Synchronizing 5G Mobile Networks

Timing Assurance

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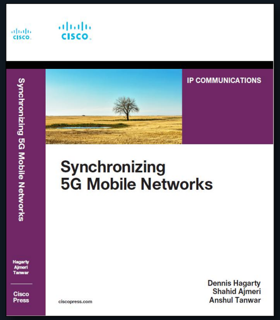
BRKSPG-3050

Agenda



- Introduction
- Satellite-based PRTC & T-GM
- National Clocks
- New features for timing assurance
- Optics Testing Examples
- ITU-T Standards Update
- Conclusion and further info

Key Abbreviations

APTS	Assisted Partial Timing Support
(a)BMCA	(alternate) Best ~~Master~~ Clock Algorithm
(a)BTCA	(alternate) Best TimeTransmitter Clock Algor.
C/A	Course/Acquisition – original GPS L1 signal
CEM	Circuit Emulation (TDM over packet)
CNI	Critical National Infrastructure
C/N_0	Carrier-to-Noise Density Ratio
cTE	Constant Time Error
dTE	Dynamic Time Error
EEC	Ethernet Equipment Clock (SyncE node)
eEEC	Enhanced EEC (with enhanced TLV)
ESMC	Ethernet Synchronization Message Channel
eSyncE	Enhanced SyncE
FDD	Frequency Domain Duplex (radio)
FTS	Full (on-path) Timing Support (PTP aware)
GNSS	Global Navigation Satellite System
MTIE	Maximum Time Interval Error
NIS2	Network & Information Security 2 (directive)
ONMSA	Open Service Navigation Message Authent.
(e) PRC	(enhanced) Primary Reference Clock (freq.)
(e)PRTC	(enhanced) Primary Reference Time Clock
PTP	Precision Time Protocol (1588)
PTS	Partial Timing Support (PTP unaware)
SDH	Synchronous Digital Heirarchy
SP	(communications) Service Provider
SyncE	Synchronous Ethernet
T-BC	Telecom Boundary Clock (ITU-T)
T-GM	Telecom Grand Master (ITU-T)
T-TC	Telecom Transparent Clock (ITU-T)
T-TSC	Telecom Time ~~Slave~~ Synchronous Clock (ITU-T)
TDM	Time Division Multiplexing
TDEV	Time Deviation
TE	Time Error
UTC	Universal Coordinated Time

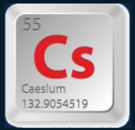
Introduction

5G Changed Sync in MAJOR way

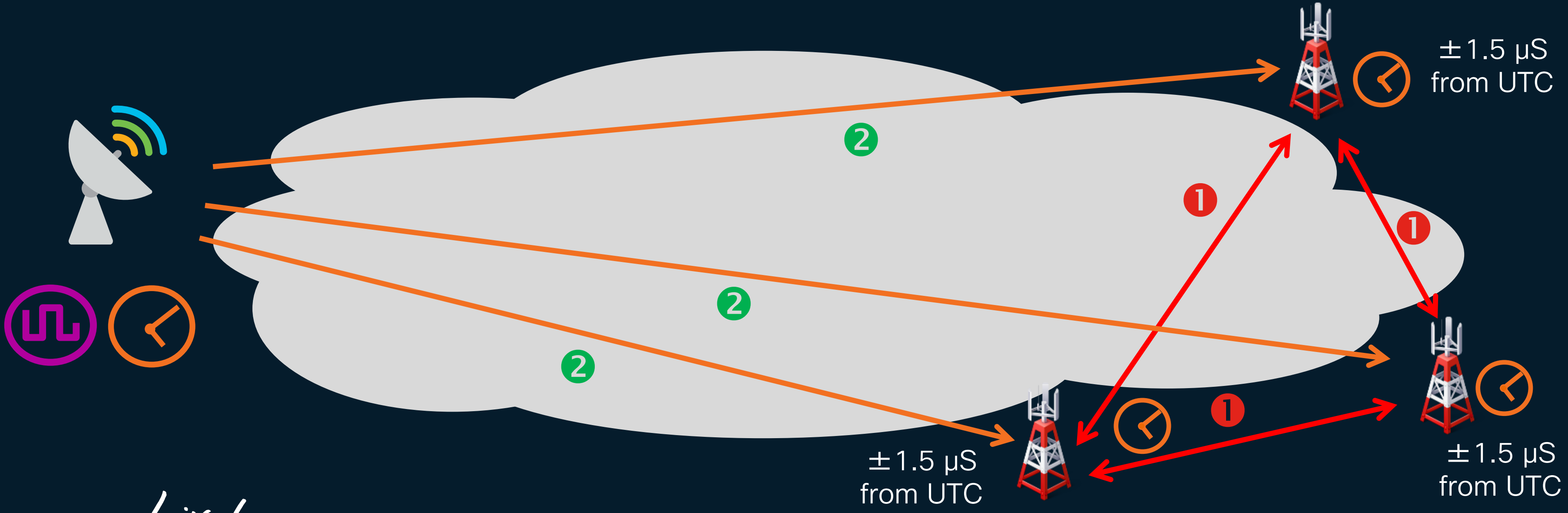
- Previous mobile networks used only frequency synchronization
  - Initially delivered using TDM and then later using SyncE/Ethernet and/or PTP
  - Circuit Emulation widely deployed in many industries (frequency timed with SyncE)
- 5G required phase/time Now many industries & use-cases use phase/time
- Combinatoin of distributed GNSS & PTP+SyncE through transport network
  - Transport N/W may need mitigation to accurately carry PTP (full on-path support)
  - Critical National Infrastructure (CNI) relying on GNSS now a real problem
- Network-based time transfer: Precision Time Protocol (PTP)/IEEE 1588
  - Accuracy of 10's of nanoseconds (10^{-9}) Time Error over 10–15 hops
  - Combined with SyncE to carry frequency (for best-case performance)
  - Solution uses specialized hardware with careful network design

Phase Synchronization for 5G

Common Reference Time



- ❶ Requirement (TDD, 5G radio co-ordination): 3 μs between base stations
- ❷ Implementation: ±1.5 μs from a common reference time (normally UTC time)



Issues covered/not covered today...

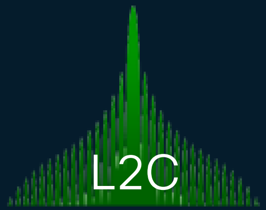
- Skipping the fundamentals of timing + sync with PTP and SyncE
- Sources of frequency & time; alternate sources; terrestrial time distribution
- New features being adopted
  - GNSS dual-band on Cisco 8000:
    - Improved CLI output to support dual-band receivers
    - Antijamming and anti-spoofing for PRTC-B receivers
    - White paper on PRTC-A versus PRTC-B
  - Passive Port Monitoring feature
  - Advanced Port Monitoring feature (G.8275.1 Annex G)
  - PTP and SyncE alignment feature
  - PTP performance statistics feature (G.8275 Annex F)

Satellite-based PRTC & T-GM

Deploying Satellite Systems

- Many GNSS transmit in several separate bands: for GPS, that’s L1, L2, L5
  - L1 is the default/legacy band for GPS, other bands were military only
  - Later generations of satellites have introduced civilian signals in L2 and then L5
  - L2C civilian signal is pre-operational on 25 satellites in GPS (July 2023)
  - L5 (aviation band) is a more robust, higher power and better performing signal
  - Introducing new L1C signal to supplement the original L1 C/A (only 6 sats today)

1176.45 MHz

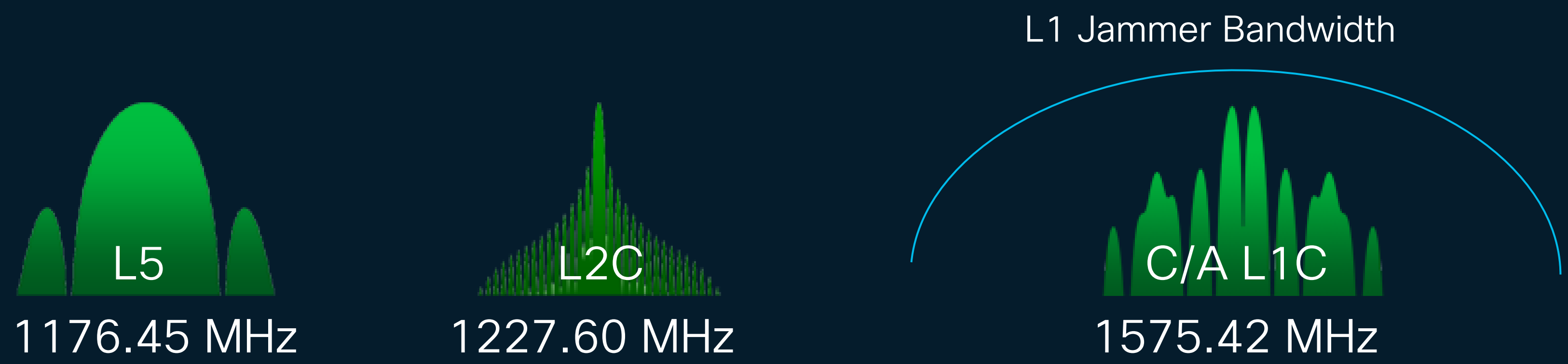


1227.60 MHz

1575.42 MHz

Deploying Satellite Systems

- Multiple bands can improve resistance to jamming/spoofing
- Spoofing multiple bands is hard, typically they spoof 1 band, jam others
- Adopting technology to improve resiliency and trust (authentication)
- GNSS receivers used for timing now adopting dual-band (Cisco 8K)



