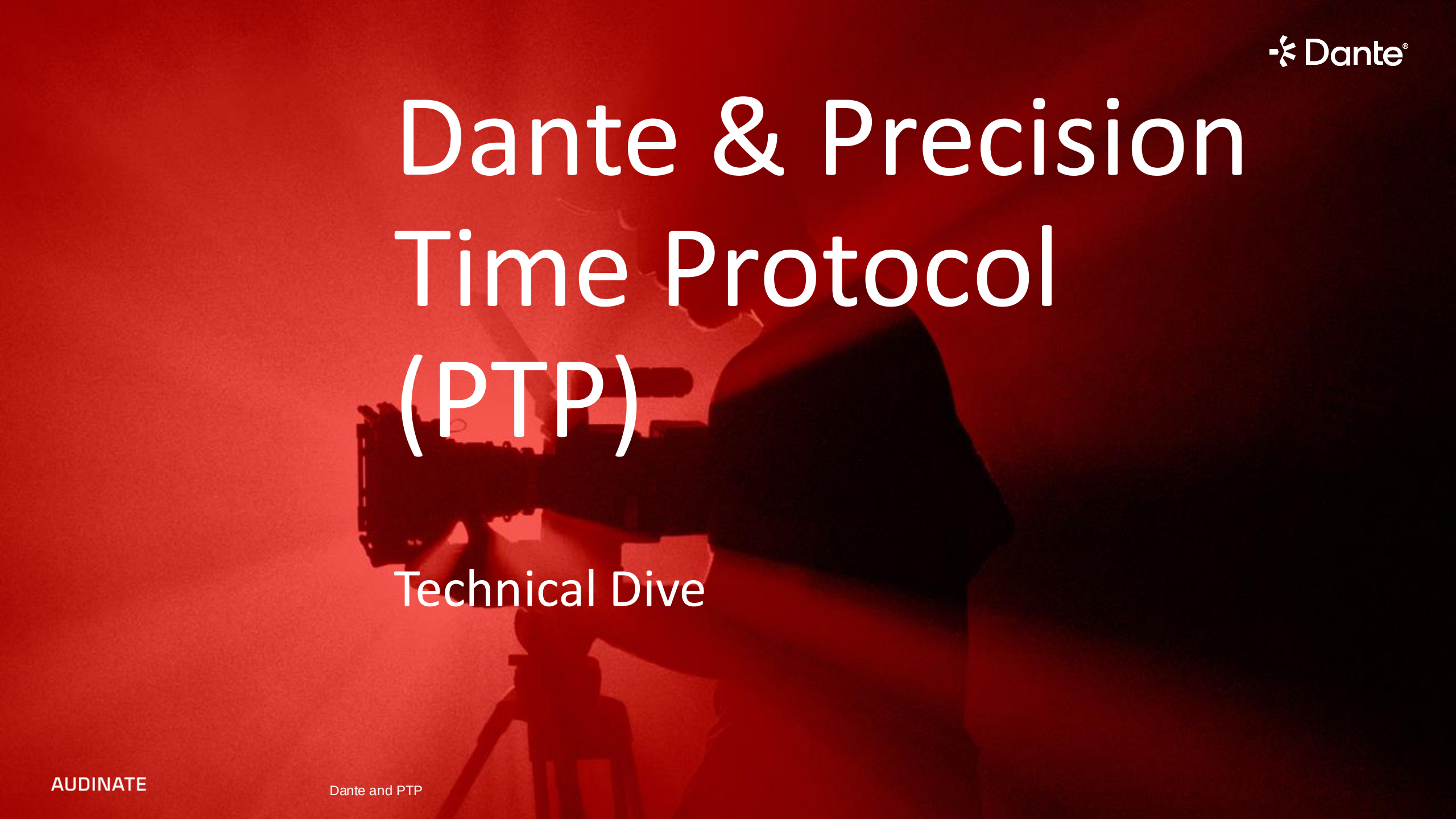


# Dante & Precision Time Protocol (PTP)

Technical Dive

# Disclaimer

We are proud to join the technology community in evolving the language we use. Rethinking the words we use is just one of the ways to reduce barriers to equity and respect.

You may notice that throughout the presentation we will attempt as much as possible to use “Leader/Follower” instead of “Master/Slave”. There could be some places where we do not due to legacy content or applications that haven’t changed yet, but are in progress.

# 01 Let's Talk about Time

# Comparison of Different Timing Sources

## GPS (Global Position System)

- GPS with proper installation and calibration can provide 100ns accuracy
- Challenging installation process (access to open air) to lock with satellites
- It's costly and not straightforward to deploy in a large scale

## IRIG (and other Serial Protocols)

- Mostly used in environments that require millisecond accuracy
- Faces the same challenges as GPS

## NTP (Network Time Protocol)

- Traditionally NTP is used to provide timing information on packet networks
- Its accuracy is limited to millisecond level

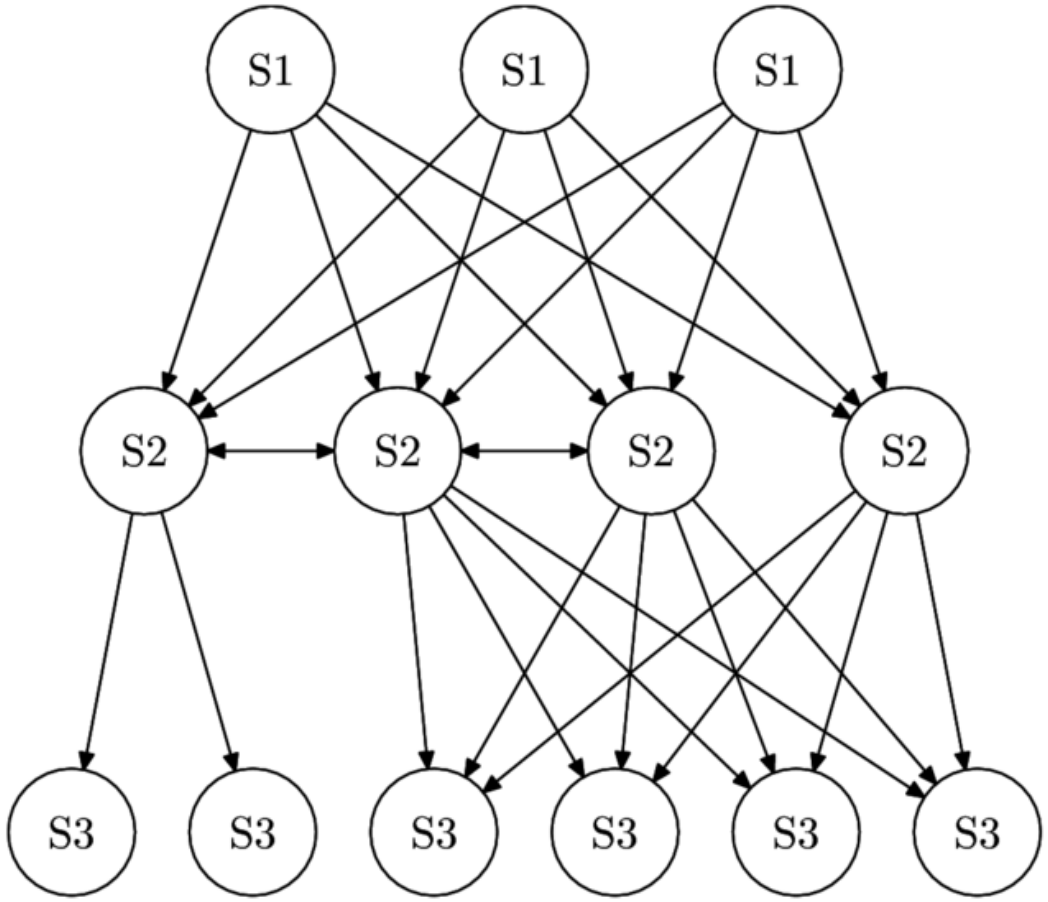
## PTP (Precision Timing Protocol)

- Defined in IEEE1588, distributed time synchronization protocol for packet network.
- Can provide nanosecond accuracy.

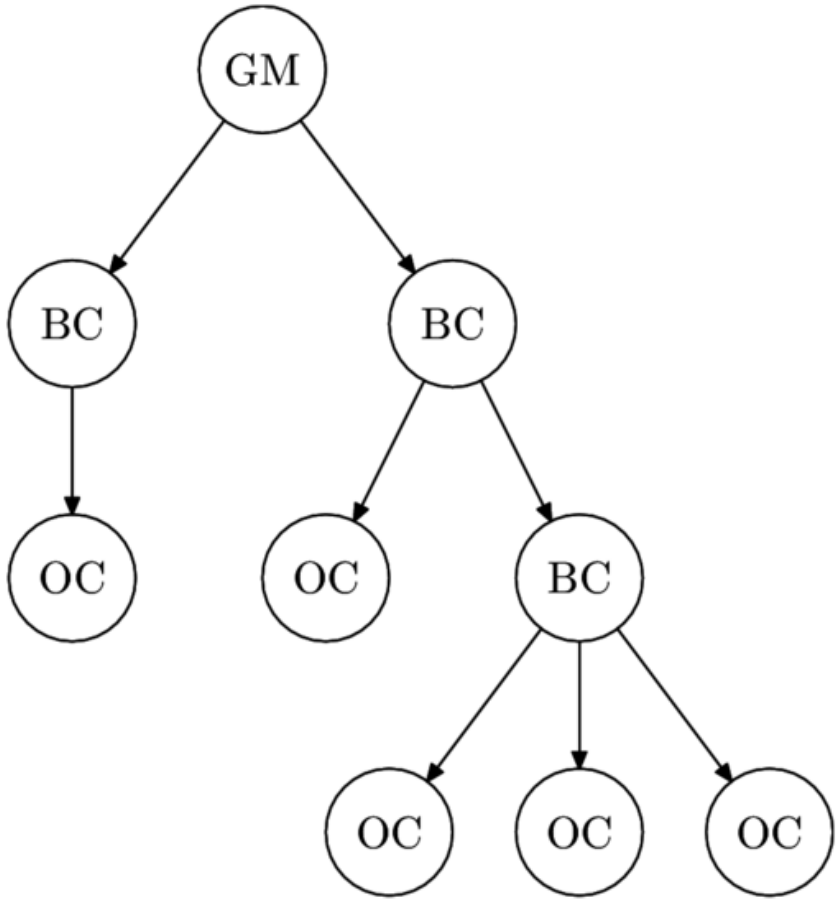
# NTP & IEEE1588 Comparison

| | NTP | IEEE 1588 PTP |
|---|---|---|
| Creation Date | 1981 | 2002 |
| Transport | Layer 3 | Layer 2 & Layer 3 |
| Scope | Internet | LAN |
| Mode of Operation | Client pulls time from Server | Leader pushes time to Follower |
| Frequency/Phase | Frequency & Phase | Frequency & Phase |
| Accuracy | Up to 1ms | Up to 100 ns (which is 0.0001 ms) |
| Timestamping | Software Timestamping* | Software or Hardware Timestamping |
| Hardware Dependency | No | Yes (higher accuracy and special hardware) |
| Cost | Cheaper | Comparatively more expensive |

# NTP & IEEE1588 Comparison: Distribution




NTP strata




PTP domain

# 02 Precision Time Protocol (IEEE 1588)

# Applications of Precision Time Protocol

**Telecommunications**
Mobile Backhaul

**Financial Trading**
High Frequency Trading

**Audio Video Distribution**
Multimedia Broadcast

**Industrial Automation**
Industrial Robots

**Military Systems**
Radar systems

**Airline Industry**
Air Traffic Control Systems

**Smart Grid**
Fault detection

# IEEE 1588 Precision Time Protocol

The IEEE 1588 Standard, also known as Precision Time Protocol (PTP), is a **high-precision distributed time and frequency synchronization protocol** for IP networks, that is used for adjusting a devices' internal clock.

1. Client / Server Architecture (PTP Leader pushes time to PTP Followers)
2. Primarily uses Hardware Timestamping to provide better accuracy than NTP
3. Low administrative effort, easy to manage and maintain
4. Can be low cost, and has low resource use, works on high-end or low-end devices
5. Supports redundancy and has fault-tolerance
6. Message-based protocol, very limited bandwidth is required for PTP data packets

# PTPv1 vs PTPv2

Dante®

**IEEE 1588-2002 is known as PTPv1**

- It is a multicast only protocol

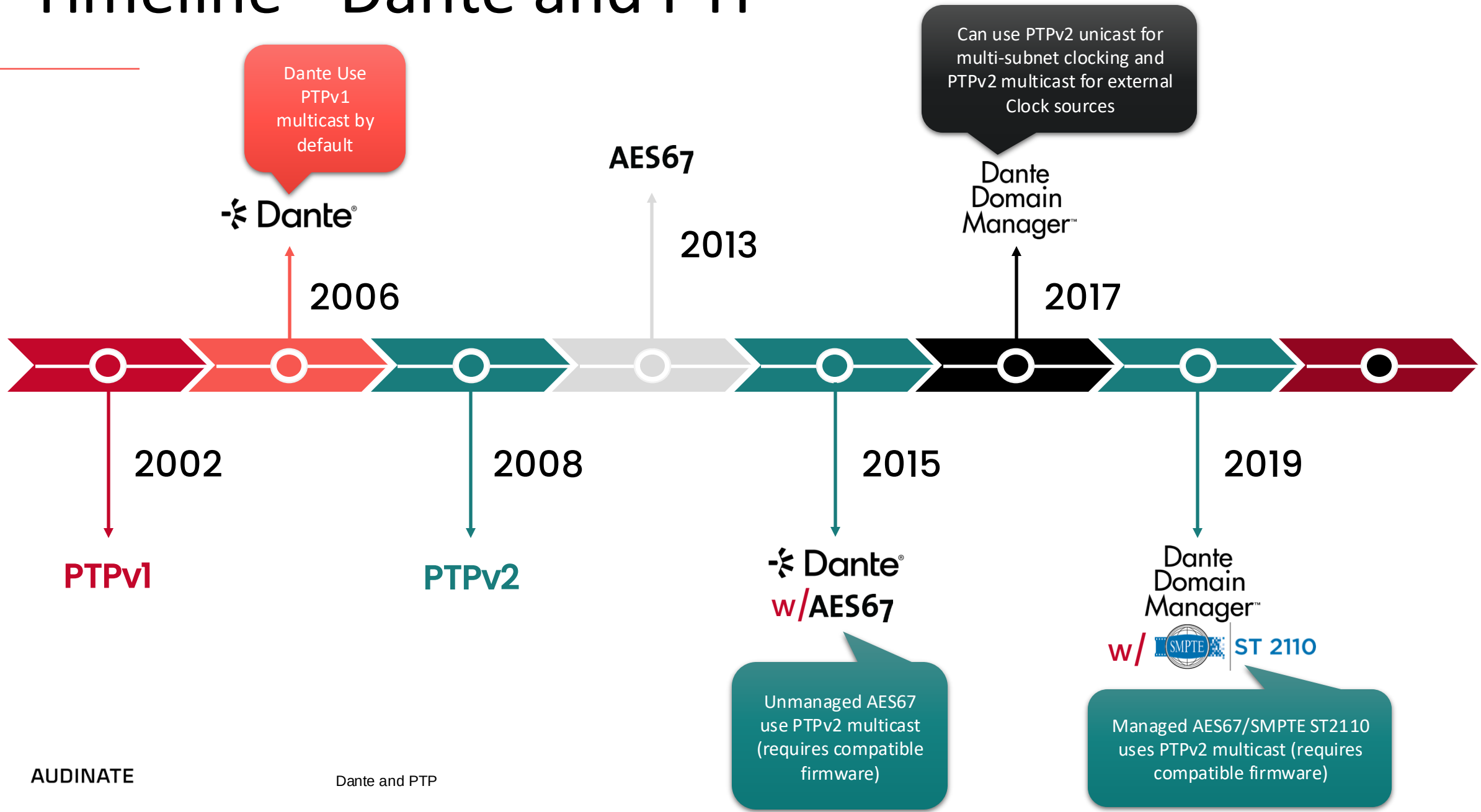
**IEEE 1588-2008 is as known PTPv2**

- IEEE 1588v2 is not backwards compatible with the IEEE 1588-2002 standard
  - But can coexist on a network with PTPv1
- Introduces features to PTPv1 that add flexibility, accuracy, and scalability like:
  - Can use unicast messaging and more flexible sync message rates.
  - Scalable on PTP aware networks where switches act as clocks (boundary or transparent) to reduce PTP traffic flooding.

