Integration of the 3GPP 5G System with IEEE TSN – Challenges and Solutions

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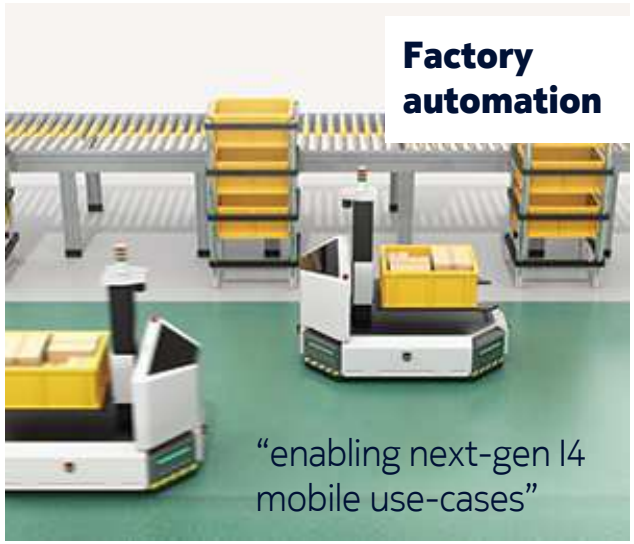
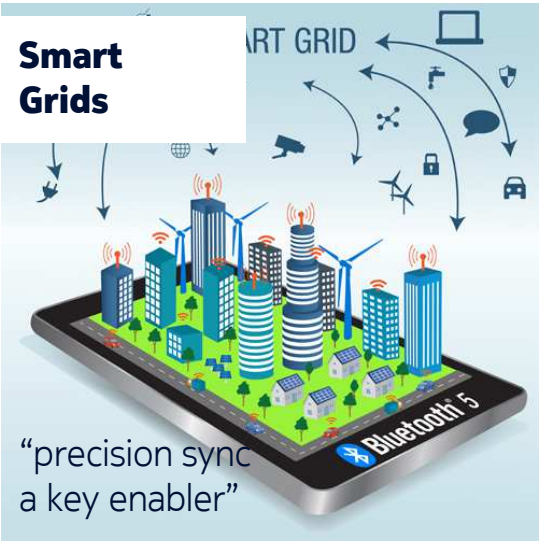
TACNET 4.0 Taktiles Internet

NEED: Time Sensitive Services – Deterministic Communication

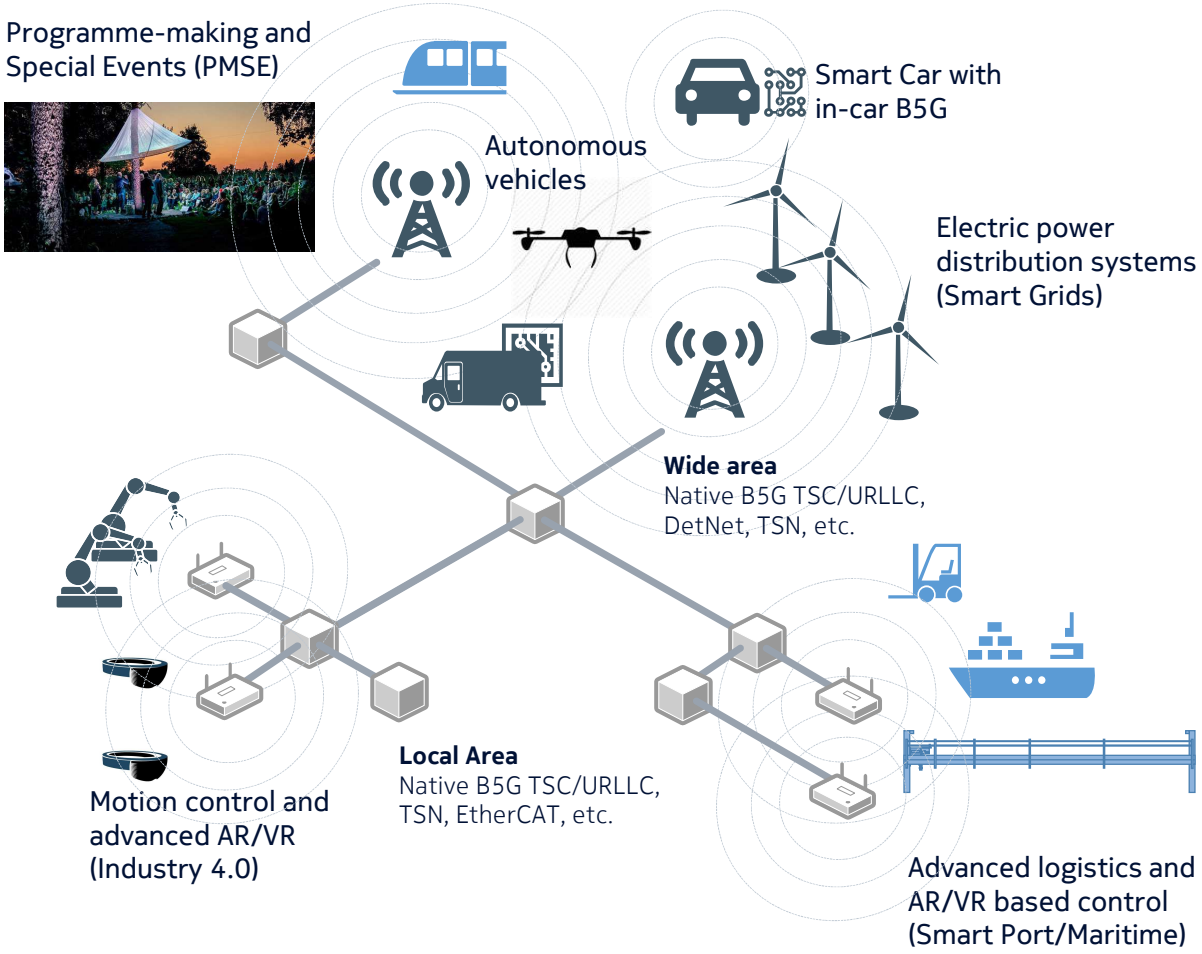
"*hen service points are tightly synchronized and/or service tasks are carried out at a specific time without any hick-ups*"
("home-grown" definition)





Deterministic communication service:
A communication service providing packet transport with bounds on latency, loss, packet delay variation (jitter), and reliability including immunity to overload. Furthermore, end systems and relay/transmit nodes can be strictly synchronized.

