DETERMINISTIC6G

Tutorial:
5G Time Sensitive Communications (TSC)

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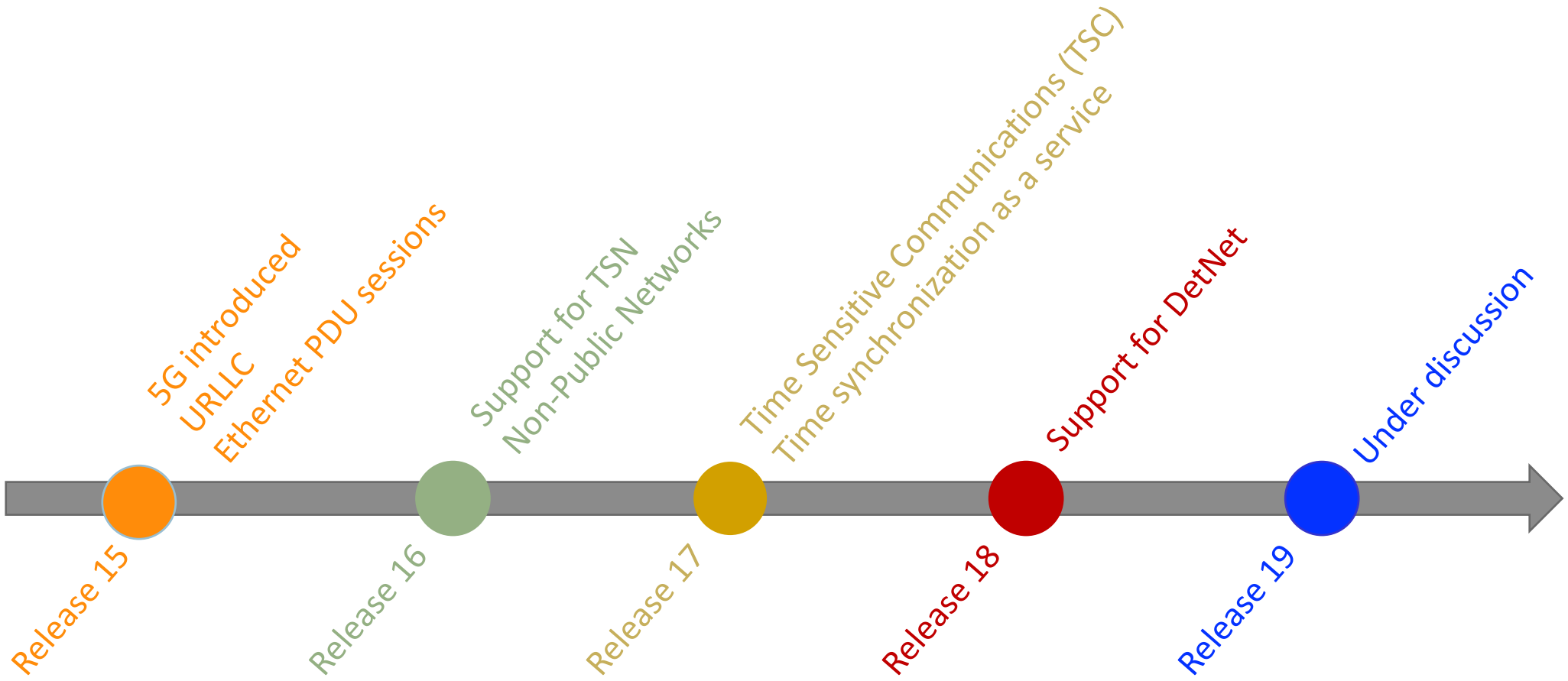
Agenda

- 3GPP Time sensitive communications (TSC) framework through releases
- URLLC features
- TSN support
  - Scheduled traffic and Hold and Forward buffers
  - Per-stream filtering and policing (PSFP)
  - Time synchronization
- General TSC support
- DetNet support

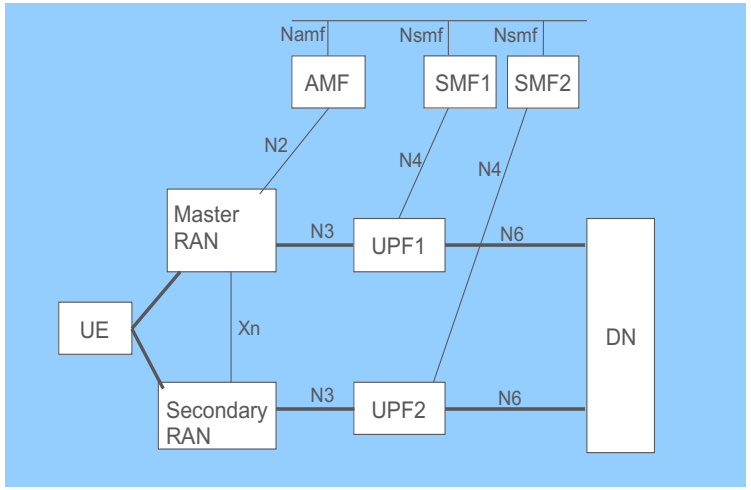
3GPP 5G Time Sensitive Communications framework



Deterministic 5G - URLLC Features

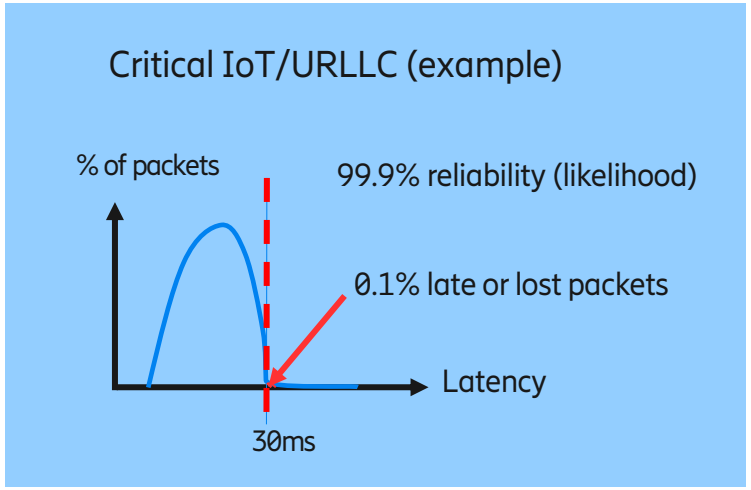
URLLC - reliability

- High reliability by new NR RAN features: automatic repetitions, antenna techniques, robust physical channels
- Redundant user planes paths, example



