Network Engineering
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Radio Link Failures principles in eNB: configuration and performance monitoring

Network Engineering Information

Krzysztof Wascinski, MBB CS NetEng

Radio Link Failures and call drop analysis

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Radio Link Failures and call drop analysis

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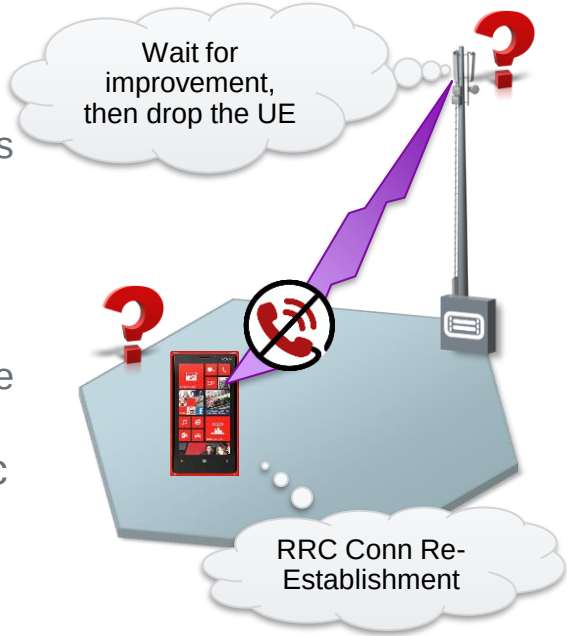
Main Menu

- Call drop ratio is one of the most important metrics used by operators to assess the performance of their networks
- It is the fraction of the phone calls (voice or data) which, due to technical reasons, were cut off before the parties had finished their conversation (or data transfer)
  - It is assumed to have direct influence on the customer satisfaction with the service provided by the network and its operator
  - The call drops are also referred as Radio Link Failures (RLF)
- The challenge of call drop measurement comes from the variety of reasons which may cause it:
  - Coverage issues
  - Sleeping cells
  - Wrong parameterization
  - UE malfunction
  - Synchronization issues
  - Handover failure
  - Transport inaccessibility
  - eNB reset
  - Physical layer problems
  - Etc…

- Due to that, **this slide set aims to collect the complete information about these aspects** with relation to counters/KPI and important parameters which may affect them

- The mechanisms dealing with RLF are implemented at both UE and eNB side
  - Due to the fact that we're not the vendor of the UE equipment, the analysis on its side is based only on 3GPP specification (final behavior is up to UE vendor)
  - eNB side is covered from NSN specification side
- The actions taken in such situation are different
  - UE initiates the RRC Conn Re-Establishment to recover
  - eNB will wait until the recovery (cancellation of RLF state), or release the UE
- The call drops can also be initiated by the eNB or MME in specific scenarios



Note:
This slide set considers only call drops triggered after successful connection setup valid for RL50. Drops during the call setup phase are out of scope of this slide set

- Stressed mobile networks are exposing the variation in the quality of the network connections across handset brands
  - the worst devices dropping, on average, more than 2.5 percent of all calls and data sessions
  - iPhones generally performed better than average on data
  - Blackberry devices were least likely to drop a voice call
  - No Lumia devices were included in the comparison
- 97 percent of subscriber issues come from data sessions, demonstrating the growth in data hunger amongst subscribers
  - Dropped data sessions can be the result of a range of factors, including: subscriber location; network capacity and congestion; interference; and the handset itself, where the quality of the radio can impact on the subscriber experience

Model	iPhone 4s	iPhone 5	iPhone 4	Galaxy S3	Galaxy S2	Galaxy S4	Blackberry 9900	Galaxy S3 mini	iPhone 3GS	Blackberry 9320
share of subscribers	16.87%	16.80%	14.64%	6.53%	3.77%	2.55%	1.91%	1.68%	1.61%	1.58%
Rank	1	2	3	4	5	6	7	8	9	10
Voice & data drops %	1.07	1.28	1.16	2.54	1.96	1.66	1.43	1.52	2.27	1.65
Voice & Data drops rank	1	3	2	10	8	7	4	5	9	6
Dropped data session rate relative to average	-31%	-57%	-17%	57%	5%	5%	35%	-25%	-61%	88%
Data drops rank	3	2	5	9	6	6	8	4	1	10
Dropped voice call rate relative to average	-17%	12%	-3%	25%	42%	12%	-17%	23%	-17%	-60%
Voice drops Rank	2	6	5	9	10	6	2	8	2	1

The top ten mobile devices ranked by subscriber share amounted to 82,994 subscribers, 68% of the total global subscriber base assessed by the research.

