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What You Make Possible

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CISCO

Synchronisation in Packet-Based Networks (SyncE/IEEE1588-2008)

BRKSPG-2170

TOMORROW starts here.

Agenda

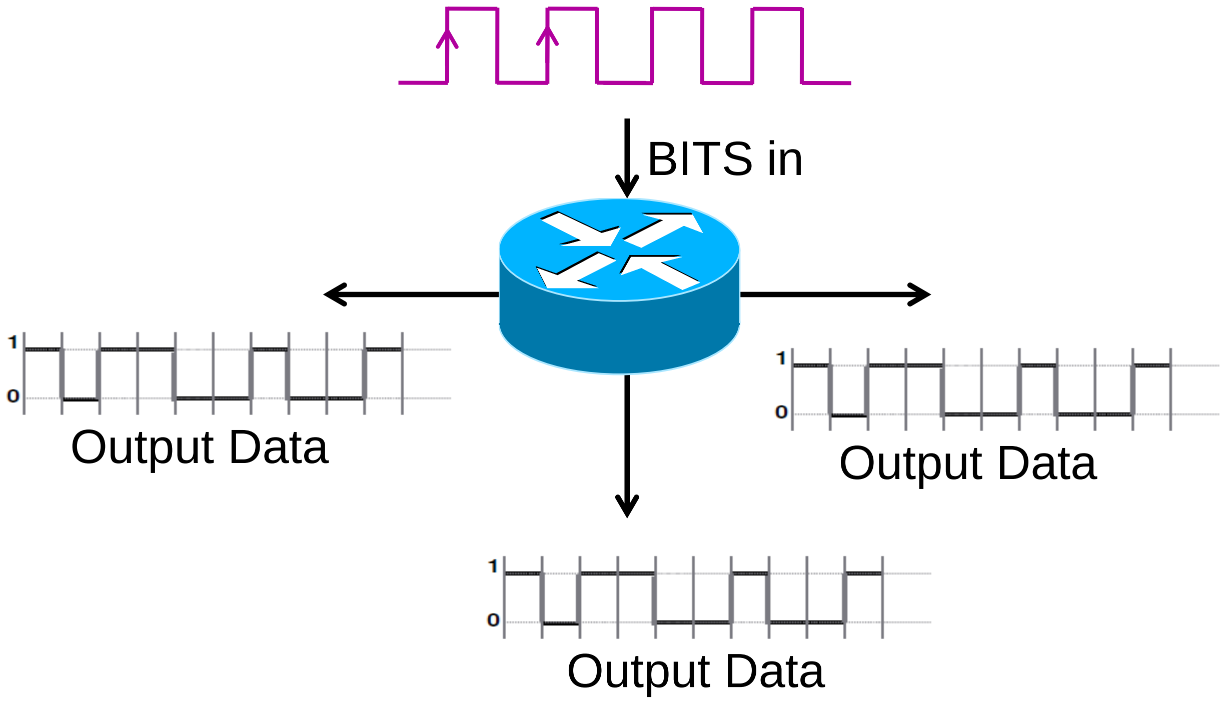
- Motivation for Synchronisation in Packet-based Networks
- Frequency and Time Synchronisation Overview
- Synchronisation Support in Cisco Products
- Deployment Considerations for
  - Industrial Solutions
  - Smart Grid
  - High Frequency Trading
  - Service Providers
- Summary and Conclusion

Motivation for Synchronisation in Packet-based Networks

There are two “Things” to synchronise

Frequency and Time

Frequency



Time

Service Providers

Industrial Solutions

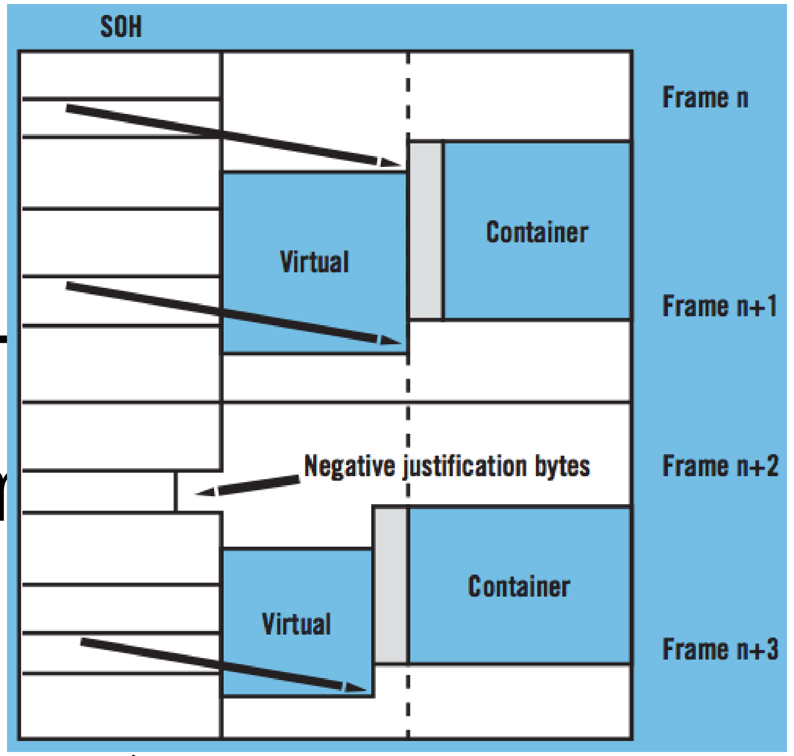
Smart Grid

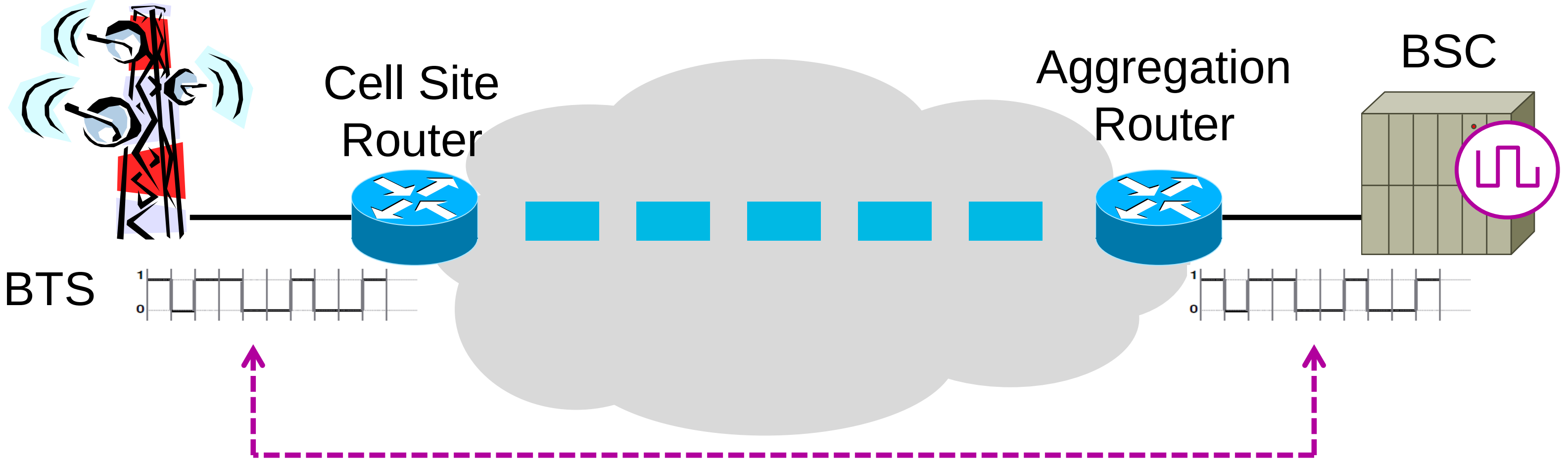
High Frequency Trading

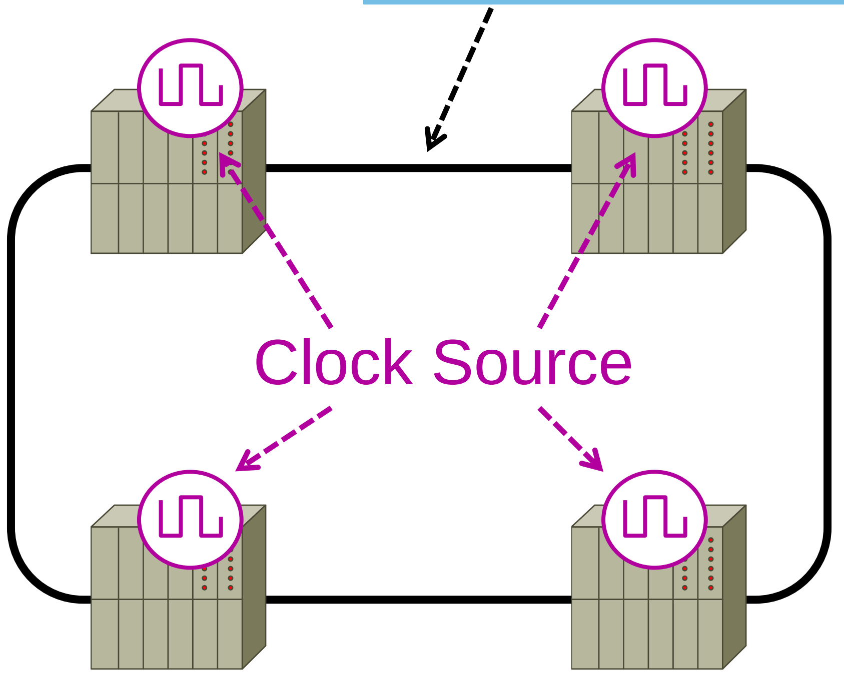
Why do we need to synchronise Frequency?

Frequency Applications

- Avoid Slips on TDM Interfaces (E1/T1, …)
- Make Synchronous Networks work (SONET/SDH
- 2G an 3G Radio Access Network (RAN) Deploym





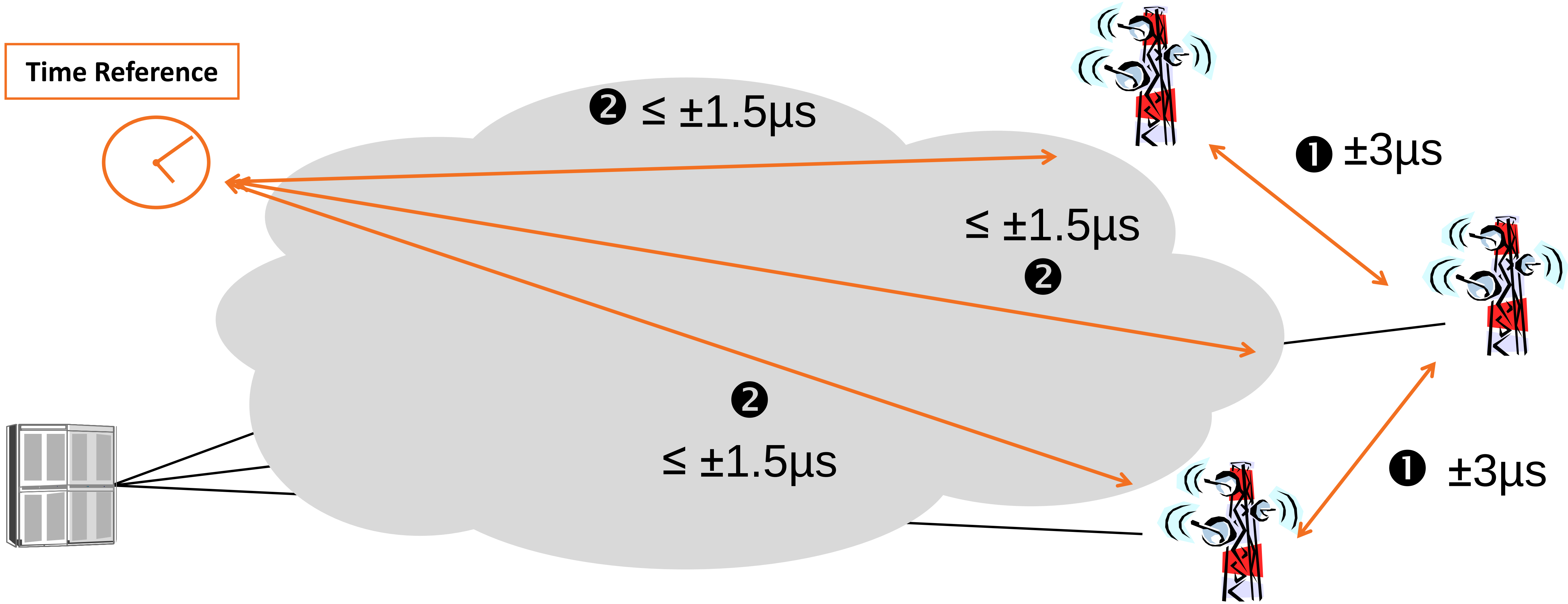


RAN … Radio Access Network; TDM … Time Division Multiplexing;
SONET … Synchronous Optical Network; SDH … Synchronous Digital Hierarchy

Why do we need to synchronise Time?

Time Applications – Mobile Network LTE TDD

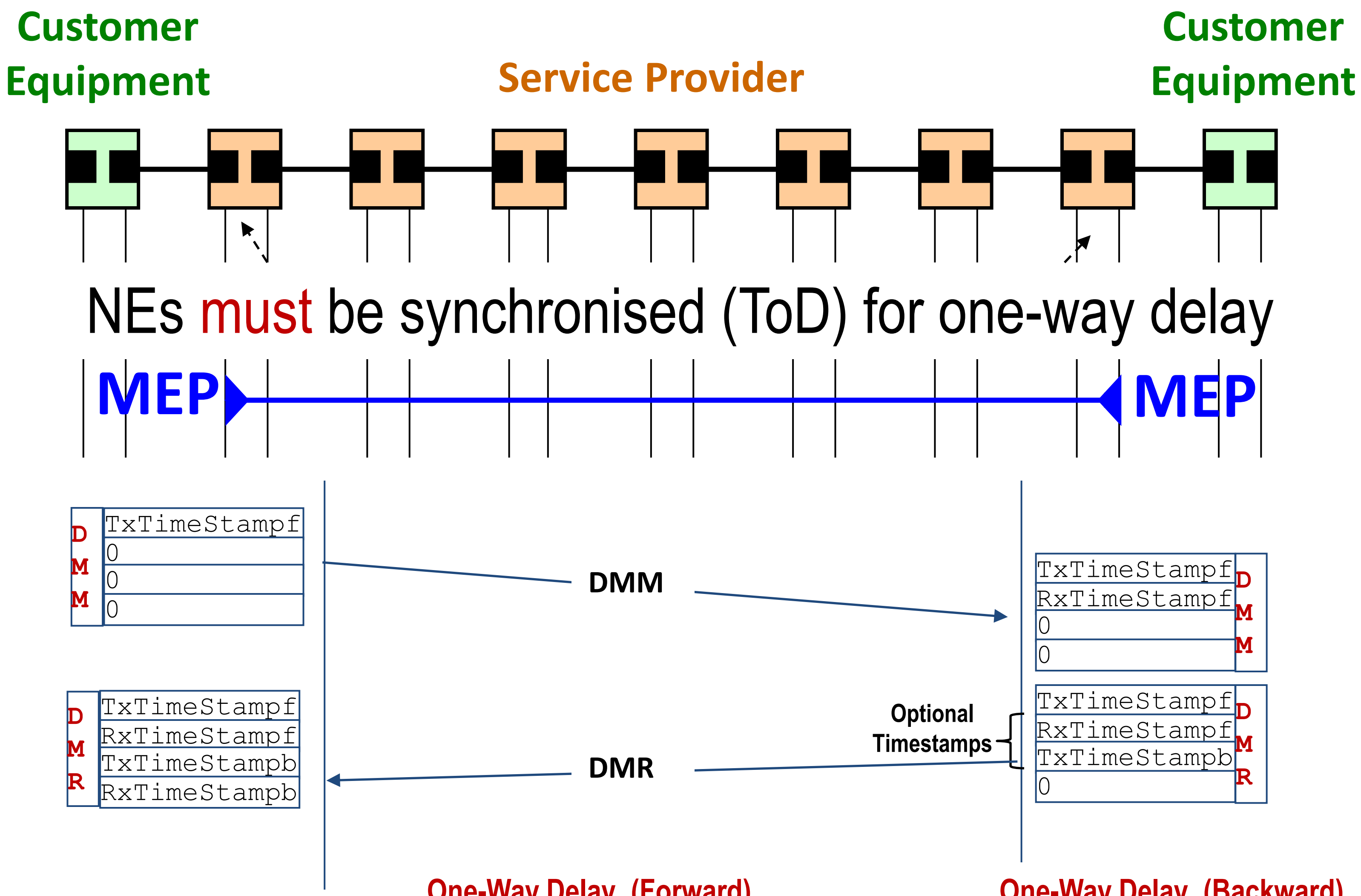
- ❶ Ex: Application requirement from 3GPP: ±3µs between BS (WCDMA/LTE TDD)
- ❷ Ex: Network objective : ≤ ±1.5µs from common reference



WCDMA … Wideband Code Division Multiple Access; LTE … Long Term Evolution; TDD … Time Division Duplex

Why do we need to synchronise Time?

Time Applications – Y.1731 Performance Management



Two-Way Delay	One-Way Delay (Forward)	One-Way Delay (Backward)
(RxTimeStampb – TxTimeStampf) – (TxTimeStampb – RxTimeStampf)	RxTimeStampf – TxTimeStampf	RxTimeStampb – TxTimeStampb

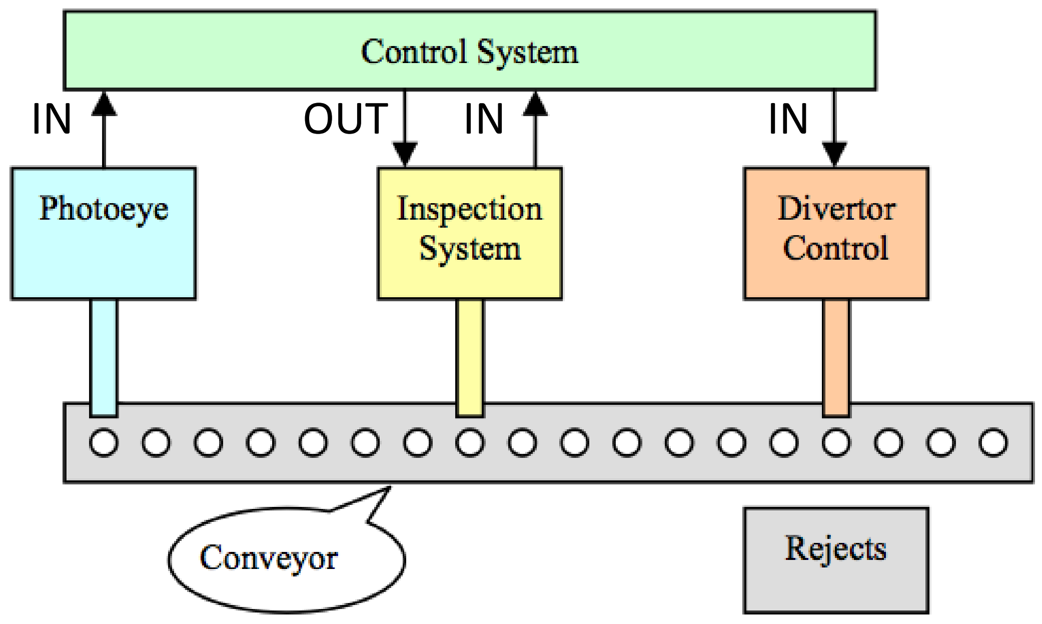
ToD … Time of Day; NE … Network Element; MEP … Maintenance End Point

Why do we need to synchronise Time?

Time Applications – Industrial Ethernet

- Traditional Scan-based control operation subject to large input-output jitter
  - Part resolution = 122 msec jitter
  - Maximum speed = 1/122 = ~8 parts/sec
  - Maximum ppm = 8*60 = **480 parts/sec**

- Time-based control greatly reduces jitter and maximises conveyor belt output
  - Part resolution = 12.4 msec jitter
  - Maximum speed = 1/12.4 = ~80 parts/sec
  - Maximum ppm = 80*60 = **4,800 parts/sec**



Jitter or Delay Source	Delay	Jitter (Scan-based)	Jitter (Time-based)
Input	0.2 msec	10 msec	0
Input Network	1 msec	1 msec	0
Controller	10 msec	100 msec	0
Output Network	1 msec	1 msec	0
Output	0.2 msec	10 msec	0
Total	12.4 msec	122 msec	0

Source: Rockwell, IEEE

ppm … Parts per Minutes

Why you don't want to rely on GNSS only

Global Navigation Satellite System (GNSS) – aka GPS, COMPASS, Galileo, …

- Reasons for using GPS
  - – nearly available everywhere
  - – A GPS disciplined oscillator can provide time accurate to within 100ns

- Reasons for not using GPS
  - – see statement on www.pnt.gov, from Nov 3rd ,2010

    GPS should not be used as the unique reference in any critical civilian system
  - – Reliability (very weak satellite signal)
  - – Attacks (jamming and spoofing)
  - – Cost of installation
  - – Local Distribution (Splitters, Amplifiers, …)

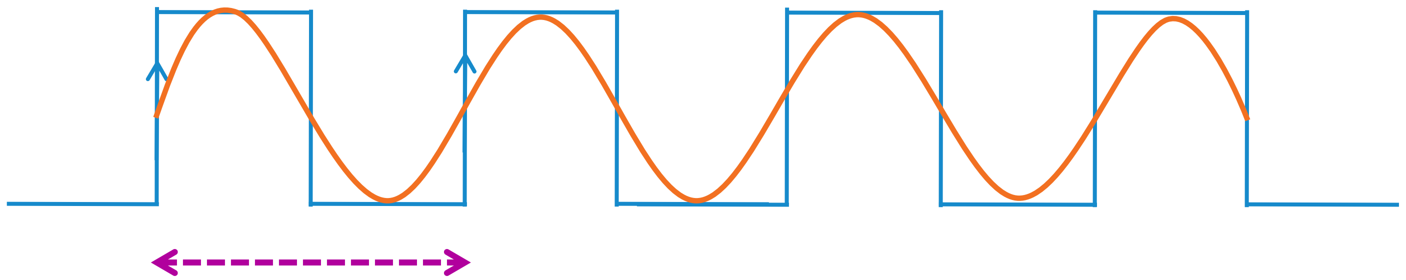
GPS Jammer Handheld

GPS …Global Positioning System; GNSS … Global Navigation Satellite System

Frequency Synchronisation Overview

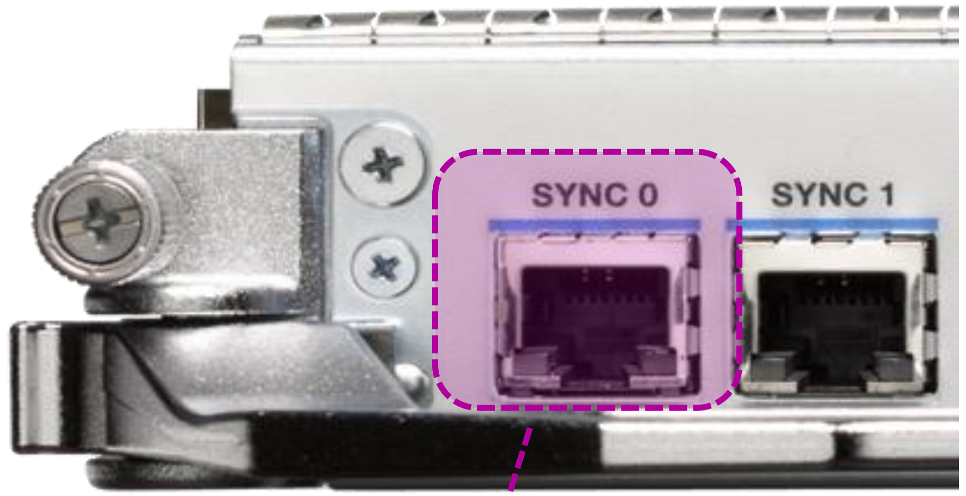
Frequency – Closer Look

Frequency = 1 / T [Hz]



Interval T [sec]

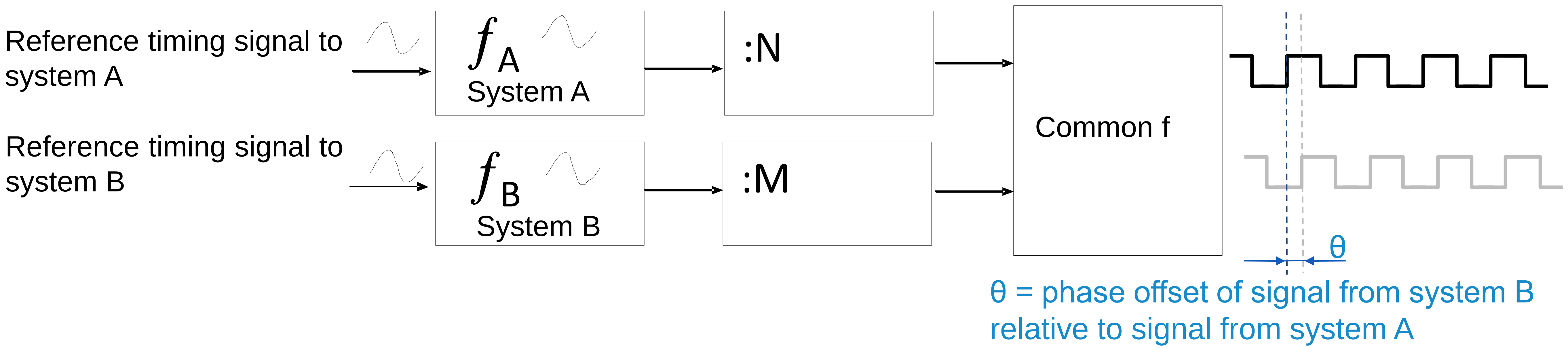
- Typical External Timing Interfaces
  - 2,048 kHz
  - E1/T1 Framed
  - 10 MHz
- Sine or Square Waves possible



Typically BITS
Pins 1&2 = External Timing Input
Pins 4&5 = External Timing Output

Line Interfaces
1GE, 10GE, …

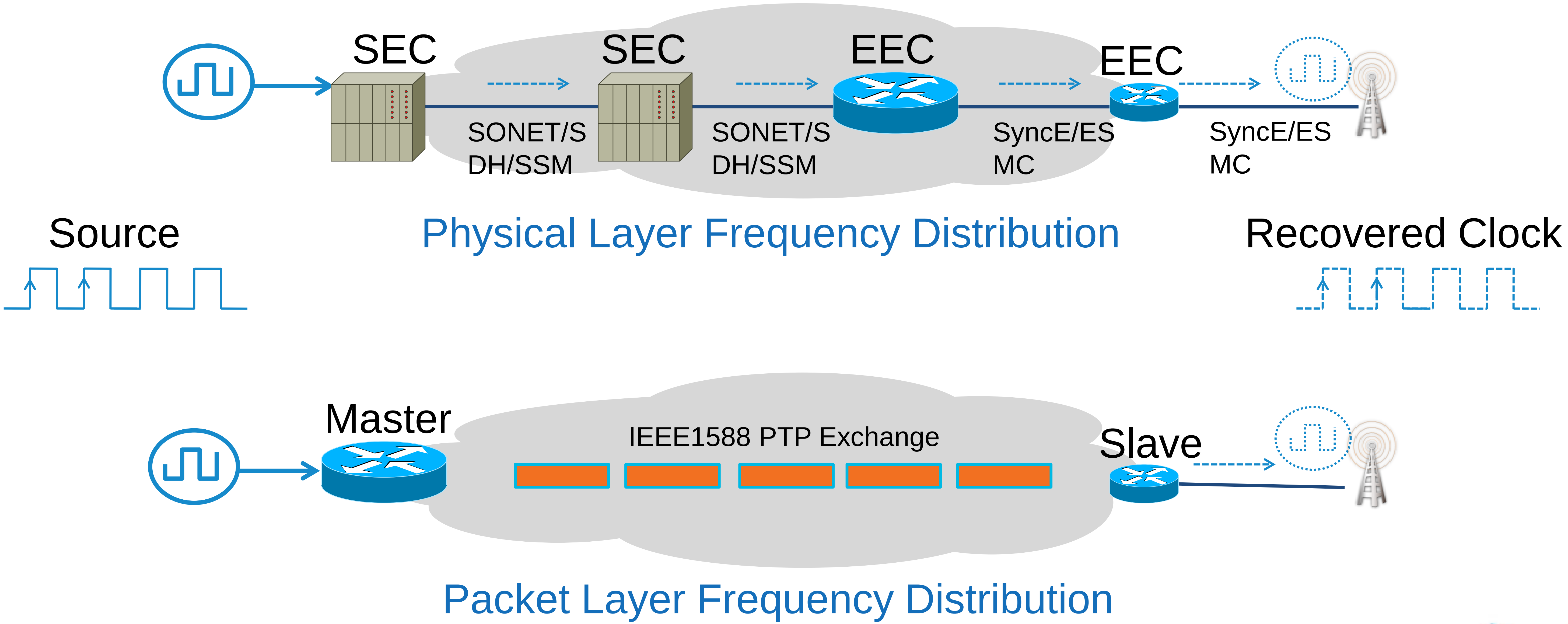
Frequency Synchronisation



- Two clocks are frequency synchronised if the frequency of the two clocks have common denominator.
- Two clocks are called plesiochronous if the difference in their common denominator is bounded.
- The difference in position of rising edges of the clocks is called phase offset.
- Two common frequencies which have constant phase offset are phase-locked and implicitly frequency synchronised.

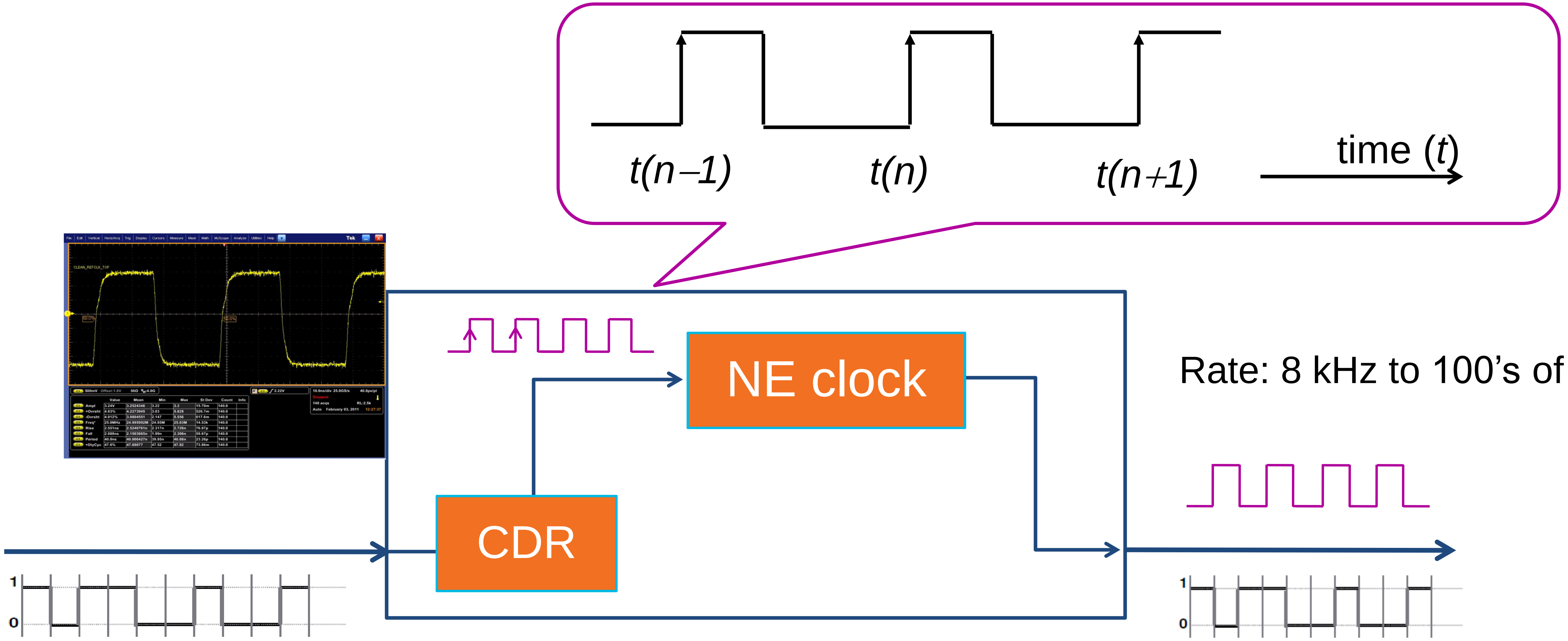
Frequency Distribution

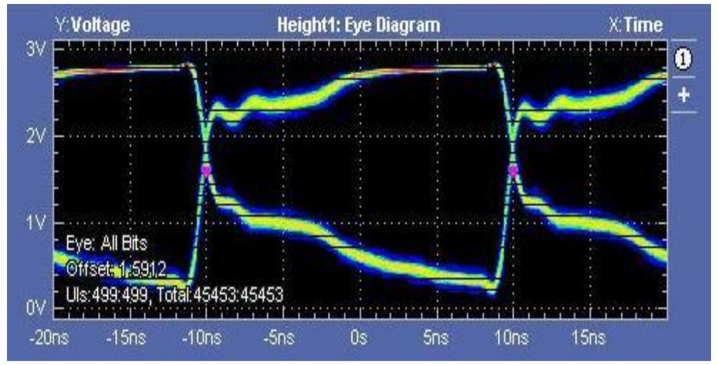
Physical or Packet Layer distributing Frequency



SEC … Synchronous Equipment Clock; EEC … Ethernet Equipment Clock; SSM … Synchronous Status Messaging
ESMC … Ethernet Synchronous Messaging Channel; PTP … Precision Time Protocol

Physical Layer Frequency Distribution





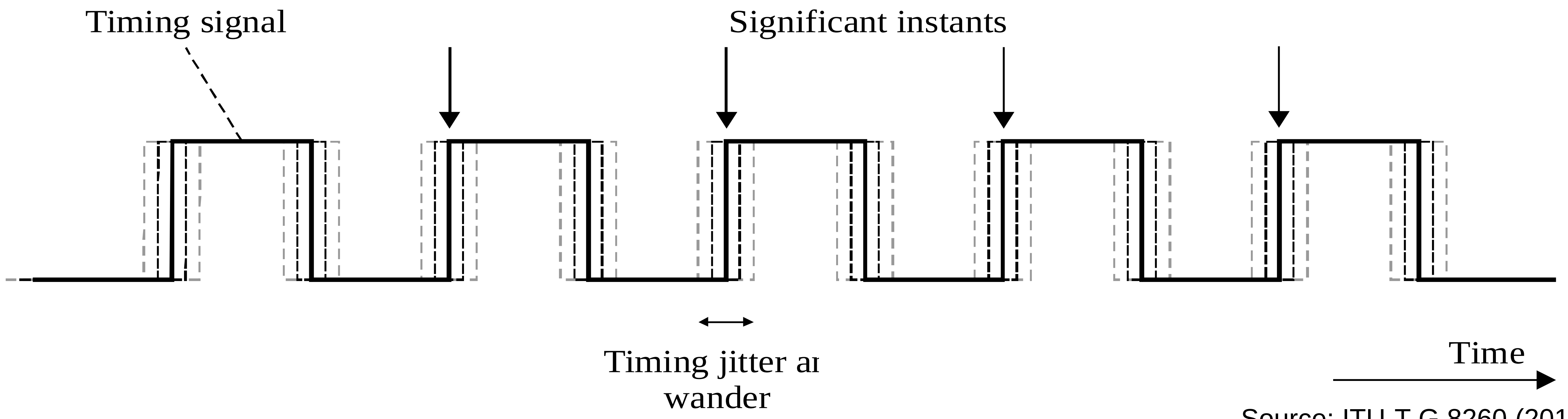
- The timing signal is typically implemented as a periodic digital signal.