URLLC - latency

- Low latency enablers in NR RAN: OFDM numerology, minislots, grant-free, pre-emption
- Bounded latency key, not necessarily low latency



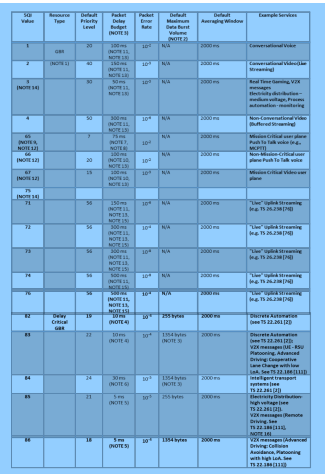
URLLC - QoS

- Standardized 5G QoS identifier (5QI) values for multiple time-critical services
- QoS monitoring (Packet Delay Budget)

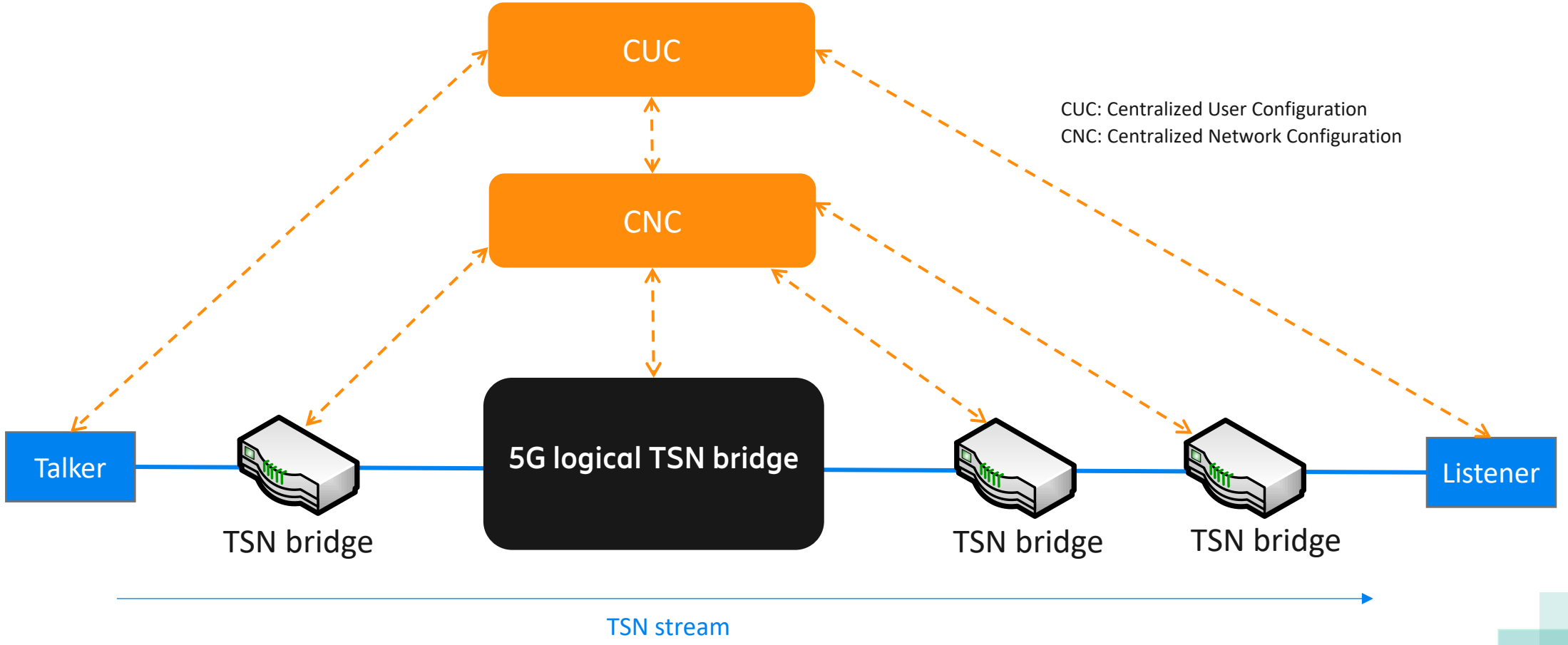
5QI values resource types:

- Guaranteed bit rate (GBR)
- (New) Delay Critical GBR

e.g., 71, 82 or 85

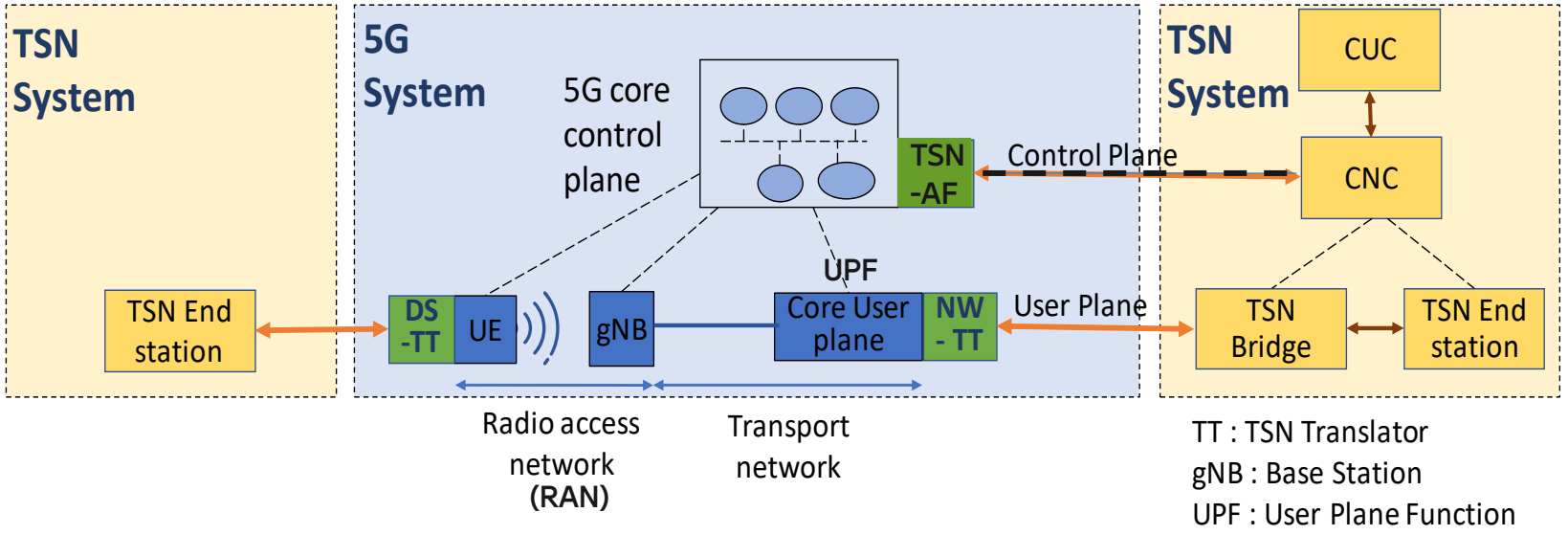


Integrating 5G and TSN



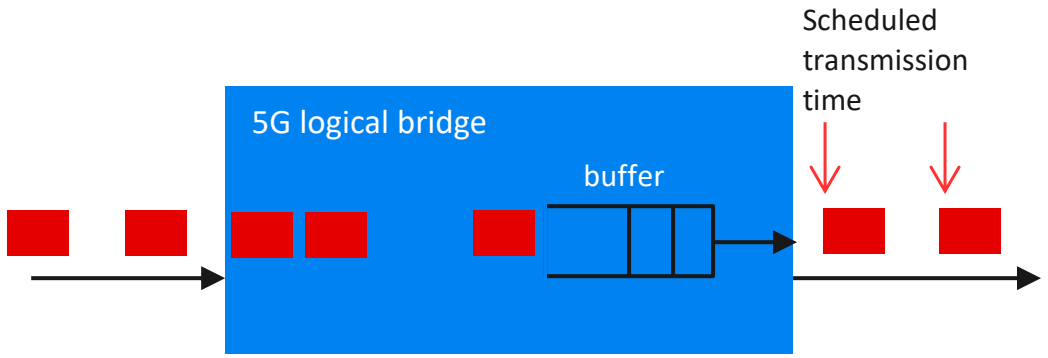
Rel-16: 5G TSN support

- **TSN Translators (TT)**
  - Control plane (Application Function, AF)
    - interaction with TSN controller (CNC)
    - QoS mapping 5G ⇔ TSN
    - port and bridge management
  - User plane (Device-side TT: DS-TT, Network-side TT: NW-TT)
    - provide Ethernet/TSN interface (port)
    - implement TSN Qbv, PSFP gating
    - support gPTP time synchronization



Supporting “scheduled traffic” (aka Qbv): Hold and Forward buffers

- Supported at the DS-TT and NW-TT to mimic the behavior of scheduled traffic per traffic class at “egress port”
- The buffer at the DS-TT or NW-TT holds the packets when the Qbv gate is closed and forwards the packets when the Qbv gate opens.

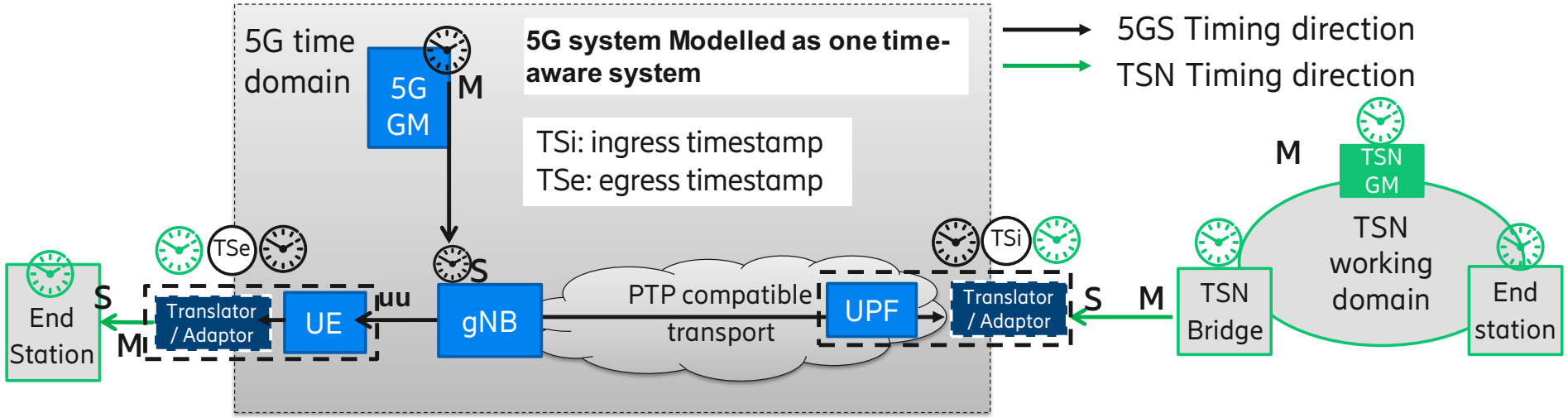


- 3GPP does not specify how the Hold and Forward buffers should be implemented

Supporting Per-Stream Filtering and Policing, PSFP (aka 802.1Qci)

- Time-gates (similar to Qbv) per TSN stream at “ingress port”
  - Open or Closed
- If a frame of a TSN stream arrives to ingress port when its TSN-stream gate is closed, the frame may be dropped
- **In 3GPP:**
  - PSFP supported and enforced at the DS-TT and NW-TT
  - “TSN stream identification” function (IEEE802.1CB) is necessary to support PSFP
  - PSFP information used in 5G to derive **QoS requirements** and **TSC assistance information** useful for RAN scheduling such as periodicity.

