WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Virtual Webinar Series

Session 1

5G and Smart Cities

May 6, 2020

Sponsored by: MICROCHIP

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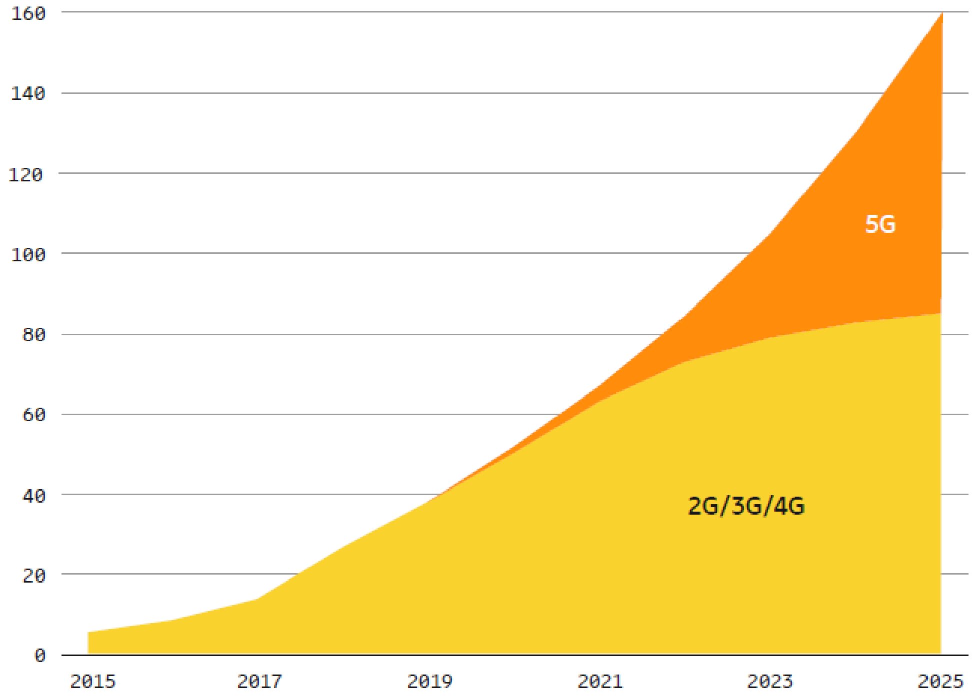
5G and Smart Cities Overview

Stefano Ruffini
Expert Ericsson Research
Ericsson

- The vWSTS webinar series is being held in place of the annual face-to-face WSTS.
- Today's webinar is the first in a series of three:
  - **May 6** – 5G and Smart Cities
  - **May 13** – Timing in Finance, Electric Power and Broadcast
  - **May 20** – Timing Security, Resilience and GNSS Issues
- Thank you to today's speakers, as well as Microchip Technology for sponsoring this webinar.
- Attendees will receive an email with the slides and a link to the recording shortly following today's broadcast.
- There are two Q&A sessions during this webinar.
  - Submit questions at any time using the question tab on the control panel located on the right side of your screen.

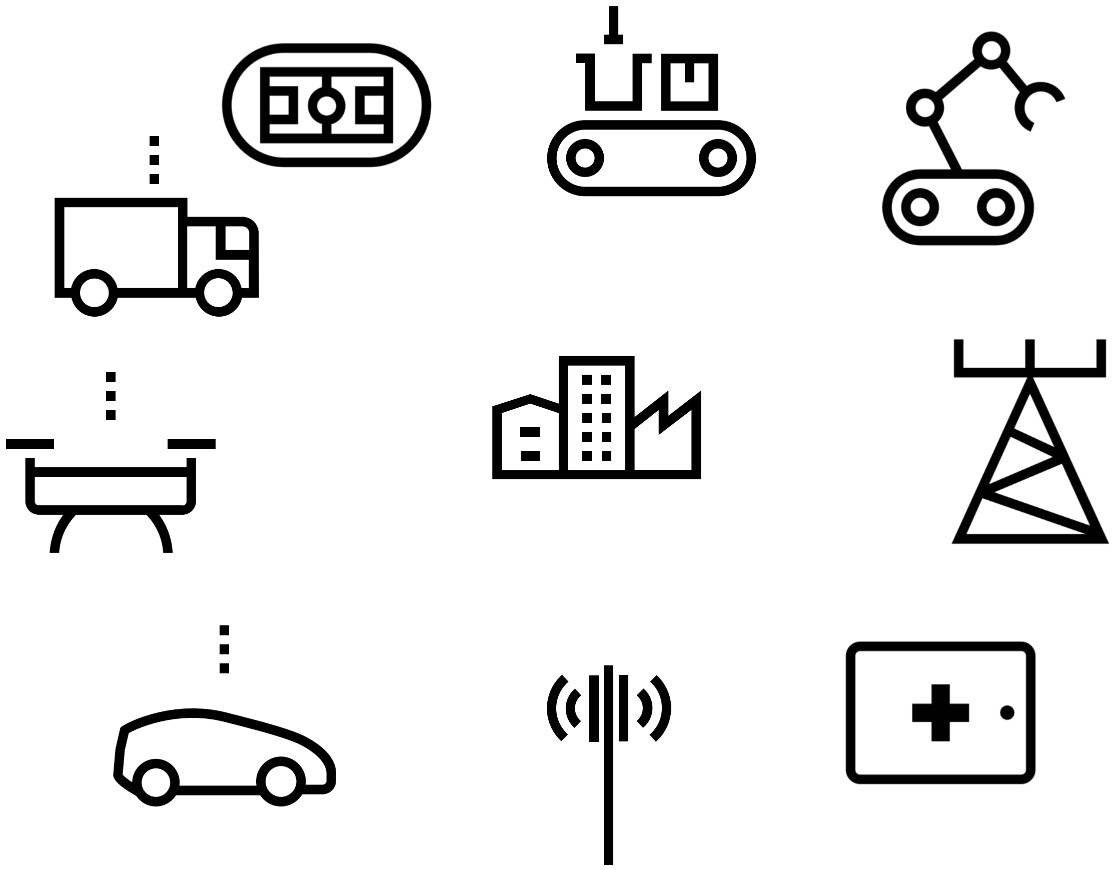
- 5G happening now
- New use cases
  - Transition from 4G to 5G will serve both consumers and multiple industries.
  - Cellular IoT (Manufacturing, Automotive, Public transport, Healthcare, Energy, …)
  - Taking advantage of Global coverage, Common standard, Security
- Sync implications
  - Wider use of TDD
  - Sync needs of applications supported by 5G

Global mobile data traffic (EB per month)



Source: Ericsson Mobility Report (Nov. 2019)

- This session addresses some of the aspects of synchronization as related to 5G and "Smart Cities" applications
  - 5G markets, Standards, ITU-T and sync
  - Network Impacts, Sync Challenges
  - New solutions to complement traditional GNSS- or PTP-based solutions
  - PNT (Position, Navigation, and Time) Smart City services



Chair: Stefano Ruffini – Expert Ericsson Research, Ericsson

Vice-Chair: Lee Cosart – Senior Technologist, Microchip Technology

Speakers: Chris Pearson – President, 5G Americas

Barry Dropping – Director Product Line Management, Microchip Technology

Anand Ram – Vice President Business Development, Calnex Solutions

Mårten Wahlström – System Developer, Ericsson

Umut Keten – Lead Architect Networks, Turk Telekom

Joe Neil – Technical Specialist, Microchip Technology

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Session 1: 5G and Smart Cities
May 6, 2020

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

The Commercial Reality of 5G

Chris Pearson
President
5G Americas

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Session 1: 5G and Smart Cities
May 6, 2020

The Commercial Reality of 5G

Chris Pearson
President
5G Americas

5GAmericas.org
Who We Are

5G Americas facilitates and advocates for the advancement and transformation of LTE, 5G and beyond throughout the Americas.

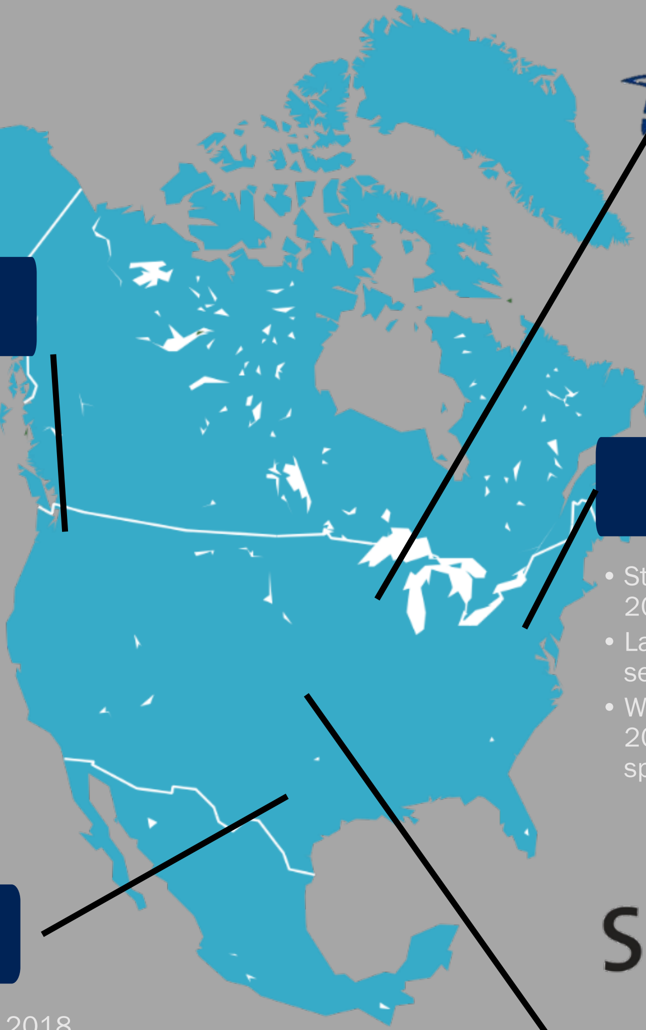
Fast Start: 5G Is A Commercial Reality

North America — **06** Deployments

World (all other) — **58** Deployments

Latin America — **05** Deployments

5G Deployments in North America (US)



T-Mobile

Launched nationwide 5G in December 2019

- Built 5G ready network in 30 cities in 2018
- Launched 5G mmWave in NY, LA, Dallas, Cleveland & Atlanta on June 28, 2019
- Launched Nationwide standardized mobile 5G on 600 MHz in December 2019, including 'pre-paid'

AT&T

Launched 5G standardized mobile service in 2018

- Initially launched mmWave in 2018
- 190 markets in 30 states have 5G lowband, 35 cities have mmWave service
- Nationwide standardized mobile 5G using sub 6GHz spectrum in early 2020

US Cellular

Launched 5G in February 2020

verizon

Initially launched pre-standard commercial Fixed Wireless 5G in 4 cities in October 2018

- Started with mmWave spectrum in 2018
- Launched standardized 5G mobility service in 30 cities in 2019
- Will cover half the U.S. population in 2020 with low, mid and mmWave spectrum

Sprint

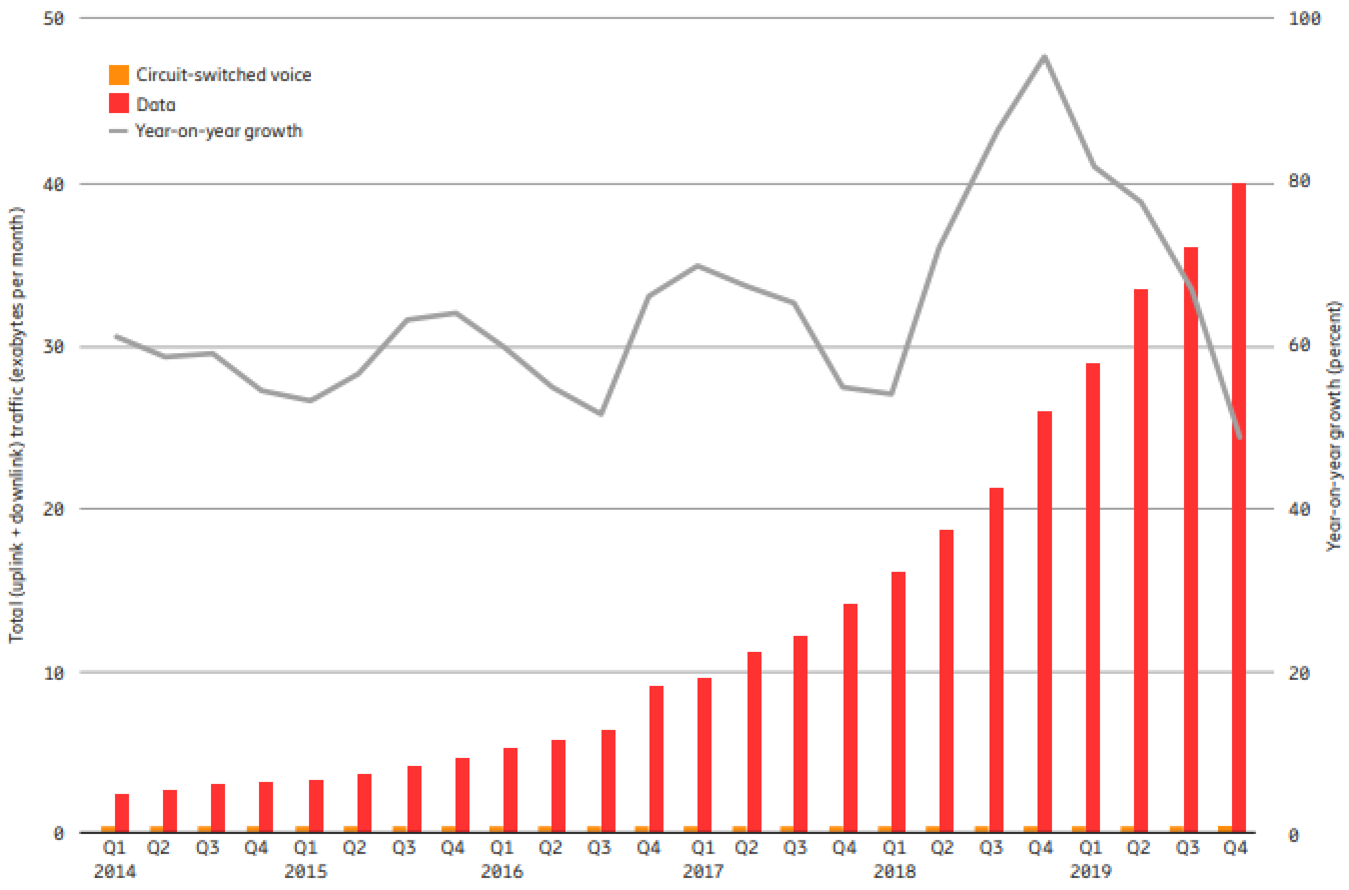
Launched standardized mobile 5G on 2.5GHz in 2019

- 9 cities launched by August 2019
- Additional launches expected

5G americas

Staggering data growth

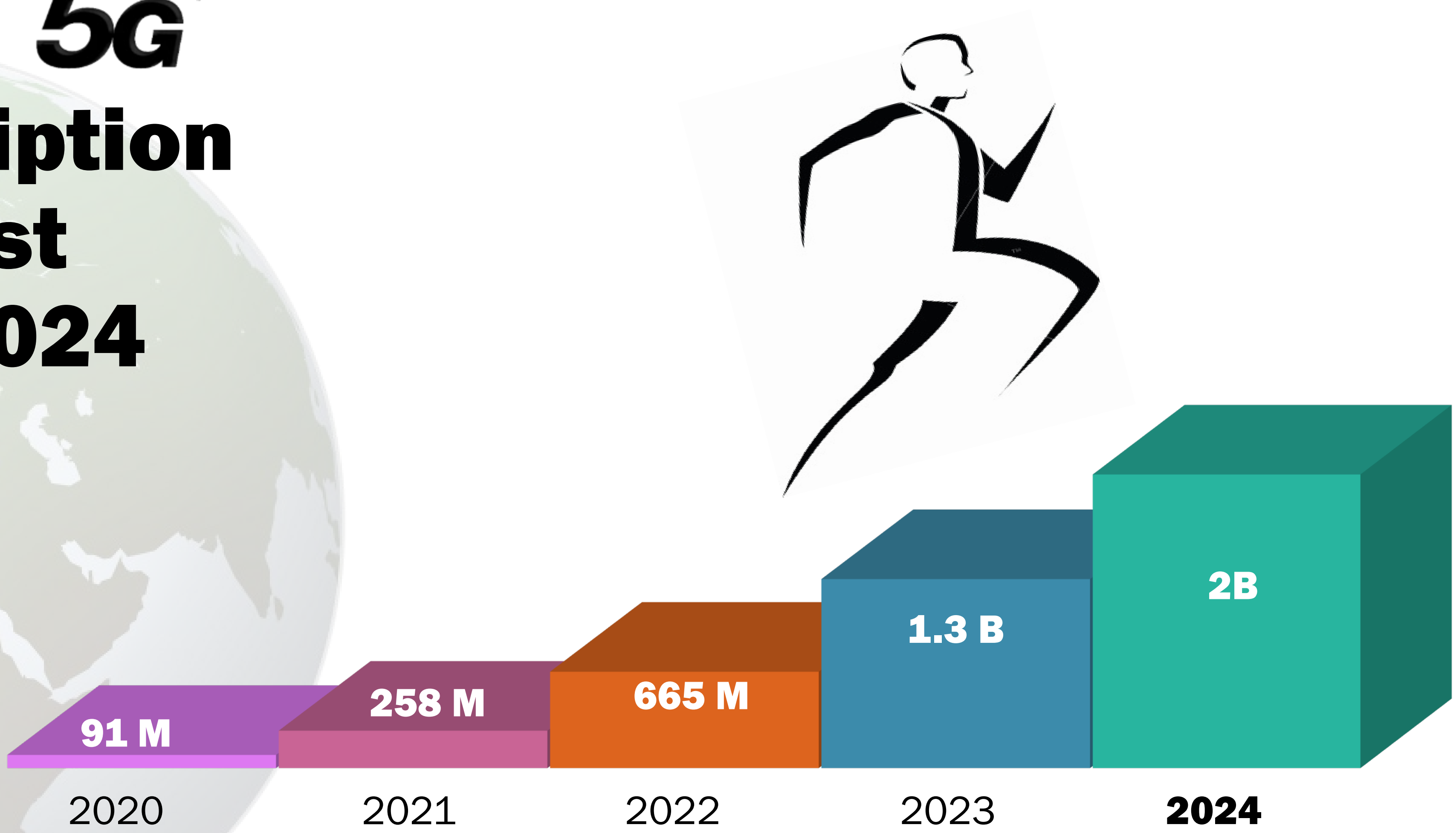
Global mobile data traffic and year-on-year growth (EB per month)



Source: Ericsson traffic measurements (Q4 2019)