"Baltic Jammer" Update

- Jamming seems to coming from Russian enclave of Kaliningrad

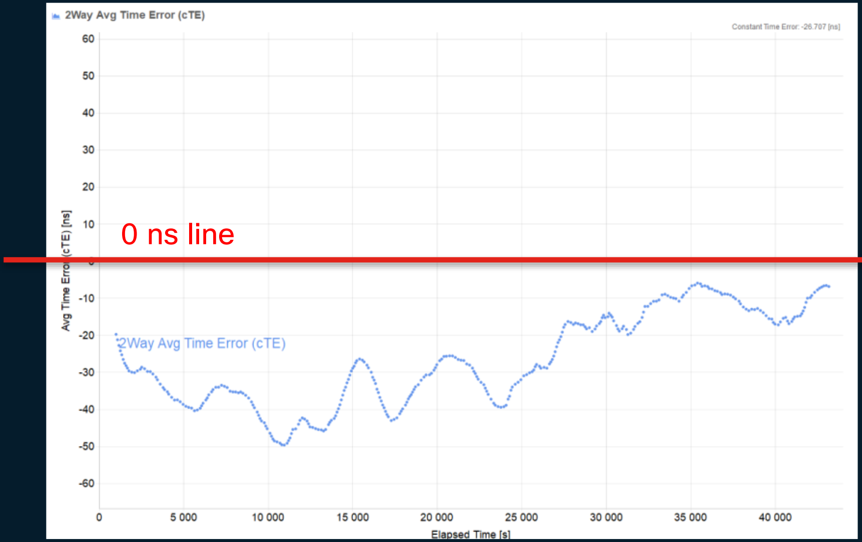
- Red spots show inaccurate fix in aircraft at altitude
- Covers much of the Baltic and also affects GNSS in half of Poland, Finland
- Impact on ground services not yet severe
- New: "circle spoofing" now applied to aircraft
- Need to plan for post-GNSS world
- Image source: gpsjam.org for Dec 1st

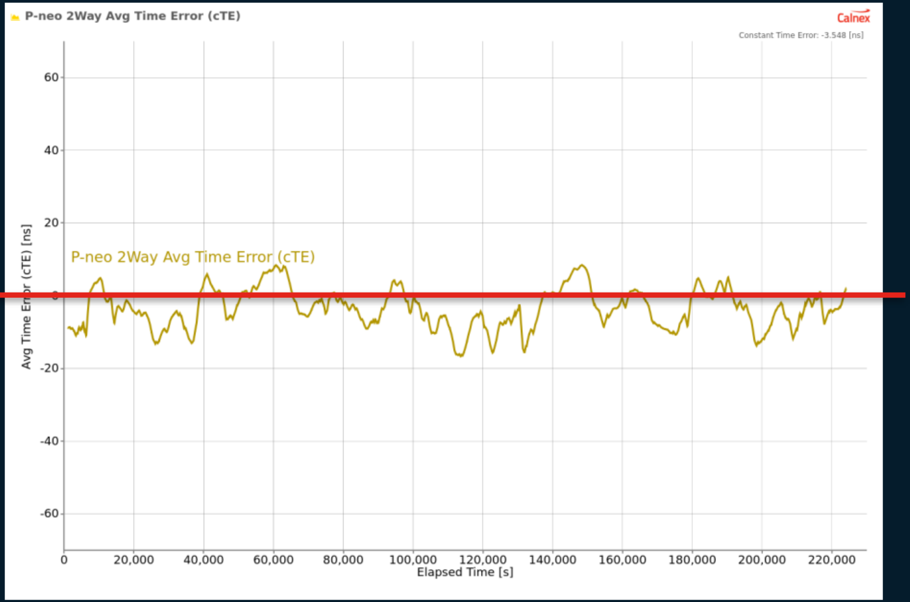
Deploying Satellite Systems

- Jamming and GNSS issues
  - Short interruptions are expected! Can you handle it?
  - Jamming is not a matter of IF, but a matter of WHEN and HOW LONG?
  - Regulators are taking a hard look at organizations' reliance on GNSS time
- Available/upcoming solutions to mitigate jamming/spoofing:
  - Multi-band and multi-constellation can help but are no guarantee!!!
  - Events like "Jammertest" in Norway help GNSS vendors improve performance
  - GPS III include "Chimera" authentication, Galileo has " OSNMA" authentication
  - "Anti-jam" antennas reject/attenuate false signals (via adaptive/null steering)
  - Geographical redundancy: separating receivers (also for weather events)

PRTC-A versus PRTC-B Performance

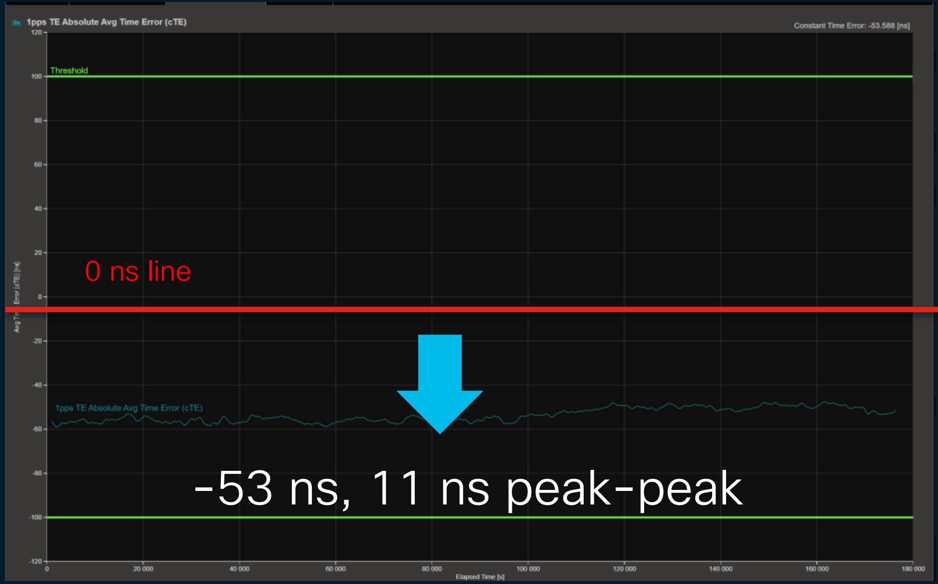
- Cisco 8K: single-band on left, dual-band on right– ave. accuracy: -27 ns vs -4 ns
- Much less wander (@ constant temp) in the PRTC-B case: Pk-pk: 45 ns vs 25 ns

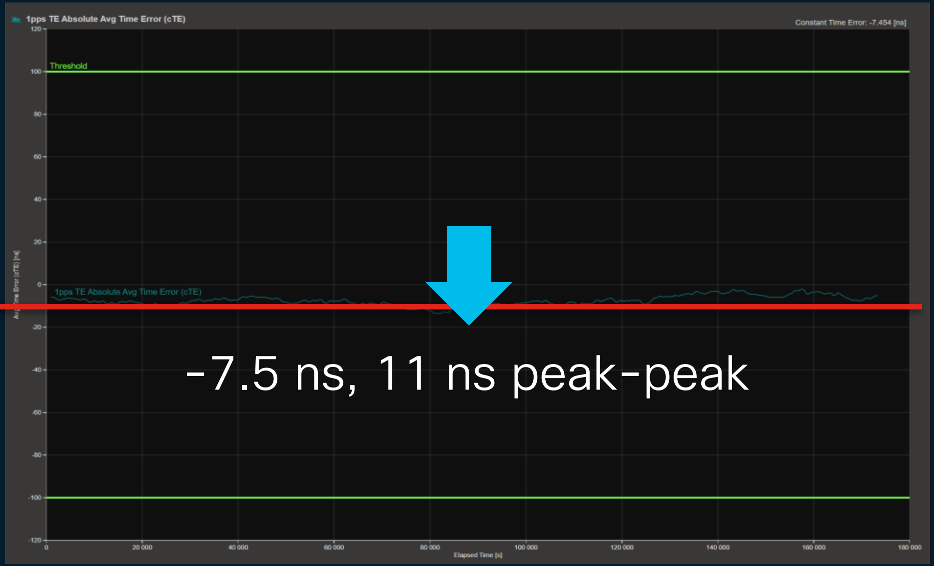




PRTC-A versus PRTC-B Performance

- PRTC-A (single band) on left, PRTC-B (dual-band) on right (with Cesium clock)
- Accuracy is -7.5 ns for PRTC-B, -53 for PRTC-A (both on Glandon)





