

PTP: The Key to ST 2110 Timing

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Precision Time Protocol – History



- Designed to synchronize clocks via a computer network, with much higher accuracy than NTP
- Widely used in industries such as telecom and finance, now being adopted for video applications to replace analog sync
- Version 1 published as IEEE 1588-2002, not used for video
- Version 2 published as IEEE 1588-2008
 - Updated with IEEE 1588-2019 (“Version 2.1”)
- Augmented with standards such as SMPTE ST 2059-2 (since 2015)
- Some terminology has changed: Master/Slave → Leader/Follower

PTP over IPv4



- User Datagram Protocol (UDP) used for transport
 - Port 319 for Event messages
 - Port 320 for General messages
- Multicast group address for most messages: 224.0.1.129
- Exchange of PTP messages may be multicast, unicast, or a mix of both

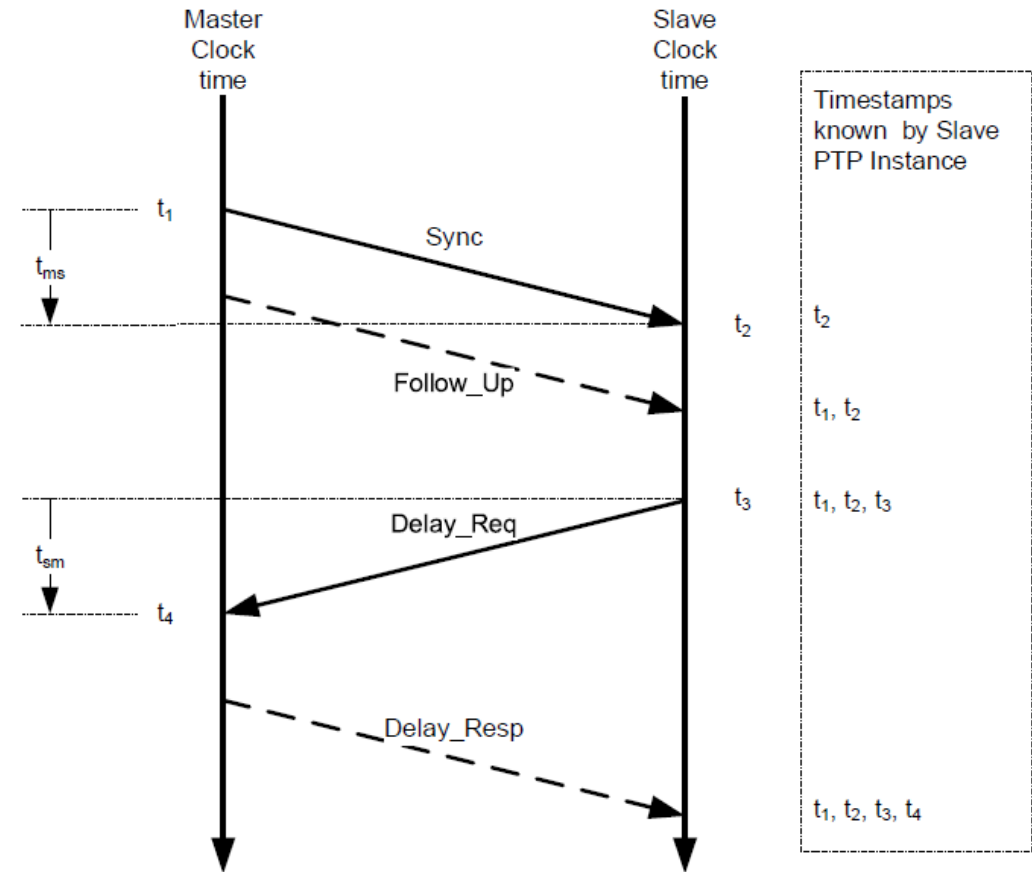
Common PTP Message Types



- Event message class
 - Sync
 - Delay_Req
- General message class
 - Announce – used to establish the synchronization hierarchy
 - Delay_Resp
 - Follow_Up
 - Management – used to query and update “data sets” used by PTP instances
- Differentiated Services used by switches to enforce high priority for event messages