CDR … Clock Data Recovery

Significant Instants – Physical Distribution

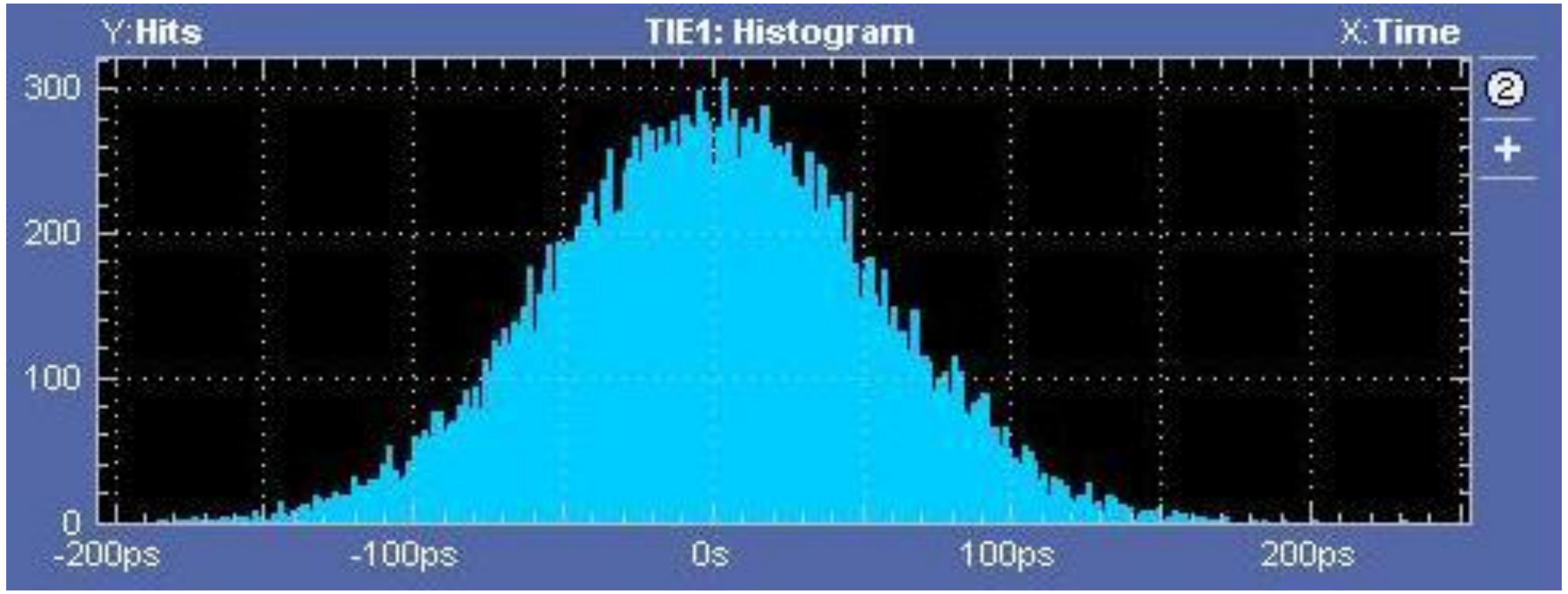
Timing Signal and Noise

Rate: 8 kHz to 100's of MHz



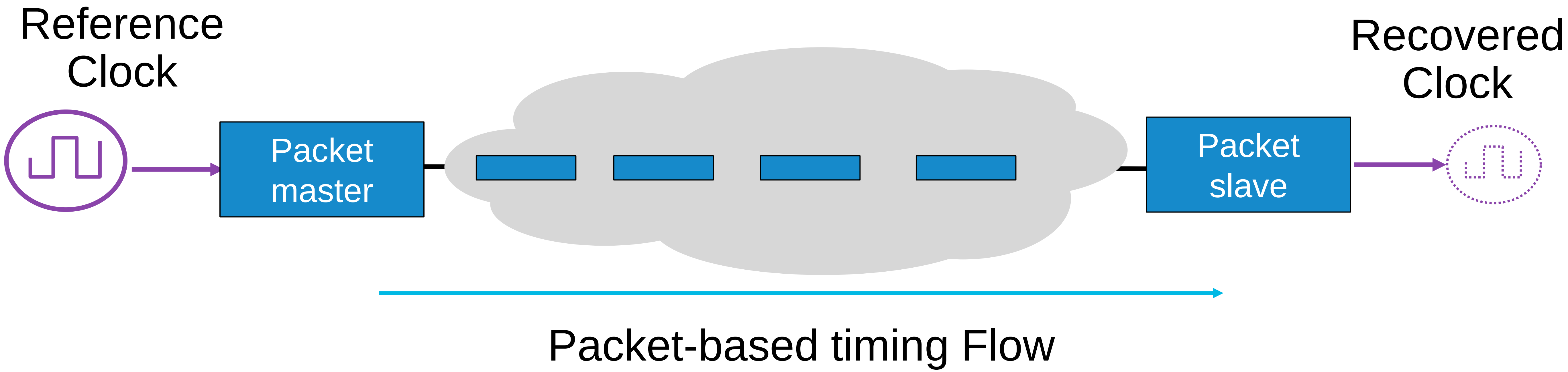
Source: ITU-T G.8260 (201007)

Example : 25 MHz signal



Packet-based Frequency Distribution

Adaptive Clock Recovery (ACR)or IEEE1588 Precision Time Protocol (PTP)

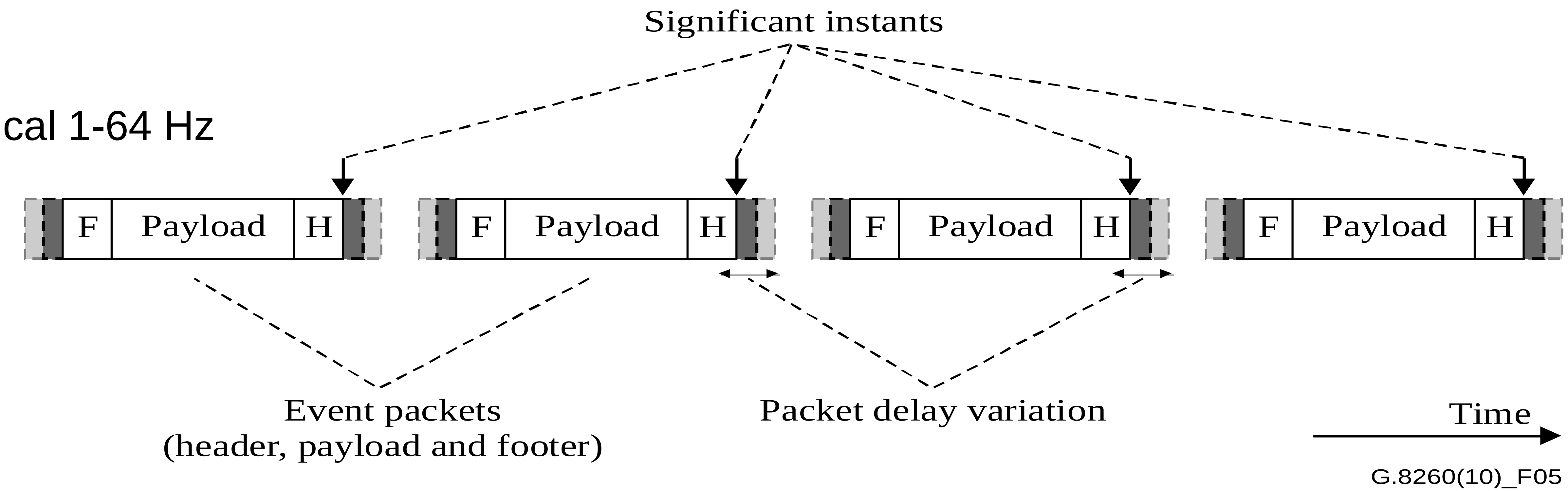


- Three key steps:
  – **Generation**: from physical signal to packet
  – **Transfer**: timing events (frame or packet flow) transmission over packet network
  – **Recovery**: from packet-based signal to physical signal

Significant Instants Packet-based Distribution

Source: ITU-T G.8260 (201007)

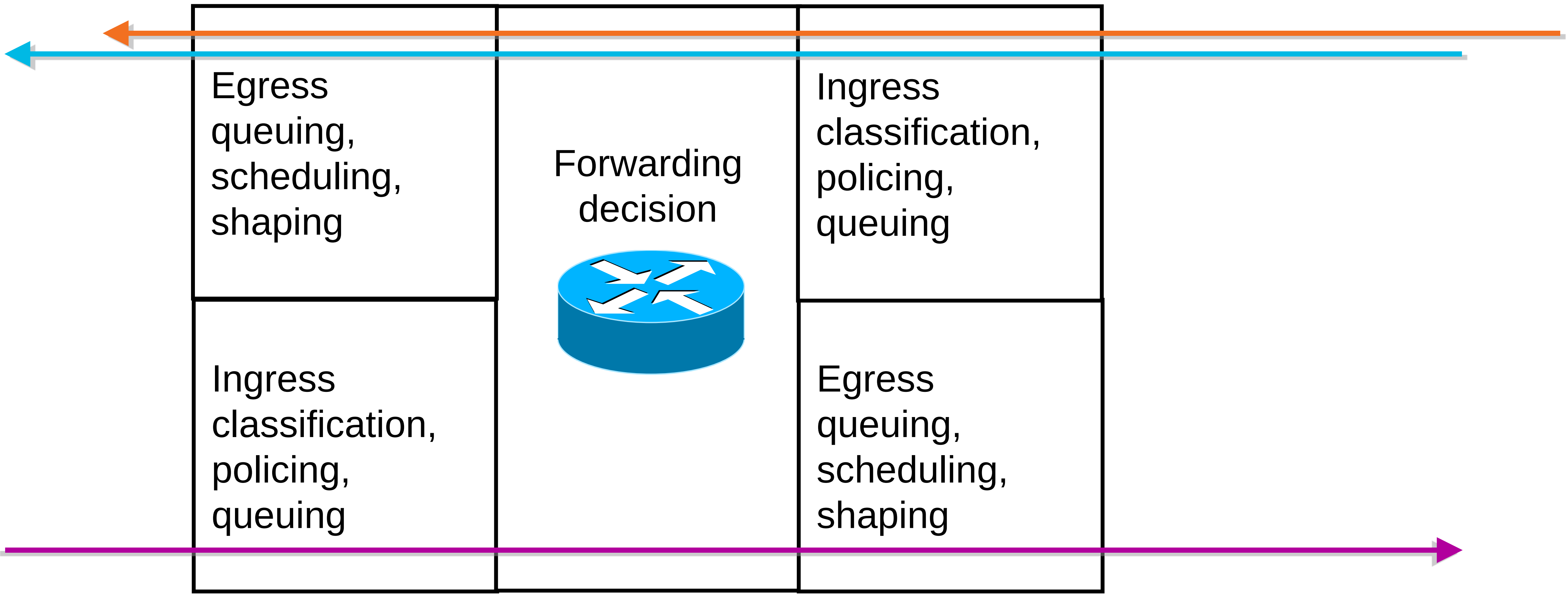
Rate : typical 1-64 Hz



- Timing signal could either be
  - periodic (e.g., CES) or
  - aperiodic (e.g., NTP, PTP) with
- Additional information (e.g., **timestamps**) defining the ideal position in time of the significant instant relative to a master time scale.

CES … Circuit Emulation Service; NTP … Network Time Protocol

Typical Router/Switch Architecture



Packet Delay Variation (PDV): prop_time_pkt#n != prop_time_pkt#m

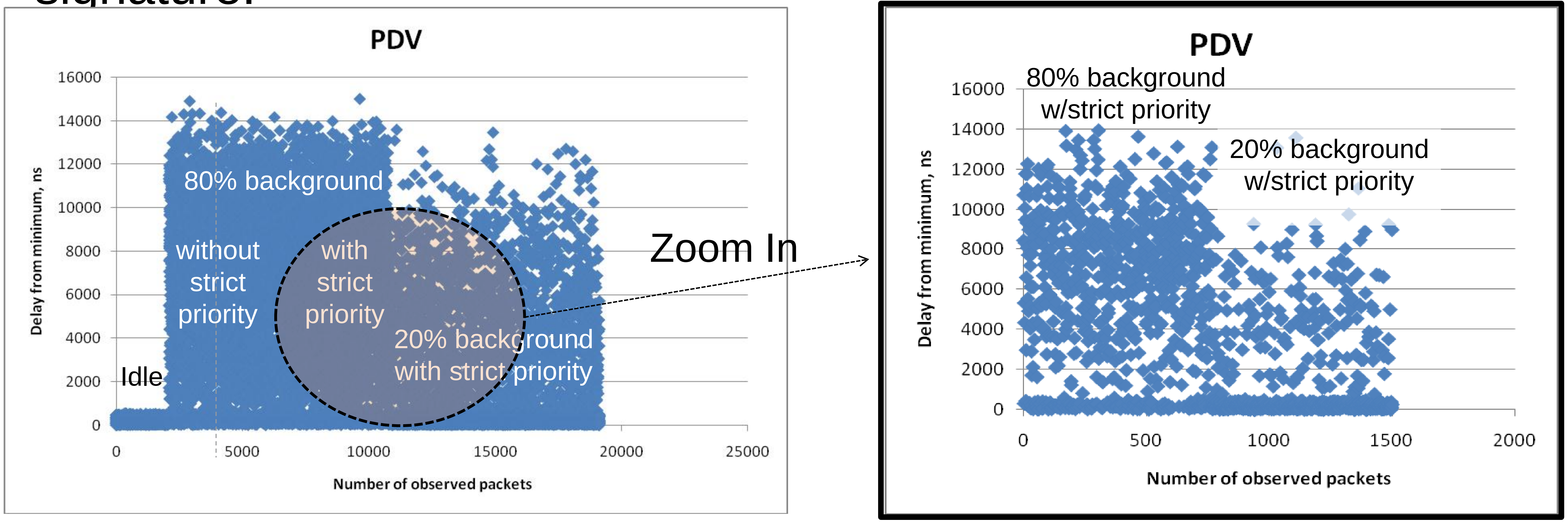
Asymmetry: prop_time != prop_time

PDV … Packet Delay Variation

Equipment Packet Delay Variation

Traffic Load & QoS

- Each equipment will have its own PDV (and asymmetry) signature.

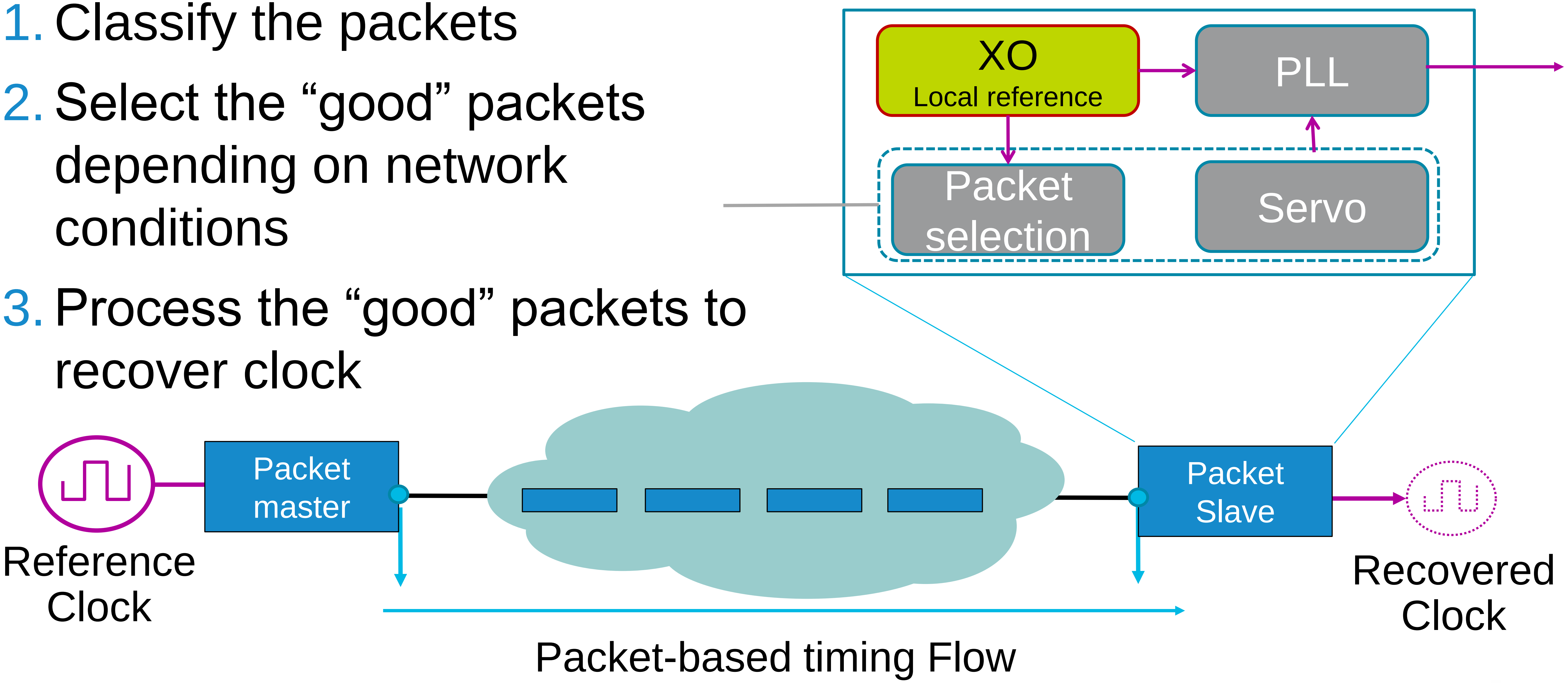


X-axis: number of observed packets
Y-axis: packet delay from the minimum delay observed during measurement

Packet-based Timing Slave Recovery

Three major Tasks

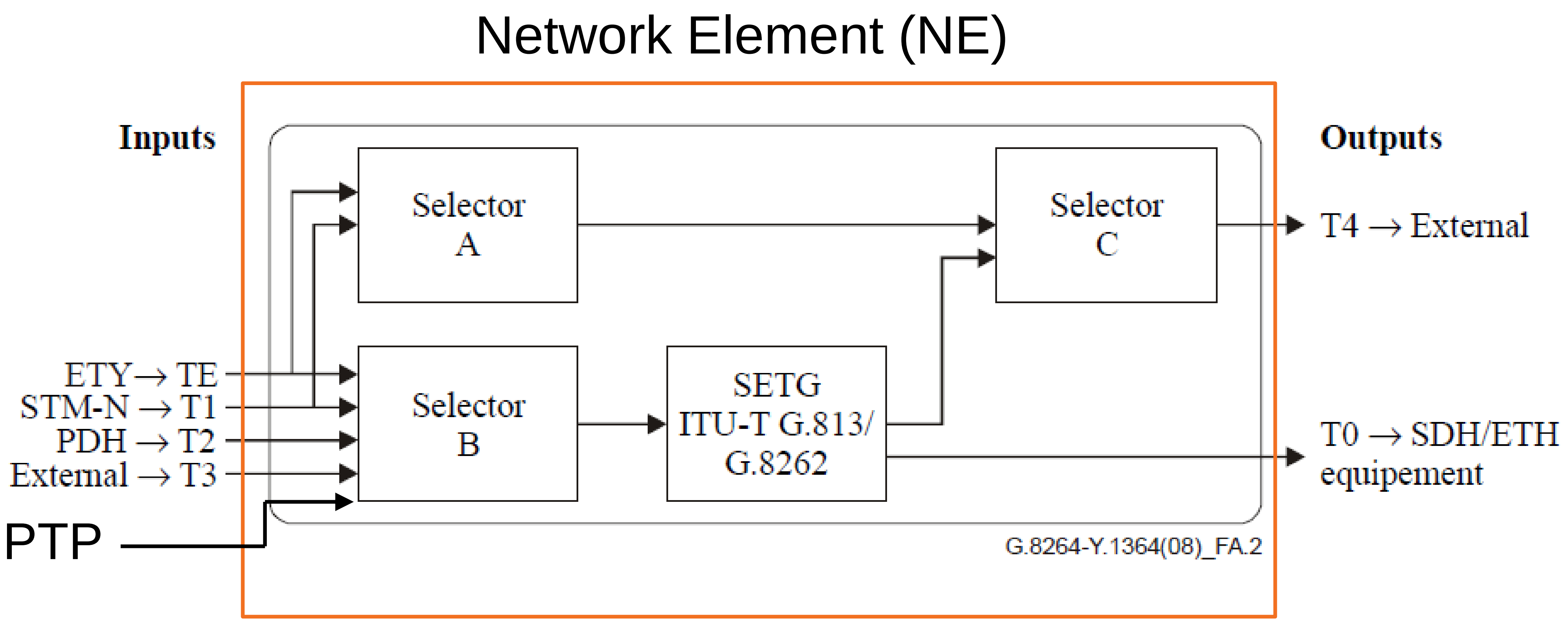
1. Classify the packets
2. Select the “good” packets depending on network conditions
3. Process the “good” packets to recover clock



XO … Oscillator; PLL … Phase Locked Loop

Clock Selection inside the Network Element

SETS - Synchronous Equipment Timing Source



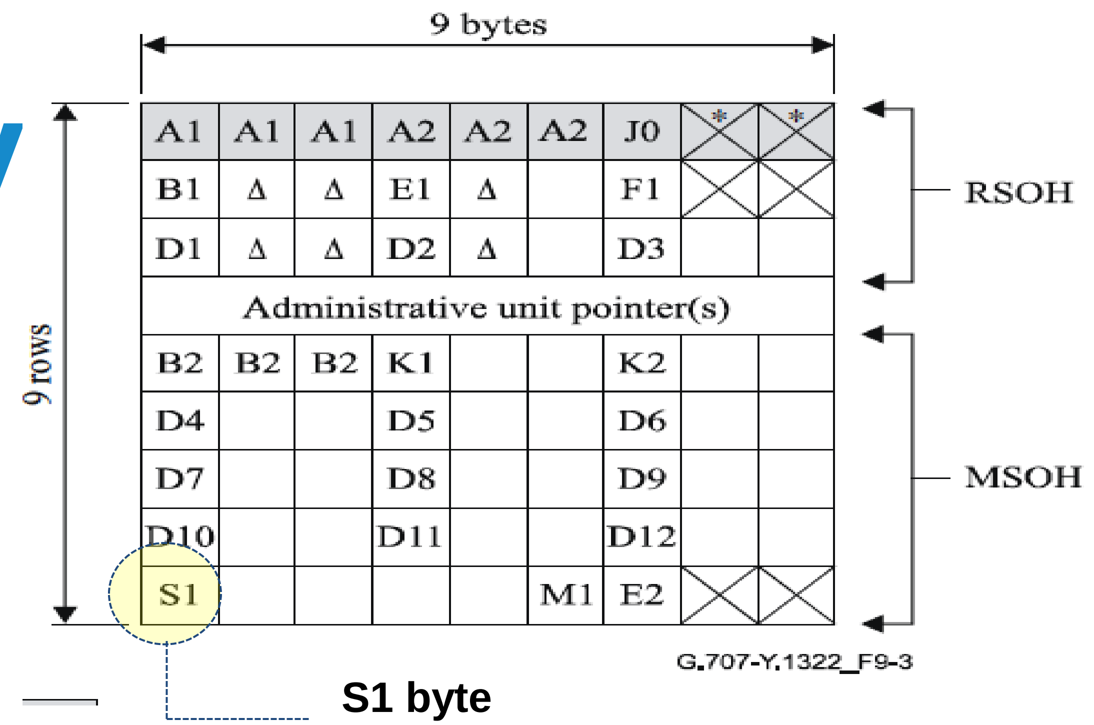
- SETG … Synchronous Equipment Timing Generator (PLL - Phase Locked Loop)
- Three Selector table to control
  - System Frequency
  - Output Interface Frequency

SETS … Synchronous Equipment Timing Source; SETG … Synchronous Equipment Timing Generator

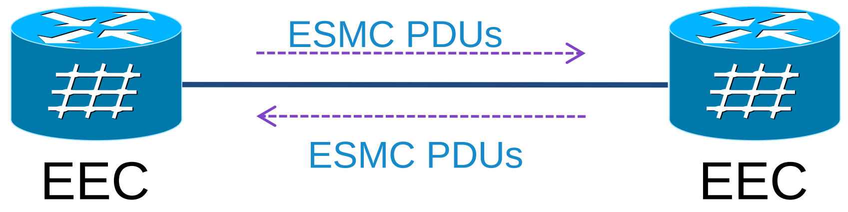
Quality Level & Traceability

Quality Level Comparison

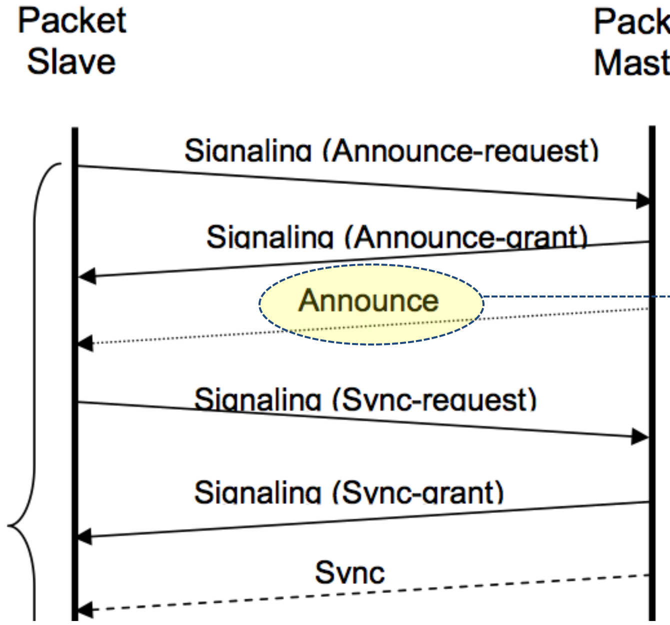
SSM QL	G.781		ESMC		PTP Clock Class
	Option I	Option II	Option I	Option II	
0001		QL-PRS			80
0000		QL-STU			82
0010	QL-PRC				84
0111		QL-ST2			86
0011					88
0100	QL-SSU-A	QL-TNC			90
0101					92
0110					94
1000	QL-SSU-B				96
1001					98
1101		QL-ST3E			100
1010		QL-ST3		QL-EEC2	102
1011	QL-SEC		QL-EEC1		104
1100		QL-SMC			106
1110		QL-PROV			108
1111	QL-DNU	QL-DUS			110



S1 byte
Bits 5-8 are used for SSM



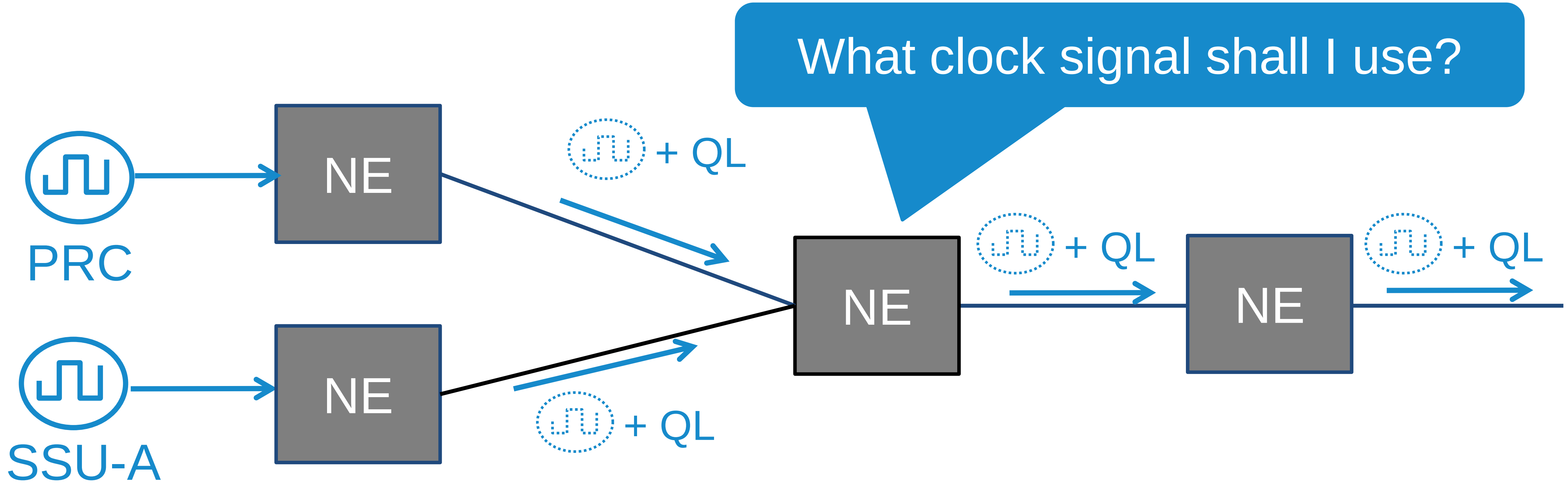
IEEE802.3 Slow Protocol
Informational and Event PDUs with TLVs



clockClass
PTP Attribute Value

Quality Level & Traceability

Determining the best available Clock



QL-Disabled Mode

1. External commands
2. Signal Failure
3. Local Priority (per interface)

QL-Enabled Mode

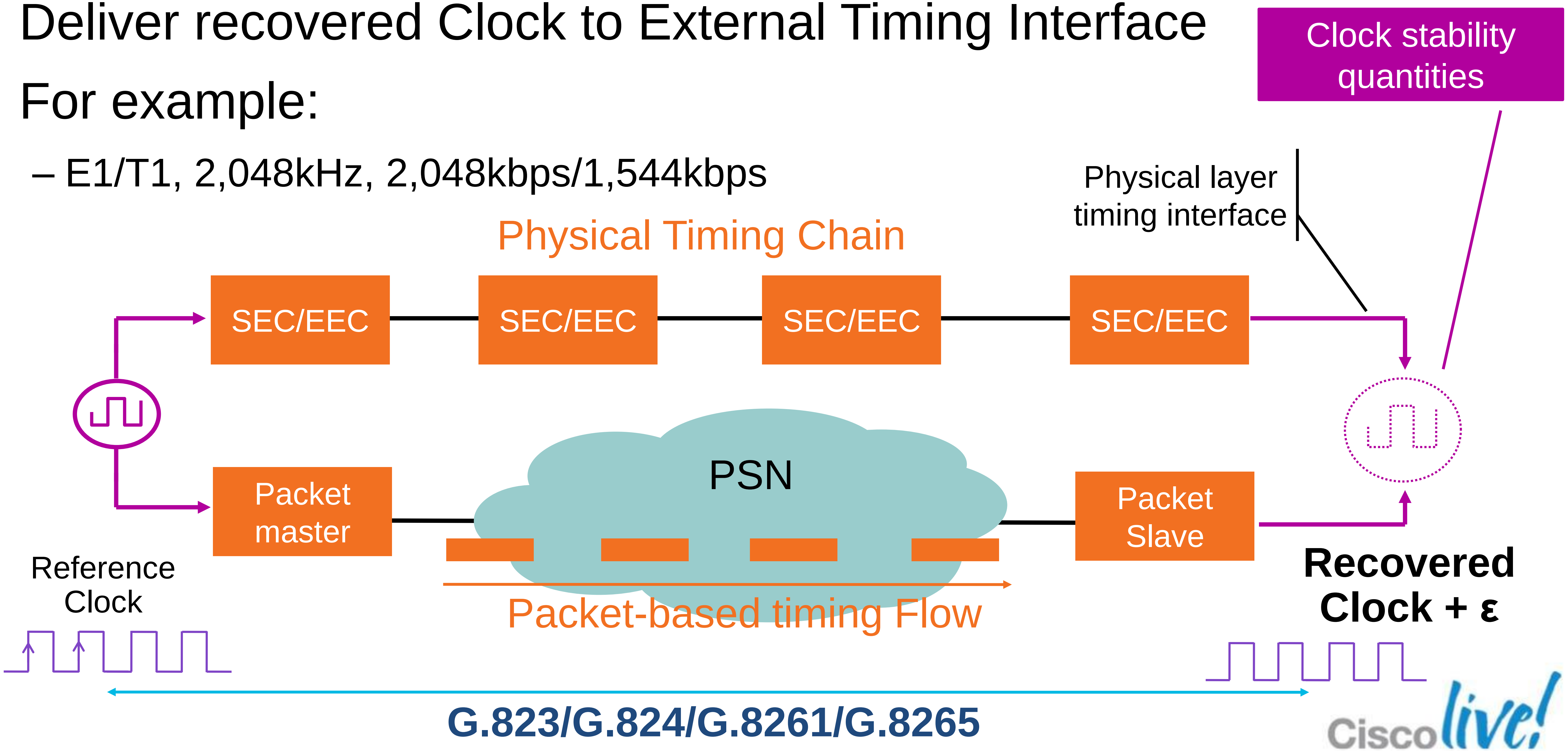
1. External commands
2. **Quality level**
3. Signal Failure
4. Local Priority (per interface)

References: ITU-T G.871 / G.8261 and Telcordia GR-253-CORE
QL … Quality Level

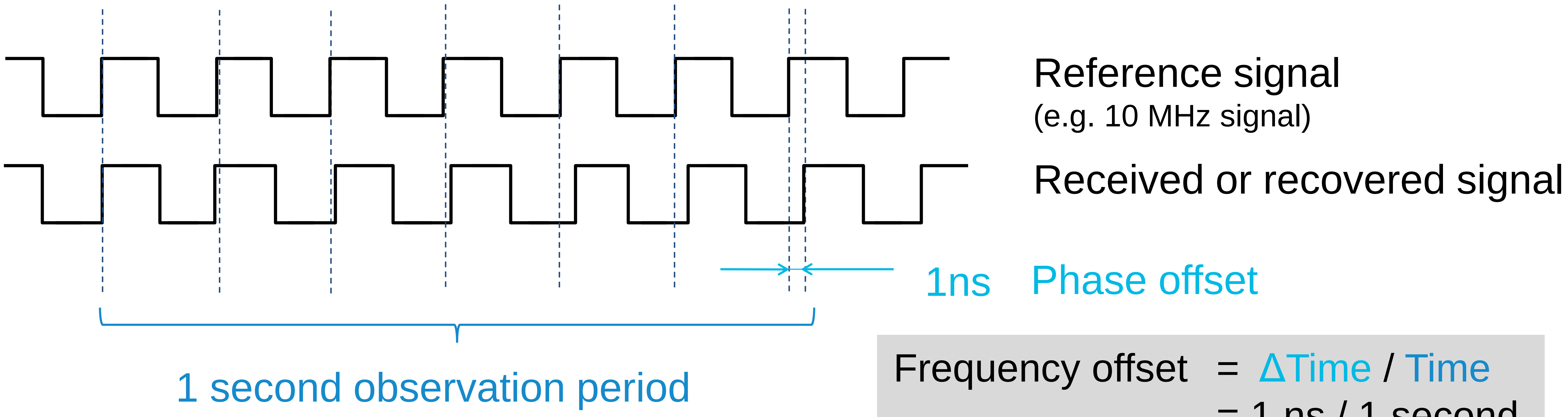
Physical Signal Re-Generation

Frequency Distribution

- Deliver recovered Clock to External Timing Interface
- For example:
  - – E1/T1, 2,048kHz, 2,048kbps/1,544kbps



Frequency Accuracy



Frequency offset = ΔTime / Time
= 1 ns / 1 second
= 1×10^{-9} = 1 ppb

Frequency accuracy is a long-term measurement based on the average phase accumulation over time.

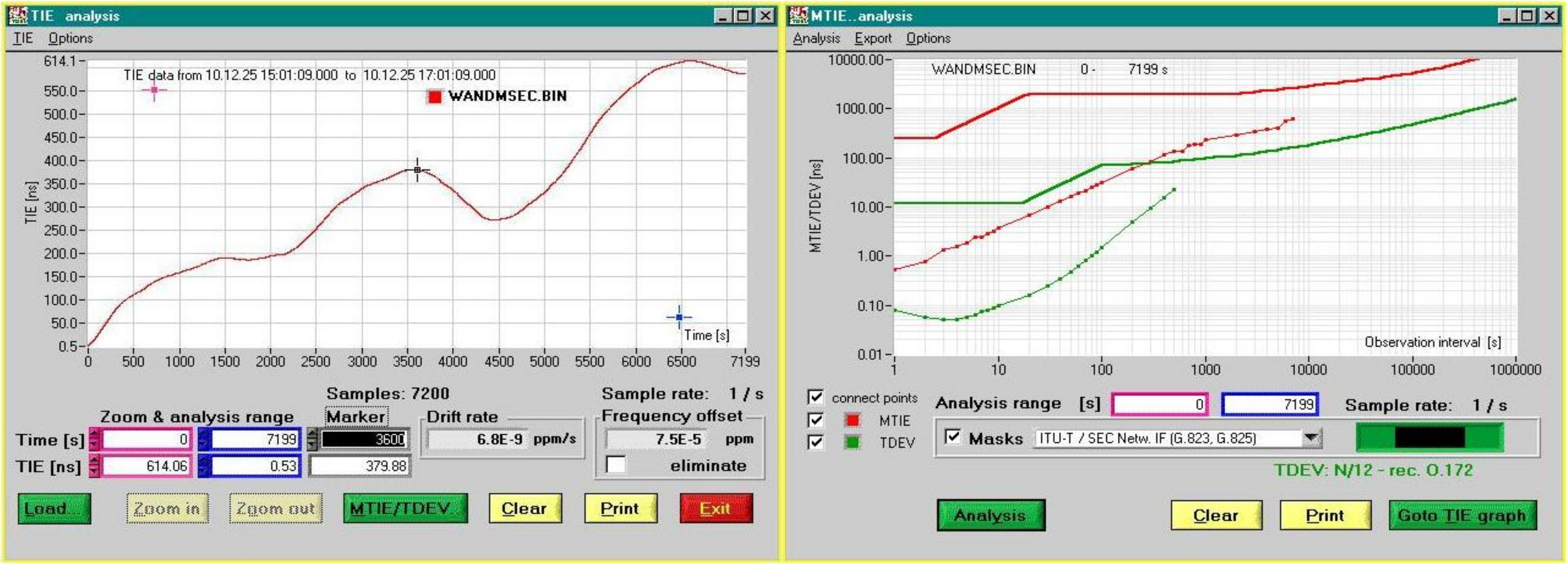
Other examples:

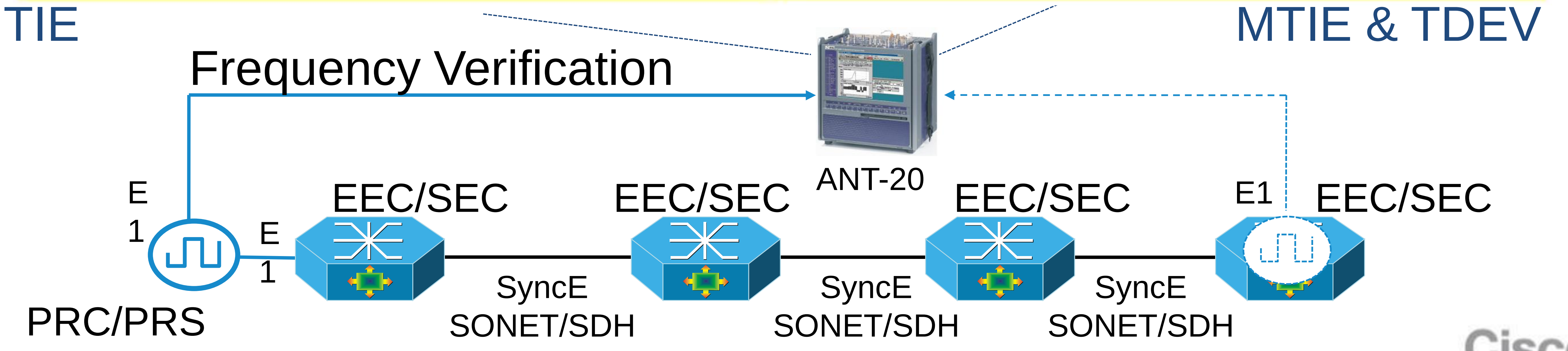
- 50 µs / 1 second = 50×10^{-8} = 0.05 ppb = 50 ppm
- 1 µs / 100 seconds = 1×10^{-5} = 10 ppb

Validating Frequency Distribution

Typical Test Setup

Masks per G.823/G.824/G.8261





Frequency Distribution Metric (Wander)

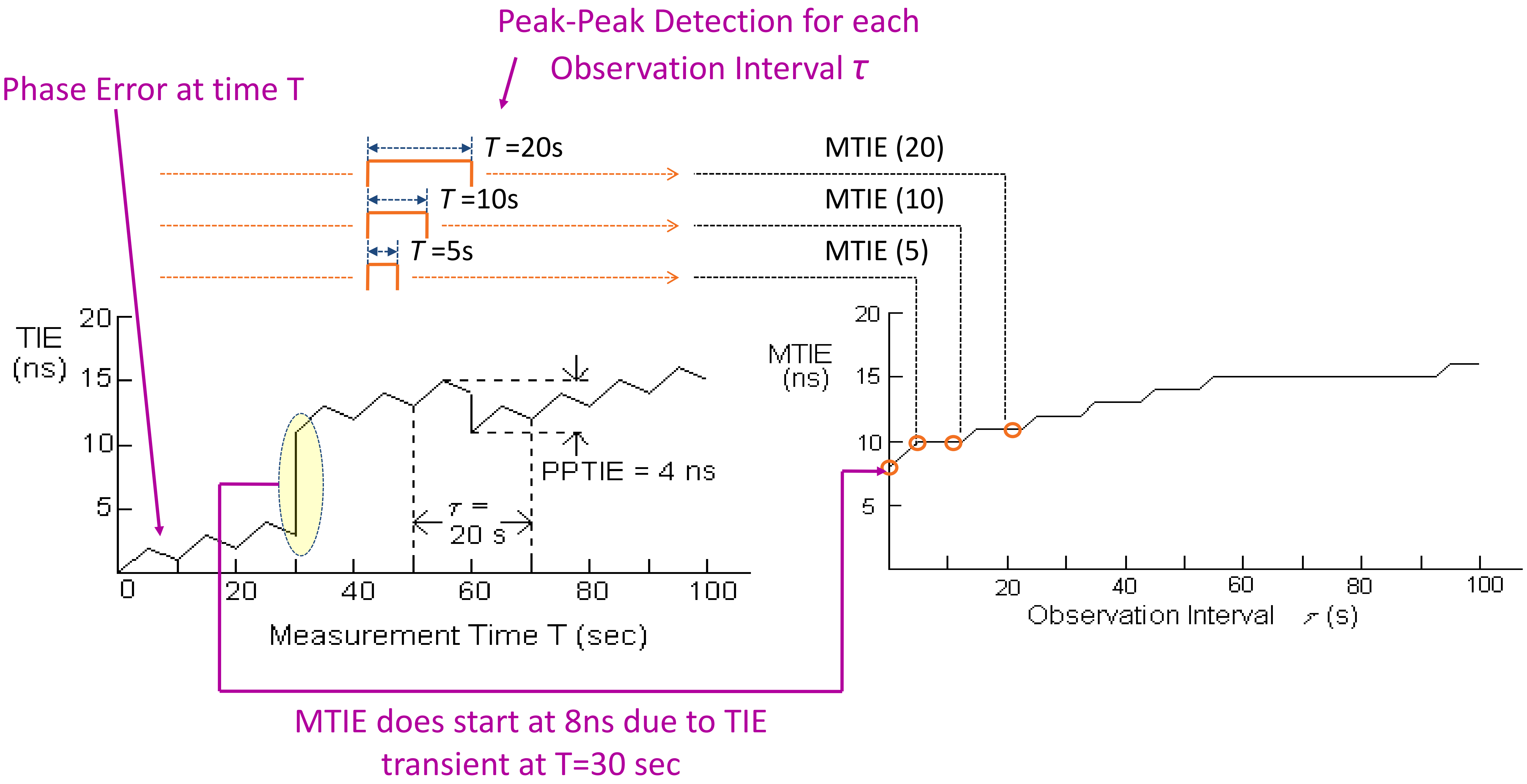
Calculations based on Phase Error Measurements

