Network Engineering
Mobile Broadband

for a world in motion™

LTE Link Adaptation

PDSCH, PUSCH and PDCCH

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Main Menu

- History and Acknowledgments
- NEI Complex Introduction

  Click above to learn why the listed features were combined in this NEI complex and what they have in common.
- Cheat Sheets

  Click above to access quick reference slides
- NEI Complex Reference Table

  Click above to see the entire set of NEI and NEI complexes Network Engineering has already created
- Abbreviations

- **Outer Link Quality Control (OLQC)**
- **Downlink Link Adaptation for PDSCH**
- **LTE1034- Extended Uplink Link Adaptation**
- **Downlink Link Adaptation and power control for PDCCH**
- **LTE1035- Outer Loop Link Adaptation for PDCCH**
- **LTE616 & LTE939- Usage based PDCCH adaptation**
- **LTE1495 – Fast Uplink Link Adaptation (F-ULA)**

History and Acknowledgements

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History

Versions	Date	Reason for Update
0.1	2012	First version of NEI complex
0.2	2013	Corrections and improvements in parameter descriptions and other
0.3	2014	LTE1495 F-ULA added

Common References

#	Source / Author	Title
1	3GPP	TS 36.211-860 - Physical Channels and Modulation
2	3GPP	TS 36.213-860 - Physical layer procedures
3	M.Chmiel, R.Benedittis, K.Dietrich, R.Golderer, M.Gussregen, G.R.Janczyk,N.Kreush,H.Kroener,I. Maniatis,W.Payer	LTE FDD RRM SFS, V.36.0.0
4	Shomik Pathak - Nov 2011	RRM in TTI traces & related System Performance

Acknowledgements

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NEI Complex Introduction

Link Adaptation concept

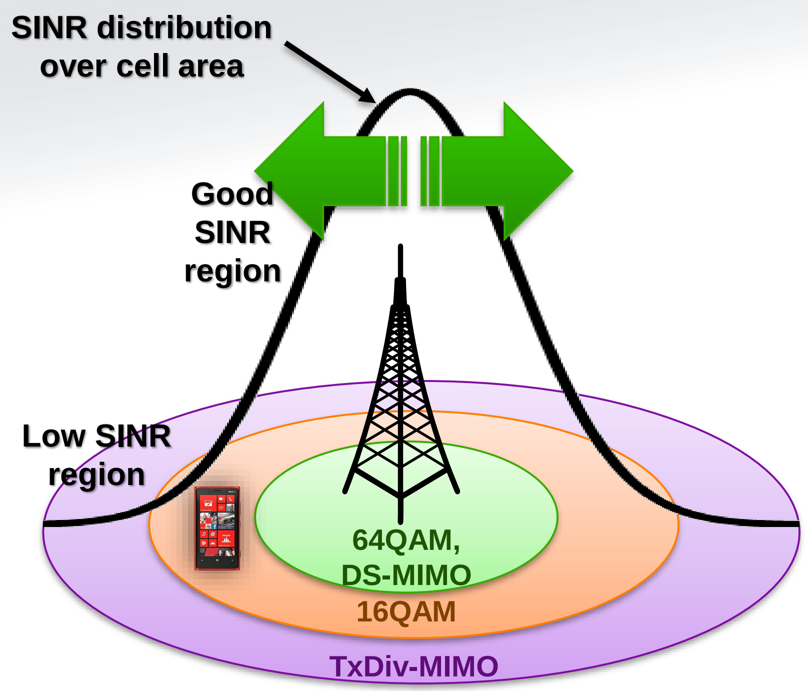
The purpose of Link Adaptation is to improve system capacity, peak data rate and coverage reliability by the adaptation of transmission settings to the radio channel conditions

- If the conditions of the radio link are good, a high-level efficient modulation scheme and a small amount of error correction is used. This gives a high data throughput on the radio channel.
- If the conditions of the radio channel are poor, a low-level, more robust, modulation scheme is used and the amount of error correction is increased. The data throughput will drop considerably.
- The same concept is re-used across different channels

NOTE

SINR distribution strictly depends on the environment and load condition; it determines how many subscribers can really exploit dual-stream MIMO (Spatial Multiplexing).

Link Adaptation concept illustration



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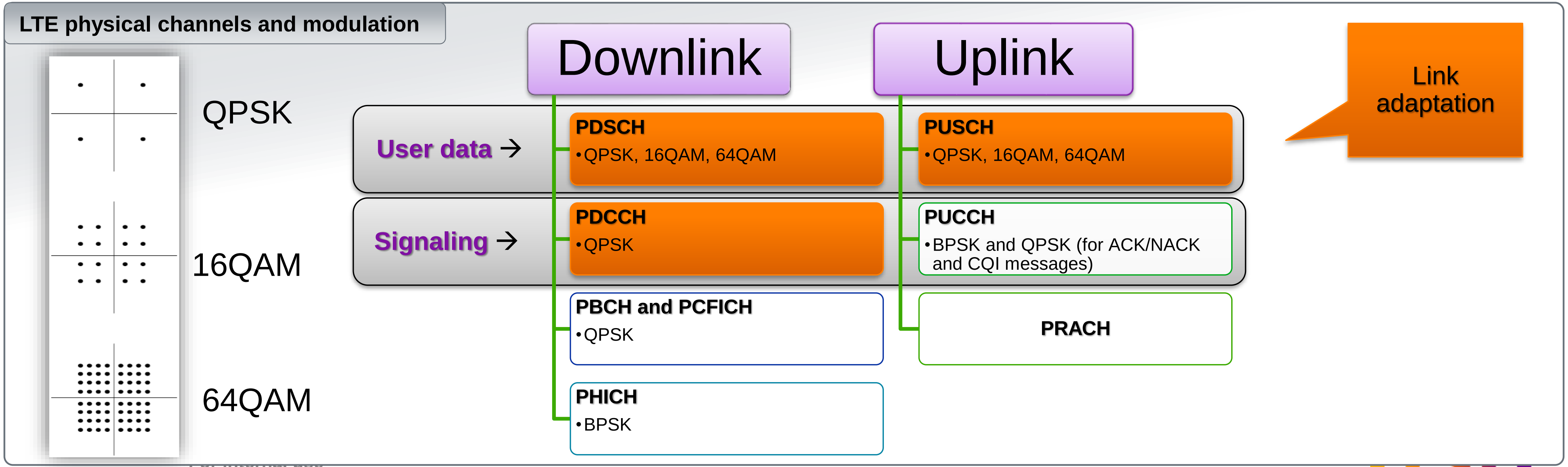
- Link adaptation for LTE is defined separately for PDSCH, PDCCH and PUSCH
- LTE PHY supports **QPSK**, **16QAM** and **64QAM** but not all of them can be applied with any physical channel
- In data channels, adjustment of the channel occur in Modulation and Coding Scheme (MCS) and number of Physical Resource Blocks (PRB) domain (UL ATB only)
- In downlink control channel, only one modulation is available, thus adaptation is performed in number of Control Channel Elements (CCE) domain



NEI Complex Introduction

Link adaptation features release history

LTE releases	PDSCH	PUSCH	PDCCH
RL10/RL05 TD	Basic LTE functionality	Basic LTE functionality	Basic LTE functionality
RL30/RL25TD		**LTE1034** Extended Uplink Link Adaptation	**LTE1035** Outer Loop Link Adaptation for PDCCH **LTE616** Usage based PDCCH adaptation *(FDD only)*
RL35TD			**LTE939** Usage based PDCCH adaptation *(TDD only)*
RL60/RL35TD		**LTE1495** Fast Uplink Link Adaptation	

NEI Complex Introduction
Downlink function dependencies

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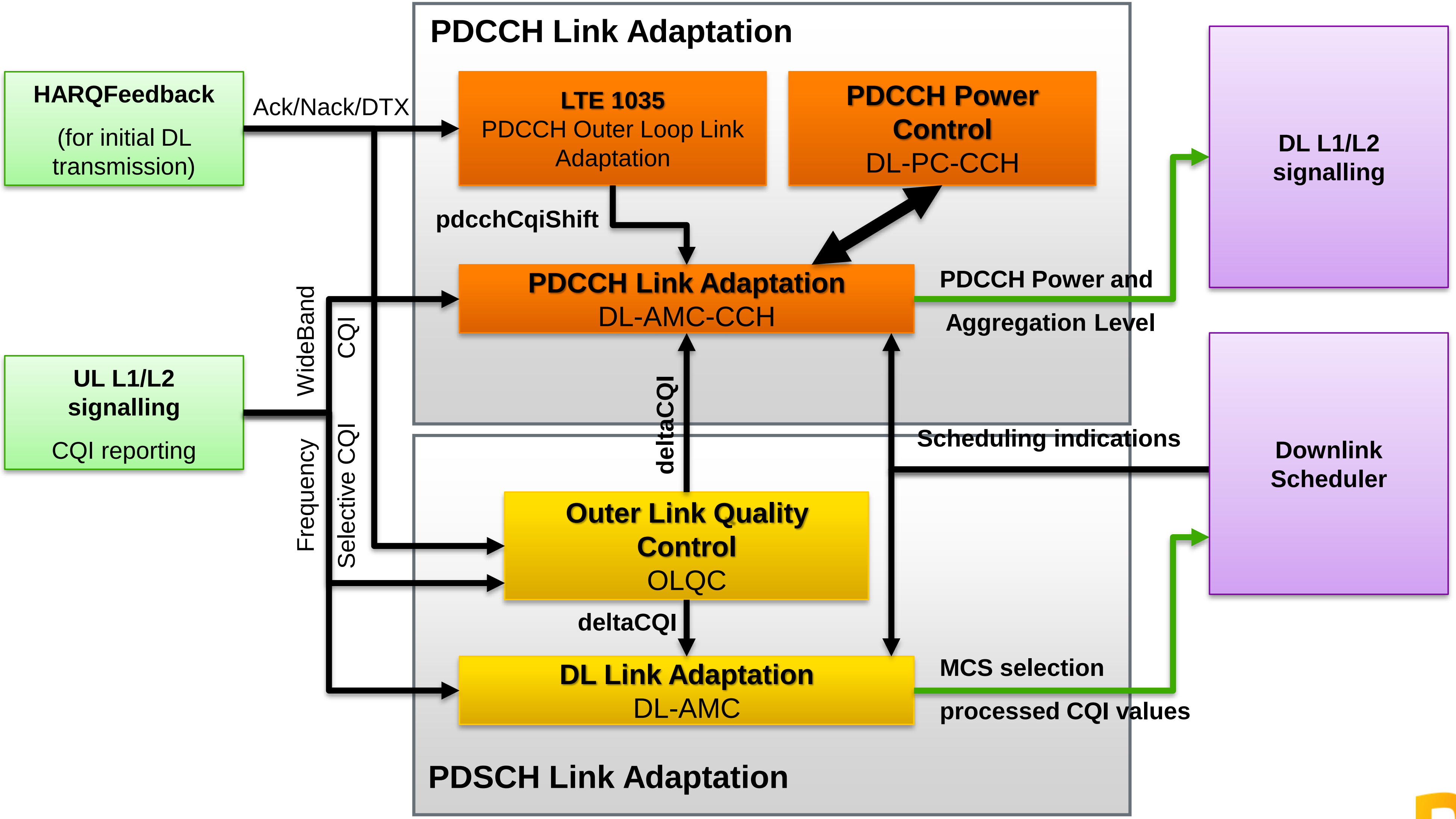


Downlink - data	Downlink - signaling	Uplink - data
– fast ▪ 1 TTI	– fast ▪ 1 TTI	– Fast, event triggered ▪ 1 TTI
– Channel aware ▪ CQI based (frequency selective)	– Channel aware ▪ CQI based (wideband CQI/RI)	– Channel partly aware ▪ average BLER based
– MCS selection ▪ Absolute:1 out of 0-28	– CCE AGG level selection ▪ Absolute:1,2,4,8	– MCS adaptation ▪ Relative:+/- 1 MCS correction ▪ F-ULA: absolute: 1 out of 0-24
– Output per UE ▪ MCS ▪ TBS	– Output per UE ▪ CCE AGG level	– Output per UE ▪ MCS ▪ ATB
– UE capabilities support ▪ max. TBS per TTI		– UE capabilities support ▪ power headroom ▪ QoS profile
– up to 64QAM support	– QPSK only	– up to 16 QAM support (*for UE cat 4)

NEI complex introduction

Terminal categories for LTE-Advanced

	LTE (Rel.8) UE categories		All commercial LTE devices in the market 2010 / 2011			LTE-Advanced devices based on these User Equipment categories		
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Peakrate DL/UL	10/5 Mbps	50/25 Mbps	100/50 Mbps	150/50 Mbps	300/75 Mbps	300/50 Mbps	300/100 Mbps	3000/1500Mbps
RF Bandwidth	20 MHz	20 MHz	20 MHz	20 MHz	20 MHz	40 MHz	40 MHz	100 MHz
Modulation DL	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM
Modulation UL	16 QAM	16 QAM	16 QAM	16 QAM	64 QAM	16 QAM	16 QAM	64 QAM
MIMO DL	optional	2 x 2	2 x 2	2 x 2	4 x 4	2x2(CA) or 4x4	2x2(CA) or 4x4	8 x 8
MIMO UL	no	no	no	no	no	no	2 x 2	4 x 4

Defined in initial LTE release (3GPP Release 8) — Classes 1–5

Defined in initial LTE-Advanced release (3GPP Rel. 10) — Classes 6–8

Carrier aggregation of up to 40MHz — Classes 6–7

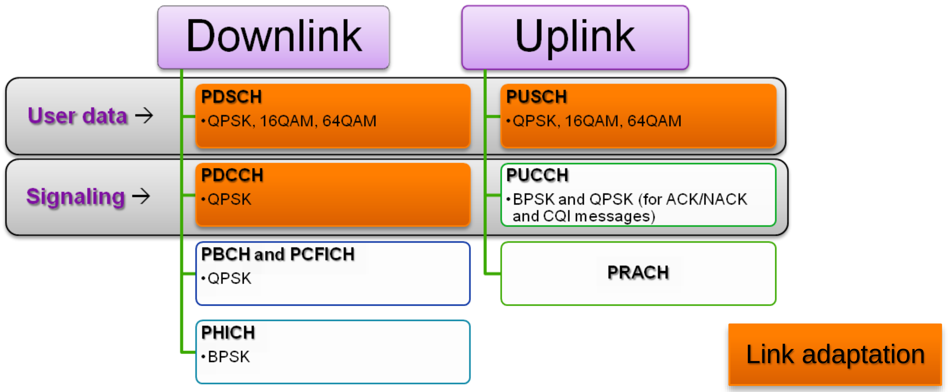
Source: TS 36.306

LTE Link Adaptation – Reference Page

PDSCH	PDCCH	PUCCH
Fast ➔ 1 TTI	Fast ➔ 1 TTI	Fast, event triggered ➔ 1 TTI
Channel aware ➔ CQI based (frequency selective)	Channel aware ➔CQI based (wideband CQI/RI)	Channel partly aware ➔ average BLER based
MCS selection ➔ Absolute:1 out of 0-28	CCE AGG level selection ➔Absolute:1,2,4,8	MCS adaptation ➔ E-ULA: Relative:+/-1 / F-ULA absolute MCS correction
Output per UE ➔ MCS,TBS	Output per UE ➔ CCE AGG level	Output per UE ➔ MCS,#PRB
UE capabilities support ➔ max. TBS per TTI		UE capabilities support ➔ power headroom,QoS profile
up to 64QAM support	16 QAM only	up to 16 QAM support (*for UE cat 4)

Useful Links PKDB LTE resource grid (external)

LTE physical channels and modulation



Mode 2-0 CQI report subband size

System Bandwidth (RBs)	Subband Size k (RBs)	M
6 – 7	NA	NA
8 – 10	2	1
11 – 26	2	3
27 – 63	3	5
64 – 110	4	6

Mode 3-0 CQI report subband size

System Bandwidth (RBs)	Subband Size k (RBs)
6 - 7	NA
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

AGG level	Code rate
1xCCE	2/3
2xCCE	1/3
4xCCE	1/6
8xCCE	1/12

Message Type	Tag Value	Priority
(highest priority)		99
DL: Broadcast, Paging, RACH Response	1	91
DL: Msq4 and Msg4 HARQ Retransmission CSS	2	85
DL: Preamble Assignment CSS	3	79
UL: HARQ Retransmission	4	73
DL: Msq4 and Msg4 HARQ Retransmission USS	5	67
DL: Preamble Assignment USS	6	61
DL: HARQ Retransmission	7	55
UL: Scheduling Request	8	49
DL/UL: SPS Allocation	9	43
DL/UL DRX Prioritised Allocation	10	37
DL/UL: Signalling Radio Bearer with or w/o Dynamic Allocation	11	31
DL/UL: Dynamic Allocation (initial transmission) GBR	12	25
DL/UL: Dynamic Allocation (initial transmission) non-GBR delay sensitive	13	19
DL/UL Dynamic Allocation (initial transmission) non-GBR non-delay sensitive	14	13
UL Proactive Assignment (Dummy Grant)	15	7
Spare with lowest priority for future use'	16 - 30	0

Reference to Key function switches (active by default)

Parameter Name	Enabling/disabling
dlamcEnable	Dynamic DL link adaptation (DL LA)
dlOlqcEnable	Outer Link Quality Control (OLQC)
actUlLnkAdp	UL link adaptation (UL LA) (value = eUlLa → RL30 EULA)
enableAmcPdcch	CQI-based AMC for PDCCH (DL-AMC-CCH)
enablePcPdcch	Power Control for PDCCH (DL-PC-CCH)
actOlLaPdcch	Activate PDCCH Outer Loop Link Adaptation
actLdPdcch	Enabling/disabling the load adaptive number of PDCCH symbols in a cell

fUlLa → RL60 FULA

Reference to Key Parameter Values

Parameter Name	Definition	Default Value
iniMcsDl	Initial MCS in DL	4
iniMcsUl	Initial MCS in UL	MCS5
iniPrbsUl	Selection of initial Bandwidth at Call Setup	10
maxNrSymPdcch	Maximum number of OFDM symbols for PDCCH per subframe	3

Outer Link Quality Control (OLQC)

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Outer Link Quality Control (OLQC)
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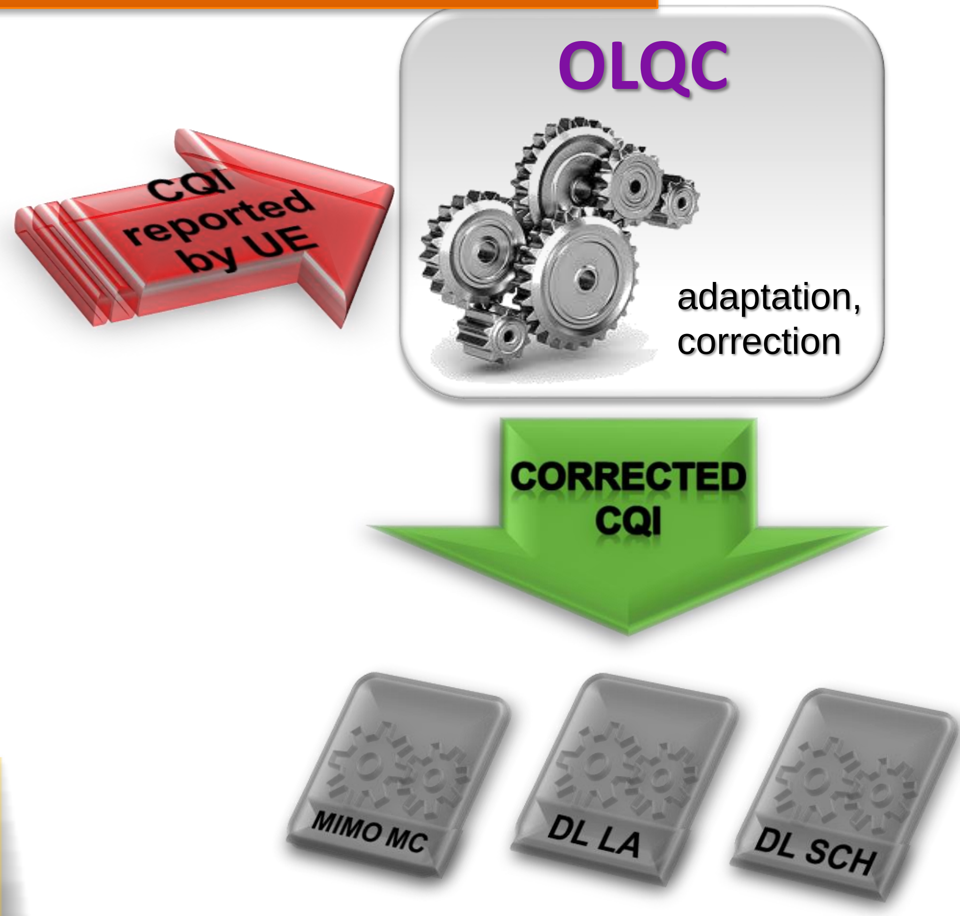
Main Menu

NEI Contact: Krzysztof Wascinski

OLQC corrects CQI reports for other RRM blocks

- The purpose of ***OLQC*** is to ***adapt/correct CQI values***, delivered by UE and later on used by DL link adaptation (DL LA) and DL scheduler (DL SCH),
- The target of this adaptation is certain target block error ratio (BLER) of the first HARQ transmission
- OLQC can be activated by network operator through O&M
  - active by default settings



Important

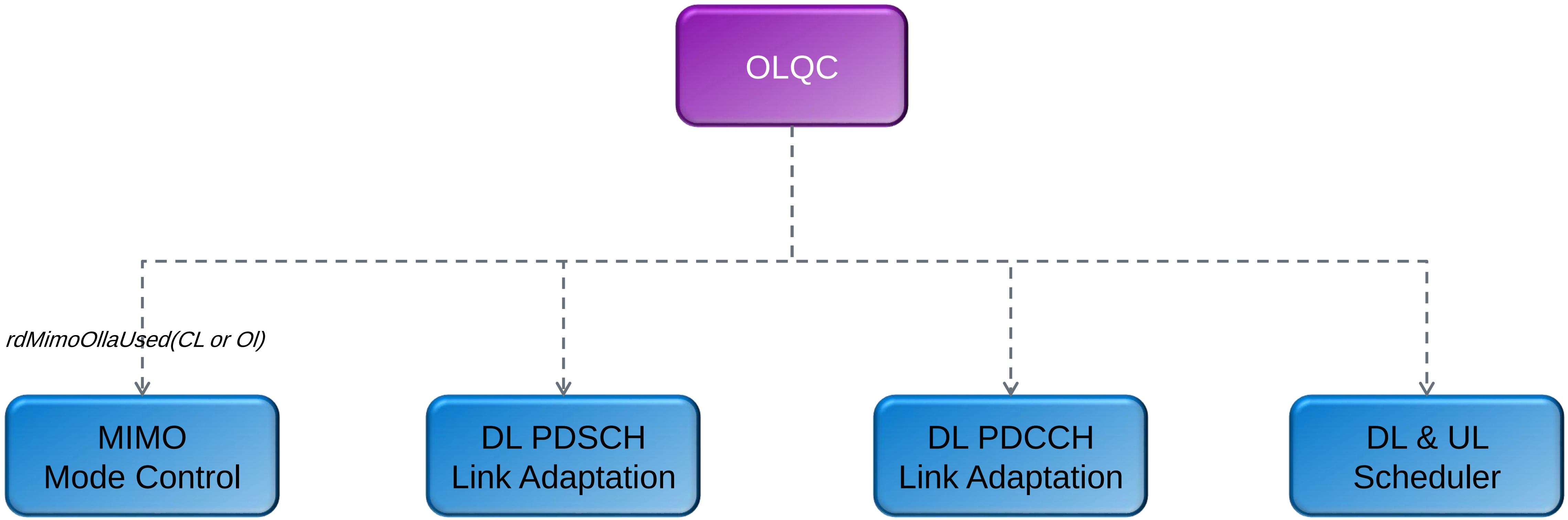
If OLQC is not active, DL LA and DL SCH fully rely on UE reported CQI values

- CQI estimation error of the UE
- CQI reporting error
- time delay between CQI measurement and the reception of the subsequent data block
- CQI interpolation error
- errors due to CQI averaging of PRBs

CQI inaccuracy sources

- If CQI inaccuracies are not corrected, target BLER might not be reached
- Inaccurate CQI values would cause retransmissions and hence visible user/cell throughput degradation

- OLQC improves other RRM blocks performance, thanks to more accurate CQI reports



OLQC corrects CQI reports for other RRM blocks

Input

Output

per UE

- CQI reports (from UL L1/L2 sig):
  - wideband
  - frequency selective
  - code word specific (starting from RL20)
- HARQ feedback (from DL HARQ)
  - ack/nack information
- MiMo mode selection (from MiMO-MC)
  - single/double code word case

- Corrected CQI reports (to DL LA):
  - wideband
  - frequency selective
  - code word specific (starting from RL20)
- Corrected CQI reports (to DL MIMO-MC):
  - means of the R&D Parameters rdMimoOllaUsedXX (XX = Ol, Cl, range 0,1 step 1) the effect of OLLA can be turned on/off separately for closed loop MIMO and open loop MIMO. Default shall be 1 meaning "On".

– **Wideband report** provides one CQI value for the entire downlink system bandwidth.

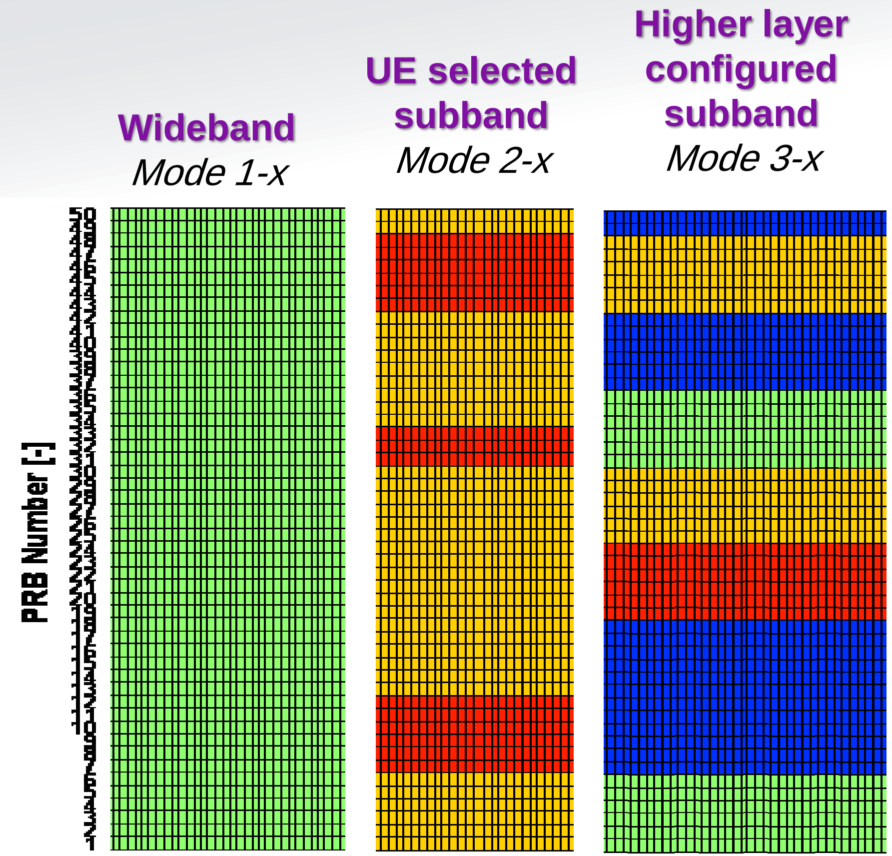
– **UE selected subband CQI report** divides the system bandwidth into multiple subbands, selects a set of preferred subbands (the best M subbands), then reports one CQI value for the wideband and one differential CQI value for the set (assume transmission only over the selected M subbands).

System Bandwidth (RBs)	Subband Size k (RBs)	M
6 – 7	NA	NA
8 – 10	2	1
11 – 26	2	3
27 – 63	3	5
64 – 110	4	6

– **Higher layer configured subband report** provides the highest granularity. It divides the entire system bandwidth into multiple subbands, then reports one wideband CQI value and multiple differential CQI values, one for each subband.

System Bandwidth (RBs)	Subband Size k (RBs)
6 - 7	NA
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

Example: 10 MHz channel bandwidth
(different colours stands for different reported CQI values)

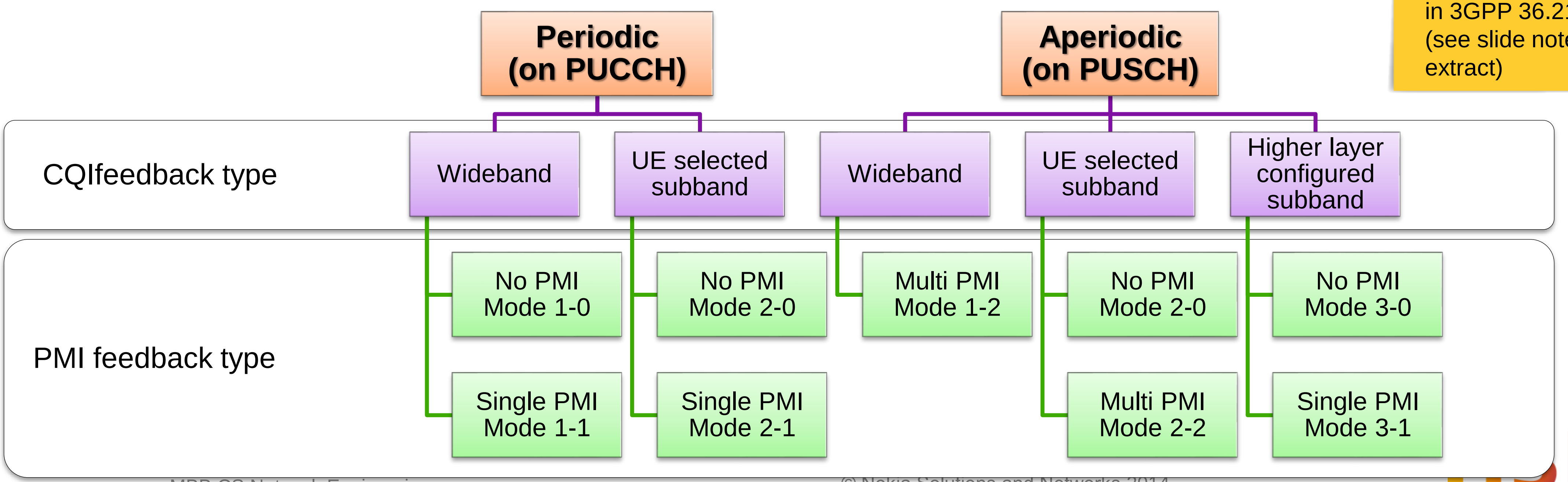


Technical Details

CQI/RI/PMI reporting modes family tree

- **Periodic**
  - Combinations of wideband / frequency-selective (sub-band) CQI and PMI are possible.
  - Frequency selected is based on best subband of a “bandwidth part”. Subband index within the part is also reported.
  - Rank indicator is always wideband. It may be delivered on a different TTI.
- **Aperiodic**
  - Combinations of wideband / frequency-selective (sub-band) CQI and precoding matrix indicator (PMI) are possible.
  - Rank indicator is always wideband. Encoded separately but sent with the CQI/PMI report on PUSCH.

Note
CQI reporting modes are defined in 3GPP 36.213 (see slide notes for extract)



- Modes can be selected through parameter *cqiAperMode*, which implements 3GPP "*cqi-ReportingModeAperiodic*".
  - Value "FTB1" selects the reporting mode 2.x.
  - Value "FTB2"selects the reporting mode 3.x

Abbreviated Name	Description	Range/ Step	Default Value
cqiAperMode	Aperiodic CQI feedback reporting mode	FBT1 (0), FBT2 (1)	FBT2 (1)

- MIMO-MC selects variant "x" automatically, i.e., PMI-enabled variants for CL and without PMI for OL.
- "Best-M" average mode is used for CQI in UE-selected type.
- Higher layer type allows for one CQI per subband report.

