VoLTE Radio Training Part II

- GS NPO Capability Creation

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- VoLTE Assessment and Optimization
    - Parameter Assessment
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            - MOS
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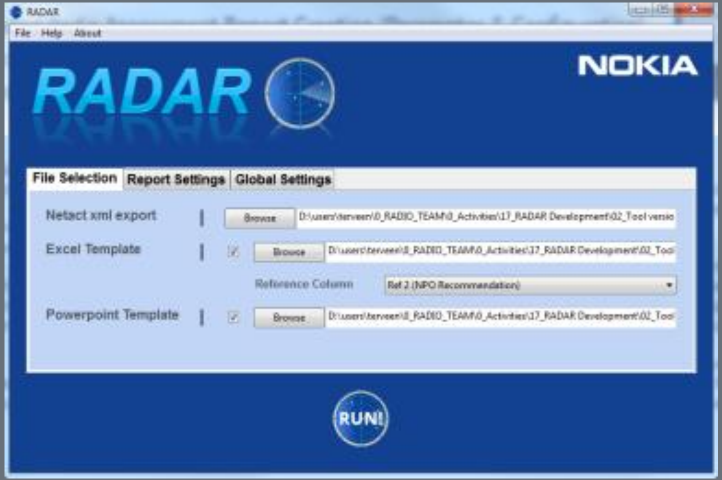
    - Project leanings

VoLTE Assessment and Optimization

- Parameter Assessment
- Performance Assessment

VoLTE Parameter Assessment

- RADAR



Radio Assessment Reporting Tool (RADAR)

Description: Automated Radio Assessment Report Creation (Parameter & Configuration)

Automation: One click analysis & report creation including charts, tables & standard text

Supported technologies: GSM, UMTS, LTE

Main use case(s):

- NPO Radio Assessment Service report creation (Parameter & Configuration) by GSD and CO
- Standardized Assessment Reporting
- Comparison of parameter values (actuals) vs. target values & ranges
- Parameter consistency checks
- Parameter Distribution creation
- Parameter Chart creation
- Neighbor checks
- Activated Feature list creation
- Parameter delta comparison of 2 xml files

Interfaces (tool chain):

Input:

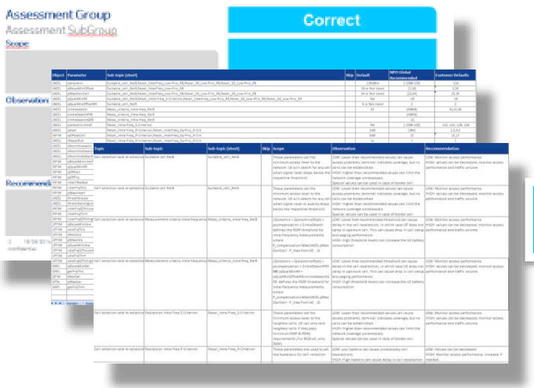
- Netact XML raml2 export file, Excel template with parameter rules, PPT report template, site list with coordinates

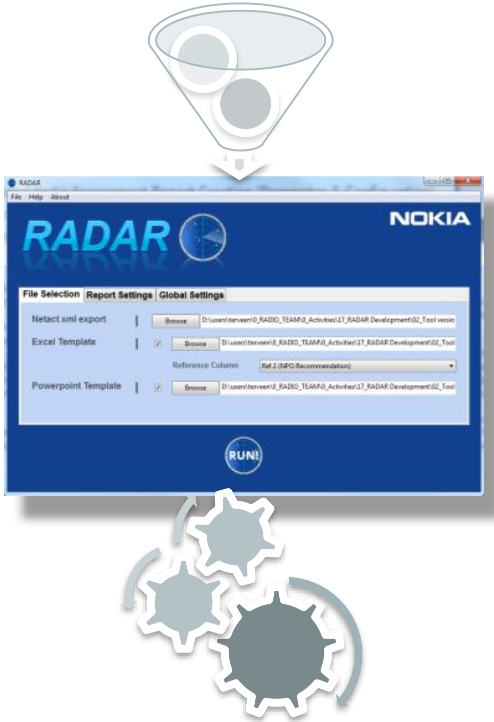
Output:

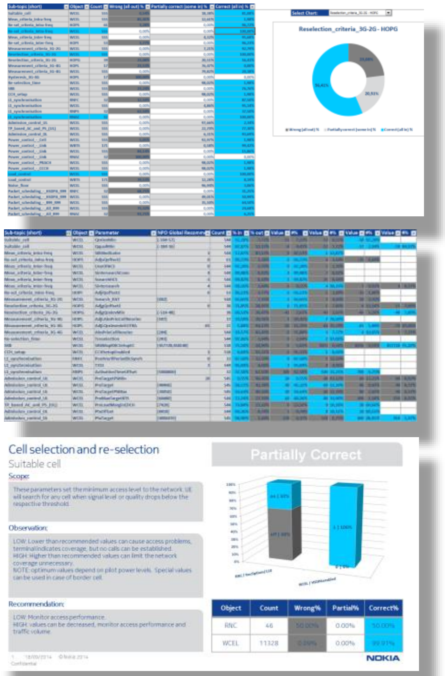
- Complete Power Point report according to given template, imported rules set & chapter definition
- Comprehensive Excel Spreadsheet showing Parameter inconsistencies distributions , graphs & tables
- HW & SW Configuration Summary
- Netact correction XML file
- Google Earth visualization of sites and issues

Radio Assessment Reporting Tool (RADAR)

Excel Import File & PPT	Easy to handle GUI	Various Output Reports







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VoLTE Parameter Assessment

VoLTE Module in RADAR

- RADAR can be used for VoLTE Parameter Assessment
- Compare the VoLTE current network parameter list with
  - Default parameter set
  - NPO Global parameter set
  - Customer default parameter set
- Identify the parameter deviations
- Identify the missing parameter values, deviations etc,
- Experts view in parameter assessment

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VoLTE Module in RADAR

How the module has been done

- Created VoLTE sub-topics to cover all the VoLTE related parameters/ features
- Map all the VoLTE related parameters under the sub-topics
  - One parameter may be under more than one subtopic
- Each subtopic populates one output slide (report), that contains
  - Scope
  - Observation
  - Recommendation + **Expert view**
- If needed user can edit the input file

VoLTE Module in RADAR

VoLTE Sub-Topics

- V_Act : VoLTE Activation
- AC : Admission Control
- Sche : Scheduler Related
- QCI1_Tcheck: QCI 1 Table Check
- QCI5_Tcheck: QCI5 Table Check
- PCDP_P1_C: PDCP Profile 1 Check
- PCDP_P101_C:PDCP Profile101 check
- RLC_P1_C: RLC Profile 1 Check
- RLC_P101_C: RLC Profile 101 Check
- DRX_P2_C: DRX Profile 2 Check
- DRX_P3_C: DRX Profile 3 Check

- RoHC: Robust Header Compression
- UpPaSeg: Uplink Packet Segmentation
- TTI_B: TTI Bundling
- Packet_Agg: Packet aggregation
- Eme_CH: Emergency Call Handling
- SRVCC_3G: SRVCC to 3G network
- SRVCC_2G: SRVCC to 2G network

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Mapping between parameters and Sub-topics

Object	Parameter	Sub-topic(short)	Skip	Default	NPO Global Recommended	Customer Defaults
LNBTS	rlcProf101tReord	RLC_P101_C		10	50	
LNBTS	tS1RelPrepU	SRVCC_3G		2000	2000	
LNBTS	actMultGbrBearers	V_Act		0	0	
LNBTS	maxNumPreEmptions	AC		20	20	
LNBTS	timDelACContPreempt	AC		100	100	
LNBTS	actIMSEmerSessR9	Eme_CH		0	0	
LNBTS	imsEmerPlmnConfig/0/emerSessLimServ	Eme_CH		0	0	
LNCEL	addEmergencySessions	Eme_CH,AC		70	70	
LNBTS	actSrvccToWcdma	SRVCC_3G		0	1	
LNBTS	actHOtoWcdma	SRVCC_3G		0	1	
LNRELW	srvccAllowed	SRVCC_3G		0	0	
LNRELW	psHoAllowed	SRVCC_3G		0	0	
LNCEL	threshold2Wcdma	SRVCC_3G		25	25	

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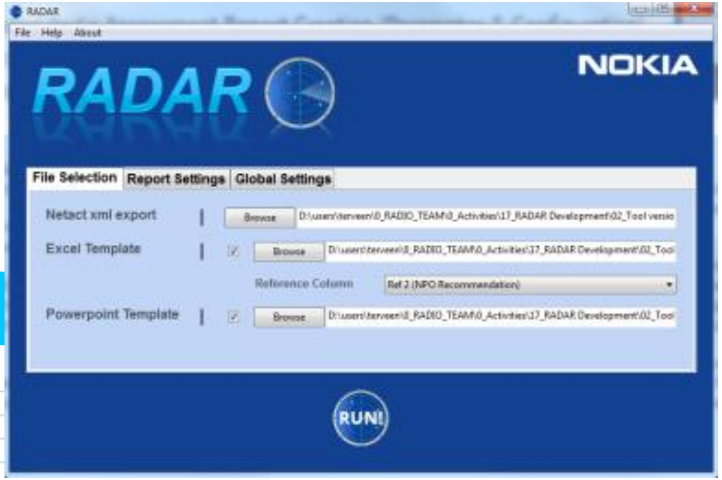
Scope , Observation and Recommendation
Experts view

Sub-topic(short)	Skip	Scope	Observation	Recommendation
V_Act		These are the basic parameters required to enable VoLTE in the network.	Features are correctly activated/not activated. Cells showing values of actConvVoice=0 or actMultBearers=0 will not have VoLTE activated	It is mandatory both parameters are set to 1 for VoLTE support.
AC		This is used to control the VoLTE users and GBR traffic during Admission Control phase	These parameters configure correctly/not	There parameters need to adjust according to the operator requirement as well as # of VoLTE users in the network.addGbrTrafficRrHo/addGbrTrafficTcHo should be configured significantly lower than parameter maxGbrTrafficLimit so HO traffic does not preempt other low priority traffic inmmediately with next cell local admission requests.
Sche		This will decide the optimize resource allocation according radio conditions, available resources ect	These parameters configure correctly/not	ulsMinTbs limits the segmentation level to avoid situations of many small packets to be retransmitted. The lower the value, the more robust MCS can be used but more radio resources are consumed due to increased RLC/MAC overhead. **harqMaxTrUlTtiBundling:** Transmissions in TTI bundling mode consist of 4 consecutive TTIs therefore possible values of the parameter are multiple of 4
QCI1_TCheck		QCI1 Table defines characteristics of GBR used for VoLTE. Parameters need to be correctly configred otherwise VoLTE will not work.	Features are correctly activated/not activated. qciTab1maxGbrDl/ qciTab1maxGbrUl parametesr controls GBR QCI1 . In addition,PCRF also controls the GBR rate for QCI1 from the Core Network	Rule: maxGBR on eNodeB must be equal or higher than PCRF GBR setting. It can be set with maximum value in case unknown value from Core Network. In low loaded systems when VoIP is small and PackeAggregation can be disabled, delayTarget can be reduced for better user experience (lower delay) i.e. Packet aggregation is effectively disabled with 50ms delaytarget value due to tighter scheduling window and thus, less VoLTE users can be supported.

Output slide



VoLTE Feature

Uplink Packet Segmentation

Scope:

Uplink scheduler is able to control the lower limit of PRBs allocated to a UE according to a minimum packet segment size and its channel condition.

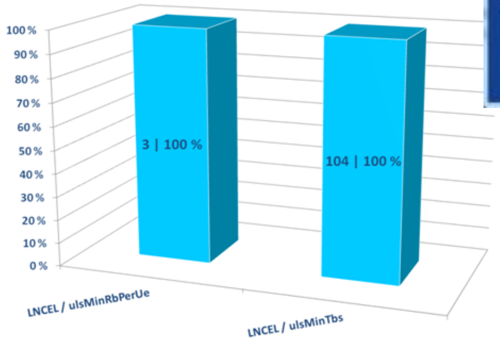
Observation:

The lower the segmentation level, the more robust MCS can be used but more radio resources are consumed due to increased RLC/MAC overhead.

Recommendation:

This improve the end user performance at cell edge, which in turn improve user experience.

Correct



Object	Count	Wrong%	Partial%	Correct%
LNCEL	445	0.00%	0.00%	100.00%

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Analysis using excel -output

Identification of problematic parameters

Sub-topic (short)	Object	Parameter	NPO Global Rec	Count #	Deviation #	% in	% out				
TTI_B	LNCEL	ttiBundlingBlerTarget	12	445	0	100.00%	0.00%	12	100.00%		
TTI_B	LNCEL	ttiBundlingBlerThreshold	15	445	445	0.00%	100.00%	12	100.00%		
TTI_B	LNCEL	ttiBundlingSinrThreshold	10	445	444	0.22%	99.78%	10	0.22%	50	99.78%
TTI_B	LNCEL	ulamcAllTbEn	1	445	0	100.00%	0.00%	1	100.00%		
TTI_B	LNCEL	ulTargetBler	10	445	3	99.33%	0.67%	5	0.67%	10	99.33%
Packet_Agg	LNBTS	ulsMaxPacketAgg	2		0	100.00%	0.00%				
Packet_Agg	LNCEL	actDlsVoicePacketAgg	1	445	0	100.00%	0.00%	1	100.00%		
Eme_CH	LNBTS	actIMSEmerSessR9	0	164	0	100.00%	0.00%	0	100.00%		
Eme_CH	LNBTS	imsEmerPlmnConfig/0/emerSessLimServ	0		0	100.00%	0.00%				
Eme_CH	LNCEL	addEmergencySessions	70	445	0	100.00%	0.00%	70	100.00%		
SRVCC_3G	LNBTS	actConvVoice	0	164	164	0.00%	100.00%	1	100.00%		
SRVCC_3G	LNBTS	tS1RelPrepU	2000	164	8	95.12%	4.88%	500	4.88%	2000	95.12%
SRVCC_3G	LNBTS	actSrvccToWcdma	1	164	0	100.00%	0.00%	1	100.00%		
SRVCC_3G	LNBTS	actHOtoWcdma	1	164	0	100.00%	0.00%	1	100.00%		
SRVCC_3G	LNRELW	srvccAllowed	0	10502	0	100.00%	0.00%	0	100.00%		
SRVCC_3G	LNRELW	psHoAllowed	0	10502	0	100.00%	0.00%	0	100.00%		
SRVCC_3G	LNCEL	threshold2Wcdma	25	445	445	0.00%	100.00%	27	100.00%		

Info | Groups | **Parameter** | Deviations | Inconsistencies | Worst | Missing_xml | Missing_template | Not_imported_xml | Features | WBTS

lter Mode

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Find inconsistencies/missing parameters- output

Sub-topic (short)	Object	BTS	Cell	distName	Parameter	actual_Value	new_Value
TTI_B	LNCEL	75760	19394573	PLMN-PLMN/MRBTS-75760/LNBTS-75760/LNCEL-13	eUlLaLowMcsThr	4	1
SRVCC_2G	LNCEL	75760	19394573	PLMN-PLMN/MRBTS-75760/LNBTS-75760/LNCEL-13	threshold2GERAN	32	23
SRVCC_3G	LNCEL	75760	19394573	PLMN-PLMN/MRBTS-75760/LNBTS-75760/LNCEL-13	threshold2Wcdma	27	25
TTI_B	LNCEL	75760	19394573	PLMN-PLMN/MRBTS-75760/LNBTS-75760/LNCEL-13	ttiBundlingBlerThreshold	12	15
TTI_B	LNCEL	75760	19394573	PLMN-PLMN/MRBTS-75760/LNBTS-75760/LNCEL-13	ttiBundlingSinrThreshold	50	10
TTI_B	LNCEL	75772	19397643	PLMN-PLMN/MRBTS-75772/LNBTS-75772/LNCEL-11	actUlLnkAdp	5	eUlLa
AC	LNCEL	75772	19397643	PLMN-PLMN/MRBTS-75772/LNBTS-75772/LNCEL-11	addNumQci1DrbRadioReasHo	40	16

Info | Groups | Parameter | Deviations | **Inconsistencies** | Worst | Missing_xml | Missing_template | Not_importe

Object	Parameter
LNBTS	ulsMaxPacketAgg
LNBTS	imsEmerPlmnConfig/0/emerSessLimServ
LNADJG	dtm
LNRELG	srvccAllowed
LNHOG	b2Threshold1GERAN

Info | Groups | Parameter | Deviations | Inconsistencies | Worst | **Missing_xml** | Missing_template | Not_importe

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VoLTE Performance Assessment and Optimization

Capacity Assessment and Optimization
Network Coverage, Quality and Mobility Assessment and Optimization

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Capacity Assessment

VoLTE services and Network Capacity

Physical Channels Capacity:

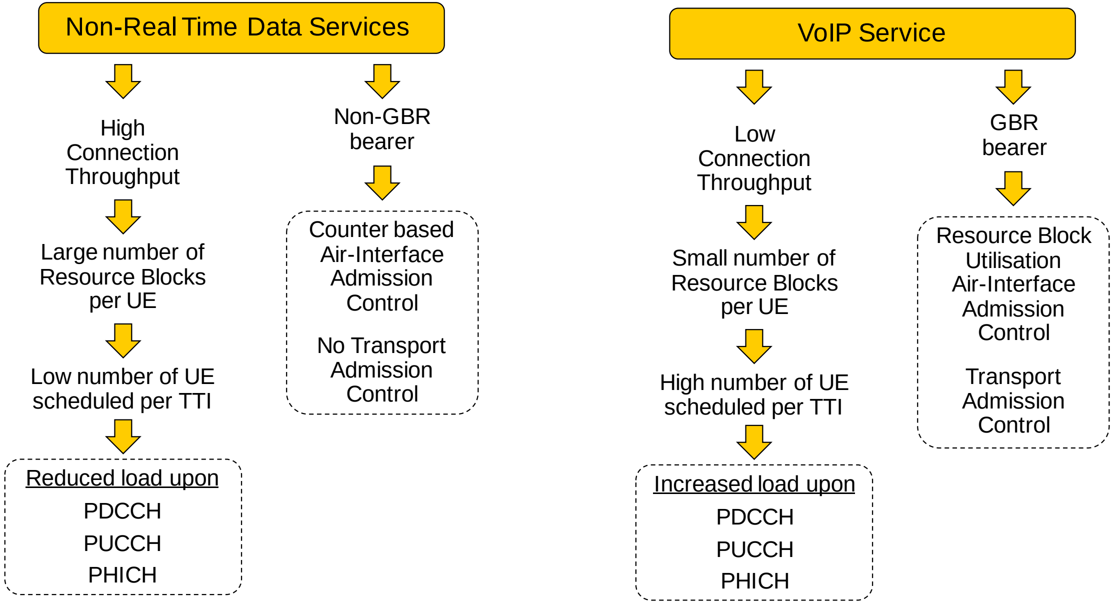
- PDCCH
- PUCCH
- Paging
- PDSCH
- PUSCH

Wrap-up

VoLTE Services impact in Network Capacity

Background

- VoLTE services bring a large number of low throughput real time users to the network. This increases the requirements upon some aspects of network capacity.



Increasing load in Physical Channels

Maximum number of VoLTE users within a cell

- The maximum number of VoLTE users within a cell can be limited by the PDCCH, PDSCH, PUSCH, PHICH or PUCCH.
- The relatively low throughput requirements VoLTE are not a threat for shared channels (PDSCH / PUSCH) capacity.
- Paging load play a important roll due to CSFB when the LTE coverage is poor
- LTE NPO Capacity Solutions document analyses the impact of VoLTE capacity (max. Number of VoLTE connections) for all the above channels. Table below summarizes the results.

Max. number of VoLTE connections per cell

	Channel Bandwidth					
	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
PDCCH	51	51	104	207	337	441
PDSCH	55	120	216	432	560	720
PUSCH	45	135	225	495	750	1035
PHICH	1920	1920	1920	1920	1920	1920
PUCCH	120	120	240	360	480	480
Limiting Channel	PDCCH / PUSCH	PDCCH	PDCCH	PDCCH	PDCCH	PDCCH

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Increasing load in Physical Channels

Maximum number of VoLTE users within a cell

- Based on previous table, PDCCH is limiting the capacity for all channel bandwidths. For 1.4MHz PUSCH channel can also limit the VoLTE capacity.

- Number of VoLTE users that can be supported by PDCCH can also be calculated using:
  - RAN Dim Tool: ‘Expert LTE tab’ -> Calculate VoIP Capacity
  - VoIP PDCCH capacity calculator tool (MBB NetEng):

VoIP PDCCH
capacity calculator

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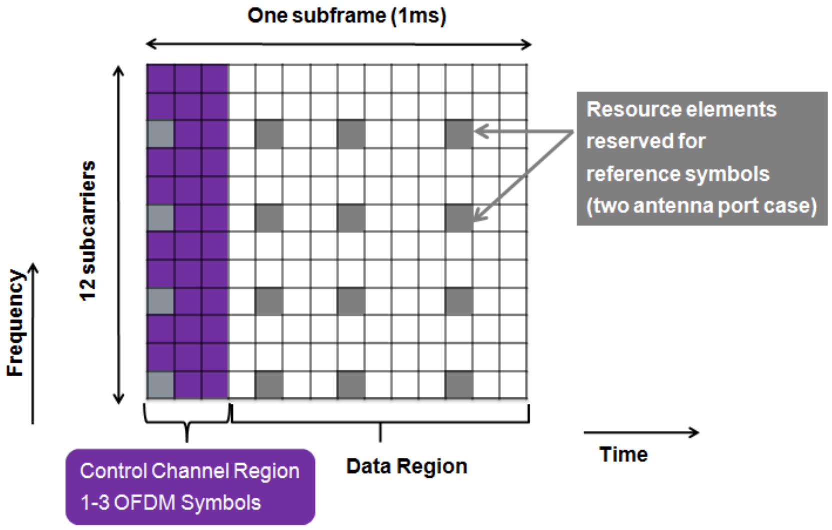
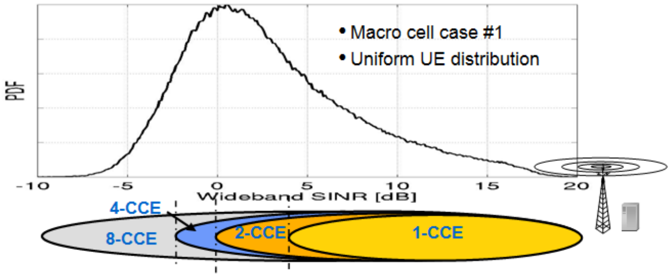
Other factors affecting VoLTE Capacity

- License for number of simultaneous bearers
- VoLTE dedicated bearer license
  - VoLTE capable handsets will add default IMS bearers (QCI5) and once VoLTE call is setup dedicated (QCI1) bearers are created as well and thus, license capacity needs to be proactively monitored and upgraded before capacity is exceeded.

PDCCH Configuration & Capacity

- PDCCH is used to transfer DCI (Downlink Control Information) for the scheduling of downlink resources on PDSCH and UL resources on PUSCH.
- 1-3 PDCCH symbols in the beginning of each sub-frame (1ms) can be dynamically adjusted based on the load (# of scheduled users) and radio conditions.





Bandwidth (MHz)	1.4	3	5	10	15	20
# of PRBs	6	12	25	50	75	100
PDCCH Symbols - 1	x	2	5	10	15	20
PDCCH Symbols - 2	2	6	13	26	40	54
PDCCH Symbols - 3	4	10	21	43	65	87
PDCCH Symbols - 4	6	x	x	x	x	x

Optimising PDCCH Capacity

- In order to be able to support higher number of users it is necessary to upgrade and optimise the PDCCH channel so it does not become a bottleneck. Possible actions include:
  - Activate usage based PDCCH Adaptation (LTE616)
  - Enable Packet Aggregation (if not already enabled)
  - Decrease PDCCH load with RL50 TTI bundling feature (applied for GBR and non-GBR bearers)
  - Optimise via parameters the PDCCH aggregation level for different types of resource allocation (system information, paging, random access, user plane resources)
  - Optimise via parameters the PDCCH outer loop link adaptation, the allocation share between uplink and downlink resource allocations or using a scaling factor for PDCCH load

VoLTE Channel Capacity Assessment
OSS KPI Analysis

Item	KPIs	Assessment
PDCCH	• LTE_1085B: 3 OFDM symbol utilization • LTE_1155a: CCE blocking ratio • LTE_xx: CCE utilization	• PDCCH blocking causes **delays on VoIP packet scheduling** . • High aggregation level (8 CCEs) share might indicate poor radio coverage or high interference, i.e. **less VoLTE users can be supported** due to lack of PDCCH resources.
PUCCH	• LTE_5231b: E-UTRAN RRC Connection Setup Failure Ratio per Cause RRMRAC • LTE_1147a: Average number of Connected UE per cell	• Insufficent PUCCH resources may result maximum channel quality indicator (CQI) or maximum scheduling request (SR) capacity to be exceeded in terms of maximum connected users which will lead to the **Admission Control rejection** – **VoLTE call setup failure** in a cell. • The admission control checks the **PRB utilisation for GBR connections** (Smart Admission Control).
Paging	• M8008C1: RRC Paging requests • M8008C2: Discarded RRC Paging requests • LTE_5031b E-UTRAN RRC Paging Discard Ratio	• Paging capacity must be sufficient to support VoLTE traffic (or CSFB). • Discarded RRC pagings (M8008C2) **increase VoLTE call setup time** due to re-paging delay. • S1 paging load - port scanning attack can cause SGWs to send high number of downlink data notifications .

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VoLTE Channel capacity Assessment
OSS KPI Analysis

Item	KPIs	Assessment
PDSCH	• LTE_5276b: E-UTRAN average PRB usage per TTI DL • LTE_410a: Percentage of Retransmitted Traffic DL_SCH	• Resource Block Group (RBG) size, AMR codec (RoHC) and radio conditions determine the number of DL **PRBs allocated for VoLTE transmission**. • HARQ retransmissons introduces **delays on VoIP packet transmissions.** • Admission Control threshold is based on DL **PBR utilisation of GBR connections**.
PUSCH	• LTE_409a: Percentage of Retransmitted Traffic UL_SCH • LTE_1073a: % Average UE power headroom for PUSCH • LTE_5273b: Average PRB usage per TTI UL	• Radio conditions and AMR codec (RoHC) determine the number of UL **PRBs allocated for VoLTE transmission**. • HARQ retransmissons introduces **delays on VoIP transmissions**. • Admission Control threshold is based on UL **PBR utilisation of GBR connections**. • UL power control settings has impact on capacity and **cell-edge VoLTE user performance**.

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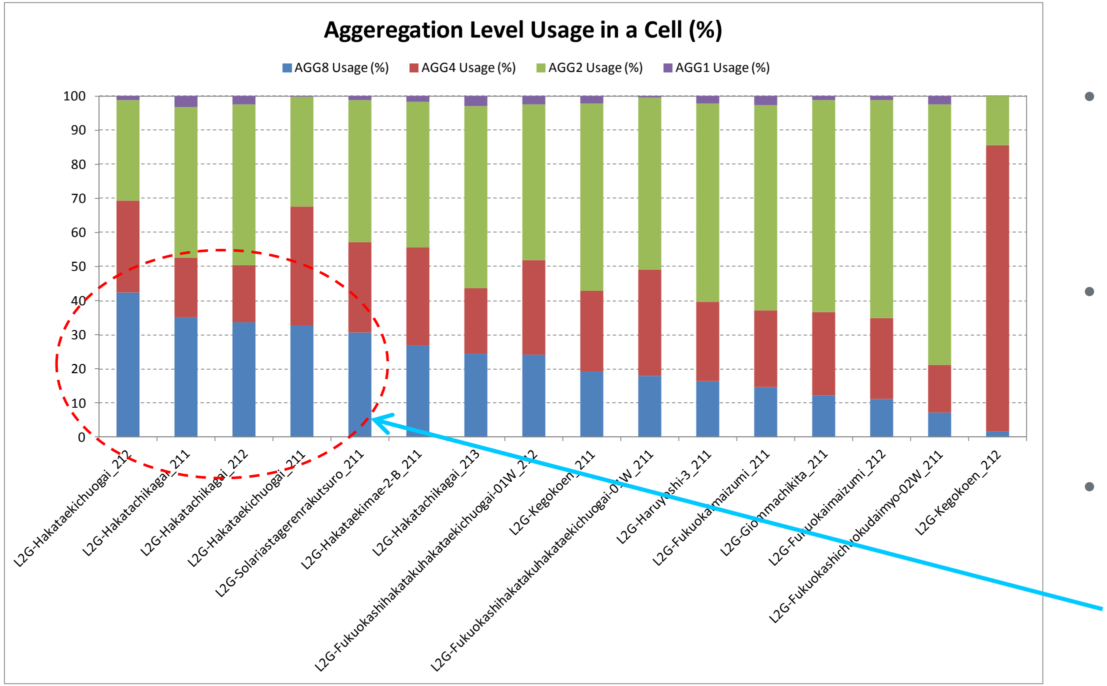
Channel Capacity Assessment: PDCCH



- PDCCH resources are aggregated in groups of 1, 2, 4 and 8 CCEs.
- UE in poor radio coverage will require 8 CCE for each PDCCH transmission where as UE in good radio conditions may need 1 CCE.
- The higher aggregation level provides more robust PDCCH transmission but has also a **higher blocking** probability due to limited PDCCH resources.
- The high share of aggregation level 8 usage in a cell might indicate that **users are experiencing poor radio coverage or interference.**

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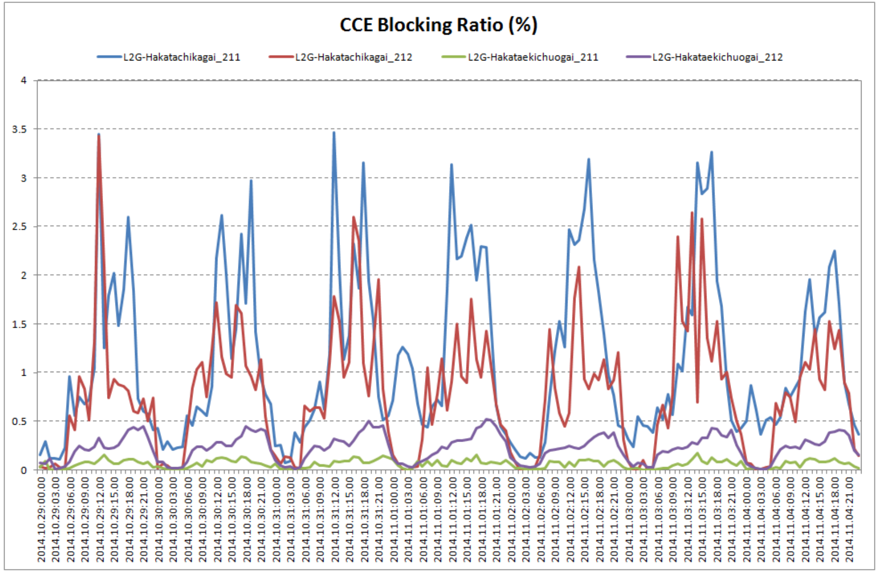
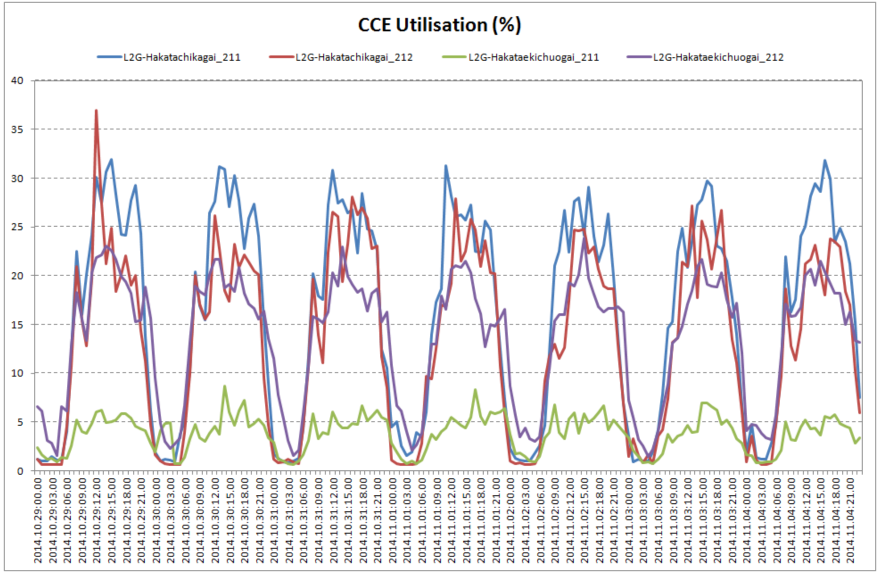
PDCCH: CCE Blocking vs. CCE Utilization





- In case of PDCCH scheduling is blocked then users will be scheduled in a later subframes but this causes higher latency for VoLTE users and data throughput reduction for non-GBR users.
- The Hakatachikagai site is experiencing the highest CCE blocking and utilization also due to less PDCCH resources on 10 MHz bandwidth.

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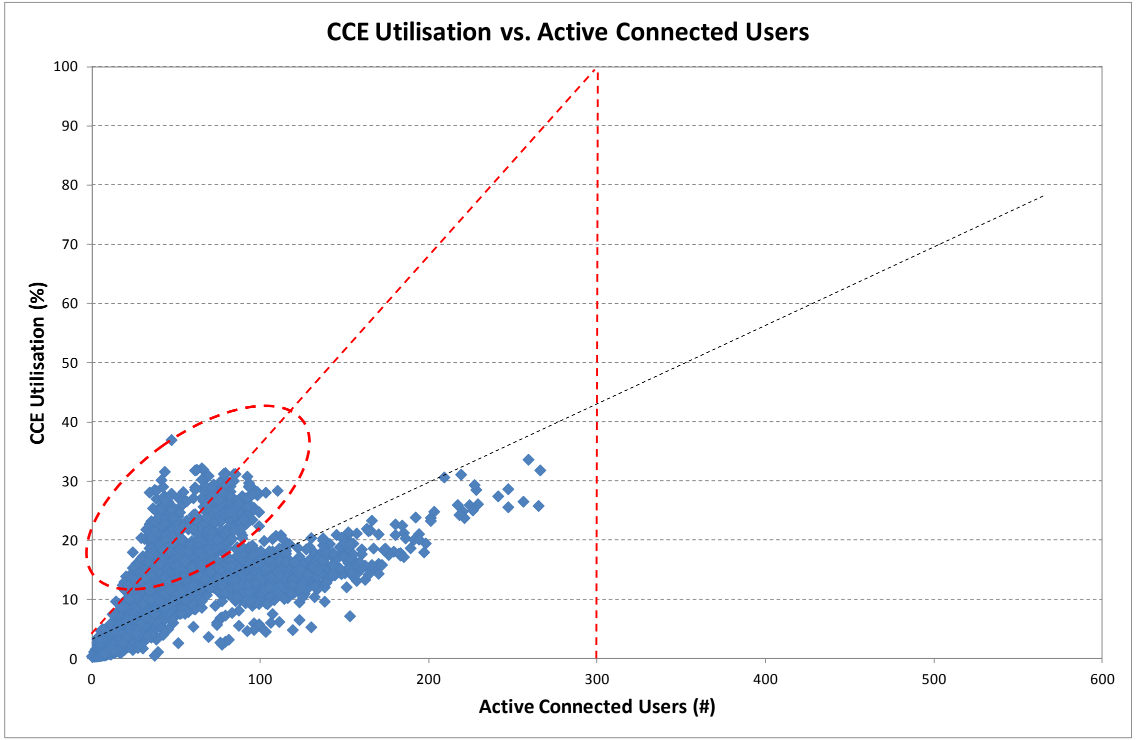
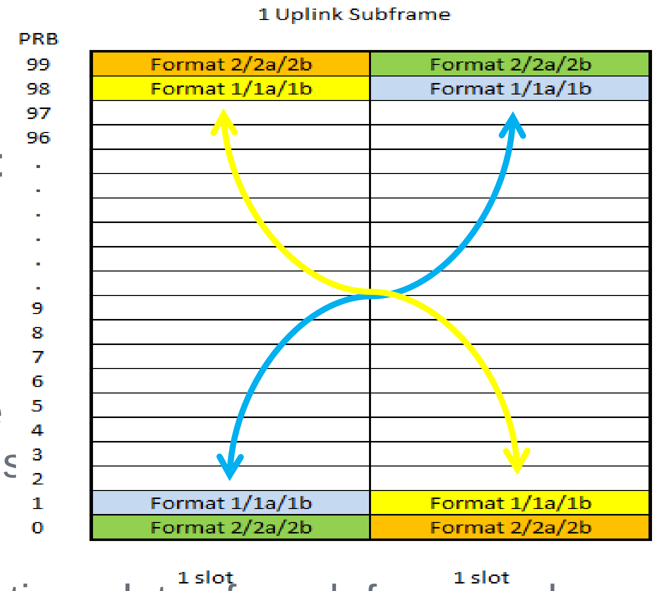
PDCCH: Scheduled Users Limited by PDCCH



- Each VoLTE user requires PDCCH resources for both UL and DL directions in every 20ms and VoLTE (GBR) users are scheduled before all non-GBR services
- The high CCE utilisation due to poor coverage (or interference) means that the number of supported VoLTE connections will be significantly less on certain cells, i.e. voice quality will be degraded due to delayed scheduling and packet loss during busy hours.

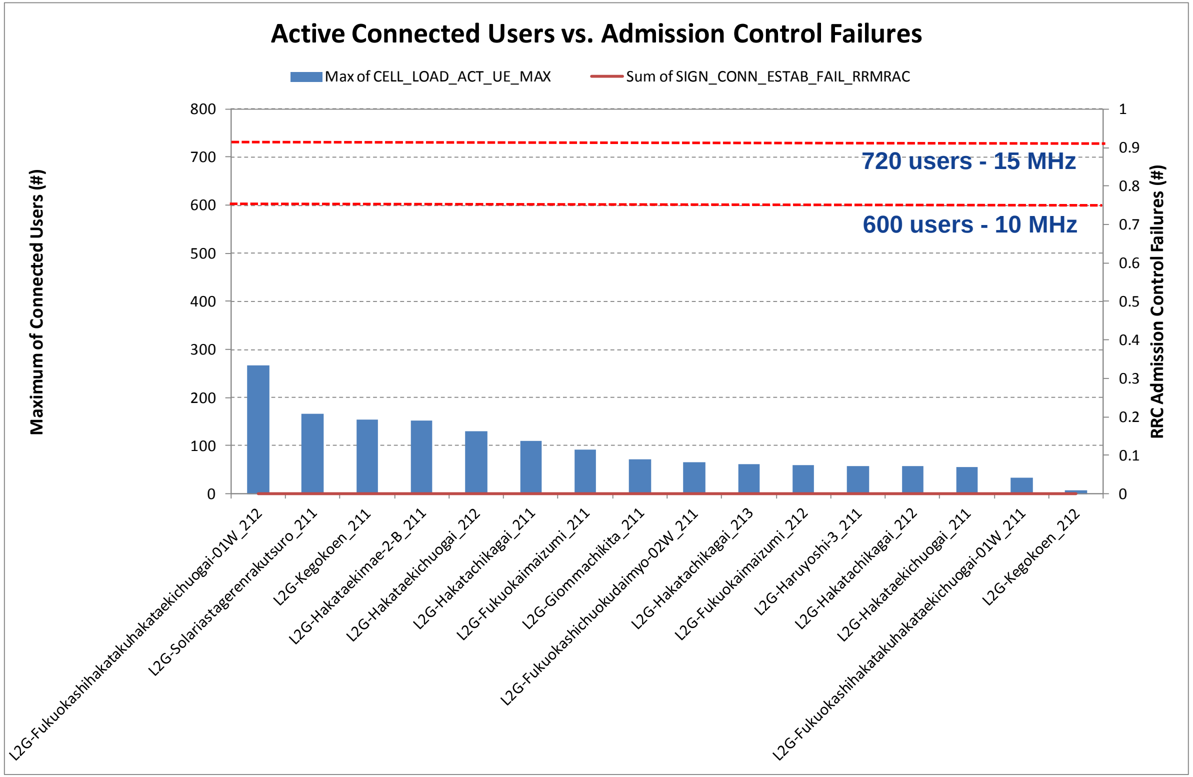
PUCCH Configuration & Capacity

- PUCCH is used to transfer Uplink Control Information (UCI):
  - Scheduling Requests (SR)
  - HARQ acknowledgements
  - Channel State Information (CSI)
- The PUCCH resources are always allocated on the extreme ends of the bandwidth to maximize the number of contiguous PRBs that can be allocated for the PUSCH.



