教育部「5G行動寬頻人才培育跨校教學聯盟計畫」

5G行動網路協定與核網技術聯盟中心

課程:5G垂直應用網路

單元4
URLLC垂直應用網路技術

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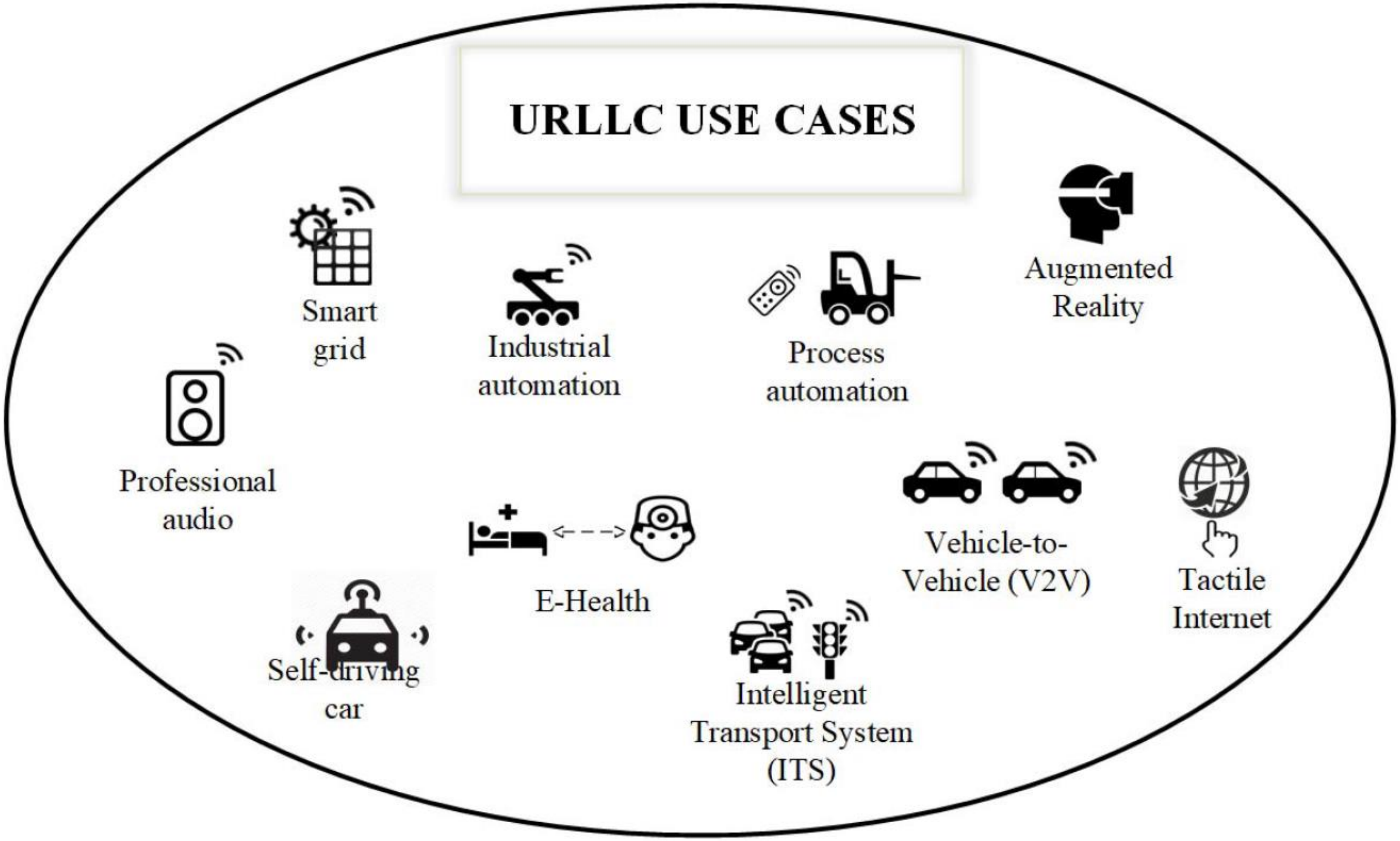
Outline

- NR and NG-RAN Vertical Supports for URLLC
  - TS 38.300 Clause 16.1
- 5GC Supports for URLLC
  - TS 23.501 Clause 5.33
- Time Sensitive Communication
  - As defined in IEEE P802.1Qcc
  - TS 23.501 Clauses 4.4.8, 5.27 and 5.28

Potential URLLC Use Cases



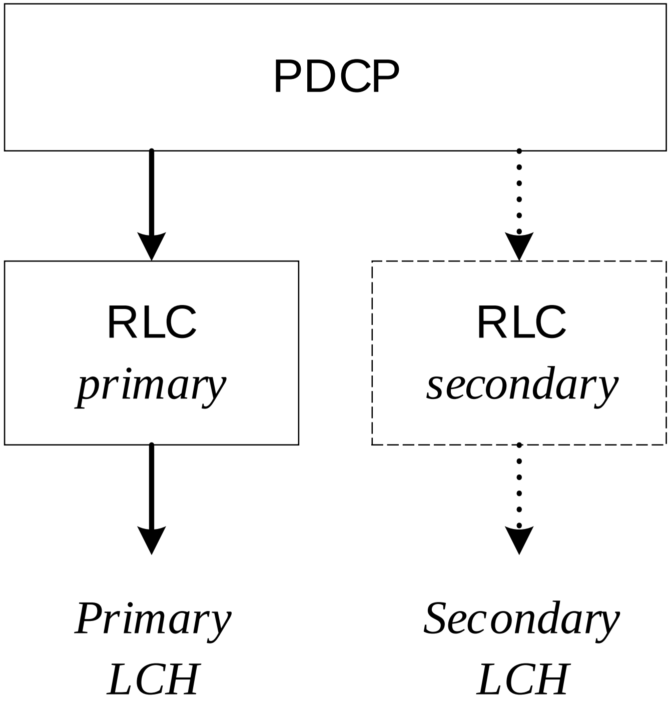
NR and NG-RAN Vertical Supports - URLLC

- The support of Ultra-Reliable and Low Latency Communications (URLLC) services is facilitated by the introduction of the mechanisms described TS 38.300 Clause 16.1
  - Those mechanisms need not be limited to the provision of URLLC services
  - Furthermore, RRC can associate logical channels with different SR (Scheduling Request) configurations
    - For instance, to provide more frequent SR opportunities to URLLC services

Logical Channel Prioritization (LCP) Restrictions

- With LCP restrictions in MAC, RRC can restrict the mapping of a logical channel to a subset of
  - the configured cells, numerologies, PUSCH transmission durations, configured grant configurations and
  - control
    - whether a logical channel can utilise the resources allocated by a Type 1 Configured or
    - whether a logical channel can utilise dynamic grants indicating a certain physical priority level
- With such restrictions, it then becomes possible to reserve
  - For instance, the numerology with the largest subcarrier spacing and/or shortest PUSCH transmission duration for URLLC services
- Furthermore, RRC can associate logical channels with different SR configurations, for instance, to provide more frequent SR opportunities to URLLC services