- OLQC has a UE scope and a time resolution of up to single TTI
- Adaptation/correction is done through a calculation of CQI offset and its addition to the initially received CQI values
- The CQI offset itself is controlled by the incoming ACK/NACK responses for the initial transmission of each transport block
- Adapted/corrected CQI is delivered to DL LA
- DL LA will base the selection of transport block size and modulation/coding scheme on corrected CQI values

- OLQC adds a CQI offset (*ΔCQI*) to the wideband/frequency selective and code word specific (starting from RL20) CQI values for codeword *x* and frequencies f_{rep} at time *t*

$$\overline{\mathrm{CQI}}_{\mathrm{corrected}}(x,t)=\overline{\mathrm{CQI}}_{\mathrm{reported}}(x,t)+\Delta\mathrm{CQI}(t)$$

$$\mathrm{CQI}_{\mathrm{corrected}}(x,f_{\mathrm{rep}},t)=\mathrm{CQI}_{\mathrm{reported}}(x,f_{\mathrm{rep}},t)+\Delta\mathrm{CQI}(t)$$

- Delta CQI is initialized in the following way

$$\Delta\mathrm{CQI}(t_{\mathrm{setup}})=\Delta\mathrm{CQI}_{\mathrm{init}}$$

- For dimensioning purposes a balance condition for the CQI offset can be defined since the CQI increase and decrease steps should be balanced.
- It is assumed that the HARQ DTX will occur with a probability *pdcchHarqTargetBler*. This parameter is set to 0.01 if PDCCH OLLA is disabled or it is taken from the O&M parameter *pdcchHarqTargetBler* if PDCCH OLLA is enabled.
- With a certain assumption the balance condition (for single codeword) is defined as:

$$\begin{cases} (1-0.01)\times(1-BLER_{target}\times CQI_{stepup} = (1-0.01)\times BLER_{target}\times CQI_{stepdown} + 0.01\times CQI_{stepdown} & \text{,if PDCCH OLLA disabled} \\ (1-pdcchHartTargetBler)\times(1-BLER_{target}\times CQI_{stepup} = (1-pdcchHartTargetBler)\times BLER_{target}\times CQI_{stepdown} & \text{,if PDCCH OLLA enabled} \end{cases}$$

- Therefore, $CQI_{stepdown}$ can be calculated from the O&M parameters CQI_{stepup} and the $BLER_{target}$ as:

$$CQI_{stepdown} = CQI_{stepup} \cdot \begin{cases} \dfrac{(1-0.01)\cdot(1-BLER_{target})}{(1-0.01)\cdot BLER_{target}+0.01}, & \text{if PDCCH OLLA is disabled} \\ \dfrac{(1-BLER_{target})}{BLER_{target}}, & \text{if PDCCH OLLA is enabled} \end{cases}.$$

- Starting from the initial value the CQI offset is adjusted in response to the ACK/NACK/DTX for the new transmission of a transport block.
- The basic algorithm is based on the well-known outer loop link adaptation algorithm used also in WCDMA. This well-known algorithm can be directly applied for the single code word case which results in the following equation:

$$\Delta\mathrm{CQI}(t) = \begin{cases} \min(\Delta\mathrm{CQI}(t-1) + \mathrm{CQI}_{stepup}, \Delta\mathrm{CQI}_{max}), & \text{for first HARQ feedback} = \text{ACK}, \\ \max(\Delta\mathrm{CQI}(t-1) - \mathrm{CQI}_{stepdown}, \Delta\mathrm{CQI}_{min}), & \text{for first HARQ feedback} = \text{NACK or DTX}, \\ \Delta\mathrm{CQI}(t-1), & \text{for first HARQ feedback} = \text{N/A}. \end{cases}$$

- For the dual code word case (MIMO) the algorithm has to be slightly adapted, since up to two HARQ feedbacks are available per TTI:

$$\Delta\mathrm{CQI}(t) = \begin{cases} \min(\Delta\mathrm{CQI}(t-1) + \mathrm{CQI}_{stepup}, \Delta\mathrm{CQI}_{max}), & \text{for first HARQ feedbacks} = \text{ACK} + \text{ACK}, \\ \max(\Delta\mathrm{CQI}(t-1) - \mathrm{CQI}_{stepdown}, \Delta\mathrm{CQI}_{min}), & \text{for first HARQ feedbacks} = \text{NACK} + \text{NACK or DTX}, \\ \min(\max(\Delta\mathrm{CQI}(t-1) + (\mathrm{CQI}_{stepup} - \mathrm{CQI}_{stepdown})/2, \\ \quad \Delta\mathrm{CQI}_{min}), \Delta\mathrm{CQI}_{max}), & \text{for first HARQ feedbacks} = \text{ACK} + \text{NACK}, \\ \min(\Delta\mathrm{CQI}(t-1) + \mathrm{CQI}_{stepup}, \Delta\mathrm{CQI}_{max}), & \text{for first HARQ feedbacks} = \text{ACK} + \text{N/A}, \\ \max(\Delta\mathrm{CQI}(t-1) - \mathrm{CQI}_{stepdown}, \Delta\mathrm{CQI}_{min}), & \text{for first HARQ feedbacks} = \text{NACK} + \text{N/A}, \\ \Delta\mathrm{CQI}(t-1), & \text{for first HARQ feedbacks} = \text{N/A} + \text{N/A}. \end{cases}$$

- Delta CQI calculation
  - shall not be performed if the latest received wideband CQI is equal to 0 or 15
- Switch between single/double code word case triggered by MiMo-MC
- ACK shall be mapped to N/A if:
  - new transmission has been done with maximum MCS which results from UE or eNodeB capabilities
  - MCS downgrade has been done for the new transmission due to the fact that the selected transport block exceeds the peak data rate or the amount of buffered data of the considered UE
- NACK shall be mapped to N/A if:
  - the minimum MCS has been reached
- Maximum and a minimum CQI offset is defined in order to suppress very large fluctuations that may arise in extreme situations

- Provide DL LA with:
  - corrected wideband CQI

$$\overline{\mathrm{CQI}}_{\mathrm{corrected}}(x,t) = \overline{\mathrm{CQI}}_{\mathrm{reported}}(x,t) + \Delta\mathrm{CQI}(t)$$

  - corrected frequency selective CQI

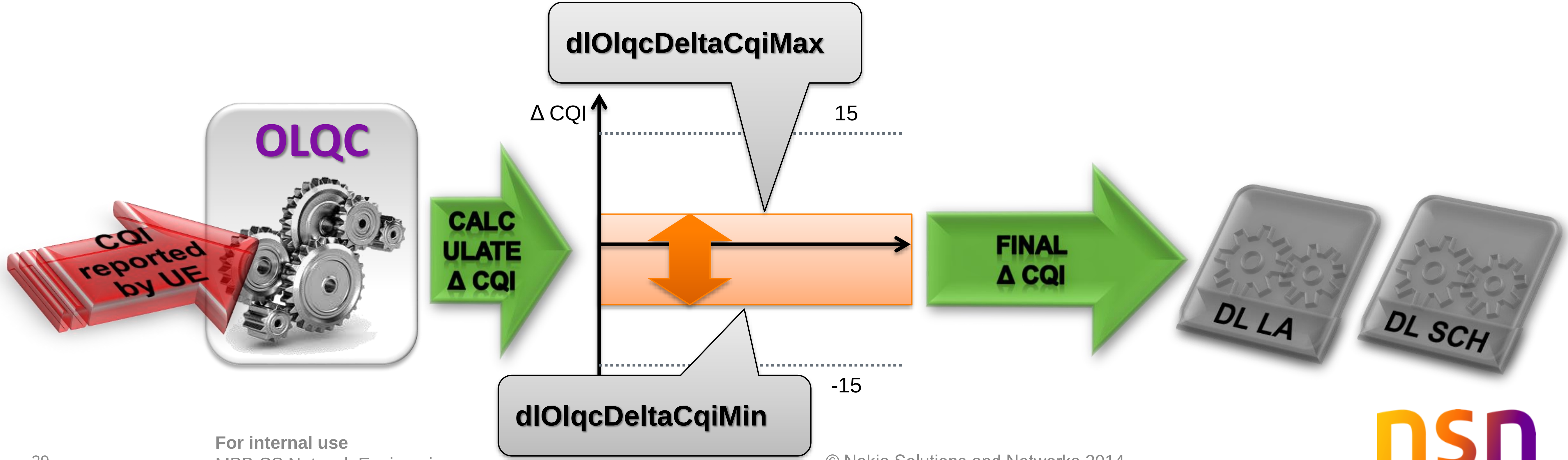
$$\mathrm{CQI}_{\mathrm{corrected}}(x, f_{\mathrm{rep}}, t) = \mathrm{CQI}_{\mathrm{reported}}(x, f_{\mathrm{rep}}, t) + \Delta\mathrm{CQI}(t)$$

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
dlOlqcEnable	Switch to enable/disable OLQC	Boolean (0/1) 0=True 1=False	True	The feature shall be enabled all the time
dlOlqcDeltaCqiIni	Initial value of CQI offset	-15 to +15 in steps of 0.1	-0.5	The value determine initial correction, delivered to DL AMC, later on modified by algorithm. •**Value close to 0**➔ UE overestimates the CQI often → reported CQI is too high •**Value close to edge (-15 or 15)** ➔ UE underestimates the CQI → reported CQI is too low
dlTargetBler	Target block error ratio of transport blocks for 1st transmission	0.001 to 0.999 in steps of 0.001	0.10	•**dlTargetBler** is not applicable if **dlOlqcEnable** = false •**pdcchHarqTargetBler** shall be at maximum one half of **dlTargetBler**
dlOlqcDeltaCqiStepUp	CQI offset increase for an ACK	0 to 1 in steps of 0.001	0.125	•**Low value** ➔ Very low CQI offset adjustment •**High value** ➔ Quick MCS adjustment (value will not be higher than **dlOlqcDeltaCqiMax** and lower than **dlOlqcDeltaCqiMin**)

Configuration Management

Minimum and maximum delta CQI

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
dlOlqcDeltaCqiMax	Maximum value of CQI offset	0 to 15 in steps of 0.1	5	The value define suppression of CQI fluctuation = degree of freedom for OLQC •**Value close to 0** → Low deltaCQI fluctuation → recommended 0+- 3 •**Value close to edge (-15 or 15)** →High deltaCQI fluctuation, MCSs will be changed more often, worse performance expected
dlOlqcDeltaCqiMin	Minimum value of CQI offset	-15 to 0 in steps of 0.1	-13.5	



Deployment Aspects

OLQC in TTI Trace

For ACK+NACK:
rrmDeltaCqi = min(max(rrmDeltaCqiprev + (dlOlqcDeltaCqiStepUp – rrmCqiStepDown)/2/ rrmDlOlqcSlowdownFactor, dlOlqcDeltaCqiMin), dlOlqcDeltaCqiMax)

StepDown value varies and is not exactly 1.125 as derived (rrmCqiStepDown = dlOlqcDeltaCqiStepUp * (1 – dlTargetBler)/ dlTargetBler) because of rrmDlOlqcSlowdownFactor.
For dual NACK or NACK+NA:
rrmDeltaCqi = max(rrmDeltaCqiprev – rrmCqiStepDown/ rrmDlOlqcSlowdownFactor, dlOlqcDeltaCqiMin)

CQI offset value in OLLA (or Outer Loop Quality Control) called rrmDeltaCQI, ranging between olqcDeltaCqiMin & olqcDeltaCqiMax

Column added manually to show step size values

SFN	eSFN	rrmMimoCqi	rrmMimoRi	trNumCw1	trNumCw2	ackNack Cw1	ackNack Cw2	modulation Cw1	Modulation Cw2	harqNum Cw1	harqNum Cw2	mcsIndex Cw1	mcsIndex Cw2	tbsCw1 (in Bytes)	tbsCw2 (in Bytes)	numUes Cs	numUes Td	numUes Fd	total PrbAvail	numOfPrbs Alloc	rrmDeltaCqi	STEP SIZE
782	8	11.37011719	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	1	9	14	14	28	28	4	4	2	25	1	-0.489257813	0
782	9	11.37011719	2	NewTx	NewTx	NACK	NACK	16QAM	16QAM	2	10	14	14	28	28	4	4	2	25	1	-0.489257813	0
783	0	11.37011719	2	NewTx	NewTx	NACK	ACK	16QAM	16QAM	3	11	14	14	28	28	4	4	2	25	1	-0.489257813	0
783	1	11.37011719	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	4	12	13	13	717	717	4	4	1	25	25	-0.473632813	0.015625
783	2	11.37011719	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	5	13	14	14	28	28	4	4	2	25	1	-0.456054688	0.017578125
783	3	11.37011719	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	6	14	14	14	28	28	4	4	2	25	1	-0.438476563	0.017578125
783	4	11.37011719	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	7	15	14	14	28	28	4	4	2	25	1	-0.420898438	0.017578125
783	7	11.37011719	2	ReTx:1	ReTx:1	ACK	ACK	16QAM	16QAM	2	10	14	14	28	28	4	4	[illegible]	25	1	-0.587890625	-0.166992188
783	8	11.37011719	2	ReTx:1	-	ACK	DTX	16QAM		3	-	14	-	28	0	4	4	[illegible]	25	1	-0.663085938	-0.075195313
783	9	11.37011719	2	NewTx	NewTx	NACK	NACK	16QAM	16QAM	0	8	13	13	26	26	[illegible]	[illegible]	2	25	1	-0.641601563	0.021484375
784	0	11.375	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	1	9	13	13	26	[illegible]	[illegible]	[illegible]	[illegible]	25	1	-0.62109375	0.020507813
784	2	11.375	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	4	12	13	13	717	717	[illegible]	[illegible]	[illegible]	25	25	-0.584960938	0.036132813
784	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ACK	16QAM	16QAM	5	13	13	13	26	26	4	4	2	25	1	-0.584960938	0
784	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ACK	16QAM	16QAM	6	14	14	14	28	28	4	4	2	25	1	-0.584960938	0
784	[illegible]	[illegible]	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	7	15	13	13	26	26	4	4	2	25	1	-0.584960938	0
784	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ACK	16QAM	16QAM	0	8	13	13	26	26	4	4	1	25	1	-0.731445313	-0.146484375
784	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ACK	ACK	16QAM	16QAM	1	9	13	13	717	717	4	4	1	25	25	-0.7109375	0.020507813
785	2	11.375	2	NewTx	NewTx	ACK	ACK	16QAM	16QAM	2	10	14	14	28	28	4	4	2	25	1	-0.66015625	0.05078125

No OLQC updates for ReTransmissions/Acks and Retransmission /Nacks, since OLQC acts on first Tx BLER

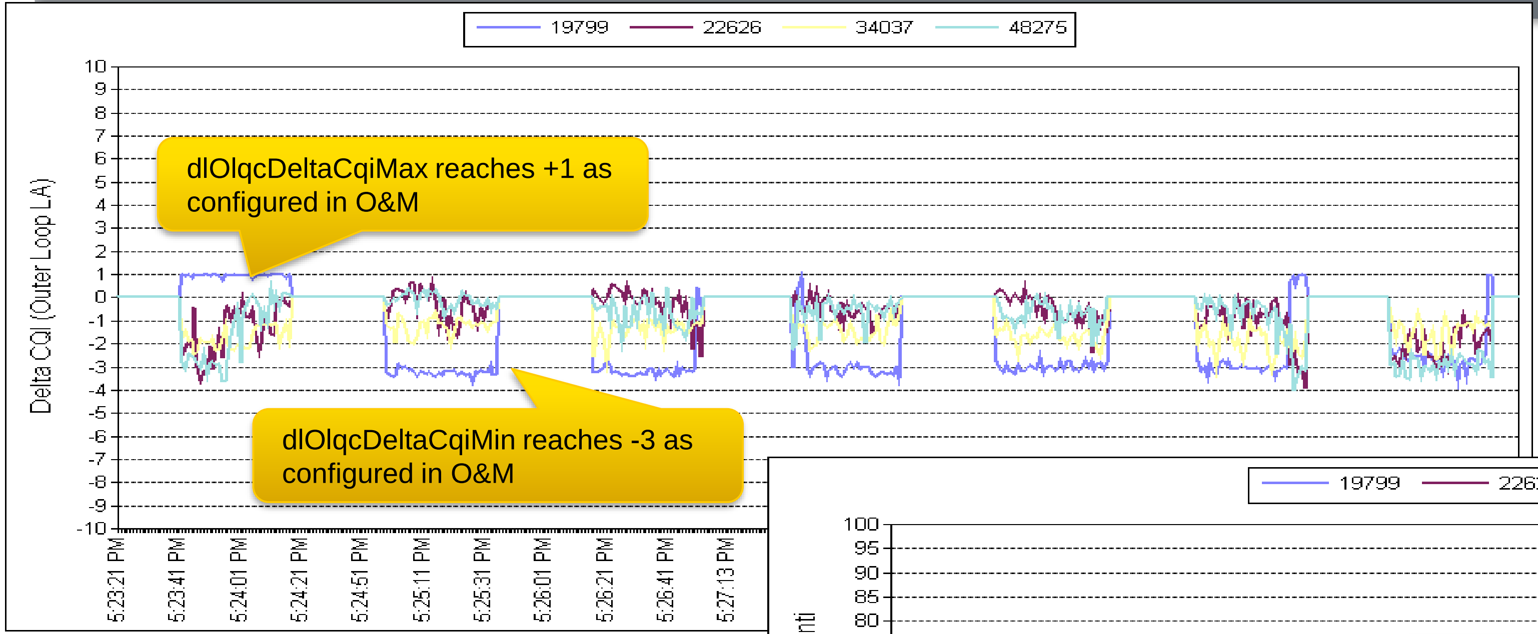
StepUp value varies and is not exactly 0.125 as configured (dlOlqcDeltaCqiStepUp) because of rrmDlOlqcSlowdownFactor.
For dual ACK or ACK+NA:
rrmDeltaCqi = min(rrmDeltaCqiprev + dlOlqcDeltaCqiStepUp/ rrmDlOlqcSlowdownFactor, dlOlqcDeltaCqiMax)

LTE MAC shall calculate OLQC slowdown factor (rrmDlOlqcSlowdownFactor) in order to slowdown OLQC update speed for frequently scheduled UE. Since the HARQ feedback is delayed by 8 TTIs a change of ΔCQI at time t will become visible in the HARQ feedback earliest at time t+8. Therefore, the step sizes CQI_{stepup} and $CQI_{stepdown}$ shall be reduced depending on the number of received HARQ feedbacks as well as the number of DL schedulings in the last 8 TTIs. The number of received HARQ feedbacks in the last 8 TTIs reflects the number of adaptations that the OLQC has done in the past and the result of those is not known in the currently considered HARQ feedback. Furthermore, the number of DL schedulings in the last 8TTIs reflects the number of coming steps that the OLQC will perform in future. Therefore, the step sizes should be downscaled in an appropriate way depending on the number of previous changes and the number of coming changes.

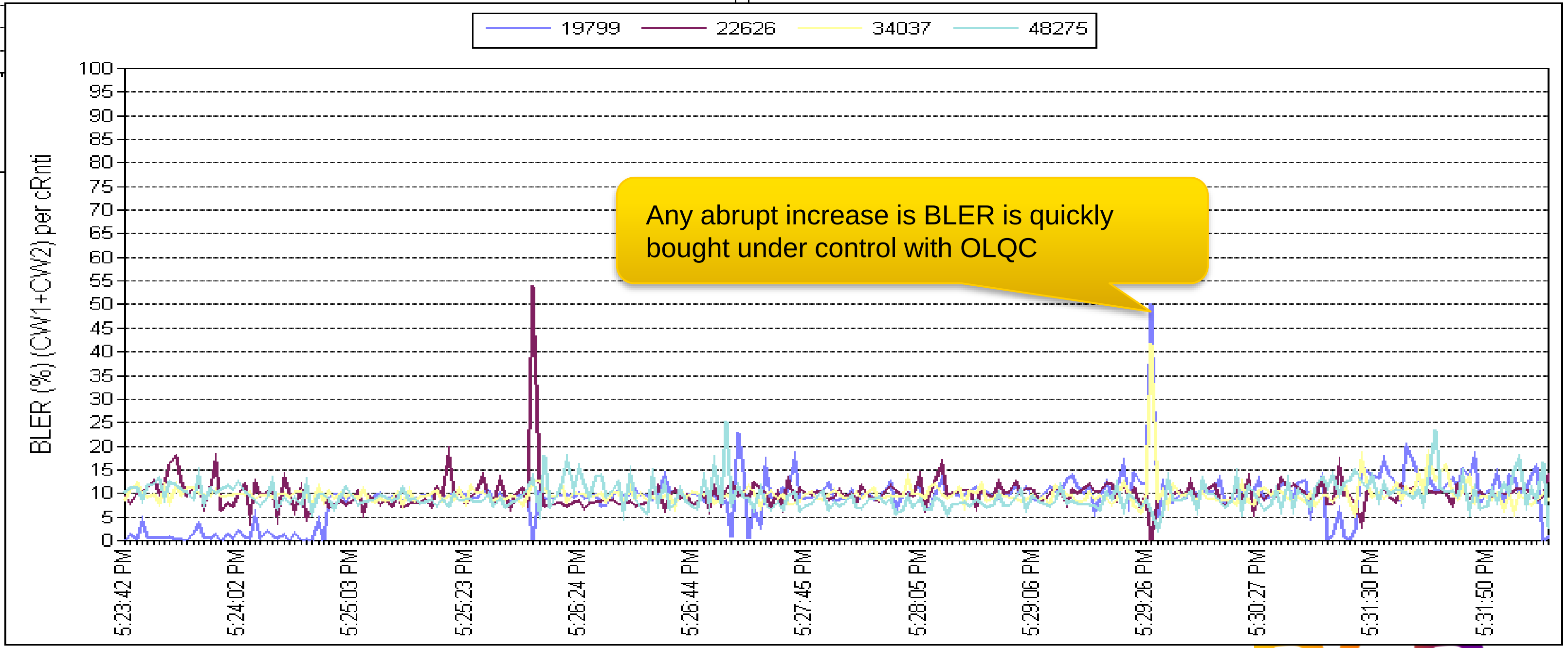
rrmDlOlqcSlowdownFactor :
IF (rrmNumOfSchedulings + rrmNumOfHarqReceived > 8),
rrmDlOlqcSlowdownFactor = max(1, rdDlOlqcSlowdownEnable * max(rrmNumOfSchedulings, rrmNumOfHarqReceived))
ELSE rrmDlOlqcSlowdownFactor = max(1, rdDlOlqcSlowdownEnable * (rrmNumOfSchedulings + rrmNumOfHarqReceived))
Where: rrmNumOfSchedulings = number of schedulings done for an UE within last 8 TTIs (HARQ feedback loop & rrmNumOfHarqReceived = number of HARQ feedbacks received for an UE within last 8 TTIs (HARQ feedback loop)

Benefits and Gains

BLER from DL Multi UE PF case



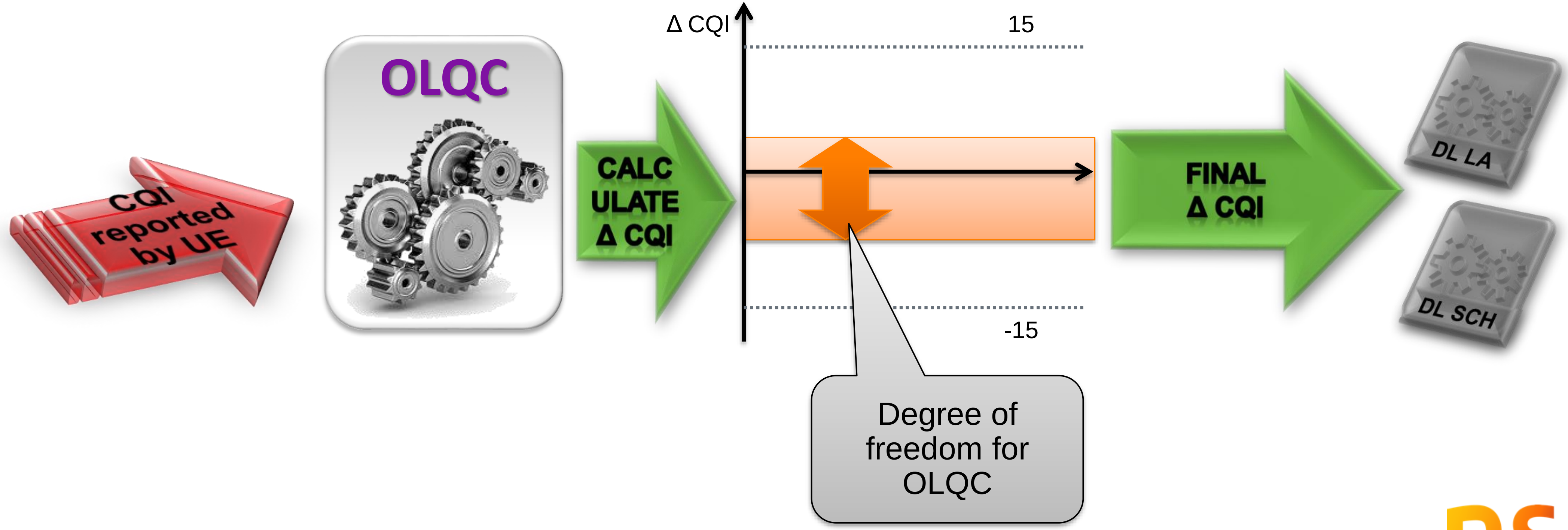
BLER is kept under the configured 10% for all UEs in the cell.



- OLQC is not relevant for link budget calculations
- Capacity figures used in RAN Dim, already consider OLQC algorithm being implemented in the system-level simulator

Energy saving aspects

- OLQC has direct impact on DL AMC performance, thus it can impact UE battery consumption as described in Downlink Link Adaptation NEI
- Low Δ CQI fluctuation reduction range can disable CQI adaptation, thus UE reported value will be used → more retransmissions due to reporting inaccuracy → higher battery consumption



- **LTE_Pwr_and_Qual_DL** family (M8010), can be used to verify CQI OLQC performance
- Histogram distribution of specific CQI usage can be drawn for every cell.
  - Without OLQC enabled – histogram variance shall be higher, and mean CQI value will be less predictive, due to more variations in the CQI reports from UE.

Abbreviated Name	Description	Comment
UE_REP_CQI_LEVEL_00 xx	• UE reported (wideband) Channel Quality Indicator CQI class **xx**	The counters inform about CQI usage histogram over the cell
CQI_OFF_MIN **CQI_OFF_MAX** **CQI_OFF_MEAN**	• Minimum/maximum CQI offset applied in link adaption process from outer loop link adaptation on the reported CQI values from UE	The counter is updated when the min/max assumed CQI in LA process is obtained from CQI reports and corrected by Outer Loop Quality Control. Mean value is also obtained – indication about average CQ offset used by Link Adaptation in a cell.

Thank you for your attention!

Network Engineering
Mobile Broadband

Downlink Link Adaptation for PDSCH

Main Menu

Downlink Link Adaptation for PDSCH

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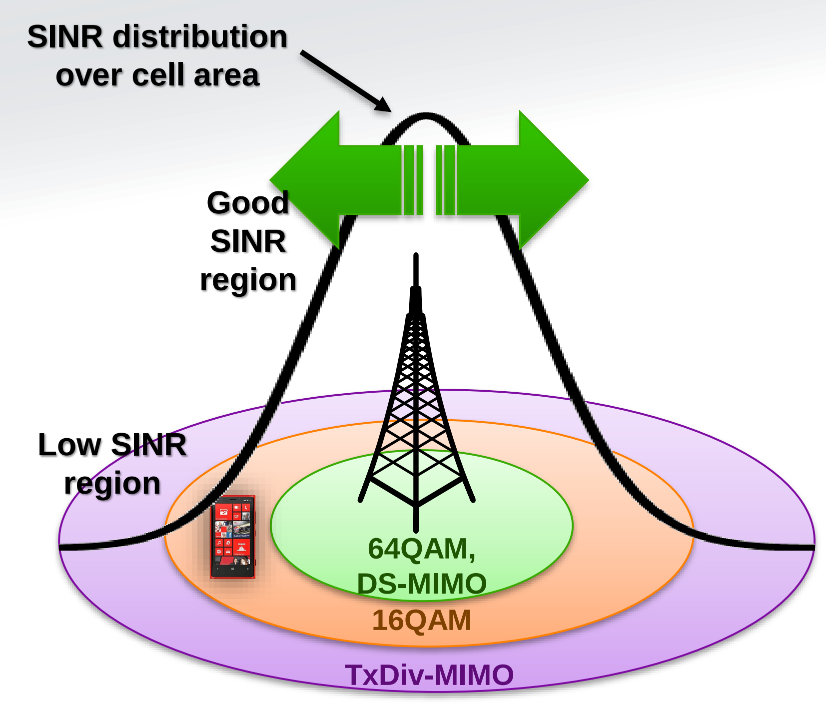
Main Menu

NEI Contact: Krzysztof Wascinski

The purpose of DL LA is to improve system capacity, peak data rate and coverage reliability by the adaptation of transmission settings to the radio channel conditions

- **DL LA determines** suitable Modulation and Coding Scheme (MCS) as well as transport block size, that shall be applied for the PRBs/RBGs assigned to a UE by the downlink scheduler, basing on the reported/corrected CQI values
- DL LA can be activated by network operator through O&M
- active by default settings
- If not active, initial MCS is used all the time

Link Adaptation concept illustration



Interdependencies

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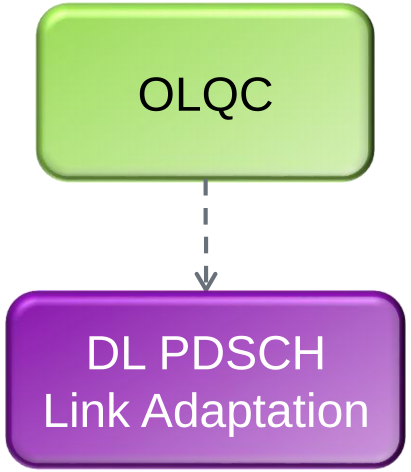
- Downlink link adaptation is basic feature and it's functionality is obligatory to achieve optimum radio performance.
- It shall be disabled only in special cases (e.g. when static MCS setting for all UEs is desired)

- One of the most important interdependencies can be drawn for OLQC feature
- Different combinations of those features configurations are described in Configuration Management section



DL LA provides transmission settings to other RRM blocks

Input

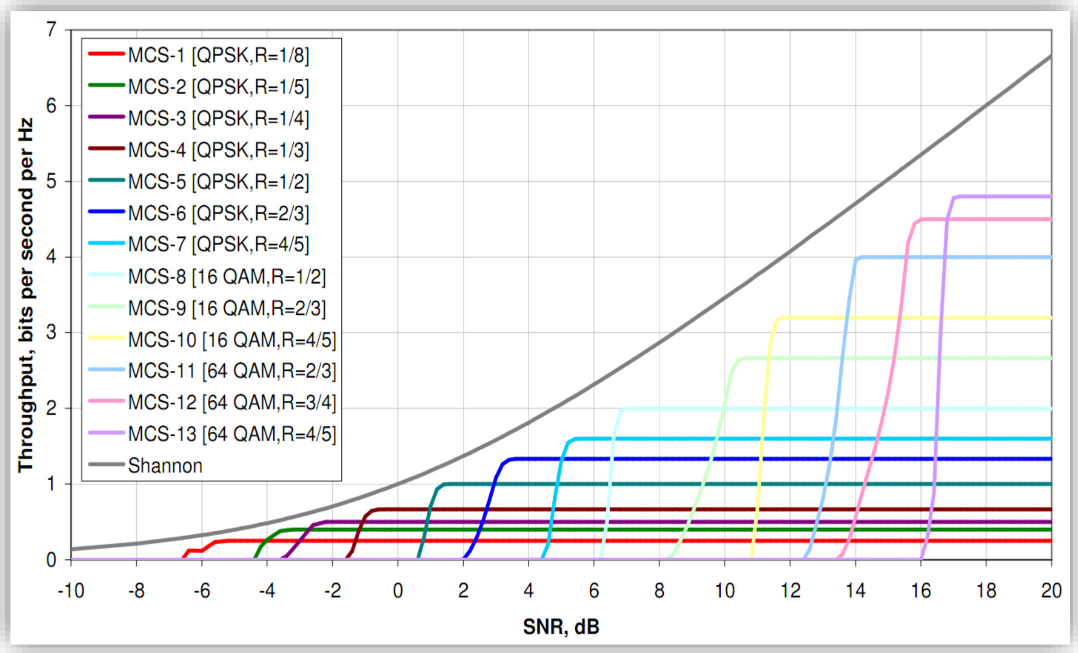
Output

per UE

- **CQI values** (from OLQC)
  - corrected wideband/frequency selective CQIs
  - If OLQC is switched off – value reported by user is used
- **Scheduling information** (from DL SCH)
  - list of PRBs/RBGs assigned to the UE
  - upper or lower downlink rate limit
- **HARQ feedback** (from DL HARQ)
  - ack/nack information
- UE capabilities (from RAC)
  - maximum allowed number of bits for single(all) DL SCH transport block(s) within a TTI according to 3GPP-36.306
- MiMo mode selection (from MiMo-MC)
  - single/double code word case
- Rank indicator (from OLQC)

- **Transmission settings (to DL SCH)**
  - modulation and coding scheme (MCS)
  - transport block size (TBS)
- Processed CQI values (to DL SCH)

- 3GPP defined set of modulation and coding schemes (MCS) is used to determine transport block size (TBS)
  - Different tables are defined for UL and DL
  - Higher modulation orders can be disabled by O&M parameters

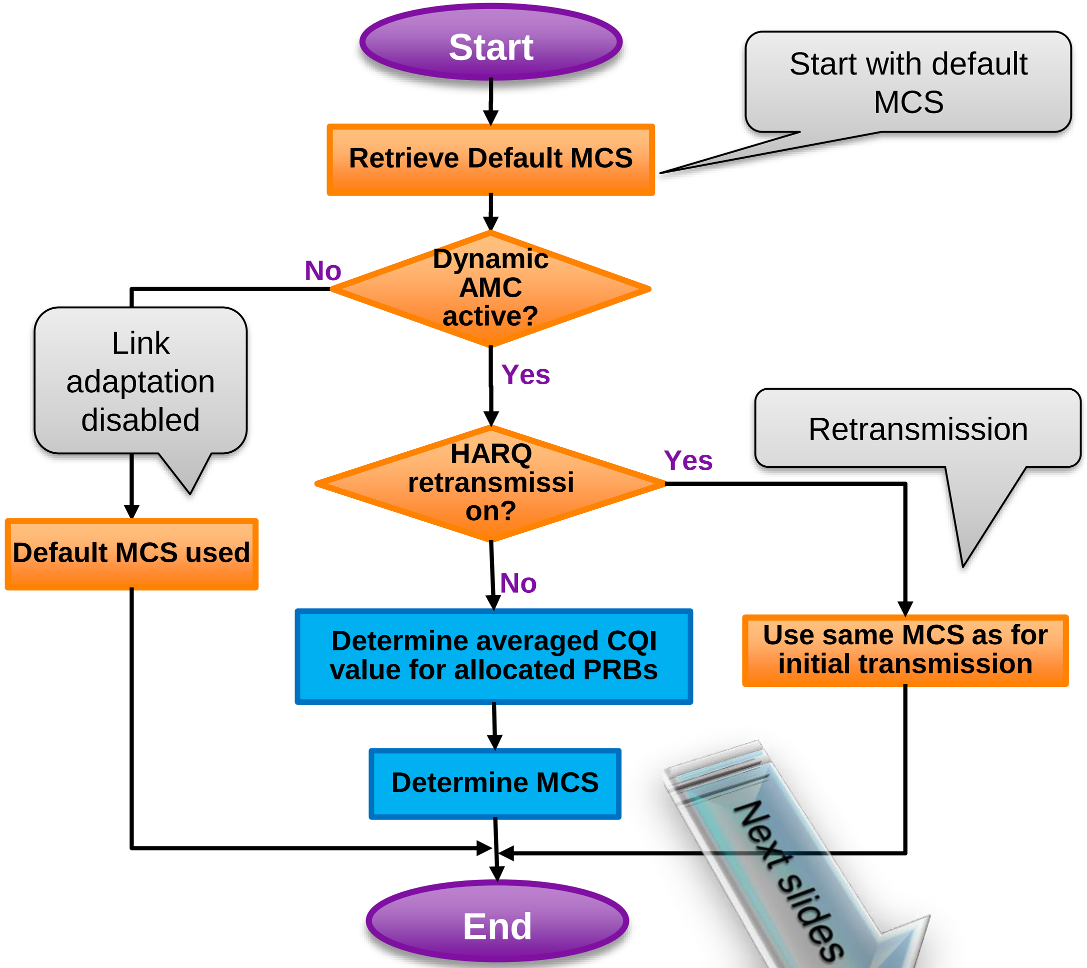


MCS Index	Modulation order	TBS index
0	2	0
1	2	1
	...	
9	2	9
10	4	9
11	4	10
	...	
15	4	14
16	4	15
17	6	15
18	6	16
19	6	17
20	6	18
	...	
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26
29	2	reserved

MODULATION AND TBS INDEX TABLE FOR PDSCH, 3GPP 36.213, TABLE 7.1.7.1-1

The degrees of freedom for the AMC consist of the modulation and coding schemes

- The DL LA algorithm responsible for selecting the MCS is called PDSCH Adaptive Modulation and Coding (AMC)
- PDSCH AMC is performed **every TTI** (1 ms)
- In case the link adaptation is disabled – default MCS is used (iniMcsDl)
- For retransmissions, the same MCS as for initial transmission is used
- Modulation order (resulting in specific code rate) is decided based on CQI (Channel Quality Indicator) reports
  - UE delivers periodic CQIs on PUCCH and aperiodic CQIs multiplexed with user data on PUSCH
- **MCS determination consists of two main steps:**
  - CQI post-processing (i.e. mapping to CIR)
  - CQI to code rate mapping
  - Determination of the MCS resulting in a code rate close to the target value



For internal use
MBB CS Network Engineering

- Average CQI can be mapped to the target code rate using a look-up table
  - If **64QAM** modulation is **not enabled** in the cell **CQI** index is limited to **9**
  - **It is up to a vendor to extend the CQI to code rate mapping table**
  - It is up to the eNB to choose the MCS which will result in a code rate similar to the target value

1 Map CQI 8 to modulation

- 16QAM

2 Determine effective coding rate

- Efficiency = 1.9141 with 16QAM (modulation order 4)
- **Code rate = 1.9141 / 4 = 0.479**

CQI-to-efficiency mapping

CQI index	Modulation	Coding Rate x 1024	Efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	[illegible]	[illegible]	0.3770
4	[illegible]	[illegible]	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	**16QAM**	**490**	**1.9141**
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

EXAMPLE FROM 3GPP 36.213, TABLE 7.2.3-1

Note:
Modulation order mapping
QPSK → 2
16QAM → 4
64QAM → 6

Note:
What is the maximum code rate?
CQI=15 → 5.5547 / 6 = **0.93**

3

Knowing ***target modulation type***, select ***possible TBS indexes*** and corresponding TB size value

- For e.g. 16 QAM = modulation order 4, and 5PRBs
  - TBS 9-15

4

Calculate ***effective coding rates***

- TBS / (#PRBs * modulation order * #PDSCH_RE_PRB)

5

Select ***TBS index*** corresponding to the transport block size for which the difference of the ***target coding rate*** (from CQI table) and the ***effective coding rate*** is minimized

- For code rate 0.479:
  the minimum difference is 0.470 ➔TBS 12

6

Finally, the ***MCS index*** corresponding to the selected ***TBS index*** should be chosen for the transmission

- TBS12 → MCS13

MCS Index	Modulation order	TBS index
	...	
7	2	7
8	2	8
9	2	9
10	4	9
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14
16	4	15
17	6	15
	...	

