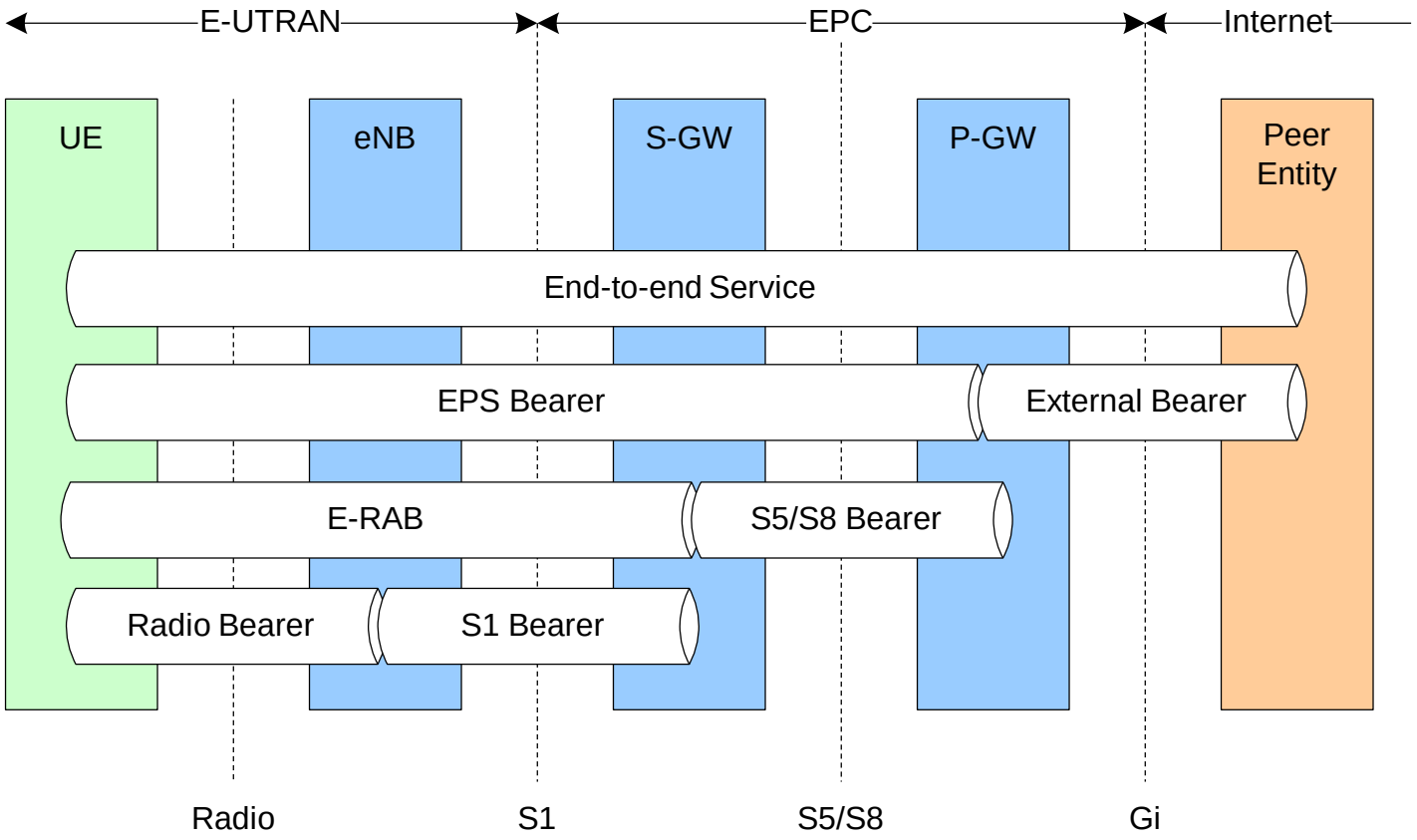
LTE QoS

Agenda

- LTE Bearer Architecture
- LTE QoS Profiles
- LTE QoS Functional Architecture

LTE Bearer Architecture

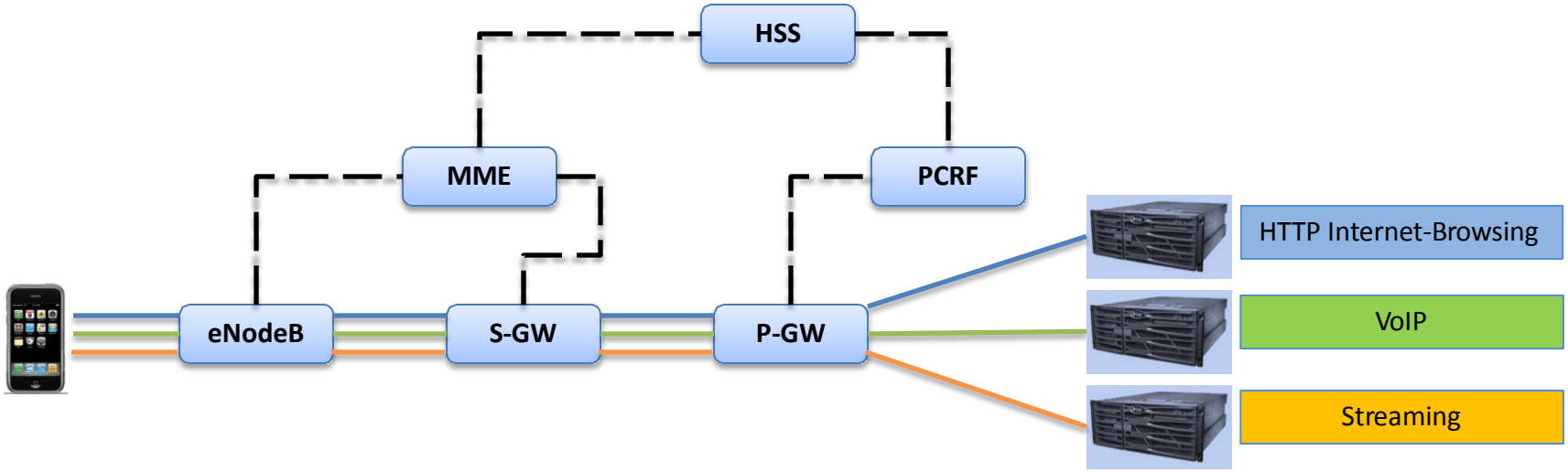


LTE Bearer Architecture *Source: 3GPP TS 36.300*

Bearer Establishment

- **MME**: typically during the attach procedure of an UE (creating a default bearer).
- **P-GW**: from the data network via the PCRF to the P-GW (referred as dedicated bearers)
- **UE**: contrary to 3G, UEs cannot create bearers, but only request/ask for one (network-initiated)

QoS-aware Bearers



A UE can have several concurrent LTE bearers each with different QoS settings (priority, latency, packet loss)

LTE Standardized QCI Profiles

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	GBR	2	100 ms	10^{-2}	Conversational Voice
2		4	150 ms	10^{-3}	Conversational Video (Live Streaming)
3		3	50 ms	10^{-3}	Real Time Gaming
4		5	300 ms	10^{-6}	Non-Conversational Video (Buffered Streaming)
5	Non-GBR	1	100 ms	10^{-6}	IMS Signalling
6		6	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc).
7		7	100 ms	10^{-3}	Voice, Video (Live Streaming) Interactive Gaming
8		8	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp,
9		9		10^{-6}	p2p file sharing, progressive video, etc).

Standardized QCI Characteristics *Source TS 23.203*

QoS in LTE

Parameter	Description QoS Class
Identifier (QCI)	Scalar which indicates a specific priority, maximum delay and packet error rate – all of which are preconfigured in the network node. The index also indicates whether the bearer has a Guaranteed Bit Rate (GBR) or not (non-GBR). The actual bit rate is signaled separately.
Allocation and Retention Policy (ARP)	Used in prioritization and preemption decisions with respect to bearers.
Guaranteed Bit Rate (GBR)	Bit rate that can be expected to be provided by a bearer. Not applicable for non-GBR bearers.
Maximum Bit Rate (MBR)	In 3GPP Release 8, MBR = GBR.

