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VoLTE Radio Training Part I

- GS NPO Capability Creation

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VoLTE Introduction

- What is VoLTE
- VoLTE Architecture
- VoLTE Bearer Combinations

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Introduction
What is VoLTE?

CS: Circuit Switched
VoLTE: Voice over LTE

- LTE networks are packet- switched. They do not include the traditional 2G/3G voice services (CS).

- VoLTE (Voice over LTE) is the solution to provide the Voice (VoIP) and SMS service capability on LTE networks. Requirements:
  - Real time traffic
  - Quality of Service
  - Interoperability to existing CS voice network

- The world's first commercial VoLTE networks were launched by LGU+ and SK Telecom beginning of August 2012 in South Korea

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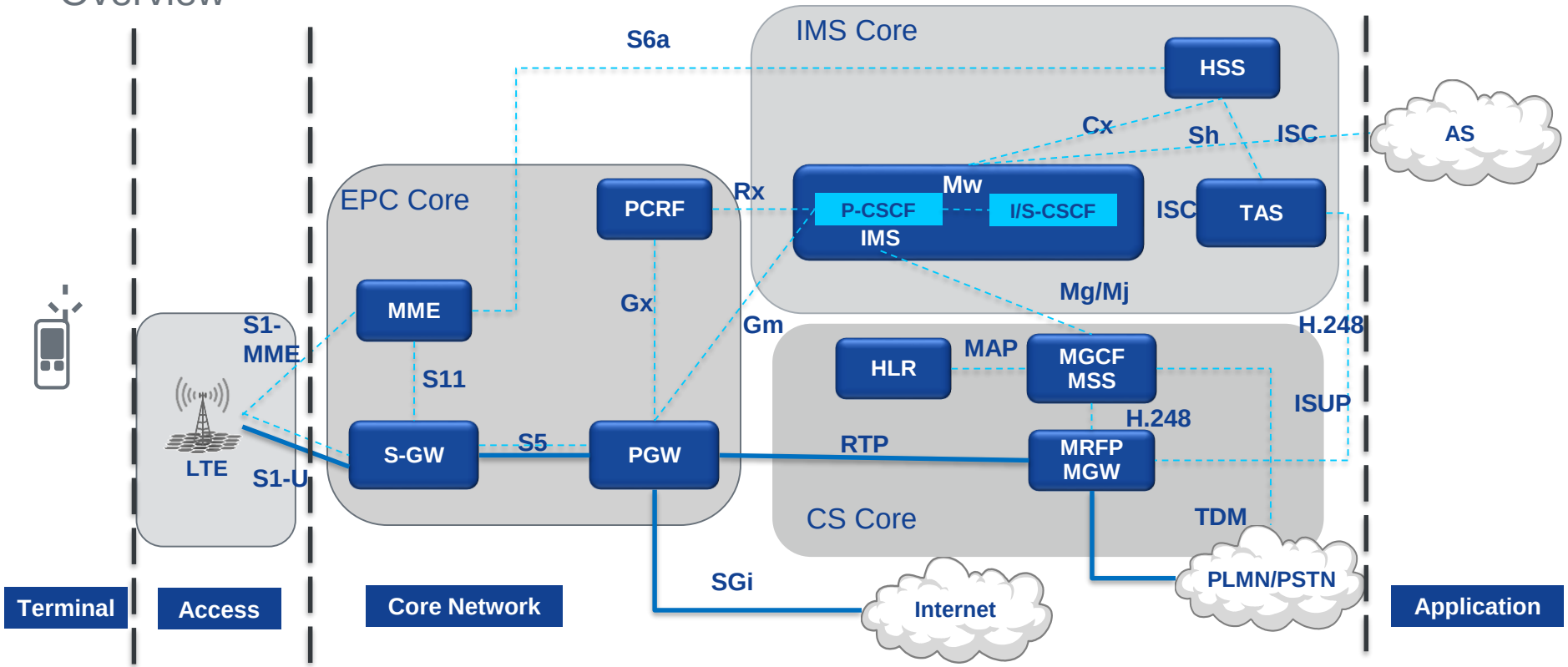
VoLTE Network Architecture

Overview



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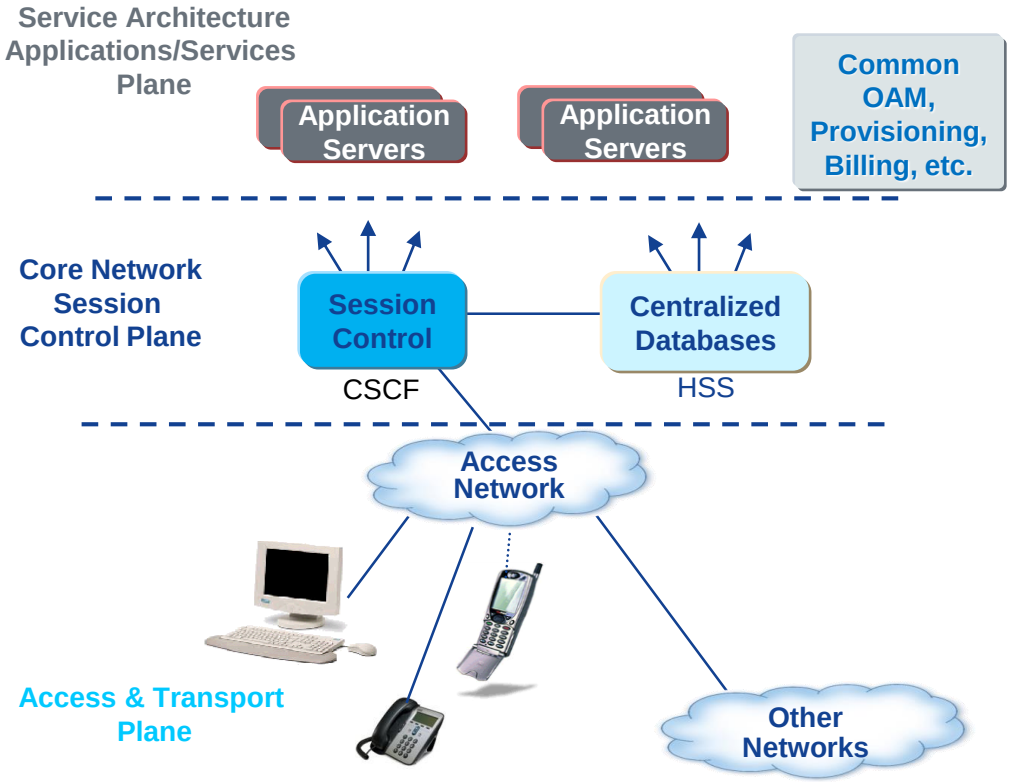
Introduction
VoLTE Architecture

- VoLTE architecture involves all domains (E2E) being the core domain the most relevant. VoIP/VoLTE requires support from IP Multimedia Subsystem (IMS)
- IMS architecture provides integrated voice, data and multi-media services interworking between different access networks.
- IMS is based on **SIP call** control for creating, modifying, and terminating sessions.
- IMS Enables integrated voice, data and multi-media services
- Interworking between different Access Networks



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VoLTE Bearer Combination

- The VoLTE service has specific bearer combination requirements (TS 23.203).
  - **QCI1** dedicated bearer for the speech.
  - **QCI5** bearer for SIP signaling to the IMS.
  - **non-GBR bearer** (QCI9) for data transfer (always-on).

QCI	Guarantee	Priority	Delay Budget	Loss Rate	Application
1	GBR	2	100 ms	1e-2	VoIP
2	GBR	4	150 ms	1e-3	Video call
3	GBR	3	50 ms	1e-3	Real time gaming
4	GBR	5	300 ms	1e-6	Streaming
5	Non-GBR	1	100 ms	1e-6	IMS signalling
6	Non-GBR	6	300 ms	1e-6	Streaming, TCP
7	Non-GBR	7	100 ms	1e-3	Interactive gaming
8	Non-GBR	8	300 ms	1e-6	Streaming, TCP
9	Non-GBR	9	300 ms	1e-6	

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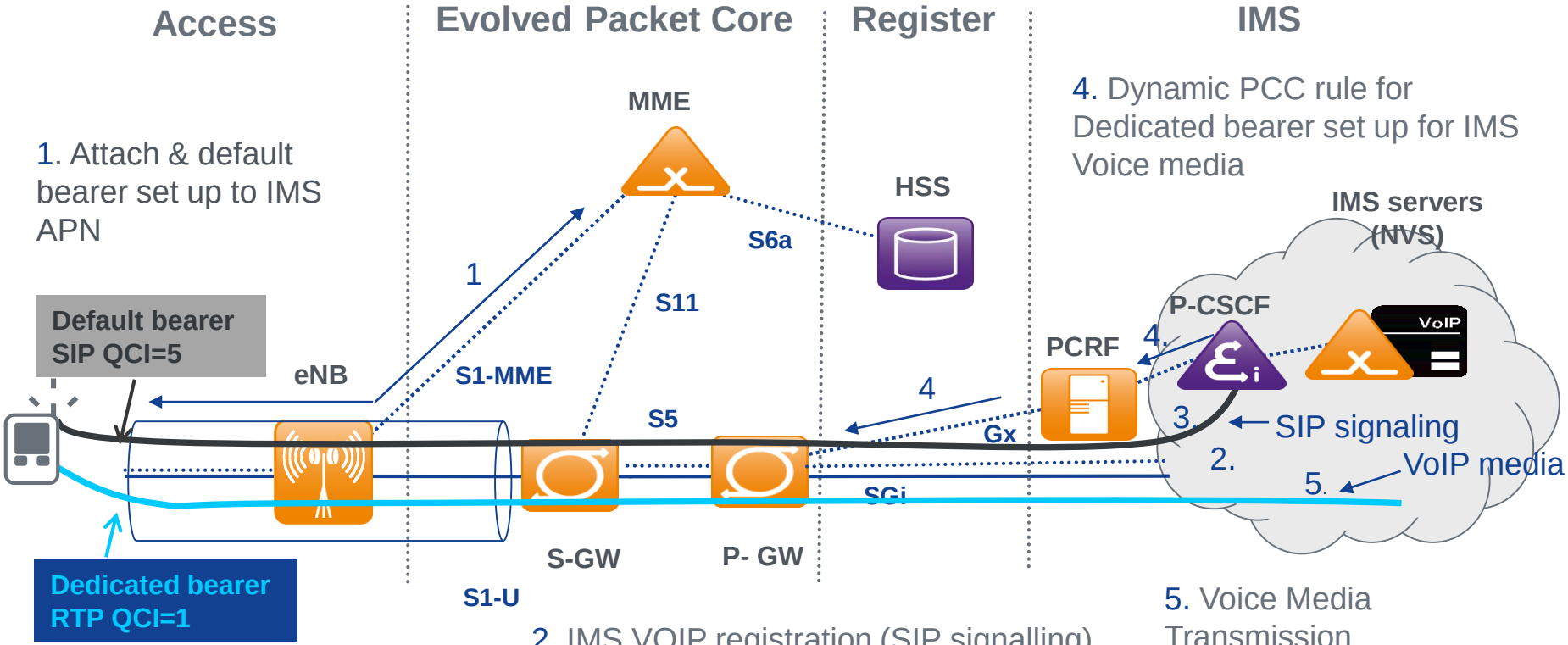
EPS default and dedicated bearers establishment for IMS APN



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VoLTE Features

- Features enabling VoLTE
- Features improving VoLTE performance
- Features handling VoLTE mobility

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Features enabling VoLTE:

LTE7: Support for Multiple EPS bearer
LTE10: EPS bearers for conversational voice
LTE572: IMS emergency call handling

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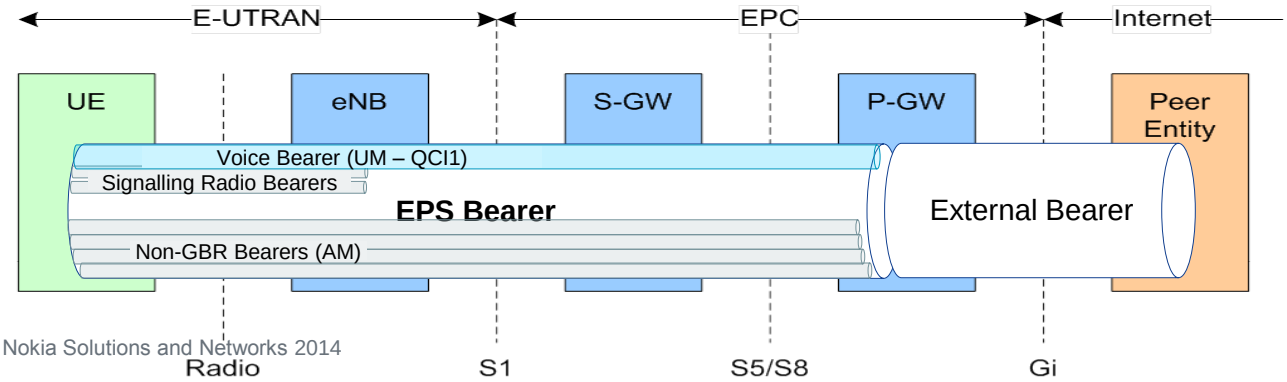
LTE7 : Support for Multiple EPS bearers