Time synchronization



Time-aware system: 5G supports generalized Precision Time Protocol (gPTP) as defined IEEE 802.1AS

Time synchronization is performed in two processes:

1. **Sync TTs with 5G grandmaster (GM):** Send 5G time to UE/DS-TT (provisioned by RAN) and to UPF/NW-TT.
2. **Transfer gPTP message DL:** (i) Add timestamp (TSi) to gPTP synchronization message at the ingress TT. (ii) At the egress TT, generate new timestamp (TSe), (iii) calculate TSe-TSi, (=5G residence time), (iv) remove timestamp Tsi from gPTP message, (v) update residence time field in (g)PTP message, and (vi) Forward to next Node.

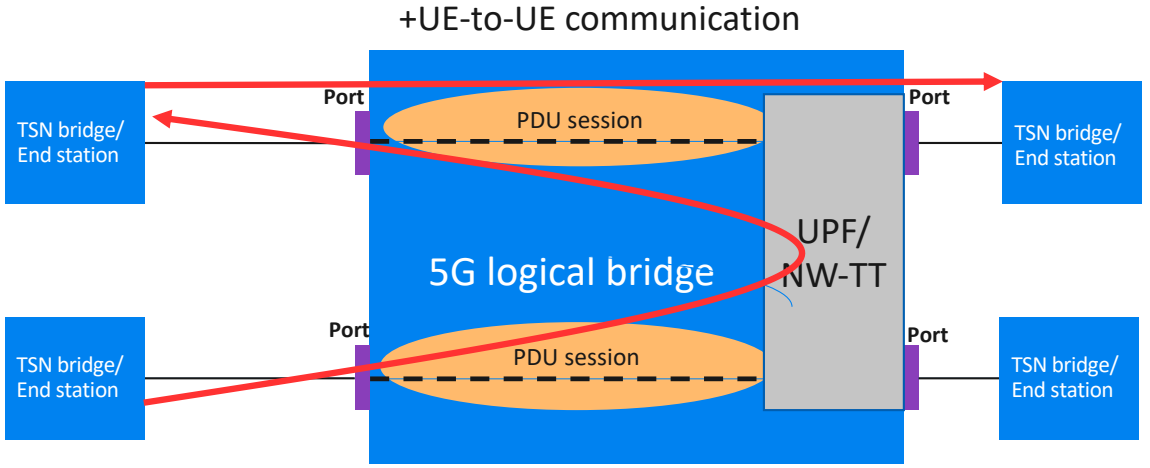
Rel-17: Time Sensitive Communications (TSC)

Rel-16 gaps

- ❑No UE-to-UE communication supported
- ❑Only Downlink time synchronization supported

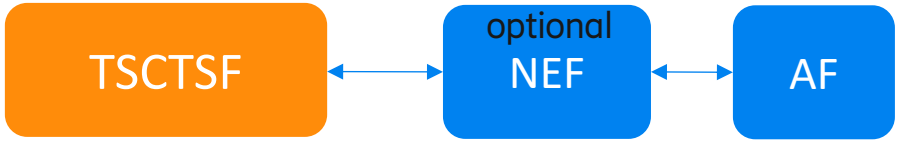
Rel-17 key solutions

- ❑UE-to-UE communication
- ❑Uplink time sync distribution, and PTP (IEEE 1588)
- ❑General support for *Time Sensitive Communications (TSC),* ***IP and Ethernet,*** i.e., not only TSN
- ❑Exposure of capabilities to external Application Function (AF)



TSN (special case of TSC)