Packet Duplication



- All RLC entities have the same RLC mode

Packet Duplication

- When duplication is configured for a radio bearer by RRC
  - At least one secondary RLC entity is added to the radio bearer to handle the duplicated PDCP PDUs
  - where the logical channel corresponding to the primary RLC entity is referred to as the primary logical channel, and the logical channel corresponding to the secondary RLC entity(ies), the secondary logical channel(s)
  - All RLC entities have the same RLC mode
- Duplication at PDCP therefore consists in submitting the same PDCP PDUs multiple times: once to each activated RLC entity for the radio bearer
- With multiple independent transmission paths, packet duplication therefore increases reliability and reduces latency and is especially beneficial for URLLC services

Duplication for DRB

- When configuring duplication for a DRB, RRC also sets the initial state of PDCP duplication (either activated or deactivated)
- After the configuration, the PDCP duplication state can then be dynamically controlled by means of a MAC control element and in DC, the UE applies the MAC CE commands regardless of their origin (MCG or SCG)
- When duplication is configured for an SRB the state is always active and cannot be dynamically controlled
- When configuring duplication for a DRB with more than one secondary RLC entity, RRC also sets the initial state of each of them (i.e. either activated or deactivated)
- Subsequently, a MAC CE can be used to dynamically control whether each of the configured secondary RLC entities for a DRB should be activated or deactivated, i.e. which of the RLC entities shall be used for duplicate transmission
- Primary RLC entity cannot be deactivated. When duplication is deactivated for a DRB, all secondary RLC entities associated to this DRB are deactivated
- When a secondary RLC entity is deactivated, it is not re-established, the HARQ buffers are not flushed, and the transmitting PDCP entity should indicate to the secondary RLC entity to discard all duplicated PDCP PDUs
- When activating duplication for a DRB, NG-RAN should ensure that at least one serving cell is activated for each logical channel of the DRB
  - And when the deactivation of SCells leaves no serving cells activated for a logical channel of the DRB, NG-RAN should ensure that duplication is also deactivated

DC / CA Duplication

- When duplication is activated, the original PDCP PDU and the corresponding duplicate(s) shall not be transmitted on the same carrier
  - The primary and secondary logical channels can either belong to the same MAC entity (referred to as CA duplication) or to different ones (referred to as DC or DC+CA duplication)
  - CA duplication can be configured together with DC duplication when duplication over more than two legs is configured in the UE
  - In CA duplication, logical channel mapping restrictions are used in MAC to ensure that the primary and secondary logical channels are not sent on the same carrier
  - When CA duplication is configured for an SRB, one of the logical channels associated to the SRB is mapped to SpCell
- When CA duplication is deactivated for a DRB, the logical channel mapping restrictions of the primary and secondary logical channels are lifted for as long as duplication remains deactivated
- When an RLC entity acknowledges the transmission of a PDCP PDU, the PDCP entity shall indicate to the other RLC entity(ies) to discard it
  - In addition, in case of CA duplication, when an RLC entity restricted to only SCell(s) reaches the maximum number of retransmissions for a PDCP PDU, the UE informs the gNB but does not trigger RLF

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5.33 Support for Ultra Reliable Low Latency Communication

- 5.33.1 General
- 5.33.2 Redundant transmission for high reliability communication
  - 5.33.2.1 Dual Connectivity based end to end Redundant User Plane Paths
  - 5.33.2.2 Support of redundant transmission on N3/N9 interfaces
  - 5.33.2.3 Support for redundant transmission at transport layer
- 5.33.3 QoS Monitoring to Assist URLLC Service
  - 5.33.3.1 General
  - 5.33.3.2 Per QoS Flow per UE QoS Monitoring
  - 5.33.3.3 GTP-U Path Monitoring

5GS Support for URLLC - Ultra Reliable Low Latency Communication

- Redundant transmission for high reliability communication
  - In current Release 16.5, URLLC applies to 3GPP access only
- When a PDU Session is to serve URLLC QoS Flow, the UE and SMF should establish the PDU Session as always-on PDU Session as described in clause 5.6.13
  - How the UE knows whether a PDU Session is to serve a URLLC QoS Flow when triggering PDU Session establishment is up to UE implementation
  - No additional functionality is specified for URLLC in order to support Home Routed roaming scenario in this Release

Potential approaches to Redundant Transmission

- Dual Connectivity (RAN)
- End-to-end Redundant User Plane Paths (5GS)
  - Two redundant PDU Sessions over the 5G network
  - Single PDU session with two redundant tunnels
    - Two N3 Tunnels
    - Two N3+N9 Tunnels
- Upper layer protocols
  - IEEE TSN (Time Sensitive Networking) FRER (Frame Replication and Elimination for Reliability) (See IEEE Standard)
  - Transport layer

How to make use of the duplicate paths for redundant traffic delivery end-to-end is out of scope of 3GPP