Source: http://www.actix.com/knowledge-centre/news/item/123-stressed-mobile-networks-demonstrated-in-dropped-calls.html

- UE can indicate that has detected radio link problems by starting RRC Connection Re-establishment
- eNodeB or MME can initiate abnormal S1 + RRC release due to various reasons
- HO failure triggered drops are covered in a separate chapter

Call drop reasons

UE detected Radio link problems	eNB Detected radio link problems	eNB initiated release
• T310 expiry • Maximum number of RLC retransmissions • Handover failure (T304 expiry) • Non-HO related random access problem	• PUSCH RLF • CQI RLF • HARQ RLF • SRS RLF • PDCCH Order failure	• TA Timer Expiry at eNB or UE • Maximum RLC Retransmissions Exceeded at eNB • GTP-U failure at eNB • S1 reset • Lack of DRB ID
•Parameter values configured in the eNB and signaled to the UE •Almost no PM counters ! (only RRC Connection Re-establishment)	**•Parameterized in the eNB (R&D parameters) •Partially covered by the PM counters**	**•Parameterized in the eNB (customer parameters) •Partially covered by the PM counters**

- In the following slides, the special notation is used to ease the study:

- **Parameters** are highlighted by colors
  - *MOC:Normal parameters → configurable via e.g. BTS Site Manager*
  - *MOC:Hidden parameters → configurable only by vendor file*
  - *R&D parameters → hardcoded in the eNB*

- Link to section with related **performance counters and KPIs** is given on the top of slide when needed

Performance

Radio Link Failures and call drop analysis

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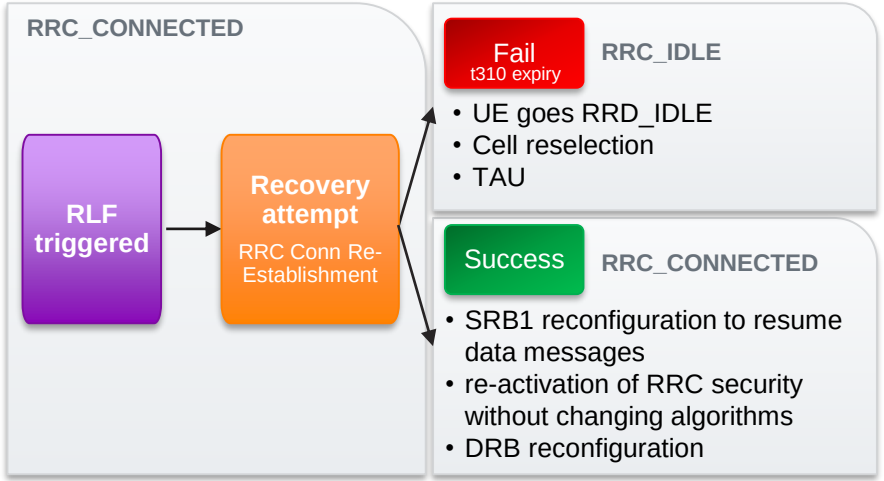
Main Menu

UE detected Radio link problems

- If UE detects radio link problems it tries to recover from RLF during specified interval of time (*LNCEL:t310*), by RRC connection re-establishment procedure:
  - When unsuccessful ➔ UE goes to idle or trigger cell reselection
  - When successful ➔ SRB and DRB reconfiguration, RRC security re-activation
- When UE is in RRC_CONNECTED and RRC security is active, it triggers **RRC Connection Re-establishment (RL30 LTE735)** upon:
  - T310 expiry
  - reaching the maximum number of UL RLC retransmissions
  - handover failure (T304 expiry)
  - non-HO related random access problem
- **UE detected radio link problems are up to the UE vendor implementation, therefore this section gives only 3GPP referenced information**