EPS Bearer QoS Profile

Parameter	Description
APN-AMBR	Aggregate maximum bit rate across all Non-GBR bearers and across all PDN connections of the same APN. Enforced by P-GW for downlink.
UE-AMBR	Aggregate maximum bit rate across all Non-GBR bearers of a UE. Enforced by eNodeB for both uplink and downlink.

Aggregate EPS Bearer QoS Parameters

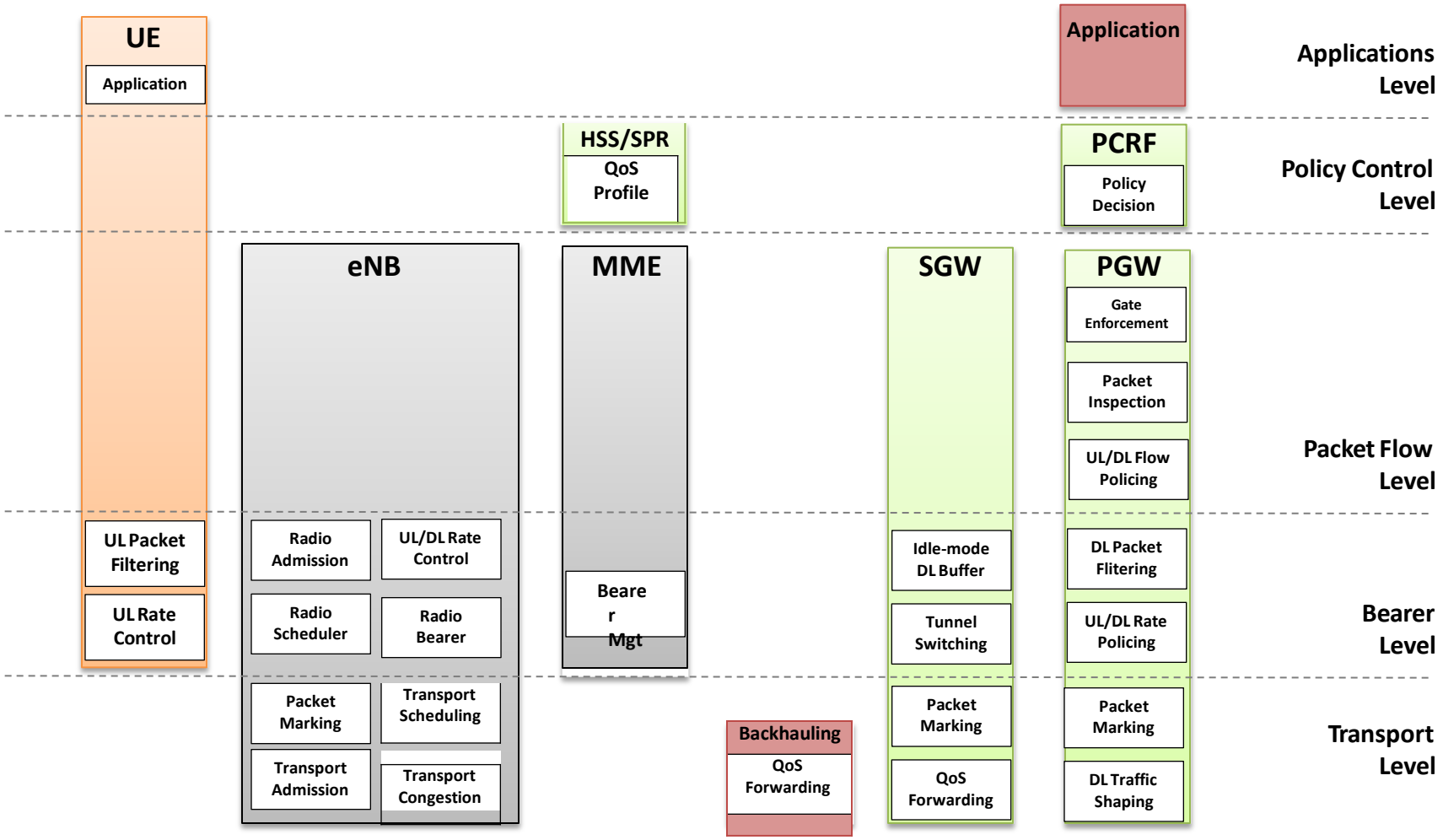
Allocation & Retention Policy (ARP)