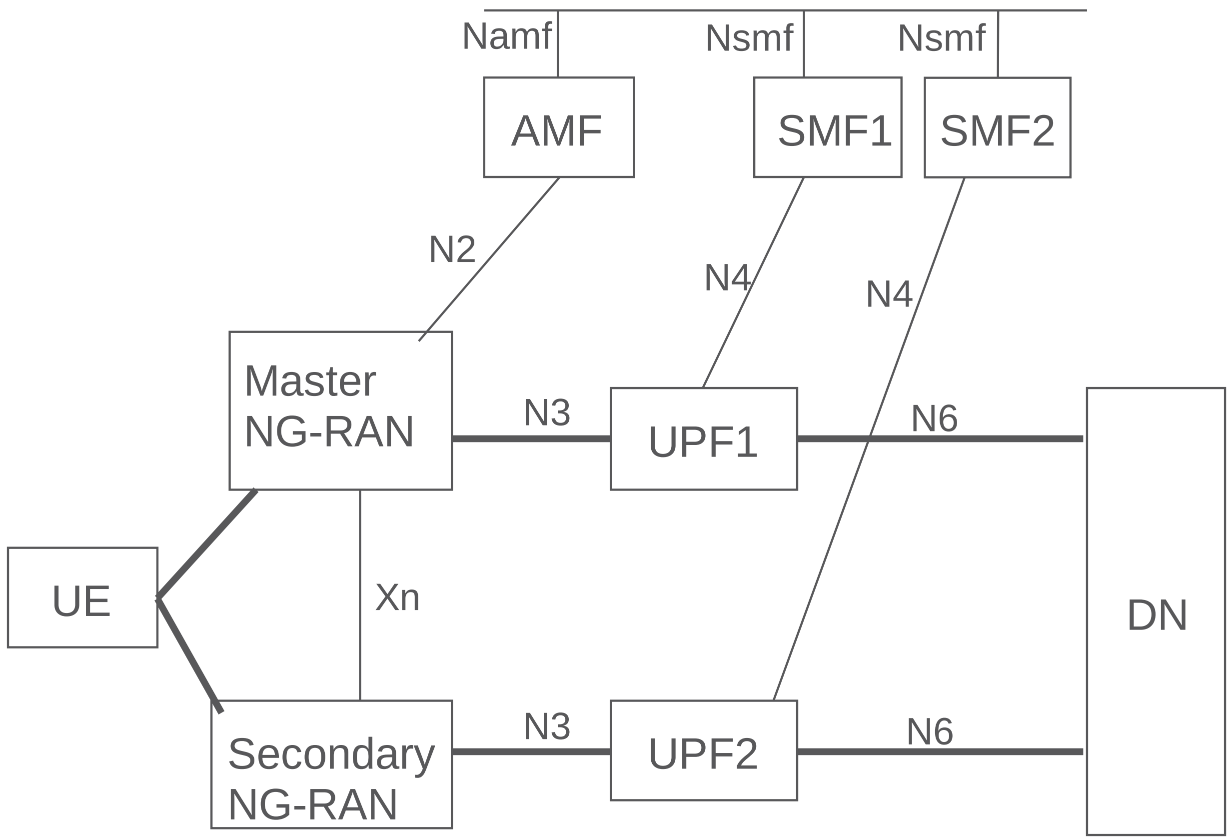
Redundant Network Deployment Aspects

- Dual connectivity
  - RAN supports dual connectivity, and there is sufficient RAN coverage for dual connectivity in the target area
  - UEs support dual connectivity
- Redundant user plane paths
  - The core network UPF deployment is aligned with RAN deployment and supports redundant user plane paths
  - The underlying transport topology is aligned with the RAN and UPF deployment and supports redundant user plane paths
- Toward higher redundancy
  - The physical network topology and geographical distribution of functions also supports the redundant user plane paths to the extent deemed necessary by the operator
  - The operation of the redundant user plane paths is made sufficiently independent, to the extent deemed necessary by the operator, e.g. independent power supplies

Redundant Transmission with End-to-End Paths

- Dual Connectivity based end-to-end Redundant User Plane Paths
  - In order to support highly reliable URLLC services, a UE may set up two redundant PDU Sessions over the 5G network
    - 5GS sets up the user plane paths of two redundant PDU Sessions to be disjoint
    - The user's subscription indicates if user is allowed to have redundant PDU Sessions and this indication is provided to SMF from UDM
  - Single PDU session with two N3 tunnels
- It is possible to rely on upper layer protocols, such as the IEEE TSN (Time Sensitive Networking) FRER (Frame Replication and Elimination for Reliability)
  - Manage the replication and elimination of redundant packets/frames over the duplicate paths
  - It can span both the 3GPP segments and possibly fixed network segments as well

Example Scenario for End to End Redundant User Plane Paths using Dual Connectivity



- Two independent user plane paths are set up
  - UPF1 and UPF2 connect to the same Data Network (DN), even though the traffic via UPF1 and UPF2 may be routed via different user plane nodes within the DN
  - The redundant user plane set up applies to both IP and Ethernet PDU Sessions

Redundancy with Two PDU Sessions

- In order to establish two redundant PDU sessions and associate the duplicated traffic coming from the same application to these PDU sessions, URSP (UE Route Selection Policy) or UE local configuration is used
- Using URSP, duplicated traffic from the application, associated to the redundant PDU Sessions, is differentiated by two distinct traffic descriptors, each in a distinct URSP rule
  - These traffic descriptors need to have different DNNs, IP descriptors or non-IP descriptors (e.g. MAC address, VLAN ID), so that the two redundant PDU sessions are matched to the Route Selection Descriptors of distinct URSP rules

Support of Redundant PDU Sessions

- UE: initiates two redundant PDU Session and provides different combination of DNN and S-NSSAI for each PDU Session
- SMF: The SMF determines whether the PDU Session is to be handled redundantly
  - The determination is based on the policies provided by PCF for the PDU Session, combination of the S-NSSAI, DNN, user subscription and local policy configuration
  - The SMF uses these inputs to determine the RSN (Redundancy Sequence Number) which differentiates the PDU Sessions that are handled redundantly and indicates redundant user plane requirements for the PDU Sessions in NG-RAN
  - The SMF's charging record may reflect the RSN information. The RSN indication is transferred from Source NG-RAN to Target NG-RAN in the case of handover
- UPF: Operator configuration of UPF selection ensures the appropriate UPF selection for disjoint paths

Support of Redundant PDU Sessions – NG-RAN

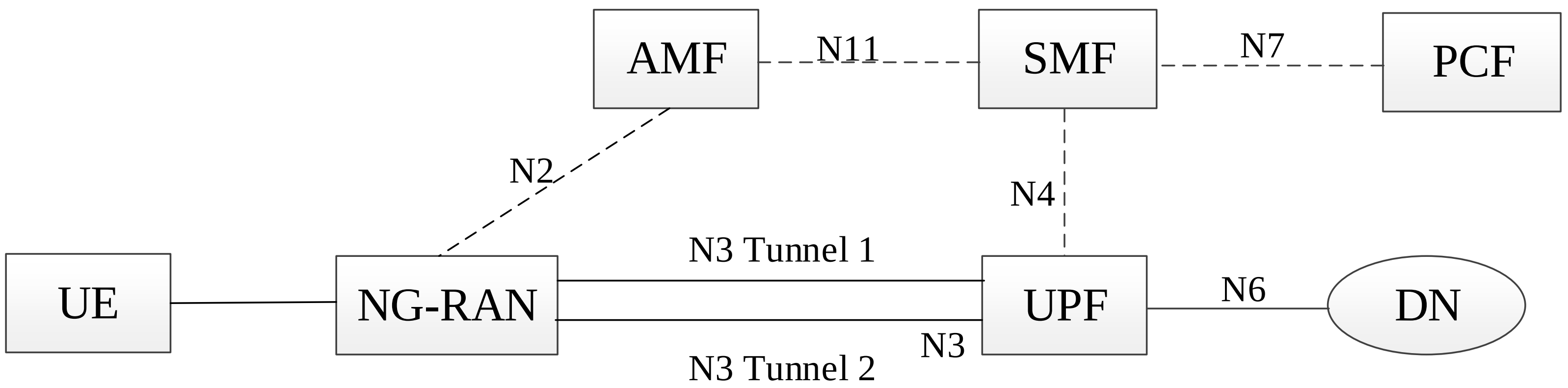
- NG-RAN: Using local configuration, NG-RAN determines whether the request to establish RAN resources for a PDU Session is fulfilled or not considering user plane requirements indicated by the RSN parameter by means of dual connectivity
  - If the request to establish RAN resources for PDU Session can be fulfilled by the RAN, the PDU Session is established even if the user plane requirements indicated by RSN cannot be satisfied
  - If the NG-RAN determines the request to establish RAN resources cannot be fulfilled then it shall reject the request which eventually triggers the SMF to reject the PDU Session establishment towards the UE
  - The decision for each PDU Session is taken independently (i.e. rejection of a PDU Session request shall not release the previously established PDU Session)
  - The RAN shall determine whether to notify the SMF if the RAN resources indicated by the RSN parameter can no longer be maintained and SMF can use that to determine if the PDU Session should be released

Support of Redundant Ethernet PDU Sessions

- In the case of Ethernet PDU Sessions, the SMF
  - has the possibility to change the UPF (acting as the PSA) and
  - select a new UPF based on the identity of the Secondary NG-RAN for the second PDU Session if the Secondary NG-RAN is modified (or added/released),
- Using the Ethernet PDU Session Anchor (PSA) Relocation procedure described in clause 4.3.5.8 of TS 23.502

