Architecting and Operating PTP

In IP based Production Facility

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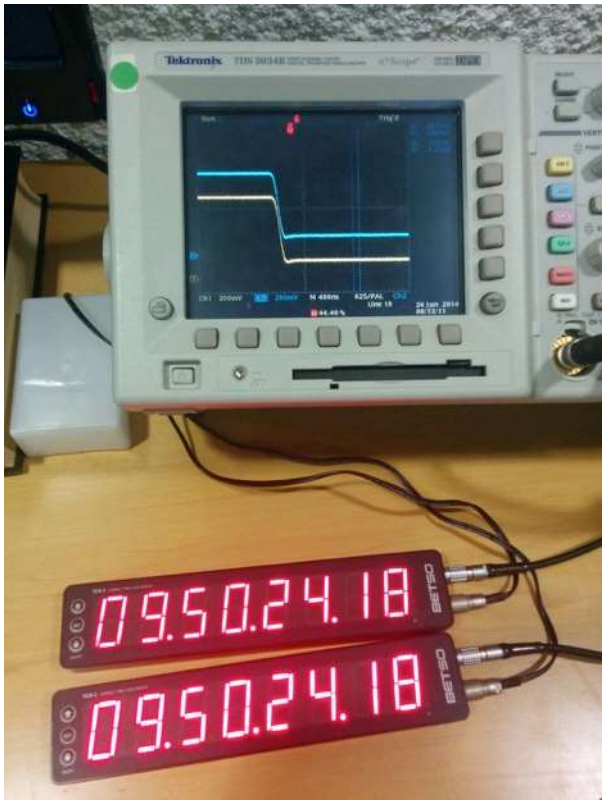
How do I generate a stable timing signal from an Ethernet port?

Source: an anonymous broadcast engineer



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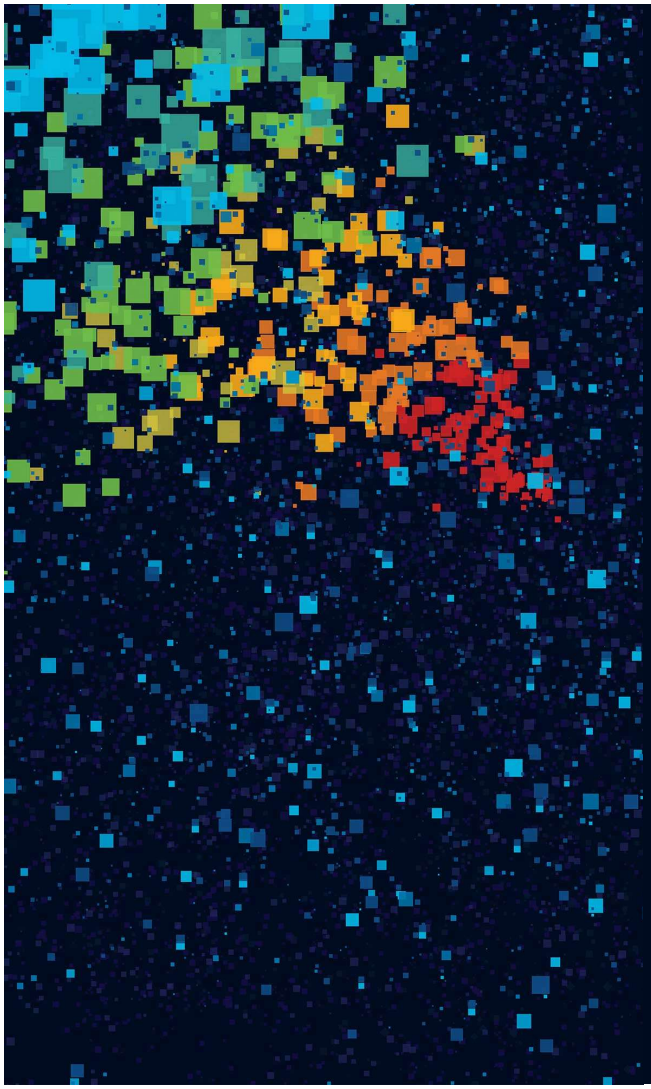

Agenda

- How PTP works
- PTP Media Profiles
- Design Considerations
- Lessons Learnt from Deployments
- Troubleshooting tips
- Conclusion

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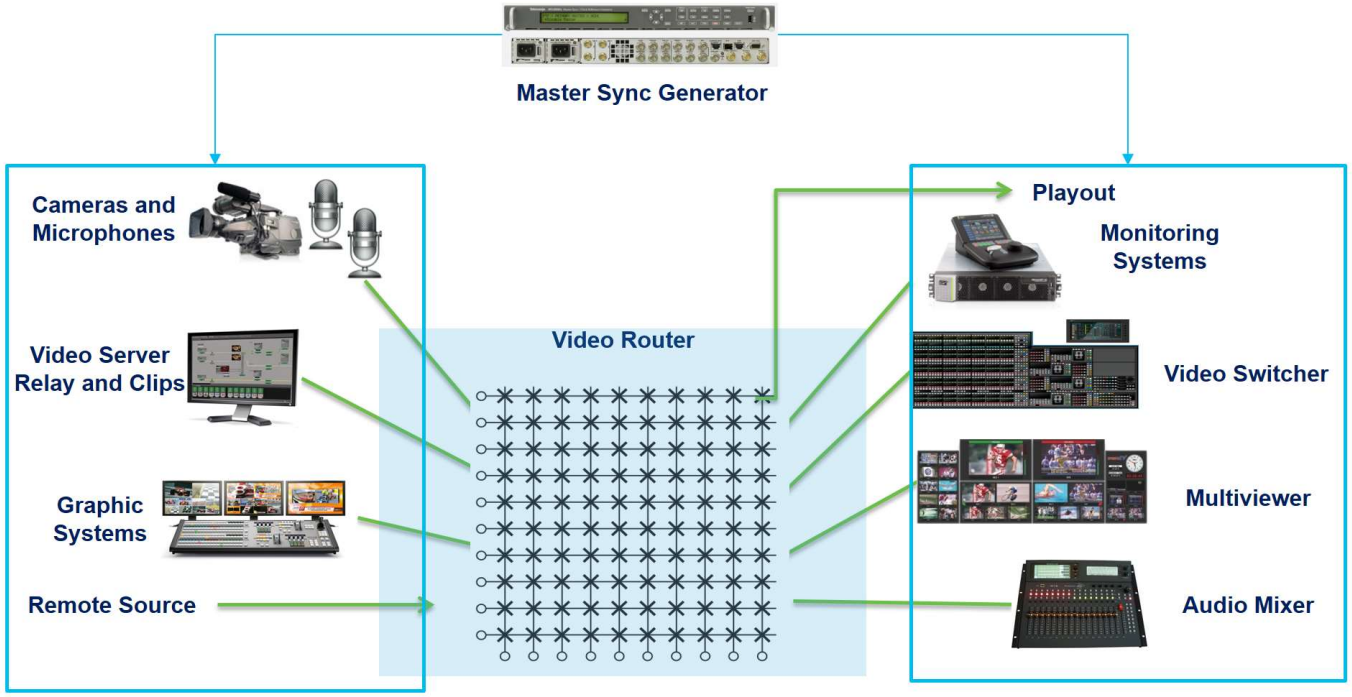
Introduction to PTP

Time Sync in SDI facility



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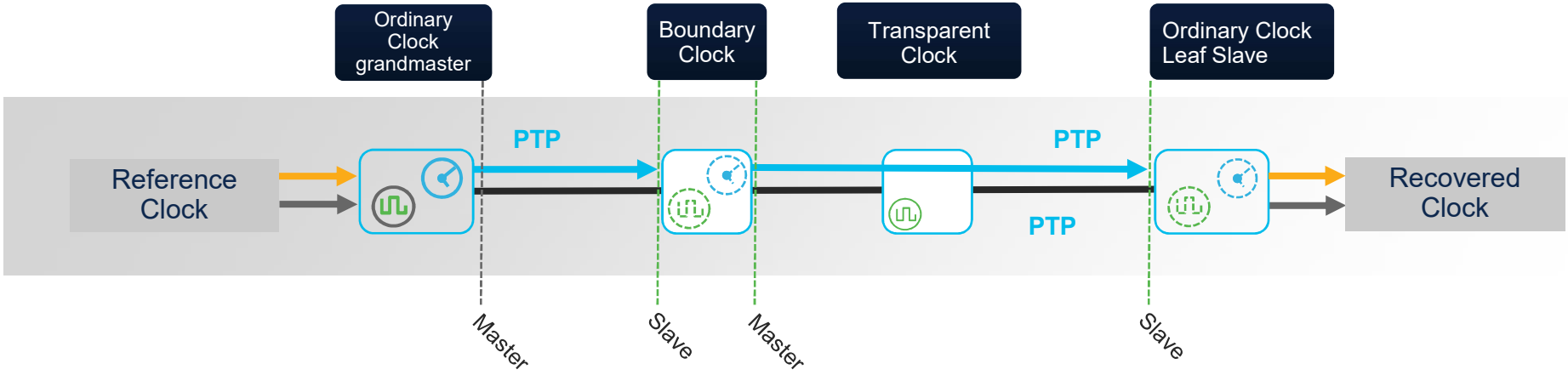
Precision Time Protocol

- Two Way Time Transfer protocol (TWTT)
- Accuracy in a well designed E2E model in the nanosecond range
- Boundary Clocks (BC) and Transparent Clocks (TC) aim correcting delay variations, in both directions (asymmetry)



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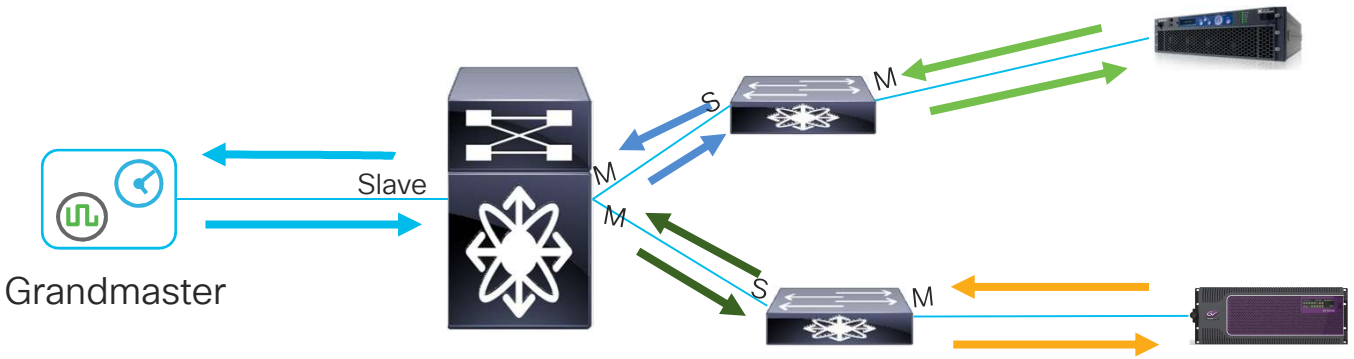
Boundary Clock