- In addition to the QCI, each bearer is assigned an ARP containing 3 parameters used in the admission control procedures:
  - The priority level: defines the relative importance of the bearer request.
  - The pre-emption capability: defines whether the incoming bearer request can pre-empt resources that are already assigned to an established bearer with a lower priority level.
  - The pre-emption vulnerability: defines whether the bearer resources (once allocated) can be pre-empted to serve another incoming bearer request with a higher priority level.
- ARP is stored in the Subscriber profile (HSS) typically on a per APN basis
- At every Radio Bearer (RB) setup request (including HO and RRC connection re--- establishment), the eNB Radio Admission Control (RAC) entity will check the current eNB hard limit capacities, which includes factors such as: maximum number of UEs and RBs, number of RBs on GBR
- ARP controls how the eNodeB reacts when there are insufficient resources to establish the new RB
  - Deny the RB request
  - Preempt an existing RB and accept the new RB request

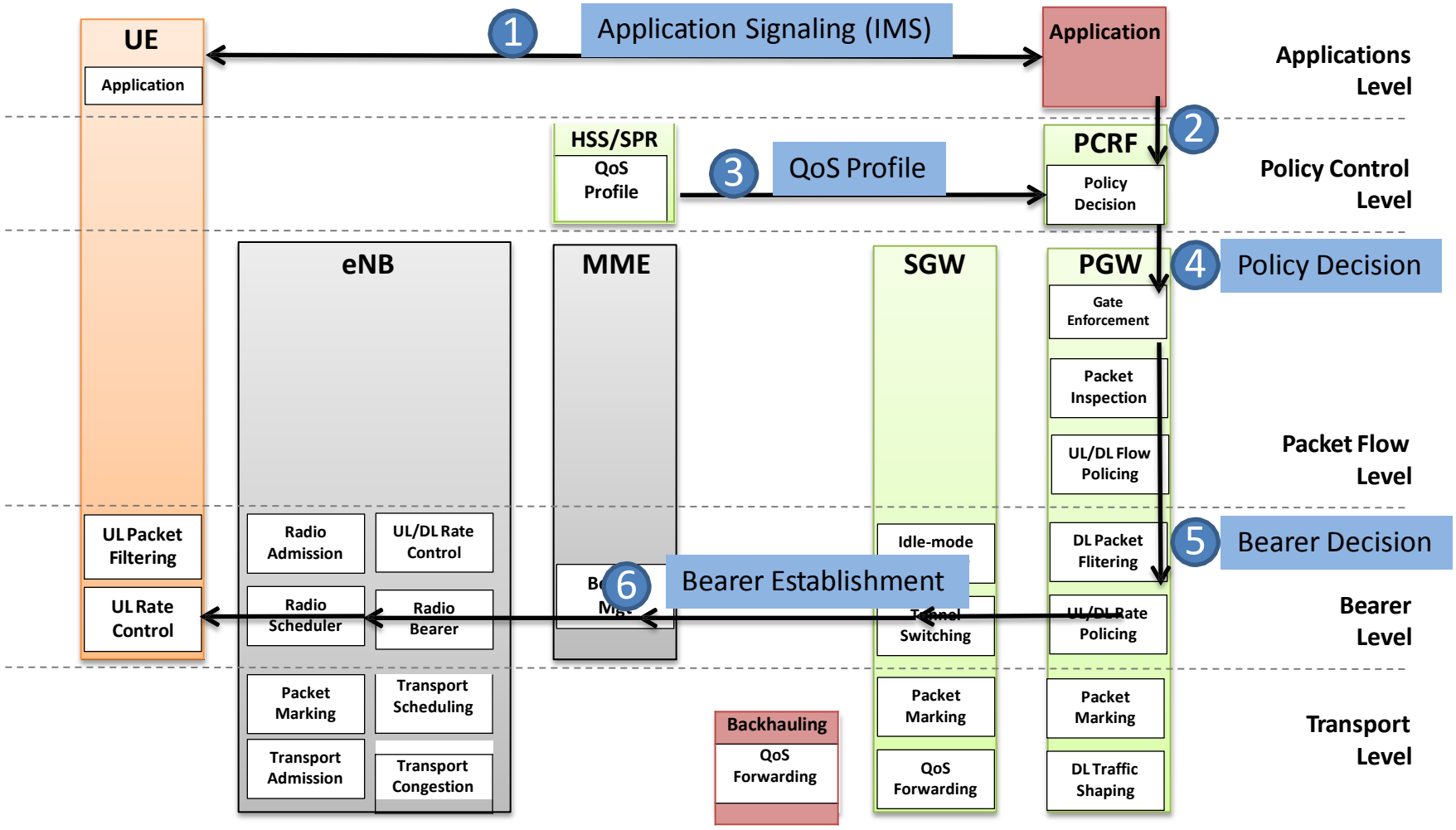
ARP Mapping

Priority	Non-GBR Bearer		GBR Bearer	
	Can pre-empt	Vulnerable	Can pre-empt	Vulnerable
1	Yes	No	Yes	No
2	Yes	No	Yes	No
3	Yes	No	Yes	No
4	Yes	No	Yes	No
5	Yes	No	Yes	No
6	No	Yes	Yes	No
7	No	Yes	Yes	No
8	No	Yes	Yes	No
9	No	Yes	Yes	No
10	No	Yes	No	Yes
11	No	Yes	No	Yes
12	No	Yes	No	Yes
13	No	Yes	No	Yes
14	No	Yes	No	Yes
15	No	Yes	No	Yes