Feature Description

- The Flexi Multiradio BTS supports up to **four** EPS bearers. Radio bearer combinations per UE supported:
  - SRB1 + SRB2 + 1 x AM DRB + 1 x UM DRB
  - SRB1 + SRB2 + 2 x AM DRB + 1 x UM DRB
  - SRB1 + SRB2 + 3 x AM DRB + 1 x UM DRB
  - SRB1 + SRB2 + 4 x AM DRB + 1 x UM DRB
- The radio admission is extended by additional check of the total number of DRB per cell and maximum number of DRB per UE



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LTE10 : EPS bearers for conversational voice

With and without the feature

LTE10
Not activated

- There are no mechanisms to ensure QoS for VoLTE users on the radio interface
  - VoLTE treated in the same way as any other traffic
  - e2e QoS support not supported

LTE10
Activated

- Dedicated GBR bearer with QCI1 is introduced for VoLTE service
  - VoLTE packets are prioritized to fit into configured delay target

Voice requires two bearers: QCI 1 for user data, QCI 5 for IMS signaling
operator can offer high quality voice services over LTE based on IMS

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LTE10 : EPS bearers for conversational voice
Impact on Radio resource Management

- To ensure QoS for voice calls, both target bit rate and delay have to be maintained
  - The Flexi BTS takes the GBR signaled via S1 interface into account for Radio Resource Management (Admission Control and Scheduler).
  - The maximum GBR for EPS bearers with QCI 1 is limited by qci1GbrLimit (default: 250kbps). EPS bearers with GBR value higher than this will be rejected by eNB.
- **Admission Control**

  Due to QoS restrictions, two new thresholds for GBR bearers are introduced to radio admission control
  - GBR threshold for new calls: maxNumQci1Drb
  - GBR threshold for incoming calls: addNumQci1DrbRadioReasHo, addNumQci1DrbTimeCriticalHo

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LTE10 : EPS bearers for conversational voice
Impact on Radio resource Management

- **Scheduler**
  - Dynamic scheduling is applied for EPS bearers with QCI 1
  - The uplink and downlink scheduler use the GBR delay budget for its scheduling decisions. The delay budget can be configured by the operator (delayTarget, schedulBSD, schedulWeight)
  - Non-GBR data transmission might be reduced in order to achieve the GBR for voice users
  - Voice service (as based on GBR bearers) *is* not subjected to rate capping functions

- During silence periods, Silence Insertion Descriptor (SID) packets are transmitted for user comfort

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LTE10 : EPS bearers for conversational voice
Feature activation

- Operator specific parameters

MOC	Abbreviated name	Values	Description
LNBTS	**actConvVoice**	range: {false, **true**} default: false	Activates the support of conversational voice bearer
LNBTS	**schedulType**	range: {**SIGNALLING**, NON-GBR} default: NON-GBR	Specifies how the EPS bearer with QCI 5 is scheduled.

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LTE10 : EPS bearers for conversational voice

Radio Admission Control related parameters

MOC	Abbreviated name	Values	Description
LNCEL	**maxNumQci1Drb**	range: 0-400, step: 1 default: 100 (for 10MHz band)	Threshold for the maximum number of established QCI1-GBR-DRBs in the cell
LNCEL	**addNumQci1DrbRadioReasHo**	range: 0-400, step: 1 default: 15 (for 10MHz band)	Additional margin for the maximum number of active GBRs in the cell accessing the cell via handover with HO-cause "HO desirable for radio reasons". This margin is added to the threshold **maxNumQci1Drb**.
LNCEL	**addNumQci1DrbTimeCriticalHo**	range: 0-400, step: 1 default: 20 (for 10MHz band)	Additional margin for the maximum number of active GBRs in the cell accessing the cell via hand over with HO-cause: "Time Critical HO". This margin is added to the threshold **maxNumQci1Drb**.

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LTE10 : EPS bearers for conversational voice

QCI1 Specific parameters for different bandwidths

Carrier BW	20 MHz		15 MHz		10 MHz		5 MHz	
max PRBs	100 PRBs		75 PRBs		50 PRBs		25 PRBs	
PRBs for UL-signaling (PUCCH)	19		17		10		8	
Parameter	range, step size	default value	range, step size	default value	range, step size	default value	range, step size	default value
maxNumQci1Drb	0…600 step 1	100	0…500 step 1	100	0…400 step 1	100	0…200 step 1	75
addNumQci1DrbRadioReasHo	0…600 step 1	40	0…500 step 1	30	0…400 step 1	15	0…200 step 1	15
addNumQci1DrbTimeCriticalHo	0…600 step 1	40	0…500 step 1	30	0…400 step 1	20	0…200 step 1	15

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LTE572: IMS emergency sessions

Operator configurable “headroom” in radio admission control for emergency sessions: **addEmergencySessions**

There are two variants of emergency session establishment:

1. UE camps on a cell in normal service state (e.g. Home PLMN of UE supported by cell).
   - User switches on his UE and enters correct PIN. UE attaches automatically to normal APN. When UE is ready, user enters 112 to start emergency call.
2. UE camps on a cell in limited service state (e.g. no valid PIN available or cell belongs to a different operator without any roaming agreement).
   - User switches on his UE and enters for example 112 as PIN (possible for some types of UEs), or
   - UE offers only emergency calls to user because UE is out of coverage of its operator. User dials 112.

   Then UE attaches automatically to emergency APN.

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LTE572: IMS emergency sessions
Feature Configuration

- **actIMSEmerSessR9** used for enabling/disabling the feature.

Parameter name	Values	Description
addEmergencySessions	Range: 0-840, step 1 default: 70	Margin for number of active UEs, DRBs and QCI1-DRBs when IMS emergency sessions activated
actIMSEmerSessR9	range: {true, false} default: false	Parameter activates the support IMS Emergency sessions for Release 9 UEs.

- Note: If the feature is disabled the emergency calls can still be performed, but they will not be prioritized over the other calls and no additional RAC thresholds will be added

addEmergencySessions values are bandwidth-dependent

Bandwidth [MHz]	addEmergencySessions	
	Range	recommended
5	0-480	50
10	0-480	70
15	0-840	70
20	0-840	90

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Features Improving VoLTE Performance:

LTE 11: Robust Header Compression
Packet Aggregation (included in LTE10)
LTE 571: Controlled UL Packet Segmentation
LTE 907: TTI Bundling
LTE 1406: Extended VoLTE Talk Time

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Features Improving VoLTE Performance
Overview

- Robust Header Compression (RoHC) within the PDCP layer reduces the overheads generated by the higher layer protocol stack.
- Packet Aggregation helps to reduce PDCCH load.
- L2 Segmentation helps to improve coverage at the cost of additional RLC/MAC overhead and PDCCH load
- TTI Bundling helps to improve uplink coverage while limiting the PDCCH load
- Extended VoLTE Talk Time feature helps to reduce battery consumption of the UEs with ongoing VoIP call
- Service based mobility trigger will help the operator to decide which radio access layer is used for VoLTE

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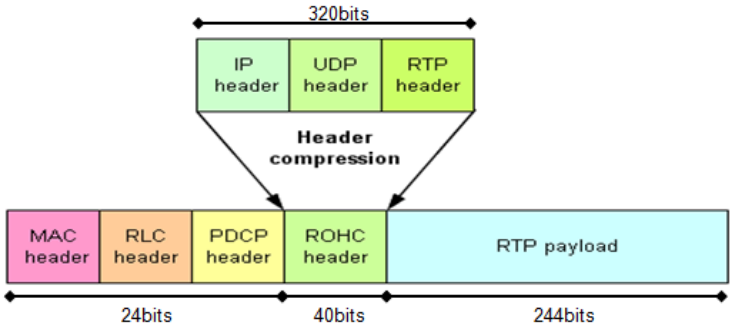
LTE11: Robust Header Compression (RoHC)

- Robust header compression compresses the header of IP/UDP/RTP packets for the EPS bearer with QCI1 to avoid to transfer high overheads across the air-interface.
  - IP/UDP/RTP headers size can be either 40 bytes for IPv4 or even 60 bytes for IPv6.

- PDCP layer is able to compress the RTP/UDP/IP headers

- **RoHC improves uplink link budget due to less bandwidth needed per user** (i.e. lower MCS can be used) which translates to greater cell range.

- Also **more VoLTE users can be supported** in terms of throughput capacity.



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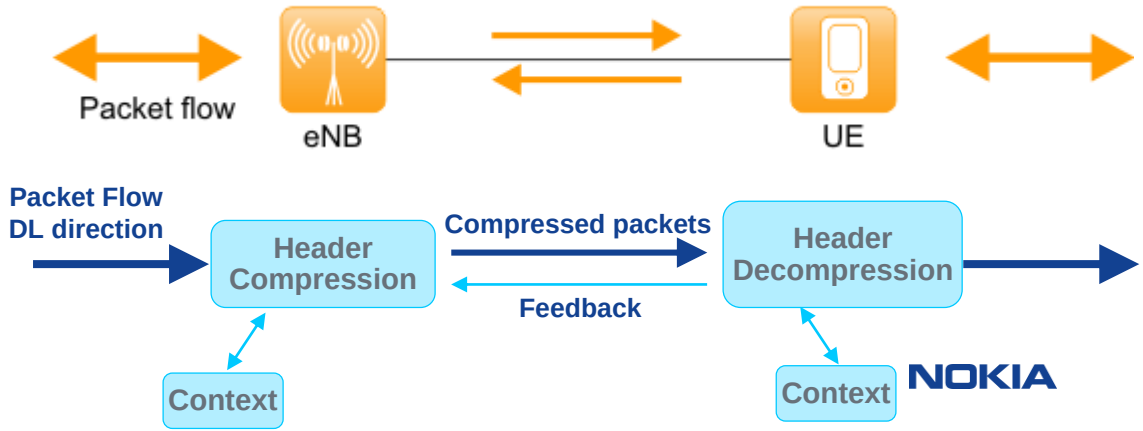
LTE11: Robust Header Compression (RoHC)
Basic Principle

- Initially, a few packets are sent uncompressed and are used to establish the context on both sides of the link
  - The context comprises information about static fields, dynamic fields and their change pattern in protocol headers
- This information is used by the compressor to compress the packet as efficiently as possible and then by the decompressor to decompress the packet to its original state
- Context is updated at compressor and decompressor at certain events depending on mode of working:
  - Periodic timeouts
  - Feedback from decompressor



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LTE11: Robust Header Compression (RoHC)

Gross throughput per user is decreased by 46% when RoHC is used. Therefore, more voice users can be scheduled or better voice codecs can be used

Significant gain (2.5dB) can be achieved when using RoHC (lower MCS due to lower throughput per user), which translates to 14% larger cell range

Area affected	Modifiable by	Abbreviated name	Values	Description
eNodeB	Operator	**actPdcpRohc**	range: true, false default: false	activates the usage of PDCP Robust Header Compression
eNodeB	Operator	**rohcMaxCid**	range: 0...16, step 1 default: 4	maximum number of ROHC contexts used for a data radio bearer in one direction

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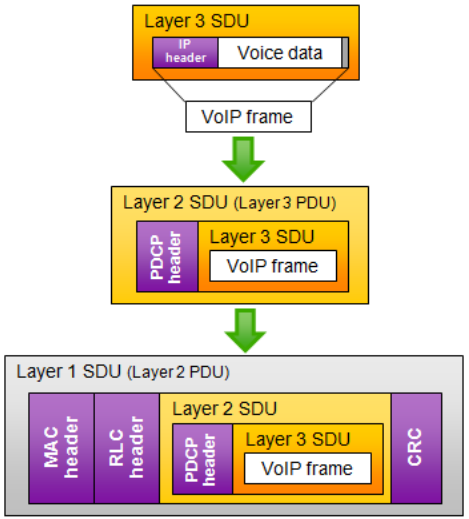
Voice Codecs & Bitrates

- Single VoIP packet transports voice data from time period of 20ms.
- VoIP throughput is defined by the voice codec and overhead introduced by lower layers.
  - This calculation assumes 40 bits for PDCP (1 byte) + RoHC (4 bytes) header size.



