Overcoming Obstacles to Deploying Precision Time Protocol (PTP) in Networks

Real-World Lessons from the Field

Daniel B. Burch - Senior Manager Business Development


OMG!
I´ve been to
Norway

Norway Fjord
Transmission
Line Span
3152m
(10,341ft)

USA Average
Transmission
Line Span
152m – 366m
(500ft – 1,200ft)

PTP LESSONS TO LIVE BY

1. Proper use of PTP Profiles to achieve budgeted accuracies
2. Understanding, measuring & adjusting for network asymmetry
3. Classes of boundary/transparent clocks
4. When to:
   - Supplement site with GNSS (GPS)
   - Add more boundary clocks
   - Implement APTS

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Smart grid time sync requirements

Application	Measurement	Accuracy	Time Interface	Sync Source
TW Fault Locator	**300 m (line span)**	**1 µs**	**PTP, IRIG-B, PPO**	**GPS, 1588 GMC**
Phasor Measurements	**± 0.1 degree**	**1 µs**	**PTP, IRIG-B (1344)**	**GPS, 1588 GMC**
Lightning Strike Correlation	Grid-wide events	1 ms	IRIG-B	GPS
Protection Relaying events	< 1 cycle	1 ms	PTP, IRIG-B IEC 61850	GPS, IRIG-B, 1588 GMC
Event/Disturbance Recorders	< 1 cycle	1 ms	PTP, IRIG-B, PPO	GPS, 1588 GM
Network, Distribution & Substation Control	Grid-wide events	1 ms	PTP, IRIG-B	GPS, Control Centre, 1588 GMC
Quality of Supply Metering	Freq, time error	0.5 sec	PTP, IRIG-B, PPO	GPS, 1588 GMC
Bulk Metering	Energy registers	0.5 sec	Proprietary, PPO	Proprietary
Customer Premises Metering	Energy registers	1 sec	NTP, Proprietary	Proprietary, NTP
SCADA/EMS/PAS	Grid-wide status	1 ms	NTP, ASCII	GPS
Frequency Measurement	Frequency	1 ms	N/A	GPS
Sampled Values	**Volt/Current**	**1 µs**	**PTP**	**1588 GM**
Telecommunication	SDH/PDH	G.812/813	PTP G.8265 2.048 Mbps/MHz	GPS, 1588 GMC

PTP Profiles for Telecom & Power Applications

Which PTP Profile is appropriate?

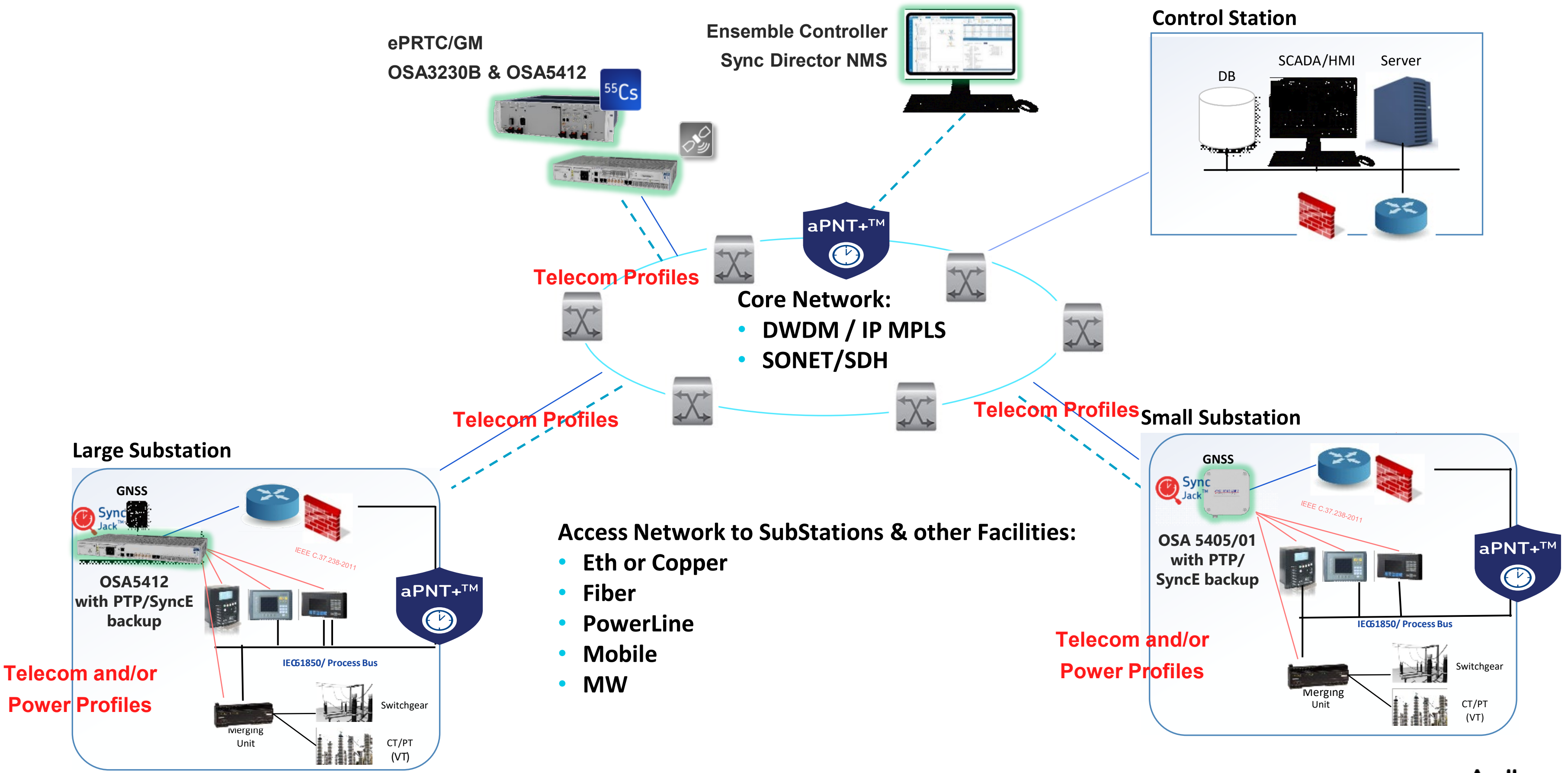
Telecom Profiles:

- G.8265.1 Layer 3 only Frequency only
- G.8275.1 Layer 2 only Frequency & Phase Network Fully Aware
- G.8275.2 Layer 3 only Frequency & Phase Network Partially Aware

Power Profiles:

- C37.238:2011 Layer 2 only
- C37.238:2017 Layer 2 only
- 61850-9-3 Layer 2 only

Typical freq/time sync delivery over optical network



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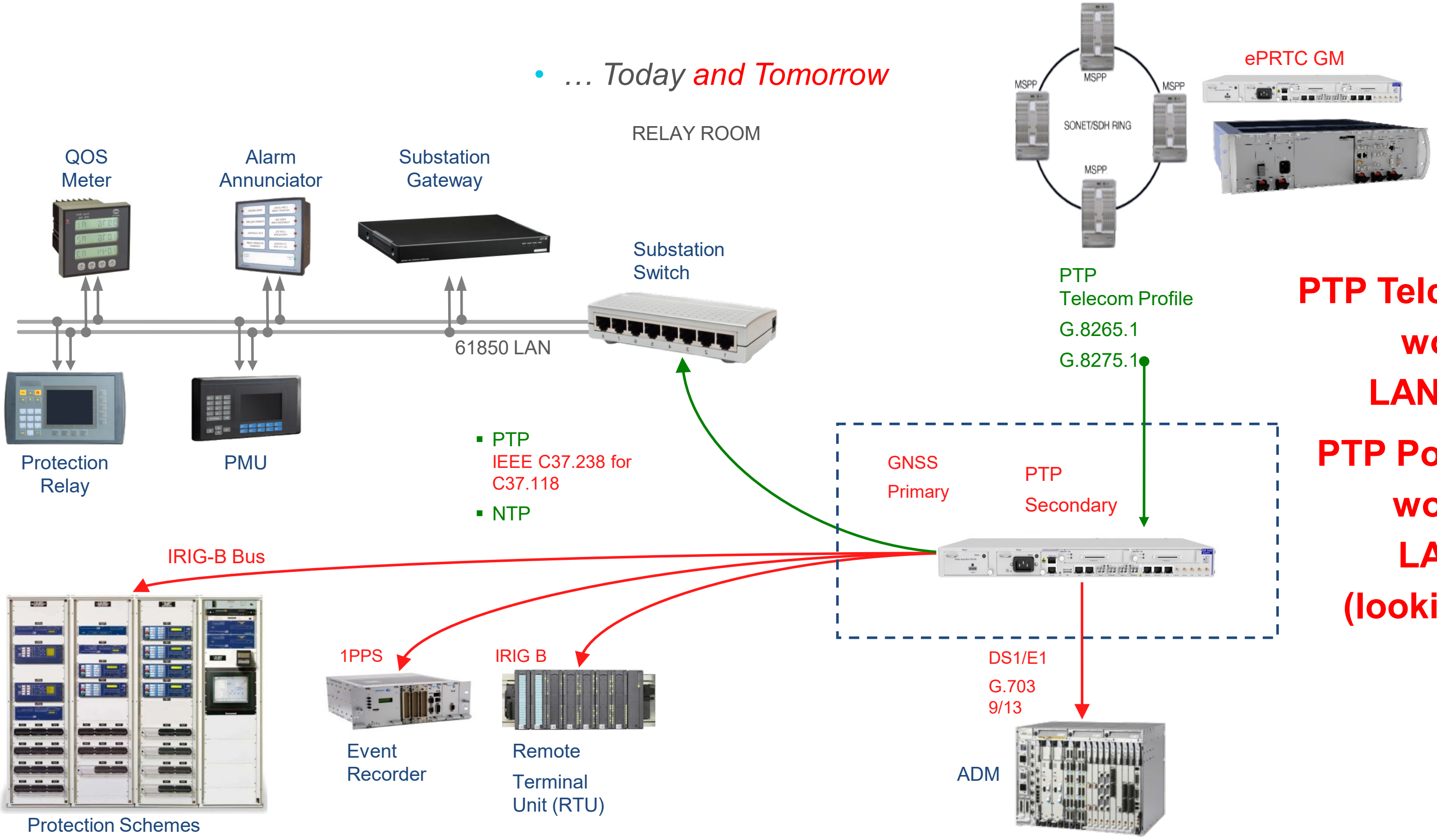
Best Practice Timing Delivery For Substations

- … *Today and Tomorrow*



PTP Telcom Profiles work on LAN or WAN

PTP Power Profile works on LAN only (looking for TC)

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PTP Profiles for Telecom Applications

G.8265.1 Annex A

G.8265.1 Annex A ITU-T Telecom Profile for Frequency	
Permitted Nodes	Grandmasters and Slave-Only Clocks
Operation	Unicast Only
Addressing	IP Addressing – Layer 3 Only
Clock Recovery	Masters must support both one-way and two-way. Slaves may support one-way, two-way or both (Note two-way supports phase)
Domain	Configurable 4-23 (No default)
Timescale	PTP or Arbitrary
Announce	1 per 16 seconds up to 8 per second (default is 1 per 2 seconds)
Sync & Follow-up	1 per 16 seconds to 128 per second
Peer Delay request/response	1 per 16 seconds to 128 per second
Protection Switching	Priority or Quality Messaging or LOS

G.8275.1 Annex A

8275.1 Annex A – ITU-T Telecom Profile for Phase/Time	
Permitted Nodes	Grandmasters, Boundary Clocks and Slave Only Clocks
Multicast/Unicast	Multicast Only
Addressing	Mac addressing – Layer 2 only
Clock Recovery	Two-way Only (Phase)
Domain	24 default (configurable 24-43
Timescale	PTP Timescale
Announce	8 per second
Sync & Follow-up	16 per second
Delay request/response	16 per second
Protection Switching	Alternate-BMCA

G.8275.2 Telecom Profile

G.8275.2 ITU-T Telecom Profile for Frequency and Phase	
Permitted Nodes	Grandmasters, Boundary Clocks and Slave Only Clocks
Operation	Unicast Only
Addressing	IP Addressing – Layer 3 Only
Clock Recovery	Both One-way and Two-way modes are supported (Two-way required for Phase)
Domain	Default is 44 – Configurable 44-63
Timescale	PTP or Arbitrary
Announce	1 per 16 seconds up to 8 per second (default is 1 per 2 seconds)
Sync & Follow-up	1 per 16 seconds to 128 per second
Peer Delay request/response	1 per 16 seconds to 128 per second
Protection Switching	Priority or Quality Messaging or LOS (ABMCA)
PTP Backup with ACDC	Standards include requirement that PTP backup with Automatic Asymmetry delay Compensation to be supported by Grandmasters

PTP Profiles for Power Utilities Applications

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IEEE PTP Profiles for Power Systems Applications

	IEEE C37.238:2011 PTP Power Profile	IEEE C37.238:2017 PTP Power Profile	IEC 61850-9-3 PTP Profile for Power Utility Automation
Network Protocol	Ethernet Layer 2	Ethernet Layer 2	Ethernet Layer 2
Delay Mechanism	Peer-to-Peer (P2P)	Peer-to-Peer (P2P)	Peer-to-Peer (P2P)
Operation Mode	One Step	One or Two Step(s)	One or Two Step(s)
Sync / Announce Message Interval	1 per second / 1 per second	1 per second / 1 per second	1 per second / 1 per second
TLV messages	Required	Optional	Optional
Grandmaster Priority	#1 and #2 = 128 Equal for all Grandmaster	Selectable, allowing to choose the best grandmaster for holdover conditions	Selectable, allowing to choose the best grandmaster for holdover conditions

IEEE PTP Profiles for Power Systems Applications

The IEEE C37.238:2017 and IEC/IEEE 61850-9-3 are completely compatible and can work together without restrictions on the same network by setting its domain number.

The C37.238:2011 was superseded by the other two standards but may be used in legacy networks and may be compatible depending on the IEEE 1588v2 network configuration.

Network Asymmetry Issues Solved
Assisted Partial Timing Support (APTS)

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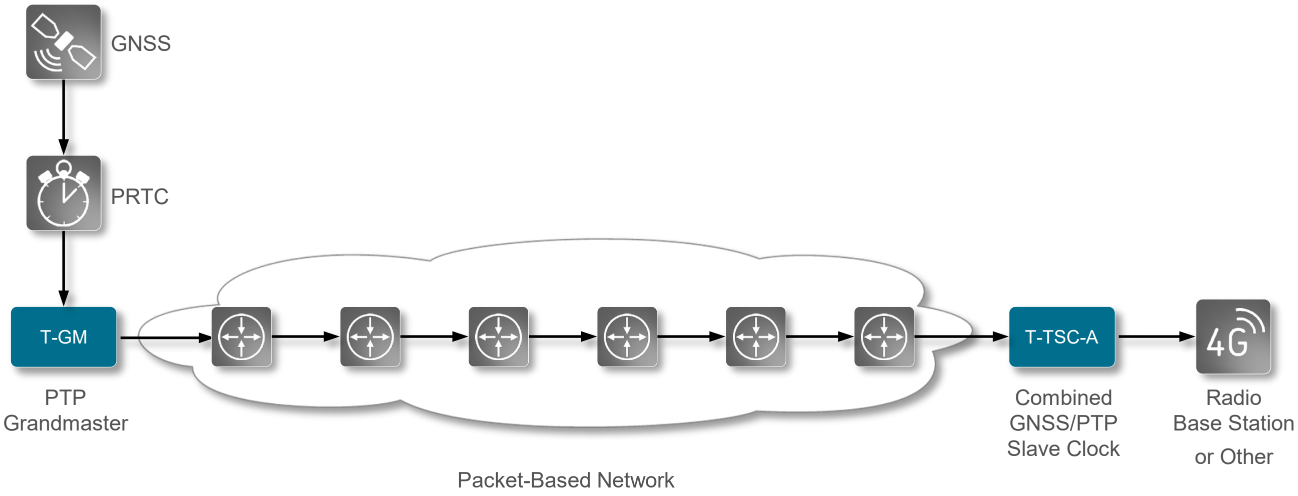
An ADVA Optical Networking Company