- Boundary Clock
  - Has multiple PTP ports in a domain and maintains the timescale used in the domain. It has both master and slave ports.
  - It terminates the PTP flow, recovers the clock and timestamp, and regenerates the PTP flow



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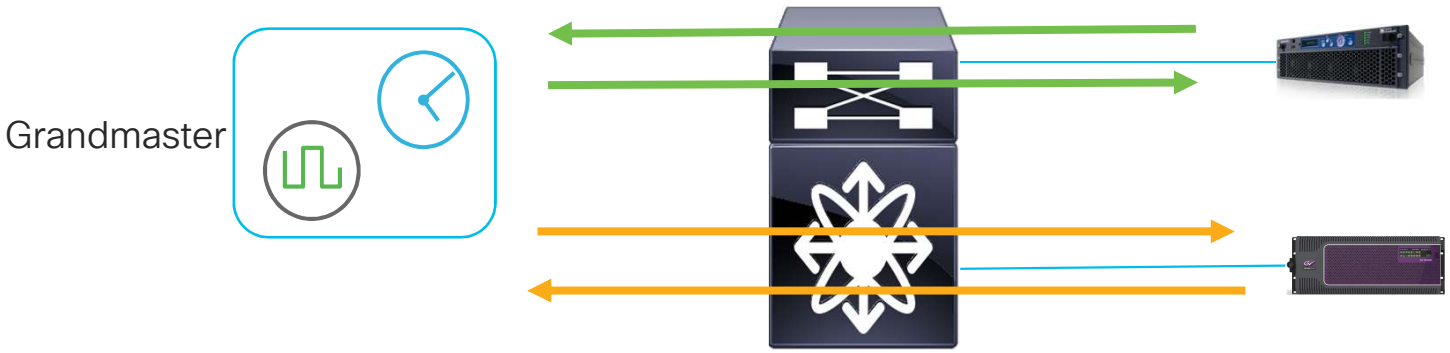
Transparent Clock

- Transparent clock (TC)
  - A device that measures the time taken for a PTP event message to transit the device and compensate the packet delay by updating the timestamp.



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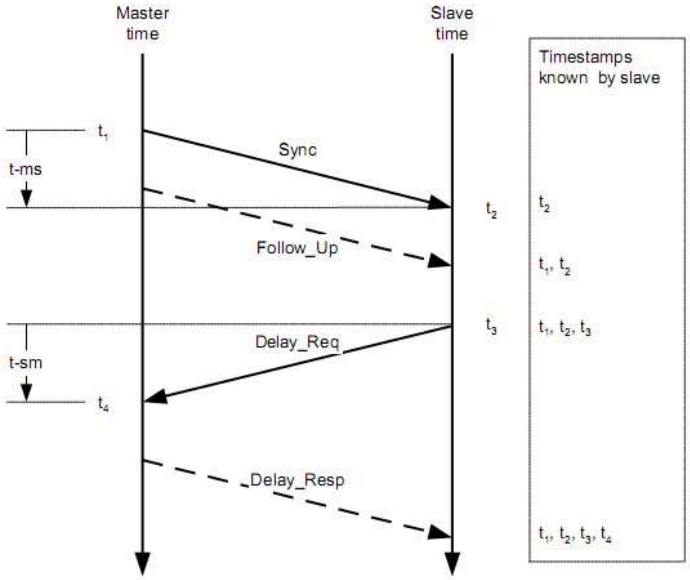
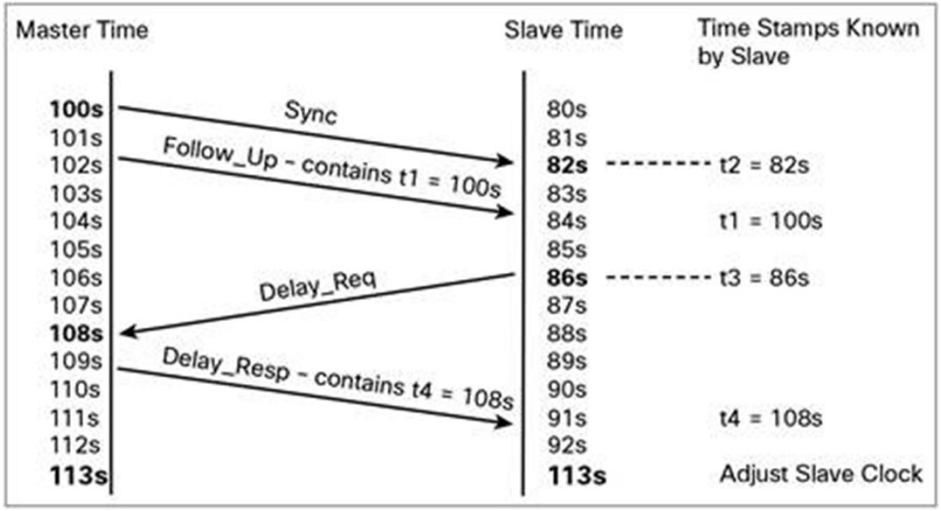
How PTP Works?



After the synchronization

Slave clock derives Time of Day, phase and frequency signals from the master



Mean Path Delay

$((t_2 - t_1) + (t_4 - t_3)) / 2$

Mean Path Delay = ((t2 - t1) + (t4 - t3)) / 2
= (-18 + 22) / 2
= 2

Clock Offset

$t_2 - t_1$- mean path delay

Offset = t2 - t1 - Mean Path Delay
= 82 - 100 - 2
= -20

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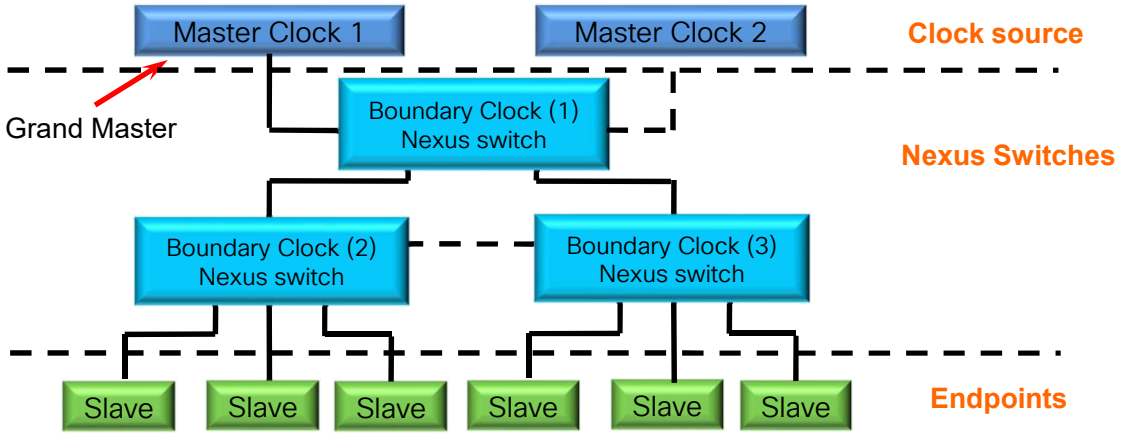
Hierarchy Network Clock Topology



1 Elect the grand master, form a master-slave hierarchy. Grand master is selected based on Best Master Clock selection Algorithm (BMCA). (Master clock 1 is selected as Grand Master in the diagram)

2 Each slave clock synchronizes itself to the master clock

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Master Clock Selection

- BMCA (Best Master Clock Algorithm) runs locally on each port.
- It determines the best clock based on the attributes with following priority:
  1. **priority1**: User configurable designation that a clock belongs to an ordered set of clocks from which a master is selected
  2. **clockClass**: Defines a clock's TAI traceability
  3. **clockAccuracy**: Defines the accuracy of a clock
  4. **offsetScaledLogVariance**: Defines the stability of a clock
  5. **priority2**: User configurable designation providing finer grained ordering among otherwise equivalent clocks
  6. **clockIdentity**: A tie-breaker based on unique identifiers
  7. **StepsRemoved**: Selection of shortest path to the GrandMaster (for BC)
- BMCA determines the status of the port: **master, slave or passive.**
- BMCA runs continuously.

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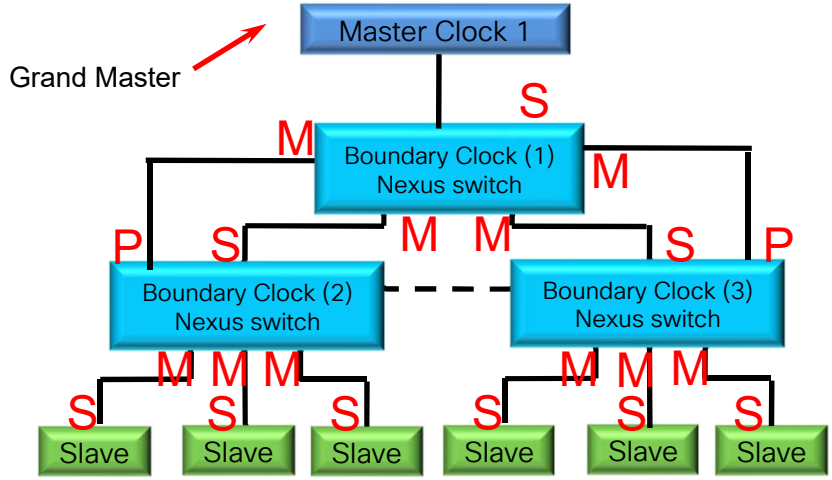
PTP Port States

- MASTER: the port is advertising the time to a slave.
- SLAVE: the port is receiving the time from a master.
- PASSIVE: the port is connected to a master which is not the best clock.