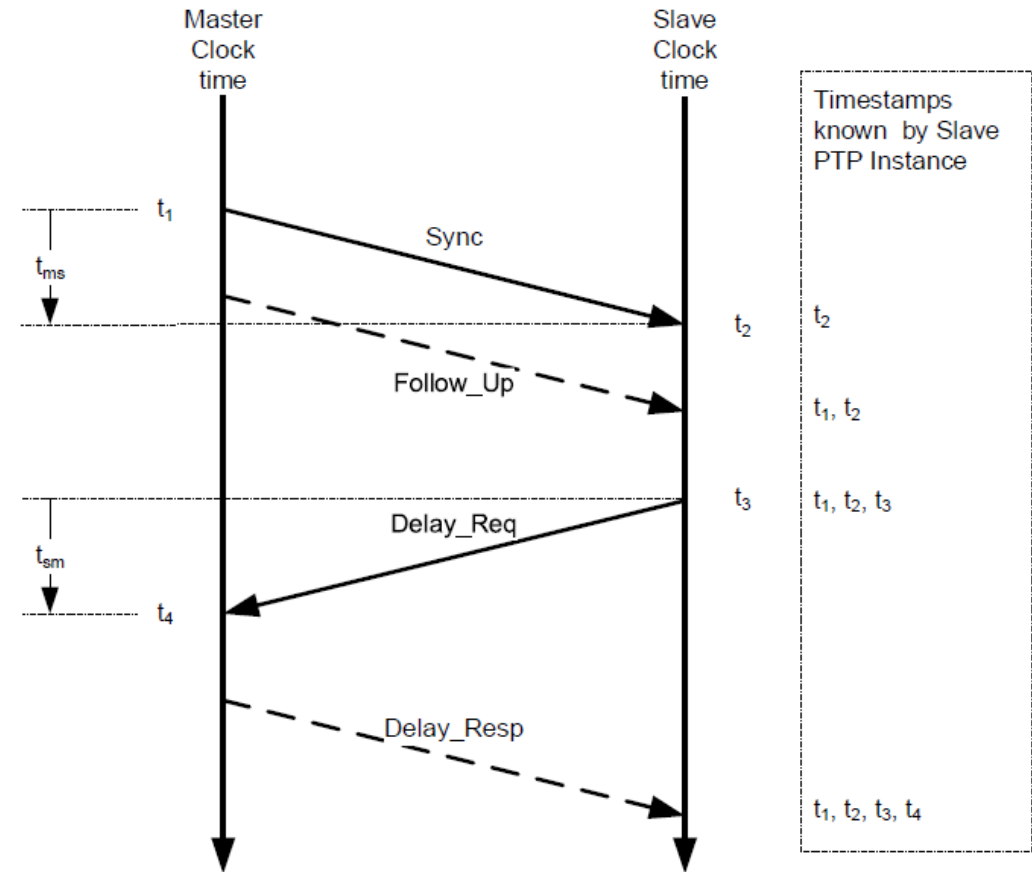
Clock Synchronization

- Sync messages sent periodically (e.g. 8 per second) from leader to followers
- Follow_Up message needed only if Sync timestamp is not included in the Sync message
- Followers send Delay_Req, typically at same rate as Sync
- After complete exchange, followers have all 4 timestamps



Clock Synchronization

- $t_{ms} = t_2 - t_1$
- $t_{sm} = t_4 - t_3$
- $meanDelay = \frac{t_{ms} + t_{sm}}{2}$
- $offset = \frac{t_{ms} - t_{sm}}{2}$
- Follower clock can be adjusted using these values
- There is also a provision for asymmetric network delays

