Synchronisation in Professional Media over IP Networks
SMPTE ST 2059-2 PTP

ABSTRACT

Since IP networks have become common in professional broadcasting, accurate synchronisation using precision time protocol (PTP) has become one of the most important considerations. As all IP studios use the SMPTE ST 2110 standards, it is important to pay attention to the accurate and reliable time transfer protocol that is one of the basic pillars of these systems. SMPTE ST 2059 is standardised according to the IEEE 1588 exact time protocol.

The network or multimedia equipment, affects the accuracy of time transmission and impacts the timing of ST 2110 media streams generated or received by the respective nodes. PTP is highly fault tolerant. However, performance degradation due to time transfer is not well known. This drop can have a significant impact, especially on live and real-time networks. Therefore, a comprehensive view of the end-to-end timing system, including network equipment, backup and standby, is required and necessary. Network timing monitoring should be common to all equipment. Monitoring examines how equipment operates with respect to time transfer and provides a framework for tracking events. This paper describes the different monitoring capabilities, and the value it provides to the monitored datasets. Then focuses on different means and achieves the common process for all monitored equipment.

KEYWORDS

ST2059-2 time transfer, PTP, synchronisation, monitoring, ST 2110

INTRODUCTION

Synchronisation has always been required in the broadcast environment and is becoming more important especially in live event broadcasting. Precision Time Protocol (PTP), as described in IEEE standard 1588 is a widely adopted technique for synchronising devices across Ethernet networks, for example as an integral part of International Telecommunication Union Standards for packet transport networks.

PTP is a message-based time transfer protocol that is used for transferring time across a packet-based network. It guarantees various points in the network are precisely synchronised to the reference (master) clock. PTP timing messages are carried within the packet payload. The precise time 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. To reduce the impact of that, some methods are used to achieve network target accuracy.

PTP uses the exchange of timed messages to communicate time from a master clock to a number of slave clocks. The SMPTE has defined the 2059-2 PTP profile to meet the needs of professional broadcast. Hence this is commonly referred to as the PTP Broadcast Profile.

Media exchange between multiple devices on a large IP network requires constant synchronisation between all transmitters and receivers. Whenever the 1μs synchronisation range is exceeded, even temporarily, the temporal relationship between the respective media flows may be interrupted, and may result in error if different video and audio streams need to be connected during the next processing cycle in the workflow.

In accordance with SMPTE ST 2110 [1-5] standards in media streams, instead of sending the full data of a video frame or set of audio samples in a burst, it must be transmitted at a high and fixed data rate to complete the relevant recording / processing. This mandatory condition ensures that the network is never disconnected, even temporarily and without additional load. If these conditions are not met, sending queues in network equipment can be filled and packets can be dropped. Therefore, the data transfer rate must be the same throughout the network.

PTP [6] is a very efficient means for accurate and reliable synchronisation of all nodes within the network. Therefore, ST 2110 has chosen PTP as the primary technology for synchronising all nodes in an IP network. ST 2059-2 [7] and ST 2110-10 are relevant SMPTE standards that define time transfer specifications. PTP is a simple two-way time transfer mechanism that can provide sub-microsecond accuracy as long as all the timestamps of the PTP messages that carry the time information are accurately embedded in the hardware. However, PTP has a basic requirement that must be met, the time of transmission of all messages over the network from the reference to the end node that requires time information, must be fixed in both directions. Thus, the accuracy of

PTP is affected by the behaviour of the entire IP network, not just the corresponding end nodes.

TIME TRANSFER MONITORING

PTP provides a significant degree of fault tolerance and always selects a device with the best (most accurate) local clock to be used as a source of reference time for the entire network. This decision-making process is done automatically, without the need for user interaction other than configuring all devices based on it during deployment and implementation. As soon as more than one device is considered to be time reference (PTP Grandmaster), PTP can tolerate the reference error that is currently active.

