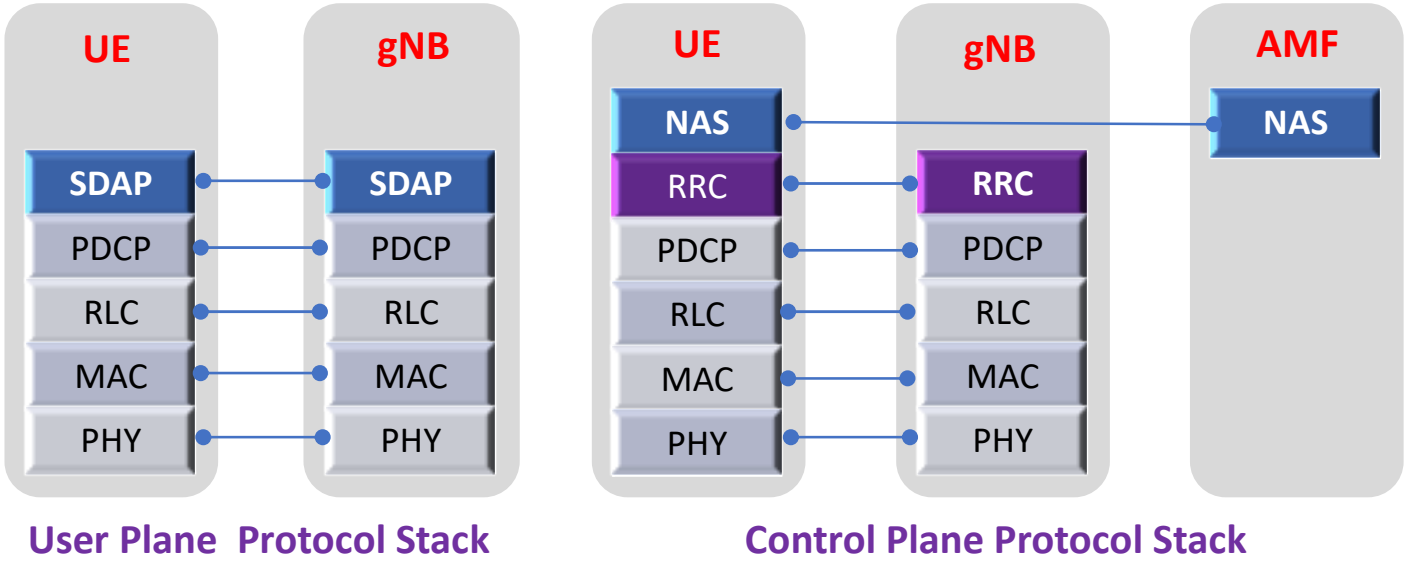
NR Protocol Stack Architecture



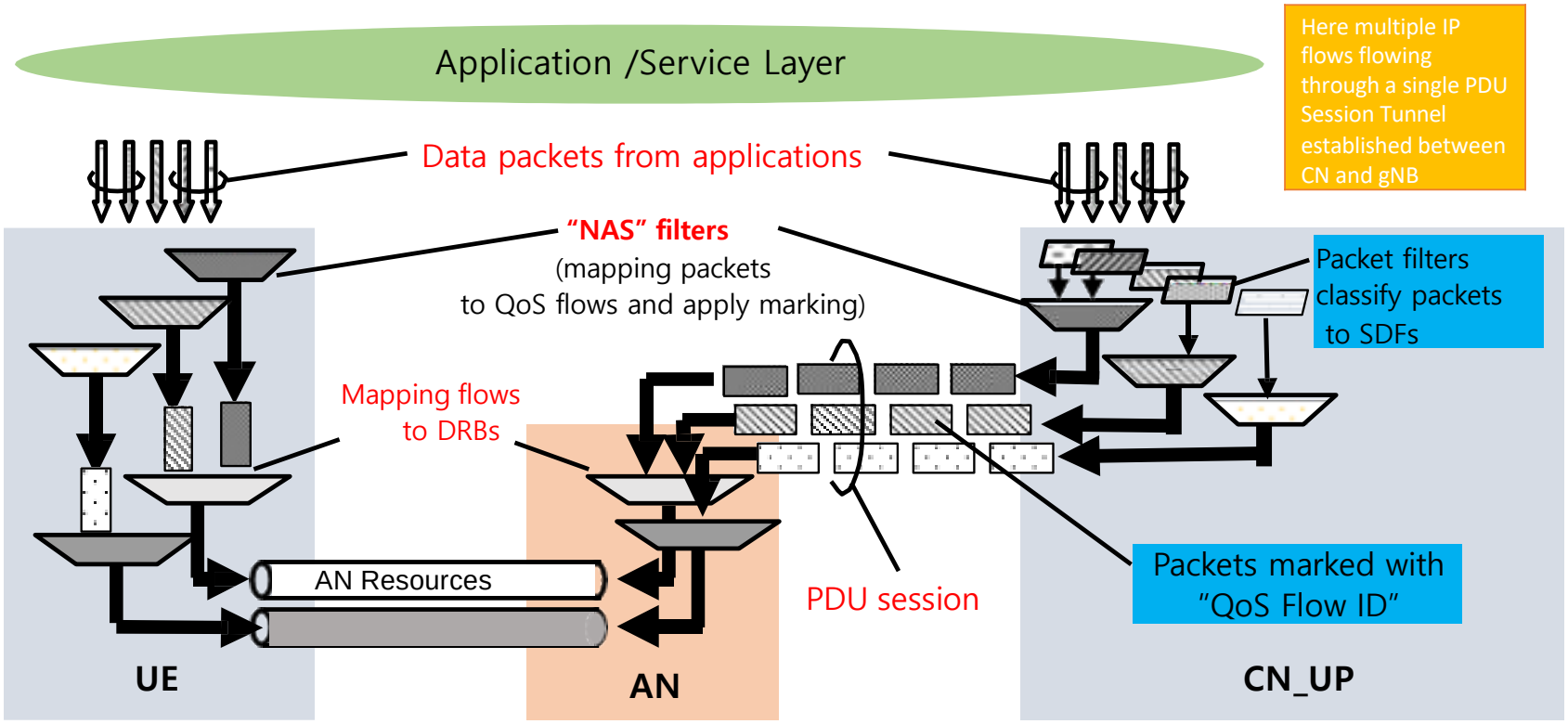
User Plane Protocol Stack **Control Plane Protocol Stack**

- NR PDCP, RLC and MAC are all new protocols but share many similarities with corresponding LTE protocols
- 5G NR protocol stack has been designed to support lower delay and higher data rates and with Quality of service. For this purpose, in 5G NR, a new sublayer is introduced called SDAP. We will describe the functionality and operation of this sublayer.
- in **5G CN QoS** is performed on the basis of IP flow instead of EPS bearers to achieve more flexible and finer QoS control thus the addition of SDAP sublayer. This enables multiple IP flows flowing through a single EPS bearer between the CN and gNB to be individually subjected to radio bearer mapping. The bearer concept is not considered in the 5G CN while 5G NG-RAN will maintain the radio bearer concept.
- In the case of the NR user plane connected to the EPC, the SDAP is not used.
- In case of C-Plane, the two layers RRC and NAS are sitting at the top of the stack. NAS layer gets connected to AMF (Access and Mobility Management Function)