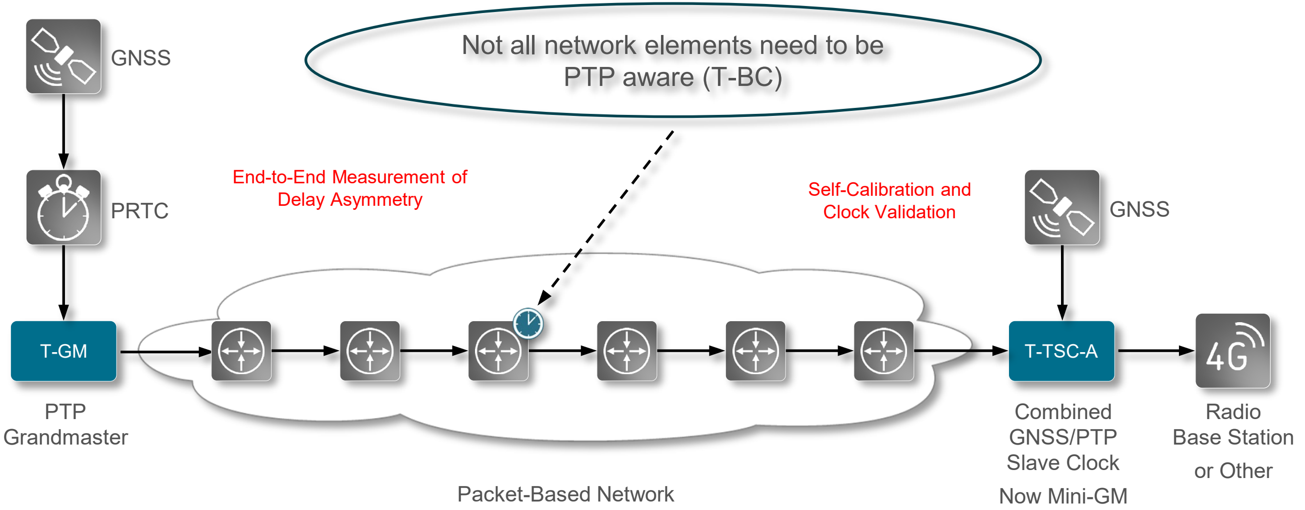
Timing Support



Operates over (existing) layer 3 networks

Assisted Partial Timing Support (APTS) Automatic Asymmetry Delay Compensation (AADC)

Auto-calibration is used to actively compensate for dynamic network asymmetries



Operates over (existing) layer 3 networks

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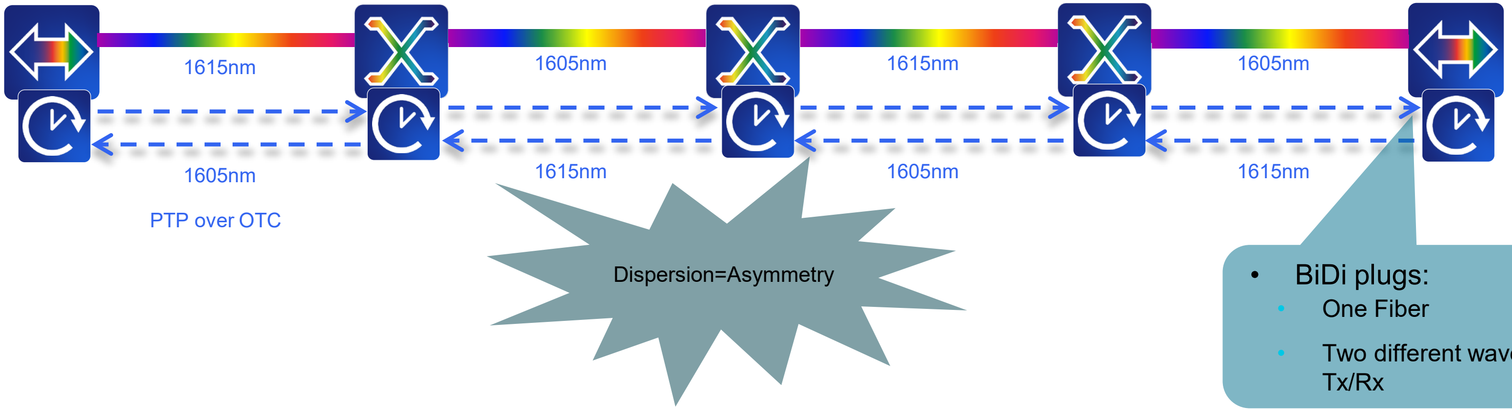
OTC Automatic delay compensation

12.5.1

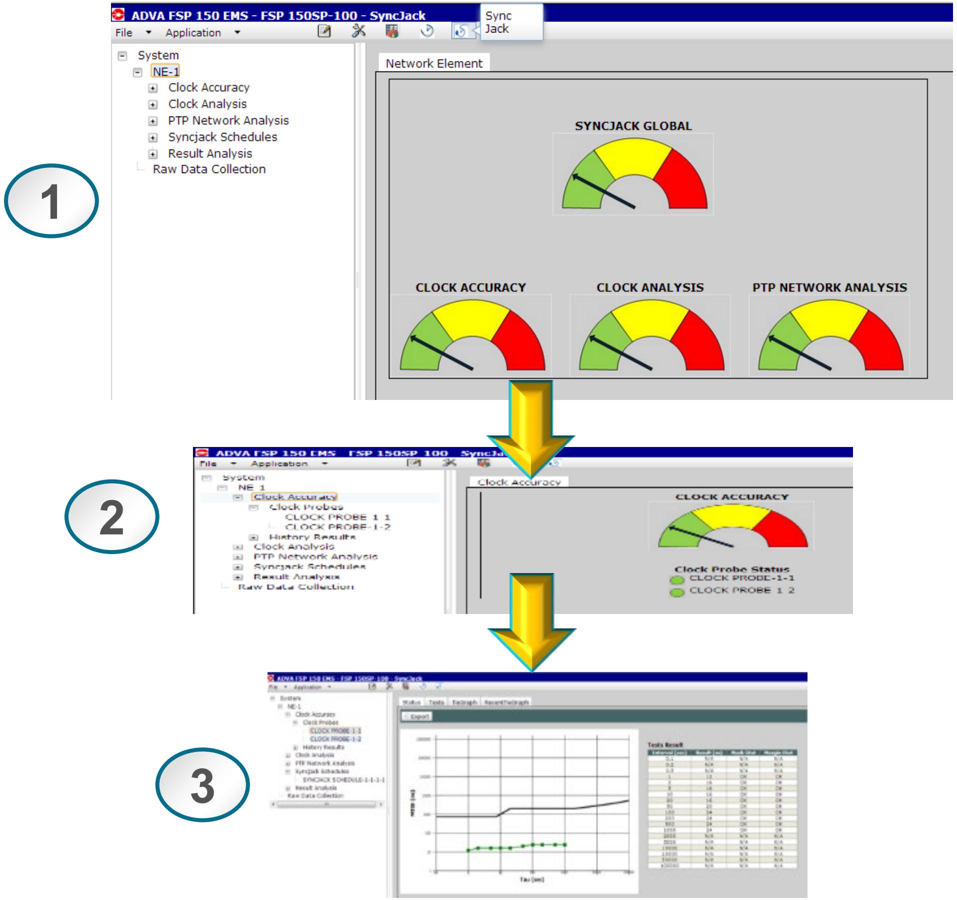


- BiDi plugs:
  - One Fiber
  - Two different wavelengths Tx/Rx

- Chromatic dispersion TE compensation:
  - Option 1: User enter Delay Asymmetry Value
  - Option 2: Calculated based on user data (wavelengths, fiber length)
  - Option 3: Calculated based on user data (wavelengths)

    Estimate delay with G.8275.1 PTP two-way measurement (t=half round-trip delay),
    Then from delay t calculate distance

Syncjack GUI Concept



Several layers of indicators allowing for step by step monitoring and troubleshooting

First layer provides global indication of the Synchronization status

Second layer shows performance indication of each reporting tool

Third layer provides detailed information for fault localization of performance analysis