**IEEE 1588-2019 known as PTPv2.1**

- Is backwards compatible and add some extra features

# Timeline - Dante and PTP



# Others and PTP

## PTPv2

Q-LAN

Livewire

RAVENNA

AES67

IPMX
IP MEDIA EXPERIENCE

SMPTE ST 2110

## gPTP

*(simplified Layer 2 PTPv2 profile)*

AVB

milan

# 03 The math behind device synchronization

# IEEE 1588 Message Types

## Event Messages

**Time Critical events used for Sync**

**Time stamped on egress from a node and ingress to a node**

- Sync
- Delay_Request

## General Messages

**Not time stamped (but might contain timestamps for other messages)**

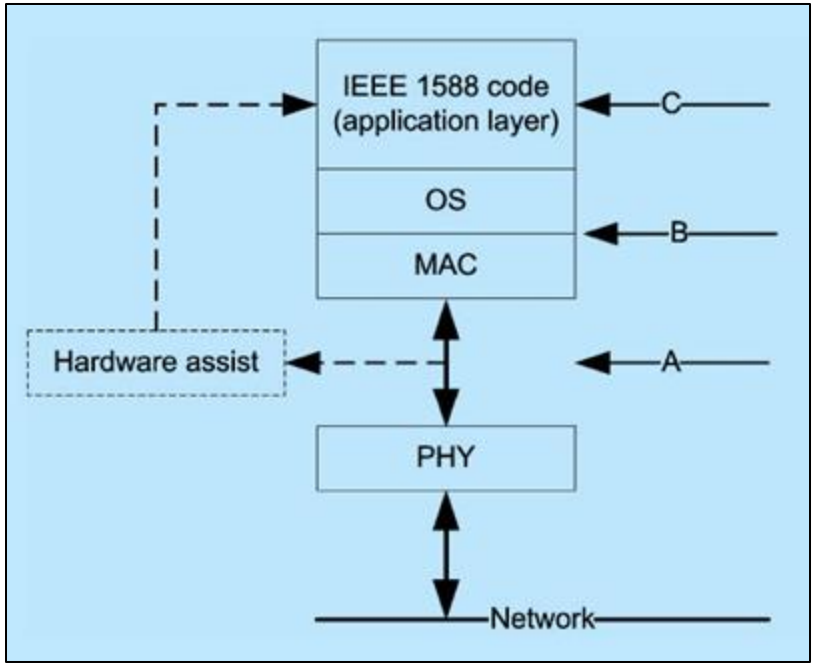
- Follow-up
- Delay_Response
- Announce (v2)

# What is Timestamping?

NTP or PTP calculations for clock synchronizations
are based on timestamps.

Network timestamping is capturing or inserting the system time at which a packet entered (**ingress**) or left (**egress**) the network stack.

Timestamping accuracy will depend on the layer it was performed.



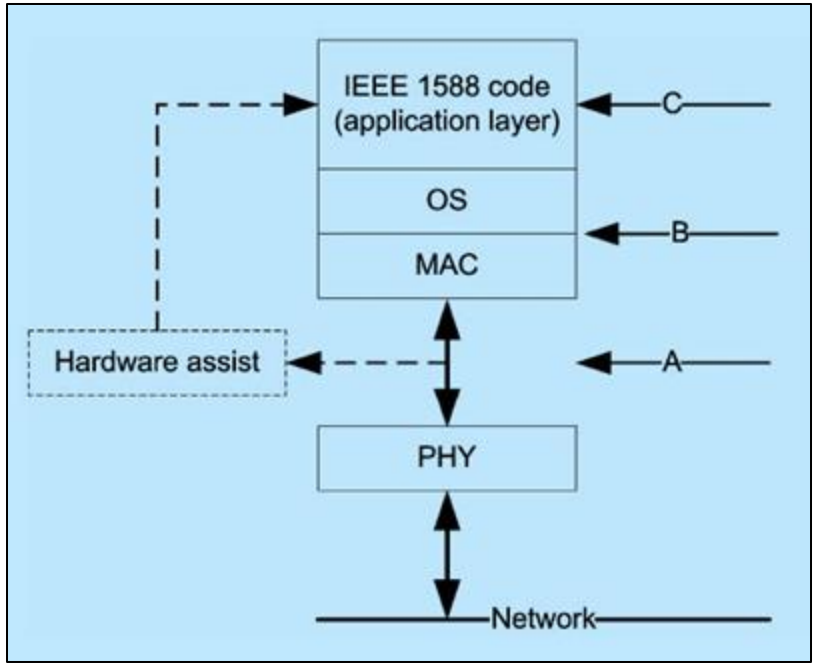
# Timestamping: Software VS Hardware

**Software Timestamping** (NTP or PTP)

- Is done as a separate step to the packet sends/receives
- Can be affected by things like OS scheduling
- Can be performed at the
  - Application Layer ( C ) - 100 µs to few ms
  - Operating System ( B ) - Tens of µs

**Hardware Timestamping**

- Is much more precise but not all NICs support it
- Performed at the
  - Physical (MAC) layer ( A ) - nanoseconds range
- Enables packets to be timestamped the moment they come and go
- Requires application-specific integrated circuit (ASIC) for a switch

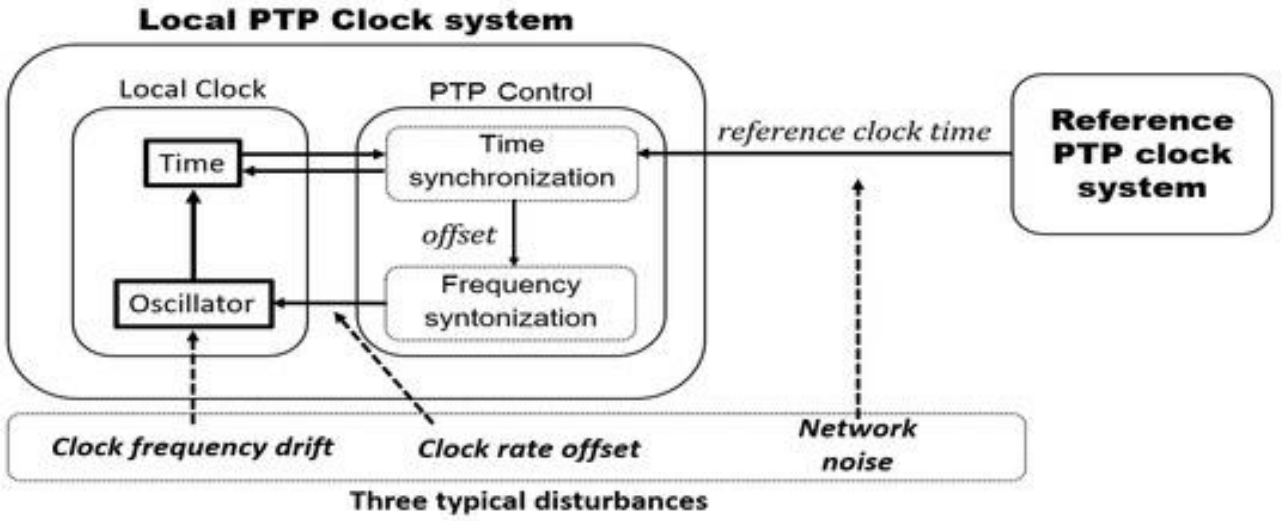


# Clock Synchronization using PTP

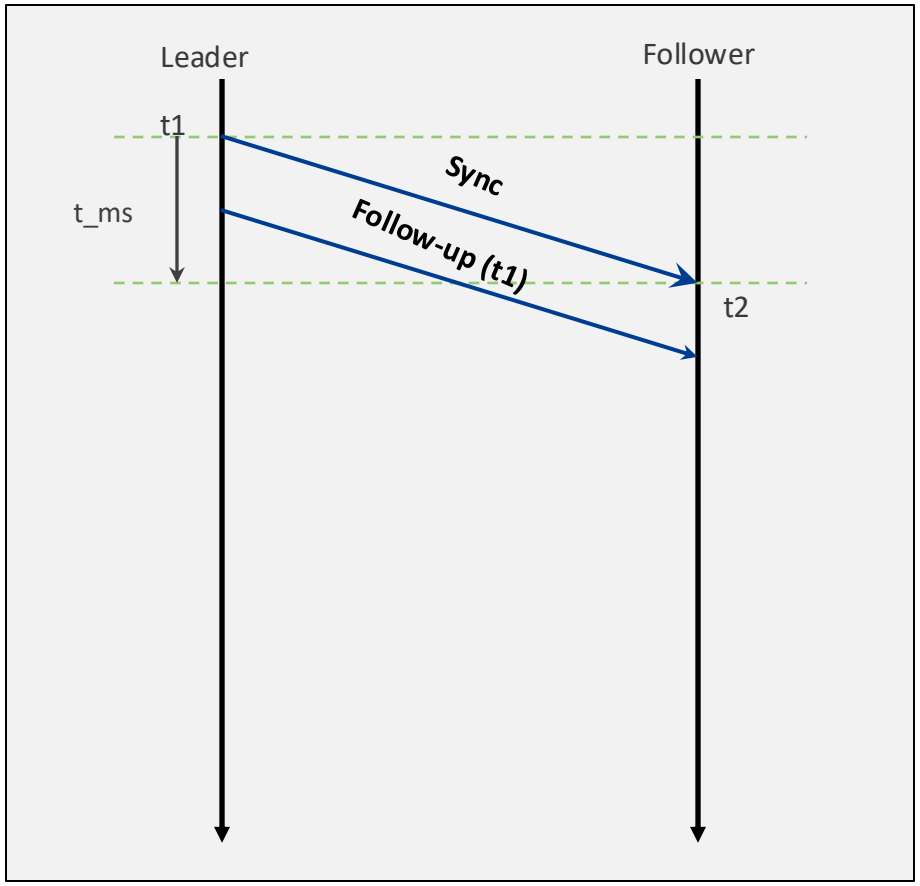
Calculations are based on the PTP Messages Timestamps and assume that network paths are symmetrical.

Followers will:

1. Measure the delay between the leader clock and themselves (End to End E2E)
2. Adjust absolute time & speed using those measurements inside a PTP Control Loop



# Clock Synchronization: Time & Speed Alignment

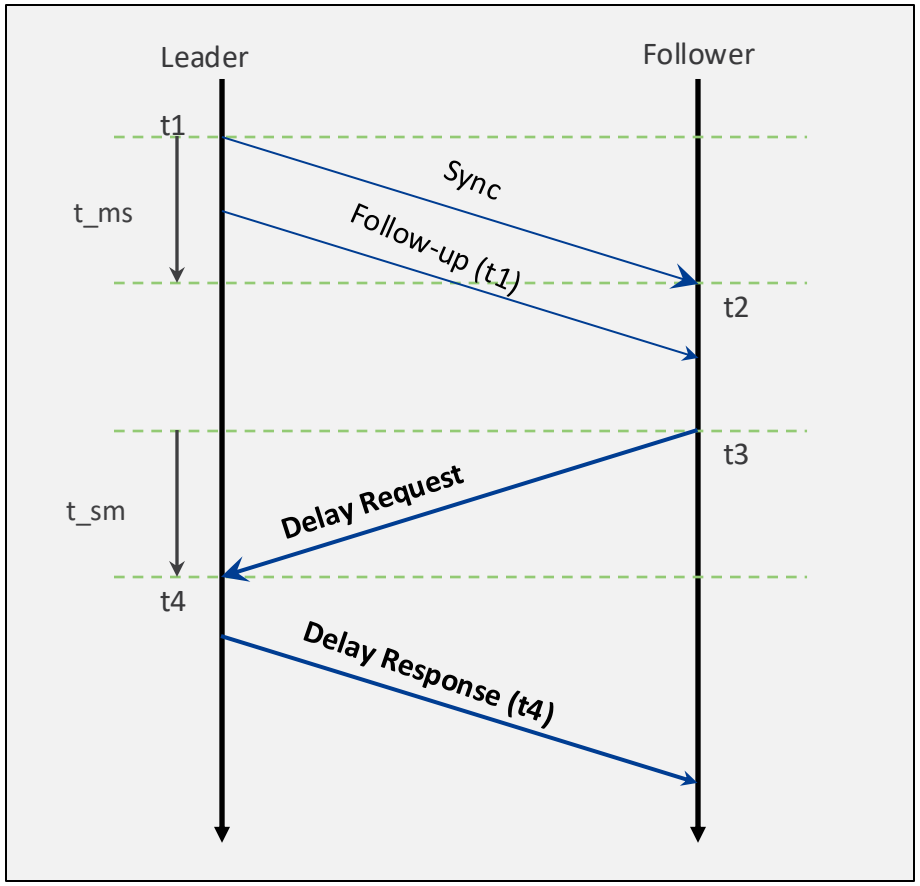



*Both Leader and Follower timestamp using their internal clocks.*

With Sync and Follow up messaged we can align clock time and speed

1. Leader timestamps the egress *Sync* message (**t1**).
   Not all devices can include the actual timestamp on the being sent packet.
   - One Step: hardware assistance allows **t1** to be included on the *Sync* packet.
   - Two Step: effective **t1** is included in the *Follow-up* message.
   - **Dante supports both One Step or Two Step in PTPv1/v2**
2. Follower timestamps the ingress *Sync* message (**t2**) and keeps the information.
3. Follower receives **t1** through the *Sync* or *Follow-up* message (One Step or Two Step)

# Clock Synchronization: Phase Alignment

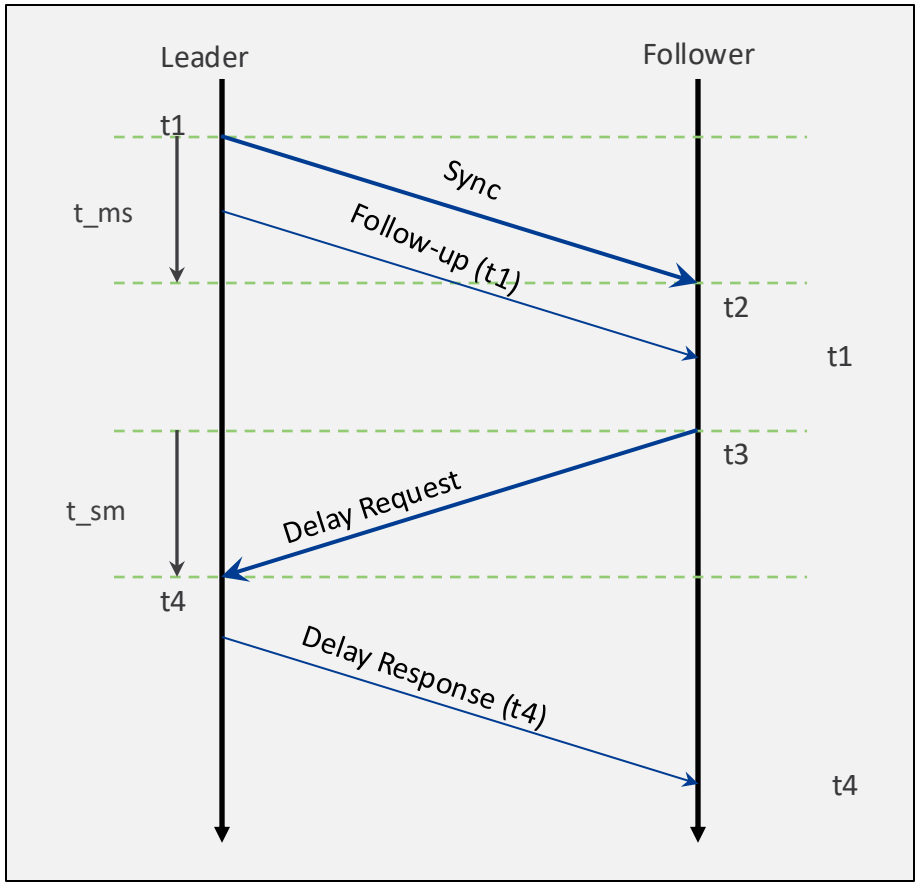



*Both Leader and Follower timestamp using their internal clocks.*

With Delay Request and Delay Response messages we can calculate the network propagation time (delay)

1. Follower timestamps the egress *Delay Request* message (**t3**) and keeps the information.
   - **t3** is not send on the *Delay Request* message
2. Leader timestamps ingress *Delay Request* message (**t4**)
3. Leader provides **t4** to the Follower over the *Delay Response* message