Redundancy with Two N3 Tunnels

- Redundant transmission can also be supported with two N3 tunnels between the PSA UPF and a single NG-RAN node



Support of Redundant Transmission on N3/N9 Interfaces

- The redundant transmission may be deployed between PSA UPF and NG-RAN via two independent N3 tunnels
  - Which are associated with a single PDU Session, over different transport layer path to enhance the reliability
- To ensure the two N3 tunnels are transferred via disjointed transport layer paths
  - The SMF or PSA UPF should provide different routing information in the tunnel information (e.g. different IP addresses or different Network Instances)
    - These routing information should be mapped to disjoint transport layer paths according to network deployment configuration
  - The SMF indicates NG-RAN and PSA UPF that one of the two CN/AN Tunnel Info is used as the redundancy tunnel of the PDU Session accordingly
- The redundant transmission using the two N3/N9 tunnels are performed at QoS flow granularity and are sharing the same QoS Flow ID

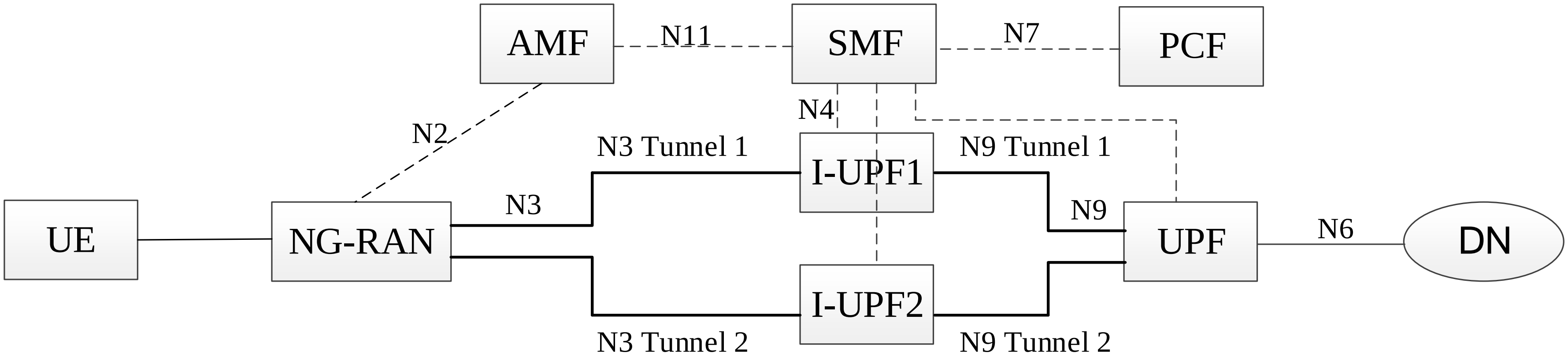
Replication and Elimination on Two N3 Tunnels

If duplication transmission is performed on N3/N9 interface

- For each downlink packet of the QoS Flow the PSA UPF received from DN,
  - The PSA UPF replicates the packet and assigns the same GTP-U sequence number to them for the redundant transmission
  - The NG-RAN eliminates the duplicated packets based on the GTP-U sequence number and then forwards the PDU to the UE
- For each uplink packet of the QoS Flow the NG-RAN received from UE
  - The NG-RAN replicates the packet and assigns the same GTP-U sequence number to them for redundant transmission
    - These packets are transmitted to the PSA UPF via two N3 Tunnels separately
  - The PSA UPF eliminates the duplicated packet based on the GTP-U sequence number accordingly
- The PSA UPF and NG-RAN may transmit packets via one or both of the tunnels per QoS Flow based on SMF instruction

Redundancy with Two N3+N9 Tunnels

- There may be two N3 and N9 tunnels between NG-RAN and PSA UPF for the URLLC QoS Flow(s) of the same PDU Session for redundant transmission established during or after a URLLC QoS flow establishment



Replication and Elimination on Two N3/N9 Tunnels

- In the case of downlink traffic
  - The PSA UPF duplicates the downlink packet of the QoS Flow from the DN and assigns the same GTP-U sequence number to them
    - These duplicated packets are transmitted to I-UPF1 and I-UPF2 via N9 Tunnel 1 and N9 Tunnel 2 separately
  - Each I-UPF forwards the packet with the same GTP-U sequence number which receives from the PSA UPF to NG-RAN via N3 Tunnel 1 and N3 Tunnel 2 respectively
  - The NG-RAN eliminates the duplicated packet based on the GTP-U sequence number
- In the case of uplink traffic
  - The NG-RAN duplicates the packet of the QoS Flow from the UE and assigns the same GTP-U sequence number to them
    - These duplicated packets are transmitted to I-UPF1 and I-UPF2 via N3 Tunnel 1 and N3 Tunnel 2 separately
  - Each I-UPF forwards the packet with the same GTP-U sequence number which receives from the NG-RAN to PSA UPF via N9 Tunnel 1 and N9 Tunnel 2 respectively
  - The PSA UPF eliminates the duplicated packets based on the GTP-U sequence number
- The I-UPFs inserted on one leg of the redundant paths shall not behave in an UL CL or Branching Point role

Redundancy at Transport Layer

- Redundant transmission can be supported within the 5G System without making any assumption on support for protocols such as IEEE FRER in the application layer (DN only)
  - At the same time it can be supported without requiring redundant GTP-U tunnel over N3
- The backhaul provides two disjoint transport paths between UPF and NG-RAN
  - The redundancy functionality within NG-RAN and UPF make use of the independent paths at transport layer
- Support of redundant transmission at transport layer requires no 3GPP protocol impact

Replication and Elimination for Redundancy at Transport Layer

- UE establishes the PDU session for URLLC services
- SMF selects a UPF that supports redundant transmission at transport layer for the PDU session
  - One N3 GTP-U tunnel is established between UPF and NG-RAN
  - The knowledge of supporting redundant transmission at transport layer can be configured in the SMF, or be configured in UPF and then obtained by the SMF via N4 capability negotiation during N4 Association setup procedure
- For DL data transmission, UPF sends the DL packets on N3 GTP-U tunnel
  - Redundant functionality in the UPF duplicates the DL data on the transport layer
  - Redundant functionality in the NG-RAN eliminates the received duplicated DL data and sends to NG-RAN
- For UL data transmission, NG-RAN sends the received UL packets on N3 GTP-U tunnel
  - Redundant functionality in the NG-RAN performs the redundant handling on the backhaul transport layer
  - Redundant functionality in the UPF eliminates the received duplicated UL data and sends to UPF

QoS Monitoring to Assist URLLC Service

In this release (V16.5), the QoS Monitoring is applied for packet delay measurement

- The packet delay between UE and PSA UPF is a combination of
  - the RAN part of UL/DL packet delay and
    - The NG-RAN is required to provide the QoS Monitoring on the RAN part of UL/DL packet delay measurement
  - UL/DL packet delay between NG-RAN and PSA UPF
    - The QoS Monitoring on UL/DL packet delay between NG-RAN and PSA UPF can be performed on different levels of granularities
      - i.e. per QoS Flow per UE level, or per GTP-U path level
      - Subject to the operators' configuration, and/or 3rd party application request, and/or PCF policy control for the URLLC services
- The PCF generates the authorized QoS Monitoring policy for a service data flow based on the QoS Monitoring request if received from the AF
  - The PCF includes the authorized QoS Monitoring policy in the PCC rule and provides it to the SMF