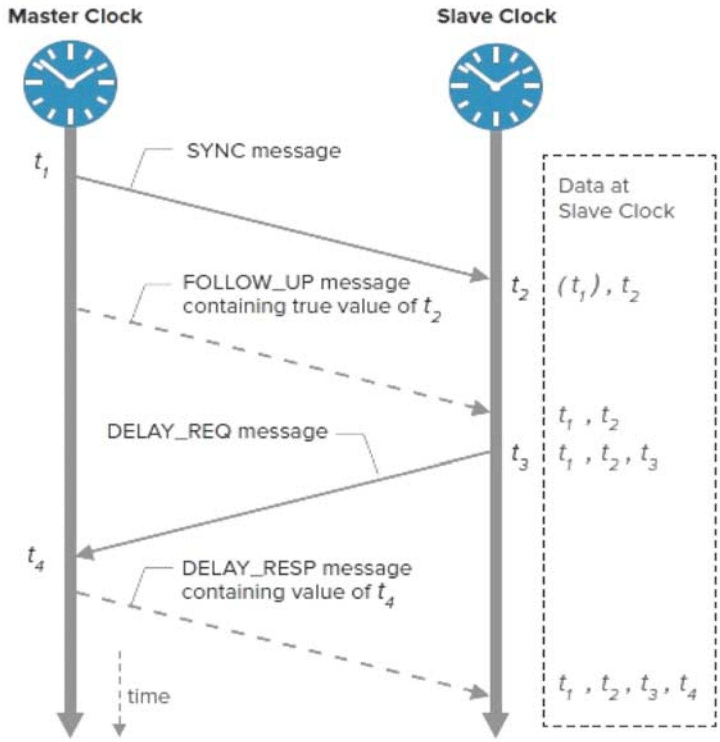
The question arises as to why there is an insistence on constantly monitoring all aspects of the PTP protocol, rather than simply collecting status information regularly, as is usually the case in many other lower layer protocols active in IP networks, such as RSTP (Rapid Spanning Tree Protocol). There are several reasons for using PTP monitoring, which is significantly higher than the base level commonly used for other network protocols. The overall accuracy of PTP is affected by the performance of all network devices in terms of sending and/or processing time information. Therefore, it is not enough to simply confirm that all messages are exchanged at a predetermined rate and that all devices follow protocol rules. In other words, in addition to the expected states, the requested state transition must be considered in a timely and correct manner.

The quality of time information must also be constantly monitored to ensure network synchronisation. If all or most network equipment operating as PTP Transparent Clocks or PTP Boundary Clocks is aware of PTP, general accuracy will be sufficiently considered. But this does not reduce the need for close monitoring of time transfer. PTP-aware network equipment manipulates PTP messages that carry time information, so they may be incorrectly configured, subject to hardware or software errors, or fall victim to a security attack.

PTP MONITORING INFORMATION

Although PTP can handle many faults inherently, several errors with the ability to corrupt or even interrupt time data transmission have not been identified. The fault tolerance improvement methods proposed in PTP have been extensively studied in various papers. For example, more than one auxiliary PTP Grandmaster significantly reduces the risk of loss of synchronisation [10]. To improve PTP flexibility, a fully redundant network infrastructure can be used, such as that specified in the SMPTE ST 2022-7 standard [11] for redundant media transfer. However, regardless of the level of fault tolerance used, monitoring is very important because of a design principle in PTP. PTP monitoring is an essential tool for tracking malfunctions or incorrect settings of the PTP configuration as well as intentional attacks on the integrity of the time transfer system, and its capabilities should not be limited to tracking the overall accuracy of the network.

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 in *Figure 1*. These messages yield four timestamps from which it is possible to calculate the round-trip time for messages from the master to the slave, and back to the master.



$$\text{Slave time offset from Master Clock} = \frac{(t_2 - t_1) - (t_4 - t_3)}{2}$$

Figure 1. PTP timed messages [8]

The monitoring system needs a list of all the nodes it needs to monitor. This can be provided manually, or it can scan the network via PTP management messages to gather the required information.

In message based offset measurement techniques led by group of PTP vendors like the NetSync Monitor, the transfer starts by sending a Delay Request message to the Follower node. This message is expanded with a special TLV (type length value) field that defines it as a monitoring message. Adding TLV to PTP messages is fully supported by IEEE 1588-2008. *Figure 2* shows the message flow of a follower monitoring system. The follower node will simply process this message by gathering the ingress timestamp and return this information back to the sender via a Delay Response message extended by a similar TLV. The data contained in the TLV triggers the device to generate one additional Sync message, again extended by a TLV. This message is sent to the monitoring system, which now has gathered the same four timestamps as the follower node is continuously using to adjust its local clock. The monitoring system will not use this data to adjust its clock, which is synchronised to the currently active Grandmaster via a separate route. It will be able to analyse the offset of the Follower node. More than one such monitoring device may be added to a PTP network.