Voice Codec	Codec Source Rate [kbps]	Frame Size [bits]	Padding [bits]	PDCP Header [bits]	L2 SDU [bits]	RLC Header [bits]	MAC Header [bits]	CRC [bits]	L1 SDU [bits]
AMR-NB 1.8	1.8	36	4	40	80	8	8	24	120
AMR-NB 4.75	4.75	95	1	40	136	8	8	24	176
AMR-NB 5.15	5.15	103	1	40	144	8	8	24	184
AMR-NB 5.9	5.9	118	2	40	160	8	8	24	200
AMR-NB 6.7	6.7	134	2	40	176	8	8	24	216
AMR-NB 7.4	7.4	148	4	40	192	8	8	24	232
AMR-NB 7.95	7.95	159	1	40	200	8	8	24	240
AMR-NB 10.2	10.2	204	4	40	248	8	8	24	288
AMR-NB 12.2	12.2	244	4	40	288	8	8	24	328
AMR-WB 1.75	1.75	35	5	40	80	8	8	24	120
AMR-WB 6.6	6.6	132	4	40	176	8	8	24	216
AMR-WB 8.85	8.85	177	7	40	224	8	8	24	264
AMR-WB 12.65	12.65	253	3	40	296	8	8	24	336
AMR-WB 14.25	14.25	285	3	40	328	8	8	24	368
AMR-WB 15.85	15.85	317	3	40	360	8	8	24	400
AMR-WB 18.25	18.25	365	3	40	408	8	8	24	448
AMR-WB 19.85	19.85	397	3	40	440	8	8	24	480
AMR-WB 23.85	23.85	477	3	40	520	8	8	24	560

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LTE571: Packet Segmentation

- Packet Segmentation algorithm is used as an extension to the uplink link adaptation to improve the UL cell edge performance.
  - In worsening radio conditions scheduler performs packet segmentation on Layer 2 in order to use more robust MCS and transmits the packet over multiple TTIs.
  - Since RLC/MAC overhead is transmitted more than once, more resources are consumed to transmit the same amount of user data.
  - As number of transmitted packets increases, more resources on PDCCH are utilized and also on PHICH due to transmission of ACKs/NACKs for HARQ purposes.

#Segments	L2 SDU	Headers	All bytes	Overhead
1	288	40	328	12%
2	288	80	368	22%
4	288	160	448	36%

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Controlled UL packet segmentation

Parameters

Area affected	Abbreviated name	Values	Description
LNCEL	**ulsMinTbs**	range: 16-1544, step 8 default 104	Defines the minimum UL TBS (segment size).
LNCEL	**ulsMinRbPerUe**	range: 1-100, step 1 default 3	Defines the minimum PRB allocation for UEs which are power limited

Controlled UL packet segmentation means that the extent of segmentation may be configured by

- ***ulsMinTbs*** defines the minimum amount of data a UE can send in a TTI. The lower this setting is, the higher the number of segments a packet can be divided in. This will increase user robustness by increasing the energy per packet, but more radio resources are consumed due to increased RLC/MAC overhead.
- ***ulsMinRbPerUe*** defines the minimum number of PRBs that can be occupied by UE which is power limited.It prevents the UE of being allocated a too low number of PRBs.

Packet segmentation is not an event-triggered mechanism, it is done automatically and only for UEs with poor radio channel.

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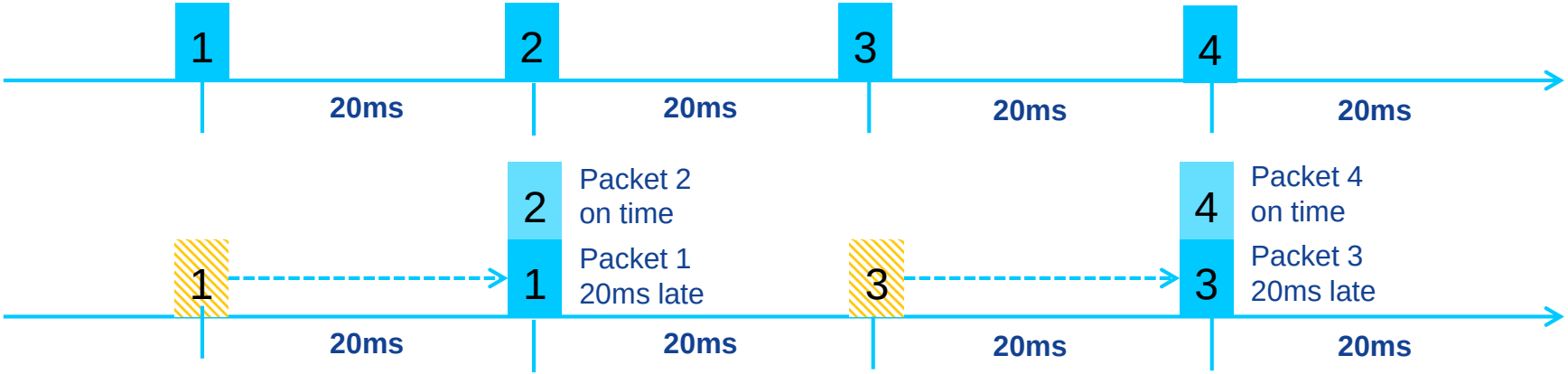
Packet Aggregation

- Packet aggregation means several packets are grouped before transmitting across the air-interface, e.g. the first packet can be delayed 20ms (in case of aggregation of 2 packets) while every second one is delivered at the correct time.
  - More VoLTE users can be served due to reduced signaling load (PDCCH & PHICH).
  - Packet delay is increased but the scheduler ensures the target delay budget.



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Packet Aggregation
Uplink

- Maximum order of packet aggregation in **uplink** is based on configured parameters:
  - ulsMaxPacketAgg Controls max. number of aggregated VoIP packets in UL.
  - delayTarget (part of the QCI1 Tab structure) determines the max. packet delay by the scheduler and affects the maximum aggregation level, i.e. if target is set too small value (< 60ms) no packet aggregation can be performed.
  - Aggregation will be used only under high GBR load.
  - Packet aggregation is not used for power limited UEs (cell edge) due to less number of PRBs available in PUSCH and packets may be segmented due to ATB limits.
  - Note :UL packet aggregation limits gains from DRX, i.e. scheduler delays UL grant until sufficient number of VoIP packets is aggregated and thus, UE stays in DRX Active mode between first Scheduling Request and UL Transmission.

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Packet Aggregation
Downlink

OLTDC: Outer Loop Target Delay Control

- Maximum order of packet aggregation in **downlink** depends on load conditions, experienced delays and OLTDC settings:
  - DL packet aggregation can be switched on/off using actDlsVoicePacketAgg but maximum number of aggregated packets cannot be configured by the parameter.
  - Number of packets to be aggregated is controlled by OLTDC mechanism, i.e. aggregation level is matched to channel conditions (HARQ ReTx, propagation delays)
  - OLDTC evaluates the actual scheduling delay of voice packet and compares it with delay target:
    - if packet exceeds delayTarget → UE priority is increased
    - if packet send within delayTarget → UE priority is decreased

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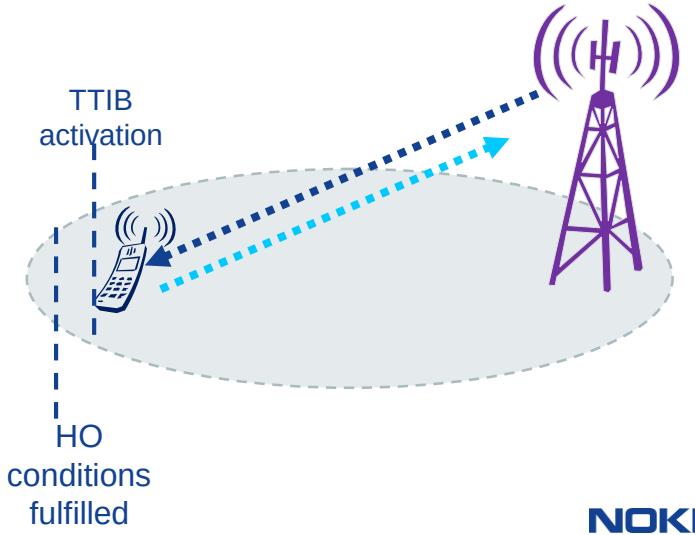
LTE907: TTI Bundling

- TTI bundling is specified in 3GPP (TS 36.213, 36.321) to allow the improved uplink performance for cell border UEs (which often hit the maximum transmission power) and for reduced PDCCH load.
- TTI bundling allows for transmitting the same transport block in 4 consecutive UL subframes (also known as bundle size), which leads to increased energy per transmitted bit and therefore improved uplink link budget.
  - When BLER increases and Link Adaptation has no more options for MCS/PRB reduction while radio conditions for handover are not fulfilled, TTI Bundling can be triggered to sustain the voice call quality before UE will either change the cell or RF conditions becomes better.
  - Note that TTI Bundling mode is also maintained during the handover (if target cell supports TTI Bundling).



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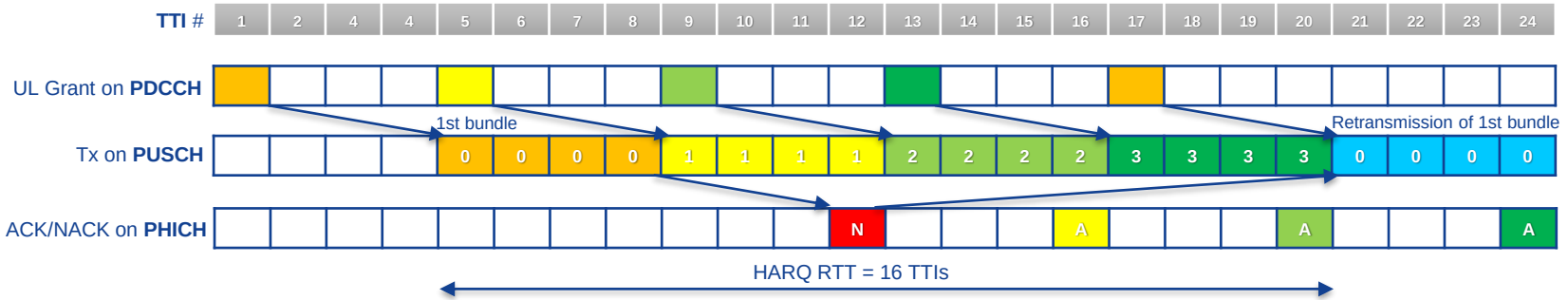
LTE907: TTI Bundling

Transmission Characteristic in TTI Bundling

- A single transport block is encoded and transmitted with different redundancy versions in four (4) consecutive UL subframes, i.e. within a bundle.
  - A single UL grant on PDCCH is used for each bundle.
  - HARQ feedback is only received (and transmitted) for the last subframe of a bundle. HARQ process ID is same for each of the bundled subframes.
  - HARQ retransmission of a TTI bundle, which is also transmitted as a bundle, occurs 16 TTIs after previous (re)transmission in order to be synchronized with normal (non-bundled) LTE HARQ retransmissions (8 TTIs)



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LTE907: TTI Bundling

Transmission Characteristic in TTI Bundling

- Modulation scheme is restricted to QPSK and the number of PRBs that can be allocated can only be <=3. Currently, only a allocation size of 3 is supported by the eNodeB.
- There can be cases when a bundle has less than 4 subframes, e.g. when a UE will start a measurement gap for handover purposes.
- TTI bundling can be only applied as soon as the UE identity is known to the eNodeB which is the case:
  - after reception of msg3 in contention-based random access (initial and non-initial) and
  - after preamble reception for non-contention based random access.