5G RESPONSE: Time Sensitive Communications (TSC)

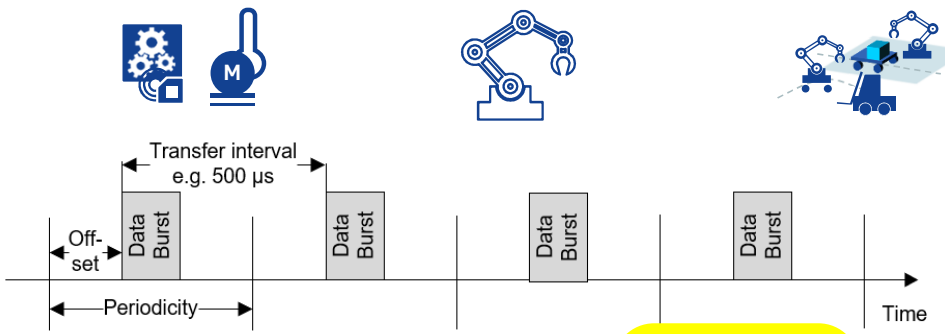


Time Sensitive Communications: Native support in 5G for LAN and WAN services that require E2E deterministic communications

- Stand-alone and standardized solution for designing wireless communication interface of time sensitive applications
- Rich and competitive eco-system with TSC devices/modems (multi-UE, UE-App interface, etc.)
- Plug-in compatibility with application eco-systems such as TSN, Profinet, DetNet, OPC UA, etc.
- Key question: TSN as convergence protocol / technology in industrial communications

Summary of Requirements

Diversity of Services - Diversity of requirements - Diversity of solutions



Periodic deterministic communication

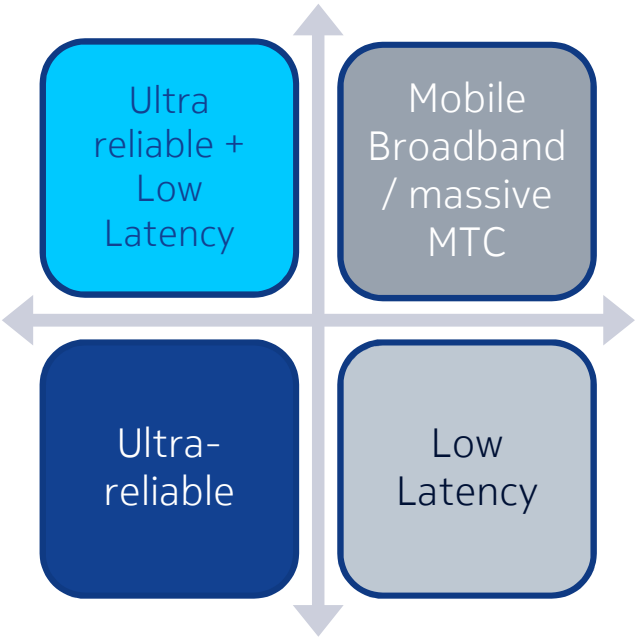
Aperiodic deterministic communication

Non-deterministic communication

Mixed traffic

via 5G QoS

- Delay critical GBR (+ optional TSCAI)
- GBR
- Non-GBR



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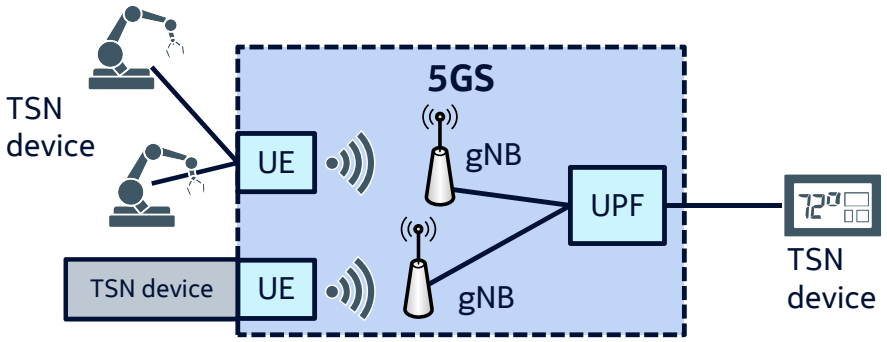
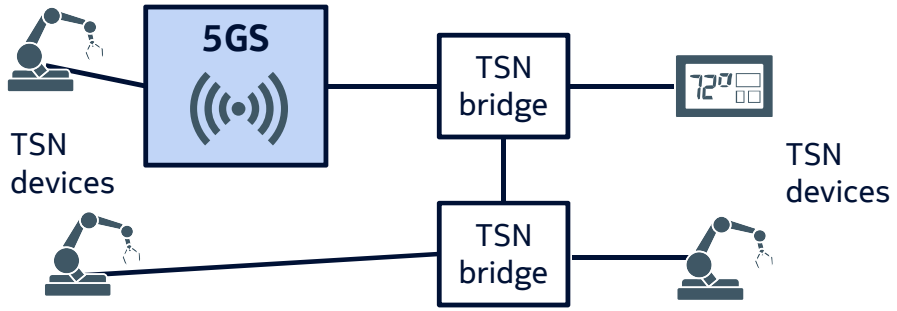
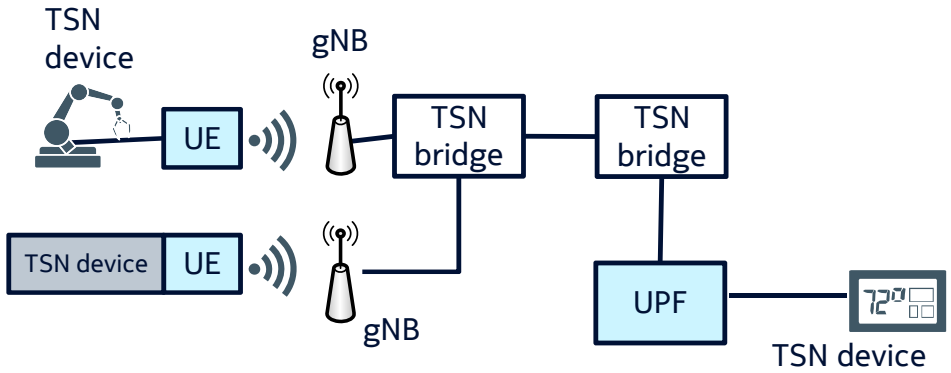
5GS integration into Industrial Ethernet (TSN)



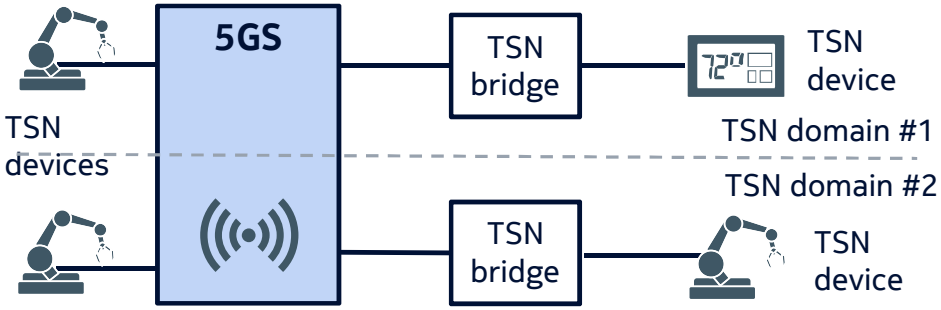
a) All-3GPP self-contained TSC (TSN compliant) service