- TIE (Time Interval Error)
  - Phase Difference measured in ns
    … indicates Accuracy at certain Moment
- MTIE (Maximum TIE)
  - Largest Peak-to-Peak TIE for a particular Observation Interval
    … indicates Accuracy & Stability
- TDEV (Time Deviation)
  - Route Mean Square of Bandpass filtered TIE (statistical representation of TIE variance)
    … indicates Systematic Effects

Source: http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm / Reference: ITU-T G.810

TIE and MTIE

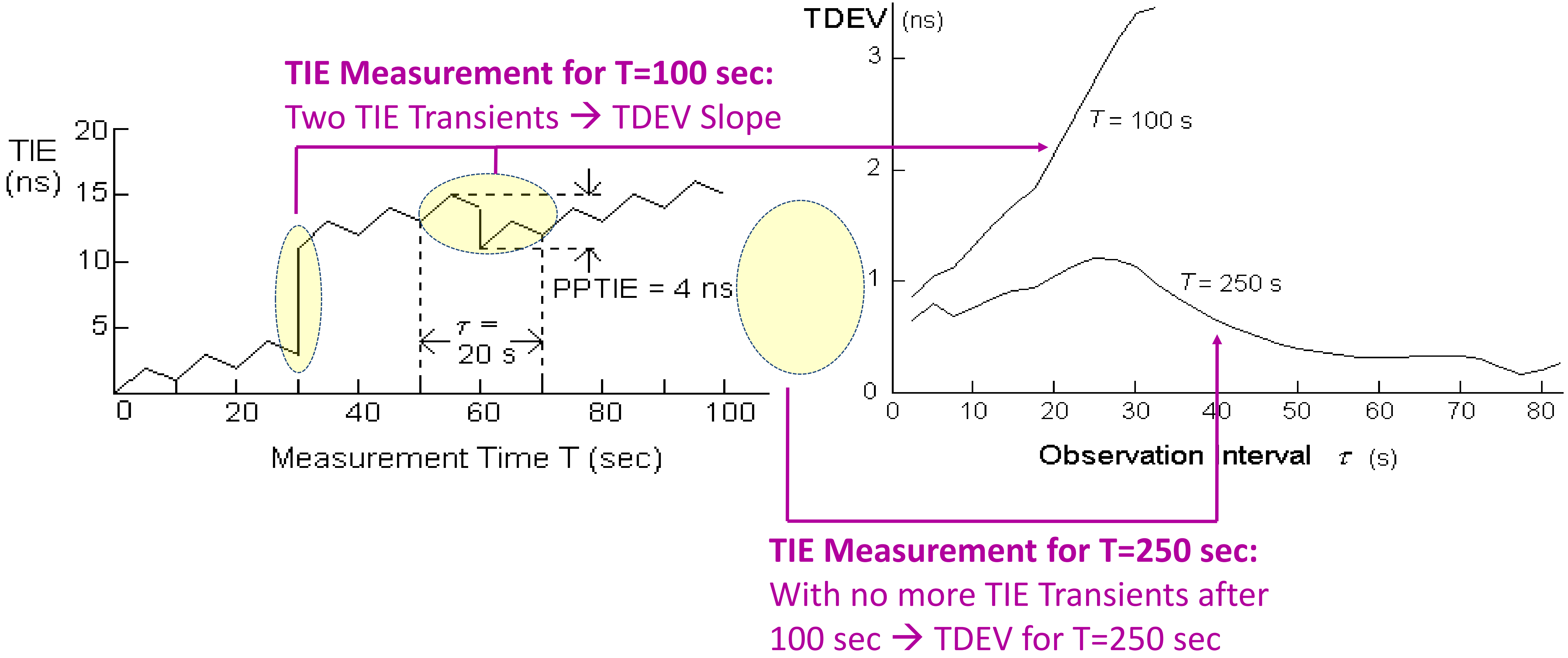
Phase Error and “Peak to Peak” Detection



Source: [http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm /](http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm)

TIE and TDEV

Statistical Measure & Spectral Content of Wander



- For TDEV of τ =X sec you normally need TIE measurement for around 3*X sec

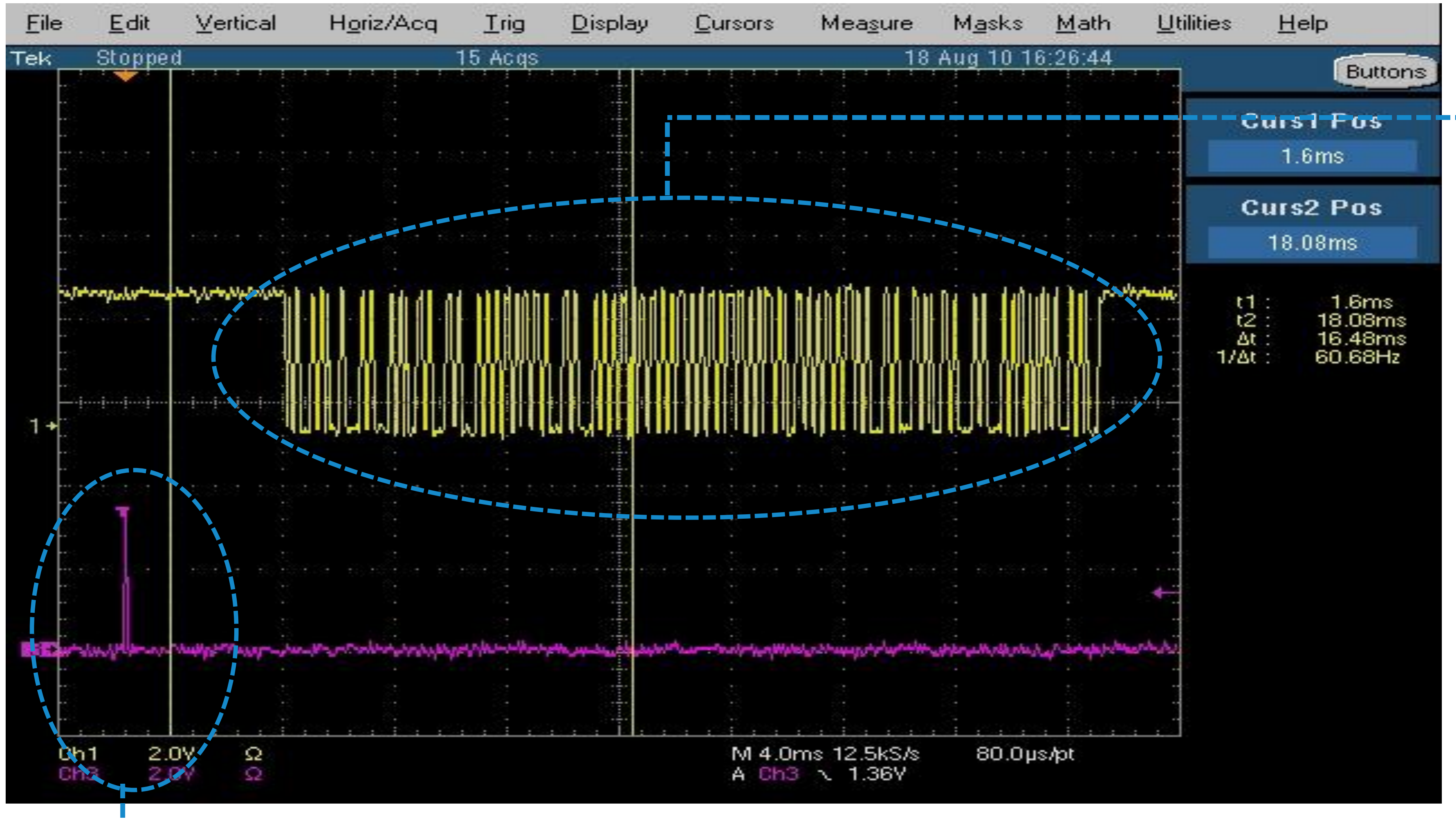
Source: http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm

Time Synchronisation Overview

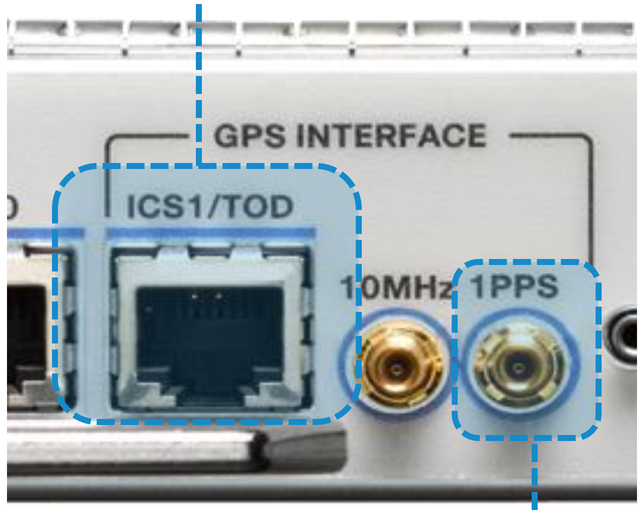
Time – A closer Look

Time = Phase + Time of Day

*13:38:54.805 UTC Mon Apr 2 2012



Time of Day (TOD) Information
(serial interface on the RJ45 connector)

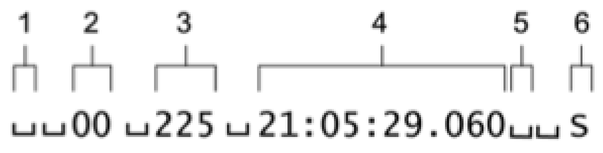


1PPS Pulse → **Phase**
(analog signal on the DIN connector)

Time of Day Formats

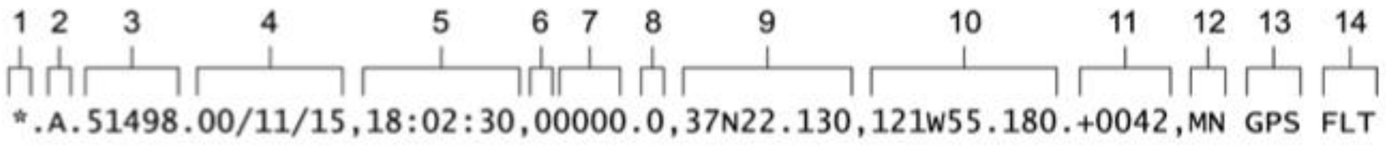
- Many different Formats available
  - NTP
  - Cisco
  - ISO8601
  - NMEA
  - UBX
  - …

NTP Format



1. Alarm field: blank space = receiver has satellite availability;? = no satellite availability
2. Year (2000 in this example)
3. Day of year (the 225th day of the year in this example)
4. Hours:minutes:seconds.milliseconds
5. Leap second: blank space = no leap second; L = upcoming leap second
6. Daylight savings time indicator: S = standard time; D = daylight savings time

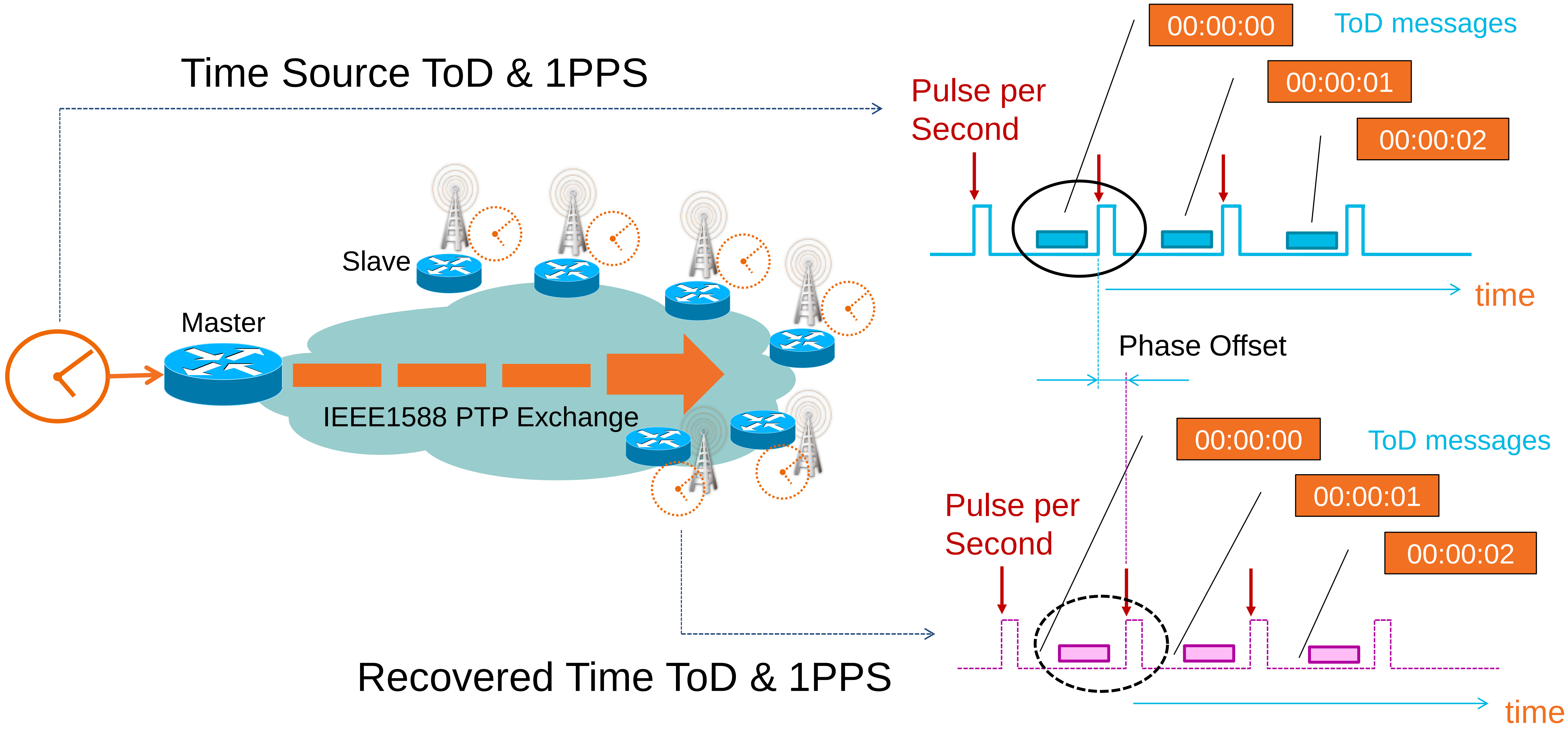
Cisco Format



1. Satellite availability: * = valid, ! = not valid
2. Revision
3. Modified Julian date (number of days past midnight, Nov. 17, 1858
4. Year/month/day
5. Hours:minutes:seconds
6. Indicator of time zone offset (+, -, or 0)
7. Time zone offset
8. Leap second indicator
9. Latitude
10. Longitude
11. Altitude above mean sea level in meters
12. Alarm severity: EV = event, MN = minor, MJ = major, CL = critical
13. Alarm source
14. Alarm cause: holdover, BT3 warm-up, or hardware fault

Time Distribution

Packet Layer distributing Phase & Time of Day



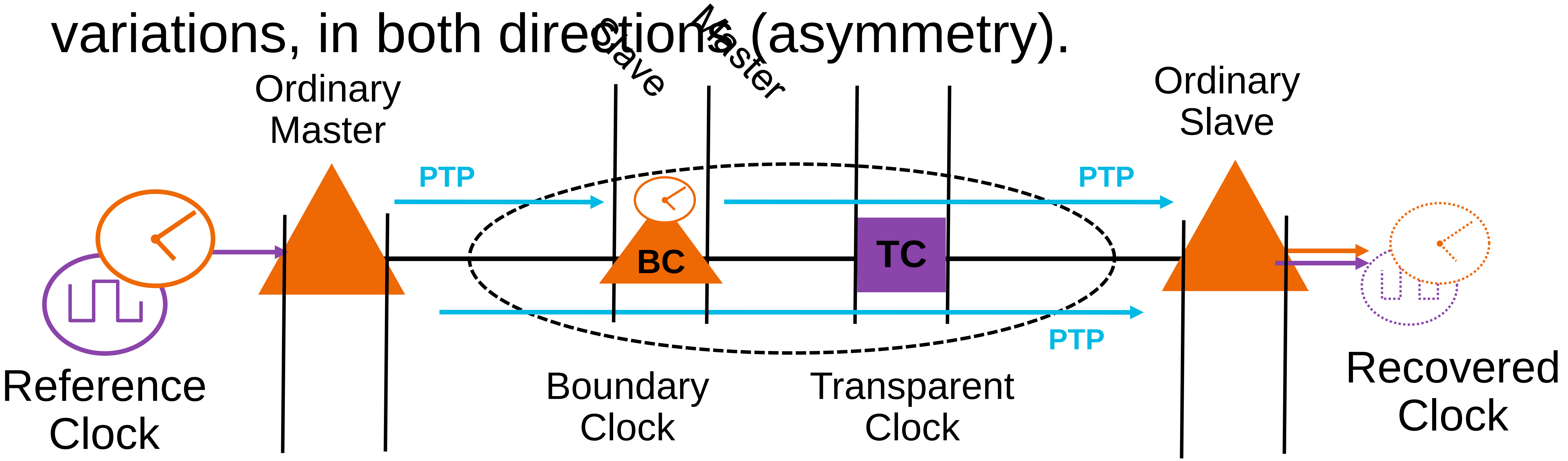
See also ITU-T G.8260

Introduction to IEEE1588-2008

- Standard for a Precision Clock Synchronisation Protocol for Networked Measurement and Control Systems
- Precision Time Protocol (PTP) is, like NTP, a Two Way Time Transfer protocol (TWTT).
- PTP has been designed to obtain accuracies down to the nanoseconds … if every elements are correctly implemented.
- IEEE 1588 has been originally specified for plug-and-play time synchronisation solution.
- Original interest for telecom because dedicated standard and "precision" marketing.

IEEE Std 1588-2008 Clocks

- OC has unique PTP port, either slave or master (defines clock state).
- As network intermediate nodes, BC and TC aim correcting delay variations, in both directions (asymmetry).

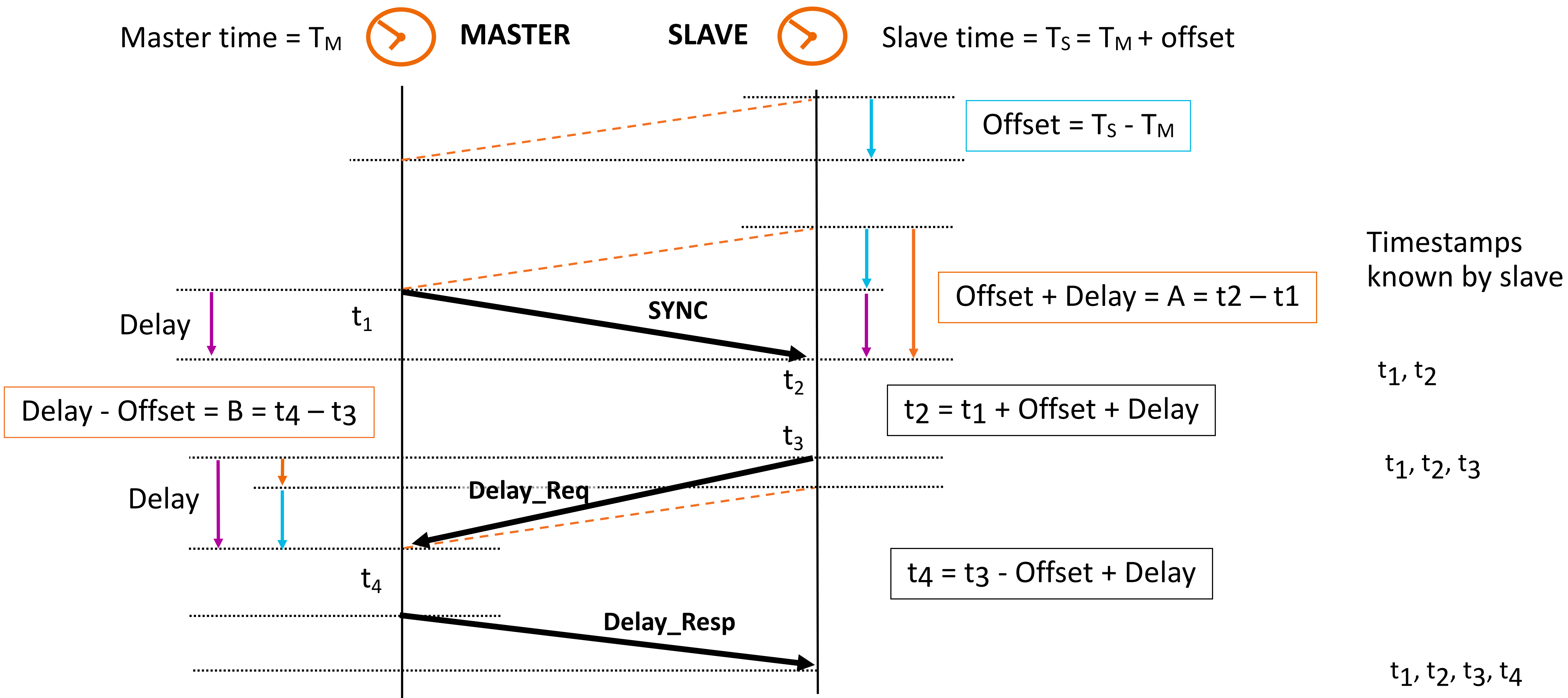


PTP v2 Messages and Transmission

- A set of event messages consisting of:
  - Sync
  - Delay_Req
  - Pdelay_Req
  - Pdelay_Resp
- A set of general messages consisting of:
  - Follow_Up
  - Delay_Resp
  - Pdelay_Resp_Follow_Up
  - Announce
  - Signalling
  - Management
- Mappings: L2 Ethernet, IPv4, IPv6 (others possible)
- Transmission modes: either unicast or multicast (can be mixed)
- Variable rate and timeout values
- Various TLVs and flexible TLV extensions

TWTT Protocol Basics

Basic PTP Message Exchange



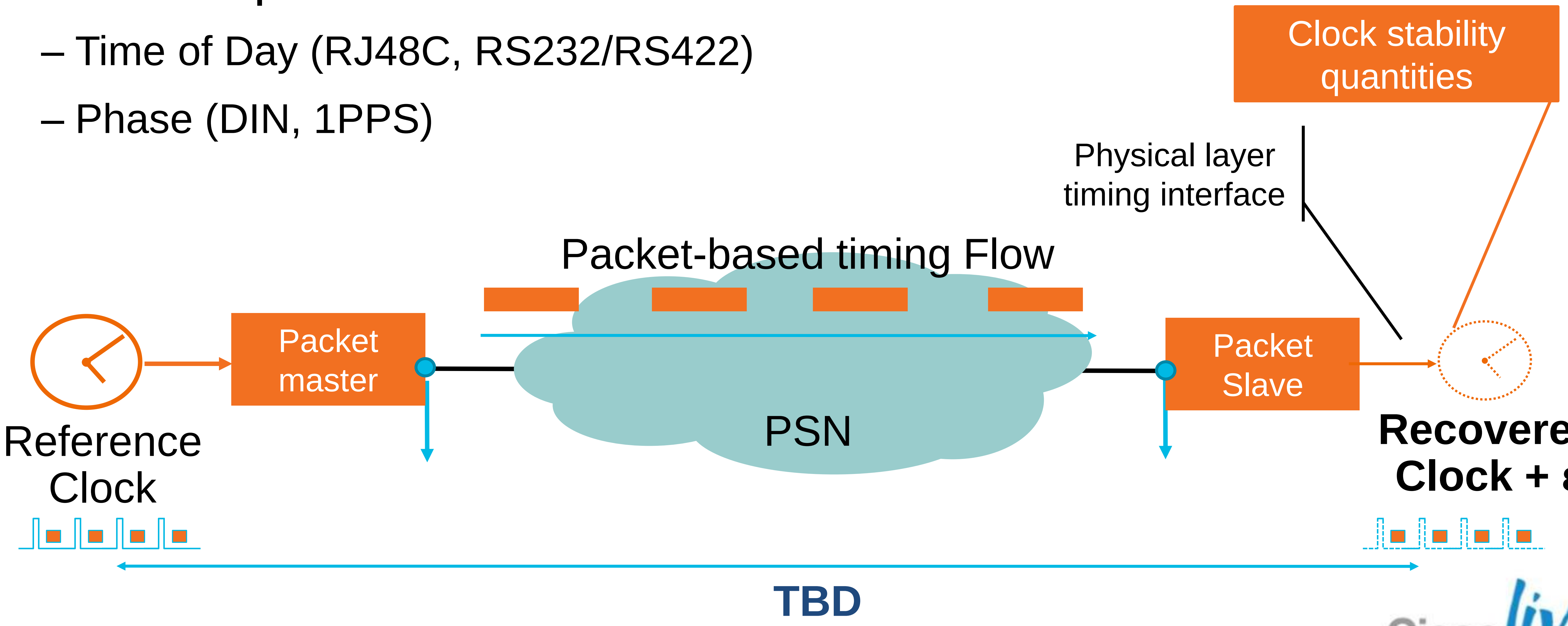
Delay = $((t_2 - t_1)+(t_4 - t_3))/2$

Offset = $((t_2 - t_1)-(t_4 - t_3))/2$

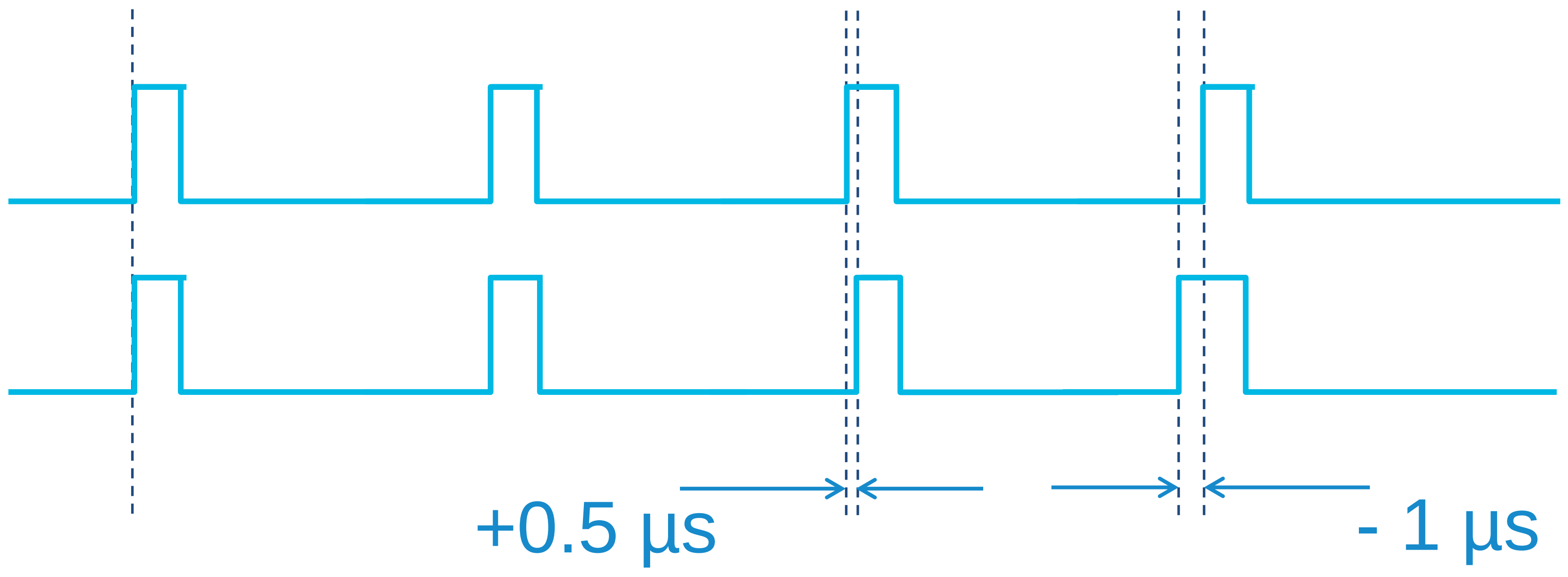
Physical Signal Re-Generation

Time Distribution

- Deliver recovered Clock to External Timing Interface
- For example:
  - Time of Day (RJ48C, RS232/RS422)
  - Phase (DIN, 1PPS)



Phase Synchronisation Accuracy



Reference A
(E.g., 1 PPS)

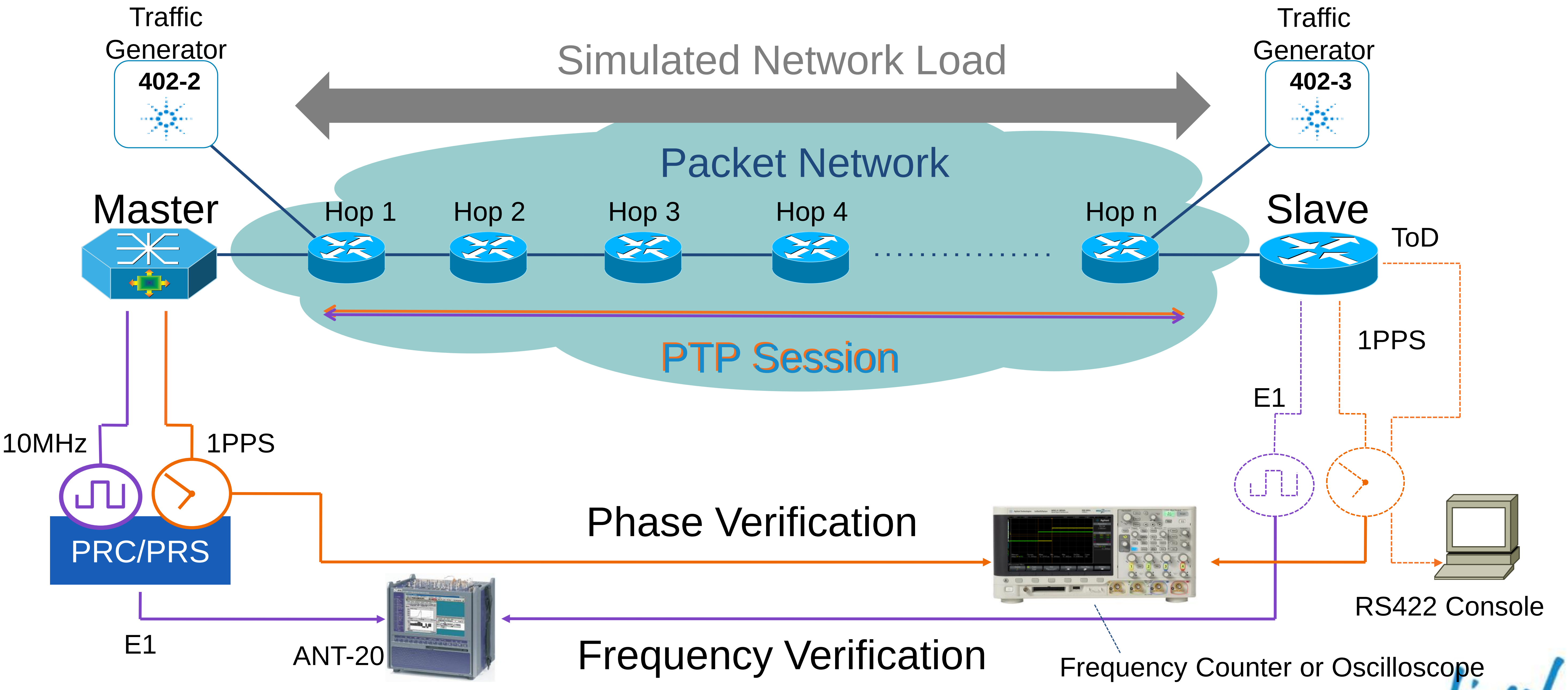
Reference B
(or recovered from A)

Phase error (accuracy)

Phase accuracy requirement defines the maximum deviation relative to the reference

Typical Test Setup

Evaluating Impact of Hop Count & Network Load



Synchronisation Support in Cisco Products

Cisco Industrial Ethernet Products

	IE3000 Rockwell Stratix 8000	IE3010	IE2000 Rockwell Stratix 5700
Hardware	Base Unit Only 1)	Hardware is IEEE1588-2008 ready Software Support to be added in the future	Cisco Models ending with "-E" Rockwell Models with "P"
SW Version	12.2(46)SE1		IOS 15.0(1)SY
Supported Clock Modes	Boundary Clock E2E Transparent Clock "Forward Mode" 2)		Boundary Clock E2E Transparent Clock "Forward Mode" 2)
PTP Transport Options	IPv4 Multicast		Layer 2 3) IPv4 Multicast

1) Configure "passthrough" to enable PTP on Expansion Modules
2) PTP Packets are not processed by the Switch, treated as normal IP Packets

E2E … End 2 End
P2P … Peer 2 Peer

Cisco Smart Grid Products

IEEE C37.238
Power Profile
supported

	CGS2520
Hardware	Both Copper only and SFP Model
SW Version	12.2(58)EY
Supported Clock Modes	Boundary Clock E2E Transparent Clock P2P Transparent Clock “Forward Mode” 1)
PTP Transport Options	Layer 2 IPv4 Multicast

1) PTP Packets are not processed by the Switch, treated as normal IP Packets

High Frequency Trading

Support for
1. PONG
2. ERSPAN type3

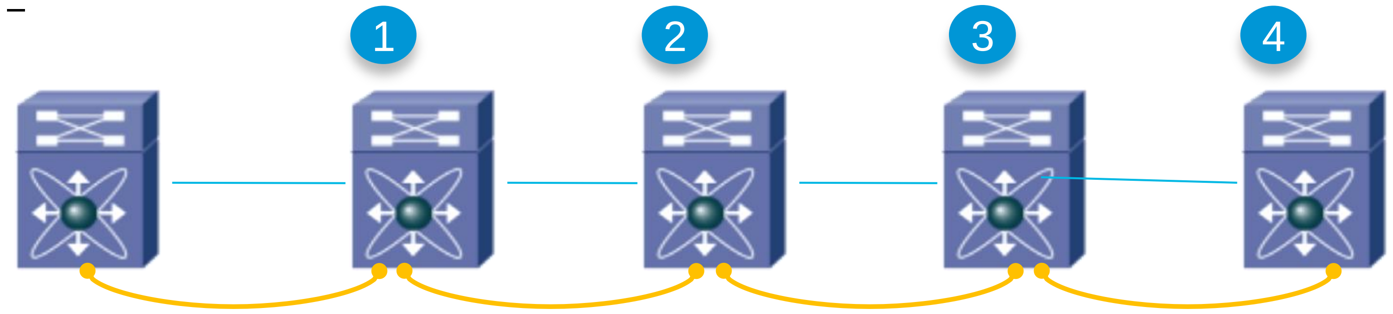
	Nexus 3000	Nexus 5500	Nexus 7000
Hardware	All Models	All Models	F1-Series Modules
SW Version	NX-OS 5.0(3)U2(2)	NX-OS 5.2(1)N1(1)	NX-OS 5.2
Supported Clock Modes	Boundary Clock	Boundary Clock	Boundary Clock
PTP Transport Options	IPv4 Multicast	IPv4 Multicast	IPv4 Multicast