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PTP Media Profiles

PTP profiles for media & broadcast

- AES67 (Audio driven)
  - Based on IEEE 1588-2008 default profile /w specific message rates
    - Announce: 1 {0,4}
    - Sync: -3 {-4,1}
    - DelayReq: 0 {-3,Sync +5}*
  - Allow all devices to be either Master or Slave
  - Multicast messages only
  - Default PTP domain: 0 {0-255}

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PTP profiles for media & broadcast

- SMPTE 2059 (Video driven)
  - Based on a 5 sec fast locking requirement for endpoints /w spec rates
    - Announce: 1 {-3,1}
    - Sync: -3 {-7,-1}
    - DelayReq: 0 {Sync +0, Sync +5}
  - Default Slave mode unless can operate as Master
  - Additional PTP TLV with media specific information
    - Daily Jam Time, Default Frame rate, …
  - Supports Multicast, Mixed (Mcast/Ucast) and Unicast modes
  - Default PTP domain: 127 {0-127}

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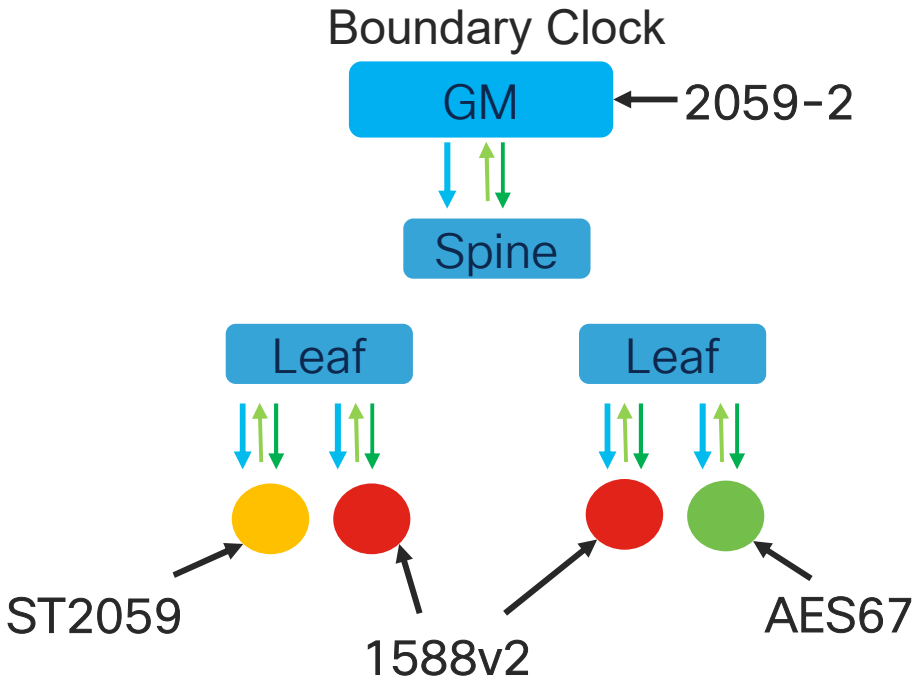
NX-OS implementation

- Support for AES67 message rates
  - ptp announce interval **aes67** <value>
  - ptp sync interval **aes67** <value>
  - ptp delay-request minimum interval **aes67** <value>
- Support for SMPTE 2059 message rates (and PTP mgmt TLV)
  - ptp announce interval **smpte-2059-2** <value>
  - ptp sync interval **smpte-2059-2** <value>
  - ptp delay-request minimum interval **smpte-2059-2** <value>



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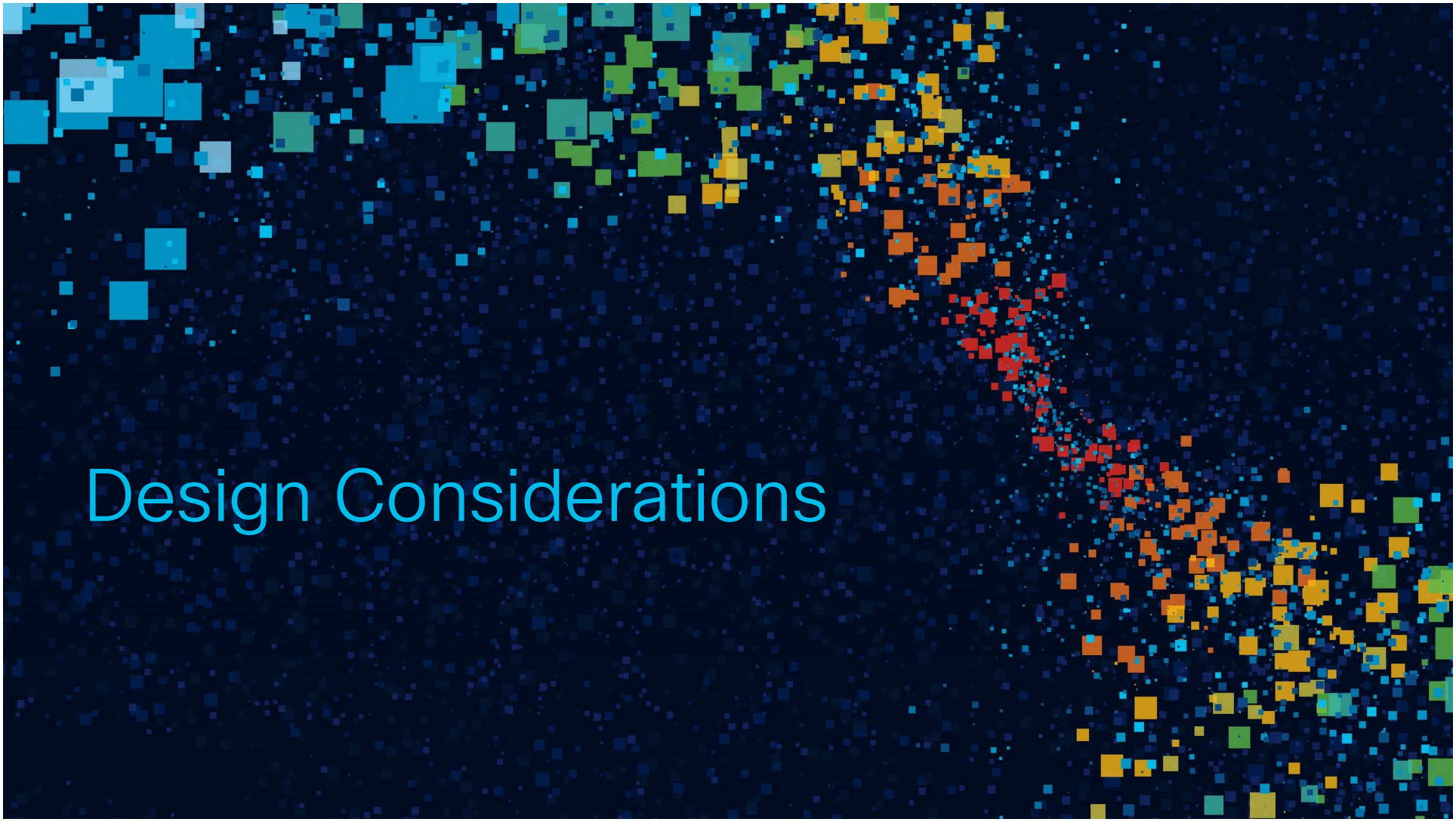
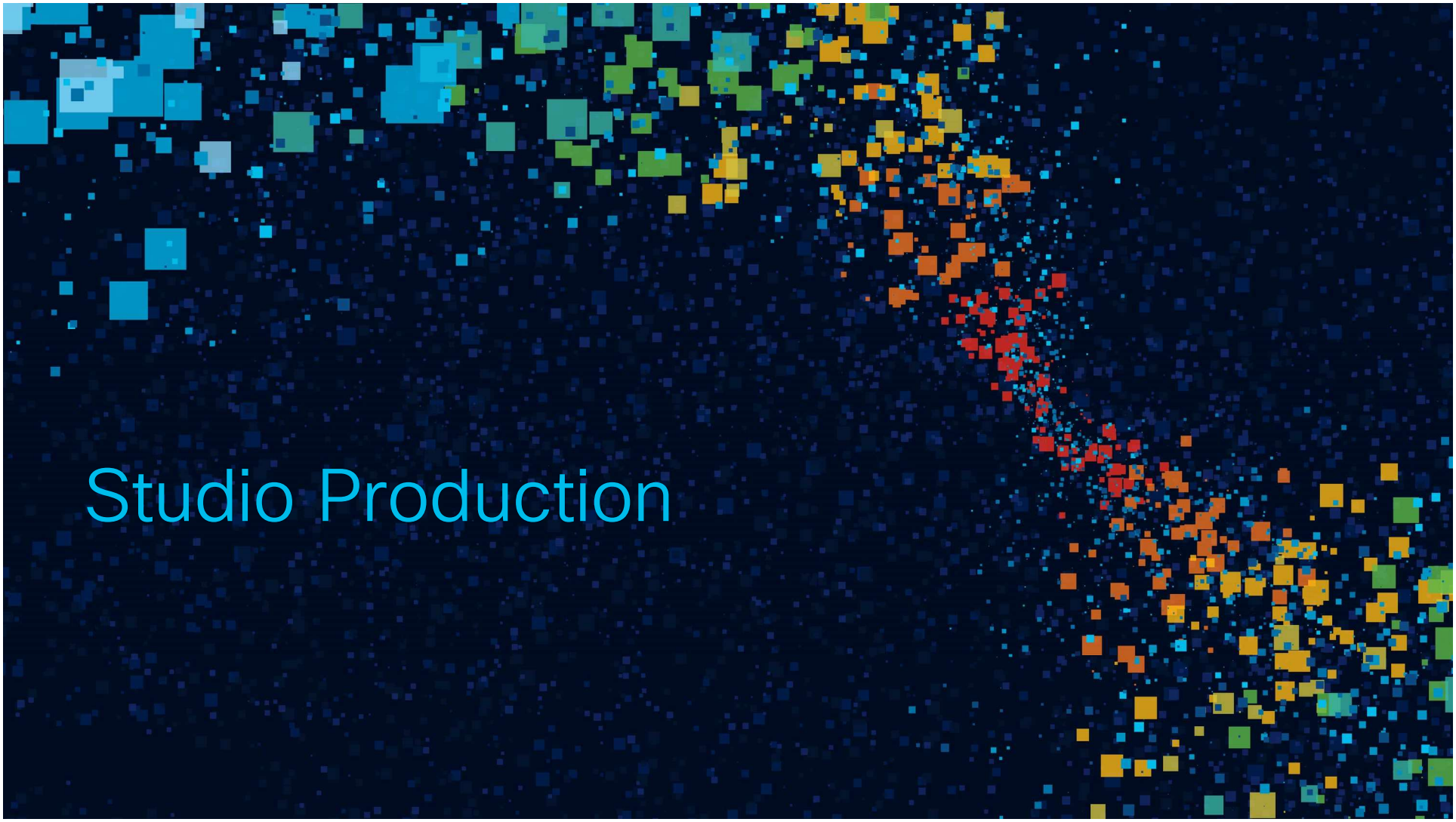
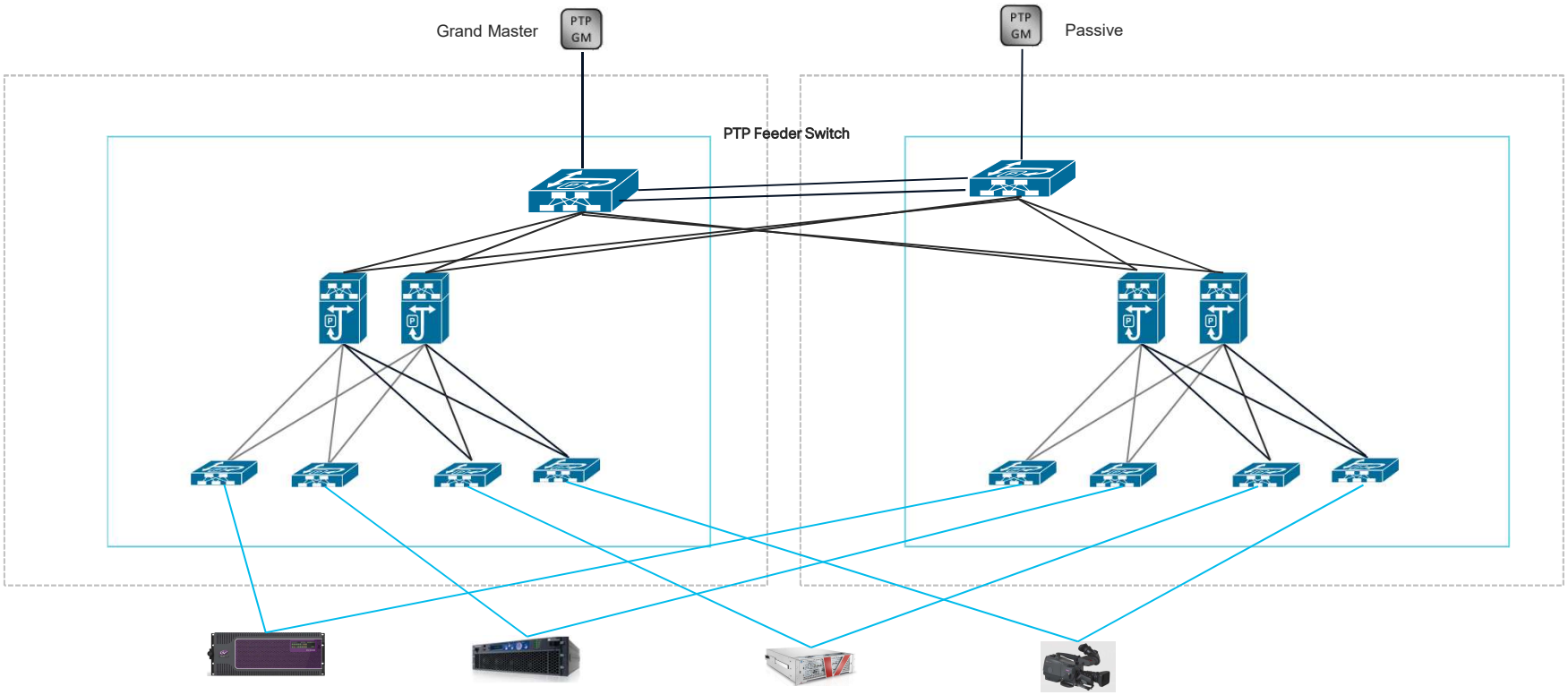