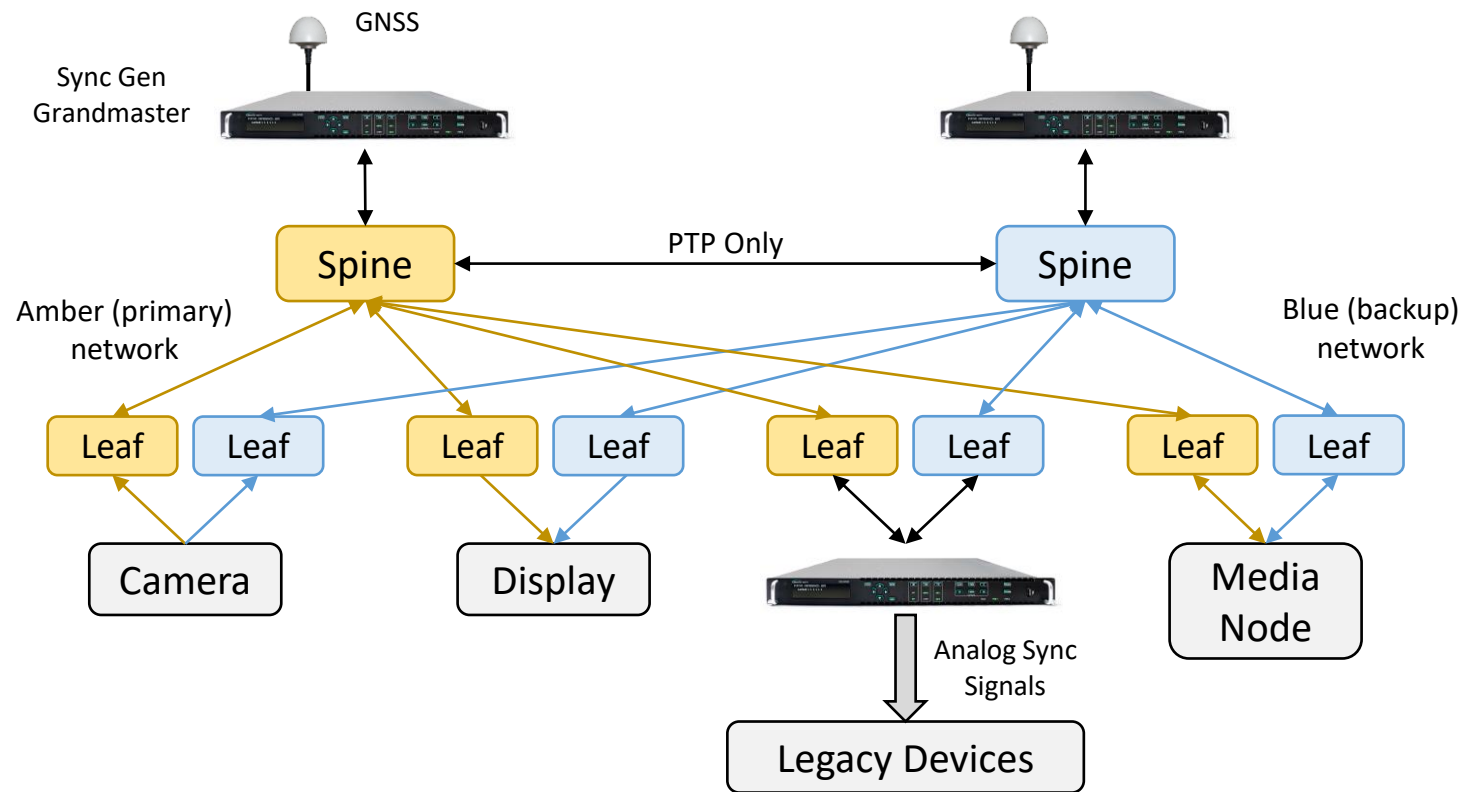


PTP Clock (Node) Types



- Ordinary Clock
 - PTP nodes with a single port on the network
 - Can be either a follower or a leader
 - Typically in video networks, we have grandmaster (GM) clocks that are leader-only and devices (cameras, etc.) that are follower-only
- Boundary Clock
 - Multi-port device (i.e. switch) with one follower (synced to the GM) and many leaders on all other ports
 - Provides scalability in large PTP networks
- Transparent Clock
 - Switch that updates timestamps in PTP messages but does not assume a role