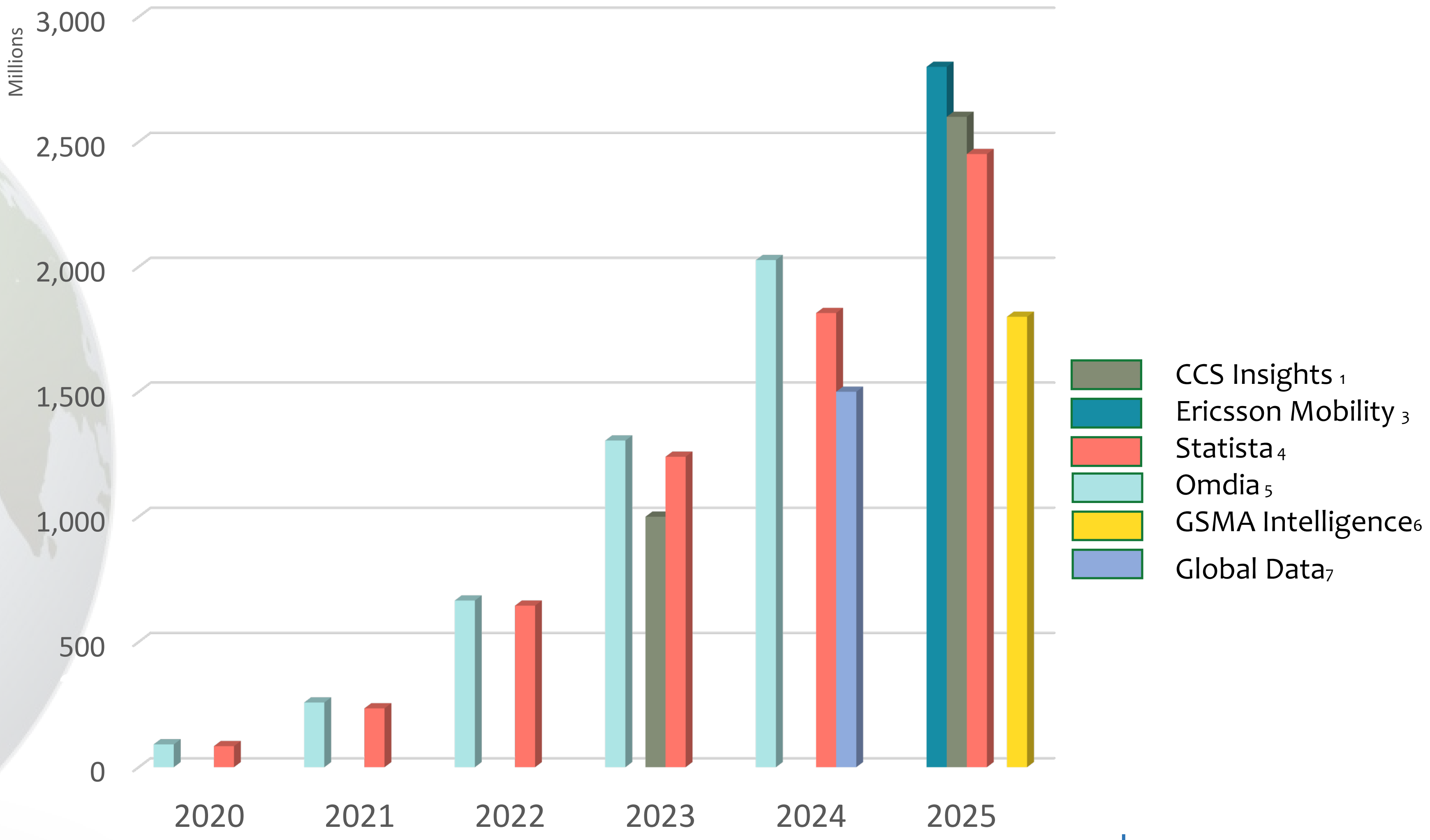
[2] Traffic does not include DVB-H, Wi-Fi or Mobile WiMAX. VoIP is included in data traffic

Global 5G Subscription Forecast 2020-2024



Source: OMDIA March 2020 Forecast includes M2M

Global 5G Subscription Forecasts Vary By Analyst



Sources:
1 CCS Insights, Networks' Ambitions to Launch 5G Early Raise Global Forecast, Sept. 2018
3 Ericsson, Mobility Report, December 2019
4 Statista, Feb 2019
5 Omdia, WCIS, December 2019
6 GSMA Intelligence, Feb 2019
7 Global Data, September 2019

Leading

for a 5G era

- US investments **$1.3 Trillion**[4]
- 4G Leadership = economic benefits and mobile digital service ecosystem added $100 Billion annual GDP[1]
- 5G leadership will drive continued innovation and associated benefits[1]

- 5G global markets are going from 31 Billion in 2020 to **$11 Trillion** in 2026[3]
- Network investment will hit **$1.1 trillion** over the next five years, focused mostly on 5G[2]

- 5G could boost US by **$500 Billion annually**[5]
- **3 Million** new jobs[5]
- Savings and benefits in excess of **$160 Billion** for local communities[5]

Sources:
1 Chairman Ajit Pai remarks at White House 5G Summit, September 2018
2 GSMA
3 ReportsnReports
4 Intel & Ovum:
5 Accenture

5G Services

The global 5G services market size is estimated to reach **USD $45.7 billion by 2020** and register a **CAGR of 32.1% from 2021 to 2025**[1]

FWA for business will be more profitable than consumer access market and also **81% of revenue**[2]

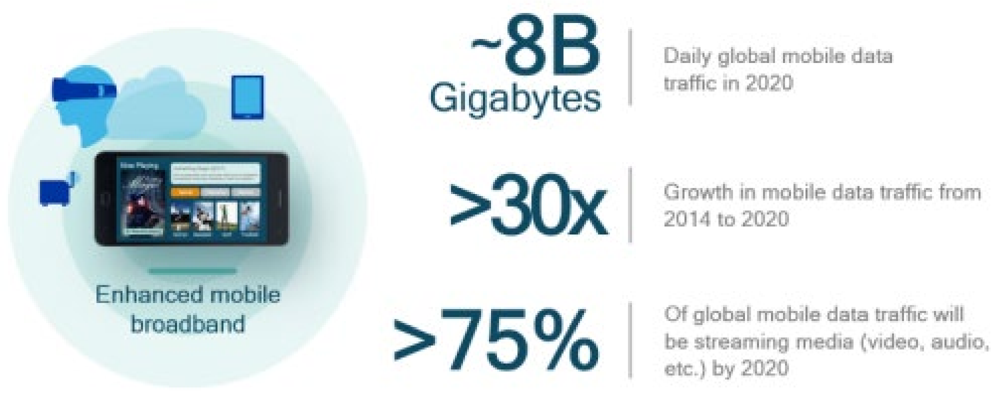


Figure 1: The insatiable demand for faster, better mobile broadband

Source:
1. Grandview Research
2. Research and Markets, Nov 2019

Fig. 1 Qualcomm & Nokia – Making 5G a Reality

5G and Smart Cities

68 percent of the world population is projected to live in urban areas by 2050, growing from **55 percent** today[2]

smart cities market to grow from USD $308 Billion in 2018 to USD **$717 Billion by 2023**, at a Compound Annual Growth Rate **(CAGR) of 18.4%** during the forecast period.

Solving urban problems

- **Smart Lighting**
- **Air Quality & Weather Monitoring**
- **Smart Parking + Metering**
- **Public Safety**
- **Traffic Sensors**
- **Public Transit Fleet Management**
- **Parks Management and Monitoring**

Source:
1. Markets and Markets
2. UN Revision of World Urbanization Prospects
Icon by Manthana Chaiwang

5G and Transportation

According to analysts at Gartner, the share of cars actively connected to a 5G service will grow from a current base of 15 per cent to **74 per cent by 2023 and 94 per cent five years later.**[1]

5.9 GHz "mid-band" for C-V2X empowers 5G communications in transportation sector

- **Autonomous Vehicles**
  - Cars & Transport trucks
  - *Convoys can reduce drag by 20-60%*
- **AI operational and inventory** decisions automated
  - Greater efficiencies and accuracy
  - Optimize stock levels and product availability
- **Finance operations**
  - Remotely track and monitor a customer's product or service usage
  - Charge customers remotely

Source:

1. Gartner
   Ericsson Insights and Reports, September 2019
   Icon by Freepik

5G and Public Safety

First Responder Network Authority (FirstNet), a nationwide network being built exclusively for first responders to streamline their communications, especially in rural areas[1]

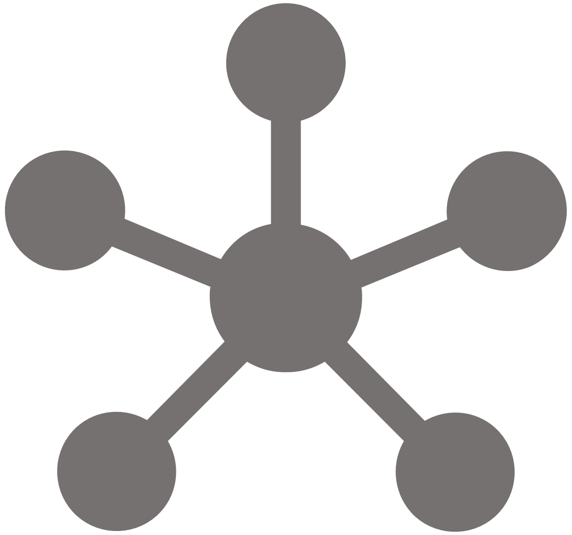
- Massive wireless sensor networks[2]
- 4K video cameras
- AR and VR headsets
- Advanced voice and video communications
  - Voice over LTE (VoLTE)
  - Mission-critical push-to-talk (MC-PTT)
  - Mission-critical push-to-video (MC-PTV)
  - other voice and messaging services

Source:
1. “What would 5G technology mean for government?” NextGov, June 2019
2. Ericsson blog

5G Key Ingredients

What will it take to get it? How will we get there?

5G Key Ingredients



Network Densification

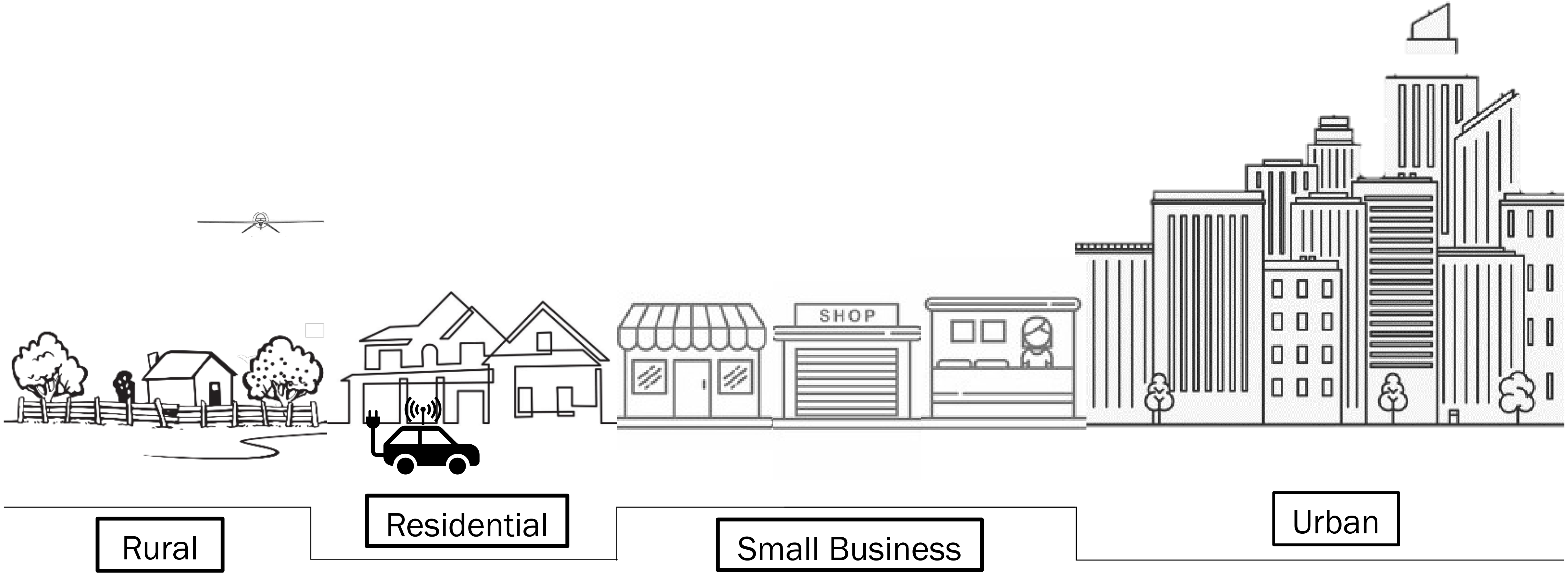
Spectrum

Network Densification

Cell site deployments and placement

Network Densification

Network Densification is a key driver for enabling 5G



Network Densification

4G and **5G** = **5G**

denser than 3G | **denser** than 4G | **10X denser** than 3G?

4G: **Macro cell towers** carried the bulk of 4G mobile traffic + **Small cells** deployed where specific capacity needed

5G:

Diverse Portfolio of cell sites

Macro cell towers carry a lot of traffic. + **Small cells** for local coverage

Variety of cells for capacity & coverage + **Offloading, Sharing and unlicensed** spectrum

Regulatory (US)

The FCC and current administration is committed to U.S. being a leader in 5G.

FCC 5G Deployment Plan:

- Transparent processes
- Reasonable fees
- Accelerated review processes

5G deployments impacted by long municipal bureaucratic review processes.

Could occur in urban, suburban or rural areas. However, 21 states have approved legislation to streamline processes.

Spectrum

National and international considerations

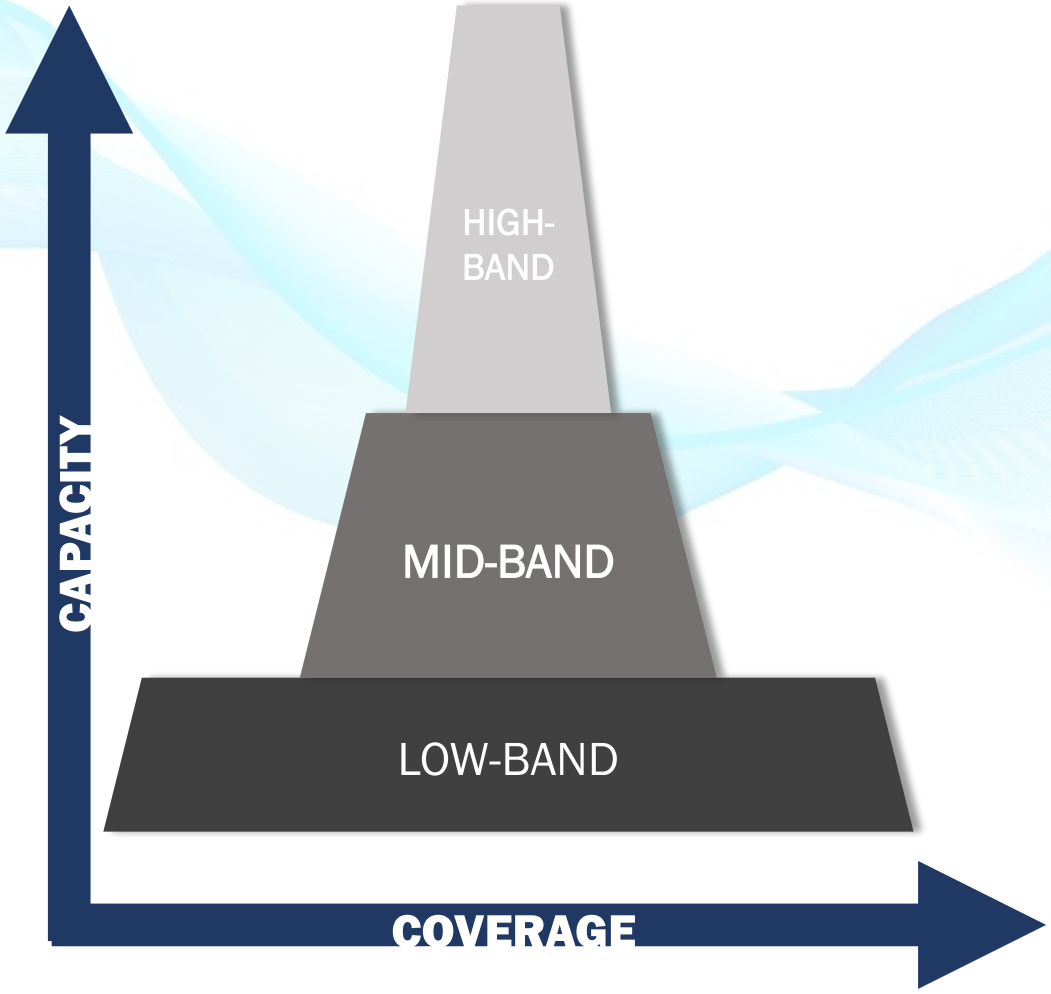
Ensure continued 5G leadership

SPECTRUM NEEDED ACROSS ALL BANDS

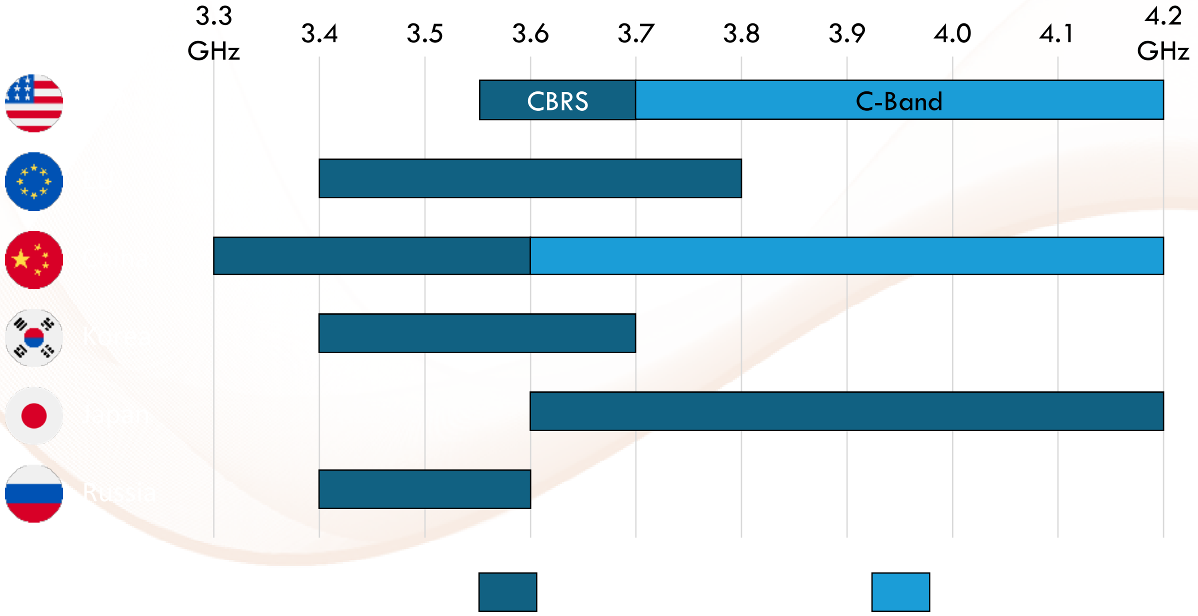
Low-band for coverage reliability

Mid-band for capacity, coverage and speed

High-band for capacity, speed, traffic hotspots and localized applications



Global 5G ecosystem is **forming around 3.5 GHz mid-band** spectrum



- **All major regions**, with the exception of US, have allocated significant amount of mid-band spectrum for 5G and are starting with it
- **Mid-band is very important** for 5G leadership in the US
- **US is a leader in mmWave** but mid-band is critical for 5G leadership

U.S. Spectrum Considerations

LOW-BAND

- Operators using existing spectrum assets below 3 GHz

MID-BAND

- CBRS Shared Spectrum 3550-3700 MHz
- FCC C-band Proposal on 3.7 GHz to 4.2 GHz
- NTIA studying 3.1 GHz to 3.55 GHz
- FCC Proposal on 5.850 GHz to 5.925 GHz

HIGH-BAND

- mmWave spectrum - Auctions
  - 28 GHz – completed January 2019
  - 24 GHz – completed May 2019
  - 37 GHz – completed March 2020
  - 39 GHz – completed March 2020
  - 47 GHz – completed March 2020

3rd mmWave Auction (US)

AT&T won 3,267 licenses in 411 PEAs, bidding about $2.38 billion

T-Mobile bid about $931 million to win 2,384 licenses in 399 PEAs, purchasing both 47 GHz and 37-39 GHz spectrum.

Verizon won 4,940 licenses across 411 PEAs after bidding about $3.4 billion

- 37, 39 and 47 GHz spectrum bands
- Top Bidders: **AT&T, T-Mobile, Verizon**
- Auction 103 ended with **$7.57 billion in gross bids**
- **$0.009 per MHz PoP**
- **Additional winning bidders not listed**
- **US continues to lead in allocation of mmWave spectrum**

5G is a Commercial Reality!