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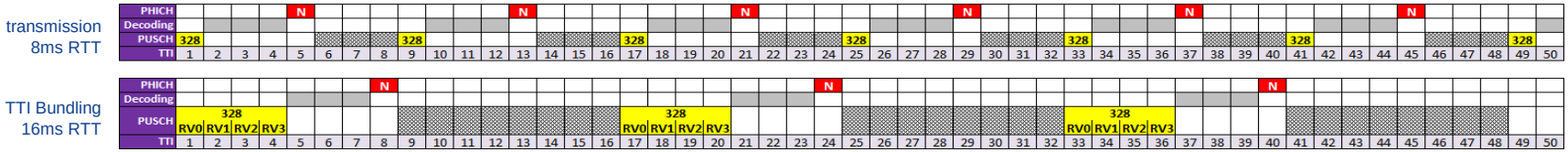
TTI Bundling UL Coverage Gain

Capacity	DL	UL
Method for modulation and coding scheme	Optimize	Optimize
Modulation and coding scheme (Optimized)	0_QPSK	12-16QAM
Modulation and coding scheme (User defined)	-	-
Service Type	AMR-WB 23.85	
Cell Edge User Thr [kbps]	560	560
VoIP Packet L2 Segmentation Order	1	1
Uplink TTI Bundling Coverage Gain	-	3.59
Residual BLER / Number of Transmissions	rBLER=2% (4Tr)	rBLER=2% (4Tr)
DL Resource Block Group Size	1	-
Limitation of UL Resource Block Group Size	-	☑
Number of PRBs per User	21	3
Channel Usage per TTI [%]	42%	6%
Transport Block Size for PDSCH/PUSCH	568	584
Modulation efficiency	0.23	1.49
Effective Coding Rate	0.11	0.37
Channel	**DL**	**UL**
Channel Model	Enhanced Pedestrian A 5 Hz	
Antenna configuration	2Tx-2Rx	1Tx-2Rx
Tx/Rx Algorithm at eNB	OL TxDiv (SFBC)	MRC
Frequency scheduler	Channel aware	Channel unaware
PDSCH Power Penalty when DL Boosting On [dB]	0.00	-
Number of users per TTI	2	10
Frequency scheduling gain [dB]	1.89	0.00
HARQ Gain [dB]	4.58	7.36
Precoding Gain [dB]	0.00	-
Required SINR @ BLER10% [reference] [dB]	-5.19	6.32
Coding Rate Offset [dB]	0.03	0.68
Required SINR at Cell Edge [dB]	-11.62	-0.36
Maximum SINR at Cell Edge [dB]	-0.03	-
Cell load [%]	50.00%	50.00%
Method For Interference Margin	User Defined	User Defined
Interference Margin [Formula/Simulation] [dB]	-	-
Interference Margin [User Defined] [dB]	1.00	1.00
Number of Received Subcarriers [dB]	27.8	15.6
Thermal Noise Density [dBm/Hz]	-174	
Subcarrier Bandwidth [kHz]	15	
Noise Power per Subcarrier [dBm]	-132.17	
Receiver Sensitivity [dBm]	-109.01	-114.77
Maximum Allowable Path Loss(clutter not consid...	**168.63**	**155.96**

- TTI Bundling feature improves UL Link Budget because it is possible to increase the number of retransmissions within a specific delay budget (i.e. time during which Transport Block retransmissions can occur before it will be dropped)
  - Maximum number of TB transmissions (within 50 ms delay budget) in normal mode is equal to 7 while in TTI Bundling mode is equal to 12 which leads to 2.34 dB (=10xlog(7/12)) gain in uplink pathloss.
  - Increasing delay budget up to 53ms, higher gains can be achieved, i.e. up to 3.59 dB (=10xlog(7/16)), as one more bundle that consist of 4 Transport Blocks can be transmitted.



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Trigger Criterion to Enter TTI Bundling Mode

- The trigger condition to start TTI bundling of a UE shall be fulfilled if:
  - UE is transmitting with **currentMCS <= *eUlLaLowMcsThr***, **AND**
  - **MAX_NUM_PRB <= max** (***eUlLaLowPrbThr***, ***ulsMinRbPerUe***), **AND**
  - TTI bundling measurements are ongoing and the percentage of NACKed transmissions is greater than ***ttiBundlingBlerThreshold***.
- This trigger condition shall be checked with every UL transmission of the UEs and if the trigger condition is fulfilled, the eNB shall inititate the process to start TTI bundling for the UE.
- The switching between ‘normal mode’ and ‘TTI bundling mode’ is performed with the help of the intra-cell handover procedure (feature LTE511 introduced in RL50 release)
  - Intra-cell handover is required to synchronize eNB and UE in the new transmission mode i.e. TTI bundling.

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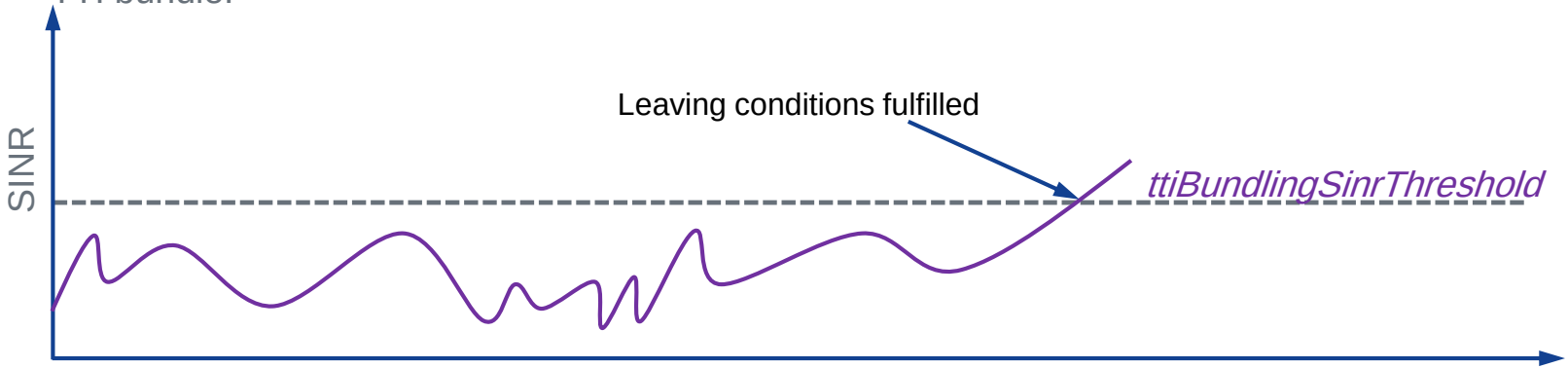
LTE907: TTI Bundling

Trigger Criterion to Leave TTI Bundling Mode

- The trigger condition to stop TTI bundling of a UE shall be fulfilled if:
  - the averaged UL SINR must be greater than, or equal to the last known SINR before the UE was switched into TTI bundling mode, plus an offset value 0.1dB.
  - Average UL SINR ≥ ttiBundlingSinrThreshold
- The UL SINR to stop TTI bundling and start normal operation mode is measured on PUSCH. In each UL TTI, one SINR sample shall be generated. This produces four SINR samples for each complete TTI bundle.



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LTE907: TTI Bundling
Configuration parameters

Area affected	Abbreviated name	Values	Description
LNCEL	**actTtiBundling**	range: true, false default: false	activates the usage TTIB
LNBTS	**enforceTtiBundling**	range: true, false default: false	This parameter enables the TTI Bundling for the QCI1 (VoIP)
LNCEL	**ttiBundlingBlerThreshold**	range: 8..50, default: 15	This parameter defines the BLER threshold which must be reached in order to switch the UE from normal UL transmission mode into TTI Bundling mode, with the help of the Intra-Cell HO procedure.
LNCEL	**harqMaxTrUlTtiBundling**	range: 4..28, step 4,default: 12	This parameter defines the maximum number of HARQ transmissions for the UEs in TTI Bundling mode.
LNCEL	**ttiBundlingBlerTarget**	range: 5..25, default: 6	The parameter specified the BLER target which is used by the Link Adaptation for UEs in TTI Bundling mode
LNCEL	**ttiBundlingSinrThreshold**	range: -10..10, default: 1	This parameter defines the SINR threshold that must be fulfilled to trigger intra-cell HO for leaving TTI Bundling mode by the UE
LNBTS	**ttiBundlingDuringHoMeas**	range: true, false default: false	This parameter defines whether switching from normal transmission mode into TTI bundling mode is allowed during ongoing inter-frequency or inter - RAT measurements.

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LTE1406: Extended VoLTE Talk Time

Feature Description

- One of the most important aspects for LTE users is a battery consumption
- If UE does not check PDCCH continously (only during DRX ACTIVE state) energy savings can be achieved
- LTE42 DRX in RRC Connected Mode feature introduces several DRX profiles. One of them is DRX Profile 2 which is optimized for VoIP traffic
- Features gain from DRX are improved by LTE 1406 introducing (example):
  - Alignment of the Scheduling Request (SR) timing with the DRX 'ON' timing
  - Adjustment of SR Periodicity to DRX Long Cycle length
  - Dedicated BLER target and number of HARQ retransmissions for VoLTE UEs
- LTE1406 can be applied only for the UEs with QCI1 bearer

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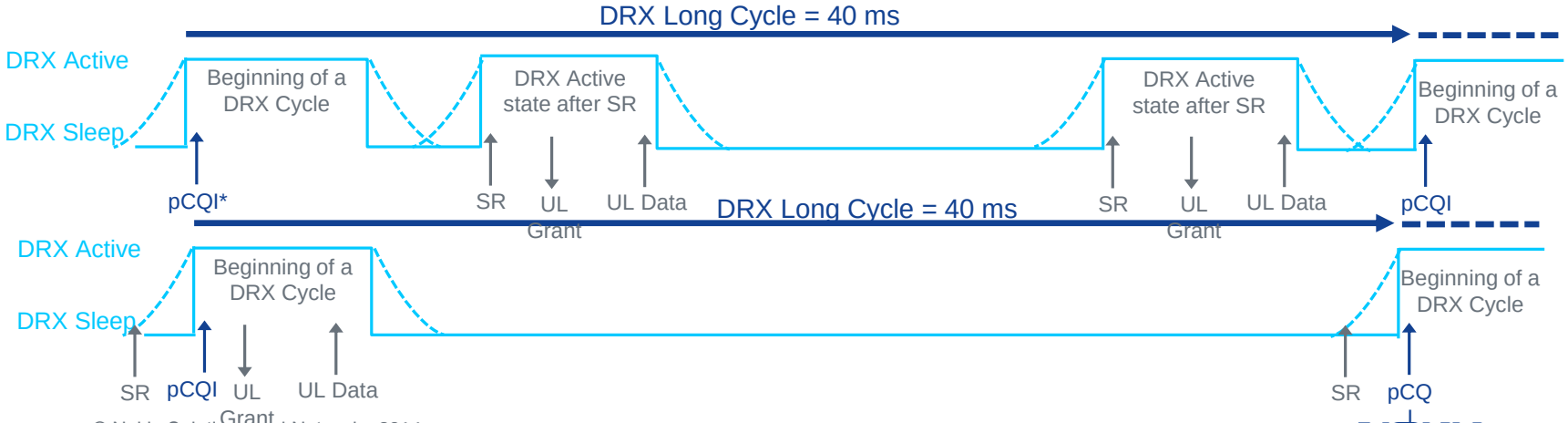
LTE1406: Extended VoLTE Talk Time

- Alignment of the Scheduling Request (SR) timing with the DRX 'ON' timing
  - Scheduling Request is allocated 3 TTIs before periodic CQI (pCQI)

    As a result UL Grant on PDCCH can be provided at earliest 1ms after pCQI (SR , 4ms) - UE is already in DRX Active state when it sends pCQI then additional DRX Active state caused by sending Scheduling Request is avoided
  - Adjustment of Scheduling Request periodicity to Long DRX Cycle for the UEs with QCI1 bearer

drxProfile2:drxLongCycle (40ms)



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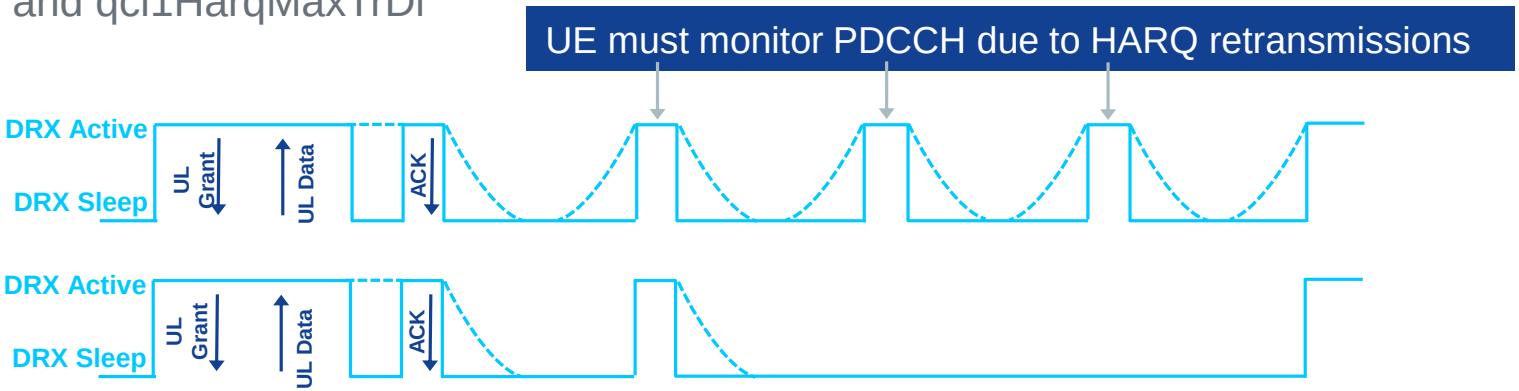
LTE1406: Extended VoLTE Talk Time