# Clock Synchronization: Offset Alignment

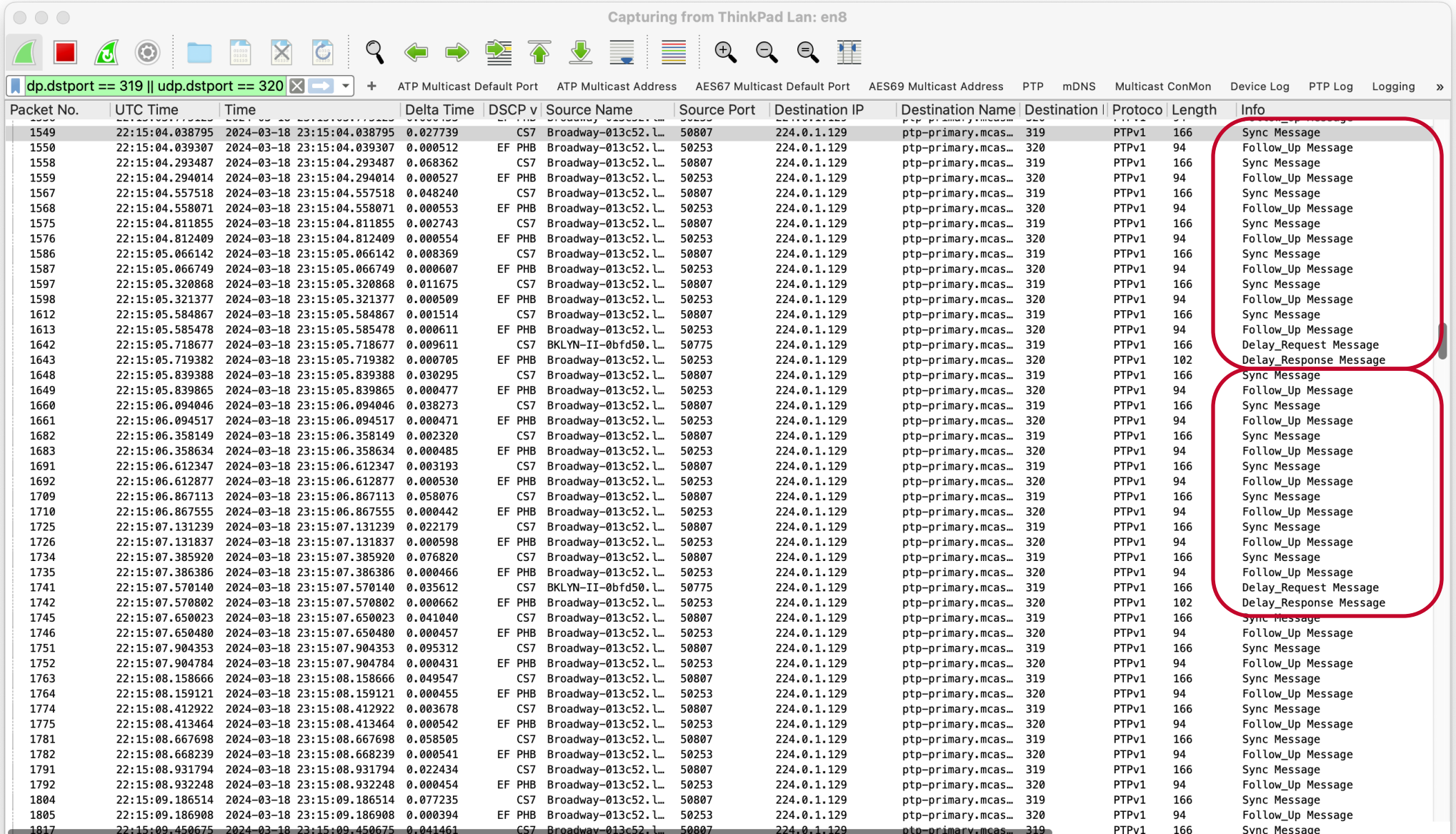



*Both Leader and Follower timestamp using their internal clocks.*

## The math behind it

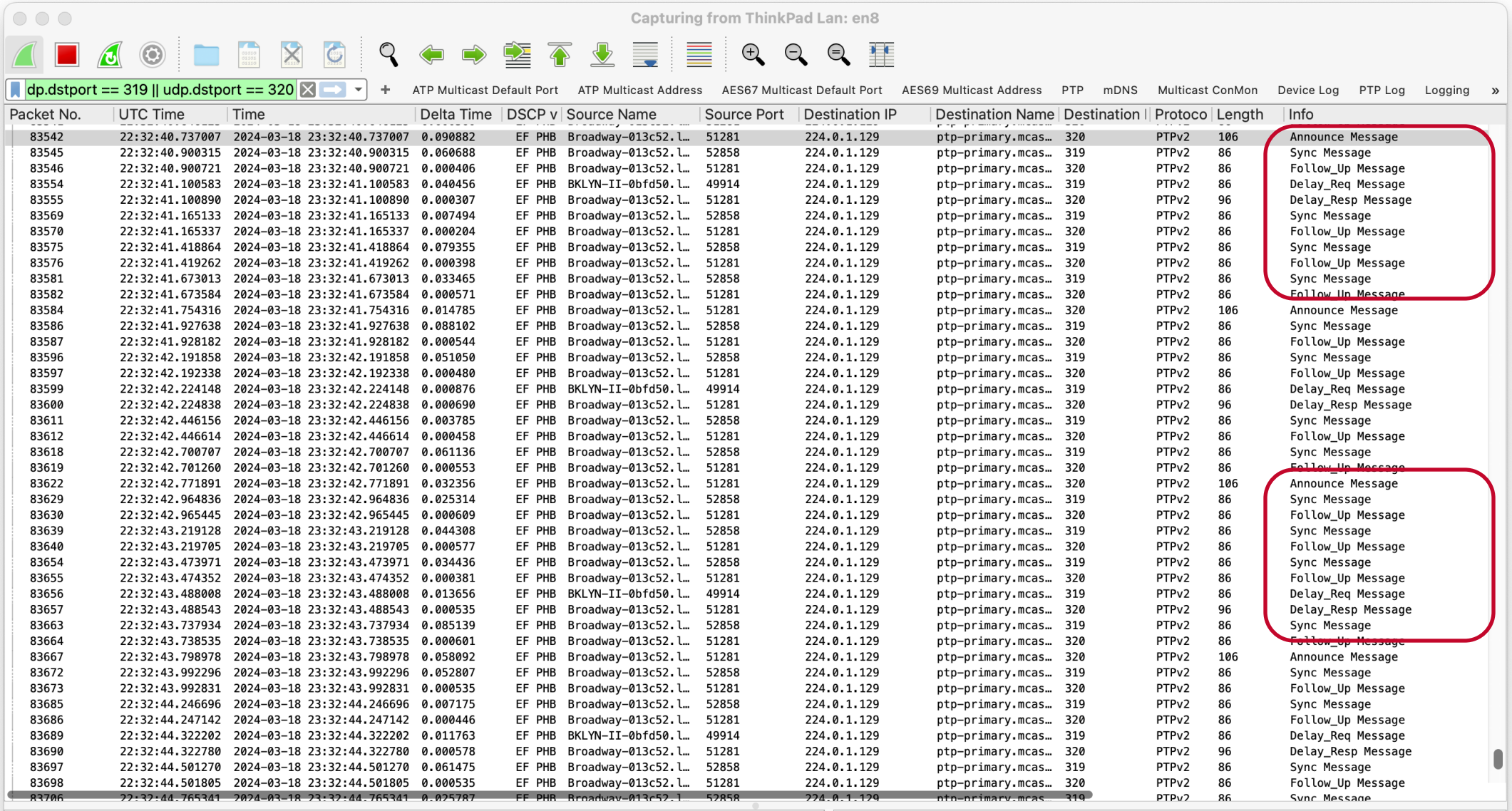
1. The Follower now has all the timestamps ($t_1$ $t_2$ $t_3$ $t_4$) needed to calculate its offset with the Leader:
   - **Delay = [ ( $t_2$ - $t_1$ ) + ( $t_4$ - $t_3$ ) ] / 2**
   - **Offset = $t_2$ – $t_1$ – Delay**
   - **Offset = [ ( $t_2$ - $t_1$ ) - ( $t_4$ - $t_3$ ) ] / 2**
2. Follower feed its PTP Control Loop with the offset to adjust its internal Clock

# Clock Sync in real life: PTPv1 sequence




| Packet No. | UTC Time | Time | Delta Time | DSCP v | Source Name | Source Port | Destination IP | Destination Name | Destination | Protoco | Length | Info |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1549 | 22:15:04.038795 | 2024-03-18 23:15:04.038795 | 0.027739 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1550 | 22:15:04.039307 | 2024-03-18 23:15:04.039307 | 0.000512 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1558 | 22:15:04.293487 | 2024-03-18 23:15:04.293487 | 0.068362 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1559 | 22:15:04.294014 | 2024-03-18 23:15:04.294014 | 0.000527 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1567 | 22:15:04.557518 | 2024-03-18 23:15:04.557518 | 0.048240 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1568 | 22:15:04.558071 | 2024-03-18 23:15:04.558071 | 0.000553 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1575 | 22:15:04.811855 | 2024-03-18 23:15:04.811855 | 0.002743 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1576 | 22:15:04.812409 | 2024-03-18 23:15:04.812409 | 0.000554 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1586 | 22:15:05.066142 | 2024-03-18 23:15:05.066142 | 0.008369 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1587 | 22:15:05.066749 | 2024-03-18 23:15:05.066749 | 0.000607 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1597 | 22:15:05.320868 | 2024-03-18 23:15:05.320868 | 0.011675 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1598 | 22:15:05.321377 | 2024-03-18 23:15:05.321377 | 0.000509 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1612 | 22:15:05.584867 | 2024-03-18 23:15:05.584867 | 0.001514 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1613 | 22:15:05.585478 | 2024-03-18 23:15:05.585478 | 0.000611 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1642 | 22:15:05.718677 | 2024-03-18 23:15:05.718677 | 0.009611 | CS7 | BKLYN-II-0bfd50.l… | 50775 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Delay_Request Message |
| 1643 | 22:15:05.719382 | 2024-03-18 23:15:05.719382 | 0.000705 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 102 | Delay_Response Message |
| 1648 | 22:15:05.839388 | 2024-03-18 23:15:05.839388 | 0.030295 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1649 | 22:15:05.839865 | 2024-03-18 23:15:05.839865 | 0.000477 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1660 | 22:15:06.094046 | 2024-03-18 23:15:06.094046 | 0.038273 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1661 | 22:15:06.094517 | 2024-03-18 23:15:06.094517 | 0.000471 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1682 | 22:15:06.358149 | 2024-03-18 23:15:06.358149 | 0.002320 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1683 | 22:15:06.358634 | 2024-03-18 23:15:06.358634 | 0.000485 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1691 | 22:15:06.612347 | 2024-03-18 23:15:06.612347 | 0.003193 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1692 | 22:15:06.612877 | 2024-03-18 23:15:06.612877 | 0.000530 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1709 | 22:15:06.867113 | 2024-03-18 23:15:06.867113 | 0.058076 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1710 | 22:15:06.867555 | 2024-03-18 23:15:06.867555 | 0.000442 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1725 | 22:15:07.131239 | 2024-03-18 23:15:07.131239 | 0.022179 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1726 | 22:15:07.131837 | 2024-03-18 23:15:07.131837 | 0.000598 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1734 | 22:15:07.385920 | 2024-03-18 23:15:07.385920 | 0.076820 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1735 | 22:15:07.386386 | 2024-03-18 23:15:07.386386 | 0.000466 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1741 | 22:15:07.570140 | 2024-03-18 23:15:07.570140 | 0.035612 | CS7 | BKLYN-II-0bfd50.l… | 50775 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Delay_Request Message |
| 1742 | 22:15:07.570802 | 2024-03-18 23:15:07.570802 | 0.000662 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 102 | Delay_Response Message |
| 1745 | 22:15:07.650023 | 2024-03-18 23:15:07.650023 | 0.041040 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1746 | 22:15:07.650480 | 2024-03-18 23:15:07.650480 | 0.000457 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1751 | 22:15:07.904353 | 2024-03-18 23:15:07.904353 | 0.095312 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1752 | 22:15:07.904784 | 2024-03-18 23:15:07.904784 | 0.000431 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1763 | 22:15:08.158666 | 2024-03-18 23:15:08.158666 | 0.049547 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1764 | 22:15:08.159121 | 2024-03-18 23:15:08.159121 | 0.000455 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1774 | 22:15:08.412922 | 2024-03-18 23:15:08.412922 | 0.003678 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1775 | 22:15:08.413464 | 2024-03-18 23:15:08.413464 | 0.000542 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1781 | 22:15:08.667698 | 2024-03-18 23:15:08.667698 | 0.058505 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1782 | 22:15:08.668239 | 2024-03-18 23:15:08.668239 | 0.000541 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1791 | 22:15:08.931794 | 2024-03-18 23:15:08.931794 | 0.022434 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1792 | 22:15:08.932248 | 2024-03-18 23:15:08.932248 | 0.000454 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |
| 1804 | 22:15:09.186514 | 2024-03-18 23:15:09.186514 | 0.077235 | CS7 | Broadway-013c52.l… | 50807 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv1 | 166 | Sync Message |
| 1805 | 22:15:09.186908 | 2024-03-18 23:15:09.186908 | 0.000394 | EF PHB | Broadway-013c52.l… | 50253 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv1 | 94 | Follow_Up Message |

# Clock Sync in real life: PTPv2 sequence




| Packet No. | UTC Time | Time | Delta Time | DSCP v | Source Name | Source Port | Destination IP | Destination Name | Destination | Protoco | Length | Info |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 83542 | 22:32:40.737007 | 2024-03-18 23:32:40.737007 | 0.090882 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 106 | Announce Message |
| 83545 | 22:32:40.900315 | 2024-03-18 23:32:40.900315 | 0.060688 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83546 | 22:32:40.900721 | 2024-03-18 23:32:40.900721 | 0.000406 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83554 | 22:32:41.100583 | 2024-03-18 23:32:41.100583 | 0.040456 | EF PHB | BKLYN-II-0bfd50.l… | 49914 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Delay_Req Message |
| 83555 | 22:32:41.100890 | 2024-03-18 23:32:41.100890 | 0.000307 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 96 | Delay_Resp Message |
| 83569 | 22:32:41.165133 | 2024-03-18 23:32:41.165133 | 0.007494 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83570 | 22:32:41.165337 | 2024-03-18 23:32:41.165337 | 0.000204 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83575 | 22:32:41.418864 | 2024-03-18 23:32:41.418864 | 0.079355 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83576 | 22:32:41.419262 | 2024-03-18 23:32:41.419262 | 0.000398 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83581 | 22:32:41.673013 | 2024-03-18 23:32:41.673013 | 0.033465 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83582 | 22:32:41.673584 | 2024-03-18 23:32:41.673584 | 0.000571 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83584 | 22:32:41.754316 | 2024-03-18 23:32:41.754316 | 0.014785 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 106 | Announce Message |
| 83586 | 22:32:41.927638 | 2024-03-18 23:32:41.927638 | 0.088102 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83587 | 22:32:41.928182 | 2024-03-18 23:32:41.928182 | 0.000544 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83596 | 22:32:42.191858 | 2024-03-18 23:32:42.191858 | 0.051050 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83597 | 22:32:42.192338 | 2024-03-18 23:32:42.192338 | 0.000480 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83599 | 22:32:42.224148 | 2024-03-18 23:32:42.224148 | 0.000876 | EF PHB | BKLYN-II-0bfd50.l… | 49914 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Delay_Req Message |
| 83600 | 22:32:42.224838 | 2024-03-18 23:32:42.224838 | 0.000690 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 96 | Delay_Resp Message |
| 83611 | 22:32:42.446156 | 2024-03-18 23:32:42.446156 | 0.003785 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83612 | 22:32:42.446614 | 2024-03-18 23:32:42.446614 | 0.000458 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83618 | 22:32:42.700707 | 2024-03-18 23:32:42.700707 | 0.061136 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83619 | 22:32:42.701260 | 2024-03-18 23:32:42.701260 | 0.000553 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83622 | 22:32:42.771891 | 2024-03-18 23:32:42.771891 | 0.032356 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 106 | Announce Message |
| 83629 | 22:32:42.964836 | 2024-03-18 23:32:42.964836 | 0.025314 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83630 | 22:32:42.965445 | 2024-03-18 23:32:42.965445 | 0.000609 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83639 | 22:32:43.219128 | 2024-03-18 23:32:43.219128 | 0.044308 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83640 | 22:32:43.219705 | 2024-03-18 23:32:43.219705 | 0.000577 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83654 | 22:32:43.473971 | 2024-03-18 23:32:43.473971 | 0.034436 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83655 | 22:32:43.474352 | 2024-03-18 23:32:43.474352 | 0.000381 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83656 | 22:32:43.488008 | 2024-03-18 23:32:43.488008 | 0.013656 | EF PHB | BKLYN-II-0bfd50.l… | 49914 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Delay_Req Message |
| 83657 | 22:32:43.488543 | 2024-03-18 23:32:43.488543 | 0.000535 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 96 | Delay_Resp Message |
| 83663 | 22:32:43.737934 | 2024-03-18 23:32:43.737934 | 0.085139 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83664 | 22:32:43.738535 | 2024-03-18 23:32:43.738535 | 0.000601 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83667 | 22:32:43.798978 | 2024-03-18 23:32:43.798978 | 0.058092 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 106 | Announce Message |
| 83672 | 22:32:43.992296 | 2024-03-18 23:32:43.992296 | 0.052807 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83673 | 22:32:43.992831 | 2024-03-18 23:32:43.992831 | 0.000535 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83685 | 22:32:44.246696 | 2024-03-18 23:32:44.246696 | 0.007175 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83686 | 22:32:44.247142 | 2024-03-18 23:32:44.247142 | 0.000446 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |
| 83689 | 22:32:44.322202 | 2024-03-18 23:32:44.322202 | 0.011763 | EF PHB | BKLYN-II-0bfd50.l… | 49914 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Delay_Req Message |
| 83690 | 22:32:44.322780 | 2024-03-18 23:32:44.322780 | 0.000578 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 96 | Delay_Resp Message |
| 83697 | 22:32:44.501270 | 2024-03-18 23:32:44.501270 | 0.061475 | EF PHB | Broadway-013c52.l… | 52858 | 224.0.1.129 | ptp-primary.mcas… | 319 | PTPv2 | 86 | Sync Message |
| 83698 | 22:32:44.501805 | 2024-03-18 23:32:44.501805 | 0.000535 | EF PHB | Broadway-013c52.l… | 51281 | 224.0.1.129 | ptp-primary.mcas… | 320 | PTPv2 | 86 | Follow_Up Message |

