Insight into Time-Sensitive Networking and its Applications

TIME

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Abstract

Time-Sensitive Networking (TSN) fills an important gap in standard networking, namely secure, guaranteed latency and delivery for critical traffic. Industry leaders and organizations are coming together to advance TSN and drive forward a common foundational network for secure, deterministic communication from sensor to cloud. Accurate and reliable Synchronization is an important function in this context.

The IEEE 802.1 TSN standards specifying the base technology are stable and have a core set applicable to multiple verticals. TSN profiles are being specified for various application areas, such as cellular, industrial automation, and in-vehicle networks to ensure interoperability and facilitate the adoption of the technology. In addition, TSN has been extended to IP and MPLS layers by IETF Deterministic Networking and 3GPP has extended 5G with support for TSN.

Introduction

- Joint tutorial on March 2: <u>Synchronization – A Key Function in TSN and Beyond</u>


- Outline of this keynote
  - Overview of IEEE 802.1 Time-Sensitive Networking (TSN)
  - TSN technology examples
  - Application areas
  - TSN & 5G for connected industries
  - Summary

IEEE 802.1 Time-Sensitive Networking (TSN)

- **The Right Packet at The Right Time**
- Deterministic data packet delivery
  Data packet delivery within a time window without loss or delay due to congestion or errors

- TSN is a set of standards specified by IEEE 802 to provide deterministic data transfer in packet networks, e.g., in Layer 2 bridged networks
  - All the benefits of open IEEE SA standards
  - Standard Ethernet: IEEE Std 802.3
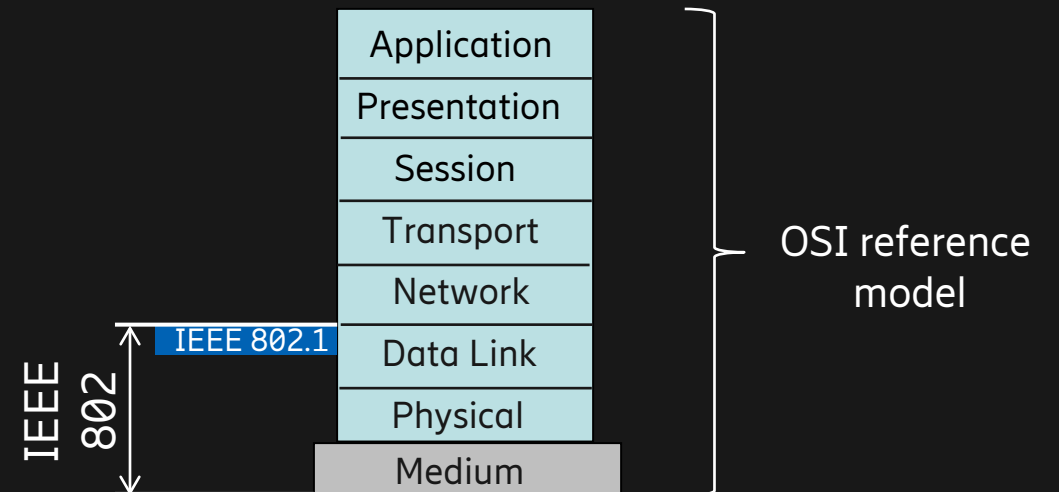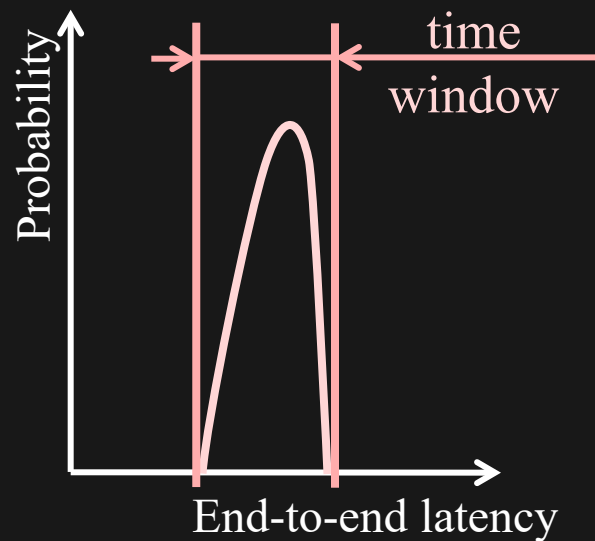
Time-Sensitive Networking (TSN) Profiles (Selection and Use of TSN tools)