Design Considerations


Studio Production

2020-7 and PTP design



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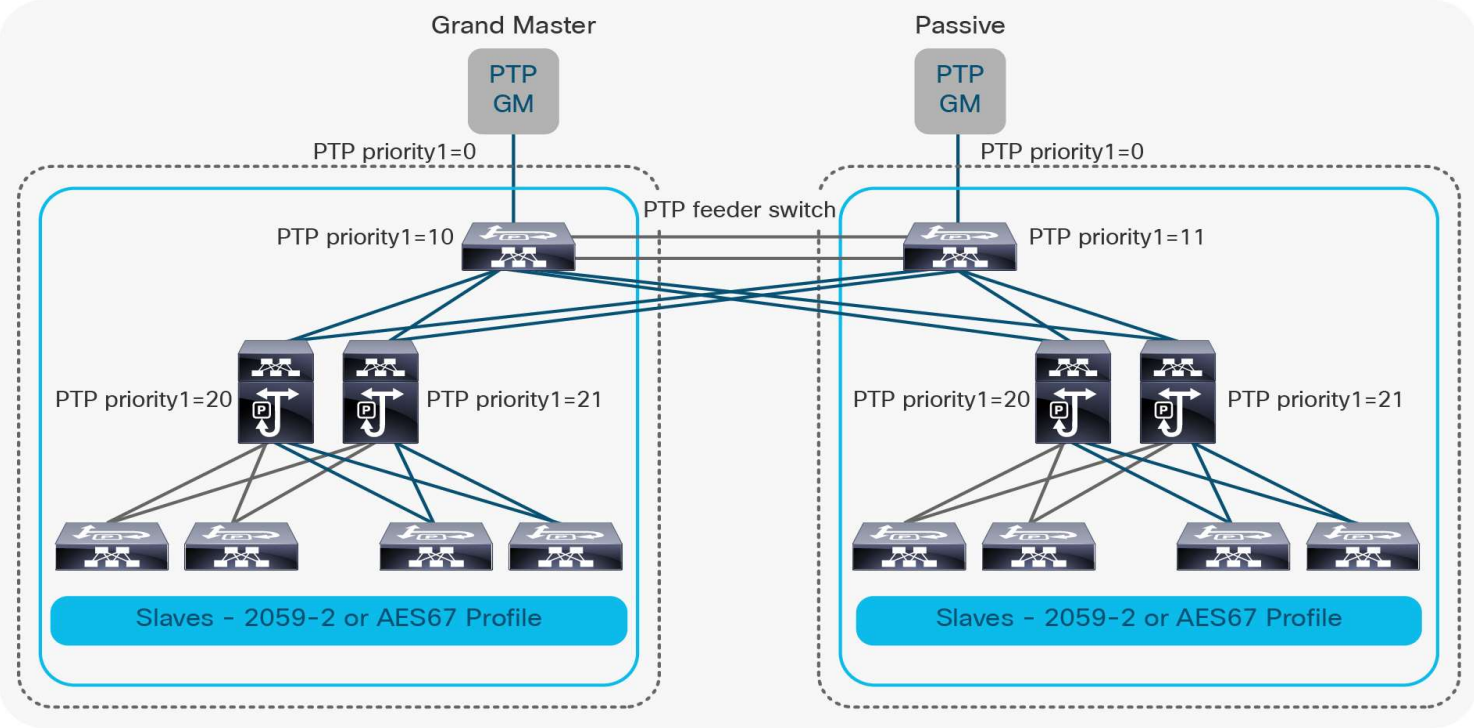
Setting the Priority1 values



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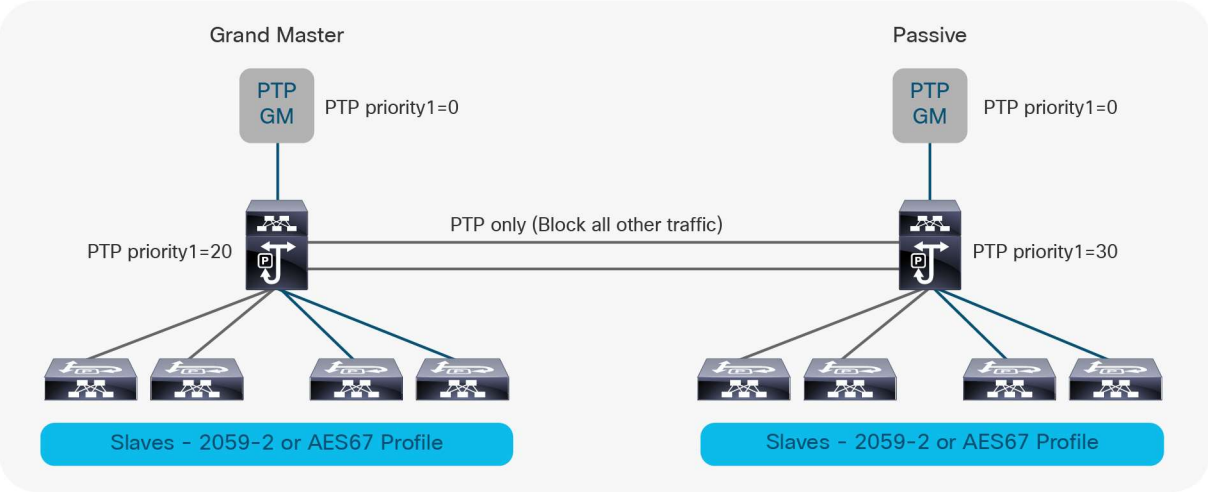
Alternate designs

No PTP feeder switch



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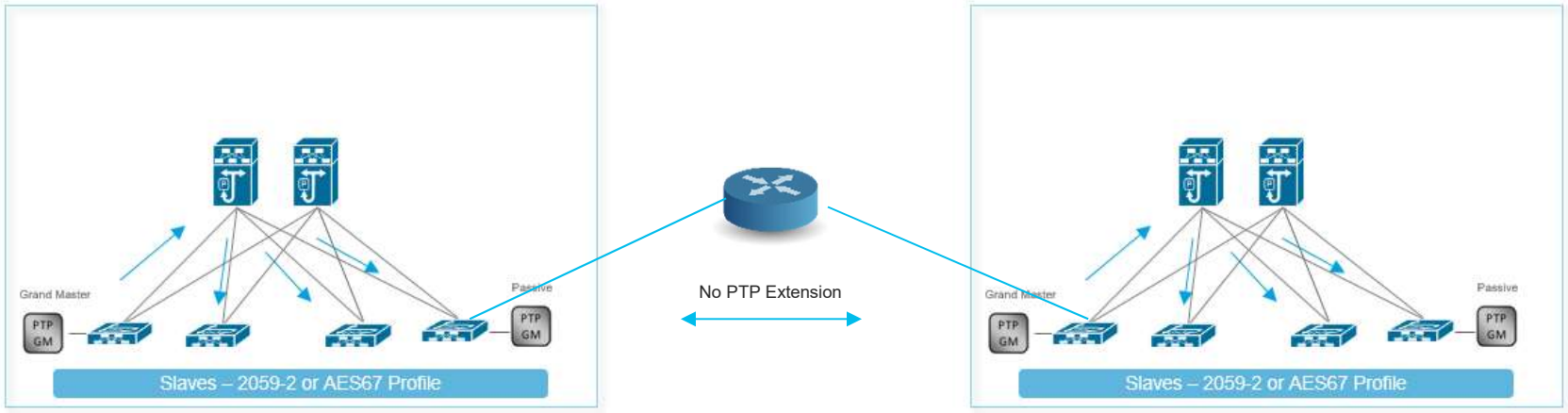
PTP and Multi Site