Lower number of HARQ Retransmissions increases gains from the DRX

- Configure lower number of HARQ retransmissions for the UEs with QCI1 bearer and eVTT profile activated - Lower number of HARQ Retransmissions increases gains from the DRX
  - Maximum number of HARQ transmissions in UL and DL, for the UEs with eVTT profile, is controlled by means of dedicated parameters, namely qci1HarqMaxTrUl and qci1HarqMaxTrDl



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LTE1406 Extended VoLTE Talk Time

- Configure lower BLER target for QCI 1

  With lower number of possible HARQ retransmissions proper MCS for the VoIP packet transmission is important

  - lower UL and DL Target BLER can be configured for the UEs with eVTT profile configured

    Two parameters :qci1UlTargetBler and qci1DlTargetBler

  - With lower Target BLER, Link Adaptation in UL and DL adjusts MCS faster to changing radio conditions

- Dedicated timer (qci1ReconfStop) is introduced to prevent ping-pong (standard and QCI1-optimized modes)

  - During VoIP call, switching between modes is caused by the throughput variations
  - The timer is started when reconfiguration is completed and next changes can be performed only when qci1ReconfStop timer expires

- Number of reconfigurations limited to 3 during single VoIP call

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LTE1406: Extended VoLTE Talk Time
Configuration

Abbreviated name	Values	Full name
LNBTS:actQci1eVTT		Activate Extended VoLTE Talk Time
LNCEL:qci1eVTTConfig		Extended VoLTE Talk Time Configuration for QCI1
LNCEL:qci1ReconStopTimer	Default 1, 1...5 s, step 0.2 s	HARQ and BLER reconfiguration timer for QCI1
LNCEL:qci1ThroughputFactorDl	Default 1.6, 1...4, step 0.2	Multiplication factor for the QCI1 traffic in downlink
LNCEL:qci1ThroughputFactorUl	Default 1.6, 1...4, step 0.2	Multiplication factor for the QCI1 traffic in uplink
LNCEL:qci1HarqMaxTrDl	Default 5, 1...16, step 1	Maximum number of HARQ transmission in DL for QCI1
LNCEL:qci1HarqMaxTrUl	Default 5, 1...7, step 1	Maximum number of HARQ transmission in UL for QCI1
LNCEL:qci1DlTargetBler	2...20 %, step 1 %	DL target BLER for QCI1
LNCEL:qci1UlTargetBler	2...20 %, step 1 %	UL AMC target BLER for QCI1

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Features handling VoLTE Mobility:

LTE 1127: Service based mobility trigger
LTE872: SRVCC to WCDMA
LTE873: SRVCC to GSM

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LTE1127 Service based mobility trigger

Feature Description

- QCI1 traffic steering to VoLTE preferred frequency layers
- By using specific frequency layer to VoLTE , average throughput of UEs served by non-VoLTE preferred frequencies is improved
- Service based handover procedures are similar to Load Balancing, but separate timers and thresholds are introduced
- SBHO has higher priority than Load Based handover
- whenever IF/IRAT event is reported by UE, Service Based (SB) and Load Based (LB) Handovers are not triggered

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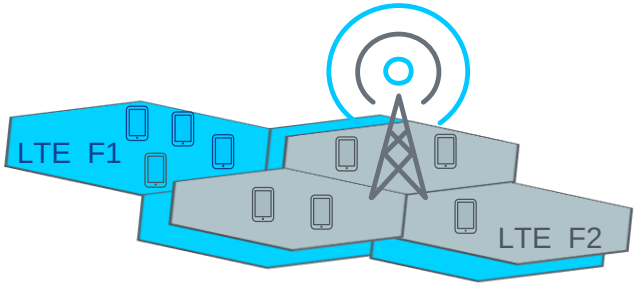
LTE1127 Service based mobility trigger

- VoLTE preferred frequencies can be chosen based on different factors
  - Coverage: higher cell range for VoLTE services will decrease number of handovers
  - Capacity: more UEs with QCI1 can be served by one layer, however limited coverage will increase number of handovers
- Steering UEs with QCI1 bearers to dedicated VoLTE frequencies can improve average throughput of UEs served by non-VoLTE preferred frequencies
  - due to lower priority non-GBR traffic has much less scheduling occasions, throughput generated by non-GBR UEs decreases when more VoIP UEs are in the network



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LTE1127: Service Based Mobility Trigger
Configuration Parameters

Area affected	Abbreviated name	Values	Description
LNBTS	***actRLFbasedRCR***	range: true, false default: false	Activate RLF based RRC connection reestablishment
LNBTS	***rlfBasedRCRsupported***	range: true, false default: false	Indicates whether RLF based connection reestablishment is supported by the neighbor eNB.
LNBTS	***rlfBasedRCRdefault***	range: true, false default: false	RLF based RRC connection reestablishment default. Defines the default value for the LNADJ parameter rlfBasedRCRsupported which is used if an LNADJ instance is autonomously created by eNB due to an activated ANR feature.
LNBTS	***mtHoRlf***	range: 0-1440, default 15	configuration of measurement type LTEHoRlf

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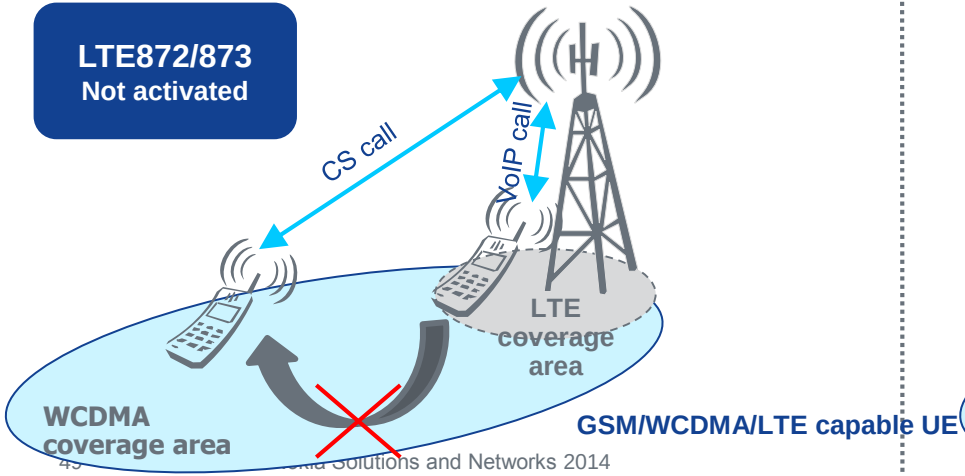
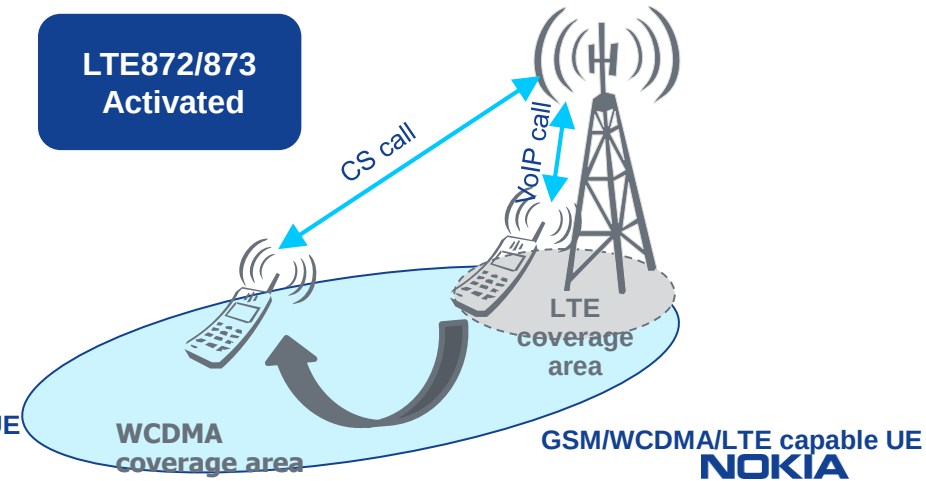
LTE872/873 – SRVCC to WCDMA/SRVCC to GSM

- There are no means to handover VoIP connections to another RAT
  - unless target RAT support PS Conversational QoS
- VoIP connections are dropped while leaving LTE coverage



- Two additional inter-working functionalities are introduced for the data connection in RRC_CONNECTED state. With the help of these features handover of VoIP calls is possible:
  - to WCDMA via SRVCC to WCDMA feature (LTE 872)
  - to GSM via SRVCC to GSM feature (LTE 873)



LTE872/873 – SRVCC to WCDMA/SRVCC to GSM

Feature Description

- The aim of the LTE872/873 feature is to command the UE to leave LTE network if the LTE coverage is ending and handover the VoIP call (QCI = 1) to either WCDMA or GSM network via Single Radio Voice Call Continuity procedure
  - SRVCC to TD-SCDMA is not supported at all
- LTE Terminal must be 2G and/or 3G capable
- EPC support for SRVCC is indicated to eNB with ‘SRVCC Operation Possible’ IE in S1AP:Initial Context Setup Request or in S1AP:Handover Request message
- Prior to the actual SRVCC procedure, measurements of 2G/3G network are triggered

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SRVCC Thresholds and Timers

- No new thresholds and time-to-trigger values are introduced for SRVCC features for triggering the inter-RAT measurement procedures or triggering the actual handover
  - LTE442 eNACC related parameters are reused for SRVCC to GSM
  - LTE56 Inter-RAT handover to WCDMA parameters are reused for SRVCC to WCDMA

LTE RSRP		SRVCC to 2G	SRVCC to 3G
A2 event	Threshold	threshold2GERAN	threshold2Wcdma
	Timer	a2TimeToTriggerActGERANMeas	a2TimeToTriggerActWcdmaMeas
B2 event	Threshold	b2Threshold1GERAN	b2Threshold1Utra
	Timer	b2TimeToTriggerGERANMeas	b2TimeToTriggerUtraMeas

Target system		SRVCC to 2G	SRVCC to 3G
B2 event	Threshold	b2Threshold2RssiGERAN	b2Threshold2UtraEcN0/b2Threshold2UtraRscp
	Timer	b2TimeToTriggerGERANMeas	b2TimeToTriggerUtraMeas

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LTE_497- Smart Admission Control

Brings the benefit for GBR traffic

- Smart admission control is a necessity when offering high guaranteed bit rate services in the network
- The counter based RAC is replaced by a measurement based function which leads to a more accurate and dynamic system behavior
- It offers a congestion handling to get rid of traffic when an overbooking of resources is detected

Managed Object	Abbreviated Name	Full Name
MRBTS/LNBTS	**actEnhAcAndGbrServices**	Activate enhanced AC and GBR services
MRBTS/LNBTS/LNCEL	**maxGbrTrafficLimit**	Maximum GBR-DRB Traffic Limit
MRBTS/LNBTS/LNCEL	**addGbrTrafficRrHo**	Add GBR-DRB Traffic for Radio Reason Handover
MRBTS/LNBTS/LNCEL	**addGbrTrafficTcHo**	Add GBR-DRB Traffic for Time Critical Reason Handover

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VoLTE KPIs

- OSS KPIs
- Drive Test KPIs

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OSS KPIs

VoLTE OSS KPIs
VoLTE Drop Call
VoLTE Acceptance and Analysis KPIs
KPI references from projects
OSS Reporting Tools

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OSS KPIs for VoLTE

Example of VoLTE related UTRAN KPIs

Note: There are no separate handover related KPIs available for QCI 1yet

LTE_5204b eRAB Setup Success Ratio – QCI1	Setup SR of the elementary E-RAB setup procedure used to setup the E-RAB between MME and UE for QCI1 DRBs. Indicates E-UTRAN contribution to network accessibility for the end-user, not the whole end-to-end service accessibility
LTE_5205b e_RAB setup Attempts -QCI1	Number of E-RAB Setup Attempts for QCI1
LTE_5572a E-RAB QCI1 Drop Ratio, RAN View	Abnormally released (dropped) QCI1 E-RABs from RAN point of view
LTE_5571b E-RAB QCI1 active drop ratio with data in the buffer	E-RABs drop ratio with data in the buffer due to RNL Radio Connection with UE Lost cause initiated by eNodeB
LTE_5805b Average Active UEs with data in the buffer for DRBs of QCI1 DL	Average number of UE with buffered data in DL
LTE_5807b E-UTRAN Average Active UEs with data in the buffer for QCI1 DRBs UL	Average number of UE with buffered data in UL
LTE_5138a Average Latency Downlink for QCI1 DRBs	Retention period (delay) of a PDCP SDU (DL) inside eNodeB for QCI1 DRBs.
LTE_1167b Fraction of lost DL PDCP SDUs for QCI1	Percentage of lost DL PDCP SDUs for QCI1 compared to all lost SDUs in DL

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VoLTE Drop Call OSS KPI Issue

LTE_5571b E_UTRAN E-RAB QCI1 with data in the Queue drop ratio RNL failure with UE lost

•QCI 1 drop is not always Volte drop call **to end user**.
• UE will try to do re-establishment if it fails with in predefine time in IMS (default 5s) then it should count as a drop call.
• LTE_5571b will not exactly show end user drop calls (QCI 1 drop is always much bigger than real drop calls) .