PONG

Determining Network Latency from CLI

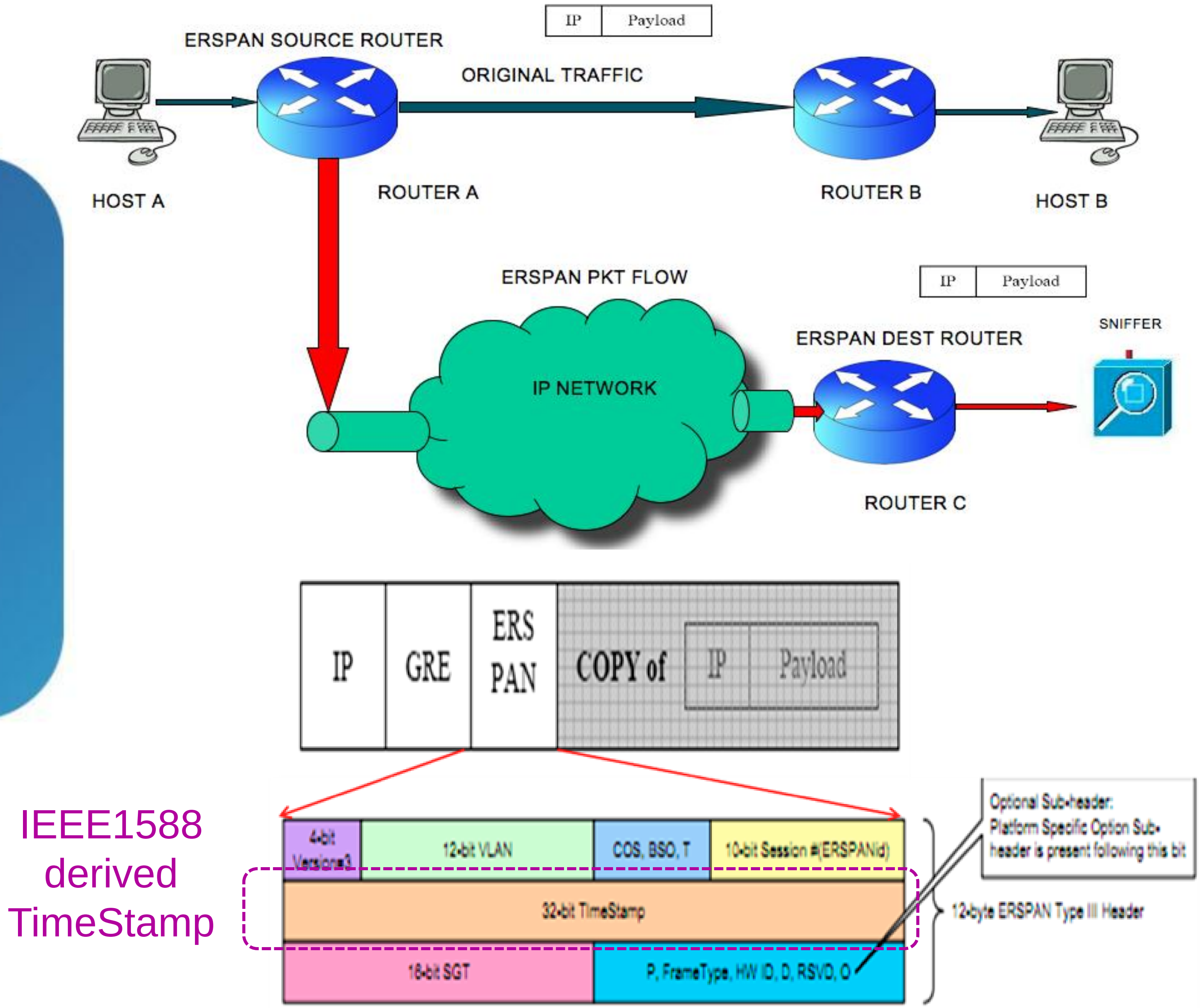
CLI

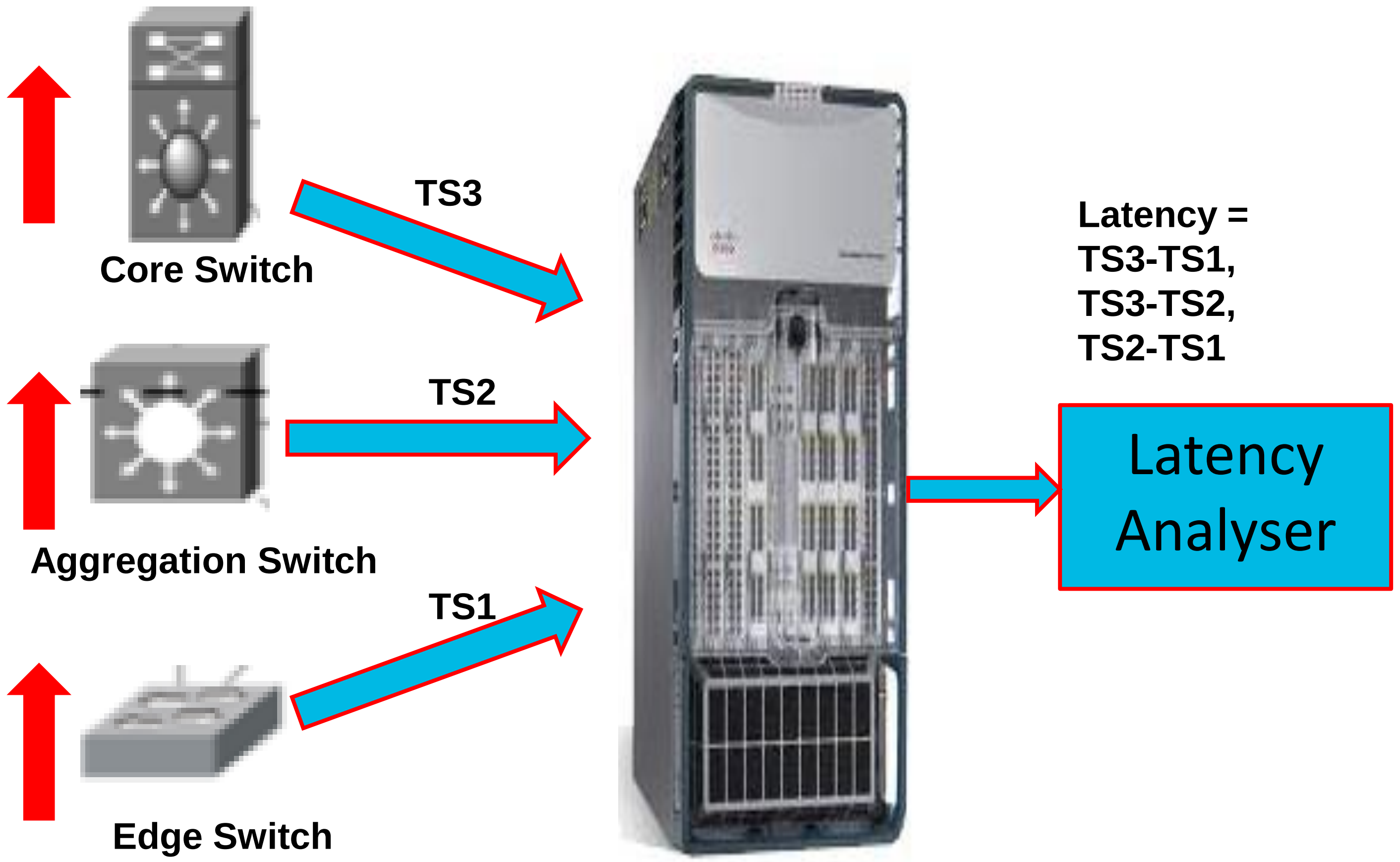
```
switch(config)# pong source 001b.54c2.9a41 destination 001b.54c2.9a43 vlan 1 count 2

Packet No. 1
--- ----------------- --------------------------
Hop Switch-id         Switching time (sec, nsec)
--- ----------------- --------------------------
1      0-1b-54-c2-9a-42   0       4800
2      0-1b-54-c2-9a-43   0       5920
3      0-1b-54-c2-9a-42   0       4848
4      0-1b-54-c2-9a-41   0       6488
Round trip time: 0sec 22056 nsec

Packet No. 2
--- ----------------- --------------------------
Hop Switch-id         Switching time (sec, nsec)
--- ----------------- --------------------------
1      0-1b-54-c2-9a-42   0       4792
2      0-1b-54-c2-9a-43   0       5912
3      0-1b-54-c2-9a-42   0       4816
4      0-1b-54-c2-9a-41   0       7120
Round trip time: 0sec 22640 nsec
```



ERSPAN Type III

Determining Network Latency using a Latency Analyser





Cisco SP Product Portfolio

Physical Layer Frequency Distribution (SyncE)

ITU-T G.8262
Compliance today

ME3600X/3800X

MWR2941

ME3600X-24CX

ASR901

	ASR9000	Cisco7600	ASR903	ME3600X ME3800X	MWR2941 ASR901
Traffic Interfaces	STM-1/4/16/64 OC-3/12/48/192 1GE 1) 10GE (LAN & WAN)	E1/T1 STM-1/4/16 OC-3/12/48 1GE 1) 10GE (LAN & WAN)	E1/T1 STM-1/4 OC-3/12 1GE 1) 2) 10GE (LAN & WAN)	E1/T1 5) STM-1 5) OC-3 5) 1GE 1) 2), 10GE (LAN only)	E1/T1 1GE 1)
External Timing Interfaces	Input/Output 2048kHz/2048kbps/1544kbps/10MHz 3)	Input/Output 2048kHz/2048kbps/1544kbps/10MHz	Input/Output 2048kHz/2048kbps/1544kbps/10MHz	Input/Output 2048kHz/2048kbps/1544kbps	Input/Output 2048kHz/2048kbps/1544kbps/10MHz 4)
SSM	Yes IOS XR 3.9	Yes IOS 15.0(1)S	Yes	Yes IOS 15.1(2)EY	Yes IOS 15.0(1)MR

1) SyncE is not supported with 1GE Coppper SFPs
2) SyncE in+out support on Fibre SFPs and 1GE Copper Interface Module
3) 10MHz on RSP440 only
4) 10MHz on ASR901 only
5) ME3600X-24CX only

Cisco SP Product Portfolio

Packet Layer Frequency & Time Distribution (IEEE1588)

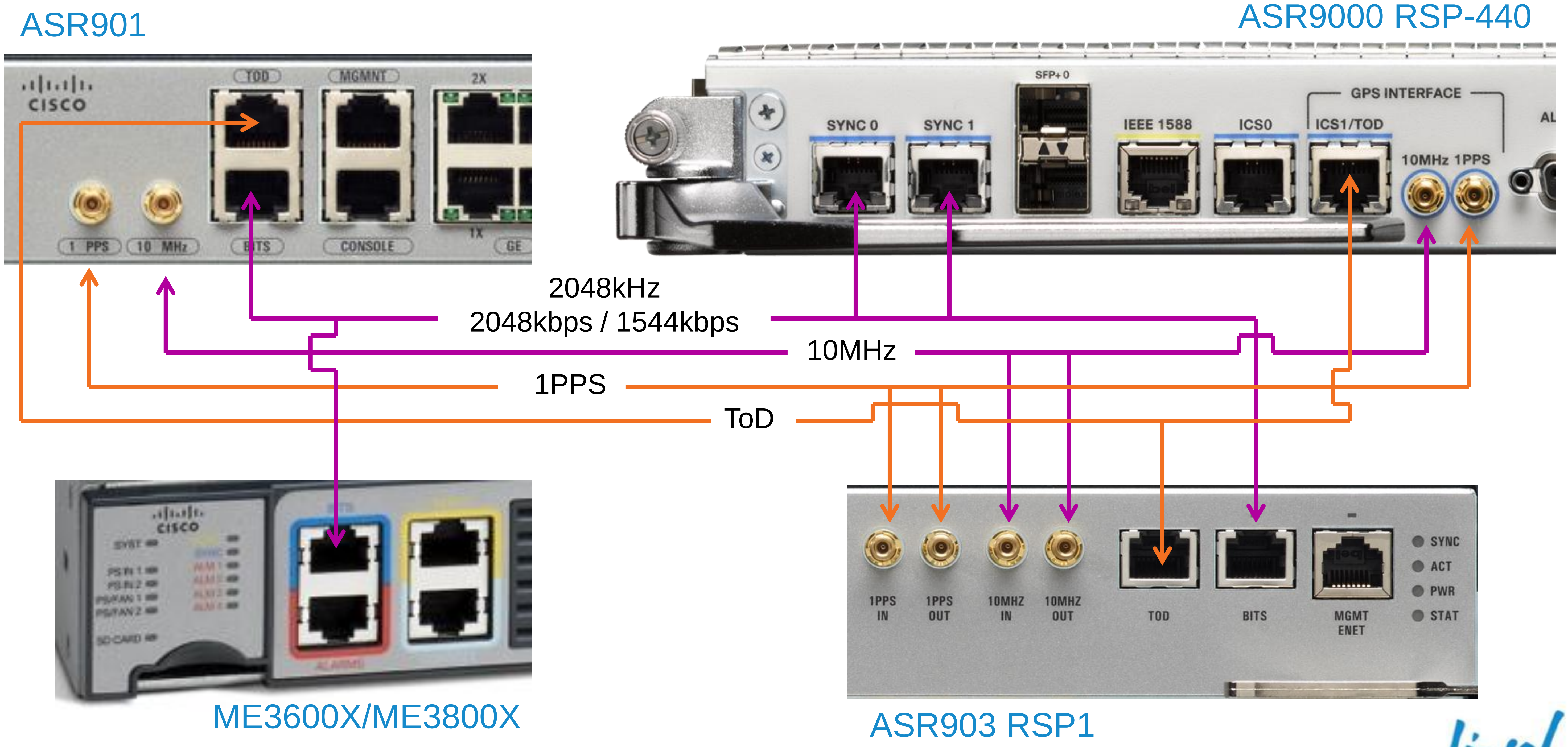
ITU-T G.8265.1 Telecom Profile compliant

	ASR9000	Cisco7600	ASR903	ME3600X-24CX	MWR2941 ASR901
Hardware	RSP440 & 2^{nd} Gen Linecards	SIP-400 SYNCE-SPA	All Interfaces	All Interfaces	All Interfaces
SW Version	IOS XR 4.2.0	IOS 15.0(1)S	IOS XE 3.5	IOS 15.2(4)S	IOS 12.4(19)MR2 2) IOS 15.1(2)SNG 3)
Supported Clock Modes	Ordinary Master Ordinary Slave Boundary Clock	Ordinary Master Ordinary Slave Boundary Clock	Ordinary Master Ordinary Slave Boundary Clock	Ordinary Master Ordinary Slave Boundary Clock	Ordinary Slave Boundary Clock
PTP Transport Options	IPv4 Unicast Negotiation	IPv4 Unicast & Unicast Negotiation IPv4 Mixed Multicast	IPv4 Unicast & Unicast Negotiation	IPv4 Unicast & Unicast Negotiation IPv4 Mixed Multicast	IPv4 Unicast & Unicast Negotiation Ipv4 Mixed Multicast 1)

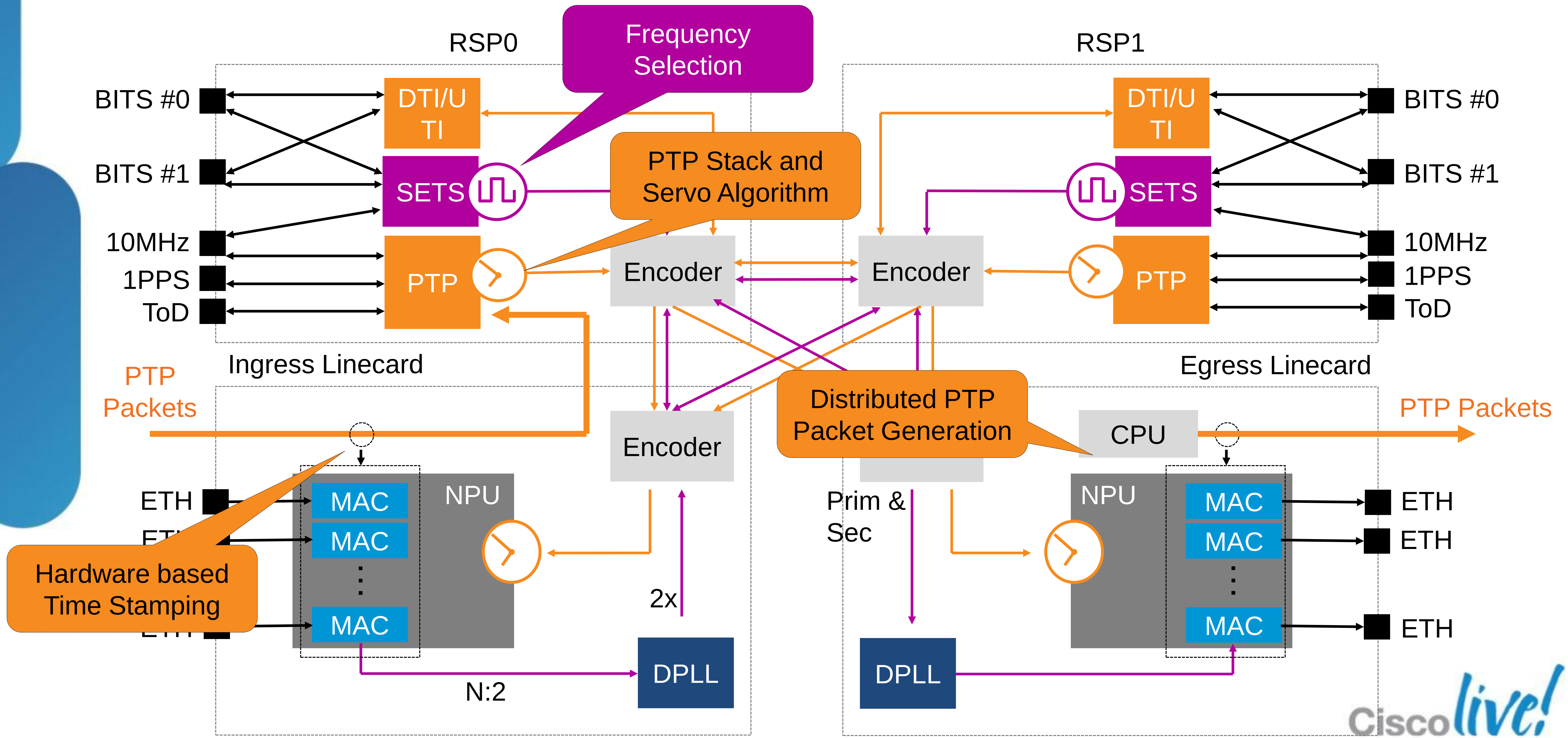
1) MWR2941 only 2) First release to support PTP on MWR2941 3) First Release to support PTP on ASR901

External Timing Interfaces

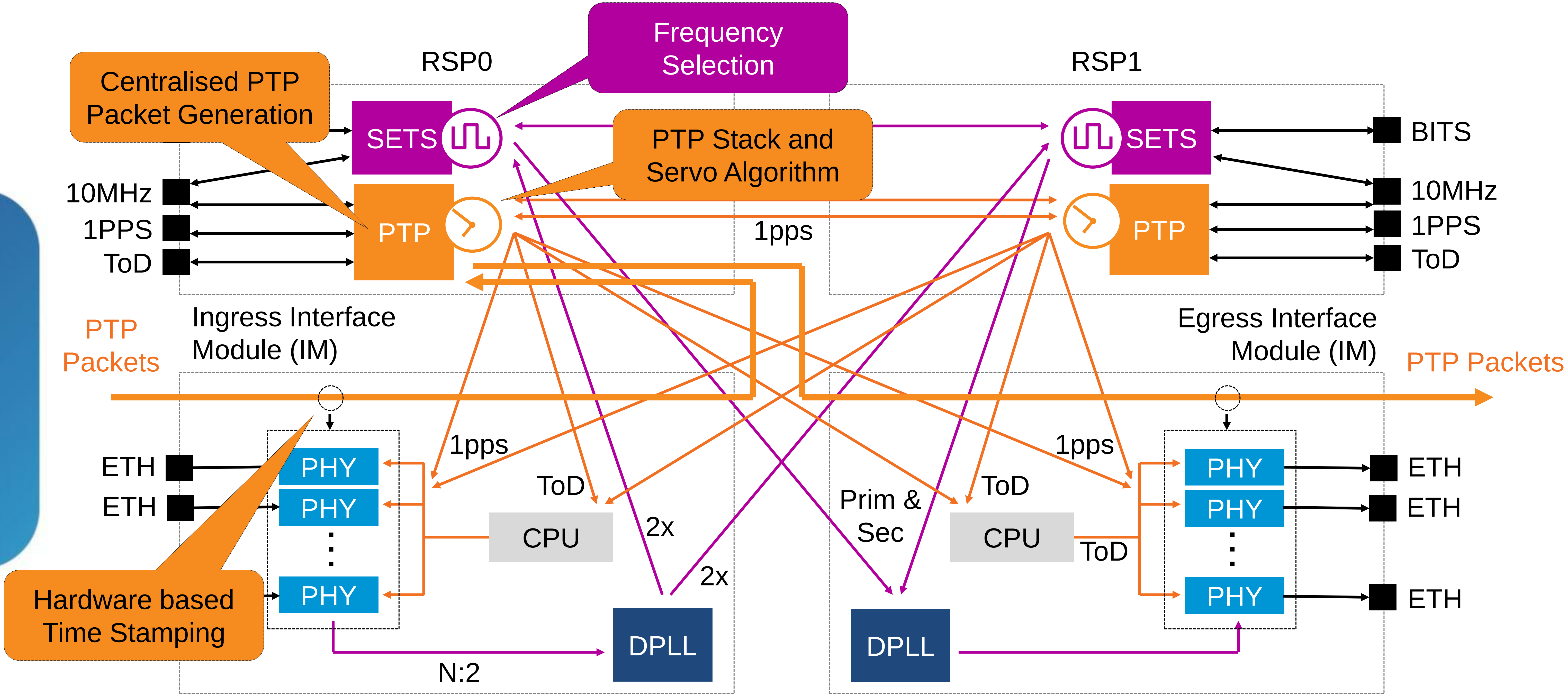
Frequency and Time



ASR9000 Synchronisation Architecture



ASR903 Synchronisation Architecture



Deployment Consideration

IEEE1588-2008 Profiles

Application specific Parameter Definition

ITU G.8275.1 Telecom Profile Time → 4G Mobile RAN

	IEEE1588 Default Profiles	ITU G.8265.1 Telecom Profile Frequency	IEEE C37.238 Power Profile
Segment	Industrial Solutions High Speed Trading	2G Mobile RAN 3G Mobile RAN	Smart Grid
Profile ID / Version	00-19-A7-00-01-00 / v1.0 00-19-A7-00-02-00 / v2.0	00-19-A7-00-01-00 / v1.0	1C-12-9D-00-00-00 / v1.0
PTP Modes	One-way & two-way One-step & two-step	One-way & two-way One-step & two-step	Two-way One-step & two-step
PTP Transport	IPv4 & Layer 2 Multicast	IPv4 Unicast Negotiation	Layer 2 Multicast
Master Selection	BMCA	Alternate BMCA • QL (Clock Class) • PTSF • Local Priority	BMCA
Path Delay Mechanism	Delay request/response Peer-to-Peer	Delay request/response	Peer-to-Peer
Management Option	Mgmt Message per Clause 15	not specified	IEEE C37.238 MIB
Node Types	Ordinary Master/Slave, Boundary and Transparent	Ordinary Master and Slave	Ordinary Master/Slave, Boundary and Transparent

BMCA … Best Master Clock Algorithm   QL … Quality Level   PTSF … Packet Timing Signal Fail

IEEE1588-2008 Profiles

Application specific Parameter Definition

ITU G.8275.1
Telecom Profile Time

	IEEE1588 Default Profiles	ITU G.8265.1 Telecom Profile Frequency	IEEE C37.238 Power Profile
Goals	• Plug & Play Deployment • CIP Sync	• Based on ITU-T G.8265 Architecture • Interoperability with SONET/SDH & SyncE • WAN Operation • Fixed Arrangement	• Performance Parameter Mapping for ○ IEC61850 ○ C37.118 ○ IRIG-B
Application	• Migrate Motion Control Systems from Scan or Event based to a Time based to improve Throughput	• Frequency Distribution in Service Provider Packet Networks	• Time Distribution to IED without Distance Limitations • Timestamping of SCADA Data • IRIG-B replacement
Status	In force	In force	In force

Time Distribution in Service Provider Networks (i.e. LTE TDD)

In development

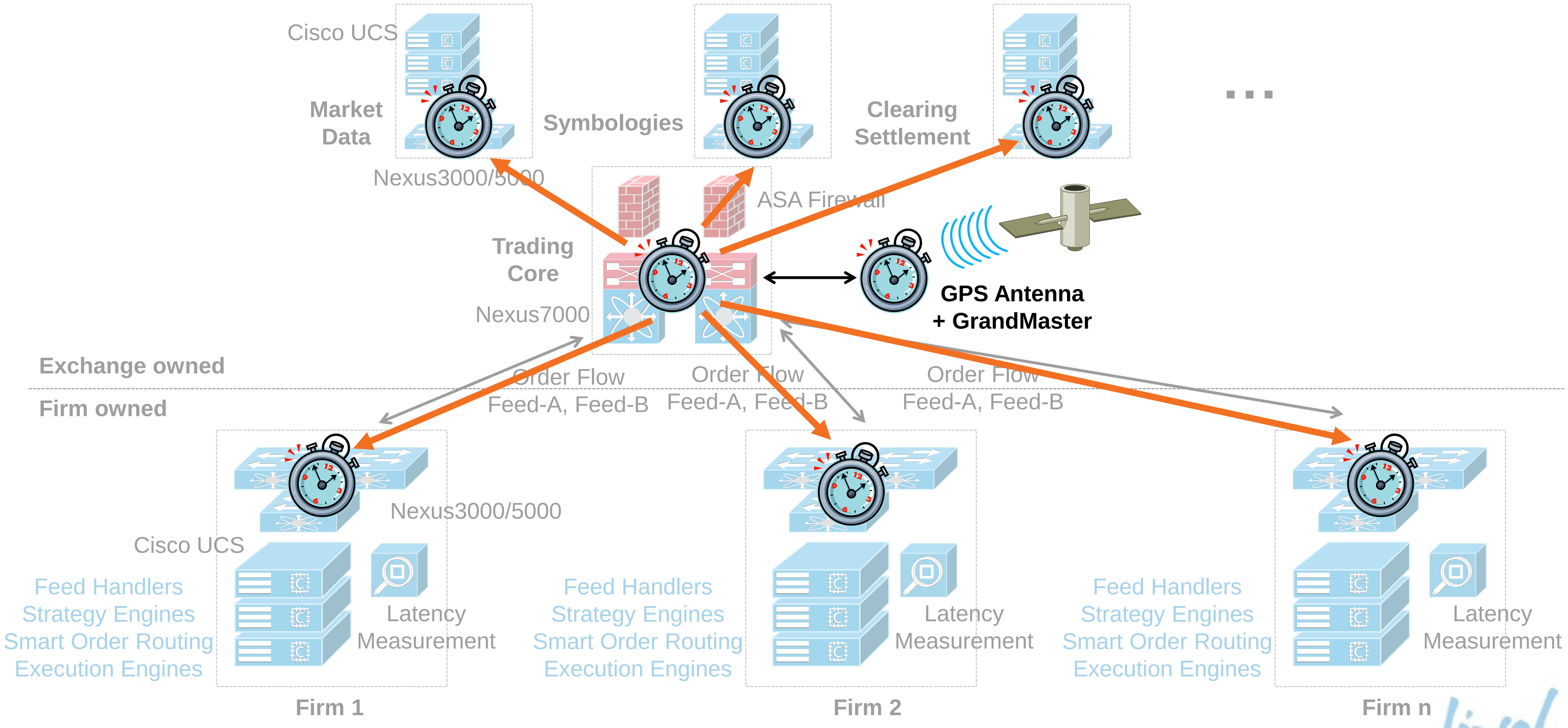
CIP … Common Industrial Protocol

Cisco live!

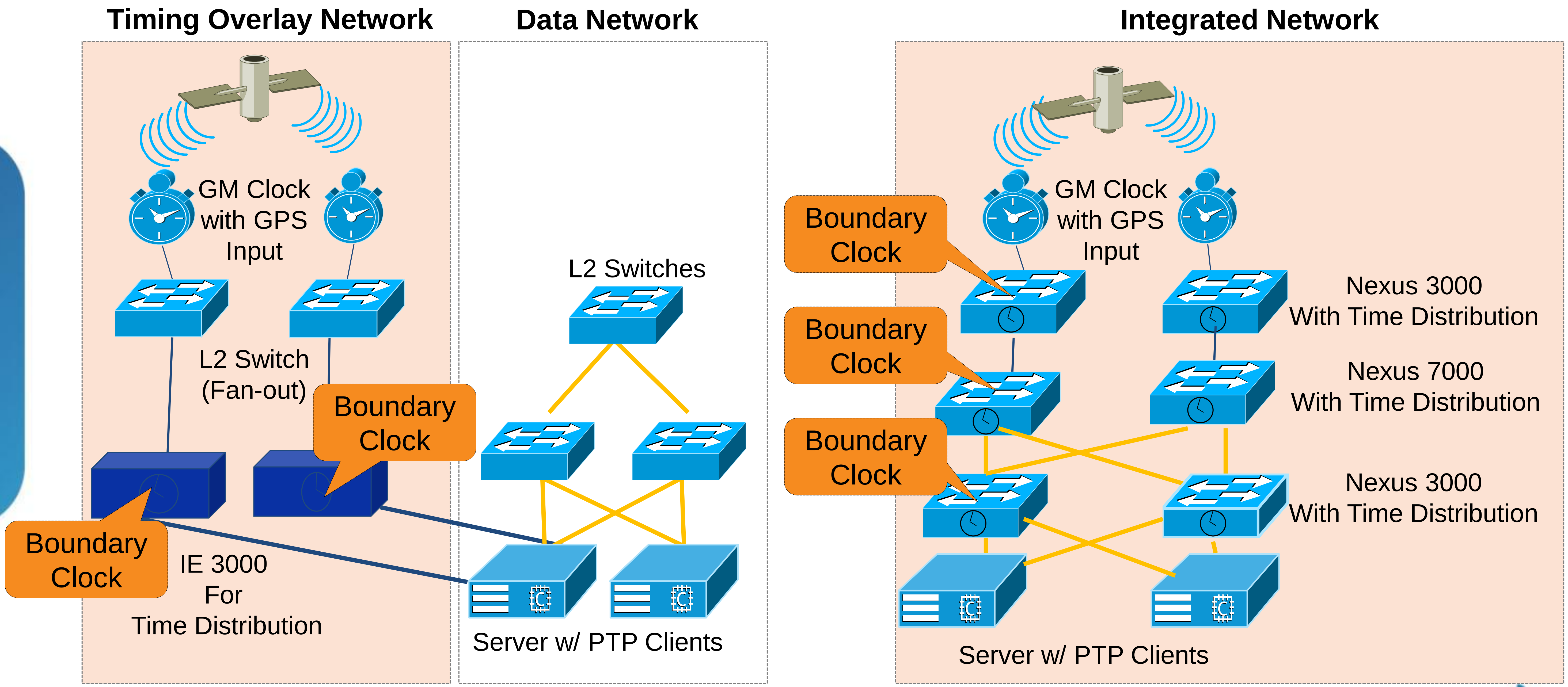
Deployment Consideration for High Frequency Trading

Typical Execution Venue Architecture

Providing Timing as a Service



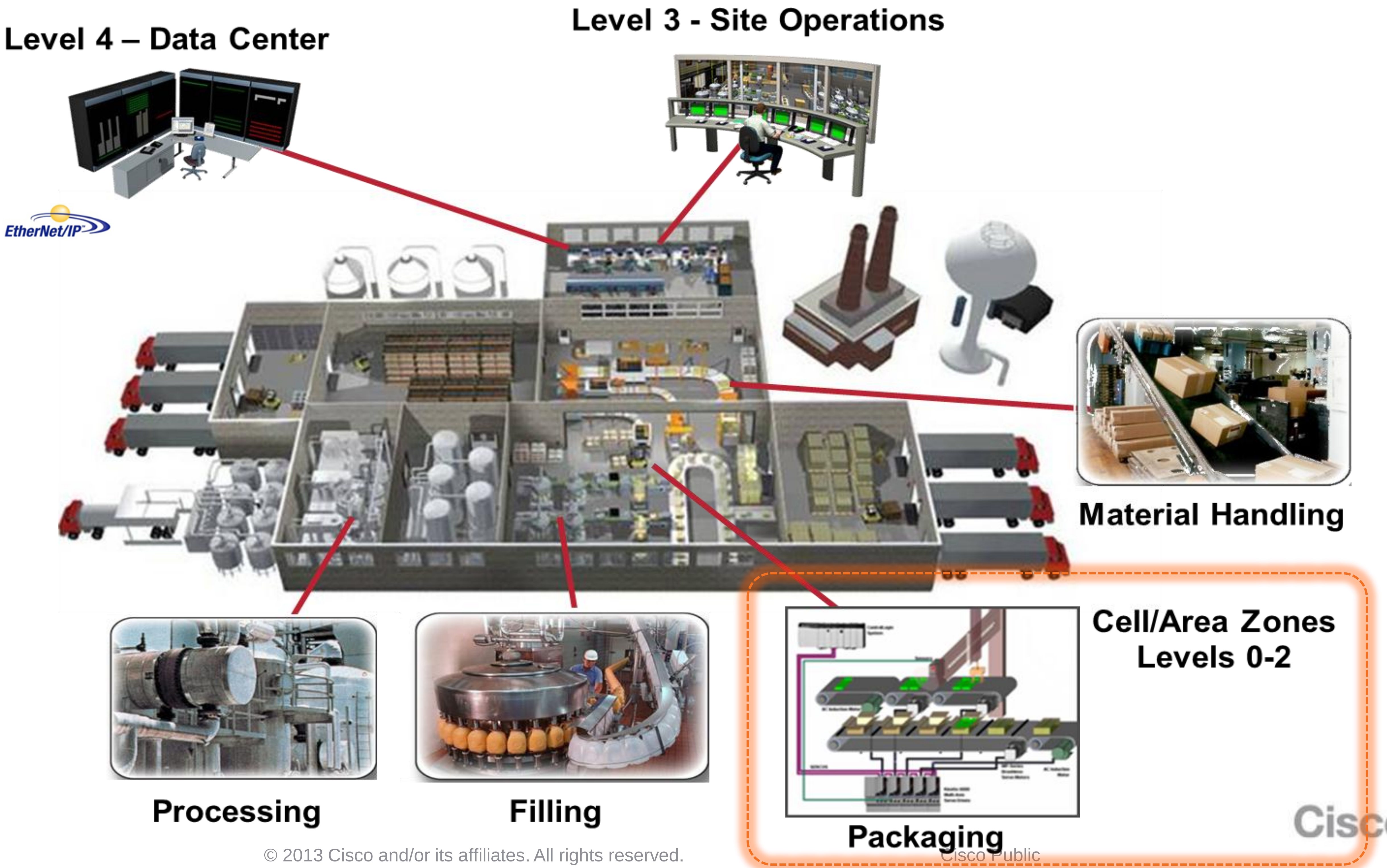
Time Services are already evolving



Deployment Consideration for Industrial Solutions

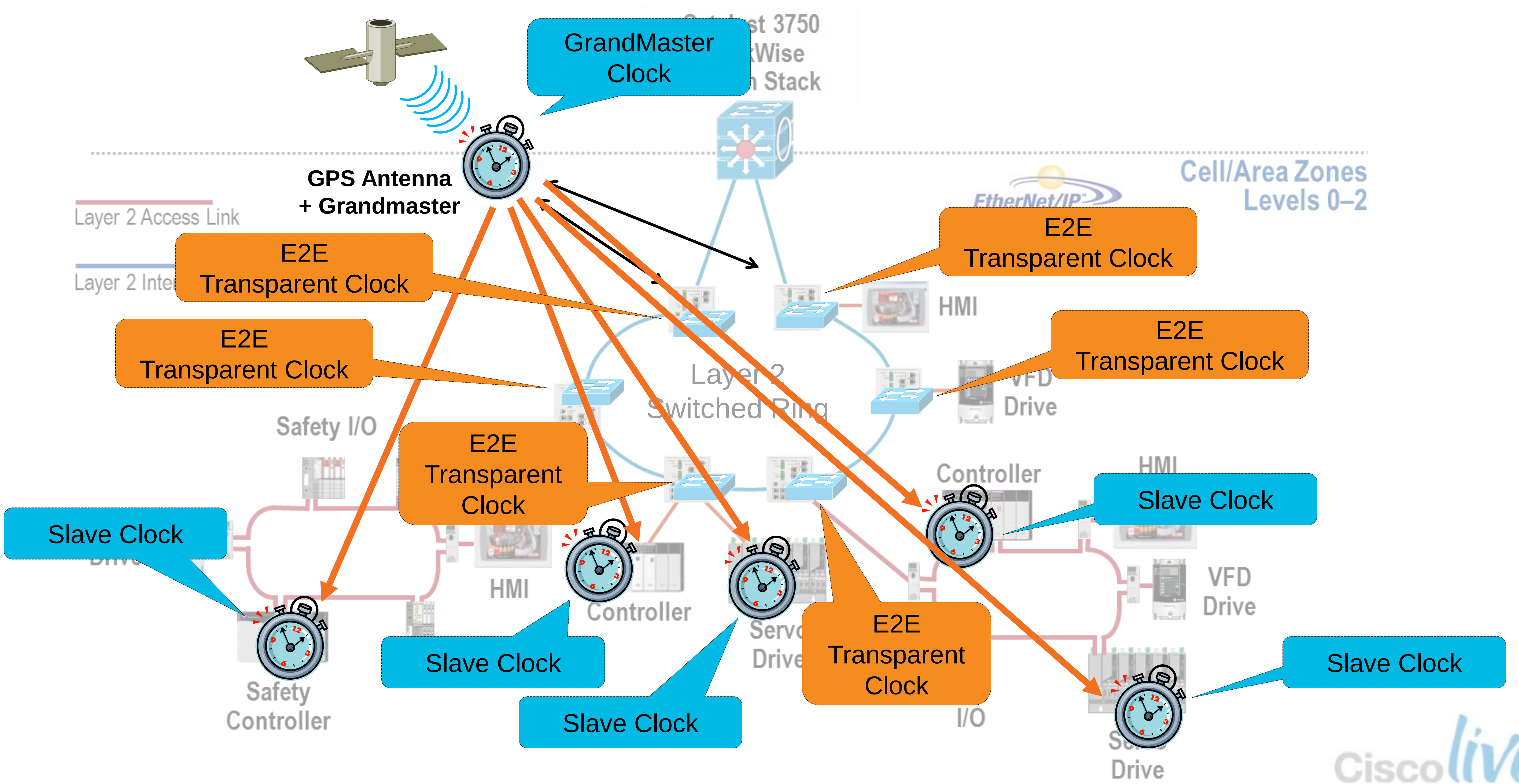
Plantwide Network Architectures

Cisco Convergence Plantwide Ethernet (CPwE) Architecture



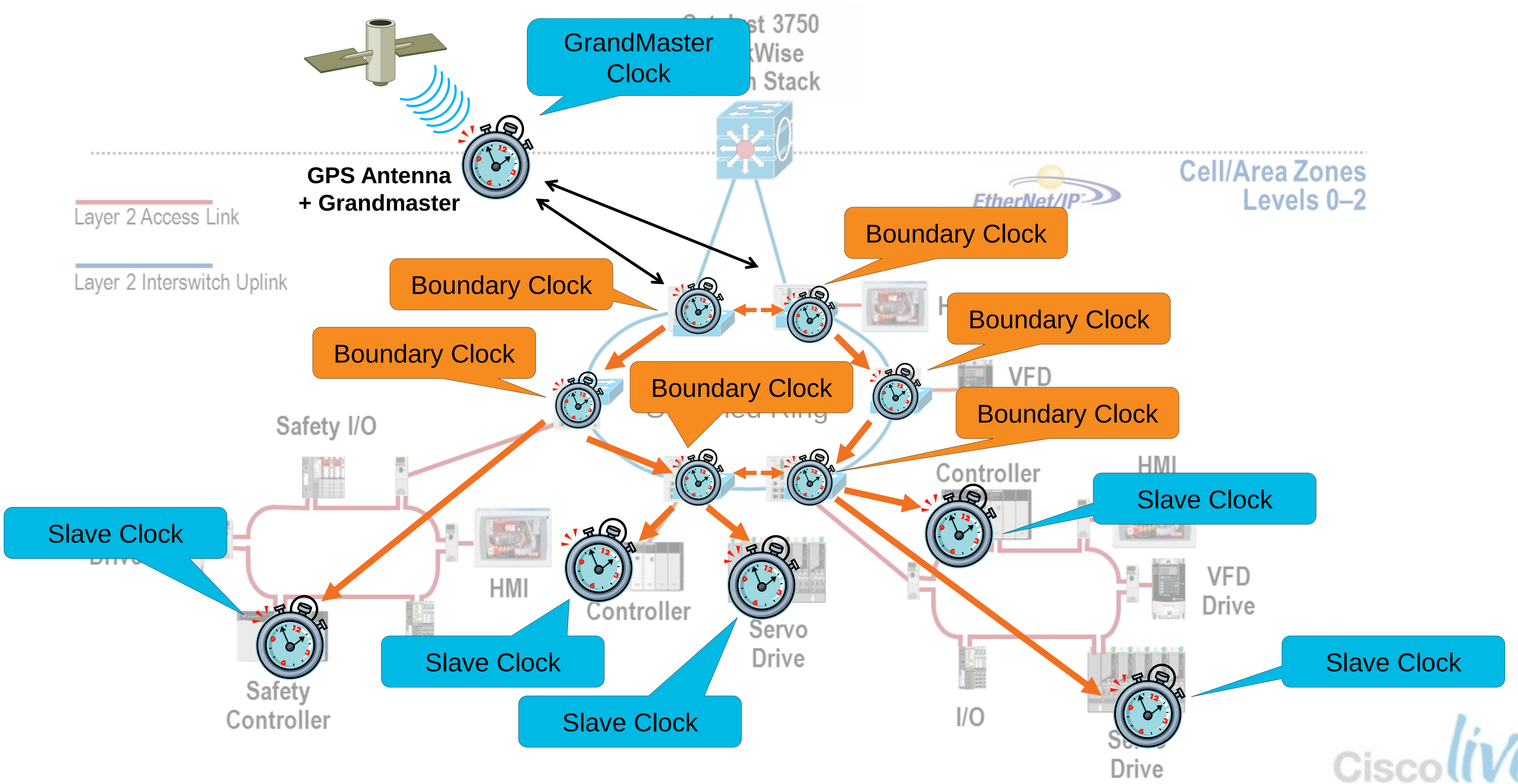
Machine Solutions – CPwE 2.2

E2E Transparent Clock – Cisco IE3000 & Rockwell Stratix 8000



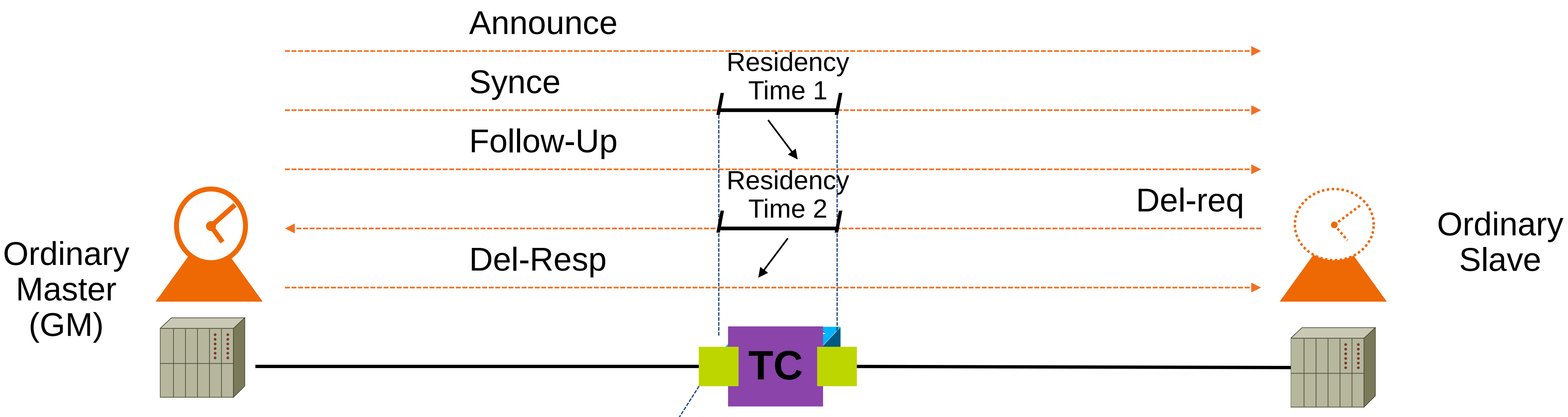
Machine Solutions – CPwE 2.2

Boundary Clock – Cisco IE3000 & Rockwell Stratix 8000



Cisco IE3000 E2E Transparent Clock

Configuration Example



interface gig 1/1
no ptp enable

Interface PTP Parameters

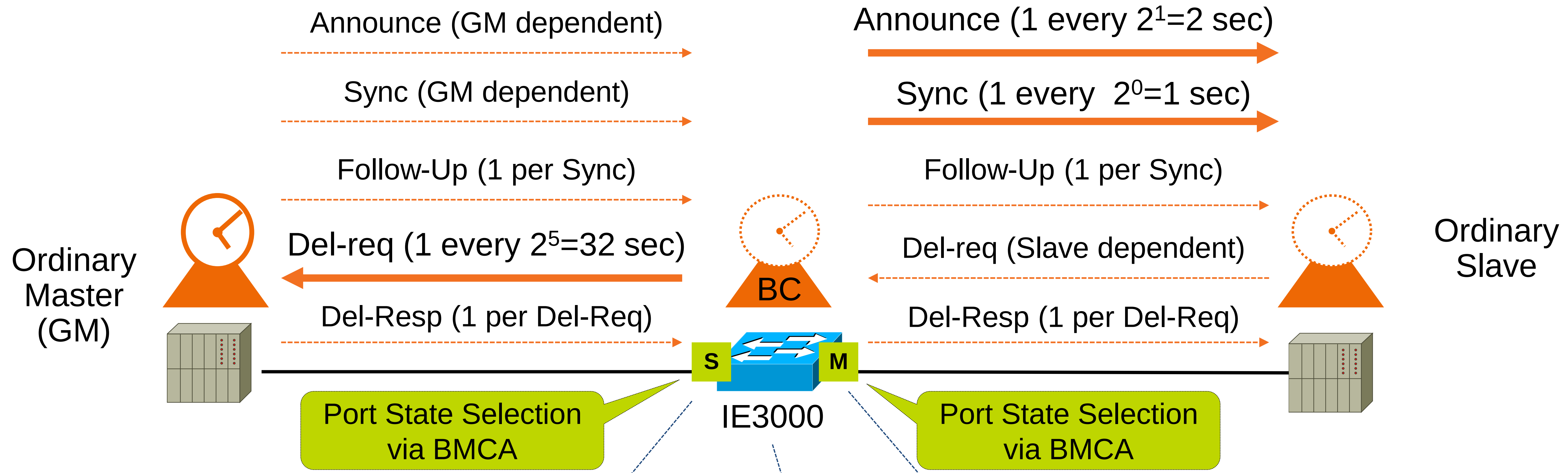
Default=enabled

ptp mode e2etransparent

Global PTP Configuration

Cisco IE3000 Boundary Clock

Configuration Example




```
interface gig 1/1
 ptp sync limit <50..500000000>
 ptp delay-req interval <-1..6>
 ptp announce timeout <2..10>
! no ptp enable
```