LTE QoS Functional Architecture



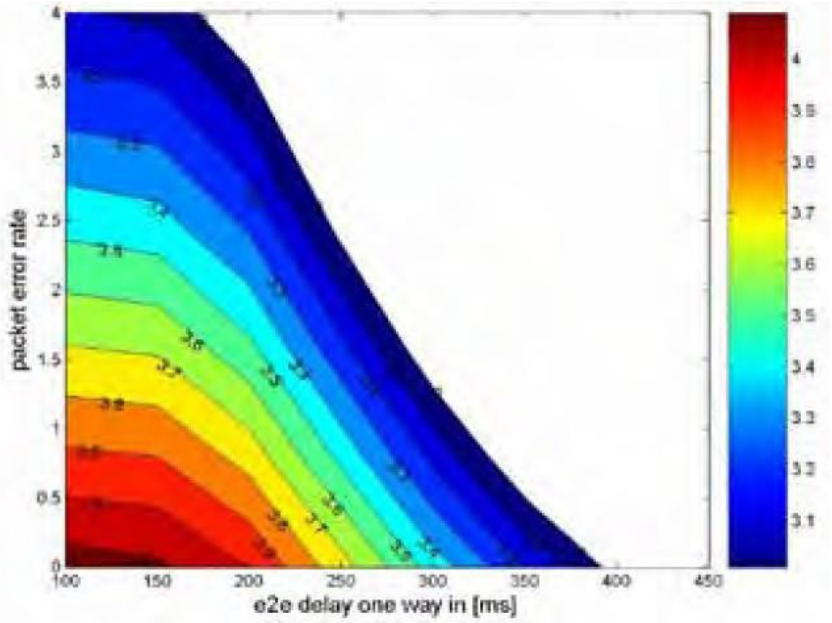
QoS Use Case : VoLTE



QoS for VoIP

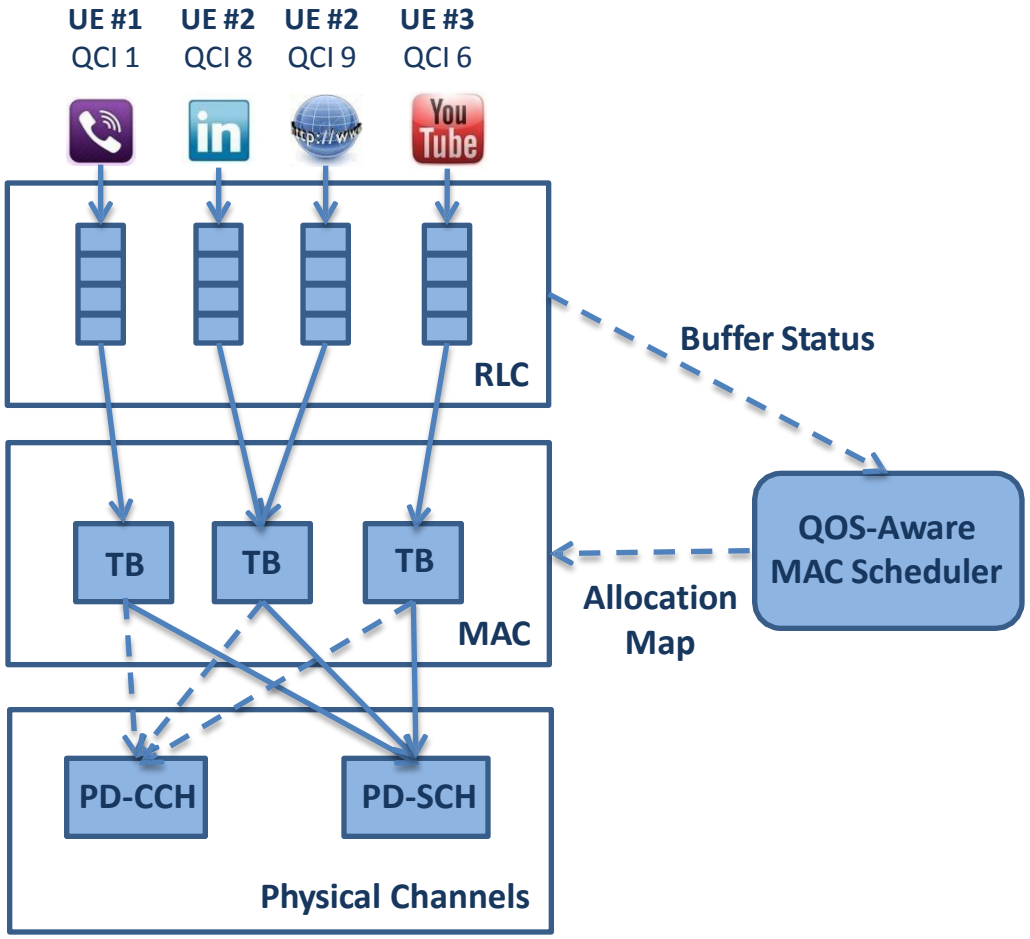
MOS	Quality	Impairment
5	Excellent	Imperceptible
4	Good / Toll Quality	Perceptible but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

Mean Opinion Score (MOS) Definitions



MOS for NB-AMR vs latency & packet loss

LTE MAC Scheduler & Radio Bearer QoS



QoS-Aware Scheduling

1. Schedule the prioritised GBR traffic.
2. Schedule the prioritised non-GBR traffic, using the chosen fairness criteria.
3. Schedule the remaining non-GBR traffic.
4. Schedule the excess GBR traffic.