- E-RAB drop ratio and retainability counters/KPIs count the drop always from network point of view meaning that the UE has lost the connection in the observed cell and trying an re-establishment in other cell (typical reason can be late handover when HO command was not sent in the source cell but HO is prepared in the target cell) despite the call continues in other (target)
- Nokia implementation has an issue with this counter, meaning that it consider only one cause “RNL Failure with UE lost” thus the KPI may provide even bigger values!

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VoLTE Drop Call OSS KPI Issue (cont.)

LTE_5572a E-UTRAN E-RAB QCI1 Drop Ratio, RAN View

- This counts all the e-RAB drops whether there is data in the buffer or not.
- There is better chance that UE will try to do re-establishment with out User recognizing it as a drop than LTE_5571b
- Therefore in VoLTE drop point of view LTE_5571b is better than the LTE_5572a during assessment phase

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OSS KPIs for VoLTE in General

UTRAN KPIs

Network Accessibility	LTE_5218 RRC Connection Setup Success Ratio LTE_5239 Cell Availability LTE_5204 E-RAB Setup Success Ratio, QCI1 LTE_5017 E-RAB Setup Success Ratio
Service Integrity(MOS)	LTE_5138 Average Latency Downlink for QCI1 (troubleshooting) LTE_5427a Average CQI (troubleshooting) LTE_5541b Average SINR for PUCCH (troubleshooting)
Service Retainability	LTE_5025 E-RAB DR, RAN view (troubleshooting) LTE_5572 E-RAB DR, RAN view, QCI1 (troubleshooting)
Mobility	LTE_5082 Inter-eNB S1 HO SR LTE_5048 Inter-eNB X2 HO SR LTE_ 5114 Inter-Frequency HO SR LTE_5195 Inter-RAT HO SR Inter RAT HO UTRAN with SRVCC Success Ratio- LTE_5564a Inter RAT HO GERAN with SRVCC Success Ratio- LTE_5567a
Usage	LTE_1067b VoLTE traffic load LTE_5805c E-UTRAN Average Active UEs with data in the buffer for DRBs of QCI1 DL LTE_5807c E-UTRAN Average Active UEs with data in the buffer for QCI1 DRBs UL LTE_5326b E-UTRAN Average UEs configured for TTI Bundling Mode

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OSS KPI Reference from the VoLTE live network

MBB Benchmarker

KPI	Max	%ile 75	Median	%ile 25	Min	Mean	Customers
LTE: eRAB Drop Ratio - QCI1 (LTE_5572) (%)	21.28	0.31	0.25	0.20	0.00	0.61	19
LTE: eRAB Setup Success Ratio - QCI1 (LTE_5204) (%)	100.00	99.83	99.69	99.56	11.11	96.38	26
LTE: eRAB Normal Release Ratio - QCI1 (LTE_5209) (%)	100.00	99.78	99.64	98.48	55.32	98.30	27
LTE: Inter-RAT HO UTRAN SRVCC Success Ratio (LTE_5564) (%)	100.00	100.00	90.46	75.00	0.00	84.32	13
LTE: Inter-RAT HO GERAN SRVCC Success Ratio (LTE_5567) (%)	100.00	75.00	34.63	15.45	0.00	42.91	6
LTE: eRAB Active Time - QCI1 (LTE_5576) (Min)	8908128	0	0	0	0	375185	87
LTE: Avg PDCP Active Cell Throughput DL per Cell, QCI1 (LTE_5293) (kbit/s)	41	0	0	0	0	1	97
LTE: Avg PDCP Active Cell Throughput UL per Cell, QCI1 (LTE_5294) (kbit/s)	27	0	0	0	0	1	97
LTE: eRAB Retainability Rate - QCI1 (LTE_5582) (/min)	5	0	0	0	0	0	25
LTE: eRAB Setup Attempts, QCI1 (LTE_5205)	4855142	0	0	0	0	159787	97
LTE: CSFB attempts, UE in idle mode (LTE_1091)	10253701	790981	309877	92996	0	752159	88
LTE: CSFB attempts, UE in connected mode (LTE_1092)	6830707	468701	163940	52355	0	447463	88
LTE: CSFB attempts, UTRAN with PS HO (LTE_1081)	2336907	0	0	0	0	46125	87
LTE: Inter-RAT HO UTRAN SRVCC Attempts (LTE_5562)	8337	0	0	0	0	31	87
LTE: Inter-RAT HO GERAN SRVCC Attempts (LTE_5565)	188	0	0	0	0	2	87

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Project experience - US

OSS KPIs used during VoLTE activation: counter based reference only

Type	VoLTE KPIs	Network PM
Accessibility	E-UTRAN E-RAB Setup Success Ratio, QCI1	LTE_5204a
Retainability	E-UTRAN E-RAB QCI1 Drop Ratio, RAN View	LTE_5572a
Mobility	E-UTRAN Inter RAT HO UTRAN with SRVCC Failure Ratio	LTE_5563a
Traffic	Voice traffic	LTE_1067b

ENB EPS bear rel req R QCI1(Radio Network)	ENB EPS bear rel req T QCI1 (Transport Layer)	ENB EPS bear rel req O QCI1(Other)	EPC EPS bear rel req D QCI1(Detach)	EPC EPS bear rel req R QCI1(Radio Network)	EPC EPS bear rel req O QCI1(Other)
M8006C134	M8006C152	M8006C143	M8006C98	M8006C107	M8006C116
77	11	0	0	1	4
121	18	0	2	0	4
307	5	0	3	2	1
733	18	0	4	0	3
189	12	0	8	1	10

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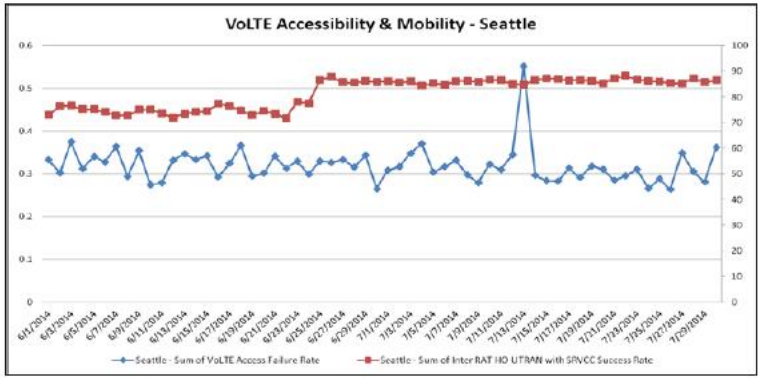
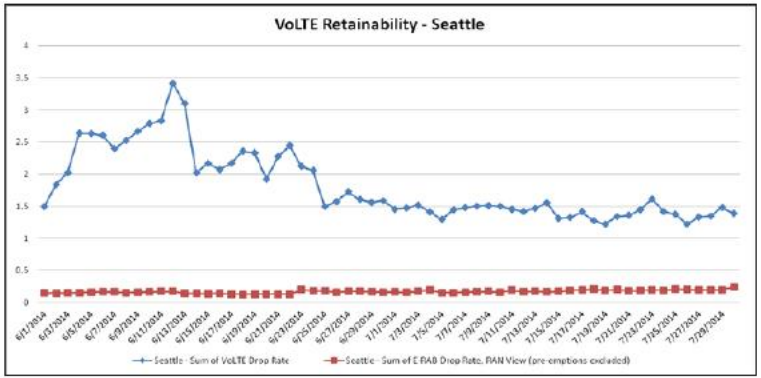
Project Experience -US

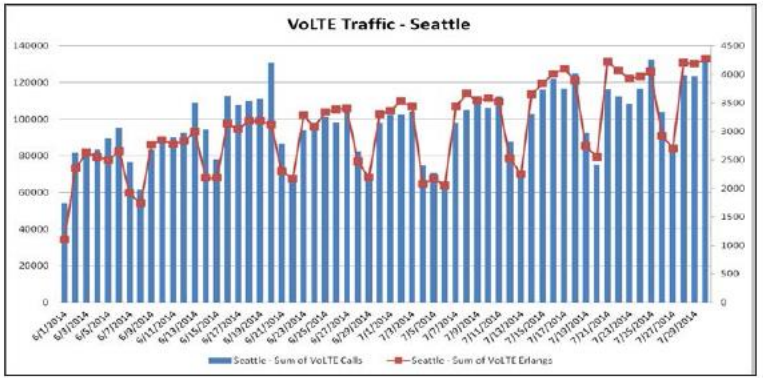
VoLTE OSS KPIs during VoLTE Activation

VoLTE OSS KPIs

- ✓ VoLTE ERAB AFR ~ 0.35%
- ✓ VoLTE Call Attempts ~ 100,000 (Daily Average)
- ✓ VoLTE ERAB DCR ~ 1.5 %
- ✓ UTRAN SRVCC ~ 86 %
- ✓ VoLTE Traffic ~ 3000 Erlang
- ✓ VoLTE Average Call Duration ~ 70 sec







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Drive Test KPIs

VoLTE Field KPIs
KPI references from projects
MOS
Drive Test and Post Processing Tools

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Drive Test KPIs for VoLTE

End User point of view

VoLTE Call Setup Success Rate	Calculated as the proportion of successful VoLTE call setup requests and all call establishment attempts.
VoLTE Call Setup Time	The Post-dial Delay of a VoIP call is defined as the elapsed time between requesting a connection and receiving the first ring tone from the network (SIP INVITE – SIP 180 Ringing). The full Session Setup procedure is defined between requesting a connection by the inviting user and receiving a positive response from the called party (SIP INVITE - SIP 200 OK (INVITE)).
MOS	End-user perceived quality of speech expressed as Mean Opinion Score (MOS). Wide-band MOS scale for wide band and mixed environments according to POLQA.
VoLTE Drop Call Rate	Two alternatives of Drop Rates are defined: Percentage of dropped calls against all successfully established calls. Number of drops per active call duration A VoIP session drops, when the RRC connection of the UE or the dedicated voice bearer is released due to LTE network (radio link or handover) failures

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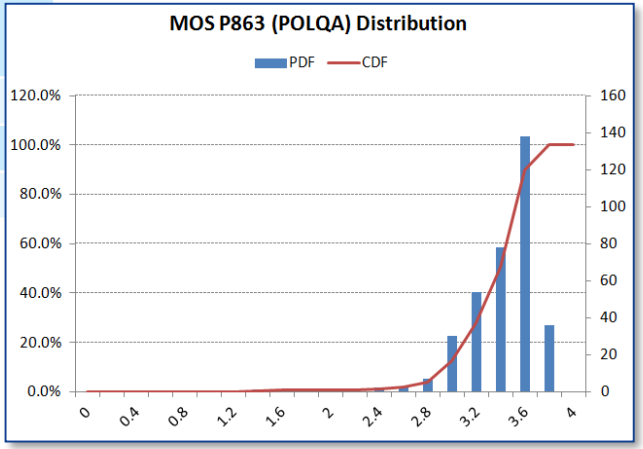
Project Experience Asia
Drive Test KPIs (XCAL)