Interface PTP Parameters for Slave Ports

Default=50000

PTP enabled per default

```
interface gig 1/1
 ptp announce interval <0..4>
 ptp sync interval <-1..1>
```

Interface PTP Parameters for Master Ports

```
ptp domain <0..255>
ptp mode boundary
ptp priority1 <0..255>
ptp priority2 <0..255>
```

Default=0, user-defined up to 127

Default=128

Global PTP Configuration

Cisco IE3000 Expansion Modules

All PTP Packets to be passed to Base Module

Base Module

Expansion Modules

Per default PTP is only enabled on the Base Module Ports

ptp passthrough

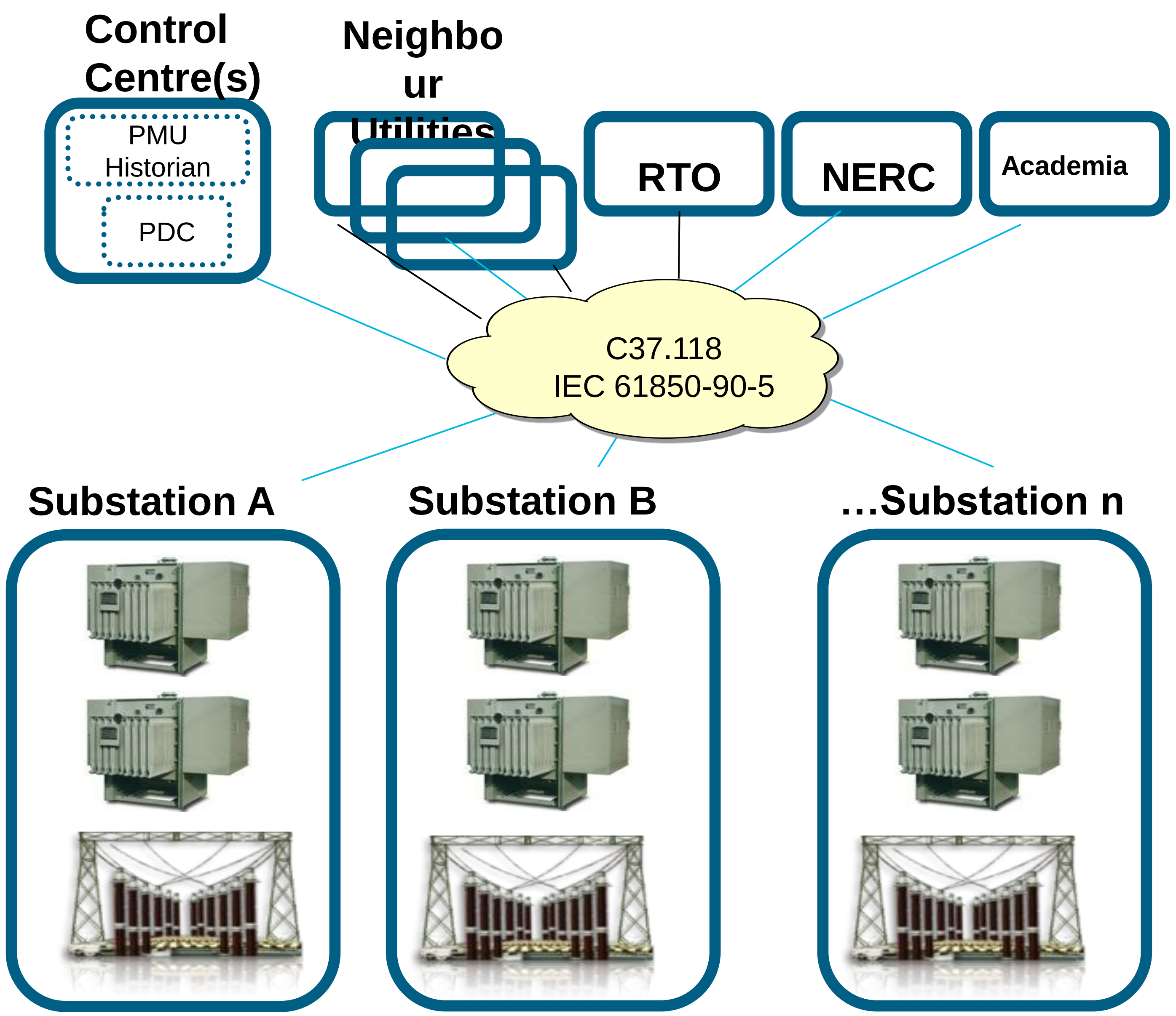
Global PTP Configuration

Enables PTP for Expansion Module Ports

Deployment Consideration for Smart Grid

Wire Area Measurement System (WAMS)

- Why WAMS?
  - Provide accurate measurement of grid state across broad regions of the transmission grid
  - Provides added grid monitoring and (eventually) real time protection & control using Phasor Measurement Units (PMUs)
  - Remediates frequency oscillations, disturbances before they cascade
- Drivers for Change
  - Variable Energy Resources
  - More cross-utility communication and control required among interchange authorities
  - Eventual closed loop control
- Characteristics
  - Low Latency
  - High Bandwidth: 120 samples/sec

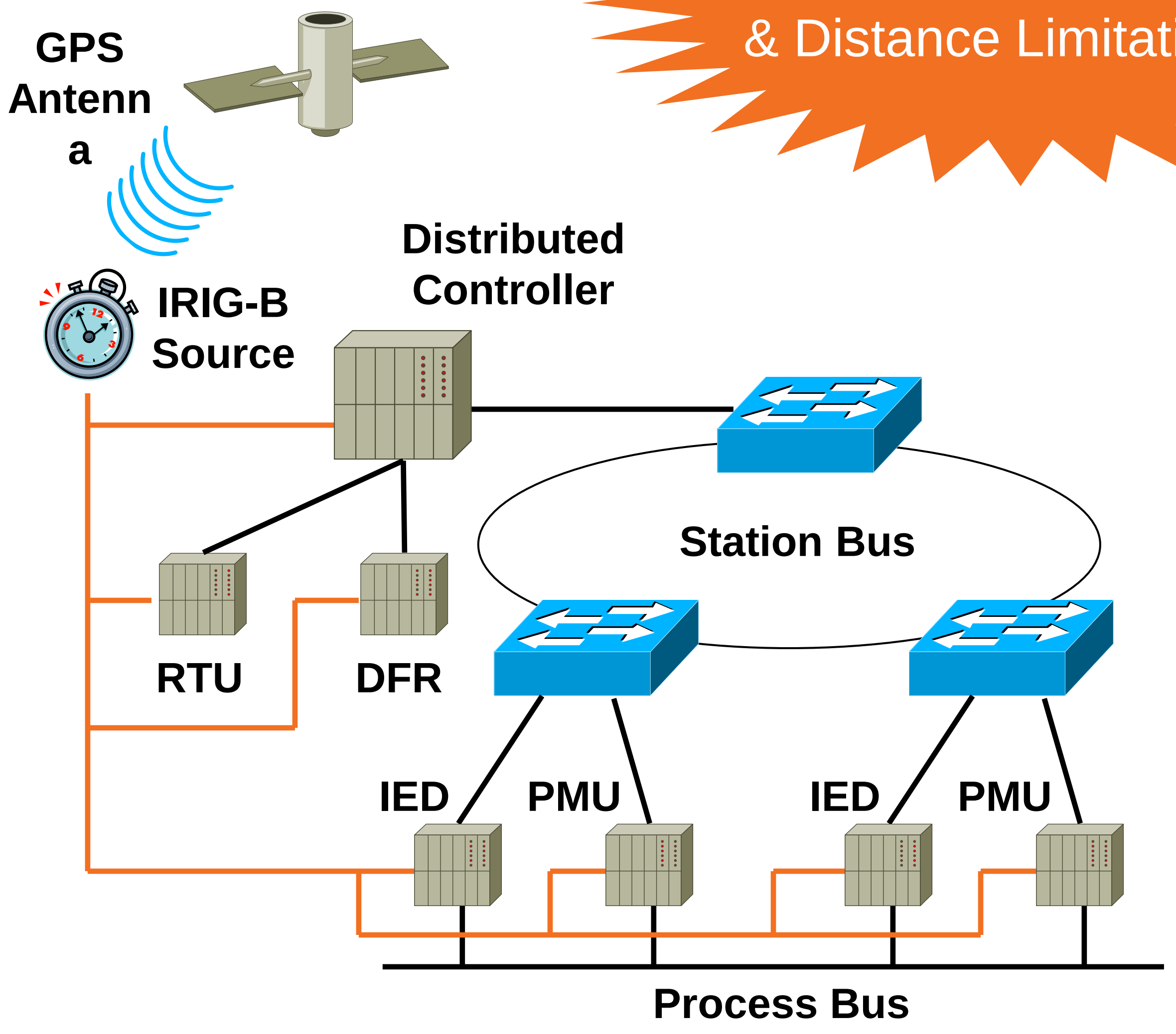


Timing Requirements

Today fulfilled by using IRIG-B or 1PPS

- General Applications (<1msec)
  - Sequence of Events
  - Digital Fault Recorder (DFR)
- High Precision Timing (<10usec)
  - Synchrophasors (C37.118)
  - Sampled Values (IEC 61850-9-2)
  - Distributed DFR Events
- IEC 61850-5-2003
  - Class T1: Events = ±1msec
  - Class T2: Syncrocheck ±0.1msec
  - Class T3: Samples Values ±25usec
  - Class T4: Samples Values ±4usec
  - Class T5: Samples Values ±1usec

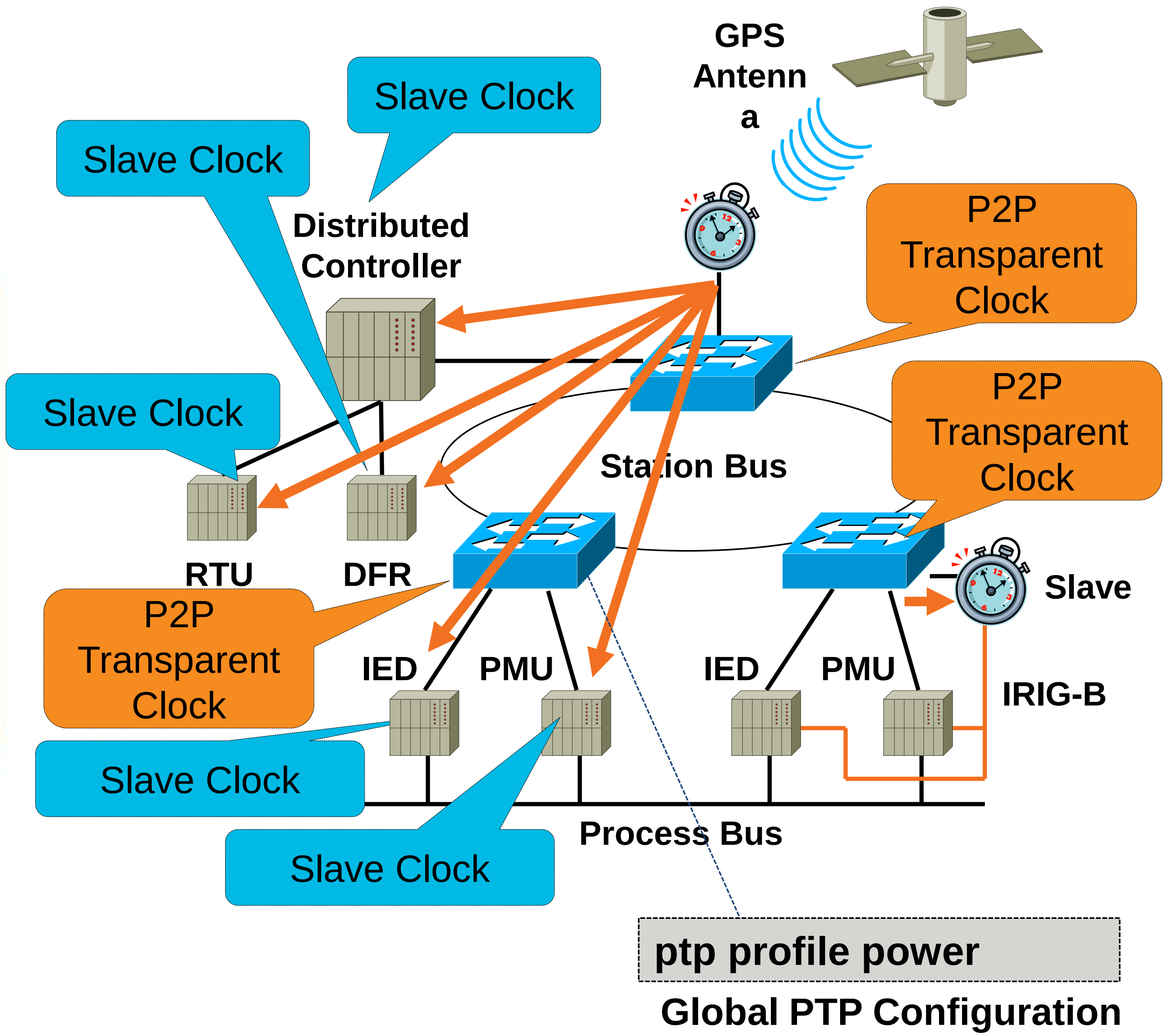
Dedicated IRIG-B Cables & Distance Limitations



RTU … SCADA Remote Terminal Unit;
DFR … Digital Fault Recorder

Migrating from IRIG-B to IEEE1588-2008

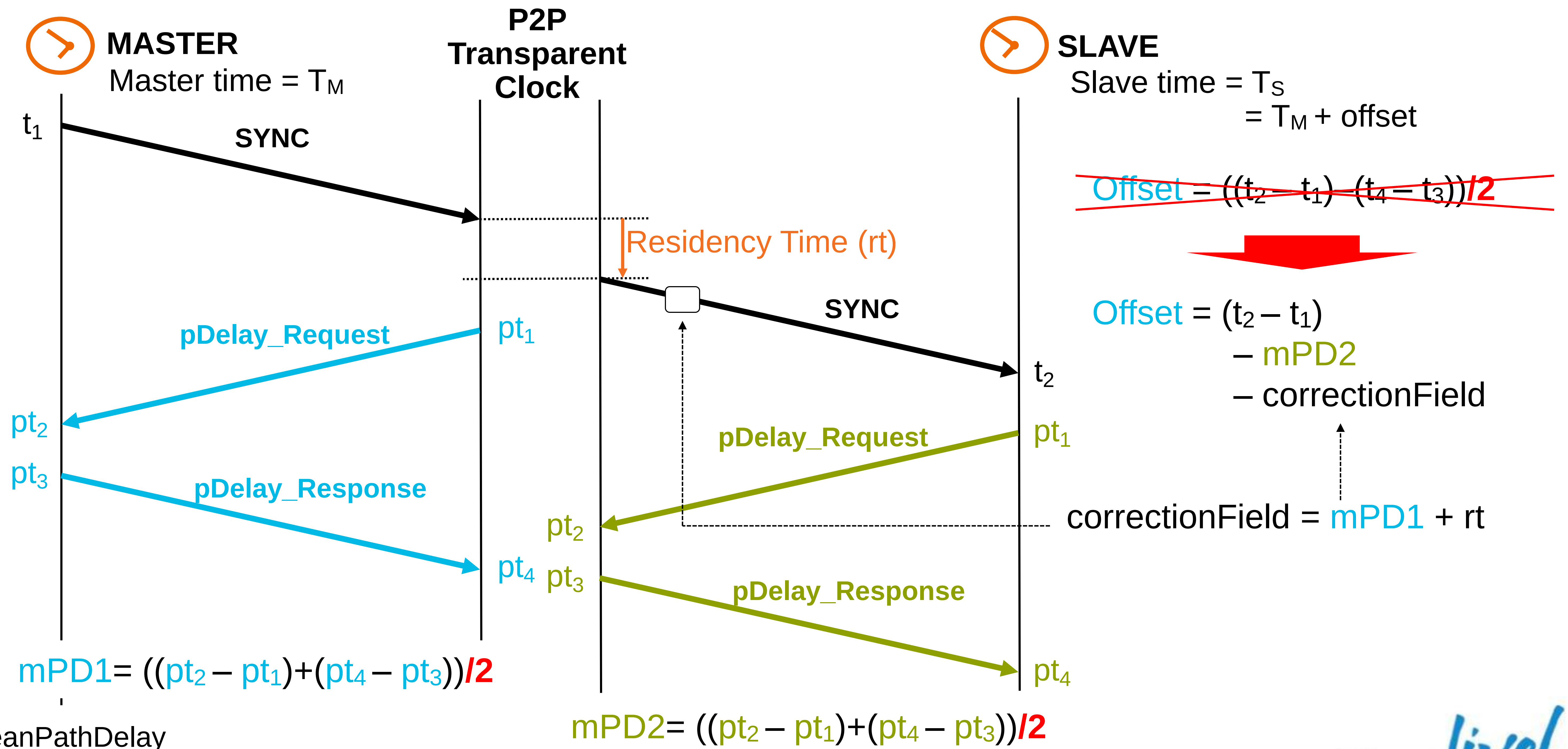
CGS2520 with Transparent Clock as per IEEE C37.238 Power Profile



1) With Peer Delay Request Mechanism
RTU … SCADA Remote Terminal Unit; DFR … Digital Fault Recorder

- PTP Message Transport
  - Layer 2 (Ethertype 0x88F7)
- PTP Domain
  - 0
- Path Delay Mechanism
  - Peer to Peer Transparent Clock
- Clock Type
  - Two Step
- PTP Packet Priority
  - COS = 0
- Slave Performance
  - <1usec for up to 16 hops

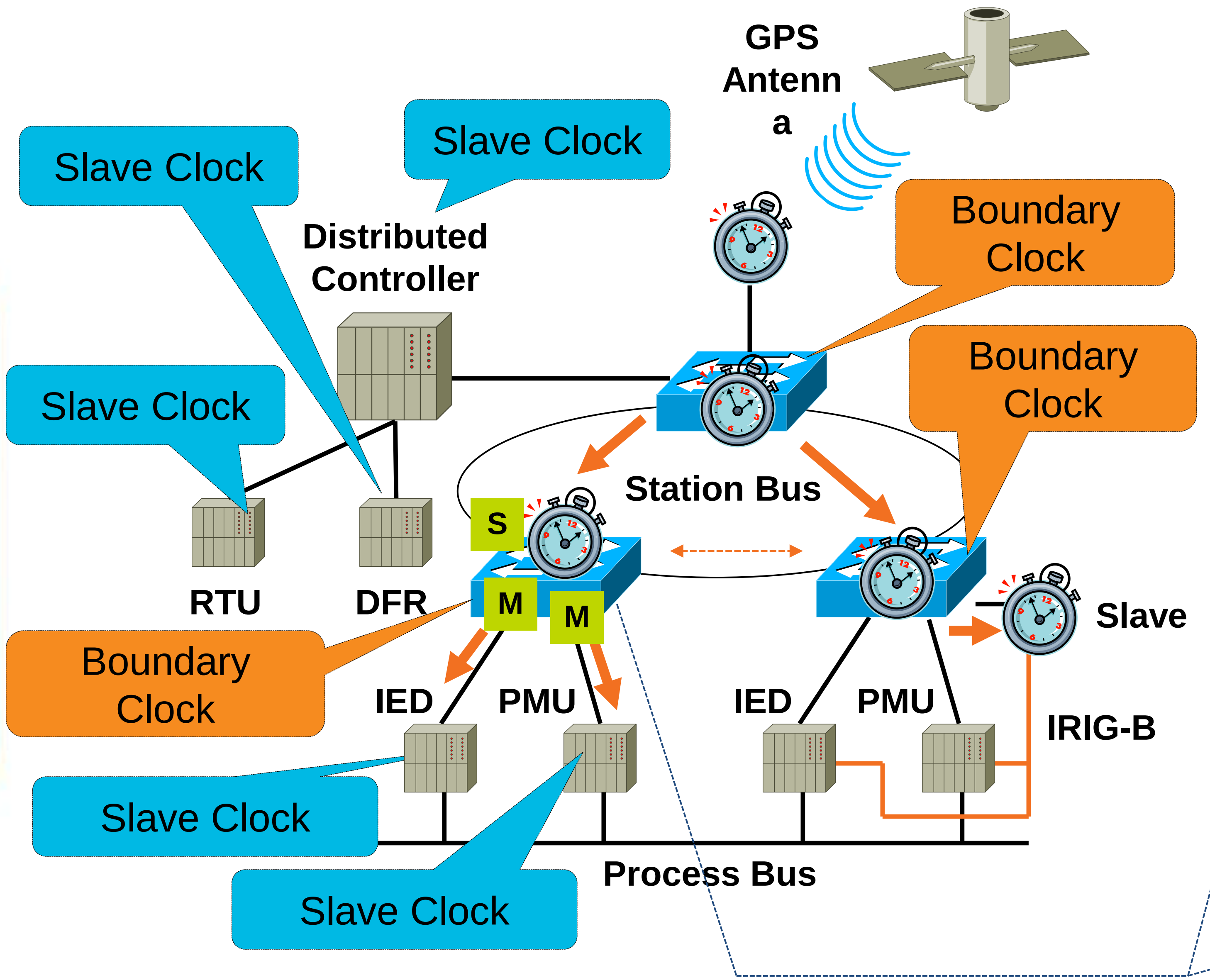
Peer to Peer Transparent Mode



mPD … meanPathDelay

Migrating from IRIG-B to IEEE1588-2008

CGS2520 with Boundary Clock



Power Profile compliant

PTP
Layer 2
Transport

Global PTP Configuration

```
ptp profile power
ptp mode boundary pdelay-req
```

PTP Port Configuration

```
inter gig 1/1
 ptp pdelay-req interval <-5..5>
```

Not Power Profile compliant

PTP
IPv4 Multicast
Transport

Global PTP Configuration

```
no ptp profile power
ptp mode boundary delay-req
```

RTU … SCADA Remote Terminal Unit; DFR … Digital Fault Recorder

IEEE C37.238 Power Profile (cont'd)

- Two mandatory TLVs
  - ORGANIZATION_EXTENSION IEEE_C37_238 TLV

    Communicates: Grandmaster ID, GrandmasterTimeInaccuracy, NetworkTimeInaccuracy
  - ALTERNATE_TIME_OFFSET_INDICATOR TLV
- IEEE C37.238 MIB
  - Time Error Estimate
  - Traceability
  - Grandmaster ID
- Mapping of C37.238 Performance Parameters into
  - IEC61850 Parameters
  - C37.118 Parameters

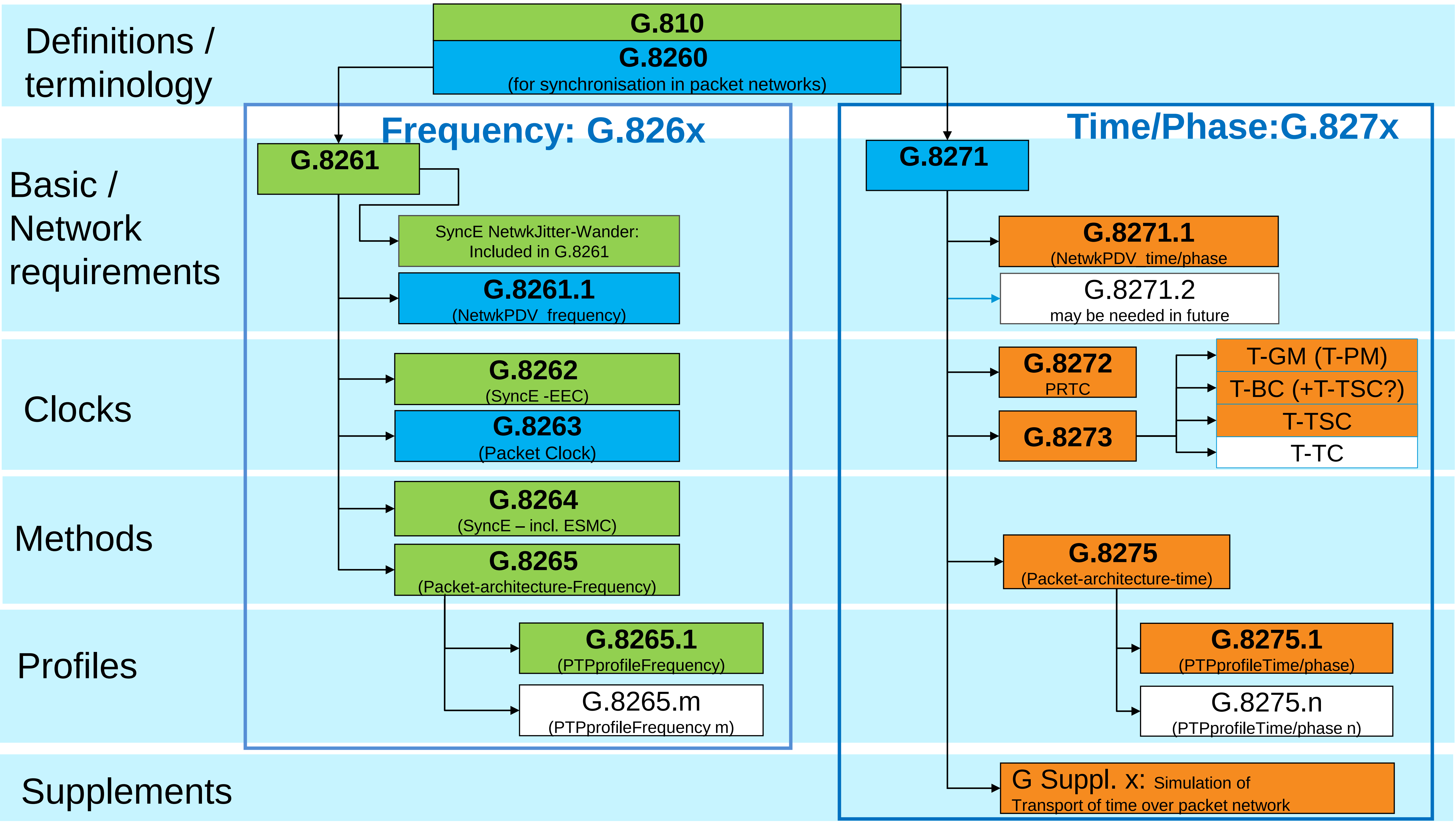
Deployment Consideration for Service Providers

Applications driving Synchronisation

Technology	Frequency Read: better than…	Phase or Time Synchronisation Read: less than…
GSM	Macro BS: ±50 ppb Pico BS: ±100 ppb	N/A
WCDMA (and LTE) FDD	WideArea BS: ±50 ppb Medium/LocalArea BS: ±100 ppb Home BS: ±250 ppb OBSAI: ±16 ppb	N/A
WCDMA TDD	WideArea BS: ±50 ppb LocalArea BS: ±100 ppb	± 2.5 µs between base stations
TD-SCDMA	WideArea BS: ±50 ppb LocalArea BS: ±100 ppb	± 3 µs between base stations
LTE TDD	WideArea BS: ±50 ppb LocalArea BS: ±100 ppb	± 3 µs between base stations May range from ±0.5µs to ±50µs
CDMA2K	Macro Cell BS: ±50 ppb Pico Cell BS and Femto Cell: ±100 ppb	ToD (UTC) sync *should* be less than 3 µs and *shall* be less than 10 µs
WiMAX Mobile	Up to ± 1 ppb Average target : ± 15 ppb	Usual values between ± 0.5µs and ± 5µs
LTE-Advanced Services	±5 ppb (CoMP)	CoMP, relaying function, carrier aggregation ± 0.5 µs [± 1 µs]
Multi-Media Bcast SFN Service	± 50ppb	± 1 µs
DVB SFN	Up to ± 1 ppb	General agreement : ± 1 µs
TDM transmission	G.823/G.824/G.8261	N/A
Network Monitoring	N/A	± 1 to 100 µs ToD synchronisation for 10 µs to 1 ms measurement accuracy

ITU-T SG15 Q13 Work Plan

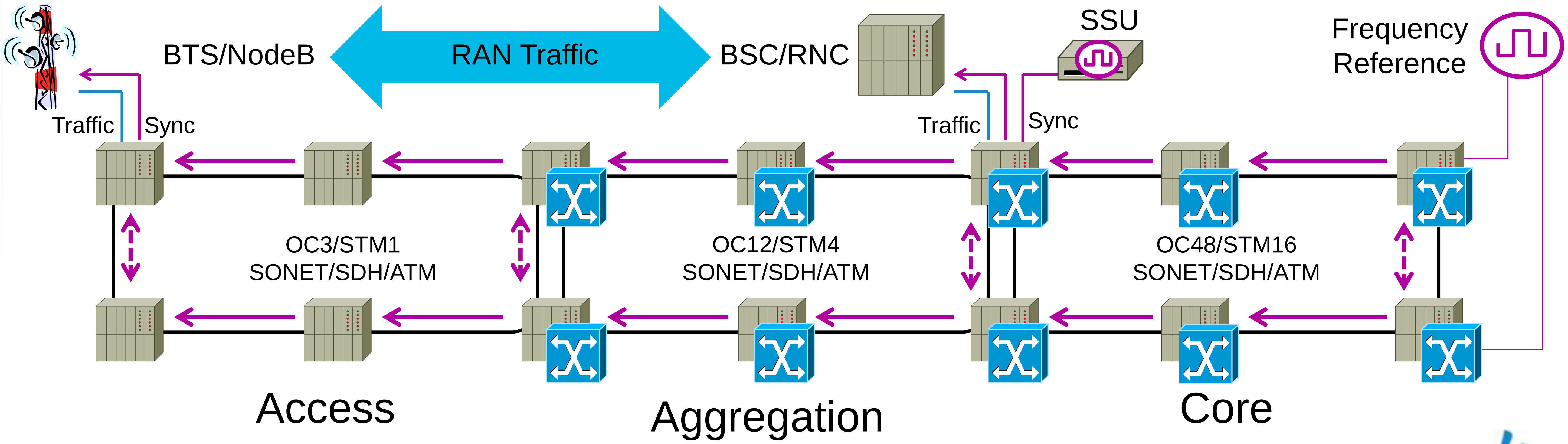
Approved « In force »	Recently approved 02/2012	Planned for 09/2012 or 07/2012	Future Working Items



PRTC … Primary Reference Time Clock, T-GM … Telecom Grandmaster; T-BC … Telecom Boundary Clock;
T-TC … Telecom Transparent Clock; T-TSC … Transparent Time Slave Clock;

SyncE + End2End IEEE1588

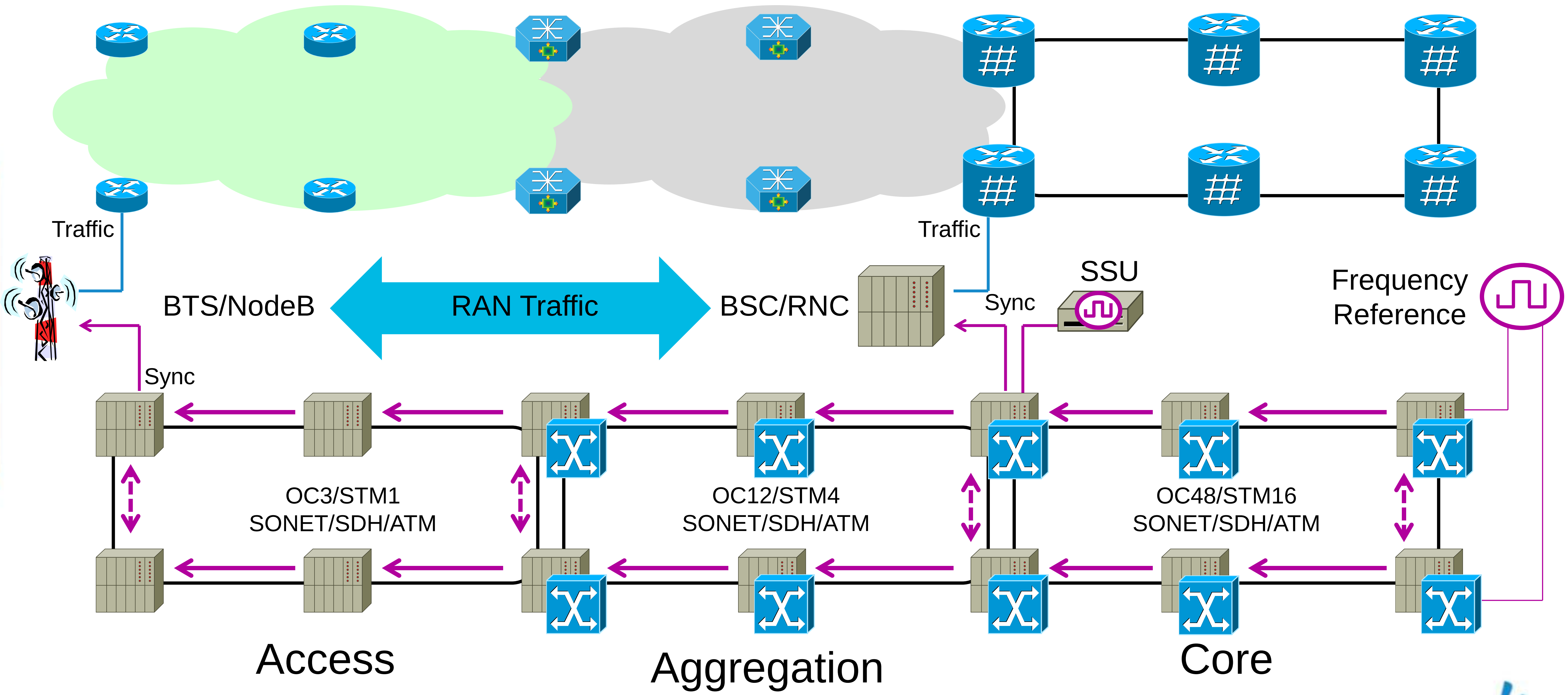
SP Mobile 2G and 3G RAN Transport Evolution