- WAN could introduce high jitter that could result in high PTP offset
- Also PTP assumes symmetric delays in all calculations

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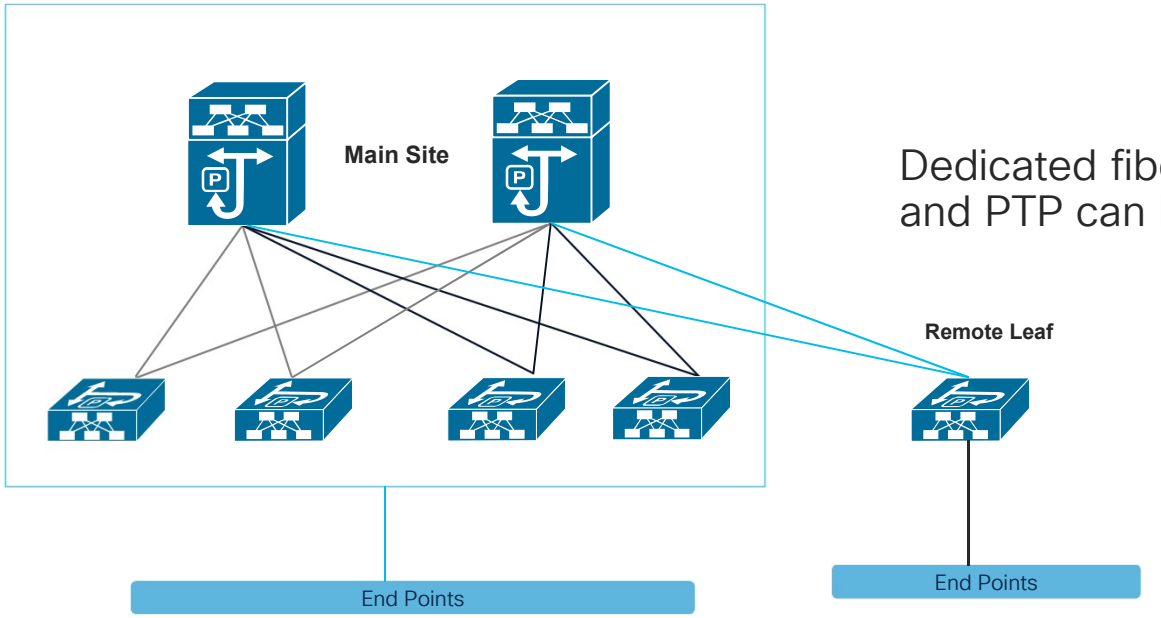
What about Remote Production

Smaller Remote Studios



Dedicated fiber offers low jitter and PTP can be extended

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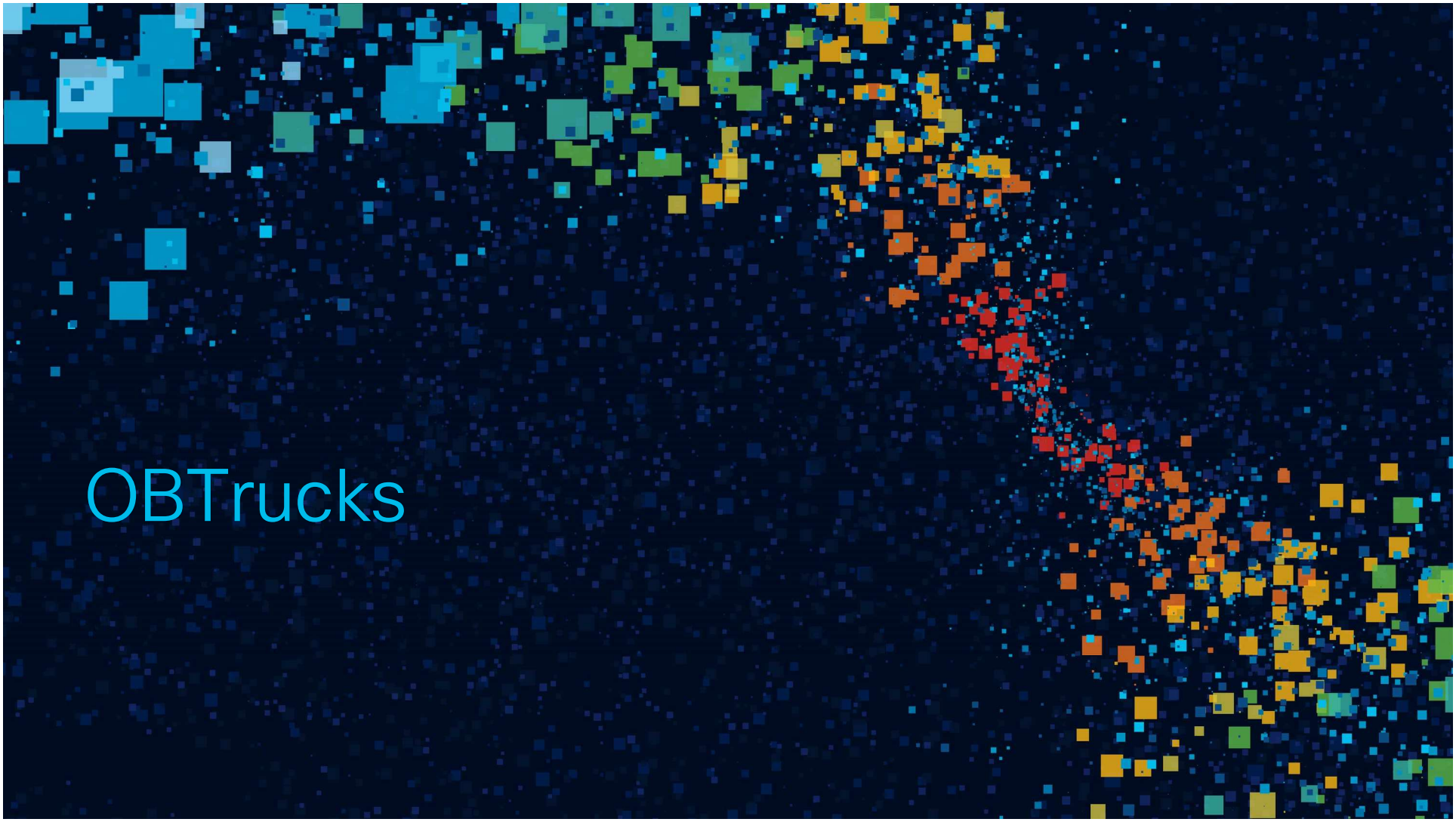
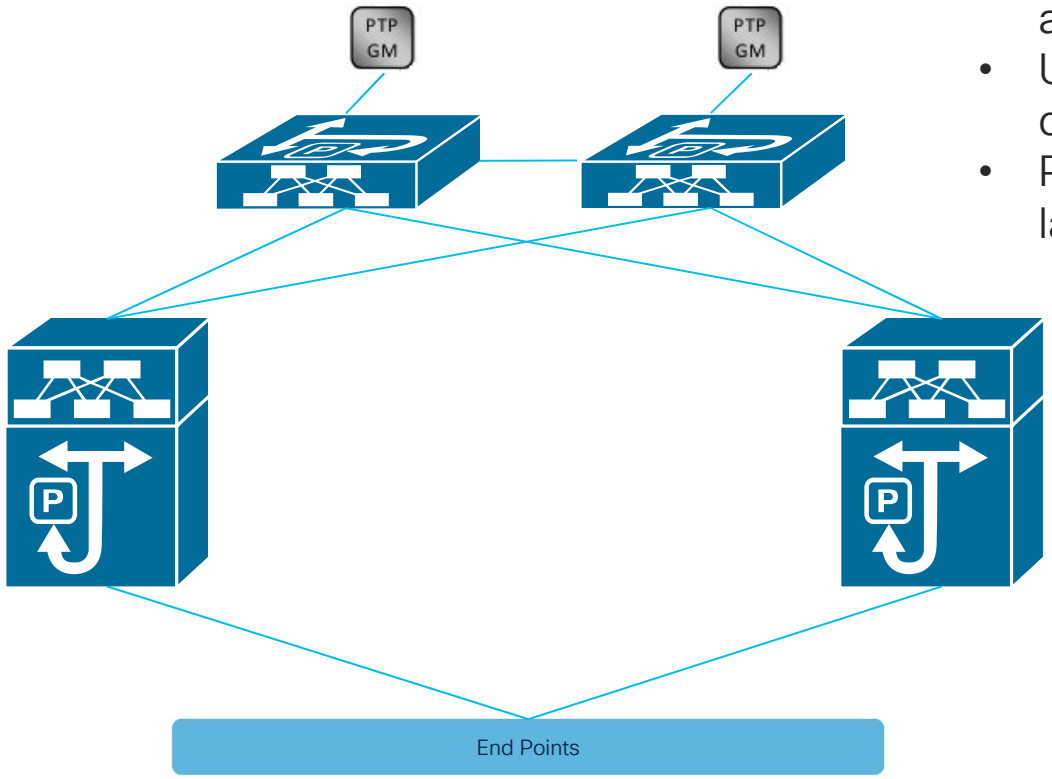

OBTrucks

Obtruck Implementation



- PTP feeder switch also leveraged for control and audio
- Use different VLAN for control, audio
- PTP interfaces can be layer 3 point to point

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What did we learn?

PTP Boundary Clock and Scale

How do you measure Boundary Clock Performance

- Questions to ask you network vendor
  - How many interfaces can PTP be enabled on (master ports)?
  - How many slaves can each interface support?
  - How many slaves can the system itself support?
  - How do you qualify the above scale?