Thank You

5GAmericas.Org

ITU-T Q13 Update

Stefano Ruffini
Expert Ericsson Research
Ericsson

Standardization in ITU-T Study Group 15 and Q13/15

Networks, Technologies and Infrastructures for Transport, Access and Home: Network Synchronization and Time Distribution Performance

Stefano Ruffini (Q13 Rapporteur)

Silvana Rodrigues (Q13 Associate Rapporteur)

SG15 mandate

SG15 is responsible for the development of standards on:

- optical transport network
- systems
- instrumentation and measurement techniques
- access network
- equipment
- maintenance
- management
- test
- home network and power utility network infrastructures
- optical fibres and cables and their related installation
- control plane technologies

to enable the evolution toward intelligent transport networks, including the support of smart-grid applications.

SG15 Working Parties

- WP1/15: Transport aspects of access, home and smart grid networks
- WP2/15: Optical technologies and physical infrastructures
- WP3/15: Transport network characteristics

WP1 – Broadband Access

G.FAST

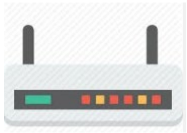
Broadband access
up to 2 Gbps

G.mgfast

Next generation
G.fast targeting 5-10 Gbps

DTA

G.fast dynamic time assignment (DTA) – downstream/upstream bit-rates responsive to customer traffic



Continue collaboration with broadband forum

G.RoF

Radio over fiber
for mobile fronthaul

NG-PON2

Next generation of converged fiber access going to higher speeds

Visible Light Communication
for home networking

Powerline communication (PLC)

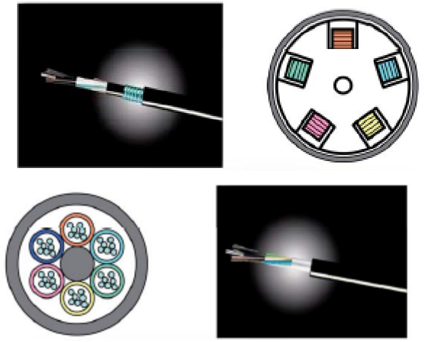
G.Hn

G.hn home networking over indoor phone, power,
and coax wires >2 Gbps

WP2 – Optical Technologies

Optical Network Infrastructure

Disaster Management issues



Optical Fibre Technologies and Cables for easy and environmentally friendly outside plants

Multichannel bi-directional DWDM applications targeted at lower cost optical solutions for applications including mobile fronthaul and backhaul

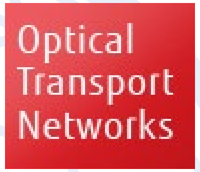
100G and future higher-rate coherent multi-vendor interoperable interfaces

200G
400G

Short-reach (OTN client) 200G and 400G interfaces reusing components developed for Ethernet applications

WP3 – Optical Transport Networks

Transport and synchronization supporting 5G mobile fronthaul and backhaul



Synchronization of packet networks and future OTN networks, e.g., beyond 100G

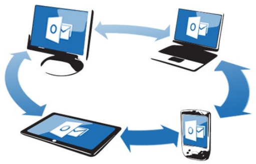
Architecture and other Transport SDN Aspects

Network survivability (protection and restoration)

New “B100G” OTN interfaces, including the use of coherent G.698.2 interfaces under development

Management aspects of control and transport planes

Equipment & management specifications for OTN, Ethernet and MPLS-TP



Core Information model enhancement for management of synchronization and optical media

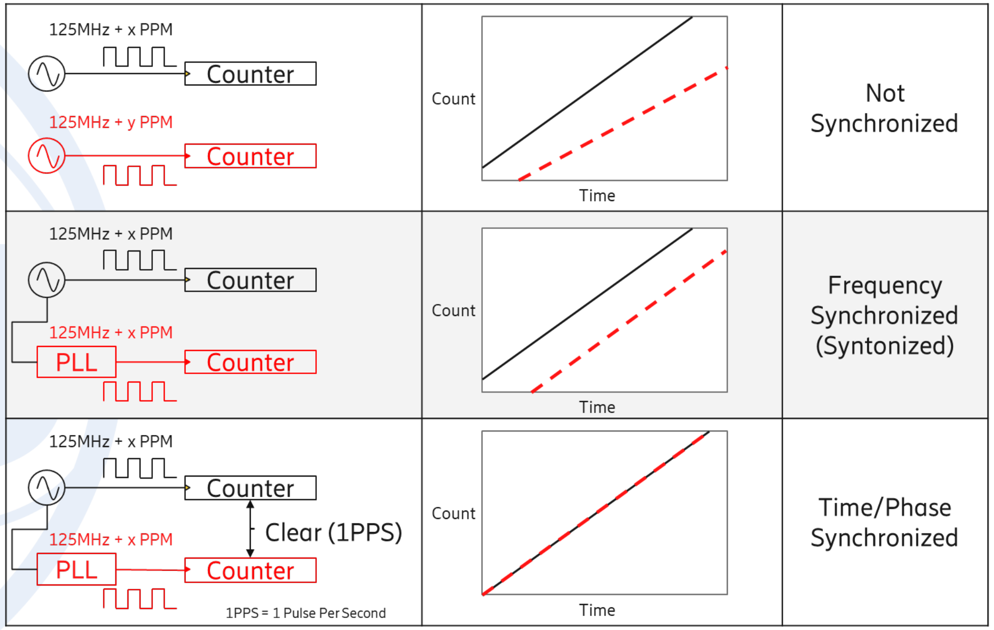
Meetings

- Past meetings since 2017
  - Geneva, 19 – 30 June 2017
  - Geneva, 29 January – 9 February 2018
  - Geneva, 8-19 October 2018
  - Geneva, 1 – 12 July 2019
  - Geneva, 27 January – 7 February 2020
- Future SG15 meeting
  - Geneva, 7-18 September 2020

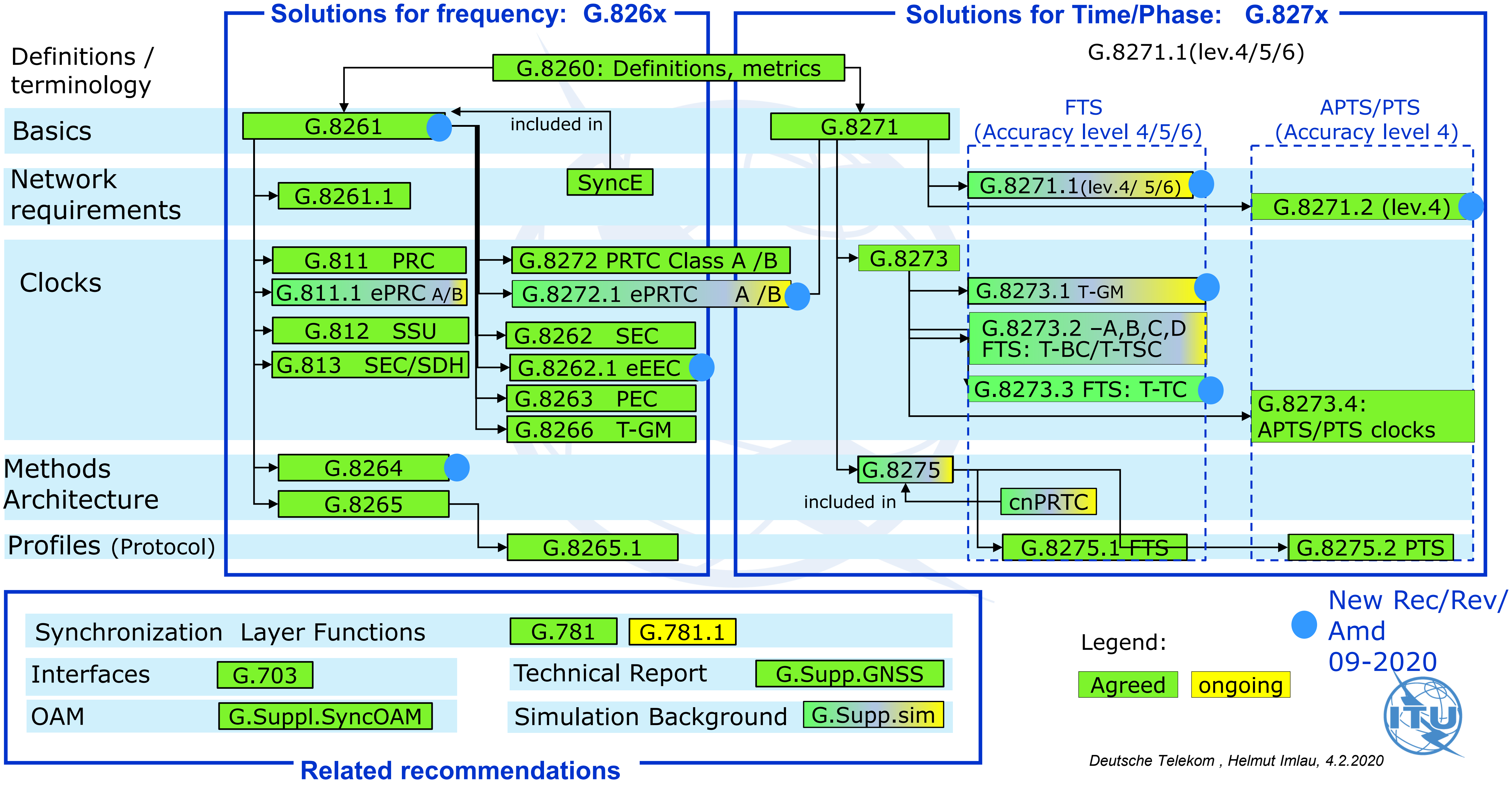
2017-2020
Study Period

Q13: Introduction

- Network synchronization and time distribution performance
  - Networks Timing Needs (e.g., OTN)
  - End Applications Timing Needs (e.g. 5G Base Stations)
- Distribution of Time-Phase and Frequency
  - Methods (e.g., over physical layer, via packets, GNSS)
  - Architectures
  - Clocks
  - IEEE 1588 profiles
  - Performance, Redundancy, Reliability, etc.
- Networks
  - From SDH to Ethernet, IP-MPLS, OTN, xPON, ... -> MTN
- Recommendations
  - G.826x series (distribution of frequency synchronziation)
  - G.827x series (Distribution fo time synchronzation)
  - G.781, G.781.1 (Sync Layer Functions)
  - «Historical» (G.803, G.810, G.811, G.812, G.813, G.823, G.824, G.825...)

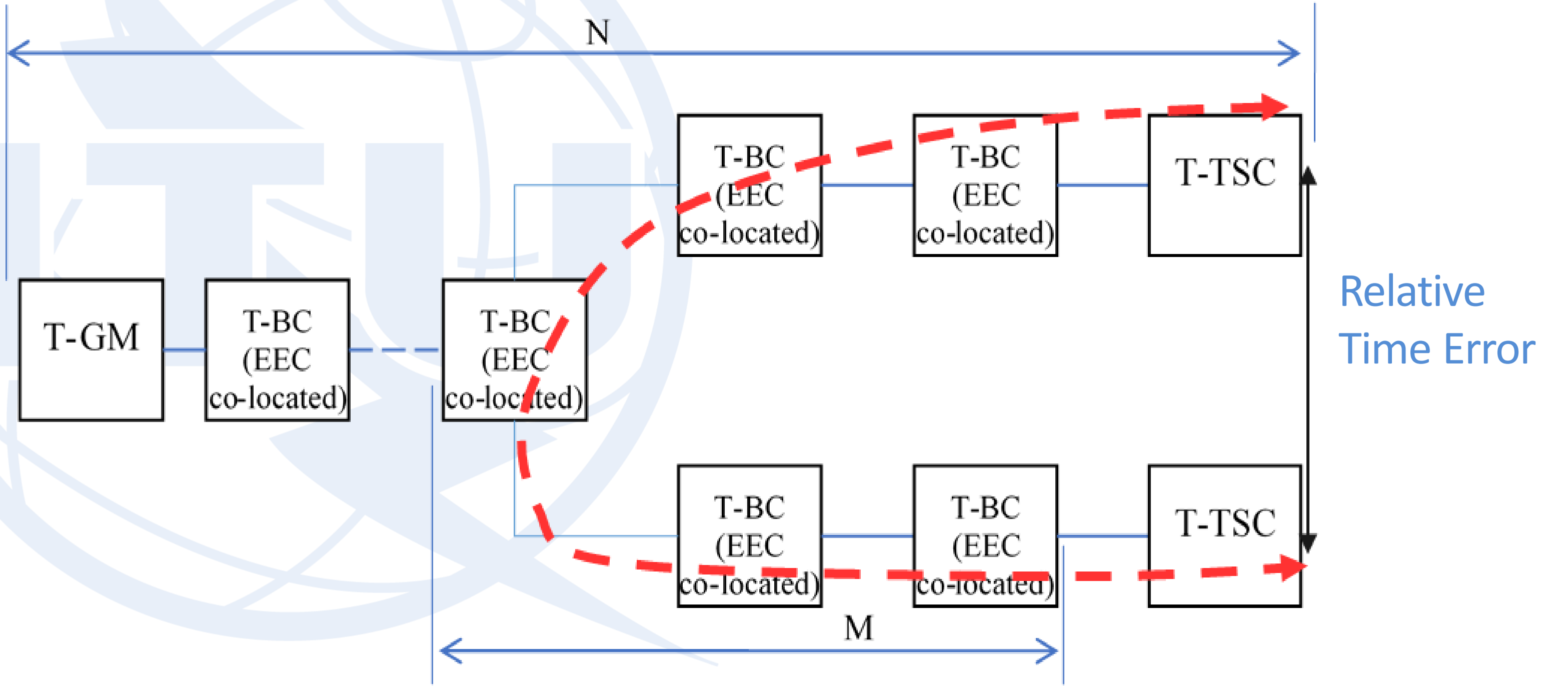


Q13 Recommendations



Ongoing Studies: Fronthaul (G.8271.1)

- Under analysis guidelines for network dimensioning
- Use of G.8273.2 Clock Class C is generally assumed
- Use of enhanced Synchronous Ethernet
- Initial assumptions : short clock chain (e.g., M < 3-5)

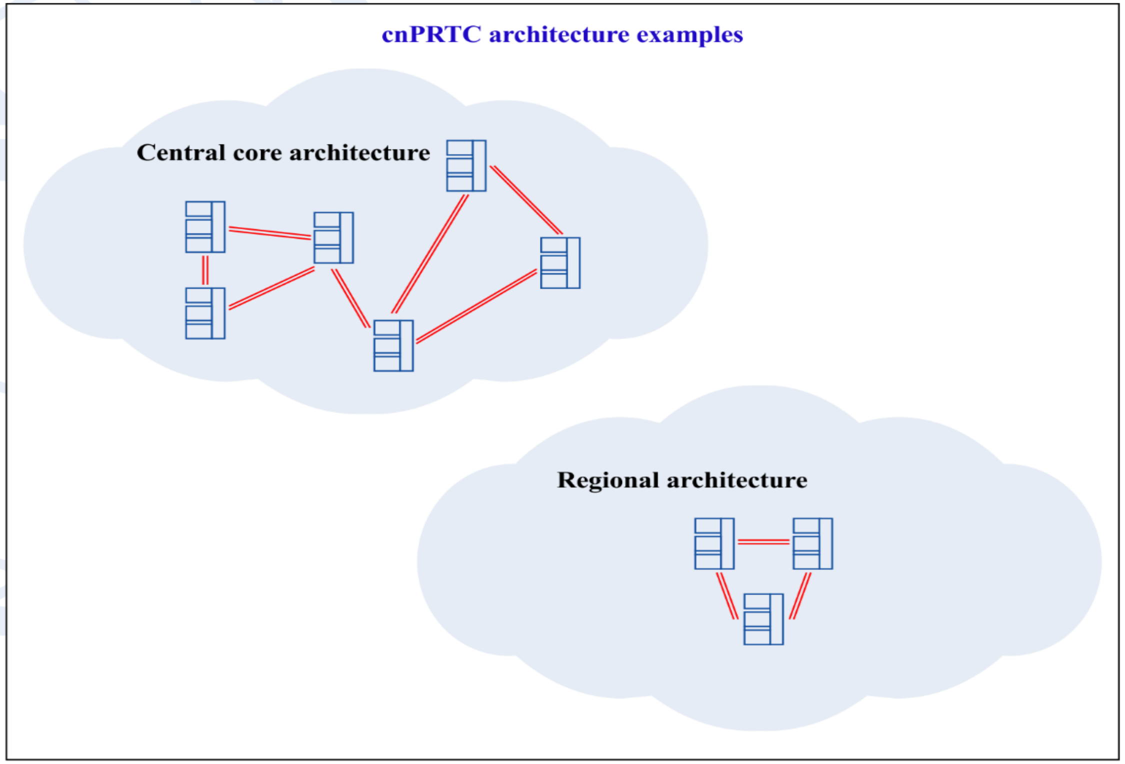


Network Performance measurement still with respect to a common master ?

What is Next ?

- MTN, Metro Transport Network (based on FlexE for 5G transport network)
  - Sync Requirements
  - Sync Architecture
  - PTP and syncE distribution
  - Clocks
- Complete work on Profile Interworking
- Complete work on cnPRTC (Coherent PRTC)
  - Requirements
  - Methods (high accuracy profile?)
- Address New Sync Requirements
  - Emerging needs in mobile networks (positioning or even use cases with less stringent requirements);
  - Future needs ?

The coherent network PRTC connects primary reference clocks at the highest core or regional network level. This provides the ability to maintain network-wide ePRTC time accuracy, even during periods of regional or network-wide GNSS loss (G.8275)



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1956 2016
CCITT / ITU-T

ITU

QUESTIONS: Submit using the question tab on the control panel located on the right side of your screen.

Stefano Ruffini
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Chris Pearson
5G Americas

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Microchip Technology Sponsor Presentation

Barry Dropping
Associate Director
Product Line Management
Microchip Technology

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Sponsor Overview

MICROCHIP

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

SMART | CONNECTED | SECURE

Barry Dropping

May 6, 2020

Microchip Corporate Overview

- **Leading Total Systems Solutions provider:**
  - High-performance standard and specialized microcontrollers, digital signal controllers and microprocessors
  - Mixed-signal, analog, interface and security solutions
  - Clock and timing solutions
  - Wireless and wired connectivity solutions
  - FPGA solutions
  - Non-volatile EEPROM and Flash memory solutions
  - Flash IP solutions
- **~ $6 Billion revenue run rate**
- **~19,000 employees**
- **Headquartered near Phoenix in Chandler, AZ**

Timing and Clocks Product Lines

Broadest Clock & Timing Portfolio | 75+ Years of Timing Experience

Wireless LTE/5G

Data Center

Networking

Automotive

Oscillators

MEMS | Crystal | OCXO | EMXO | TCXO
MCXO | VCXO | VCSO

Clock Generation

Low Jitter | Low Power | Any In/Any Out
Clock Tree On a Chip | Integrated MEMS/Xtal

Clock Distribution

Low Additive Jitter | Any In/Any Out | Fan-Out Buffer
Zero-Delay Buffers | Dividers | Multiplexers

Real Time Clock and Calendar

I^2C | SPI | Battery Backup
Unique ID / MAC Address | Digital Trimming

Jitter Attenuation

Jitter Filtering | Clock Translation | Any In/Any Out
Internal EEPROM | Advanced PLL

Synchronization

Synchronous Ethernet | IEEE1588 | Servo Algorithm
OTN/GPS/PLLS | Firmware/Software Support

Complementary

Logic Translators | Cross Point Switches | 555 Timers
Backplane & Cable | Flip Flop/Logic Gates | Skew Mgmt.

FTS Atomic Clocks

CS Beam Tube | Hydrogen Maser
Chip Scale Atomic Clock (CSAC) | Rb Oscillators

IoT & Smart Devices

Healthcare

Aerospace

Military

MICROCHIP

Microchip in 5G

5G Infrastructure

Radio & Small Cell

Precision Oscillators
Network Synchronization
SAW Filters
Power over Ethernet
Ethernet Switch/PHY
FPGA
Security
AC-DC, DC-DC

Baseband

Precision Oscillators
Network Synchronization
FPGA
Security
AC-DC, DC-DC

X-Haul

Ethernet PHYs w/ Security & Timing
OTN / Ethernet Fronthaul Processors
Precision Oscillators
Network Synchronization
FPGA
Security
AC-DC, DC-DC

Edge Compute

FPGA / MPU / MCU
Flash/Storage Controllers
PCIe Switch
Network Synchronization
FPGA
Security
AC-DC, DC-DC

5G Enabled Markets

Automotive

Ethernet, PCIe®
FPGA / MPU / MCU
SAW Filters
Timing
Security
AC-DC, DC-DC

Industry 4.0

Ethernet,
FPGA
MPU / MCU
SAW Filters
Timing
Security
AC-DC, DC-DC

Medical Devices

FPGAs
MPU / MCU
SAW Filters
Security
AC-DC, DC-DC

Smart Home

MPU / MCU
SAW Filters
Security
AC-DC, DC-DC

Frequency and Time Systems

Mission

Be the trusted source of sync and timing solutions where precision, accuracy, and reliability matter.