BTS … Base Transceiver Station; BSC … Base Station Controller

SyncE + End2End IEEE1588

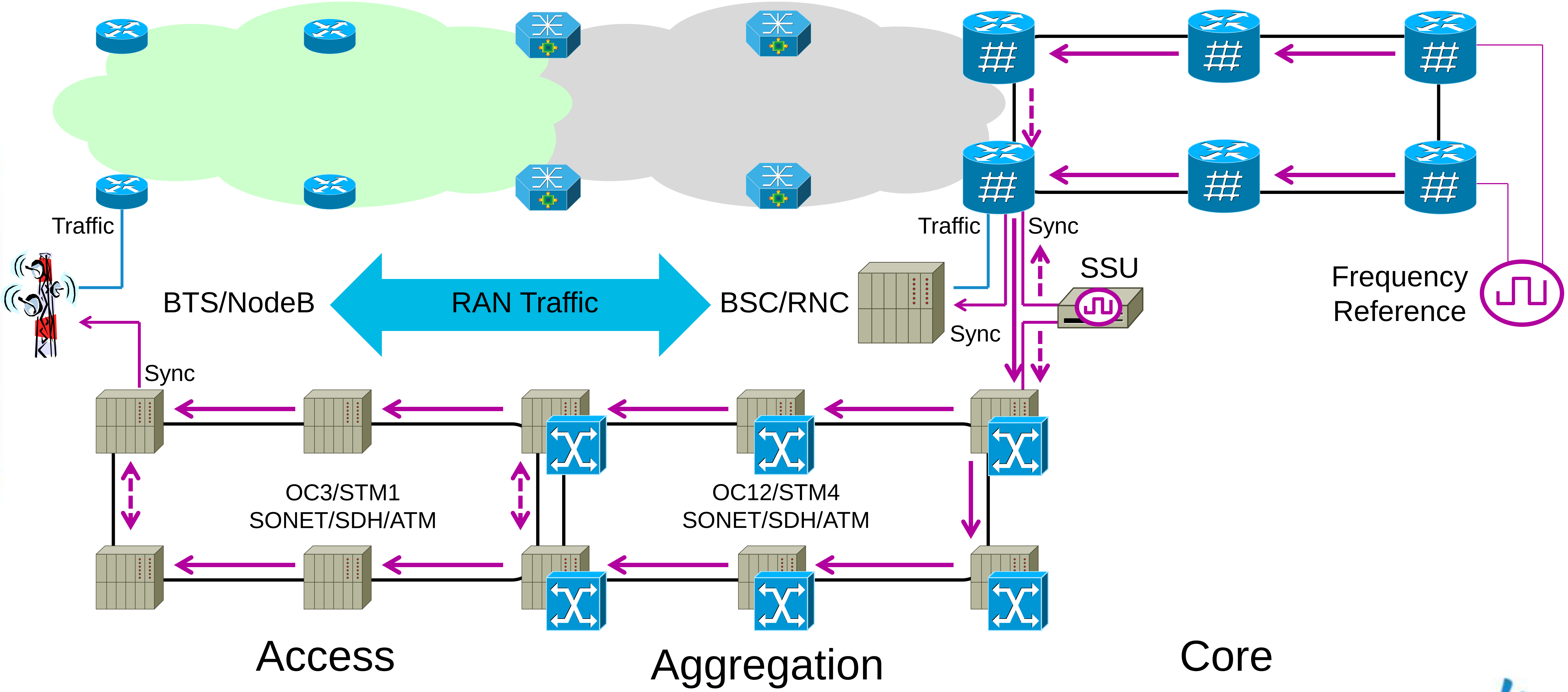
SP Mobile 2G and 3G RAN Transport Evolution



BTS … Base Transceiver Station; BSC … Base Station Controller

SyncE + End2End IEEE1588

SP Mobile 2G and 3G RAN Transport Evolution



BTS … Base Transceiver Station; BSC … Base Station Controller

SETS Configuration Options

Cisco IOS XR

- Enabling Frequency Synchronisation

```
RP/0/RSP0/CPU0:201-14(config)#frequency synchronization
```

- Selecting SSM Option

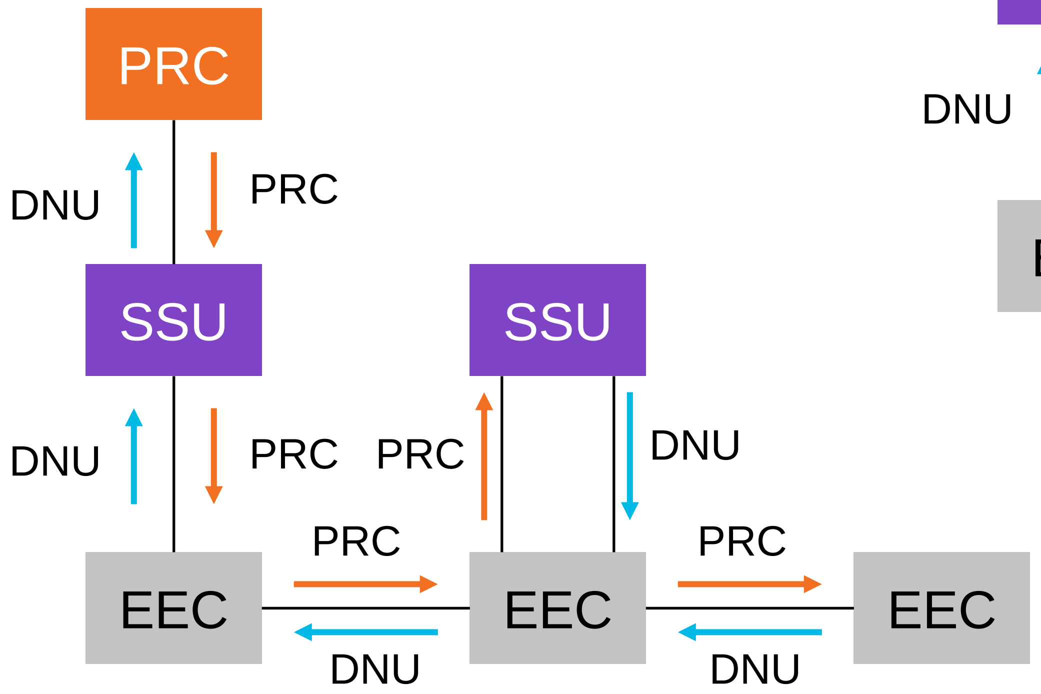
```
RP/0/RSP0/CPU0:201-14(config-freqsync)#quality itu-t option ?
  1  ITU-T QL option 1
  2  ITU-T QL option 2
```

- Selecting Generation 1 or 2 for Option 2

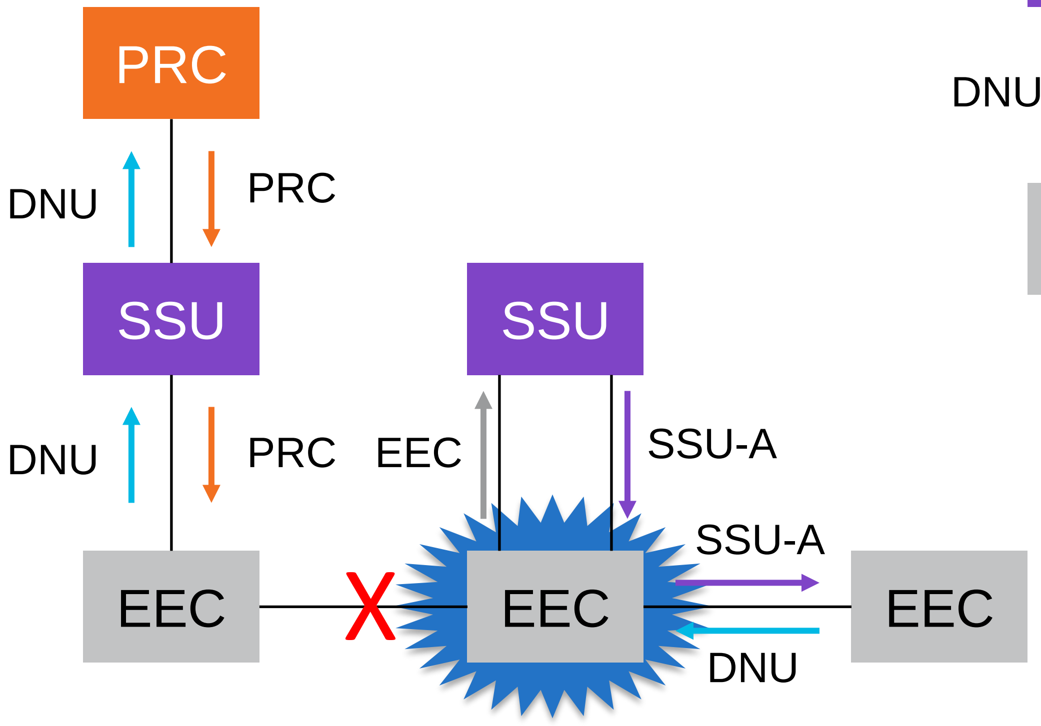
```
RP/0/RSP0/CPU0:201-14(config-freqsync)#quality itu-t option 2 ?
  generation  ITU-T QL option 2 generation

RP/0/RSP0/CPU0:201-14(config-freqsync)#quality itu-t option 2 generation ?
  1  ITU-T QL option 2, generation 1
  2  ITU-T QL option 2, generation 2
```

Chain of SyncE Clocks

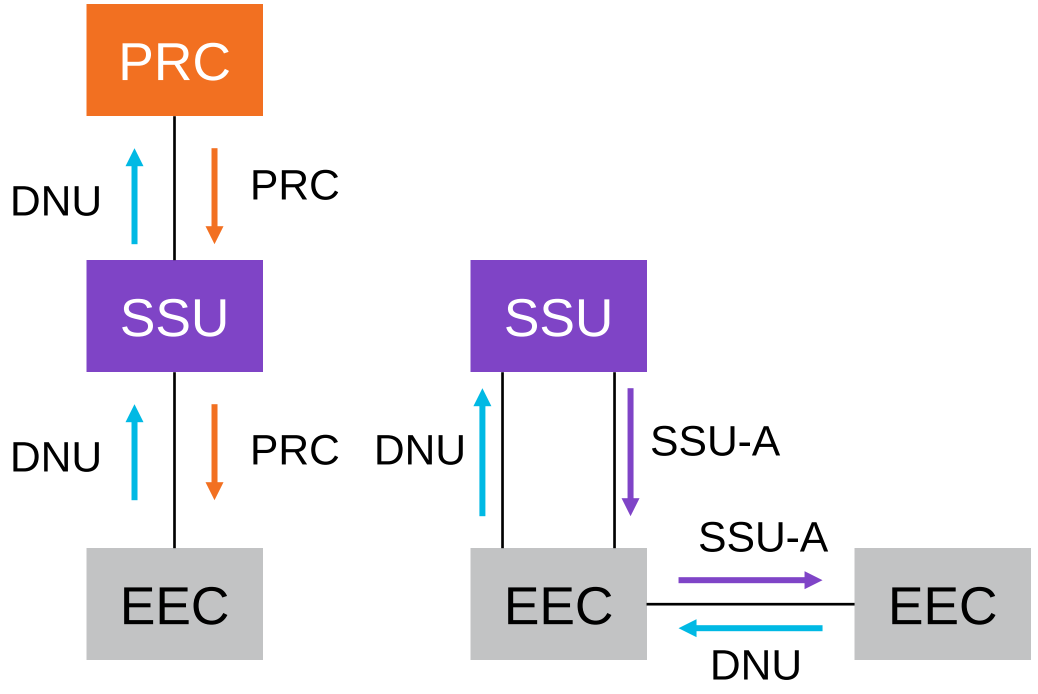
Signalling upon Failure and Chain Convergence



Before the Failure
(PRC traceable)



Transient State

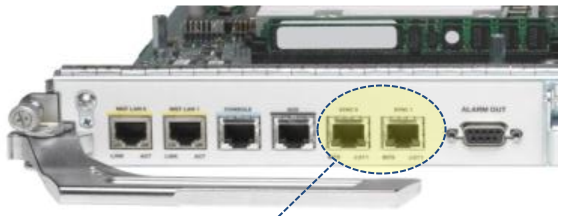


Restored Chain
(SSU-S traceable)

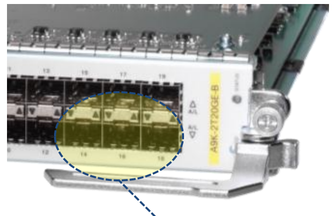
You want to avoid/minimise Holdover of SECs !!

Node connected to SSU

Cisco IOS XR Configuration



Timing Inputs



Synce Line Interface

```
interface TenGigE0/1/0/0
 frequency synchronization
  selection input
  priority 20
  wait-to-restore 0
```

Make SyncE Line a Nominated Source

```
clock-interface sync 1 location 0/RSP0/CPU0
 port-parameters
  bits-output e1 crc-4 sa8 hdb3
```

```
interface GigabitEthernet0/2/0/32
 frequency synchronization
```

Priority of External Input **MUST** be better (lower) than Line Interfaces

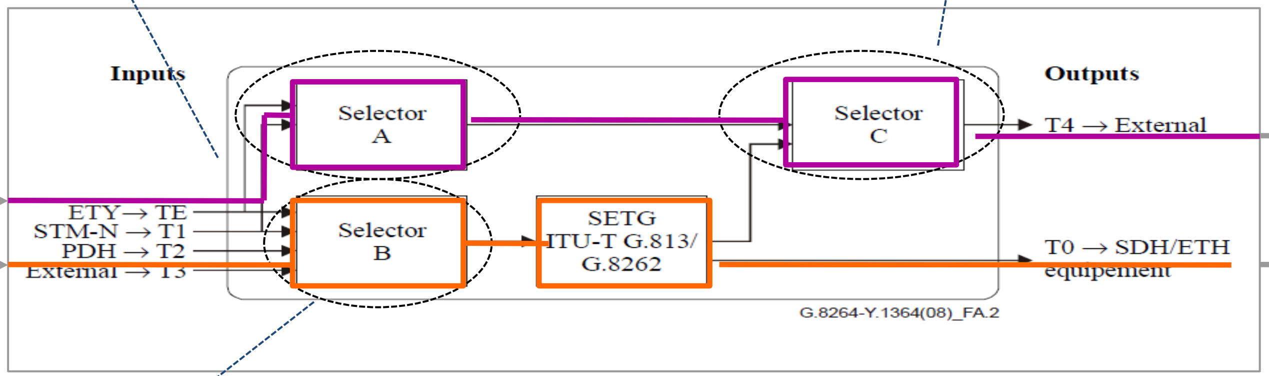
SSU

10GE (Te0/1/0/0)

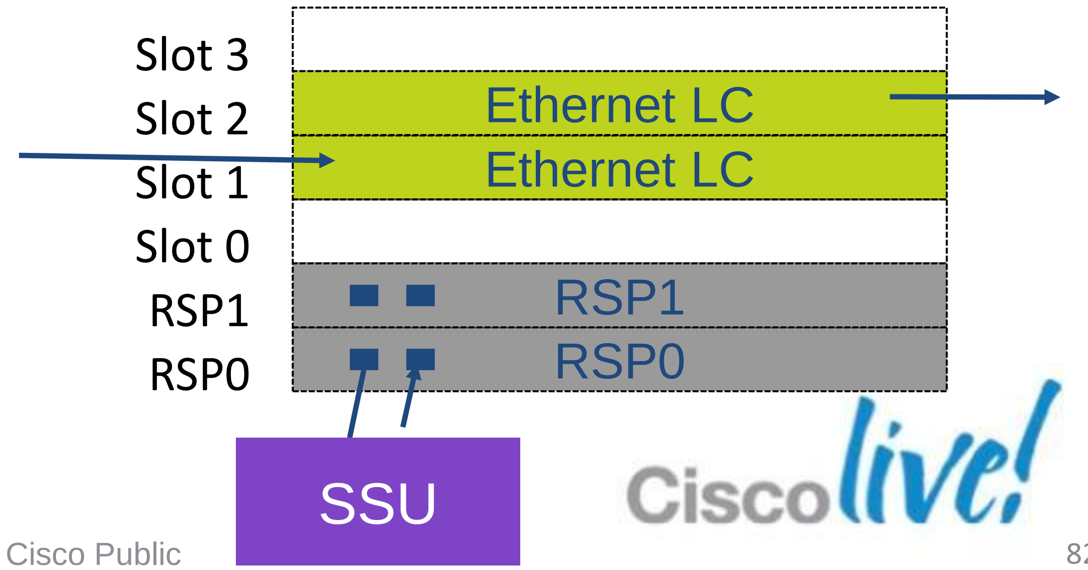
Rsp0 / Sync0

Rsp0 / Sync1

1GE (Gi0/2/0/32)

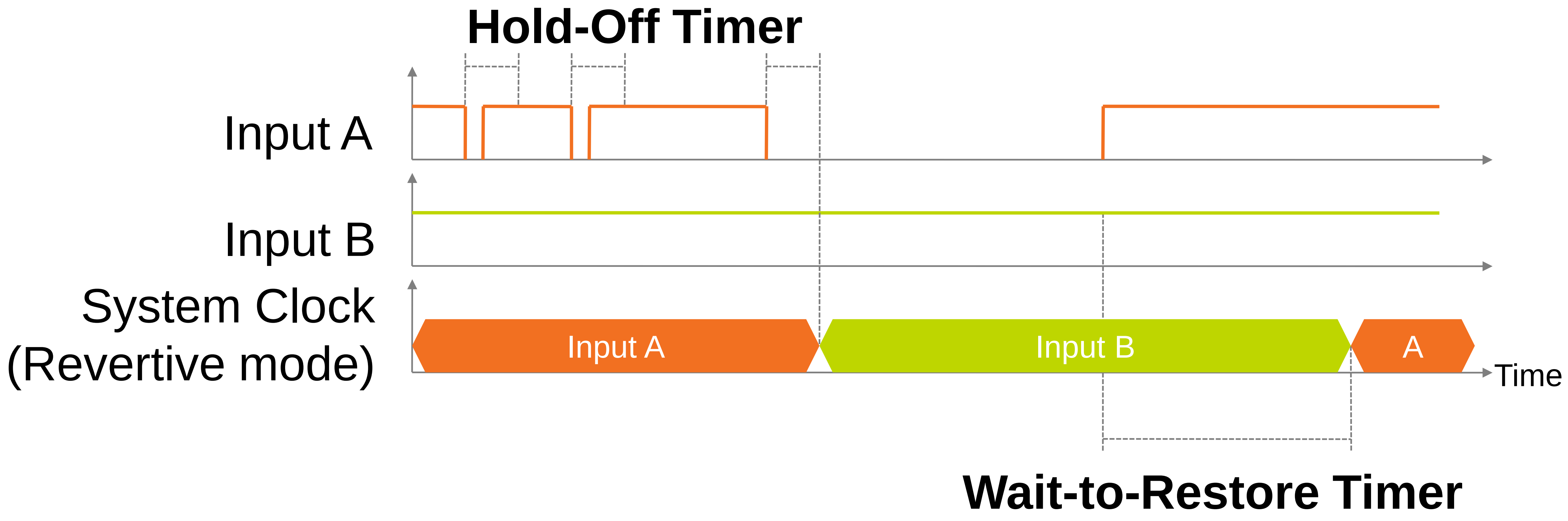



```
clock-interface sync 0 location 0/RSP0/CPU0
 port-parameters
  bits-input e1 crc-4 sa8 hdb3
 !
 frequency synchronization
  selection input
  priority 5
  wait-to-restore 0
```



Configurable Timers

Ensuring SETS Stability

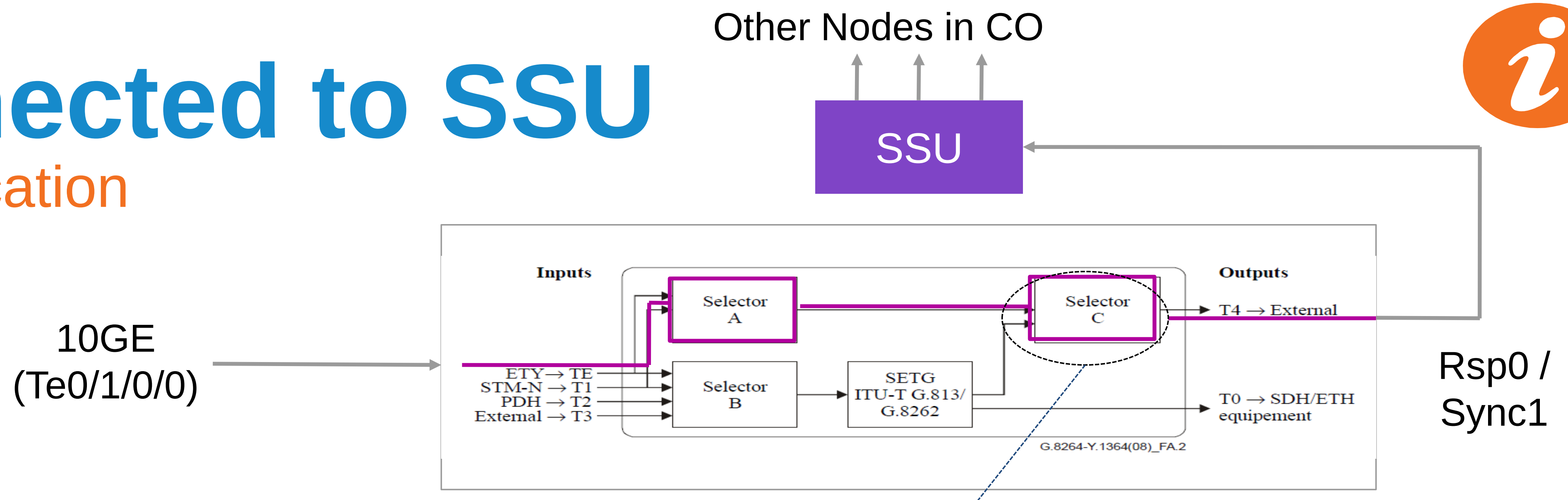


- Hold-Off Timer dampens short Activations of Input Signal Fail
- Wait-to-Restore Timer does ensure Input is fault-free again

Reference: G.781, page 23

Node connected to SSU

Cisco IOS XR Verification

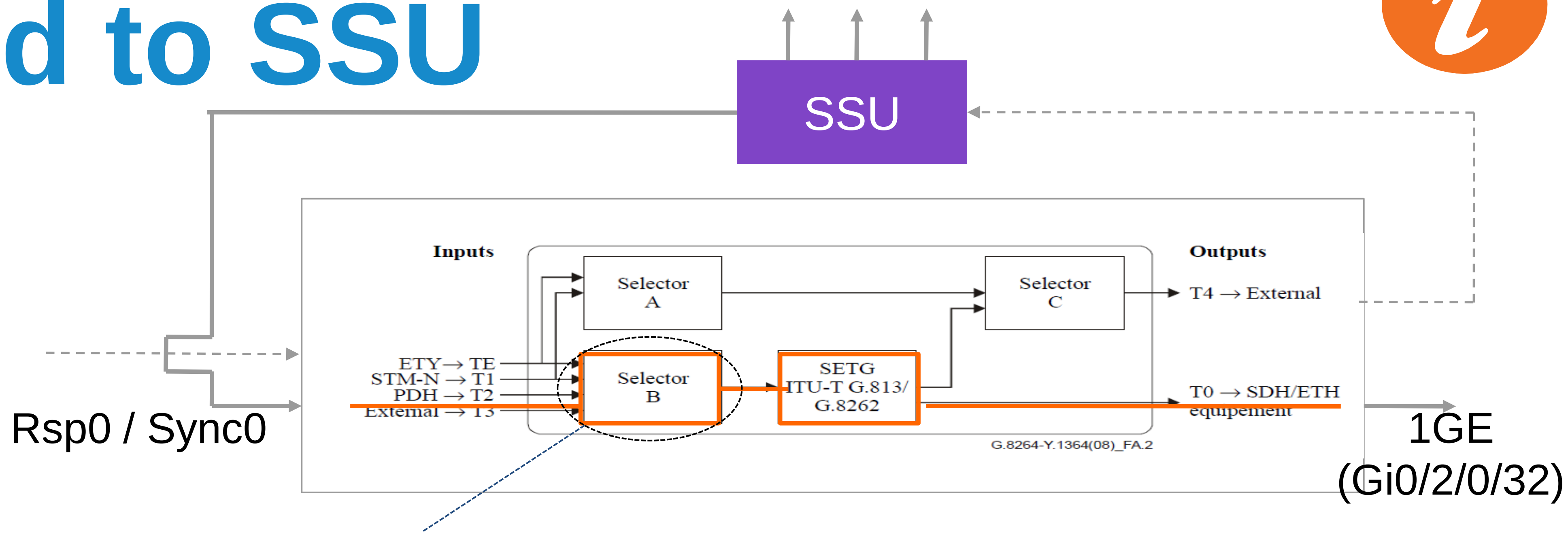



```
RP/0/RSP0/CPU0:201-14#show frequency synchronization selection
Thu Apr 14 13:22:44.065 UTC
Node 0/RSP0/CPU0:
==============
...
Selection point: T4-SEL-C (2 inputs, 1 selected)
  Last programmed 00:00:14 ago, and selection made 00:00:07 ago
  Next selection points
    SPA scoped    : None
    Node scoped   : None
    Chassis scoped: None
    Router scoped : None
  Used for local clock interface output
  S  Input                  Last Selection Point        QL  Pri  Status
  == ====================== ======================= ===== === ==========
  1  TenGigE0/1/0/0         0/RSP0/CPU0 T4-SEL-A 1    PRC   20  Locked
     Sync0 [0/RSP0/CPU0]    0/RSP0/CPU0 T0-SEL-B 1    PRC    5  Available
```

Implicit Implementation:
External Input will never drive External Output

Node connected to SSU

Cisco IOS XR Verification

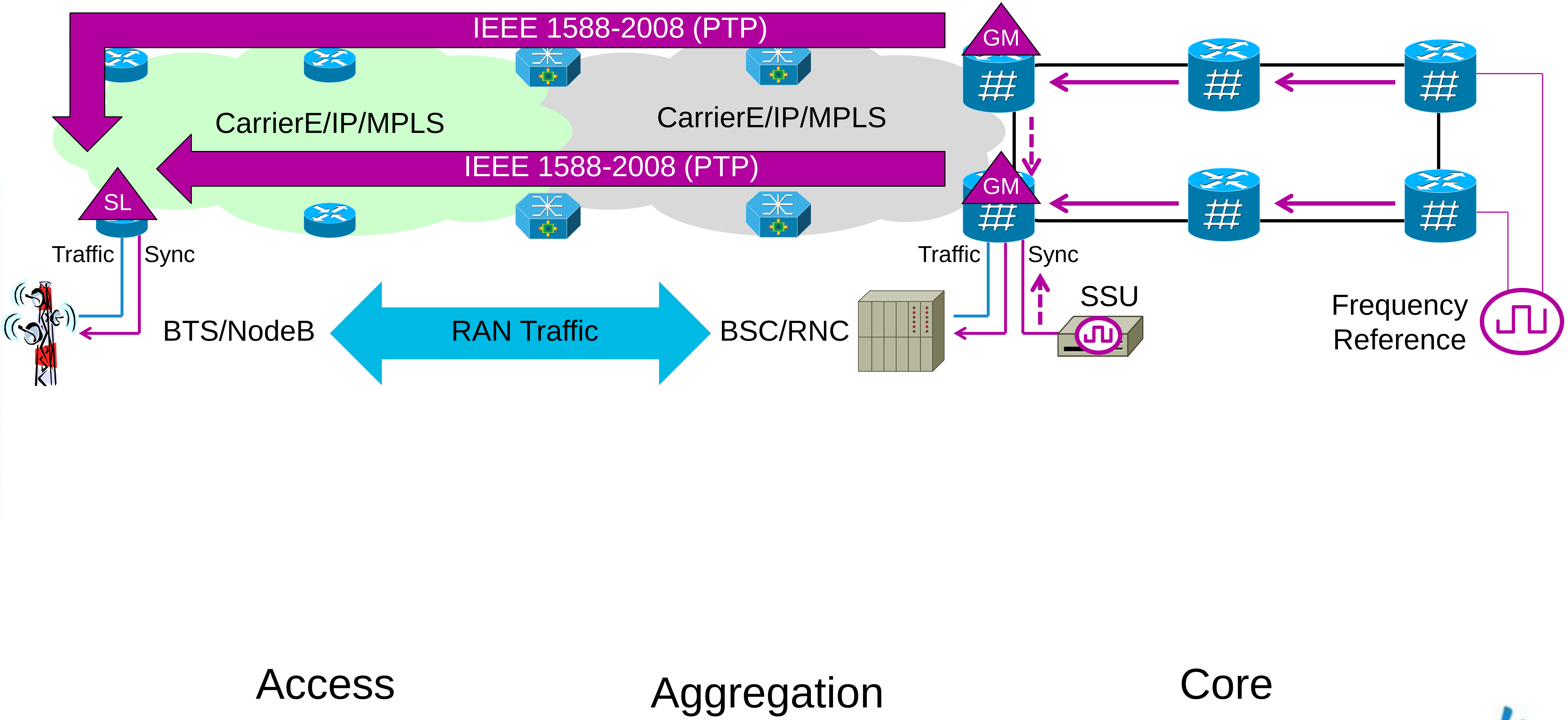



```
RP/0/RSP0/CPU0:201-14#show frequency synchronization selection
Thu Apr 14 13:22:44.065 UTC
Node 0/RSP0/CPU0:
==============
Selection point: T0-SEL-B (3 inputs, 1 selected)
  Last programmed 00:00:15 ago, and selection made 00:00:07 ago
  Next selection points
    SPA scoped     : None
    Node scoped    : T4-SEL-C
    Chassis scoped: LC_TX_SELECT
    Router scoped : None
  Used for local line interface output
  S  Input                    Last Selection Point        QL  Pri  Status
  == ======================== ======================== ===== === ==========
  1  Sync0 [0/RSP0/CPU0]      n/a                         PRC   5  Locked
     TenGigE0/1/0/0           0/1/CPU0 ETH_RXMUX 1        PRC  20  Available
     Internal0 [0/RSP0/CPU0]  n/a                         SEC 255  Available
```

External Input preferred due to local priority

SyncE + End2End IEEE1588

SP Mobile 2G and 3G RAN Transport Evolution



BTS … Base Transceiver Station; BSC … Base Station Controller

1st Telecom Profile: ITU-T G.8265.1

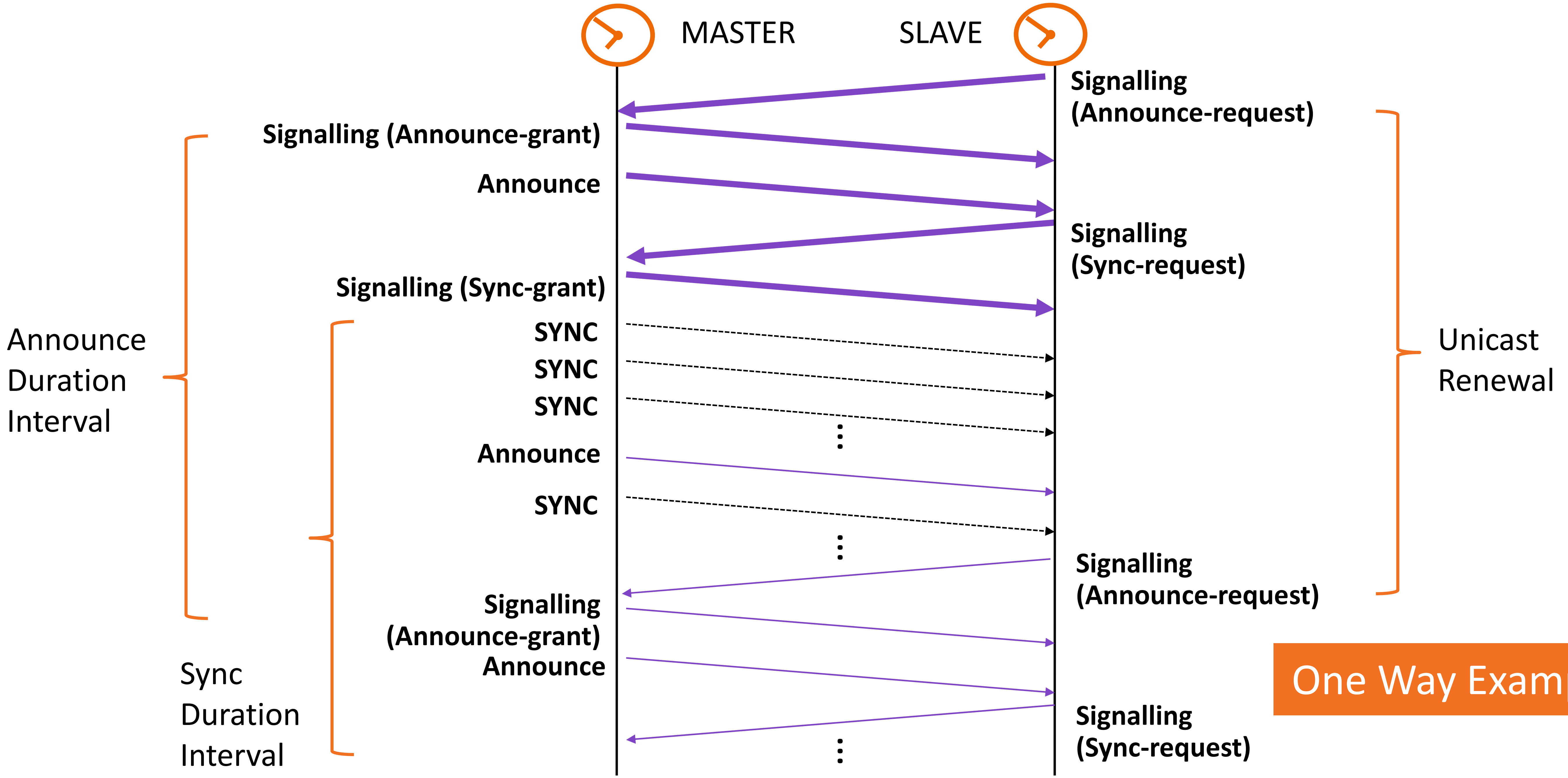
Frequency Distribution

- Supports Frequency Delivery, with no Network Assistance (to PTP)
  - Operation across managed Wide Area Networks (WANs)
  - Slave and Master only (End-to-End PTP) Model
  - IPv4 negotiated unicast transport (defined in IEEE1588-2008 as option),
- Seamless Interoperability with existing Networks
  - SONET/SDH (G.813)
  - SyncE (G.8262)
  - Quality Level for Traceability (G.781)
- Protection Scheme inline with Telecom Best Practices
  - Static master and slave port state
  - Clock selection (based on G.781 model) based on QL Values and Local Priorities

BMCA … Best Master Clock Algorithm
WAN … Wide Area Network

PTP Negotiation Message Exchange

Option to IEEE1588-2008, used by G.8265.1 1)

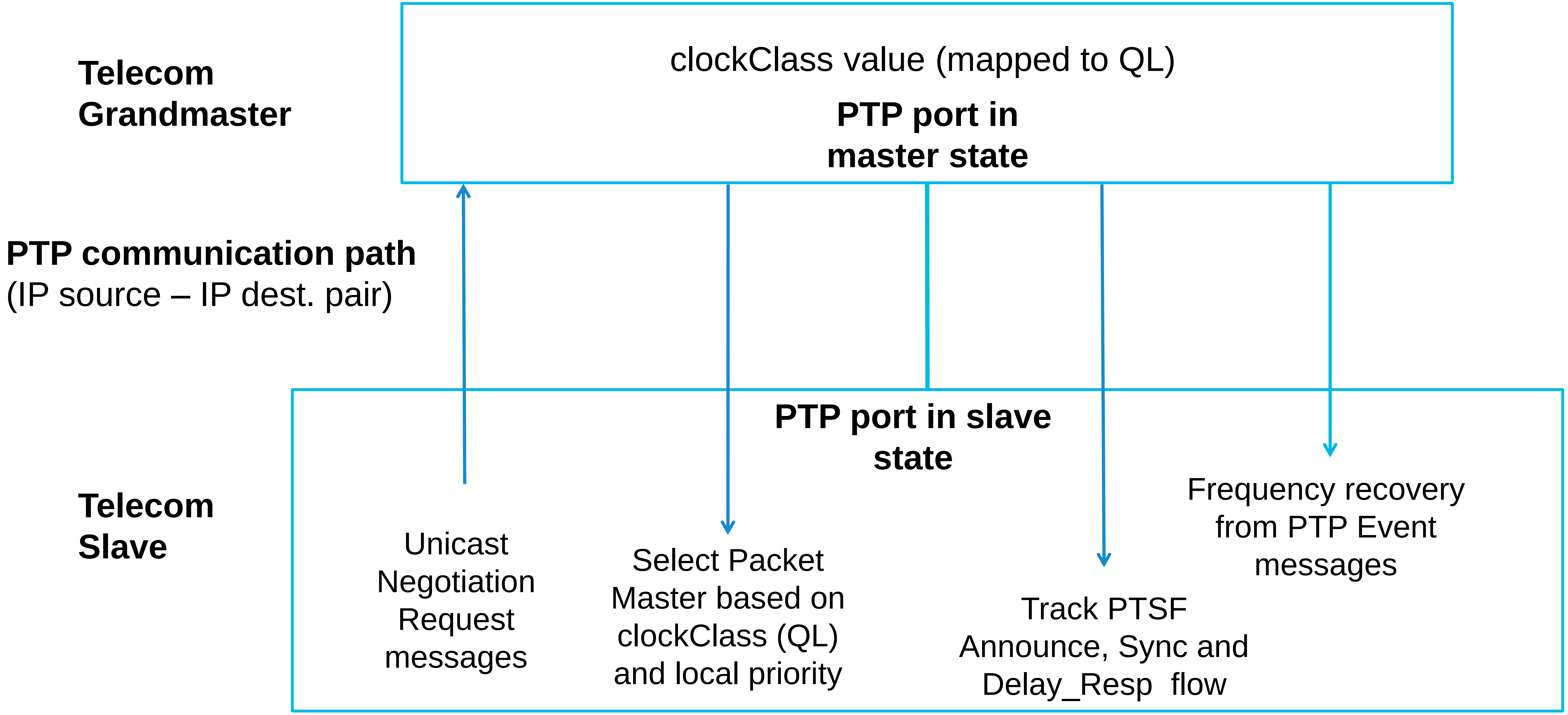


One Way Example!