# Clock Sync in real life: PTPv2 packets detail

## Announce

Precision Time Protocol (IEEE1588)

| majorS... 0x0 | messag... Announ... | minorV... 0 | version... 2 | messageLength 64 |
|---|---|---|---|---|
| domainNumber 0 | | minorSdoId 0 | | flags 0x0000 |
| correctionField: 0.000000 nanoseconds ✓ | | | | |
| messageTypeSpecific 0 | | | | |
| ClockIdentity 0x001dc1fffe0bfd50 | | | | |
| SourcePortID 2 | | | | sequenceId 1411 |
| controlField Other Message | logMessagePeriod 0 | | | |
| originTimestamp (seconds) 0 | | | | |
| originTimestamp (nanoseconds) 0 | | | | |
| originCurrentUTCOffset 0 | | | | priority1 128 |
| grandmasterClockCl... 248 | grandmasterClockAc... Accuracy Unknown | | | grandmasterClockVariance 61536 |
| priority2 128 | | | | |
| grandmasterClockIdentity 0x001dc1fffe0bfd50 | | | | |
| | localStepsRemoved 0 | | | TimeSource INTERNAL_OSCILLA... |

Sync

Follow-up

Precision Time Protocol (IEEE1588)

| majorS... 0x0 | messag... Sync M... | minorV... 0 | version... 2 | messageLength 44 |
|---|---|---|---|---|
| domainNumber 120 | | minorSdoId 0 | | flags 0x0200 |
| correctionField: 0.000000 nanoseconds ✓ | | | | |
| messageTypeSpecific 0 | | | | |
| ClockIdentity 0x000c29fffe828487 | | | | |
| SourcePortID 2 | | | | sequenceId 24841 |
| controlField Sync Message | logMessagePeriod -2 | | | |
| originTimestamp (seconds) 0 | | | | |
| originTimestamp (nanoseconds) 0 | | | | |

Precision Time Protocol (IEEE1588)

| majorS... 0x0 | messag... Follow_... | minorV... 0 | version... 2 | messageLength 44 |
|---|---|---|---|---|
| domainNumber 120 | | minorSdoId 0 | | flags 0x0000 |
| correctionField: 0.000000 nanoseconds ✓ | | | | |
| messageTypeSpecific 0 | | | | |
| ClockIdentity 0x000c29fffe828487 | | | | |
| SourcePortID 2 | | | | sequenceId 24841 |
| controlField Follow_Up Message | logMessagePeriod -2 | | | |
| preciseOriginTimestamp (seconds) 1711038782 | | | | |
| preciseOriginTimestamp (nanoseconds) 428082241 | | | | |

Delay Request

Delay Response

Precision Time Protocol (IEEE1588)

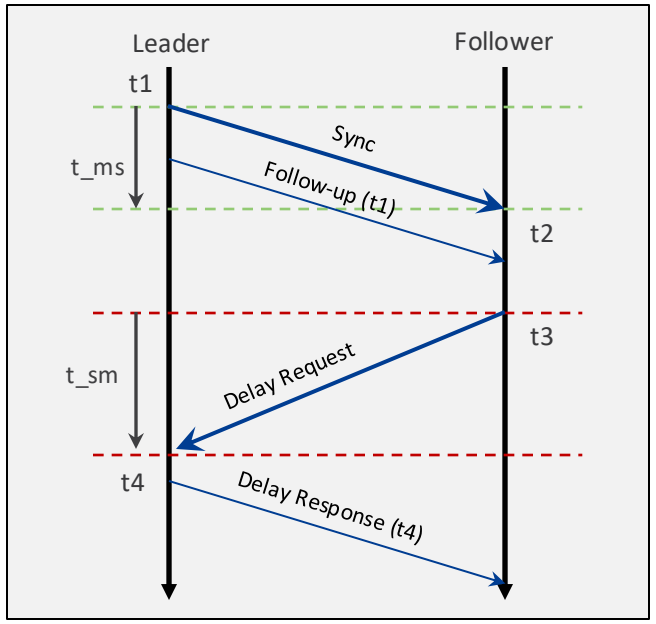
| majorS... 0x0 | messag... Delay_R... | minorV... 0 | version... 2 | messageLength 44 |
|---|---|---|---|---|
| domainNumber 0 | | minorSdoId 0 | | flags 0x0000 |
| correctionField: 0.000000 nanoseconds ✓ | | | | |
| messageTypeSpecific 0 | | | | |
| ClockIdentity 0x001dc1fffe196058 | | | | |
| SourcePortID 2 | | | | sequenceId 1409 |
| controlField Delay_Req Message | logMessagePeriod 127 | | | |
| originTimestamp (seconds) 1711031550 | | | | |
| originTimestamp (nanoseconds) 685135822 | | | | |

Precision Time Protocol (IEEE1588)

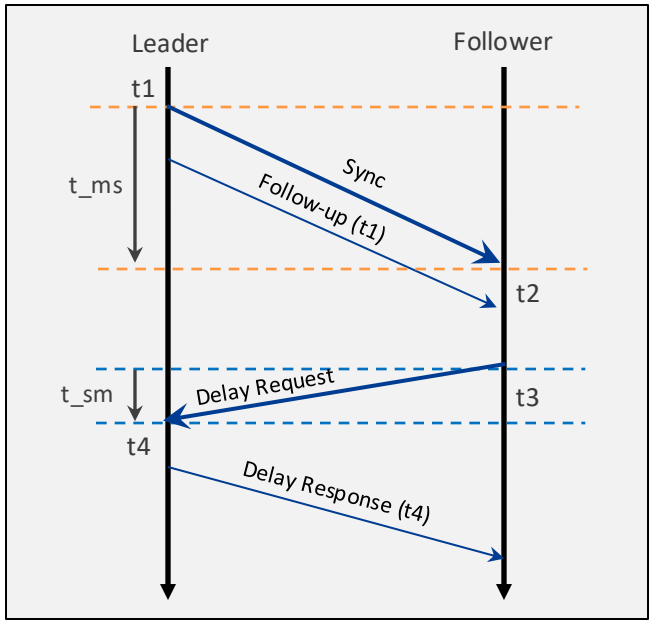
| majorS... 0x0 | messag... Delay_R... | minorV... 0 | version... 2 | messageLength 54 |
|---|---|---|---|---|
| domainNumber 0 | | minorSdoId 0 | | flags 0x0000 |
| correctionField: 0.000000 nanoseconds ✓ | | | | |
| messageTypeSpecific 0 | | | | |
| ClockIdentity 0x001dc1fffe0bfd50 | | | | |
| SourcePortID 2 | | | | sequenceId 1409 |
| controlField Delay_Resp Message | logMessagePeriod 0 | | | |
| receiveTimestamp (seconds) 1711038783 | | | | |
| receiveTimestamp (nanoseconds) 246595295 | | | | |
| requestingSourcePortIdentity 0x001dc1fffe196058 | | | | |
| requestingSourcePortId 2 | | | | |

# Jitter and Clocking

- If there's too much jitter, calculated times (t_ms and t_sm) will vary too much resulting in irregular clock offset adjustments.




**Sequence 1**




**Sequence 2**

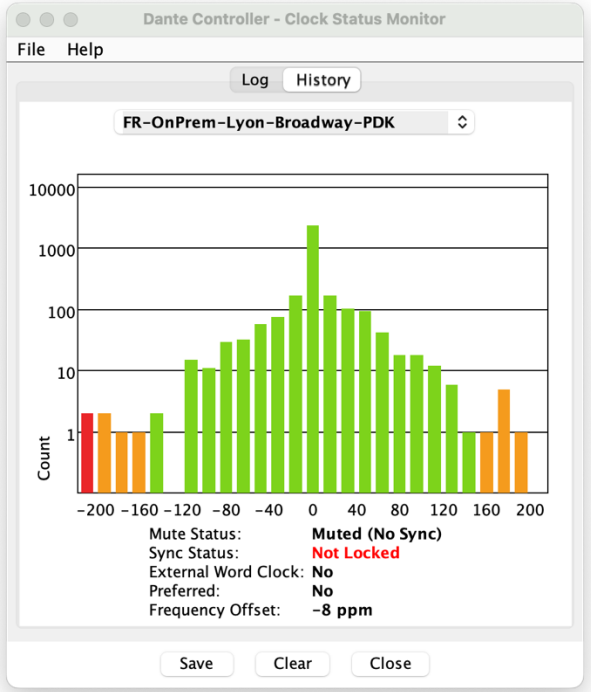
**PTP Offset = [ ( $t_2$ - $t_1$ ) - ( $t_4$ - $t_3$ ) ] / 2**

# PPM (Parts Per Million)

The frequency offset in DC is not the PTP offset/drift

The offset value in DC is calculated based on frequency difference and the correction applied to the follower internal control loop.

This value is presented in DC in PPM (parts per million); i.e.  1 part per million (worst case 1 sec gain/loss every 11.5 days).



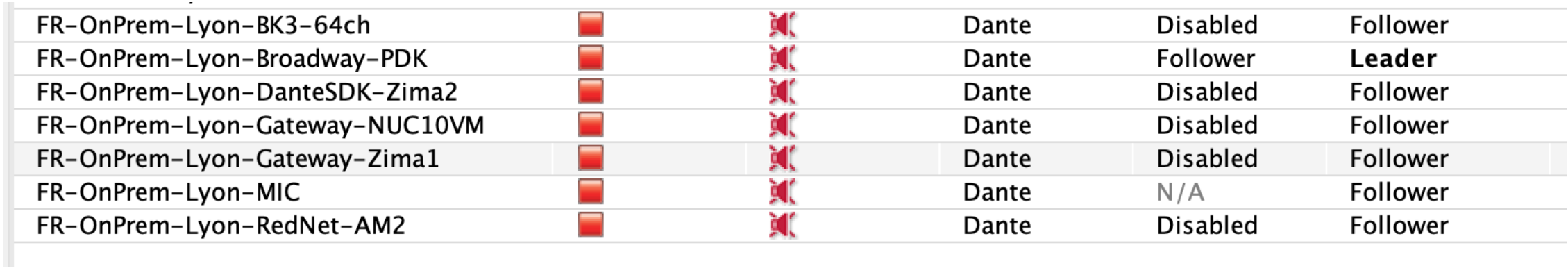
# Jitter and Clocking

When PTP fails to achieve synchronization, Dante devices will mute.

This can be the case:

- over encrypted VPN links or locations connected with intermediate firewalls.
- on Energy Efficient Ethernet (EEE) switches.

| | Jitter Tolerances |
|---|---|
| Dante Hardware | Up to 250us |
| Dante Software | Up to 1ms |

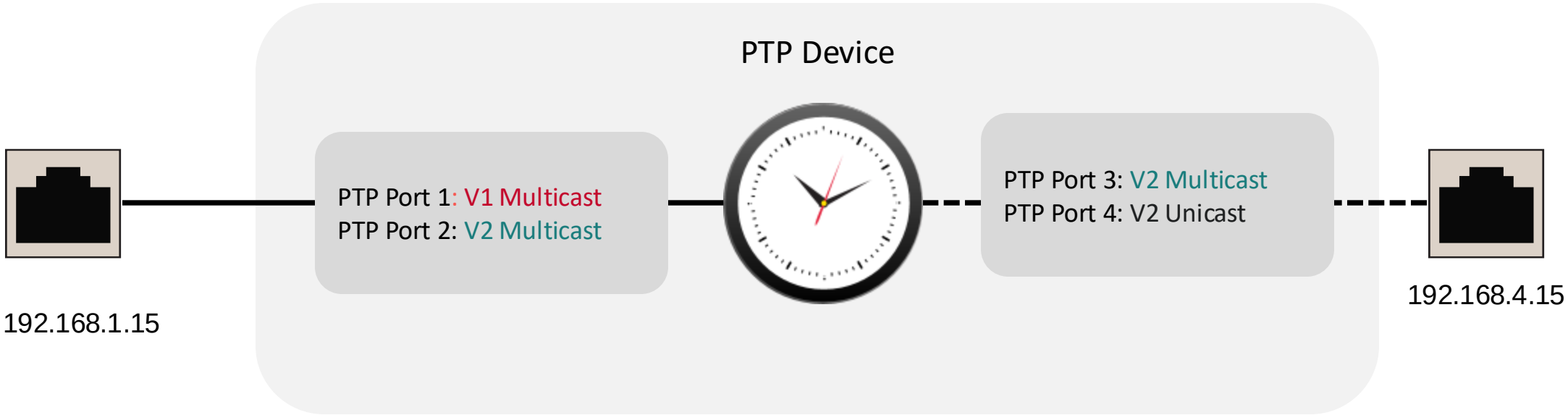


| | | | | | |
|---|---|---|---|---|---|
| FR-OnPrem-Lyon-BK3-64ch | | | Dante | Disabled | Follower |
| FR-OnPrem-Lyon-Broadway-PDK | | | Dante | Follower | **Leader** |
| FR-OnPrem-Lyon-DanteSDK-Zima2 | | | Dante | Disabled | Follower |
| FR-OnPrem-Lyon-Gateway-NUC10VM | | | Dante | Disabled | Follower |
| FR-OnPrem-Lyon-Gateway-Zima1 | | | Dante | Disabled | Follower |
| FR-OnPrem-Lyon-MIC | | | Dante | N/A | Follower |
| FR-OnPrem-Lyon-RedNet-AM2 | | | Dante | Disabled | Follower |

# 04 PTP Organizational Principles

# PTP Ports

- A PTP Port refers to an entity within a device that participates in PTP communication
- Multiple PTP ports can co-exist on a single NIC
- PTP Ports can have multiple states



# IEEE 1588 PTP Ports States

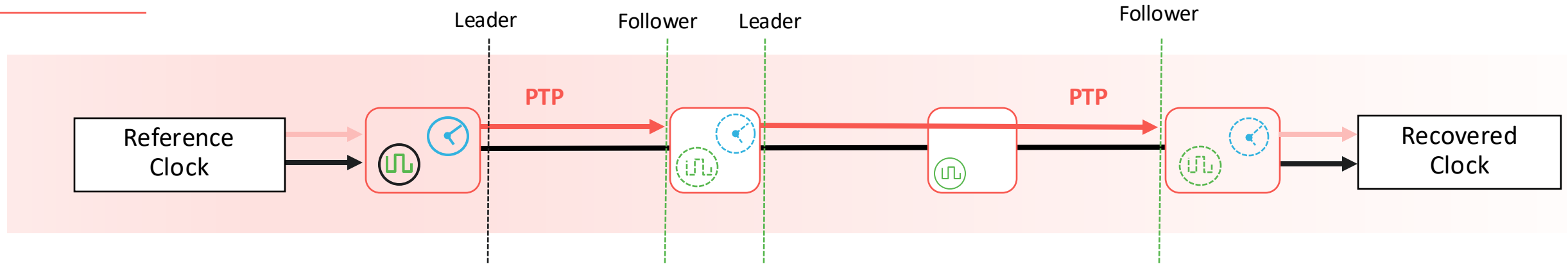
| Multicast | Unicast | State | Description |
|---|---|---|---|
|  |  | **Leader** | The port is the source of time on the path served by the port |
| | | **PreLeader** | Transit state before becoming Leader |
|  |  | **Follower** | The port synchronizes with the device on the path on the port that is in the Leader state |
| | | **Listening*** | Transit state before assuming a role |
|  |  | **Passive/Standby** | This state prevents timing loops at the PTP level |

1. You can **NOT** be Follower on multiple ports
2. You **CAN** be Leader on multiple ports



**Can also be the state of Follower only devices waiting for a Leader*

# PTP Clock types




## Grand Master Clock

- Primary reference source for all other PTP devices
- Highest-ranking clock in the network

## Boundary Clock

- Has multiple PTP Ports
- Terminates the PTP flow, recovers the clock and regenerates a new PTP flow

## Transparent Clock

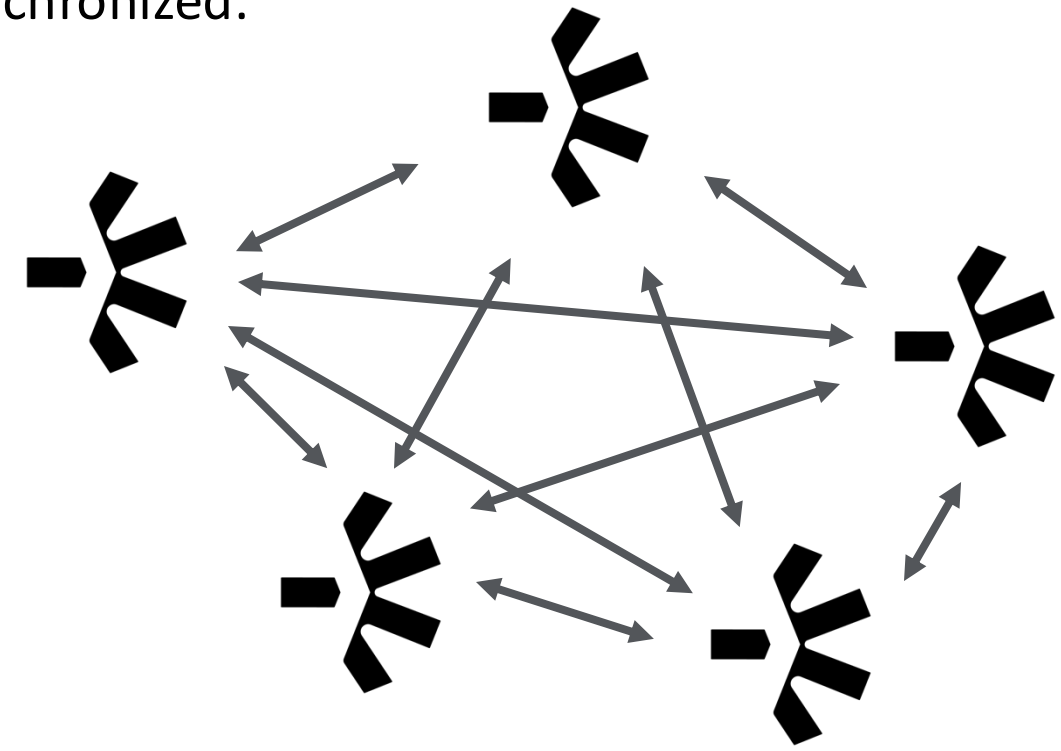
- General switching device in a PTP aware network
- Can correct for queuing delay/resident delay