<u>AADC – Automatic Asymmetry Delay Compensation</u>

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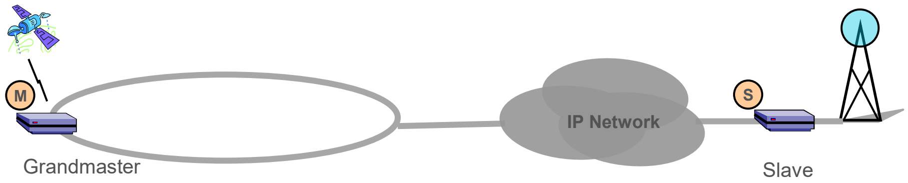
PTP Boundary & Transparent Clocks

Original Concept – Grandmaster Clock



Haul PTP across the entire network

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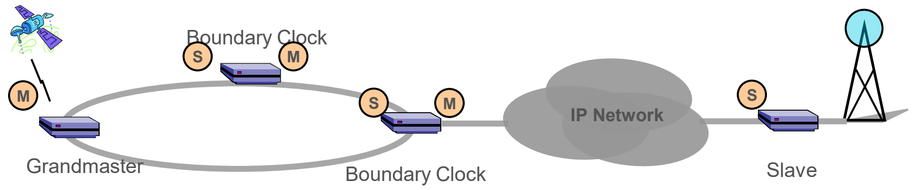
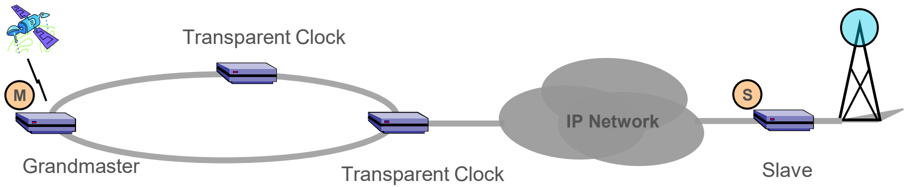
Deploy Boundary Clocks to unburden links



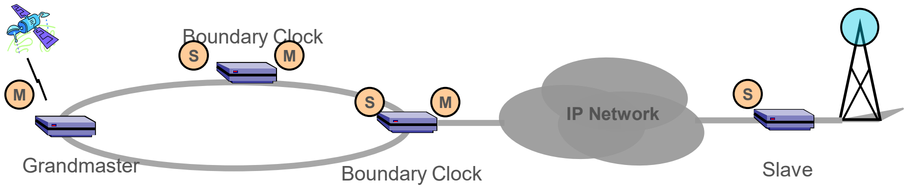
Segment the network with Boundary Clocks
(contains oscillator and optional GNSS Receiver)

Introduction of Transparent Clocks

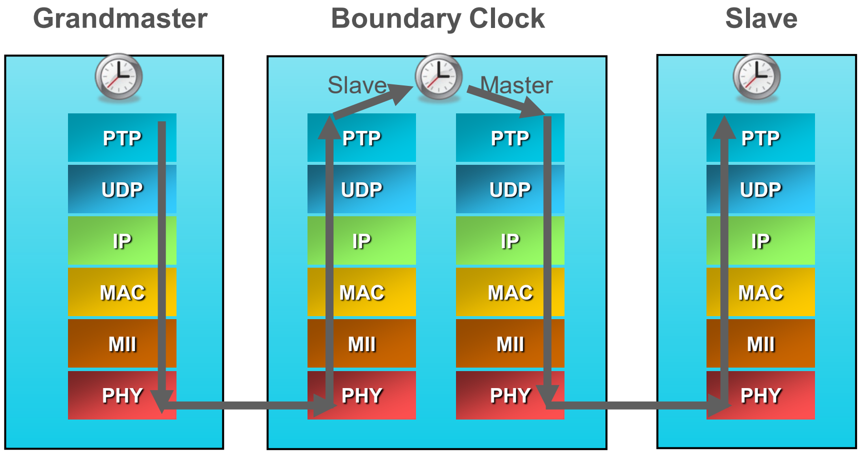


Lower cost and feature of Bridges and Routers
(no oscillator or GNSS Receiver)

What is a Boundary clock



A Boundary Clock extends synchronization across an intermediate network element



- A boundary clock has an internal oscillator:

- The oscillator is slaved to the upstream Grandmaster
- The slaved oscillator is then used as Grandmaster to downstream devices
- Boundary clocks can be used to extend the reach of the timing or offload capacity from the GM.

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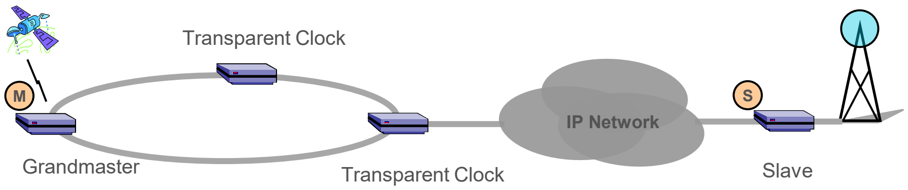
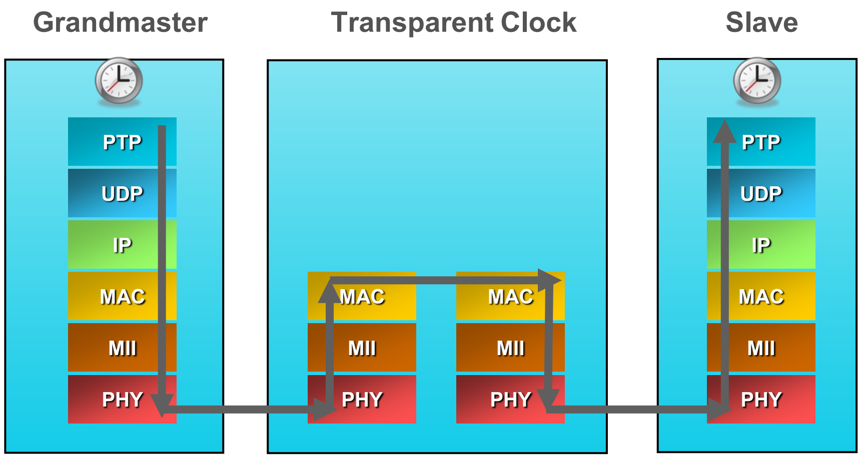
Transparent clock



A Transparent Clock is neither a master or a slave. It is a switch that adjusts a PTP timestamp to compensate for its own delay



- A Transparent Clock has no internal oscillator
- Timestamp on outgoing message is modified to include it's own delay

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G.8273.2 T-BC Classes

Class A and Class B Clock Classes defined

		T-BC, T-TSC (nsec)			
		Class A	Class B	Class C	Class D
maxITEI	unfiltered	100	70	30	15 (LL)
$maxITE_{L}I$	Filtered	-	-	-	5
cTE		50	20	10	4 (LL)
dTE_{LP} (MTIE)	constant temp. up to 1.000 sec	40	40	10	3 (LL)
	var. temp. up to 10.000 sec	40	40	FFS	FFS
dTE_{LP}(TDEV)	constant temp. up to 1.000 sec	4	4	2	1 (LL)
dTE_{HP}	up to 1.000 sec	70	70	FFS	15 (LL)