Per QoS Flow Per UE QoS Monitoring

- SMF may activate the end to end UL/DL packet delay measurement between UE and PSA UPF for a QoS Flow during the PDU Session Establishment or Modification procedure
  - The SMF sends a QoS Monitoring request to the PSA UPF via N4 and NG-RAN via N2 signalling to request the QoS monitoring between PSA UPF and NG-RAN
  - The QoS Monitoring request may contain monitoring parameters determined by SMF based on the authorized QoS Monitoring policy received from the PCF and/or local configuration
- The NG-RAN initiates the RAN part of UL/DL packet delay measurement based on the QoS Monitoring request from SMF
  - NG-RAN reports the RAN part of UL/DL packet delay result to the PSA UPF in the UL data packet or dummy UL packet.

Time Synchronization Issues

- If the NG-RAN and PSA UPF are time synchronized
  - The one way packet delay monitoring between NG-RAN and PSA UPF is supported
- If the NG-RAN and PSA UPF are not time synchronized
  - It is assumed that the UL packet delay and the DL packet delay between NG-RAN and PSA UPF is the same

For both time synchronised and not time synchronised between NG-RAN and PSA UPF, the PSA UPF creates and sends the monitoring packets to the RAN

Sending Monitoring Packets by PSA UPF

1. The PSA UPF encapsulates in the GTP-U header with
   - QFI
   - QoS Monitoring Packet (QMP) indicator (which indicates the packet is used for UL/DL packet delay measurement) and
   - the local time T1 when the PSA UPF sends out the DL monitoring packets
2. The NG-RAN records
   - the local time T1 received in the GTP-U header and
   - the local time T2 at the reception of the DL monitoring packets

   The NG-RAN initiates RAN part of UL/DL packet delay measurement
3. When receiving an UL packet from UE for that QFI or when the NG-RAN sends a dummy UL packet as monitoring response (in case there is no UL service packet for UL packet delay monitoring), the NG-RAN encapsulates in the GTP-U header of the monitoring response packet
   - QMP indicator
   - the RAN part of UL/DL packet delay result
   - the time T1 received in the GTP-U header
   - the local time T2 at the reception of the DL monitoring packet and
   - the local time T3

   when NG-RAN sends out this monitoring response packet to the UPF via N3 interface

Receiving Response Packets by PSA UPF

4. The PSA UPF records the local time T4 when receiving the monitoring response packets and calculates the round trip (if not time synchronized) or UL/DL packet delay (if time synchronized) between NG-RAN and anchor PSA UPF based on the time information contained in the GTP-U header of the received monitoring response packet

- The PSA UPF calculates the UL/DL packet delay between the NG-RAN and the PSA UPF based on the (T2-T1+T4-T3)/2
- The PSA UPF calculates the UL/DL packet delay between UE and PSA UPF based on the received RAN part of UL/DL packet delay result and the calculated UL/DL packet delay between RAN and PSA UPF
- The PSA UPF reports the result to the SMF based on some specific condition, e.g. when threshold for reporting to SMF is reached

GTP-U Path Monitoring

- The SMF sends the QoS monitoring policy to each involved UPF and the (R)AN via N4 interface and via N2 interface respectively
  - The SMF can request to activate QoS monitoring for the GTP-U path(s) between all UPF(s) and the (R)AN based on locally configured policies
  - Alternatively, the SMF activates QoS Monitoring for all UPFs currently in use for this PDU Session and the (R)AN
    - When a QoS monitoring policy is received in a PCC rule and the QoS monitoring is not yet active for the DSCP corresponding to the 5QI in the PCC rule
- A GTP-U sender performs an estimation of RTT to a GTP-U receiver on a GTP-U path by sending Echo messages and measuring time that elapses between the transmission of Request message and the reception of Response message
  - A GTP-U sender computes an accumulated packet delay
    - by adding RTT/2, the processing time and, if available, an accumulated packet delay from an upstream GTP-U sender (i.e. an immediately preceding GTP-U sender in user plane path)
    - thus the measured accumulated delay represents an estimated elapsed time since a user plane packet entered 3GPP domain

Periodical Monitoring

- It is expected that a GTP-U sender determines RTT periodically in order to detect changes in transport delays
- QoS monitoring is performed by a GTP-U end-point (UP function) that receive and store QoS including a packet delay budget parameter for QoS flow by comparing a received accumulated packet delay with the stored QoS parameter possibly also taking into the account the measured delay of GTP-U path to next GTP-U end-point processing time
- If the GTP-U end-point determines that the packet delay exceeds the requested packet delay budget then the node triggers QoS monitoring alert signalling to a control plane network function, e.g. SMF or to an OA&M function
- Echo Request message and Echo Response message are sent outside GTP-U tunnels (the messages are using TEID set to 0)
  - If underlying transport is using QoS differentiation (e.g. IP DiffServ) then it is up to the implementation to ensure that the Echo messages are classified correctly and receive similar treatment by the underlaying transport as GTP-U GTP-PDUs carrying QoS flows (user data)

QoS Monitoring and Flow-Mapping

- Delay measurement by using GTP-U Echo Request/Response
  - RAN measures the RAN part of UL/DL packet delay and calculates UL packet delay of N3 interface. RAN provides UL packet delay of RAN part and N3 interface towards SMF (via N2)
  - The PSA UPF calculates the UL/DL packet delay of N3/N9 interface (N9 is applicable when I-UPF exists)
  - UPF and RAN reports QoS Monitoring result to the SMF based on some specific conditions, e.g. first time, periodic, event triggered, when thresholds for reporting towards SMF (via N4) are reached
- UPF does measurement of network hop delay per transport resources that it will use towards a peer network node identified by an IP destination address (the hop between these two nodes) and port
  - The network hop measured delay is computed by sending an Echo Request over such transport resource (Ti) and measuring RTT/2 when Echo Response is received.
  - UPF maps {network instance, Differentiated Services Code Point(DSCP)} into Transport Resource and measures delay per IP destination address and port. Thus, for each IP destination address, the measured delay per (network instance, DSCP) entry is determined.
  - The UPF performing the QoS monitoring can provide the corresponding {Network instance, DSCP} along with the measured packet delay for corresponding transport path to the SMF
- Based on this, SMF can determine QoS Flow mapping to the appropriate {Network instance, DSCP} considering {5QI, QoS characteristics, ARP} for the given QoS flow

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3GPP 5G Time Sensitive Communication