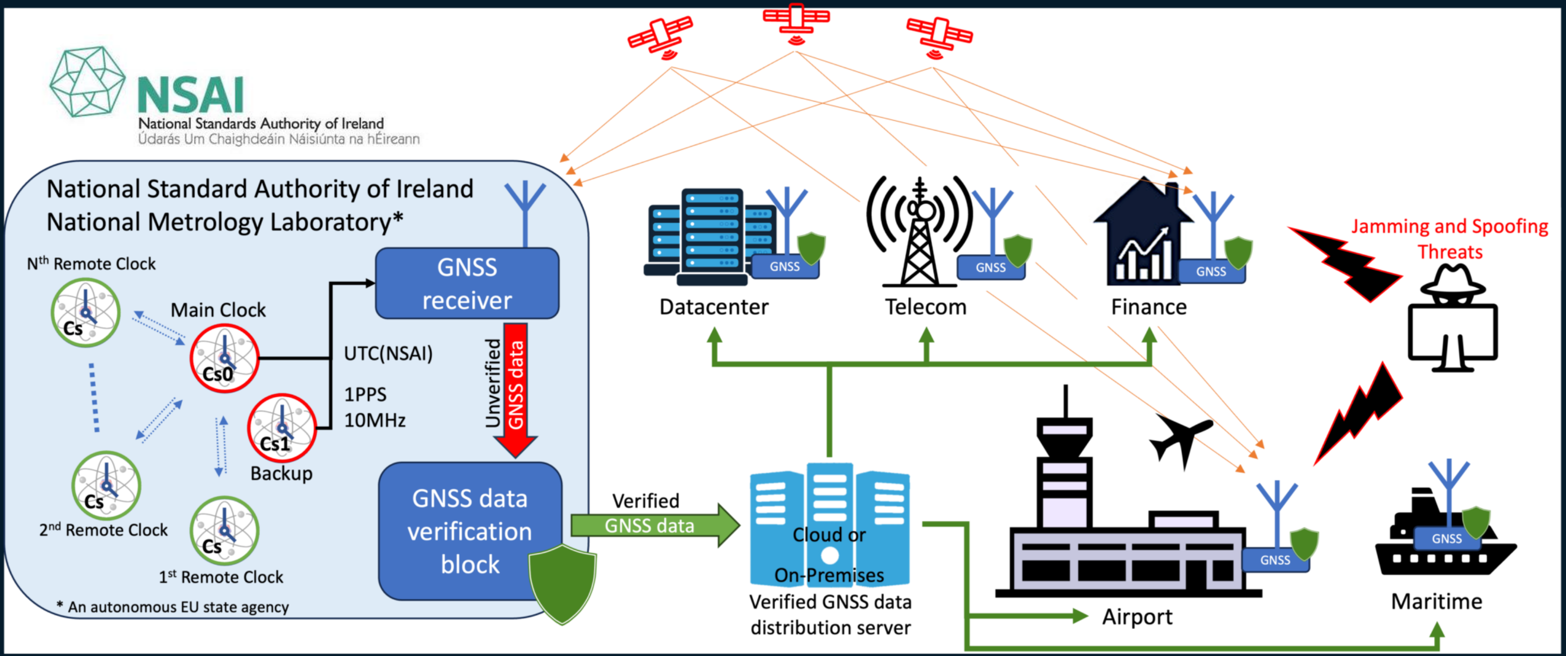
NIS2 Directive & Verified GPS/GNSS Data Stream

- NSAI NML *Verified GPS/GNSS Data Stream* provides access to verified GNSS data distributed to customers using "out of band" methods
- Verified data stream provides verification for all constellations and all signals, so that the receivers can "sanity check" what they receive
- Enables exceptional resiliency against spoofing and GNSS satellite data errors, based on the National Timing Grid of Ireland (www.ntg.ie)
- Provides support for NIS2 Directive compliance for wider industry
- NSAI NML's data validation service is available in EMEA
  - Discussing with other NMLs to extend the service coverage

Source: Zdenek Chaloupka, Timing Solutions (Limited)

Deploying Satellite Systems

- NSAI NML – Verified GNSS (GPS) Data Stream with EU wide coverage



Deploying Satellite Systems

- Innovators producing ways to use multiple bands to improve performance
- “Common view” technique using authenticated data from remote source…

National Clocks

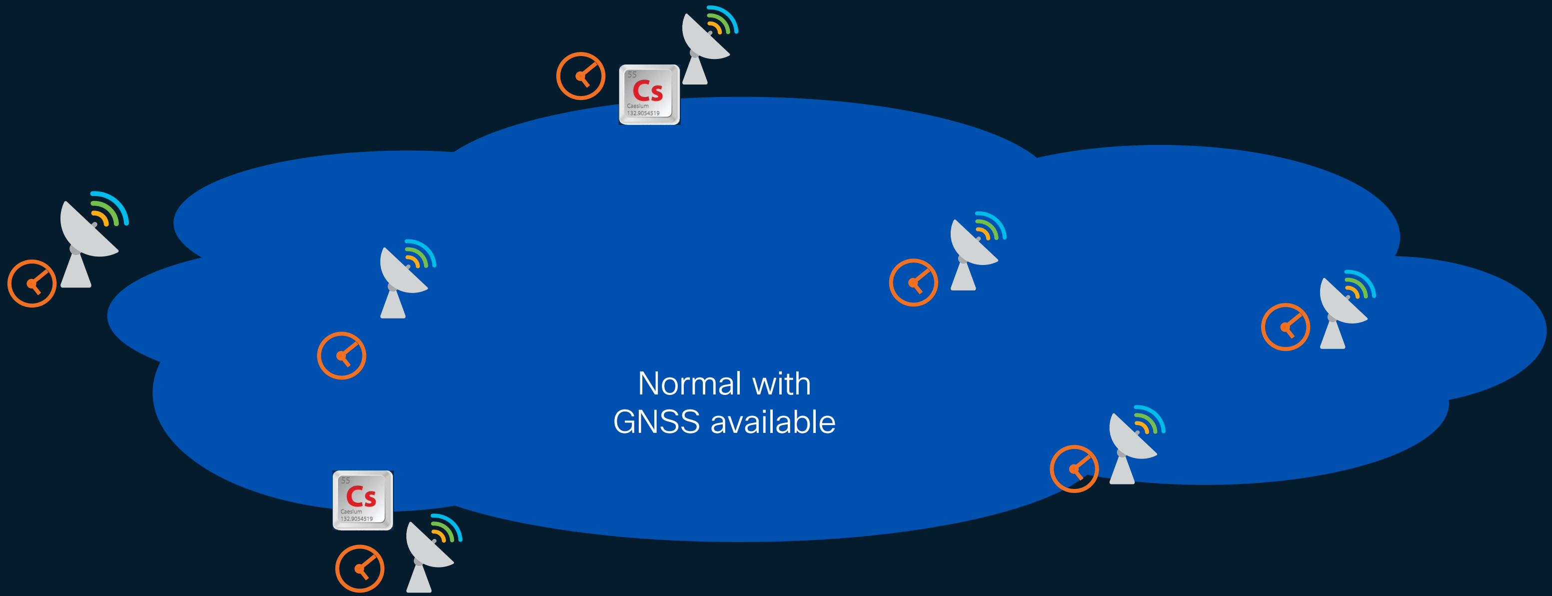
Timing as a (National) Service

- Regulators demanding critical national infrastructure free of GNSS
  - EU: *Critical Entities Resilience Directive* targets eleven sectors
  - Includes digital infrastructure, energy, finance, banking, water and transport
- Countries define National Time Standard for UTC time
  - Many countries already do this, known as UTC(k)
  - But connectivity to clocks at national physics laboratories is limited
  - What many countries do NOT do, is to distribute it widely
- Now building national timing distribution networks
  - EU: *Terrestrial Timing Backbone Service* for Complimentary (C-)PNT
  - Build POPs for user orgs to connect to – Q? How is this funded?
- National clock keeps time error low between organizations/operators