b) Self-contained, single TSN domain



c) Distributed into TSN domain



d) Self-contained, multiple TSN domains

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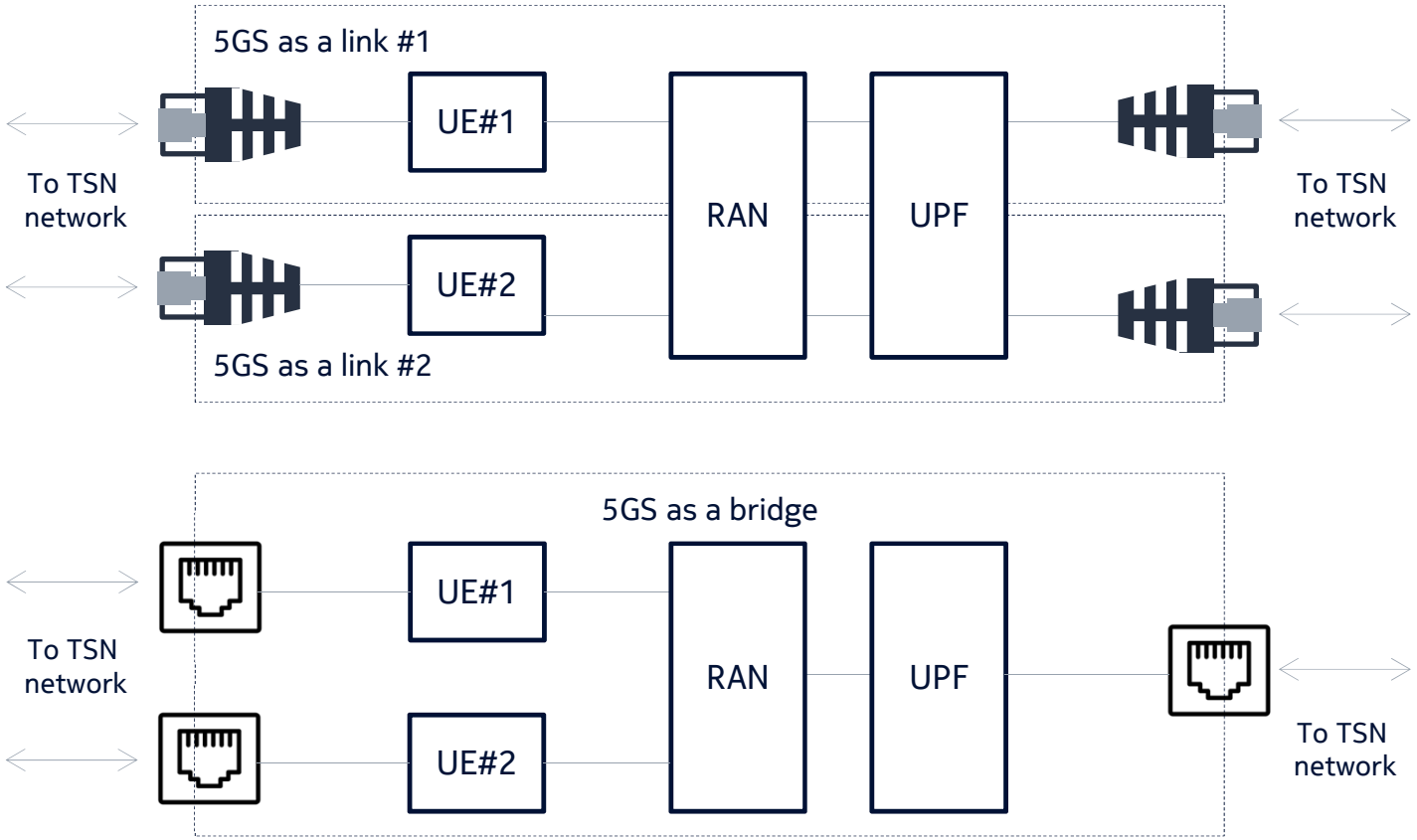
5GS represented as TSN link or bridge model?



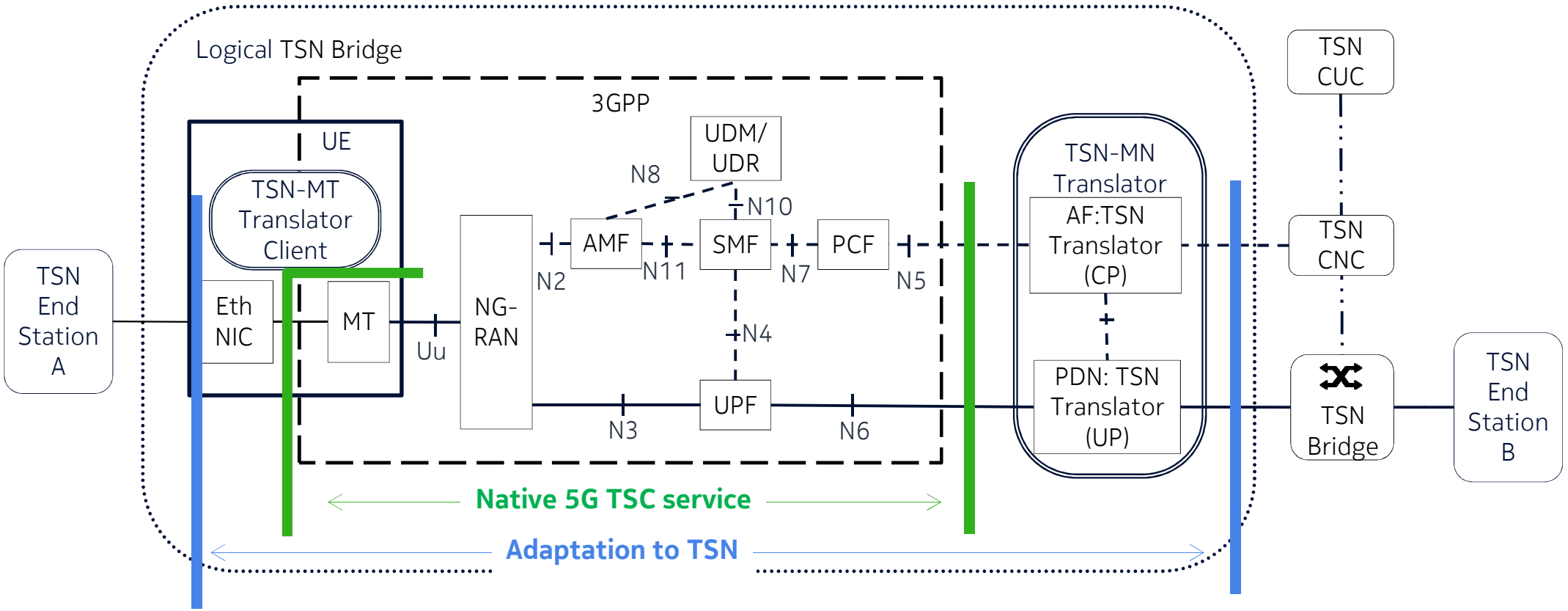
Link model (~cable)

- 5GS to be characterized as "specified media" towards TSN (e.g. 1GBE, etc.)
- Cable must have maximum delays, very low jitter, etc. Performance can be different between UE (cable length) but must be guaranteed
- No switching between UE expected (switching done outside of 5GS)

Bridge model

- 5GS to be characterized as bridge
- Bridge must have characterized behavior and support TSN configuration (centralized by CNC and distributed), but can be different for each port pair (e.g. different UE with different delay)
- Internal switching capability between UE expected (switching done inside of 5GS)