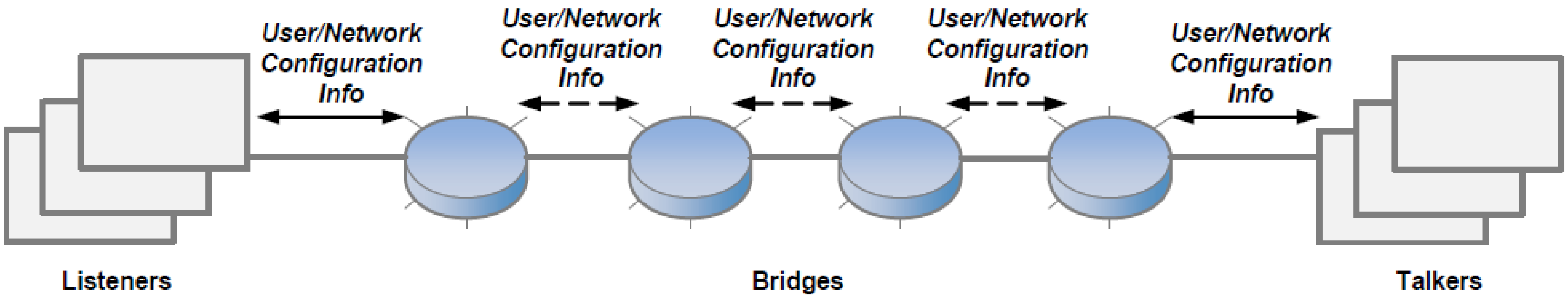
The 5G System is extended to support Time Sensitive Communication as defined in IEEE P802.1Qcc

- Time-Sensitive Networking (TSN) is a collection of features in IEEE 802.1 standards that define mechanisms for the time-sensitive (i.e. deterministic) transmission of data over Ethernet networks
  - Time synchronization among Bridges and end stations
  - Significant reduction in frame loss due to faults in network equipment
  - Significant reduction in, or the elimination of, frame loss due to egress Port congestion
  - Bounded latency
- Three TSN configuration models
  - Fully distributed model
  - Centralized network/distributed user model
  - Fully centralized model

  Only the fully centralized model is supported in this release (V16.5.0 2020-07)

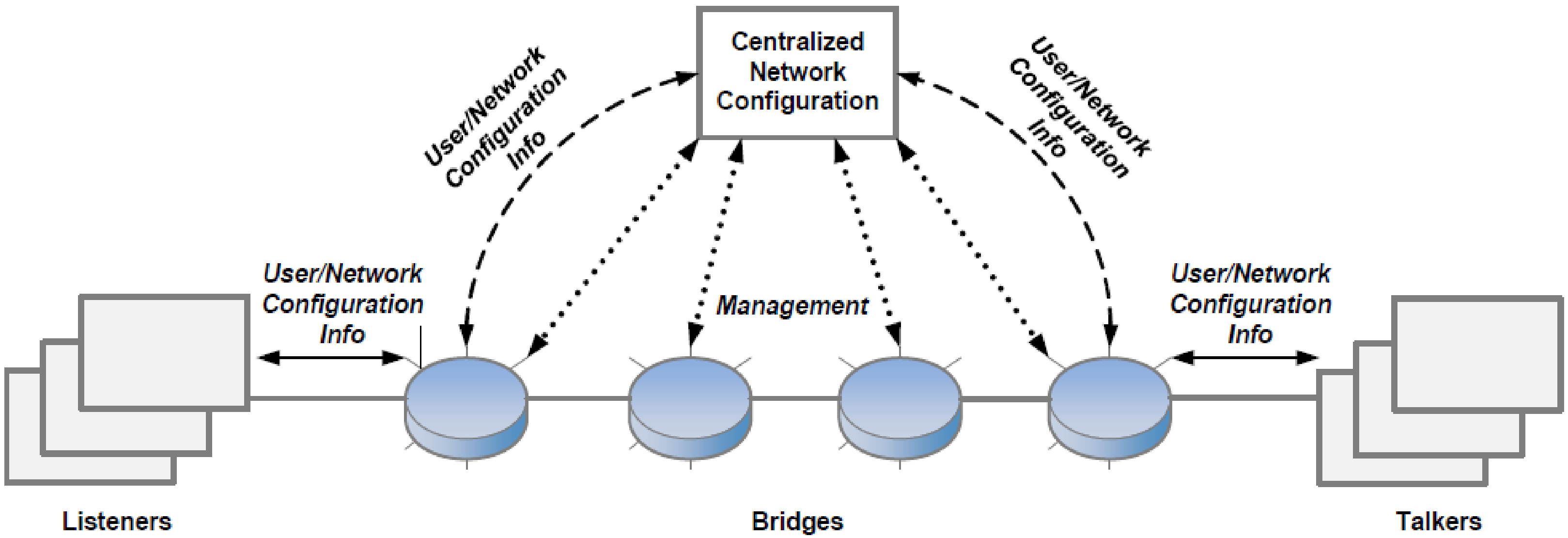
IEEE P802.1Qcc: "Standard for Local and metropolitan area networks - Bridges and Bridged Networks - Amendment: Stream Reservation Protocol (SRP) Enhancements and Performance Improvements“, https://doi.org/10.1109/IEEESTD.2018.8514112

IEEE P802.1Qcc TSN
Fully Distributed Model



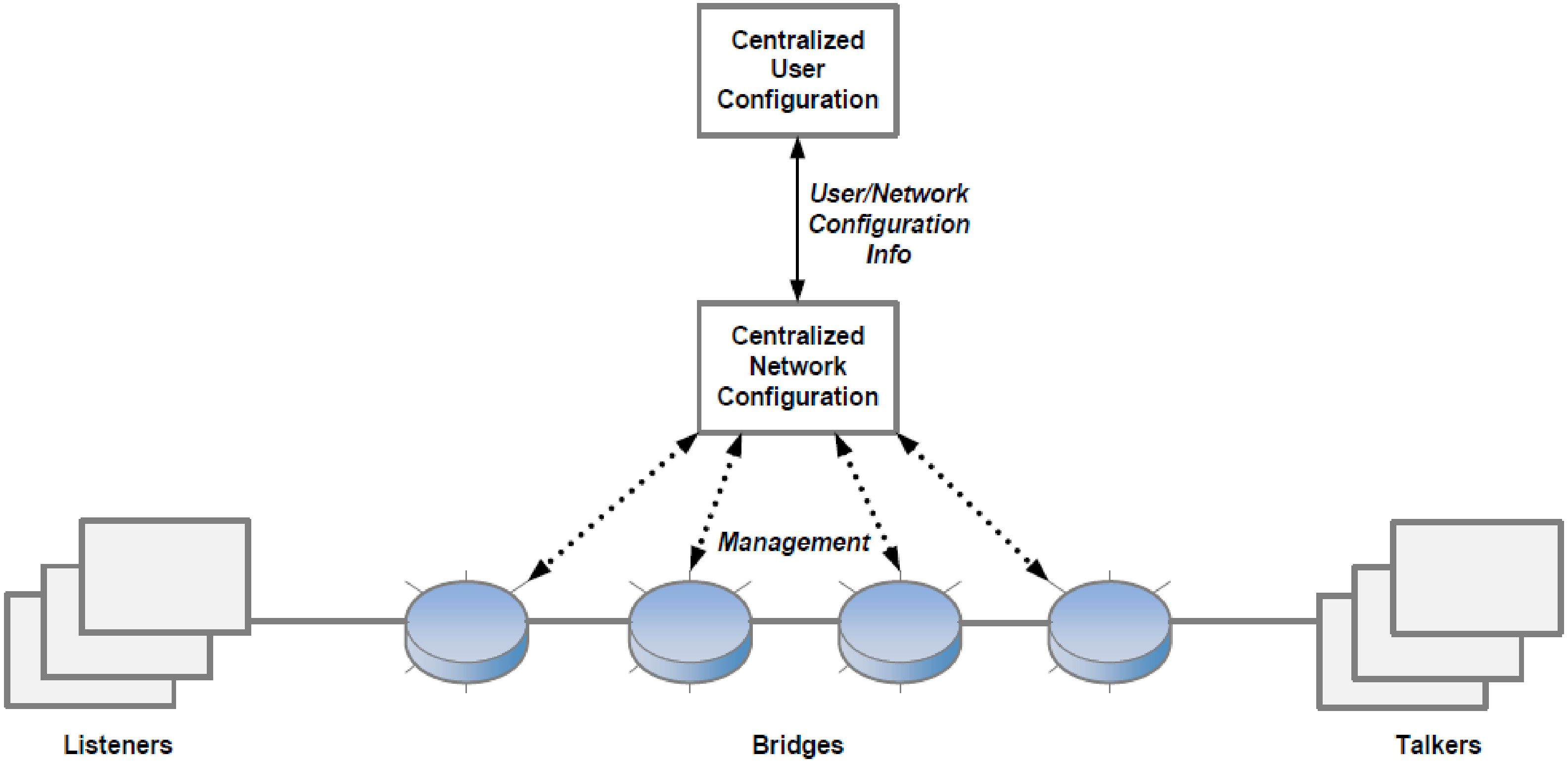
- The end stations that contain users of Streams (i.e., Talkers and Listeners) communicate the user requirements directly over the TSN user/network protocol
- The distributed network configuration is performed using a protocol that propagates TSN user/network configuration information along the active topology for the Stream (i.e., Bridges in the tree from Talker to Listeners)