QoS Concept in NR

- In 5G CN QoS is performed on the basis of IP flow instead of EPS bearers to achieve more flexible and finer QoS control thus the addition of SDAP sublayer. This enables multiple IP flows flowing through a single EPS bearer between the CN and gNB to be individually subjected to radio bearer mapping.
- In NR each QoS flow packets are classified and marked using QoS Flow Identifier (QFI). The 5G QoS flows are mapped in the Access Network to DRBs (Data Radio Bearers) unlike in 4G where mapping is one to one between EPC and Radio Bearers.
- 5G-RAN and 5G-Core ensure quality of service (e.g. reliability and target delay) by mapping packets to appropriate QoS Flows and DRBs. Hence there is a 2-step mapping of IP-flows to QoS flows (NAS) and from QoS flows to DRBs (Access Stratum).
- Core network establishes one or more PDU sessions for each UE based on his traffic subscription.
- RAN establishes at least one radio bearer for each session. Additional bearers – configured for QoS flows of that session
- More than one flow can be mapped onto the same radio bearer in 5G NR. In LTE, one-to-one mapping between EPC and radio bearers.
- 5G NR RAN maps packets belonging to different PDU sessions to different bearers.
- QFI for each flow mapped onto 5G QoS identifier, Flow bit- rates, tolerable packet loss rate, etc.
- As with 4G LTE both non-GBR flows and GBR flows are supported in 5G, along with a **new delay-critical GBR.** 5G also introduces a new concept – **Reflective QoS.**
- The 5G QoS flows are mapped in the AN (Access Network) to DRBs (Data Radio Bearers) unlike 4G LTE where mapping is one to one between EPC and radio bearers.

New QoS Framework

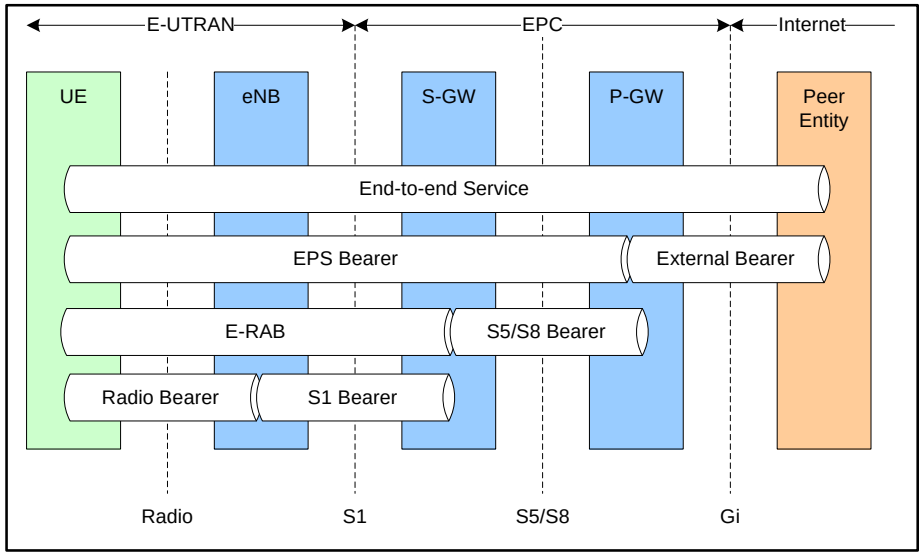


- QoS flow based marking in Core Network instead of EPS bearers to differentiate QoS "streams" in a PDU session
- RAN continue to use DRBs
  - All packets in a DRB will receive same QoS treatment
- Mapping of QoS flow to DRB is left to gNB implementation (new concept)
  - Results in two step mapping:
    - IP to QoS flow in NAS
    - QoS flow to DRB in AS