## Ordinary Clock

- Single PTP Port Device
- Can act as Leader

# Grand Master Clock Election: BMCA

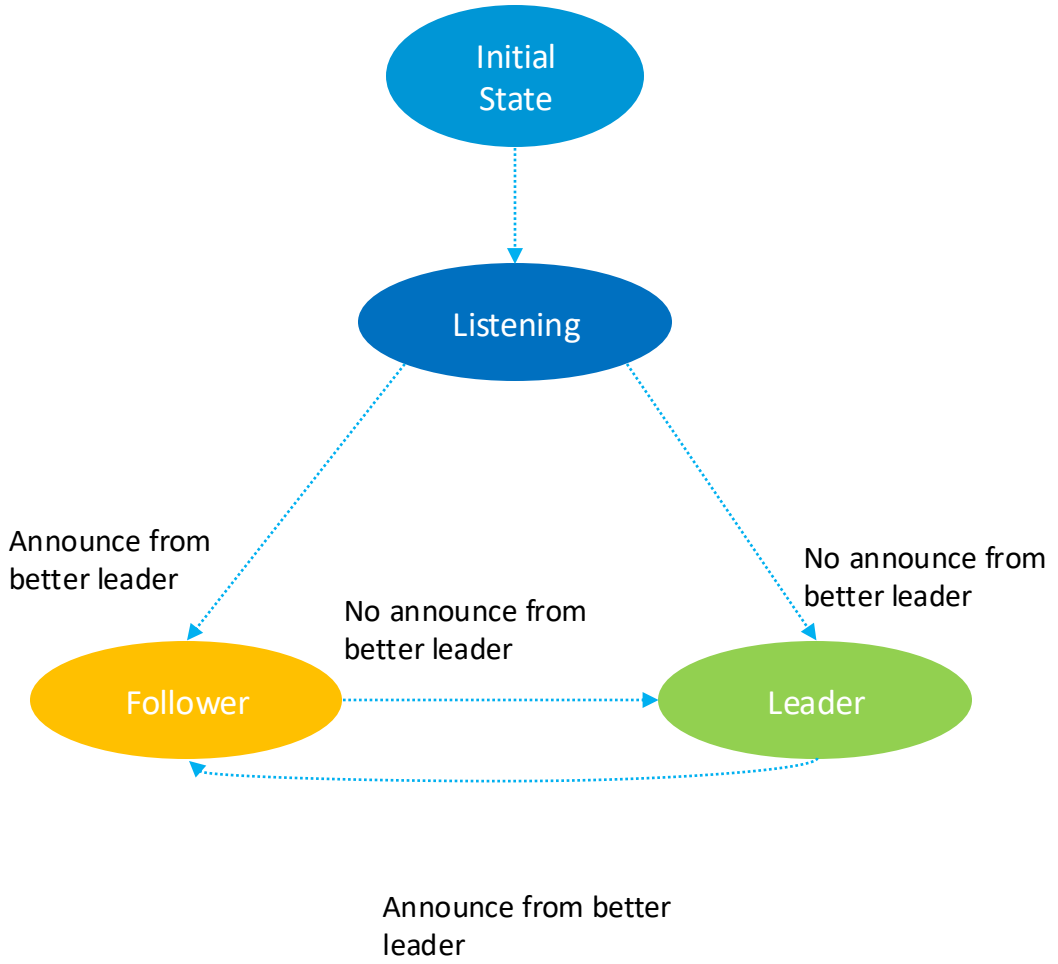
The **Best Master Clock Algorithm (BMCA)** is a self configuring mechanism that will automatically pick the best Clock on a network segment to which other devices will be synchronized.



# Grand Master Clock Election: BMCA state

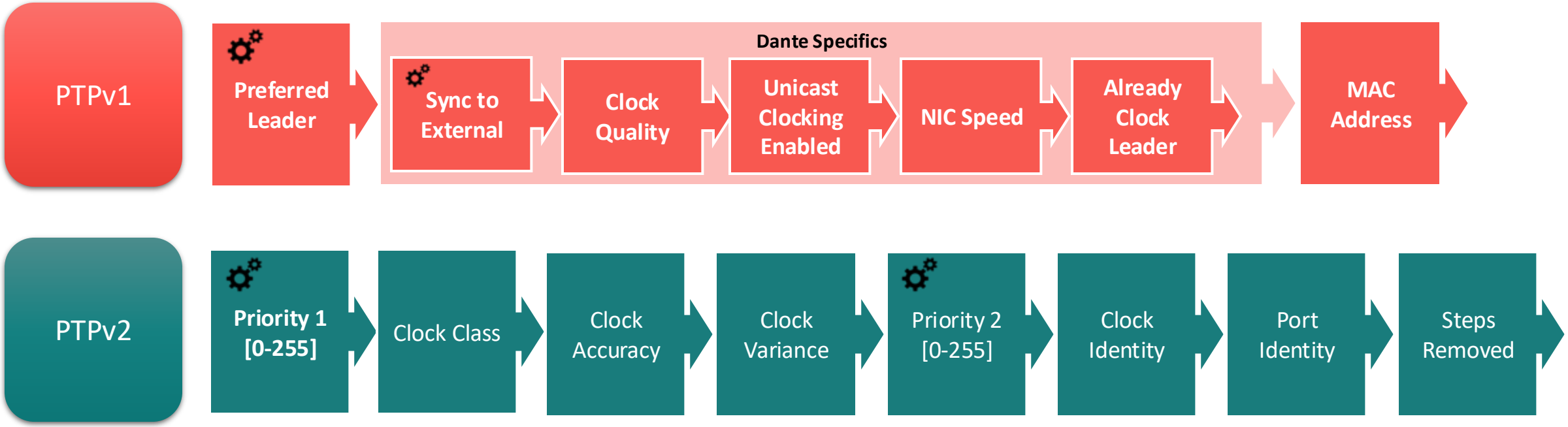
BMCA runs continuously on each device and determines the status of each PTP port (Listening, Leader, Follower, etc.)

- PTPv1: is based on the content of the **Sync** message
- PTPv2: is based on the content of the **Announce** message



# Grand Master Clock Election: BMCA

BMCA compares its own data set with the received data sets on different attributes for PTPv1 or PTPv2






User settable

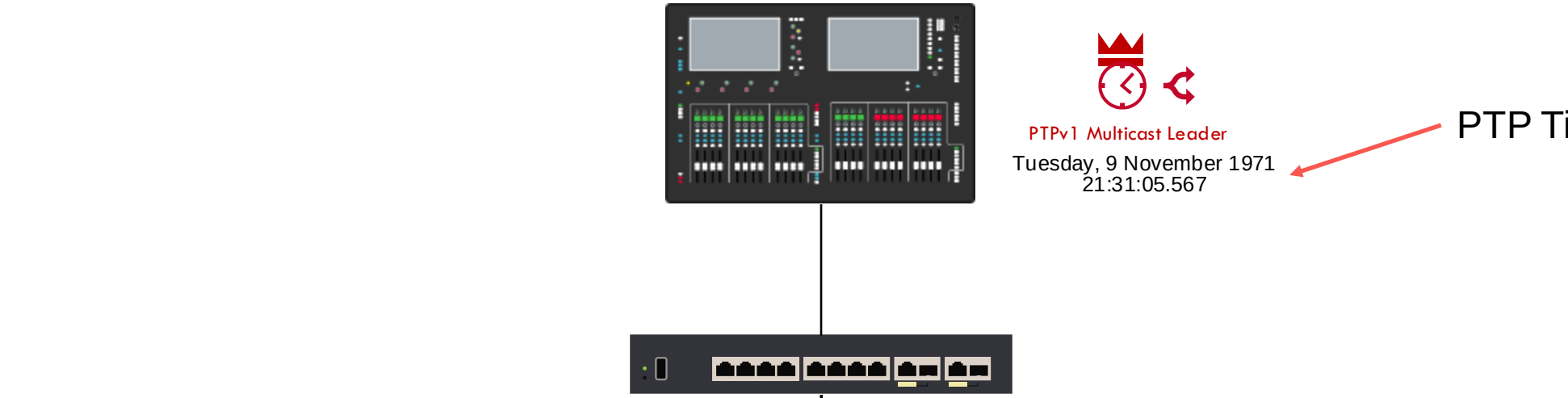
# Grand Master Support in Dante Devices

| Dante Product | PTP v1 | PTP v2 |
|---|---|---|
| UltimoX<br>AVIO<br>Dante Pro S1 | ✓ Up to 40 Followers | ⚠ Unmanaged AES67<br>DDM (from fw 4.2) |
| Brooklyn II<br>Broadway<br>HC<br>PCIe<br>IP Core | ✓ Up to 250 Followers | ✓ Unmanaged AES67<br>DDM |
| Dante AV Ultra | | ⚠ DDM |
| DEP<br>Dante AV-H<br>Dante AV-A | ⚠ Leader if no<br>Dante Hardware | ⚠ Unmanaged AES67 |
| Dante VIA<br>Dante Studio<br>Dante Virtual Soundcard Pro | | ⊘ Unsupported |
| Dante Virtual Soundcard<br>DAL | ⊘ Follower only | |



Full details on https://www.getdante.com/support/faq/dante-devices-ptp-clocking-support/

# Ordinary Clocks



PTPv1 Multicast Leader
Tuesday, 9 November 1971
21:31:05.567

PTP Timestamp

PTPv1 Multicast Follower
Tuesday, 9 November 1971
21:31:05.567

PTPv1 Multicast Follower
Tuesday, 9 November 1971
21:31:05.567

PTPv1 Multicast Follower
00:00:00.261.552902315

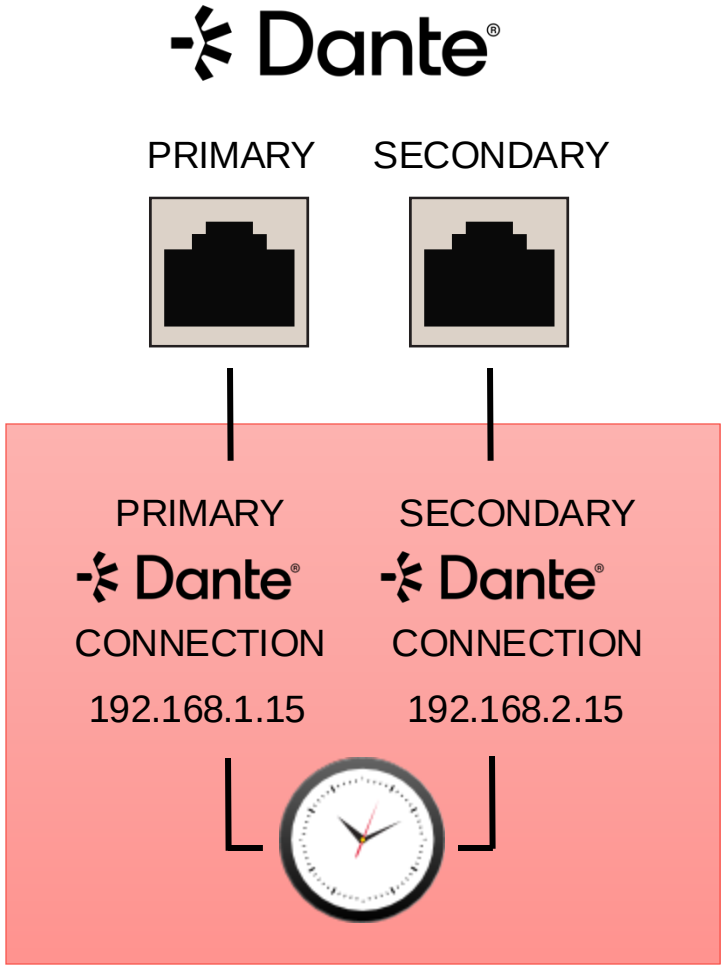
PTPv1 Multicast Follower
Tuesday, 9 November 1971
21:31:05.567

On hardware devices, it is the time since the Unix Epoch (January 1, 1970)

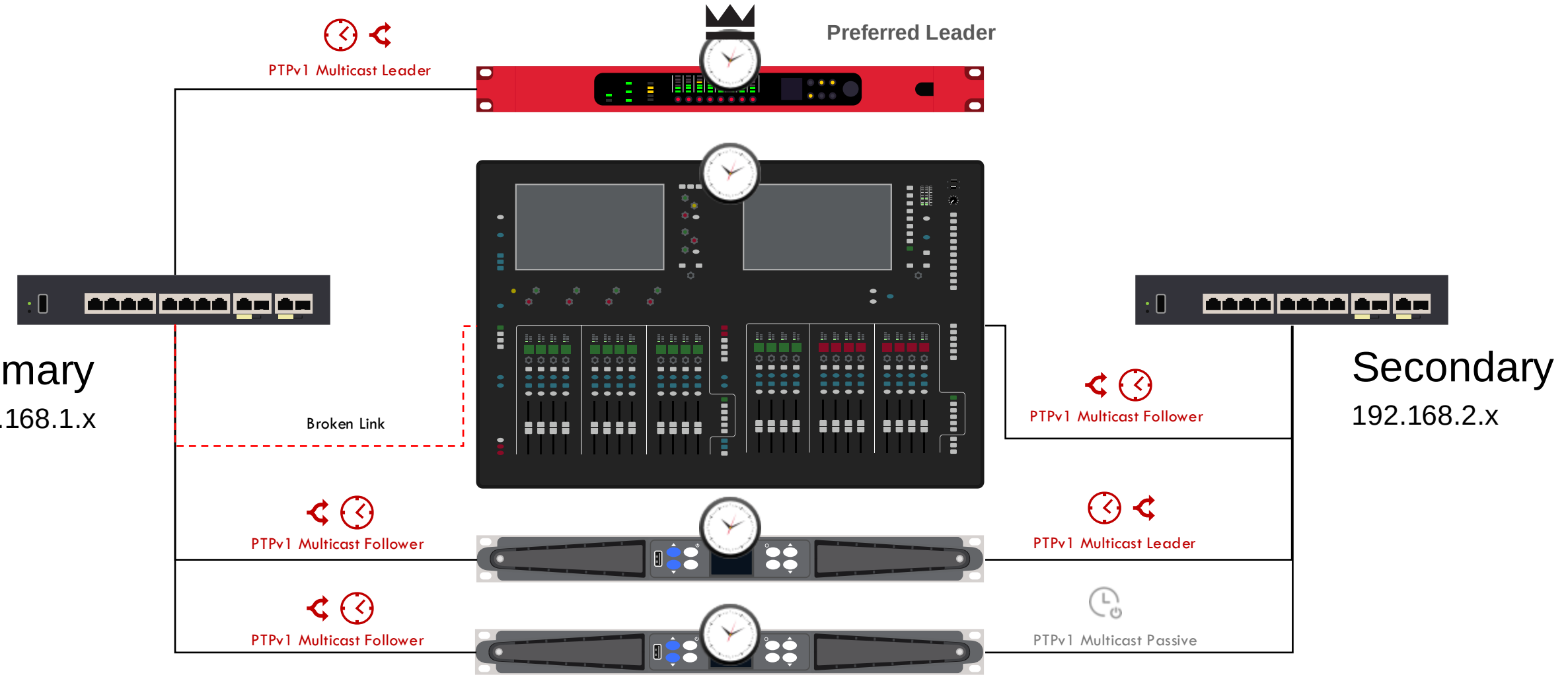
On software devices, **it is simply the value of the monotonic counter**

# Boundary Clocks: Redundant Dante Devices

1. Redundant Dante Devices have multiple PTP Ports
2. The device internal clock can be potentially driven from both PTP Ports
3. PTP Ports on the Primary Network have higher priority than those on the Secondary Network