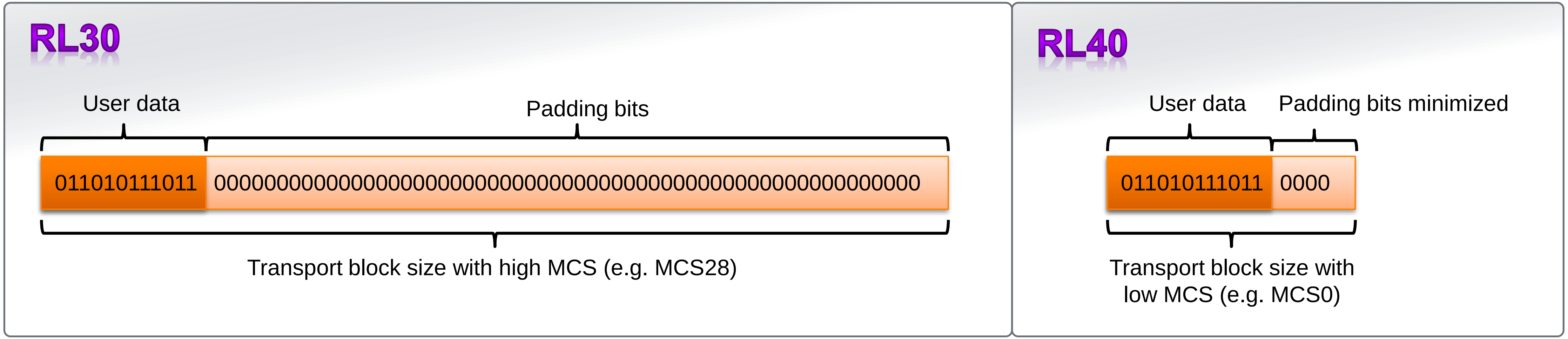
Note for step 4:

#PDSCH_RE_PRB
➔ number of PDSCH symbols per PRB. With 3 symbols for PDCCH, 2 antennas, and normal cyclic prefix **= 120**

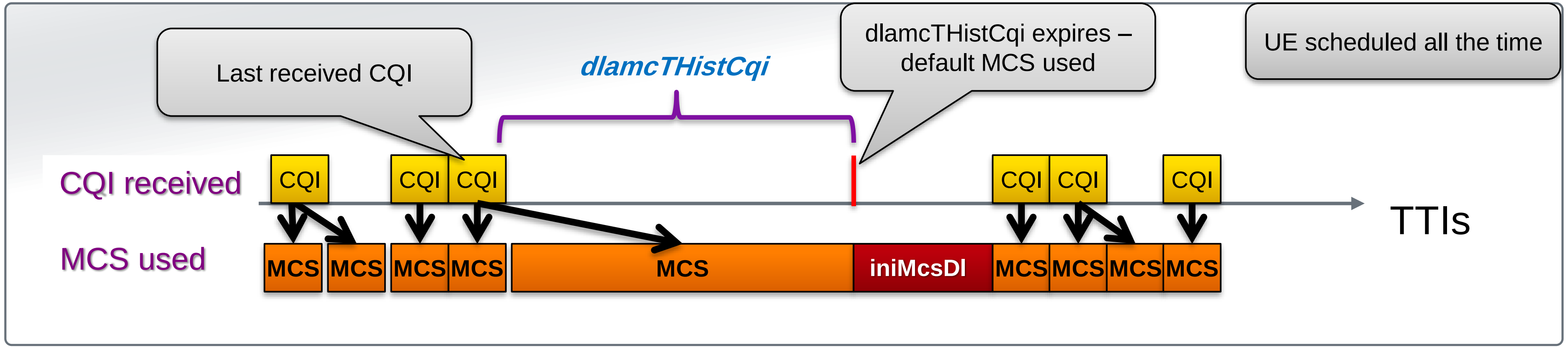
PDSCH TRANSPORT BLOCK SIZE
3GPP 36.213
TABLE 7.1.7.2.1-1 - ONE LAYER
TABLE 7.1.7.2.2-1 – TWO LAYERS

TBS index	Number of PRBs 1	2	3	4	5	6	...
...	...	...	...	...	...	...	...
8	120	[illegible]	392	536	680	808	...
9	136	0.323	[illegible]	616	776	936	...
10	144	0.363	[illegible]	680	872	1032	...
11	176	0.417	[illegible]	776	1000	1192	...
12	208	0.470	[illegible]	[illegible]	1128	1352	...
13	224	0.523	[illegible]	1000	1256	1544	...
14	256	0.590	[illegible]	1128	1416	1736	...
15	280	0.643	[illegible]	1224	1544	1800	...
16	328	[illegible]	[illegible]	1288	1608	1928	...
...	...	...	...	...	...	...	...

- RL40 introduces a change in the scheduler implementation in order to avoid too much padding in transport blocks, which directly refers to Link Adaptation algorithm
  - **MCS is downgraded until the data fits "perfectly" into the TB.**
    - In case of low data volume in DL buffers this leads to a downgrade to very low MCS‘s (even MCS 0 is possible)
  - RL30 always uses the MCS requested by link adaptation.
    - This could lead to cases where we schedule only 10 bytes in a big TB with MCS 28



- If no new CQI values are available for a UE, and the UE is scheduled nevertheless, the MCS is determined based on the latest available CQI information is not older than *dlamcTHistCqi*
- If *dlamcTHistCqi* is already exceeded (or CQI values are not yet available) the ***initial MCS*** shall be applied.



Abbreviated Name	Description	Range/ Step	Default Value
iniMcsDl	Initial modulation and coding scheme	0..28, step: 1	4
dlamcTHistCqi	Timer for the lifetime of historical CQI	0..1000, step: 1, unit: ms	1000

- DL AMC delivers processed CQI values to DL scheduler with PRB/RBG granularity
- Triggered by new CQI reporting received from OLQC

Input

- Wideband CQI per code word
- Frequency selective CQIs per code word

Output

- CQI values for PRBs/RBGs for which no CQI reporting has been received

- Assumption:
  – if only wideband CQI is available, no CQI processing is necessary
  – otherwise, proceed with CQI processing in order to map CQI values to PRBs/RBGs for which no frequency selective CQIs have been reported

- Algorithm:
  1. Map wideband and frequency selective CQIs to CIR values

$$\overline{CQI_i(x,t)} \quad CQI_i(x, f_{rep}, t) \Rightarrow \overline{CIR_i(x,t)} \quad CIR_i(x, f_{rep}, t)$$

  2. Calculate CIR for remaining PRB/RBG:

$$CIR(x, f_{no\_rep}, t) = \frac{N * \overline{CIR(x,t)} - \sum_{f_{rep}} CIR(x, f_{rep}, t)}{N - N_{rep}}$$

where:

N - total number of frequencies (i.e. PRBs or RBGs/sub-bands, subject to configuration)

Nrep - total number of available frequency-selective CQI reports

fno_rep - frequencies for which no frequency-selective CQI report is available

  3. Map this CIR to CQI
  4. Provide DL-Scheduler with originally UE delivered frequency selective CQIs and recently calculated CQIs for remaining frequencies

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
dlamcEnable	Enabling/disabling dynamic DL link adapatation	Boolean (true, false)	true	It is highly recommended to enable link adaptation, otherwise **iniMcsDl** Is used all the time
iniMcsDl	Initial modulation and coding scheme	0..28, step: 1	4	•In case if DL AMC is disabled – this is the only MCS used in the cell. Otherwise, the value reflecting the minimum MCS shall be set •iniMcsDl is applicable only if both, dlOlqcEnable and dlamcEnable are set to 'false'.
dlamcTHistCqi	Timer for the lifetime of historical CQI	0..1000, step: 1, unit: ms	1000	•**Low value (1-250)** ➔ not recommended, MCS will be quickly reset to **iniMcsDl** •**Medium value (250-750)** ➔ Shall be adjusted accordingly to environment: •Lower value → quickly changing conditions, high UE speed, low fading dominating •Higher value → Low UE mobility, high fast fading •**High (750-1000)** ➔ timer impact on historical CQI is practically disabled

Configuration Management

Main Menu

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
enableDl16Qam	Parameter controls if DL-AMC is allowed to select 16QAM modulation for PDSCH.	enable / disable	enable	•Must be **true** if **dl64QamEnable**=false •If set to **false, iniMcsDl** can be set to 9 at maximum •Enabling this parameter is required to achieve high cell throughput •Should be disabled only in special cases
dl64QamEnable	Parameter controls if DL-AMC is allowed to select 64QAM modulation for PDSCH.	enable / disable	enable	•Must be **false** if **enableDl16Qam**=false •**enableDl16Qam** must be set to true if this parameter is set to **true** •If set to **false, iniMcsDl** can be set to 16 at maximum •Enabling this parameter is required to achieve high cell throughput •Should be disabled only in special cases
cqiCompSmRi1Ol	CQI compensation value for UE reported RI=1 while MIMO mode setting is 2.	-10..0 step: 0.1 unit: CQI step	-3.0	-
cqiCompTdRi2Ol	CQI compensation value for UE reported RI=2 while MIMO mode setting is 1.	0..10 step: 0.1 unit: CQI step	3.0	-

Main Menu

dlamcEnable =TRUE
dlOlqcEnable =TRUE

"Regular" link adpatation with activated inner loop component for the mapping from corrected CQI to transport format and with activated outer loop component for control of BLER target on 1st transmission via CQI offset being added to reported CQI (reported CQI + CQI offset corresponds to corrected CQI).

dlamcEnable = TRUE
dlOlqcEnable = FALSE

Pure inner loop component based link adaptation. Reported CQI is mapped directly to the transport format, the BLER on 1st transmission is not controlled.

AMC fully relies on UE CQI reports

dlamcEnable = FALSE
dlOlqcEnable = TRUE

Pure outer loop component based link adaptation (BLER on 1st transmission controlled). CQI offset is added to the O&M configurable inital MCS; the results is then mapped into a transport format

dlamcEnable = FALSE
dlOlqcEnable = FALSE

Fixed O&M configurable value for initial MCS is used for the mapping into a transport format.

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Deployment Aspects

DL AMC in TTI Trace

DL AMC receives from OLQC the following:

1. CQI reports (corrected according to OLQC settings)
2. RI values (MIMO compensation added only if reported RI mismatches the current MIMOModeSetting based on OAM parameters OlMimoCqiCompRiTxD and OlMimoCqiCompRiSM

UE selected sub-band Aperiodic CQI reports are the preferred choice. Periodic reports also have sub-band reports.

SFN	eSFN	cRnti	mimoMode	rrmMimoCqi	rrmMimoRi	trNumCW1	trNumCW2	ackNack Cw1	ackNack Cw2	modulation CW1	Modulation CW2	harqNum Cw1	harqNum Cw2	mcsIndex Cw1	mcsIndex Cw2	tbsCw1 (in Bytes)	tbsCw2 (in Bytes)	numOfPrbs Alloc	wbCqi Cw1	SbCqi Cw1Rbg1
1016	9	59789	TX div	6.193359375	1.000976563	NewTx	-	ACK	DTX	16QAM		6	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	0	59789	TX div	6.193359375	1.000976563	NewTx	-	ACK	DTX	16QAM		4	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	1	59789	TX div	6.193359375	1.000976563	NewTx	-	ACK	DTX	16QAM		3	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	2	59789	TX div	6.235351563	1.000976563	NewTx	-	ACK	DTX	16QAM		5	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	3	59789	TX div	6.235351563	1.000976563	NewTx	-	ACK	DTX	16QAM		2	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	4	59789	TX div	[illegible]	1.000976563	NewTx	-	ACK	DTX	16QAM		7	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	5	59789	TX div	6.284179688	1.000976563	NewTx	-	ACK	DTX	16QAM		1	-	12	-	1239	0	50	9	8;8;8;8;8;8;9;9;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	6	59789	TX div	6.284179688	1.000976563	NewTx	-	ACK	DTX	16QAM		0	-	12	-	1239	0	50	9	8;8;8;8;8;8;9;9;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	7	59789	TX div	[illegible]	1.000976563	NewTx	-	ACK	DTX	16QAM		6	-	12	-	1239	0	50	9	8;8;8;8;8;8;9;9;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	8	59789	TX div	6.334960938	1.000976563	NewTx	-	ACK	DTX	16QAM		4	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1017	9	59789	TX div	6.334960938	1.000976563	NewTx	-	ACK	DTX	16QAM		3	-	12	-	1239	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1018	0	59789	TX div	6.334960938	1.000976563	NewTx	-	ACK	DTX	16QAM		5	-	13	-	1431	0	50	9	8;8;8;8;8;8;8;8;12;12;12;12;12;9;0;0;0;0;0;0;0
1018	1	59789	TX div	[illegible]	[illegible]	NewTx	-	ACK	DTX	16QAM		2	-	12	-	1239	0	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	2	59789	TX div	7.387695313	1.500976563	NewTx	-	ACK	DTX	16QAM		7	-	12	-	1239	0	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	3	59789	TX div	[illegible]	1.500976563	NewTx	-	ACK	DTX	16QAM		1	-	12	-	1239	0	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	4	59789	TX div	[illegible]	[illegible]	NewTx	-	ACK	DTX	16QAM		0	-	12	-	1239	0	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	5	59789	TX div	7.940429688	1.750976563	NewTx	-	ACK	DTX	16QAM		6	-	12	-	967	0	38	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NACK	NACK	16QAM	16QAM	4	12	16	16	1908	1908	50	9	0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0
1018	7	59789	2x2 Mimo	8.639648438	1.875976563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	3	11	6	6	645	645	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	8	59789	2x2 Mimo	8.639648438	1.875976563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	5	13	5	5	549	549	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1018	9	59789	2x2 Mimo	8.639648438	1.875976563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	2	10	6	6	645	645	50	8	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	0	59789	2x2 Mimo	[illegible]	[illegible]	NewTx	NewTx	ACK	ACK	QPSK	QPSK	7	15	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	1	59789	2x2 Mimo	8.120117188	1.938476563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	1	9	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	2	59789	2x2 Mimo	8.120117188	1.938476563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	0	8	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	3	59789	2x2 Mimo	7.88671875	1.969726563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	6	14	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	4	59789	2x2 Mimo	7.88671875	1.969726563	ReTx: 1	ReTx: 1	ACK	ACK	16QAM	16QAM	4	12	16	16	1908	1908	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	5	59789	2x2 Mimo	7.88671875	1.969726563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	3	11	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	6	59789	2x2 Mimo	7.717773438	1.985351563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	5	13	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	7	59789	2x2 Mimo	7.717773438	1.985351563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	2	10	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	8	59789	2x2 Mimo	7.717773438	1.985351563	NewTx	NewTx	ACK	ACK	QPSK	QPSK	7	15	6	6	645	645	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1019	9	59789	2x2 Mimo	7.665039063	1.993164063	NewTx	NewTx	ACK	ACK	QPSK	QPSK	1	9	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	0	59789	2x2 Mimo	7.665039063	1.993164063	NewTx	NewTx	ACK	ACK	QPSK	QPSK	0	8	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	1	59789	2x2 Mimo	7.665039063	1.993164063	NewTx	NewTx	ACK	ACK	QPSK	QPSK	6	14	6	6	645	645	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	2	59789	2x2 Mimo	7.659179688	1.997070313	NewTx	NewTx	ACK	ACK	QPSK	QPSK	4	12	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	3	59789	2x2 Mimo	7.659179688	1.997070313	NewTx	NewTx	ACK	ACK	QPSK	QPSK	3	11	6	6	645	645	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	4	59789	2x2 Mimo	[illegible]	[illegible]	NewTx	NewTx	ACK	ACK	QPSK	QPSK	5	13	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	5	59789	2x2 Mimo	[illegible]	[illegible]	NewTx	NewTx	ACK	ACK	QPSK	QPSK	2	10	6	6	501	501	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	6	59789	2x2 Mimo	[illegible]	2	NewTx	NewTx	ACK	ACK	QPSK	QPSK	7	15	5	5	549	549	50	7	0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0
1020	7	59789	2x2 Mimo	7.682617188	2	NewTx	NewTx	ACK	ACK	QPSK	QPSK	1	9	6	6	645	645	50	7	0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0;0
1020	8	59789	2x2 Mimo	7.721679688	2	NewTx	NewTx	ACK	ACK	QPSK	QPSK	0	8	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1020	9	59789	2x2 Mimo	[illegible]	[illegible]	NewTx	NewTx	ACK	ACK	QPSK	QPSK	6	14	6	6	645	645	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1021	0	59789	2x2 Mimo	7.721679688	2	NewTx	NewTx	ACK	ACK	QPSK	QPSK	4	12	5	5	549	549	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1021	1	59789	2x2 Mimo	[illegible]	[illegible]	NewTx	NewTx	ACK	ACK	QPSK	QPSK	3	11	6	6	645	645	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0
1021	2	59789	2x2 Mimo	7.767578125	2	NewTx	NewTx	ACK	ACK	QPSK	QPSK	5	13	6	6	645	645	50	7	7;7;7;7;7;7;7;7;7;7;7;7;7;7;7;0;0;0;0;0;0;0

Filtered WBCQI value

- rrmMimoCqi is initialized to mimoOlCqiThD
- newCqi = CQI + rrmDeltaCqi //OLLA compensation value is added
- newCqi = newCqi + mimoOlCqiComp //WB CQI values related to SM is compensated to correspond to TX Diversity
- rrmMimoCqi = (1-mimoOlCqiAvg)*rrmMimoCqi + mimoOlCqiAvg*newCqi //Filter updated when WB CQI value is received
- rrmMimoCqi = max (mimoOlCqiThD, rdMimoCqiAgeing ^ rounddown(delta_t/10) * rrmMimoCqi) //Filter updated when WB Cqi value is missing and rrmMimoCqi > mimoOlCqiThD
- delta_t indicates time in subframes from latest updated of filter and rdMimoCqiAgeing is internal R&D parameter

MCS is chosen per CW, mapped to chosen transport block and coding rate

Retransmission uses same MCS as Initial transmission

Filtered RI value

- rrmMimoRi is initialized to mimoOlRiThD
- rrmMimoRi = (1-mimoOlRiAvg)*rrmMimoRi + mimoOlRiAvg*RI //Filter updated when WB CQI value is received
- rrmMimoRi = max (mimoOlRiThD, rdMimoRiAgeing ^ rounddown(delta_t/10) * rrmMimoRi) //Filter updated when RI value is missing and rrmMimoRi > mimoOlRiThD

If only WB CQI is available, the corresponding MCS level can be mapped directly without CQI averaging

If no new CQI values were received for a scheduled UE, the MCS shall be determined from the latest available CQI information not older than T_HIST_MCS_DL; if T_HIST_MCS_DL is already exceeded, the initial MCS (determined by INI-MCS_DL) shall be applied.

Deployment Aspects

DL Fast AMC graphs

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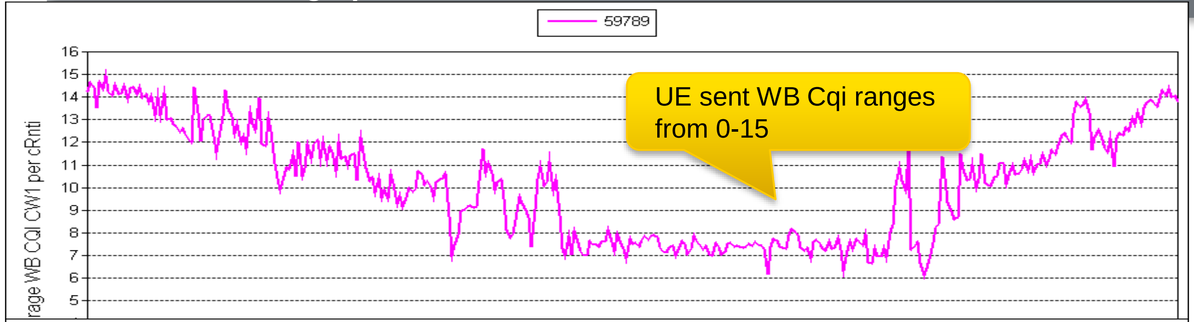
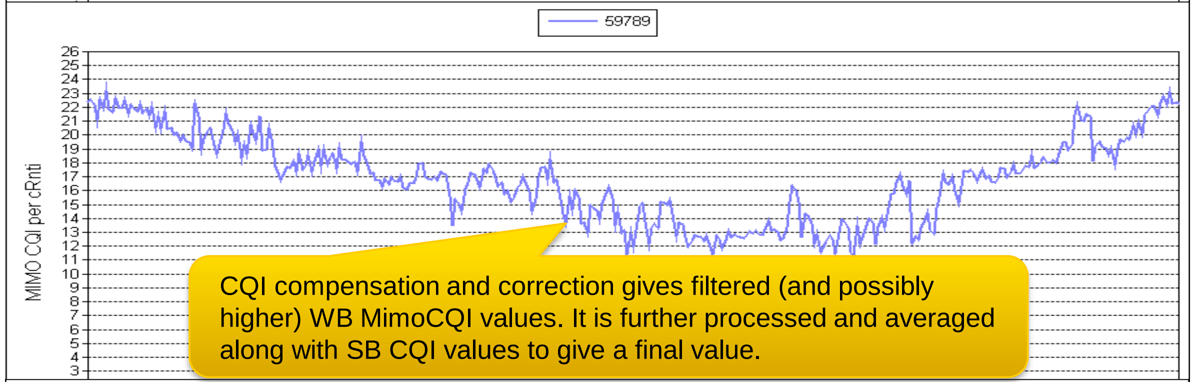
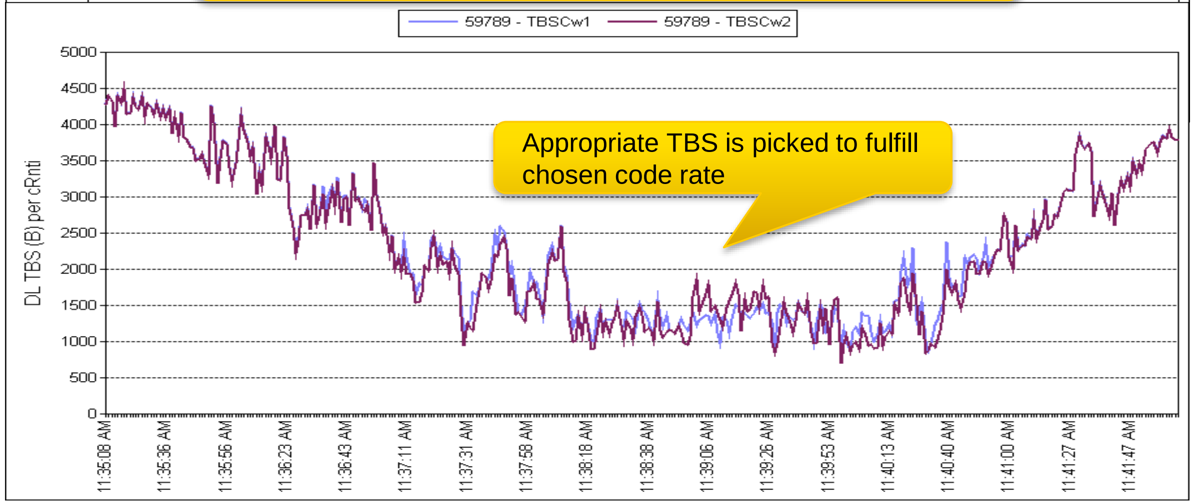
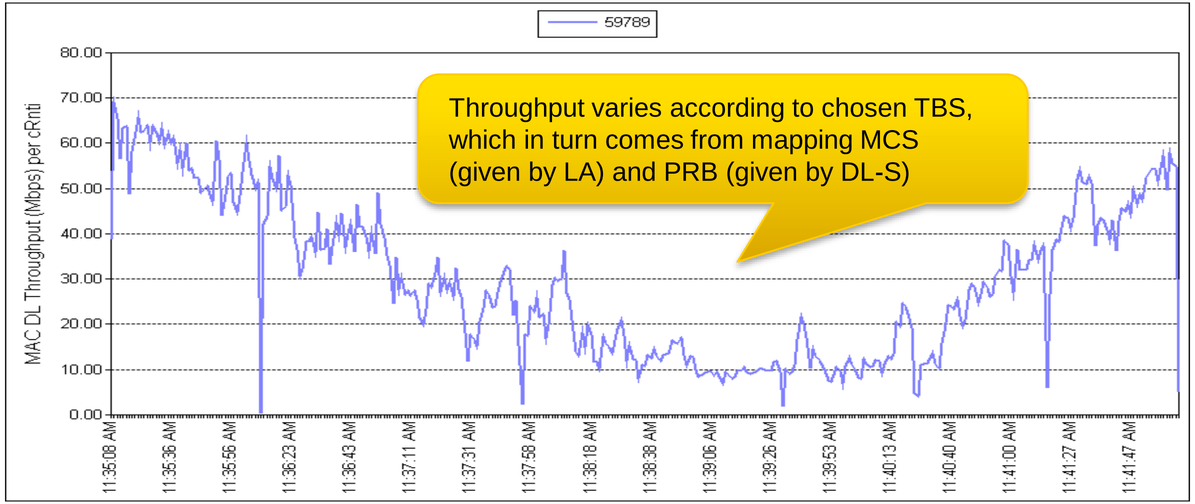
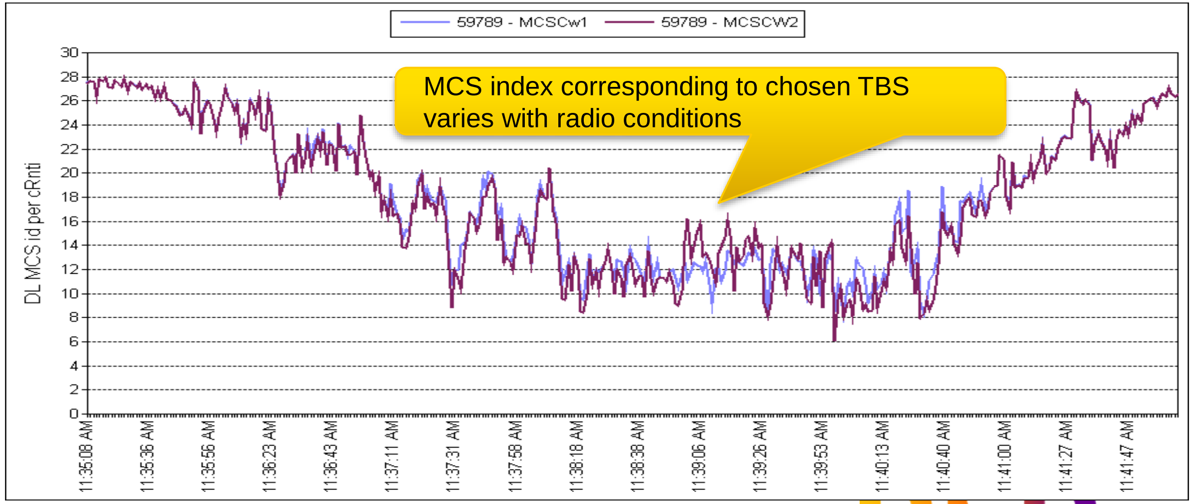










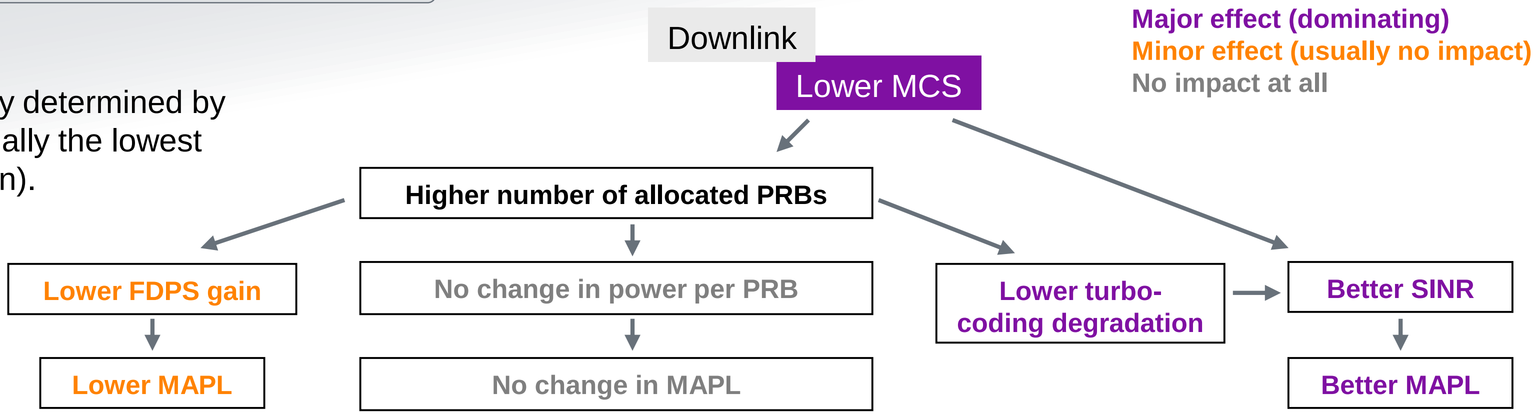
- RAN Dim supports link budget calculation for either manual or optimized MCS setting for given throughput requirement

	User Defined	Optimize
Method for modulation and coding scheme	User Defined	Optimize
Modulation and coding scheme (Optimized)	-	5_QPSK
Modulation and coding scheme (User defined)	1_QPSK	-

- Capacity figures used in the tool, were obtained in the product aligned system level simulator with full DL-AMC implementation

DL basic effects impacting MAPL

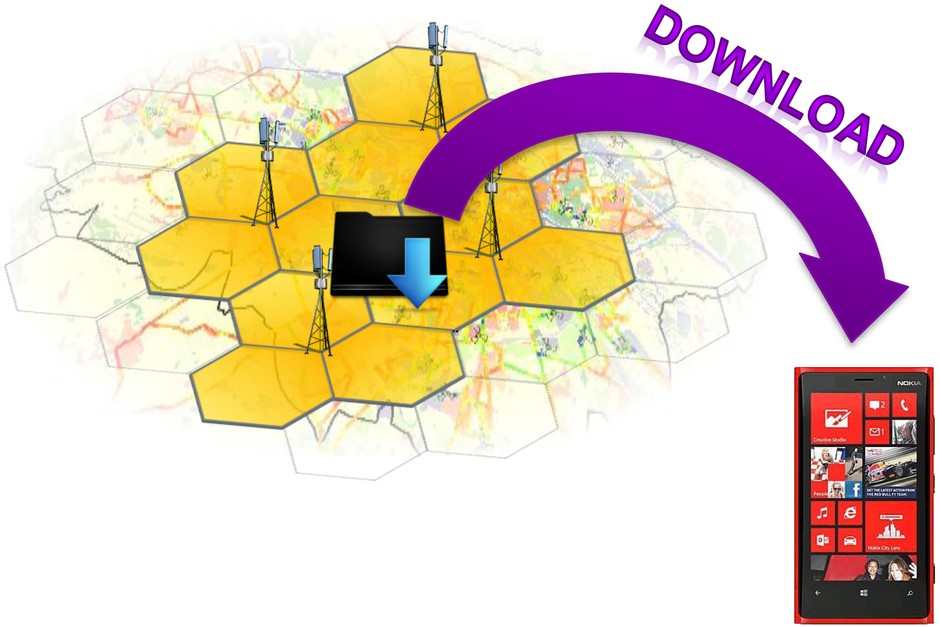
MCS selection is mainly determined by the required SINR (usually the lowest possible MCS is chosen).