IEEE P802.1Qcc TSN
Centralized Network/Distributed User Model



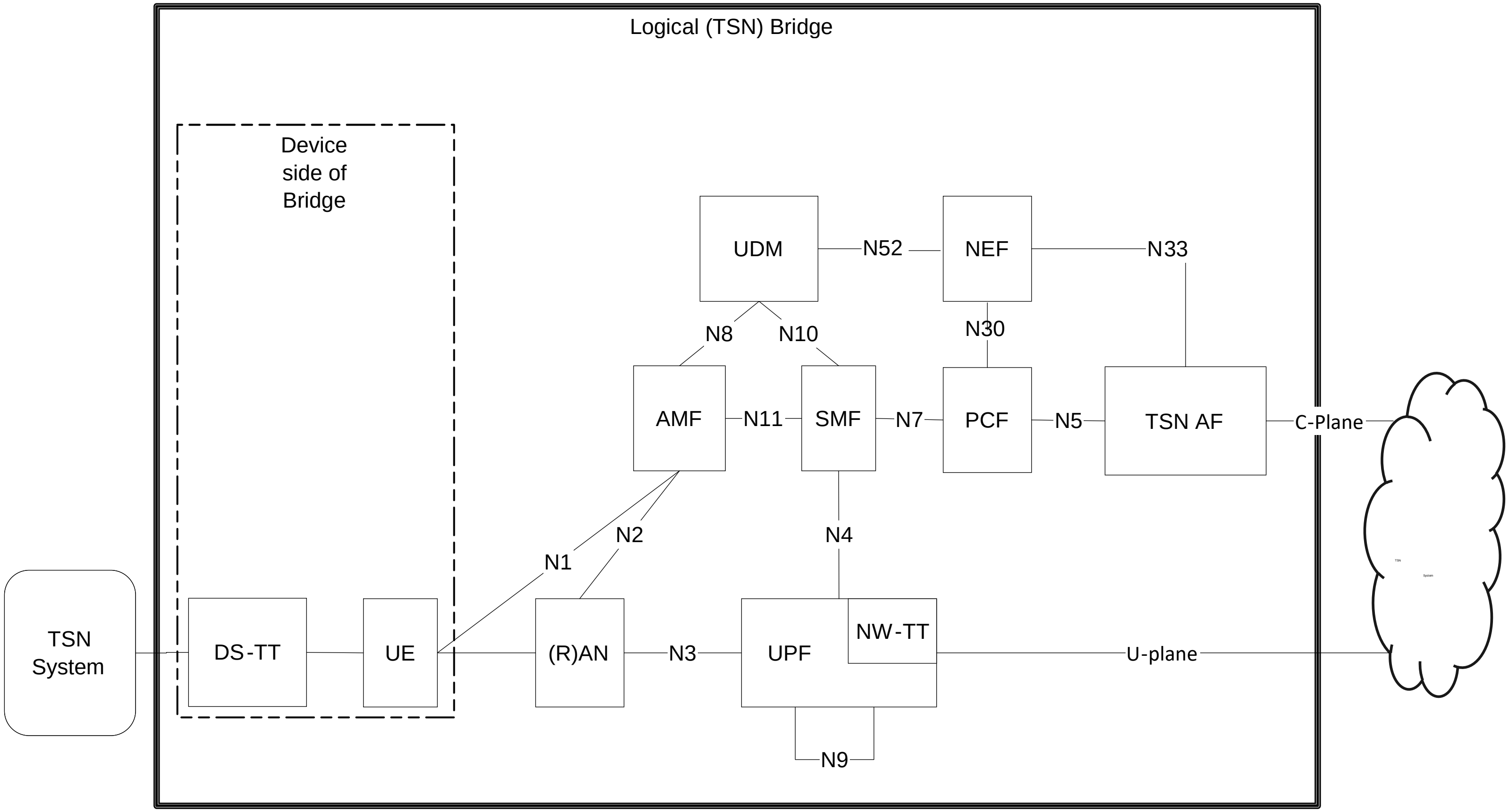
- In the centralized network/distributed user model, the configuration information is directed to/from a Centralized Network Configuration (CNC) entity
- All configuration of Bridges for TSN Streams is performed by this CNC using a remote network management protocol

IEEE P802.1Qcc TSN
Fully Centralized Model



- The fully centralized model enables a Centralized User Configuration (CUC) entity to discover end stations, retrieve end station capabilities and user requirements, and configure TSN features in end stations
- The protocols that the CUC uses for this purpose are specific to the user application and outside the scope of this standard
  - All user requirements are exchanged between the CNC and CUC