LL – LIVING LIST (proposed values)
FFS – For Further Study

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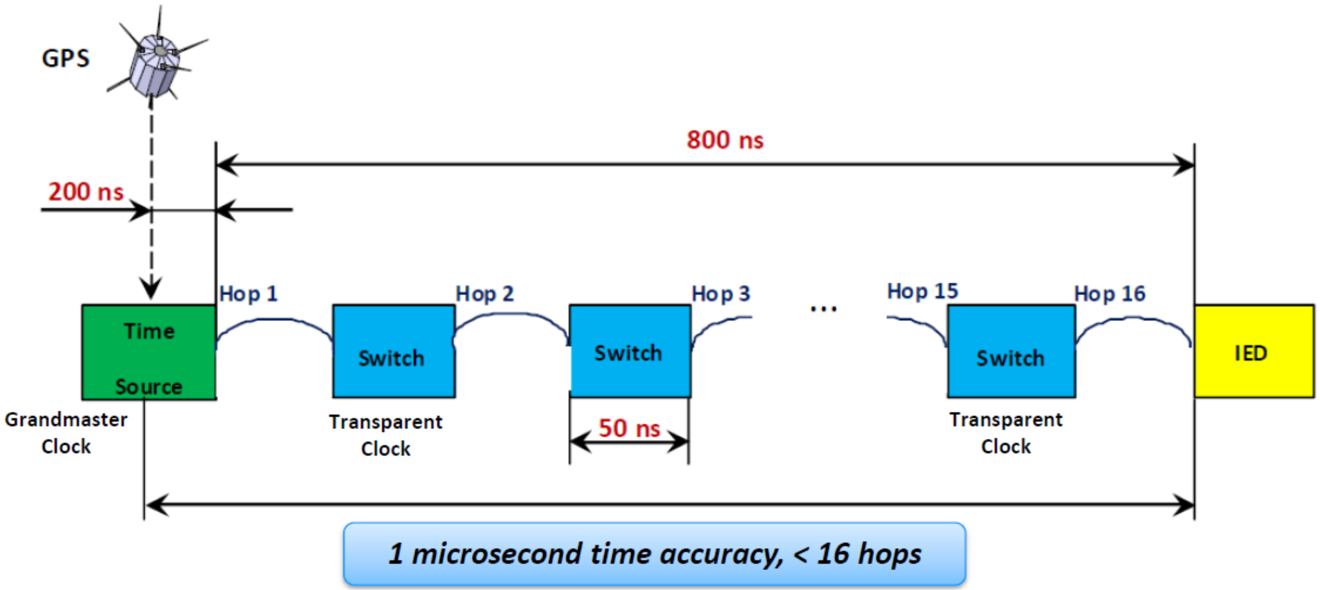
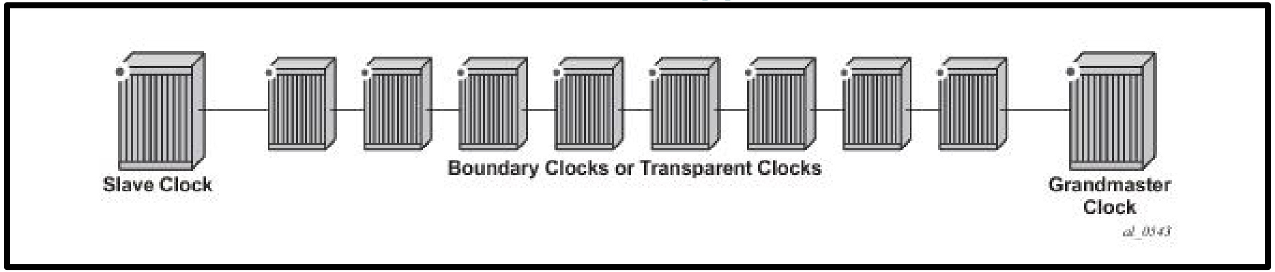
PTP Power Profile Network Model For Substation Timing