Bridge model with adaptation



NOKIA reference architecture developed for TACNET 4.0: Hochzuverlässige und echtzeitfähige 5G Vernetzung für Industrie 4.0

CNC: Centralized Network Configuration
CUC: Centralized User Configuration
TSC: Time-Sensitive Communications
MT: Mobile Termination
NIC: Network Interface Card

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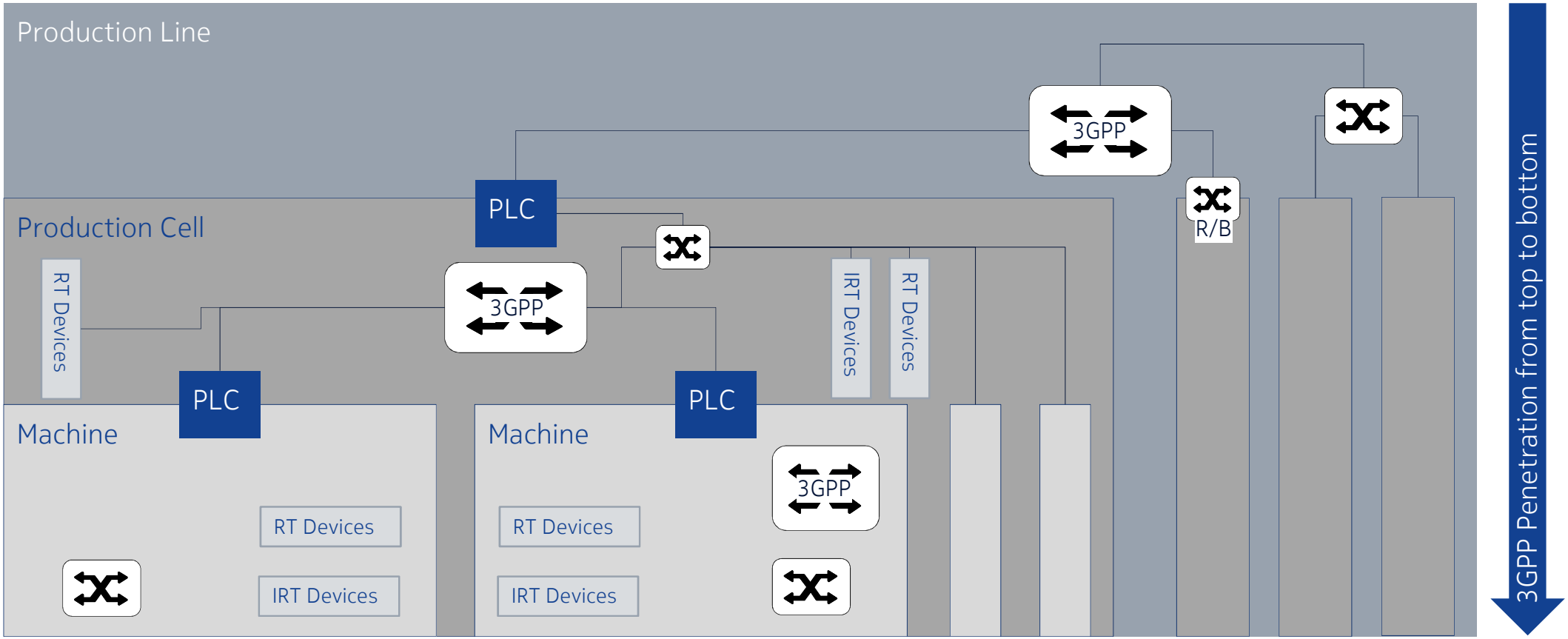
Bridge model with adaptation

Hierarchical structure (example based IEC 60802, Figure 1)



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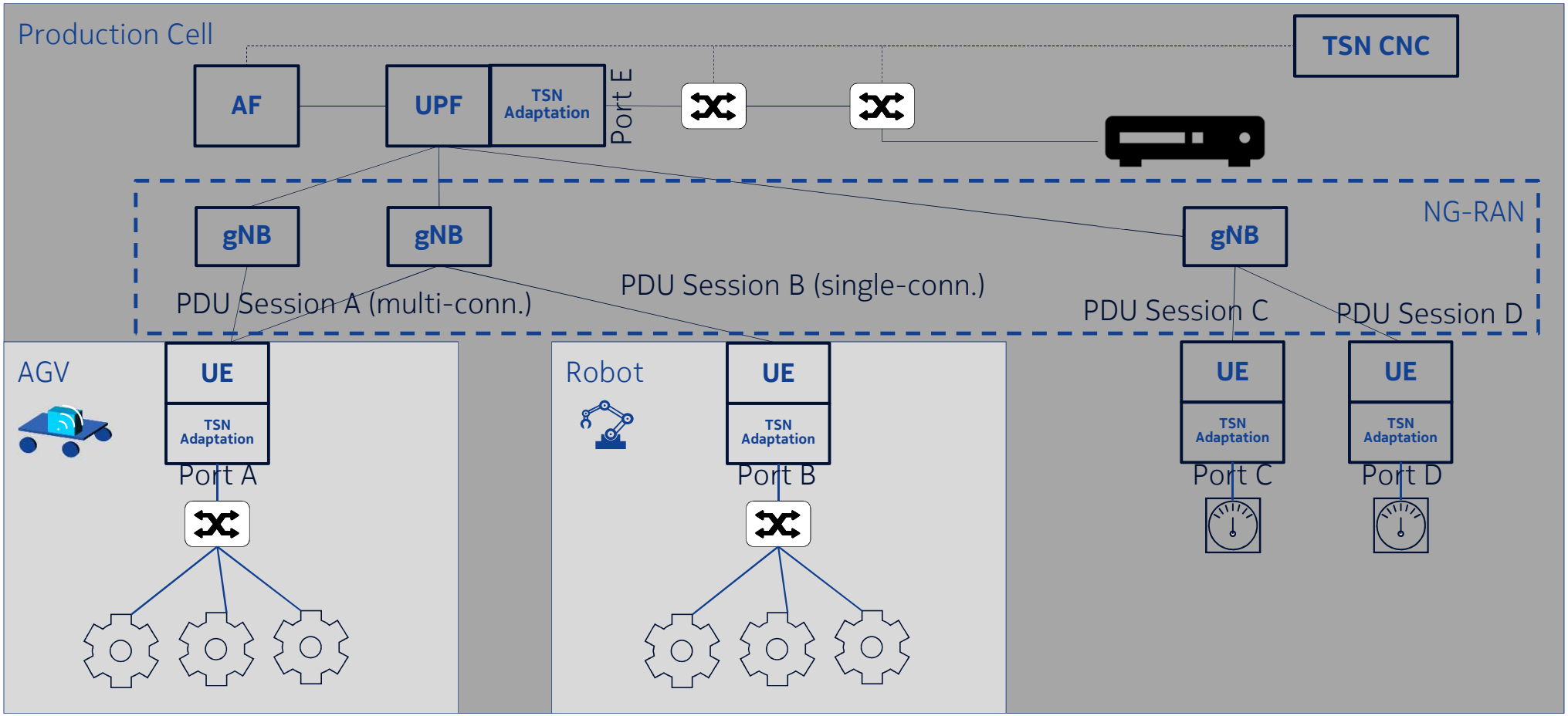
Bridge model with adaptation