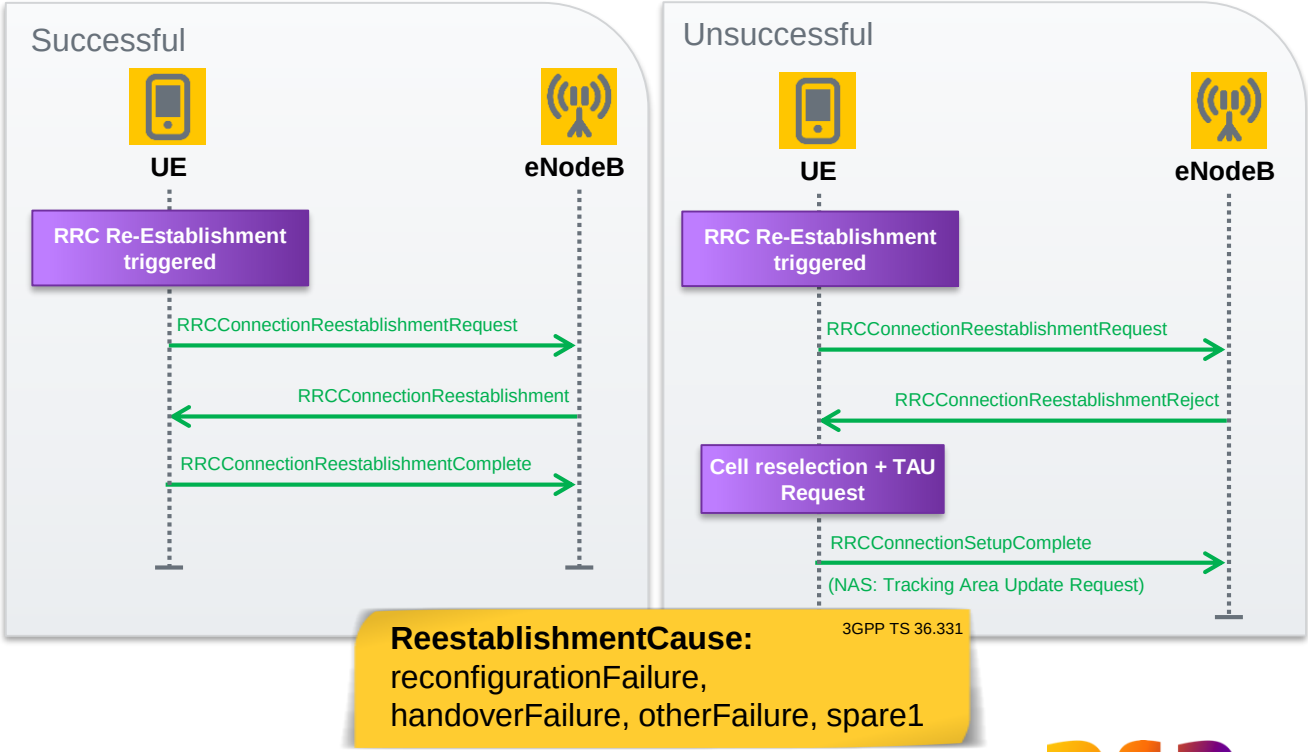
Note

If UE is in RRC_CONNECTED while **RRC security is not active**, in case of RLF UE goes to RRC_IDLE immediately and performs cell reselection and TAU

- RRC Conn Re-Establishment can only succeed in a cell that has:
  - short MAC-I of the target cell
  - PCI of the source cell
  - C-RNTI in the source cell
- **The feature is not supported in RL20, where eNB always responds with reject**
  → UE performs cell reselection + TAU
  - LTE735 introduced RRC connection re-establishment in the RL30/RL25TD

For more information please refer to LTE735 NEI

RRC Re-Establishment procedure



ReestablishmentCause:
reconfigurationFailure, handoverFailure, otherFailure, spare1

3GPP TS 36.331

- When the UE has completed the re-establishment successfully, it shall respond by sending an *RRC: RRC CONNECTION RE-ESTABLISHMENT COMPLETE* to the eNB

Information Element/ Group Name	Need	Source	Semantics description / Comments
RRCConnectionReestablishmentComplete		UE	
> rrc-TransactionIdentifier		UE	This IE contains an identification of the RRC procedure transaction local for the type of the message this IE was included within.
rlf-InfoAvailable-r9	**optional**	**UE**	**This field is used to indicate the availability of radio link failure related measurements**
nonCriticalExtension	optional		Shall be ignored, if received