- PUCCH always occupies 2 PRBs distributed across the two time slots of a sub frame and opposite edge of the bandwidth to provide frequency diversity gain for PUCCH transmissions.
- The capacity of each format 1.x and 2.x is defined as follows:
  - **Format 2.x**: CSI Reporting Capacity (Drx On) = (***nCqiRb*** * 6 * ***cqiPerNp***) / 2
  - **Format 1.x**: Scheduling Request Capacity = ***cellSrPeriod*** * ***n1pucchAn***

PUCCH: Active Connected Users' Capacity



- Once a number of RRC connected users has reached the maximum connected users capacity then admission control starts to reject new RRC setup (or incoming HO) attempts.
- However, no issues with PUCCH capacity (no AC failures) with the current cell load and a margin for the potential increase of connected users due to VoLTE traffic seems to be sufficient.

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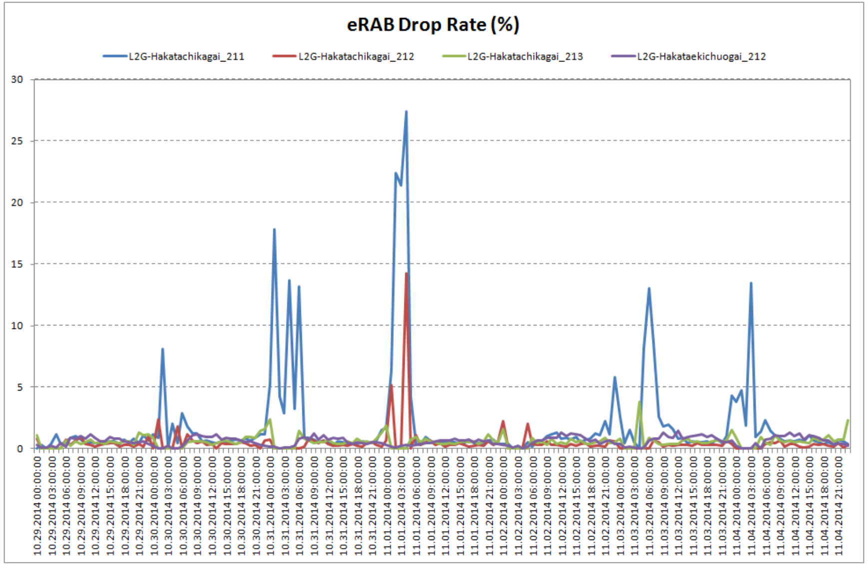
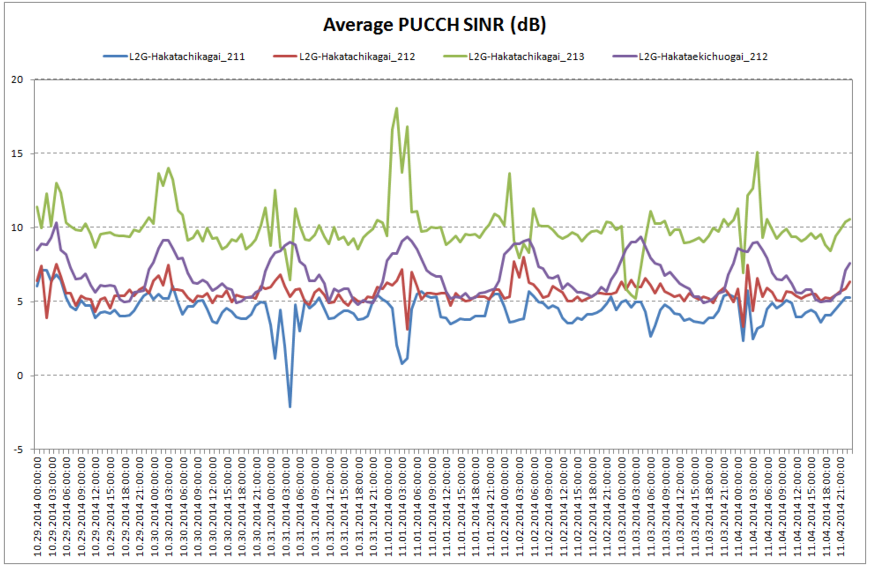
PUCCH: eRAB Drop Rate vs. PUCCH SINR





- PUCCH SINR impacts on the dropped call rate due to fact that a radio link failure detection (by eNodeB) is based on periodical CQI reporting on PUCCH.
- Sudden reduction of the signal strength due to changing UE propagation conditions leads to low SINR

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Paging Configuration & Capacity

- The paging procedure is applicable to UE in RRC idle (or RRC connected) state and is used to the following procedures:
  - Initiate a mobile terminating PS data connection
  - Initiate a mobile terminating SMS connection
  - Initiate a mobile terminating CS fallback connection
  - Initiate a mobile terminating VoLTE connection
  - Trigger a UE to re-acquire system information
- The UE monitors only one paging occasion (PO) every DRX cycle (defPagCyc).
- The total number of paging occasions (PO) per paging cycle is defined by pagingNb
- The eNB receives S1AP: Paging message from MME and constructs RRC: Paging message which can include multiple S1AP paging messages, i.e. maximum of 16 paging records within one RRC message.

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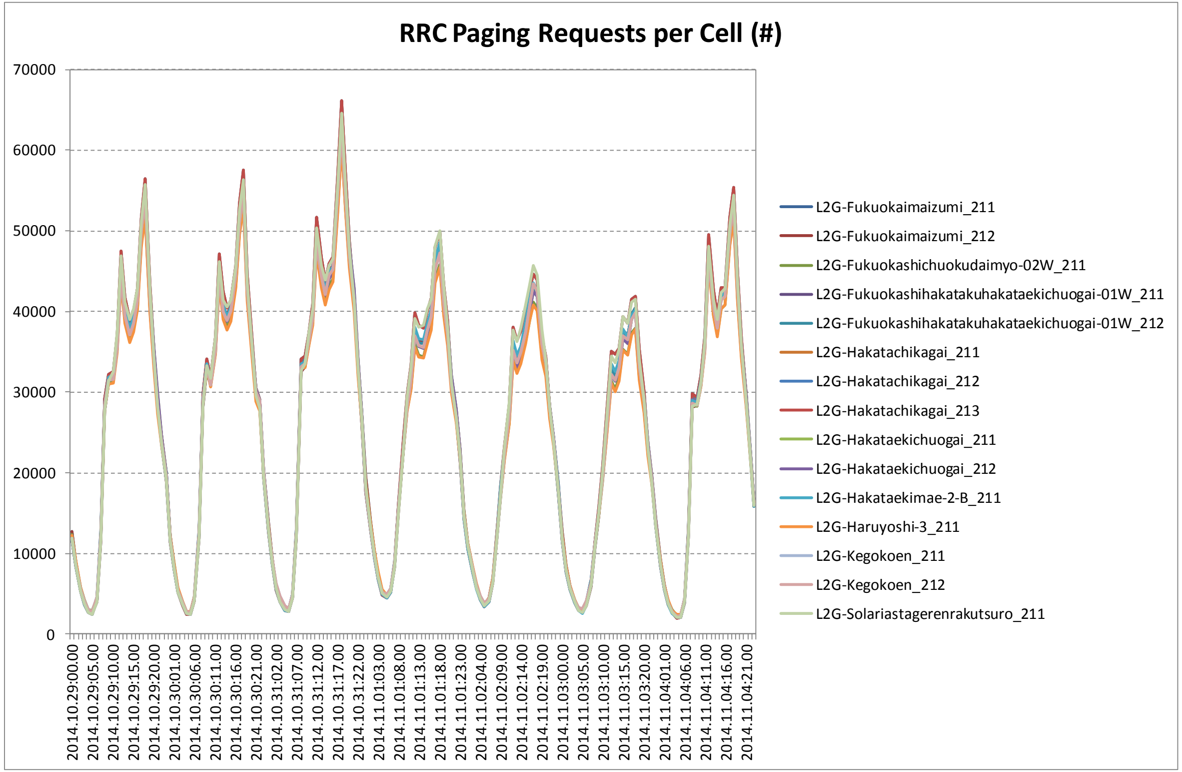
Paging: Paging Requests per Cell



- In case of pagingNb = 1, one PO is available in every radio frame which means 100 paging occasions per second - > 100*16 records = 1600 pagings/s
- The current paging load is 69679 pagings / hr -> 19.4 pagings/s in average (bursts can occur).
- The paging load is not likely to be significantly increased after VoLTE launch in case of CSFB is currently used in the network.

M8008C1: RRC Paging requests

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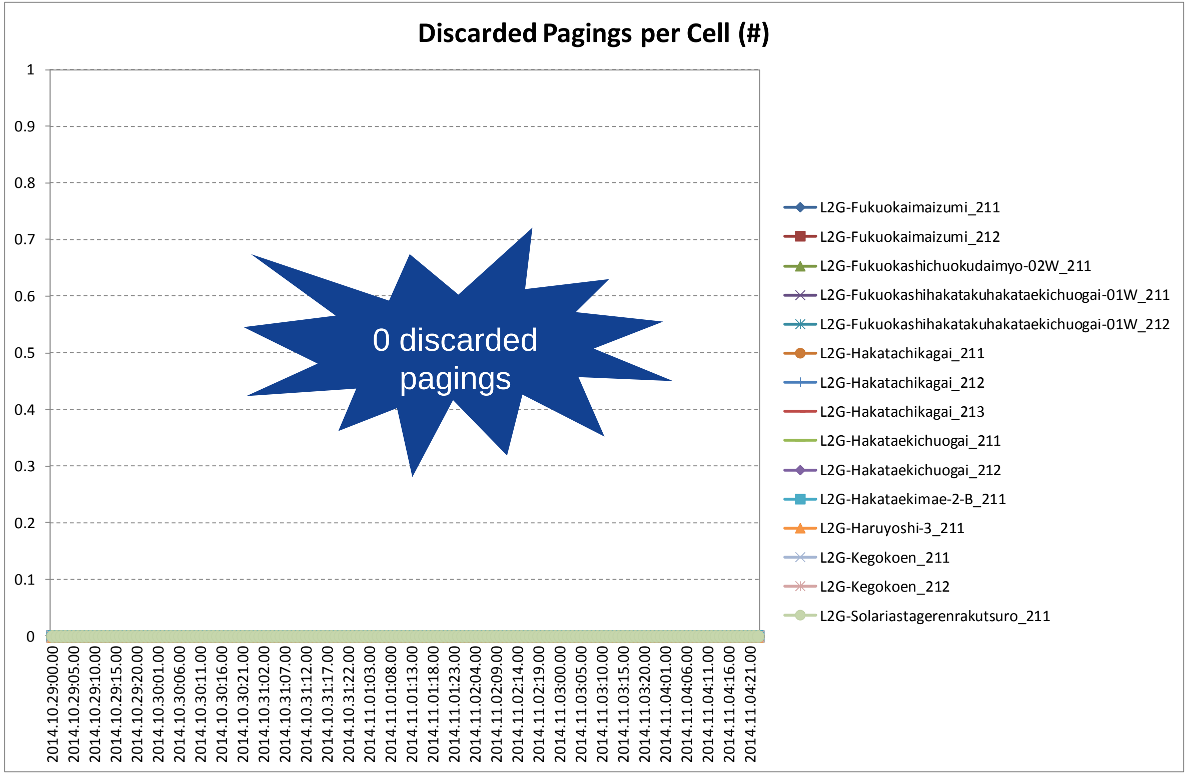
Paging: Pagings Discarded by eNB



- In case of a paging record cannot be transmitted at the next paging occasion it is discarded by eNB, i.e. this happens if the maximum number of paging records per paging occasion (=16) is already reached.
- Discarded RRC pagings have impact on the increased VoLTE call setup time due to re-paging delay.

LTE_5031b E-UTRAN RRC Paging Discard Ratio

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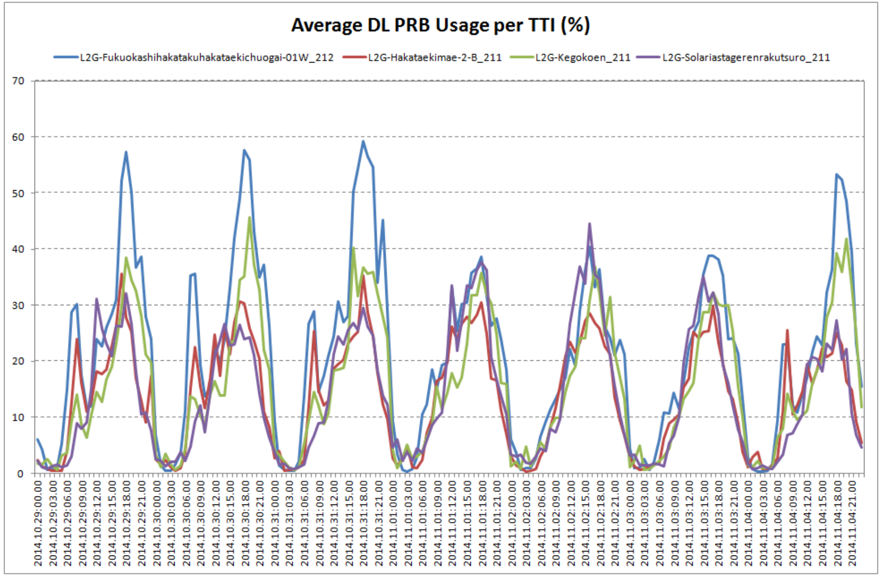
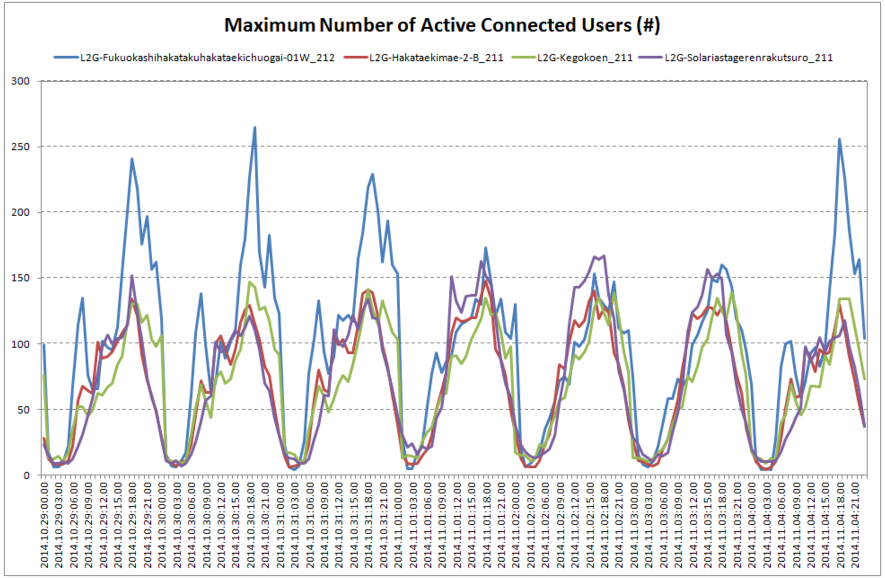
PDSCH Capacity

- Physical Downlink Shared Channel (PDSCH) is used to transfer:
  - System information
  - Paging and other RRC signaling messages
  - Application data
- PDSCH capacity for VoLTE depends on the following factors:
  - Number of resource elements allocated to the PDSCH: channel bandwidth, normal or extended Cyclic Prefix, Overheads from PDCCH, PCFICH, PHICH channels and reference signals
  - Modulation scheme and redundancy applied by physical layer processing related on radio conditions.
  - Multiple antenna transmission schemes, i.e. 2x2 MIMO, 4x4 MIMO etc.
  - Admission control thresholds: *maxNumQci1Drb (if smart admission control disable), maxGbrTrafficLimit (if smart admission control enable)*
  - Number of connections which can be schedules per sub frame : *maxNumUeDl*

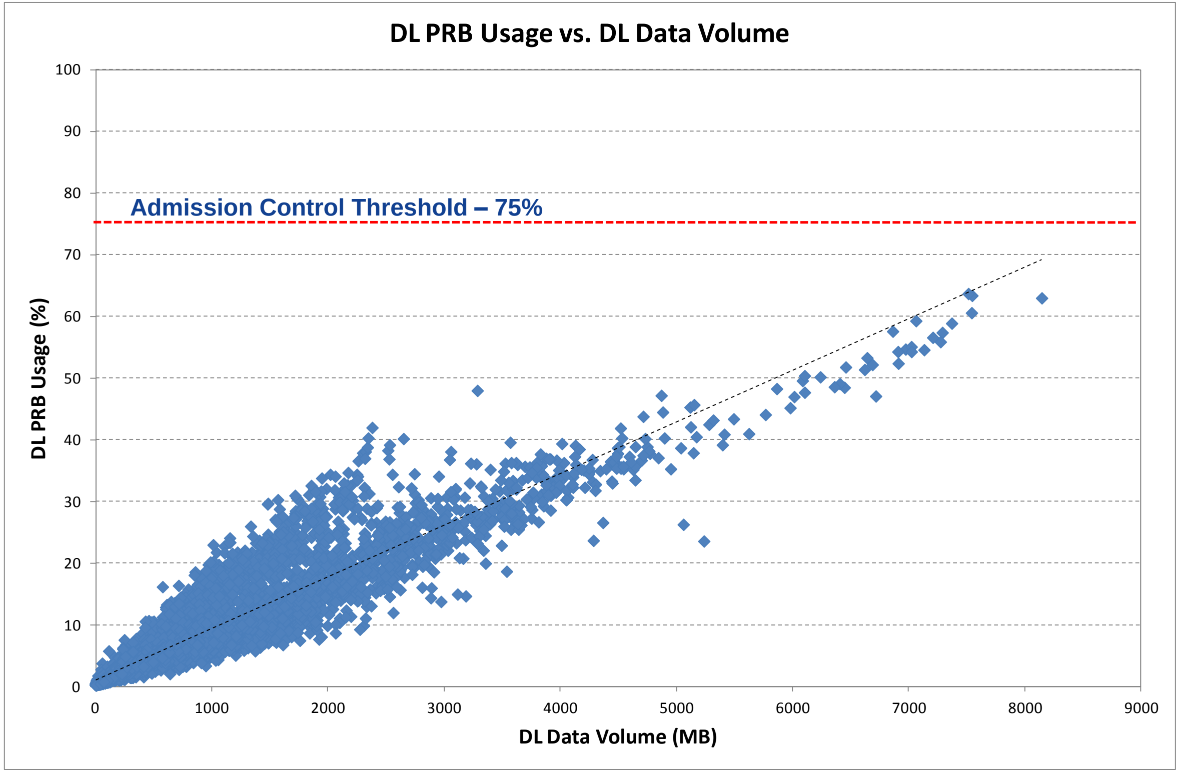
PDSCH: DL PRB Utilization vs. Active Connected Users

- The PRB utilization has a direct relation to the number of scheduled users.
- PDSCH capacity is typically not a bottleneck due to low throughput requirements for VoLTE transmission although under poor radio conditions more PRBs need to be allocated due to low effective coding rate.





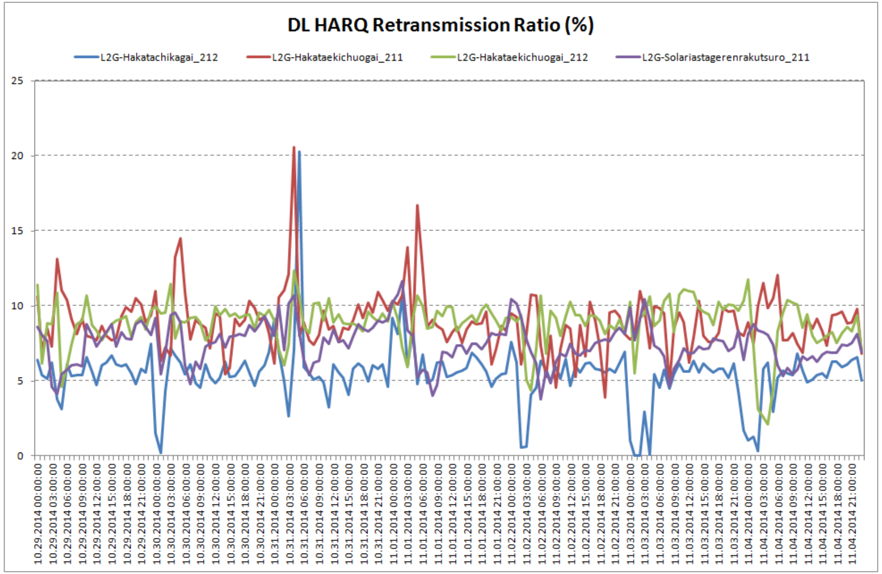
PDSCH: Admission Control Threshold for GBR Connections

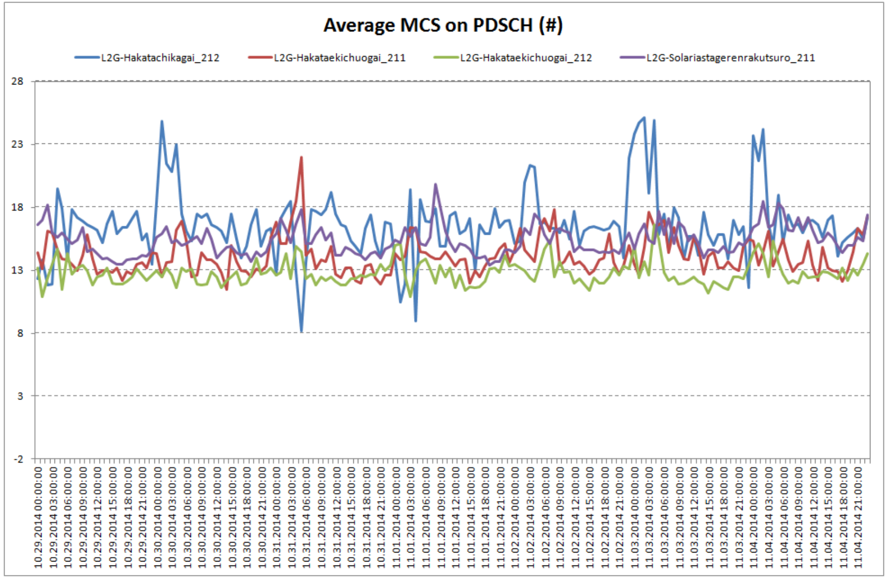


- Smart Admission Control checks the resource availability for GBR connection based on PRB utilisation threshold (maxGbrTrafficLimit) to ensure air interface resources are left for non-GBR traffic as well.
- The GBR bearers are prioritised and can also pre-empt existing non-GBR bearers if needed.
- In poor radio conditions, a VoLTE call might not be established if the bit rate (maxGbrDl/UL) cannot be guaranteed.

PDSCH: HARQ Retransmission vs. PDSCH MCS

- Each HARQ retransmission introduces approximately 8ms delay on VoIP transmissions and thus, excessive BLER fluctuations might cause degradation in a voice quality.
- Link adaptation adjusts MCS according to radio conditions to maintain BLER target.
- UE is in poor coverage will use lower order MCS and require increase quantities of redundancy : more RBG to transfer speech information

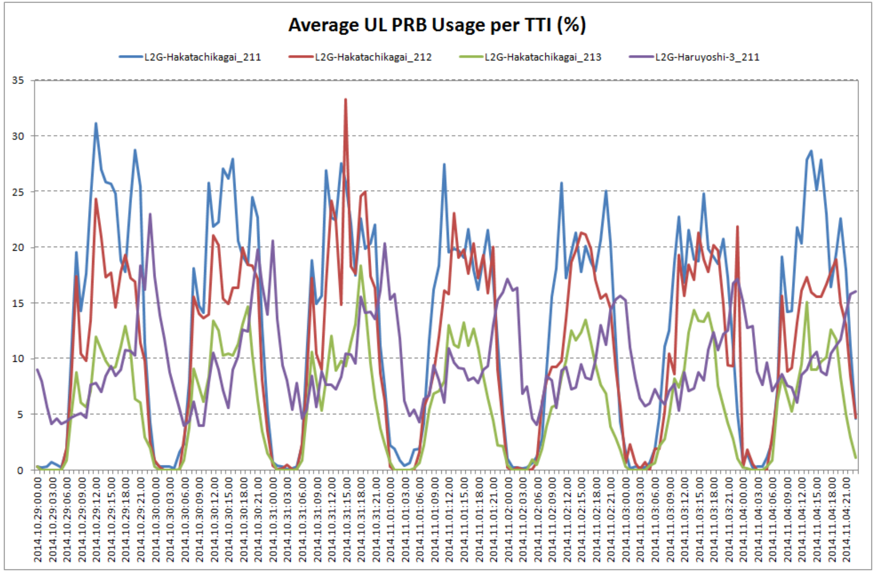


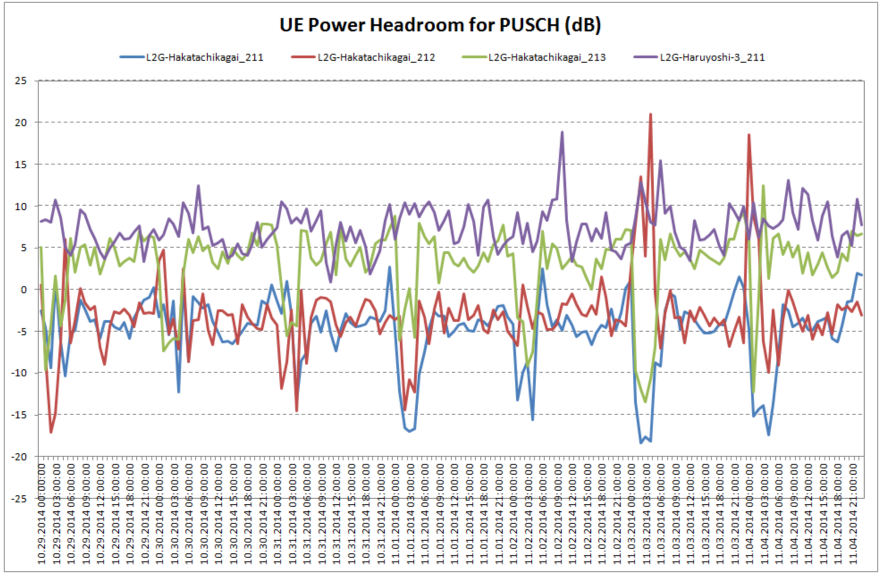


PUSCH Capacity

- Physical Uplink Shared Channel (PUSCH) is used to transfer:
  - RRC signaling messages
  - Uplink Control Information (UCI)
  - Application data
- PUSCH capacity on the following factors:
  - Number of resource elements allocated to the PUSCH: Channel bandwidth, Normal or extended Cyclic Prefix, Overheads from PUCCH, PRACH and Reference Signals
  - Modulation scheme and redundancy applied by physical layer processing related to radio conditions.
  - Admission control thresholds: *maxNumQci1Drb (if smart admission control disable), maxGbrTrafficLimit (if smart admission control enable)*
  - Number of connections which can be schedules per sub frame : *maxNumUeUl*

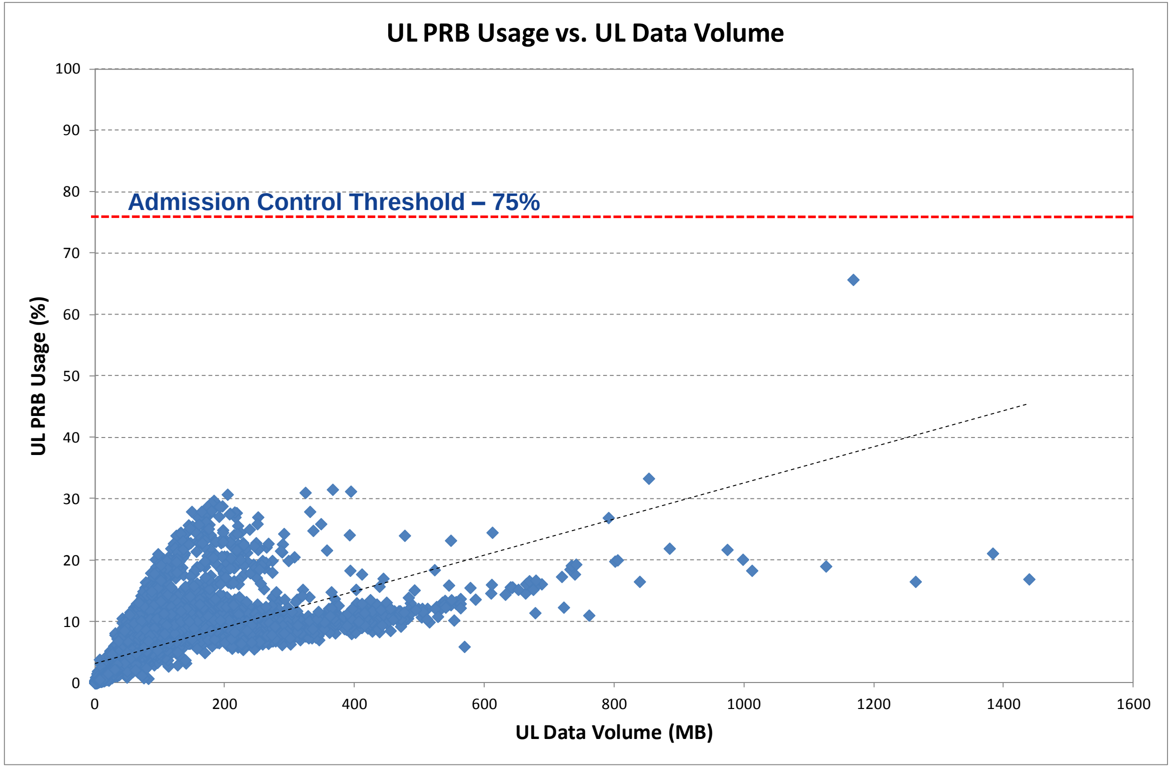
PUSCH: UL PRB Utilization vs. UE Power Headroom





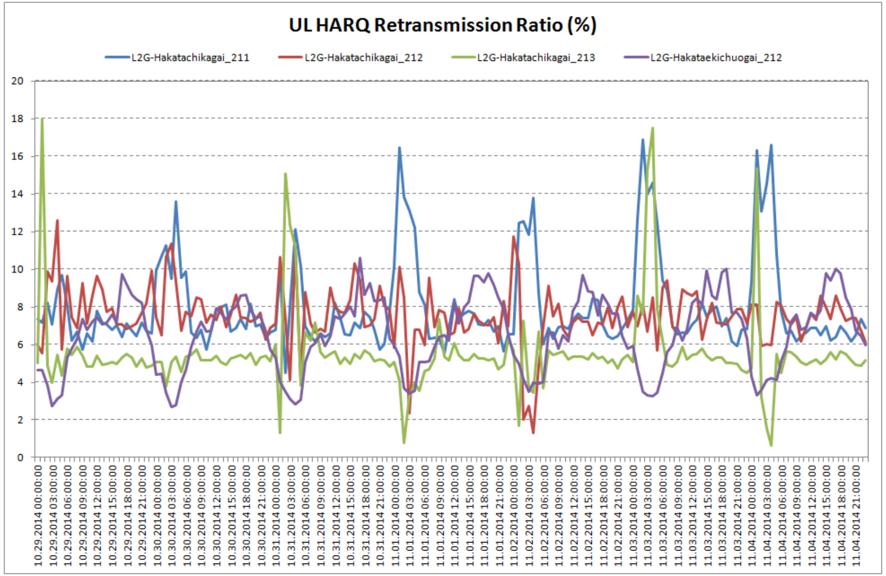
- UL PRB utilisation has a relation to the number of scheduled users but also to UE transmission power control due to bandwidth factor (allocated PRBs) and radio conditions (path loss).
- UL power control settings has impact on capacity and interference experienced by VoLTE users on the cell edge.

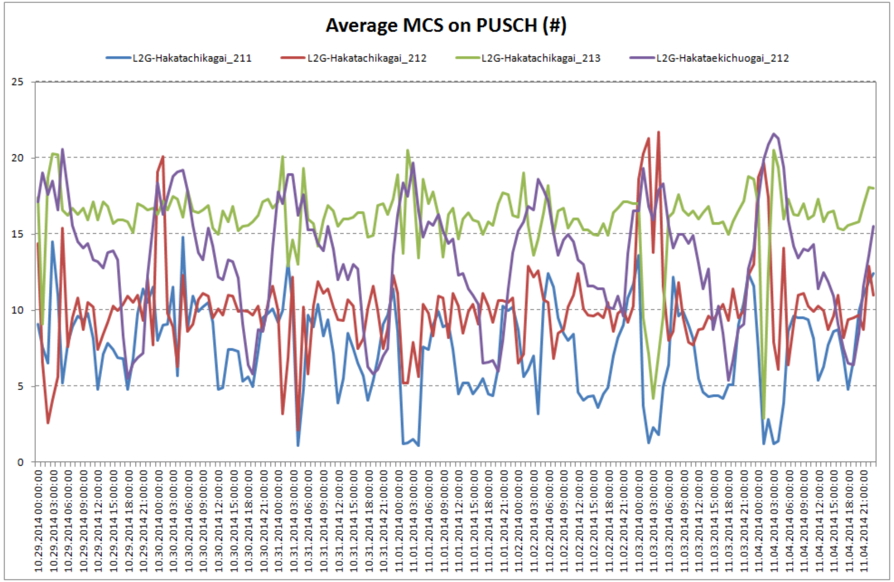
PUSCH: Admission Control Threshold for GBR Connections



- Smart Admission Control checks the resource availability for GBR connection based on PRB utilisation threshold (maxGbrTrafficLimit) to ensure air interface resources are left for non-GBR traffic as well.
- The GBR bearers are prioritised and can also pre-empt existing non-GBR bearers if needed.
- In poor radio conditions, a VoLTE call might not be established if the bit rate (maxGbrDl/UL) cannot be guaranteed.

PUSCH: HARQ Retransmission vs. PUSCH MCS





- Each HARQ retransmission introduces approximately 8ms delay on VoIP transmissions and thus, excessive BLER fluctuations might cause degradation in a voice quality.
- Link adaptation adjusts MCS according to radio conditions to maintain BLER target.

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Wrap-up

PDCCH channel capacity

- PDCCH is the most likely physical channel to cause an initial limitation
- The PDCCH capacity can be increased by
  - allocating the maximum number of OFDMA symbols
  - enabling PDCCH link adaptation
  - power control
- PDCCH load can be reduced by enabling packet aggregation for the VoIP service
- TTI Bundling can be used to help reduce the PDCCH load
  - Nokia implementation does not configure DRX simultaneously with TTI Bundling as there could be some impact upon the UE battery life

Wrap-up

Facts to consider

Increasing PUCCH capacity decreases PUSCH capacity

Increasing PHICH capacity decreases PDCCH capacity

Physical channels should not be over-dimensioned

VoLTE Network Expansion
Checking the need for capacity expansion

- By using KPI analysis it is possible to see the need for VoLTE capacity expansion
  - Resource utilization related KPIS
  - Number of user related KPIs
  - MCS Usage
- If network is already saturated with heavy traffic loads then a new cell is required either by:
  - increased sectorization
  - addition of a new RF carrier
  - addition of a new site

Network Performance, Quality and Mobility: Assessment and Optimization

Network Performance
SRVCC
MOS
TTI Bundling
SIP Signalling Analysis
Call Setup Analysis
Project learning

Network Performance Assessment and Optimization

Network Performance Requirements
Radio Conditions

- Ensuring good radio conditions is a pre-requisite for VoLTE Services:
  - VoLTE is a GBR (Guaranteed Bit Rate) service. In poor radio conditions, a VoLTE call might not be established if the bit rate cannot be guaranteed.
    - Under poor radio conditions, the average coding rate is low and each new bearer requires more resources.
    - Smart Scheduler (RL40) introduces a limit to the amount of resources available for GBR traffic (*maxGbrTrafficLimit*, %) to ensure air interface resources are left for the lower priority non-GBR traffic. If adding the new GBR bearer implies going over that threshold then it is rejected.
  - Voice bearer has typically worse retainability due to longer call sessions compared with non-GBR data traffic. Poor radio conditions accentuate the low retainability (VoLTE call drops).

