclusion

Finally, endpoints such as the MuoN and FusioN gateways will work in both transparent clock and boundary clock systems. But for scalability and accuracy, the boundary clock system should be implemented over the transparent clock.

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