- If the message is not received within the timer for min lifetime of half-open RRC connection ***LNBTS: tHalfRrcCon*** (default 2s) the **M8013C6 SIGN_EST_F_RRCCOMPL_MISSING** counter will be pegged and UE will be dropped
- If the feature *LTE678 MDT - UE Radio Link Failure report evaluation* (RL65TD) is activated both on eNB and cell level, eNB has to check, if the 3GPP R9 IE "*rlf-Info Available-r9*" is included within the response
  - If yes, eNB shall send the message *RRC UEInformationRequest* to the UE, to demand the sending of an **RLF Report** (see [UESTATE.1541]), which can be later used to enhance the RLF analysis capabilities
  - The RLF report contains information about the last serving and neighbor cell measurements before the radio link failure happened
- Please note that MDT features are out of the scope of this slideset

Call drop reasons

UE detected Radio link problems

- **T310 expiry**
- Maximum number of RLC retransmissions
- Handover failure (T304 expiry)
- Non-HO related random access problem

eNB Detected radio link problems

- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

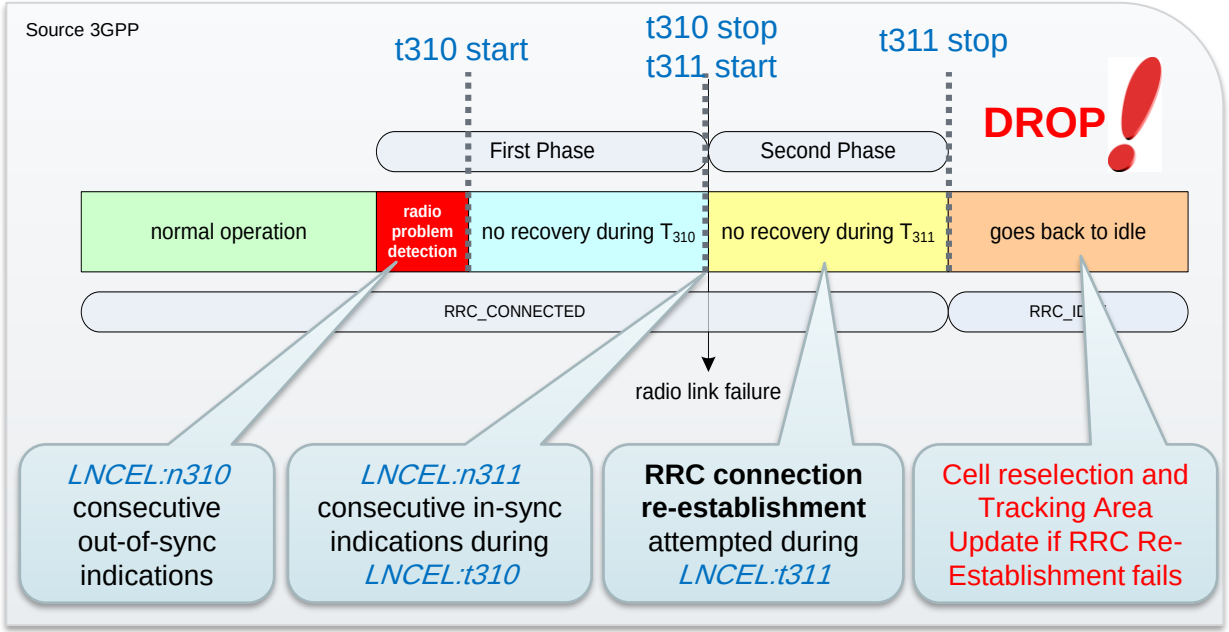
- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

UE detected radio link problems

T310 expiry

Main Menu

- During the UE operation various timers/counters are checked:
  - **Counter *N310*** specifies maximum number of out-of-sync indications
  - **Timer *T310*** supervises the recovery from physical layer problems. Started after ***N310*** successive out-of-sync indications from physical layer
  - **Timer *T311*** supervises the RRC connection re-establishment
- Radio link failure is triggered by UE after T310 expiry
- UE "normal operation" means that other operations supervised by timers are not running:
  - UE not waiting for RRC Connection Setup/Reject (*T300* not running)
  - UE not waiting for RRC Re-establishment Establishment/Reject (*T301* not running)
  - handover not ongoing (*T304* not running)
  - No RLF recovery ongoing (*T311* not running)



Note

The terms in-sync and out-of-sync refer to **L1 problems**, not to timing alignment (see next slide)