Network Performance Requirements
Radio Conditions

- Voice bearer is also more sensitive to HO failures than non-GBR bearer due to longer time in connected mode.
- AMR codec bit rate (VoLTE quality) is better under good RF conditions
- Potential contributors to poor radio conditions are:
  - No clear dominance
  - Frequent handovers
  - Overshooting eNodeBs
  - Excessive handover attempts
  - High RRC attempts to distant eNodeB
  - Missing neighbors
  - eNodeB, MME and other Network Parameters not set correctly

Counters for VoLTE Monitoring

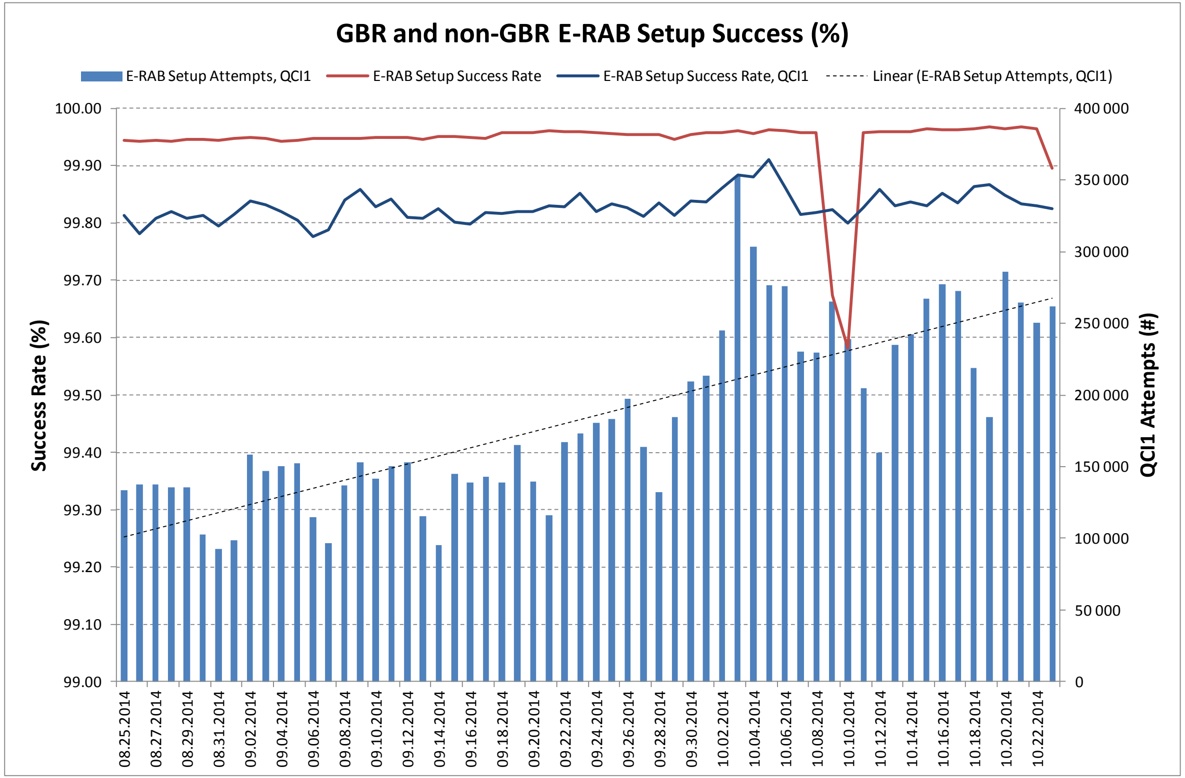
Counter assessment

Item	counters	Assessment
VoLTE in Erlangs	• M8006C181 ERAB_IN_SESSION_TIME_QCI1	• This counter unit is seconds and measuring on an hourly basis. • By dividing 3600 this provides the VoLTE traffic in Erlangs
VoLTE throughput	• M8012C116 PDCP_DATA_RATE_MEAN_UL_QCI_1 • M8012C143	• These counters quantify the total uplink and downlink throughputs in terms of kbps • Dividing by the throughput associated with a single connection generates a measure of the average number of connections. • The throughput associated with a single connection will depend upon the codec as well as the speech activity factor
QCI Bearer setup	• M8006C17 EPS_BEARER_STP_ATT_INI_QCI_1 • M8006C26 EPS_BEARER_STP_ATT_ADD_QCI_1 • M8006C35 • M8006C44	• VoIP connection establishment failures can be measured as a decrease in the establishment success rate • The establishment success rate can be quantified as setup completes / setup attempts • The actual end-to-end VoIP connection establishment could fail after a successful QCI 1 bearer establishment
Discard VoIP packets	• M8001C323: PDCP_SDU_DISC_DL_QCI_1	• This quantifies the number of discarded downlink VoIP packets • This counter must be almost 0 during normal operating conditions • Non-zero values indicate that network congestion and capacity optimization need

Counters for VoLTE Monitoring
Counter assessment

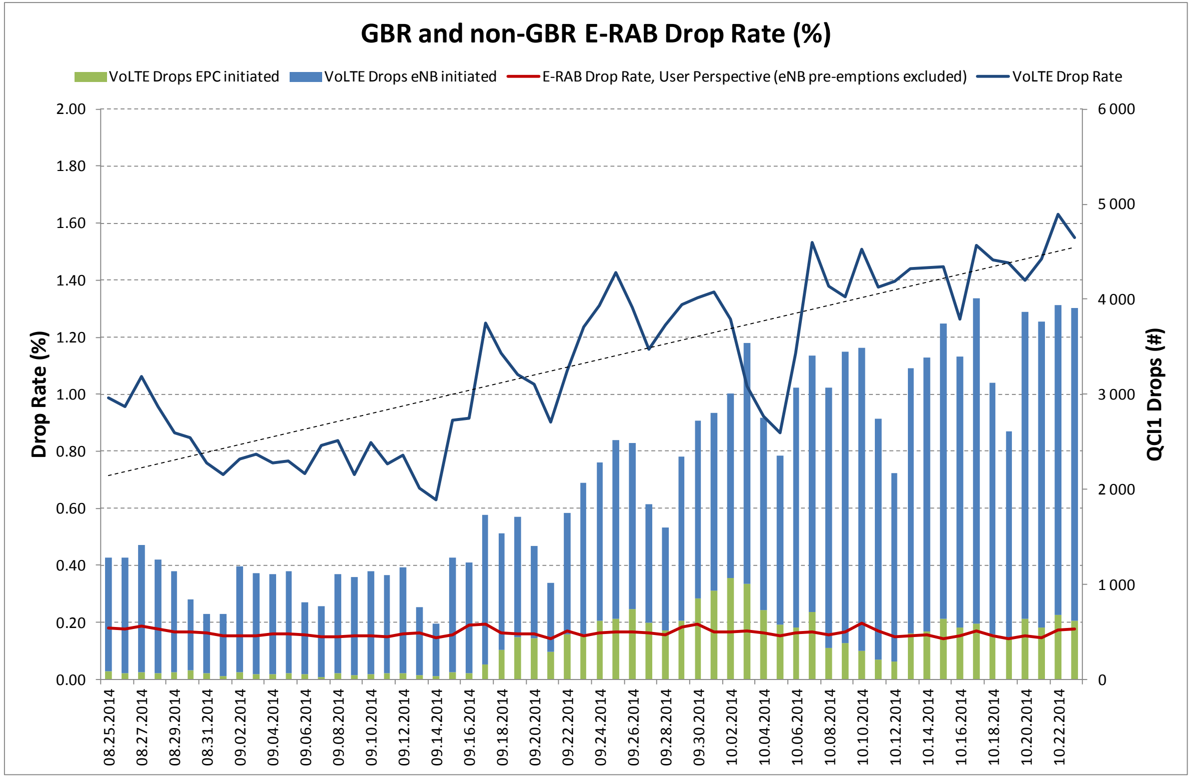
Item	counters	Assessment
VoLTE Delay	• M8001C269 PDCP_RET_DL_DEL_MEAN_QCI_1	• This counter measures the average downlink VoIP packet delay • Increases in the average delay indicate network congestion
Number of VoLTE users	• M8001C227 UE_DRB_DL_DATA_QCI_1 • M8001C419 UE_DRB_UL_DATA_QCI_1	• This counter measures average number of UE with QCI 1 data in their uplink and downlink buffers • Increases in these counters can also be used to indicate growth in traffic levels

VoLTE Impact on Network KPIs: eRAB Setup Performance



- The non-GBR setup success is not affected by the increased VoLTE traffic and maintained around 99.95%.
- VoLTE (QCI1) bearer setup success rate is maintained at 99.85%, i.e. no admission issues due to connected users capacity.

VoLTE Impact on Network KPIs: eRAB Release Performance



- The non-GBR drop rate is still maintained stable at 0.2% with increased VoLTE traffic.
- VoLTE (QCI1) bearer drop rate has an increasing trend up to 1.6% with increased voice traffic.
- The VoLTE (QCI1) bearer releases are mostly initiated by the eNB due to radio link failures (coverage, interference, mobility failures etc.)

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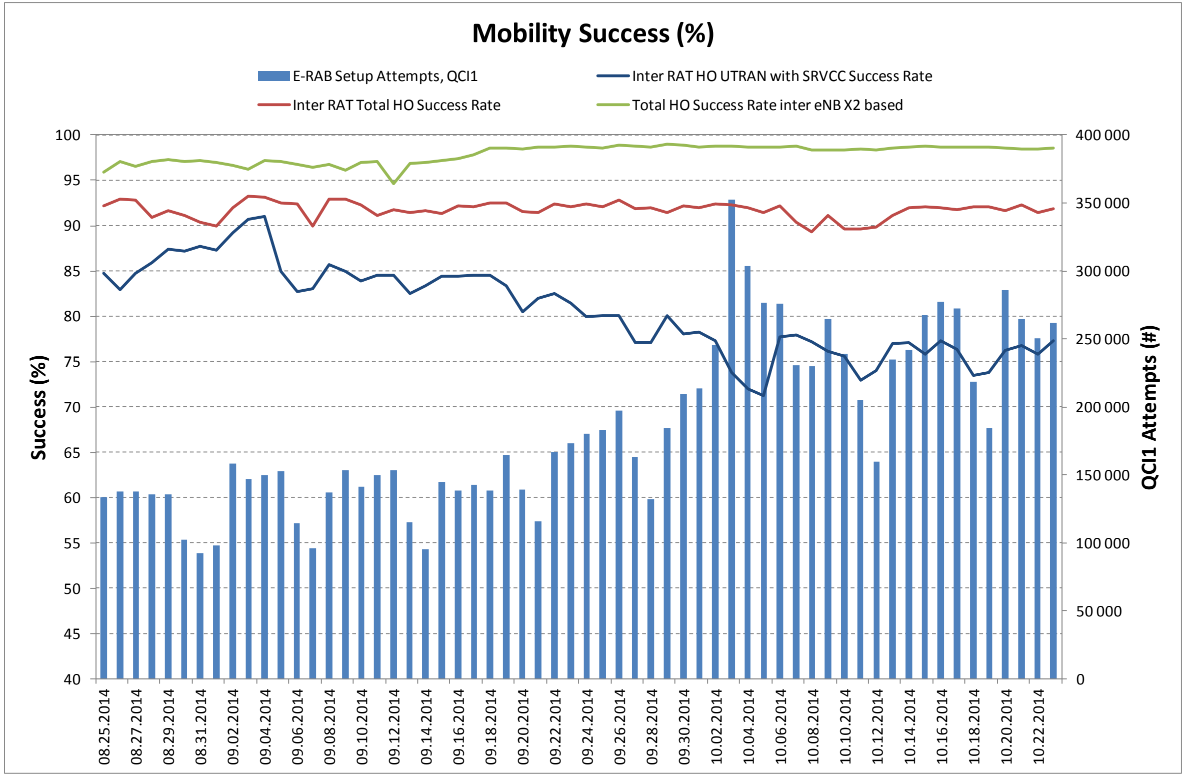
VoLTE Impact on Network KPIs: Handover Performance



- Typically voice bearer is more sensitive to HO failures than non-GBR bearer due to longer time in connected mode.
- Intra-LTE mobility performance is not affected by VoLTE traffic but overall handover success improved also due to neighbour relation optimisation.
- SRVCC success rate for VoLTE has declining trend down to 72% with increased VoLTE traffic.

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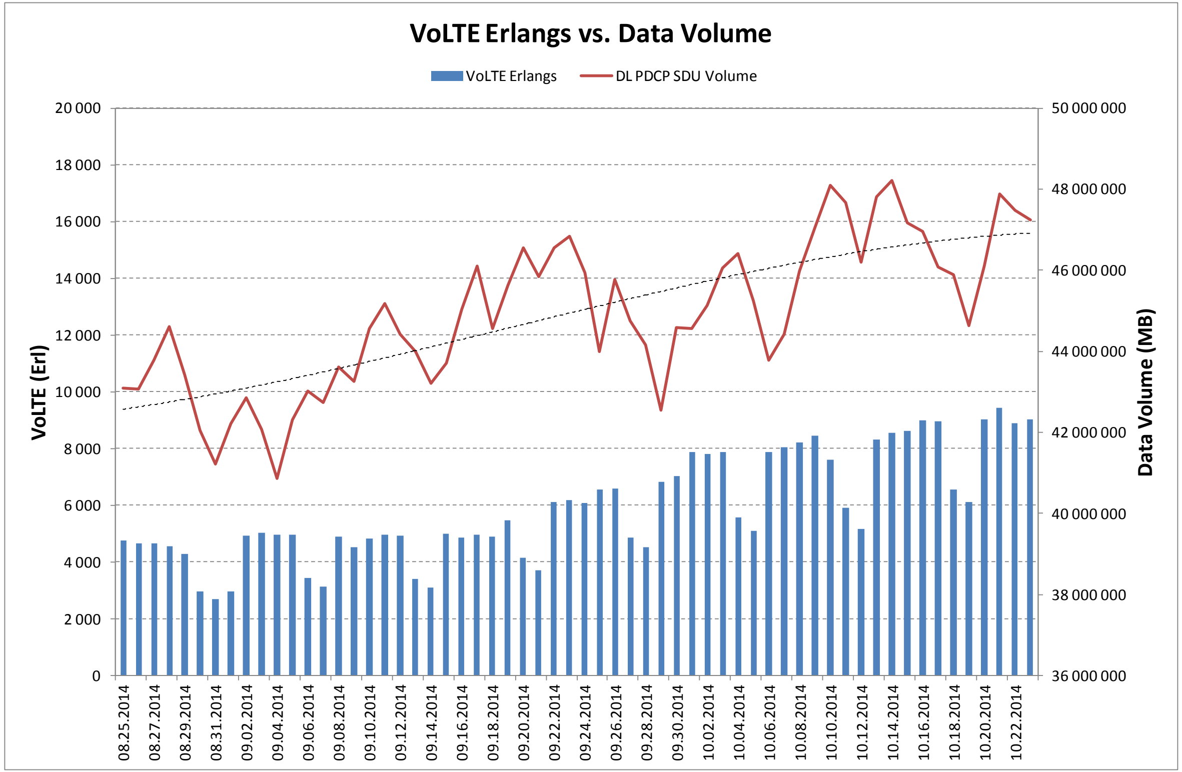
VoLTE Impact on Network KPIs: non-GBR Throughput



- The non-GBR throughput degradation due to higher priority GBR bearer scheduling is not visible in DL data volume due to low VoLTE traffic load.

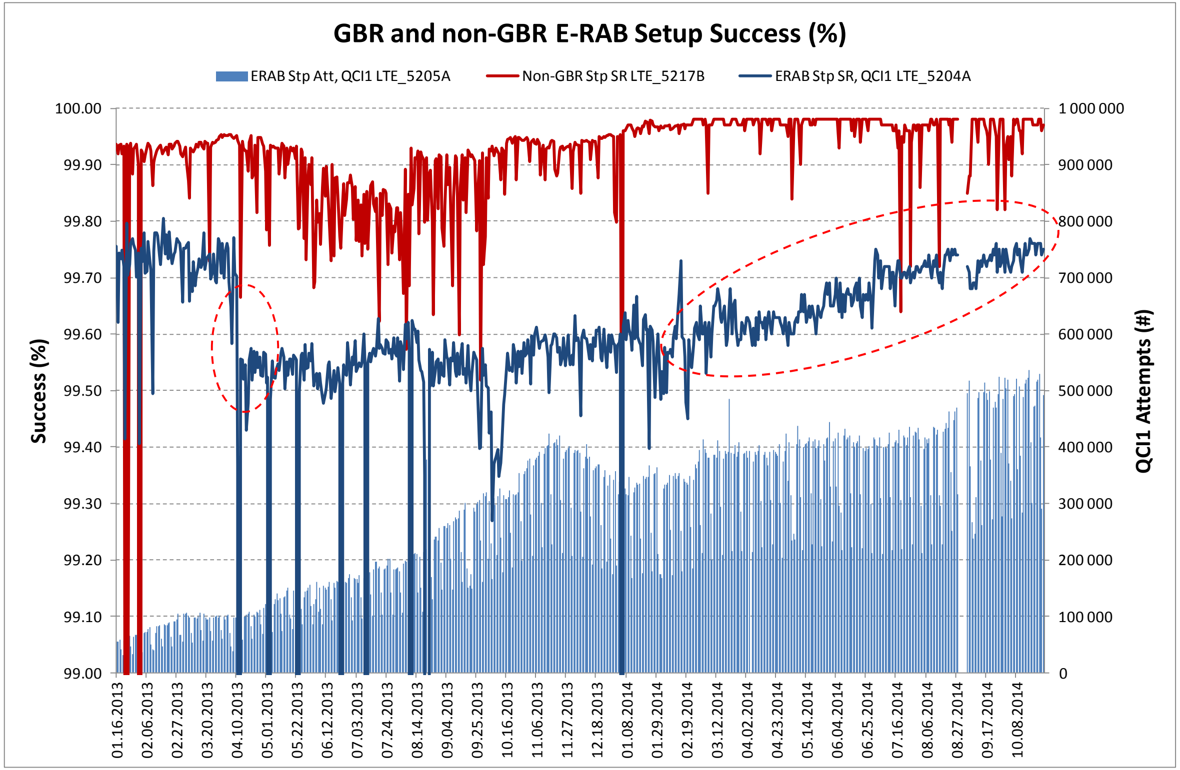
VoLTE Impact on Network KPIs

Other GBR bearer activation impact (before)

- GBR (QCI2) bearer activation for video has a impact on both data (QCI9) and voice (QCI1) bearer setup success performance
- There is a possibility of drop rate for both data (QCI9) and voice (QCI1) increase due to eNB triggered radio link failures or admission control reasons
- This has a dependency with scheduling weight settings, pre-emption capability ect.

VoLTE Impact on Network KPIs: When QCI 2 is activated

eRAB Setup Performance



- The non-GBR setup success has some fluctuations but high success rate eventually maintained with VoLTE traffic.
- Video(QCI2) bearer activation had impact on both data (QCI9) and voice (QCI1) setup performance.
- GBR (QCI1) bearer setup success rate has been improved up to 99.76% due to optimization activities.

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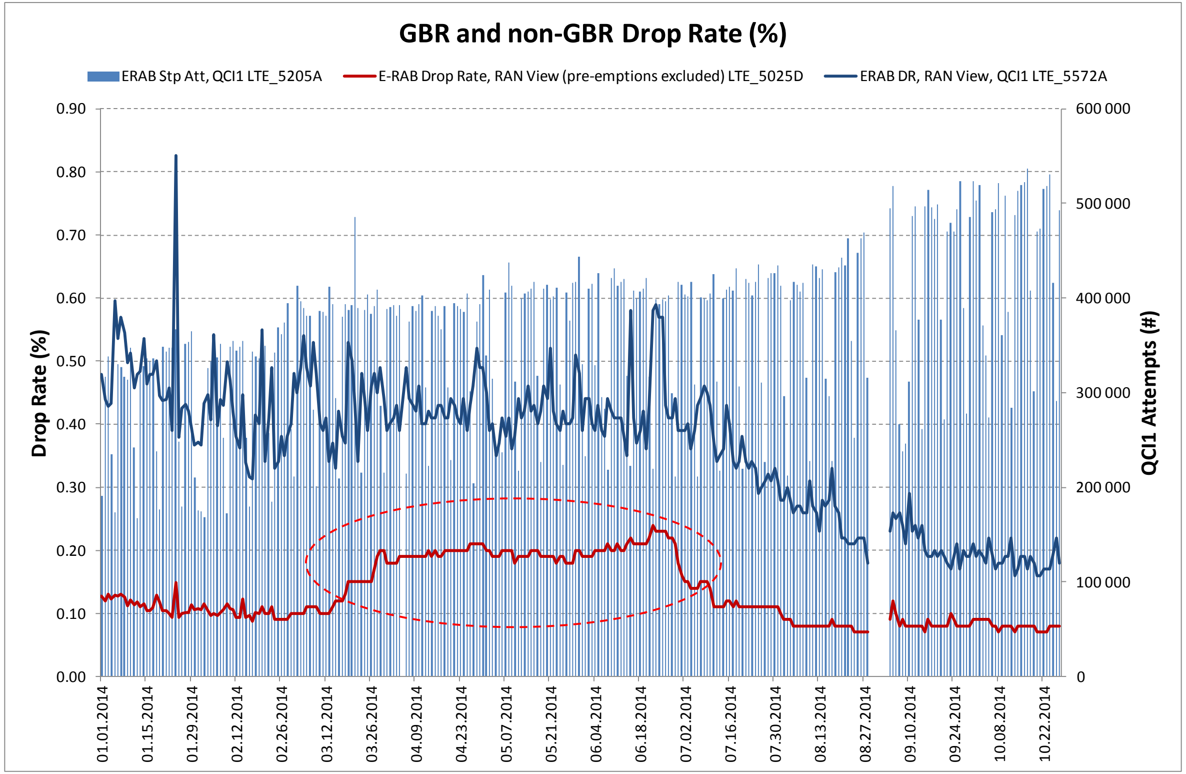
VoLTE Impact on Network KPIs: eRAB Release Performance



- The non-GBR drop is maintained around 0.08% with increased VoLTE traffic.
- GBR (QCI1) bearer drop has a declining trend down to 0.18%.
- Samsung S5 firmware had issues by sending CQI reports and thus, drop rate for both data (QCI9) and voice (QCI1) was increased during this time

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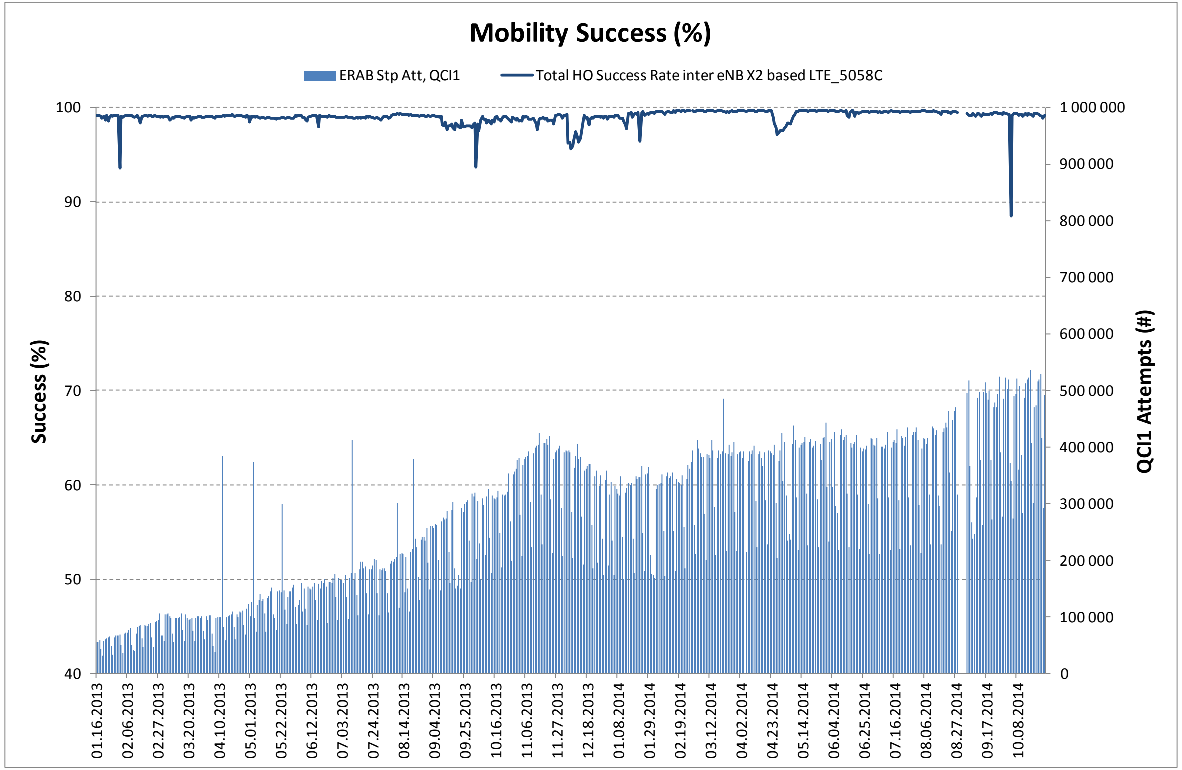
VoLTE Impact on Network KPIs

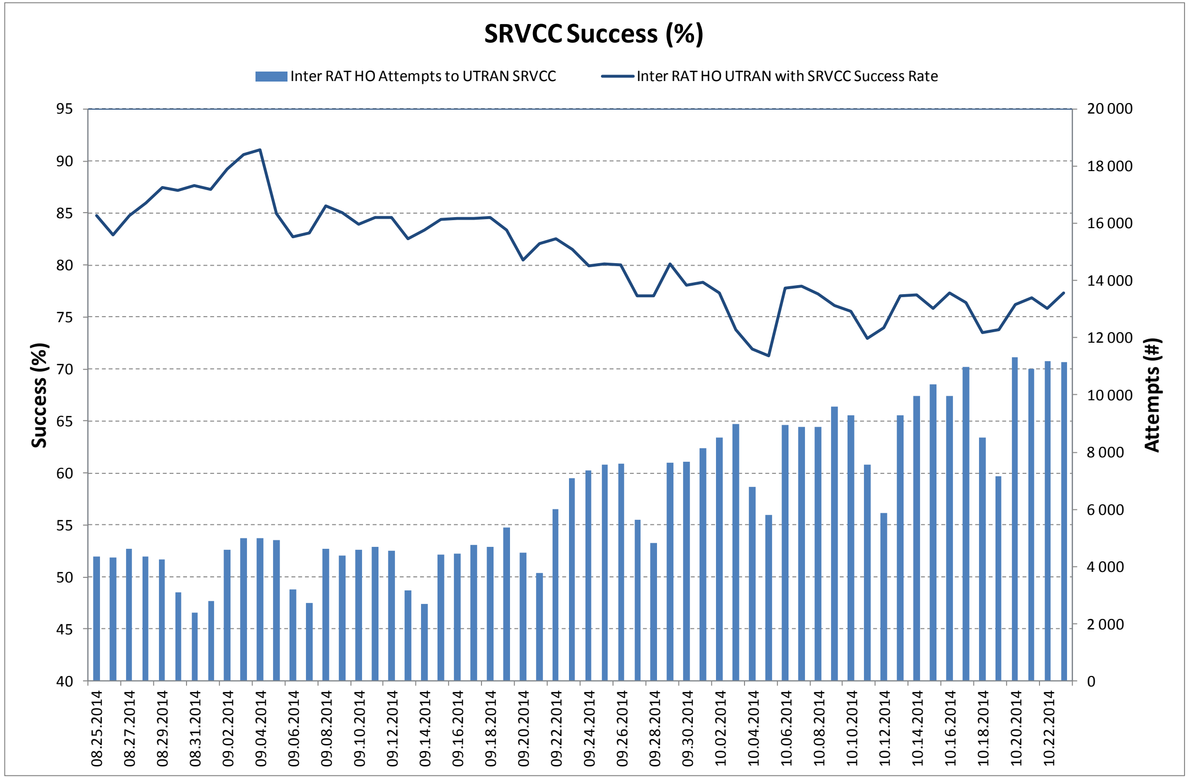
Handover Performance



- Typically voice bearer is more sensitive to HO failures than non-GBR bearer due to longer time in connected mode.
- Intra-LTE mobility performance is not affected by VoLTE traffic.
- SRVCC is not deployed in this area.

SRVCC Assessment and Optimization

VoLTE Impact on Network KPIs (Operator A): SRVCC Performance



- SRVCC performance for VoLTE has declining trend with increased SRVCC attempts.
  - In this particular project SRVCC is degraded due to an issue in MSS not sending proper cause code for successful SRVCC HO and thus, SRVCC success counter is not correctly incremented.
- The IMS network was not supporting SRVCC during the Alert phase and therefore, the customized firmware was created for the phones to do CSFB instead of VoLTE when the RSRP is less than -115 dBm.

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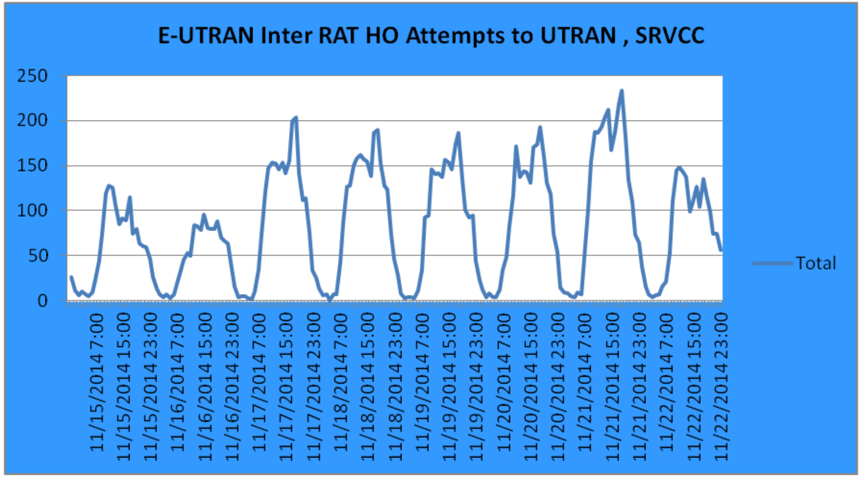
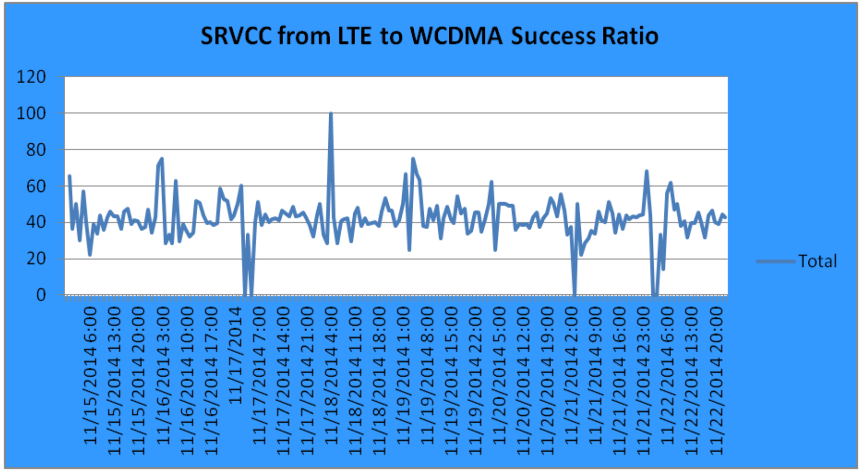
SRVCC Assessment: Project in Asia

Project Example for Asian Customer

- Network handover of VoIP calls is activated to WCDMA via SRVCC to WCDMA feature (LTE 872)
- SRVCC from LTE to WCDMA can be degraded because of: missing neighbors, coverage gaps or PCI collision
- SRVCC attempts are very low in the network wide and due to this SRVCC success rate also low
- WCDMA network is equipped with other vendor than Nokia. Therefore correct definition of neighbors are required for better IRAT handover performance.
- LTE to 3G neighbors are created only for R99 F1(2100) frequency but where there is not sufficient coverage overlapping between LTE to 3G 2100 band,3G 900band is considered for external neighbors.
- These cases usually identified from the drive test data





SRVCC Assessment and Optimization

- SRVCC threshold settings

VoLTE Improvement ideas based on SRVCC

Based on project experience

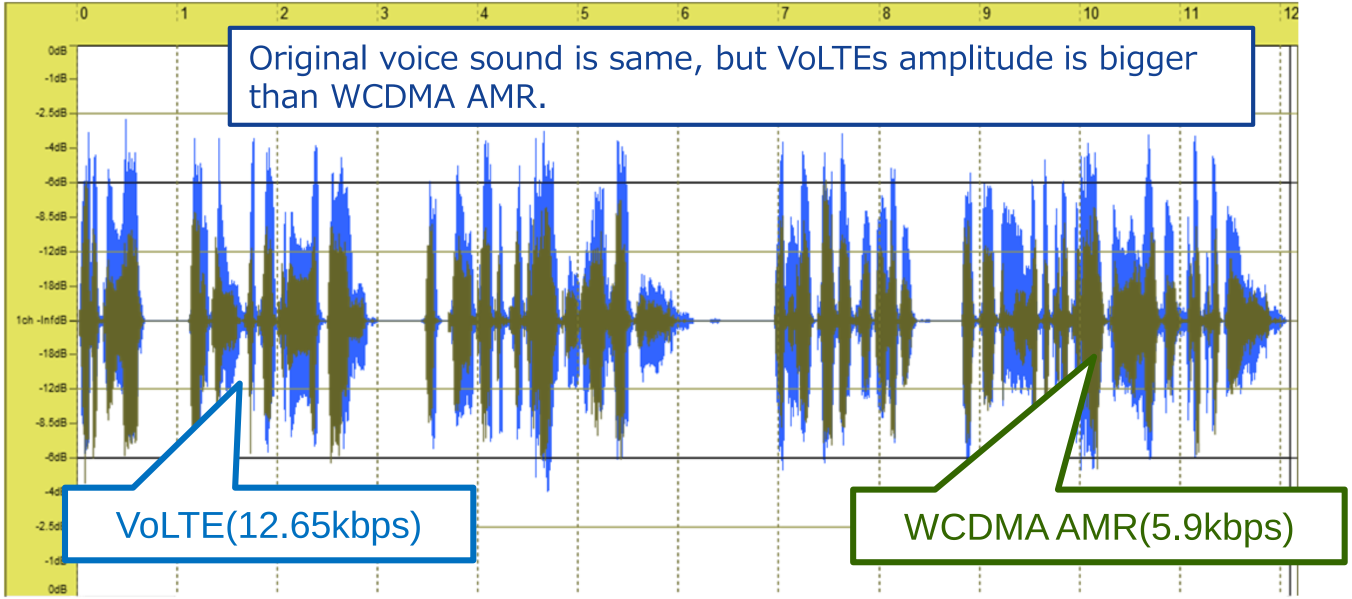
- Project is in Asia
- Scope: Expand VoLTE coverage without call drop risks
- RSRQ based SRVCC handover study (customer requirement)
- Issues with high speed trains during SRVCC

SRVCC Threshold Settings

Voice quality comparison (VoLTE& WCDMA AMR)

Operator wants to expand VoLTE coverage as much as possible

- VoLTE voice quality is better than WCDMA AMR, because VoLTE uses higher bit rate. (VoLTE : 12.65kbps, WCDMA AMR : 5.9kbps)



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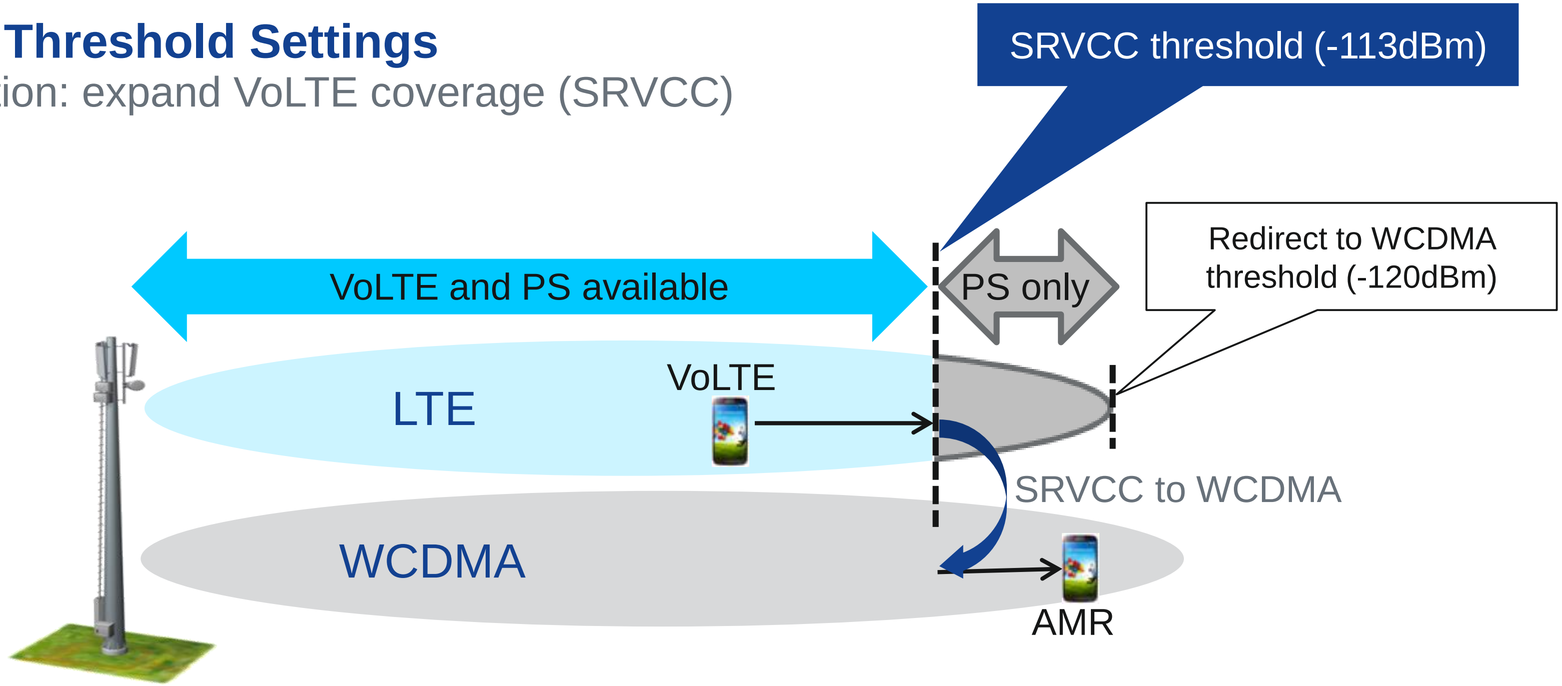
SRVCC Threshold Settings

Key function: expand VoLTE coverage (SRVCC)



- To expand VoLTE coverage, the most important design is SRVCC threshold
- By setting lower SRVCC threshold it is possible to achieve wider VoLTE coverage
- Effect of parameter changes to VoLTE performance need to be studied

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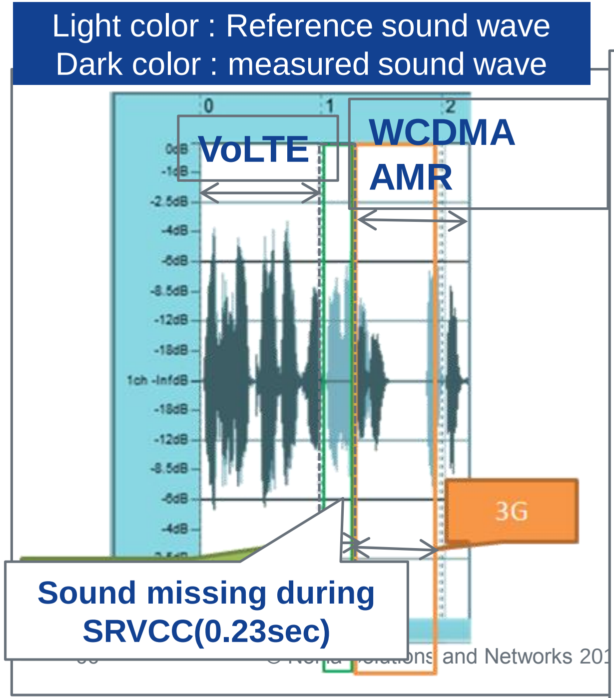
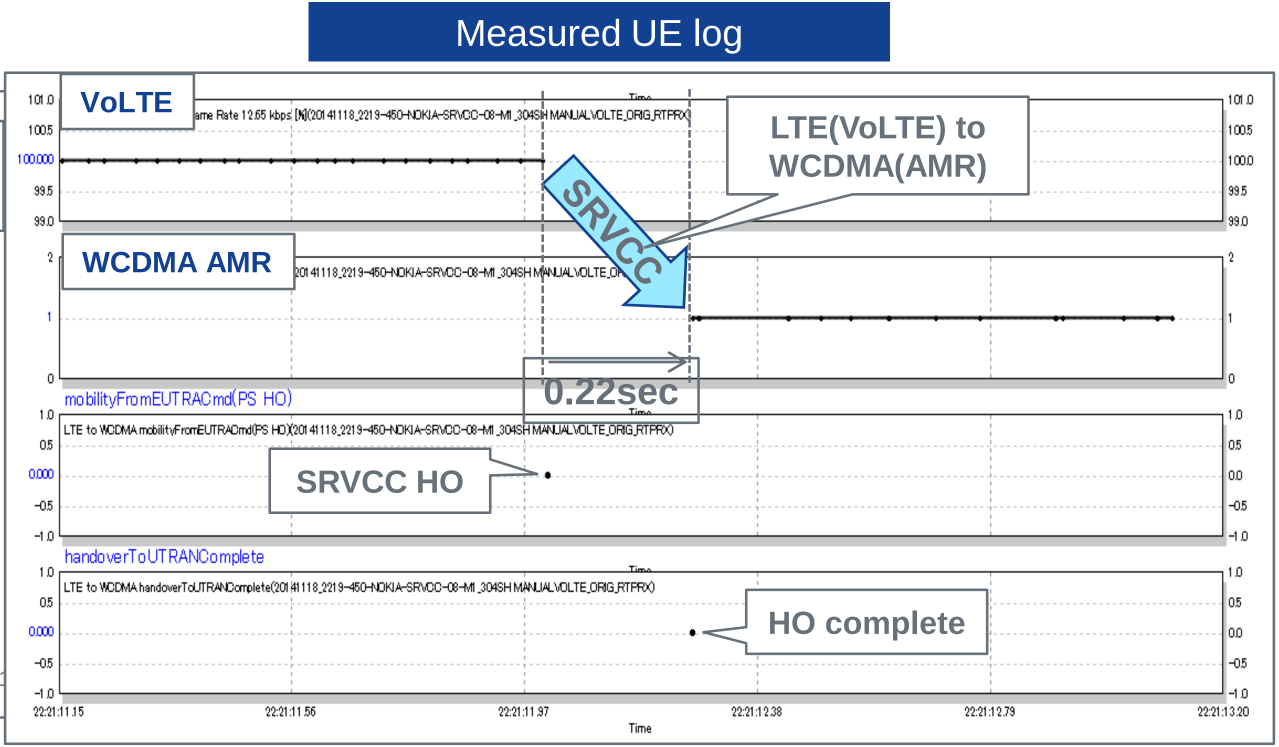
Performance degradation check during SRVCC

Missing sound during SRVCC

- There is a short missing period during SRVCC.
- This period is not long, but user can notice that some words are missing.





Performance degradation check during SRVCC

Frequency of SRVCC HO

Target is to minimize frequency of SRVCC as much as possible

- Measured how often UEs move to WCDMA by SRVCC in three area. (Dense / Rural / Highway)
- Observed UE experiencing SRVCC every 7 minutes (averagely) in rural are and highway.