FAIRNESS CRITERIA

- **Max-Min Fair**. Aims to maximise the minimum rate for all bearers (e.g.round-robin algorithm).
- **Proportionally Fair**. Aims to maximise the overall rate for all bearers favouring UEs with better channel conditions which are able to transfer data with a higher spectral efficiency, while still ensuring that UEs with poor channel conditions, e.g. at the cell edge, still get some service.(e.g. WFQ algorithm).
- **Max Throughput**. Aims to maximise the overall rate for all bearers. This approach is skewed completely towards the most spectrally efficient UEs.(e.g.strict priority algorithm).

Scheduling algorithms are not standardised

Transport QoS

- The use of Diffserv CodePoint (DSCP) is a means of prioritizing IP transport
- **EF**: the Expedited Forwarding DSCP class (RFC3246) provides transport prioritization that optimizes for low delay, loss and jitter = DSCP 46
- **AFxy**: Assured Forwarding (RFC 2597) where x = IP precedence value (1 to 4) and y drop precedence value (1 to 3) with the higher value denoting higher likelihood of dropping = DSCP 10/12/14, 18/20/22, 26/28/30, 34/36/38
- **CSx**: Class Selector (RFC2474) where x corresponds to the IP precedence value (1 to 7) = DSCP 8,16,32,40,48,56
- **BE**: Best Effort of Default Marking value (RFC2474) = DSCP 0
- Mapping of the QCI to the DSCP is not specified in 3GPP standards, thus is operator configurable

Transport QoS - Example

QCI	Resource Type	Scheduler Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services	DSCP Mapping	L2 p-bit Mapping
1	GBR	2	100 ms	10-2	Conversational Voice	EF	6
2		4	150 ms	10-3	Conversational Video (Live Streaming)	EF	6
3		3	50 ms	10-3	Real Time Gaming	EF	6
4		5	300 ms	10-6	Non-Conversational Video (Buffered Streaming)	AF42	5
5	Non-GBR	1	100 ms	10-6	IMS Signalling	AF41	5
6		6	300 ms	10-6	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive	AF42	5
7		7	100 ms	10-3	Voice,Video (Live Streaming), Interactive Gaming	AF22	1
8		8	300 ms	10-6	Video (Buffered Streaming)	AF21	1
9		9			TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)	BE	0
					Signalling	AF41	5
					OAM	AF11	1
					Timing	EF	6
					Other	BE	0