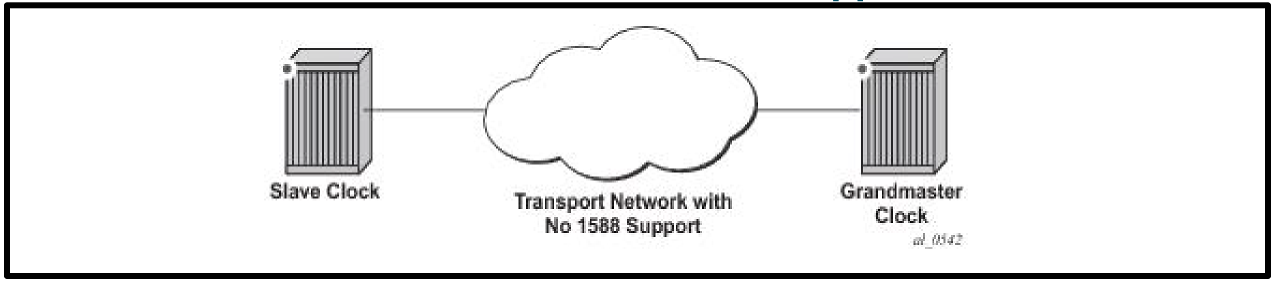


PTP Deployment Terms

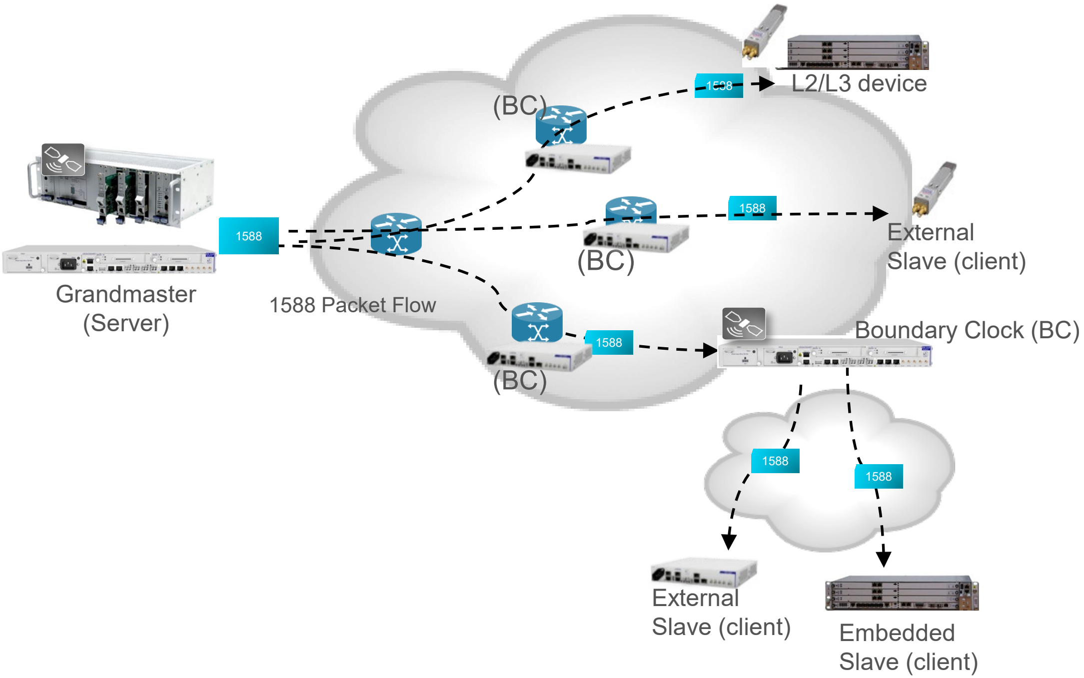
Full ON-Path Support



Partial or No ON-Path Support

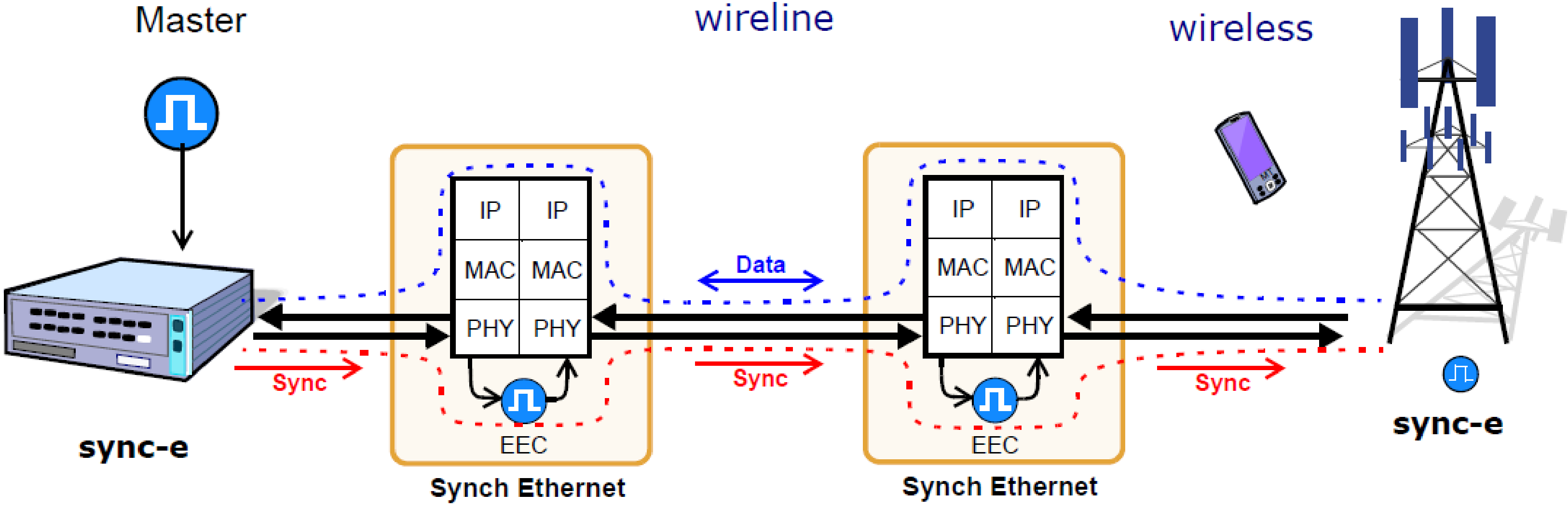


Precision Time Protocol (PTP) Explained



- Protocol used to synchronize clocks throughout a network.
- The Grandmaster (GM) “reference clock” sends a series of time-stamped messages to slaves
- Slaves receive the messages, and eliminate the round-trip delay by synchronizing to the Grandmaster.
- Frequency/Time-of-Day/Phase is recovered from the accurate time of day reference from the GM.
- Boundary Clocks (BC) can receive PTP as a reference, while providing GM functionality downstream to other clients.

Synchronous Ethernet



Also referred as **Sync-E**, is an ITU-T standard for computer networking that facilitates the transference of frequency reference signals over the Ethernet physical layer. This signal can then be made traceable to an external clock.

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Lucky Packet Concept

Lucky Packet Concept

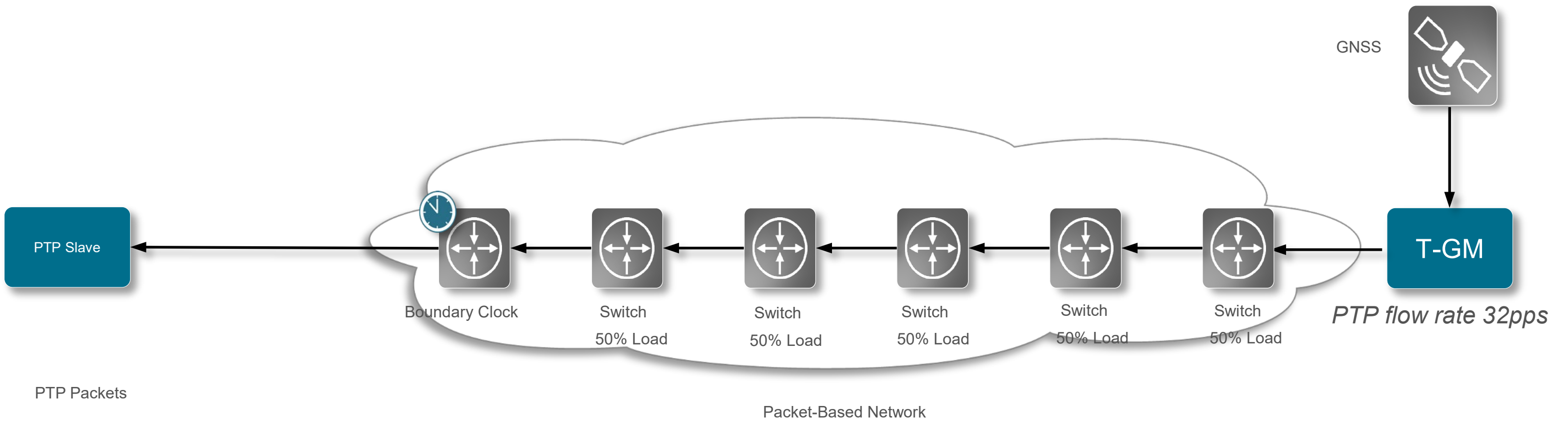
What is a Lucky Packet?

Networks will present a percentage of packets that get across the network with minimal queuing delays. These are referred to as ‘lucky’ packets. Since these lucky packets are never waiting in queues or have minimal wait times, their transit across the network is relatively consistent.

PTP Slave Clocks run a selection filter on all 1588 packets to find the lucky packets. Only lucky packets are used in the clock recovery algorithm. The impacts of PDV are thus filtered and greatly mitigated.

Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

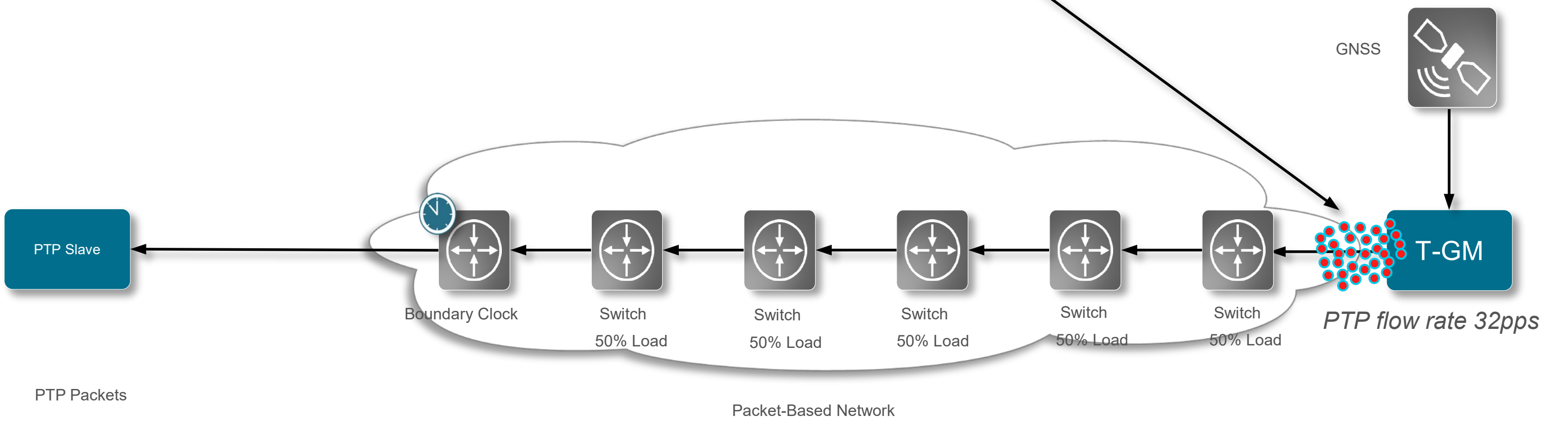


Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

All packets are lucky when leaving the GM!