Audio Video Bridging [802.1BA]	Fronthaul [802.1CM/de]	Industrial Automation [IEC/IEEE 60802]	Automotive In-Vehicle [P802.1DG]	Service Provider [P802.1DF]	Aerospace [P802.1DP]

TSN Components
(Tools of the TSN toolbox)

Time synchronization:
Timing and Synchronization [802.1AS-2020]
(a profile of IEEE 1588)
Hot Standby [P802.1ASdm]
YANG [P802.1ASdn]

Bounded low latency:
Credit Based Shaper [802.1Qav]
Frame Preemption [802.1Qbu & 802.3br]
Scheduled Traffic [802.1Qbv]
Cyclic Queuing and Forwarding [802.1Qch]
Asynchronous Traffic Shaping [802.1Qcr]
QoS Provisions [P802.1DC]

Synchronization

Reliability

Latency

Resource Management

Zero congestion loss =
Bounded latency

High availability / Ultra reliability:
Frame Replication and Elimination [802.1CB]
Path Control and Reservation [802.1Qca]
Per-Stream Filtering and Policing [802.1Qci]
Reliability for Time Sync [802.1AS-2020]

Dedicated resources & API:
Stream Reservation Protocol [802.1Qat]
Link-local Registration Protocol [802.1CS]
TSN Configuration [802.1Qcc]
Foundational Bridge YANG [802.1Qcp]
YANG for CFM [P802.1Qcx]
YANG for LLDP [P802.1ABcu]
YANG for 802.1Qbv/Qbu/Qci [P802.1Qcw]
YANG & MIB for FRER [P802.1CBcv]
Extended Stream Identification [P802.1CBdb]
Resource Allocation Protocol [P802.1Qdd]
TSN Configuration Enhancements [P802.1Qdj]
LLDPv2 for Multiframe Data Units [P802.1ABdh]
Multicast and Local Address Assignment [P802.1CQ]

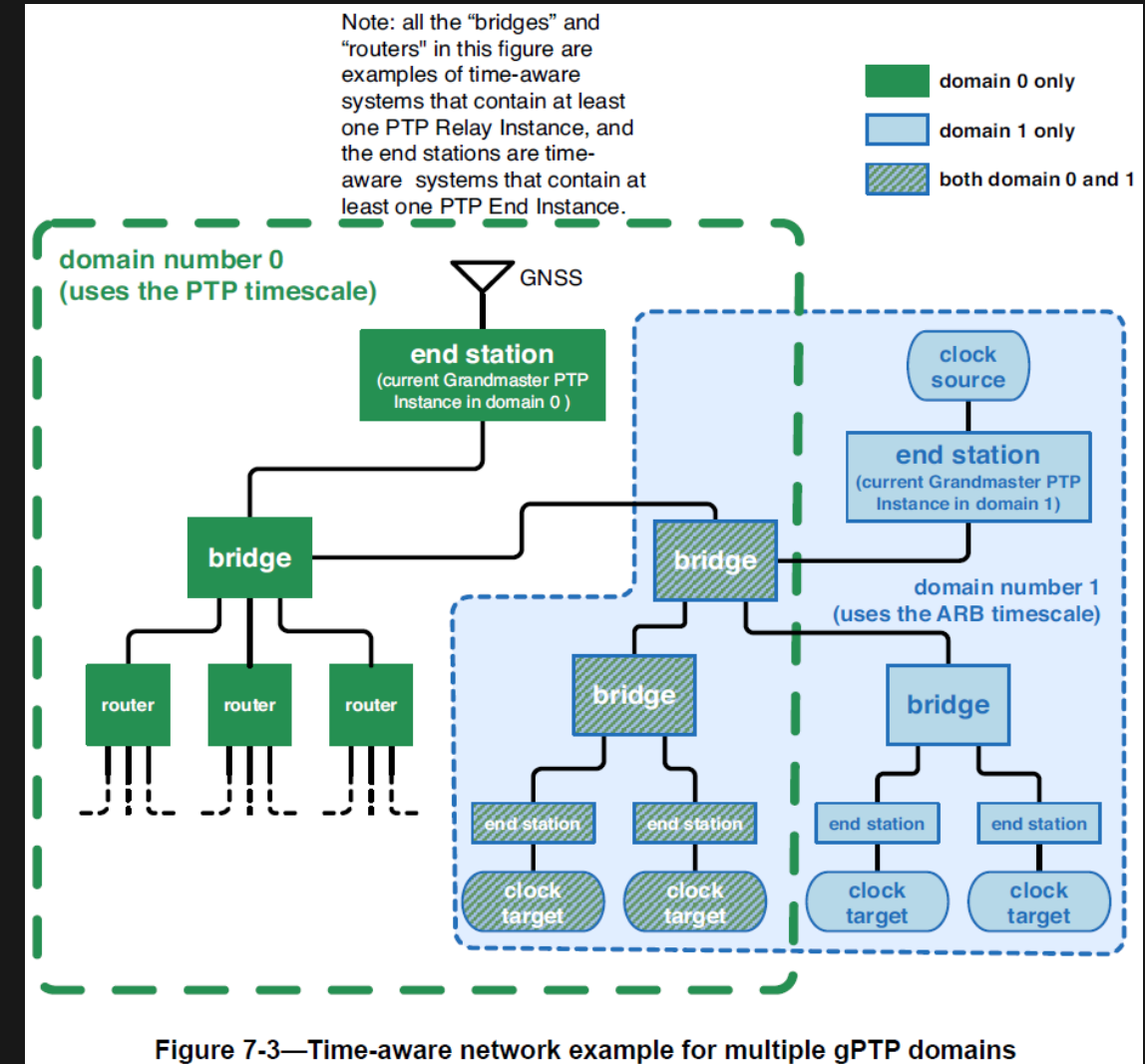Note: A 'P' in front of an ID indicates an ongoing Project.