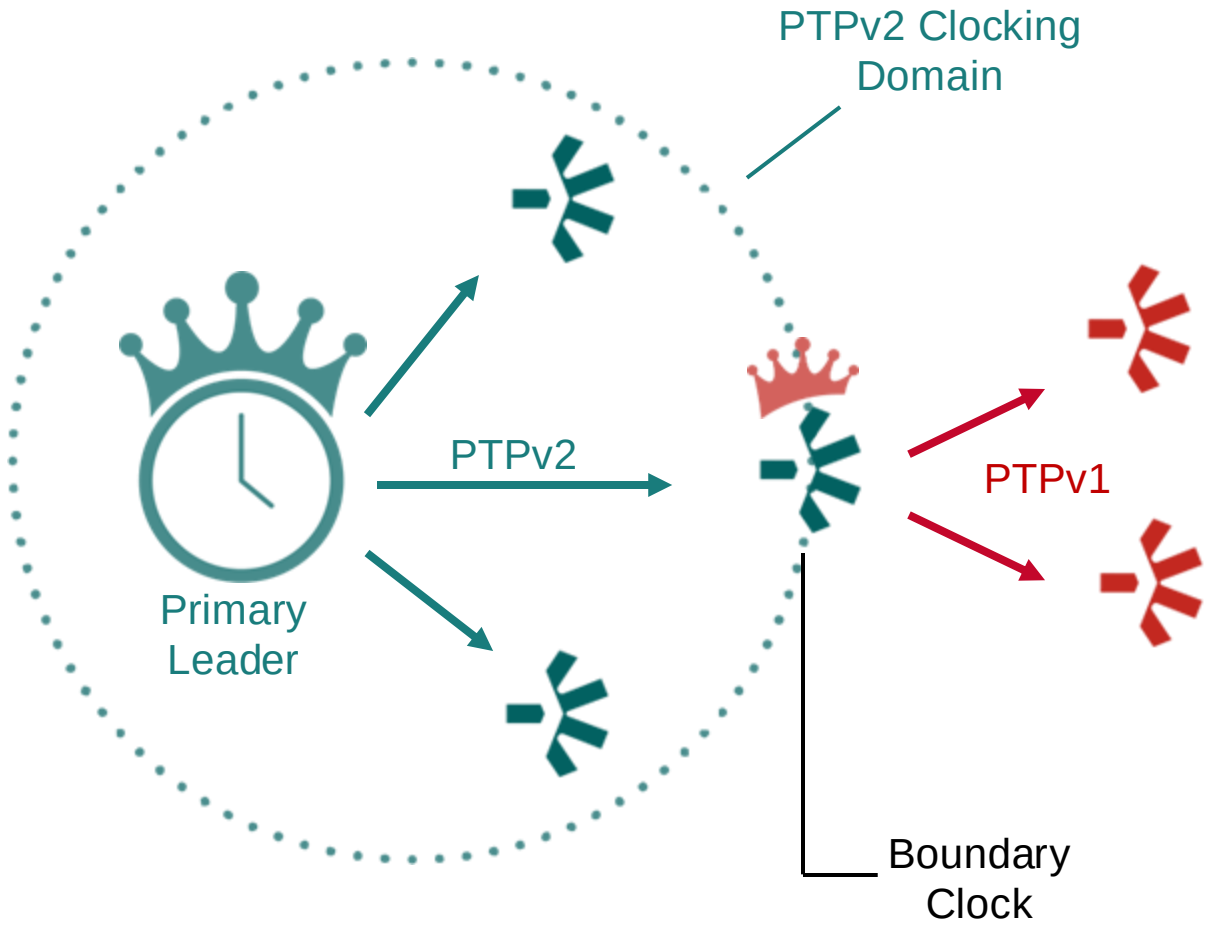
# Boundary Clocks: Redundant Dante Devices



# Boundary Clocks: Multicast PTPv1 & PTPv2

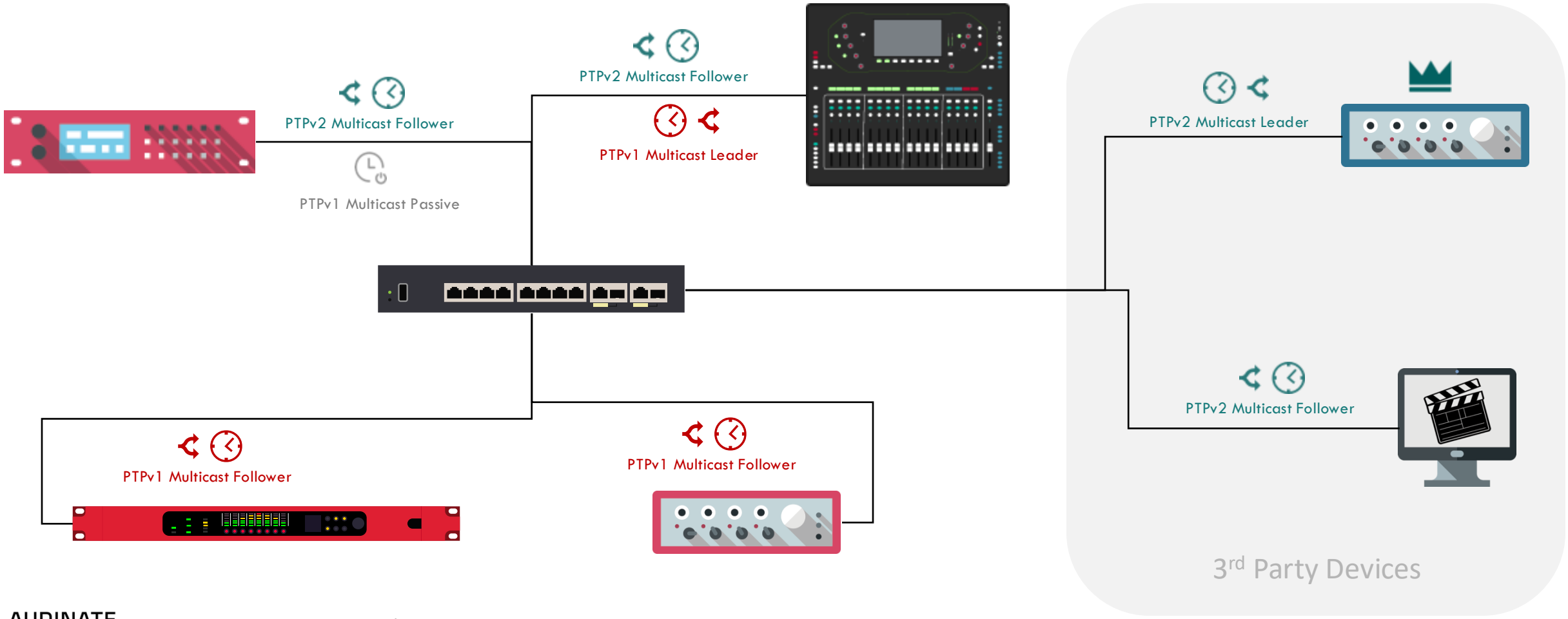
Dante devices with supported firmware can act as Boundary Clocks between PTPv1 and PTPv2 in multiple situations:

1. Unmanaged AES67 networks
2. Managed Networks with Dante Domain Manager
    1. Native Dante v1 + v2
    2. AES67
    3. SMPTE 2110



# Boundary Clocks: Multicast PTPv1 & PTPv2

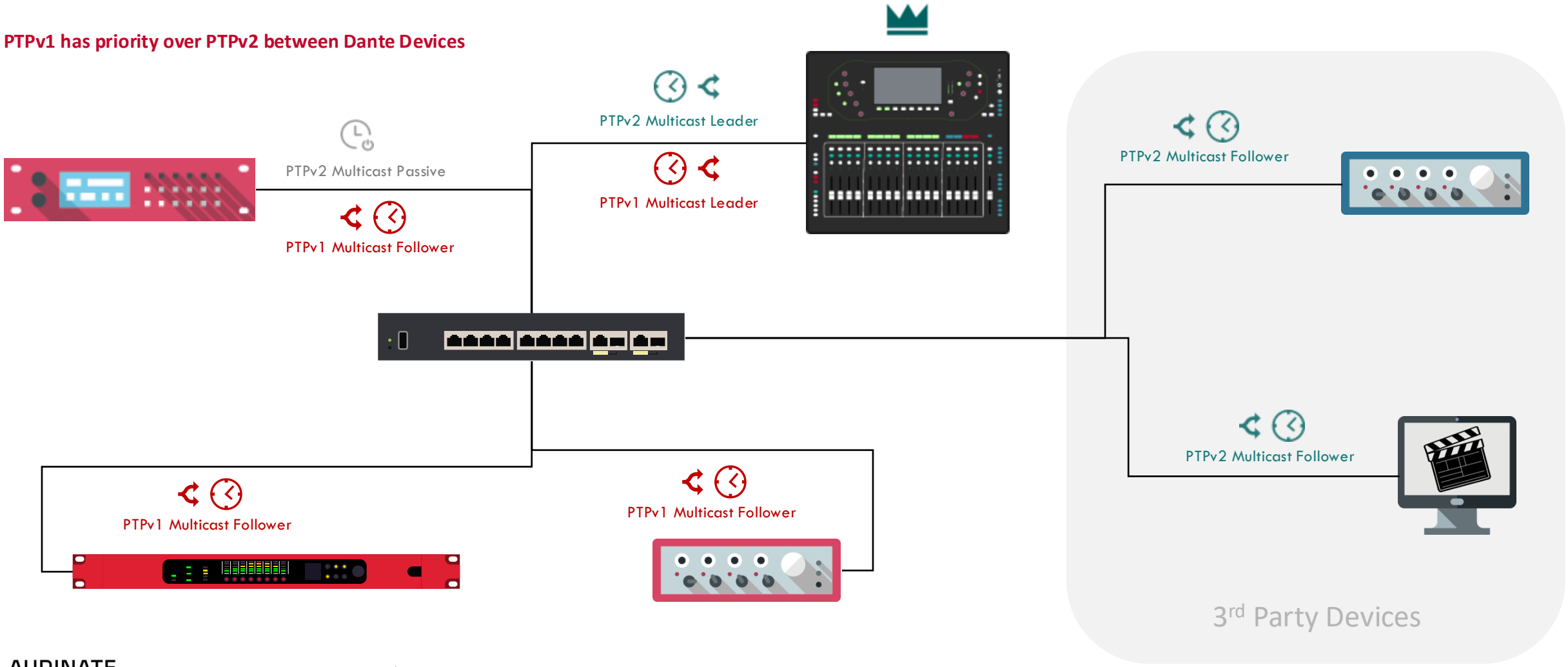
## Using an external PTPv2 Grand Master



# Boundary Clocks: Multicast PTPv1 & PTPv2

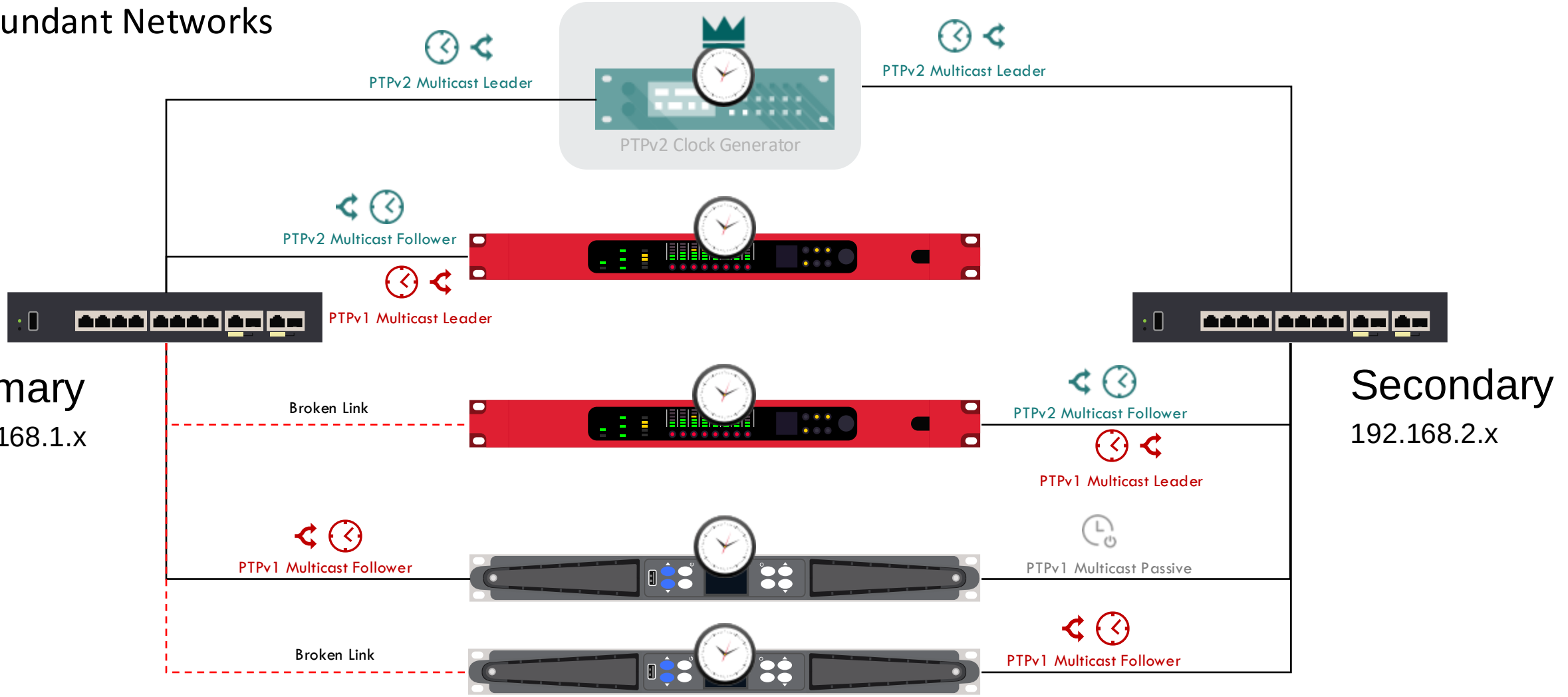
## Dante as the PTPv2 Grand Master

**PTPv1 has priority over PTPv2 between Dante Devices**



# Boundary Clocks: Multicast PTPv1 & PTPv2

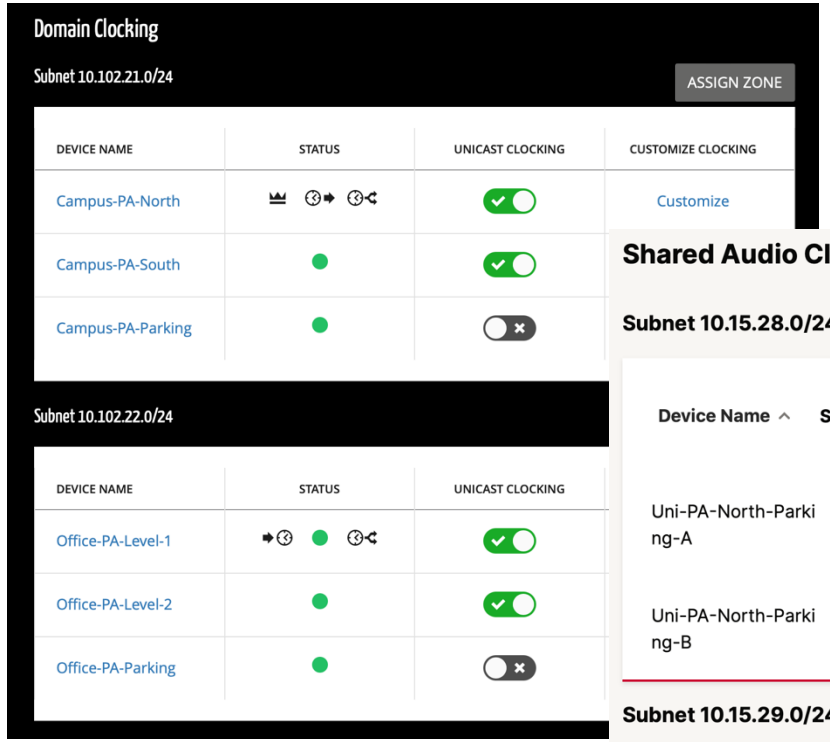
## Redundant Networks

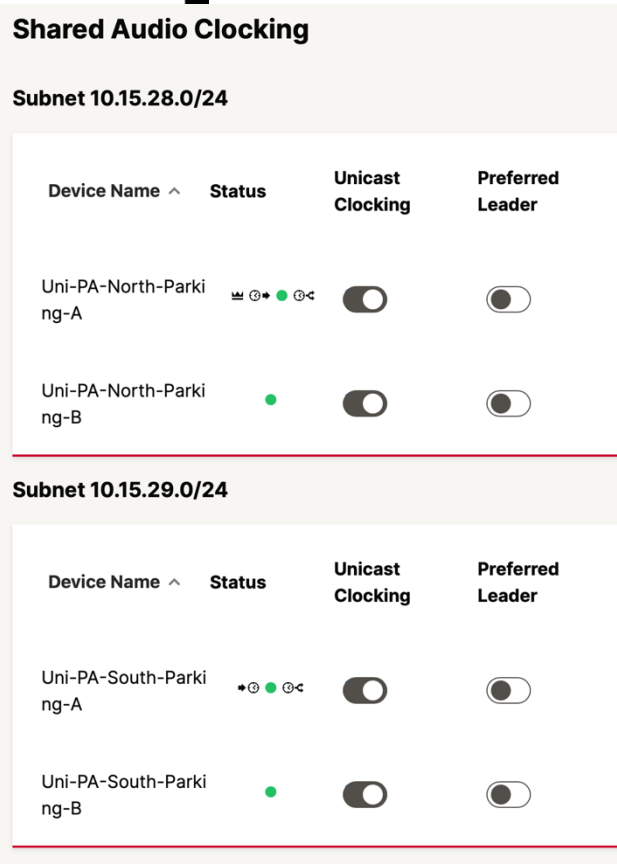


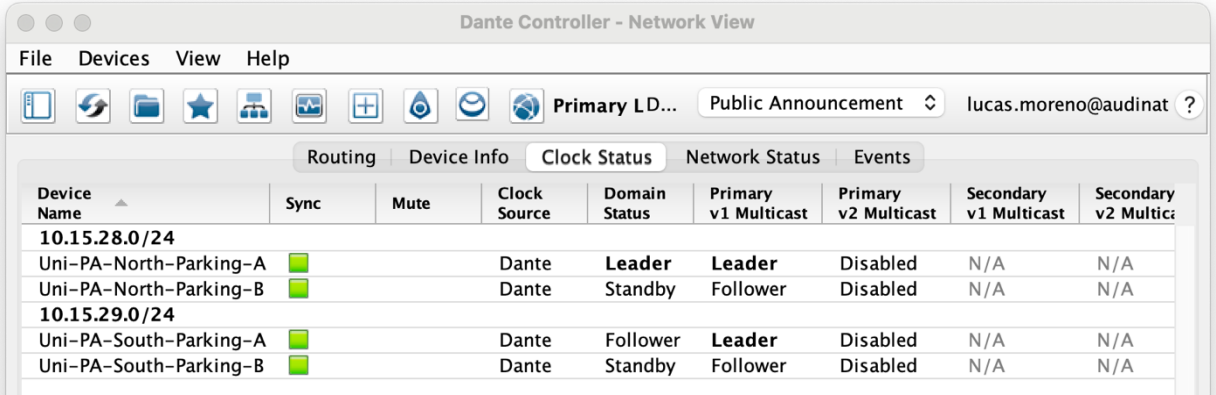
# Boundary Clocks: Unicast PTPv2

Supported by all Hardware Dante* devices on Managed Networks (Dante Domain Manager or Dante Director)

- Unicast Clocking is only available on the Primary Port
- Unicast Clocking is reflected under the *Domain Status* column on the Dante Controller Clock tab.