Field test result

	Dense area	Rural area	Highway
# of SRVCC	0	12	7
Total missing period during SRVCC	0.00	2.85s	1.81s
Total call duration	51min39s	49min16s	27min21s

On average UE experienced SRVCC Every 7 minutes

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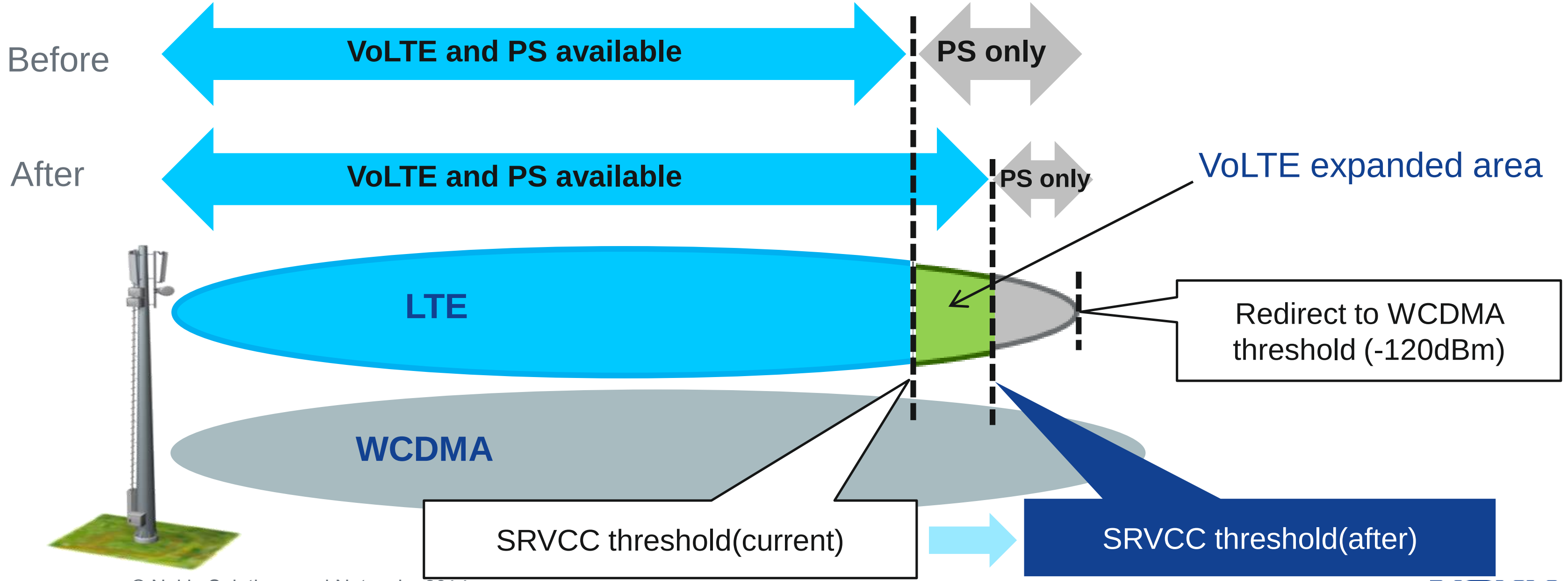
Possible SRVCC design

- To expand better quality area (= VoLTE area)
- Reduce chances of missing voice (by SRVCC

➡ Change SRVCC threshold to lower value.



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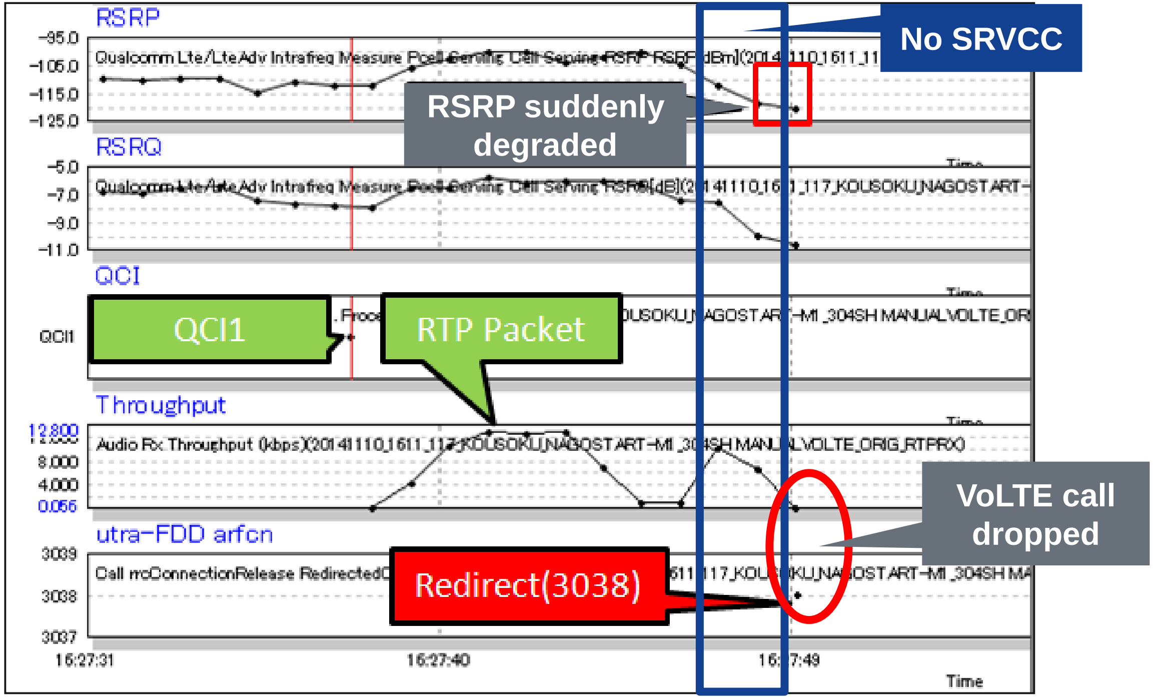
Possible problems due to SRVCC change

- If Redirect is performed before SRVCC for VoLTE user the VoLTE call drops. Especially high speed mobility users can experience this problem.
- This VoLTE drop may cause user claim, to avoid that enough margin between SRVCC and Redirect threshold need to assign (next slide).

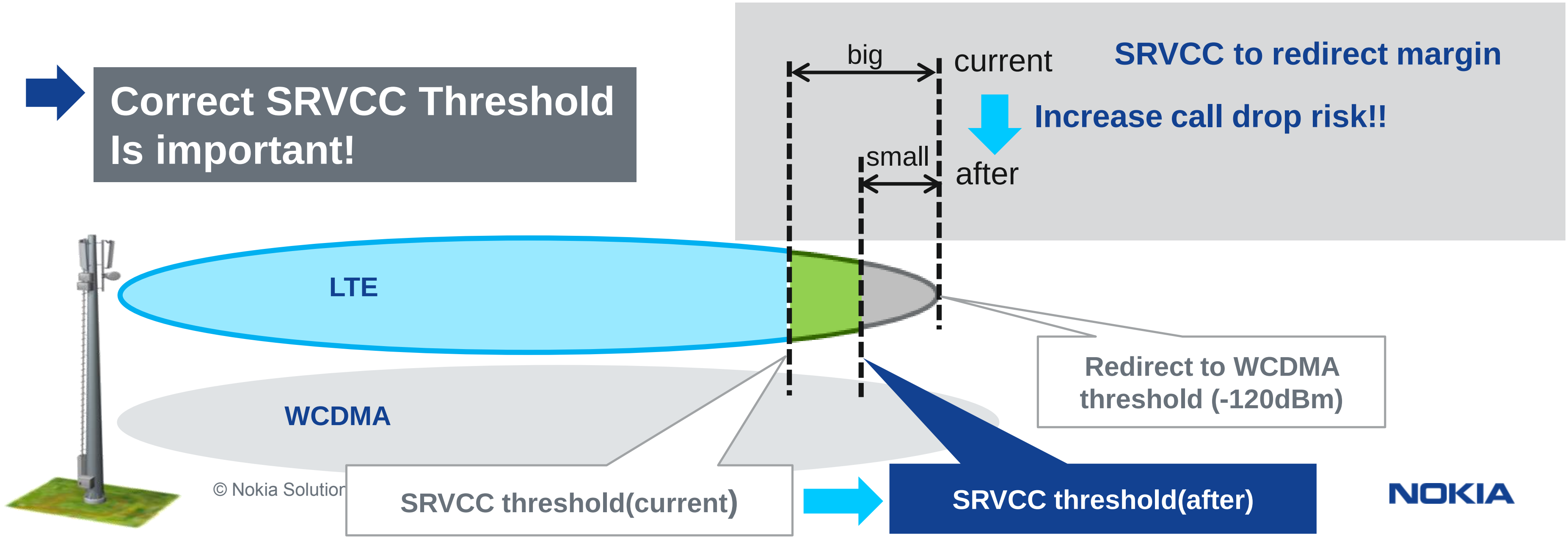
VoLTE call drop case by redirect (from field measurement)



Considerations during SRVCC threshold change

SRVCC threshold cannot be reduced dramatically

- If SRVCC threshold change to lower value with current implementation VoLTE call drop risk may increase. So it is not possible apply big change to this threshold
- Redirect threshold has been -120dBm so far and it is not possible to change this to lower value because PS call(QCI9) drop ratio increases

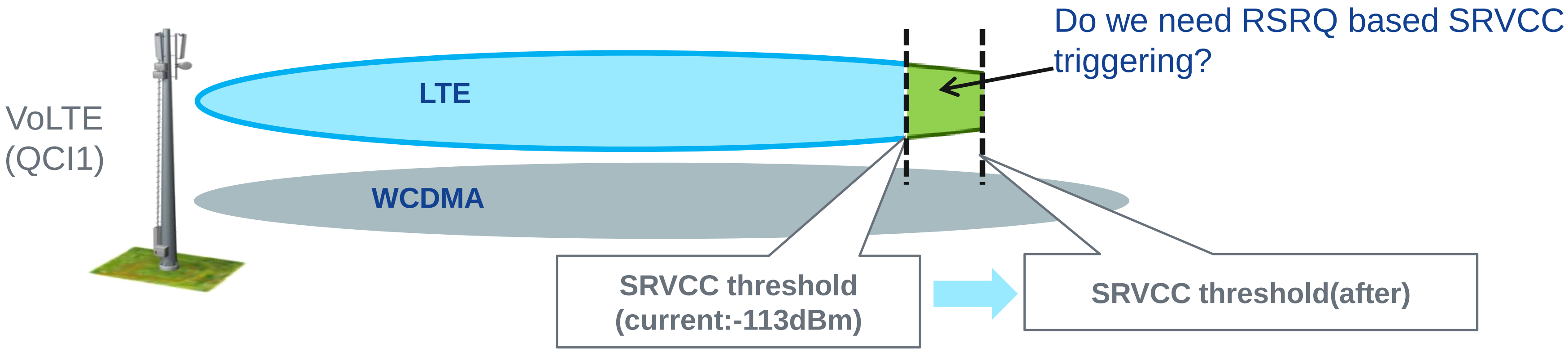


SRVCC Assessment and Optimization

•RSRQ based SRVCC HO Study

RSRQ based SRVCC HO
Background

- If SRVCC triggering threshold is changed to lower value, user can use VoLTE in worse RF condition.(study target : RSRP-113dBm -> -122dBm)
- Fixed to RSRP based SRVCC triggering now, so we can not use SRVCC when RSRQ degrades.
- Studied the requirement to introduce RSRQ based SRVCC triggering ,if SRVCC triggering threshold is changed to lower value.



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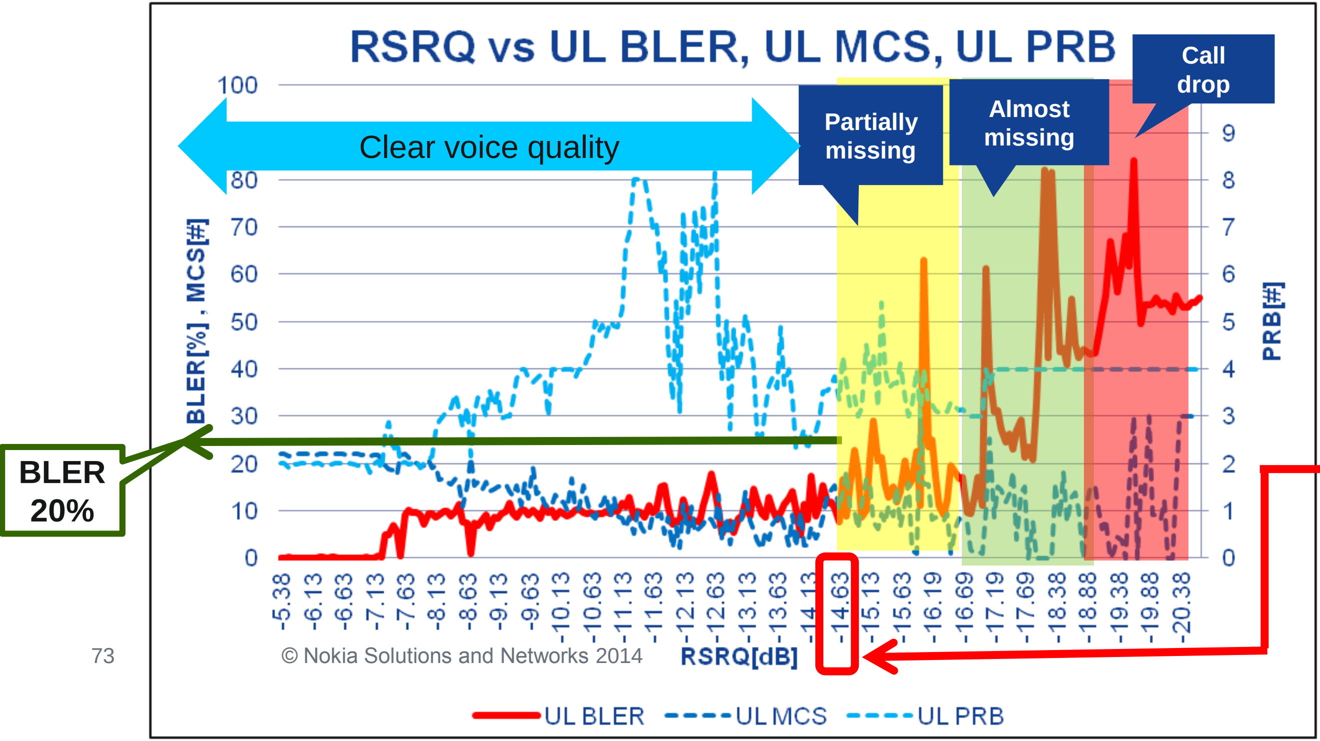
Relation between RSRQ and UL BLER (From Lab test)

- Relation between RSRQ and UL BLER. (normally UL becomes bottleneck in Nokia NW) VoLTE can not keep clear quality when RSRQ becomes lower than -14dB(UL BLER = 20%)
- Defined RSRQ -14dB as a reference value of voice quality degradation.



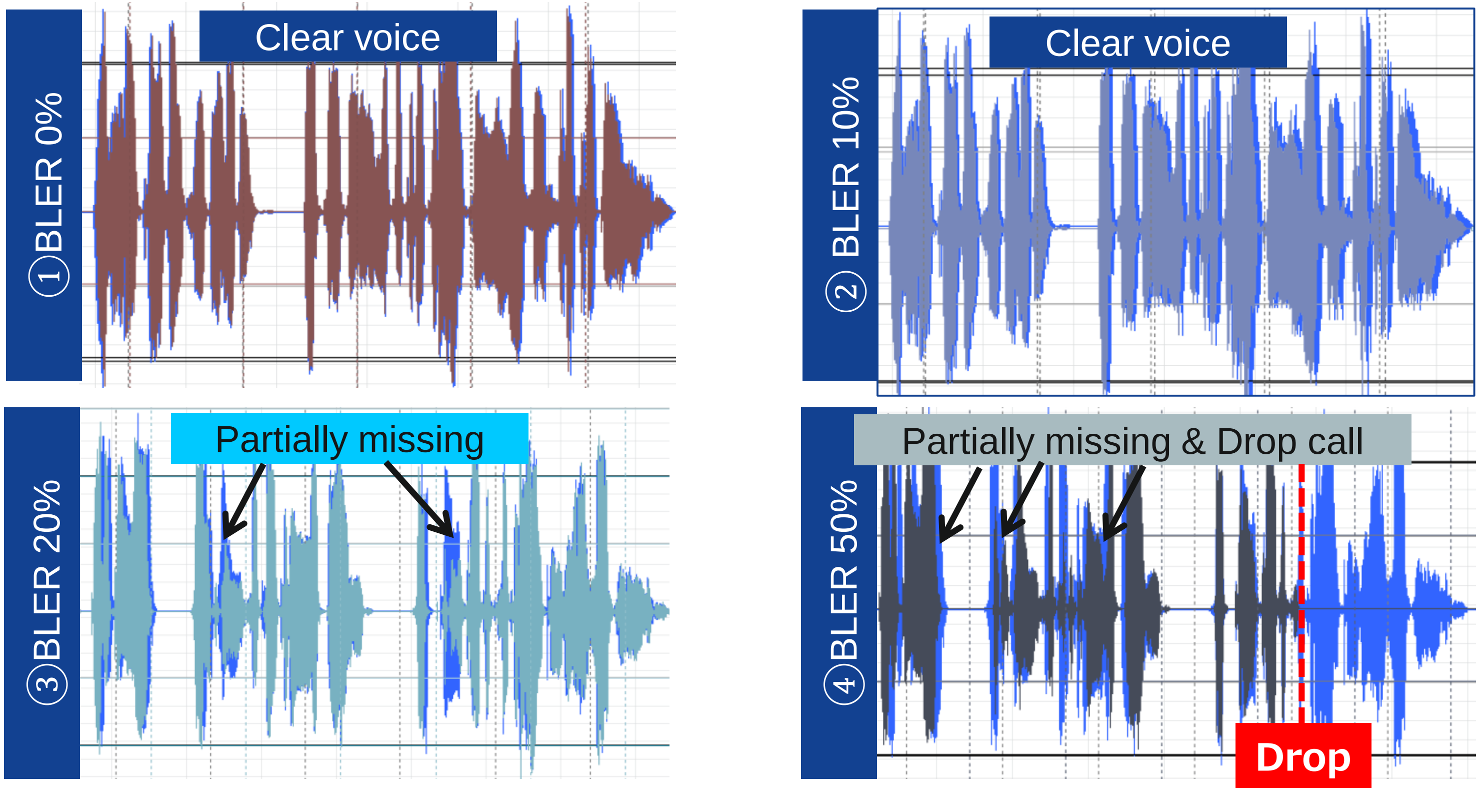
RSRQ	
-5	○
-6	○
-7	○
-8	○
-9	○
-10	○
-11	○
-12	○
-13	○
-14	△
-15	△
-16	△
-17	▲
-18	▲
-19	×

Relation between voice quality and RSRQ

Legend	
○	Clear voice
△	Partially missing voice
▲	Almost Missing voice
×	Call drop

Voice quality test result

- When UL BLER becomes 20%, VoLTE voice quality starts degradation
- When UL BLER becomes above 50% VoLTE call dropped



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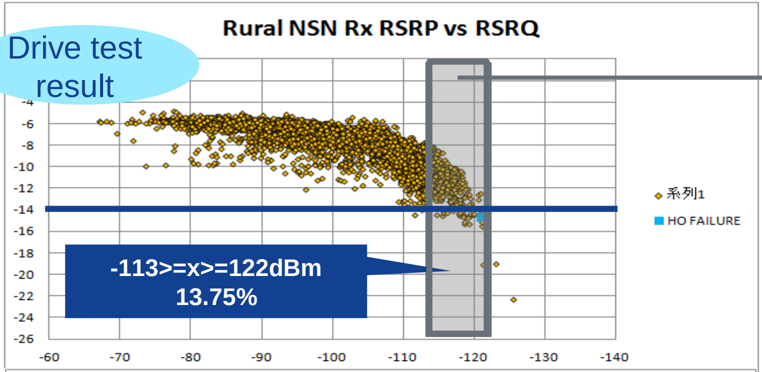
Relation between RSRQ and VoLTE

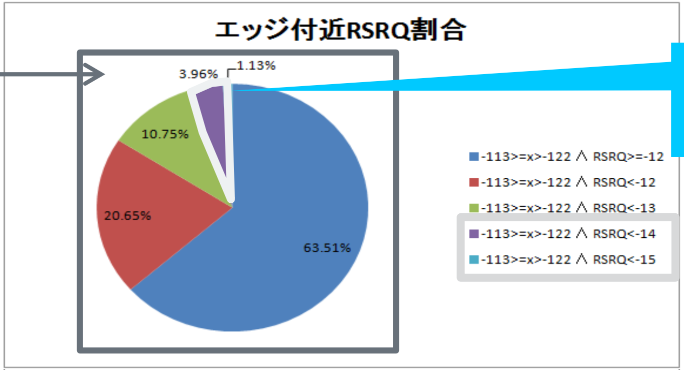
- SRVCC threshold is changed from -113dBm to -122dBm.
- Portions below RSRQ -14dB are 5%(in Rural) and 10%(in Highway) and VoLTE can not guarantee good quality for these users.

Conclusion: RSRQ based SRVCC should be introduced

Drive test result

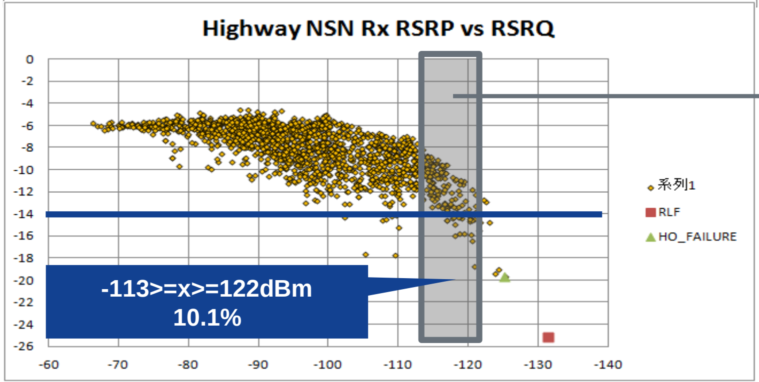


-113>=x>=122dBm
13.75%

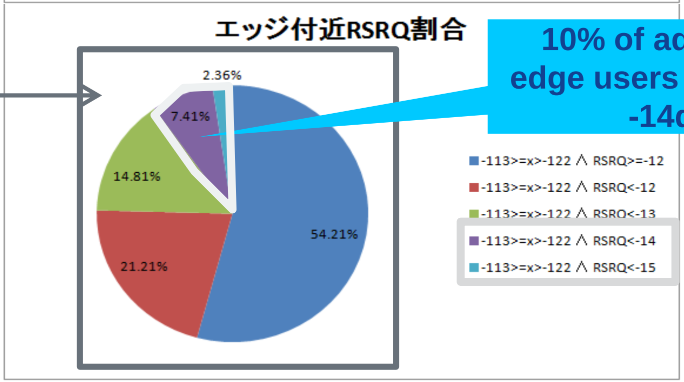


5% of additional edge users are below -14dB

These users should move to WCDMA by SRVCC



-113>=x>=122dBm
10.1%



10% of additional edge users are below -14dB

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SRVCC Assessment and Optimization

- SRVCC (VoLTE Performance) Issues in high speed trains

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VoLTE performance in high speed trains

Background

- One of the most difficult problem in Operators network is VoLTE Performance in High speed train, especially when Train goes through a tunnel.
- Studies has done to evaluate Voice performance in VoLTE and WCDMA AMR in high speed trains when train is going through the tunnel
- Both drive test and OSS KPIs were used
- Effect of Parameter changes is studied

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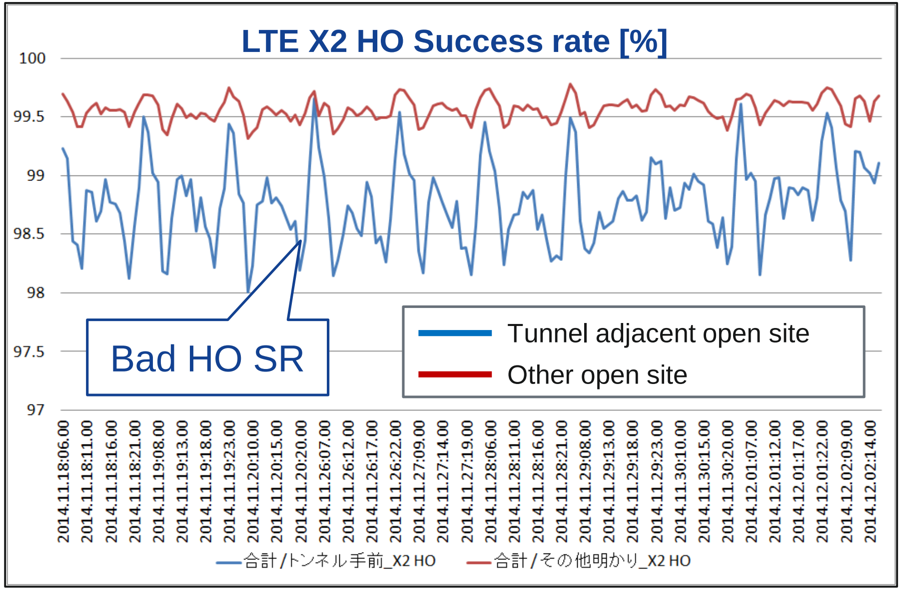
VoLTE performance in high speed trains

Tunnel adjacent site (KPI)

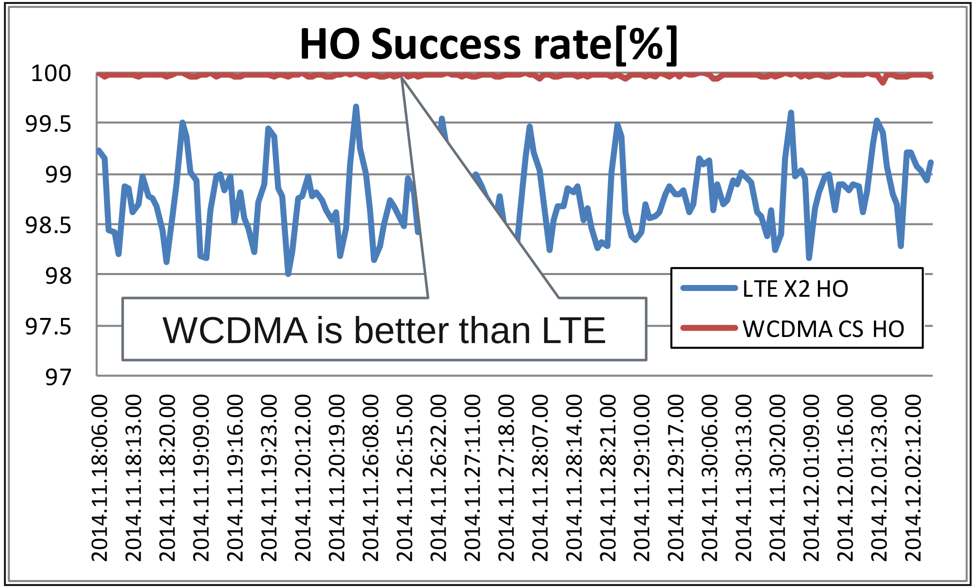
- Tunnel adjacent site's HO success rate is lower than other open sites from KPI point of view.
- WCDMA site's HO success rate is better than LTE in the tunnel adjacent site.

➡ **WCDMA AMR should be used when Train enters a tunnel**

Tunnel adjacent site vs. other site



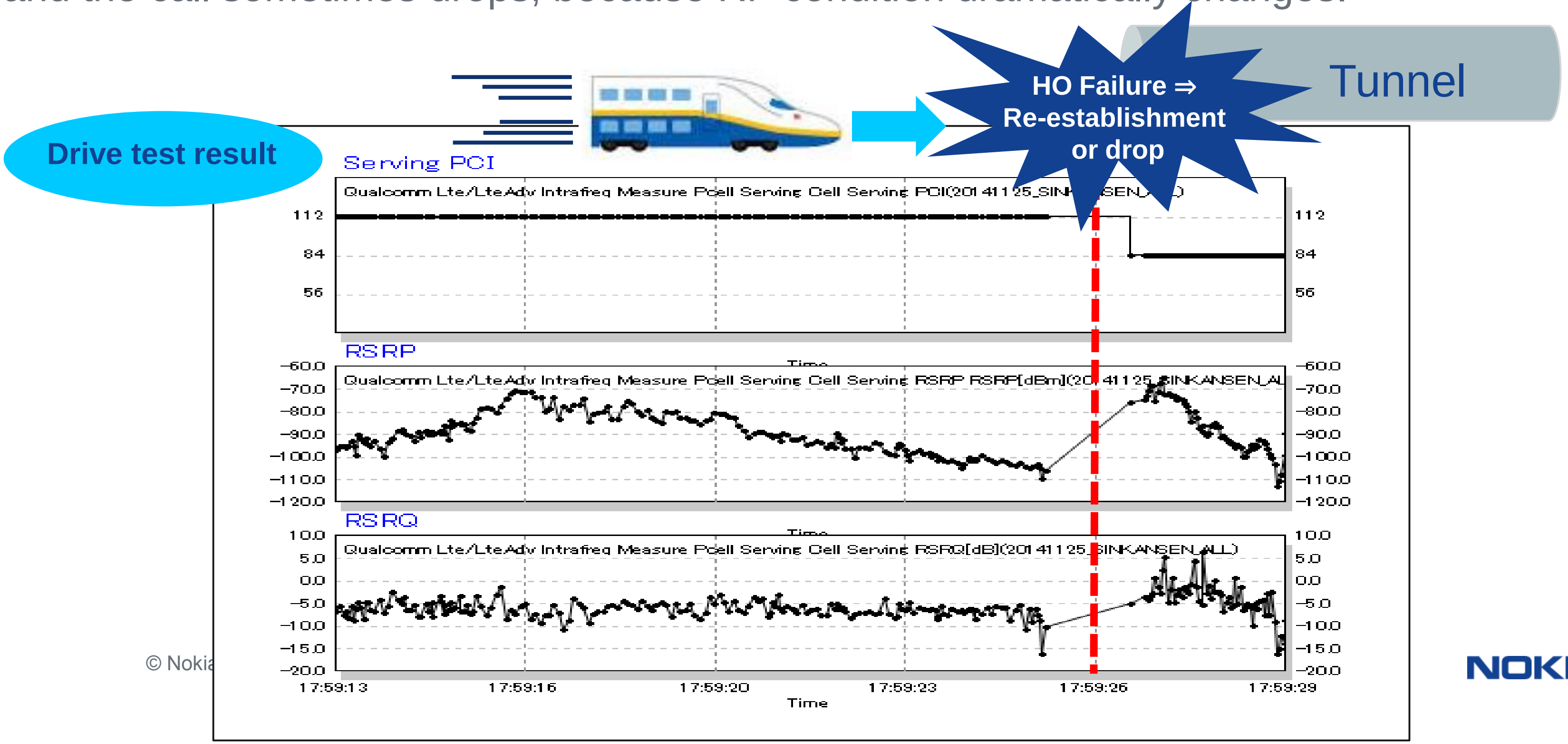
LTE vs. WCDMA (Tunnel adjacent site)



VoLTE performance in high speed trains

High Speed Train tunnel adjacent site (Drive test result)

- When high speed train enters a tunnel, VoLTE call easily fails Handover to the tunnel site and the call sometimes drops, because RF condition dramatically changes.



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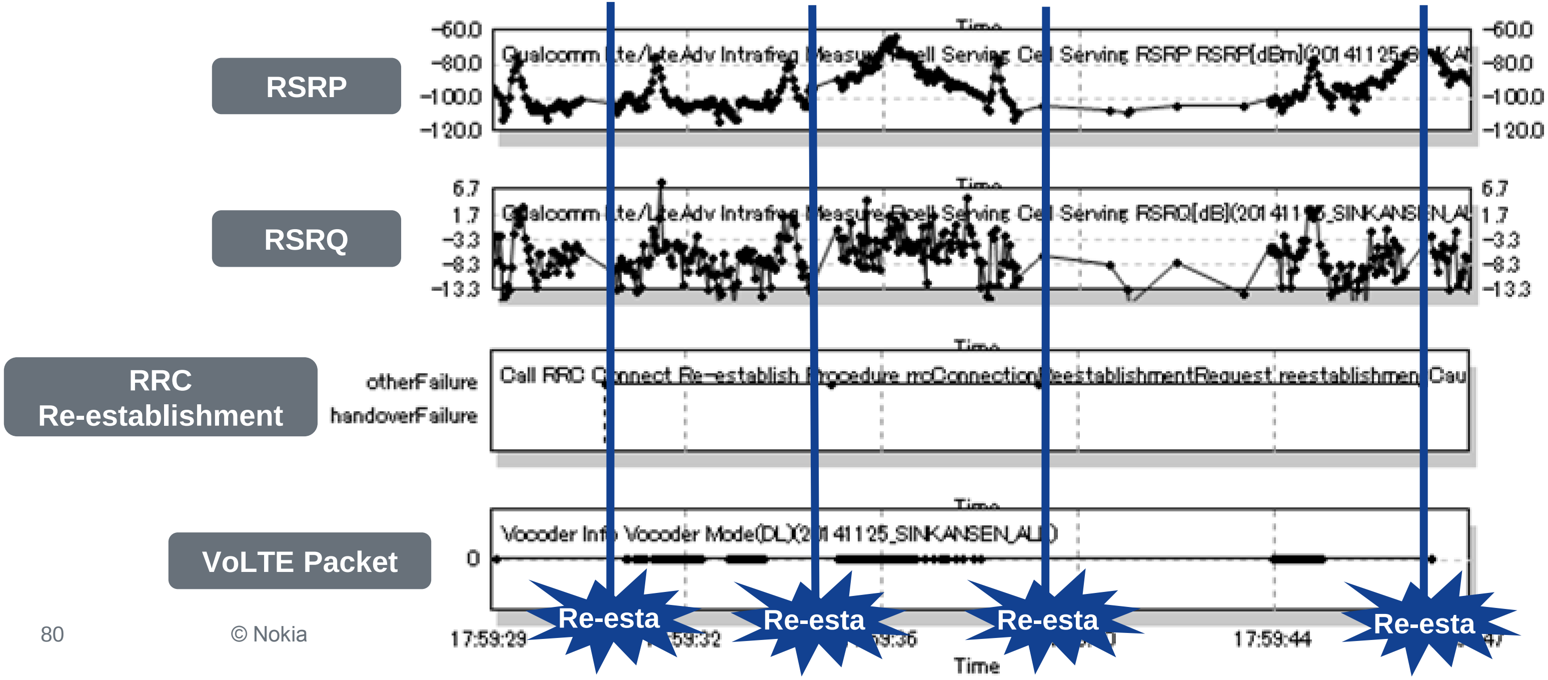
VoLTE performance in high speed trains
Tunnel site (Drive test result)

- There are many RRC Re-establishment of VoLTE call when Train goes through a tunnel
- This Re-establishment causes missing Voice, VoLTE call can not keep good quality in tunnels.

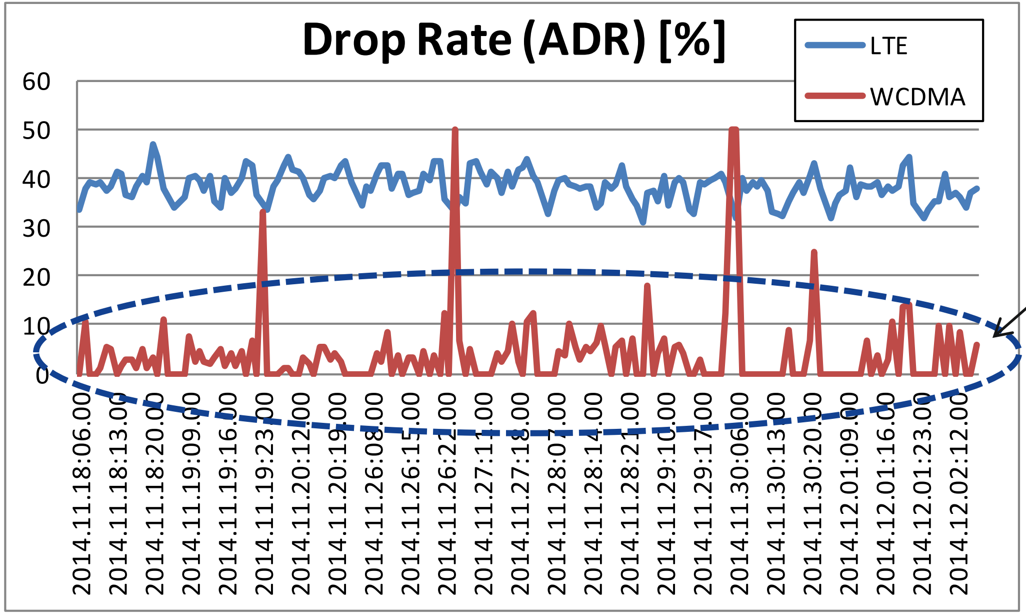


VoLTE performance in high speed trains

Tunnel site (KPI)

- LTE drop rate is around 38%
- WCDMA's drop rate is lower than LTE in tunnel sites.

WCDMA AMR should be used when Train goes through a tunnel



Lower drop rate

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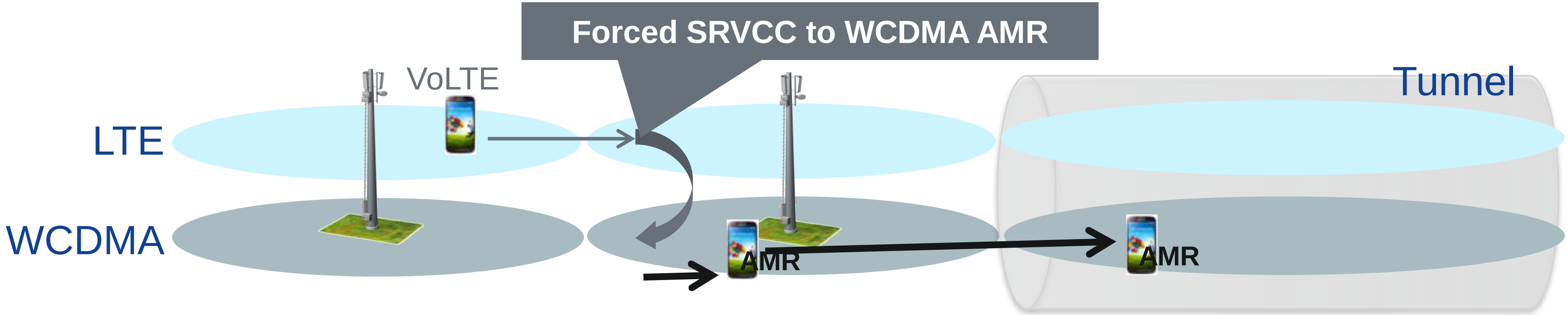
VoLTE performance in high speed trains

Possible Design concept

- To make UEs enter tunnels continuously without drop, our new design forces VoLTE UEs to move to WCDMA by SRVCC in tunnel adjacent sites and tunnel sites.



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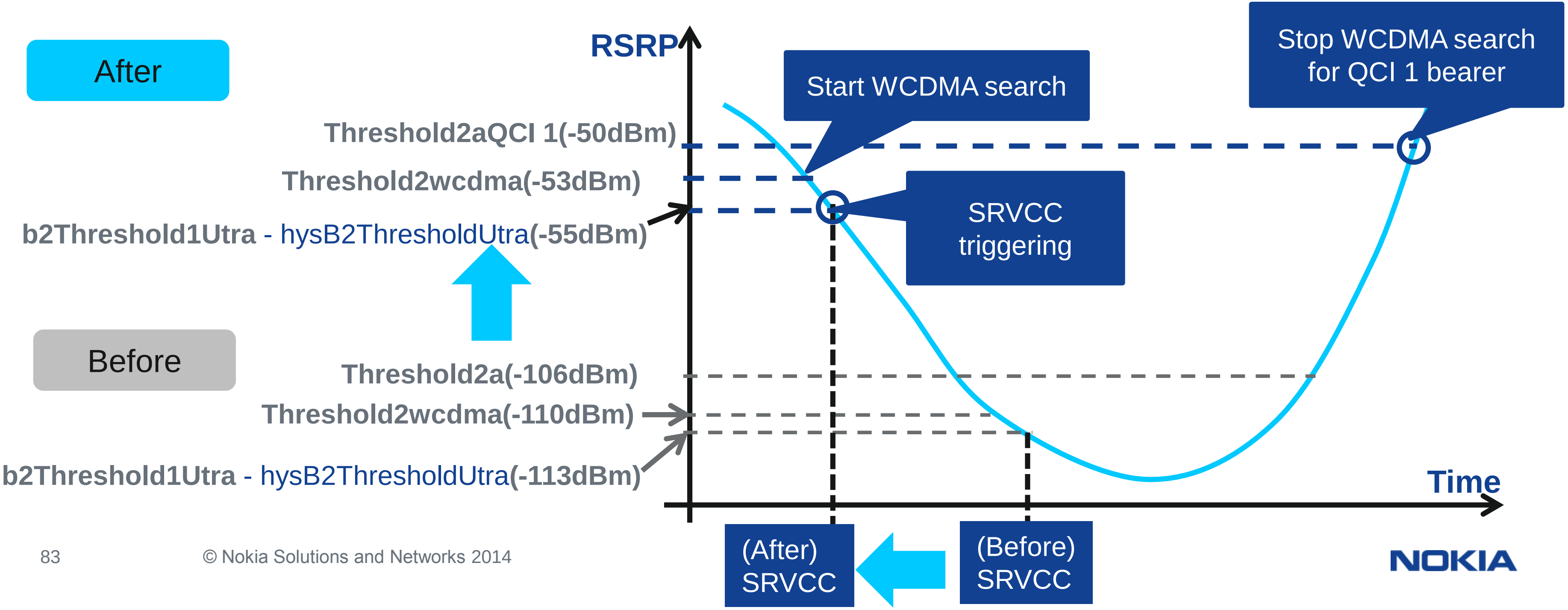
VoLTE performance in high speed trains

Possible Parameter change

- By changing WCDMA search and SRVCC triggering threshold to higher value, SRVCC will be triggered for almost all VoLTE user, then all user will use WCDMA AMR.