Vision

Synchronize the world - from the ocean floor to satellites in space…and everything in between.

Synchronization Products

- Frequency & Time Distribution Systems
- 1588 Grand Masters
- NTP Servers
- GPS Instruments

Clock Products

- CSAC / Rubidium Clocks
- Cesium Clocks
- Hydrogen Masers

Government Systems and SDA

- Frequency References
- High Performance Time & Frequency Solutions
- Space Qualified and Military Oscillators
- Custom and Configurable Systems

MICROCHIP

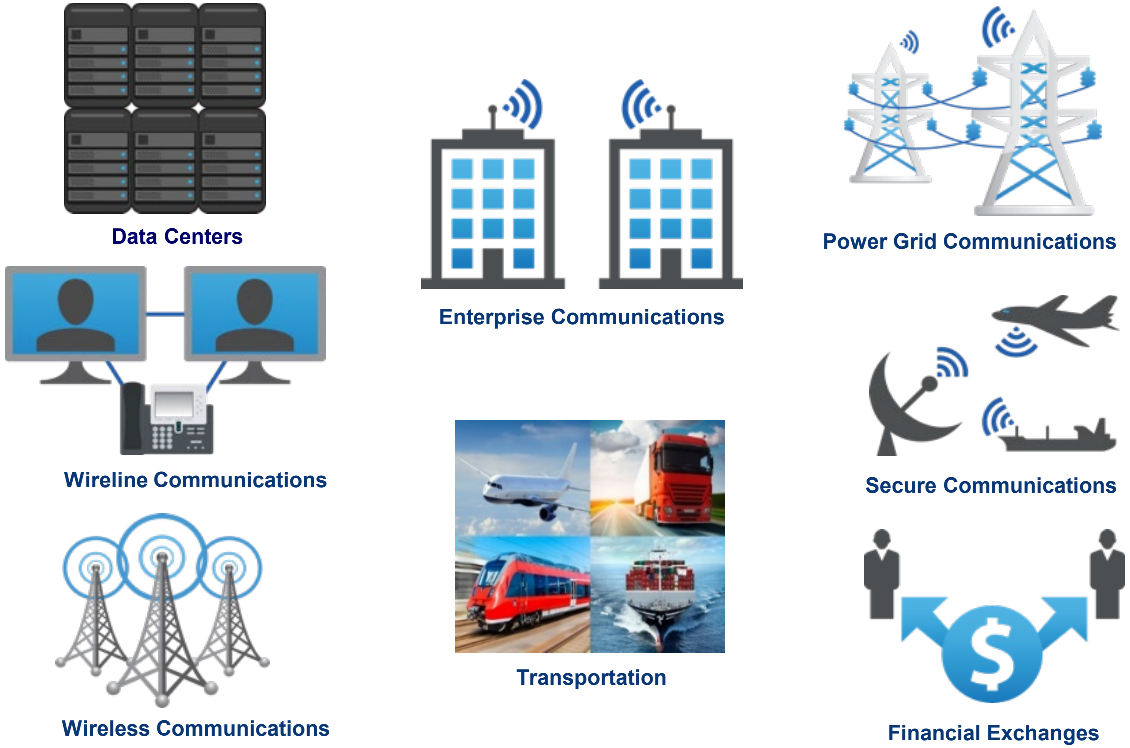
Frequency and Time Systems

Symmetricom → Microsemi → MICROCHIP

Frequency and Time Systems Lineage

Time is Essential

Critical infrastructure requires increasingly accurate, precise, secure and reliable time.



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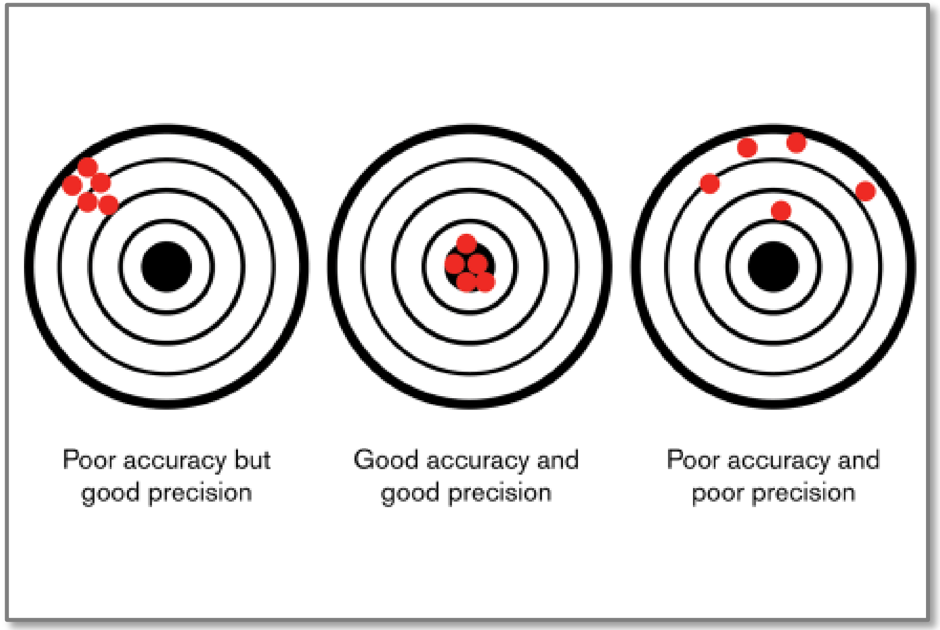
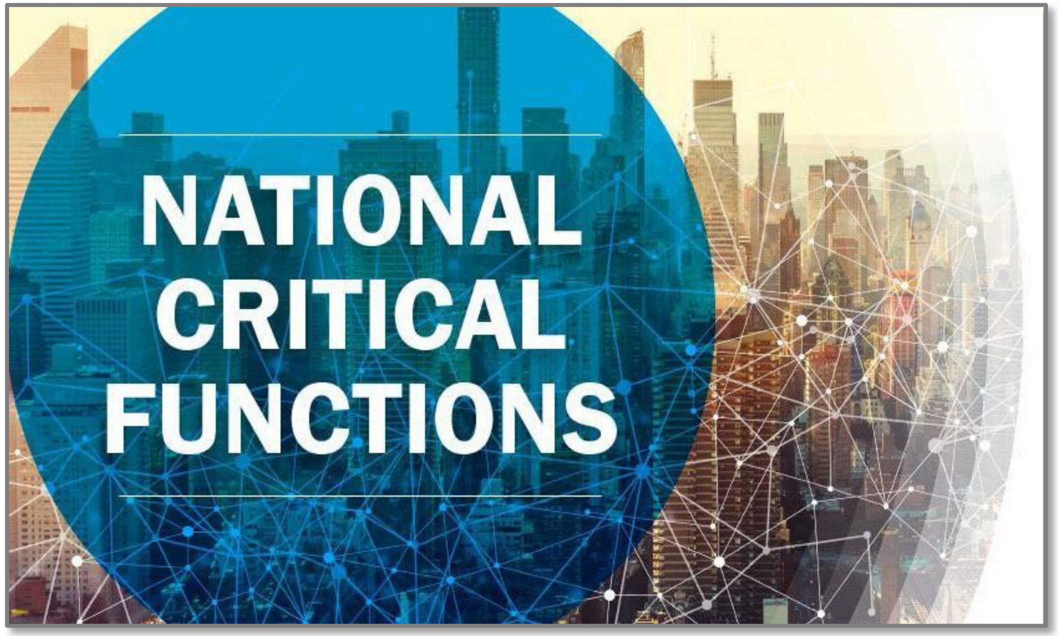
Conversation is Changing



TIMING



SECURITY

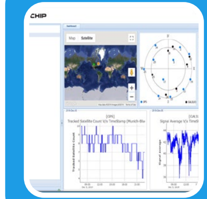
Timing Hygiene

Trusted Source

- Validated Timing Source
- Trusted Supply Chain

Validation

- Live Sky Monitoring
- Anomaly Detection



Visibility

- Analytics
- Situational Awareness
- Heat Maps

Resiliency

- Integrated & External Holdover Clocks
- Autonomous Time-Scales
- Alternate Sources (e.g. eLORAN)

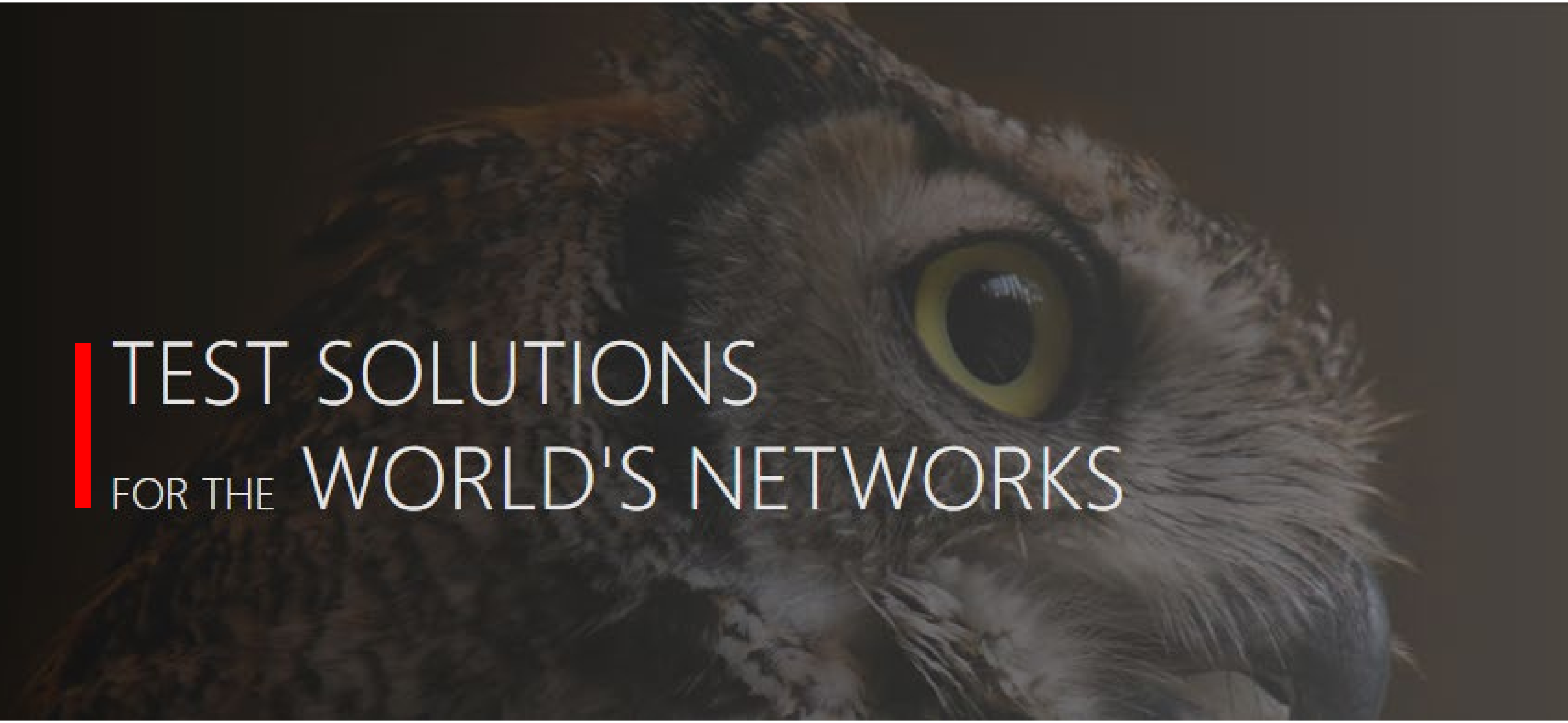
Thank You

Three Steps to 5G

Anand Ram
Vice President
Business Development
Calnex Solutions

3 Steps to 5G

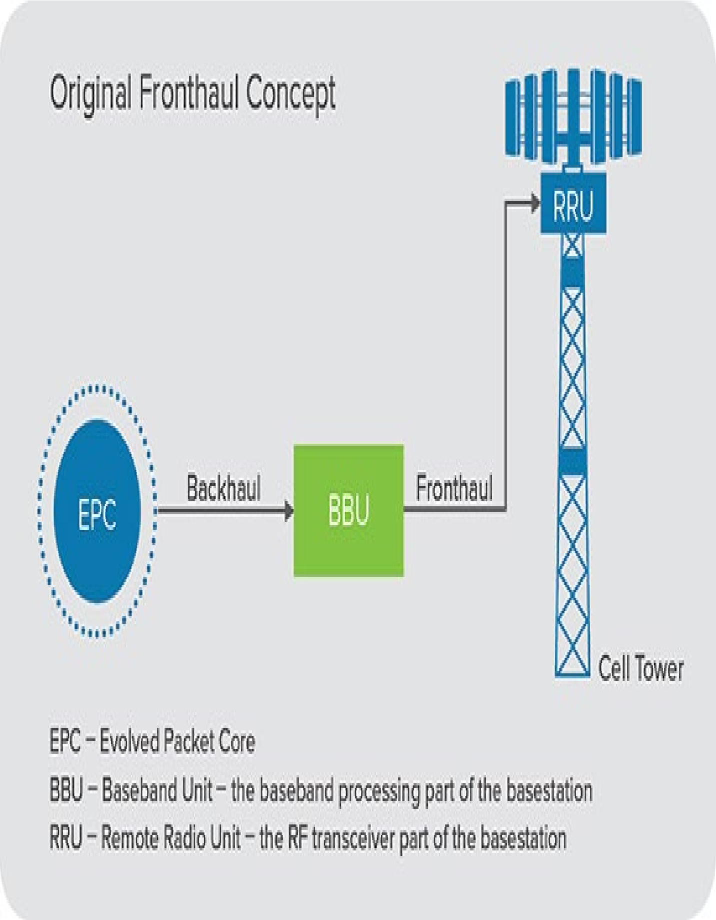
Anand Ram
vWSTS 2020

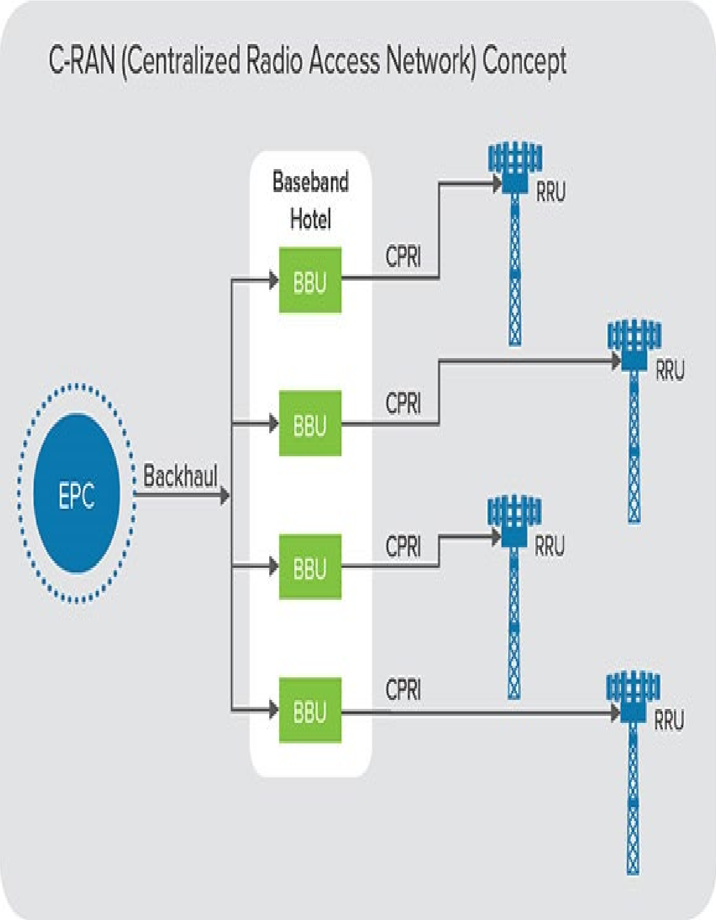


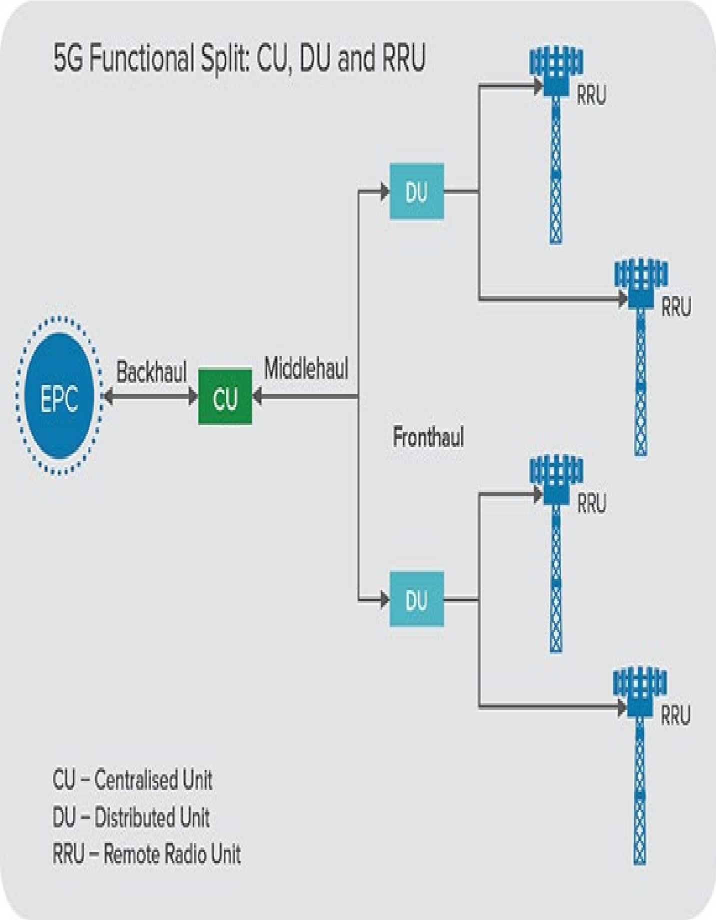
The 3 Considerations

- What the Haul?!
- Timing & Synchronisation
- Disaggregation & Virtualization

What the Haul?!