Exemplary physical deployment of “3GPP Bridge”: Physical setup



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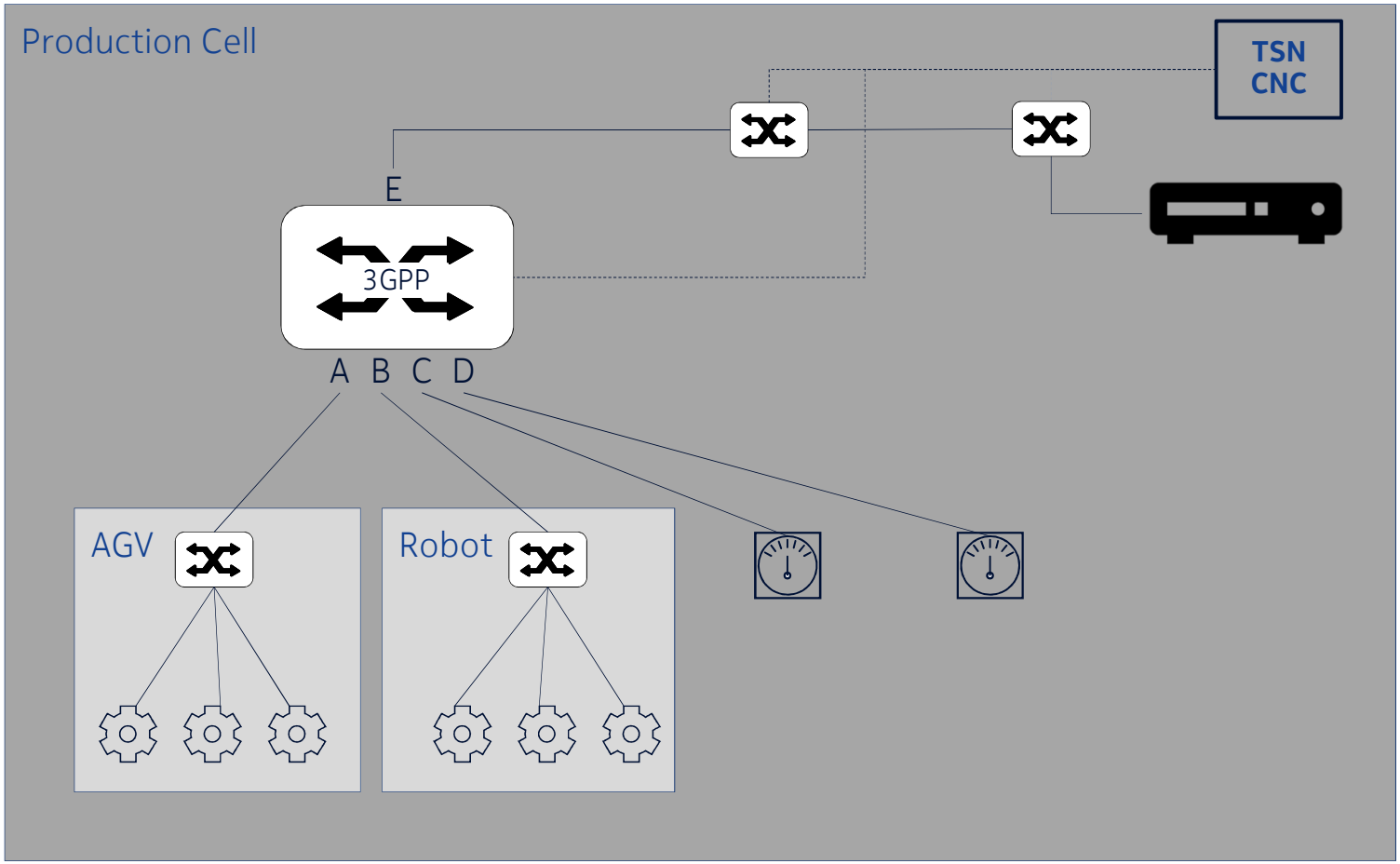
Bridge model with adaptation

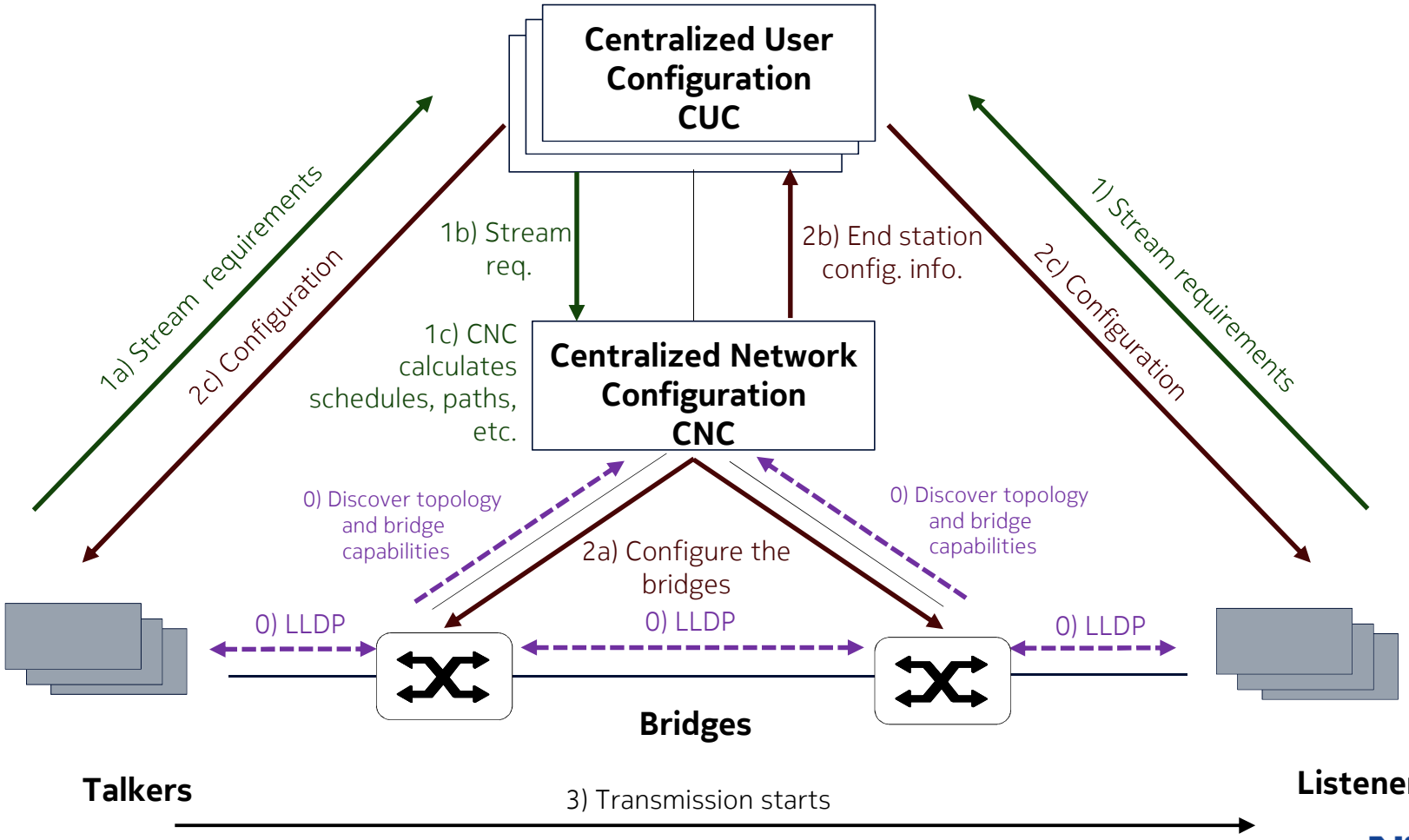
Exemplary physical deployment of “3GPP Bridge”: Logical setup