G.8265.1 … PTP Telecom Profile for Frequency Synchronisation

Simplified Functional Model of G.8265.1

IEEE1588-2008 End2End Master/Slave Model



PTP Negotiation Message Exchange

Option to IEEE1588-2008, used by G.8265.1

- Slaves send requests to Master to establish PTP exchange

	One Way	Two Way
Announce	☑	☑
Sync	☑	☑
Delay_Response		☑

- Requests can be sent via multiple messages or by packing multiple TLVs in a single request message
- Messages include information on the desired message rates
- Master can grant, reject or proposes other values
- G.8265.1 Master needs to support both one- and two-way
- G.8265.1 Slave needs may use one-way or two-way

Quality Level

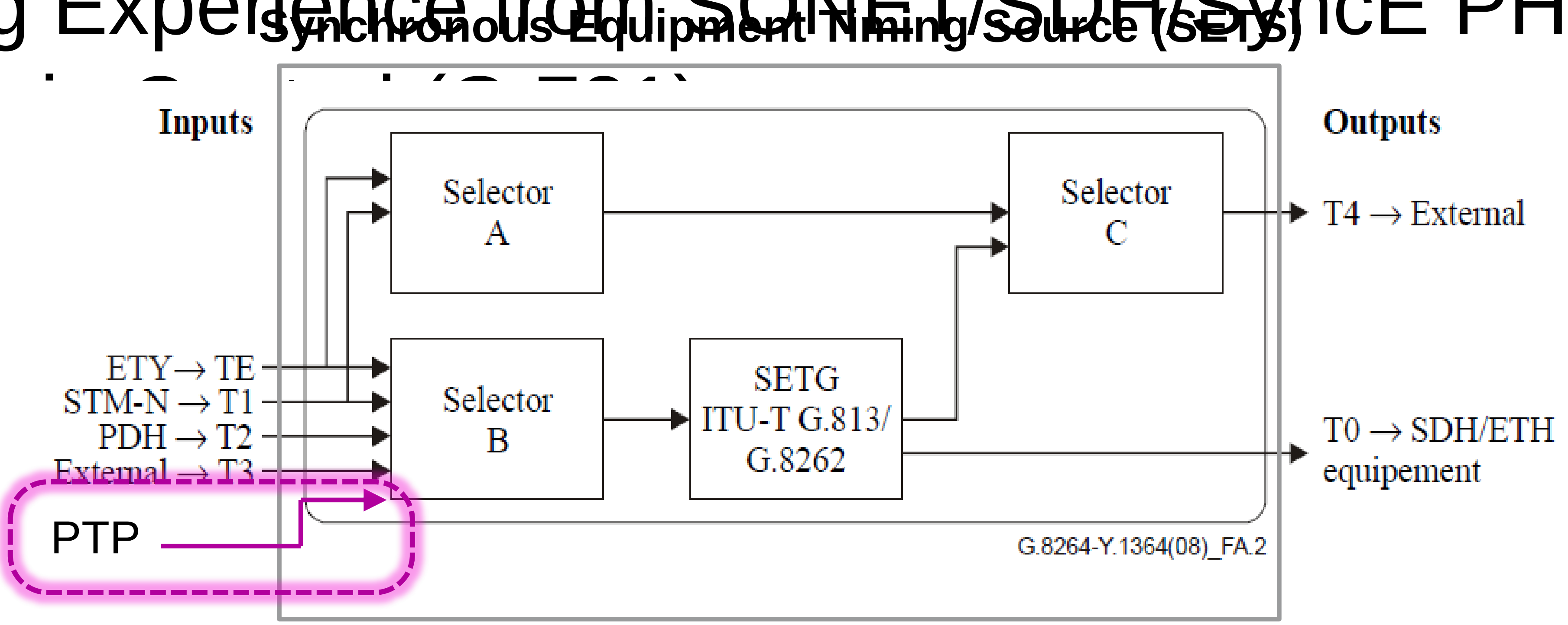
Mapping between SSM/G.781 QL and the PTP clockClass Attribute

SSM QL	G.781		ESMC		PTP Clock Class
	Option I	Option II	Option I	Option II	
0001		QL-PRS			80
0000		QL-STU			82
0010	QL-PRC				84
0111		QL-ST2			86
0011					88
0100	QL-SSU-A	QL-TNC			90
0101					92
0110					94
1000	QL-SSU-B				96
1001					98
1101		QL-ST3E			100
1010		QL-ST3		QL-EEC2	102
1011	QL-SEC		QL-EEC1		104
1100		QL-SMC			106
1110		QL-PROV			108
1111	QL-DNU	QL-DUS			110

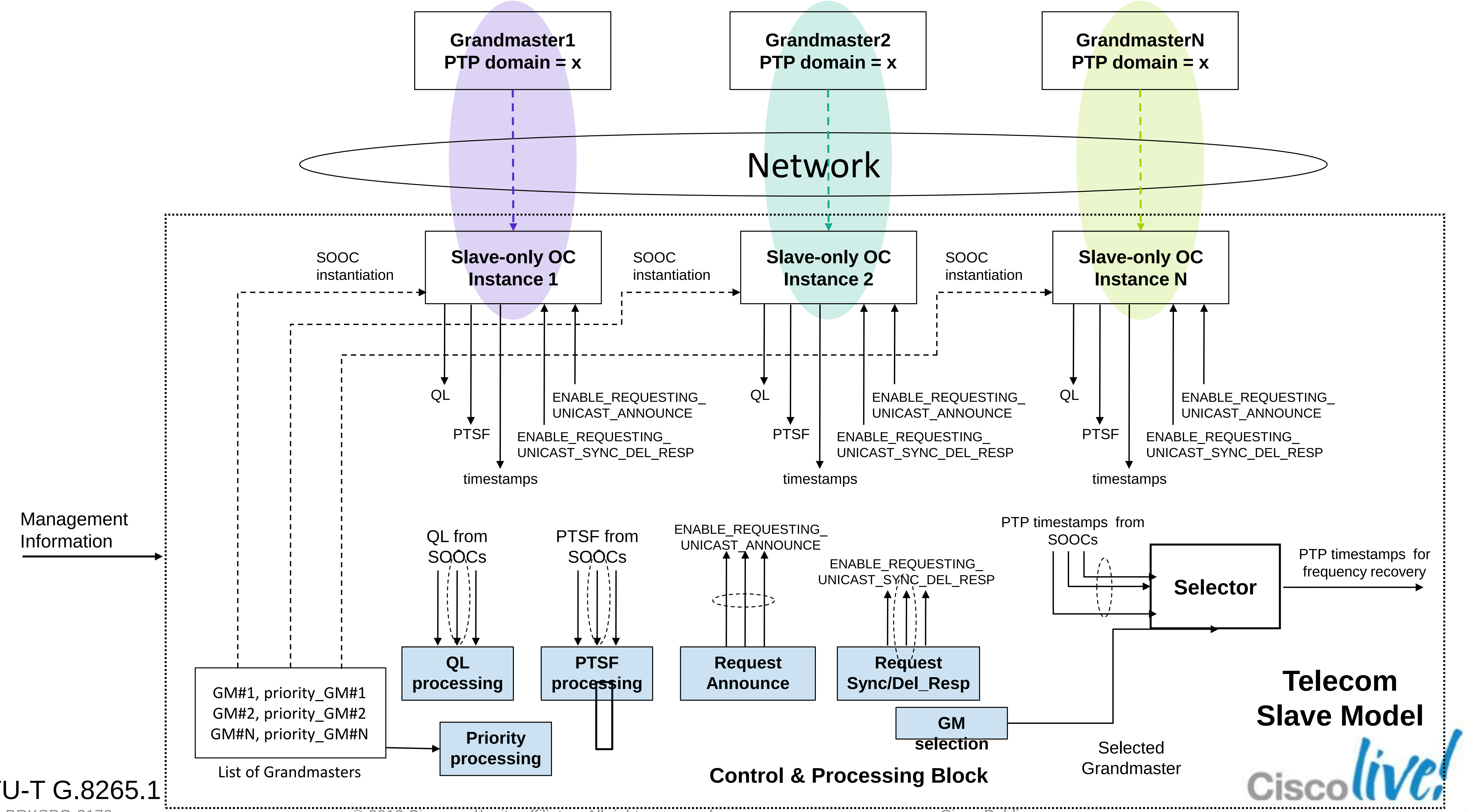
The default value should correspond to the holdover quality of the master.

Clock Selection Process

- The following parameters contribute to the master selection process:
  - Quality Level (in clockClass parameter)
  - Packet Timing Signal
  - Priority
- Leveraging Experience from SONET/SDH/SyncE PHY-layer Timing Ch



ITU-T Telecom Slave



Source: ITU-T G.8265.1

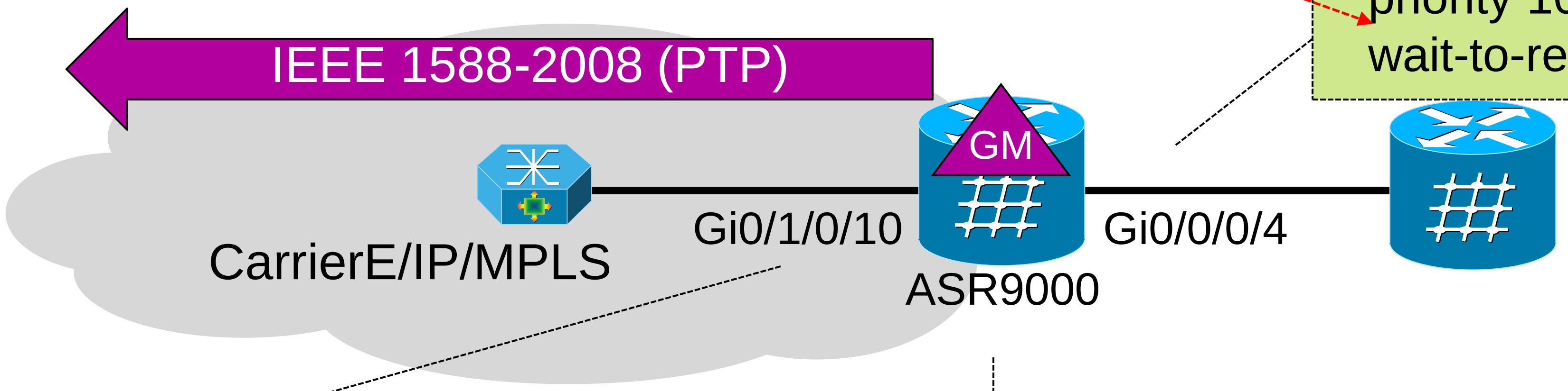
ASR9000 PTP Master Example

Gateway between SyncE and IEEE15880

PTP Master uses System Frequency

Drive System Frequency by SyncE Line

```
interface gi 0/0/0/4
 frequency synchronization
  selection input
  priority 10
  wait-to-restore 0
```



Interface Freq-Sync Configuration

Interface PTP Configuration

```
interface gi 0/1/0/10
 ipv4 address 2.205.209.2/30
 ptp
  profile Master
```

PTP has to be configured per port

Number of Del-req Messages per Second sent by the Master

Global PTP Configuration

```
ptp
 clock domain <0..255>
 clock priority1 <0..255>
 clock priority2 <0..255>

ptp profile Master
 announce interval <1..16>
 sync frequency <1..64>
 delay-request frequency <1..64>
```

Default = 0, user-defined up to 127

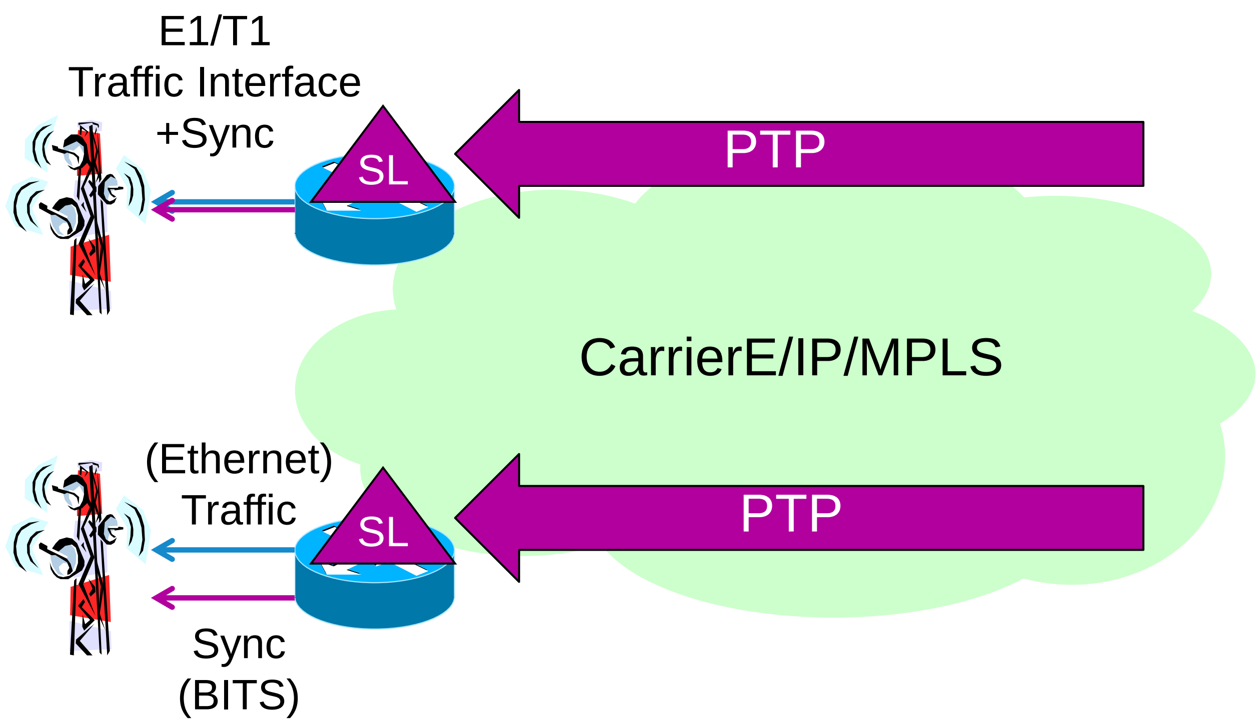
Priority must be lower value than on Slaves

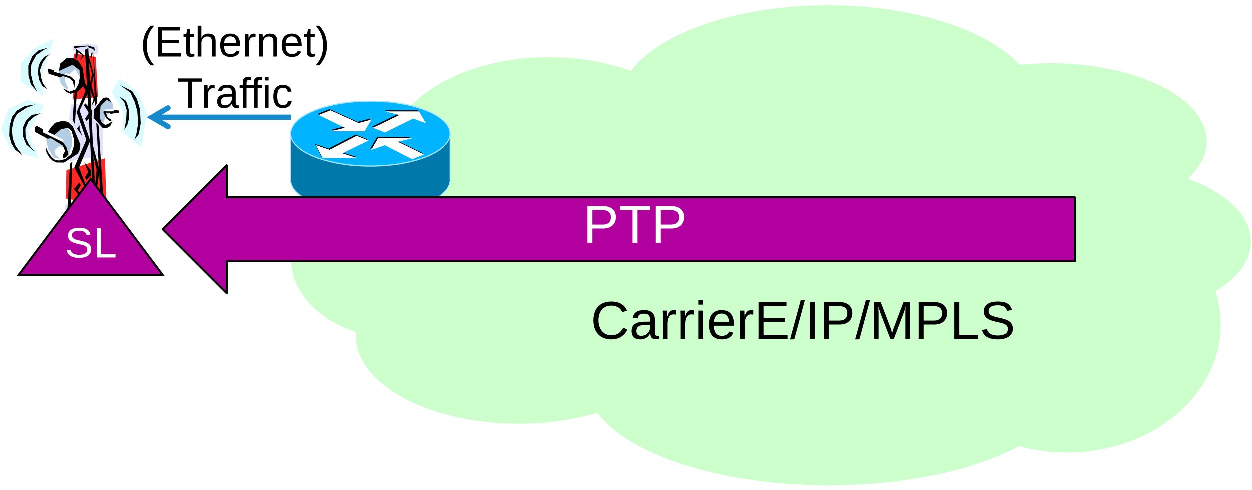
Seconds between Announce Messages

Max. Sync Messages per Second to be granted

IEEE1588-2008 Cell Site Design Options

Ordinary Slave on Base Station vs Cell Site Router





- "Legacy" Base Stations
  - Frequency Recovery on Cell Site Router (CSR)
  - E1/T1 Clock is driven by CSR System Frequency
- Ethernet Base Stations
  - Need external Timing Interface to provide Frequency

- Ordinary Slave implemented on Base Station directly
- CSR is part of the "RAN cloud" which is transparent to IEEE1588

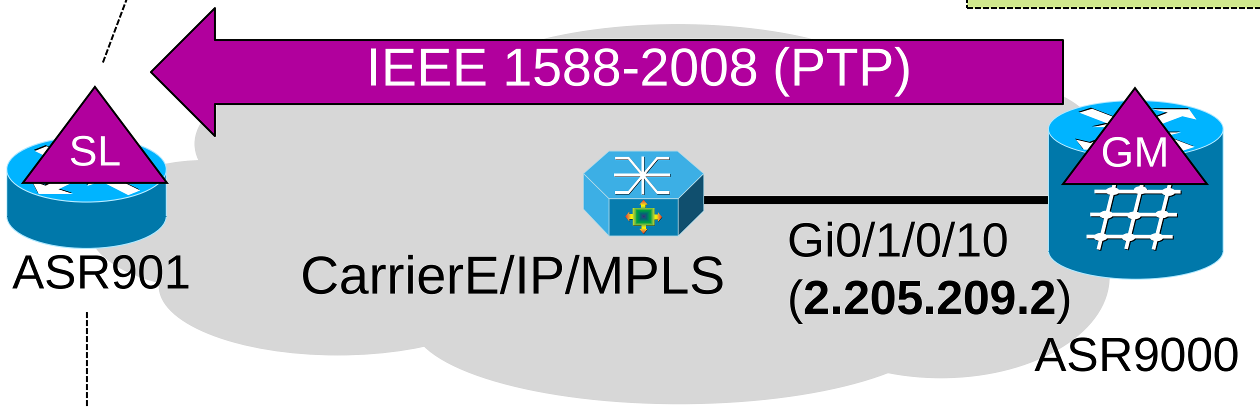
CSR … Cell Site Router

ASR901 PTP Slave Example

Recovering Frequency via IEEE1588

Global IP Configuration

```
interface Loopback1588
 ip address 15.88.0.231 255.255.255.255
```



This is the Source IP Address of the Slaves PTP Session that the Master will see

Default = 0, user-defined up to 127

Global PTP Configuration

```
ptp clock ordinary domain <0..255>
 priority1 <0..255>
 priority2 <0..255>

 clock-port ASR9000 slave
  sync interval -6
  delay-req interval -6
  transport ipv4 unicast interface Lo1588 negotiation
  clock source 2.205.209.2
```

2^6=64 Sync Messages per Second to be negotiated with GrandMaster (range: -7..1)

64 Del-req Messages per Second to be negotiated with GrandMaster (range: -7..5)

Default=128, Priority must be higher value than on GrandMaster

Slave will contact Master and negotiate Parameters via TLVs

ASR901 PTP Slave Example

SETS and Frequency Distribution to Base Station

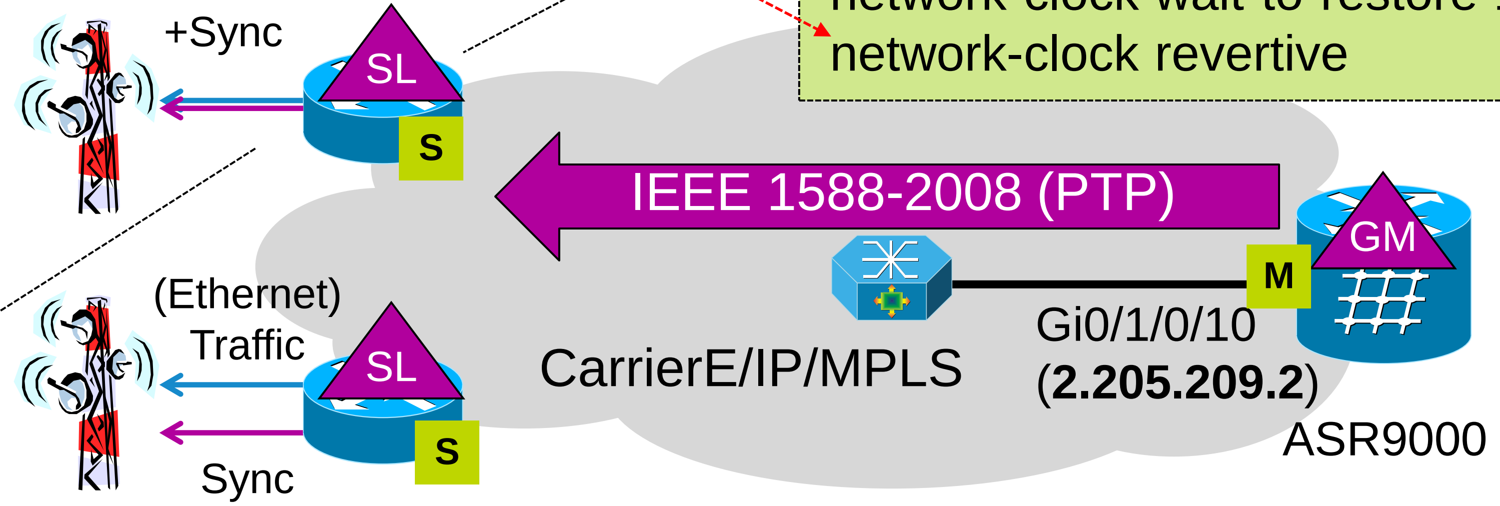
Enable G.781 compliant Clock Selection

Wait 100 seconds before considering a restored Input for Selection again (default=300sec)
“Revertive” → automatically switch back

Common Global Network-Clock Configuration

```
network-clock synchronization automatic
network-clock synchronization mode QL-enabled
network-clock input-source 10 interface ToP0/12
network-clock wait-to-restore 100 global
network-clock revertive
```

E1/T1 Traffic Interface +Sync



Sync (BITS)

Configure IEEE1588 recovered Frequency as valid Source

Frequency provided via External Timing Output (BITS)

```
network-clock output-source system 10 External 0/0/0
```

All E1/T1 Interfaces are using System Frequency per default

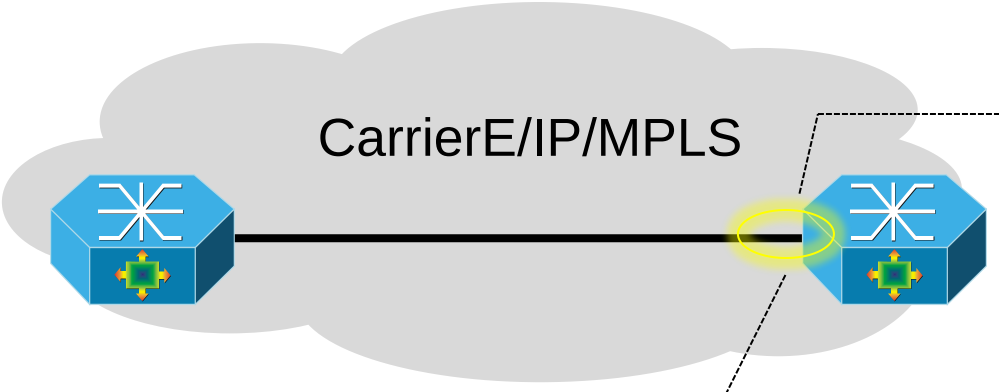
```
ASR901#show controllers e1 0/0
E1 0/0 is up.
  Applique type is Channelized E1 - balanced
  ...
  Framing is crc4, Line Code is HDB3, Clock Source is Internal
```

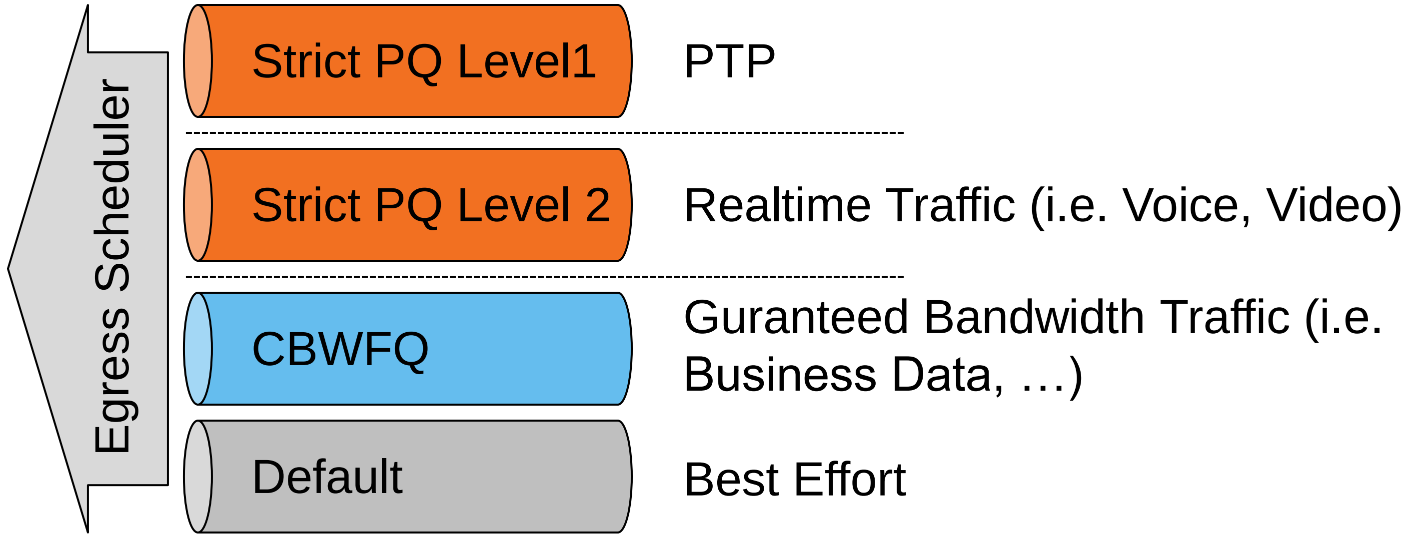
IEEE1588 Transport in Access/Aggregation

- Security
  - EoMPLS
  - VPLS
  - L3 MPLS VPN
- Packet Delay Variation
  - Packet Marking
  - Priority Queuing
- Performance/SLA Monitoring
  - IP SLA
  - Y.1731
- Transport Caveats such as Microwave Links

Quality of Service for IEEE1588-2008

Queuing - Guaranteed Transport for PTP






```
interface GigabitEthernet2/30
 service-policy output ptp
```

QoS is activated by referencing the policy-map under the interface

```
class-map match-all ptp
 match dscp ef

policy-map ptp
 class ptp
  police cir percent 5
  priority level 1
 class voice
  police cir percent 10
  priority level 2
 class business
  bandwidth percent 50
 class class-default
  random-detect
```

Strict PQ

CBWFQ

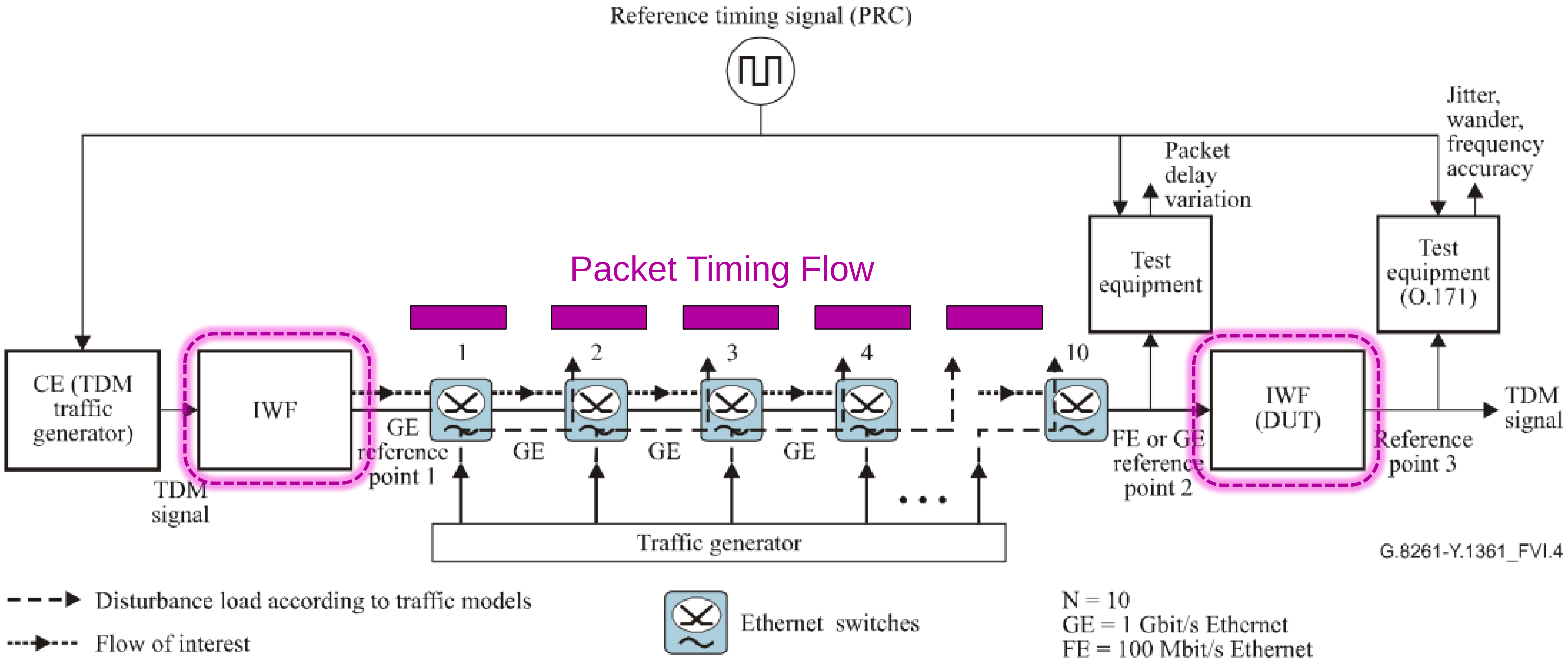
WRED

QoS is defined via
1. class-maps (Traffic?)
2. policy-maps (Action?)

CBWFQ … Class Based Weighted Fair Queuing
PQ … Priority Queuing   WRED … Weighted Random Early Discard

ITU-T Rec for Evaluating Impact of PDV

G.8261 – Timing and Synchronisation Aspects in Packet Network

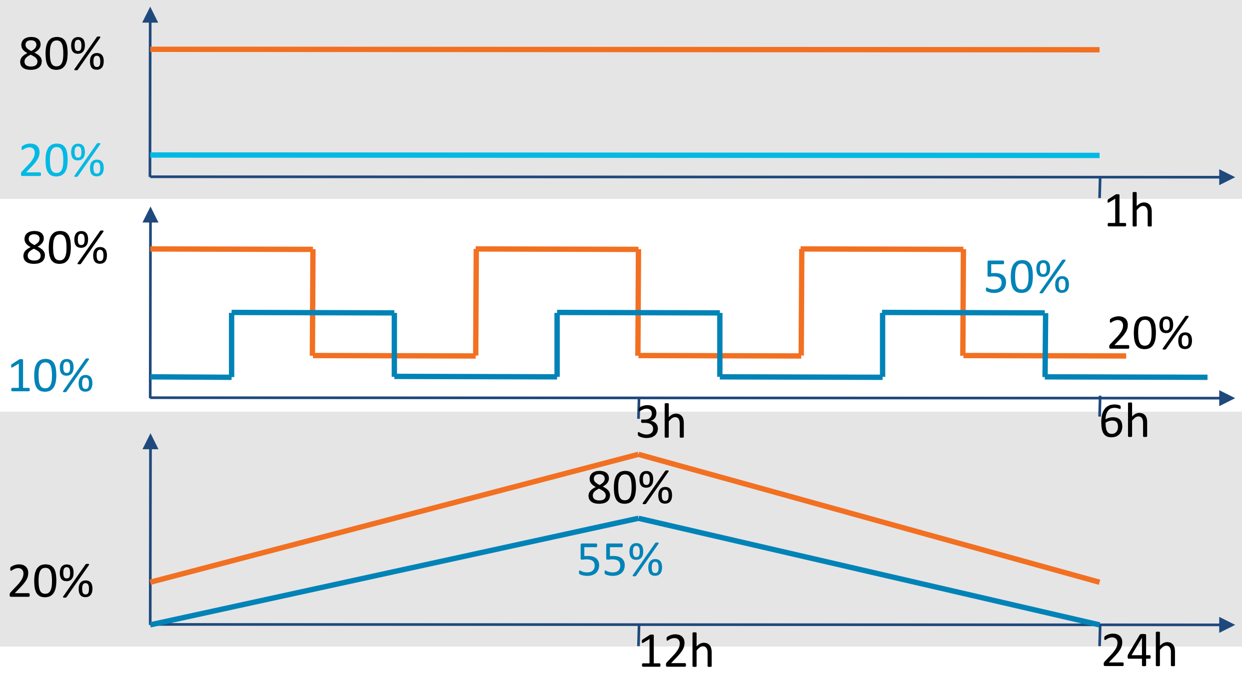


Simulated Network Load

ITU-T G.8261 – Timing & Sync Aspects in PSNs

- Appendix VI.5 – Test for Two Way Protocols
- Baseline Test (no Network → Master/Slave back to back)
- Performance Tests (Network & Load)

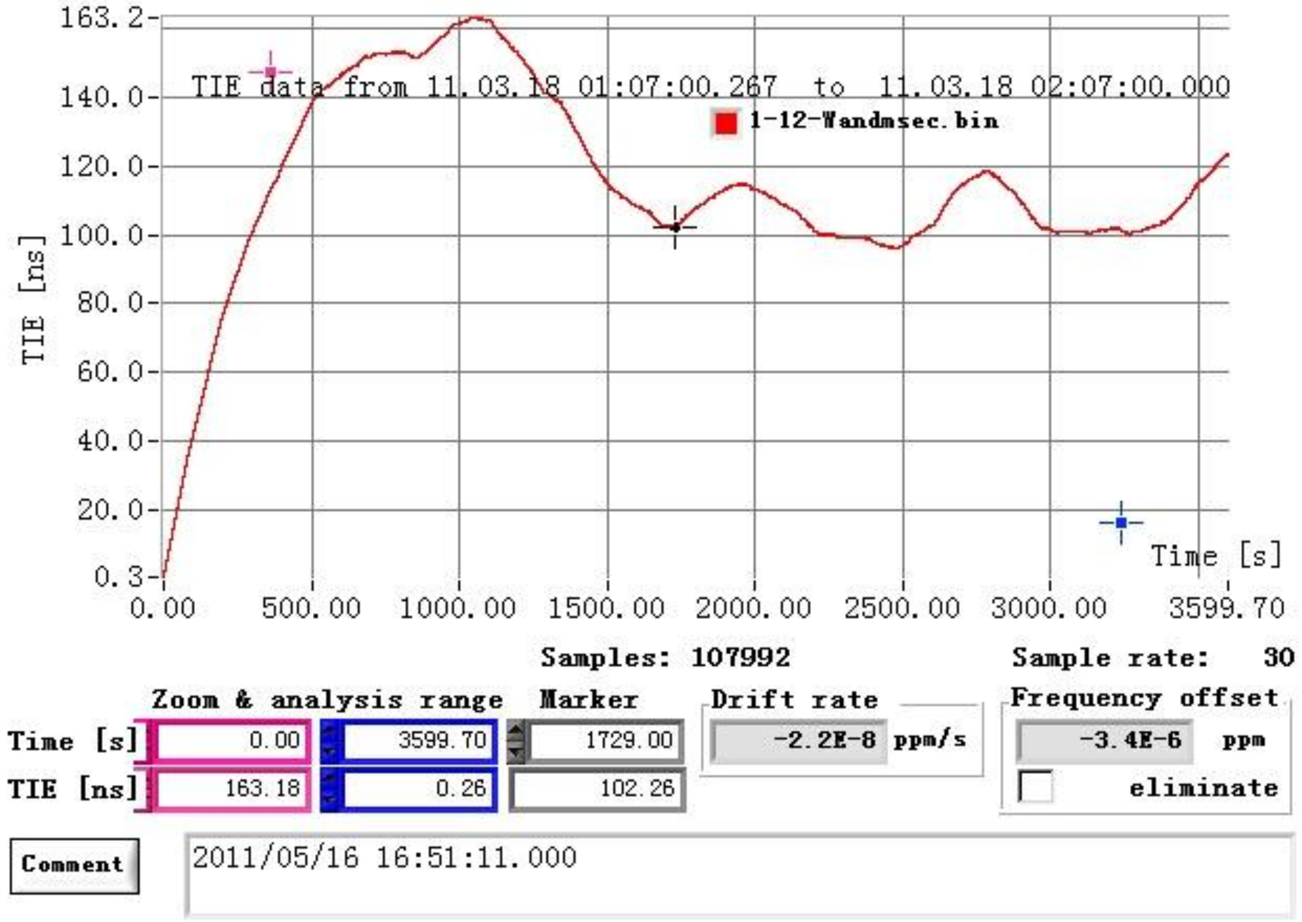
Test Case	Description	Network Load
12	Static Packet Load	
13	Sudden large and persistent Load Changes	
14	Slow Load Change over extremely long Time	
15	Temporary Network Outage	
16	Temporary Congestion	
17	Routing Changes caused by failures	