National Time as a Service

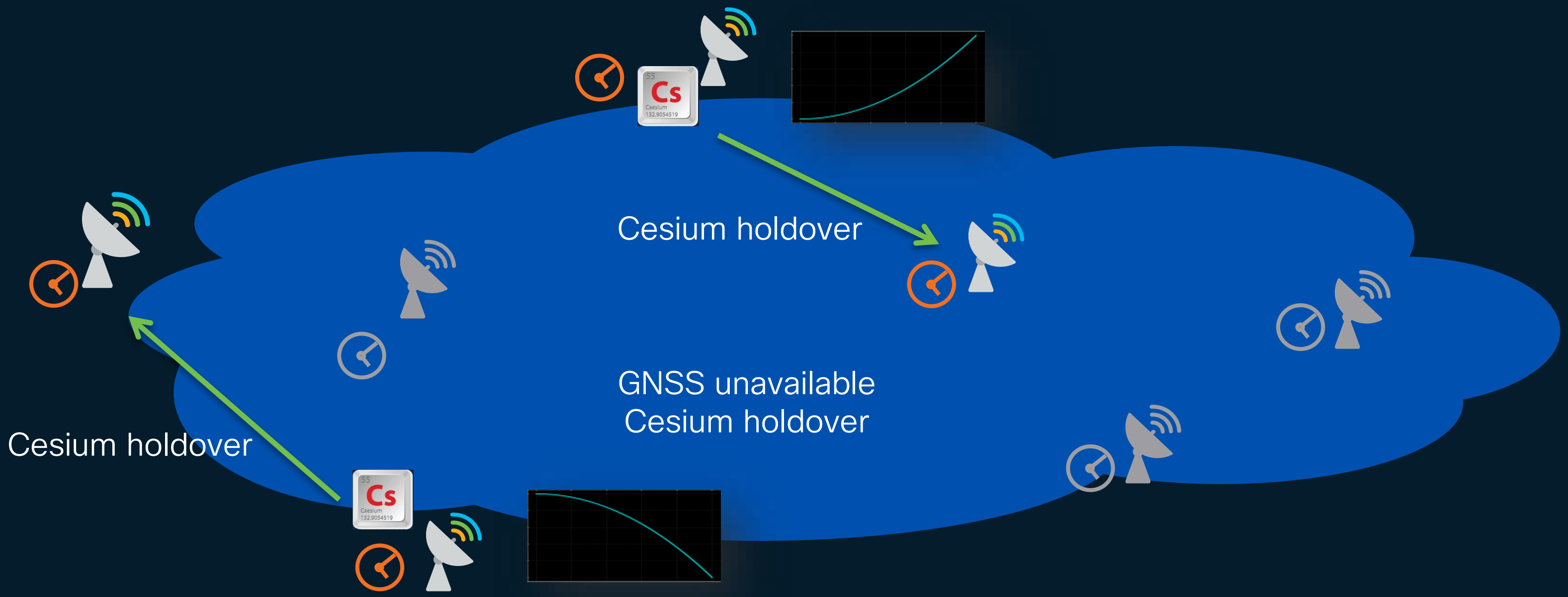
UTC
Reference
Time

- Many countries already have a time service to maintain local UTC source
- Distribution of that signal is typically limited to specialist users (labs, etc)



National Time as a Service

- With GNSS lost, Cesium provides holdover in well-designed networks
- However, Cesiums will slowly start to wander against each other & UTC



National Time as a Service

UTC
Reference
LOST

- The solution is a nation-wide interconnected Cesium clock network
- Users & service providers align their Cesium clocks to national clocks

New Features

New Features on Cisco SP Routers

- After deployment, hardest task is timing service assurance
- Developing a range of features to help perform this vital role
- Some are standards based, others are implementation improvements
- Helps to identify that a problem exists, without additional hardware
  - Ensure that time is internally consistent across the network

Feature: GNSS Dual-Band on Cisco 8000

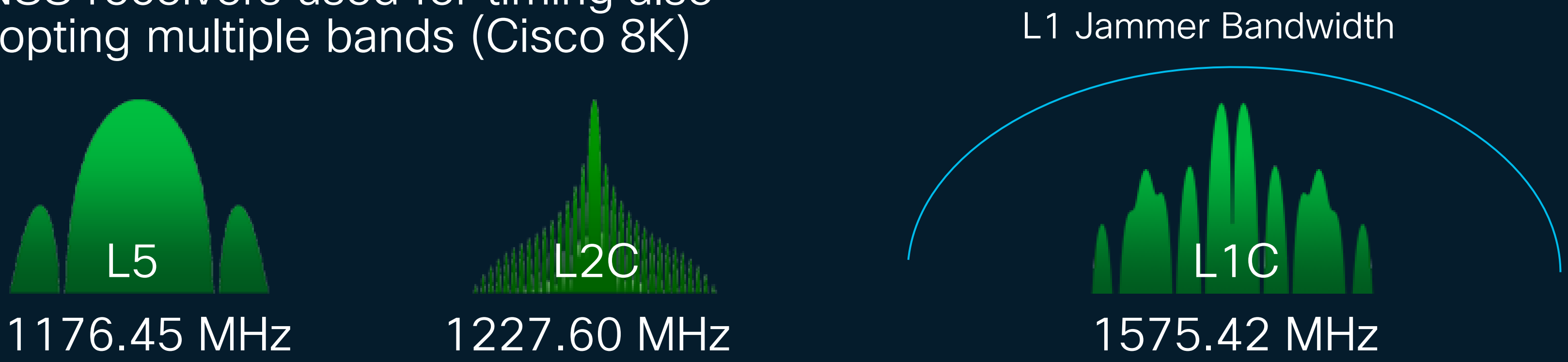
GNSS Dual Band on Cisco 8000

- Dual band helps increase the accuracy of the receiver
  - Generates timestamps closer to UTC time
  - Reduces the diurnal wander typical of single-band GNSS
  - Better modeling of ionospheric effects
  - Increases holdover time since it starts holdover in more stable state
- Increases resilience against:
  - Changing ionospheric conditions
  - Bad space weather
  - Jamming and spoofing events

Improved: location services security resilience holdover

GNSS Dual Band on Cisco 8000

- GNSS systems transmit in several bands: for GPS, that's L1, L2, L5
  - L1 is the default/legacy band, other bands (L2) were military only
  - Later generations of satellites have introduced civilian signals in L2 and then L5
  - New L1C (GPS) signal is coming to update the original L1 C/A (6 satellites today)
  - Similar bands for other constellations
- GNSS receivers used for timing also adopting multiple bands (Cisco 8K)



GNSS Dual Band on Cisco 8000

- Cisco 8000 with GNSS receiver supports dual-band
  - GPS, GLONASS: L1/L2, Galileo: E1/E5b, Beidou: B1/B2
  - Accurate to UTC within 40 ns (-B) versus 100 ns (-A) (according to G.8272)
  - Enhancing CLI output to show bands received by the receiver
  - White paper on real-world performance: “PRTC-A versus PRTC-B” coming
- Antijamming and anti-spoofing reporting for PRTC-B receivers:
  - Receiver will alarm when it detects on-going jamming is in progress
  - Show command also outputs new information on spoofing state
  - Syslogs when jamming is triggered or cleared, or a spoofing event is detected
  - Allows more operational visibility for the customer

```
GNSS-receiver 0 location 0/0/CPU0 detected an apparent jamming event, mitigation in progress
```

Multi-band Information in *show gnss*

```
RP/0/RP0/CPU0:ios#sh gnss-receiver
    Satellite Info:
        CHN: Channel, AQUN: Aquisition, EPH: Ephemeris
        PRN   CHN   AQUN   EPH    SV             Signal
        No.   No.   Flag   Flag   Type           Strength   Elevat'n   Azimuth    Signals
        ---   ---   ----   ----   -----------    --------   --------   --------    -------
          6   n/a   On     On     GPS              45.000     86.000     17.000    L1 C/A|L2C
         13   n/a   On     On     GPS              34.000     20.000    226.000    L1 C/A
         17   n/a   On     On     GPS              43.000     25.000     30.000    L1 C/A|L2C
         24   n/a   On     On     GPS              38.000     22.000    310.000    L1 C/A|L2C
         30   n/a   On     On     GPS              41.000     28.000    160.000    L2C|L1 C/A
          2   n/a   On     On     QZSS             39.000     24.000     88.000    L1 C/A|L2C
          3   n/a   On     On     QZSS             39.000     25.000     52.000    L1 C/A|L2C
          7   n/a   On     On     QZSS             34.000     32.000    101.000    L1 C/A|L2C
         14   n/a   On     On     GLONASS          46.000     53.000    109.000    L1 OF|L2 OF
         15   n/a   On     On     GLONASS          45.000     53.000      5.000    L1 OF|L2 OF
         18   n/a   On     On     GLONASS          44.000     58.000    270.000    L1 OF|L2 OF
         19   n/a   On     On     GLONASS          32.000     26.000    228.000    L2 OF|L1 OF
```

Multi-band Information in *show gnss*

```
RP/0/RP0/CPU0:ios(config)#gnss-receiver 0 location 0/RP0/CPU0
RP/0/RP0/CPU0:ios(config-gnss)#constellation galileo
RP/0/RP0/CPU0:ios(config-gnss)#commit
RP/0/RP0/CPU0:ios#sh gnss-receiver
    Satellite Info:
        CHN: Channel, AQUN: Aquisition, EPH: Ephemeris
        PRN   CHN   AQUN   EPH    SV             Signal
        No.   No.   Flag   Flag   Type           Strength   Elevat'n   Azimuth    Signals
        ---   ---   ----   ----   -----------    --------   --------   --------    -------
          2   n/a   On     On     Galileo          42.000     36.000    332.000    E1|E5b
          5   n/a   On     On     Galileo          37.000     10.000    176.000    E1|E5b
          9   n/a   On     On     Galileo          36.000      6.000    127.000    E1|E5b
         11   n/a   On     On     Galileo          38.000     27.000     26.000    E1|E5b
         24   n/a   On     On     Galileo          41.000     31.000    130.000    E1|E5b
         25   n/a   On     On     Galileo          43.000     76.000     63.000    E1|E5b
         34   n/a   On     On     Galileo          42.000     36.000    248.000    E1|E5b
         36   n/a   On     On     Galileo          42.000     62.000    328.000    E1|E5b
```