Energy saving aspects

Base station capacity, site count

- LTE Link Budget is limited by uplink in most of the cases, therefore DL AMC settings manipulation will not change site count number resulting from link budget calculation
- Preventing the using high MCSs, may lead to higher UE battery consumption



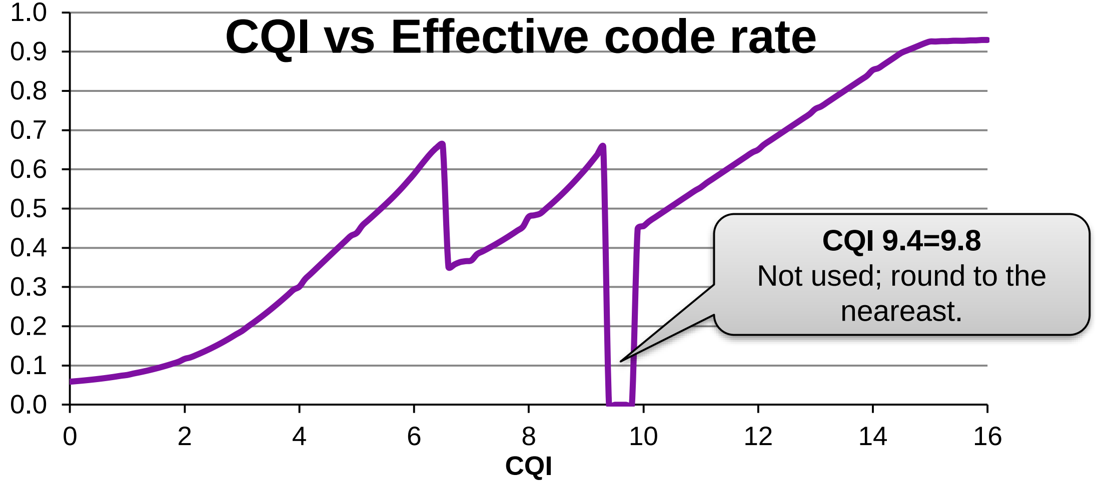
- LTE cell load measurements family (M8001) and cell throughput (M8012), can be used to verify DL-AMC performance
- With such counters, histogram distribution of usage per every MCS can be drawn for every cell (next slide)

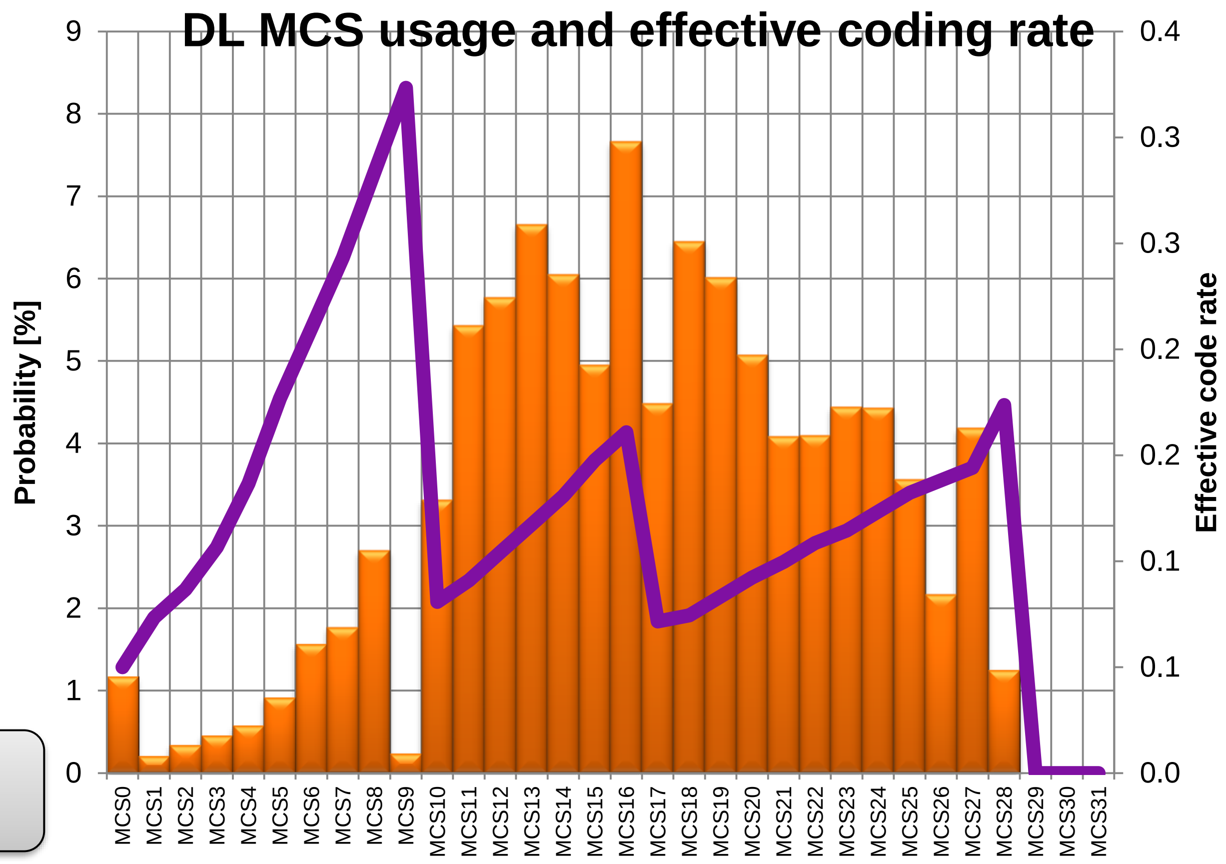
Abbreviated Name	Description	Comment
PDSCH_TRANS_USING_MCSxx	• The number of transmissions on PDSCH over the measurement period using MCSxx	The counter is updated when MCSxx is used for transmission. SIB, Paging and RA response excluded.
PDSCH_TRANS_NACK_MCSxx	• The number of unacknowledged transmissions on PDSCH using MCSxx	This counter will be incremented 4 times before TB_BAD_PDSCH_MCSxx will be increased
TB_BAD_PDSCH_MCSxx	• number of unsuccessful transmissions on PDSCH using MCSxx • Only not transmitted TBs exceeding max HARQ retransmissions are considered.	This counter is updated when the maximum number of HARQ retransmissions has been exceeded for the TB.
TB_VOL_PDSCH_MCSxx	• volume (kbytes) of MAC PDUs on PDSCH transferred by using MCSxx • The volume of MAC PDUs is considered.	This counter is updated when MAC PDU is scheduled. Retransmissions are included.
TB_BUNDyy_NACK_PDSCH_MCSxx	• The number of negative acknowledged transmissions with bundle size yy using MCSxx on PDSCH.	The counter is updated in each TTI scheduling period when bundle NACK received on PDSCH using bundle size yy from MCSxx

Performance Aspects

DL AMC – performance counters

- MCS usage from exemplary customer network shows that MCS11-MCS20 are used the most
- MCS9 is used rarely, because CQI's reported within its range (~9) are mapped to MCS10





Effective coding rate (code rate / modulation order) plotted for 3 PDCCH symbols and 5 PRBs

Thank you for your attention!

Network Engineering
Mobile Broadband

LTE1034 - Extended Uplink Link Adaptation

Main Menu

LTE1034 - Extended Uplink Link Adaptation

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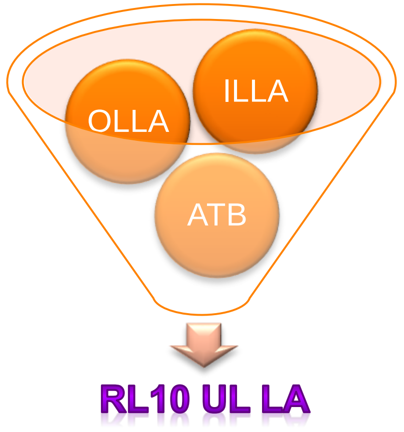
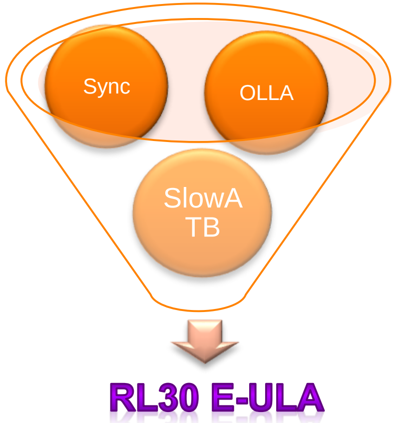
Main Menu

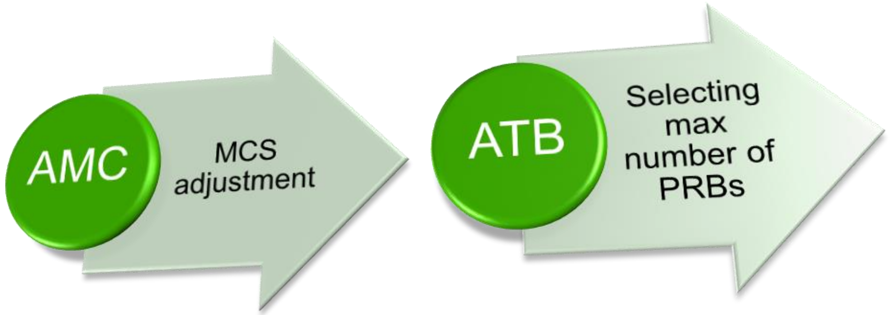
NEI Contact: Krzysztof Wascinski

Uplink Link Adaptation consist of AMC and ATB

- UL Adaptive Modulation and Coding (UL AMC) which ***selects appropriate MCS*** for UL transmission taking actual transmission reliability (BLER). UL-AMC is split into:
  - **Inner Loop Link Adaptation (ILLA) – slow periodic AMC**
    - Periodic ACK/NACK information is used for calculating BLER (Block Error Rate) after 1st transmission or *n*th retransmission
  - **Outer Loop Link Adaptation (OLLA) – event-triggered aperiodic AMC**
    - Periodic ACK/NACK information is used for calculating BLER after 1st transmission of a Transport Block in order to derive a compensation factor
- Adaptive Transmission Bandwidth (ATB)
  - responsible for ***defining maximum number of PRBs*** that can be assigned to a particular UE by UL SCH
  - At call setup, starts with default initial number of PRBs defined by O&M parameter ***iniPrbsUl***







New Uplink Link Adaptation concept has been introduced in RL30

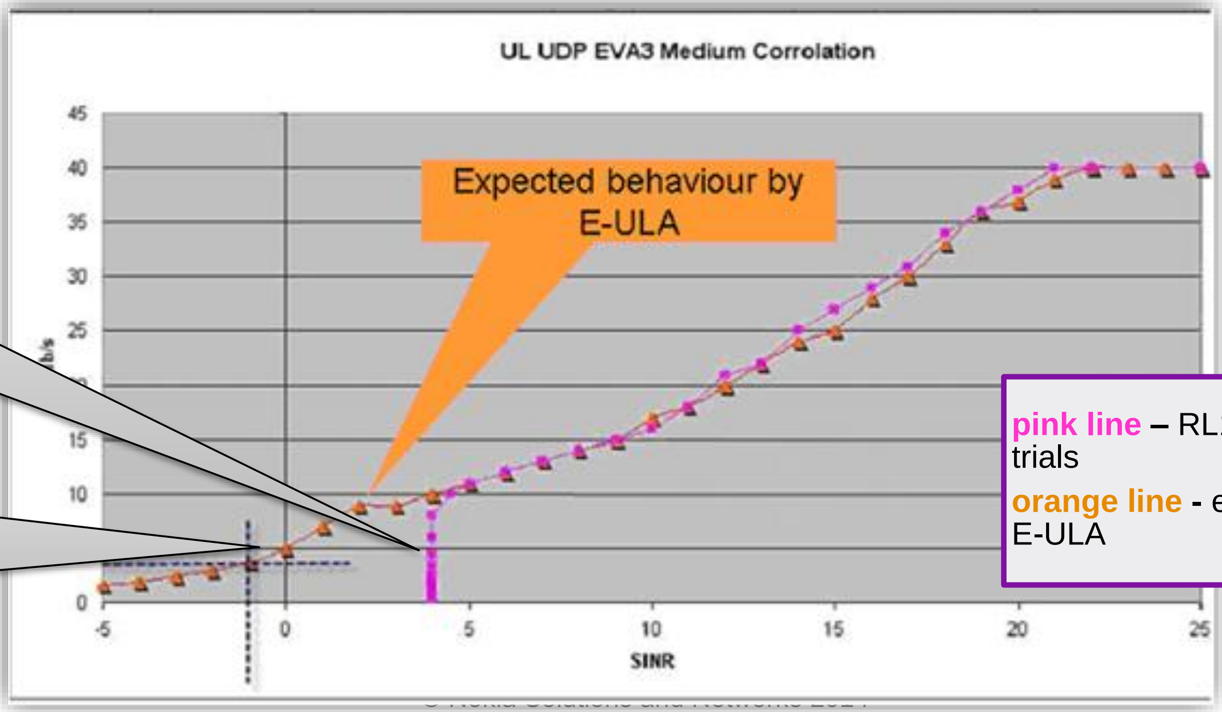
RL10 UL LA	RL30 E-ULA
• OLLA	• OLLA • Remains unchanged
• ILLA	• ILLA • Not used when E-ULA is active
• SlowATB PHR based	• NewATB PHR and BLER based algorithm
	• OLLA and ATB synchronization algorithm

E-ULA copes better with extreme UL power control settings

- **SlowATB algorithm, PHR-only based**, acting independently from the other two algorithms (Slow AMC and OLLA) in certain condition **react too fast reducing drastically the BW** allocated to a UE not allowing taking advantage of the full range MCS adaptation.
  - The bigger the path-loss is the more number of PRBs is reduced and the higher the MCS level is selected.
- **A new Uplink LA concept** has been then developed and investigated following Shannon's principle in order to **better cope with these extreme settings** in power control.

SlowATB is affecting drastically the UE throughput
The pink line shows ATB drastically reducing the number of PRBs allocated to UE

E-ULA maximizes UE throughput
The orange line shows E-ULA maintains the maximum number of PRBs, optimally syhcronized with MCS setting



pink line – RL10 behaviour noticed in trials
orange line - expected behaviour by E-ULA

nsn

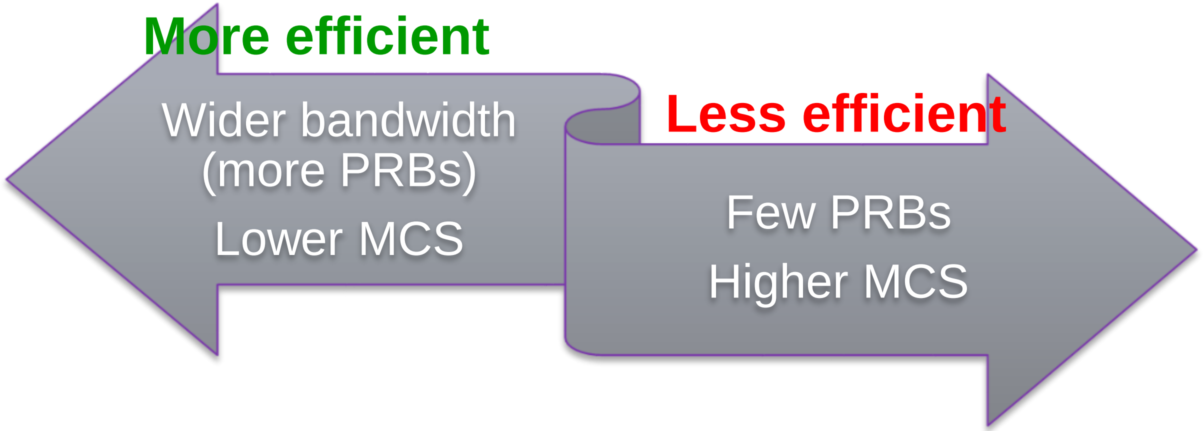
Introduction

Extended Uplink Link Adaptation motivation 2/3

It is more efficient to distribute the power over a wider bandwidth (more PRBs) using lower MCS

- **If a UE is power limited** (corresponding to bad RF conditions)
- This fact is due to **Shannon‘s formula for the channel capacity** of a bandwidth and power limited channel.

$$C = B_w \log_2\left(1 + \frac{S}{N}\right)$$

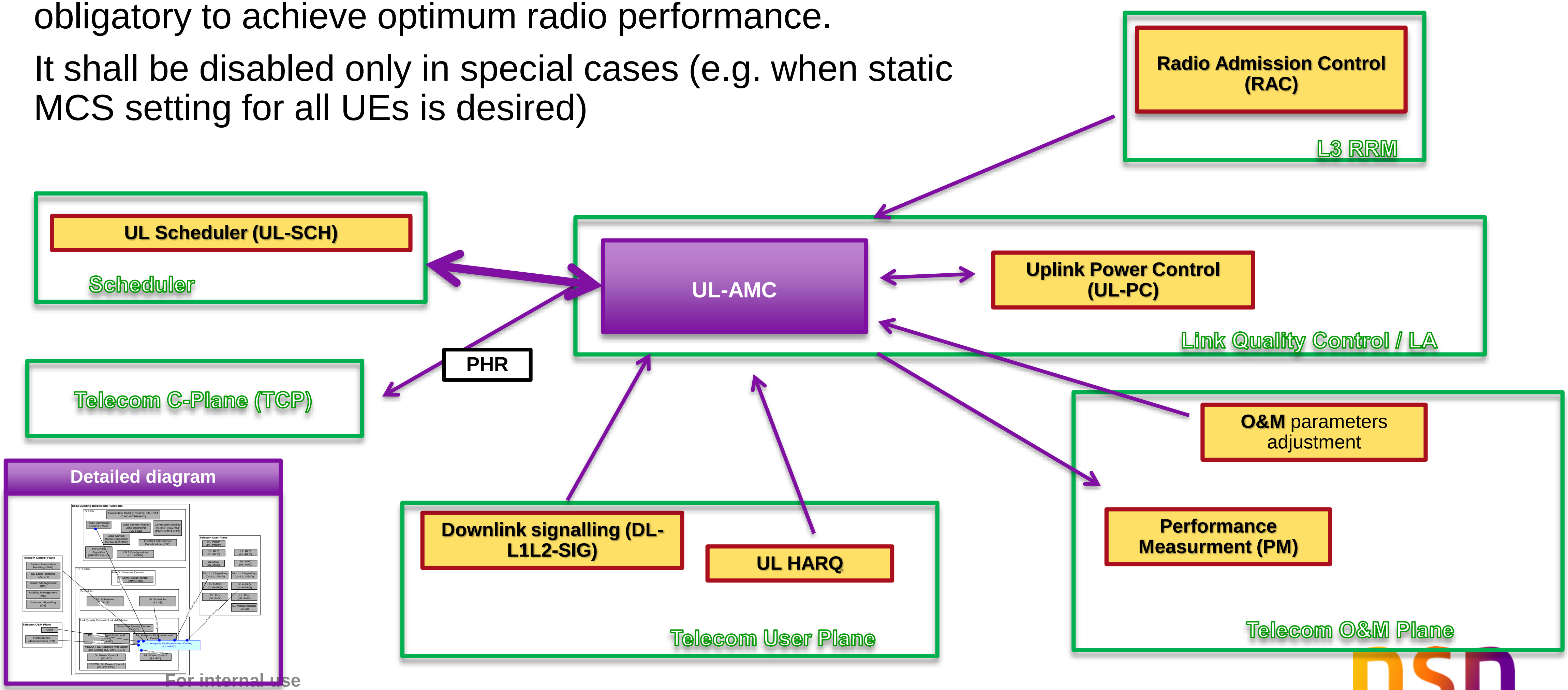


Summary

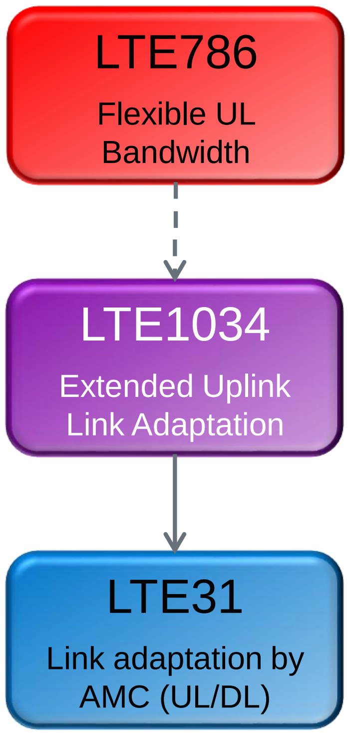
- It introduces a **coordination between SlowATB-Algorithm and OLLA**
- SlowATB algorithm becomes BLER based even if PHR is still used in the algorithm.
- **It Improves performances in case of high P0 settings** (which are required to transmit peak data rates) retarding the reduction of the maximum number of allocable PRBs and improving consequently throughput performances (especially when under very low load condition in the cell).
- It introduces **a more power efficient strategy** trying, when possible, to transmit with a bigger number of PRBs and lower MCS level according to the required data rate, this is especially advantageous with power limitations.

- The new **E-ULA** method **assumes that in bad RF** conditions (corresponding to power limitations, e.g. at cell edge or with too high P0 and alpha settings) **the SINR is limited**

- Uplink link adaptation is basic feature and it's functionality is obligatory to achieve optimum radio performance.
- It shall be disabled only in special cases (e.g. when static MCS setting for all UEs is desired)



- Basic LTE AMC functionality is affected by LTE1034 in term of change of parameterization for feature activation.
- Additionally Flexible UL Bandiwdth (LTE786), can limit LTE1034 performance.



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Main Menu

E-ULA provides transmission settings to other RRM blocks

Measurments:
BLER, PHR

Input

Output

per UE

- For outer loop link adaptation (OLLA):
  - ACK/NACK information (from UL HARQ Process)
    - only first transmission of TB
  - Inactivity or DRX/DTX Periods characterized by no UL scheduling indications
- For ATB:
  - indication of UE status scheduled/not scheduled (from UL SCH)
  - number of PRBs allocated to UE (from UL SCH)
  - maximum/minimum UL UE bitrates (from RAC)
  - UE Power Control Headroom Report (from UL PC)
  - **Block Error Rate (BLER)**

- Transmission settings (to UL SCH)
  - only changes indicated
  - **modulation and coding (MCS)**
  - **maximum number of PRBs**
- UE PHR configurations (to Telecom C-PLANE)

Technical Details

Definitions of MCS for PUSCH

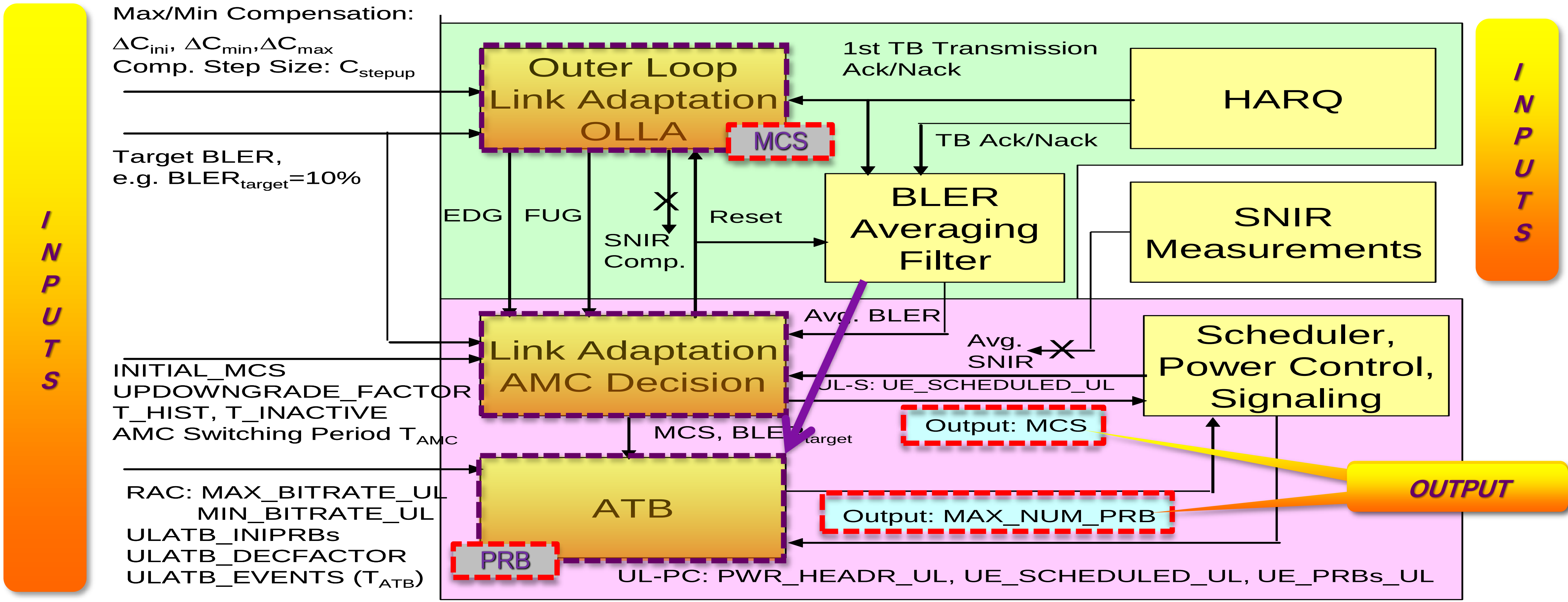
AMC adapts MCS according to current radio channel conditions

- ***RL 30*** uses only ***MCS 0-20*** (QPSK and 16QAM)
- ***Feature LTE829 (I****ncreased uplink MCS range)* enables ***MCS21-24*** as 16QAM (Modulation order 4)
  - 25% higher UL peak rate
  - Enabled/disabled by parameter *actModulationSchemeUL*
  - Cat5 devices are supported with max MCS20 even if **LTE829** is enabled as in RL30 there is no support of 64-QAM in UL.

MCS Index	Modulation order	TBS index	Redundancy Version
0	2	0	0
1	2	1	0
2	2	2	0
3	2	3	0
4	2	4	0
5	2	5	0
6	2	6	0
...	...	...	...
20	4	19	0
21	4	19	0
22	4	20	0
23	4	21	0
24	4	22	0
25	6	23	0
26	6	24	[illegible]
27	6	25	0
28	6	26	0
29	reserved		1
30			2
31			3

MODULATION, TBS INDEX AND REDUNDANCY VERSION TABLE FOR PUSCH, 3GPP 36.213, TABLE 8.6.1-1

In RL30 ATB becomes BLER based too



For internal use
MBB CS Network Engineering

With LTE1034 the 3 processes (UL AMC, UL ATB and UL OLLA) that rule the UL Link Adaptation, work synchronized but independently to each other.

1

Eliminate any possibility of BLER target drifting by:

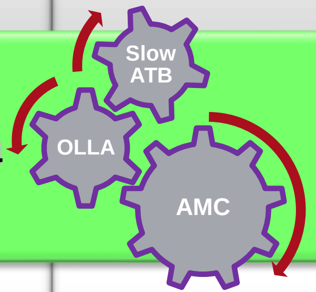
- **stopping the SLOW AMC algorithm (ILLA)**
- **leaving the MCS regulation the OLLA algorithm**

OLLA reacts relatively fast when it comes to reduce MCS index and slowly enough when it comes to upgrade MCS index

2

Therefore **OLLA algorithm is unchanged** and become the **only one ruling the MCS** index up and down

The main idea



3

ATB is no longer PHR based but BLER based (with PHR correction).

It will become active only when the OLLA has already reached the lower possible limit for the MCSindex

4

Most of all **SlowATB is coordinated with OLLA.**

This means that **SlowATB acts** only when **OLLA has no longer margin left** in term of reaction.

OLLA is an aperiodic event triggered algorithm based on a detection of fast channel conditions changes

- **OLLA** is acting on the **1st TBs transmissions** and performs following calculation:

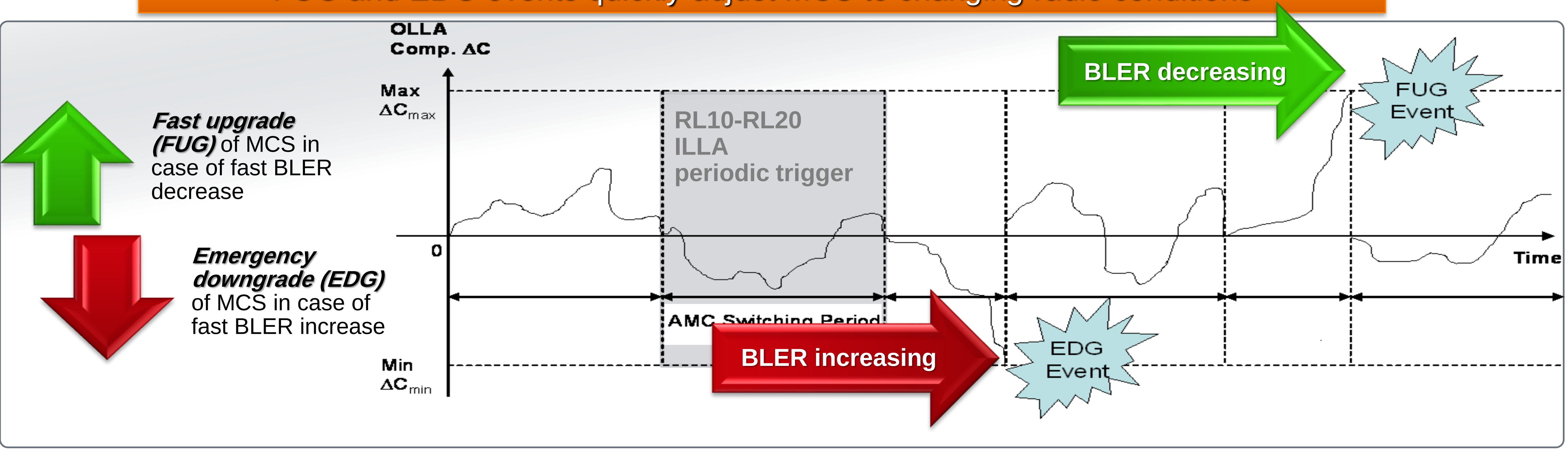
$$\Delta C(t) = \begin{cases} \min(\Delta C(t-1) + C_{stepup}, \Delta C_{max}), & \text{for first HARQ feedback} = \text{ACK}, \\ \max(\Delta C(t-1) - C_{stepdown}, \Delta C_{min}), & \text{for first HARQ feedback} = \text{NACK}, \\ \Delta C(t-1), & \text{for first HARQ feedback} = \text{N/A}. \end{cases}$$

$$\Delta C(t_{setup}) = \Delta C(t_{reset}) = \text{ULAMC\_DELTA\_CINI}.$$

  - DeltaC is called compensation factor
  - ***DeltaCmax*** and ***DeltaCmin*** give upper and lower limits of the compensation factor
  - ***CstepUp*** and ***CstepDown*** are incremental compensation steps sizes, which obey to the following formula:

$$C_{stepdown} = C_{stepup} \cdot \frac{1 - BLER_{target}}{BLER_{target}}$$

FUG and EDG events quickly adjust MCS to changing radio conditions



Abbreviated Name	Range(Stepsize/Granularity)	Default	Description
ulamcSwitchPer	10 TBs, 20 TBs. …., 500 TBs / 10 TBs	30 TBs	AMC switching Period
ulamcDeltaCmin	0.0, …, -10.0 / -0.1	-5.0	OLLA minimum Limit for Compensation
ulamcDeltaCmax	0.0, …, 10.0 / 0.1	5.0	OLLA maximum Limit for Compensation

Example

- Settings:
  - ***BLER target*** = 10%
  - ***CstepUp*** = 0.2
  - ***CstepDown*** = 0.2*(1-0.1)/0.1 = **1.8**
  - ***DeltaCini*** = 0
  - ***DeltaCmin*** = **-5**
  - ***DeltaCmax*** = **5**

deltaC = deltaCini = 0

1st unsuccessful 1st transmission

➔ *delta deltaC– CstepDown = 0 - 1.8 = -1.8*

2nd unsuccessful 1st transmission

➔ *delta deltaC– CstepDown = -1.8 -1.8 = -3.6*

3rd unsuccessful 1st transmission

➔ *delta deltaC – CstepDown = -3.6 - 1.8 =* ***-5.4***

EDG will be triggered because *DeltaCmin=-5* has been exceeded

- EDG will be triggered after 3 unsuccessfully received consecutive 1st transmissions of TBs. Note that by such an adjustment OLLA will be able to switch down the MCS after 3 ms (3 TTIs) even if the ILLA reaction time would be rather high with e.g. 30 TBs (~30ms)

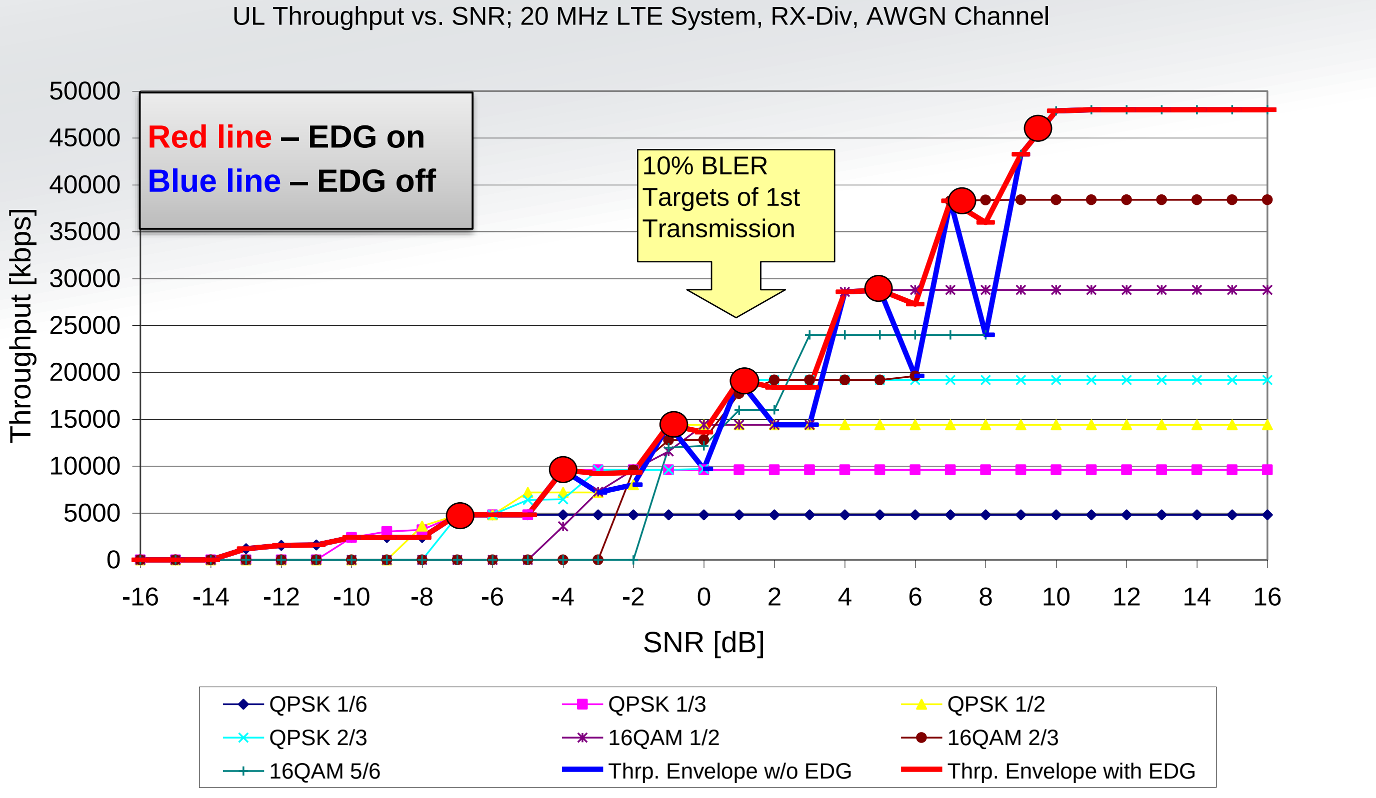
Performance evaluation in link level simulations

- Settings:
  - ***Target BLER*=10%**
  - ***CstepUp*=0.1**
  - CstepDown=0.9
  - ***DeltaCini=0***
  - ***DeltaCmin*=-9**

- *EDG will be triggered after:*

DeltaCmin / CstepDown = 10

unsuccessfully received consecutive 1st transmission (10 TTIs)



UL Throughput vs. SNR for 20 MHz LTE System assuming SIMO 1x2 RX Diversity (MRC) with Incremental Redundancy (up to 3 HARQ Retransmissions). Different MCS Performance presented in combination with LA/AMC curves with/without EDG (LL Source Josef Forster, 4GMAX).