Fiber

- Fixed and known latency (low), asymmetry.
- Almost no packet loss and jitter

Network

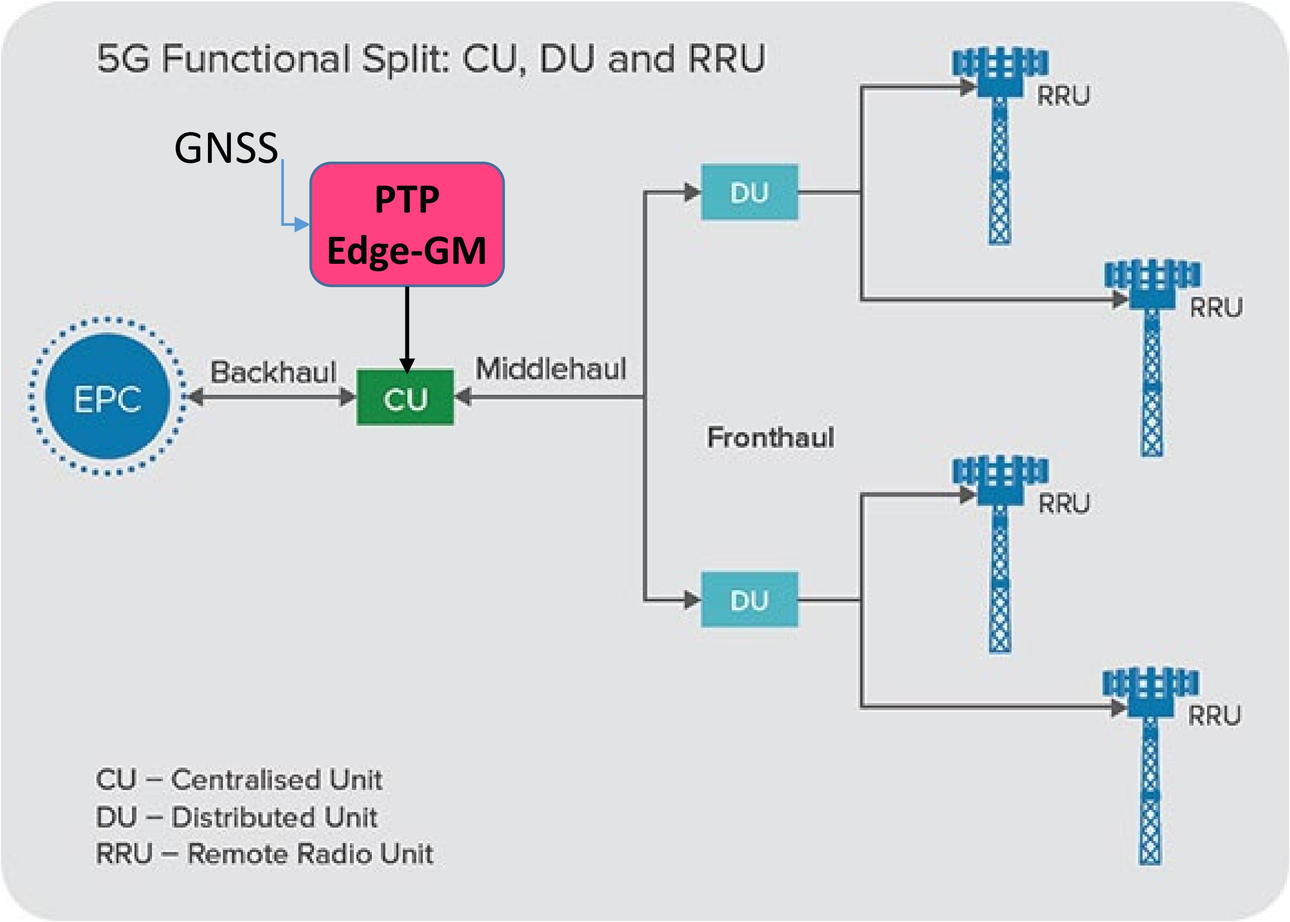
- Variable latency, loss and jitter, etc.

Timing & Synchronisation

- 5G Standalone (SA) and DSS driving new PTP deployment
- What's the right Architecture? Profile? Accuracy?
- Are there other new challenges/issues?

Example Deployment – Tier 1 Operator

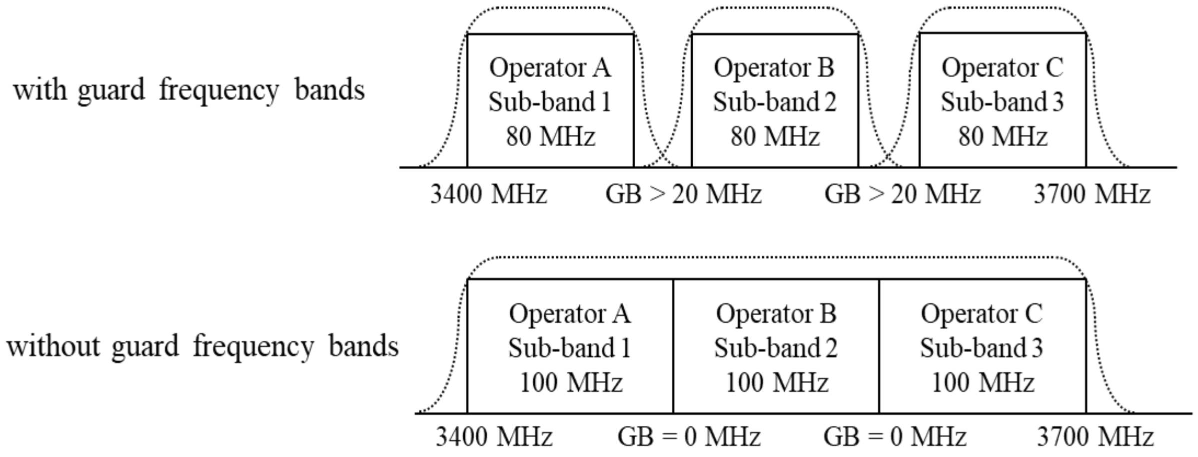
Calnex



- Max 2 Nodes between GM and Slave
- G.8275.1 used
- Plenty of headroom to meet $\pm$ 1.1µs
- Need to deploy 1 Edge-GM per CU ($$)
- Other options:
  - Fewer GMs deeper in network
  - G.8275.2
  - Co-ordinated PRTCs in Core

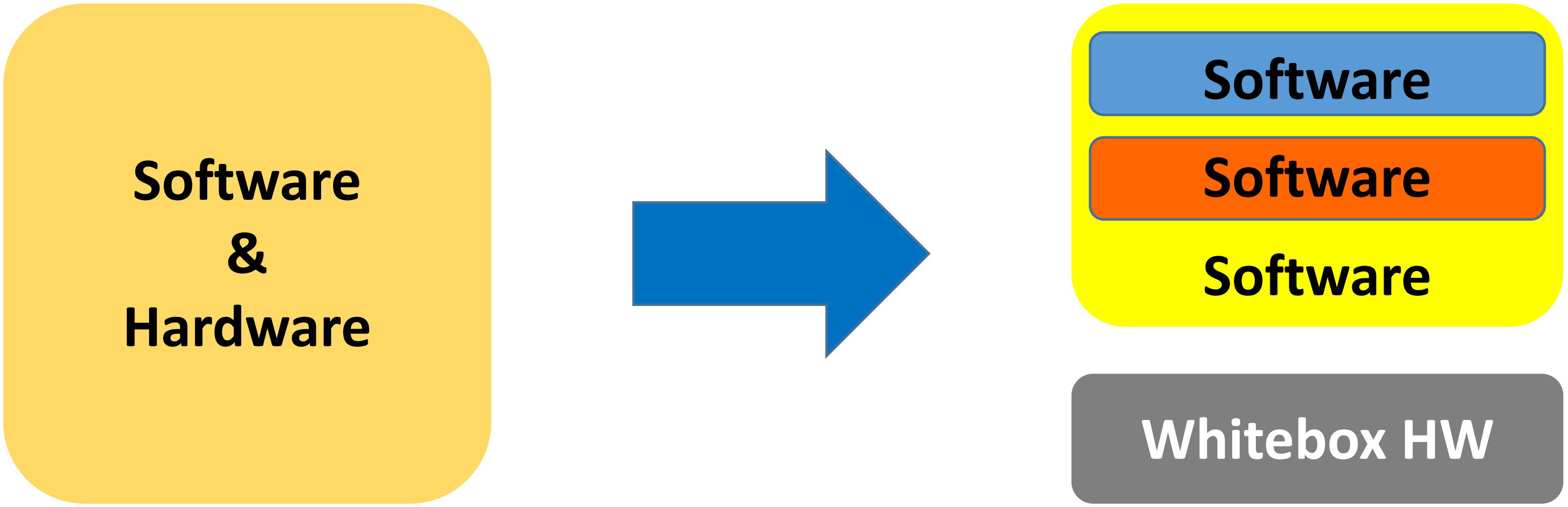
Other Challenges / Issues

- Removal of guard-bands to use full spectrum
  - Need to sync to the same reference
  - Need to ensure and check intra-operator sync



- RRUs can't do low-pass filtering and have greater environmental stress
  - Short-term clock wander issue – under discussion at standards bodies

Disaggregation / Virtualization



- Extensive Features
- Portfolio of Hardware options
- Integrated and Tested
- Single vendor support

- Faster SW Feature Development
- HW Independence
- New Deployment options
- New Operational options
- (*eventually*) Cost benefits

Disaggregation / Virtualization

Calnex

- Who will integrate? Who will test? Who will support?

OPEN Compute Project ® O-RAN ALLIANCE TELECOM INFRA PROJECT , etc.

all members & players have a collective role

- Specifications, methodologies, plugfests, deployments

Summary – Consider these

- New xHaul architecture changes network parameters
- 5G SA is driving new timing deployments
  - Many options on architectures
- Some new gotchas for 5G timing
- 5G infrastructure will be Disaggregation in Datacenters
  - Collective effort to integrate, test, prove & deploy

Sync Accuracy Challenges in 5G

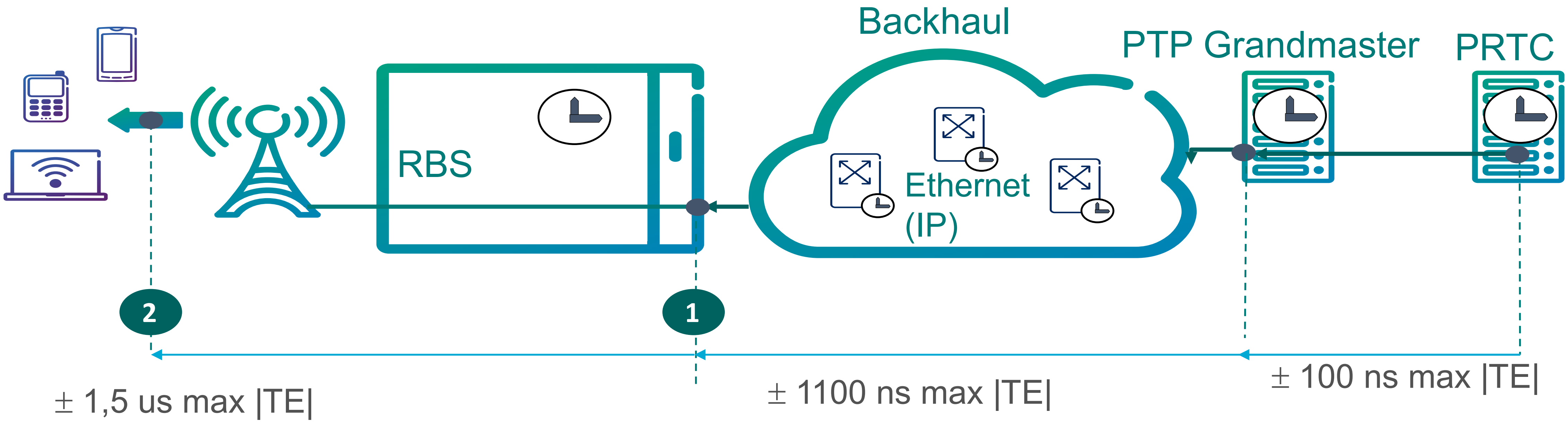
Mårten Wahlström
System Developer
Ericsson

Addressing the Sync Accuracy Challenges of 5G RAN

Mårten Wahlström
RBS Synchronization System Responsible

ERICSSON

Baseline - Challenges

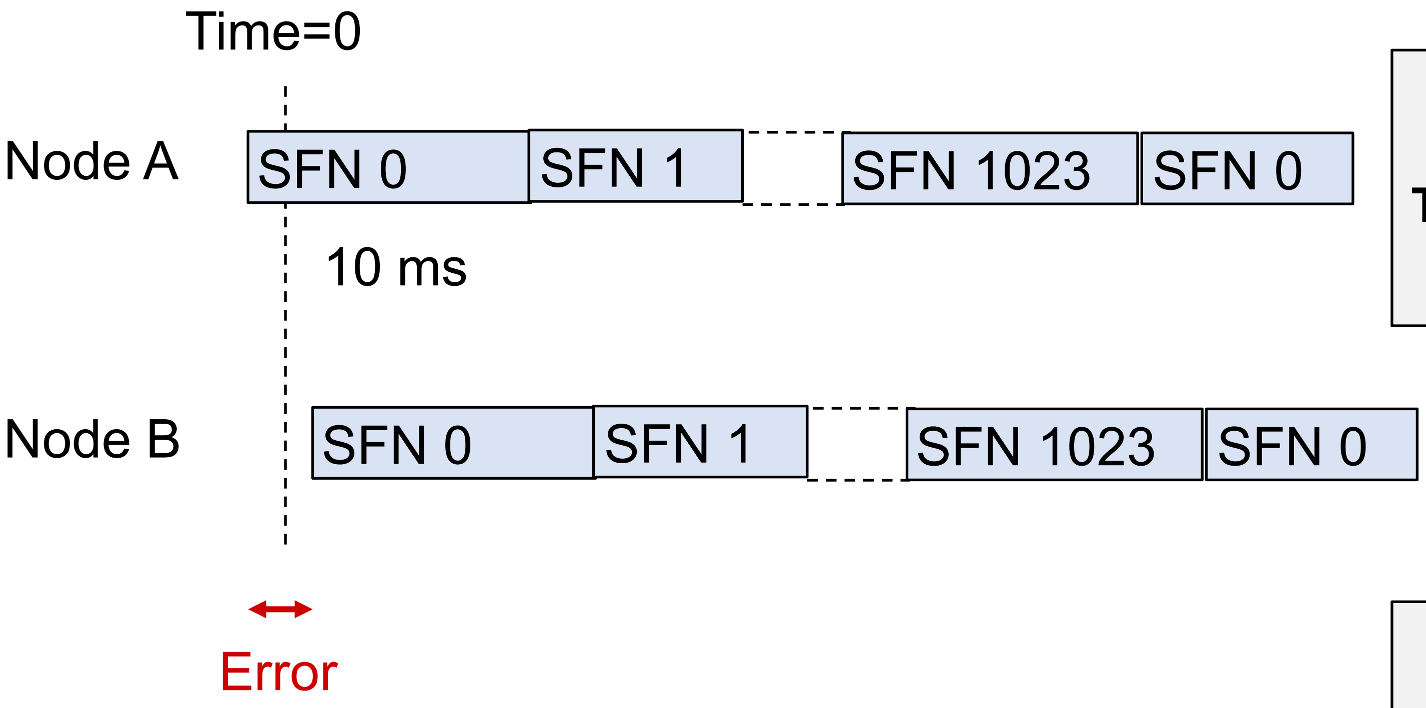


Baseline: ITU-T reference path allocates 400 ns to the BS (G.8271.1&2)

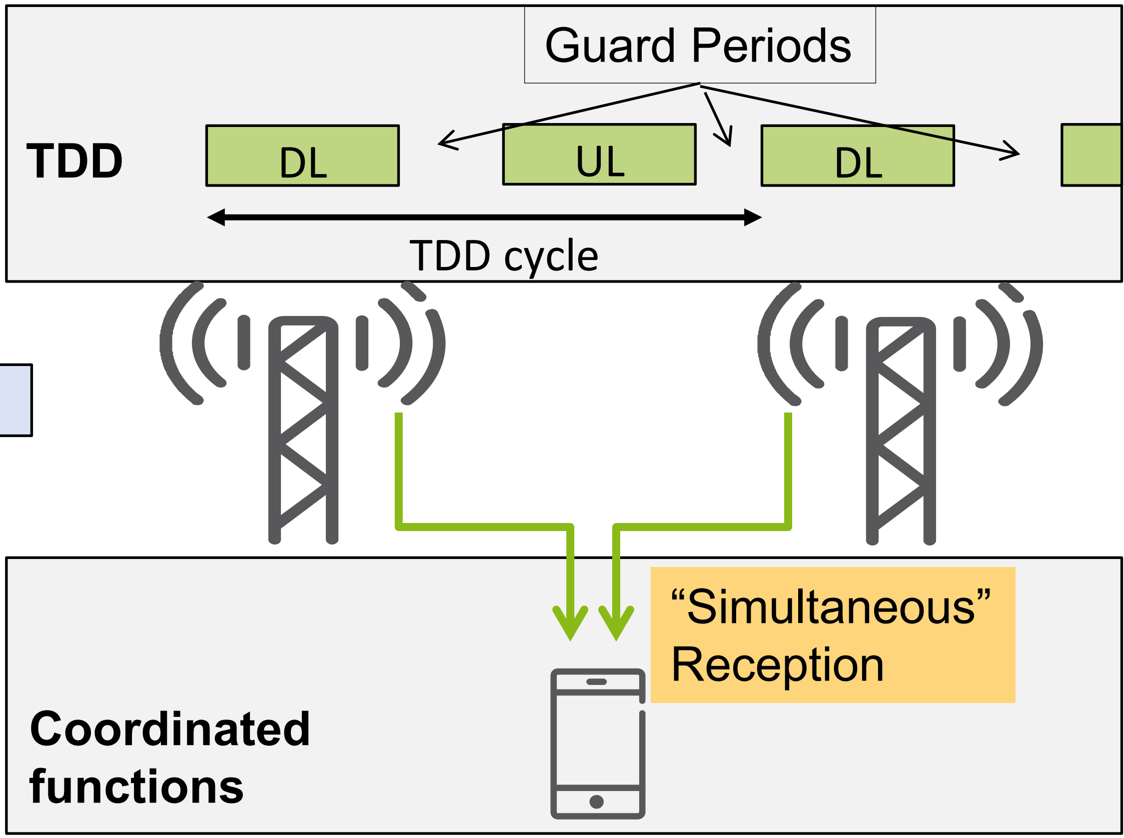
Challanges:

- Industrial IOT: High Accuracy Time transparency required across 5G NW including the UE(s)
- Integrated Access and Backhaul: RAN faces the same accuracy budget problem as PTP
- UE Positioning: Unrealistic expectations on Synchronization accuracy.

Synchronization – of what?

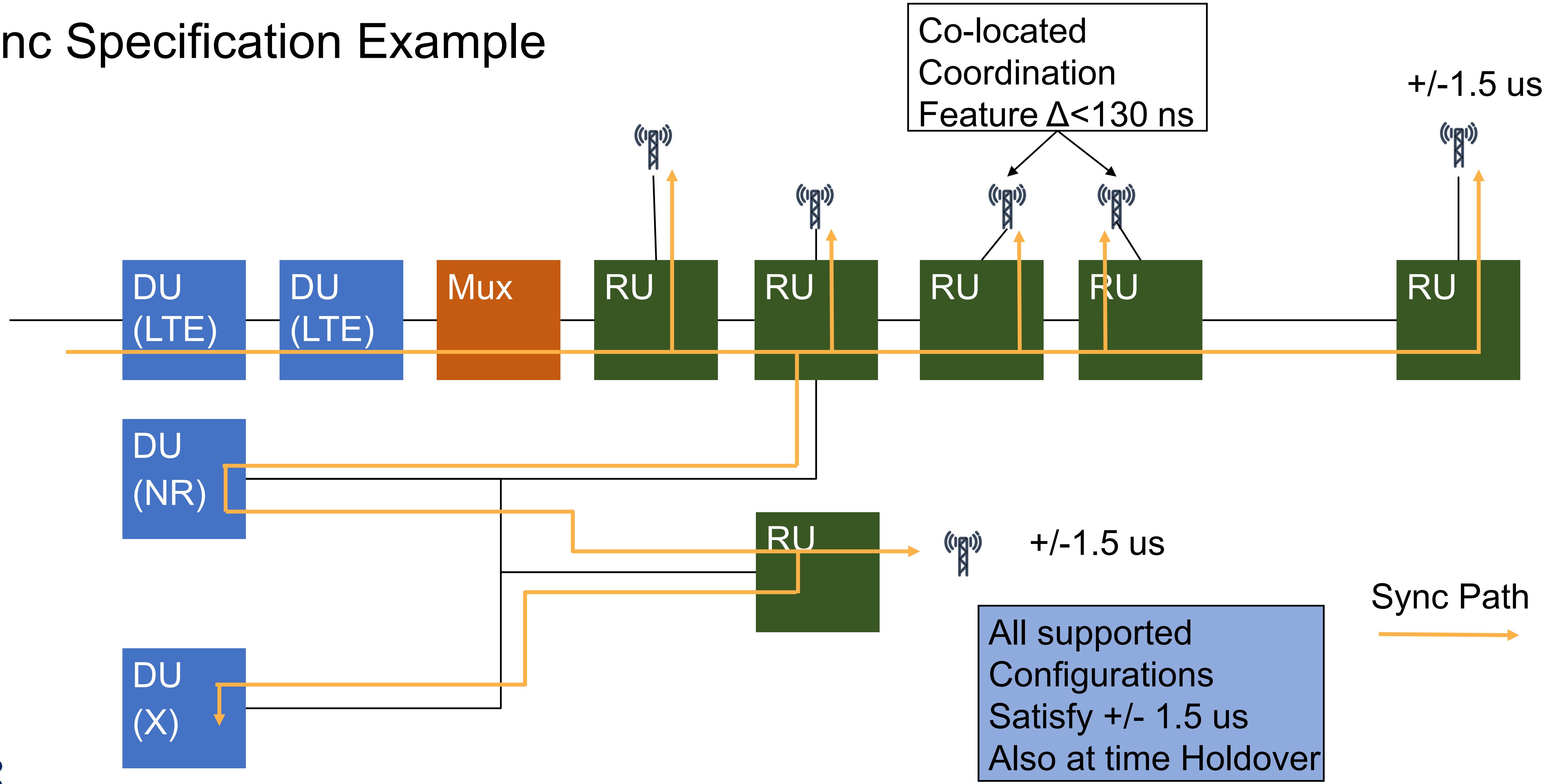


Max Error between non-colocated antennas
for NR TDD according to 3GPP: 3 us



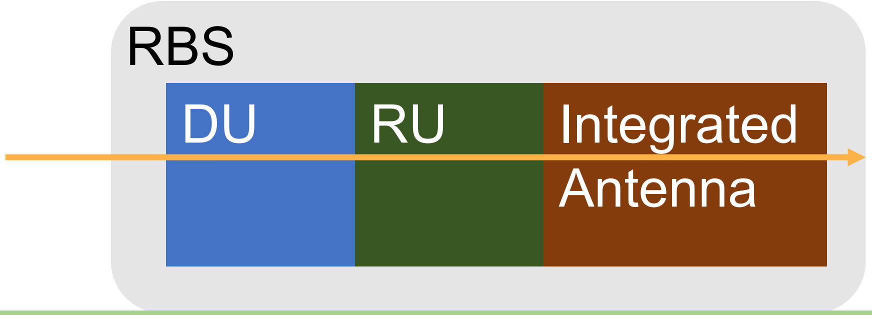
What is an RBS?