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Achieving PTP Scale on a Modular Chassis

Innovation through PTP Offload

- PTP Offloaded to Line card CPU
- Main Supervisor synchronizes the line card
- Each Line card services endpoints connected to it
- Results in increased scale with superior accuracy

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Cisco Nexus 9000 PTP scale

- Fixed Platform Nexus 9300 EX, FX, FX2, FX3,GX
  - Max PTP interfaces : 64 (Shipping), 144 (NXOS 9.3(5) and later)
  - Max number of slaves behind each interface – 48
  - Max number of slaves – 256

- Modular Platform like 9500-R
  - Max PTP interfaces per line card: 64 (Shipping) , 144 (9.3(5) and later)
  - Max PTP interfaces per chassis : 512 (future release can support 1152)
  - Max number of slaves behind each interface – 48
  - Max number of slaves per system – 1152

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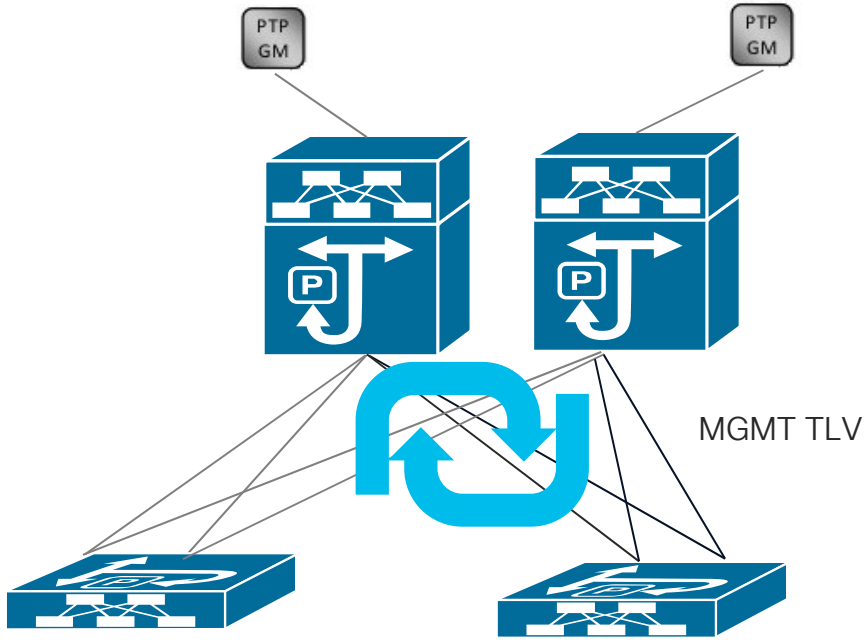
ST2059-2 and Management TLV

Watch out for those loops!

- During GM failure BMCA kicks in to elect new GM
- Interfaces state could go from slave to pre-master/master
- During that phase MGMT TLVs can loop
- NX-OS does not forward TLV on passive interfaces or pre-master



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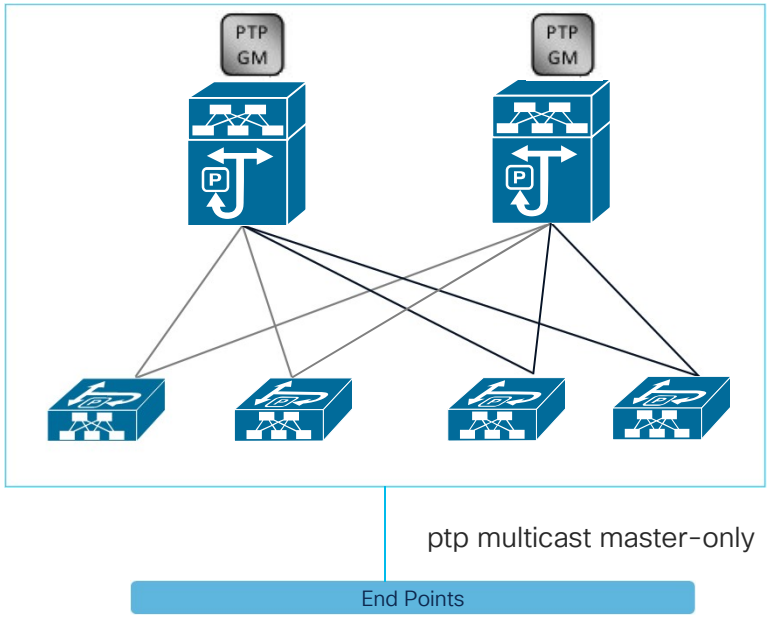
Who becomes the Master?

Basic Network Security for PTP



- PTP BMCA elects the GM
- Any device can send Announce messages with superior values
- Device can take over as GM!!

```
interface et1/1
description IPG
ptp
ptp multicast master-only
```

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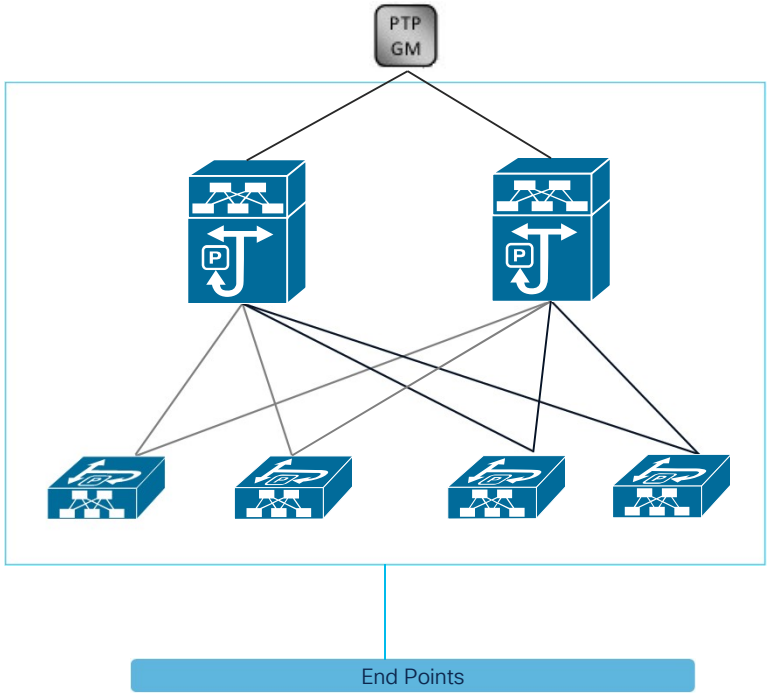
Using Redundant interfaces on GM

Make sure they are isolated



- Make sure different interfaces on the GM are in isolated mode
- This ensures the delay request sent from one system does not get forwarded to other

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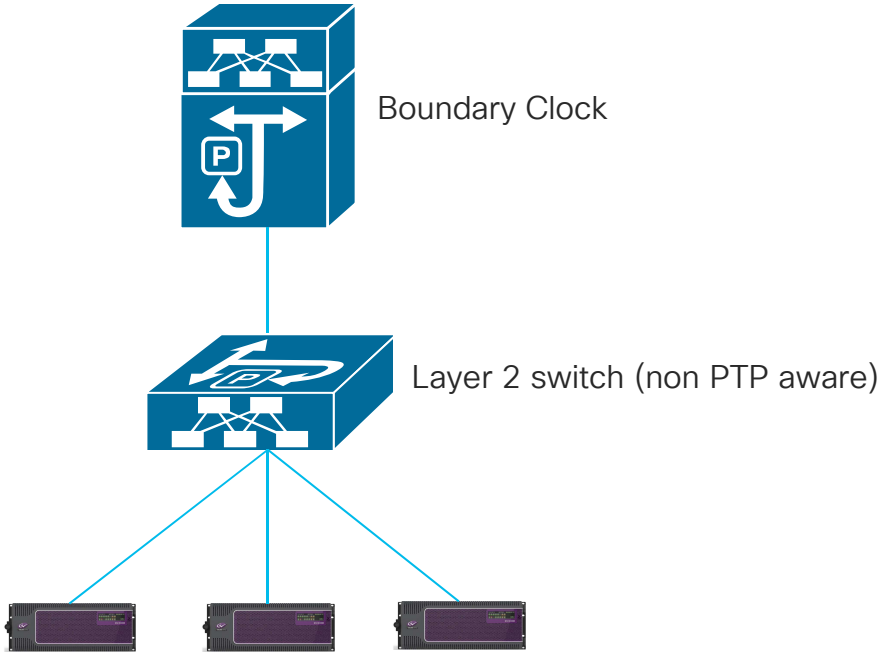
Multicast mode vs Mixed Mode

- PTP multicast mode – all messages are multicast
- PTP mixed mode – Unicast delay request and response
- Mixed mode reduces the number of PTP packets hitting an endpoint
- Improved performance as a result of fewer PTP packets to be processed



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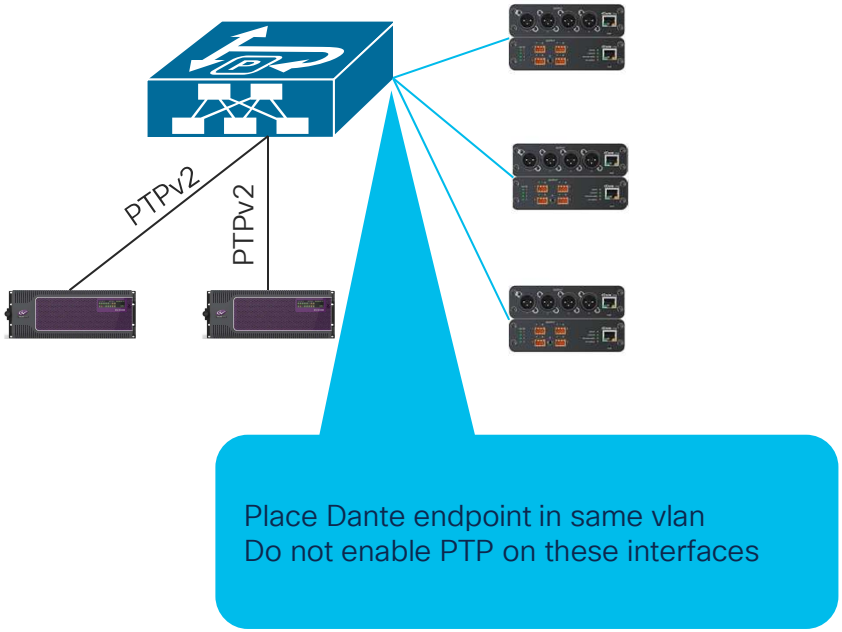
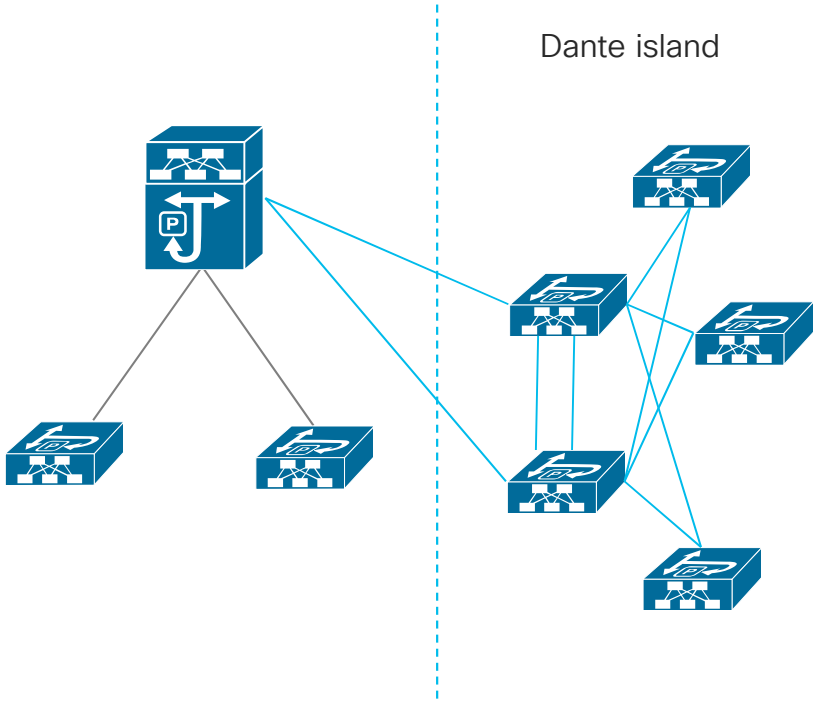
Working with Dante (PTPv1)