ATB calculates maximum number of PRBs that UL scheduler can assign to a particular UE

- **Takes into account:**
  - **Maximum and minimum bitrates** – given by Admission Control and QoS **OR** by O&M (***minBitrateUl*** and ***maxBitrateUl***)
  - **BLER** - calculation is based on running average filter acting continuously on all of the incoming ACK/NACK of a certain UE, the averaging windows are defined by a related O&M the parameter called ***eUlLaBlerAveWin***
  - **Available UE power headroom** (as a correction) - based on running average filter acting continuously on all of the incoming power headroom reports of a certain UE. The averaging period is defined by O&M parameter called ***ulatbPhrAvgF***
- At call setup, starts with default initial number of PRBs defined by O&M parameter ***iniPrbsUl***
- Is **synchronized with AMC**
- In RL30 ATB is **triggered by EDG or periodically**

Abbreviated Name	Range	Default	Note
eUlLaBlerAveWin	{1, 2, 3, 4}	1	*It is expressed in number of TTI when UE has been actively scheduled E-ULA.*
ulatbPhrAvgF	0.0, …., 1.0 / 0.05	0.9	**Running Averaging Factor for processing filter for Power Headroom Reports**
iniPrbsUl	1, 2, ..., 100 / 1	10	*Reference: [3GPP-36.213]*

ATB Bandwidth limits

- **Bandwidth limitations resulting from UE QoS profile**
  – **UPPER**
  MAX_BIT ...) / (MCS_THROUGHPUT_per_PRB(1- ULAMC_TARGET_BLER))*
  – **LOWER**
  MIN_BIT ...) / (MCS_ ... B(1-ULAMC_TARGET_BLER))*
  – values to ... at end of ATB period
- **Bandwidth limitations resulting from UE power headroom**
  – *PWR_HEADR_PRBs(t) = UE_PRBs_UL(t) * PWR_HEADR_UL(t)*
  – *RUNAVG_PRBs(n) = (1 - ulatbPhrAvgF)*RUNAVG_PRBs(n-1) + ULATB_T_AVG*PWR_HEADR_PRBs(n)*

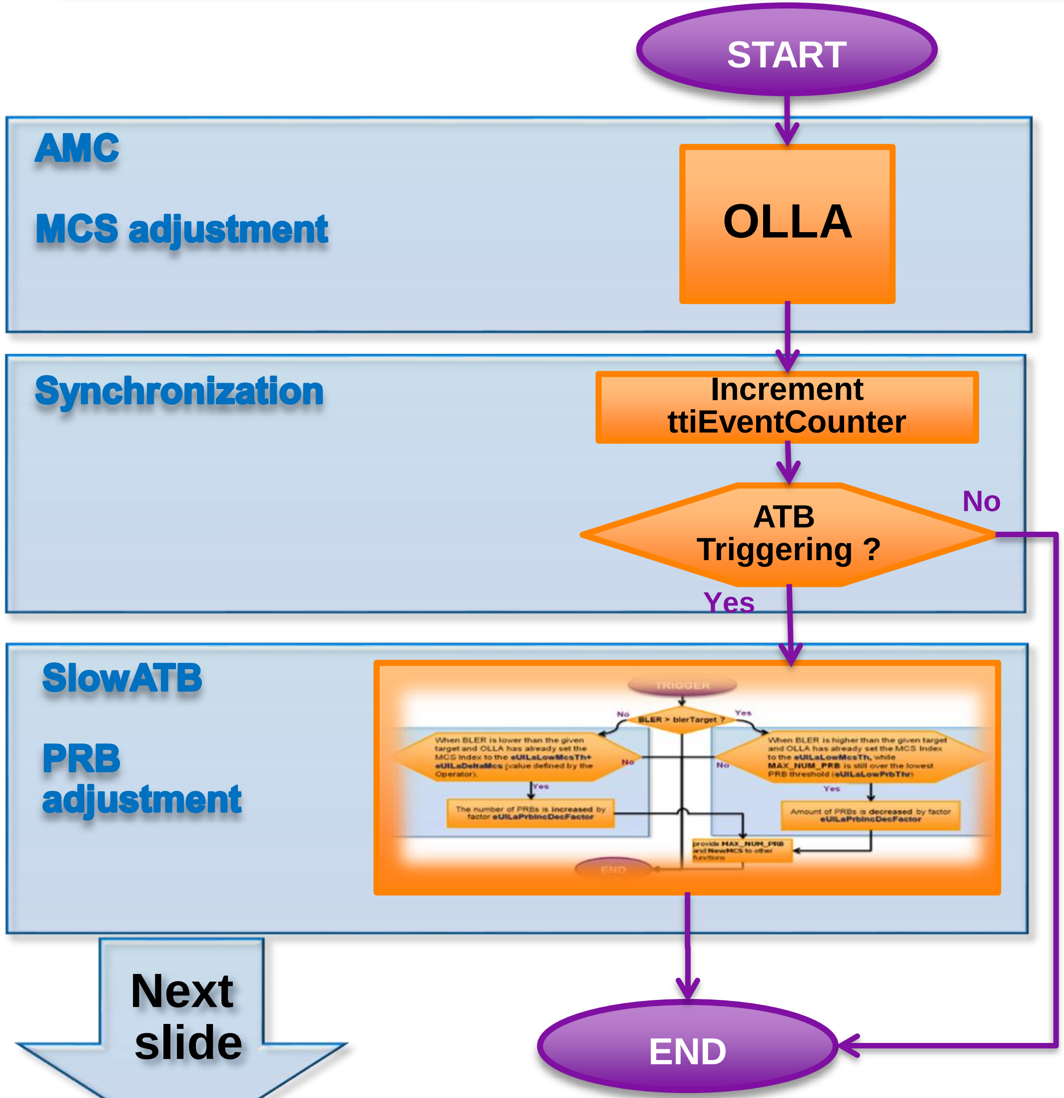
  – last two formulas calculated when both UE PH reporting and number of assigned UL PRBs are available
  – **MAX_NUM_PRBs = floor(RUNAVG_PRBs)**
    - value to be recalculated at end of ATB period
    - check if obtained maximum number of PRBs fits between upper and lower limits
- **UL scheduler is informed about maximum number of PRBs only if this value has changed**

Note that with ***ulatbPhrAvgF = 1*** always the last power headroom report is used and with ***ulatbPhrAvgF = 0*** the ATB is disabled and always the initial static O&M setting ***iniPrbsUl*** is used (this is a second possibility to switch the algorithm off).

Format -23 to 40.

Thus value needs to be linearized

MCS dependent UE throughput under ideal radio conditions (0% BLER) assuming a fictive allocation of 1 PRB per TTI



Next slide

- **OLLA verifies BLER** conditions and **triggers FUG or EDG** events when necessary as in former releases
- Counter is **incremented in every TTI** when user is **actively scheduled**
- **ATB is triggered for:**
  - ttiEventCounter threshold for periodical ATB triggering **(eUlLaAtbPeriod)**

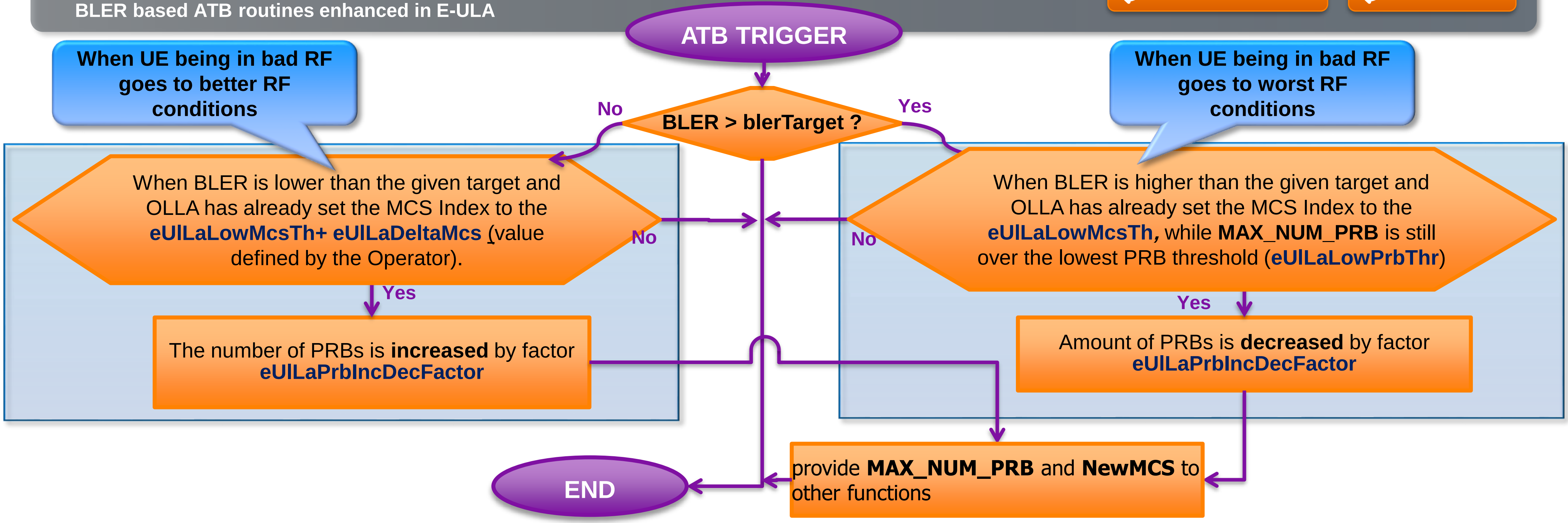
OR

  - EDG trigger - *is sent by OLLA when EDG event happens and the **lowest MCS Index** has been already **reached**. Therefore **EDG cannot further decrease** this MCS index. In this case **OLLA triggers the earlier activation** of the SlowATB process.*

Abbreviated Name	Range (Stepsize/Granularity)	Default
eUlLaAtbPeriod	{10, 15, 20, 30, 35, 40, 45, 50}	30

Technical Details

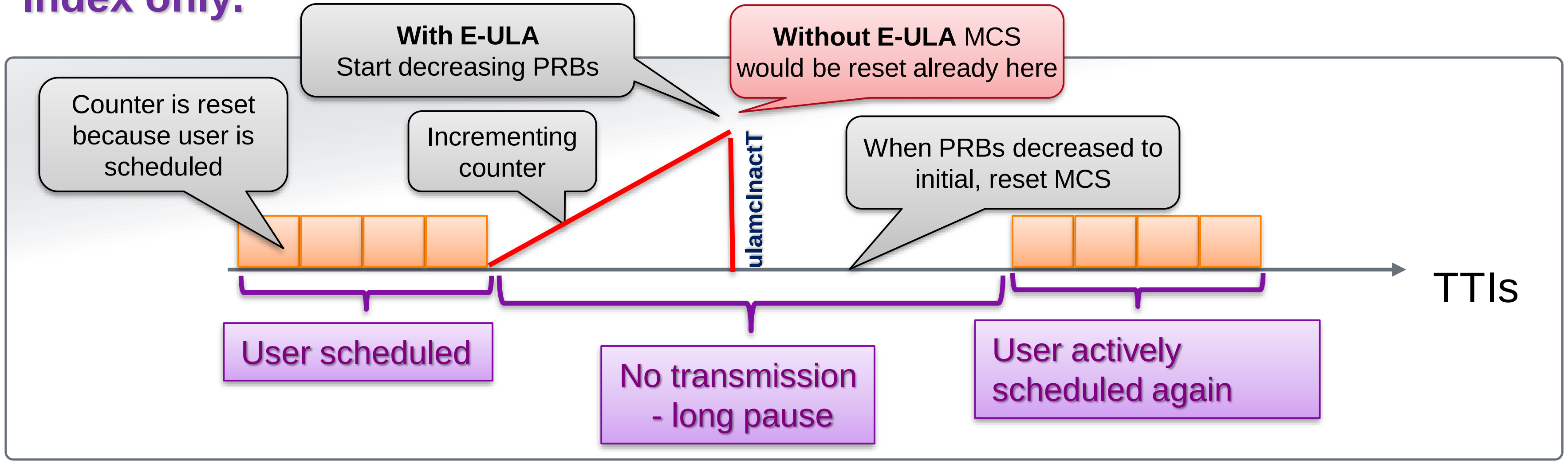
BLER based ATB routines enhanced in E-ULA



Abbreviated Name	Range	Default	Remark
eUlLaLowPrbThr	{1, 2, 3, 4, 5}	1	This shall be always bigger than or equal to **redBwMinRbUl**
eUlLaLowMcsThr	{1, 2, 3, 4}	1	-
eUlLaPrbIncDecFactor	{0.5, 0.6, 0.7, 0.75, 0.8, 0.85, 0.9}	0.8	-
eUlLaDeltaMcs	{1, 2, 3, 4, 5, 6}	3	Defines ***how many MCS indexes above the minimum MCS index*** are required before ATB may increase the amount of allocable PRBs

It is necessary to define how to react to long pauses between TTIs where UE is actively scheduled.

- UL-AMC defines already the parameter/timer ***ulamcInactT*** for the purpose of **resetting the MCS-index** after the expiration of this timer.
- To **avoid parameter multiplications** those parameters are utilized with a similar function in E-ULA but in E-ULA instead the algorithm acts as well on the **number of allocable PRBs instead of the MCS Index only.**



Note
If numer of PRBs is already under the initial value at the time ***ulamcInactT*** is reached, no further action is taken.

Abbreviated Name	Range(Stepsize/Granularity)	Default	Description
ulamcInactT	10 ms, 20 ms, …., 1000 ms / 10 ms	100 ms	**Timer for Inactivity and DRX/DTX Periods**

If user is still not active after expiration of timer, its resource assigments should be gradually decreased

User is not scheduled

- No transmission – long pause
- Wait until counter ***ulamcInactT*** is reached

If meantime user was scheduled again, the counter is reset and no further LA adjustment is done

Start decreasing PRBs

- When counter reached and PRB > ***iniPrbsUl*** –> start decreasing PRBs by ***eUlLaPrbIncDecFactor***

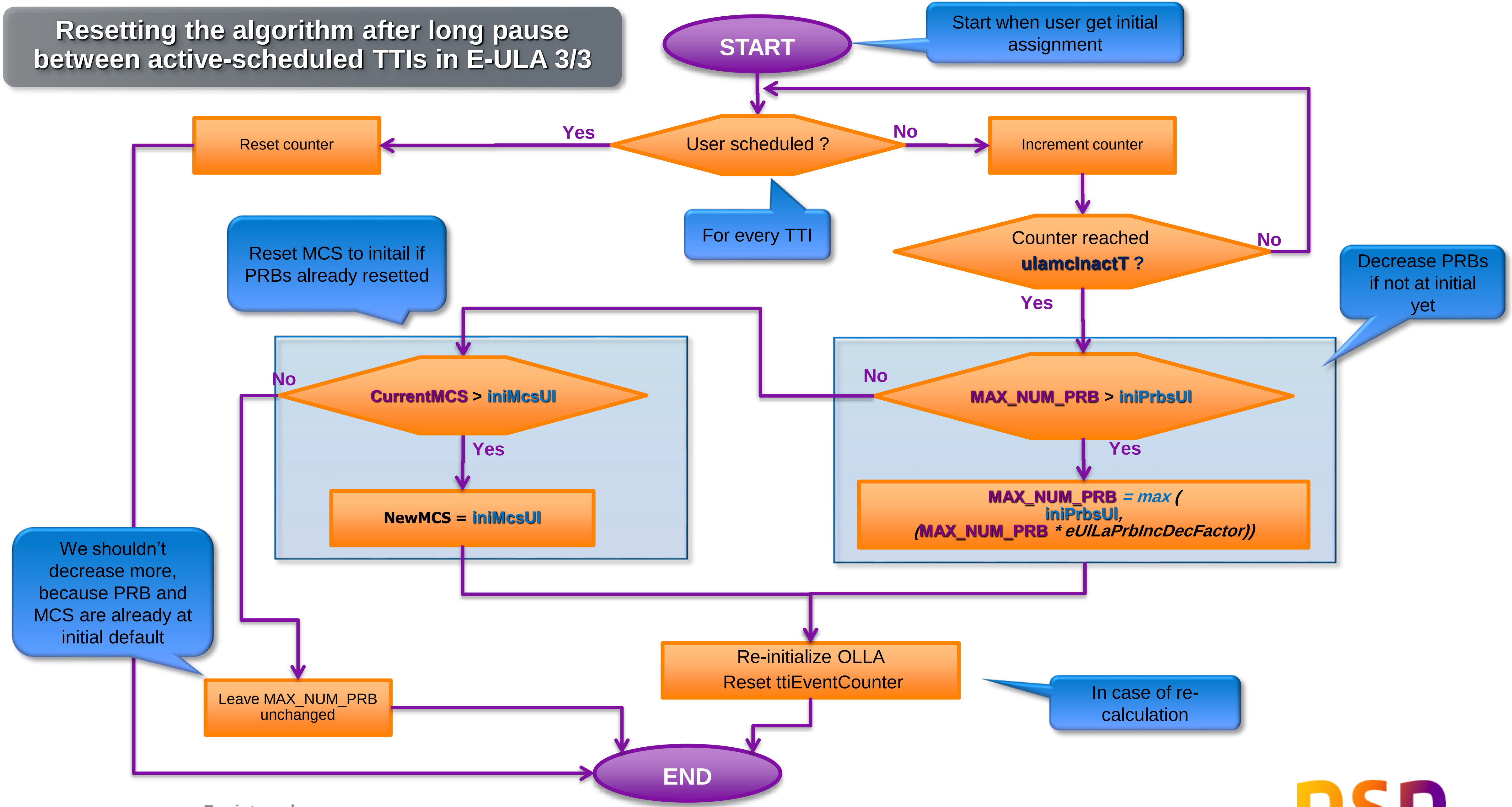
Reset MCS

- When PRBs already at ***iniPrbsUl*** set MCS to ***iniMcsUl***

Reset counters and re-initialize OLLA in case of any recalculation

Abbreviated Name	Range(Stepsize/Granularity)	Default
iniPrbsUl	1, 2, ..., 100 / 1	10
iniMcsUl	MCS0, MCS2, …, MCS20	MCS5

Resetting the algorithm after long pause between active-scheduled TTIs in E-ULA 3/3



- **The UL AMC/ATB delivers to Telecom C-Plane the relevant configuration data for the UE Power Headroom Configuration**
  - The UE shall be configured to report **PERIODIC PWR_HEADR_UL** reports. For this the period shall be configured by RRC - if applicable. The parameter **tPeriodicPhr** is available from O&M. Also the minimum time period in-between two reports is available by O&M with **tProhibitPhr**. Event driven Parameter such as rapid change in path loss shall be set according to **dlPathlossChg**. Also the latter data is taken from O&M parameter settings.
- **So the UE shall be configured as follows by:**
  - event triggered reporting

    DL_PATHLOSS_CHANGE = dlPathlossChg with {dB1, **dB3**, dB6, infinity}
  - periodical reporting

    PERIODIC_PHR_TIMER = tPeriodicPhr with {sf10, **sf20**, sf50, sf100, sf200, sf500, sf1000, infinity}
  - report prohibit timer

    PROHIBIT_PHR_TIMER = tProhibitPhr with {**sf0**, sf10, sf20, sf50, sf100, sf200, sf500, sf1000}

Parameter section

-
- **If the periodic PHR Timer is set to infinity and the DL path loss change, too, then no PWR_HEADR_UL indications are received during the whole call. Then in this case the ATB stays with the initial static setup ULATB_INIPRBs.**

Abbreviated Name	Description	Range/ Step	Default Value	Recommendation / Note
iniMcsUl	**Selection of initial MCS** ***Reference:*** *[3GPP-36.213]*	MCS0, MCS2, …, MCS20	**MCS5**	Default recomended
ulTargetBler	**Target BLER for AMC UL** ***Reference:*** *[3GPP-36.213]*	0 %, …, 50 % / 1 %	**10%**	
ulamcUpdowngrF	**Factor to calculate Downgrade and Upgrade BLER Thresholds**	1.0, …… 3.0 / 0.05	**1,20**	
ulamcAllTbEn	**BLER calculation based on 1st TB Transmission or all Transmissions**	enable / disable	**enable**	Better results are obtained with enable value
ulamcSwitchPer	**AMC switching Period**	10 TBs, 20 TBs. …., 500 TBs / 10 TBs	**30 TBs**	ILLA related parameter which is not used in case E-ULA is activated
ulamcHistMcsT	**Timer for "historical MCS"**	0 ms, 100 ms, …., 20000 ms / 100 ms	**1000 ms**	•ILLA related parameter which is not used in case E-ULA is activated
ulamcInactT	**Timer for Inactivity and DRX/DTX Periods**	10 ms, 20 ms, …., 1000 ms / 10 ms	**100 ms**	

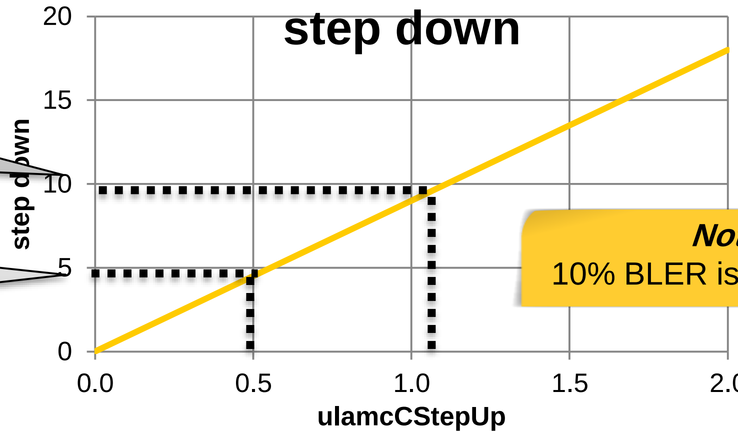
Configuration Management

UL LA – OLLA parameters

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
ulamcDeltaCmin	OLLA minimum Limit for Compensation	0.0, …, -10.0 / -0.1	-5.0	The difference beteween those two parameters shall be big enough to accommodate variance of deltaC, which is impacted by ***ulamcCStepUp***
ulamcDeltaCmax	OLLA maximum Limit for Compensation	0.0, …, 10.0 / 0.1	5.0	
ulamcDeltaCini	OLLA initial value for Compensation	0.0, …, 10.0 / 0.1	0	The default value is recomended, since marginal parameter impact is expected to values other than 0
ulamcCStepUp	OLLA Compensation Step size Up (Step size Down is calculated according to formula)	0.0, …., 2.0 / 0.05	0.2	Increasing the value to higher than 0.55 leaving the default for ***ulamcDeltaCmin*** will cause unstable system performance lading to excessive MCS downgrade events triggered by every NACK

With **CStepUp>1.1** MCS will be downgraded with every NACK even if the **DeltaCmin = -10** (minimum possible value)

Default value of **DeltaCmin = -5,** therefore with **CStepUp=0.55** **MCS will be downgraded with every NACK**



Note
10% BLER is assumed

OLLA

For internal use
MBB CS Network Engineering

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
iniPrbsUl	Selection of initial Bandwidth at Call Setup *Reference:* *[3GPP-36.213]*	1, 2, ..., 100 / 1	10	High allocation is recommended for the initial transmission, as long as it would be quickly decreased, when not needed. Following the E-ULA principle low value may cause inefficient transmission.
ulatbEventPer	ATB update period in multiples of AMC switching periods and EDG/FUG events	1, …., 50 /1	1	The parameter is no longer valid with RL30/RL25TD onwards where ILLA algorithm is not used anymore and eUlLaAtbPeriod replaces that parameter for the calculation of ATB period
ulatbPhrAvgF	Running Averaging Factor for processing filter for Power Headroom Reports	0.0, …., 1.0 / 0.05	0.9	

Abbreviated Name	Description	Range/ Step	Default Value	Recomendation
dlPathlossChg	**Trigger Condition for Power Headroom submission due to Downlink Path loss change** *Reference:* *[3GPP-36.331]*	dB1, dB3, dB6, infinity	3 dB	
tPeriodicPhr	**UE configuration for sending periodic power headroom reports (PHR)** *Reference:* *[3GPP-36.331]*	sf10, sf20, sf50, sf100, sf200, sf500, sf1000, infinity	20 ms = sf20	
tProhibitPhr	**Minimum Intermediate Time within 2 consecutive Power Headroom reports controlled by Prohibit Timer** *Reference:* *[3GPP-36.331]*	sf0, sf10, sf20, sf50, sf100, sf200, sf500, sf1000	0 ms = sf0	

PHR

Abbreviated Name	Description	Range / Step	Default Value	Recomendation
actUlLnkAdp	**Activates Uplink Link Adaptation and defines Link Adaptation mode** When set to **"off"** no Uplink link Adaptation function is active at all. When set to "**eUlLa**" the **new extended Uplink Link Adaptation** function is activated. The **other choices** allow to configure the **old UL Link Adaptation functions** as it was up to RL20 so by "slowAMC" only old SlowAMC is activated, by "slowAmcOlla" the SlowAMC and EDG and FUG are active, by "slowAmcATB" only old SlowAMC and SlowATB functions are active and finally by "slowAmcOllaATB" all the 3 old function are active together as up to RL20 Adaptation and defines Link Adaptation mode	{off, slowAmc, slowAmcATB, slowAmcOlla, slowAmcOlla ATB, eUlLa}	**eUlLa**	E-ULA is recommended from RL30/RL25TD onwards
eUlLaAtbPeriod	When not externally triggered by Outer Loop Link Adaptation (OLLA), the Adaptive **Transmission Bandwidth (ATB) algorithm will be activated** ***when the amount of TTI events*** here defined has been reached	{10, 15, 20, 30, 35, 40, 45, 50}	**30**	Usually OLLA triggers necessary PRB adjustment by ATB if needed, therefore the counter has no major impact on the network performance.
eUlLaPrbIncDecFactor	**Incremental and decremental factor for the Adaptive Transmission Bandwidth's calculation of allocable PRBs** *Multiplying the amount of PRBs by this factor the total amount of allocable PRBs is decreasing.* *Dividing the amount of PRBs by this factor, then the number of allocable PRB is increasing*	{0.5, 0.6, 0.7, 0.75, 0.8, 0.85, 0.9}	**0.8**	Parameter determines how quickly PRB limit is decreased/increased, when MCS has been already minimized
eUlLaDeltaMcs	Defines ***how many MCS indexes above the minimal MCS index*** are required before ATB may increase the amount of allocable PRBs	{1, 2, 3, 4, 5, 6}	**3**	

Minimum number of PRBs assigned in uplink

Defines the minimum number of PRBs which may be assigned to a UE scheduled in UL when **LTE786 Flexible UL Bandwidth** feature in uplink is enabled

Abbreviated Name	Description	p	Value	Recomendation
eUlLaLowPrbThr	**Defines the lowest possible amo… allocable PRBs** This shall be always bigger than or equal to **redBwMinRbUl**	{1, 2, 3, 4, 5}	**1**	
eUlLaLowMcsThr	**Defines the lowest possible MCS index before Adaptive Transmission Bandwidth (ATB) algorithm may act and decrease the amount of allocable PRBs.**	{1, 2, 3, 4}	**1**	
eUlLaBlerAveWin	**Averaging window for BLER in E-ULA.** ***It is expressed in number of TTI when UE has been actively scheduled E-ULA.***	{1, 2, 3, 4}	**1**	The new feature takes into account BLER measurements. L1/L2 HARQ process periodically submits the UE specific Ack/Nacks for both 1st TB transmissions and all TB transmissions (including also retransmissions), which result in a BLER level. To make it stable, the calculation is based on the running average filter. If the BLER has been derived from the 1st HARQ transmissions only, i.e. the BLER does not take into account any HARQ gains achieved by soft combining. If the BLER has been derived from all TB transmissions (ulamcAllTbEn = true) the HARQ gain is included leading to small decision errors. However, the BLER calculation window get much more regular and stable by taking into account all TB transmissions. Short window (<20), can lead to unstable BLER and UL Link adaptation => frequent MCS changes. Parameter is expressed in number of TTI when UE has been actively scheduled E-ULA.

Configuration Management

Parameters deleted RL30

With implementation of E-ULA some parameters is no longer available

Abbreviated Name	Description	Name
ulamcEnable	O&M switch for enabling/disabling the whole uplink Adaptive Modulation and Coding functionality and use an initial UL MCS instead.	***Enable UL AMC***
ulamcEdgFugEn	O&M switch for enabling/disabling the 1st transmission BLER based Emergency Downgrade and Fast Upgrade functionality included in the UL AMC under Outer Loop Link Adaptation.	***Enable UL AMC EDG and FUG***
ulatbEnable	O&M switch for enabling/disabling the uplink Adaptive Transmission Bandwidth (ATB) functionalities. ATB is based on Power Headroom Reports (PHRs) from the UE.	***Enable UL ATB***

Deleted

Parameter **actUlLnkAdp** activates Link Adaptation and defines its mode

	actUlLnkAdp	ILLA	OLLA	ATB	
				PHR based	BLER based
	off	✗	✗	✗	✗
RECOMMENDED NEW DEFAULT	eUlLa	✗	✓	✓	✓
	slowAmc	✓	✗	✗	✗
	slowAmcATB	✓	✗	✓	✗
	slowAmcOlla	✓	✓	✗	✗
	slowAmcOllaATB	✓	✓	✓	✗

Deployment aspects

ATB in TTI

Table of Contents | Main Menu

UE delivers (enb configured) Power Headroom Reports to the eNodeB, which are processed there in UL PC and UL ATB functions. UL ATB is derived from selected MCS according to radio conditions (by AMC) and QoS information MAX_BITRATE_UL, MIN_BITRATE_UL commanded by RAC as well as UE Power Headroom information delivered by UL PC.