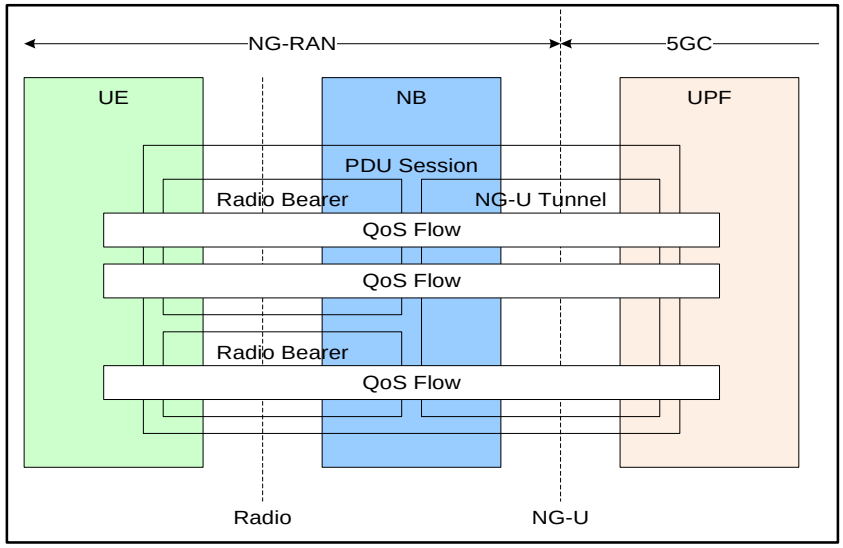
Refer to TS 23.501

LTE vs NR QoS Architecture

LTE QoS Architecture

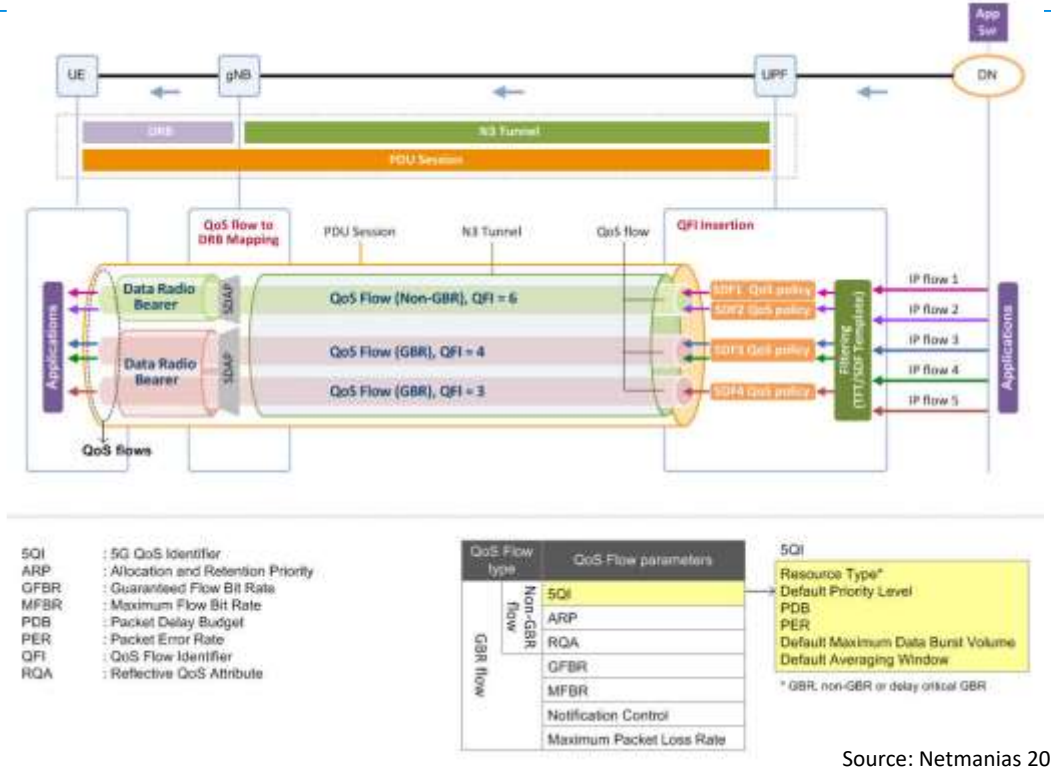


5G QoS Architecture



- In 4G/LTE, QoS is applied at the level of Evolved Packet Service (EPS) bearer. There's a one-to-one mapping, which really means that for an EPS bearer there's a corresponding EPS Radio Access Bearer (RAB), an S1 bearer and a Radio Bearer (RB).
- 5G provides a more flexible QoS model with QoS Flow being the finest granularity at which QoS is applied. The abstraction of QoS flow allows us to decouple the roles of 5G Core and NG-RAN. SMF in the 5G Core configures how packets ought to be mapped to QoS flows.
- AN independently decides how to map QoS flows to radio bearers. This is a flexible design since gNB can choose to map multiple QoS flows to a single RB if such an RB can be configured to fulfil the requirements of those QoS flows. The figure shows an example in which QoS flow 1 goes on DRB1; QoS flows 2 and 3 go on DRB2.
- To summarize, 4G QoS is at the EPS bearer level and 5G QoS is at the QoS flow level.