Media Network Architecture



- Redundant network for resiliency
- Leaf/Spine switches (boundary clocks) for scalability
- Hybrid facility with PTP → analog to support legacy devices

Lead Clock Determination

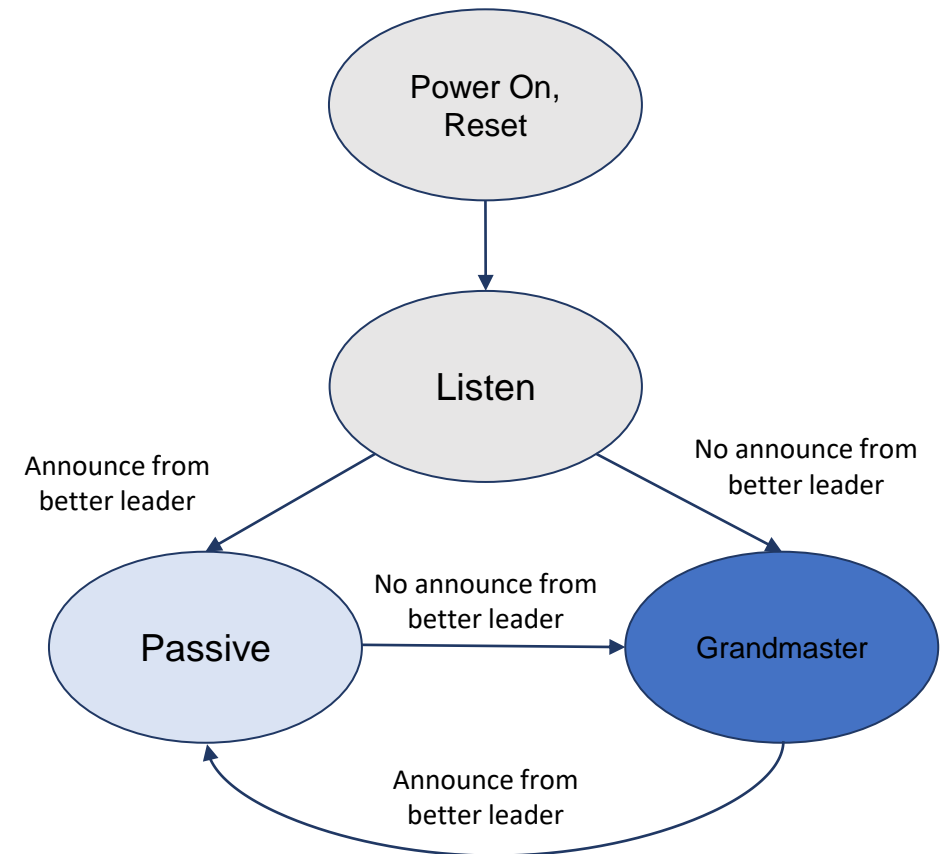


- Announce messages are sent periodically (typ. 1 per second) and include (in priority order):
 1. Priority 1 – user-configured
 2. Clock Class – GNSS locked, holdover, free-running, etc.
 3. Clock Accuracy – estimate based on time source, e.g. “within 25 ns”
 4. Clock Variance – computed stability of local clock
 5. Priority 2 – user-configured
 6. Clock Identity – (tie-breaker) based on MAC address
- Potential leaders use the Best Master Clock Algorithm (BMCA) to decide which node is the sync source

Best Master Clock Algorithm



- Leader clocks listen for other Announce messages
- Start sending Announce when better than received Announce
 - Or when no Announce received (timeout is usually 3s)
- Stop sending Announce (go to Passive) when a better leader is seen



PTP Domains



- Domain is simply a numeric identifier (0-255) for a logical PTP network
- Multiple domains can co-exist on a physical network
 - For example, separate audio (AES67) and ST 2110 domains
- Every PTP message includes the domain number so nodes can accept or discard the message as appropriate