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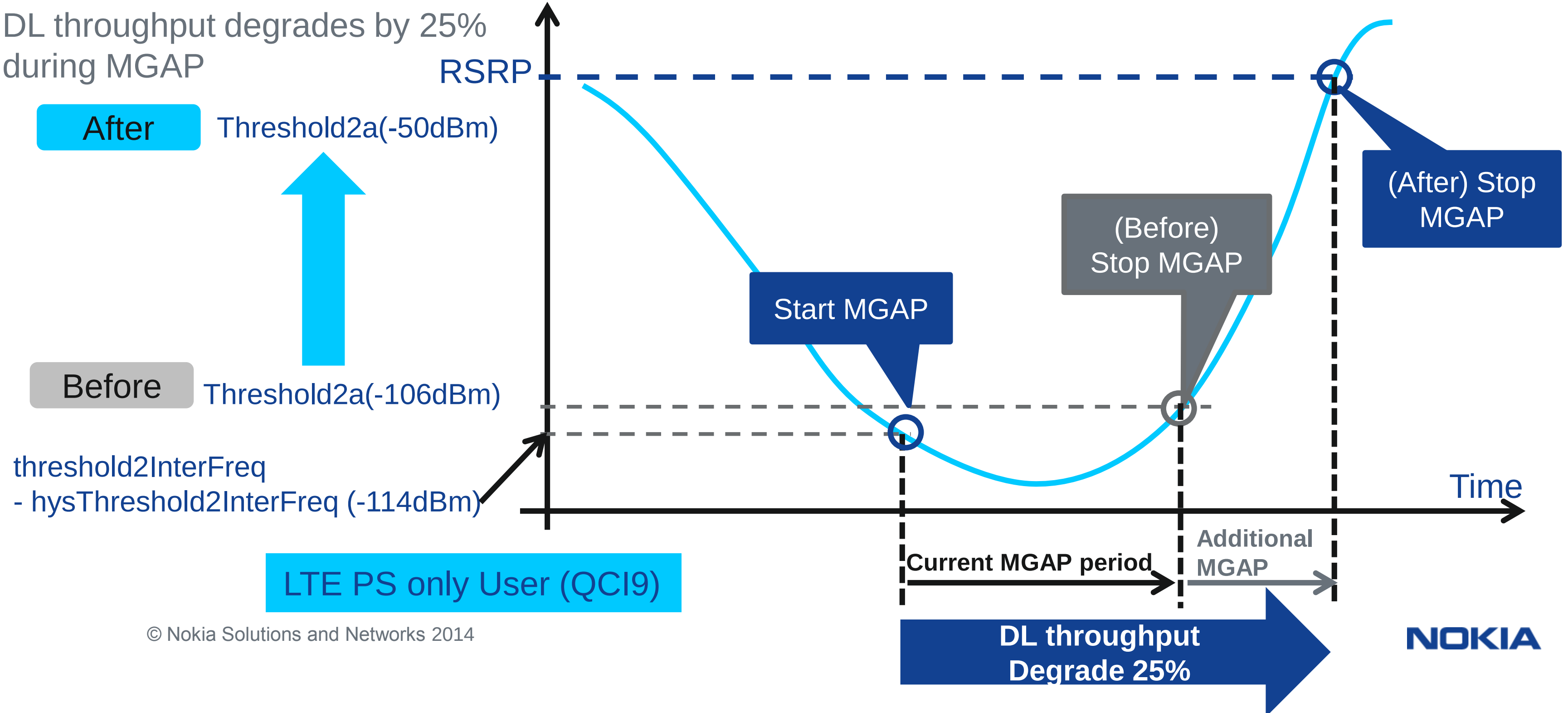
VoLTE performance in high speed trains

Challenge with Parameter change before RL 70

- If we change "Threshold2a" to higher value like previous slide, LTE PS user can not release MGAP (Measurement gap) setting once the UE enters MGAP
- DL throughput degrades by 25% during MGAP



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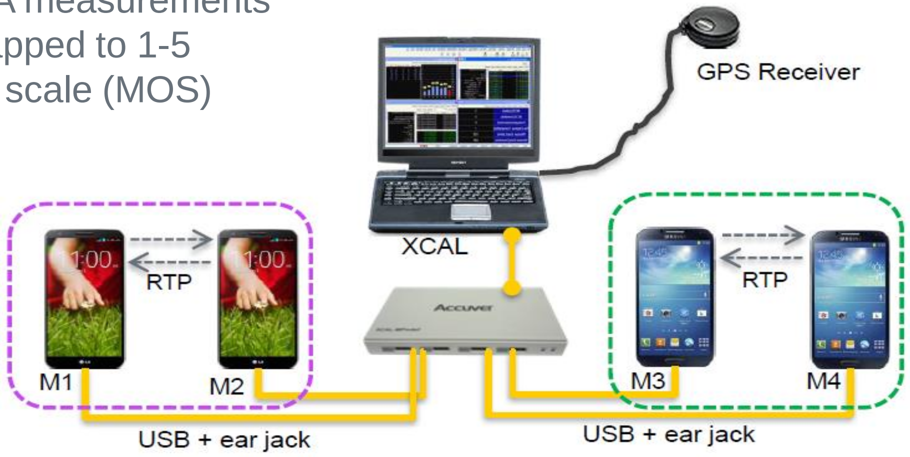
VoLTE MOS Assessment and Optimization

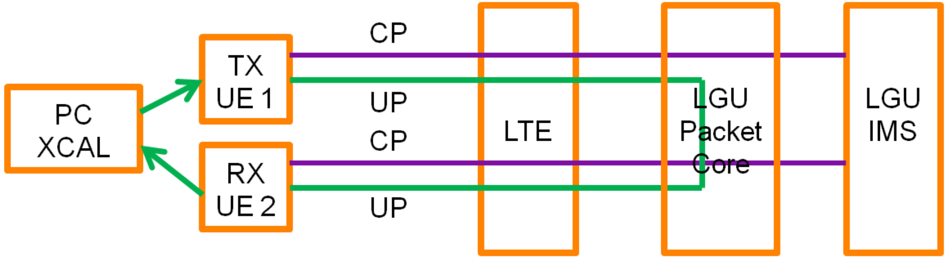
MOS Optimization

- This is from a project experience, case might be different in other case
- Investigate the correlation between voice quality MOS (POLQA863) and various network quality measures
- One of biggest contributor in MOS is peak delay. Potential contributors to delay can be:
  - HARQ retransmissions in transmitting UE Uplink
  - HARQ retransmissions in receiving UE Downlink
  - Scheduling delays of QCI1 bearer
  - Transmitting UE processing the RTP packets
  - Receiving UE processing the RTP packets
  - Other delays in transport network or in EPC

VoLTE POLQA Measurement Setup

POLQA measurements are mapped to 1-5 quality scale (MOS)

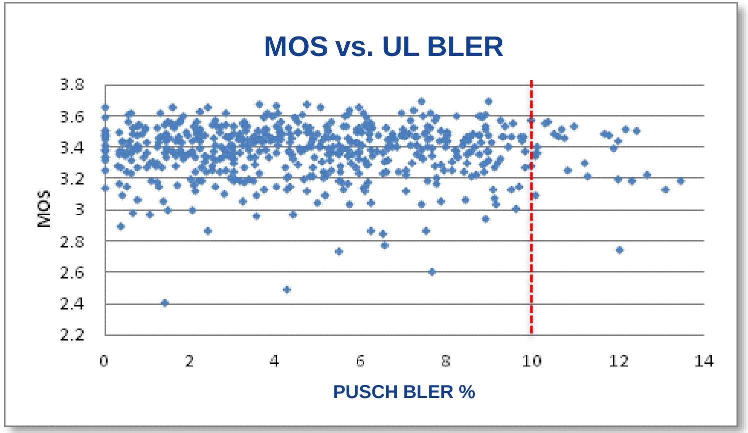


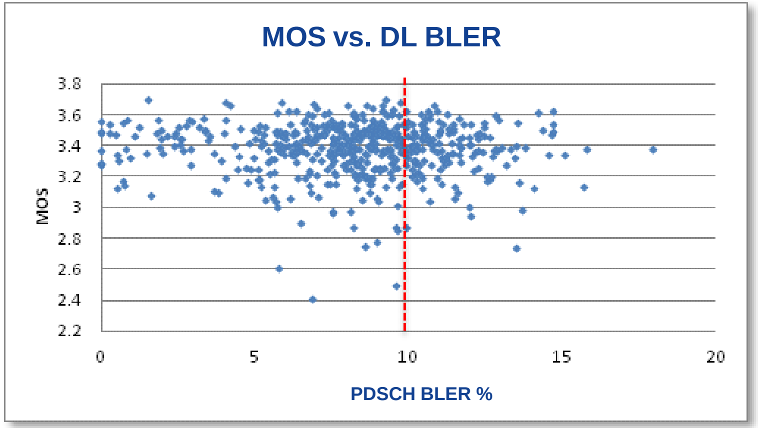


- VoLTE capable UEs: Samsung S4 and LGU G2
- VoLTE calls were made by a single computer running XCAL software
- MOS POLQA P863, 6 sec voice sample, AMR-WB 23.85 kbps codec
- The long VoLTE (mobile-to-mobile) call was setup to collect POLQA call quality values

UL & DL BLER vs. MOS Quality

- VoLTE QCI1 bearer retransmissions cause additional delay and variations to RTP packet delivery.
  - Each HARQ retransmission takes approximately 8ms and e.g. up to 7 retransmission causes up to 56ms delay.
- BLER has no impact on MOS values as long as 10% BLER target is maintained in both UL and DL transmissions.





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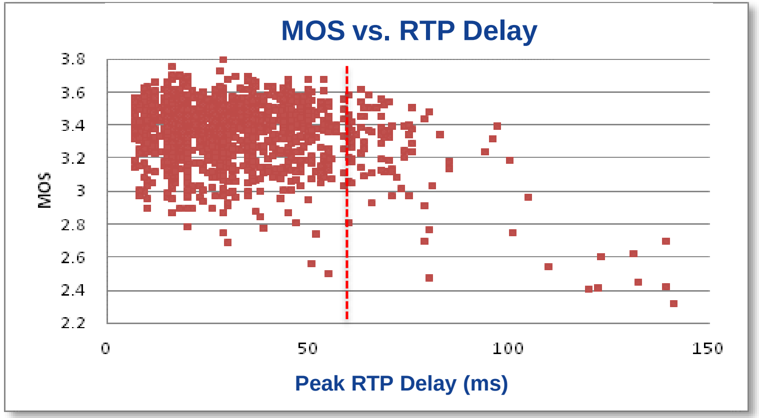
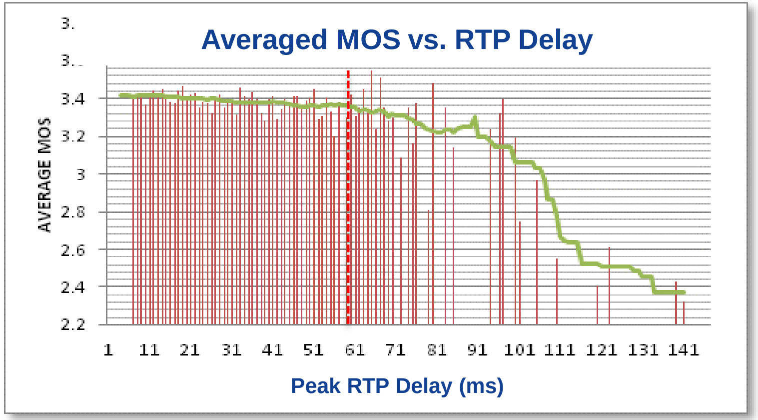
RTP Delay vs. MOS Quality

- RTP delay variation was measured by the receiving UE as the time difference of current and the previous arrival timing of the RTP packet (Rj-Sj)-(Ri-Si).
- RTP packet delay has a significant MOS degradation from 60 ms delay point onwards.
- The following factors are causing the delay:
  - HARQ retransmissions.
  - Interruption time during handovers.
  - Scheduling delays of RTP packets over the radio interface.
  - UE TX/RX end processing of RTP packets.
  - Transport or EPC network congestion.





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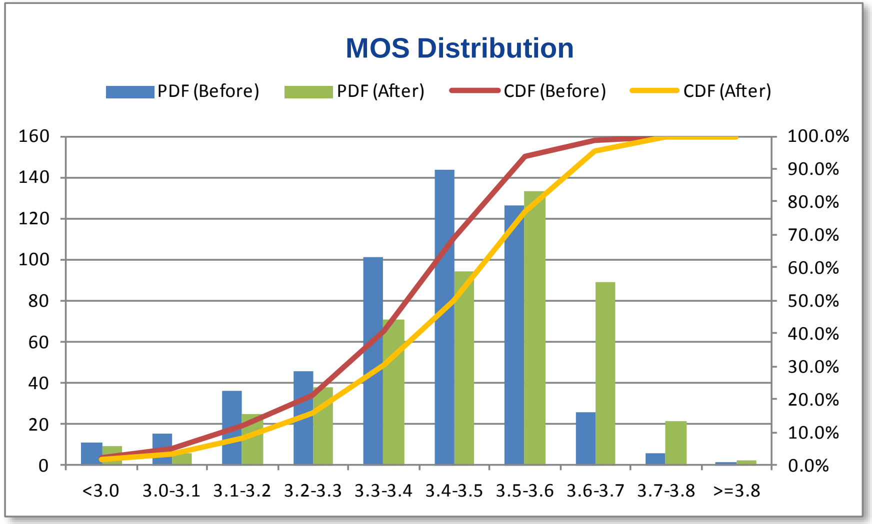
MOS Delay Target Optimization

- The eNB scheduling delay target (delayTarget) was changed 80ms → 50ms and probability (dlsOldtcTarget) 98% → 99%
- The impact to MOS was noticeable, i.e. scheduling delay target has a significant impact on MOS values
- Average MOS improved from 3.4 to 3.45
- However, the voice quality is improved with a shorter delay but less VoLTE users can be served because a packet aggregation cannot be effectively performed with a tight scheduling delay requirement (i.e. trade off between quality and capacity)



Distribution of MOS > 3.5:
- Before = 31%
- After = 50%

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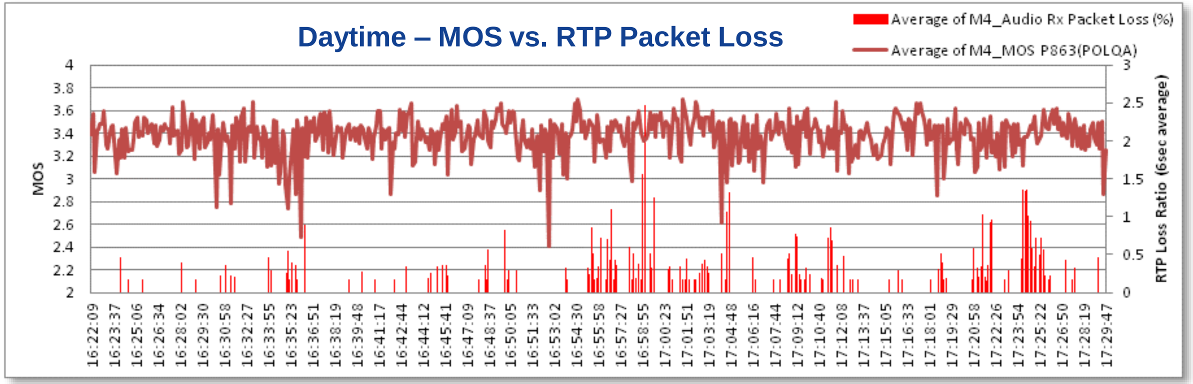
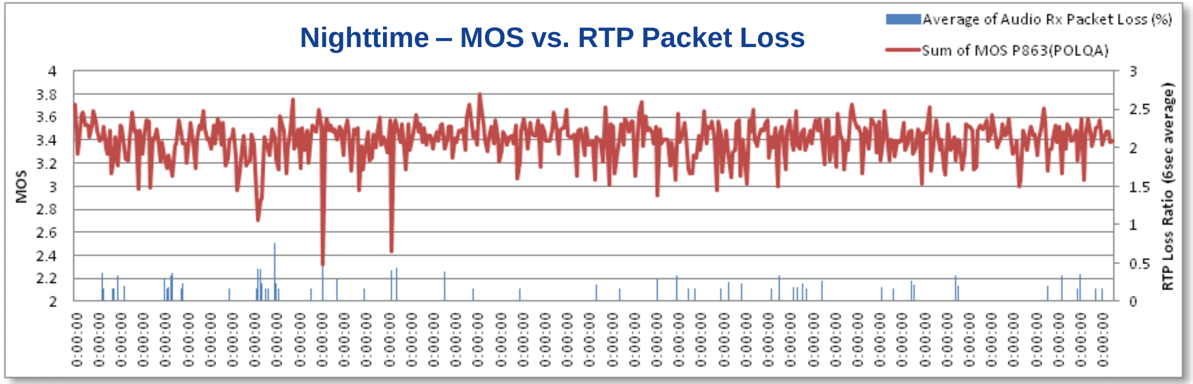
RTP Packet Loss and Network Load

- During the daytime (busy hour) when the network load is higher, the RTP packet loss is much higher → possibly issues with QoS deployment in EPC domain.
- Also there seems to be more MOS variations during the higher load, but MOS is not significantly impacted due to a low packet loss ratio.





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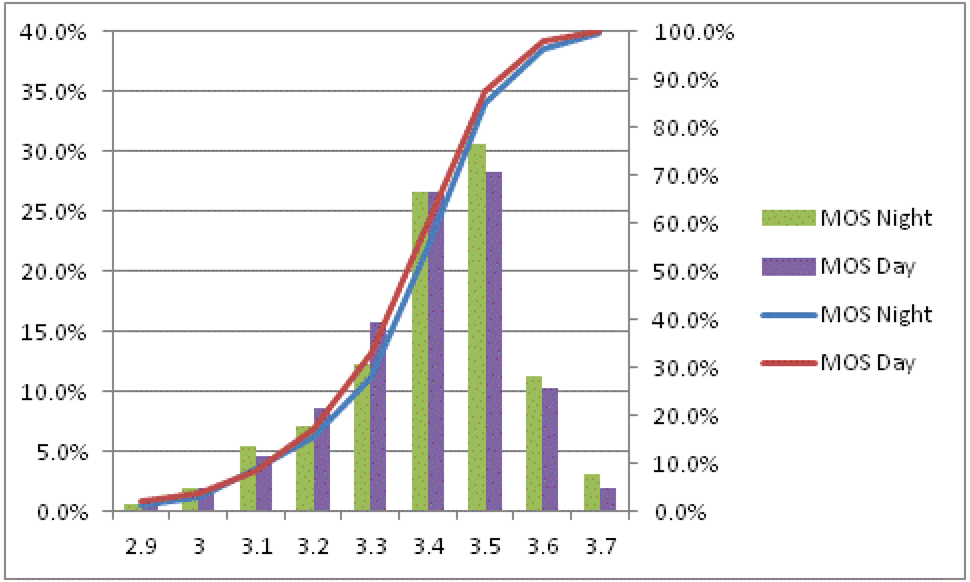
RTP Packet Loss and Network Load

- MOS distribution shows only minor difference between the tests even though the packet loss more frequent during daytime with higher loading.
- Packet drops seem to have a minor impact on MOS.
- Average MOS:
  - Night time 3.404
  - Day time 3.381



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Summary

- Network radio performance does not seem to have great correlation with MOS
  - UL BLER no impact
  - DL BLER no impact
- Some delay components have correlation with MOS
- Surprisingly RTP packet Drop ratio does not seem to have impact on MOS
- Recommendations:
  - Reduce delayTarget to 50ms and dlsOldtcTarget to 99%

VoLTE TTI Bundling Analysis

- TTI Bundling entering condition analysis
- TTI Bundling analysis with KPIs

TTI Bundling entering condition analysis

TTIB triggering conditions

Analyze the effect of ttiBundlingBlerThreshold

- To trigger the Intra-cell HO procedure, for entering TTIB mode, following criteria must be fulfilled:
  1. UE is transmitting with currentMCS ≤ *eUlLaLowMcsThr*, **AND** → MCS1
  2. MAX_NUM_PRB ≤ max (*eUlLaLowPrbThr*, *ulsMinRbPerUe*), **AND** → PRB3
  3. *ttiBundlingBlerThreshold* threshold is reached → BLER 15 / 13 / 11%

	Triggering criteria	Parameter	Value
General Parameter	UL MCS	eUlLaLowMcsThr	1 (default setting)
General Parameter	UL PRB	eUlLaLowPrbThr	1 (default setting)
		ulsMinRbPerUe	3 (default setting)
Parameter for TTIB	UL BLER	ttiBundlingBlerThreshold	Set1 : 15% Set2 : 13% Set3 : 11%

TTIB triggering conditions

ttiBundlingBlerThreshold impact for TTIB

- TTI Bundling test were carried out with 3 different ttiBundlingBlerThreshold: 15/13/11% but entering conditions were not changed
- eNodeB tries to keep UL BLER to 10%, but BLER fluctuates with big dynamic range(from 0% to 50%)
- Controlling by BLER is not good solution

RSRP value when UE entered TTI Bundling mode

Fading condition	ttiBundlingBlerThreshold		
	15%	13%	11%
No Fading	-113.5dBm	-113.6dBm	-112.5dBm
EPA 3km/h	-108dBm	-113dBm	-105dBm
EVA 50km/h	-110dBm	-109dBm	-111dBm
ETU 3km/h	-108dBm	-108dBm	-108dBm

Almost same (15% vs 13%)   Almost same (13% vs 11%)

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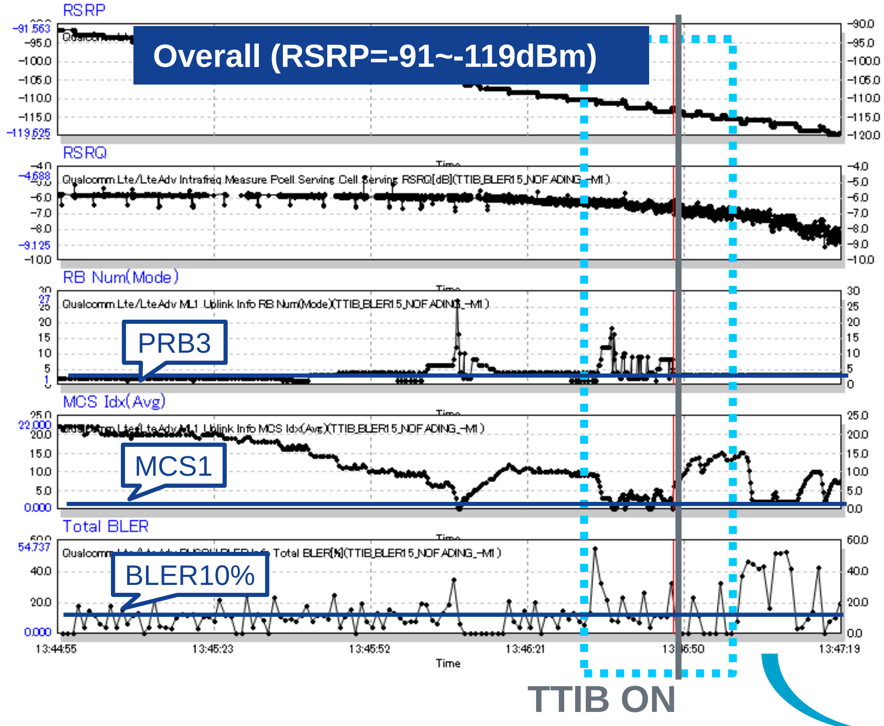
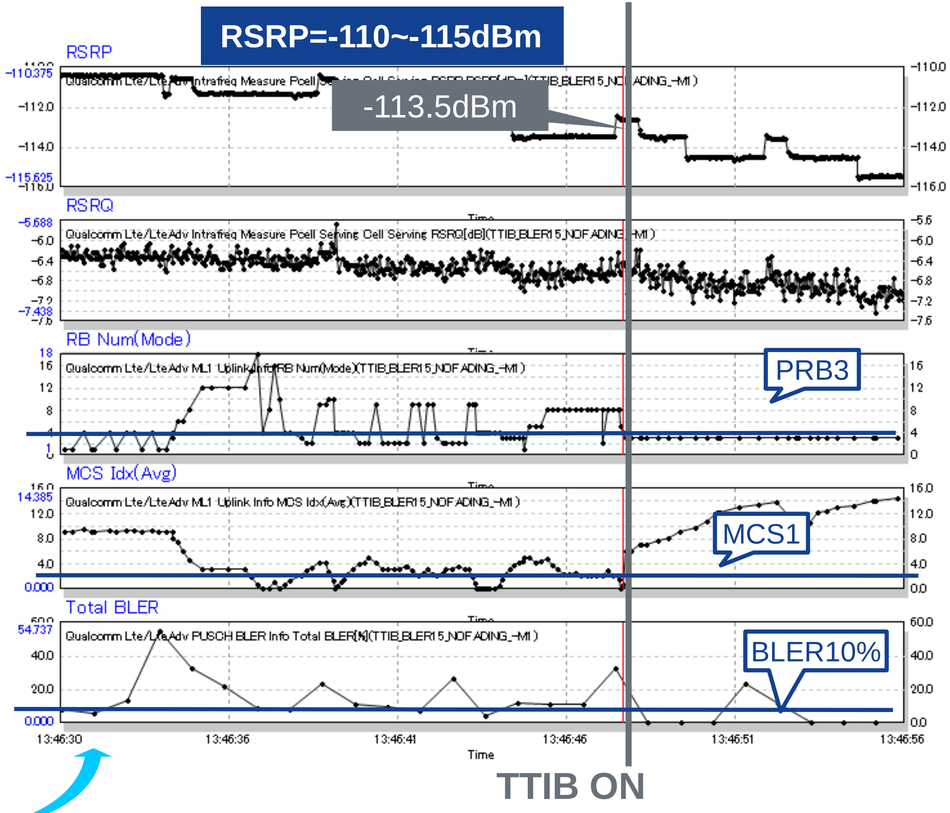
TTIB triggering conditions

Effect of UL PRB, MCS

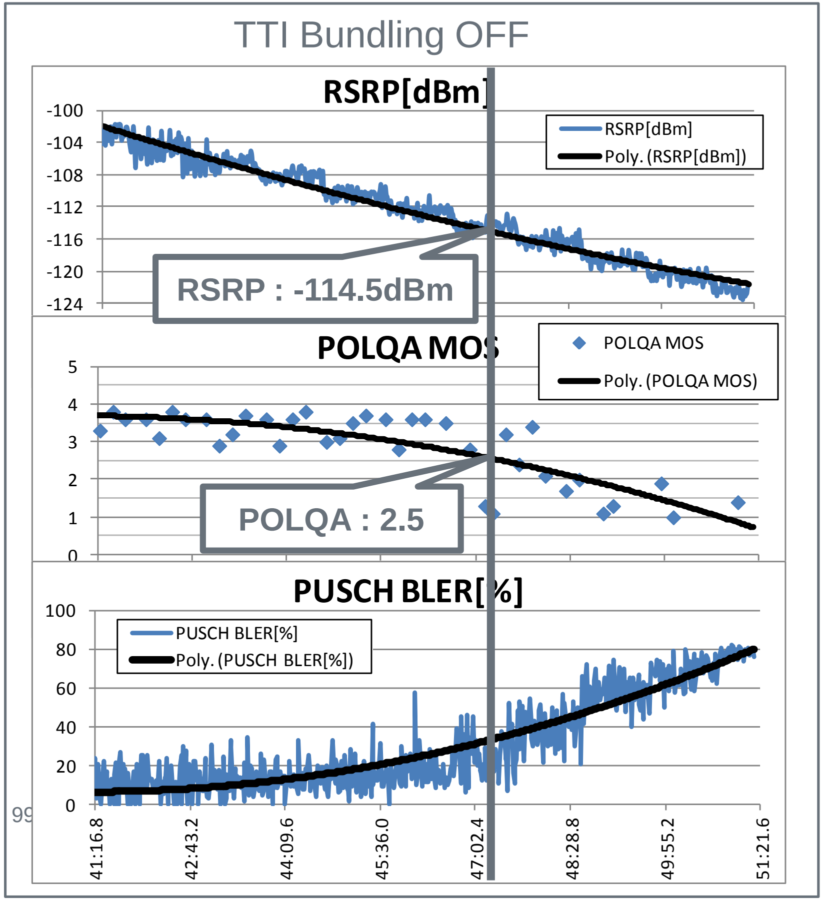
- UL PRB and BLER are easy to fluctuate and have no trend, so these are not good criteria to control TTI bundling
- **MCS** has some trends

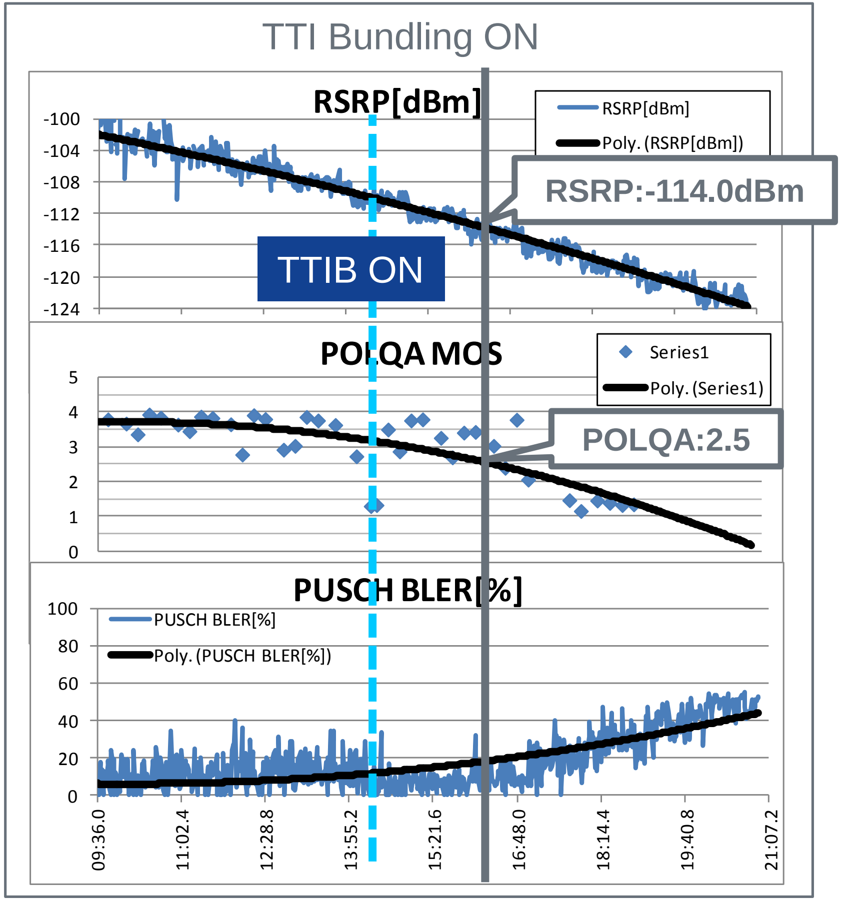




TTI Bundling OFF vs ON(retransmission 12times)

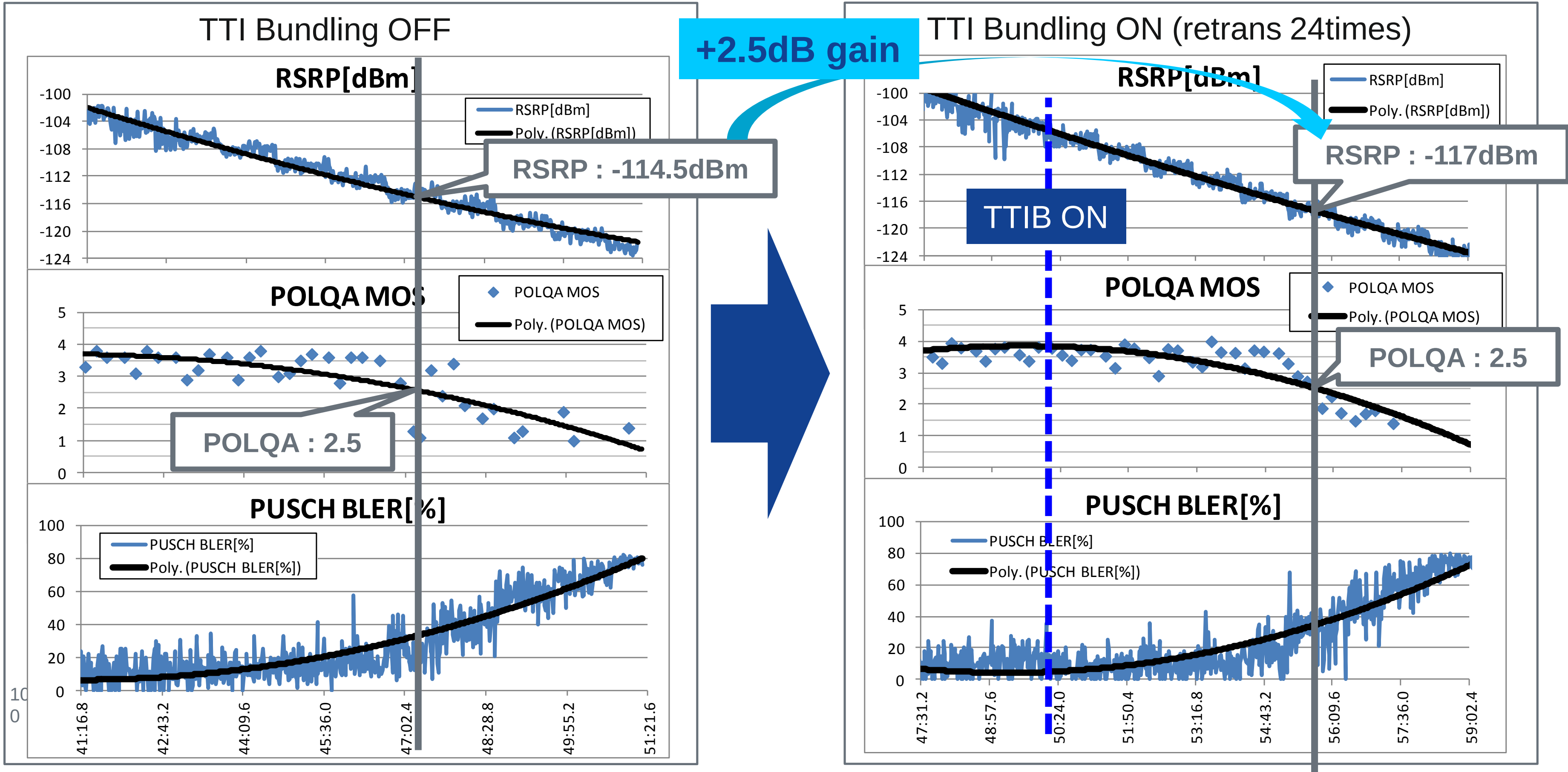
Difficult to see TTI Bundling Gain if harqMaxTrUlTtiBundling is 12





TTI Bundling OFF vs. ON(retransmission 24times)

VoLTE coverage (above POLQA2.5) increased by 2.5dB if harqMaxTrUlTtiBundling is 24



TTIB triggering conditions

Effect of harqMaxTrUlTtiBundling (POLQA test Summary)

Settings

Setting / Parameter	TTIB OFF	TTIB ON	TTIB ON (retrans24)
TTI Bundling	OFF	ON	ON
ttiBundlingBlerThreshold	-	15%	15%
harqMaxTrUlTtiBundling	-	12	24

Result

- We defined POLQA 2.5 as a reference value of good VoLTE quality.

Result	TTIB OFF	TTIB ON (retrans12)	TTIB ON (retrans24)
RSRP @ POLQA(2.5)	-114.5dBm	-114.0dBm	-117dBm

No Gain...