- 3GPP bridge may connect other bridges or devices
- Mapping of PDU Sessions to Port-Pairs (here: [A,E], [B,E], [C,E], [D,E])
- Mapping of TSN streams to QoS flows (not shown in the figure)
- TSN CNC may be connected through a dedicated management port (and IP)
- Can be incorporated with slices, NPN deployments, hierarchical deployments, …

TSN Procedures supported by 3GPP

0. **Network topology and capability discovery**
1. **Stream requirements and schedule computation**
2. **Configuration of Bridges and End stations**



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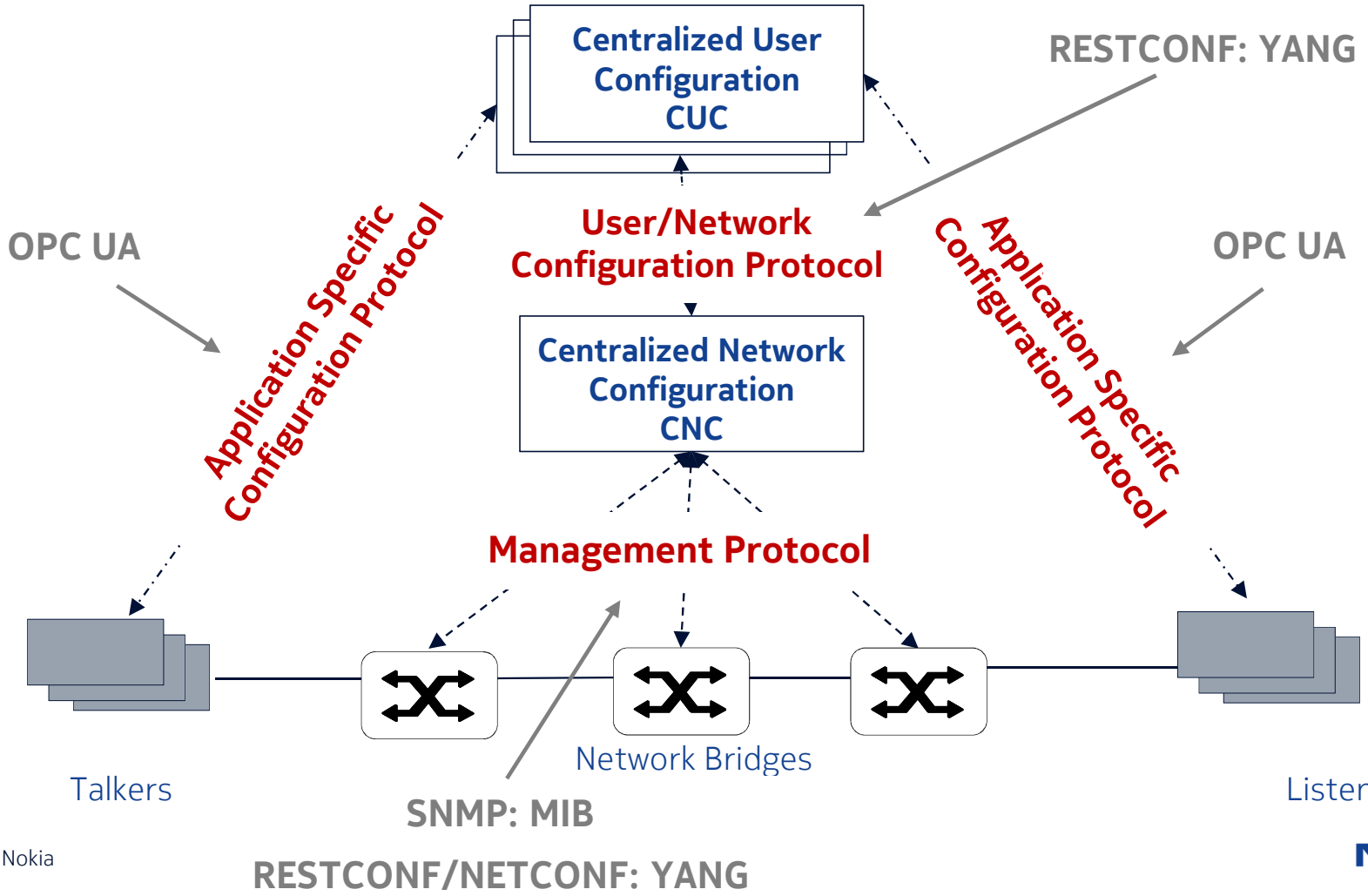
TSN Management System Protocols and Data Models