Only when changed, UL Scheduler is informed by slow UL AMC/ATB about the maximum Number of PRBs per TTI (MAX_NUM_PRBs per TTI is only an upper allocation limit and UL-S can reduce it).

sfn	esfn	cRnti	trNum	ackNack	harqNum	modulation	mcsIndex (TFI)	tbs (Bytes)	numUes Cs	numUes Cs3List	numUes Td	numUes Fd	total PrbAvail	first AllocPrb	numOf PrbsAlloc	rrm DeltaC	rrmNum OfTrans	rrmNumOf Nacked Trans	rrmMcs Switches	PHR	rrmMax NumPrbs
877	2	47657	NewTx	NACK	4	QPSK	10	261	4	0	4	3	19	10	12	-26	23	3	0	9	14
877	4	47657	ReTx: 1	ACK	6	QPSK	10	261	4	0	4	3	19	10	12	-44	24	4	0	9	14
877	6	47657	NewTx	ACK	0	QPSK	9	17	4	0	4	2	19	21	1	-10	0	0	0	9	14
877	7	47657	ReTx: 1	ACK	1	QPSK	10	261	4	[illegible]	4	3	19	3	12	-10	0	0	0	9	14
878	0	47657	ReTx: 1	ACK	4	QPSK	10	261	4	0	4	3	19	3	12	-26	2	1	0	9	14
878	6	47657	NewTx	ACK	2	QPSK	9	17	4	0	4	2	[illegible]	21	1	-24	5	1	0	12	14
878	7	47657	NewTx	NACK	3	QPSK	9	233	4	0	4	3	19	3	12	-24	6	1	0	12	14
878	9	47657	NewTx	ACK	5	QPSK	9	17	4	0	4	2	19	3	1	-24	6	1	0	12	14
879	0	47657	NewTx	NACK	6	QPSK	9	233	4	[illegible]	4	3	19	3	12	-24	6	1	0	12	14
879	2	47657	NewTx	ACK	0	QPSK	9	17	4	0	4	2	19	3	1	-24	6	1	0	12	14
879	3	47657	NewTx	NACK	1	QPSK	9	233	4	0	4	3	19	3	12	-22	7	1	0	12	14
879	5	47657	ReTx: 1	ACK	3	QPSK	9	233	4	0	4	3	19	3	12	-40	8	2	0	12	14
879	7	47657	NewTx	ACK	5	QPSK	8	15	4	0	4	2	19	21	1	-6	0	0	0	12	25
879	8	47657	ReTx: 1	ACK	6	QPSK	9	233	4	0	4	3	19	3	12	-6	0	0	0	12	25
879	9	47657	NewTx	NACK	7	QPSK	8	317	4	0	4	2	19	3	18	-4	1	0	0	12	25
880	0	47657	NewTx	NACK	0	QPSK	8	317	4	0	4	2	19	4	18	-22	2	1	0	12	25
880	1	47657	ReTx: 1	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-22	2	1	0	12	25
880	2	47657	NewTx	NACK	2	QPSK	8	317	4	0	4	2	19	4	18	-22	3	1	0	12	25
880	3	47657	NewTx	NACK	3	QPSK	8	317	4	0	4	[illegible]	[illegible]	4	18	-22	3	1	0	12	25
880	5	47657	NewTx	[illegible]	[illegible]	[illegible]	[illegible]	15	4	0	4	[illegible]	[illegible]	[illegible]	[illegible]	-20	5	1	0	12	25
880	6	47657	NewTx	NACK	6	QPSK	8	317	4	0	4	2	19	4	18	-38	6	2	0	12	25
880	7	47657	ReTx: 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	-56	7	3	0	12	25

The format of PWR_HEADR_UL is -23 to +40 dB in steps of 1 dB If it is positive then UE has still power reserve available, if it is negative then UE runs out of power.

Slow UL ATB shall act in line (synchronously) with slow UL AMC by slowly adapting the control interval limits of the ATB with multiples of ULAMC_SWITCH_PERIOD. The multiplicity is given by ULATB_EVENTS O&M parameter. Note that after every EDG and FUG event the slow ATB limits have to be recalculated independent from ULATB_EVENTS settings since the MCS might have changed.

- ATB shall be based on a running average filter (O&M parameter ULATB_T_AVG) acting continuously on all of the incoming power headroom reports of a UE. PWR_HEADR_UL is tightly coupled with the UE allocation of a certain TTI. Therefore UL-S indicates to AMC/ATB whenever the UE is scheduled by UE_SCHEDULED_UL and gives the number of allocated PRBs by UE_PRBs_UL (From Step 2.3 of UL Scheduler slides)
- ATB stores UE_PRBs_UL and transforms PHR is into equivalent number of PRBs: PWR_HEADR_PRBs(t) = UE_PRBs_UL(t) * PWR_HEADR_UL(t) , where PWR_HEADR_UL is leniarized.
- The running average filter (acting continuously on all of the incoming power headroom reports of a certain UE) output is given by
  - RUNAVG_PRBs(0) = ULATB_INIPRBs ,or,
  - RUNAVG_PRBs(n) = (1 - ULATB_T_AVG)*RUNAVG_PRBs(n-1) + ULATB_T_AVG*PWR_HEADR_PRBs(n).
- At any ATB decision point, the present value of the running average filter is read and MAX_NUM_PRBs is set to a rounded integer value by:
  - MAX_NUM_PRBs = floor(RUNAVG_PRBs).
- if MAX_NUM_PRBs < LOWER_LIMIT_PRBs, then MAX_NUM_PRBs = LOWER_LIMIT_PRBs, where LOWER_LIMIT_PRBs = MIN_BITRATE_UL (given by Admission Control and QoS) / (MCS_THROUGHPUT_per_PRB*(1-ULAMC_TARGET_BLER)).
- if MAX_NUM_PRBs > UPPER_LIMIT_PRBs, then MAX_NUM_PRBs = UPPER_LIMIT_PRBs, where UPPER_LIMIT_PRBs = MAX_BITRATE_UL (given by Admission Control and QoS) / (MCS_THROUGHPUT_per_PRB*(1-ULAMC_TARGET_BLER))

Deployment aspects

E-ULA in TTI (1/3)

All TBs (ULAMC_ENABLE_ALLTBS = true) are used for BLER calculation, so that HARQ gain achieved by soft combining is included leading to small decision errors and more stable and regular BLER calculation.

LTE MAC updates running average filter bit mask (rrmEUlLaBlerBitMask) telling amount of NACKs for recent transmission on UE basis. Bit mask is moved and set every TTI based on received HARQ feedback. the averaging windows shall be defined by a related O&M the parameter called eLAULBlerAveWin (30 in this case)

Time (h:min:sec:ms)	sfn	esfn	cellId	cRnti	trNum	ackNack	harqNum	modulation	mcsIndex (TFI)	tbs (Bytes)	total PrbAvail	numOf PrbsAlloc	sinr Pusch	rrm DeltaC	rrmNum OfTrans	rrmNumOf Nacked Trans	rrmMcs Switches	PHR	rrmMax NumPrbs
14:25:06:395	293	9	2561	25190	NewTx	ACK	3	QPSK	5	533	48	48	1	44	27	0	39	0	50
14:25:06:396	294	0	2561	25190	NewTx	ACK	4	QPSK	5	533	48	48	1	46	28	0	39	0	50
14:25:06:397	294	1	2561	25190	NewTx	ACK	5	QPSK	5	437	42	40	3	48	29	0	39	0	50
14:25:06:398	294	2	2561	25190	NewTx	NACK	6	QPSK	6	621	48	48	2	0	0	0	39	0	50
14:25:06:399	294	3	2561	25190	NewTx	NACK	7	QPSK	6	621	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39	0	50
14:25:06:400	294	4	2561	25190	NewTx	NACK	0	QPSK	6	621	48	48	[illegible]	[illegible]	[illegible]	[illegible]	39	0	50
14:25:06:401	294	5	2561	25190	NewTx	ACK	1	QPSK	6	621	48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39	0	50
14:25:06:402	294	6	2561	25190	NewTx	NACK	2	QPSK	6	621	48	48	[illegible]	[illegible]	[illegible]	[illegible]	39	0	50
14:25:06:403	294	7	2561	25190	NewTx	NACK	3	QPSK	6	621	48	48	[illegible]	[illegible]	[illegible]	[illegible]	39	0	50
14:25:06:404	294	8	2561	25190	NewTx	NACK	4	QPSK	6	621	48	48	1	12	6	0	39	0	50
14:25:06:405	294	9	2561	25190	NewTx	NACK	5	QPSK	6	621	48	48	1	-6	7	1	39	0	50
14:25:06:406	295	0	2561	25190	ReTx: 1	ACK	6	QPSK	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	2	39	0	50
14:25:06:407	295	1	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-
14:25:06:408	295	2	2561	25190	ReTx: 1	ACK	0	QPSK	6	621	48	[illegible]	[illegible]	-40	10	3	39	0	50
14:25:06:409	295	3	2561	25190	NewTx	ACK	1	QPSK	5	533	48	[illegible]	[illegible]	[illegible]	11	4	40	0	50
14:25:06:410	295	4	2561	25190	ReTx: 1	ACK	2	QPSK	6	621	48	48	1	-26	12	5	40	0	50
14:25:06:411	295	5	2561	25190	ReTx: 1	ACK	3	QPSK	6	621	48	48	1	-44	13	6	40	0	50
14:25:06:412	295	6	2561	25190	ReTx: 1	ACK	4	QPSK	6	621	48	48	1	-62	14	7	40	0	50
14:25:06:413	295	7	2561	25190	ReTx: 1	ACK	5	QPSK	6	621	48	48	1	-62	14	7	40	0	50
14:25:06:414	295	8	2561	25190	NewTx	ACK	6	QPSK	4	437	48	48	1	-12	14	7	41	0	50
14:25:06:415	295	9	2561	25190	ReTx: 2	ACK	7	QPSK	6	621	48	48	1	-12	14	7	41	0	50
14:25:06:416	296	0	2561	25190	NewTx	ACK	0	QPSK	4	437	48	48	1	-10	15	7	41	0	50
14:25:06:417	296	1	2561	25190	NewTx	ACK	1	QPSK	4	357	42	40	3	-10	15	7	41	0	50
14:25:06:418	296	2	2561	25190	NewTx	ACK	2	QPSK	4	437	48	48	1	-10	15	7	41	0	50
14:25:06:419	296	3	2561	25190	NewTx	ACK	3	QPSK	4	437	48	48	1	-10	15	7	41	0	50
14:25:06:420	296	4	2561	25190	NewTx	ACK	4	QPSK	4	437	48	48	1	-10	15	7	41	0	50
14:25:06:421	296	5	2561	25190	NewTx	ACK	5	QPSK	4	437	48	48	1	-8	16	7	41	0	50
14:25:06:422	296	6	2561	25190	NewTx	ACK	6	QPSK	4	437	48	48	1	-8	16	7	41	0	50
14:25:06:423	296	7	2561	25190	NewTx	ACK	7	QPSK	4	437	48	48	1	-6	17	7	41	0	50
14:25:06:424	296	8	2561	25190	NewTx	ACK	0	QPSK	4	437	48	48	1	-4	18	7	41	0	50
14:25:06:425	296	9	2561	25190	NewTx	ACK	[illegible]	QPSK	4	437	48	48	1	-2	19	7	41	0	50
14:25:06:426	297	0	2561	25190	NewTx	ACK	[illegible]	QPSK	4	437	48	48	1	0	20	7	41	0	50
14:25:06:427	297	1	2561	25190	NewTx	ACK	3	QPSK	4	357	42	40	3	2	21	7	41	0	50
14:25:06:428	297	2	2561	25190	NewTx	ACK	4	QPSK	4	437	48	48	1	4	22	7	41	0	50
14:25:06:429	297	3	2561	25190	NewTx	ACK	5	QPSK	4	437	48	48	1	6	23	7	41	0	50
14:25:06:430	297	4	2561	25190	NewTx	ACK	6	QPSK	4	437	48	48	1	8	24	7	41	0	50
14:25:06:431	297	5	[illegible]	[illegible]	NewTx	ACK	7	QPSK	4	437	48	48	[illegible]	[illegible]	25	[illegible]	[illegible]	0	50
14:25:06:432	297	6	[illegible]	[illegible]	NewTx	ACK	0	QPSK	4	437	48	48	[illegible]	12	26	7	41	0	50
14:25:06:433	297	7	[illegible]	[illegible]	NewTx	ACK	1	QPSK	4	437	48	48	[illegible]	14	27	7	41	0	50
14:25:06:434	297	8	2561	25190	NewTx	ACK	2	QPSK	4	437	48	48	1	16	28	7	41	0	50
14:25:06:435	297	9	2561	25190	NewTx	ACK	3	QPSK	4	437	48	48	1	18	29	7	41	0	50
14:25:06:436	298	0	2561	25190	NewTx	ACK	4	QPSK	4	357	48	40	2	0	0	6	41	0	40
14:25:06:437	298	1	2561	25190	NewTx	ACK	5	QPSK	4	357	42	40	3	2	1	5	41	0	40

PHR reports are used to speed up PRB allocation under special condition. Like in RL20 slow ATB, a running average filter output gives MAXNUMPRB_PHR to eLA

OLLA reduces MCS because of EDG just like in RL20. No change.

No PRB reduction, since EDG is triggered but lowest MCS 0 not yet reached. See ATB trigger #2 on next slide. Neither is eUlLaAtbPeriod expired for ATB trigger #1.

UE being in bad RF goes to worst RF conditions …
If (CurrentMcs <= eUlLaLowMcsThr and MAX_NUM_PRB >= eUlLaLowPrbThr and BLER > blerTarget)
// decreases PRB amount
Set MAX_NUM_PRB = MAX_NUM_PRB * eUlLaPrbIncDecFactor [= 48 * 0.8~40]
//as calculated in RRM.4066 for the SlowATB filter input
GET MaxNumPRB_PHR [say x, since this is not shown in tti trace but calculated internally as old RL20 ATB]
MAX_NUM_PRB = max (MAX_NUM_PRB, MaxNumPRB_PHR, eUlLaLowPrbThr)) [=max(40,x,1)=40]
else do nothing // OLLA only shall act under this condition

The low MCS threshold eUlLaLowMcsThr of 4 reaches

ATB Trigger #1: Periodic when ttiEventCounter = eUlLaAtbPeriod (30 here)

SlowATB algorithm based on BLER situation shall increment or decrement the amount of allocable PRB based on eUlLaPrbIncDecFactor

LTE MAC calculates actual BLER:
rrmEUlLaBler = rrmEUlLaNacksInAveWin / eUlLaBlerAveWin= 6/30=20% which is > 10%

Time (h:min:sec:ms)	sfn	esfn	cellId	cRnti	trNum	ackNack	harqNum	modulation	mcsIndex (TFI)	tbs (Bytes)	total PrbAvail	numOf PrbsAlloc	sinr Pusch	rrm DeltaC	rrmNum OfTrans	rrmNumOf Nacked Trans	rrmMcs Switches	PHR	rrmMax NumPrbs
14:23:39:783	848	5	2561	48275	NewTx	NACK	5	QPSK	1	113	48	25	-3	12	1	0	35	9	25
14:23:39:784	848	6	2561	48275	NewTx	NACK	6	QPSK	1	113	48	25	-3	14	2	0	35	9	25
14:23:39:785	848	7	2561	48275	NewTx	NACK	7	QPSK	1	113	48	25	-2	-4	3	1	35	9	25
14:23:39:786	848	8	2561	48275	ReTx:1	ACK	0	QPSK	1	113	48	25	-3	-2	4	1	35	9	25
14:23:39:787	848	9	2561	48275	NewTx	NACK	1	QPSK	1	113	48	25	-4	-2	5	1	35	9	25
14:23:39:788	849	0	2561	48275	ReTx:1	ACK	2	QPSK	1	113	48	25	-2	0	6	1	35	9	25
14:23:39:789	849	1	2561	48275	NewTx	NACK	3	QPSK	1	113	42	25	-2	2	7	1	35	9	25
14:23:39:790	849	2	2561	48275	NewTx	NACK	4	QPSK	1	113	48	25	-4	-16	8	[illegible]	[illegible]	9	25
14:23:39:791	849	3	2561	48275	ReTx:1	ACK	5	QPSK	1	113	48	25	-1	-34	9	3	35	9	25
14:23:39:792	849	4	2561	48275	ReTx:1	ACK	6	QPSK	1	113	48	25	-1	-52	10	4	35	9	25
14:23:39:793	849	5	2561	48275	ReTx:1	ACK	7	QPSK	1	113	48	25	0	-52	10	4	35	9	25
14:23:39:794	849	6	2561	48275	NewTx	ACK	0	QPSK	0	67	48	20	-4	0	0	5	36	9	20
14:23:39:795	849	7	2561	48275	ReTx:1	ACK	1	QPSK	1	113	48	25	-3	0	0	5	36	9	20
14:23:39:796	849	8	2561	48275	NewTx	ACK	2	QPSK	0	67	48	20	-2	-18	1	6	36	9	20
14:23:39:797	849	9	2561	48275	ReTx:1	ACK	3	QPSK	1	113	48	25	0	-36	2	7	36	9	20
14:23:39:798	850	0	2561	48275	ReTx:1	ACK	4	QPSK	1	113	48	25	-3	-36	2	7	36	9	20

Lowest MCS threshold is 0 reached

ATB Trigger #2: when EDG is triggered and lowest MCS i.e.0 is reached

LTE MAC calculates actual BLER:
rrmEUlLaBler = rrmEUlLaNacksInAveWin / eUlLaBlerAveWin= 5/30=17% which is > 10%

UE being in bad RF goes to worst RF conditions …

If (CurrentMcs <= eUlLaLowMcsThr and MAX_NUM_PRB >= eUlLaLowPrbThr and BLER > blerTarget)
// decreases PRB amount
Set MAX_NUM_PRB = MAX_NUM_PRB * eUlLaPrbIncDecFactor [= 25 * 0.8~20]
//as calculated in RRM.4066 for the SlowATB filter input
GET MaxNumPRB_PHR [say x, since this is not shown in tti trace but calculated internally as old RL20 ATB]
MAX_NUM_PRB = max (MAX_NUM_PRB, MaxNumPRB_PHR, eUlLaLowPrbThr)) [=max(20,x,1)=20]
else do nothing // OLLA only shall act under this condition

Deployment aspects

E-ULA in TTI (3/3)

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Time (h:min:sec:ms)	sfn	esfn	cellId	cRnti	trNum	ackNack	harqNum	modulation	mcsIndex (TFI)	tbs (Bytes)	total PrbAvail	numOf PrbsAlloc	sinr Pusch	rrm DeltaC	rrmNum OfTrans	rrmNumOf Nacked Trans	rrmMcs Switches	PHR	rrmMax NumPrbs
14:25:08:989	553	3	2561	25190	NewTx	ACK	5	QPSK	6	117	48	9	12	48	24	0	63	3	9
14:25:08:990	553	4	2561	25190	NewTx	ACK	6	QPSK	7	137	48	9	5	0	25	0	63	3	9
14:25:08:991	553	5	2561	25190	NewTx	ACK	7	QPSK	7	137	48	[illegible]	[illegible]	[illegible]	26	0	63	3	9
14:25:08:992	553	6	2561	25190	[illegible]	[illegible]	[illegible]	QPSK	7	137	48	[illegible]	[illegible]	[illegible]	27	[illegible]	63	2	9
14:25:08:993	553	7	2561	25190	NewTx	ACK	1	QPSK	7	137	48	[illegible]	[illegible]	[illegible]	27	0	63	2	9
14:25:08:994	553	8	2561	25190	[illegible]	DTX	2	QPSK	6	117	48	9	-18	[illegible]	27	0	63	2	9
14:25:08:995	553	9	2561	25190	ReTx: 4	DTX	3	QPSK	6	117	48	9	-20	-14	28	1	63	2	9
14:25:08:996	554	0	2561	25190	ReTx: 1	ACK	4	QPSK	6	117	48	9	-12	-12	29	1	63	2	9
14:25:08:997	554	1	2561	25190	NewTx	ACK	5	QPSK	7	185	42	12	9	0	0	1	63	2	12
14:25:08:998	554	2	2561	25190	NewTx	ACK	6	QPSK	7	185	48	12	11	2	1	1	63	2	12
14:25:08:999	554	3	2561	25190	NewTx	ACK	7	QPSK	7	185	48	12	10	[illegible]	[illegible]	[illegible]	63	2	12
14:25:09:000	554	4	2561	25190	NewTx	ACK	0	QPSK	7	185	48	12	5	[illegible]	[illegible]	[illegible]	[illegible]	2	12
14:25:09:001	554	5	2561	25190	NewTx	ACK	1	QPSK	7	185	48	12	10	[illegible]	[illegible]	[illegible]	[illegible]	2	12
14:25:09:002	554	6	2561	25190	ReTx: 3	DTX	2	QPSK	6	117	48	9	-16	[illegible]	[illegible]	[illegible]	[illegible]	2	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NewTx	ACK	3	QPSK	7	185	48	12	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48	12	11	8	4	1	63	2	12
14:25:09:005	554	9	2561	25190	NewTx	ACK	5	QPSK	7	185	48	12	9	10	5	1	63	2	12
[illegible]	555	0	2561	25190	[illegible]	ACK	6	QPSK	7	185	48	12	5	12	6	1	63	2	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QPSK	7	185	42	12	8	14	7	1	63	2	12
14:25:09:008	555	2	2561	25190	NewTx	ACK	0	QPSK	7	185	48	12	4	16	8	1	63	2	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ACK	1	QPSK	7	185	48	12	11	16	8	1	63	2	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QPSK	6	117	48	9	-16	18	9	1	63	2	12
14:25:09:011	555	5	2561	25190	NewTx	ACK	3	QPSK	7	185	48	12	11	20	10	1	63	2	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	185	48	12	10	22	11	1	63	2	12
14:25:09:013	555	7	2561	[illegible]	[illegible]	ACK	5	QPSK	7	185	48	12	11	24	12	1	63	0	12
14:25:09:014	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ACK	6	QPSK	7	185	48	12	12	26	13	1	63	0	12
14:25:09:015	555	9	2561	25190	NewTx	ACK	7	QPSK	7	185	48	12	3	28	14	1	63	0	12
14:25:09:016	556	0	2561	25190	NewTx	ACK	0	QPSK	7	185	48	12	3	30	15	1	63	0	12
14:25:09:017	556	1	2561	25190	NewTx	ACK	1	QPSK	7	185	42	12	11	30	15	1	63	0	12
14:25:09:018	556	2	2561	25190	NewTx	ACK	2	QPSK	7	185	48	12	11	32	16	1	63	0	12
14:25:09:019	556	3	2561	25190	NewTx	ACK	3	QPSK	7	185	[illegible]	[illegible]	[illegible]	[illegible]	17	1	63	0	12
14:25:09:020	556	4	2561	25190	NewTx	DTX	4	QPSK	7	185	48	12	-17	36	18	1	63	0	12
14:25:09:021	556	5	2561	25190	NewTx	DTX	5	QPSK	7	185	[illegible]	[illegible]	[illegible]	[illegible]	19	1	63	0	12
14:25:09:022	556	6	2561	25190	NewTx	DTX	6	QPSK	7	185	48	12	-16	40	20	1	63	0	12
14:25:09:023	556	7	2561	25190	NewTx	DTX	7	QPSK	7	185	48	12	-16	[illegible]	21	1	63	0	12
14:25:09:024	556	8	2561	25190	NewTx	DTX	0	QPSK	7	185	48	12	-15	44	[illegible]	[illegible]	[illegible]	0	12
14:25:09:025	556	9	2561	25190	NewTx	ACK	1	QPSK	7	185	48	12	10	46	23	[illegible]	63	0	12
14:25:09:026	557	0	2561	25190	NewTx	ACK	2	QPSK	7	185	48	12	7	48	24	[illegible]	[illegible]	0	12
14:25:09:027	557	1	2561	25190	NewTx	DTX	3	QPSK	7	185	42	12	-15	48	25	1	63	0	12
14:25:09:028	557	2	2561	[illegible]	ReTx: 1	DTX	4	QPSK	7	185	48	12	-19	[illegible]	[illegible]	1	63	0	12
14:25:09:029	557	3	2561	25190	ReTx: 1	DTX	5	QPSK	7	185	48	12	-16	48	27	1	63	0	12
14:25:09:030	557	4	2561	[illegible]	[illegible]	[illegible]	6	QPSK	[illegible]	[illegible]	[illegible]	12	-14	48	28	1	63	0	12
14:25:09:031	557	5	2561	25190	ReTx: 1	DTX	7	QPSK	7	185	48	12	-19	48	29	1	63	0	12
14:25:09:032	557	6	2561	25190	ReTx: 1	DTX	0	QPSK	7	185	48	12	-15	50	30	1	63	0	12
14:25:09:033	557	7	2561	25190	NewTx	DTX	1	QPSK	8	277	48	16	-18	0	0	1	63	0	16

CurrentMcs >= eUlLaLowMcsThr + eUlLaDeltaMcs = 4 + 3 = 7

ATB Trigger #1: Periodic when ttiEventCounter = eUlLaAtbPeriod (30 here)

LTE MAC calculates actual BLER:
rrmEUlLaBler = rrmEUlLaNacksInAveWin / eUlLaBlerAveWin= 1/30=3% which is < 10%

Being in bad RF goes to better RF conditions …

if (BLER =< blerTarget and MAX_NUM_PRB < ulChBw and CurrentMcs >= eUlLaLowMcsThr + eUlLaDeltaMcs)

// increases PRB amount by factor eUlLaPrbIncDecFactor

Set MAX_NUM_PRB = MAX_NUM_PRB / eUlLaPrbIncDecFactor [= 9 / 0.8~12]

//as calculated in RRM.4066 for the SlowATB filter input

GET MaxNumPRB_PHR [say x, since this is not shown in tti trace but calculated internally as old RL20 ATB]

MAX_NUM_PRB = min (max (MAX_NUM_PRB, MaxNumPRB_PHR), ulChBw)) [=max(12,x,1)=12]

else do nothing // OLLA only shall act under this condition

RRMNumofTrans in eULLA updates for NewTX including DTX, but not for RsTx

RRMNumofNack in eULLA updates for both NewTx and ReTX Nack, but not for DTX

CurrentMcs >= eUlLaLowMcsThr + eUlLaDeltaMcs > 4 + 3 > 7

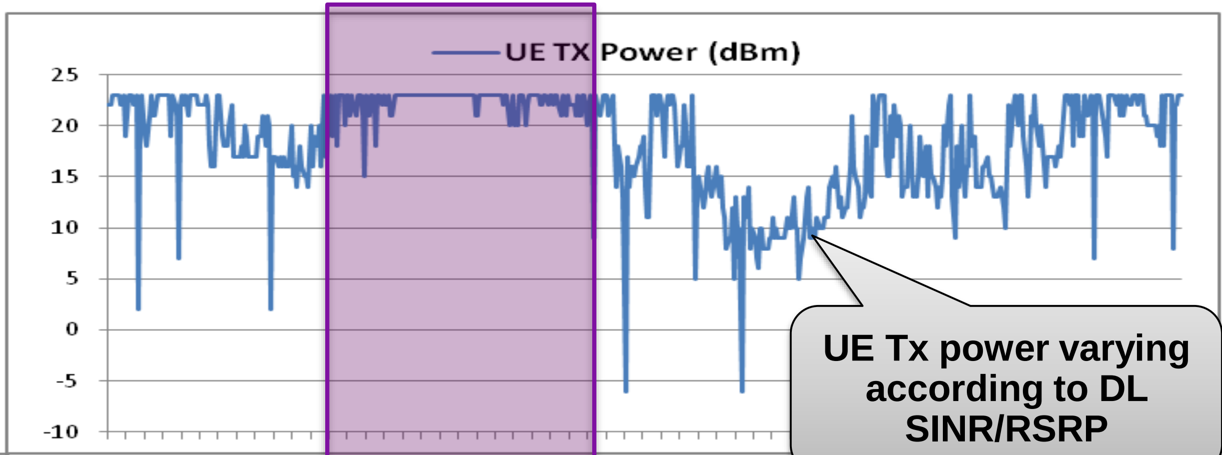
PRB increased: 12/0.8=16

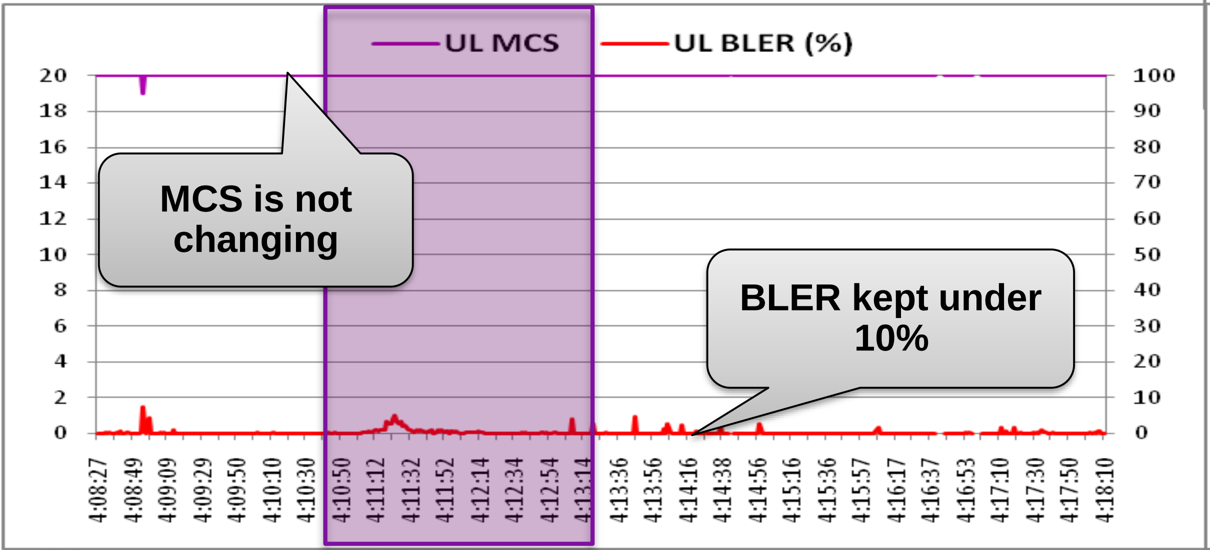
Trial tests show inefficient RL10 ATB behaviour

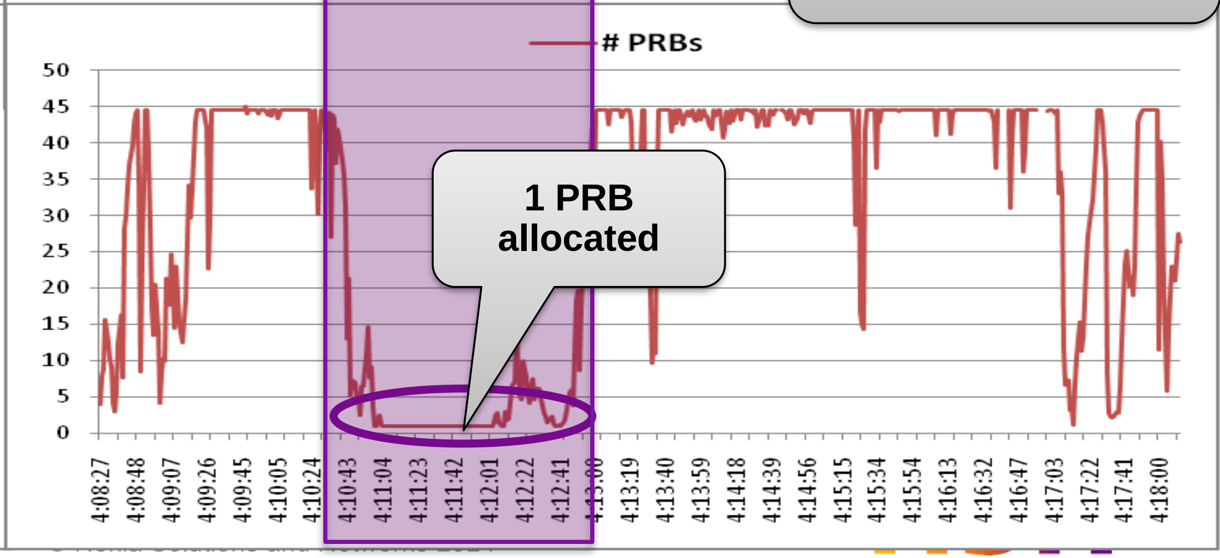
- When **UE Power reaches the maximum**, **eNB allocates only 1 PRB** in UL, decreasing throughput, **when MCS is not decreased** (always 20)
- *Avg UL SINR = 21.07dB*

BLER → **OLLA (MCS)** →

PHR → **ATB (#PRBs)** ↘

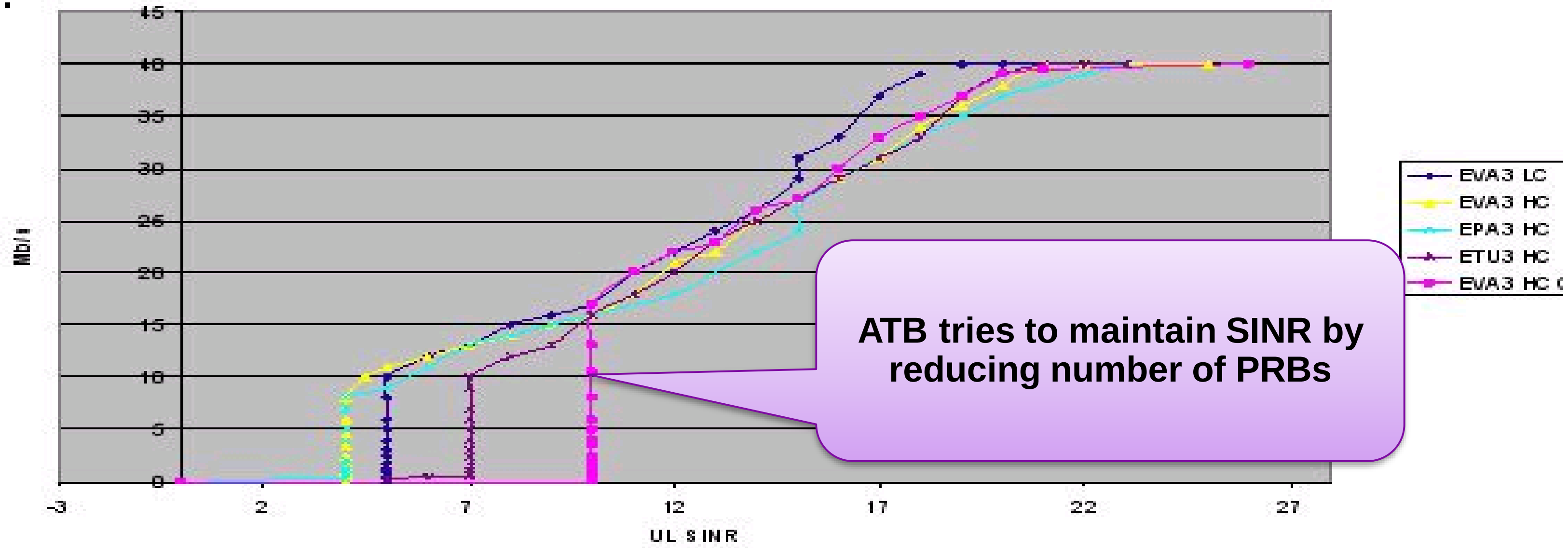






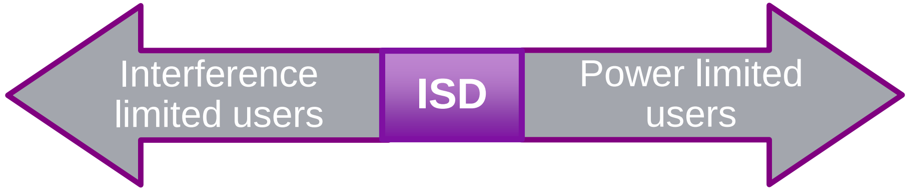
Telstra observations

- Service contour tests yielded **lower than expected** maximum allowable TPLs, particularly the 3 Mbps nominal throughput target. Some **strange behaviour** was observed with throughput to SINR curves
- To get a **full throughput vs SINR** curve, it was necessary to **prevent the UE issuing power headroom reports** that approach 0% by **fixing attenuation** for the DL such that the DL always had “good” TPL / SINR, while the TPL / SINR was varied independently for the UL. **As a side effect,** the normal functioning of ULPC was also interrupted (since the DL path loss was fixed).