# A TSN Tool: Timing and Synchronization [802.1AS-2020]

- IEEE Std 802.1AS
  - specifies the generalized Precision Time Protocol (gPTP)
  - is a proper profile of the IEEE Std 1588 Precision Time Protocol (PTP)
  - includes protocol features additional to PTP
  - includes performance requirements
  - provides transport of time synchronization
  - specifies the Best Master Clock Algorithm
- 802.1AS-2020 adds
  - multiple gPTP domains
  - external port configuration
  - basic redundancy
  - and more …

Note: all the "bridges" and "routers" in this figure are examples of time-aware systems that contain at least one PTP Relay Instance, and the end stations are time-aware systems that contain at least one PTP End Instance.

domain 0 only
domain 1 only
both domain 0 and 1

domain number 0 (uses the PTP timescale)

GNSS

end station (current Grandmaster PTP Instance in domain 0)

clock source

end station (current Grandmaster PTP Instance in domain 1)

bridge

bridge

domain number 1 (uses the ARB timescale)

router router router

bridge

bridge

end station end station

end station end station

clock target clock target

clock target clock target

Figure 7-3—Time-aware network example for multiple gPTP domains

A TSN Tool: Scheduled Traffic [802.1Qbv-2015]

- Reduces latency variation for frames with known timing
- Time-based control and programming of the bridge queues
- Time-Gated queues
- Gate (G): Open or Closed
- Periodically repeated time schedule
- Time synchronization is needed

Transmission selection
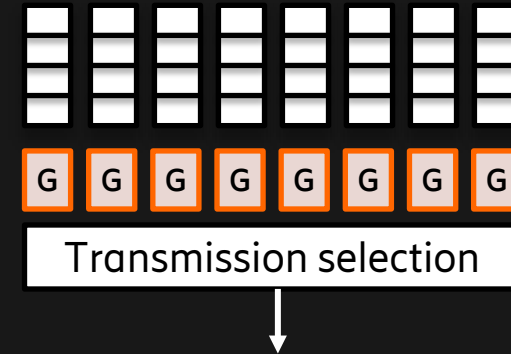
frame transmitted:
critical / non-critical

	critical		critical		critical	

open	Closed	open	Closed	open	Closed	open

gate(s) for non-critical traffic

TSN Application Area Examples

- An IEEE 802.1 TSN Profile specification
  - Selects features, options, defaults, protocols, and procedures to ease interoperability and deployment