5G Architecture to Support Time Sensitive Communication



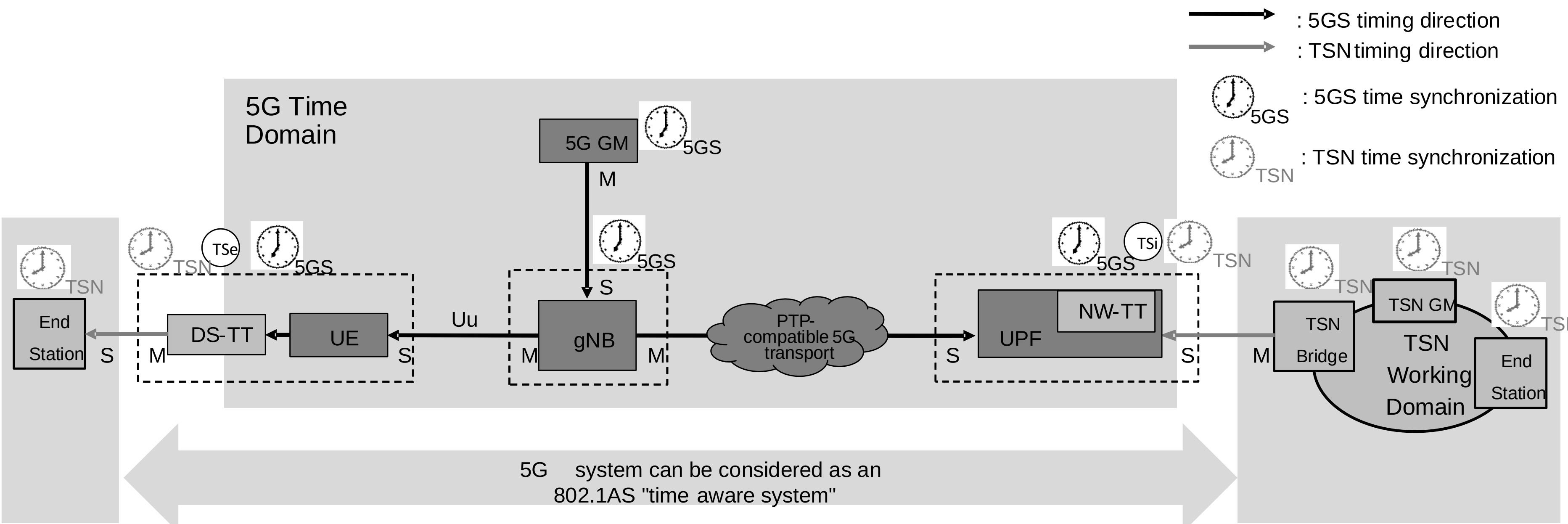
- The 5G System is integrated with the external network as a TSN bridge
- This "logical" TSN bridge includes TSN Translator functionality for interoperation between TSN System and 5G System both for user plane and control plane

Time Sensitive Communications

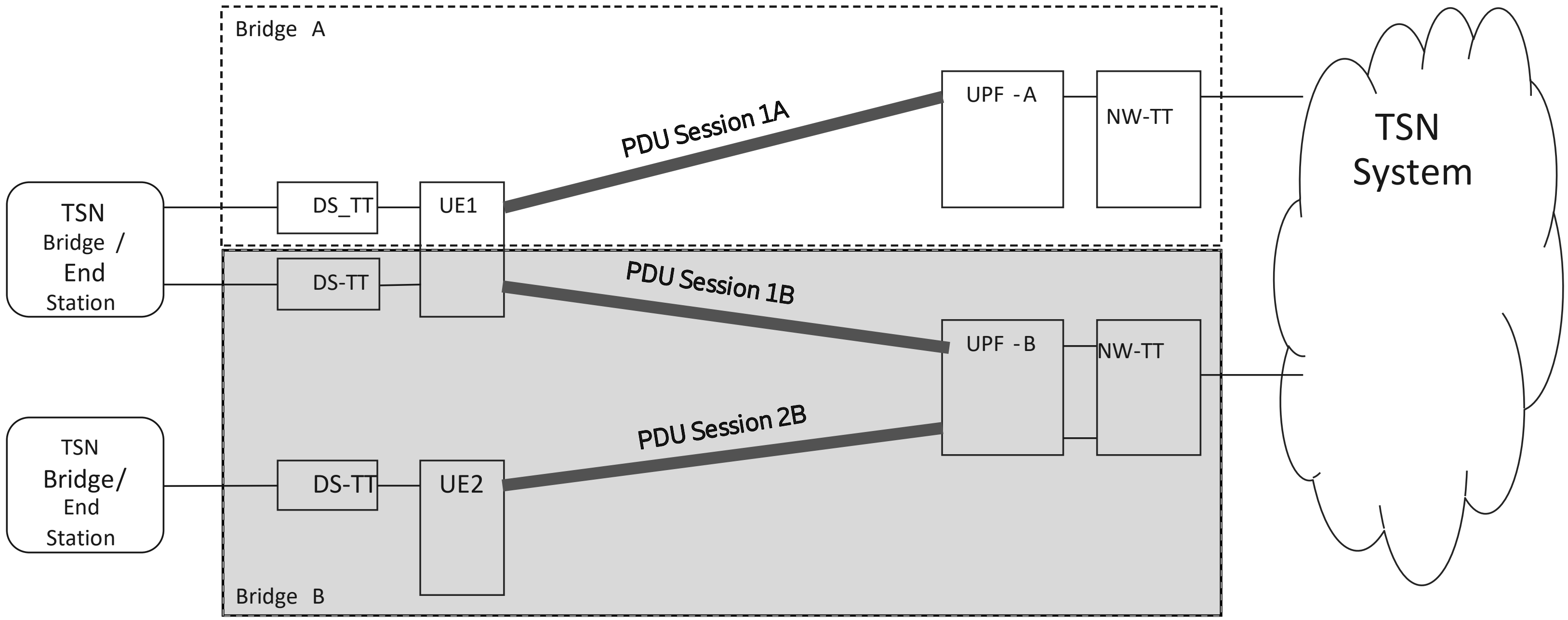
- During the PDU Session establishment
  - The UE shall request to establish a PDU Session as an always-on PDU Session, and
  - The PDU Sessions used for TSC are established as Always-on PDU session
- In this release of the specification
  - Home Routed PDU Sessions are not supported for TSC services
  - TSC PDU Sessions are supported only with PDU Session type Ethernet and SSC mode 1
  - Service continuity for TSC PDU Sessions is not supported when the UE moves from 5GS to EPS

TSN Time Synchronization

- For supporting TSN time synchronization, the 5GS is integrated with the external network as a TSN bridge
- For TSN Synchronization, the entire E2E 5G system can be considered as an IEEE 802.1AS "time-aware system"



Support of Integration with TSN



Per UPF based 5GS bridge

- 5GS supports TSN traffic scheduling over 5GS Bridge with the following functions
  - Configure the bridge information in 5GS.
  - Report the bridge information of 5GS Bridge to TSN network after PDU session establishment.
  - Receiving the configuration from TSN network as defined in clause 5.28.2.
  - Map the configuration information obtained from TSN network into 5GS QoS information (e.g. 5QI, TSC Assistance Information) of a QoS Flow in corresponding PDU Session for efficient time-aware scheduling

Summary

URLLC supports are based on packet duplication and redundancy elimination at different levels

- NR/NG-RAN: Duplication at PDCP for DRB with DC/CA Duplication
- End-to-end Redundant User Plane Paths (5GS)
  - Two redundant PDU Sessions over the 5G network
  - Single PDU session with two redundant tunnels
    - Two N3 Tunnels
    - Two N3+N9 Tunnels
- Redundancy at upper layer protocols
  - IEEE TSN (Time Sensitive Networking) FRER (Frame Replication and Elimination for Reliability)
  - Transport layer