32 Lucky Packets

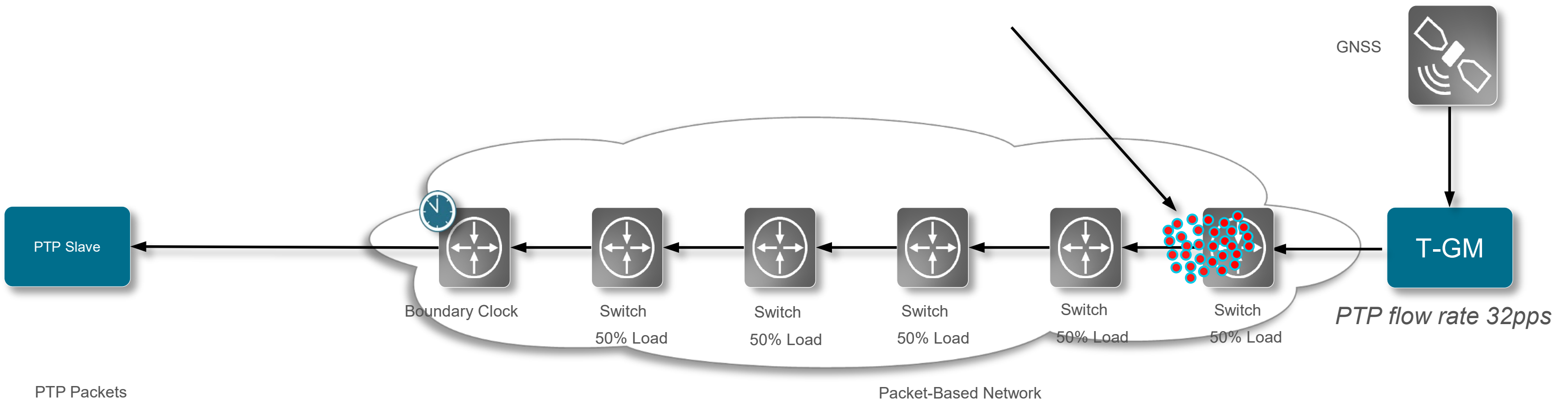


Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

50% of Packets impacted by queueing delays at 1st Switch

16 Packets remain lucky

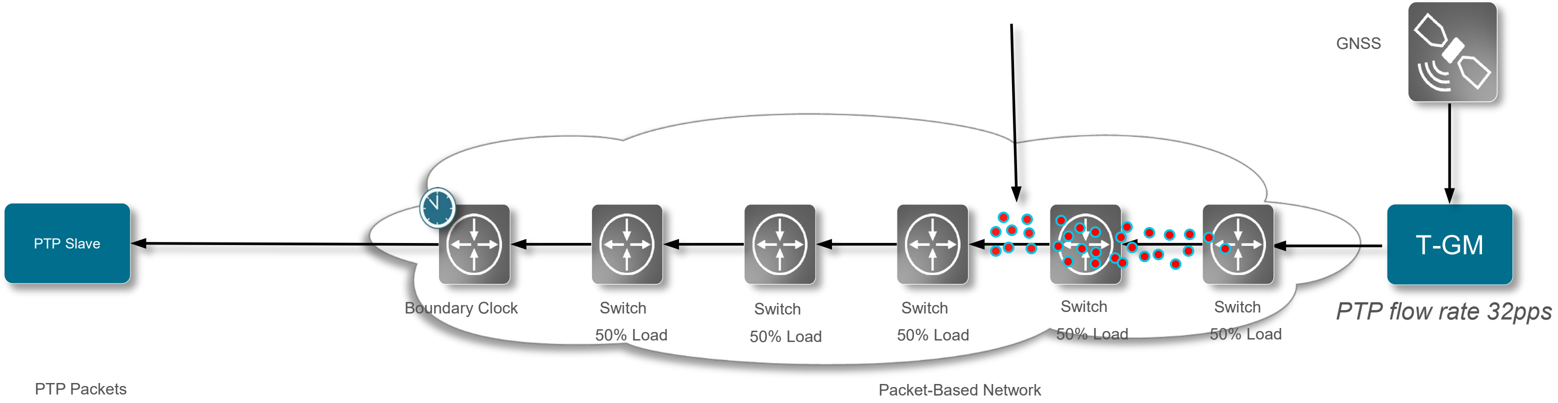


Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

50% of Packets impacted by queueing delays at 2nd Switch

8 Packets remain lucky

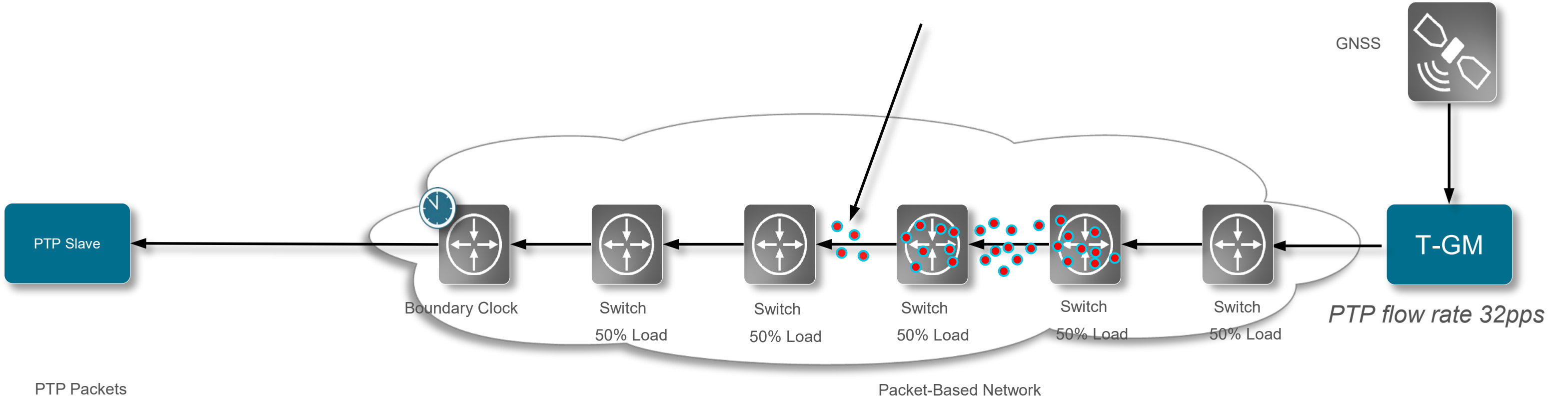


Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

50% of Packets impacted by queueing delays at 3nd Switch

4 Packets remain lucky

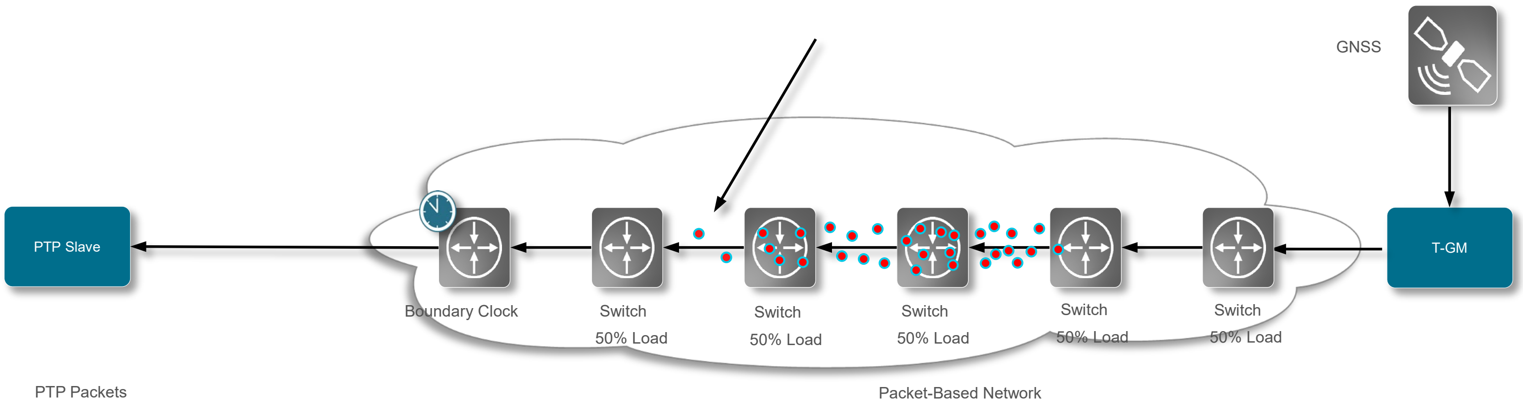


Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

50% of Packets impacted by queueing delays at 4nd Switch

2 Packets remain lucky



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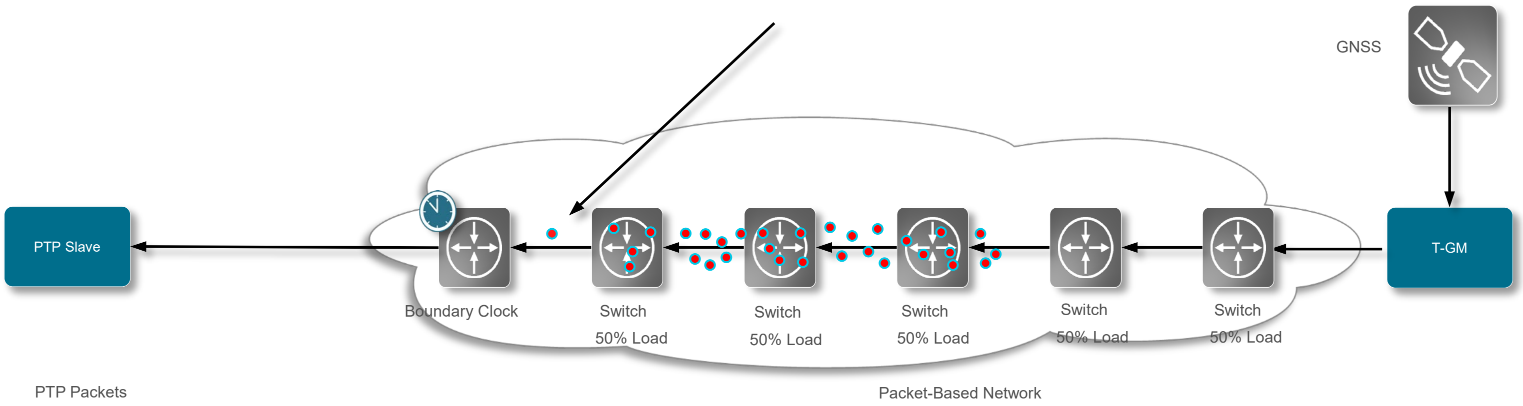
Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

50% of Packets impacted by queueing delays at 5th Switch

1 Packets remain lucky



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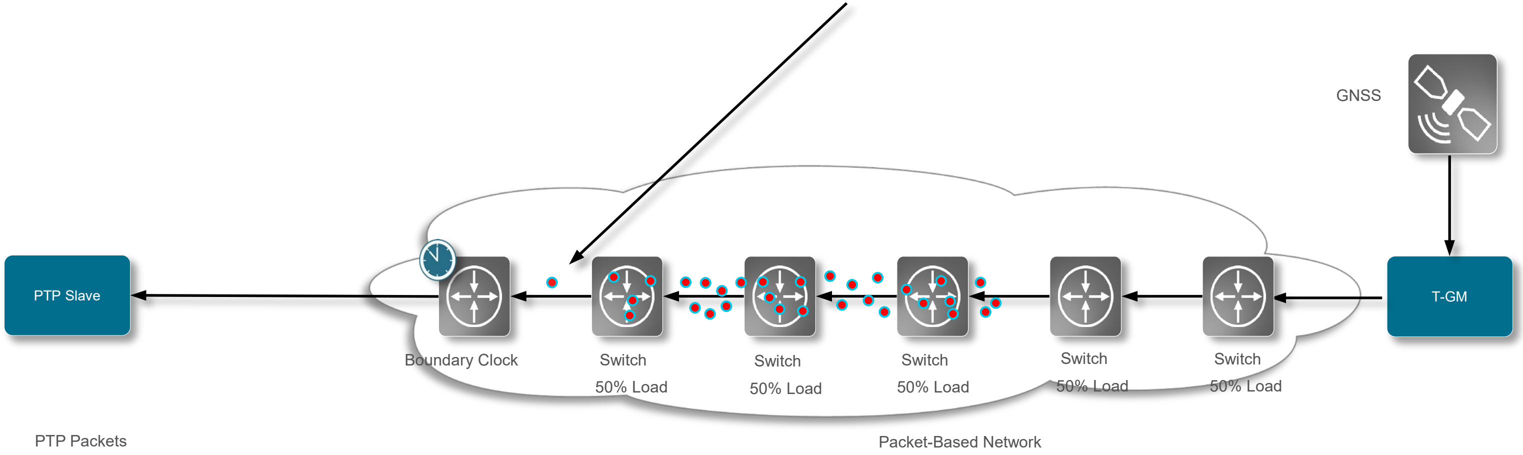
Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

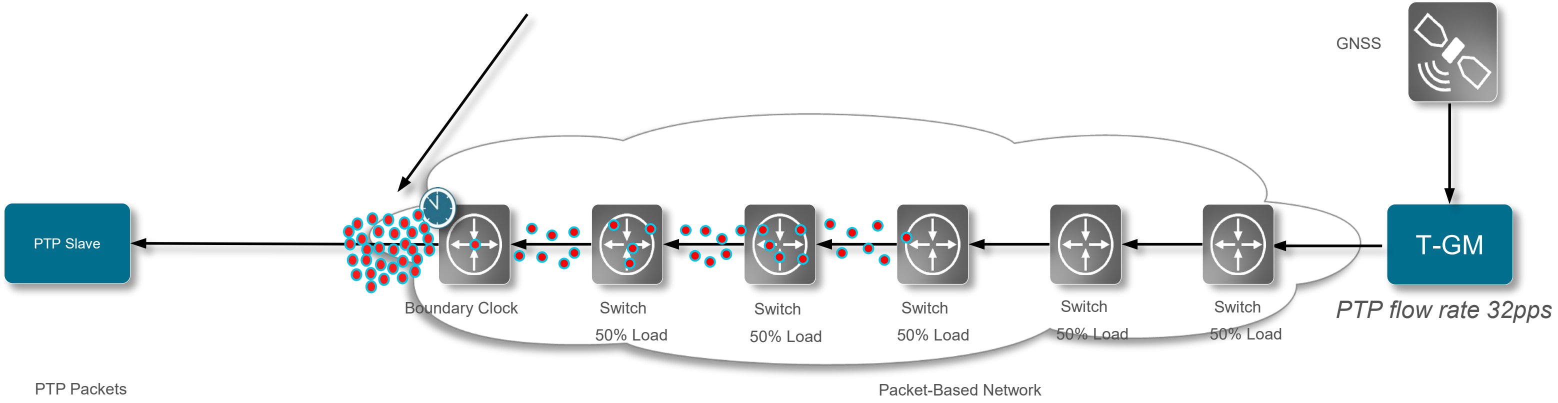
What happens at the Boundary Clock?



Lucky Packet Concept

PTP flow through a network operating at 50% load capacity

*Boundary Clock trains it's internal oscillator to the recovered clock and generates **32 brand new Lucky Packets!***



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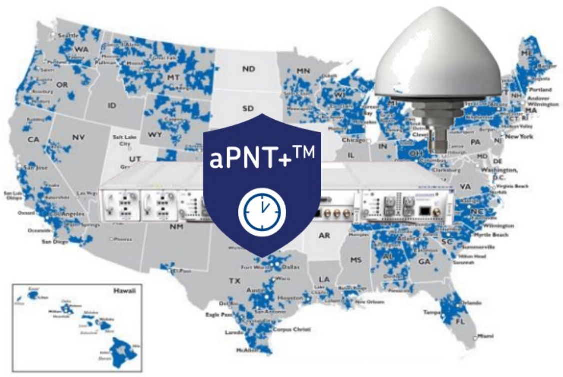