+2.5dB Gain

TTI Bundling analysis with KPIs

VoLTE TTI Bundling Analysis

- TTI bundling mode comparing with non-TTI Bundling mode by using PM counter and MOS quality measurement
  - **Reduce PDCCH load**

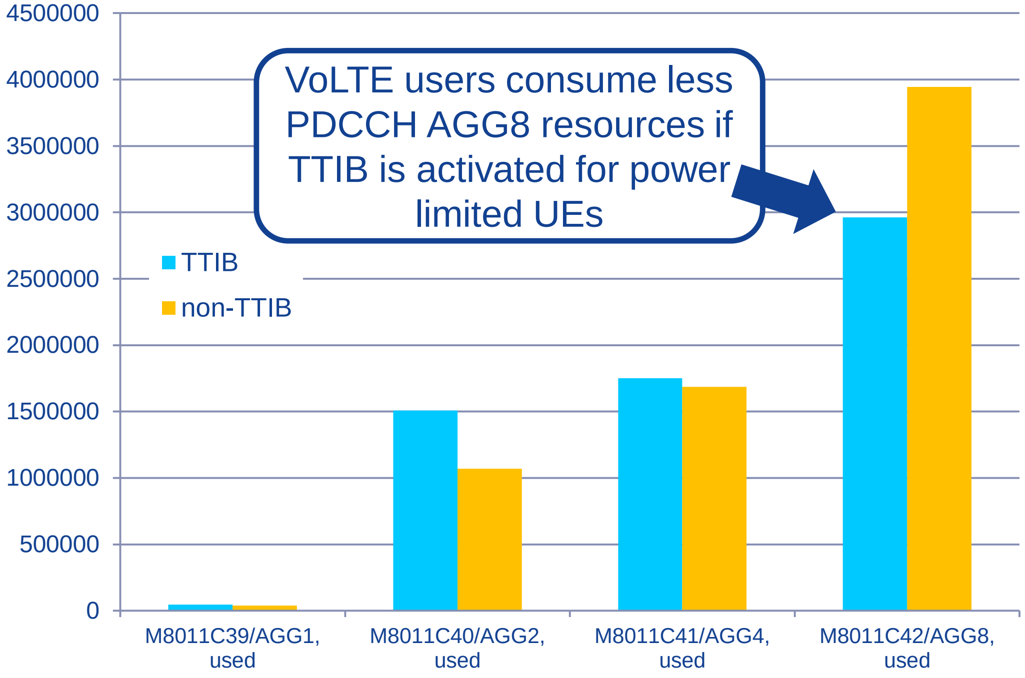
    OSS KPIs- PDCCH aggregation level usage and distribution
  - **Improved UL performance**

    OSS KPIs - UL MCS distribution & UL-SCH reception measurements(UL TB decoding)
  - **Improve Voice quality (MOS)**

    Drive Test Tools - MOS for whole testing period
- Network performance was compared with and without feature activated

Reduce PDCCH load

Result: PDCCH aggregation level usage



In poor coverage area, where UE has UL power limited, VoLTE users with TTI Bundling Mode show:

- Less PDCCH AGG8 usage resources
- Reduced PDCCH load used for VoLTE in poor coverage area

Counters:

USED_CCE=SUM[AGGi_USED_PDCCH] i=1,2,4,8 where:

AGG1_USED_PDCCH (M8011C39)

AGG2_USED_PDCCH (M8011C40)

AGG4_USED_PDCCH (M8011C41)

AGG8_USED_PDCCH (M8011C42)

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Improve UL Performance

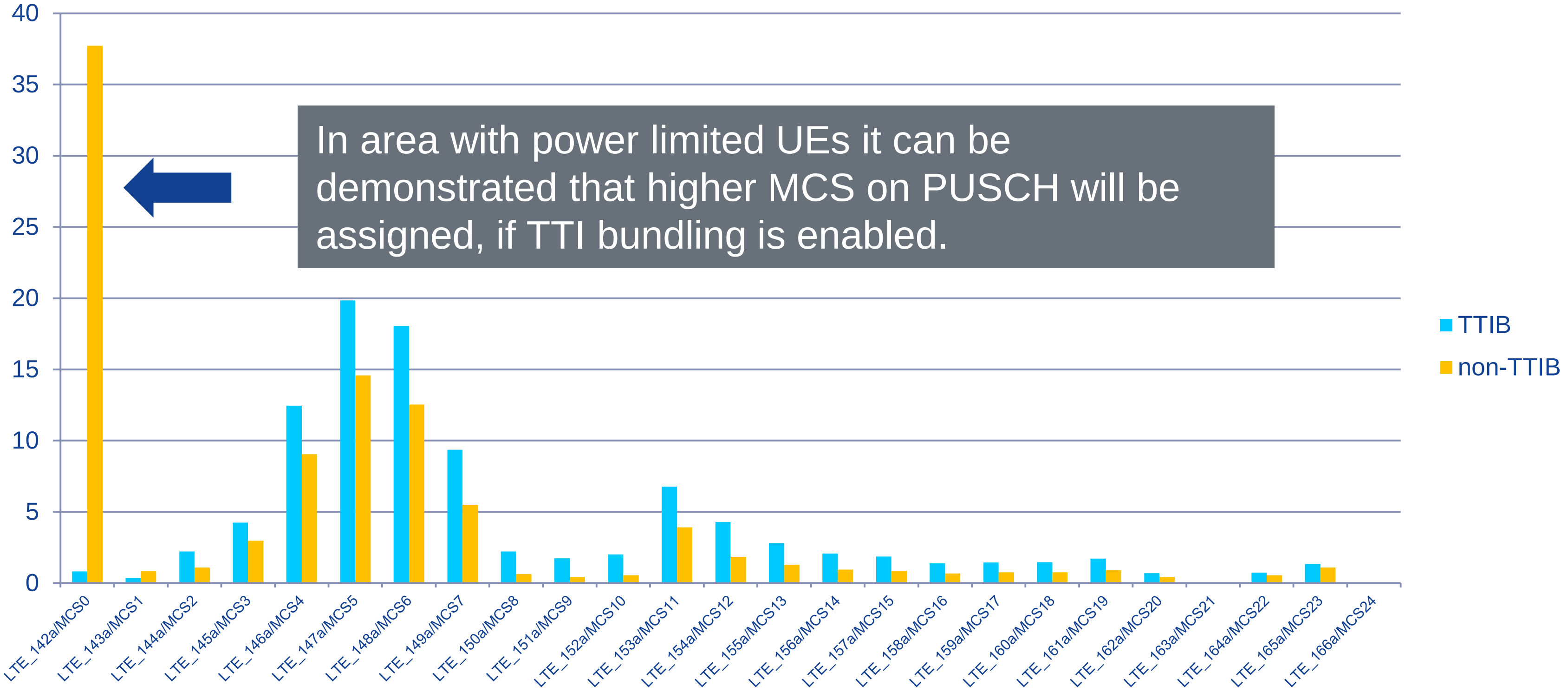
Monitor: PUSCH MCS distribution

Below are related PM counters

How to measure	Feature impact
Counters: *%PUSCH MCS distribution =Used UL MCSi/SUM[UL MCSi_USED]* *i=0,1,2,3….24* where: PUSCH transmissions using MCS0(M8001C16) PUSCH transmissions using MCS1 (M8001C17) PUSCH transmissions using MCS2 (M8001C18) PUSCH transmissions using MCS3 (M8001C19) PUSCH transmissions using MCS4 (M8001C20) : : PUSCH transmissions using MCS22 (M8001C38) PUSCH transmissions using MCS23 (M8001C39) PUSCH transmissions using MCS24 (M8001C40)	UEs on the cell edge in TTI Bundling mode allow LA to utilize higher UL MCS in comparison to UEs on the cell edge without TTI Bundling.

Improve UL Performance

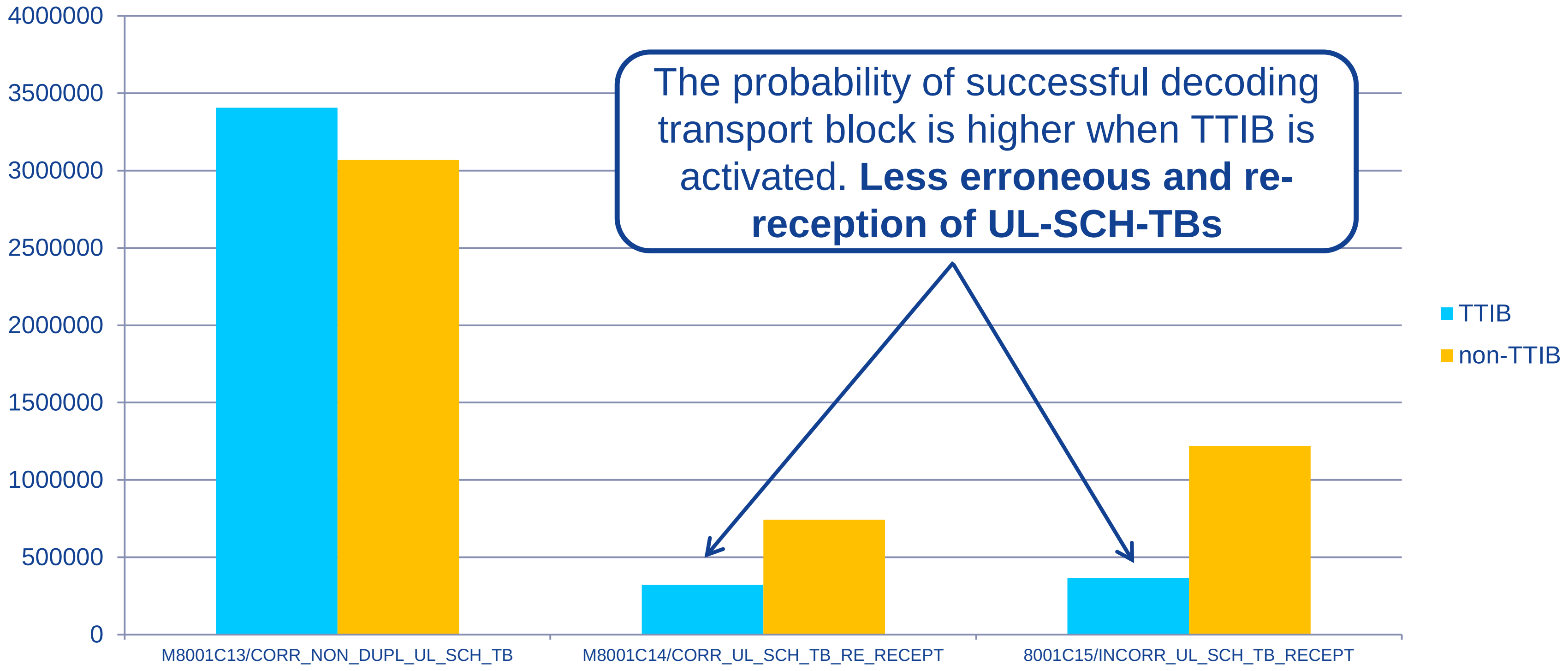
Result: PUSCH MCS distribution



In area with power limited UEs it can be demonstrated that higher MCS on PUSCH will be assigned, if TTI bundling is enabled.

Improve UL Performance

Result: UL SCH TB Decoding



Improve UL Performance

Monitor: Successful of UL SCH TB Decoding

Below are related PM counters

Feature impact	How to measure
TTI Bundling **increases the probability of successful TB decoding by eNodeB**. Ratio between the number of erroneous UL-SCH TB receptions and the total number of received transport blocks on UL-SCH should be reduced upon introduction of TTI Bundling.	KPIs: • UL_SCH TB error ratio (LTE_141a) = 100 * sum(INCORR_UL_SCH_TB_RECEPT) / {sum(CORR_NON_DUPL_UL_SCH_TB + CORR_UL_SCH_TB_RE_RECEPT + INCORR_UL_SCH_TB_RECEPT) } Counters: •CORR_UL_SCH_TB_RE_RECEPT(M8001C14) •CORR_NON_DUPL_UL_SCH_TB (M8001C13) •INCORR_UL_SCH_TB_RECEPT(M8001C15)

Improve UL Performance
Result: UL SCH TB Decoding

PM Counters	TTIB ON	TTIB OFF
M8001C13/Correct non-duplicate UL-SCH TB with original reception	3407086	3069117
M8001C14/Correct UL-SCH TB with re-reception	322699	742930
M8001C15/Erroneous UL-SCH TB receptions	365905	1217932
M8001C15/M8001C13	10.7%	39.7%
UL_SCH TB error ratio (LTE_141a)	8.93%	24.21%

- The probability of successful TB decoding by eNodeB is higher when TTI bundling is activated for power limited UEs.
- This implicates that packet loss rate is lower and in general UL latency is improved.

Improve Voice Quality
MOS Indicator

A stationary field test with two test UEs, measuring M2M voice quality (MOS) show improvements under very poor RF conditions

actTtiBundling	UE #	MOS	UL PRB	MCS	Tx Power PUSCH [dBm]	Tx Power PUCCH [dBm]	PUSCH BLER [%]	PUSCH Phy Thrp [Mbps]	PUSCH PDCP Thrp [Mbps]	DL RSRP [dBm]	DL RSRQ [dB]	DL SINR [dB]
FALSE (15:15-16:00)	1	2.35	5.0	0.1	24.0	24.0	54.4	0.047	0.013	-118.7	-13.3	0.7
	2	1.78	4.9	0.1	23.9	23.8	39.6	0.038	0.015	-120.6	-13.0	0.8
TRUE (16:15-17:00)	1	3.16	3.0	10.1	23.5	23.9	0.6	0.125	0.014	-122.1	-15.2	-2.2
	2	3.00	3.0	12.0	23.3	23.8	0.1	0.128	0.015	-115.6	-11.7	4.1

Note: drive test measurements for UE1 and UE2 without TTIB (15:15-16:00) and with TTIB (16:15-17:00)

SIP Signaling Analysis

VoLTE Call Flow
SIP Signaling Procedure- Initial Registration

- Initial registration procedure consists of UE sending an unprotected REGISTER request to S-CSCF (via P-CSCF)
- UE can register a public user identity with any of its contact addresses at any time after it has acquired an IP address, discovered a P-CSCF, and established an IP-CAN bearer that can be used for SIP signalling
- UE shall only initiate a new registration procedure when it has received a final response from the registrar for the ongoing registration, or the previous REGISTER request has timed out
- Authentication is performed during initial registration. S-CSCF acquires user authentication information from HSS
- UE will receive a 401 (Unauthorized) response to the REGISTER request
  - UE calculates the response and sends it to S-CSCF in REGISTER message
  - S-CSCF downloads and stores service control information from HSS and notifies to the UE about completed registration

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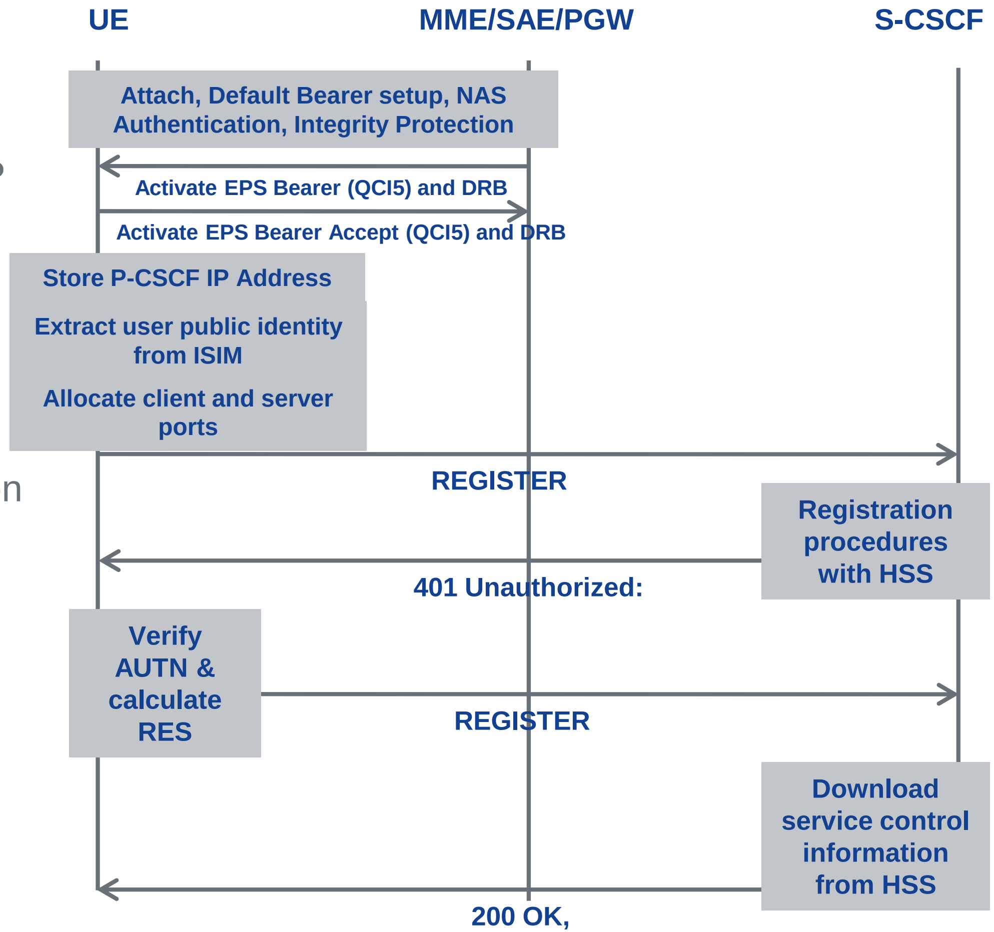
Registration - Success Case

1. UE Attaches to the network, the PGW assigns IP address and identifies P-CSCF to the terminal.
2. Terminal sets the IMEI and IMS communication identifier ICSI value
3. UE sends Registration Request to S-CSCF (via P-CSCF) in REGISTER message
4. S-CSCF performs registration procedures with HSS and acquires user authentication information
5. S-CSCF sends UE a challenge in 401 Unauthorized message
6. UE calculates the response and sends it to S-CSCF in REGISTER message
7. After the authentication has succeeded the S-CSCF downloads and stores service control information from HSS
8. S-CSCF notifies the terminal about completed registration



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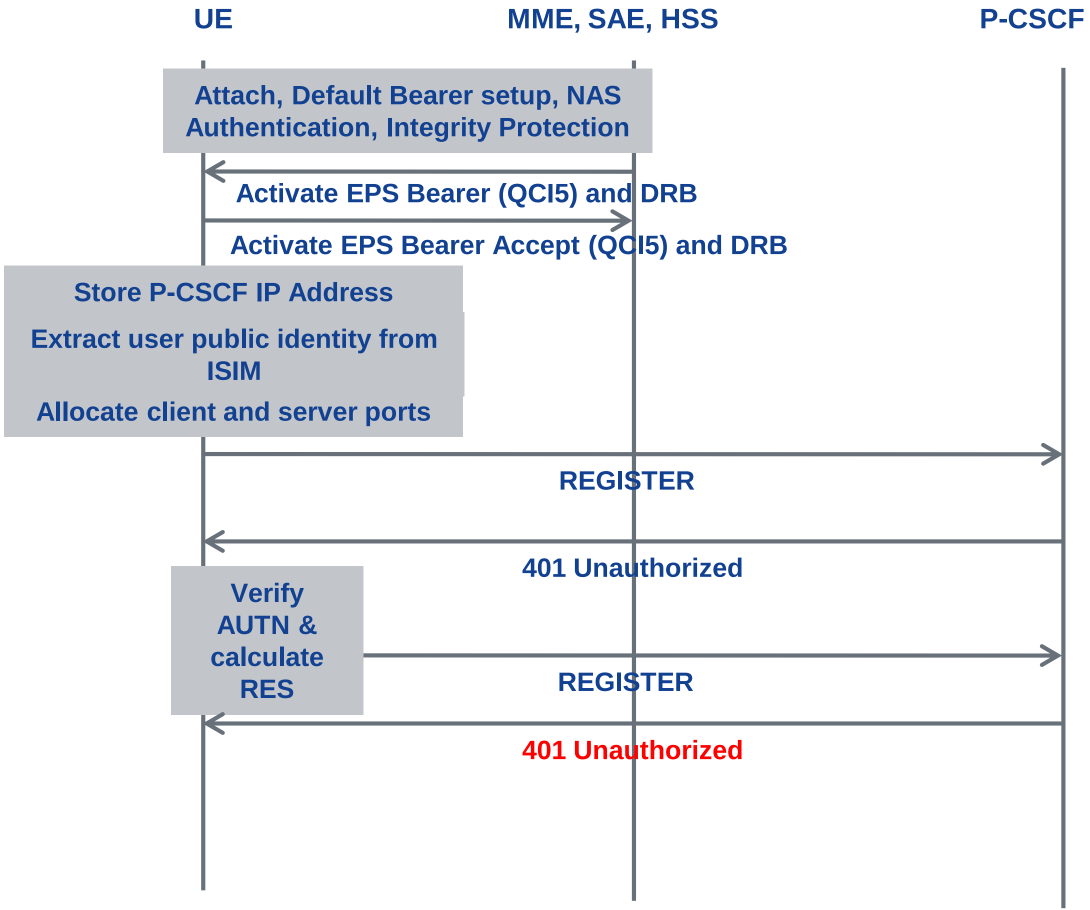
Registration

Failure Case

- The SIP server attempts to validate the user's credentials, but they are not valid (the user's password does not match the password established for the user's account). The server returns a response (401 Unauthorized) to users SIP client.



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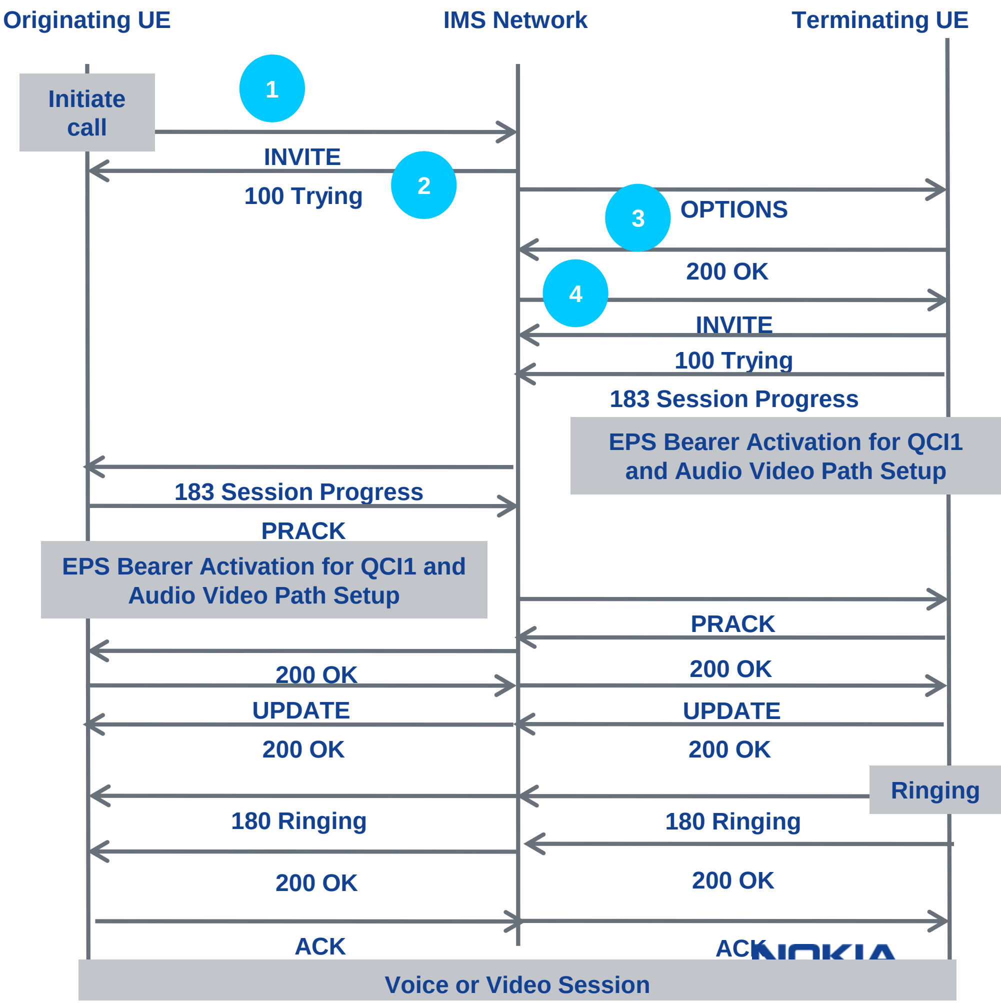
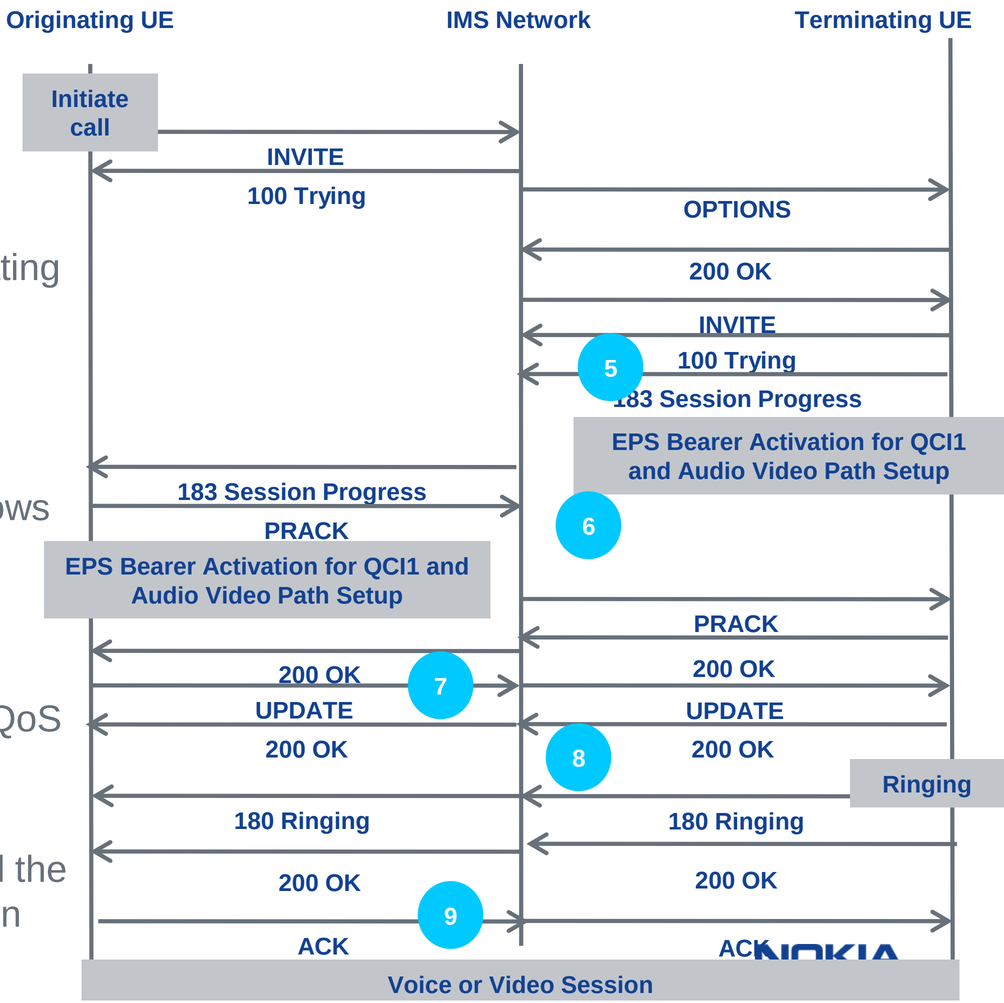
UE to UE VoLTE call flow using precondition mechanism

1. MO UE generates an INVITE request, which is sent to the IMS.
2. The P-CSCF acknowledges the INVITE to the MO UE with "100 Trying" message indicating that the call setup is in progress.
3. The SIP method OPTIONS allows a IMS to query another UA or a proxy server as to its capabilities. This allows a client to discover information about the supported methods, content types, extensions, codecs, etc.
4. At MT UE the INVITE message contains: *Session Description Protocol (SDP)* parameters: declaration for using precondition, type of media, codec to use and the protocol for transporting the media.



UE to UE VoLTE call flow using precondition mechanism

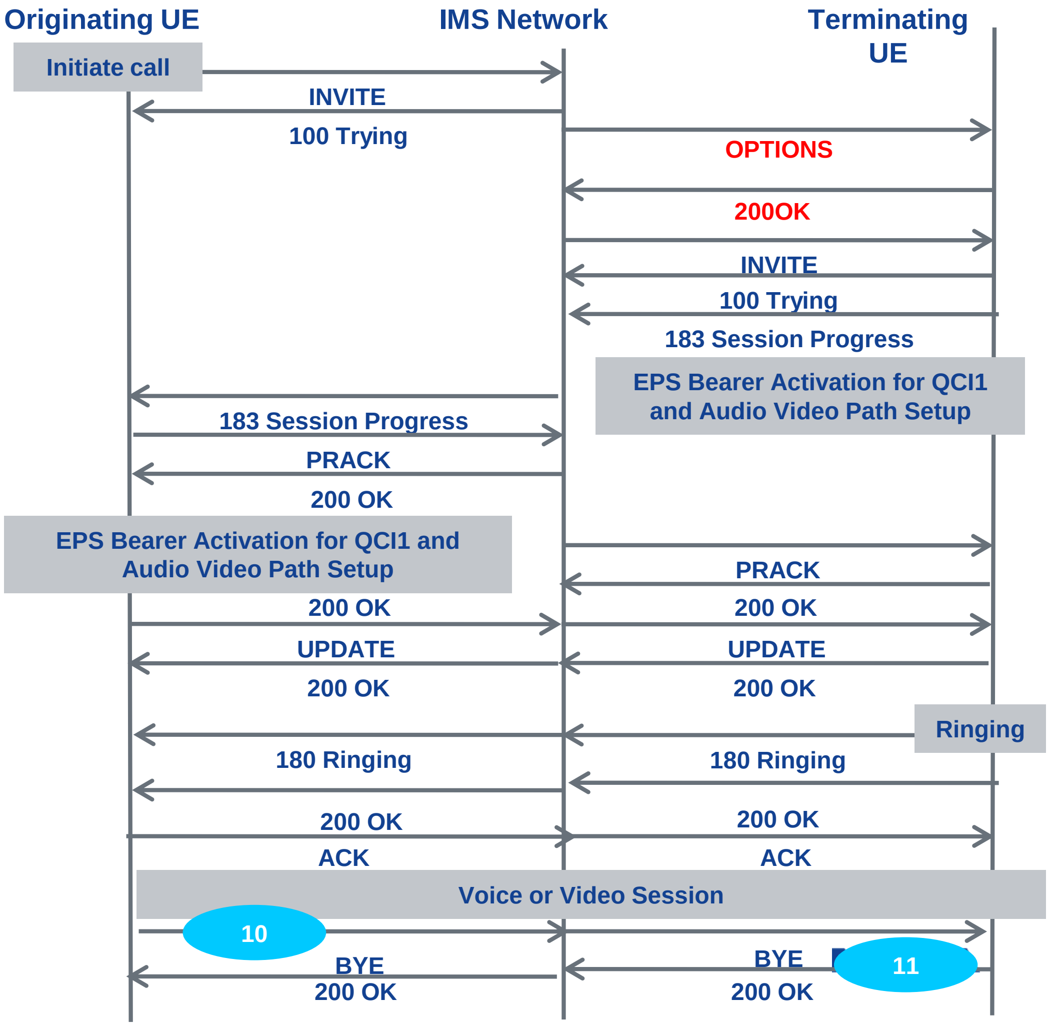
5. When precondition mechanism is supported P-CSCF would send 183 Session Progress to originating UE which then compares the terminating UE capabilities with its own and determines the codec to be used.
6. Originating UE notifies the terminating UE using PRACK the selected codec. OK 200 is received from terminating UE. EPS Bearer Activation follows for both UEs.
7. UPDATE message contains an updated current status attribute for this particular media stream.
8. Both terminals confirm the setup of bearer with QoS according to UPDATE & 200 OK message, terminating UE start ringing.
9. Once both UEs receive 200 OK, they ACK it and the SIP session is established - voice communication starts.



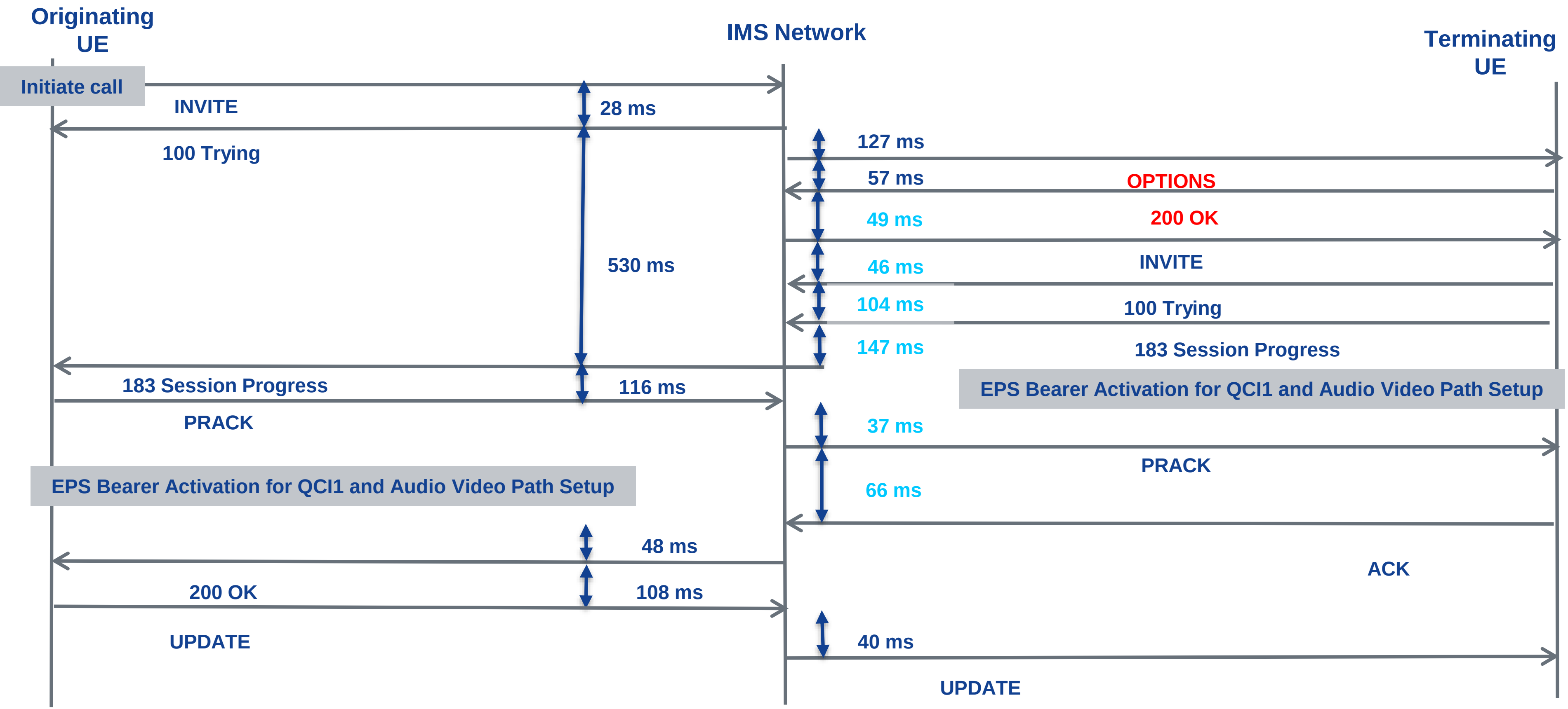
UE to UE VoLTE call flow using precondition mechanism

10. MT or MO can release the voice communication by sending BYE message

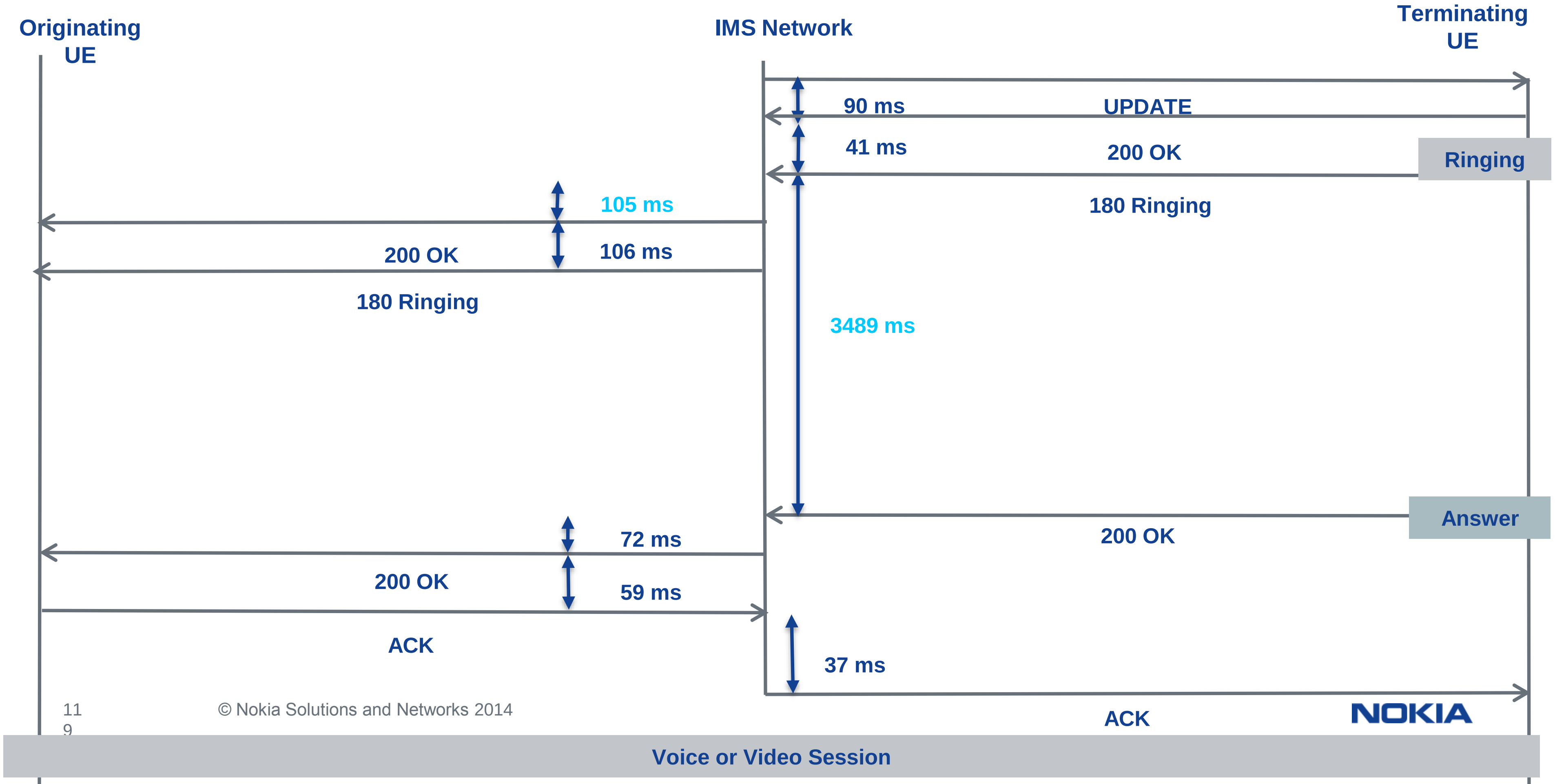
11. This is the acknowledge message to BYE from terminating UE.