Multi-band Information in *show gnss*

```
RP/0/RP0/CPU0:ios(config)#gnss-receiver 0 location 0/RP0/CPU0
RP/0/RP0/CPU0:ios(config-gnss)#constellation beidou
RP/0/RP0/CPU0:ios(config-gnss)#commit
RP/0/RP0/CPU0:ios#sh gnss-receiver
 Satellite Info:
       CHN: Channel, AQUN: Aquisition, EPH: Ephemeris
       PRN   CHN   AQUN   EPH    SV            Signal
       No.   No.   Flag   Flag   Type          Strength   Elevat'n   Azimuth    Signals
       ---   ---   ----   ----   -----------   --------   --------   --------    -------
         1   n/a   On     On     BeiDou          38.000     14.000     95.000    B1|B2
         7   n/a   On     On     BeiDou          41.000     43.000     62.000    B2|B1
         8   n/a   On     On     BeiDou          43.000     65.000     98.000    B2|B1
        10   n/a   On     On     BeiDou          35.000     50.000     43.000    B2|B1
        21   n/a   On     On     BeiDou          43.000     29.000    119.000    B1
        24   n/a   On     On     BeiDou          47.000     67.000    202.000    B1
        25   n/a   On     On     BeiDou          43.000     41.000    306.000    B1
        26   n/a   On     On     BeiDou          42.000     23.000    158.000    B1
```

Feature: Passive Port Monitoring

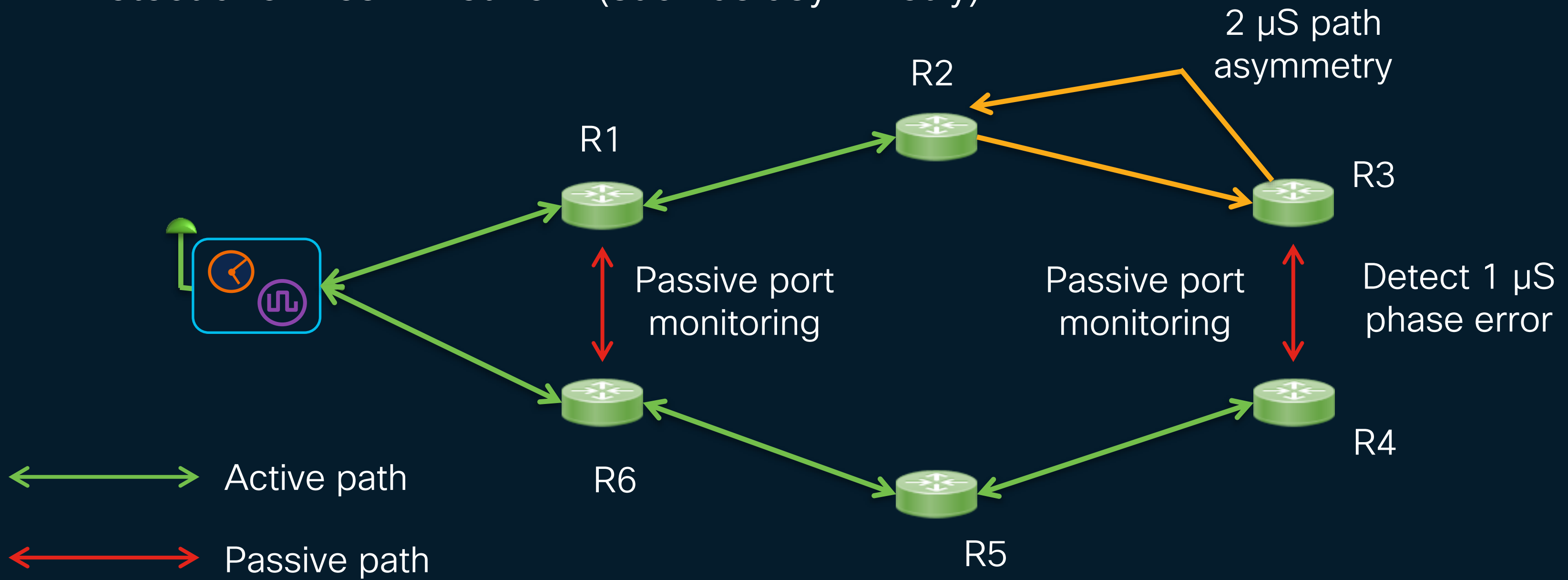
Passive Port Monitoring

- PTP slave port locked to an upstream clock collects 4 timestamps
- PTP servo calculates the "offset from master" and "mean path delay"
- New: PTP recovers 4 timestamps on "passive" ports and calculates offset & delay
- Activated with *detect-ptsf-unusable* and *phase-difference-threshold-breach*
- Phase differences in *show ptp foreign-masters & show ptp platform servo sessions*
- Following data models are also enhanced:
  - Cisco-IOS-XR-ptp-cfg.yang
  - Cisco-IOS-XR-um-ptp-cfg.yang
- Syslog message when configured threshold is exceeded:

```
Phase difference for clock ACDE48FFFE234567, steps removed 1, receiving-port 1, received on
interface GigabitEthernet0/2/0/3 is 40ns, configured threshold is 30ns. Raising phase difference
alarm.
```

Passive Port Monitoring

- Cross-validation of timing signals in rings/mesh topology
- Detect anomlies in network (such as asymmetry)



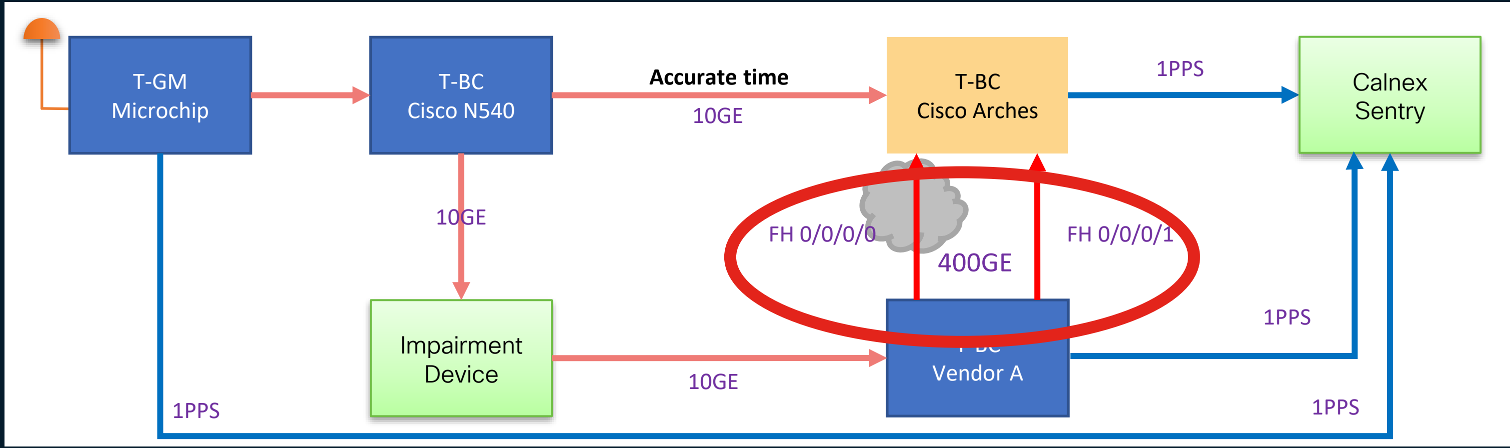
Passive Port Monitoring

- Output: *show ptp foreign-masters & show ptp platform servo sessions*

```
Router# show ptp platform servo sessions

Interface FourHundredGigE0_0_0_1:
Primary session: FALSE
Clock-id: 0xfe050da8, Receiving port:2, Steps-removed:3
Servo-running: TRUE
Has frequency: TRUE, Has time: TRUE
Source-type: 0
Timescale: 0, asymmetry:0 Phase-offset from PTP source: 632
Previous Received Timestamp T1: 1709030957.503025147 T2: 1709030957.503030685 T3:
1709030957.461855393 T4: 1709030957.461859674
Last Received Timestamp T1: 1709030957.503025147 T2: 1709030957.503030685 T3: 1709030957.525861272
T4: 1709030957.525865546
Clock-offset: 0.108079 ppb
```

Passive Port Monitoring

- Example of real-world example from EANTC interoperability testing (2024)
- Cisco 540 connected by 2 x 400GE coherent optics to “Vendor A”, 1 over DWDM
- Vendor “A” had not “tuned” their platform to compensate for this 400GE optic
- Arches has another 10GE connection to Cisco NCS540 with accurate time