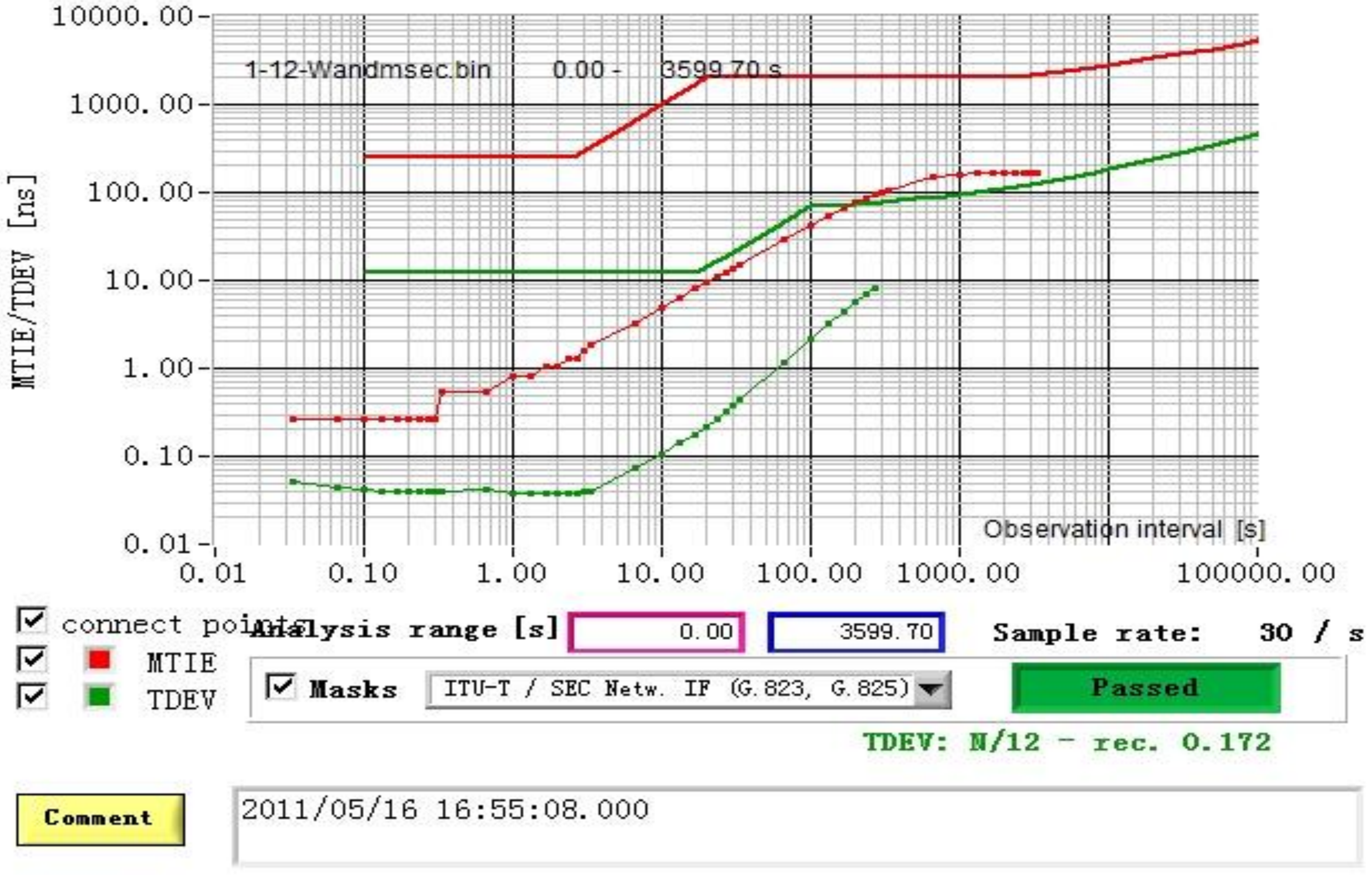
G.8261 – Test Case 12 Results

OC Slave, MWR2941, Cisco IOS 15.1(1)MR, 10 hops

Frequency - TIE



Frequency – MTIE/TDEV



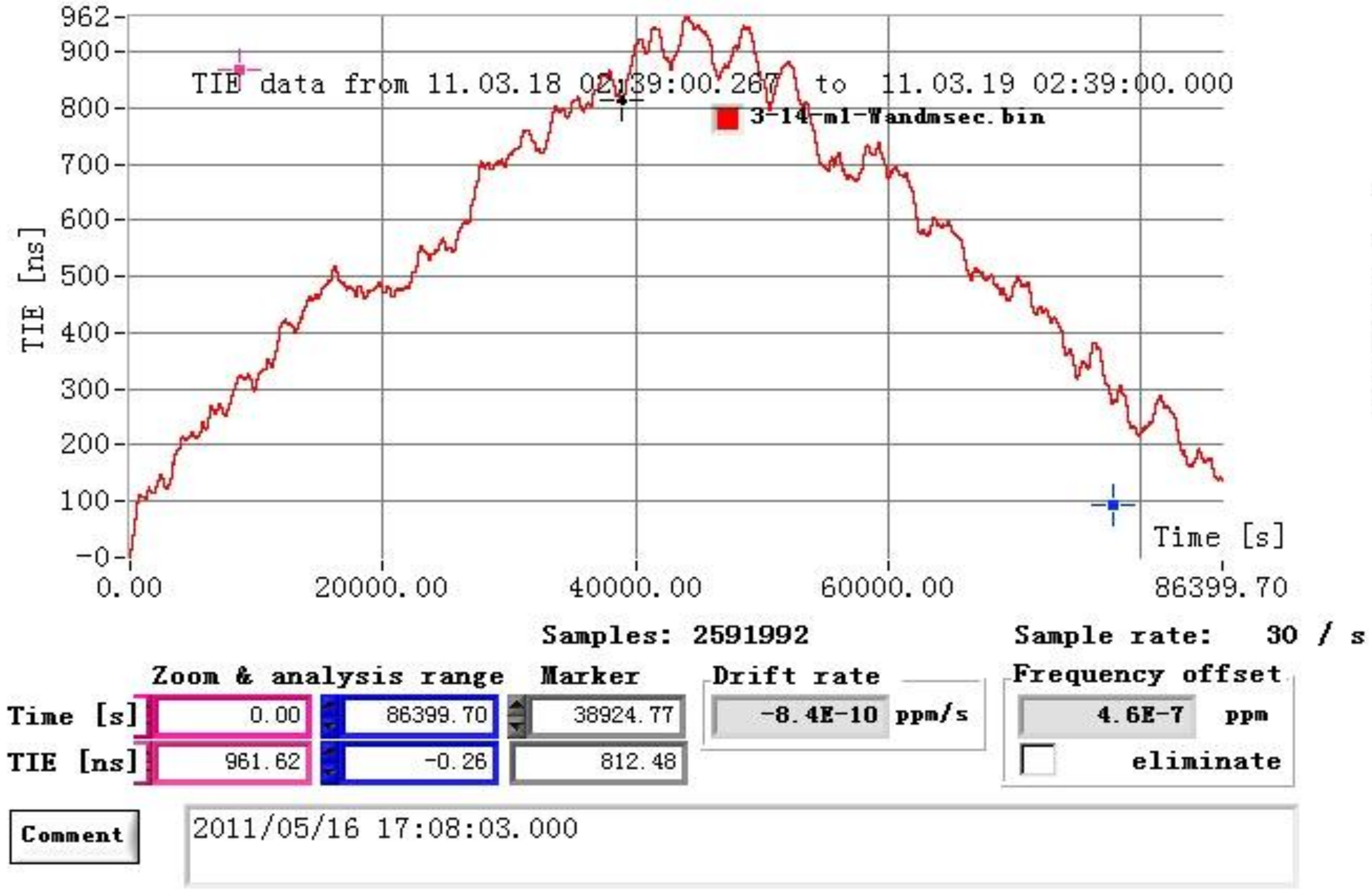
Network Load

OC … Ordinary Clock

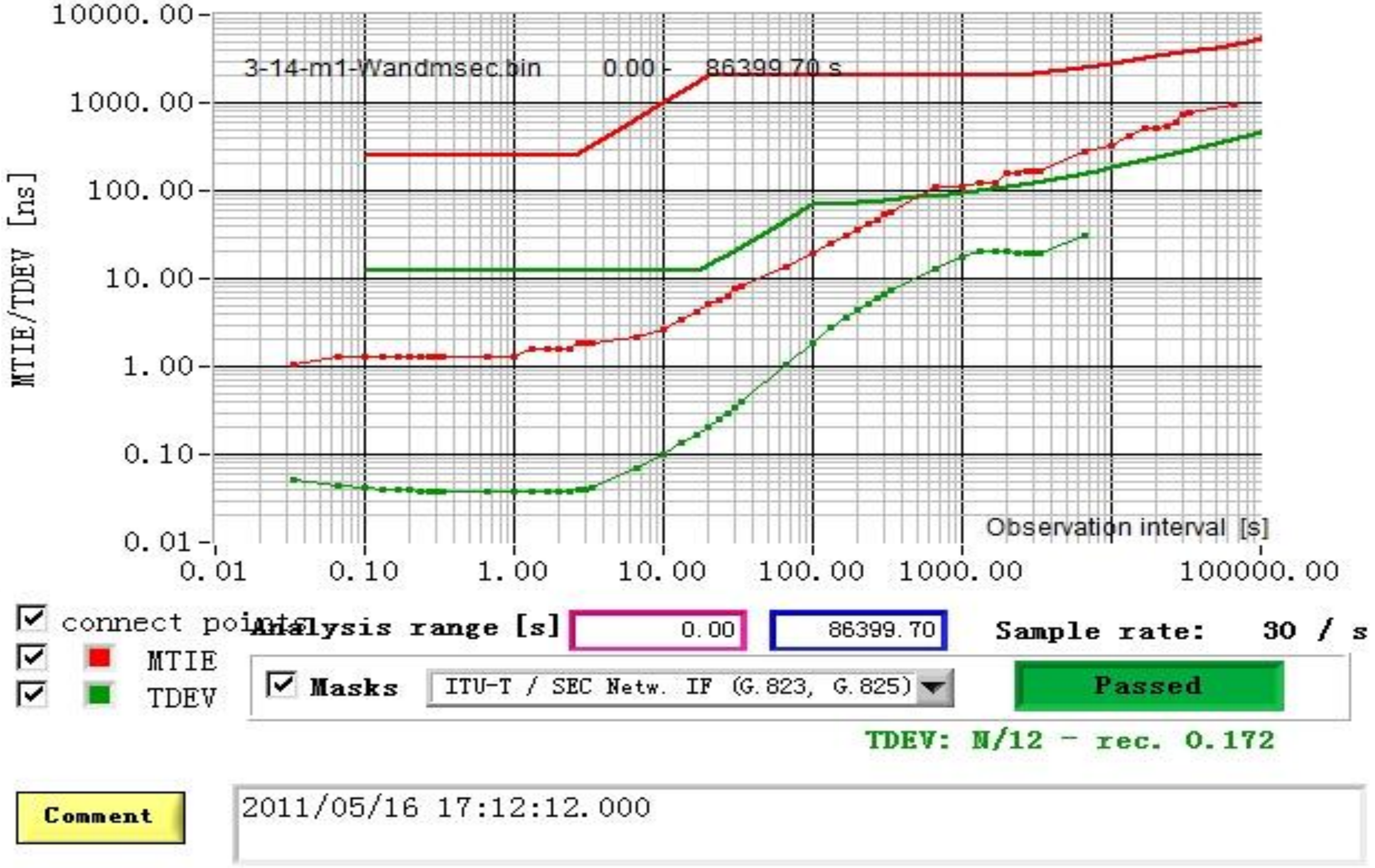
G.8261 – Test Case 14 Results

OC Slave, MWR2941, Cisco IOS 15.1(1)MR, 10 hops

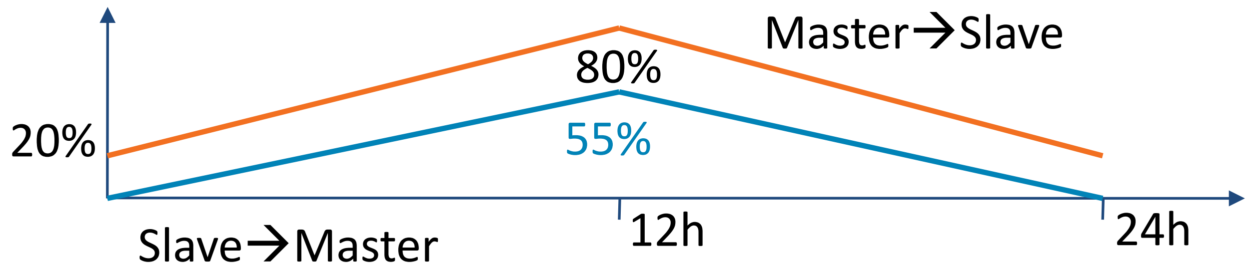
Frequency - TIE



Frequency – MTIE/TDEV



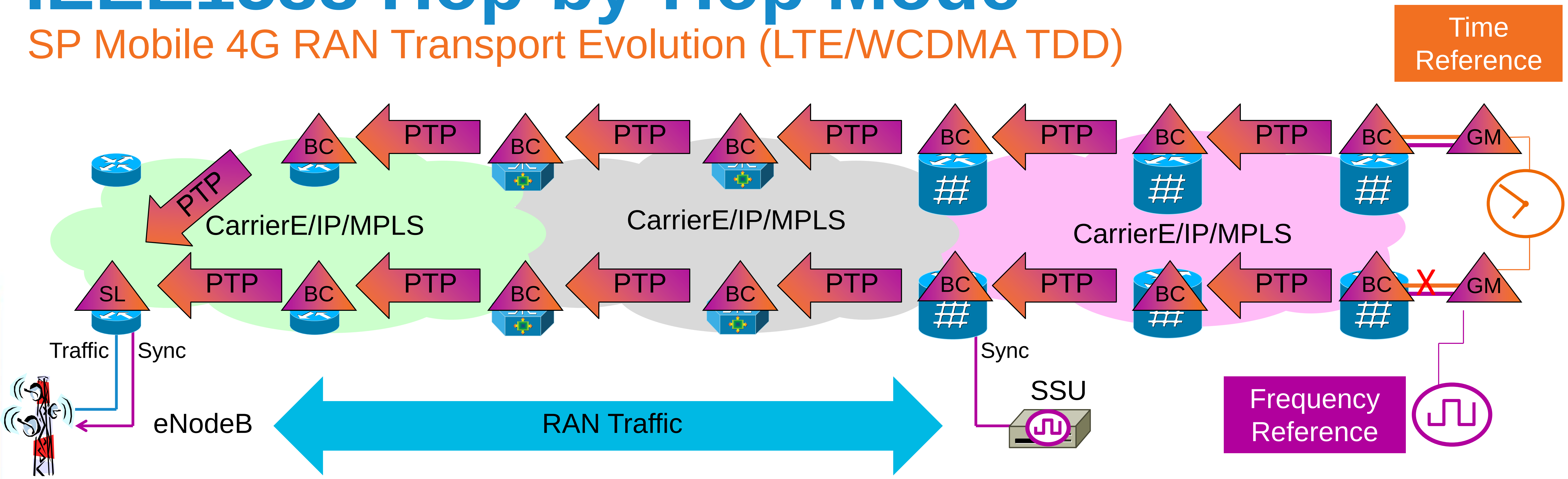
Network Load



OC … Ordinary Clock

IEEE1588 Hop-by-Hop Mode

SP Mobile 4G RAN Transport Evolution (LTE/WCDMA TDD)



Access

Aggregation

Core

eNodeB … Enhanced NodeB

2nd Telecom Profile: ITU-T G.8275

Time/Phase Transfer

Work in progress !!
Only early draft

- Full network assistance for IEEE1588/PTP
- Hop-by-hop distribution model: chain of Telecom BCs (T-BCs)
- Physical layer frequency (hybrid mode) recommended
  - T-TSC and T-BC syntonisation and holdover
- Mapping: Ethernet (confirmed), IP (to be discussed)
- Transmission: Layer 2 multicast (confirmed), IP (to be discussed)
- Mode: two-way only, one- and two-step
- BMCA: TBD
  - Master and Slave Port State again static on T-TSC and T-GM as in G.8265.1
- Network limit and node characterisation: TBD
  - G.827x Specifications (work in progress)

T-TSC … Telecom Time Slave Clock   T-BC … Telecom Boundary Clock
T-GM … Telecom Grand Master

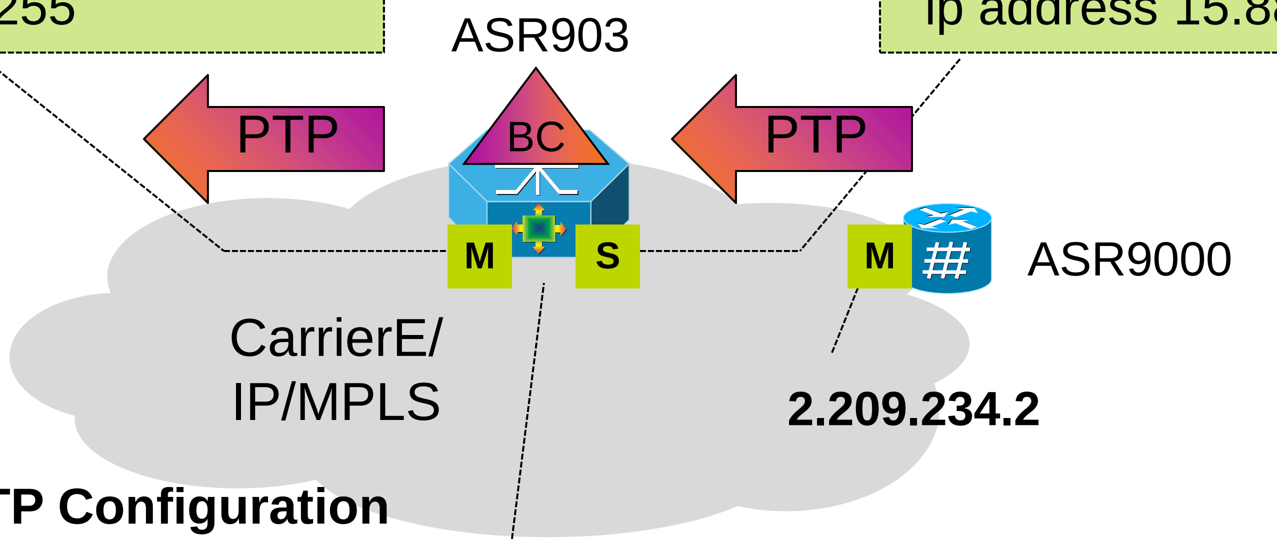
ASR903 Boundary Clock Example

Global IP Configuration

```
interface Loopback102
 ip address 15.88.2.234 255.255.255.255
```

Global IP Configuration

```
interface Loopback101
 ip address 15.88.1.234 255.255.255.255
```



Boundary Clock Master Port that will grant downstream BCs or Ordinary Slave requests

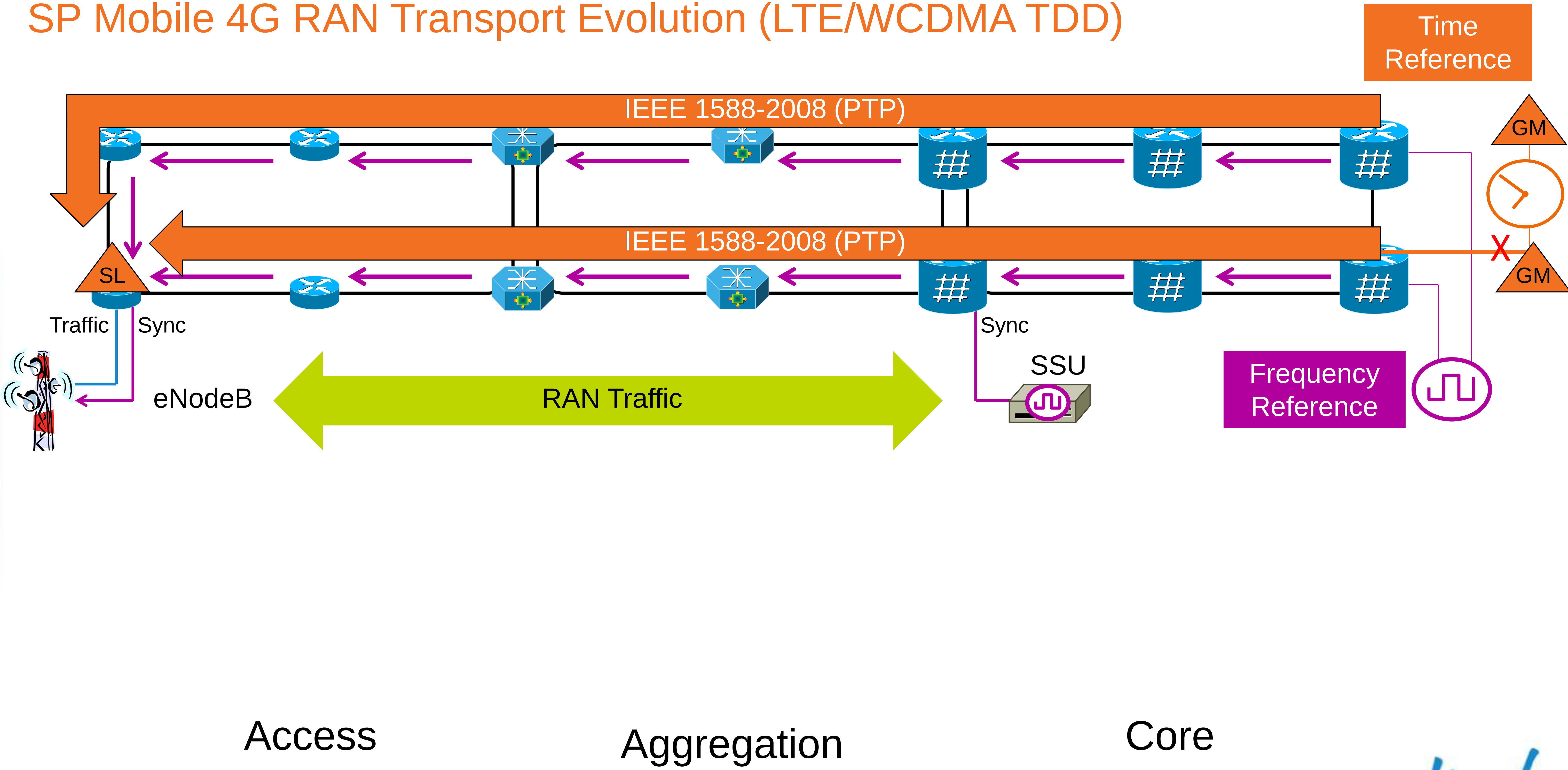
Slave Port of Boundary Clock will contact upstream BC or GM

Global PTP Configuration

```
ptp clock ordinary domain <0..255>
 priority1 <0..255>
 priority2 <0..255>

 clock-port ASR9000 slave
  sync interval -6
  delay-req interval -6
  transport ipv4 unicast interface Lo101 negotiation
  clock source 2.209.234.2

 clock-port ASR90x master
  sync interval -6
  delay-req interval -6
  transport ipv4 unicast interface Lo102 negotiation
```

IEEE1588 End2End Hybrid Mode

SP Mobile 4G RAN Transport Evolution (LTE/WCDMA TDD)



eNodeB … Enhanced NodeB

Node connected to NodeB or BTS

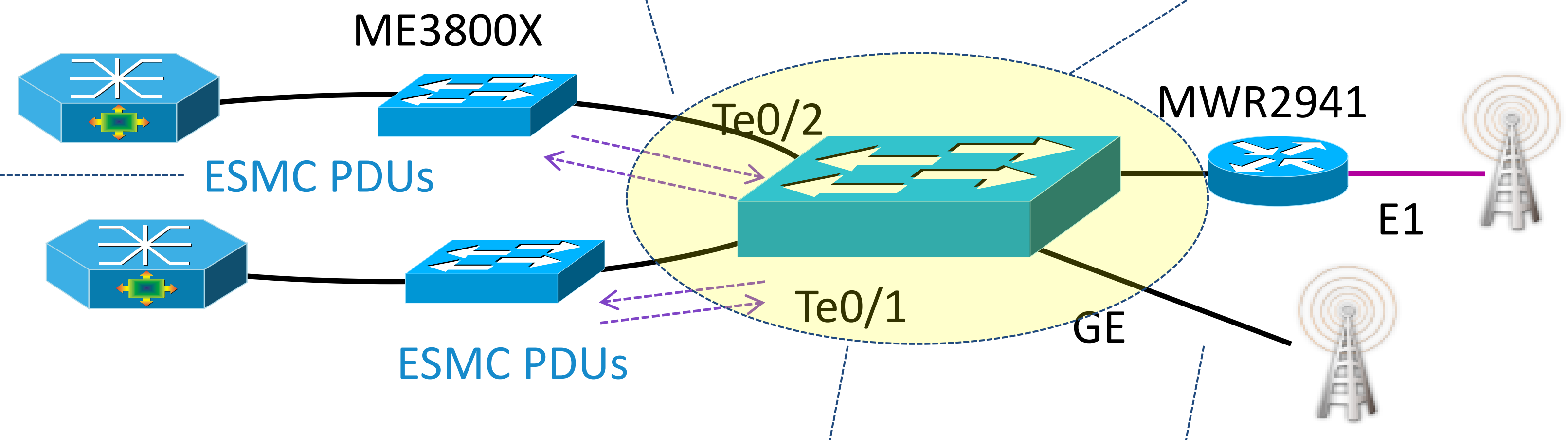
Cisco IOS Configuration – ME3600/3800X

- SETS Configuration Options similar to Cisco7600

network-clock **input-source** 10 interface TenGigabitEthernet0/1
network-clock input-source 20 interface TenGigabitEthernet0/2

network-clock synchronization automatic
network-clock synchronization mode QL-enabled

esmc process



1GE & 10GE Interfaces are per default in “Line” Mode

interface TenGigabitEthernet0/1
synchronous mode
interface TenGigabitEthernet0/2
synchronous mode

interface GigabitEthernet0/2
synchronous mode

If not “selected” Source Interface takes Clock from System (Internal)

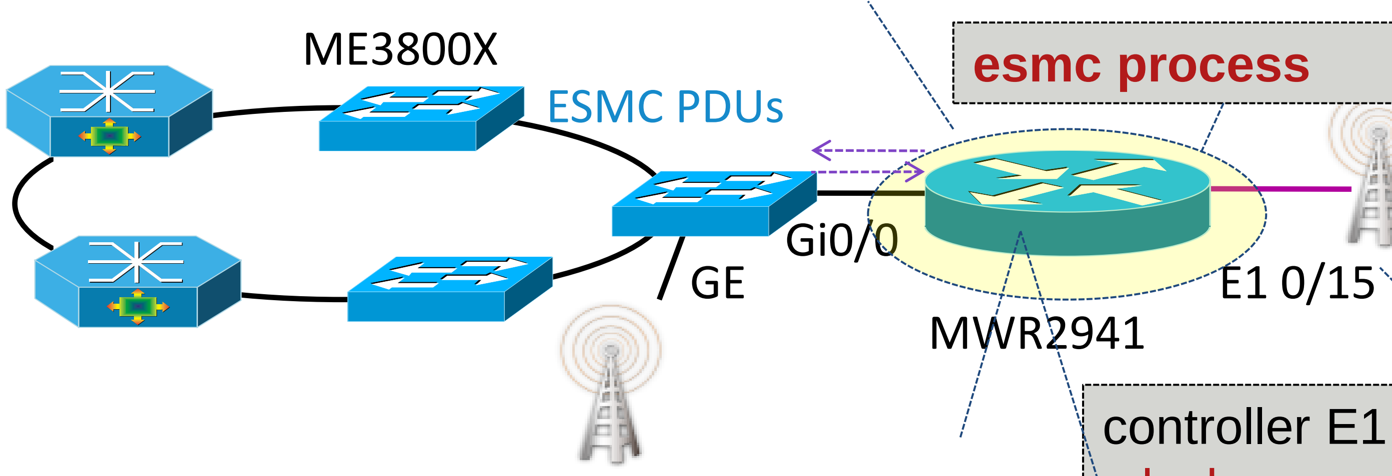
Node connected to NodeB or BTS

Cisco IOS Configuration – MWR2941

G.781 Compliant Clock Selection

```
network-clock synchronization automatic
network-clock synchronization mode QL-enabled
network-clock-select hold-timeout infinite
network-clock-select mode nonrevert
```

```
esmc process
```



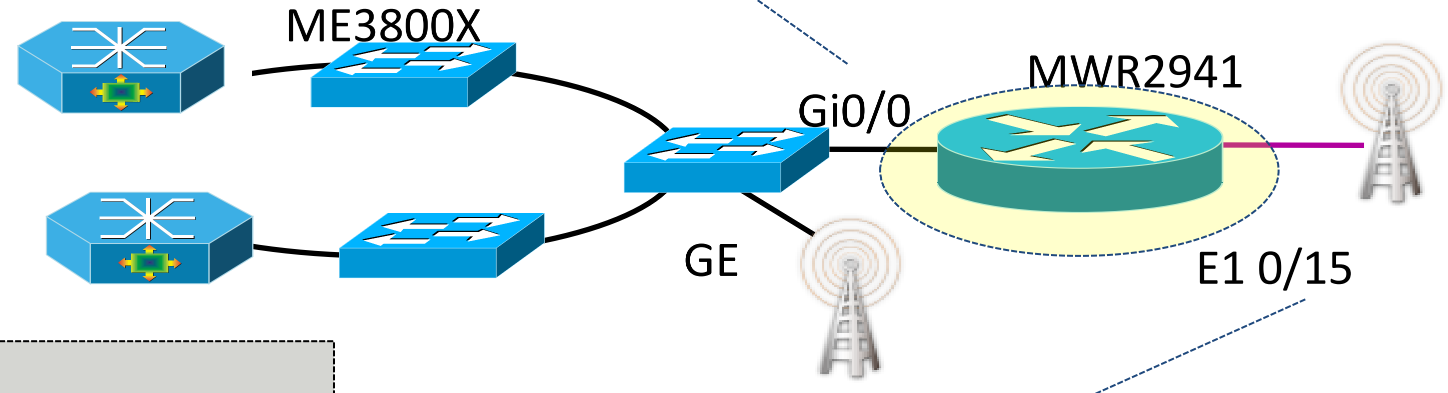

```
controller E1 0/15
 clock source internal
```

```
interface GigabitEthernet0/0
 synchronous mode
```

```
network-clock input-source 10 interface GigabitEthernet0/0
```

Priority Based Clock Selection

```
network-clock-select 10 SYNCE 0
```




```
controller E1 0/15
 clock source internal
```

- ESMC supported
- No concurrent support of IEEE1588-2008 and SyncE

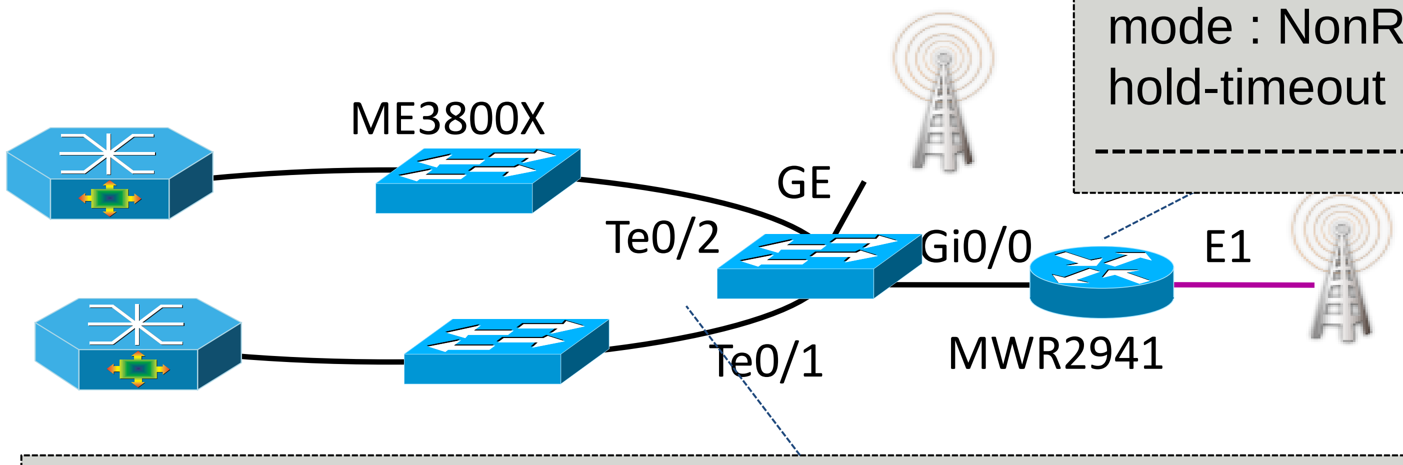
- No ESMC support
- Concurrent support of IEEE1588-2008 and SyncE

Node connected to NodeB or BTS

Cisco IOS Verification – ME3600/3800X & MWR2941

```
205-13#sh network-clocks
Network Clock Configuration
Priority  Source           Status   Type    Selected
---------------------------------------------------
 10      Gi0/0             OK       SYNCE   Y
---------------------------------------------------
 Current Clock State: LOCK
 clock input Stratum level: 3
 mode : NonRevertive
 hold-timeout : infinite
---------------------------------------------------
```

Priority Based Clock Selection

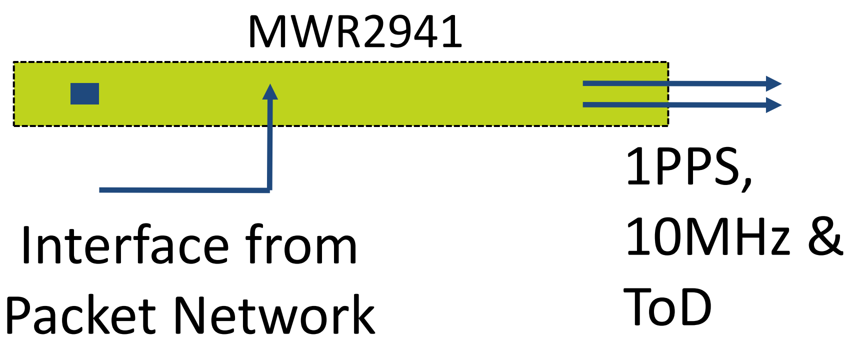


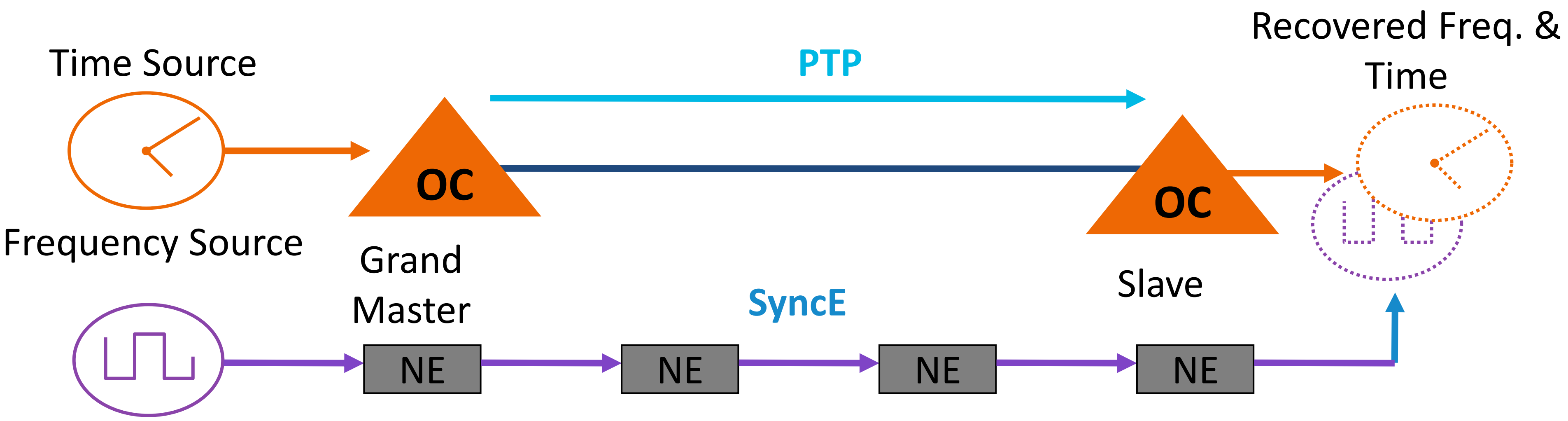
G.781 Compliant Clock Selection

```
203-15#show network-clocks synchronization
...
Nominated Interfaces
 Interface          SigType     Mode/QL      Prio  QL_IN  ESMC Tx  ESMC Rx
 Internal           NA          NA/Dis       251   QL-SEC   NA       NA
*Te0/1              NA          Sync/En      10    QL-PRC   -        -
 Te0/2              NA          Sync/En      20    QL-PRC   -        -
```

IEEE1588-2008 Hybrid Mode

Cisco IOS Configuration – MWR2941



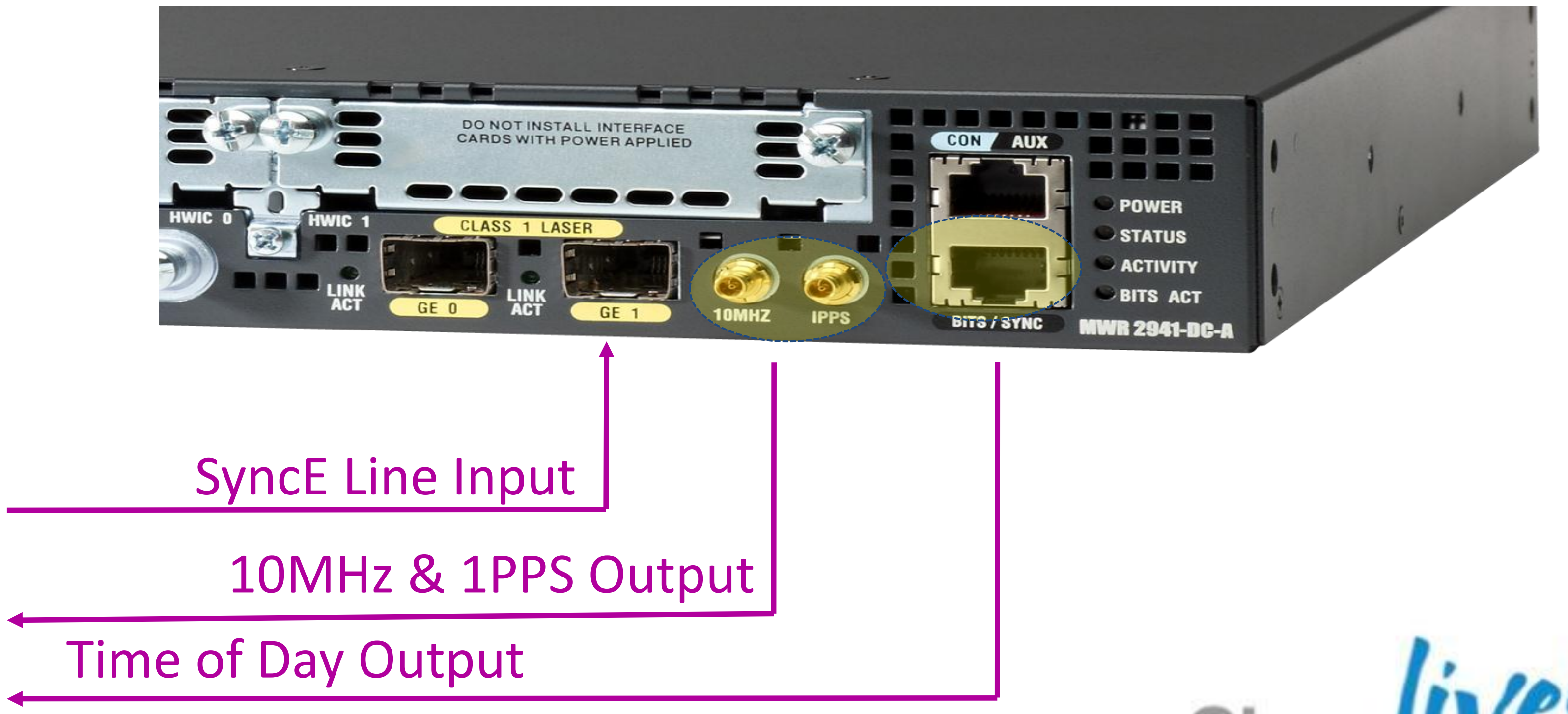


- Configuration

```
interface Vlan213
 ptp sync interval -6
 ptp delay-req interval -6
 ptp slave unicast negotiation hybrid
 ptp clock-source 25.1.0.2
 ptp enable
```

```
network-clock-select 1 SYNCE 1
```

```
ptp output 10M 1pps
ptp tod ntp
```



IEEE1588-2008 Hybrid Mode

Cisco IOS Verification – MWR2941

- SyncE Line Interface coming up

```
*Feb 22 23:58:07.935: %LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to up
*Feb 22 23:58:14.944: %NET_CLK_SEL-6-NETCLK_STATE_CHANGE: Network clock state change to LOCK (Gi0/1)
```

- Bring Interface VLAN up to enable PTP

```
*Feb 22 23:59:42.898: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan213, changed state to up
```

- PTP recovering Time and aligning to SyncE Frequency

```
*Feb 23 00:04:27.105: %TOP_MODULE-6-CLK_STATUS_CHANGE: Hybrid clock status changed to WAIT_FOR_DPLL
*Feb 23 00:04:27.109: %TOP_MODULE-5-APPL_UPDOWN: Timing over packet application is up on Vlan213
*Feb 23 00:04:29.783: %TOP_MODULE-6-CLK_STATUS_CHANGE: Hybrid clock status changed to WAIT_FOR_CLOCKSTREAM
*Feb 23 00:04:30.622: %TOP_MODULE-6-CLK_STATUS_CHANGE: Hybrid clock status changed to WAIT_FOR_ALIGN
*Feb 23 00:04:44.882: %TOP_MODULE-6-CLK_STATUS_CHANGE: Hybrid clock status changed to START_REALIGN
*Feb 23 00:04:48.238: %TOP_MODULE-6-CLK_STATUS_CHANGE: Hybrid clock status changed to DONE_REALIGN
```

Summary and Conclusion

What we have discussed

- Motivation for Synchronisation in Packet-based Networks
- Frequency and Time Synchronisation Overview
- Synchronisation Support in Cisco Products
- Deployment Considerations for
  - Industrial Solutions
  - Smart Grid
  - High Speed Trading
  - Service Providers
- Summary and Conclusion

Key Take Aways (1/2)

- Synchronisation has two aspects
  - Frequency
  - Time
- Need for Synchronisation is growing and growing
  - Service Providers → Mobile Networks
  - Industrial Solutions → more efficient Manufacturing
  - Smart Grid → replacing legacy Time Distribution with Ethernet
  - High Frequency Trading → Regulatory and Market Differentiation

Key Take Aways (2/2)

- Use Physical Frequency Distribution where ever possible
  - SyncE, SONET/SDH
- IEEE1588-2008 provides a “Toolbox” and Profiles define Framework for various Use Cases
  - IEEE1588-2008 Default Profile → Industrial Solutions & High Frequency Trading
  - ITU-T G.8265.1 PTP Profile for Frequency Synchronisation → Service Providers
  - IEEE C37.238-2011 PTP Profile for Power Systems Applications → Smart Grid
- When using IEEE1588-2008 evaluate
  - Packet Network QoS Configuration
  - Network Security (L2/L3 VPN, Access-Lists, …)
  - Packet Delay Variation (PDV)

Q & A

Complete Your Online Session Evaluation

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