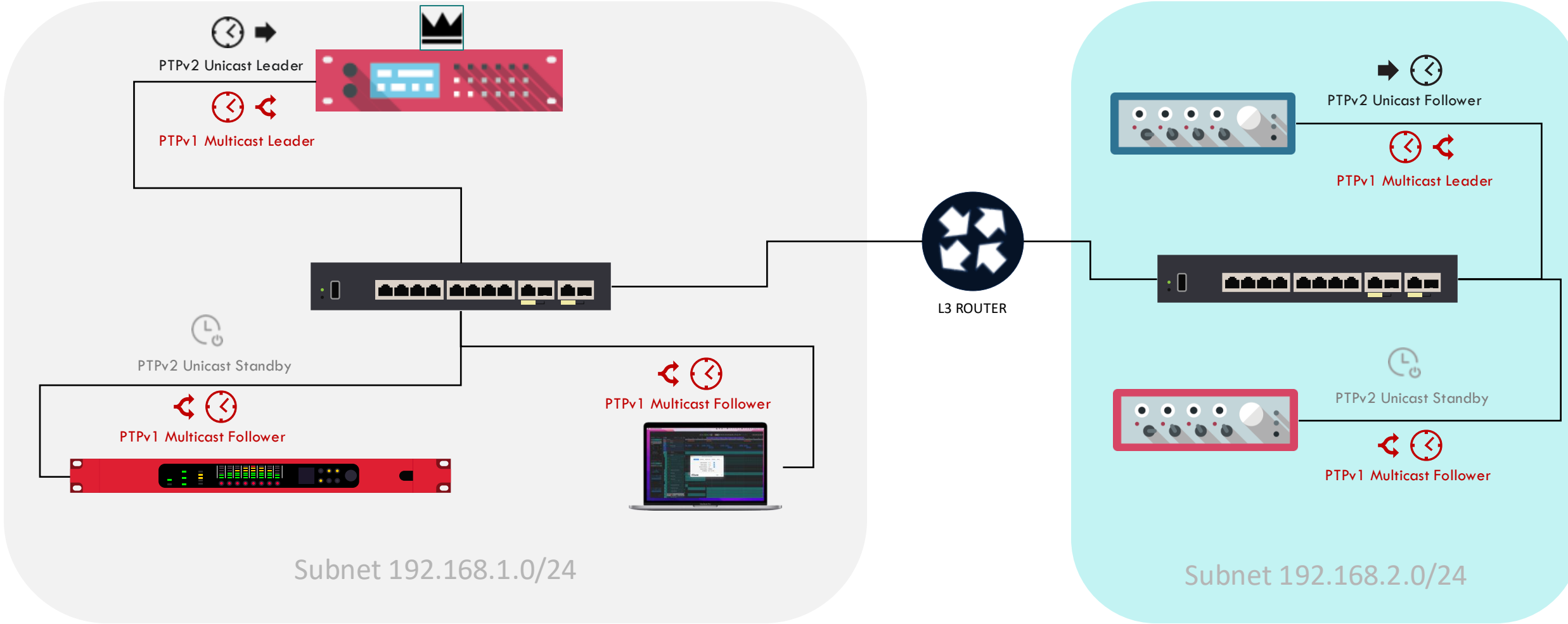



*Max 40 devices per clocking Domain

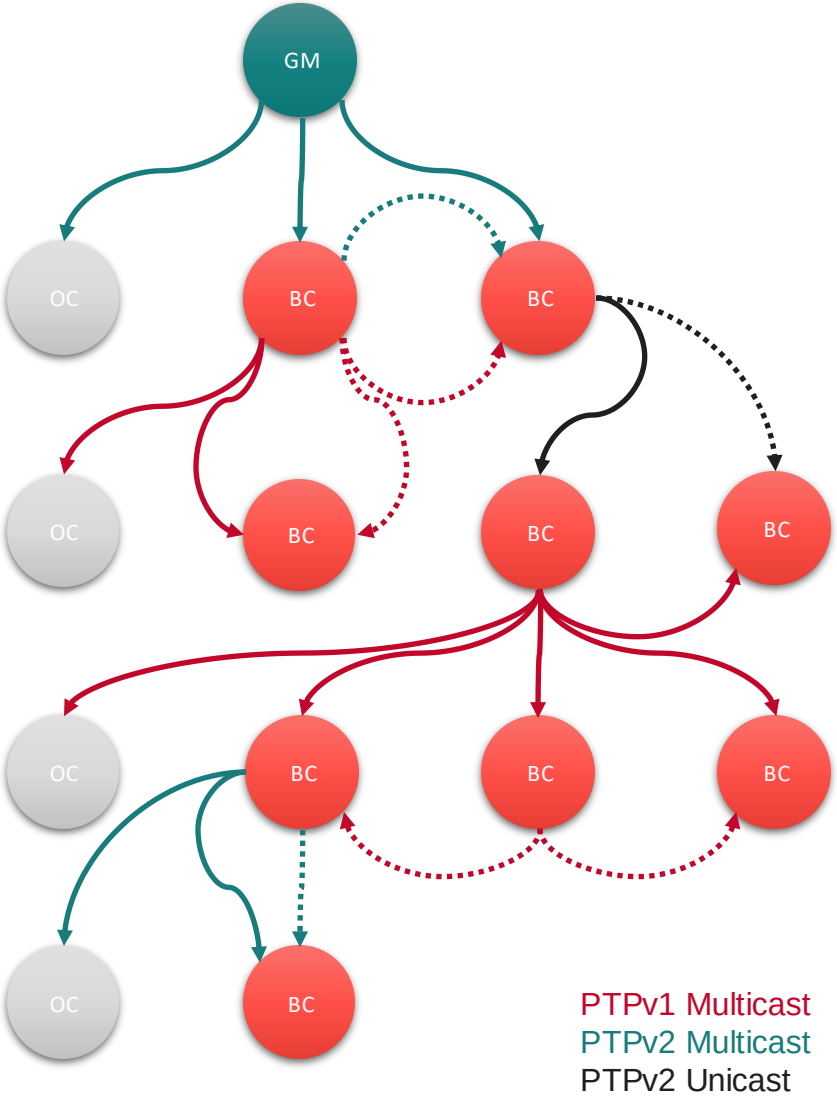
# Boundary Clocks: Unicast PTPv2



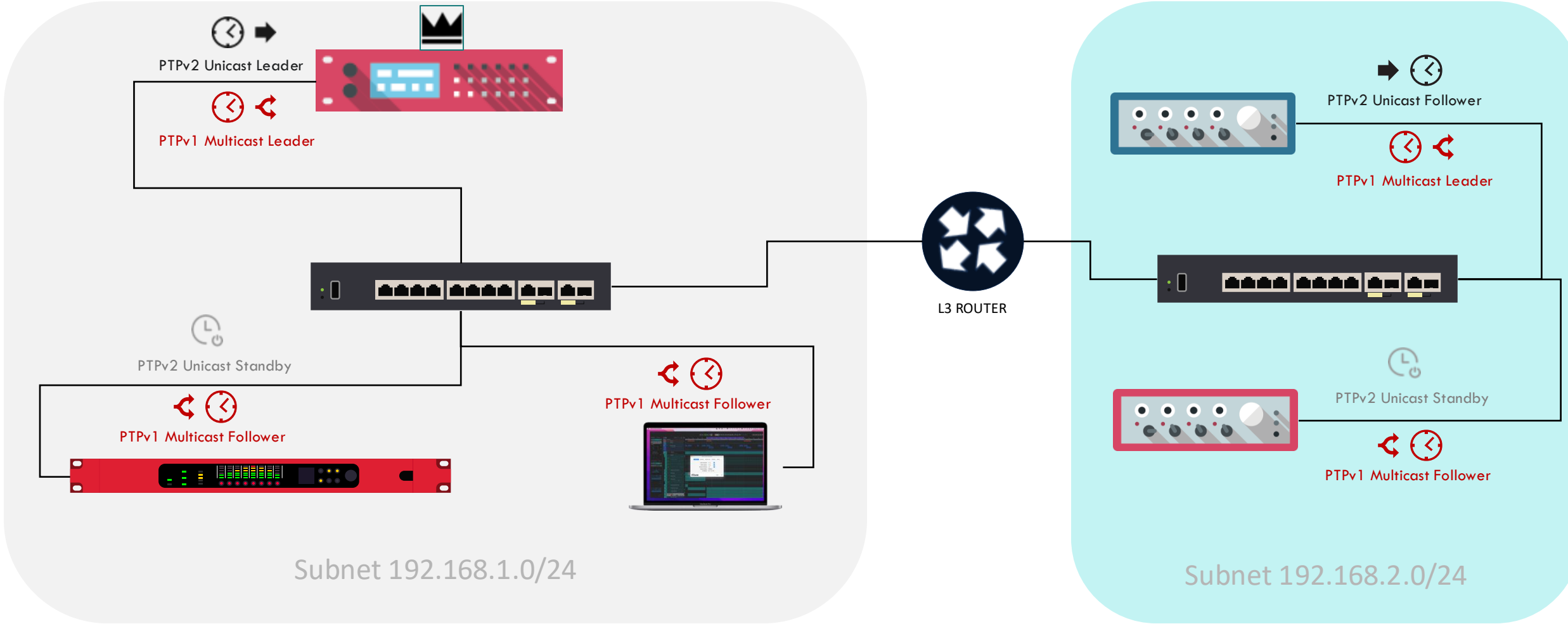
# Boundary Clocks: Multicast & Unicast PTPv1+v2

Hybrid clocking configurations can be achieved under Dante Domain Manager for PTPv2 or AES67 or SMPTE Domains

1. Overall Clocking structure needs to expand like a tree from the Grandmaster
2. It's OK to have dormant clocks or redundant links



# Boundary Clocks: Unicast PTPv2

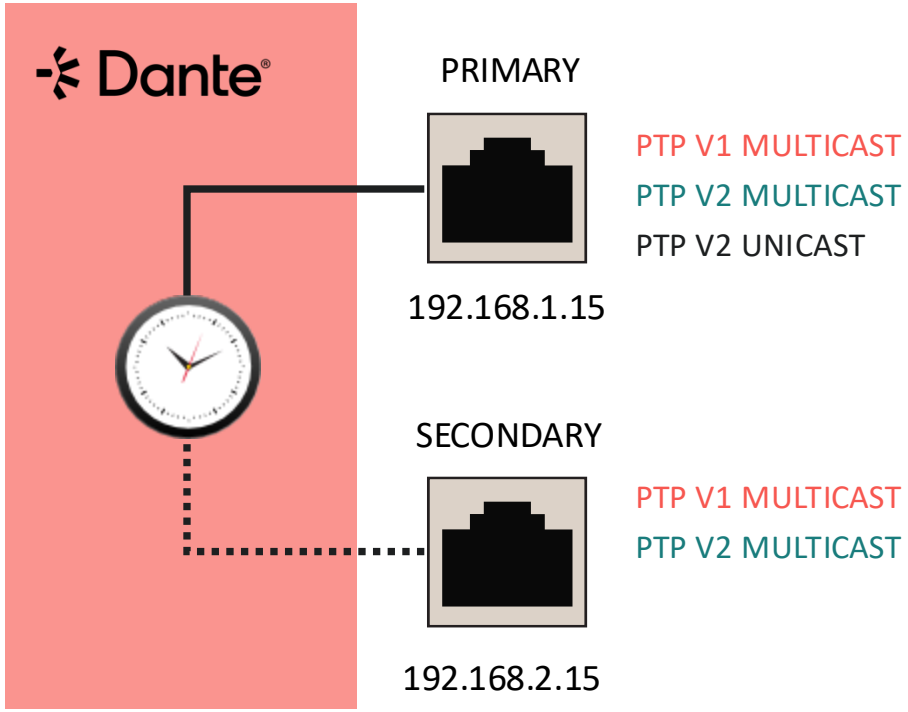


# Boundary Clocks: Dante Devices as 5 Port PTP Devices

Compatible Dante Devices can run up to 5 PTP Ports over the Primary and Secondary NICs

Depending on the Network / PTP Topology:

1. Multiple Ports can be Leader / Passive
2. A single Port can be Follower




1. You can **NOT** be Follower on multiple ports
2. You **CAN** be Leader on multiple ports

# 05 Additional PTP Information

# PTP Domains/Subdomains

PTP Domains/Subdomains are logical groups of PTP devices that synchronize to each other using the PTP protocol

| | PTPv1 Subdomain (automatic) | PTPv2 Domain (can be user settable) |
|---|---|---|
| Default Dante AES67 Mode | _DFLT | 0 |
| Pull-up/down DDM | _ALT1 | 1 |
| | _ALT2 | 2 |
| | _ALT3 | 3 |
| DDM | Custom value Ex: “H~OSL” | 4 ~ 255 |

# PTP Transport & Packet Details

| | | PTPv1 | PTPv2 |
|---|---|---|---|
| Layer 4 | UDP | Port 319 (Event Messages)<br>Port 320 (General Messages) | |
| Layer 3 | DiffServ | CS7 #56 (Event Messages)<br>EF #46 (General Messages) | EF #46 (All messages) |
| | IPv4 Multicast | 224.0.1.129 (default subdomain)<br>224.0.1.130-132 (pull-up/down or DDM subdomains) | 224.0.1.129 |
| | | TTL=1 | TTL=16 (configurable) |
| | IPv4 Unicast | Unicast Delay Request/Response | All messages (Unicast clocking) |
| Layer 2 | Ethernet | 0x88F7 (Ethertype field)<br>01:1B:19:00:00:00/01:80:C2:00:00:0E (Ethernet multicast address) | |

# PTPv2 Profiles and Dante

"The purpose of a PTP profile is to allow organizations to specify a specific selection of PTP parameter values and optional features that work together…"

Among the other PTP profiles for Telecom, Power, gPTP (802.1AS)… we can mention*:

| Profile | AES67 profile | SMPTE 2059-2 profile |
|---|---|---|
| Defined by | AES67-2018 Annex A, the Media profile for AES67 | ST 2059-2, the Media profile for ST 2110 |
| Priority 1 & 2 | Device specific (configurable in DDM) | 0 ~ **128** ~ 255 |
| Domain | 0 | 0 ~ **127** |
| Transport | Multicast | Multicast |
| Announce Interval | 0 | -3 ~ **-2** ~ +1 |
| Sync Interval | -2 | -7 ~ **-3** ~ -1 |



**This table contains only the PTP profile settings implemented in Dante*

# 06 Scaling PTP:

## Large/Distant Networks

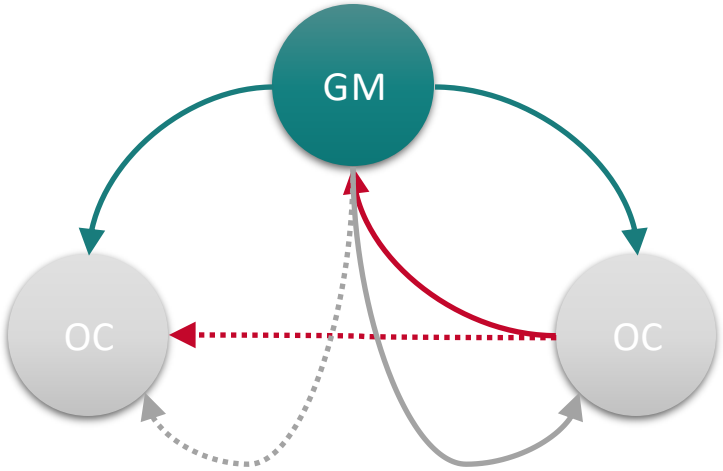
# PTP is usually Multicast

Multicast can be a 1:N or N:N relationship.

On large networks, PTP can become very chatty:

1. The Sync and Follow-up messages from the Leader are sent to everyone (1:N) but this is **OK**
2. However, all the Delay Request and Delay responses between each of the Followers and the Leader are also seen by everyone else (N:N)

This is due to all PTP messaged being sent to the same PTP Multicast addresses.