Sync Specification Example



Improved accuracy of the RBS?

With a completely Integrated RBS/RU,
you get best possible accuracy

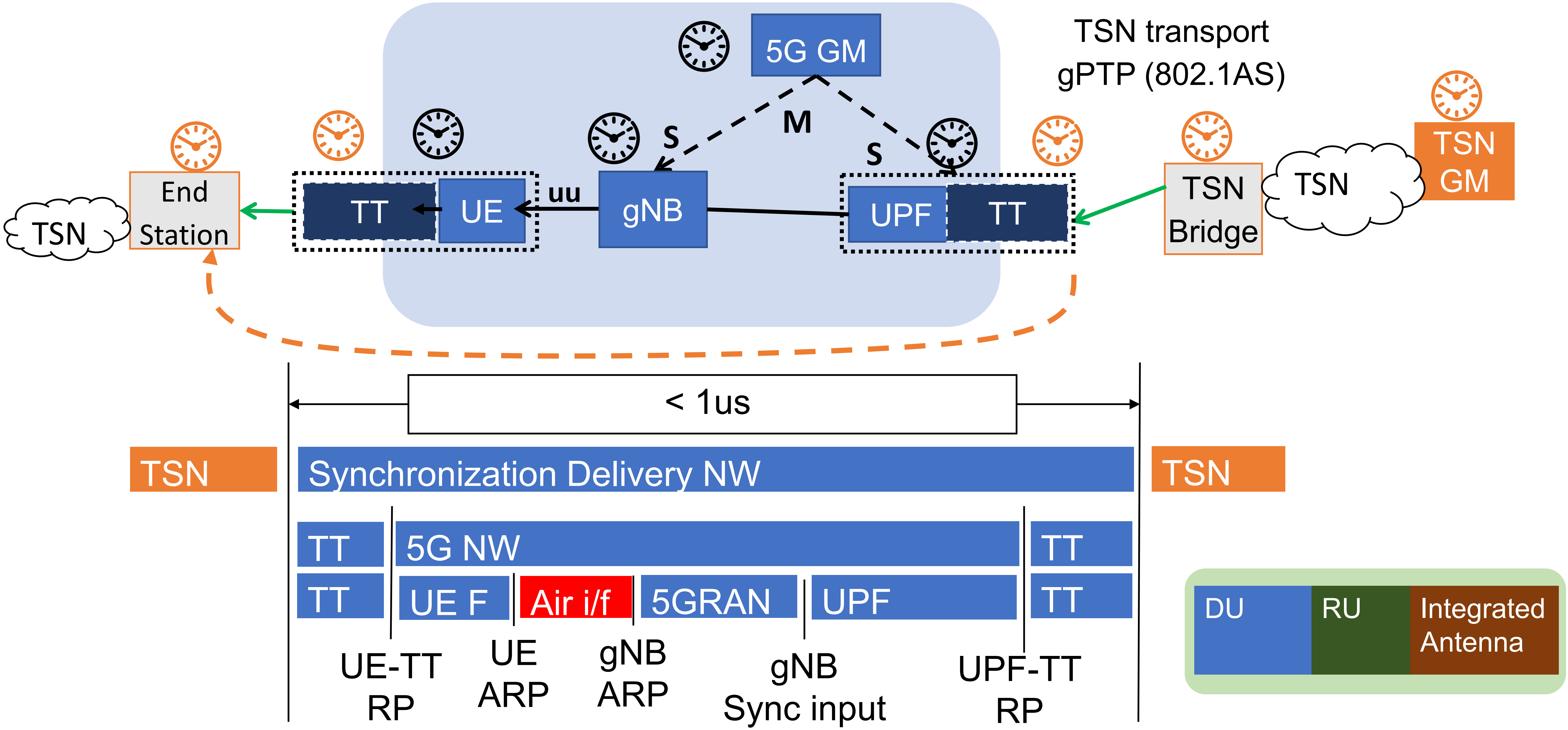


Bottlenecks

- PTP or GNSS accuracy.
- Holdover margin for GNSS outage.
- Radio signal Filters.
  - E.g Cavity filters. Even when compensated have a large temperature dependent group delay.

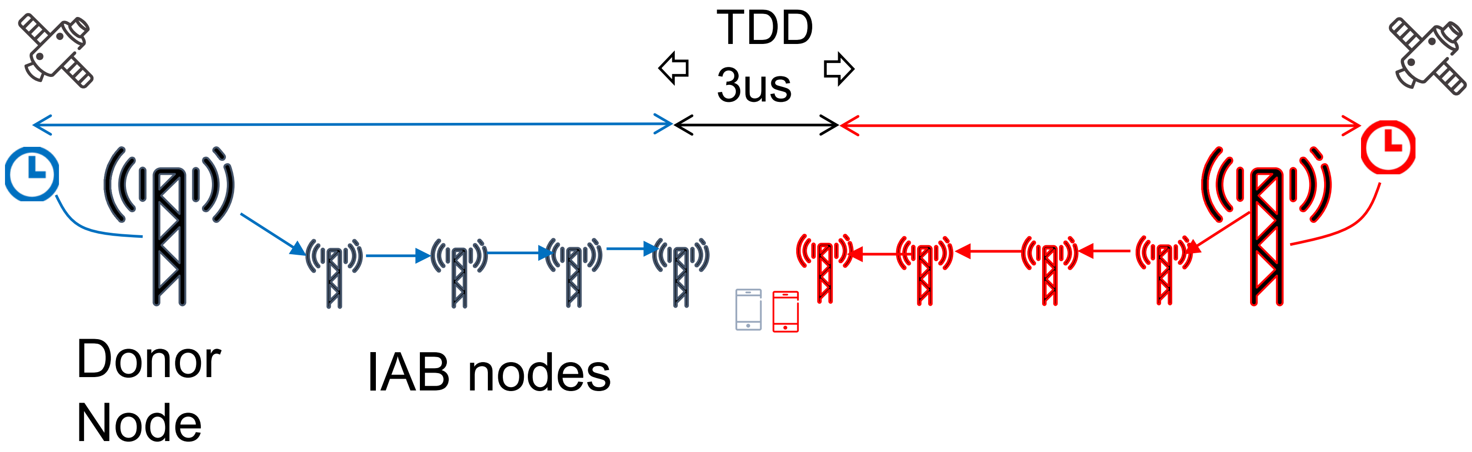
Applications requiring much higher accuracy require special RBS designs and special Sync distribution design

Industrial IoT Challenge



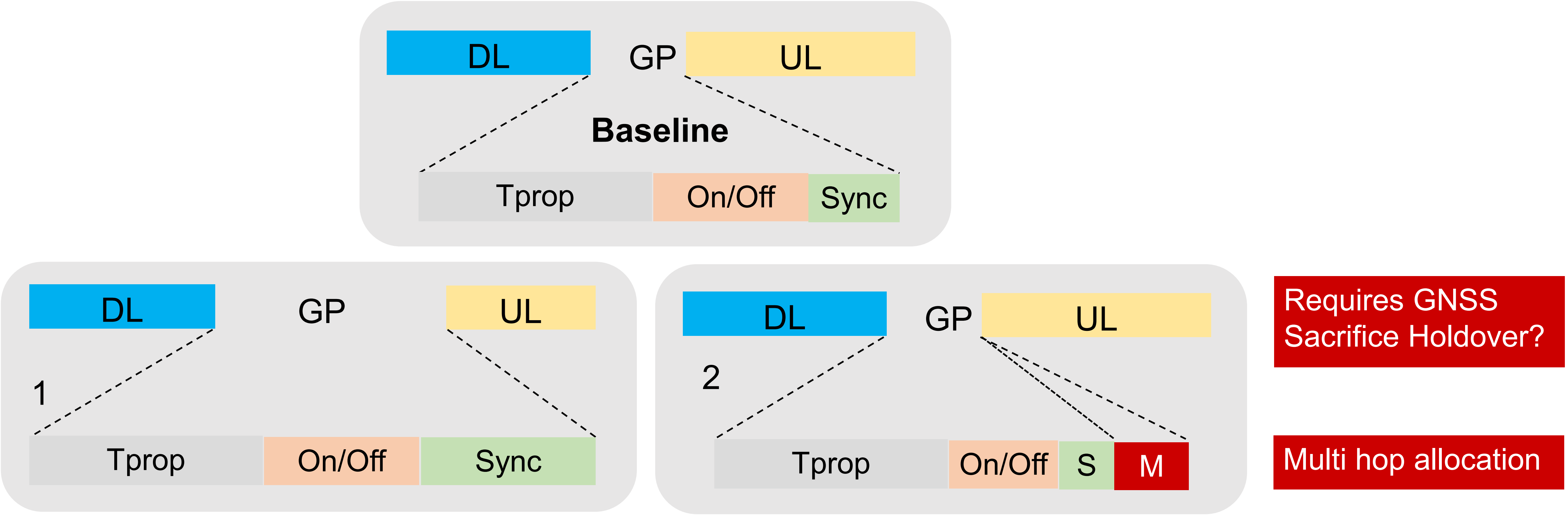
IAB

Integrated Access and Backhaul



- IAB nodes have no fixed line transmission. Only the ordinary Radio Access Interface (Same as UE)
- It is TDD. (Nodes send and receive on the same frequency)
- Synchronization options:
  - GNSS.
    No Challenge. Legacy requirements and solutions apply.
  - Over The Air (Radio interface)
    Legacy Time budget is not sufficient.
    Holdover not required at IAB nodes. (But at Donor node)

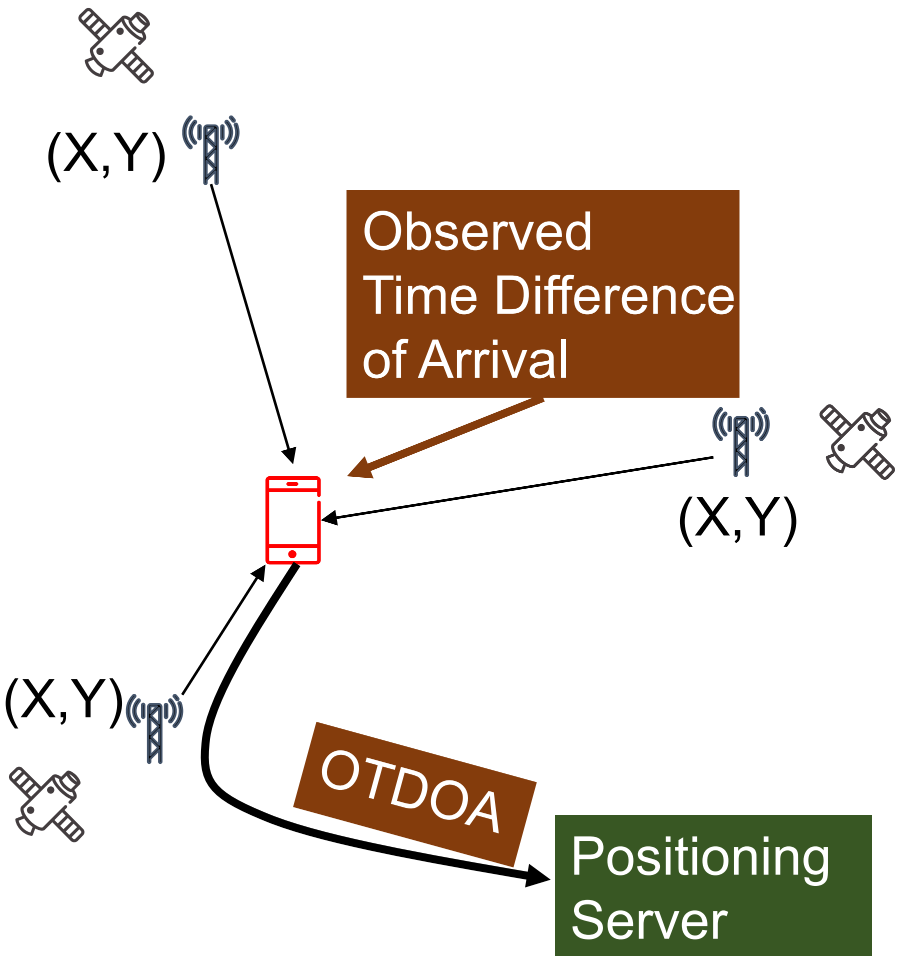
IAB Options



Time budget for IAB can be obtained from following:

1. Additional Guard Period symbols. Ample margins. Takes capacity.
2. Better than standard IAB nodes. Increases Cost. Reduces Availability

UE Positioning



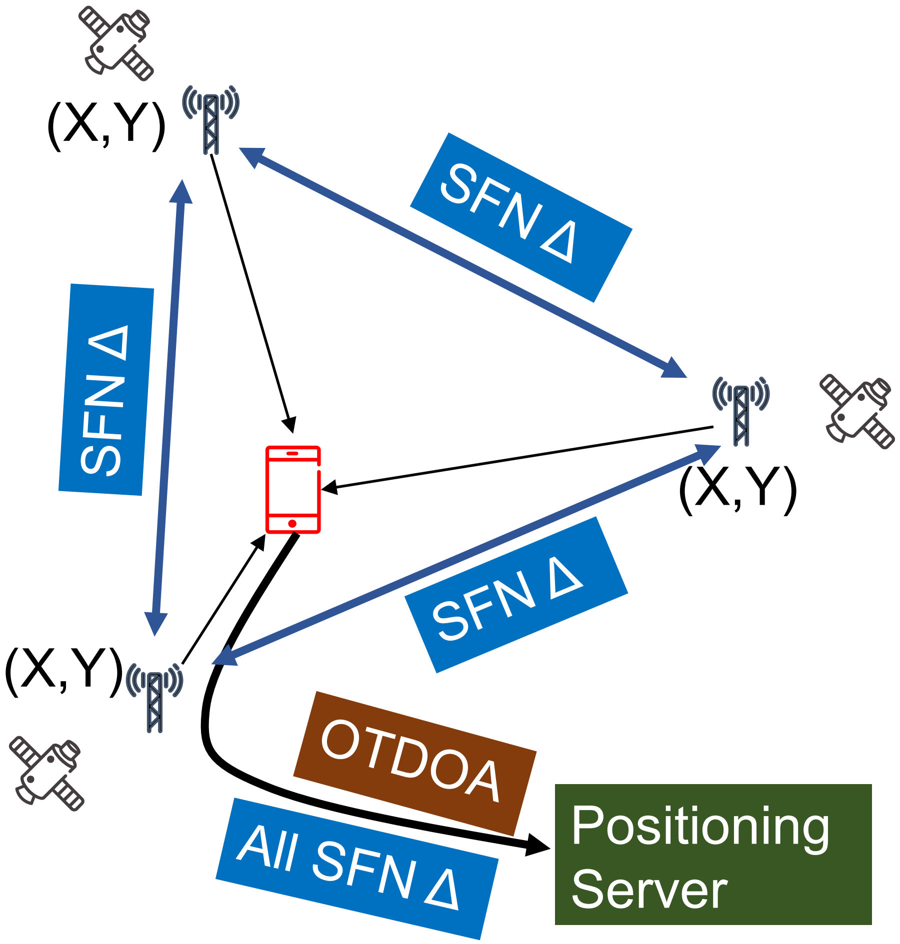
All ranges of positioning accuracy are discussed.
From 100 m to a few cm.

Some methods rely on accurate Synchronization.
But far from all.

Round trip time measurement to the UE would
Remove requirement for Sync.
Heuristic methods like Fingerprinting etc.

- <u>ALI Accuracy Standards:</u> The FCC adopted the following revised standards for Phase II location accuracy and reliability:
  - For handset-based solutions: 50 meters for 67 percent of calls, 150 meters for 95 percent of calls;
  - For network-based solutions: 100 meters for 67 percent of calls, 300 meters for 95 percent of calls.

Positioning by Sync – How to Improve



Measure the SFN Δ between all RBSes over the radio interface.

Correct the triangulation calculation with deltas

More accurate since measurements of SFN Δ is made close to the radio interface

Mainly applicable to TDD. RBS can send and receive on same frequency.
More Complex for FDD.
Still limited by antenna feeder accuracy and Radio filter accuracy
Radio parameters like receiver noise and multi-path poses problems.

Conclusions

A modular and complex RBS can meet the 3GPP requirement of +/- 1.5 us,
But the 400 ns allocated by ITU-T is used up by components and time holdover.

A fully integrated RBS could provide better accuracy for IoT, IAB, and Positioning.
But are vendors and operators willing to pay the extra cost?

Restricted deployments for industrial IoT,
More margin for Sync through added Guard slots for IAB,
Non Sync dependent or SFN Δ measurements can be applied for UE positioning

Can reduce synchronization accuracy requirements
Which will reduce cost of deployment

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Alternative Approach for Time Sync Over Telco Networks

Umut Keten
Lead Architect Networks
Turk Telecom

Sponsored by: MICROCHIP

Session 1: 5G and Smart Cities
May 6, 2020

An alternative approach to transport Time Sync over Telco Networks

Umut (Udo) Keten

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

Türk Telekom

- Turk Telekom Group
- The Problem(s)
- The Solution
- The TurSwe Approach (Turkish, Swedish)

Turk Telekom builds efficient media transport network with DTM

Turk Telekom recently put in place a dynamic synchronous transfer mode (DTM) solution to run over its MPLS network to provide a better media infrastructure for broadcasters in Turkey. Typically, most broadcasters

Umut Udo Keten, Senior Architect, Service and Product, Turk Telekom

Umut (Udo) Keten

Lead Architect

- 18 years of Telco Network and Broadcaster experience.