Passive Port Monitoring

- Uncalibrated 400GE port on "Vendor A" introducing ~608 ns of time error

```
Interface             Type           State    Phase-offset    Clock-offset(ppb)
=========             ====           =====    ============    =================
FH_GigE0_0_0_1        Primary        Running  00000022        -0.253867     The slave port
TenGigE0_0_0_2        Monitored      Running  -0000608        -0.420705     This is accurate time
FH_GigE0_0_0_0        Monitored      Running  00000026        0.257291
```

- Added 1220 ns of asymmetry to both the 400GE links

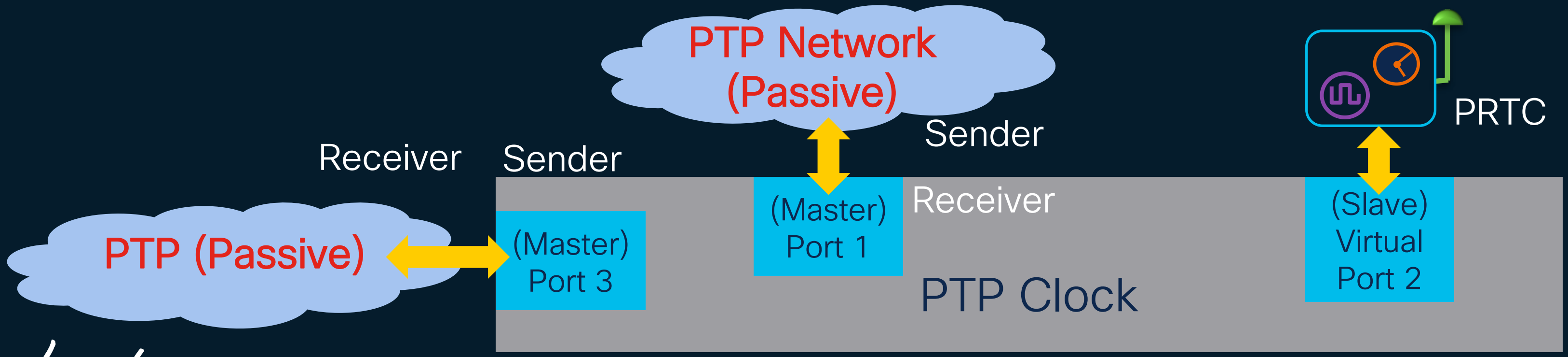
```
Interface             Type           State    Phase-offset    Clock-offset(ppb)
=========             ====           =====    ============    =================
FH_GigE0_0_0_1        Primary        Running  00000008        0.000005      All now approximately
TenGigE0_0_0_2        Monitored      Running  -0000014        -0.143197     agree with each other
FH_GigE0_0_0_0        Monitored      Running  -0000001        -0.149201
```

Note: Output from *show ptp platform servo sessions brief*

Feature: Advanced Port Monitoring

Advanced Port Monitoring and OAM

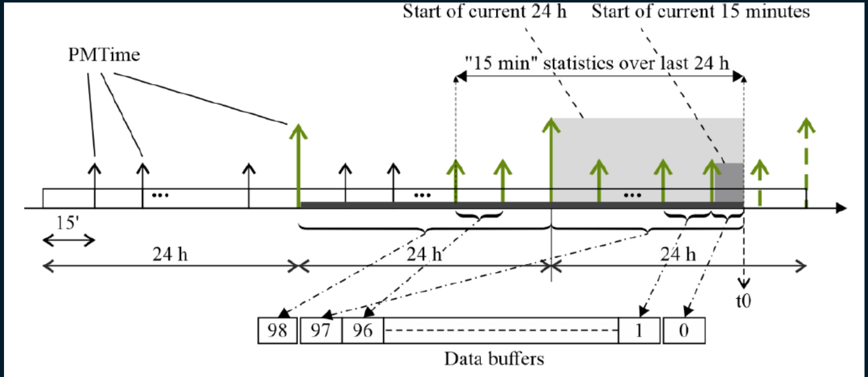
- Annex G (G.8275.1) added “Monitoring alternate timeTransmitter time”
  - Extends the basic passive port monitoring
  - Uses CLI: monitorReceiver, monitorSender & alternateMasterFlag fields
  - Extremely useful in rings and/or meshed networks
  - Also possible to monitor PTP time error via local GNSS + Virtual Port

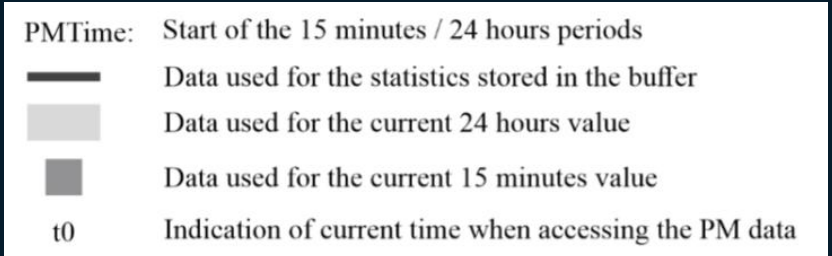


Feature: PTP Performance Monitoring

PTP Performance Monitoring

- Annex F (G.8275) added “Performance Monitoring”
  - Collection of PTP performance data (based on Annex J of 1588-2019)
  - Collect forward/reverse path delay, mean path delay, offset from master
    - Also captures packet counters for PTP messages
    - Data stored in 15 minute buckets for up to 24 hours
    - Simplified data store in 3 minute buckets up to 1 hour





PTP Performance Monitoring

- Activated with the *performance-monitoring* command
  - *show ptp dataset performance* and *show ptp platform performance-counters*
- Yang models updated to allow access to data

PTP Performance Monitoring

```
Router# show ptp dataset performance clock

Clock ID aaaabbbecccc00, steps removed 1, receiving-port 2:
Start of time window: Wednesday, January 1, 2025 14:18:59
Measurement is not valid
Period is not complete
Measurement has been taken with reference to system clock

Master slave delay:
Average: 50ns
Min: 50ns
Max: 70ns
Std: 1ns
Slave master delay:
Average: 51ns
Min: 51ns
Max: 71ns
Std: 2ns
```

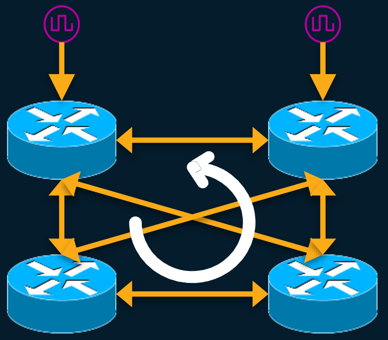
```
Mean path delay:
Average: 52ns
Min: 52ns
Max: 72ns
Std: 3ns
Offset from master:
Average: 53ns
Min: 53ns
Max: 73ns
Std: 4ns
```

PTP Performance Monitoring

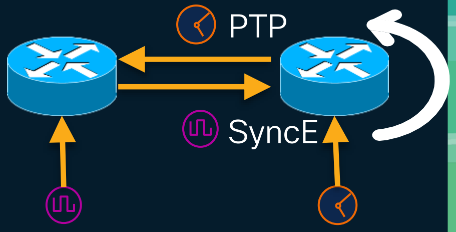
```
Router# show ptp platform performance-counters detail

PTP Current record index 15 min: 96
PTP Current record index 3 min: 119
PTP performance monitoring statistics:
===============================================================================================================
15 min stats
[0] 12 December 2024 09:09:59 UTC 15 min statistics
---------------------------------------------------------------------------------------------------------------
Stat                    Min(sec.nsec)      Max(sec.nsec)       Mean(sec.nsec)     Std deviation       Samples
---------------------------------------------------------------------------------------------------------------
Master-slave-delay  -000000000.15937     000000000.333      -000000000.1780   000000000.71191        154
Slave-master-delay   000000000.319       000000000.16593     000000000.2437   000000000.74103        154
mean-path-delay      000000000.322       000000000.334       000000000.327    000000000.4057         154
offset-from-master  -000000000.16263     000000000.6        -000000000.2108   000000000.72546        154
```

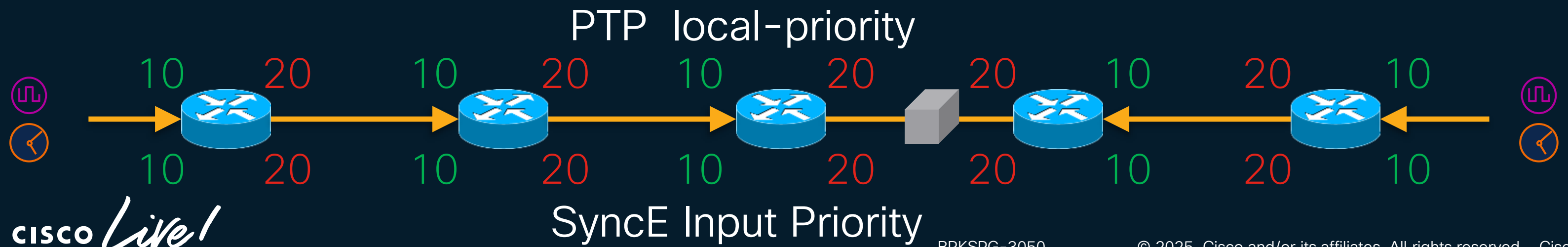
Feature: PTP and SyncE (path) Alignment

Avoiding Timing Loops (previously)