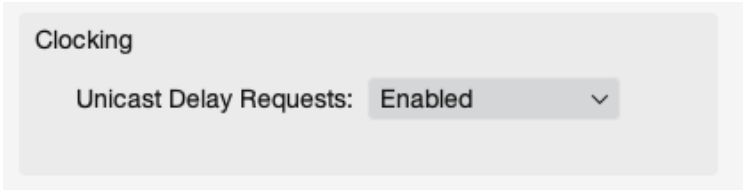


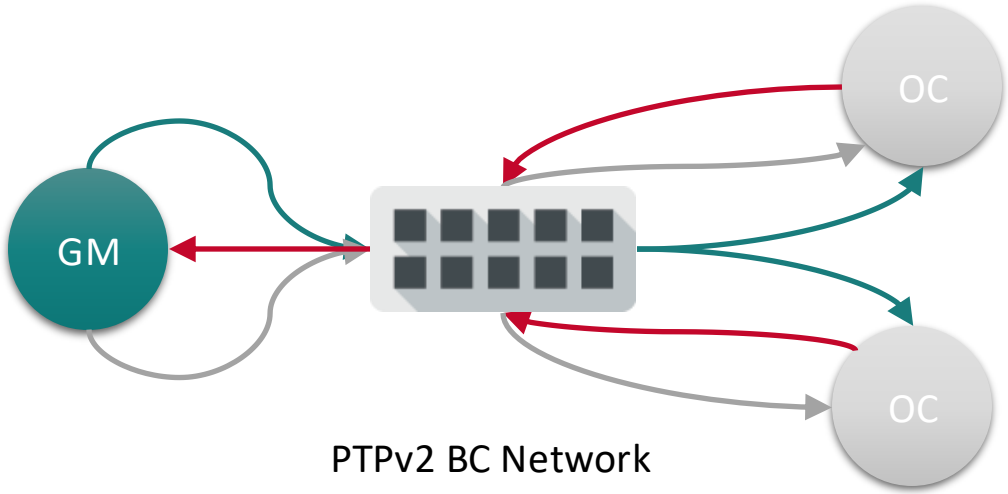

Sync / Follow Up
Delay Request
Delay Response

# Better PTP Multicast Management

PTP Multicast N:N traffic can be reduced by:

1. Using the Unicast Delay request in Dante Devices (PTPv1 only)
2. Deploying PTPv2 aware networks with Switches acting as Boundary Clocks




PTPv2 BC Network Switch

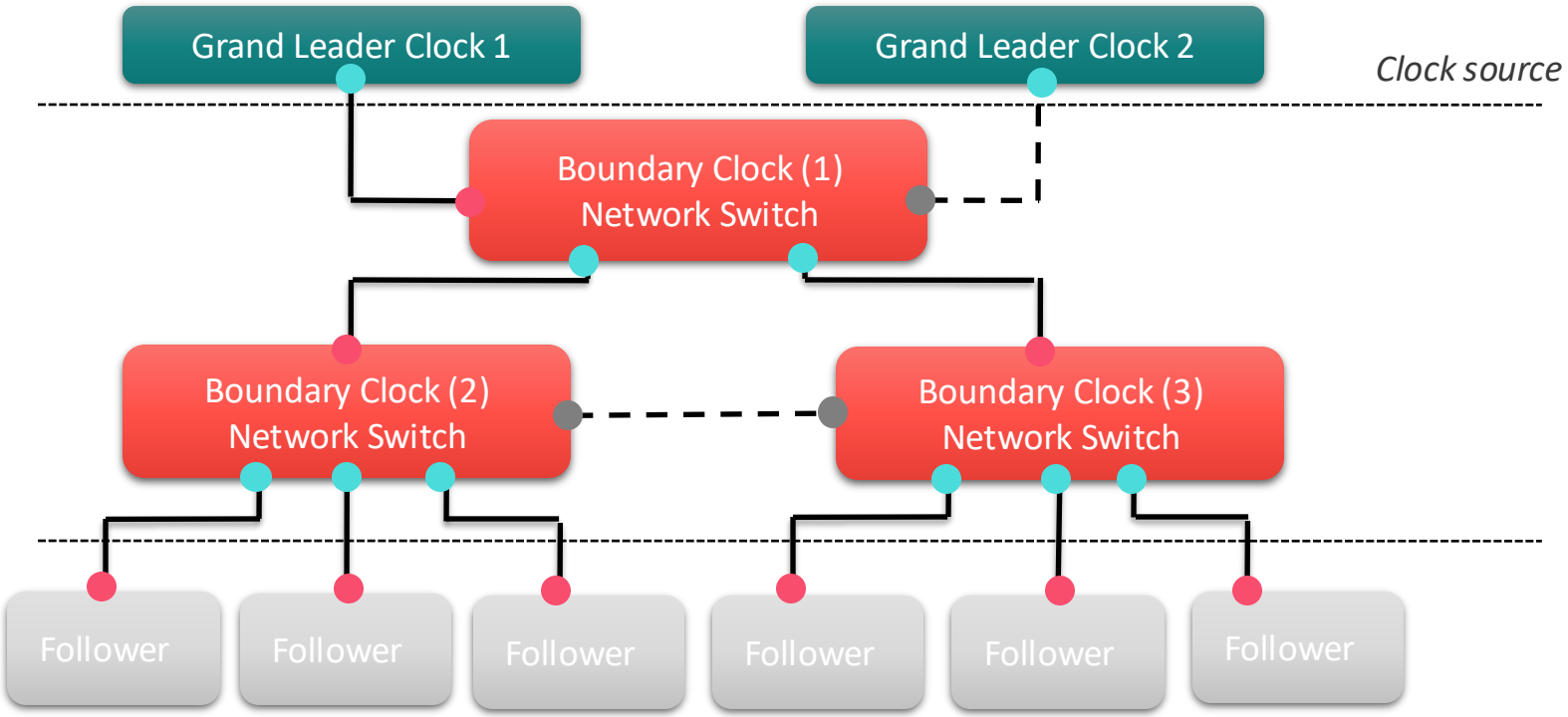
Sync / Follow Up
Delay Request
Delay Response

# PTPv2 Aware Networks

All the network switches are Boundary Clocks that participate on the PTP distribution

Port states:

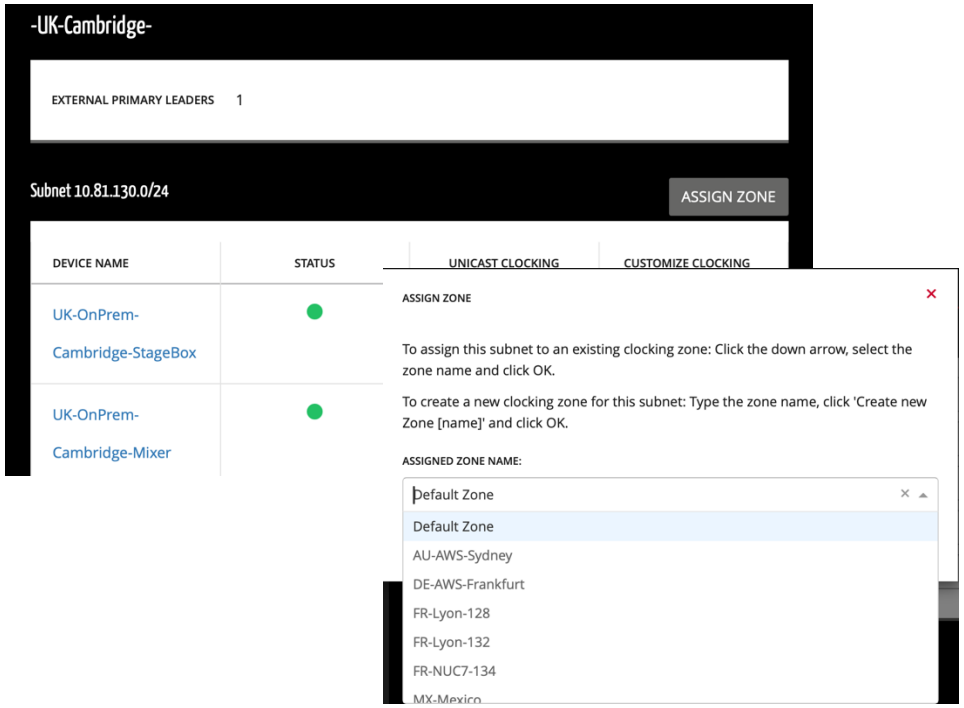
- Leader
- Follower
- Passive

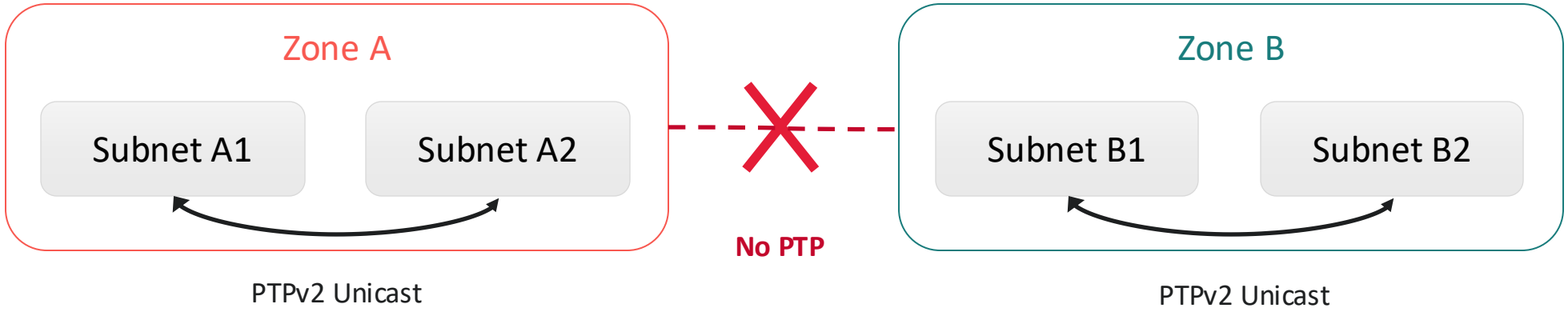


# DDM Clock Zoning

Clock zoning is a feature available on Dante Domain Manager managed networks.

1. Subnets can be assigned into different Clocking Zones.
2. PTPv2 Unicast clocking will be disabled between Zones.
3. Clocking distribution between zones is to be managed externally

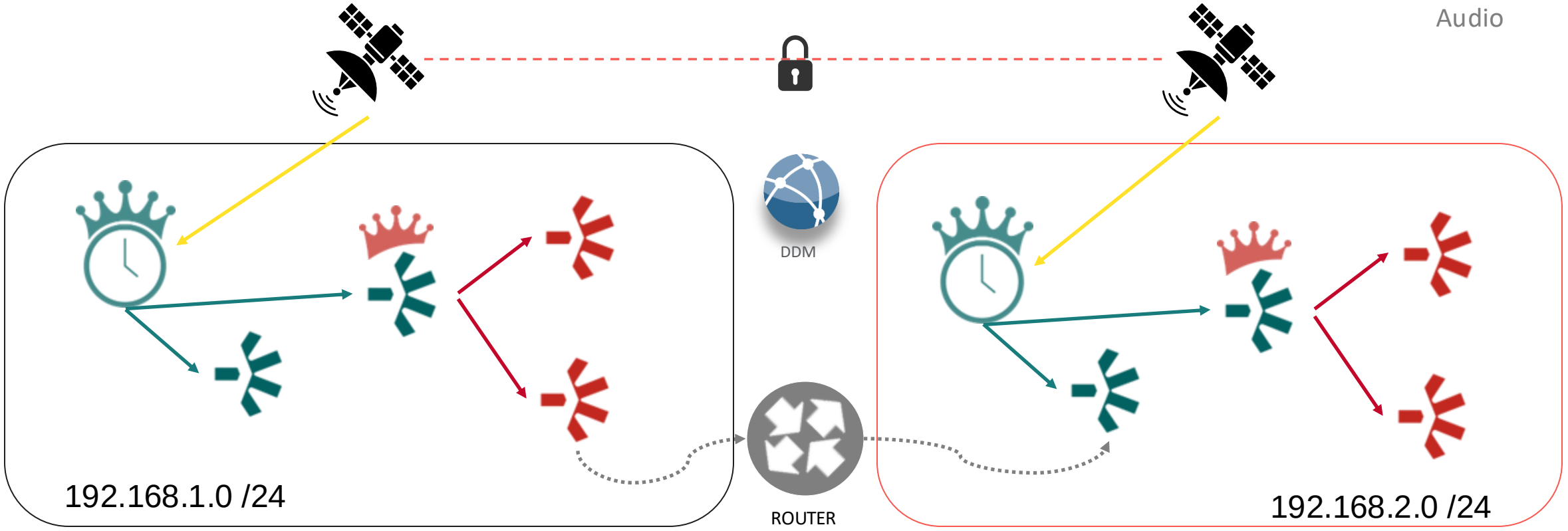


# DDM Clock Zoning: GPS distribution

GPS enabled Grand Master devices on each Zone:

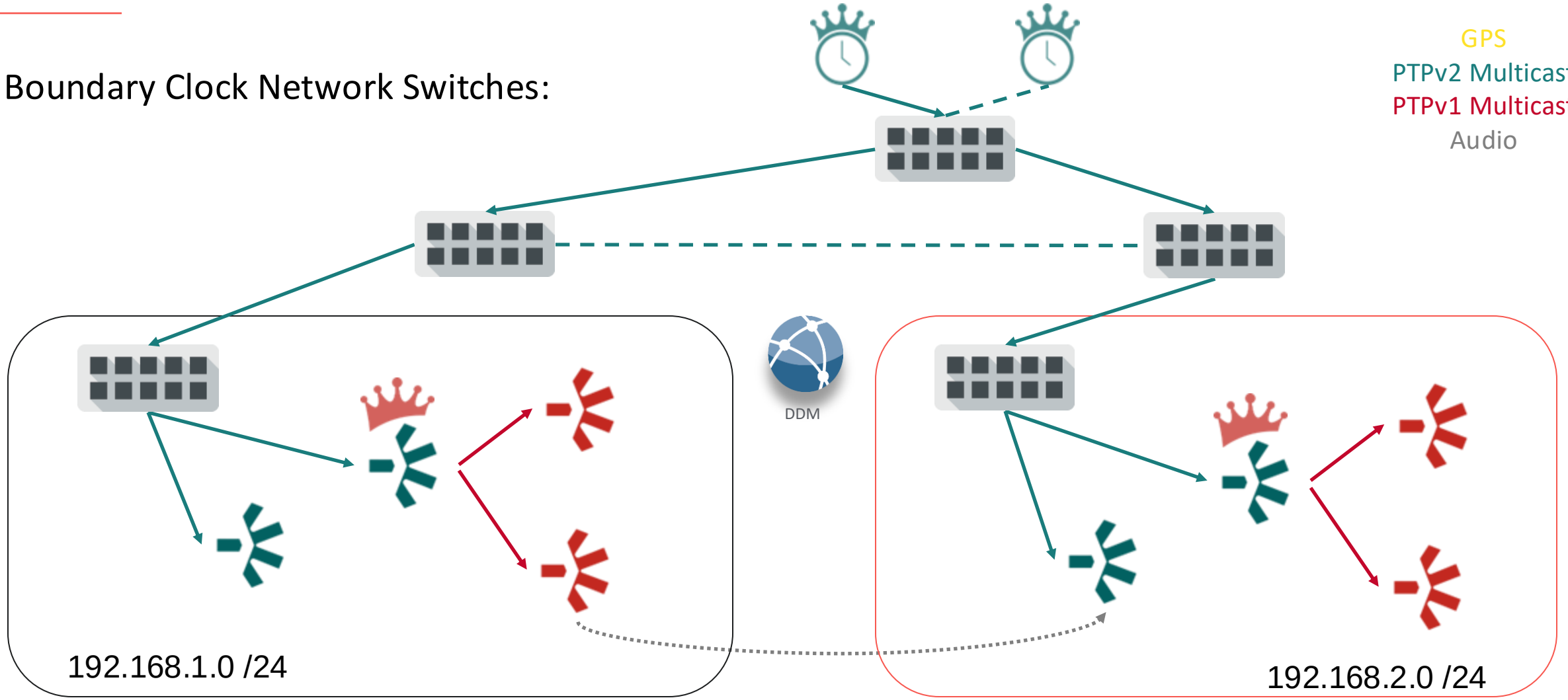
GPS
PTPv2 Multicast
PTPv1 Multicast
Audio




*Audio packets still go through the routed network

# DDM Clock Zoning: PTPv2 aware network

Boundary Clock Network Switches:




*Audio packets still go through the routed network

# 07 Troubleshooting PTP

# Clocking not Working?

- IGMP Snooping misconfiguration
- Energy Efficient Ethernet (EEE) network switches
- Asynchronous Networks
- Network Jitter
- Clock Hierarchy inconsistency
- PTPv2 Network misconfiguration

# Useful links

https://www.getdante.com/support/faq/dante-devices-ptp-clocking-support/

https://www.getdante.com/support/faq/ptp-ip-addresses-used-by-dante/

https://www.getdante.com/support/faq/ptpv2-clocking-options-for-aes67-smpte-interoperability-with-dante/

https://www.getdante.com/support/faq/dante-over-distance-considerations/

https://www.getdante.com/support/faq/dante-clocking-on-a-cisco-sda-network/

# Special Thanks

Work on this file is a spin off the “PTP Networking Shots” webinar created by Audinate and Cisco (Chris Lapp)


[Webinar: Audinate and Cisco Networking Shorts: PTP - It's About Time]


Questions?