UE to UE VoLTE single call – SIP setup time measured in S1 interface



UE to UE VoLTE single call: SIP setup time measured in S1 interface



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Nokia SmartLab UE to UE VoLTE single call

SIP setup time measured in S1 interface

- Call setup time (to ACK) is 4935 ms from MO UE INVITE message to MT UE last ACK message
- Answering the call took 3489 ms
- Nokia IMS is sending 180 Ringing to MO UE
- Call setup time calculated from MO INVITE to MO 180 Ringing is 1315 ms

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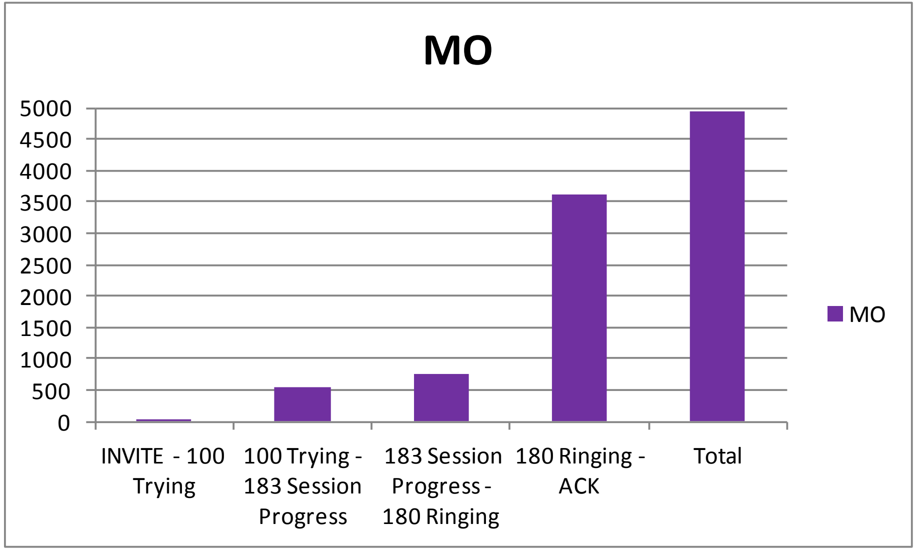
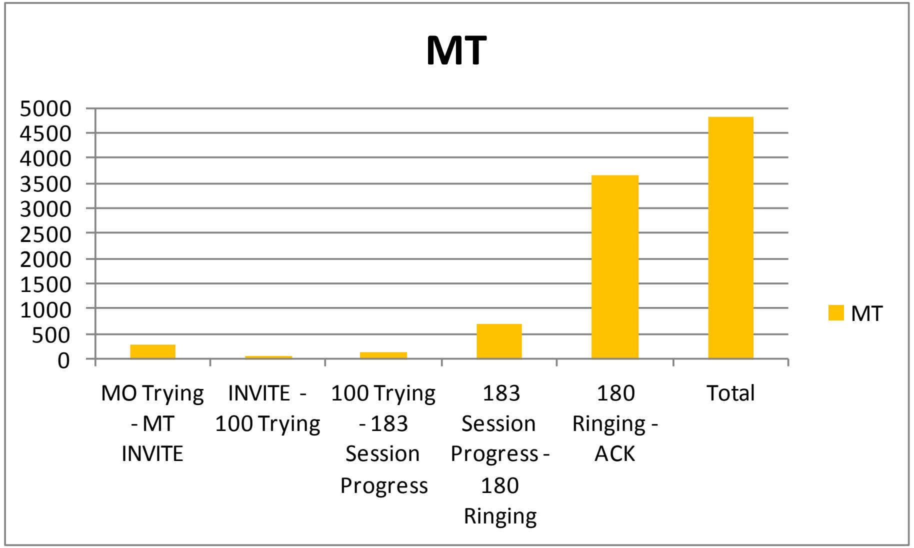
Nokia SmartLab UE to UE VoLTE single call

SIP setup time measured in S1 interface





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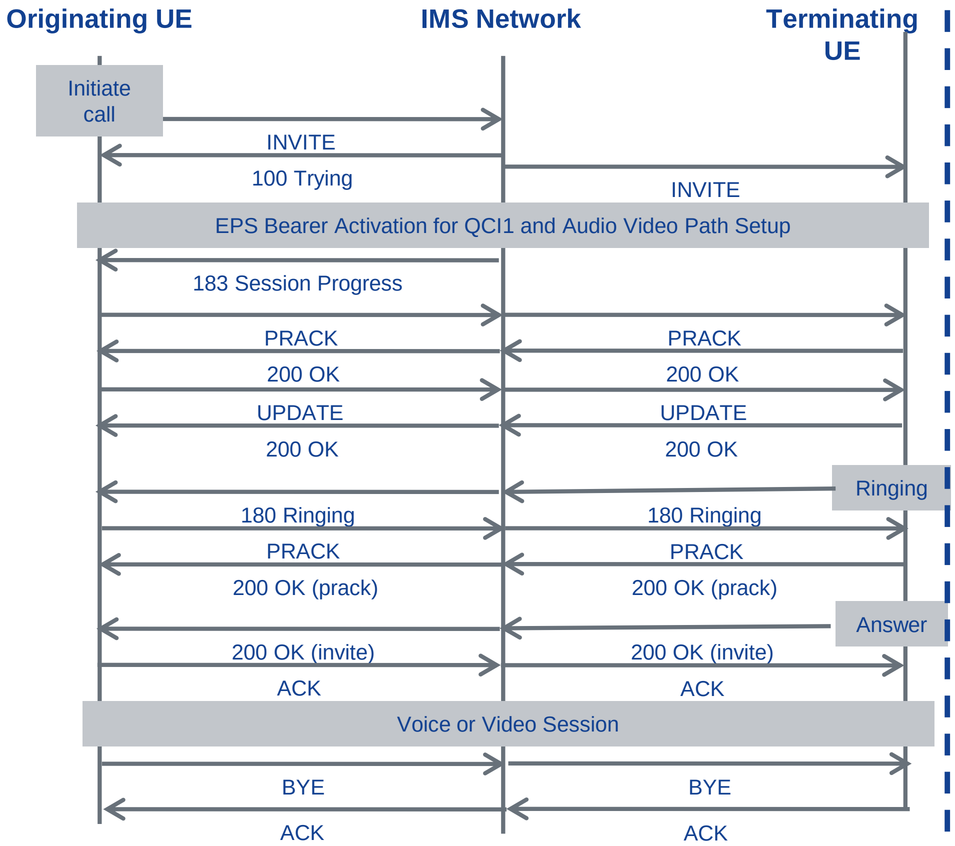
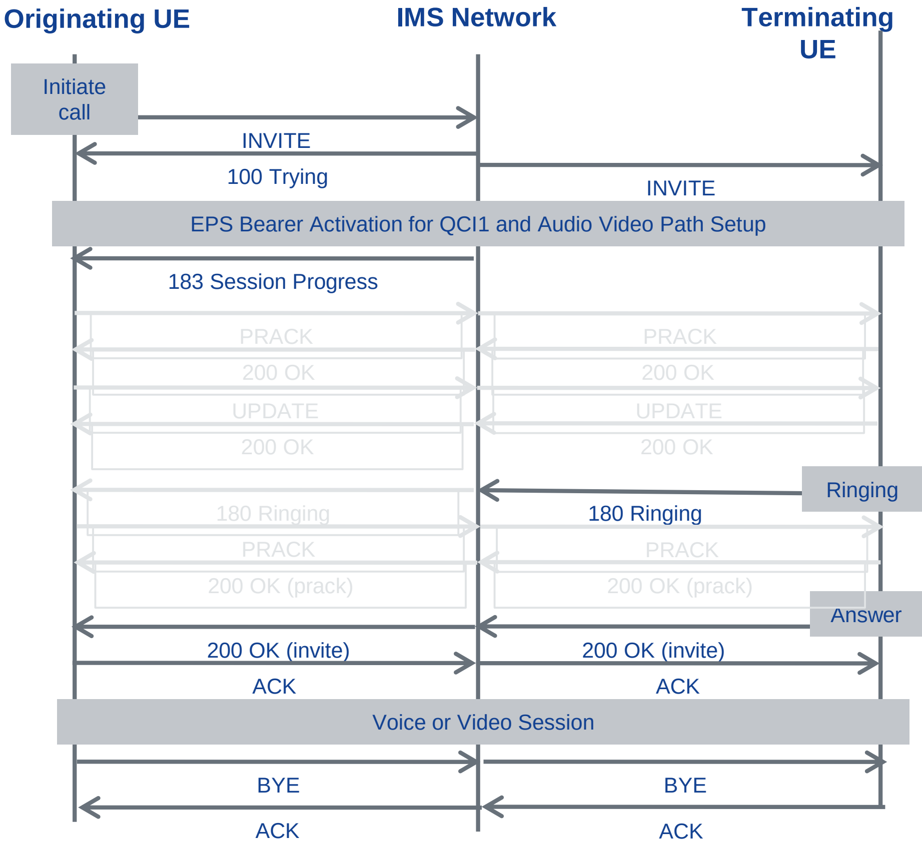
Session Setup Flow (precondition)



Session Setup Flow (no precondition)

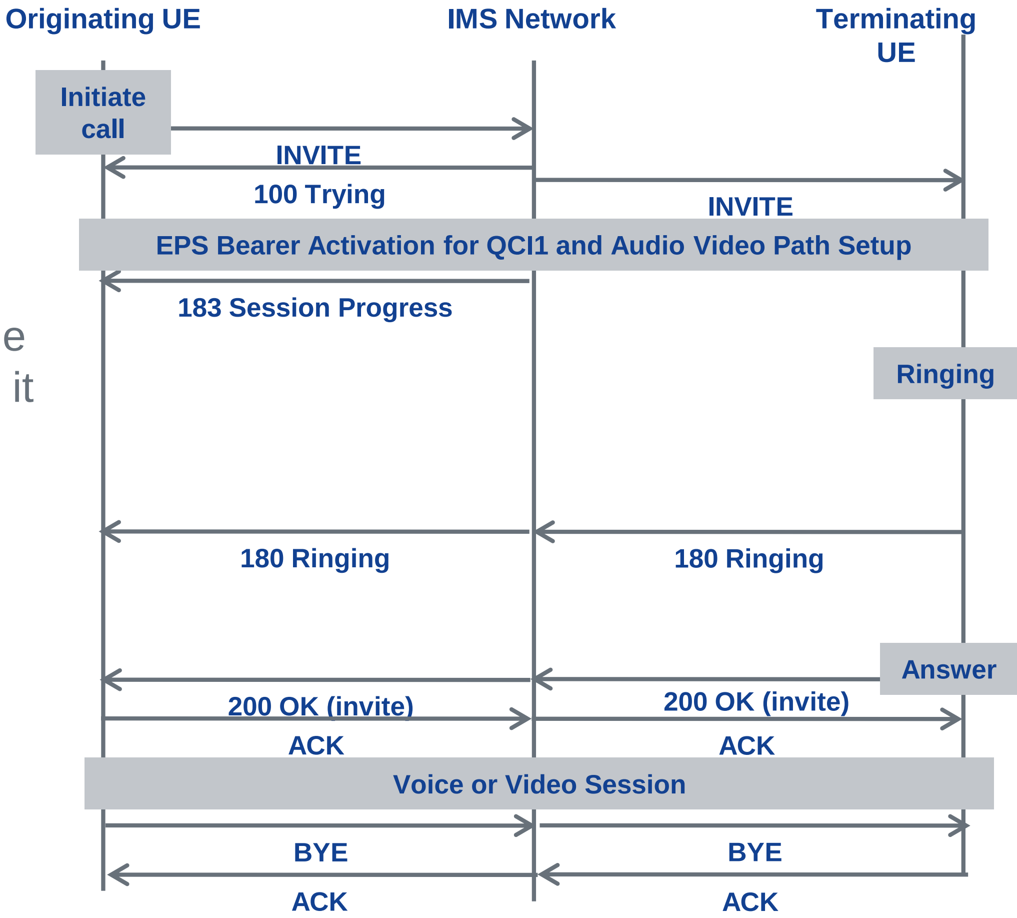


UE to UE VoLTE call flow (no precondition mechanism)

When no preconditions are required the setup procedure is more simple. IMS may decide to use certain codec and request the originating UE to reserve the resources for it already in 183 Session Progress message

No PRACK and UPDATE messages are used for negotiating the codec

B starts ringing once received INVITE in case no preconditions are used



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VoLTE Call Setup Analysis

VoLTE Call Setup Time

MO M1 – MT M2

MO

	Time	Code	Message	Detail
	3-12-03 00:13:32.341	Voice Call	Recording Information	
	3-12-03 00:13:32.341	Voice Call	Recording Information	
	3-12-03 00:13:32.341	Voice Call	Setup Start	
10	2013-12-03 00:13:32.384	Voice Call	Common Call Event - ADB Command Dial	
11	2013-12-03 00:13:32.387	Voice Call	Call Start - M to M Org	
12	2013-12-03 00:13:34.182	UDP Tx-SIP		5060, 5060, INVITE tel:+82-10-2233-1718 SIP/2.0
13	2013-12-03 00:13:34.182	Voice Call	SIP Call Event - SIP Method	invite tel:+82-10-2233-1718, with session description
14	2013-12-03 00:13:34.182	Voice Call	SIP Call Event - SIP Connecting	2001:4430:0022:2171:0000:0000:00B1:F625
15	2013-12-03 00:13:34.182	UDP Tx-SIP		5060, 5060, INVITE tel:+82-10-2233-1718 SIP/2.0
16	2013-12-03 00:13:34.183	Voice Call	LTE-L Event-Service Request	
17	2013-12-03 00:13:34.183	UL EPS MM	Service request	
18	2013-12-03 00:13:34.183	UL EPS MM	Service request	
19	2013-12-03 00:13:34.183	Voice Call	LTE-L Event-RRCStart	
20	2013-12-03 00:13:34.183	UL-CCCH [Lte]	rrcConnectionRequest	mo_Data, s-TMSI(mmec 1, m-TMSI 3412681509)
21	2013-12-03 00:13:34.227	Voice Call	LTE-L Event-RRCConnectionSetup	
22	2013-12-03 00:13:34.227	DL-CCCH [Lte]	rrcConnectionSetup	
23	2013-12-03 00:13:34.227	Voice Call	LTE-L Event-RRCComplete	
24	2013-12-03 00:13:34.227	UL-DCCH [Lte]	rrcConnectionSetupComplete	Service request
25	2013-12-03 00:13:34.243	Voice Call	LTE-L Event-SecurityModeCommand	
26	2013-12-03 00:13:34.243	DL-DCCH [Lte]	securityModeCommand	
27	2013-12-03 00:13:34.243	Voice Call	LTE-L Event-securityModeComplete	
28	2013-12-03 00:13:34.243	UL-DCCH [Lte]	securityModeComplete	
29	2013-12-03 00:13:34.244	Voice Call	LTE-L Event-RRCConnection Reconfigura	
30	2013-12-03 00:13:34.244	DL-DCCH [Lte]	rrcConnectionReconfiguration	
31	2013-12-03 00:13:34.269	Voice Call	LTE-L Event-RRCConnection Reconfigura	
32	2013-12-03 00:13:34.269	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
33	2013-12-03 00:13:34.289	Voice Call	LTE-L Event-RRCConnection Reconfigura	
34	2013-12-03 00:13:34.289	DL-DCCH [Lte]	rrcConnectionReconfiguration	
35	2013-12-03 00:13:34.300	Voice Call	SIP Call Event - SIP Response	100 trying
36	2013-12-03 00:13:34.300	UDP Rx-SIP		5060, 5060, SIP/2.0 100 TRYING
37	2013-12-03 00:13:34.327	Voice Call	LTE-L Event-RRCConnection Reconfigura	
38	2013-12-03 00:13:34.327	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
39	2013-12-03 00:13:34.887	Voice Call	SIP Call Event - SIP Response	183 session progress, with session description
40	2013-12-03 00:13:34.887	UDP Rx-SIP		5060, 5060, SIP/2.0 183 Session Progress
41	2013-12-03 00:13:37.486	Voice Call	LTE-L Event-RRCConnection Reconfigura	
42	2013-12-03 00:13:37.486	DL-DCCH [Lte]	rrcConnectionReconfiguration	Security protected NAS message/Activate dedicated EPS bearer context request
43	2013-12-03 00:13:37.489	Voice Call	SIP Call Event - SIP Response	200 ok, with session description (Invite)
44	2013-12-03 00:13:37.486	UDP Rx-SIP		5060, 5060, SIP/2.0 200 OK
45	2013-12-03 00:13:37.489	DL EPS MM	Security protected NAS message	Activate dedicated EPS bearer context request
46	2013-12-03 00:13:37.489	Voice Call	LTE-L Event-RRCConnection Reconfigura	
47	2013-12-03 00:13:37.489	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
48	2013-12-03 00:13:37.502	Voice Call	LTE-L Event-Activate dedicated EPS bea	
49	2013-12-03 00:13:37.502	DL EPS SM	Activate dedicated EPS bearer context re	
50	2013-12-03 00:13:37.502	Voice Call	LTE-L Event-Activate dedicated EPS bea	
51	2013-12-03 00:13:37.502	UL EPS SM	Activate dedicated EPS bearer context ac	
52	2013-12-03 00:13:37.502	UL EPS MM	Security protected NAS message	Activate dedicated EPS bearer context accept
53	2013-12-03 00:13:37.502	UL-DCCH [Lte]	ulInformationTransfer	Security protected NAS message/Activate dedicated EPS bearer context accept
54	2013-12-03 00:13:37.542	Voice Call	SIP Call Event - SIP Method	ack sip:10.113.16.13:5067
55	2013-12-03 00:13:37.542	UDP Tx-SIP		5060, 5060, ACK sip:10.113.16.13:5067 SIP/2.0
56	2013-12-03 00:13:37.691	PCCH [Lte]	Paging	
57	2013-12-03 00:13:37.781	Voice Call	Call Connected	
58	2013-12-03 00:13:37.781	Voice Call	Traffic Setup Start	
59	2013-12-03 00:13:37.781	Voice Call	Recording Information	
60	2013-12-03 00:13:37.781	Voice Call	Recording Information	

3.306s

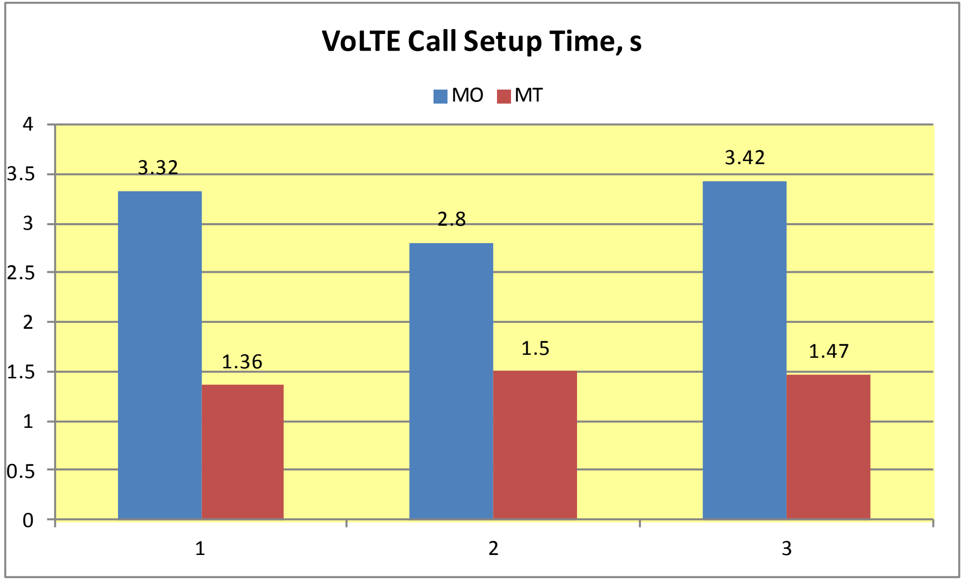
MT

	Time	Code	Message	Detail
	13-12-03 00:13:33.559	PCCH [Lte]	Paging	
	13-12-03 00:13:36.040	PCCH [Lte]	Paging	
	13-12-03 00:13:36.040	Voice Call	LTE-L Event-Service Request	
9	2013-12-03 00:13:36.040	UL EPS MM	Service request	
10	2013-12-03 00:13:36.040	UL EPS MM	Service request	
11	2013-12-03 00:13:36.040	Voice Call	LTE-L Event-RRCStart	
12	2013-12-03 00:13:36.040	UL-CCCH [Lte]	rrcConnectionRequest	mt_Access, s-TMSI(mmec 2, m-TMSI 3731444950)
13	2013-12-03 00:13:36.052	Voice Call	LTE-L Event-RRCConnectionSetup	
14	2013-12-03 00:13:36.052	DL-CCCH [Lte]	rrcConnectionSetup	
15	2013-12-03 00:13:36.052	Voice Call	LTE-L Event-RRCComplete	
16	2013-12-03 00:13:36.052	UL-DCCH [Lte]	rrcConnectionSetupComplete	Service request
17	2013-12-03 00:13:36.109	Voice Call	LTE-L Event-SecurityModeCommand	
18	2013-12-03 00:13:36.109	DL-DCCH [Lte]	securityModeCommand	
19	2013-12-03 00:13:36.111	Voice Call	LTE-L Event-securityModeComplete	
20	2013-12-03 00:13:36.111	UL-DCCH [Lte]	securityModeComplete	
21	2013-12-03 00:13:36.112	Voice Call	LTE-L Event-RRCConnection Reconfigura	
22	2013-12-03 00:13:36.112	DL-DCCH [Lte]	rrcConnectionReconfiguration	
23	2013-12-03 00:13:36.121	Voice Call	LTE-L Event-RRCConnection Reconfigura	
24	2013-12-03 00:13:36.121	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
25	2013-12-03 00:13:36.133	Voice Call	LTE-L Event-RRCConnection Reconfigura	
26	2013-12-03 00:13:36.133	DL-DCCH [Lte]	rrcConnectionReconfiguration	
27	2013-12-03 00:13:36.133	UDP Rx-SIP		42468, 5060, 5060, INVITE sip:01022331718@10.12 .238.61:5060 SIP/2.0
28	2013-12-03 00:13:36.133	Voice Call	SIP Call Event - SIP Method	invite sip:01022331718@10.126.238.61:5060, with se sion description
29	2013-12-03 00:13:36.134	Voice Call	Recording Information	
30	2013-12-03 00:13:36.134	Voice Call	Recording Information	
31	2013-12-03 00:13:36.134	Voice Call	Recording Information	
32	2013-12-03 00:13:36.133	Voice Call	Setup Start	
33	2013-12-03 00:13:36.133	Voice Call	Call Start - M to M Ter	
34	2013-12-03 00:13:36.133	Voice Call	SIP Call Event - SIP Connecting	10.126.238.61
35	2013-12-03 00:13:36.133	UDP Rx-SIP		42468, 5060, 5060, Fragmented IP, Offset = 0
36	2013-12-03 00:13:36.173	Voice Call	LTE-L Event-RRCConnection Reconfigura	
37	2013-12-03 00:13:36.173	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
38	2013-12-03 00:13:36.199	Voice Call	SIP Call Event - SIP Response	100 trying
39	2013-12-03 00:13:36.199	UDP Tx-SIP		0, 5060, 5060, SIP/2.0 100 Trying
40	2013-12-03 00:13:36.275	Voice Call	SIP Call Event - SIP Response	180 ringing
41	2013-12-03 00:13:36.275	UDP Tx-SIP		0, 5060, 5060, SIP/2.0 180 Ringing
42	2013-12-03 00:13:36.777	Voice Call	Start Receiving Call	
43	2013-12-03 00:13:36.777	Voice Call	Common Call Event - ADB Command Pick	
44	2013-12-03 00:13:37.307	UDP Tx-SIP		46479, 5060, 5060, SIP/2.0 200 OK
45	2013-12-03 00:13:37.313	Voice Call	SIP Call Event - SIP Response	200 ok, with session description (Invite)
46	2013-12-03 00:13:37.313	UDP Tx-SIP		46479, 5060, 5060, Fragmented IP, Offset = 0
47	2013-12-03 00:13:37.399	Voice Call	SIP Call Event - SIP Method	ack sip:01022331718@10.126.238.61:5060
48	2013-12-03 00:13:37.399	UDP Rx-SIP		0, 5060, 5060, ACK sip:01022331718@10.126.238.6 5060 SIP/2.0
49	2013-12-03 00:13:37.399	Voice Call	LTE-L Event-RRCConnection Reconfigura	
50	2013-12-03 00:13:37.399	DL-DCCH [Lte]	rrcConnectionReconfiguration	Security protected NAS message/Activate dedicated PS bearer context request
51	2013-12-03 00:13:37.399	DL EPS MM	Security protected NAS message	Activate dedicated EPS bearer context request
52	2013-12-03 00:13:37.399	Voice Call	LTE-L Event-RRCConnection Reconfigura	
53	2013-12-03 00:13:37.399	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
54	2013-12-03 00:13:37.399	Voice Call	LTE-L Event-Activate dedicated EPS bea	
55	2013-12-03 00:13:37.399	DL EPS SM	Activate dedicated EPS bearer context re	
56	2013-12-03 00:13:37.424	Voice Call	LTE-L Event-Activate dedicated EPS bea	
57	2013-12-03 00:13:37.424	UL EPS SM	Activate dedicated EPS bearer context ac	
58	2013-12-03 00:13:37.424	UL EPS MM	Security protected NAS message	Activate dedicated EPS bearer context accept
59	2013-12-03 00:13:37.424	UL-DCCH [Lte]	ulInformationTransfer	Security protected NAS message/Activate dedicated EPS bearer context accept
60	2013-12-03 00:13:37.769	Voice Call	Call Connected	

1.359s

VoLTE Call Setup Time

- The call setup time is calculated from RRC Connection Setup until RRC Configuration Complete where QCI1 bearer is setup successfully.
- Challenge: when drop call happen, the EPC will deactivated the QCI1 bearer after new RRC setup and previous call will be ended. New voice call could be initiated later in the same RRC connection, thus difficult to calculate the call setup time
- **MO = 3.18s**
- **MT = 1.47s**



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VoLTE Radio Optimization Project Learnings

VoLTE Project in Singapore (SG)

RACH Optimization

- Root Sequence Index (RSI) planning plays an important role in the Random access performance of a network.
- Overlapping on root sequence index could lead to potential interference, causes “ghost RACHs” and degrade the RACH performance.
- In SG Customer, measures have been taken to detect and fix the RSI collisions to improve the RACH performance in over all network using MUSA tool.

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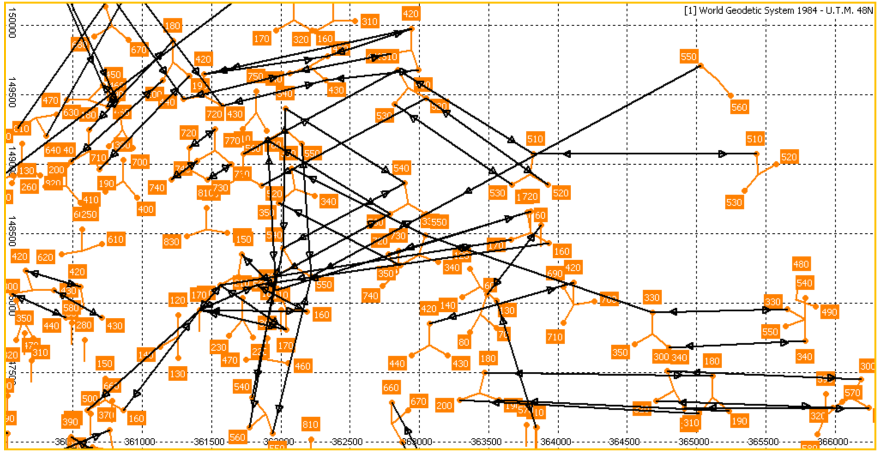
RACH Optimization

RSI Collision Detection

- Properly defined neighbor database was imported to MUSA tool
- MUSA detected the collision where same RSI present in the source cell’s neighbor list and the distance between colliding cells was not more than 5Km.



- Note: SG Customer is a dense network where site to site distance were quite small, therefore 5Km distance between the colliding cells was considered as a safe assumption for RSI re-use distance.
- Picture shows RSI collision scenario in one of the areas tat need to consider before RSI modification.
- Total 989 sites in L1800 and 169 sites in L2600 were found affected due to RSI collision and re-planned using MUSA.

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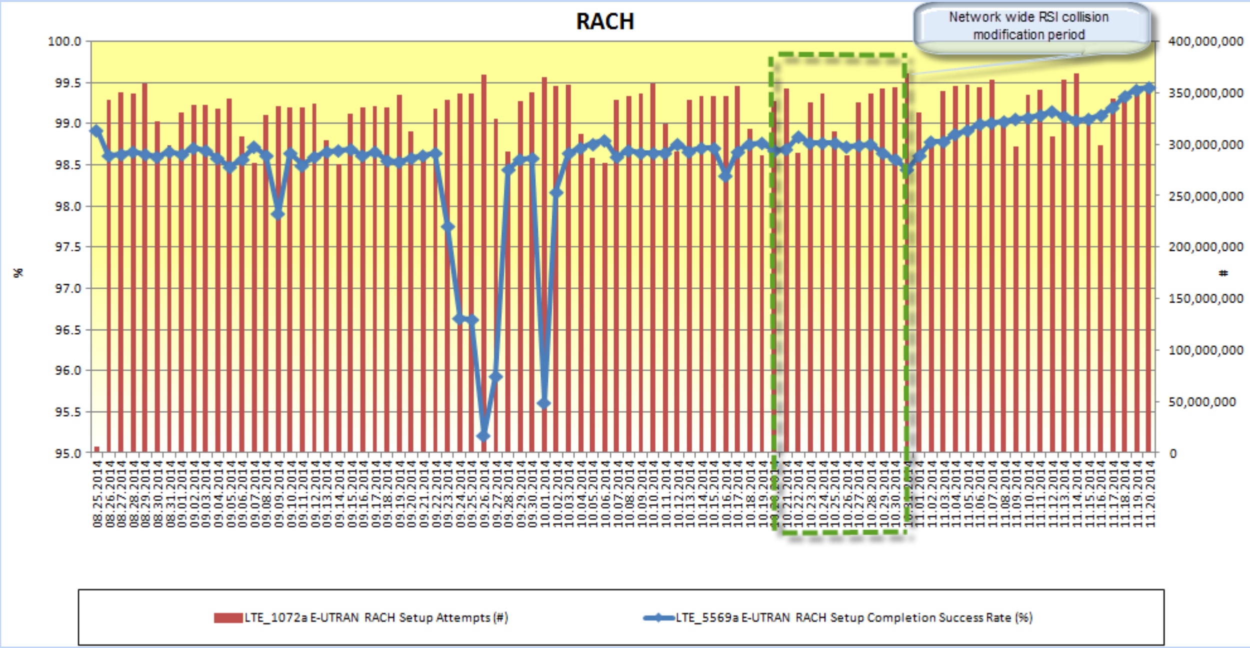
RACH Optimization

RACH Performance after RSI Re Planning

- 989 sites in L1800 and 169 sites in L2600 were found affected due to RSI collision and re-planned using MUSA.
- Implementation was done in batches at night as site reset is required during modification of RSI.
- RACH setup completion success ratio (LTE_5569a) KPIs improved after the all RSI modification was implemented.



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VoLTE Optimization
Experience from Other Networks

- PUCCH power control optimization
  - PUCCH power control tuning indicates that lowering the OLPC settings further improved the DCR indicates where terminals are using too high power and increasing the SINR window in turn indicates that UEs cannot properly maintain minimum required SINR of ~-1…-2dB unless up to 10dB margin is added to target SINR.
- Neighbor relation optimization
  - LTE1383 – Cell-specific neighbor relation & PCI handling helped with adding missing neighbor relations and thus, eNB handover decision ratio was significantly increased.
- Physical antenna optimization
  - Antenna tilt optimization mitigated inter-cell interference and as a result, the improved cell dominance significantly increased SINR as well as reduced handover attempts.

VoLTE Project in US (Drive test Analysis)

VoLTE Drop Call analysis
Drive Test Setup (Actix)

Device	Setup
MS1	LTE Scanner
MS2	UMTS Scanner
MS3	VoLTE Call: 2min call / 10s wait - Samsung Galaxy Note 3 Unlocked
MS4	FTP DL/UL - Samsung Galaxy Note 3 – LTE Locked
MS5	CS Call: 2min call / 10s wait - Samsung Galaxy Note 3

VoLTE (MS3)

- VoLTE DCR*: 1.60%
- VoLTE Setup FR: 5.7%
- LTE Handover FR: 0.8%
- LTE to UMTS Continuity FR: 5.6%

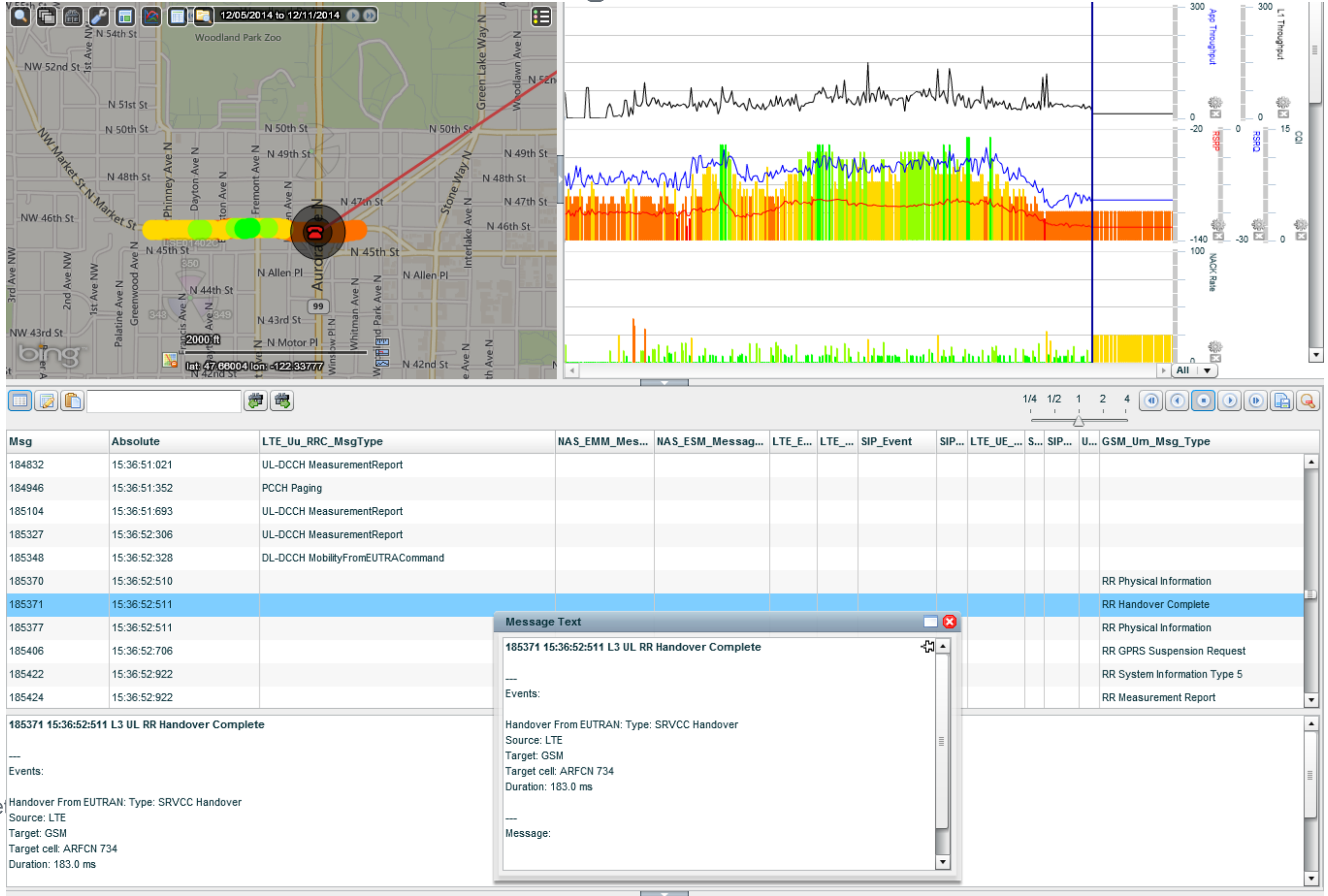
CSFB (MS5)

- CS DCR*: 1.2% / CSFB DCR*: 0.62%
- CSFB Setup failure rate : 1.0%
- No Fail Events visible

VoLTE: SRVCC

Not VoLTE Drop call: SRVCC due to Missing LTE site

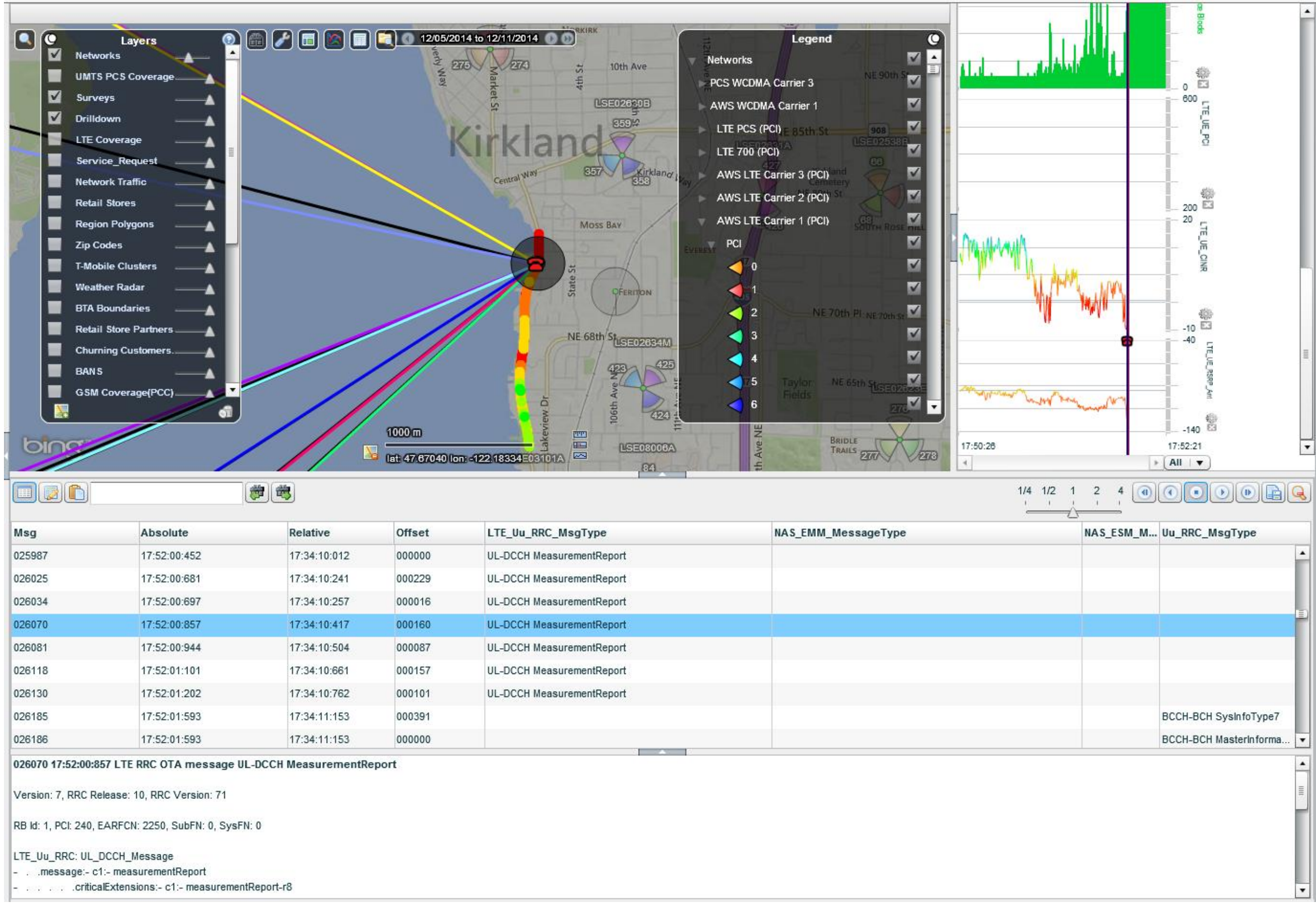
- Missing LTE site x, so poor LTE coverage
- SRVCC handover completed and normal call clearly



VoLTE Drop Call -1

Interference

- Sudden Interference from other sites due to location
- Hand Over Fails due to fast signal degradation
- Sudden drop of UE RSRP ~ -125dBm and UE CINR collapses to -8dB
- RF Conditions then quick degrade and not able to recover – multiple measurement reports



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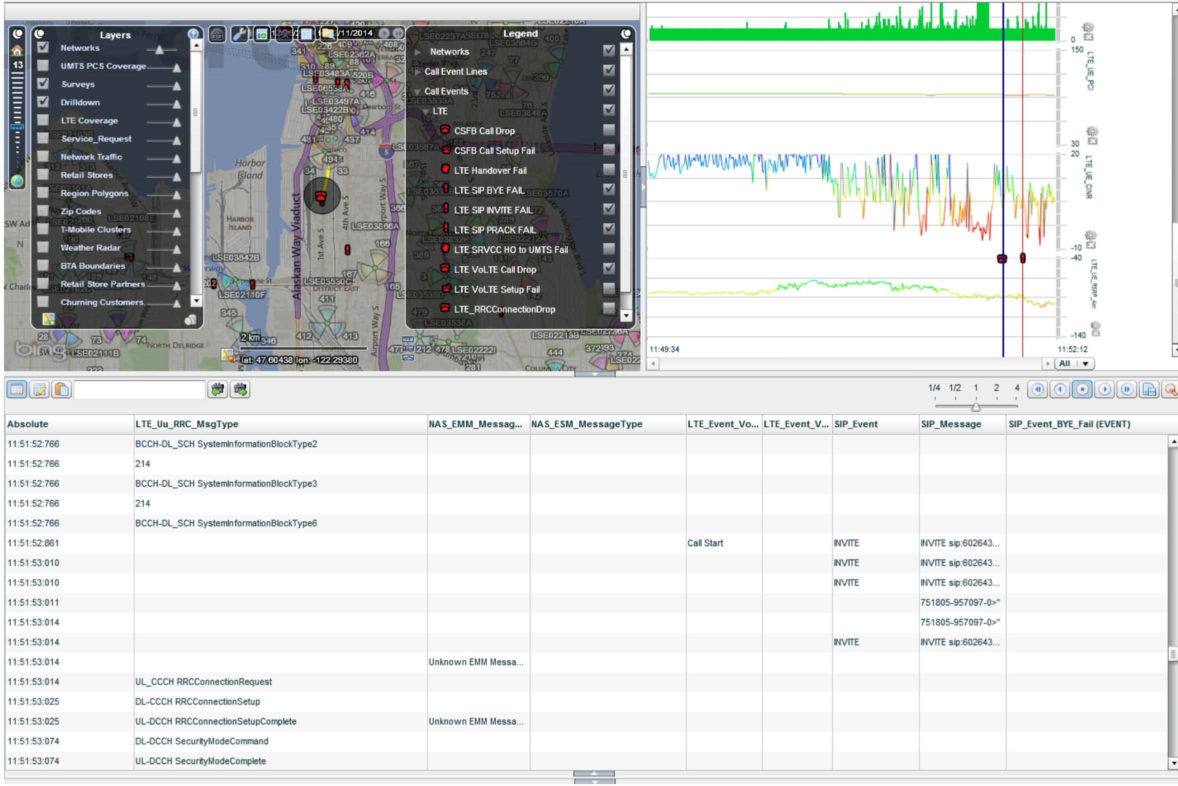
VoLTE Drop Call–2 (1/3)

Possible Application Layer Issue?