- A profile is a set of PTP options and attributes for a given application
 - Message rate defaults and permitted limits (Announce, Sync, etc.)
 - Communication models (e.g. multicast, unicast, mixed)
- IEEE 1588-2019 specifies the “Delay Request-Response Default PTP Profile”
- SMPTE 2059-2:2021 specifies the “SMPTE profile for synchronization in a professional broadcast environment”
- AES67-2018 specifies the “PTP profile for media applications”
- Other profiles for telecom and other applications

- Specifies the PTP profile used by ST 2110
- Permits three communication models:
 - Multicast for all messages
 - Unicast for all messages. Followers are configured with a list of potential leaders and use a “grant” mechanism to request that the leader send unicast Announce, Sync, and Delay_Resp messages
 - Mixed – Announce, Sync (& Follow_Up) and Management messages are sent by multicast. Delay_Req/Delay_Resp are sent by unicast (without grant)
- Adds a synchronization metadata TLV in Management messages to signal time code information to media nodes (e.g. next jam time)

- Create a solid network plan
 - Redundant amber/blue networks
 - Switches that support PTP, ideally Boundary Clock mode
 - Scalable switch architecture – Spine/Leaf
- Use PTP-only link between amber/blue networks so that GMs can see each other's Announce messages
 - All devices see the same GM on both networks
- Configure switch ports “role master” to prevent rogue leaders
- Use SMPTE 2059-2 profile and default message rates
 - Use Mixed Multicast/Unicast communication model

Troubleshooting Tools



- PTP monitoring and measurements



- Wireshark packet captures for offline analysis

No.	Time	Source	Destination	Protocol	Length	Clockidentity	Text item	correction	Info
101.	1608.334904	172.16.201.101	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628417521529854	Delay_Req Message
101.	1608.386944	172.16.201.101	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628417509913690	Delay_Req Message
101.	1608.398569	172.16.201.99	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628417462548446	Delay_Req Message
101.	1608.445922	172.16.201.109	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628417337748294	Delay_Req Message
101.	1608.570734	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628417323680634	Delay_Req Message
101.	1608.584799	172.16.201.99	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628417297457542	Delay_Req Message
101.	1608.611010	172.16.201.101	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628417249357798	Delay_Req Message
101.	1608.659109	172.16.201.101	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		1844662841721949718	Delay_Req Message
101.	1608.696535	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628417193367030	Delay_Req Message
101.	1608.715140	172.16.201.101	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628417087149362	Delay_Req Message
101.	1608.821319	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628417077915126	Delay_Req Message
101.	1608.830549	172.16.201.99	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628417055422262	Delay_Req Message
101.	1608.853049	172.16.201.101	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628417011835470	Delay_Req Message
101.	1608.896631	172.16.201.99	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628416962349146	Delay_Req Message
101.	1608.946133	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628416883459962	Delay_Req Message
101.	1609.025006	172.16.201.101	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628416837548794	Delay_Req Message
101.	1609.070922	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628416817870070	Delay_Req Message
101.	1609.090612	172.16.201.99	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628416712748794	Delay_Req Message
101.	1609.195732	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628416661407186	Delay_Req Message
101.	1609.247869	172.16.201.99	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628416641459902	Delay_Req Message
101.	1609.267007	172.16.201.101	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628416586950066	Delay_Req Message
101.	1609.321526	172.16.201.109	224.0.1.129	PTPv2	86	0x00090dffffe0fff5		18446628416462149862	Delay_Req Message
101.	1609.446318	172.16.201.109	224.0.1.129	PTPv2	86	0x0010b1ffffe0b8		18446628416455898174	Delay_Req Message
101.	1609.452564	172.16.201.99	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7		18446628416411460004	Delay_Req Message
101.	1609.497001	172.16.201.101	224.0.1.129	PTPv2	86	0x0010b1ffffe0b7			

Any Questions?