- Configuring too many redundant paths risks timing loops
- Symptom: PHASE-ALIGNED ⇔ FREQUENCY-LOCKED
- Rings are especially a problem, need to “break the ring”
- Giving SyncE to a node that provides PTP back is a loop!!
- Best practices BEFORE THIS FEATURE:
  - Make PTP and SyncE traceable back to the same clock source
  - Use PTP “local-priority” to mirror SyncE input priority





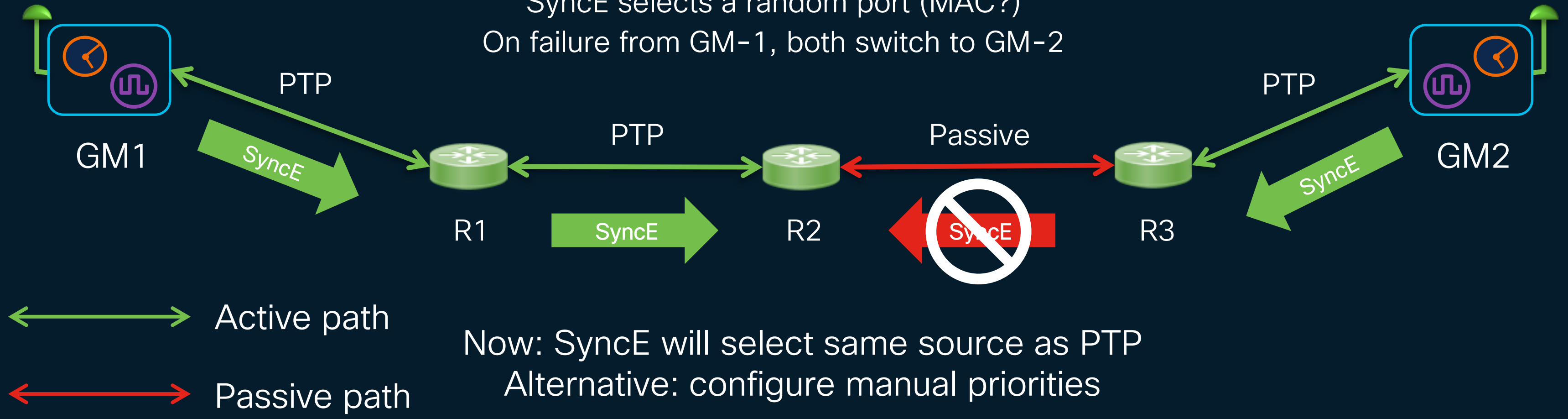
PTP and SyncE Alignment

- Problem: G.8275.1 uses aBMCA/aBTCA to select i/f to become slave port
- SyncE uses local priority and ESMC clock quality to select reference i/f
- Result: PTP and SyncE may come from different interfaces & PRTC sources
  - Problem: PTP and SyncE should trace to the same PRTC/T-GM
  - Having different sources can cause timing to “bounce”
- Solution: Feature to have the SyncE interface selection follow PTP’s lead
- Activated with: *synchronous-ethernet prefer-interface ptp-receiver*
- SyncE follows PTP interface change if ESMC QL & priority are equal to current i/f

PTP and SyncE Alignment

- Helps clocks in middle of a chain align their PTP and SyncE
  - Avoids a loop between the PTP and the SyncE

Before: aBTCA selects T-GM by tie-breaker (port # on slave)
SyncE selects a random port (MAC?)
On failure from GM-1, both switch to GM-2



Now: SyncE will select same source as PTP
Alternative: configure manual priorities

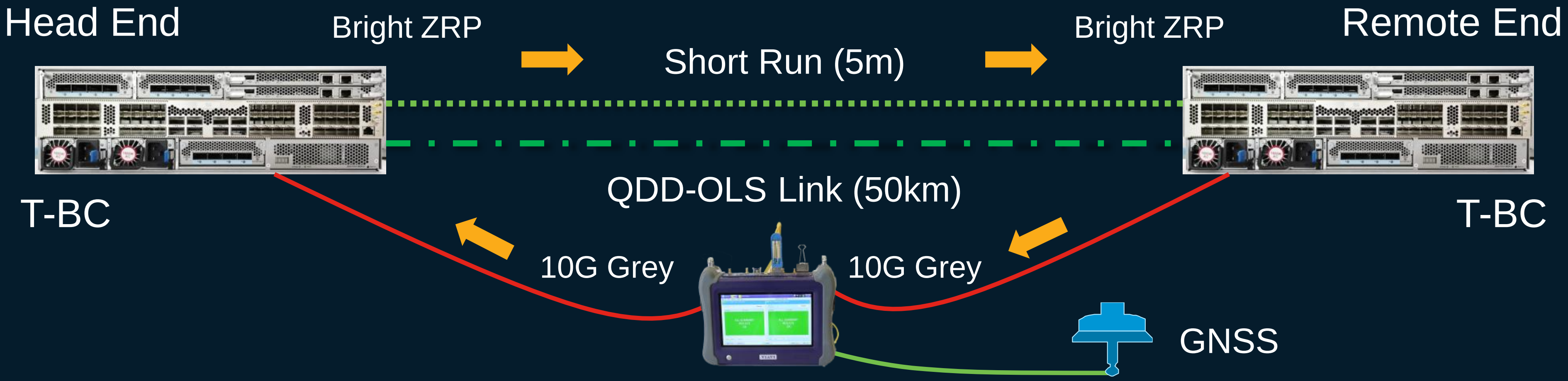
Optics Testing

ZR+ Testing: Short run and 50km OLS fiber

- Sync testing for 400GE (@100GE) on “Bright ZR+” optics
  - DP04QSDD-HE0 = Cisco QSFP-DD 400G BRT ZRP Pluggable Optics Module
  - Wavelength=1546.901nm, DAC Rate = 1x1.50 (100GE)
  - NCS-57C3-MODS-SYS nodes running 24.3.1 at both ends
  - NC57-MPA-2D4H = 2X400G or 4X200/100G QSFP-DD MPA
  - ONS-QDD-OLS = QSFP-DD Pluggable Optical Line System
  - Enhanced SyncE and G.8275.1 PTP Telecom Profile
- Both short run (5 meters) and long-run (50km) fiber pairs
  - Short run removed everything except an attenuator (to reduce the power)
  - Also tested short run with 100G grey and 10G grey optics
- Measured with Viavi MTS5800-100G with timing module

ZR+ Testing: Short run and 50km OLS fiber

Also tested: 10G, 100G (grey) over 5m and 1G PTP (1510/1514) over both



Long fiber run = 263,060 nanoseconds mean path delay

ZR+ Testing: Short run and 50km results

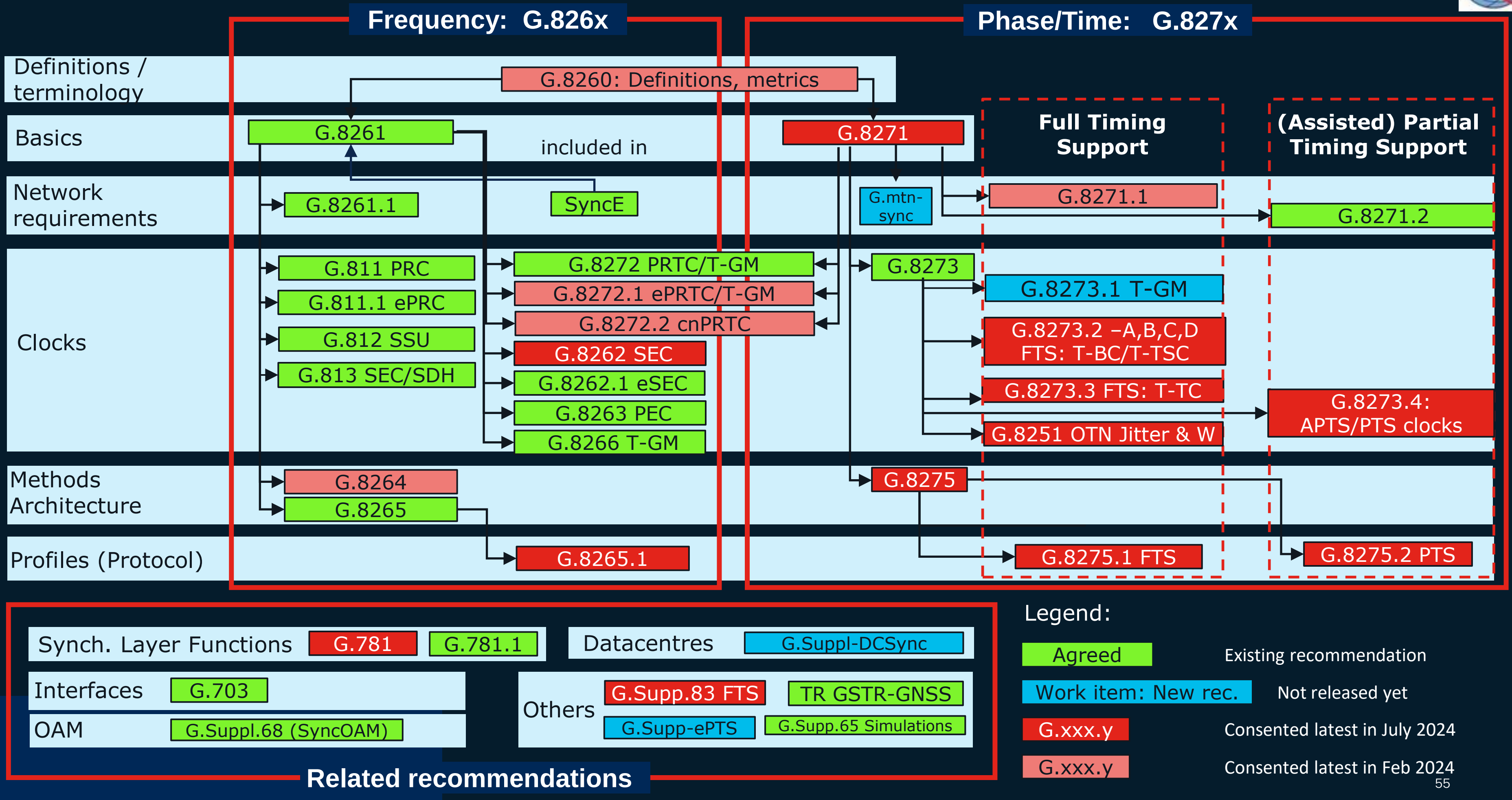
Test Case	Fiber Length	Constant Time Error (cTE)	Max Time Error (TE)
10G grey optics (baseline)	5m	1 ns	8 ns
1G PTP 1510/1514	5m	-3 ns	8 ns
100G grey optics	5m	7 ns	16 ns
100G/400G ZR+	5m	-12 ns	20 ns
100G/400G ZR+	50km	3869 ns	3876 ns
1G PTP 1510/1514	50km	3881 ns	3887 ns