How to onboard Dante endpoints





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PTP and Control Plane Policing

Modify Default CoPP

- CoPP protects CPU
- PTP rate limited by default to 128kbps
- Increase CIR to 1024 Kbps

```
Leaf-1 # show policy-map interface control-plane class nbm-copp-class-redirect

Control Plane

Service-policy  input: nbm-copp-policy-strictv

    class-map nbm-copp-class-redirect (match-any)

      match access-group name nbm-copp-acl-ptp

      match access-group name nbm-copp-acl-ptp-l2

      match access-group name nbm-copp-acl-ptp-uc

      set cos 1

      police cir 1024 kbps , bc 32000 bytes

      module 1 :

        transmitted 1724750 bytes;

        dropped 0 bytes;
```

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PTP and Quality of Service

Prioritizing PTP

- Ensure PTP is in highest Priority queue
- Nexus automatically places PTP in highest priority queue (control)

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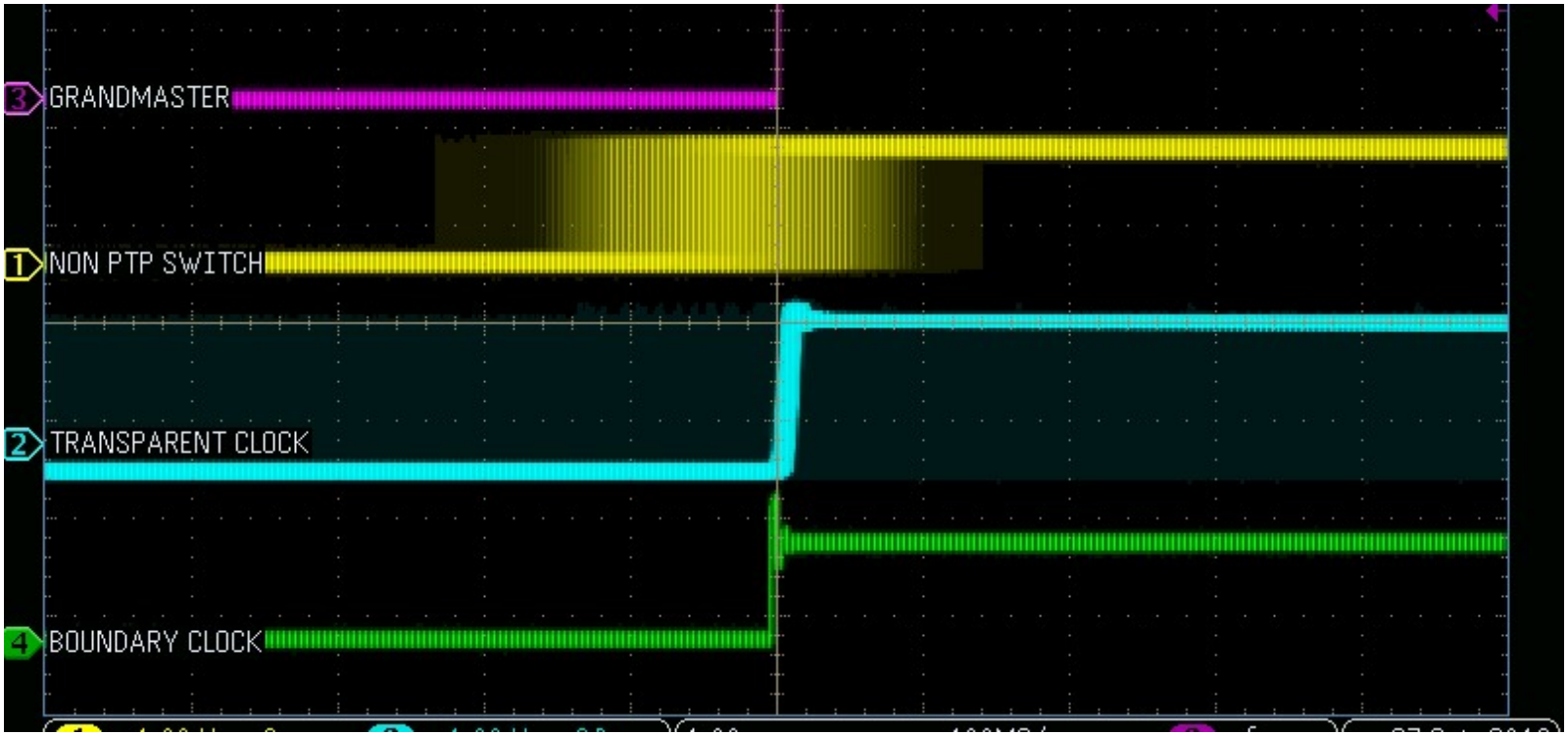
Comparing PTP performance



SMPTE PTP Demo at Annual Tech Conference 2016

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Troubleshooting Tips

Checking PTP at the Switch

- show ptp brief
- show ptp clock
- show ptp parent

```
Spine1# sh ptp brief

PTP port status
-----------------------------------
Port                State
------------------- ------------
Eth1/1              Master
Eth1/3              Master
Eth1/33             Slave
Eth1/34             Disabled
Eth1/35             Disabled
Eth1/36             Master
```

```
Spine1# show ptp clock
PTP Device Type : boundary-clock
PTP Device Encapsulation : layer-3
PTP Source IP Address : 172.16.1.1
Clock Identity : a8:b4:56:ff:fe:0c:f7:f3
Clock Domain: 100
Slave Clock Operation : Two-step
Master Clock Operation : Two-step
Slave-Only Clock Mode : Disabled
Number of PTP ports: 6
Priority1 : 255
Priority2 : 255
Clock Quality:
        Class : 248
        Accuracy : 254
        Offset (log variance) : 65535
Offset From Master : 40
Mean Path Delay : 176
Steps removed : 2
Correction range : 100000
MPD range : 1000000000
Local clock time : Tue Jun 11 19:39:37 2019
Hardware frequency correction : NA
```

```
Spine1# show ptp parent

PTP PARENT PROPERTIES

Parent Clock:
Parent Clock Identity: 6c:b2:ae:ff:fe:9f:3e:1f
Parent Port Number: 208
Observed Parent Offset (log variance): N/A
Observed Parent Clock Phase Change Rate: N/A

Parent IP: 172.16.1.4
Grandmaster Clock:
Grandmaster Clock Identity: 00:04:b3:ff:fe:f0:19:ca
Grandmaster Clock Quality:
        Class: 6
        Accuracy: 45
        Offset (log variance): 16542
        Priority1: 1
        Priority2: 2
```

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Checking PTP Messages at the Switch Port

- sh ptp port interface ethernet 1/x counters
- sh ptp corrections

```
Spine1# sh ptp counters int e1/36

PTP Packet Counters of Interface Eth1/36:
------------------------------------------------------------
Packet Type          TX                  RX
---------------  ------------------  ------------------
Announce                  66                   0
Sync                     523                   0
FollowUp                 523                   0
Delay Request              0                 131
Delay Response           131                   0
PDelay Request             0                   0
PDelay Response            0                   0
PDelay Followup            0                   0
Management                 0                   0
------------------------------------------------------------
```

```
Spine1# sh ptp corrections

PTP past corrections
--------------------------------------------------------------------------------
Slave Port          SUP Time                 Correction(ns)   MeanPath Delay(ns)
---------  ----------------------------  ----------------  ----------------
Eth1/33    Tue Jun 11 19:37:08 2019 988176          24               184
Eth1/33    Tue Jun 11 19:37:08 2019 738202          2               184
Eth1/33    Tue Jun 11 19:37:08 2019 487105          16               184
Eth1/33    Tue Jun 11 19:37:08 2019 235536          16               176
Eth1/33    Tue Jun 11 19:37:07 2019 991135          56               176
Eth1/33    Tue Jun 11 19:37:07 2019 733451          -85              176
Eth1/33    Tue Jun 11 19:37:07 2019 486743          -12              176
Eth1/33    Tue Jun 11 19:37:07 2019 233045          40               180
Eth1/33    Tue Jun 11 19:37:06 2019 982194          16               180
Eth1/33    Tue Jun 11 19:37:06 2019 736855          -1               180
Eth1/33    Tue Jun 11 19:37:06 2019 481447          32               180
Eth1/33    Tue Jun 11 19:37:06 2019 230463          0               172
Eth1/33    Tue Jun 11 19:37:05 2019 979343          40               172
Eth1/33    Tue Jun 11 19:37:05 2019 733087          -57              172
Eth1/33    Tue Jun 11 19:37:05 2019 477642          8               172
Eth1/33    Tue Jun 11 19:37:05 2019 228712          24               188
Eth1/33    Tue Jun 11 19:37:04 2019 981574          16               188
Eth1/33    Tue Jun 11 19:37:04 2019 727055          -2               188
Eth1/33    Tue Jun 11 19:37:04 2019 476039          36               188
```

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Logging PTP state change

From Boundary Clock Switch

```
2020 Mar  3 13:48:57 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction -98302(nsec)
2020 Mar  3 13:48:57 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction 110720(nsec)
2020 Mar  3 14:14:45 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction -32759(nsec)
2020 Mar  3 14:14:45 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction 55334(nsec)
2020 Mar  3 14:14:46 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction -16304(nsec)
2020 Mar  3 14:18:57 PTPstackA %VSHD-5-VSHD_SYSLOG_CONFIG_I: Configured from vty by admin on 192.168.10.150@pts/0
2020 Mar  3 14:35:49 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction -32737(nsec)
2020 Mar  3 14:35:49 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction 55350(nsec)
2020 Mar  3 14:35:49 PTPstackA %PTP-2-PTP_HIGH_CORR: Slave port Eth1/1 High correction -16319(nsec)
PTPstackA#
```