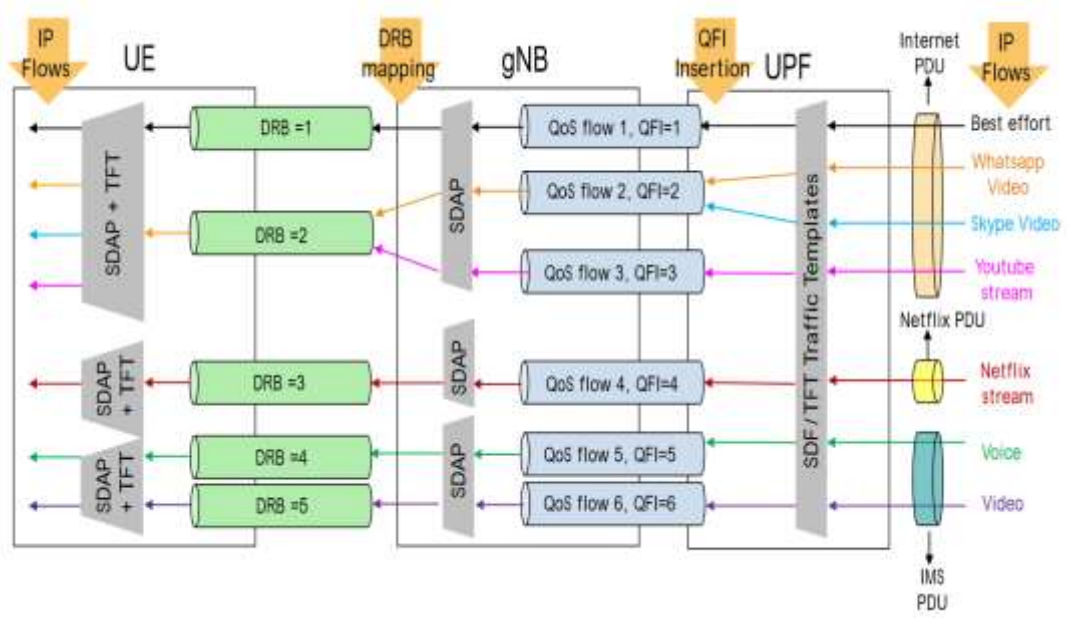
Overview of QoS in 5G System



Source: Netmanias 2019

- 5G Quality of Service (QoS) model is based on QoS Flows. Each QoS flow has a unique identifier called QoS Flow Identifier (QFI). There are two types of flows: Guaranteed Bit Rate (GBR) QoS Flows and Non-GBR QoS Flows. The QoS Flow is the finest granularity of QoS differentiation in the PDU Session. User Plane (UP) traffic with the same QFI receive the same forwarding treatment.
- At the Non-Access Stratum (NAS), packet filters in UE and 5GC map UL and DL packets respectively to QoS flows. At the Access Stratum (AS), rules in UE and Access Network (AN) map QoS flows to Data Radio Bearers (DRBs).
- Every QoS flow has a QoS profile that includes QoS parameters and QoS characteristics. Applicable parameters depend on GBR or non-GBR flow type. QoS characteristics are standardized or dynamically configured.

5G QoS Flow to DRB Mapping



Source: Rodini 2017

- Consider multiple PDU sessions, each of which could be generating packets of different QoS requirements. For example, packets from the Internet may be due to user browsing a website, streaming a video or downloading a large file from an FTP server. Delay and jitter are important for video but less important for FTP download.
- Between the User Equipment (UE) and the Data Network (DN), PDU sessions and Service Data Flows (SDFs) are set up. Each application gets its own SDF. In our example, we may say that Internet, Netflix and IMS are PDU sessions. The Internet PDU session has four SDFs and the IMS PDU session has two SDFs.
- Multiple IP flows can be mapped to the same QoS flow. QoS flow 2 is an example that carries both WhatsApp video and Skype video. On the radio interface, QoS flows are mapped to data radio bearers (DRBs) that are configured to deliver that QoS. Multiple QoS flows can be mapped to a single DRB. DRB2 is an example and it carries QoS flows 2 and 3.