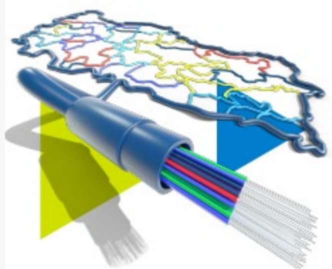
Türk Telekom

Türk Telekom International | innova | ARGELA | sebit | assistt

In numbers
Türk Telekom

Serving
47.8 mn
Subscribers

Most valuable
telco brand for
11 CONSECUTIVE YEARS



304K km
fiber network in
81 cities

32.180
EMPLOYEES
Turkey's
largest employer

21.9 mn
Fiber Homepass*

*Homepass includes FTTC & FTTH/B

The **Challenge**

For deploying Sync in WAN Networks

- There are challenges and threats to using only **GPS/GNSS**.
- PTP provides an alternative/additional solution, deployment of PTP in WAN type of operation brings other challenges, risks and costs.

The **Problem**

GPS/GNSS

- Most of us will consider that overall GNSS provides a high degree of reliability, that is not the issue here.
- But this degree of reliability is not applicable at the Mobile LTE TDD/5G domain.
- The main issue is that each individual base station and it’s GNSS receiver becomes a challenge.
- Malfunction of the antenna/receiver, a limited view of the sky(dark clouds), or jamming activities are common threats.

The **Challenge**

Deployment PTP in WAN

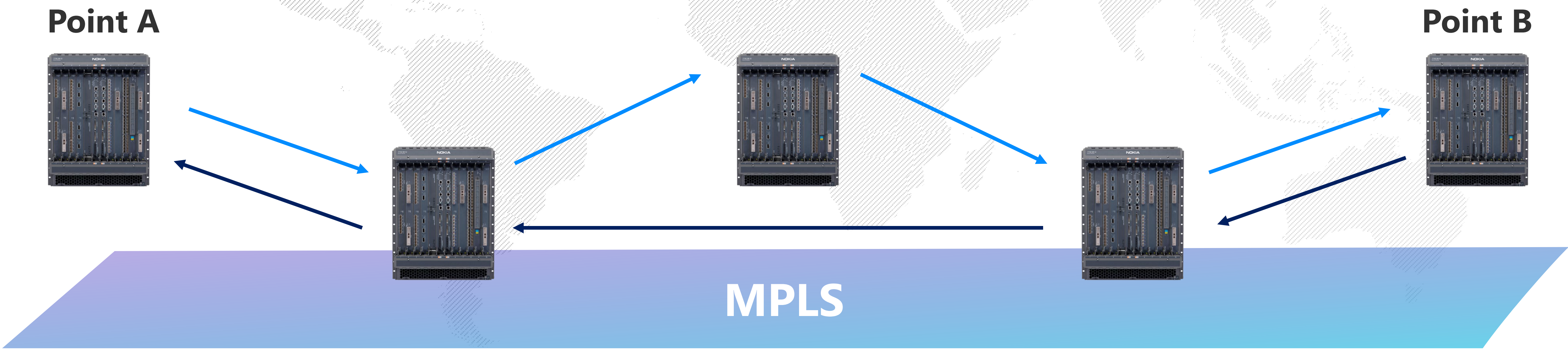
- **8275.1** is very hard to accomplish in a WAN.
- **8275.2** is relying too much on Satellite signals which is previous advised problem and there is still a portion of WAN.

The WAN **Challenge**

Layers of Networks

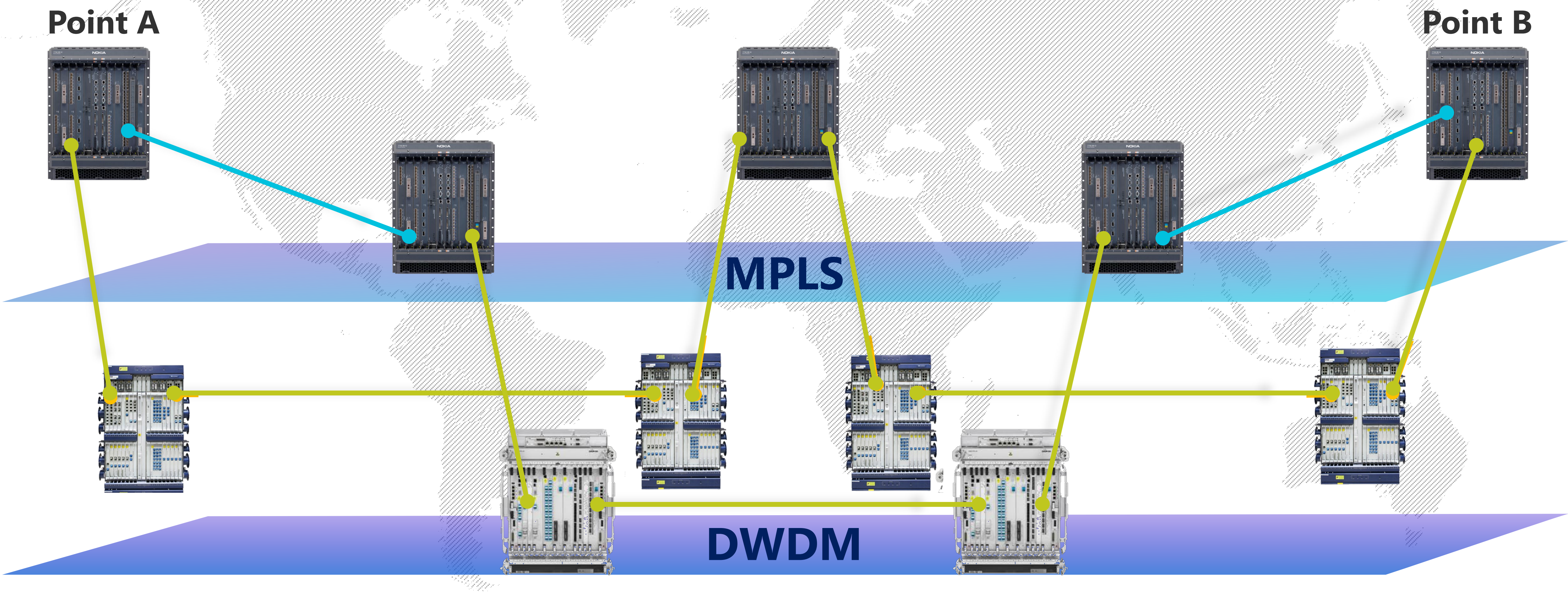
Layers are unaware of each other

- All networks require an end to end design engineering on all the layers.
- Any change in any of the layers has the risk not being design engineered as all operations of each network layer is separate from the other.



Layers of Networks

Layers are unaware of each other



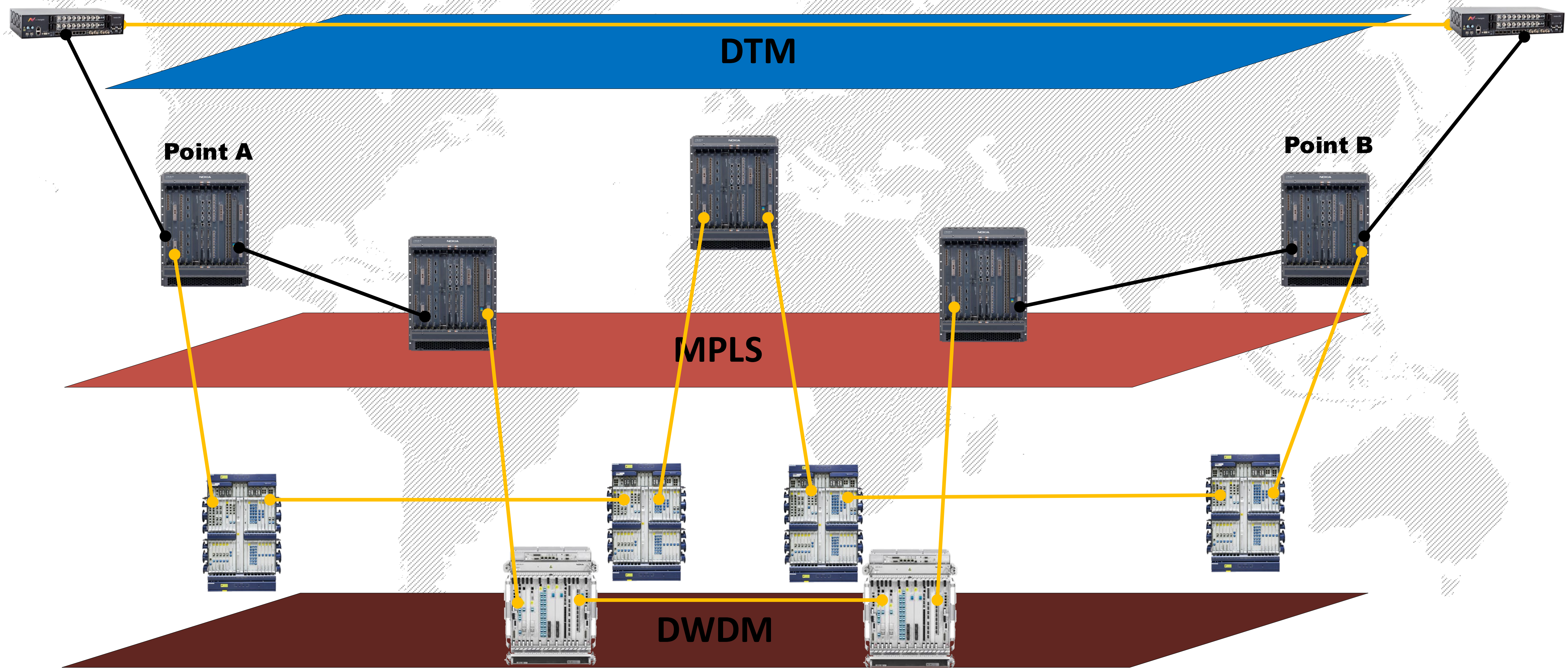
The TurSwe

DTM
Dynamic synchronous Transfer Mode

ETSI ES 201 803

DTM over IP

A new layer to transfer Time



GPS Independent Time Distribution

GPS Independent

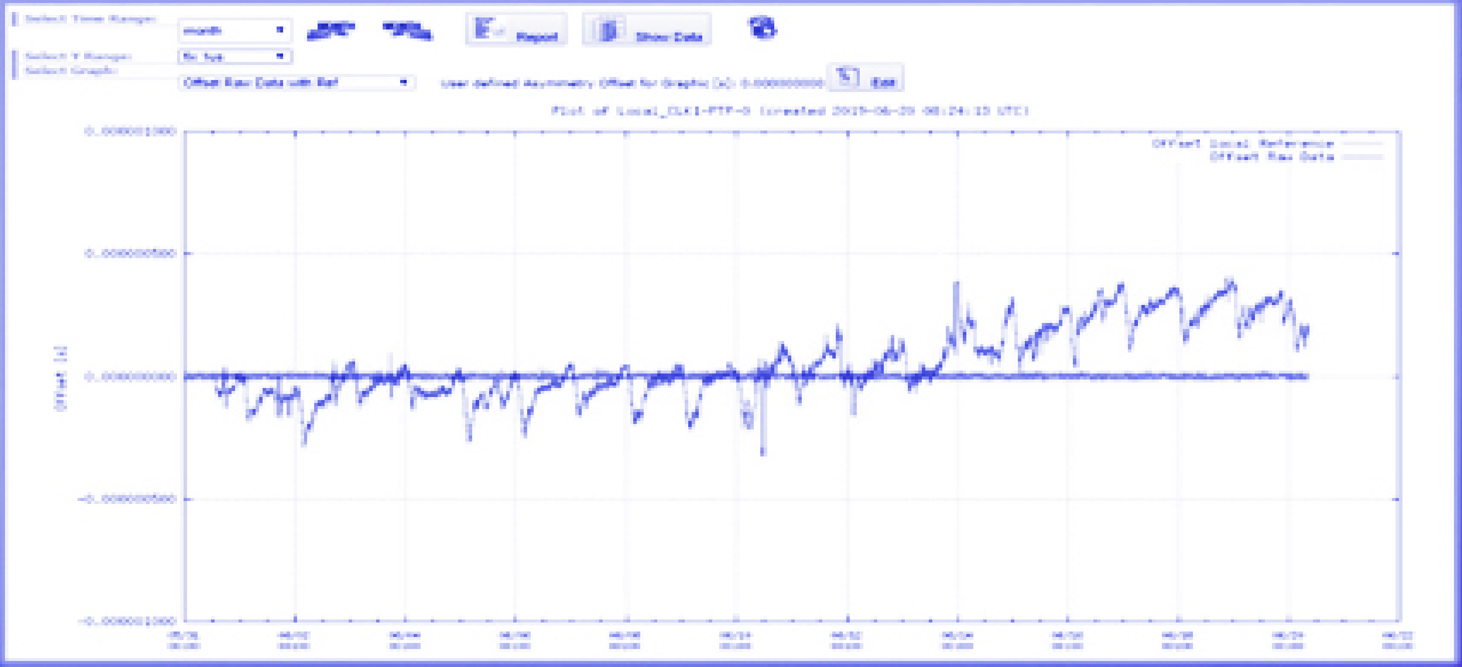
No Full Timing Support

No Partial Timing Support

No Asymmetry Issue

Only IP Connectivity

No PDV Issue



Measured &Verified

Asymmetry and PDV solved with DTM

DTM Over MPLS/DWDM

~1000 km Distance

11/14 Hop

Total Test Topology Live Network

Thank you…

Smart City Precision Timing

Joe Neil
Technical Specialist
Microchip Technology

Precision Timing in Smart Cities

microPNT For Autonomous Vehicles

MICROCHIP

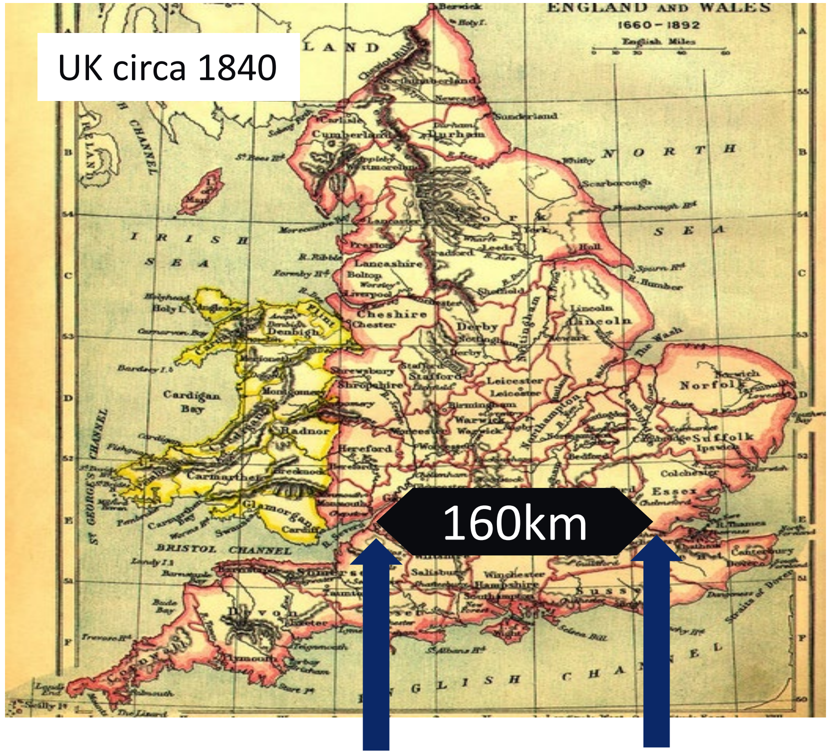
A Leading Provider of Smart, Connected and Secure Embedded Solutions

SMART | CONNECTED | SECURE

Joe Neil

6 May 2020

Navigation Safety Is Based On Precise Time: Understood Since the Mid 1800's



Bristol:10.50am London:11am
(relative to local midday sun)

In the early 1800s time keeping errors caused frequent train collisions.

A 10 minute time error at 60 kph equates to +/- 10 km location uncertainty for both trains.

Royal Commission investigation (1849):

Both trains should not have been in the same place at the same time.

In our words :

The cause was poor clock synchronization.

Position Requirements & Awareness

Navigation Norm today: +/- 5 m fuzzy location / 10's of seconds
HAV requirement: +/-2 cm "continual absolute" location / < 100ms

Distance Travelled / Vehicle Speed more elastic (inaccurate) as vehicle speed increases

Speed Kph	Meters Per Second	Meters Per 100 ms	centimeters per 10 ms
50	15	1.5	15
100	30	3	30

Positional Awareness and Processing Times *(NHTSA)*

Autonomy Level	Longitude Accuracy	Lateral Accuracy	Max Processing Latency
1	+/- 200 - 500 cm	+/- 100 - 200 cm	100 millisec
3 - 5	+/- 2 - 5 cm	+/- 2 - 5 cm	10 millisec

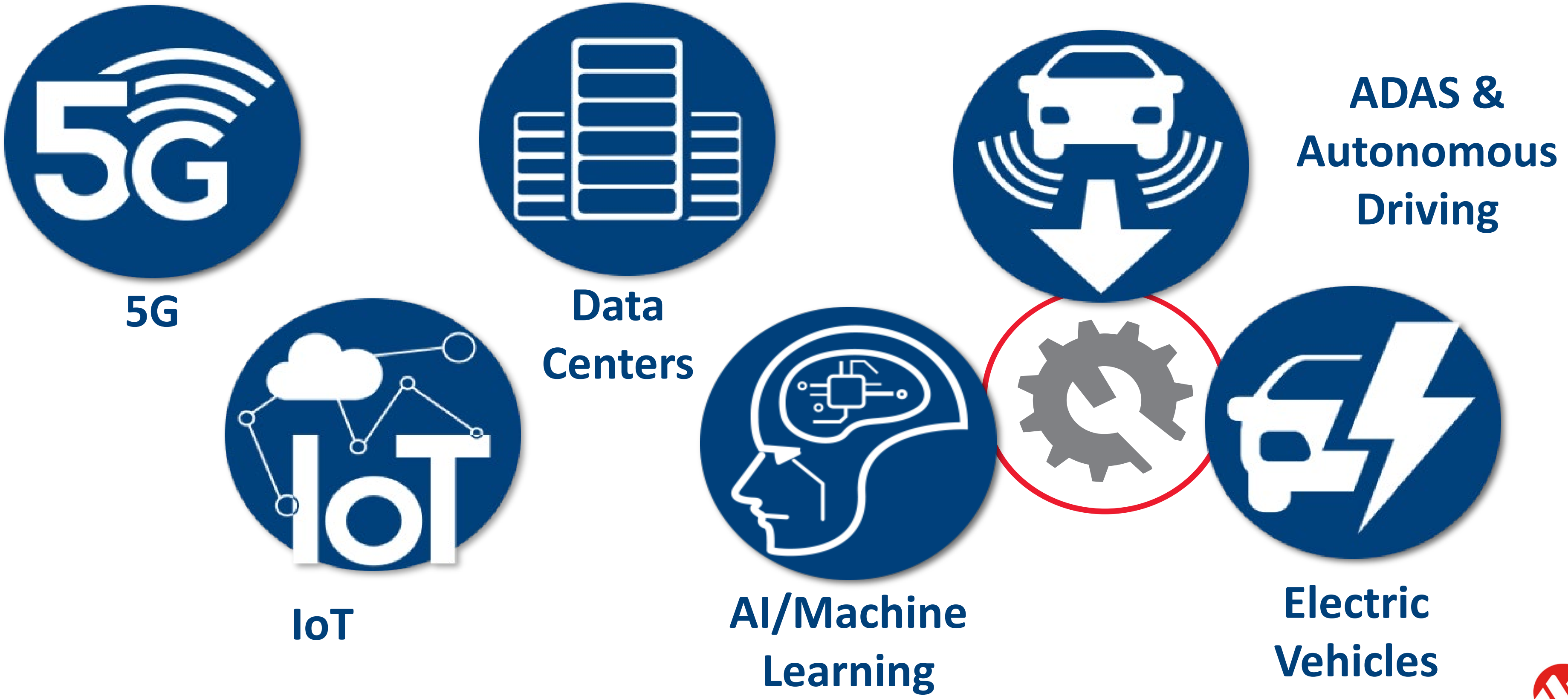
Note: Average driver reaction to hit brake = 2.3 seconds (IEA2000_ABS51. pdf)

Autonomous Driving in Smart Cities

How can we achieve 2-5cm accuracy, in real time, at normal driving speed?

In-vehicle intelligence & control with millions of powerful AI instances optimizing for trajectory and time!