TSC general case

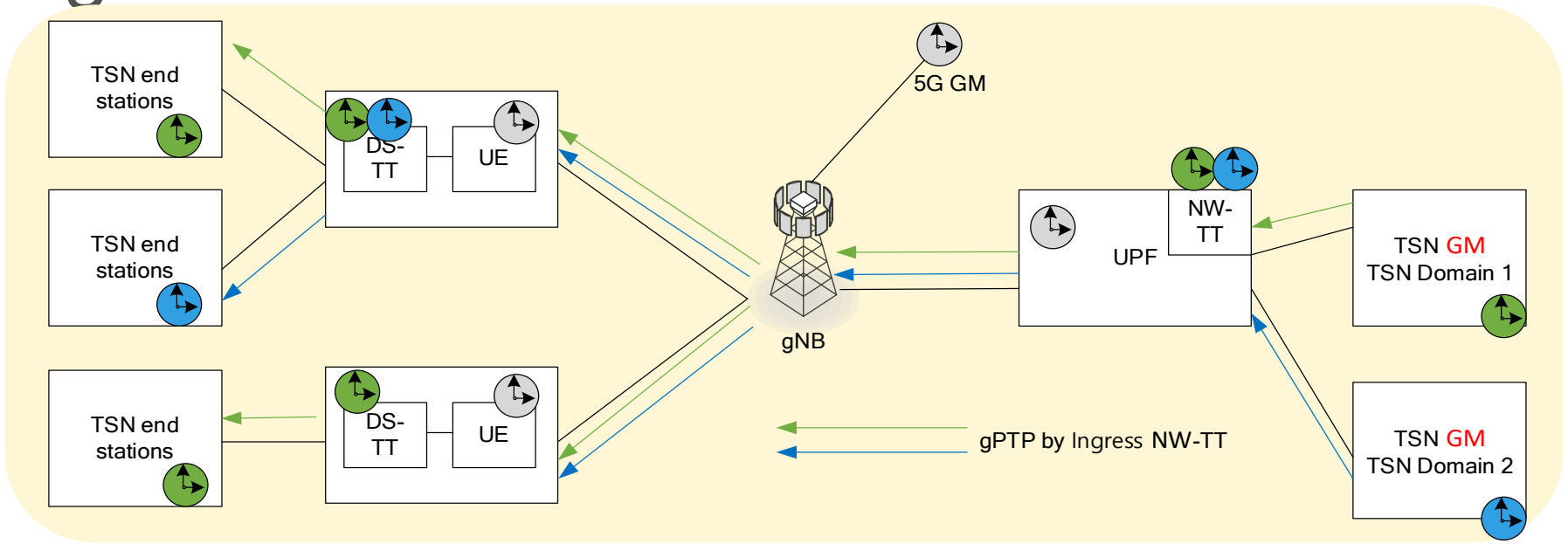


NEF: Network Exposure Function
TSCTSF: TSC and Time Synchronization Function

Time sync message distribution in 5G

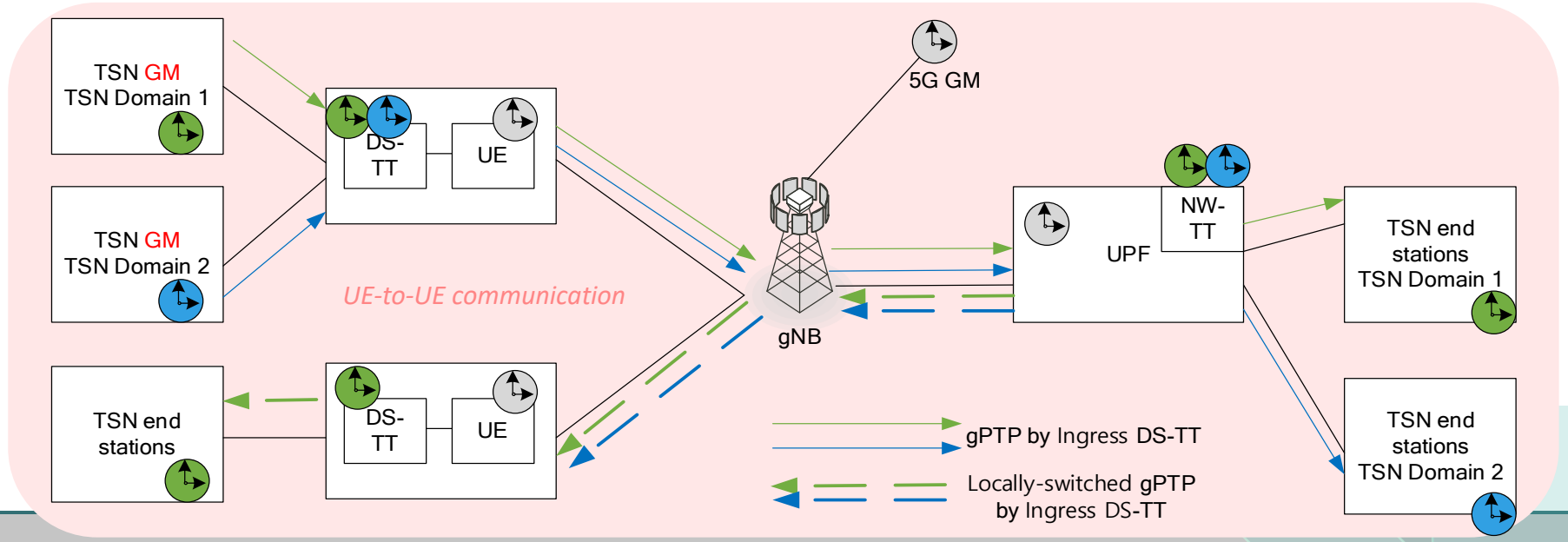
Downlink direction: Grandmaster (GM) is behind UPF (**Rel-16**)

Every (g)PTP message is sent downlink to all UEs/DS-TTs.