#	KPI Item	Unit	Result	Remarks
1	RRC Setup Success Rate	%	100%	Short Call
2	Call Setup Time	s	MO – 4.84 * MT - 1.94s	Short Call
3	Drop Call Rate	%	0%	Long Call
4	Handover Success Rate	%	100%	Long Call
	Handover InterruptionTime	s	0.0755 (MO – Tx) 0.1245 (MT – Rx)	Long Call
5	BLER (DL)	%	9.23	Long Call
6	MOS	#	3.33	Long Call
	MOS Jitter Delay	s	0.175	Long Call



* XCAP defines the call setup time from “Call Start” - “Call Connected” internal events

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Project Experience US

VoLTE Drive Test KPIs

KPI
Volte Voice Call Setup Fail Rate
Volte Voice Drop Rate
% of Voice Quality samples < 2
% of CSFB calls
SRVCC Failure rate
VoLTE Handover Failure rate
Average Voice Quality

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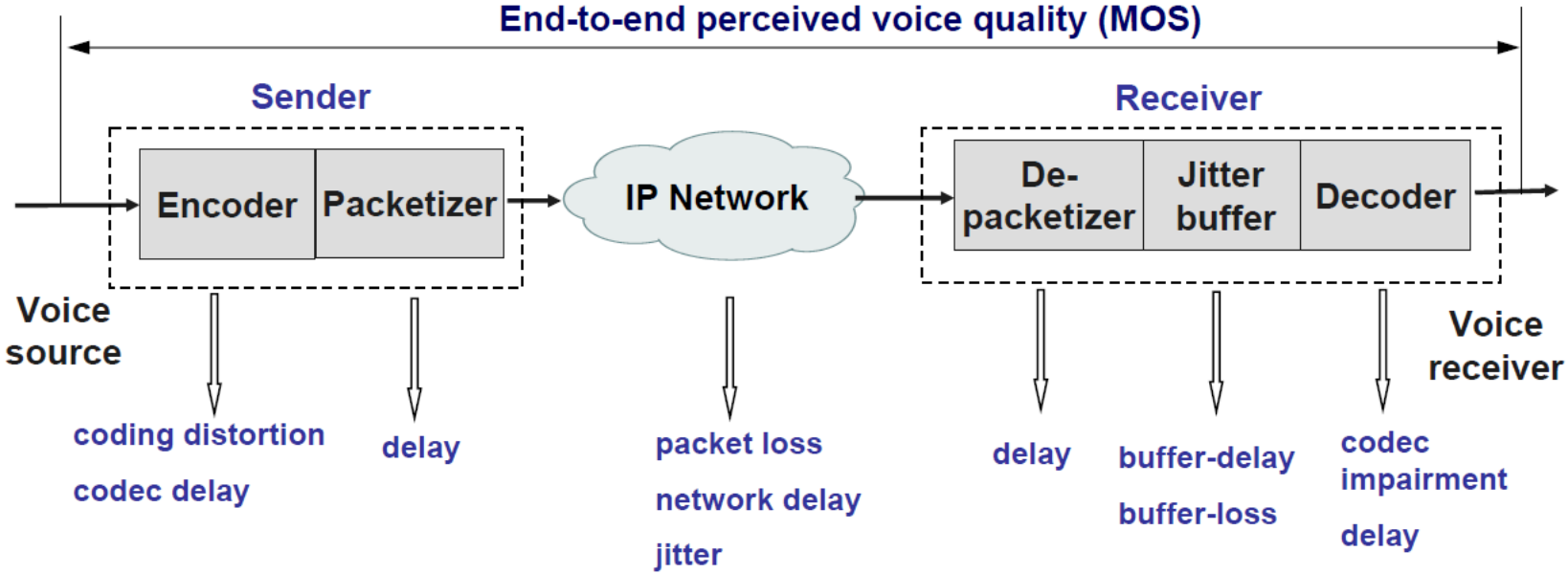
Voice Quality Analysis: MOS



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Voice Quality Measurement Methods

- Perceptual methods (POLQA) try to model the human perception.
  - Transforms the original and degraded speech signals into a psychophysical representation that approximates human perception and maps this into an objective MOS score.
  - E2E delay (mouth-to-ear) is not taken into account by POLQA as a degradation of the speech signal but only delay variations that happen during active speech, i.e. Listening Quality.
- Non-perceptual methods (E-Model with R-Factor) are general physical or technical measures.
  - Combines a number of values measuring the effect of various network impairments such as codec bitrate, jitter, packet loss as well as mouth-to-ear delay which contributes to Conversational Quality.

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What is POLQA?

- POLQA (Perceptual Objective Listening Quality Analysis) is voice quality testing standard for fixed, mobile and IP-based networks that was adopted in 2011 as ITU-T Recommendation P.863 and successor to P.862/PESQ.
  - The POLQA perceptual measurement algorithm is the joint development of OPTICOM, SwissQual, and TNO, protected by copyrights and patents and available under license as software for various platforms.
- POLQA provides strong support for testing of new wideband 4G/LTE networks delivering HD-quality voice services, i.e. wideband and super-wideband speech signals (50–14000 Hz).
- POLQA can handle effects like stretching and compression of speech signals in the time domain, improves the quality prediction for new and old codecs and combines an excellent psychoacoustic and cognitive model with a new time alignment algorithm that perfectly handles varying delays.

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Drive Test Measurement Tools

Note: All Drive Test measurement tools are multivendor

- Nemo Outdoor (Anite)
- TEMS Investigation (Ascom)
- RANAdvisor E6474A (JDSU)
- XCAL (Accuver)

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Drive Test Post-Processing Tools

Note: All Drive Test Post-Processing tools are multivendor

- Actix Analyzer
- Nemo Analyze (Anite)
- TEMS Discovery (Ascom)
- G-Station (JDSU)
- XCAP (Accuver)

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VoLTE Performance

- Coverage Levels and VoLTE
- Capacity and VoLTE
- TTI bundling and VoLTE Performance

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Coverage Levels and VoLTE

RSRP Requirements for VoLTE performance

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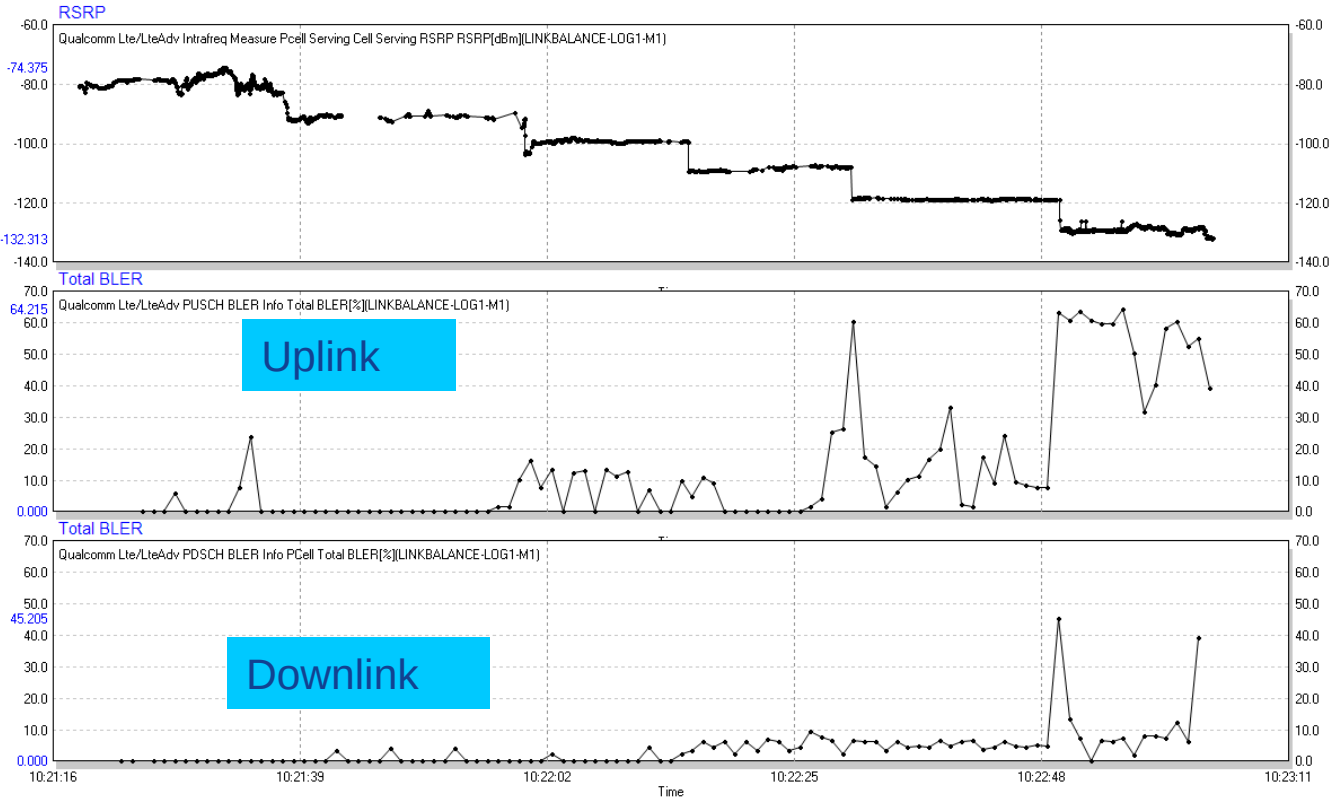
VoLTE Performance

Test in lab environment



Note: RRC Release with Redirection was disabled to avoid controlled release

Uplink BLER increases prior to downlink BLER

Uplink BLER reaches higher rates in poor coverage

RSRP = -110 dBm VoLTE call works well

RSRP= -120 dBm VoLTE works with some performance degradation

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Capacity and VoLTE

Impact in cell throughput capacity and in overall system capacity
Impact in non-GBR traffic

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Capacity impact (cell and system) when introducing VoLTE services
Background

- VoLTE is a GBR (Guaranteed Bit Rate) service impacting overall system capacity and performance due to the higher priority than regular data services.

- Due to the fact that VoLTE is a Guaranteed Bit Rate (GBR) service, it is served before all non-GBR services (such like regular data transmission) – that causes less scheduling occasions for non-GBR services leading to average cell throughput degradation.

- Next slide show (based on simulations) the impact of VoLTE in cell throughput capacity and in overall system capacity.

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VoLTE users per cell vs. Cell Throughput

Simulation (MORSE) results

Source: MoRSE simulations from NetEng

- KPI trends when number of VoLTE UEs increases from 10 to 375 per cell. Baseline configuration, mean values:

TP: Throughput

		Downlink				Uplink			
Baseline		**10 UEs**		**375 UEs**	**change**	**10 UEs**		**375 UEs**	**change**
Total Cell TP	**Mb/s**	15,1	↘	7,3	-52%	5,4	↘	3,8	-30%
Non-GBR TP	**Mb/s**	15,0	↘	4,6	-69%	5,3	↘	1	-81%
VoIP TP	**Mb/s**	0,1	↗	2,7	+2600%	0,1	↗	2,7	+2600%
Packet aggregation	**#**	1,0	↗	1,4	+40%	2,0	↗	2,2	+10%
Packet delay	**ms**	3,7	↗	15,2	+311%	23,1	↗	24,5	+6%
Lost VoIP packets	**%**	0,05%	↗	0,11%	+0,06pp	0,08%	↗	0,34%	+0,26pp

Total cell TP decreases due to non-GBR TP decreases.

Non-GBR TP decreases because more VoLTE UEs are in the cell, have higher prio and require more resources.

More UEs, more TP.

Higher VoIP (VoLTE) load, higher congestion probability, higher aggregation to avoid packet lost.

Higher VoIP (VoLTE) load, higher congestion probability, higher packet delay.

Higher VoIP (VoLTE) load, higher congestion probability, higher probability of lost VoIP packets.