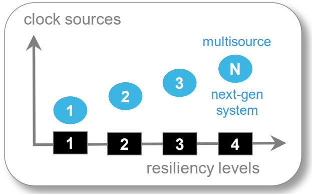
Oscilloquartz - 75 years of know-how in network sync



- ✓ **#1** - Industry's first supplier of sync solutions
- ✓ **#1** - The leader in resilient & assured PNT & packet-based timing
- ✓ **#1** - Leading-edge technologies in defense-in-depth PNT cyberthreat protection, including multilayer detection, zero-trust multisource backup & multilevel fault-tolerant mitigation, aligned with these industry standards:



- ✓ **#1** - The leader in field-proven, vendor-agnostic & intelligent sync network management
- ✓ **#1** - Industry's best complete portfolio of trusted sync services, from network design to installation to commissioning

The #1 trusted secure sync solution provider globally

AUTHOR BIO

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Daniel B. Burch has enjoyed a 47-year, award-winning career in Telecommunications, serving roles with national responsibility at GTE/Verizon Communications, Director of Research & Development at Teradyne Broadband Test Division and senior positions in multiple Silicon Valley firms with expertise in Timing & Synchronization, portable and remote automated expert testing solutions, and developing new methods for analyzing complex circuits and services. Burch is now responsible for Oscilloquartz business development in Federal, Smart Grid, Transportation & Public Safety/911 markets.

Thank you!

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