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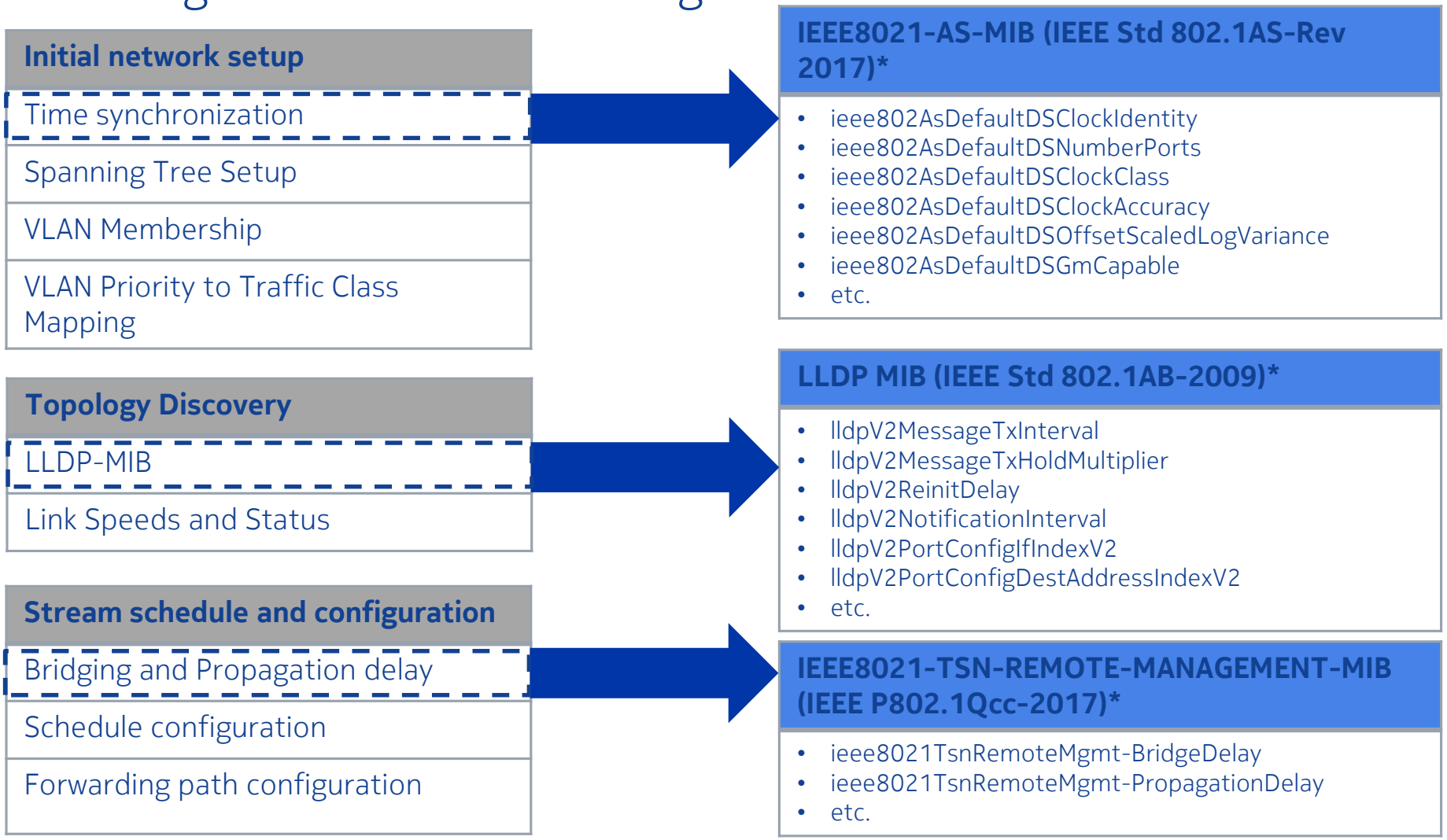
MIBs for configuration of network bridges

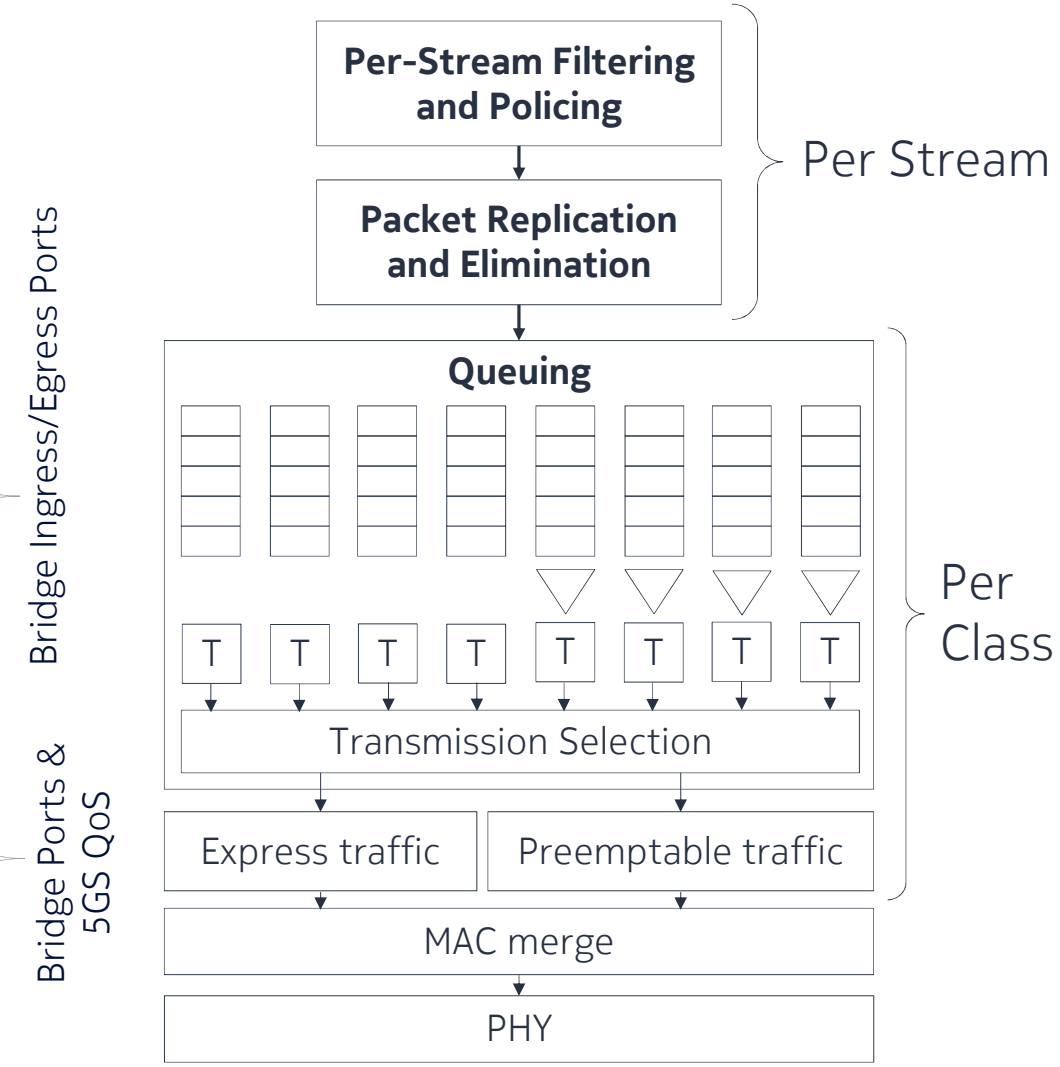


*exemplary extracts of MIB objects

E2E TSN QoS and Scheduling

Traffic management in TSN is very complex. TSN include sub-standards for:

- **Ingress Policing (.1Qci)**
  - Protection against bandwidth violation, malfunctioning, etc.
  - Violating Frames can be discarded
- **Frame Replication and Elimination (.1CB)**
  - Send copies through two or more separate paths. Identify and discard copies upon reception.
- **Frame Preemption (.3br and .1Qbu)**
  - Two classes: preemptable and non-preemptable (express) traffic.
- **Scheduled Traffic (.1Qbv)**
  - 8 priority queues
  - Credit-based Shapers ▽
  - Time gates: closed (C) or open (O) T