- UL Power Control parameters (P_0, α) for PUSCH
- Scenario type – inter-site distance (ISD).

Strictly internal !



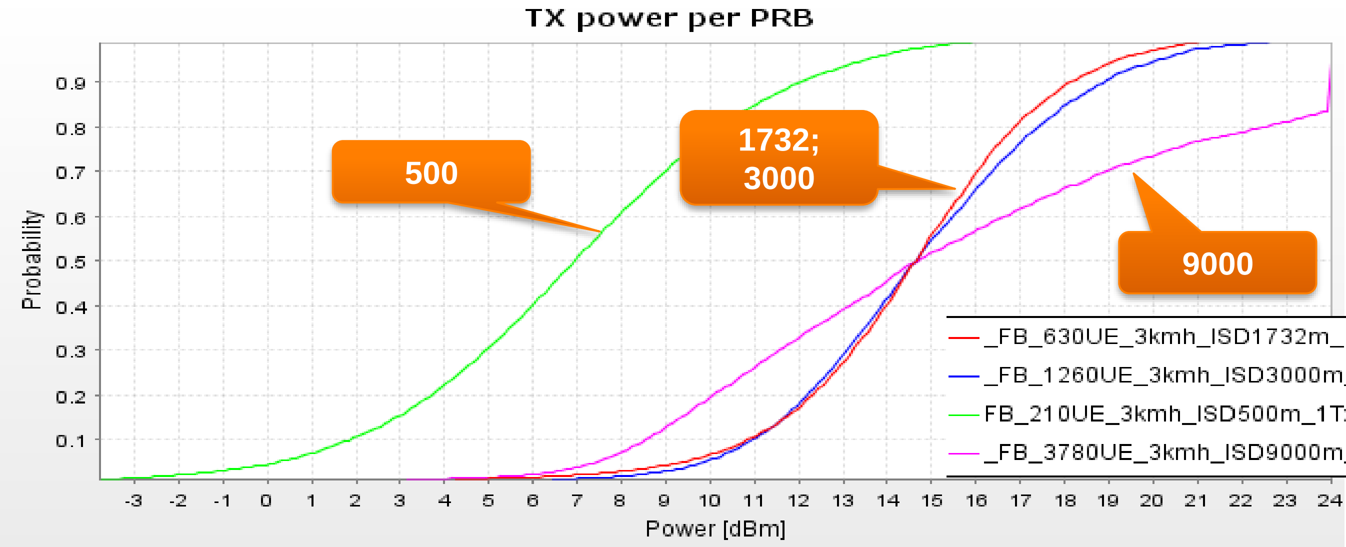
Solutions

RL10-RL20

Simple **extension of the SlowATB** algorithm which **reduces** the reported **PHR** value by a fixed amount (=15 dB) (***PHR shift*** R&D parameter - it couldn't be fine tuned)

RL30

- **E-ULA** – It **postpones ATB activation** and choose most robust PRB/MCS configuration

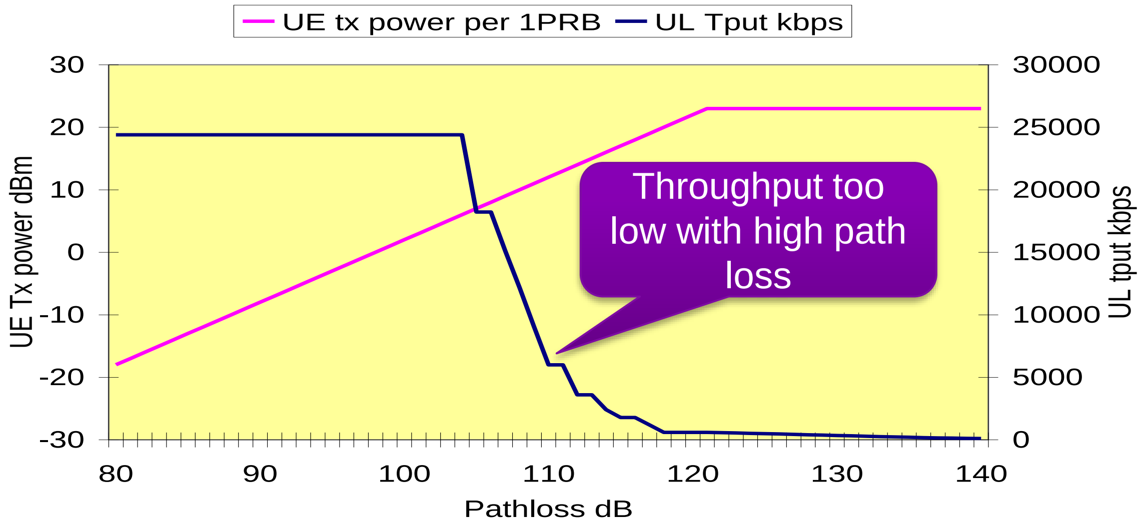


ISD [m]	P0	Alpha
500	-58 dBm	0.6
1732	-61 dBm	0.6
3000	-64 dBm	0.6
9000	-67 dBm	0.6

ATB behaviour highly depends on UE transmission power

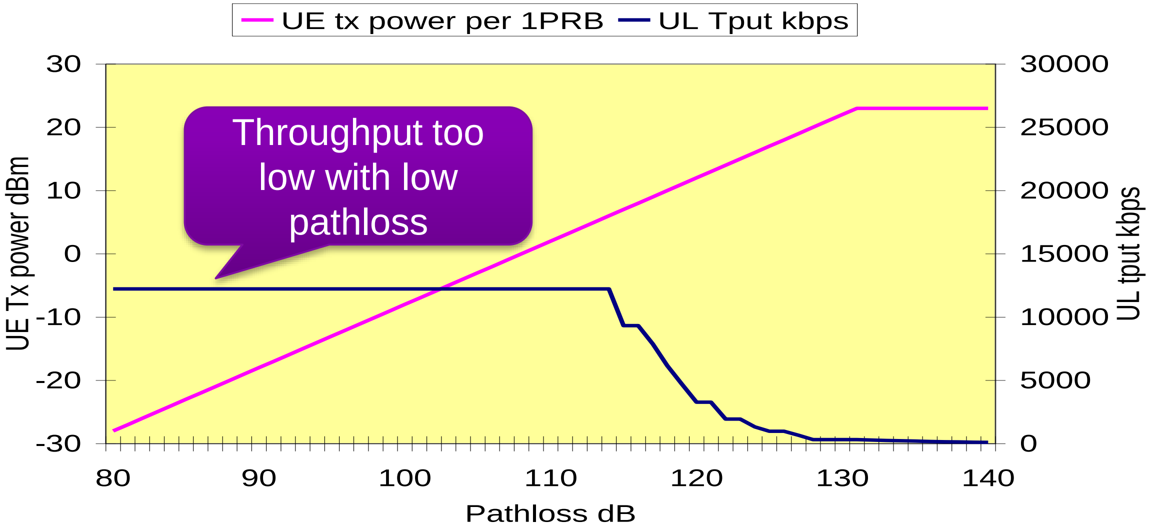
High P_0

- Too low number of PRBs is used with high path loss because ATB tries to maintain SINR



Low P_0

- Too low SINR is used close to BTS



- **Default value of P_0** is quite **low** (-100 dBm or -96 dBm) and does **not provide the maximum** peak rates when close to BTS. It would be better to provide higher SINR values.
- **High value** of **P_0 reduces the number of PRBs** when UE runs out of power.

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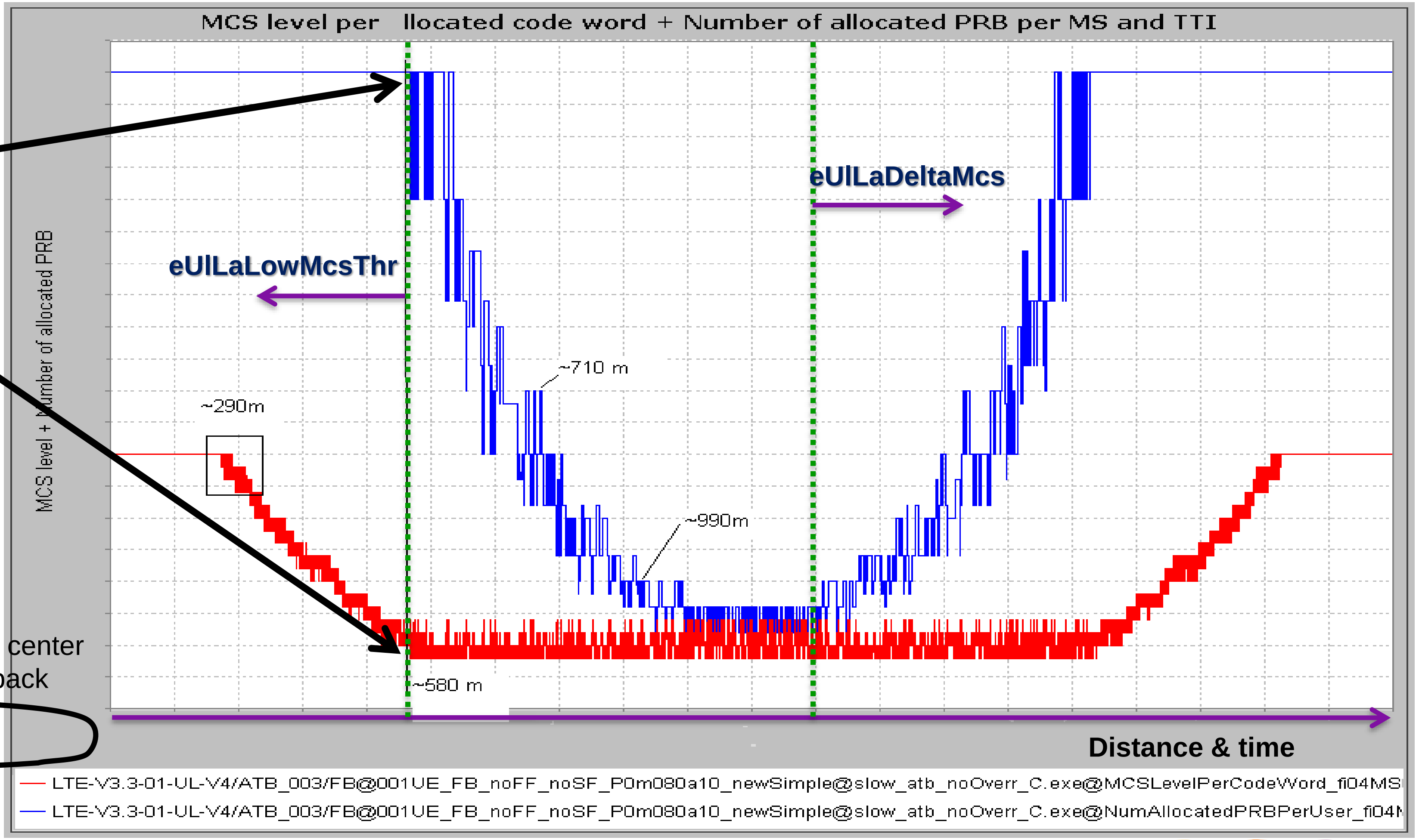
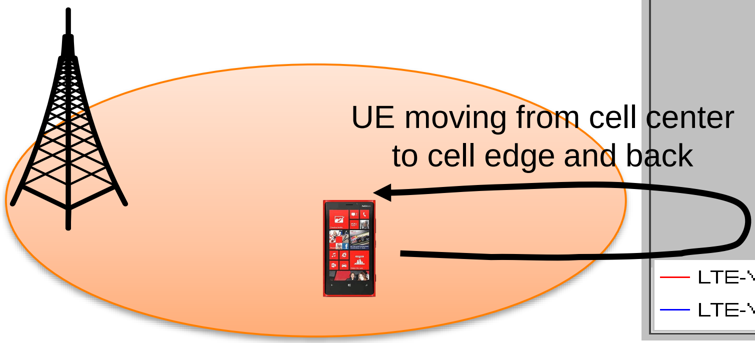
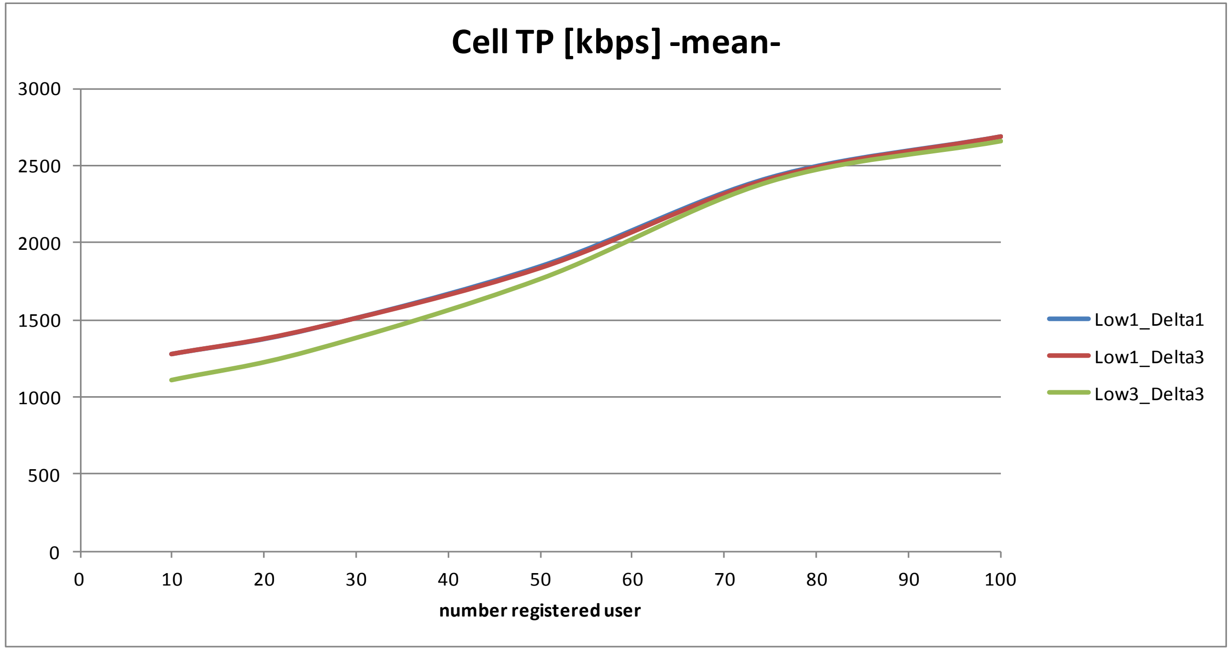
The simulation with the new algorithm shows a UE moving from cell center to cell edge and back

The figure shows that the **Number of allocated PRBs** are changing only when **MCS index** has reached the lowest possible value and UE keep moving to the cell border, according with our expectations



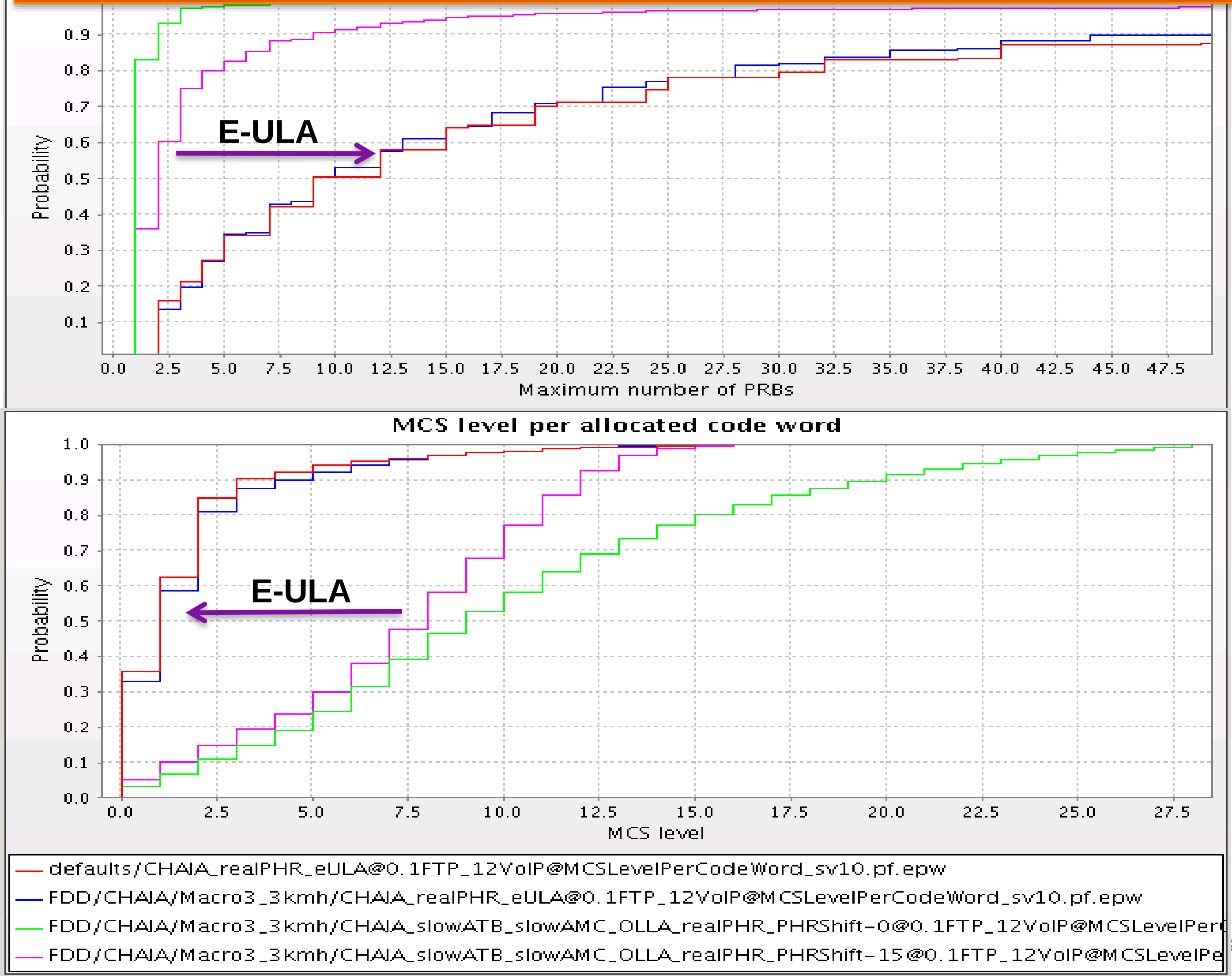


- Further simulations for the E-ULLA settings shown, that parameters have **minor influence on the system capacity**
  - Increasing *eUlLaDeltaMcs* has shown no effect at all.
  - Changing *eUlLaLowMcsTh* resulted in small changes only. 3 is behaving worse than 1 in low loaded cells which can be explained with Shannon.



Reference [6]

With E-ULA mobile gets more PRBs while lowering the MCS level



- Red and blue lines represent simulation wit E-ULA
- Green – old SlowATB
- Pink – old SlowATB with PHR shift

- Results show that with E-ULA probability of getting more PRB increases and at the same time MCS level is lower
- Thus, simulation results follow E-ULA algorithm assumptions

Macro3 (ISD 1732)
Extreme low load conditions:
0.1 FTP + 12 VoIP user / cell

nsn

Benefits and Gains

Conclusions

End-user benefits

- It **improves performances** in case of **high P0 settings** (which are required to transmit peak data rates) **retarding the reduction of the maximum number of allocable PRBs** and improving consequently throughput performances (especially when under very low load condition in the cell).

Operator benefits

- The E-ULA algorithm makes the eNodeB **less sensitive to wrong P0 settings**
- It introduces a more power efficient strategy trying, when possible, to transmit with a bigger number of PRBs and lower MCS level according required data rate. This is especially advantageous with power limitations.

Comparison between slowATB with PHR shift and E-ULA:

With E-ULA slightly better (< +10%) capacity can be achieved, escpecially in small cells

slowATB gives better coverage specifically in Macro3 cells with low loads.
In general the difference is below 10%.

E-ULA field verification

- Test Execution
  - Single Isolated cell UL UDP drives were executed along main lobe of ATC site in order to measure performance gain in different radio conditions from E-ULA feature
  - Drive with E-ULA disabled was performed with RL20 , however no gain is expected from IAS since All 3 Scheduling areas were seen to measure the same interference (-119dBm)

Test cases

P1_Cc31 (Test 51):Link budget drive with only ATC on air with UL UDP throughput. (E-ULA on)

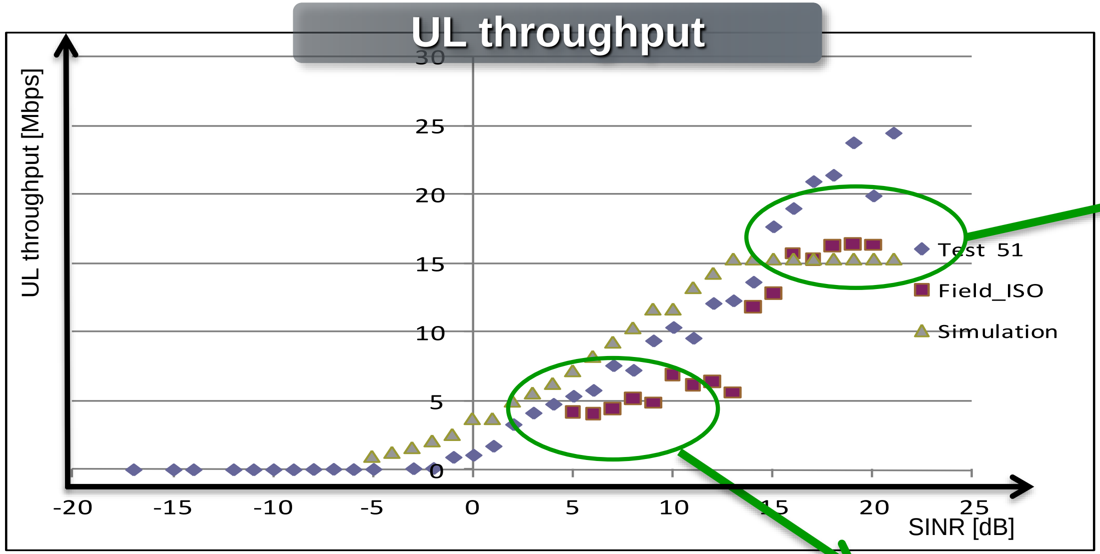
C1_ccX : Macro cell Link Budget Isolated Drive with UL UDP throughput. No E-ULA

E-ULA field verification brought expected benefits

Objective: Verification of E-ULA and compare the performance of the UE with and without this feature.

Results: Higher gains observed at the cell edge with this feature turned, as expected.

The UL throughput vs. SINR curve is closer to the ETU70 simulation



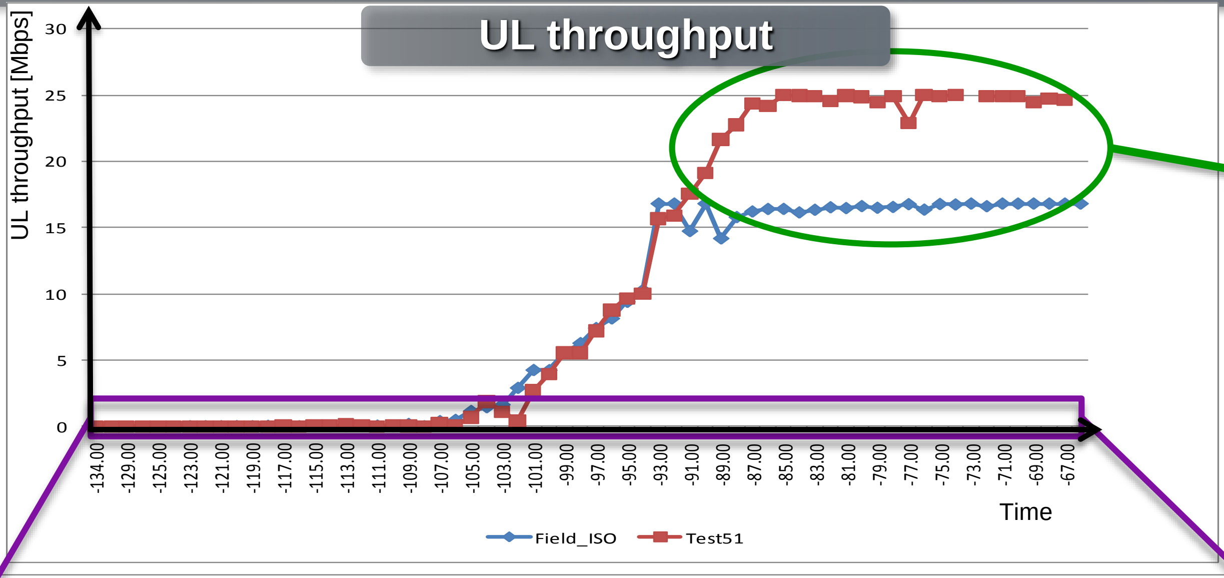
Higher throughput than simulation because simulation uses maximum MCS of 20 and in Test 51 the MCS goes to 24.

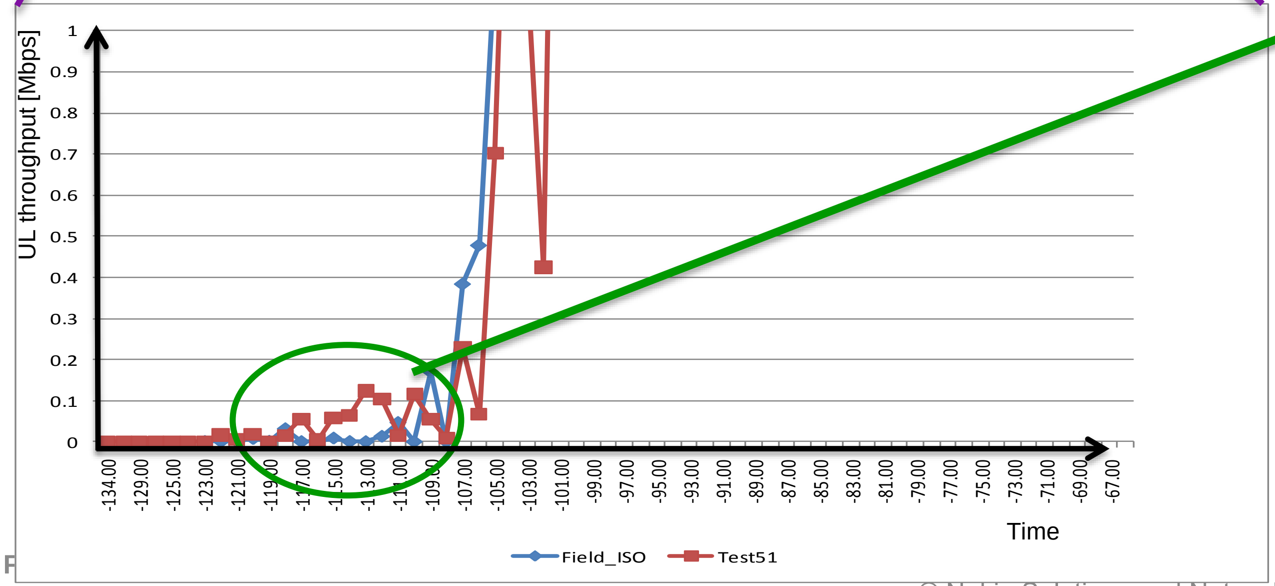
In Test 51 the curve is closer to simulation as compared to RL20 (without E-ULA)

***Test 51 :** Macrocell UL UDP Link budget drive with E-ULA*
***Field_ISO :** Macrocell UL UDP Link Budget drive without E-ULA*

Benefits and Gains

VzW RL30 Trial in Dallas: UL throughput





This is due to difference in MCS (24 vs. 20) and maximum PRB's which can be allocated to a single UE

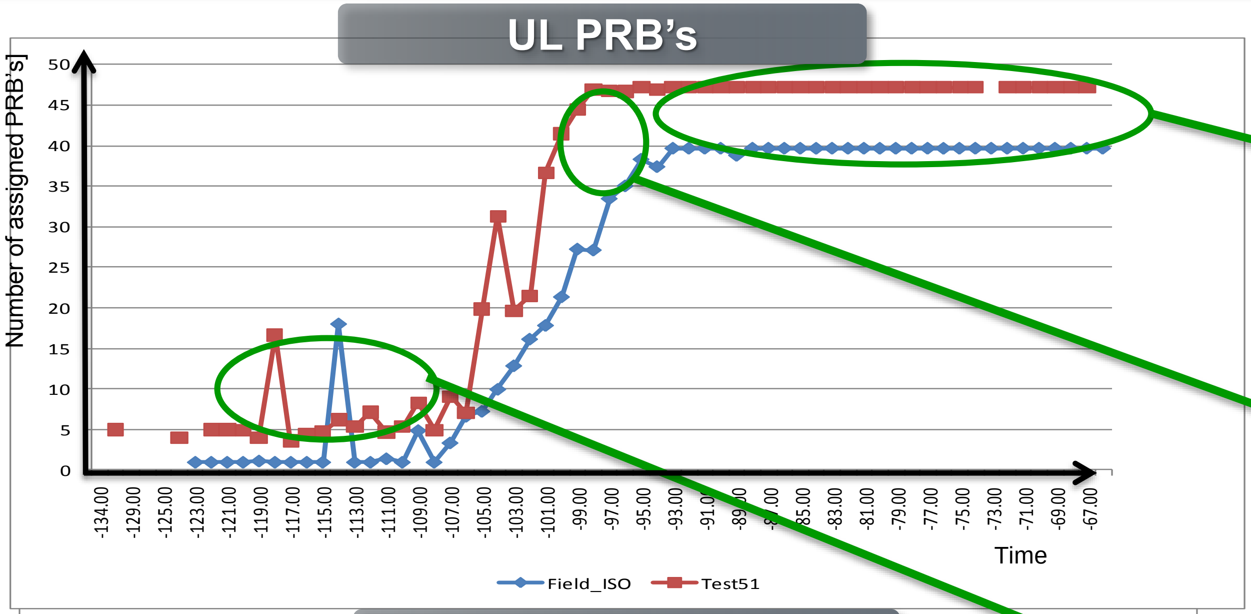
E-ULA has better Performance in the low RSRP area.

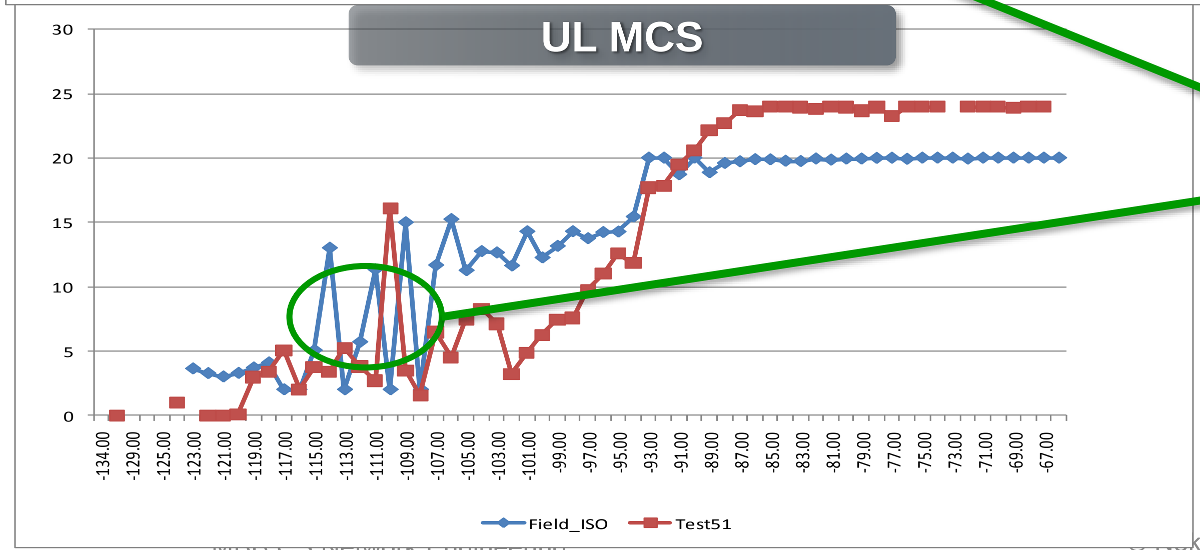
Test 51 : *Macrocell UL UDP Link budget drive with E-ULA*
Field_ISO : *Macrocell UL UDP Link Budget drive without E-ULA*

Benefits and Gains

VzW RL30 Trial in Dallas: UL PRB's and UL MCS

Main Menu





The difference is because settings for maximum number of PUCCH PRB's is different in the two cases. (Test 51 = 2, Field_ISO = 6)
Max PRB's available for Test 51 is 48 and for Field_ISO is 40.

Maximum PRB's allocated for longer time in Test 51 in sync with E-ULA.