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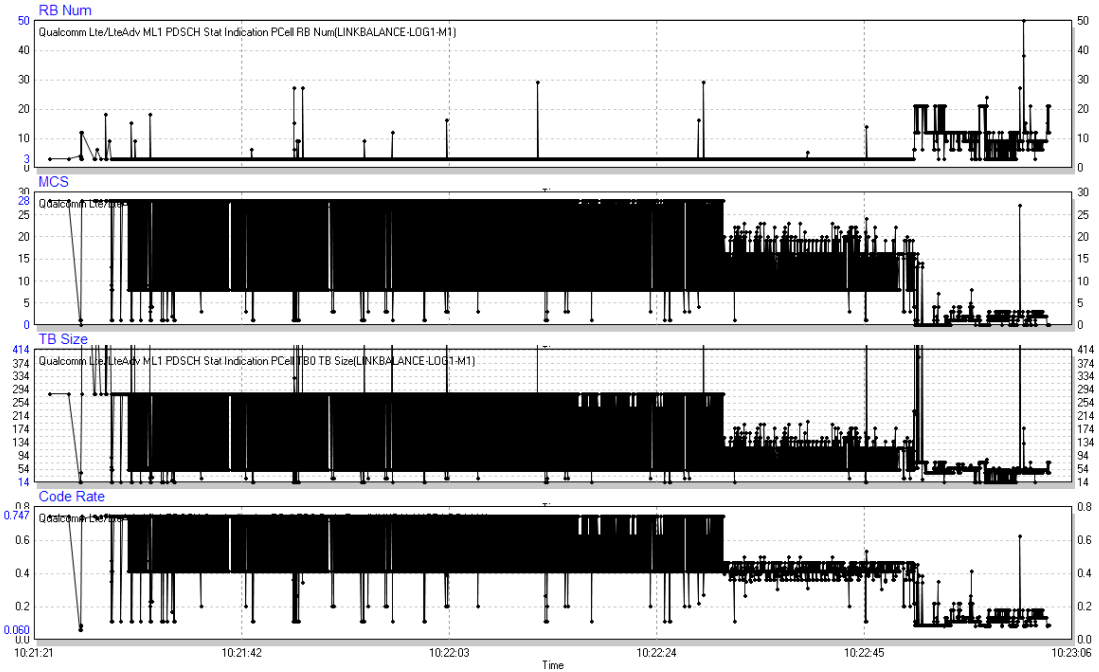
Possible impact for Non-GBR user throughput by VoLTE User

Capacity Impact

Coverage of data services because GBR is given priority by the scheduler: there are fewer RB available for non-GBR.

Cell edge data users will have fewer Resource Blocks: less throughput



1 RBG allocated until MCS is reduced to minimum When RSRP become -120dBm

MCS steps down as the coverage becomes weaker

Transport Block size is determined by combination of Resource Blocks and MCS

Redundancy is increased as the coverage becomes weaker, i.e. coding rate decreases

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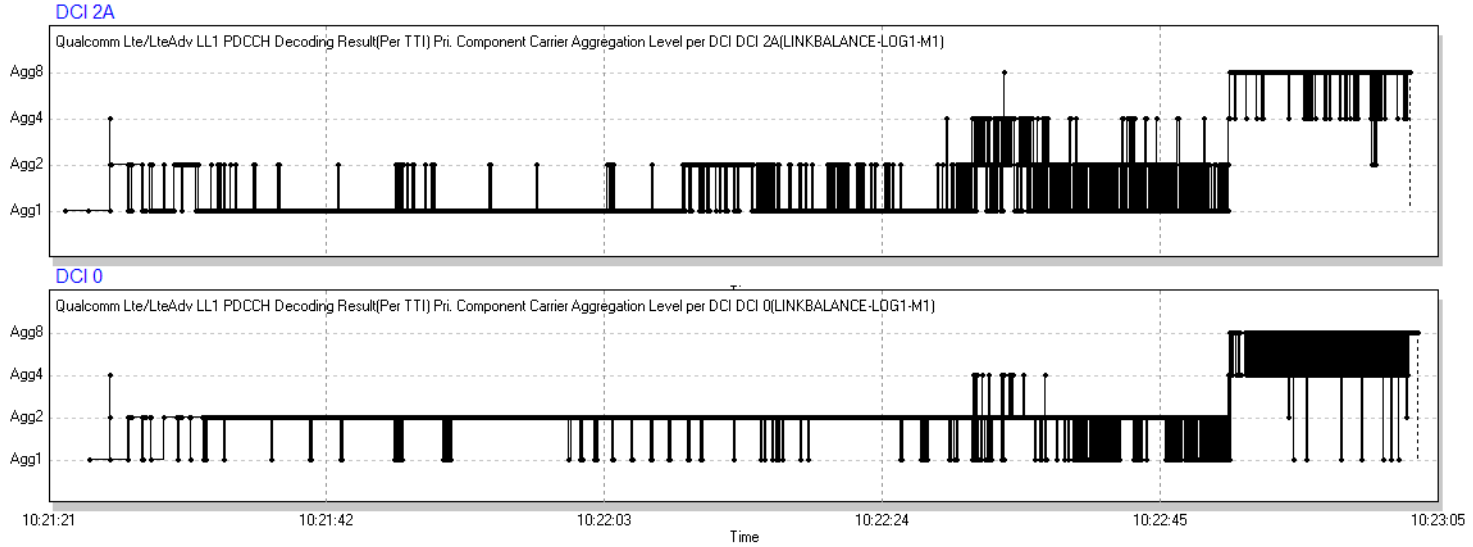
Possible impact for Non-GBR user throughput by VoLTE User

Capacity Impact

VoLTE Users steal PDCCH capacity from data users-it may not be possible to use the same higher aggregation levels for data connections towards cell edge



- **DCI Format 2A is used for downlink resource allocations - small payload size allows use of aggregation level 1 in good coverage**
- **DCI Format 0 is used for uplink resource allocations - requires aggregation level 2 in good coverage**

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TTI Bundling and VoLTE Performance

RSRP and MOS with/without TTI Bundling
TTI Bundling impact on DCR

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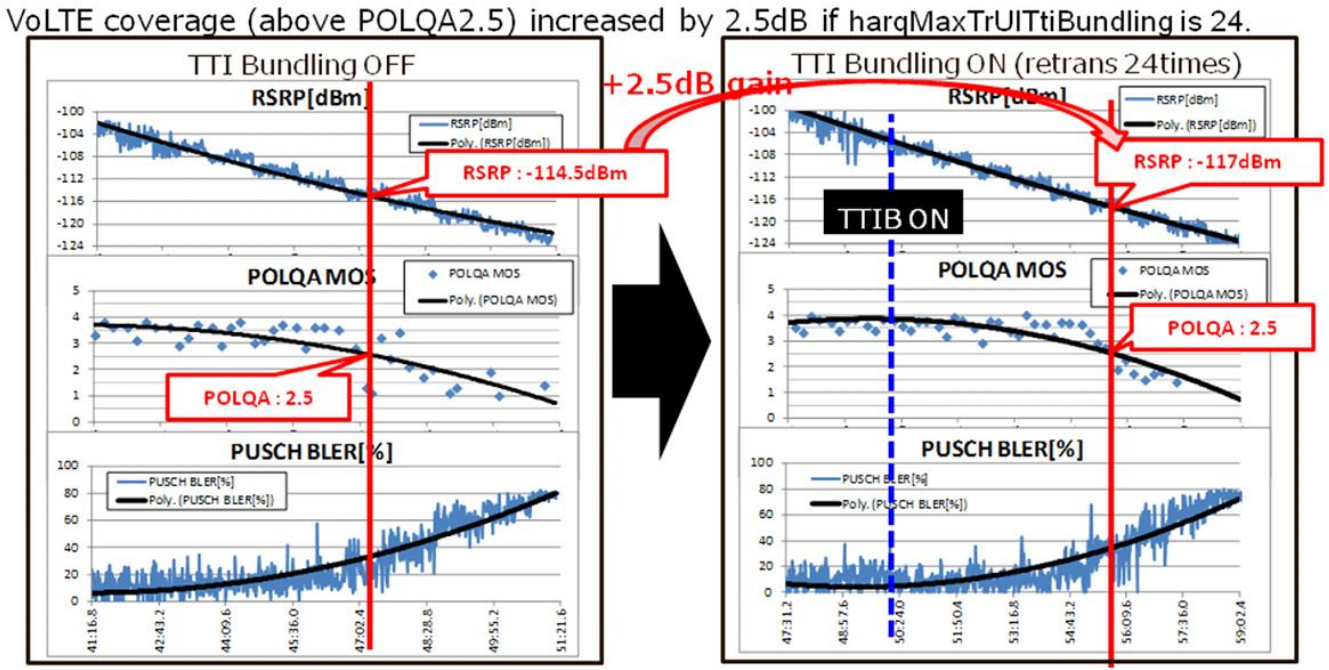
Relationship between RSRP and MOS with and without TTI Bundling

Acceptable voice quality is assumed to be above MOS 2.5

- With TTI Bundling the RSRP level will go down to -117dm, i.e. 2.5 dB gain achieved with TTIB.
- TTI Bundling HARQ was set to 24 instead of default 12.



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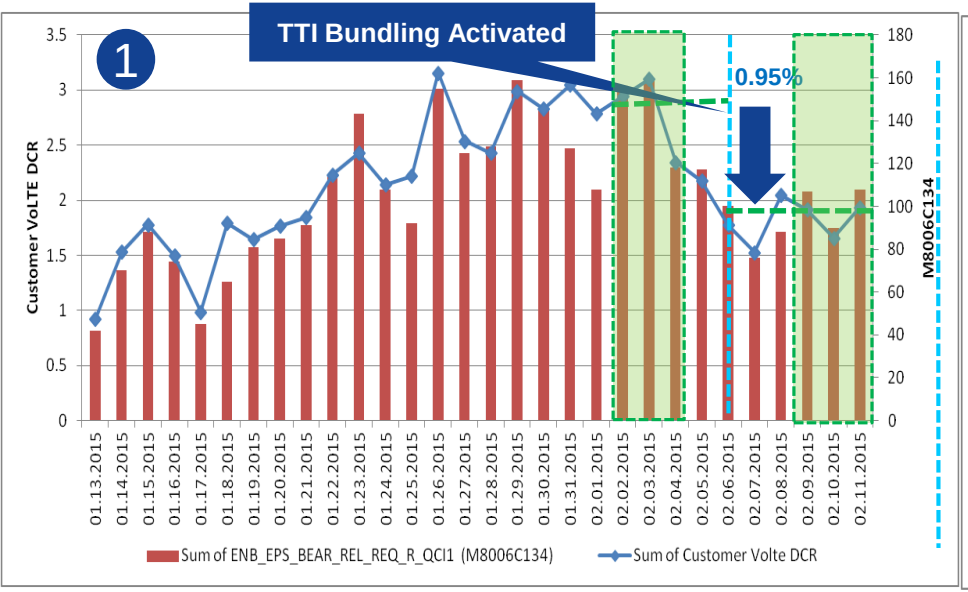
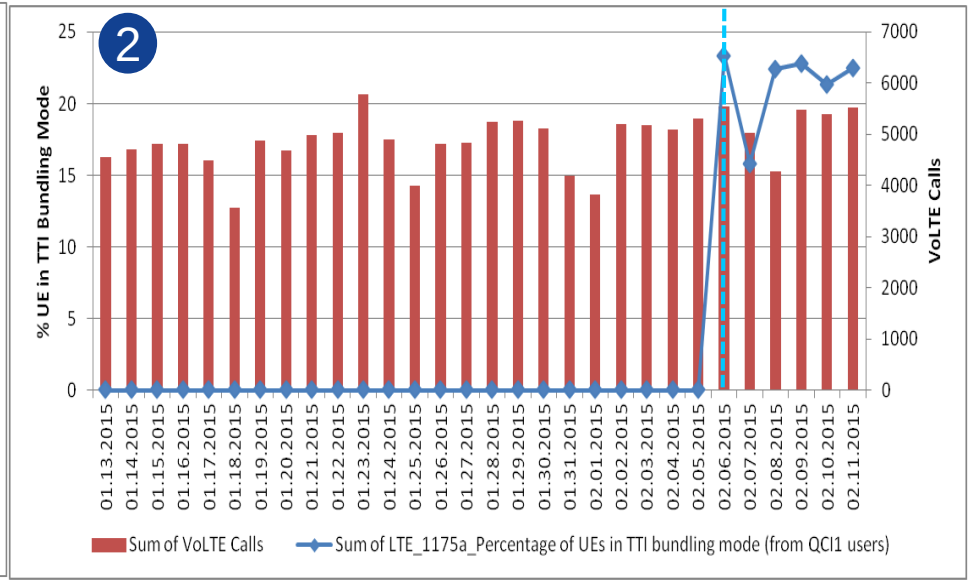
TTI Bundling Impact for CDR

Highest VoLTE Traffic Site ‘X’ Performance





1. 0.95% improvement in customer VoLTE DCR after TTI Bundling activation
2. This improvement resulted from high % of UE in TTI bundling mode and high traffic of VoLTE calls

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