This what we have now!



Sophisticated Brains at Work……

Three Aspects to Vehicle Location and Timing

- **Timing and Clocks Inside Vehicles:**
  - Plethora of protocols/standards, many proprietary, TSN may eventually unify
- **On-Board Sensors: Position/Movement Relative to Neighbors**
  - To complement/replace GNSS information
- **Position, Navigation and Time (PNT) Relative to UTC**
  - Depends on satellite visibility and receiver integrity

These aspects are not yet well linked, In-Vehicle or Vehicle 2 Vehicle.
… and each takes significant computing effort

Navigation = Precise Location & Precise Time

Autonomous Driving will depend on precise time co-ordination to a common reference both between and inside vehicles

Critical Parameters

- **Relative Location:**
  - the location of a vehicle relative to adjacent vehicles
- **Relative time:**
  - the time used by a vehicle relative to the time used by adjacent vehicles

Simple Solutions

- **Easily solved with sensors…..**
- **Easily solved with GNSS……**

GNSS

- GNSS Problems
  - Weak signal / interference
  - Not always available
  - Tunnels
  - Parking garages
  - Urban canyons / skyscrapers
- Solutions
  - Even more sensors !
  - Real time maps & GPU/CPU intensive supplementary AI systems
  - Low Earth Orbit
  - Dedicated Short Range Comms (DSRC)
  - Signals Of Opportunity

In Vehicle Sensors

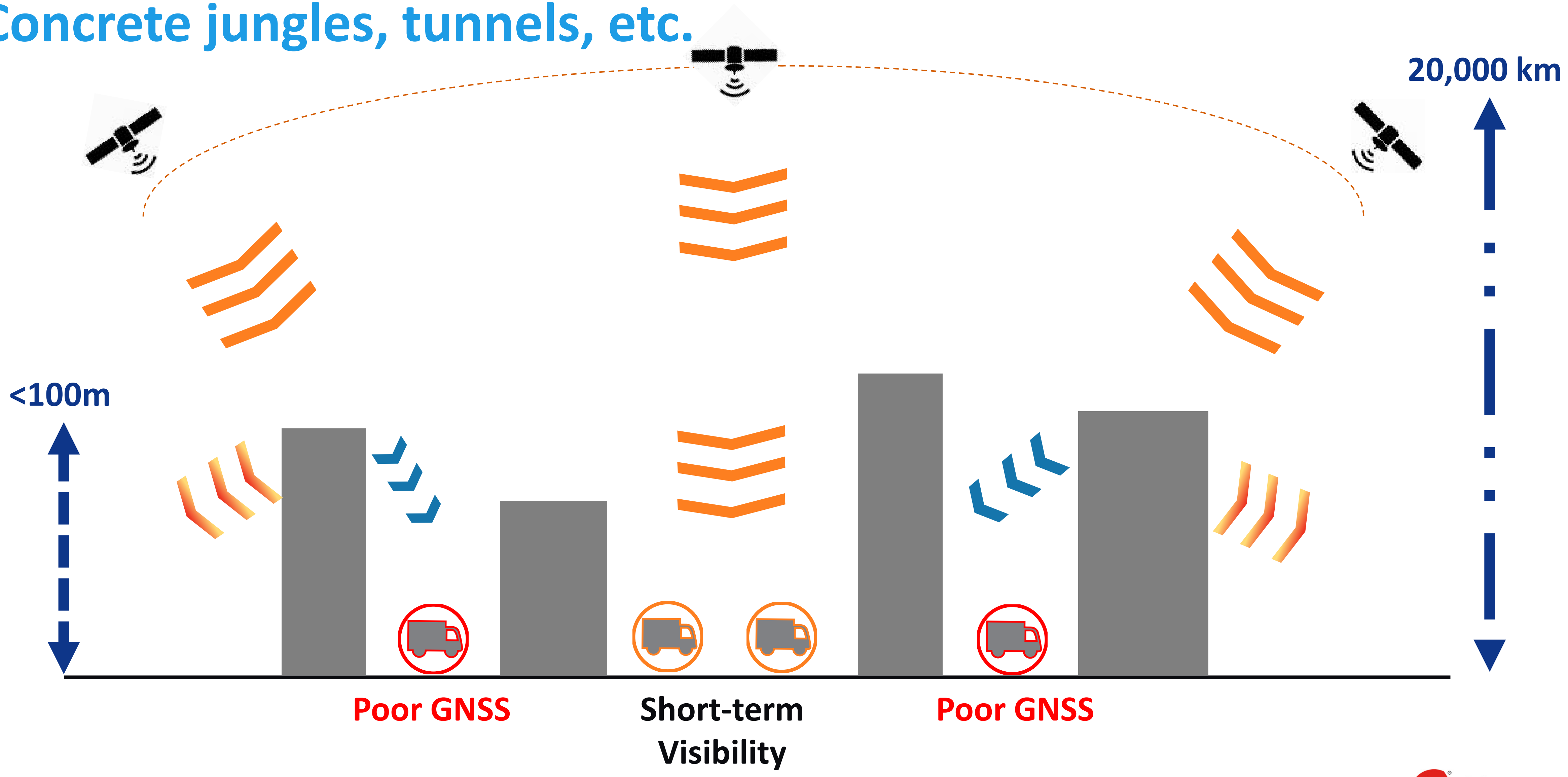
Sensor	Problems
RADAR	Lobe elasticity & strobing increases with speed, mutual interference
Map Matching + LIDAR	Database must be rapidly updated - requires precise location info from GNSS ! Heavily AI focused
Cameras	Inhibited by smoke, fog, precipitation
IMU	Rapidly inaccurate over short distances
SOP	***Comments***
LEO	*Generally same accessibility issues as GNSS*
DSRC	*Needs real time network access - (may have RF regulatory issues)*
Cellular, WiFi, TV	*May be useful for determining range or bearing. Coverage not ubiquitous, RF issues*

In-Vehicle Timing: Low Cost Oscillators

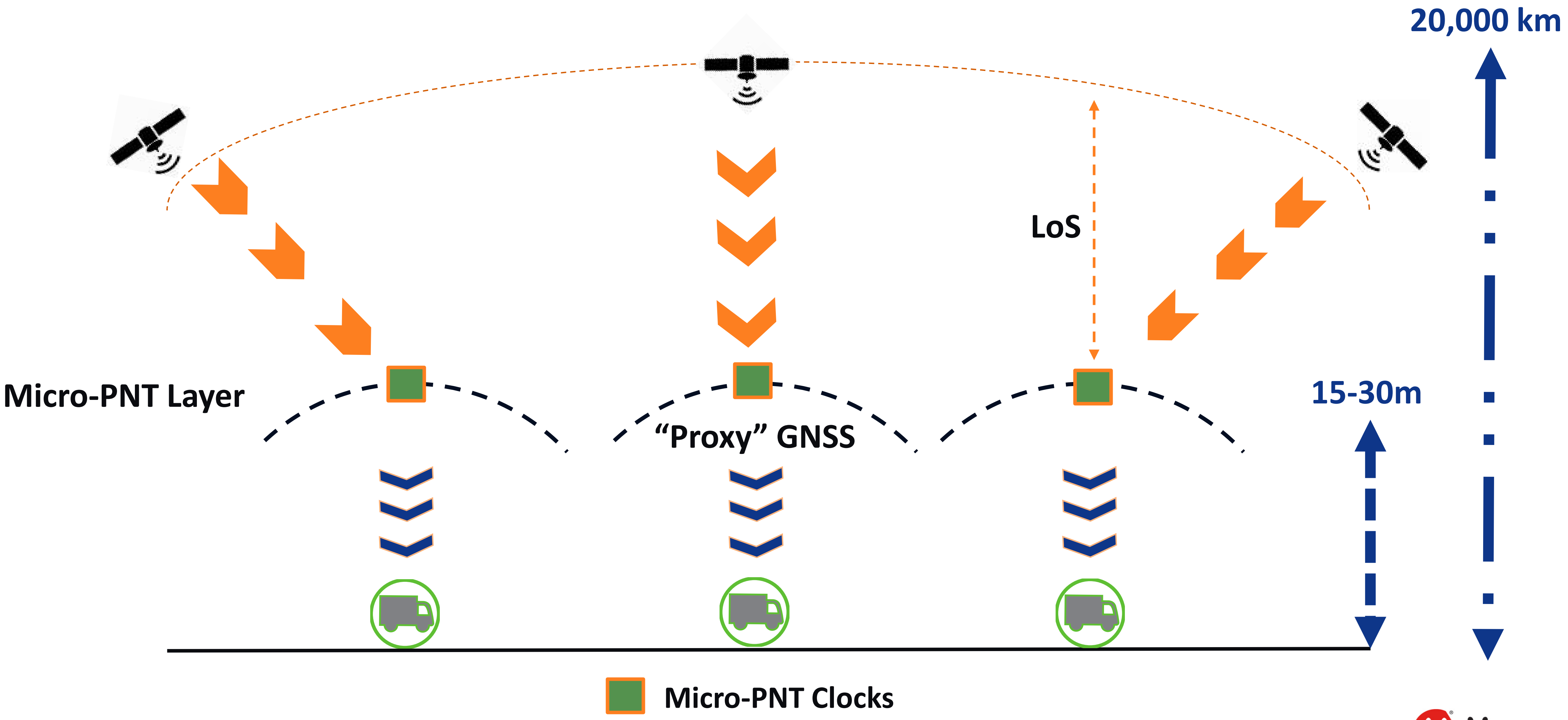
- **Many on-board timing requirements**
  - Critical: ECU, IMU, MCU, emergency braking
  - Non-Critical: Media
  - ***Navigation ?***
- **Many different In vehicle networks**
  - Linking control, sensors, mechanical systems, media etc.
- **Vehicles use low cost oscillators**
  - GNSS considered too unreliable
  - Clock quality depends on oscillator stability
  - GNSS considered too unreliable
- **Oscillators Drift**
  - Aging, short-term noise
  - Temperature variation
  - Supply voltage, shock, vibration…..
  - Initial frequency deviation - this will cause sharp drift in a short time on restart
  - ***No problem if vehicle timing is self contained***
- **Dilemma**
  - Problem for "situationally aware" systems
  - 1 autonomous vehicles cannot use on-board clocks that are drifting
  - 2 GNSS is not enough, convergence time, visibility

GNSS: The Urban Canyon Challenge

Concrete jungles, tunnels, etc.



Street-level Micro-PNT – a Smart City Solution



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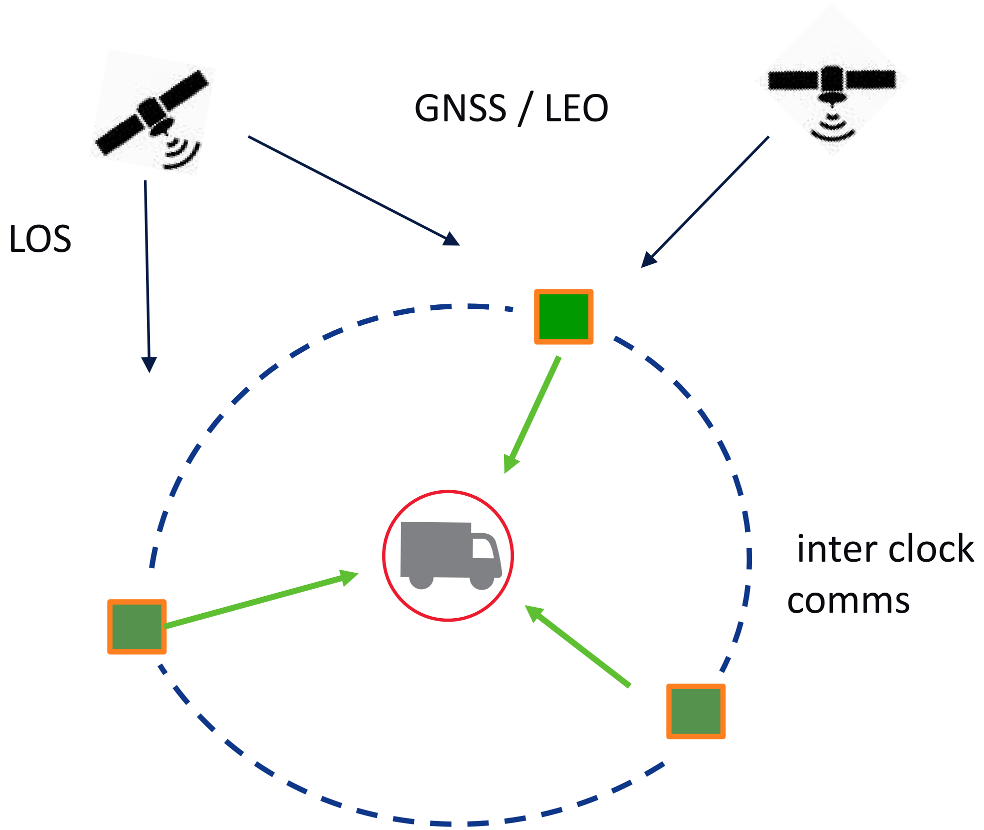
Micro-PNT Clock Mesh Creates MicroTimescales



mPNT Clock

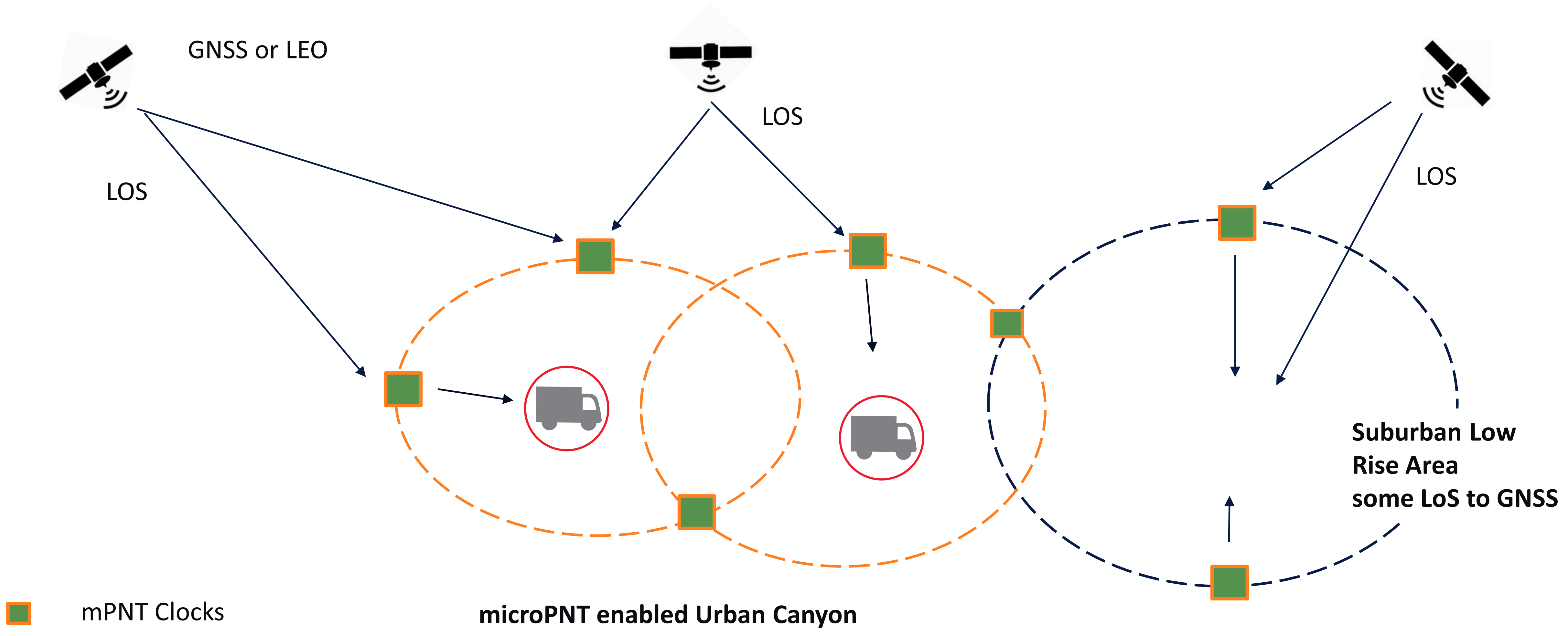
- GNSS Receiver
- Ultra-stable clock using Chip Scale Atomic Clock or HP OCXO
- Generic RF to vehicle (e.g. UWB)

In-Vehicle

- Generic low cost, low power transceiver to request/receive GNSS info from micro-PNT mesh

- Urban Canyon miniature timescale (meshed clocks) tied to UTC
- Extremely fast delivery of loc/time data to receiving vehicles

City Block "microTimescales" can mesh.



MICROCHIP

GNSS Enhancement & mPNT Compared

Method	Convergence	Receiver	Requires	Precision
microPNT	**Milliseconds**	**LoS to mPNT nodes**	**Dense mPNT network**	**< 5cm up to 200km/h**
RTK: Real Time Kinematics	> 30 mn	limited range **Needs LoS** to reference nodes	Calibrated reference nodes	1 cm – static 10cm @100kph
PPP: Precise Point Positioning	10 - 30 mn	**Needs LoS** to GNSS	Multi band receivers	10cm static 5m @ 100kph
SBAS Space Based Augmentation System	> 30 mn	**Needs LoS** to reference nodes & GNSS	Heavily calibrated reference nodes	20cm static 2m @100kph

What infrastructure is most suitable?

Scalable, fixed infrastructure, powered, new or retrofittable and close to vehicles …

Source: Signify

Smart City Micro-PNT

- **Bring GNSS closer to the vehicle**
  - Provides ubiquitous ultra precise location and traceable precise time with reference to UTC
  - Provide security and protection for existing GNSS/LEO signals

- **Creates highly distributed miniature "Timescales" that are difficult to disrupt**
  - Peer-to-peer exchange of timing info between City and Vehicle sensors in a localized system tied to UTC

- **Leverages Well Established Timing models**
  - Leverages high performance clocking systems e.g. Chip Scale Atomic Clocks & powerful compensation techniques and clocking algorithms derived from decades of experience - no need to reinvent the mapping or location wheel

- **Simple and low cost**
  - Easy to deploy at different densities by campuses towns, cities, freeways
  - Cheap enough to implement with any vehicle – cars, bikes, scooters, trains, trucks ...

Summary

- **Quasi or Fully Autonomous Vehicles of all kinds need smart timing solutions**
  - Mitigate GNSS Denial of Service from malicious activity and Urban Canyon that is increasingly complex and difficult to navigate
- **GNSS & Sensor solutions do not address the problem adequately**
  - Too expensive, too complex, too slow, too unwieldy, too vehicle centric…
- **Vehicles, & people, need much tighter location data, much faster, at low cost,**
  - RARR “Rapid Access/Rapid Return” model, more nimble, more assured, more reliable
- **Just as we engineered the Global Timescale using Satellite Systems, we now need to engineer the Smart City for the *Internet of Moving Things***
  - Miniature Timescales based on scalable, economically viable micro-positioning technologies

Notions Discussed In This Presentation

- **Bringing reliable fast precise secure PNT into Urban Canyons**
  - Offloading cost of PNT from vehicle to Smart City
- **Tying autonomous vehicles to a global reference time (UTC)**
  - Unifying relative and absolute vehicle time/location
- **Ensembling micro-clocks to create miniature Timescales**
  - Flexible, localized, and tied to UTC
- **Complementing on board sensors with high availability PNT**
  - Offloading high intensity compute required by AI map matching

- ***Precise Timing enables "The Internet of Moving Things"***

MICROCHIP

Frequency and Time Systems

Thank You

joe.neil@microchip.com

WORKSHOP ON SYNCHRONIZATION AND TIMING SYSTEMS

QUESTIONS: Submit using the question tab on the control panel located on the right side of your screen.

Moderator

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Calnex

Mårten Wahlström
Ericsson

Umut Keten
Turk Telekom

Joe Neil
Microchip

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Session 1: 5G and Smart Cities
May 6, 2020

The Insights Continue:

- **Session 2: Timing in Finance, Electric Power and Broadcast**
  - Wednesday, May 13
- **Session 3: Timing Security, Resilience and GNSS Issues**
  - Wednesday, May 20

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