- Published IEEE 802.1 TSN profile standards:
  - IEEE Std 802.1BA for Audio-Video Bridging (AVB) networks
  - IEEE Std 802.1CM TSN for Fronthaul
  - IEEE Std 802.1CMde Amendment on enhancements

- Ongoing IEEE 802.1 TSN profile projects:
  - IEC/IEEE 60802 TSN Profile for Industrial Automation
  - P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications
  - P802.1DF TSN Profile for Service Provider Networks
  - P802.1DP TSN Profile for Aerospace onboard Ethernet

- Furthermore:
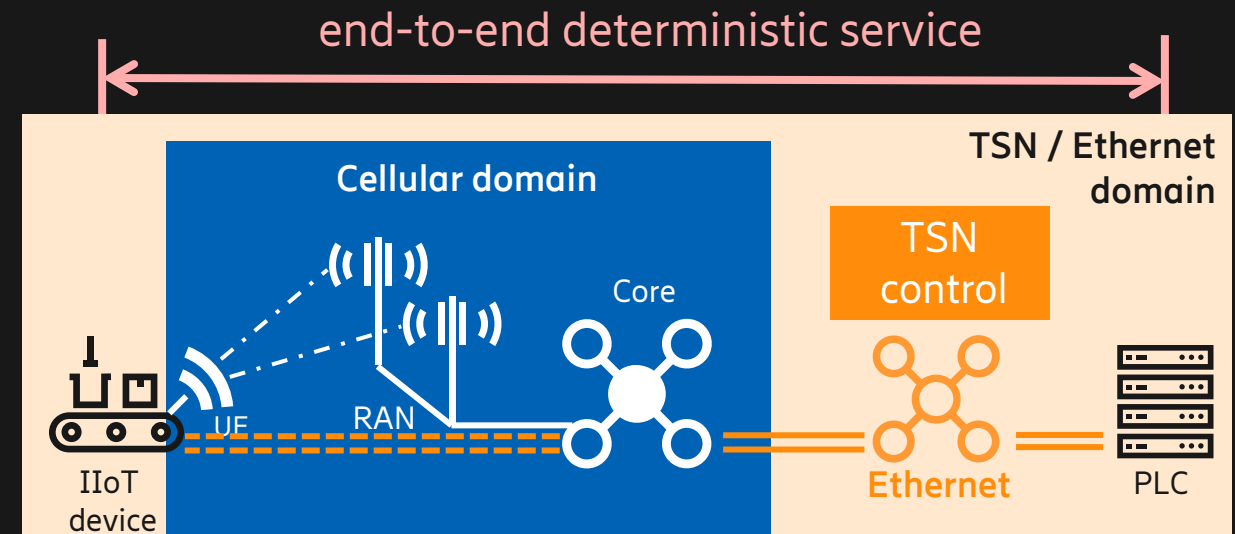 - Power utility automation: IEC TR 61850-90-13