The E-ULA gain at cell edge because information is now sent with lower MCS and higher PRB's

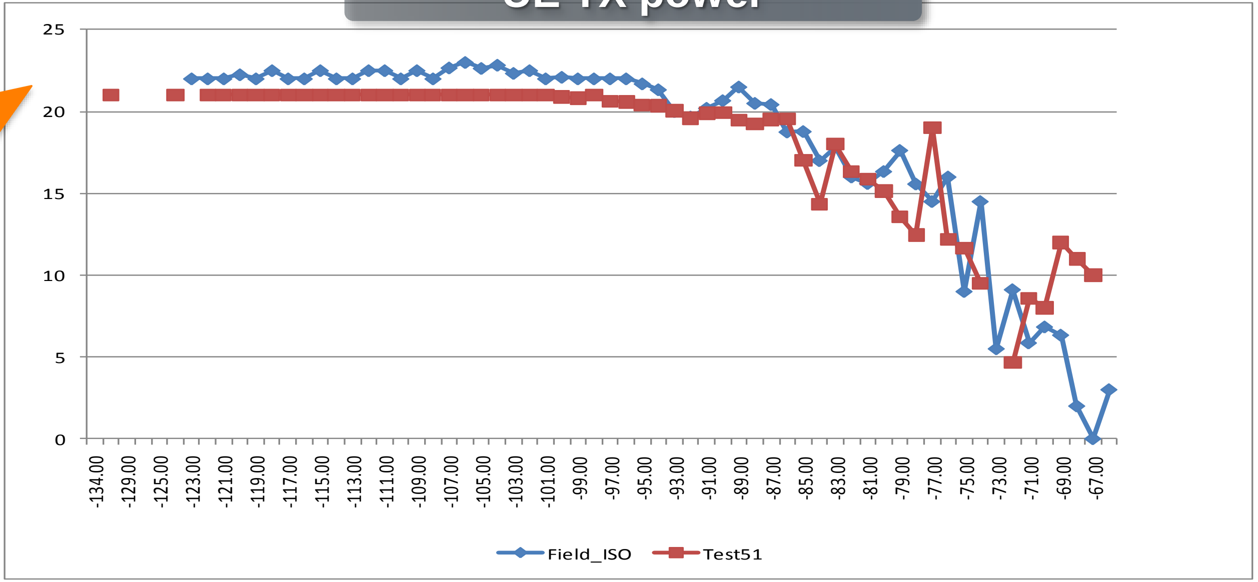
Test 51 : *Macrocell UL UDP Link budget drive with E-ULA*
Field_ISO : *Macrocell UL UDP Link Budget drive without E-ULA*

Benefits and gains

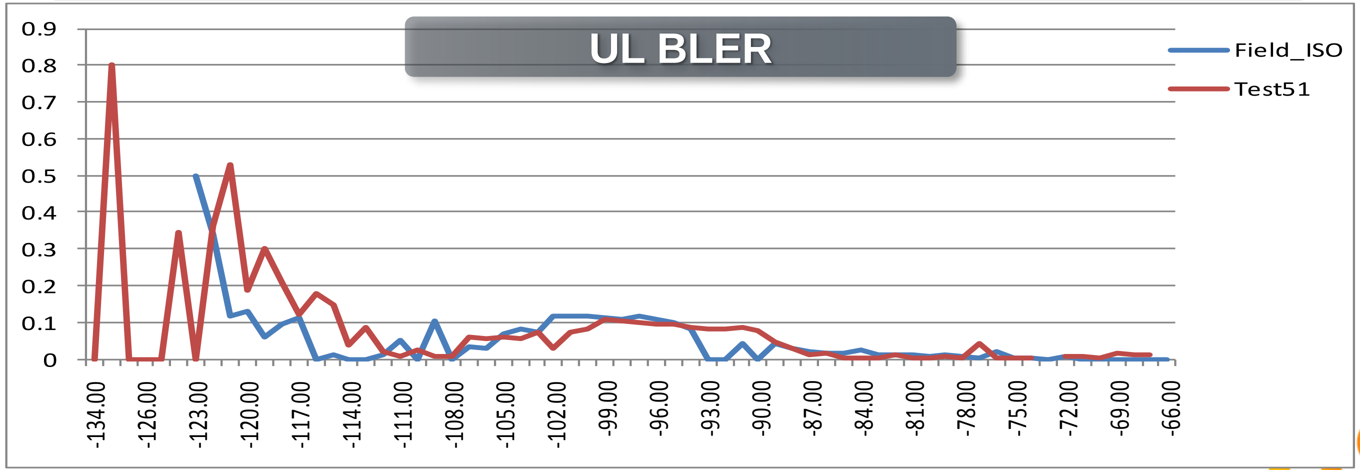
VzW RL30 Trial in Dallas: UE TX power and UL BLER

UL Tx Power was limited to 21 dBm for when test was executed with e-ULA on. Even with less UE TX power cell edge performance with E-ULA was better

UE TX power



UL BLER



***Test 51 :** Macrocell UL UDP Link budget drive with E-ULA*
***Field_ISO :** Macrocell UL UDP Link Budget drive without E-ULA*

Benefits and Gains

Comparison of UL PHR and UL BLER

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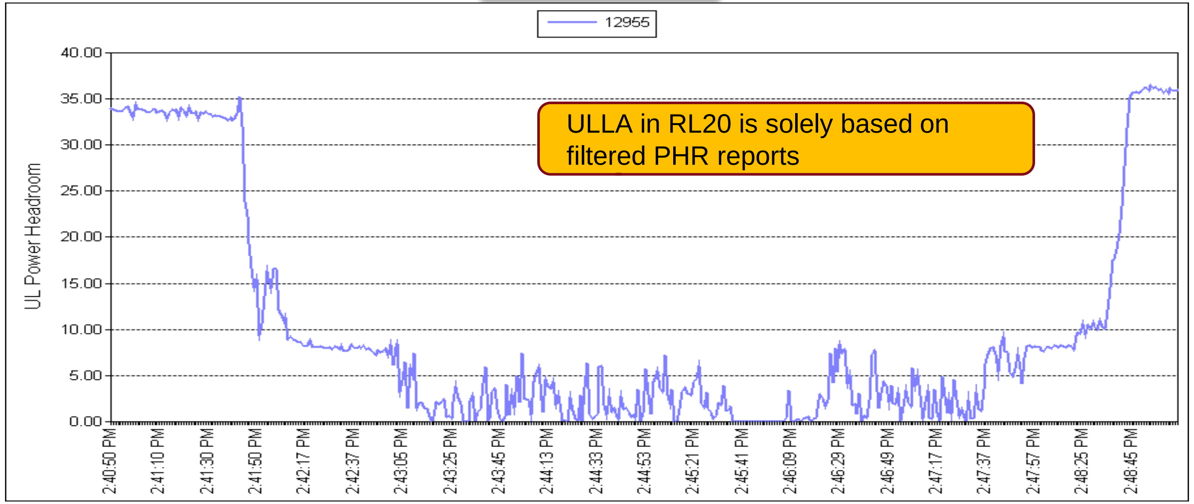
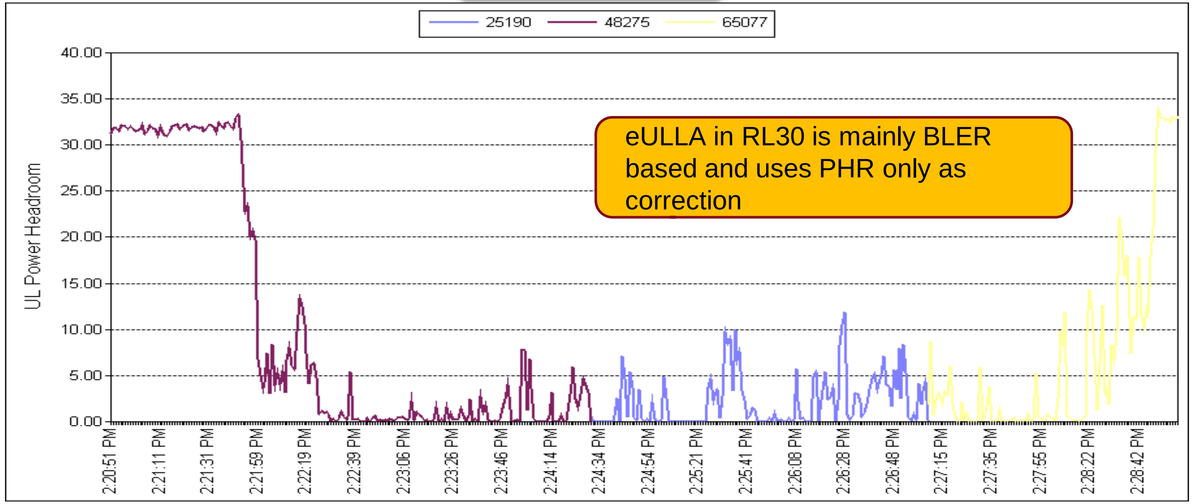
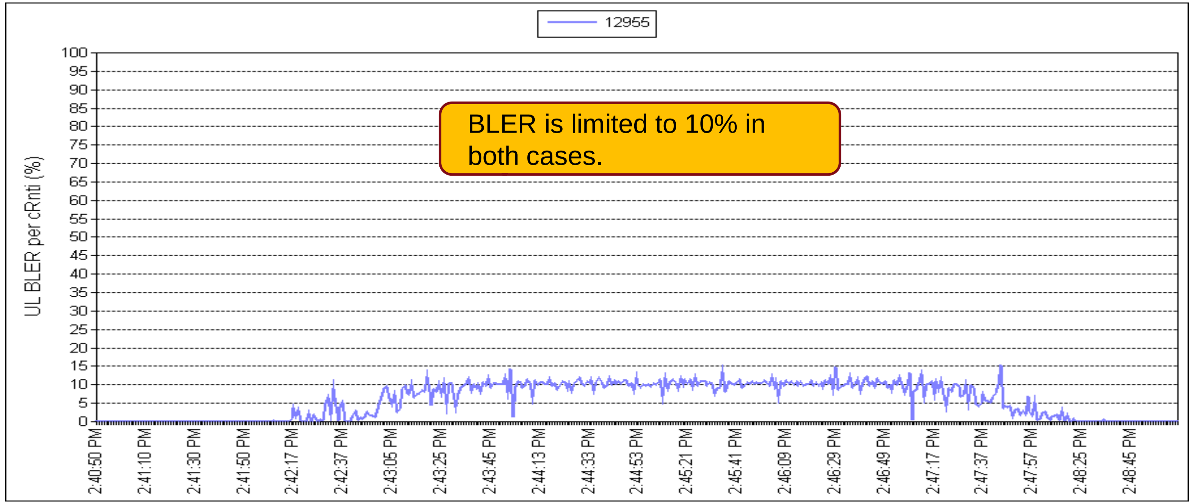
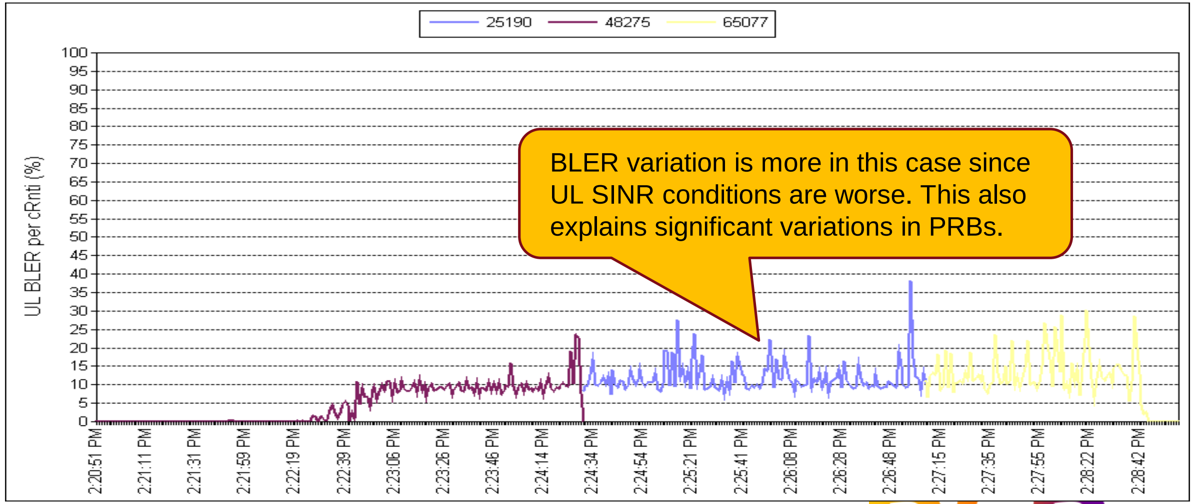
RL20 ULLA



RL30 eULLA





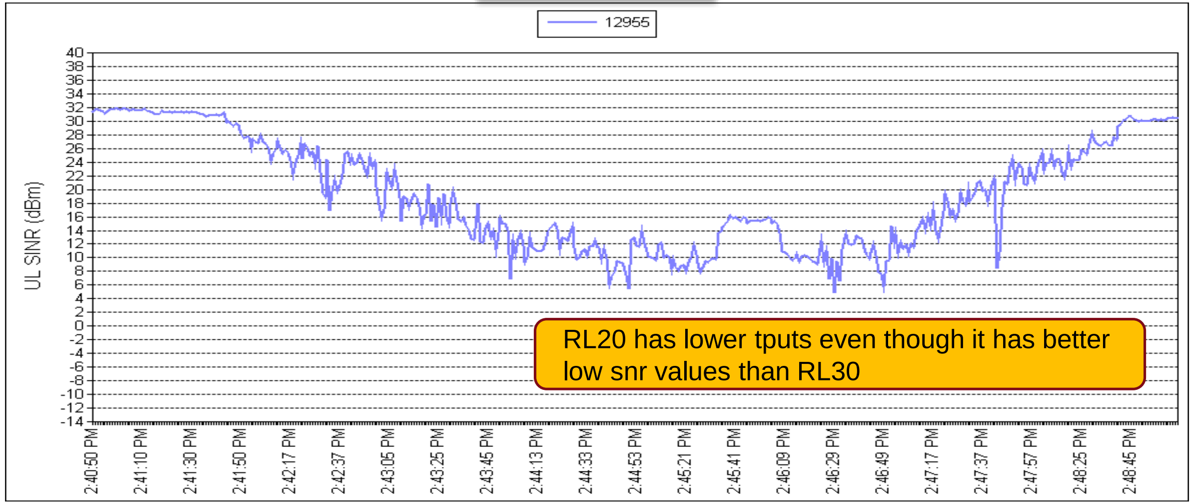


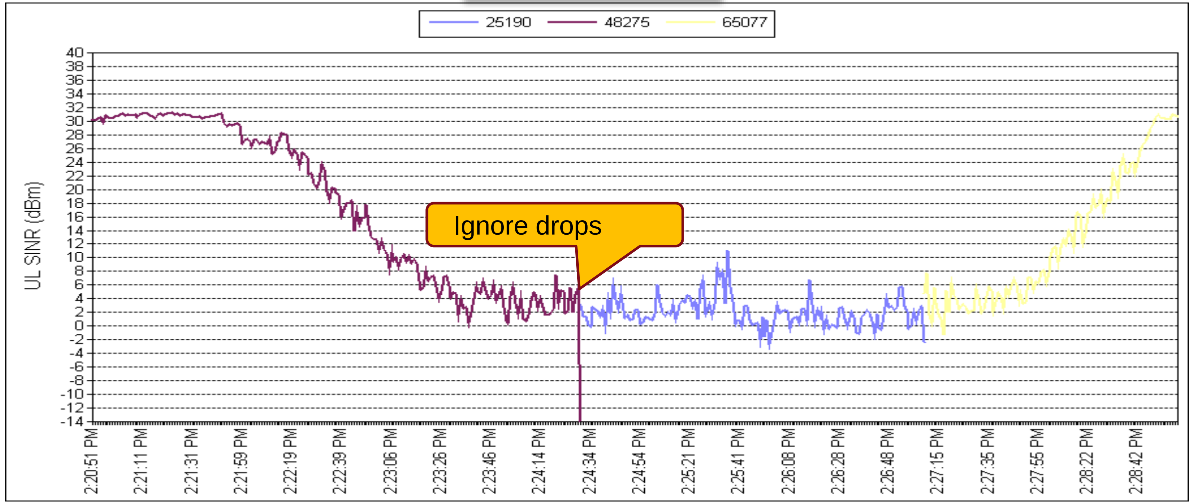
Benefits and Gains

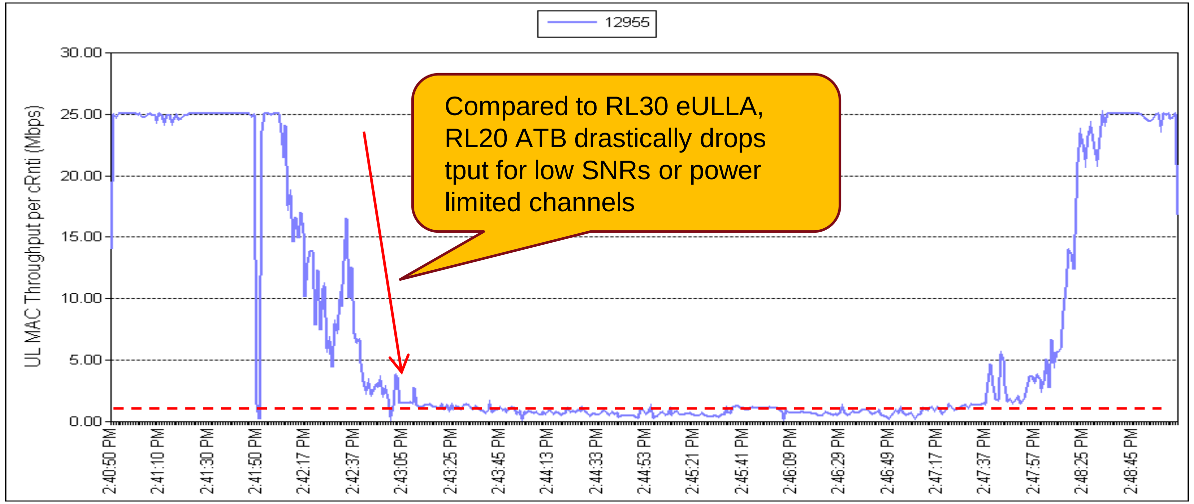
Comparison of UL SINR and UL Throughput

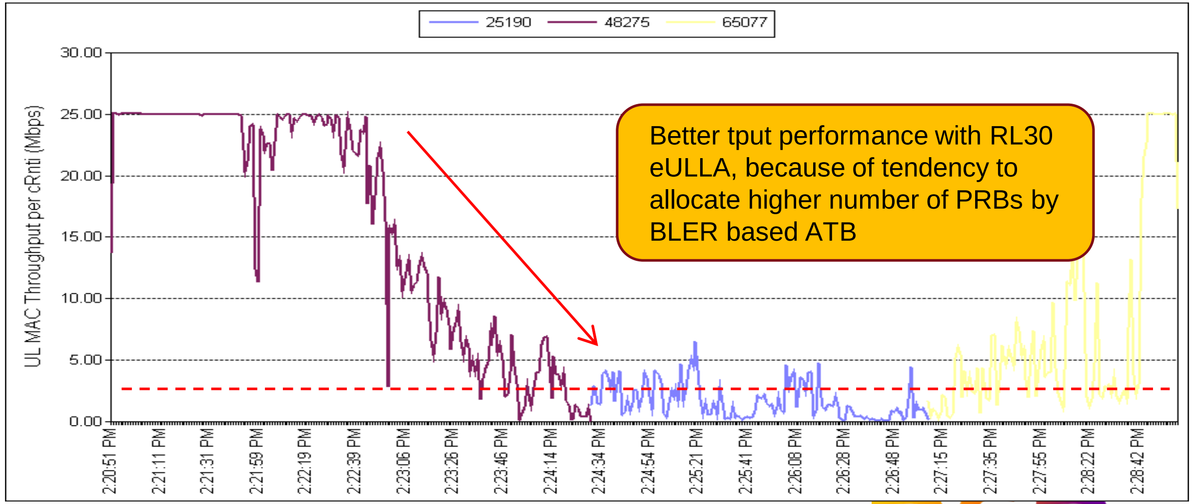
RL20 ULLA

RL30 eULLA









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Benefits and Gains

Comparison of UL MCS and UL PRB

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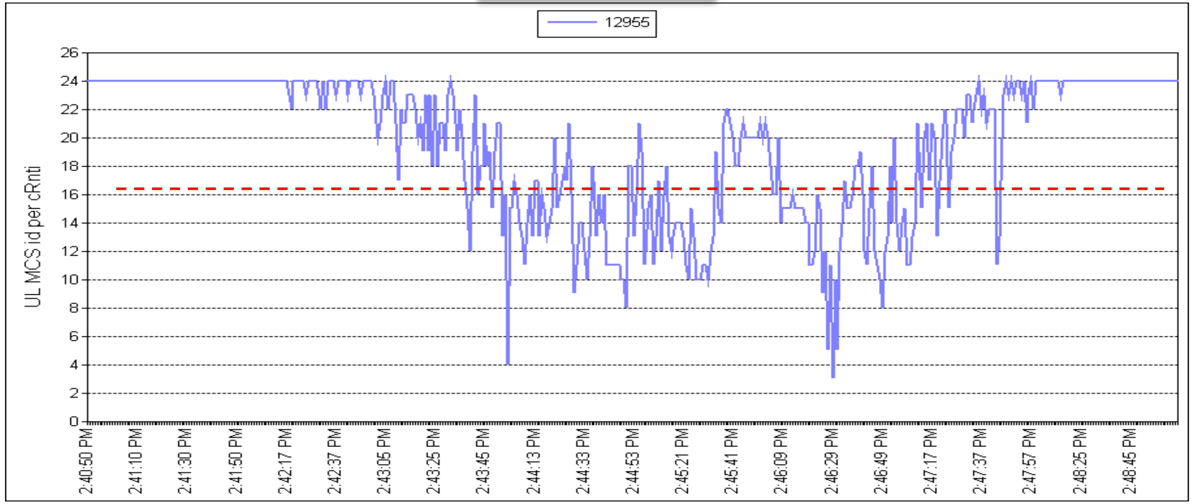
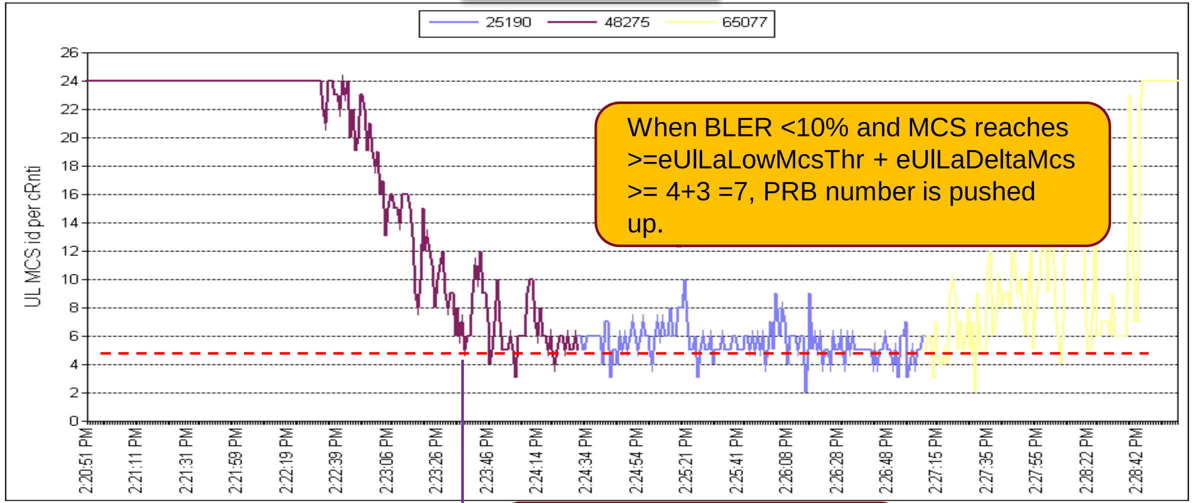
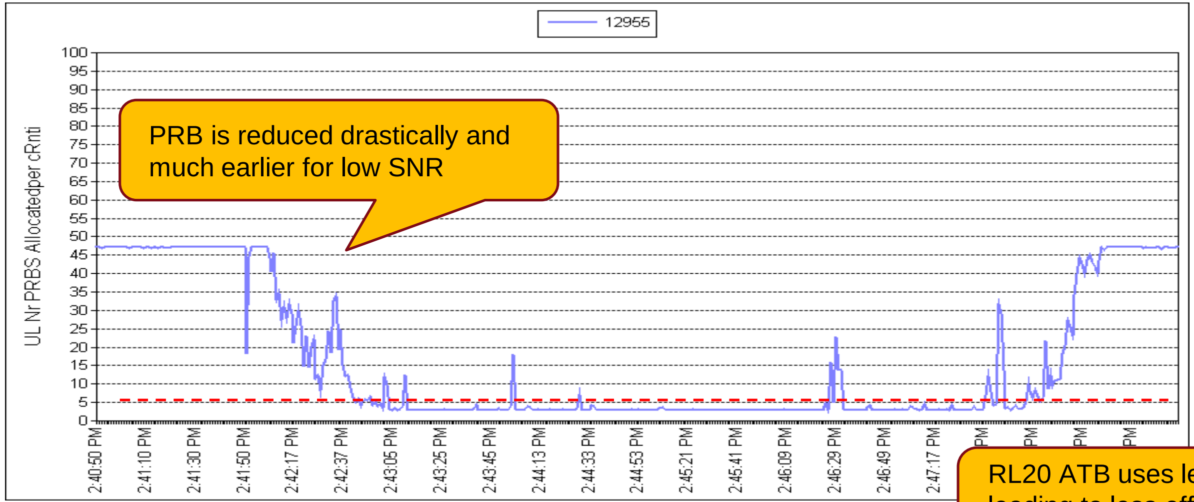
ToC

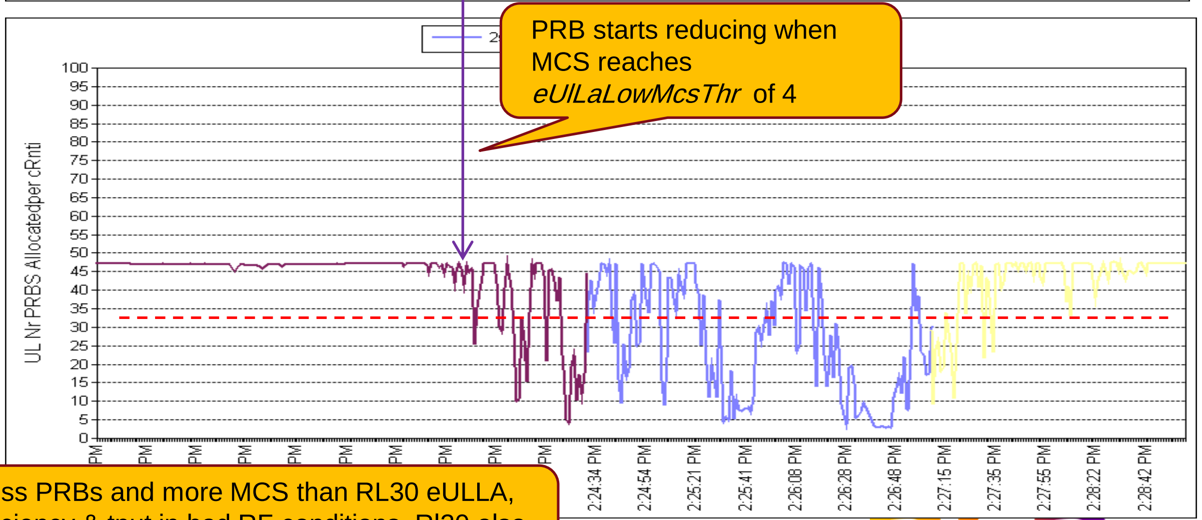
RL20 ULLA

RL30 eULLA







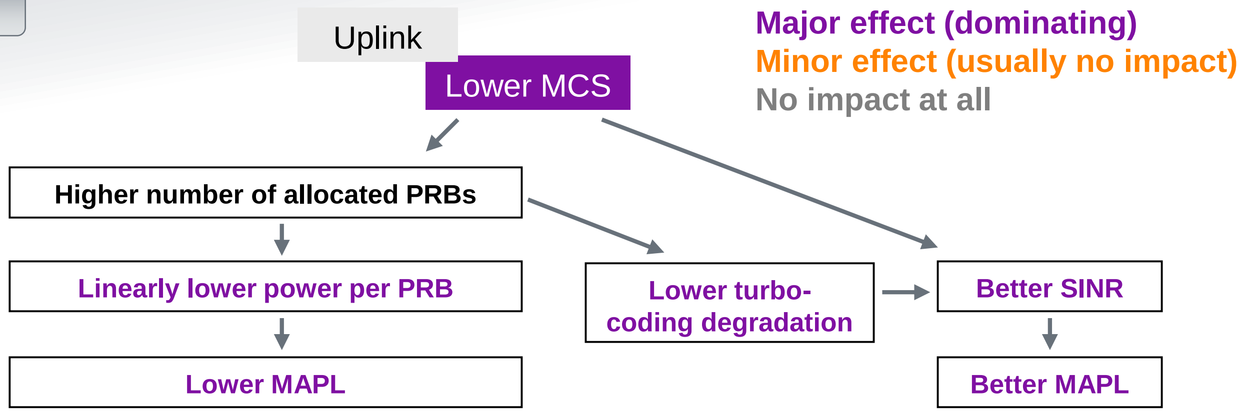


RL20 ATB uses less PRBs and more MCS than RL30 eULLA, leading to less efficiency & tput in bad RF conditions. Rl20 also provides better cell tput compared to eLA in RL30.

- Similarly as DL Link Adaptation, uplink MCS setting is considered in link budget as well as in capacity figures obtained from product aligned system-level simulator

DL basic effects impacting MAPL

Two effects significantly impact the MAPL. A trade-off between the MCS level and the number of allocated PRBs is needed. The MCS can be lowered to some extent only.



Performance Aspects

Performance counters for UL Link Adaptation

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- LTE cell load measurements family (M8001) and cell throughput (M8012), can be used to verify DL-AMC performance
- Histogram distribution of specific MCS usage can be drawn for every cell (next slide)

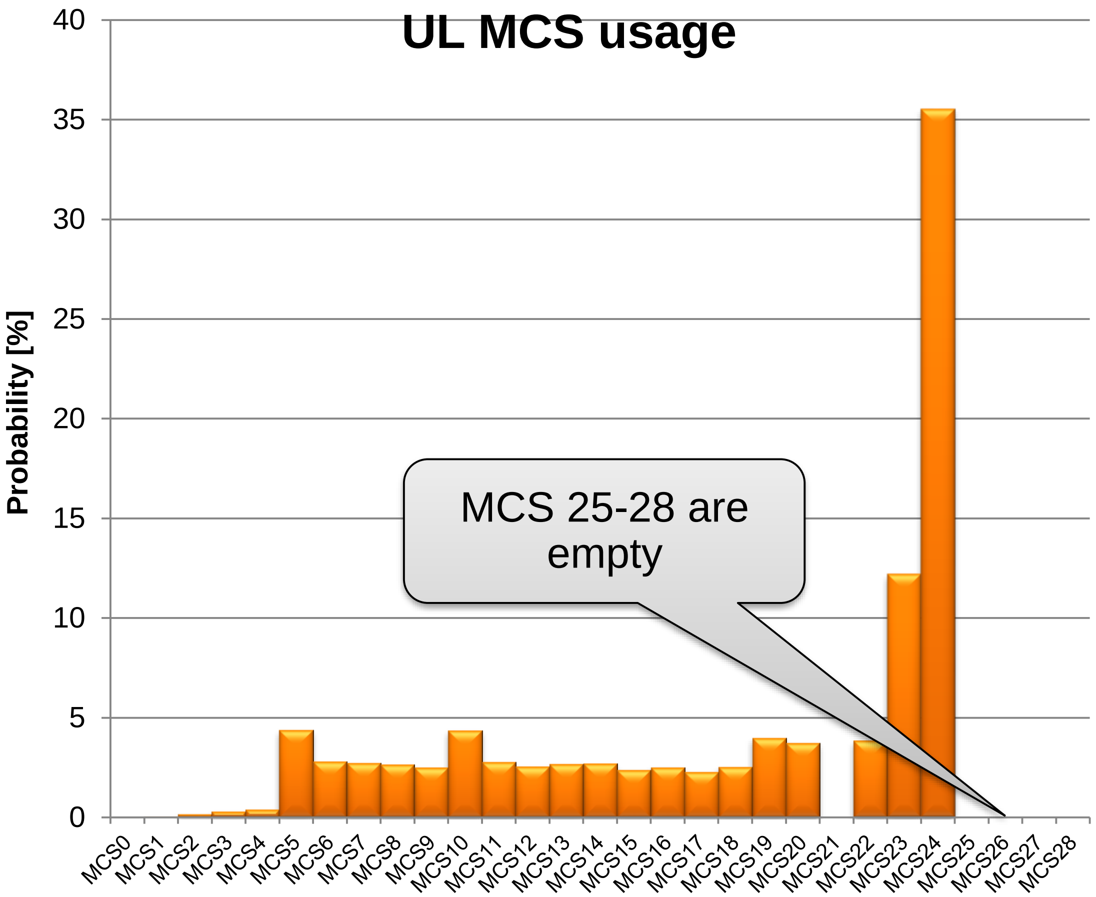
Note
Counters MCS 25-28 will always be empty with currently available terminal classes, not supporting 64QAM

Abbreviated Name	Description	Comment
PUSCH_TRANS_USING_MCSxx	• The number of transmissions on PUSCH over the measurement period using MCSxx	The counter is updated when MCSxx is used for transmission. SIB, Paging and RA response excluded.
PUSCH_TRANS_NACK_MCSxx	• The number of unacknowledged transmissions on PUSCH using MCSxx	
TB_BAD_PUSCH_MCSxx	• number of unsuccessful transmissions on PUSCH using MCSxx • Only not transmitted TBs exceeding max HARQ retransmissions are considered.	This counter is updated when the maximum number of HARQ retransmissions has been exceeded for the TB.
TB_VOL_PUSCH_MCSxx	• volume (kbytes) of MAC PDUs on PUSCH transferred by using MCSxx • The volume of MAC PDUs is considered.	This counter is updated when MAC PDU is scheduled. Retransmissions are included.
TB_BUNDyy_NACK_PUSCH_MCSxx	• The number of negative acknowledged transmissions with bundle size yy using MCSxx on PUSCH.	The counter is updated in each TTI scheduling period when bundle NACK received on PUSCH using bundle size yy from MCSxx
PUSCH_1ST_TRANS_NACK_MCSxx	• First transmission NACKs on PUSCH using MCSxx	The number of not acknowledged 1st transmissions on PUSCH for used Modulation and Coding Scheme.

Performance Aspects

Exemplary usage of counter data for MCS histogram

- The data from exemplary customer network shows that during 35% of the time maximum available MCS was used
- This can reflect very good radio conditions resulting from low network load



Thank you for your attention!

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