ZR+ Testing: Short run and 50km OLS fiber

- So, what are the lessons?
  - The 5m results are excellent, including for the ZR+ optic
  - The 50km results are terrible
    - Amplifier makes minimal difference, the QDD-OLS only adds 10-20 ns
    - In the end, problem isolated to fiber pair, turns out fibers were NOT the same!!
  - cTE generated when tested through 2 devices interconnected by coherent 100G is about 12 ns. Whether this makes an individual device “Class C” is up for debate, since there are 2 devices involved. However, the dTE_L MTIE and cTE would likely pass as “class C” when hooked up alone to a tester.
  - CHECK the topology before making any conclusions
- With increasing distance, the problem is likely to be the fiber not the optic

ITU-T Standards Update

ITU-T SG15 Question 13 Recommendations



What’s Happening in the Standards?

- ITU-T standards developments
  - Security options (inc 1588-2019 Accuracy TLV) in Appendix XIII G.8275 08/24
  - Monitoring (OAM) and YANG models for Telecom Profiles (G.7721.1)
    - ITU-T Yang models will be reflected in Cisco Yang sync models for Telecom Profiles
  - Work on supplement addressing timing in data centre (G Suppl.DCSync)
- IEEE standards developments
  - 1588a Amend. 3: PTP enhancements for aBMCA with “Enhanced Accuracy TLV”
  - 1588e (MIB + YANG model for PTP) https://ieeexplore.ieee.org/document/10289672
  - Left-overs from 1588-2019 (e.g. P1588d: GDOI Key Exchange for Security)
  - P1588.1 a “new” PTP profile for DC: Client-Server PTP (servers are stateless)
  - IEEE P1952: Resilient Positioning, Navigation, and Timing User Equipment

Conclusions

Synchronization Hot Topics

- DWDM and timing at higher bandwidth over long-distances
  - Optical systems
  - Fibre issues
- GNSS jamming and resilience of critical national infrastructure (CNI)
- Alternative sources of frequency and time
  - National clock
  - Timing as a Service (TAAS)
  - Alternatives for timing/sync signal distribution (eLORAN) not moving quickly
- Many of these SP issues are now shared by other industries
  - Transport, broadcasting, power grids, financial services, data centres, defence

Further Information: Conferences and Standards

- WSTS Workshop on Sync & Timing Systems, May 12-15, Savannah, Ga: https://wsts.atis.org/
- ITSF International Timing & Sync Forum, Oct 27-31, Prague, CZ: https://itsf2025.executiveindustryevents.com/Event/index.php
- ITU-T Study Group 15 Question 13: https://www.itu.int/en/ITU-T/studygroups/2025-2028/15/Pages/default.aspx
- Next ITU-T Sync Plenary Meeting, 17-28 March 2025, Geneva: https://www.itu.int/en/ITU-T/studygroups/2025-2028/15/Pages/default.aspx
- Next ITU-T Sync Interim Meeting, 8-12 June 2025, Ispra, Italy: https://www.itu.int/en/ITU-T/studygroups/2025-2028/15/Pages/default.aspx

Further Information

"Synchronizing 5G Mobile Networks"

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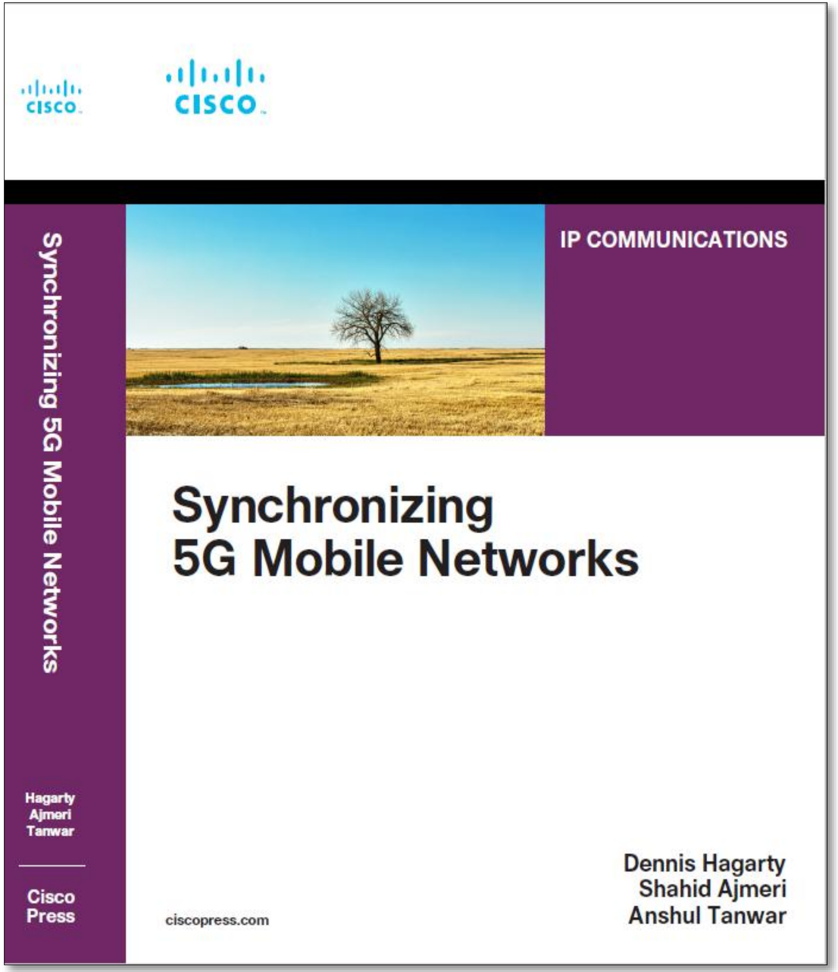
Published: June 2021



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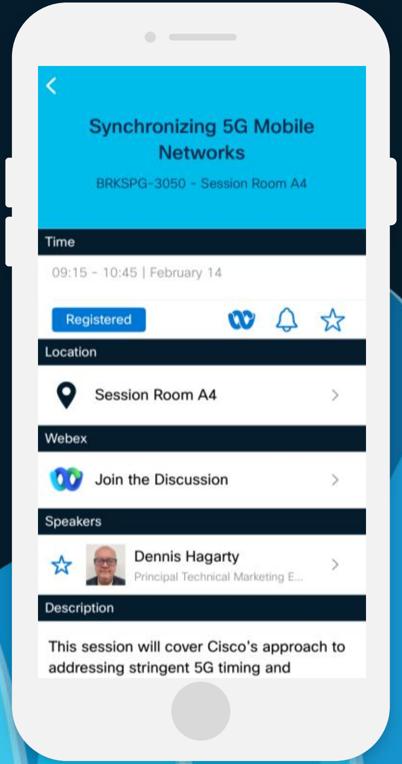

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  - BRKSPG-2133 Event: 2024 Las Vegas Synchronizing 5G Mobile Networks
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