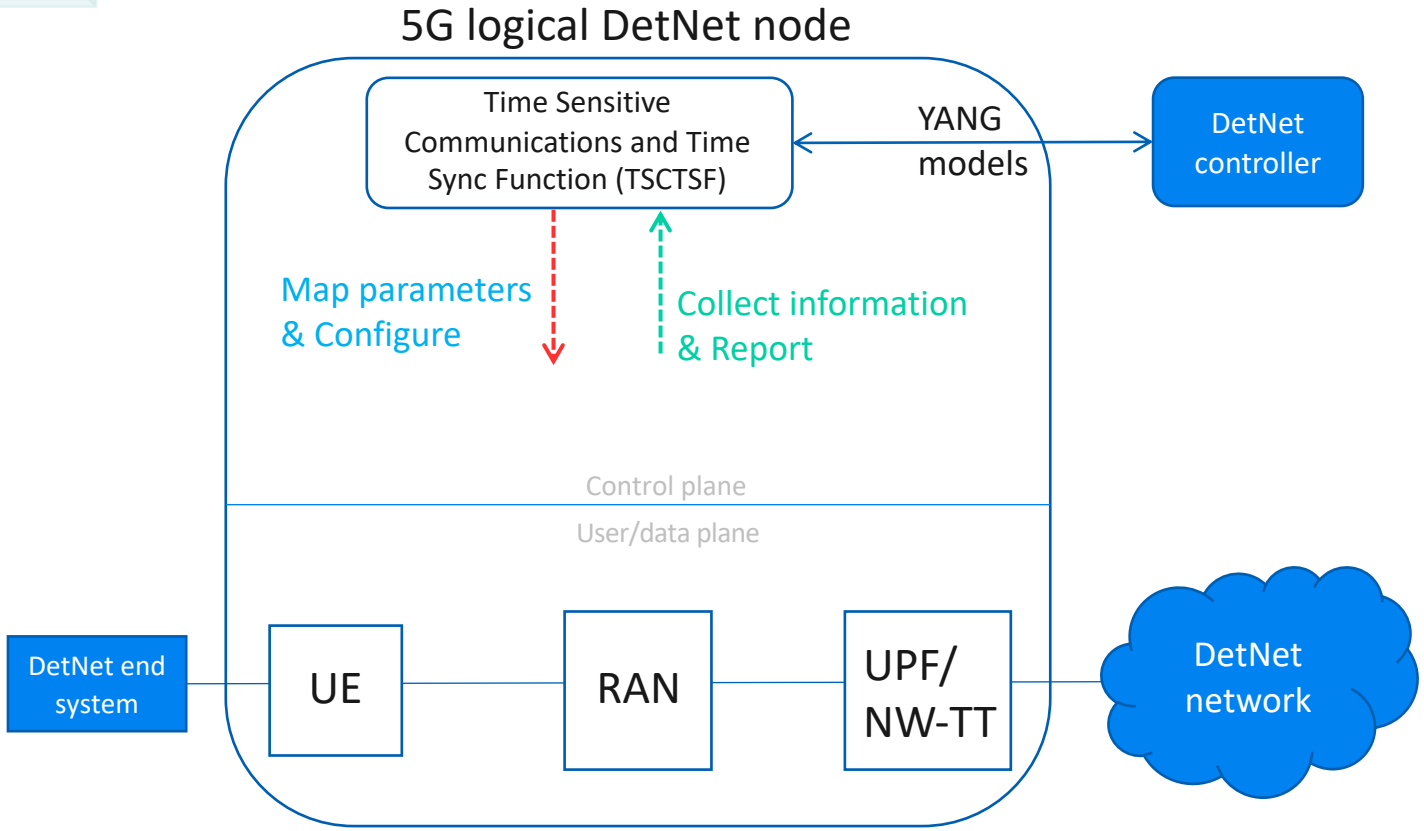


Uplink direction: Grandmaster GM is behind a Device (**Rel-17**)

Messages are distributed uplink to NW-TT and also downlink (using local switching at UPF) towards all other DS-TTs.



Rel-18: 5G support for DetNet



- 5G system modelled as a logical DetNet node with IP data plane
- 3GPP reuses the TSC framework from Rel-17
- No RAN impacts, no need for DS-TT
- Interface with DetNet controller via a management protocol (e.g., Netconf) and using YANG models
  - TSCTSF does the mapping between YANG and 5G QoS parameters

Further Reading

- 3GPP, TS 23.501, “System architecture for the 5G System (5GS)”: Specification # 23.501 (3gpp.org)
- 3GPP, TR 23.700-46, “Study on 5GS DetNet interworking”: Specification # 23.700-46 (3gpp.org)
- IEC/IEEE, “IEC/IEEE 60802 TSN Profile for Industrial Automation”: https://1.ieee802.org/tsn/iec-ieee-60802/
- 5G-ACIA, white paper “Integration of 5G with Time-Sensitive Networking for Industrial Communications”,
- EU project 5G-SMART, “Second report on new technological features to be supported by 5G standardization and their implementation impact”: https://5gsmart.eu/wp-content/uploads/5G-SMART-D5.3-v1.0.pdf