QoS Parameter

- **5G QoS Identifier (5QI):** An identifier for QoS characteristics that influence scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.
- **Allocation and Retention Priority (ARP):** Information about priority level, pre-emption capability (can pre-empt resources assigned to other QoS flows) and the pre-emption vulnerability (can be pre-empted by other QoS flows).
- **Reflective QoS Attribute (RQA):** Optional parameter. Certain traffic on this flow may use reflective QoS.
- **Guaranteed Flow Bit Rate (GFBR):** Measured over the Averaging Time Window. Recommended to be the lowest bitrate at which the service will survive.
- **Maximum Flow Bit Rate (MFBR):** Limits bitrate to the highest expected by this QoS flow.
- **Aggregate Maximum Bit Rate (AMBR):** Session-AMBR is per PDU session across all its QoS flows. UE-AMBR is for each UE.
- **QoS Notification Control (QNC):** Configures NG-RAN to notify SMF if GFBR can't be met. Useful if application can adapt to changing conditions. If alternative QoS profiles are configured, NG-RAN indicates if one of these matches currently fulfilled performance metrics.
- **Maximum Packet Loss Rate**: In Release 16, this is limited to voice media.

5G QoS Flow Table

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume (NOTE 2)	Default Averaging Window	Example Services
1	GBR (NOTE 1)	20	100 ms	10-2	N/A	2000 ms	Conversational Voice
2		40	150 ms	10-3	N/A	2000 ms	Conversational Video (Live Streaming)
3		30	50 ms	10-3	N/A	2000 ms	Real Time Gaming, V2X messages Electricity distribution – medium voltage Process automation -monitoring
4		50	300 ms	10-6	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
65		7	75 ms	10-2	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66		20	100 ms	10-2	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67		15	100 ms	10-3	N/A	2000 ms	Mission Critical Video user plane
75		25	50 ms	10-2	N/A	2000 ms	V2X messages

5G QoS Flow Table

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume (NOTE 2)	Default Averaging Window	Example Services
5	Non-GBR	10	100 ms	10-6	N/A	N/A	IMS Signalling
6		60	300 ms	10-6	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp,p2p file sharing, progressive video, etc.)
7		70	100 ms	10-3	N/A	N/A	Voice, Video (Live Streaming) Interactive Gaming
8		80	300 ms	10-6	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp,p2p file sharing, progressive video, etc.)
9		90					

5G QoS Flow Table

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
69	Non-GBR	5	60 ms	10-6	N/A	N/A	Mission Critical delay sensitive signalling(e.g., MC-PTT signalling)
		5	60 ms	10-6	N/A	N/A	Mission Critical delay sensitive signalling(e.g., MC-PTT signalling)
70		55	200 ms	10-6	N/A	N/A	Mission Critical Data (e.g. example services are the same as QCI 6/8/9)
79		65	50 ms	10-2	N/A	N/A	V2X messages
80		68	10 ms	10-6	N/A	N/A	Low Latency eMBB applications, Augmented Reality
82	Delay Critical GBR	19	10 ms (NOTE 4)	10-4	255 bytes	2000 ms	Discrete Automation (see TS 22.261 [2])
83		22	10 ms (NOTE 4)	10-4	1358 bytes (NOTE 3)	2000 ms	Discrete Automation (see TS 22.261 [2])
84		24	30 ms (NOTE 6)	10-5	1354 bytes	2000 ms	Intelligent transport systems (seeTS 22.261 [2])
85		21	5 ms (NOTE 5)	10-5	255 bytes	2000 ms	Electricity Distribution-high voltage (seeTS 22.261 [2])