From 2110 IPG

```
2019-11-14 17:17:08,859 - Interface in use changed: ETH2
2019-11-14 17:17:08,859 - Grand master clock id changed: ec:46:70:ff:fe:0a:9b:19
2019-11-14 17:17:08,859 - Parent clock id changed: 00:3a:9c:ff:fe:6d:77:47
2019-11-14 17:17:08,859 - Steps removed changed: 5
2019-11-14 17:17:09,859 - Eth1 ptp status changed: Uncalibrated
2019-11-14 17:17:09,859 - Eth2 ptp status changed: Listening
2019-11-14 17:17:09,859 - Interface in use changed: ETH1
2019-11-14 17:17:09,859 - Grand master clock id changed: 08:00:11:ff:fe:23:19:66
2019-11-14 17:17:09,859 - Parent clock id changed: 00:3a:9c:ff:fe:6d:78:c7
2019-11-14 17:17:09,859 - Steps removed changed: 4
2019-11-14 17:17:10,958 - Eth1 ptp status changed: Listening
2019-11-14 17:17:10,958 - Eth2 ptp status changed: Uncalibrated
2019-11-14 17:17:10,958 - Interface in use changed: ETH2
2019-11-14 17:17:10,958 - Time source changed: Internal Oscillator
2019-11-14 17:17:10,959 - Grand master clock id changed: 00:3a:9c:ff:fe:6d:77:47
2019-11-14 17:17:10,959 - Parent clock id changed: 00:3a:9c:ff:fe:6d:77:47
```

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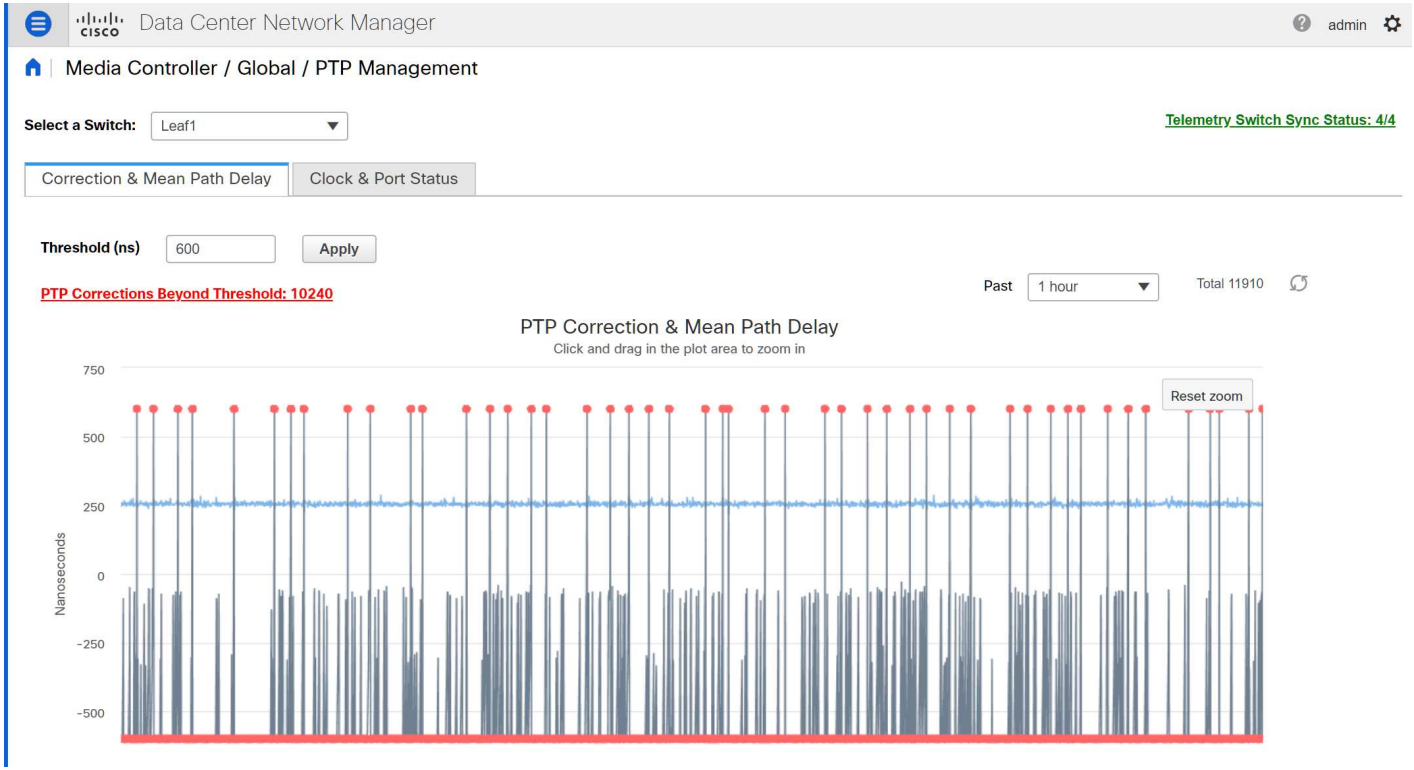
DCNM PTP Monitoring

Leveraging Streaming Telemetry



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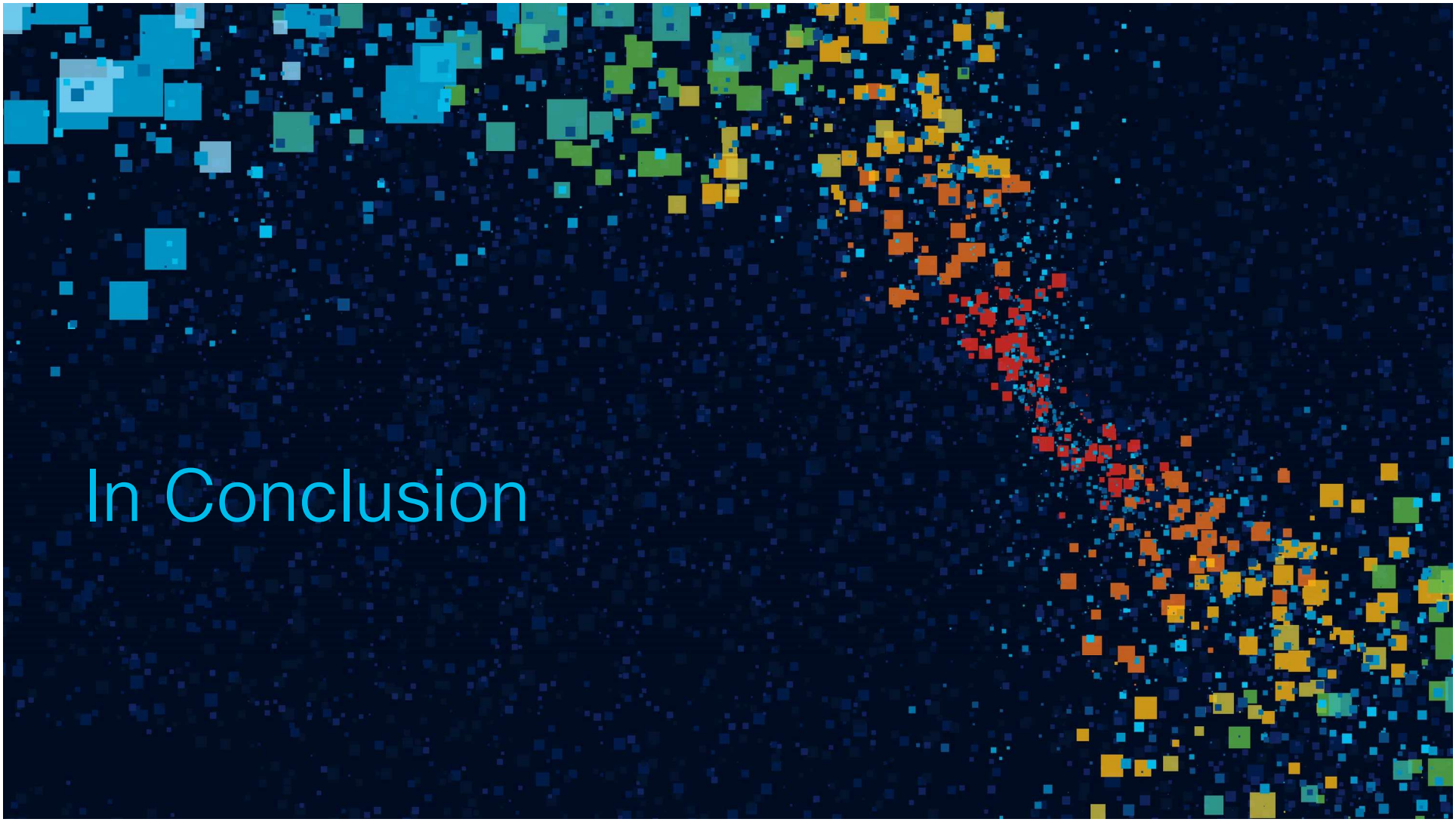
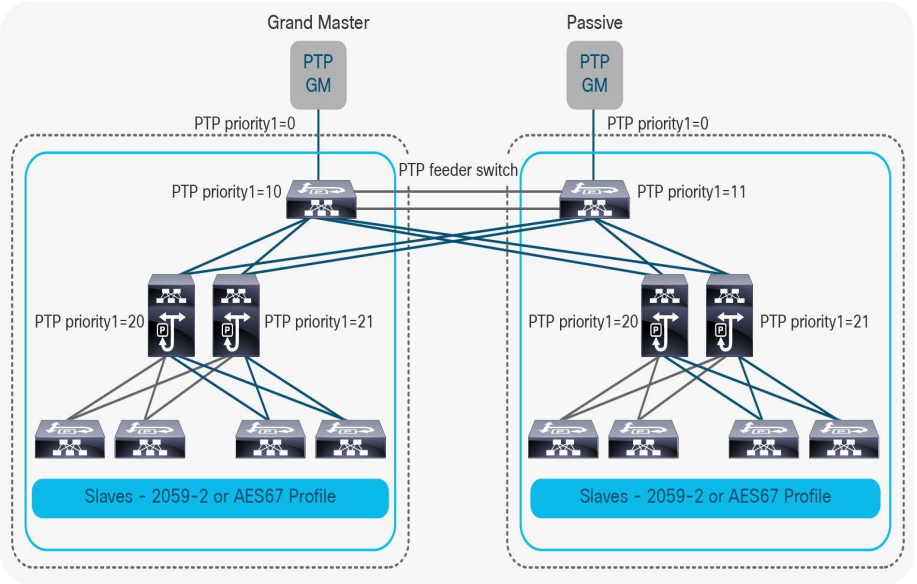

In Conclusion

Conclusion

- PTP provides very precise and accurate time synchronization
- Boundary Clock enables distributed PTP architecture
- Ensure design accounts for failures
- Take Boundary Clock scale into consideration
- Ensure some amount of security is in place
- Leverage operations tools to monitor PTP performance



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Useful Links

PTP Design Guide

https://www.cisco.com/c/en/us/products/collateral/switches/nexus-9000-series-switches/guide-c07-742142.html

IPFM Design Guide

https://www.cisco.com/c/en/us/products/collateral/switches/nexus-9000-series-switches/white-paper-c11-738605.html

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