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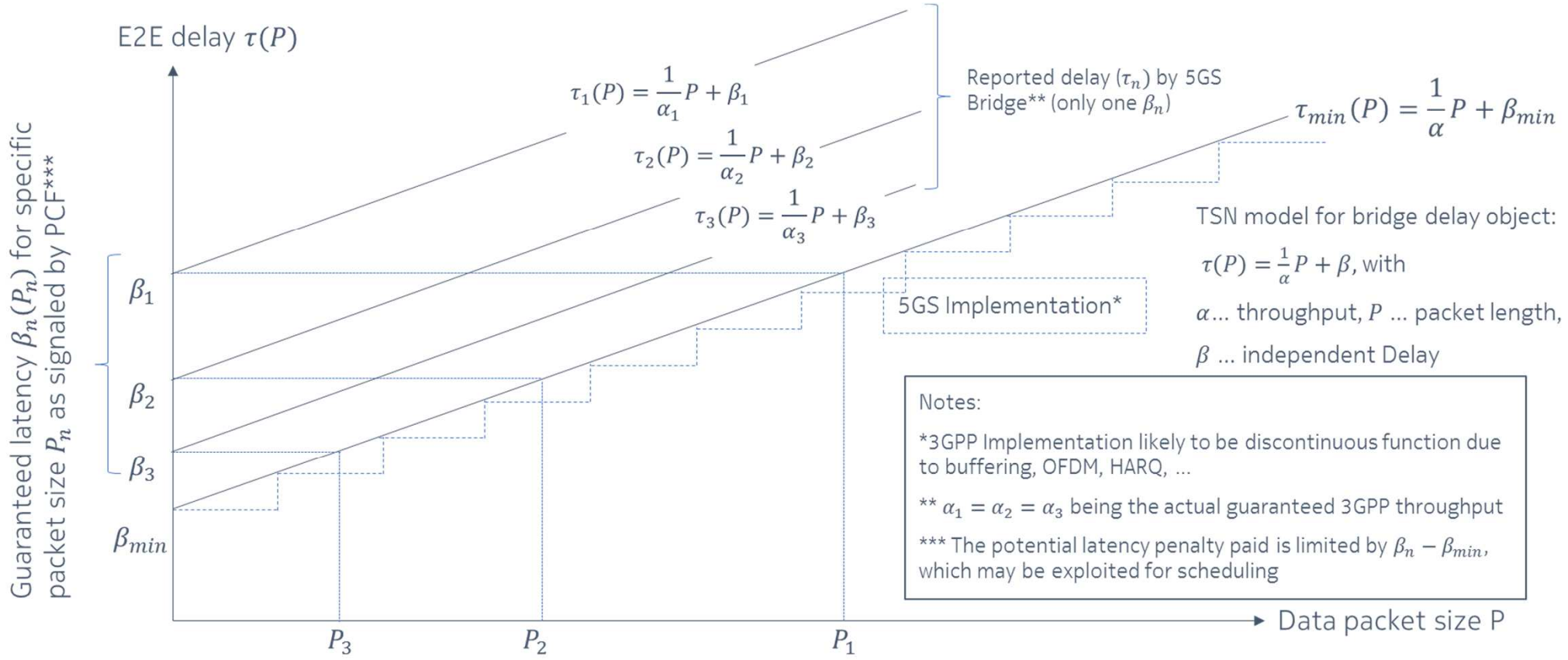
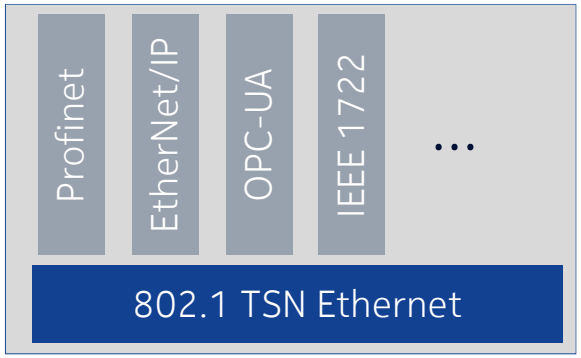
Proposal for QoS mapping
Simplified depiction – reported delays

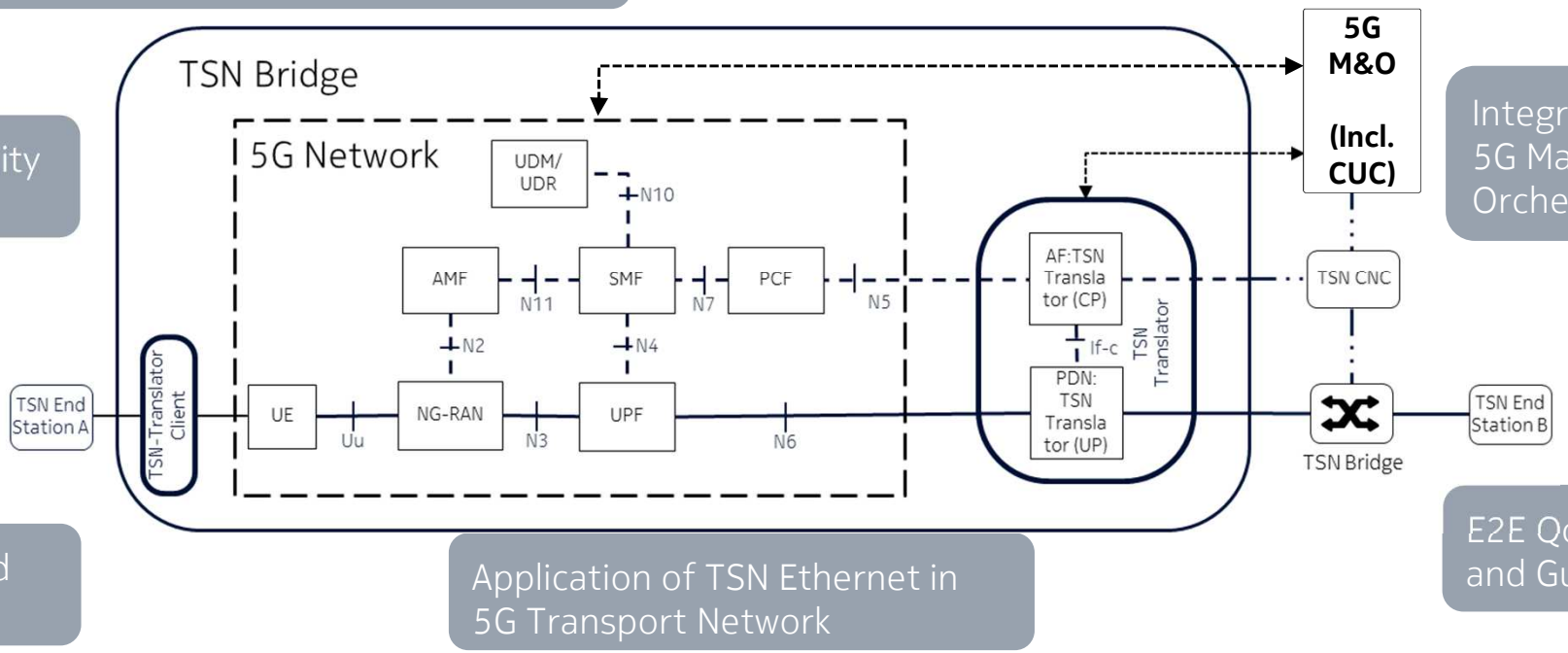


Further challenges

Hold and Forward – enable Gating Schedules and Policing/Filtering



E2E TSN Synchronicity (beyond timing).



Integration with 5G Management & Orchestration

Other protocols and standards

Application of TSN Ethernet in 5G Transport Network

E2E QoS Control and Guarantees

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