IEEE 802

AVB

Profiles

Fronthaul

Industrial Automation

Automotive

Service Provider

Aerospace
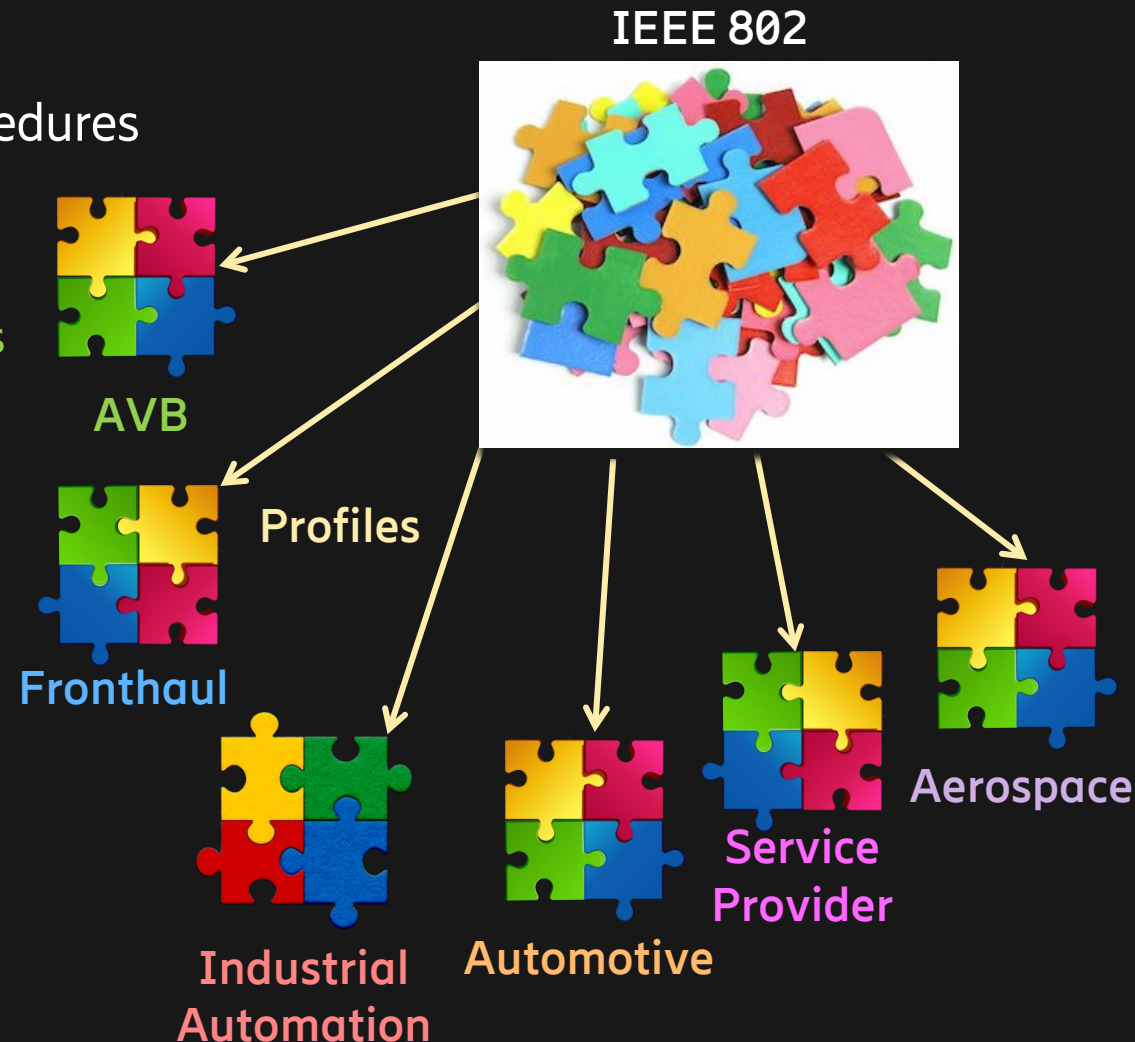
TSN and Cellular Networks

A) TSN as a building block of a cellular network
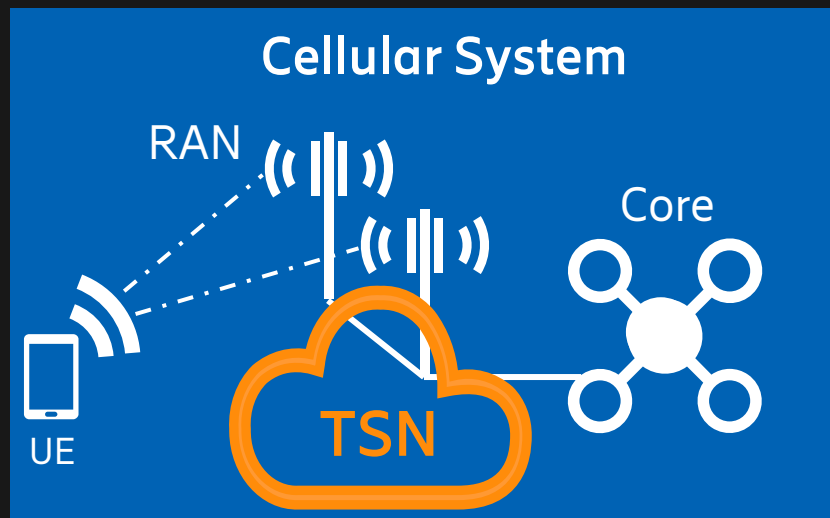
B) 5G & TSN for end-to-end deterministic service, e.g., for industrial automation