THANK YOU

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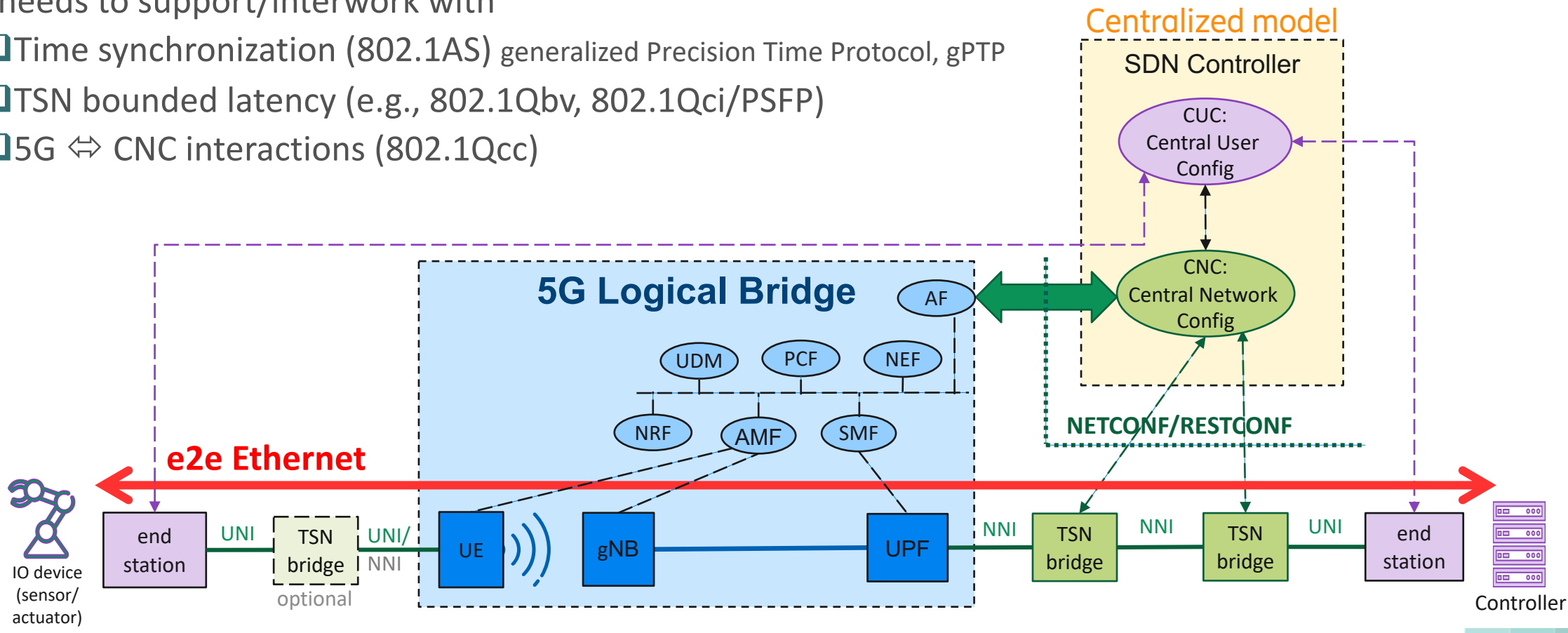
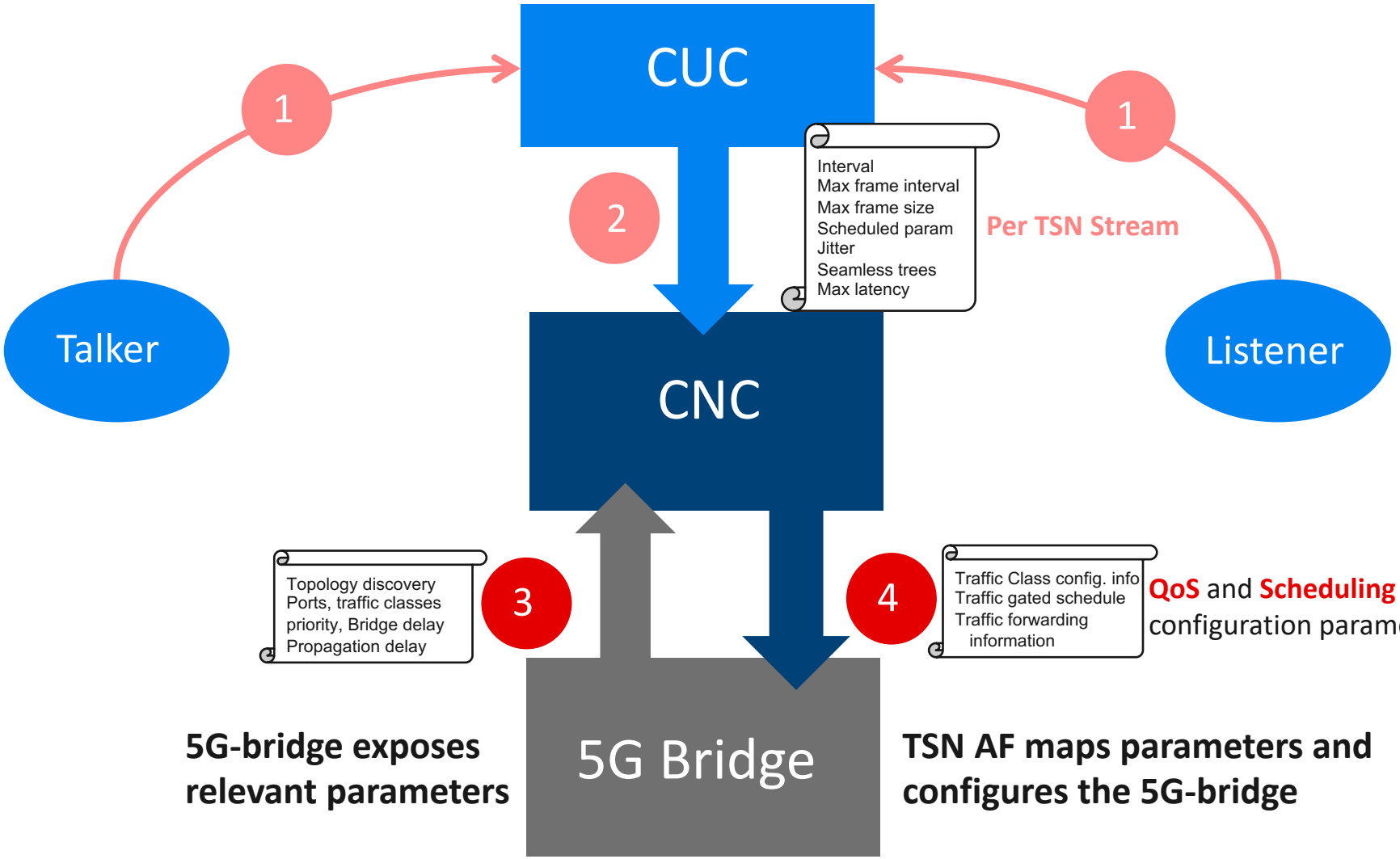
Extra material

Rel-16: 5G-TSN integration

- *Time Sensitive Networking (TSN): a set of IEEE 802.1 standards used to guarantee delivery (with zero loss or delay due to congestion) of a data packet within a guaranteed time window.*
- 5G needs to support/interwork with
  - Time synchronization (802.1AS) generalized Precision Time Protocol, gPTP
  - TSN bounded latency (e.g., 802.1Qbv, 802.1Qci/PSFP)
  - 5G ⇔ CNC interactions (802.1Qcc)