Roaming QoS

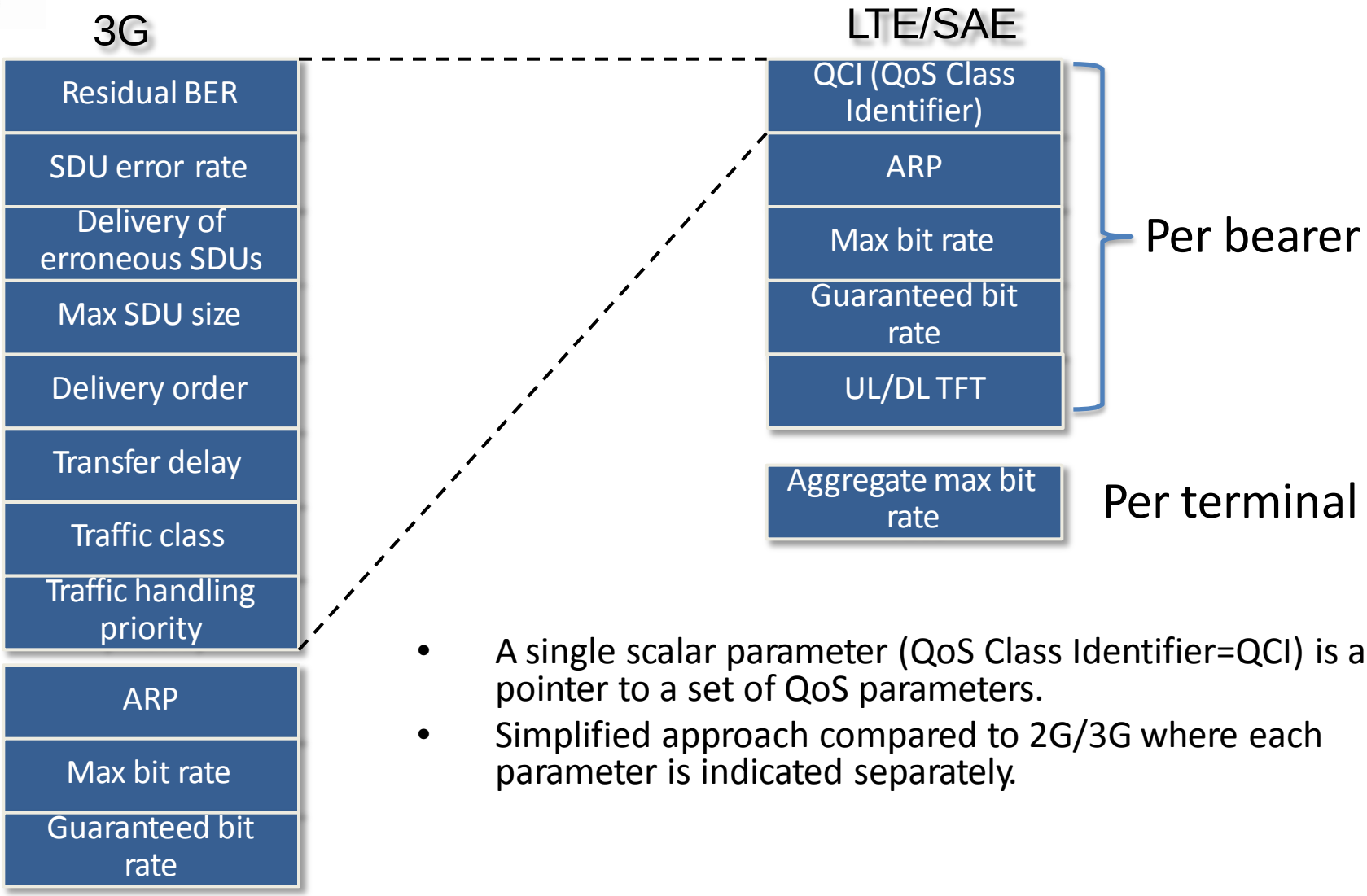
EPS	QoS Information			IP Transport	
QCI	Traffic Class	THP	Signalling Indication	Diffserf PHB	DSCP
1	Conversational	N/A	N/A	EF	101110
2					
3					
4	Streaming	N/A	N/A	AF41	100010
5	Interactive	1	Yes	AF31	011010
6			No	AF32	011100
7		2	No	AF21	010010
8		3	No	AF11	001010
9	Background	N/A	N/A	BE	000000

Source : IR.34 – Guidelines for IPX Provider networks

Bandwith Management

- For non-GBR bearers
  - APN-AMBR: Access Point Name Aggregate Maximum Bit Rate
  - UE-AMBR: User Equipment Aggregate Maximum Bit Rate
- For GBR bearers
  - GBR : guaranteed bit rate
  - MBR : Maximum Bit Rate : absolute maximum amount of bandwidth a GBR bearer can utilize once it has been admitted

3G vs LTE Bearer QoS Attributes



- A single scalar parameter (QoS Class Identifier=QCI) is a pointer to a set of QoS parameters.
- Simplified approach compared to 2G/3G where each parameter is indicated separately.

Applicable Standards

3GPP

- 3GPP TS 36.300 – LTE Overall Description
- 3GPP TS 23.203 – LTE Policy and charging control architecture

GSMA

- IR.34 – Guidelines for IPX Provider networks

RFC

- RFC 2474, Definition of the Differentiated Service Field (DS Field)
- RFC 2475, An Architecture for Differentiated Service
- RFC 2597, Assured Forwarding PHB Group
- RFC 2598, An Expedited Forwarding PHB
- RFC3168, The Addition of Explicit Congestion Notification (ECN) to IP

THANK YOU