e.g., IEEE Std 802.1CM TSN for Fronthaul

e.g., 5G support for TSN in 3GPP TS 23.501, also described in 5G-ACIA whitepaper

5G as a Time-Aware System for TSN Interworking
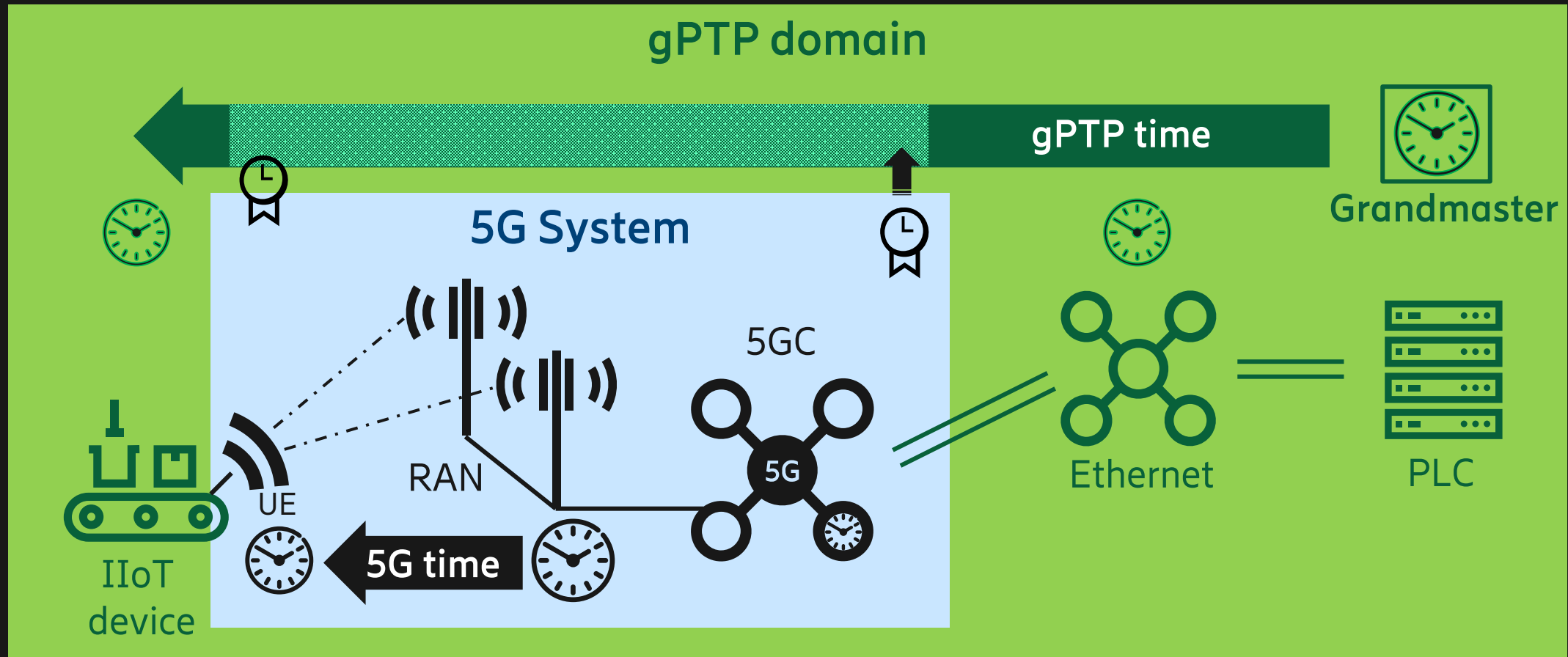
Summary:
Network Convergence for Time-Sensitive Everything

Operations Technology

- TSN has the benefits of open standards, such as IEEE SA standards
- TSN profiles specified via collaboration of experts of the application area and TSN

- TSN brings the opportunity of converged and flexible networking for industrial automation

Information Technology

Telecom

Thank You!