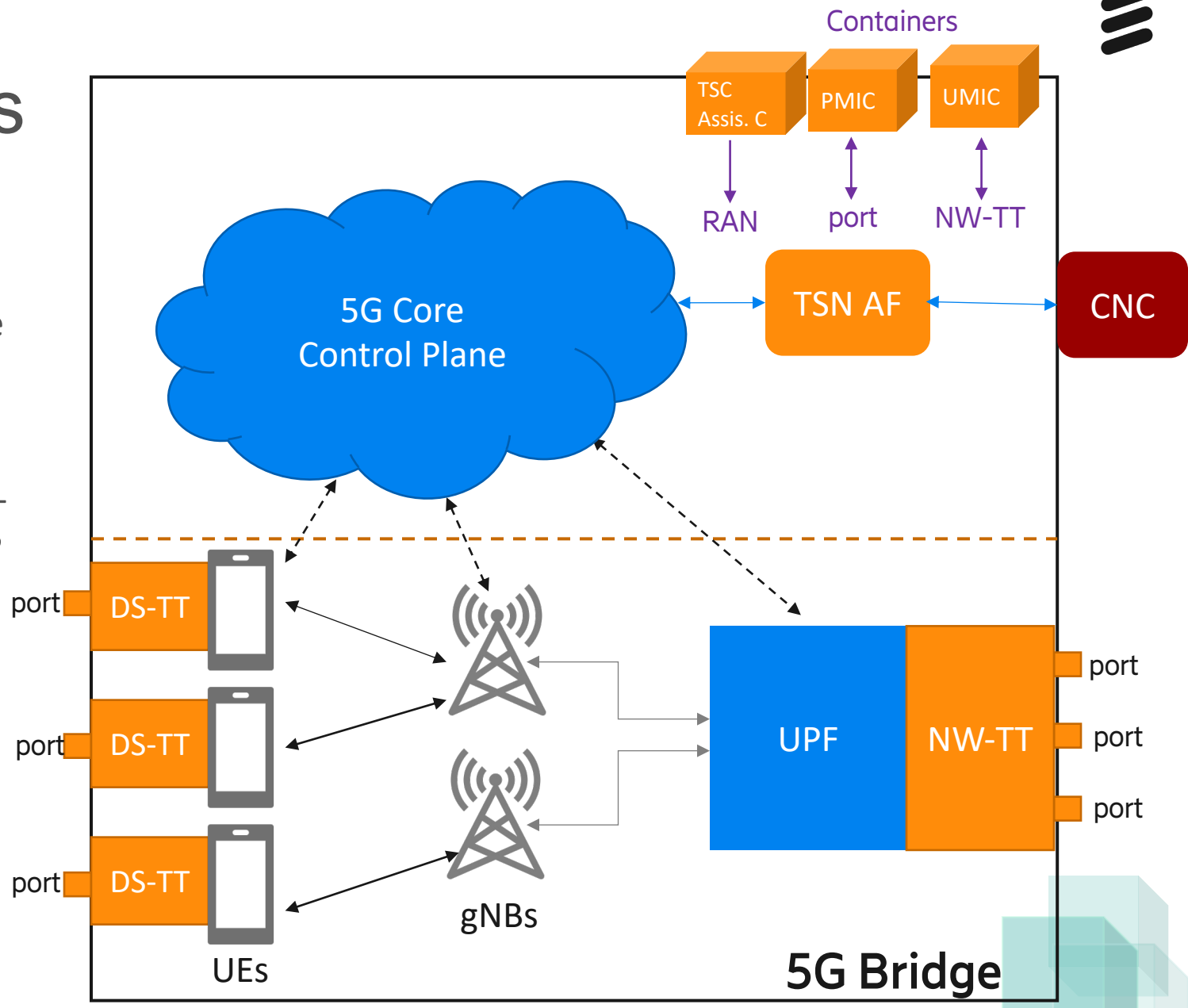


5G-TSN interactions



5G (TSN) components

- DS-TT and device-side ports
- NW-TT and network-side ports
- TSN AF: interact with **CNC** to expose bridge and port information, and to configure the 5G bridge and its ports
- Port Management Information Container (PMIC): exchange information between DS-TT and TSN-AF, contain **Qbv, PSFP, 802.1AS** information
- User-plane Management Information Container (UMIC): exchange information between NW-TT and TSN-AF
- Time Sensitive Communication (TSC) Assistance container
  - Transports TSC assistance information (TSCAI) useful for RAN scheculing



TSC Assistance Information

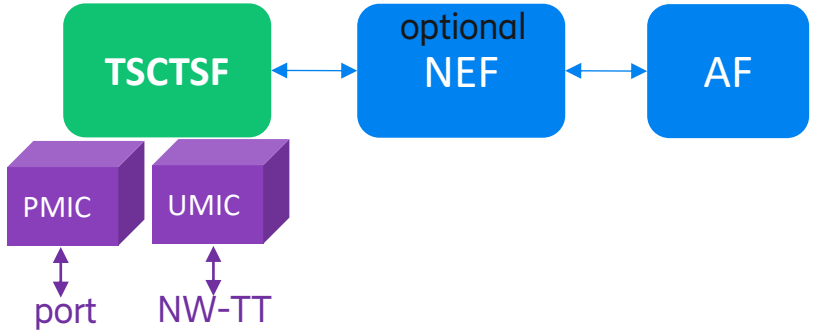
TSCAI:

- is provided to RAN (gNB)
- is based on traffic characteristics initially obtained by AF
- is optional
- allows the 5G-RAN more efficiently schedule radio resources for periodic traffic

TSCAI

- Burst Arrival Time is the latest possible time when the first packet of the data burst arrives at the RAN (DL) or the egress of the UE (UL)
- Periodicity is the time period between start of two bursts
- Flow Direction (UL or DL), corresponds to the Direction of the QoS flow
- Survival Time (new, Rel-17) refers to the time period an application can survive without any burst.

Rel-17:
Time Synchronization as a service



- **AF**:
  - learns the 5GS capabilities to support time synchronization
  - may request Activation/ Deactivation of the Time Synchronization Service for targeted UEs
  - may provide requirements used to configure the time synchronization distribution to targeted UEs
- **NEF**: authorizes the AF requests if AF is 3rd party
- **TSCTSF** (or TSN AF):
  - determines the (g)PTP functionalities supported by DS-TT and NW-TT ports based on information in PMICs
  - configures the port states (master, slave…) based on results of BMCA running in NW-TT and shared with TSCTSF/TSN AF via UMIC
  - configures clock parameters (provided by AF) using PMIC/UMIC in case the 5GS acts as GM clock
  - calculates per-UE air interface error budget based on requested time error budget provided by AF, and delivers it to RAN, such that RAN may decide whther to apply a delay compensation method to guarantee time error budget.

Interaction with DetNet Controller

- TSCTSF reports the following information to DetNet controller for each interface/port:
  - Type of interface,
  - IP address,
  - subnetwork (prefix length),
  - Neighbor address
  - MAC address
  - MTU size.

- TSCTSF maps DetNet configuration parameters into 5G parameters:

DetNet parameters	5G parameters
Max-latency	Required delay
Min-bandwidth	Guaranteed Flow Bit Rate (GFBR)
Max-loss	Required Packet Error Rate (PER) -new parameter for Release 18
Max-consecutive-loss-tolerance	Survival time– when such mapping is possible, such as when there is only a single packet per interval.
Interval	Periodicity
max-pkts-per-interval * (max-payload-size + protocol header size)	Max burst size
max-pkts-per-interval * (max-payload-size + protocol header size)/ Interval	Requested Maximum Flow Bit Rate (MFBR)
DetNet flow specification	3GPP flow description (also including the DSCP value and optionally IPv6 flow label and IPSec SPI)