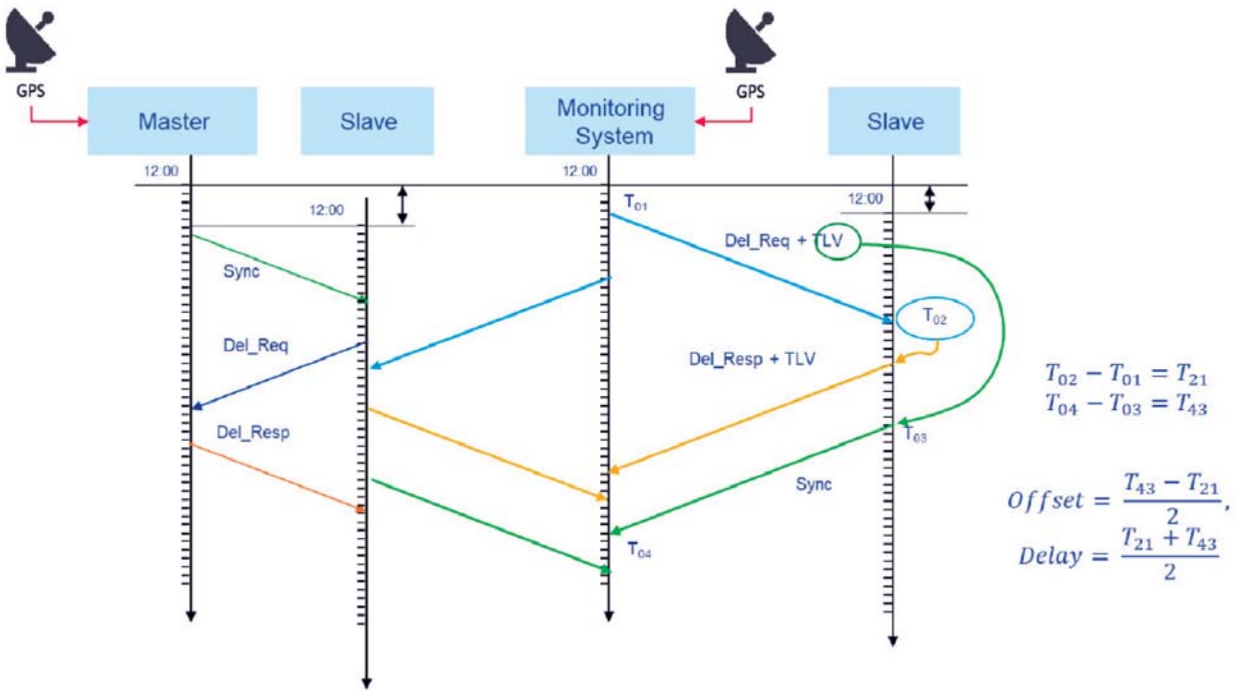


Figure 2: Message Flow of Monitoring system [9]

The data collected by these monitoring systems can be used to evaluate the synchronisation accuracy of all follower nodes that support this extension.

All significant PTP error conditions can be identified when a significant amount of monitoring data is continuously collected from each PTP device. This data should include the current configuration as well as message rates, or even better the total number of processed node messages for a given period of time. If data processing and collection is done effectively, errors can be immediately detected, and it is possible to take action before the affected nodes lose synchronisation.

REFERENCE MODEL FOR MONITORING

There are many ways to collect and aggregate PTP information, including multiple data formats, data structures, and specific vendor implementations. Due to this inconvenient situation, it is necessary to have a unified representation of PTP related data. There is a need for a tool not only to compare such data, but also to validate it in different settings, which should take into account the compatibility and coordination in the data collected.

For this purpose, traditional approaches are defined using SNMP for PTPv2 [14], with a generic PTP Management Information Base (MIB) which is limited to IEEE 1588 PTPv2 only and does not cover the SMPTE ST 2059 specification. To address this gap, the 32NF Technology Committee of SMPTE has launched a project to produce a reference model containing a set of parameters to check the status of ST 2059-2 PTP equipment.

The proposed SMPTE 2059-15 method, which is currently under development [16], defines a YANG[1] (the YANG model, which has been widely defined in the IETF [15]) data model that includes all aspects of the time transfer monitor, including reference clock input such as GNSS[2], its PTP time passes through PTP-aware equipment to the end node and retrieves transfer time.

In the IRIB R&D lab there are various committees and work groups focussed on production over IP platforms and research on synchronising professional broadcast and try to improve monitoring capabilities according to the standard method. We plan to perform PTP accuracy tests by using message-based offset measurement methods offered by various PTP vendors, such as NetSync monitors or the Dataminer Skyline Communications analysis tool. If the standard model is finalised, that method will be used.

CONCLUSION

PTP is a critical part of an all-IP studio that relies on all network devices for synchronisation between devices. PTP inherently provides a significant level of fault tolerance, which can even be increased for mission-critical applications, using redundant networks for time transfer. Continuous monitoring of all equipment is mandatory, especially for large networks, this allows PTP errors to be detected and prevented from occurring before they impair overall accuracy.

A consistent and standard method has not been considered in this field and if available, it has been implemented using a wide range of designs and models by various vendors in the industry. The best way to overcome this limitation is to agree on a common data model and dataset provided by each PTP node.

[1] Yet Another Next Generation
[2] Global Navigation Satellite System

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AUTHOR

Sepideh Ghandali
Senior Researcher in the IRIB R&D
Email: s.ghandali@irib.ir

Sepideh Ghandali is a senior researcher in the IRIB R&D. She obtained a master's degree in electrical-telecommunication engineering from Amirkabir University of Technology (Tehran Polytechnic) and is currently a PhD candidate in electrical-telecommunication-system engineering at Semnan University. She has been working in the IRIB R&D since 2010. During this time she has been working in the field of Contribution and Distribution in signal Transmission, Terrestrial and Satellite Broadcast, new platforms for signal transmission such as high throughput satellite, IP, LTE-Broadcast, 5G and 6G.

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