- No RRC Drop or RRC Connection Reestablishment
- RF Conditions are marginal
- Also Deactivate EPS Bearer Context Request following “BYE” message
- Actix states reason was due to a “New Invite” message.
- Also there is SIP_Event_BYE_Fail



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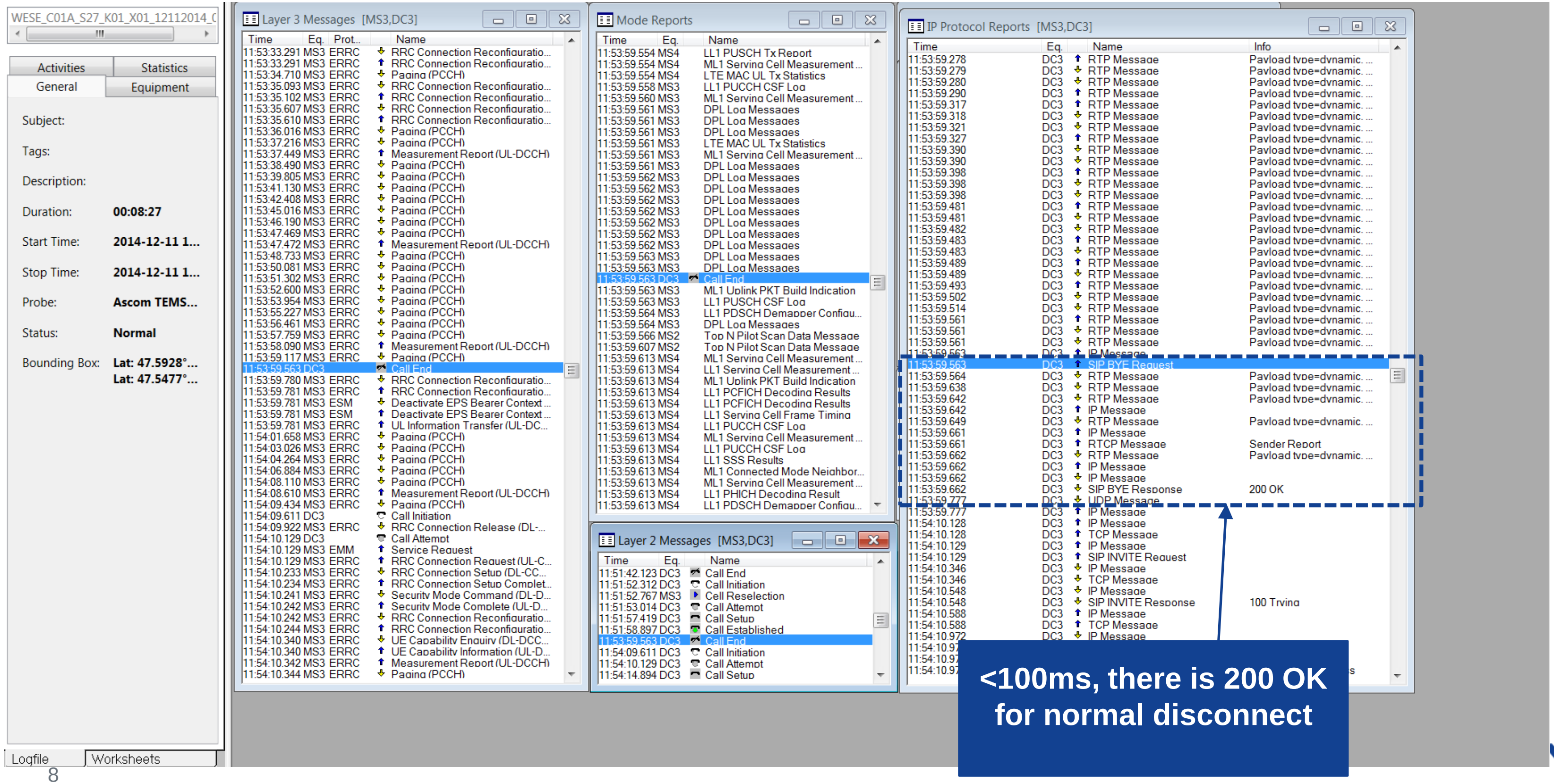
VoLTE Drop Call–2 (3/3)

Example of Normal Release



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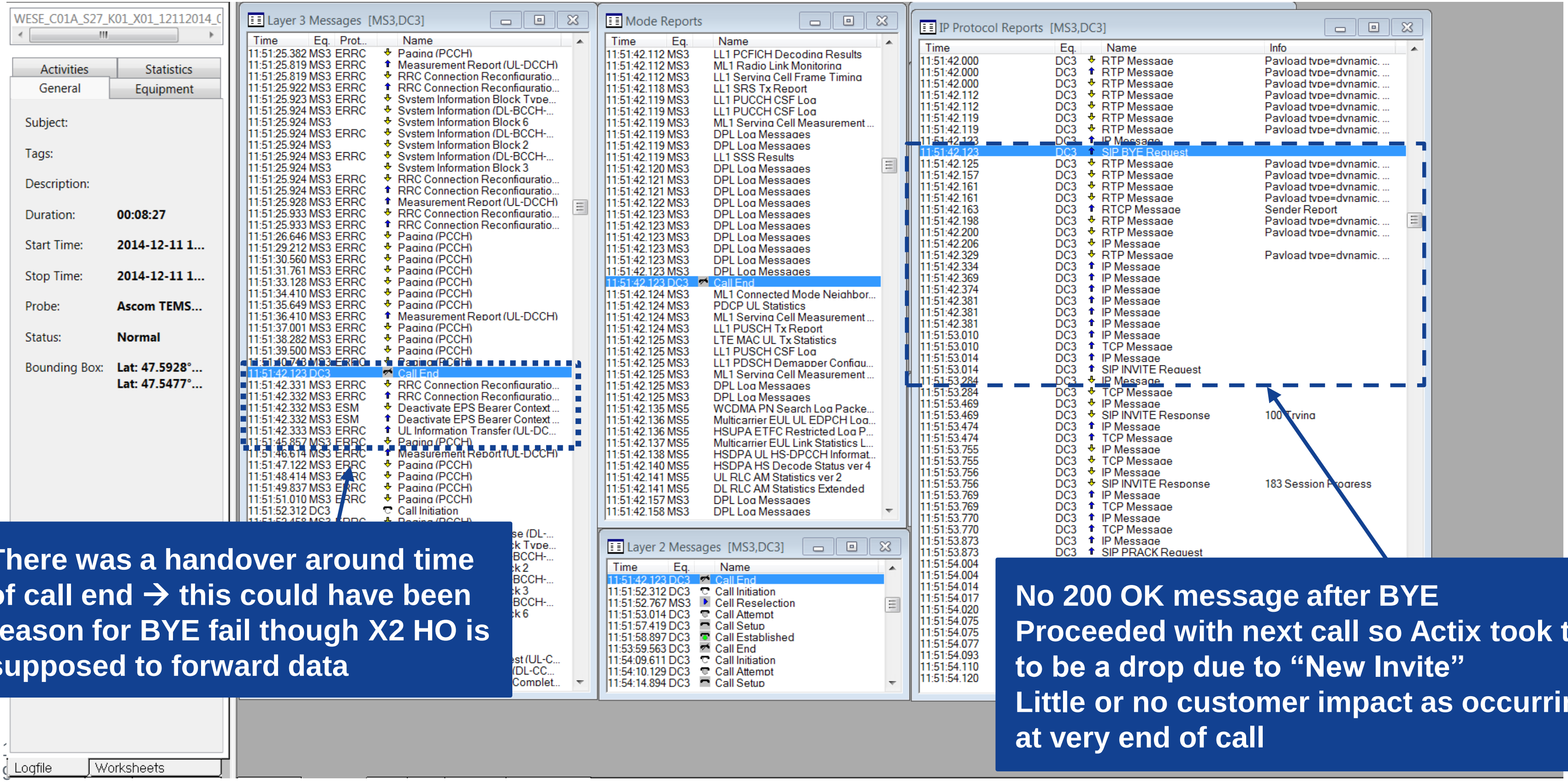
VoLTE Drop Call–2 (2/3)

No 200 OK message after BYE

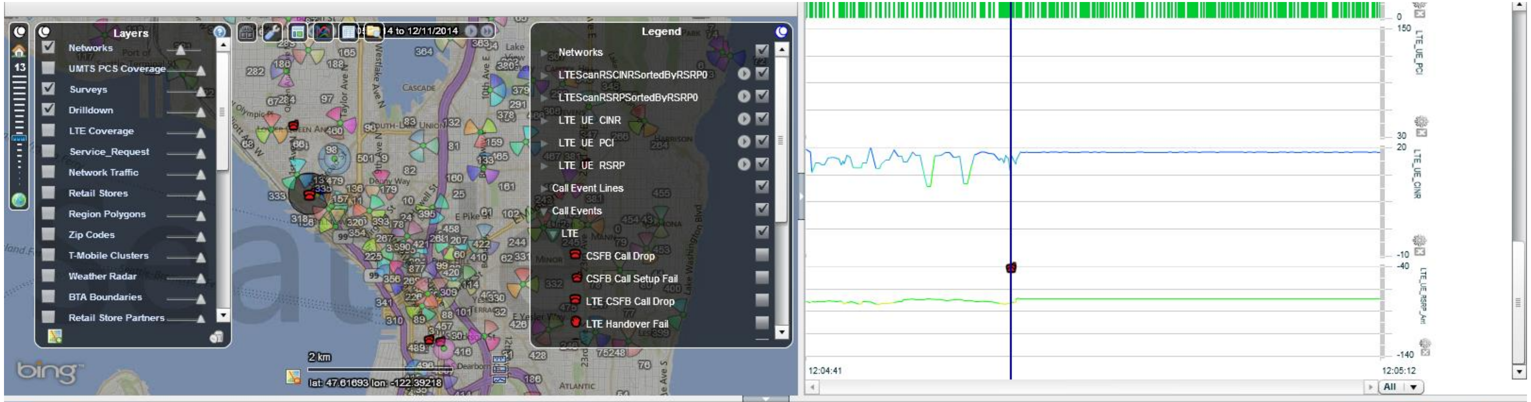


There was a handover around time of call end → this could have been reason for BYE fail though X2 HO is supposed to forward data

No 200 OK message after BYE
Proceeded with next call so Actix took this to be a drop due to "New Invite"
Little or no customer impact as occurring at very end of call

VoLTE Setup Fail - 1

SIP Message 503 Service Unavailable



Msg	Absolute	LTE_Uu_RRC_MsgType	NAS_EMM_Messag...	NAS_ESM_Messag...	LTE_E...	LTE_...	SIP_Event	SIP_Message	SIP_Event_BYE_Fail (EVENT)
039402	12:04:52:772						PRACK	PRACK sip:sgc_c@[FD00:976A:C206:1801::5]:65529;transport=tcp SIP/2.0	
039403	12:04:52:772						PRACK	PRACK sip:sgc_c@[FD00:976A:C206:1801::5]:65529;transport=tcp SIP/2.0	
039409	12:04:52:773						503 Unassigned	SIP/2.0 503 Service Unavailable	
039410	12:04:52:773						503 Unassigned	SIP/2.0 503 Service Unavailable	
039419	12:04:52:876						ACK	ACK sip:6026433599;phone-context=msg.pc.t-mobile.com@msg.pc.t-mobile....	
039420	12:04:52:876						ACK	ACK sip:6026433599;phone-context=msg.pc.t-mobile.com@msg.pc.t-mobile....	
039421	12:04:52:876						ACK	ACK sip:6026433599;phone-context=msg.pc.t-mobile.com@msg.pc.t-mobile....	
039436	12:04:52:937						481 Unassigned	SIP/2.0 481 Call/Transaction Does Not Exist	
039437	12:04:52:937						481 Unassigned	SIP/2.0 481 Call/Transaction Does Not Exist	
039474	12:04:53:022	DL-DCCH RRCConnectionReconfiguration							
039479	12:04:53:095	UL-DCCH RRCConnectionReconfigurationCo...							

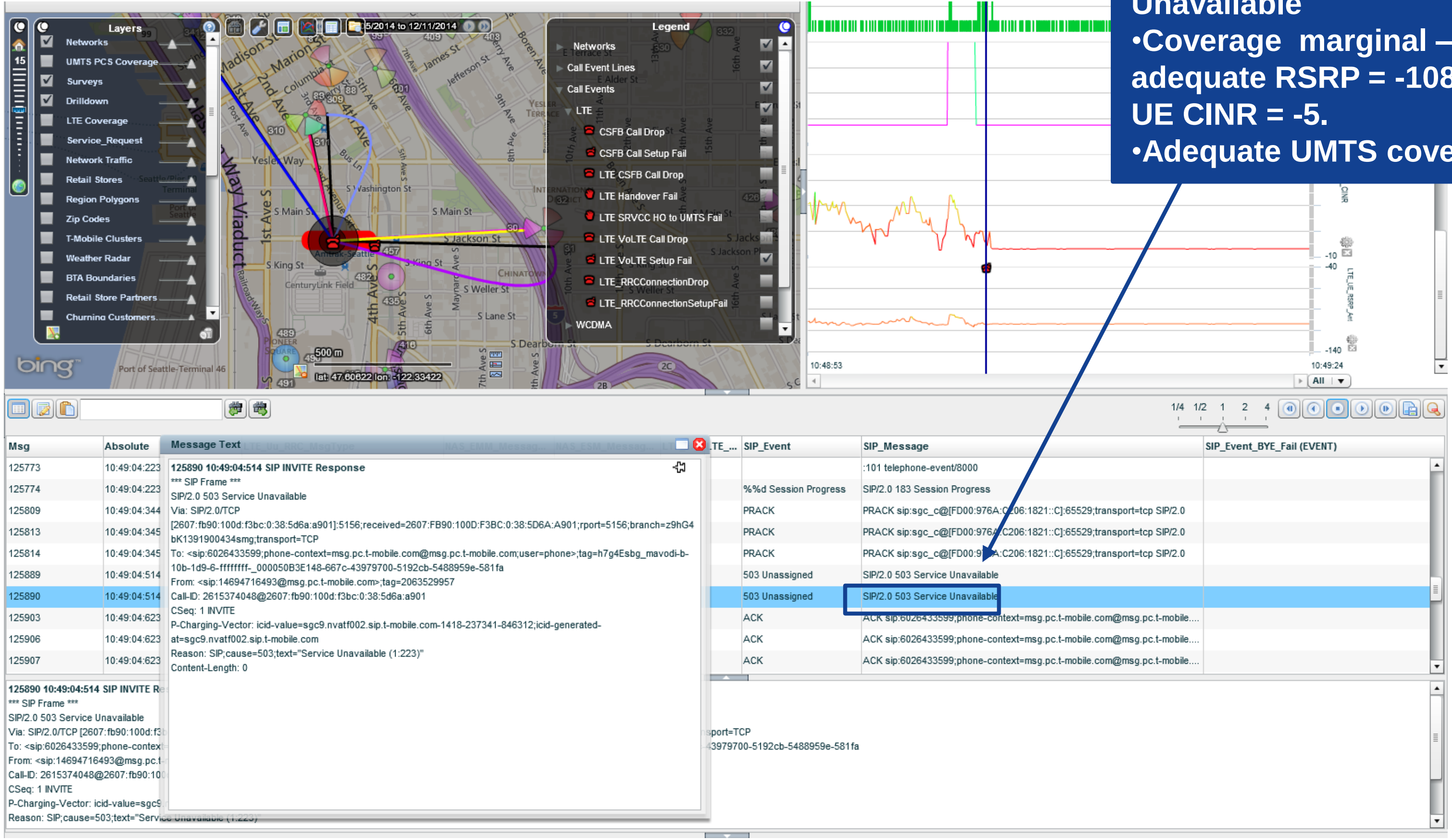
039409 12:04:52:773 DPL log message
DPL_ID: 3735808
SEQ_NUM: 5784
SEG_NUM: 2
Final: 1
Segment of 220 bytes*** ESP Frame ***
Security Parameter Index (SPI): 2718367744
Sequence Number: 419430400
Next Protocol: 6

- SIP Invite Response Service Unavailable
- Coverage excellent UE RSRP =-80dBm, UE CINR = 18
- Immediately goes to CSFB

VoLTE Setup Fail - 2

SIP Message 503 Service Unavailable

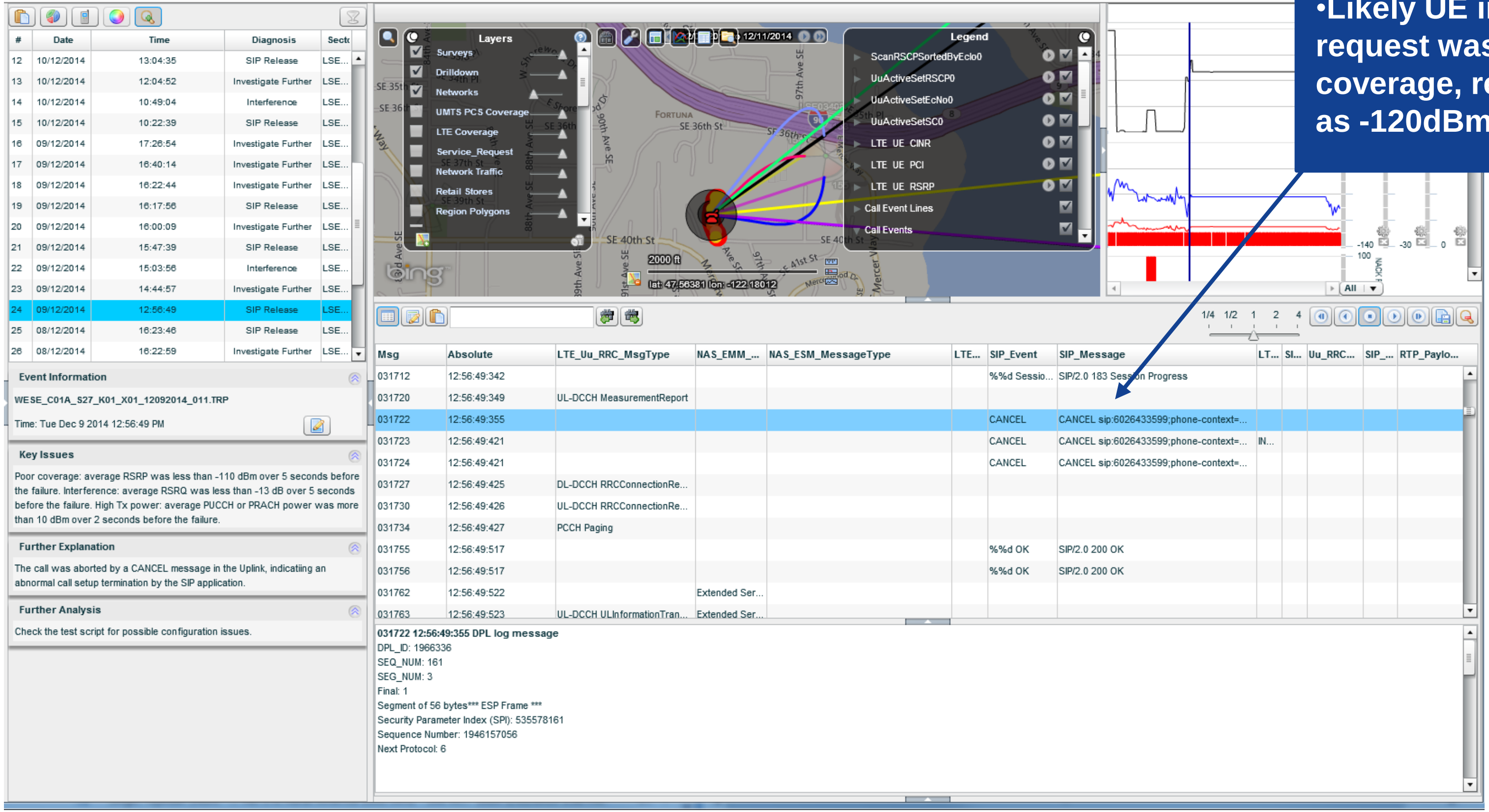
- SIP Invite Response Service Unavailable
- Coverage marginal – adequate RSRP = -108, poor UE CINR = -5.
- Adequate UMTS coverage



VoLTE Setup Fail - 3

Due to Cancel Message from UE - Poor Coverage Area

- UE initiated cancel request
- Likely UE initiation request was due to poor coverage, reading as low as -120dBm



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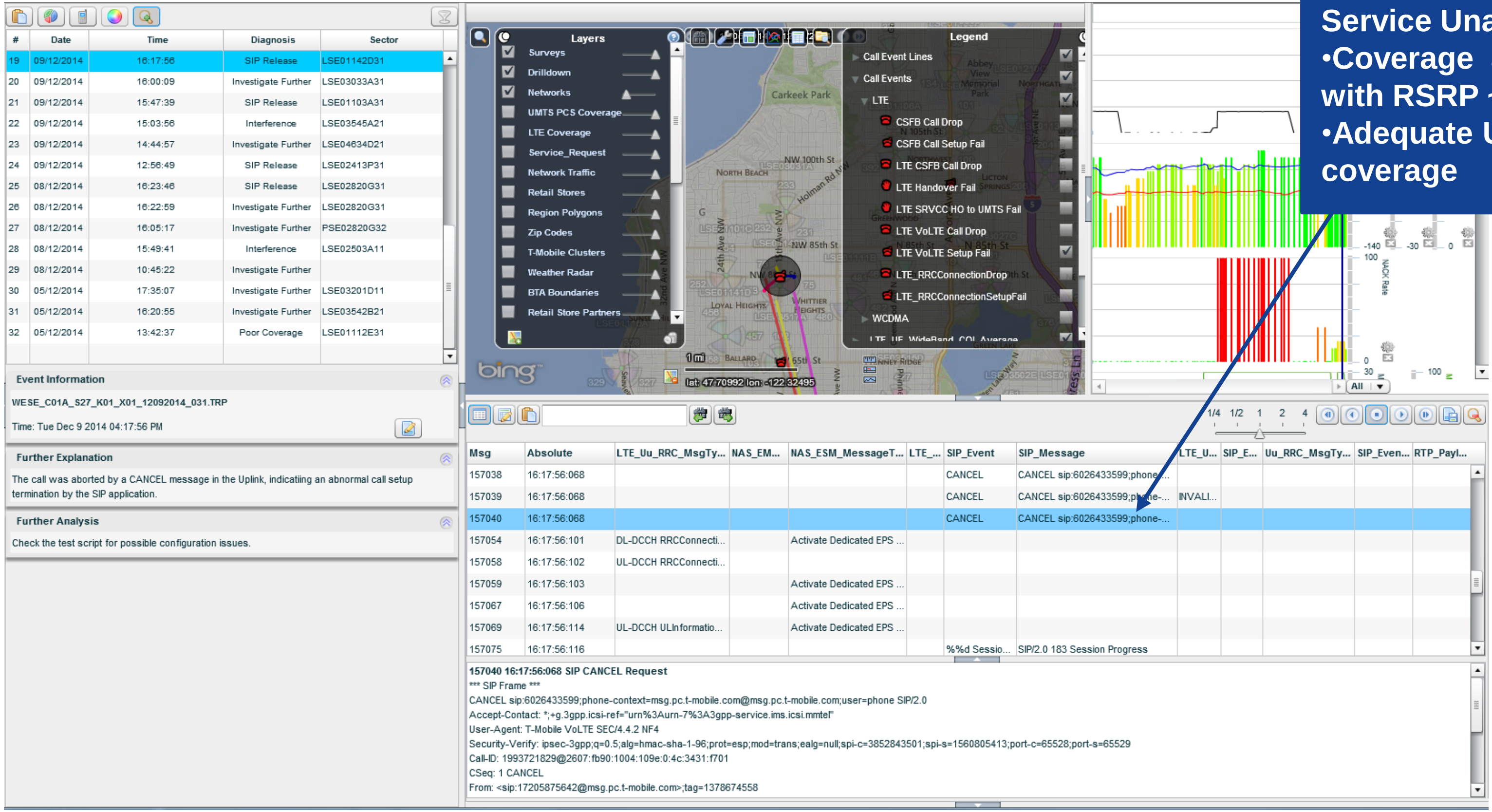
VoLTE Setup Fail - 4

SIP Message 503 Service Unavailable

- SIP Invite Response Service Unavailable
- Coverage adequate with RSRP ~-98dBm
- Adequate UMTS coverage



What is SIP 503 Message?
“Server Failure” Response

- RFC 3261 definition from IETF web site: http://tools.ietf.org/html/rfc3261#section-21.5.4

```
21.5.4 503 Service Unavailable

   The server is temporarily unable to process the request due to a
   temporary overloading or maintenance of the server.  The server MAY
   indicate when the client should retry the request in a Retry-After
   header field.  If no Retry-After is given, the client MUST act as if
   it had received a 500 (Server Internal Error) response.

   A client (proxy or UAC) receiving a 503 (Service Unavailable) SHOULD
   attempt to forward the request to an alternate server.  It SHOULD NOT
   forward any other requests to that server for the duration specified
   in the Retry-After header field, if present.

   Servers MAY refuse the connection or drop the request instead of
   responding with 503 (Service Unavailable).
```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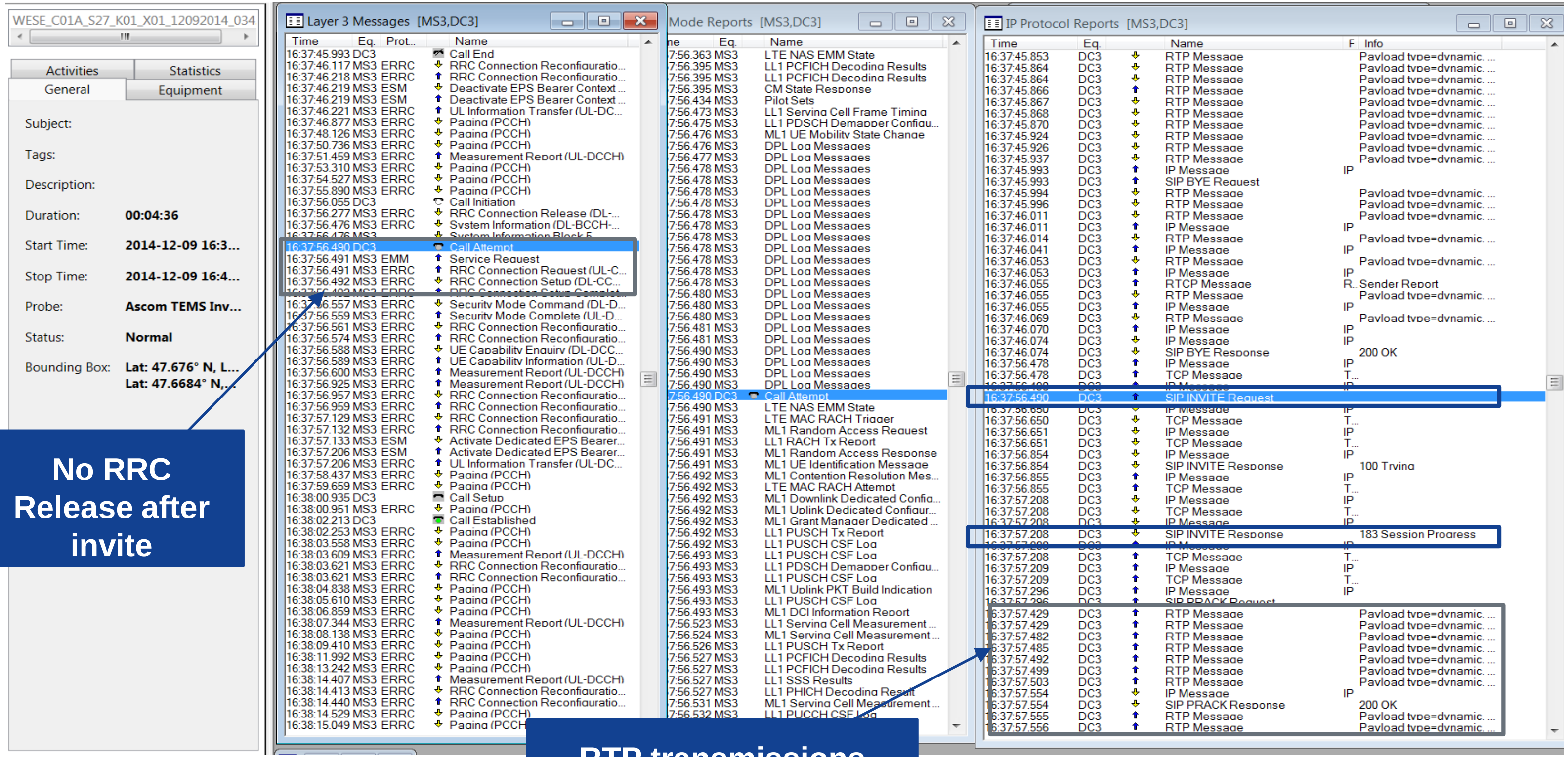
Setup Fails Observed Due to 503 Error

Observations

- The impact of the RRC Connection Release was a delay in the setup of the Voice Path – a new Service Request would be sent but this would occur approximately half a second later. When compared to a Normal VoLTE call, if the Voice Path needed to be set up again the service request would be immediate at the same time as the INVITE request.
- For **Normal VoLTE call setup**, typically the RTP messages were visible after “183 Session In Progress”. This would occur around 0.9s after INVITE request.
- However, for the **Failed VoLTE call Setup** scenario when a 503 error was received, the error message timing is approximately 0.8s, just a little sooner than when we would expect RTP messages which do not arrive for this scenario
- Following slides show examples from TEMS of VoLTE Failed Scenario vs. Normal Setup

Log comparison between Successful/unsuccessful call

Successful Call logs



No RRC Release after invite

RTP transmissions 0.94s later after INVITE

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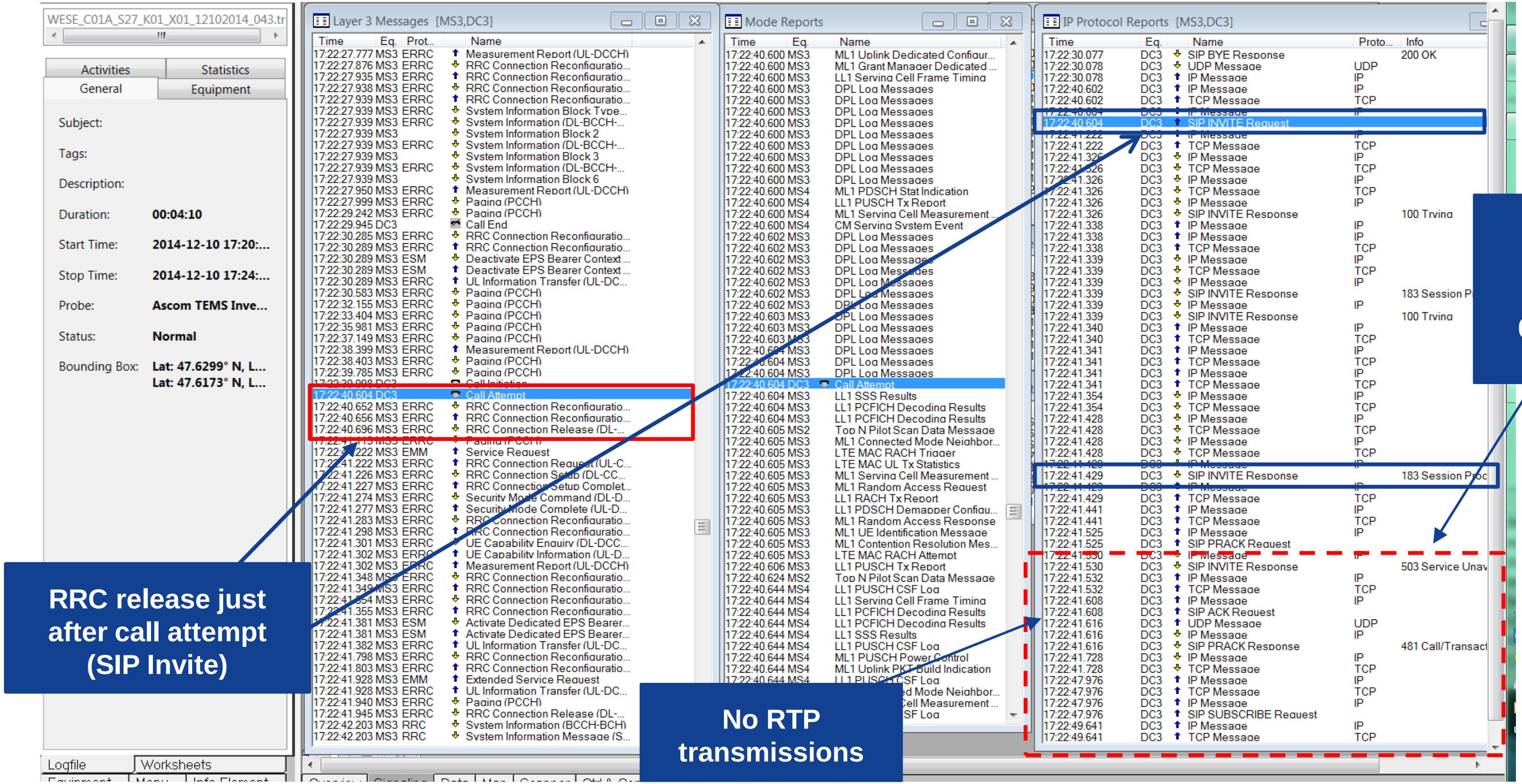
Log comparison between Successful/unsuccessful call

Unsuccessful Call logs



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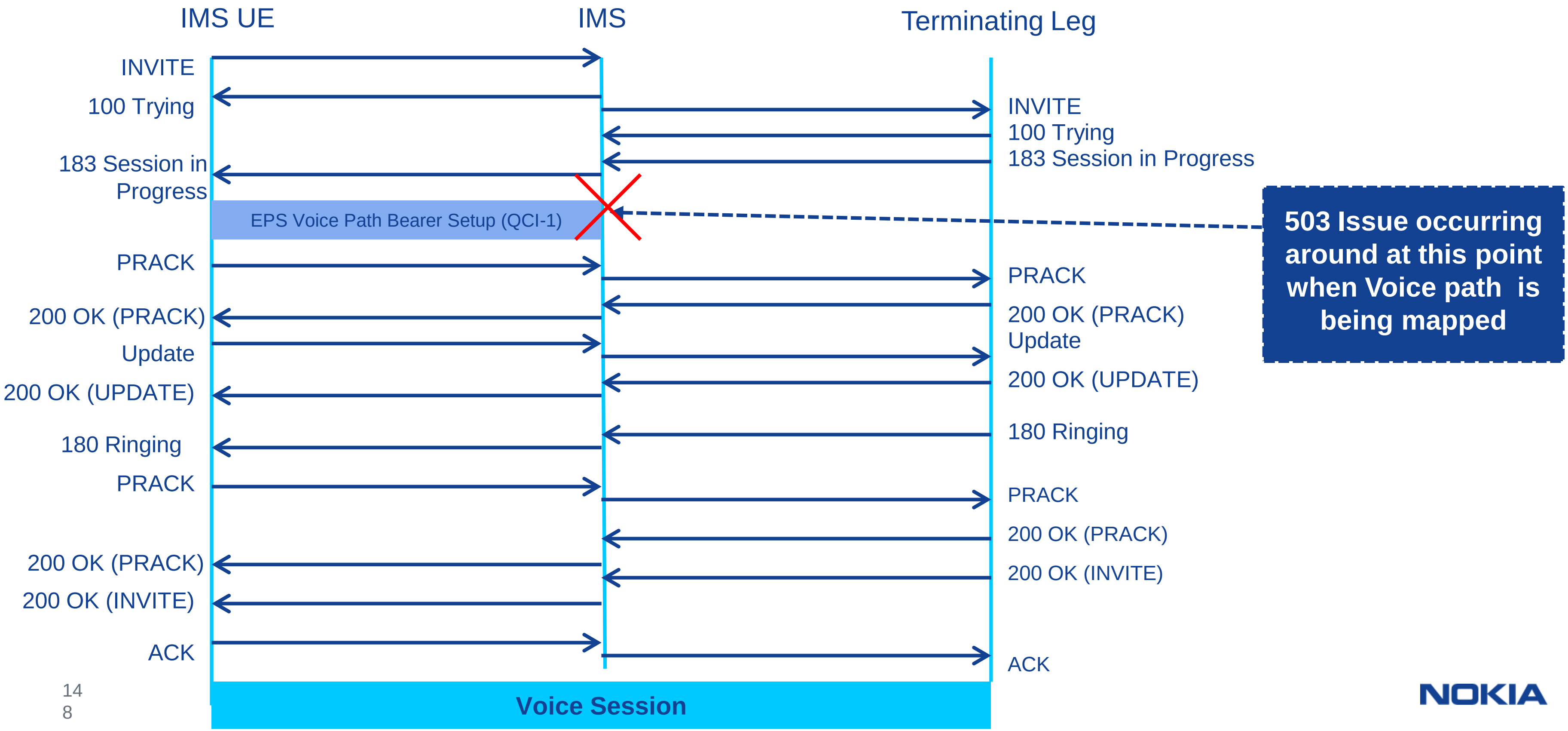
SIP Call Flow Mobile Originating
Phase of Failure



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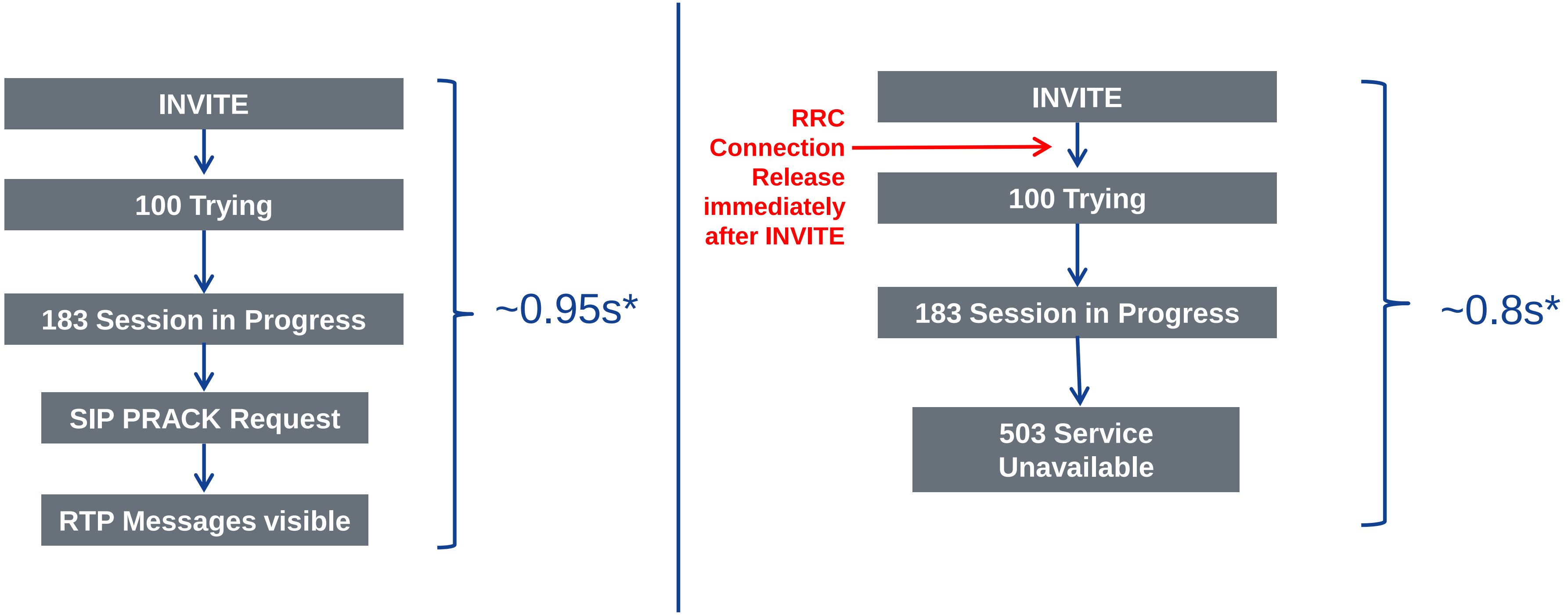
SIP Call Flow Comparison

Successful Call Setup (LEFT) vs. Setup Fail due to Cause 503 (RIGHT)



*approx times, some variation observed

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Conclusions

Based on the drive test results

- UE was dragging LTE down to very low levels, closer to< -120dBm where recovery can become unreliable (noting LTE → UMTS Continuity FR was 5.6%). This also would have indirectly impacted the intra-LTE HO fail rate with UE making last ditch efforts to handoff to other sites
- Currently B2 Event:**b2Threshold1Utra** is set to -121dBm: With 3dB DLRS power boosting and 1dB hysteresis, UE is handing off when (effective) coverage is -125dBm
  - RL70 does have feature that allows dedicated A2 IRAT thresholds to be set for SRVCC HO down to 2G/3G. This feature allows to set different thresholds for QCI-1 bearers to normal data bearers
- It would be helpful to have input from IMS team on how to mitigate scenario for VoLTE setup where the RRC Connection is lost just as the INVITE is sent. That is, accommodating situation where invite is sent but Voice EPS QCI-1 bearer setup is delayed.
  - i) IMS network having allowance delay of EPS bearer setup
  - ii) IMS Re-attempt mapping of RTP path in core after failed attempt

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