UE detected radio link problems

T310 expiry: in-sync and out-of-sync definition without DRX

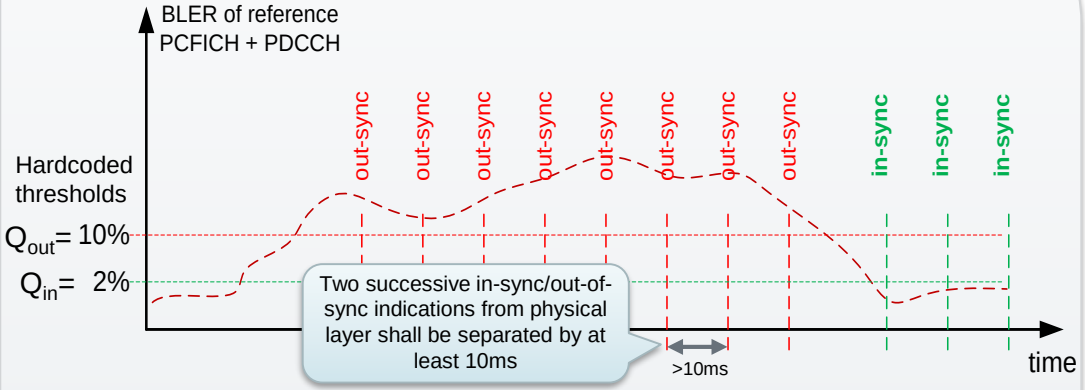
Main Menu

- Depending on the BLER variation, in-sync and out-of-sync indication are reported
- It can lead to start of UE ***timer T310*** after ***n310*** successive out-of-sync indications

- When the estimated downlink radio link quality:
  - becomes worse than the threshold Q_{out} (10%) Layer 1 of the UE sends an out-of-sync indication to the higher layers
  - becomes better than the threshold Q_{in} (2%) Layer 1 of the UE sends an in-sync indication to the higher layers

- In-sync and out-of-sync are measured during time window which depends on the DRX settings
  - For more details on DRX feature check NEI

PDCCH transmission taking into account the PCFICH errors with transmission parameters specified in Table 7.6.1-2



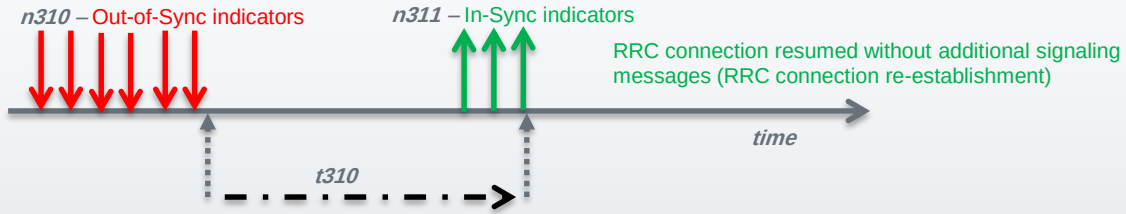
Measurement window size

Without DRX	With DRX	
	DRX cycle length [s]	**Evaluation time**
Q_{out} → 200 ms Q_{in} → 100 ms	≤ 0.01	Same as w/o DRX
	0.01 < DRX cycle ≤0.04	20 × DRX cycle
	0.04 < DRX cycle ≤ 0. 64	10 × DRX cycle
	0.64 < DRX cycle ≤ 2.56	5 × DRX cycle

3GPP TS 36.133 Sec 7.6

- To optimize the call drops following parameter recommendations are given
  - **n310: maximum number of consecutive "out-of-sync" indications received from lower layers**
    - The recommended value for cells with high call drop rate is n310=n20 (internal value 7)
  - **n311: maximum number of consecutive "in-sync" indications received from lower layers**
    - The recommended value for cells with high call drop rate is n311=n1(internal value 0)
  - **t310: supervises the recovery from physical layer problems**
    - The recommended value for cells with high call drop rate is t310=2000ms(internal value 6)
  - **t304IntraLte: supervises the successful completion of a handover or cell change**
    - To increase HO success rates and decrease call drops in HO region timer increasing could be considered t304IntraLte= 1000ms(internal value 5)
  - **t311: Timer T311 supervises the RRC connection re-establishment.**
    - The recommended value is t311=3000ms(internal value 1)

Example with n311 = 3



Note
Periods in time where neither "in-sync" nor "out-of-sync" is reported by layer 1 do not affect the evaluation of the number of consecutive "in-sync" or "out-of-sync" indications.

Call drop reasons

UE detected Radio link problems

- T310 expiry
- **Maximum number of RLC retransmissions**
- Handover failure (T304 expiry)
- Non-HO related random access problem

eNB Detected radio link problems

- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

UE detected radio link problems

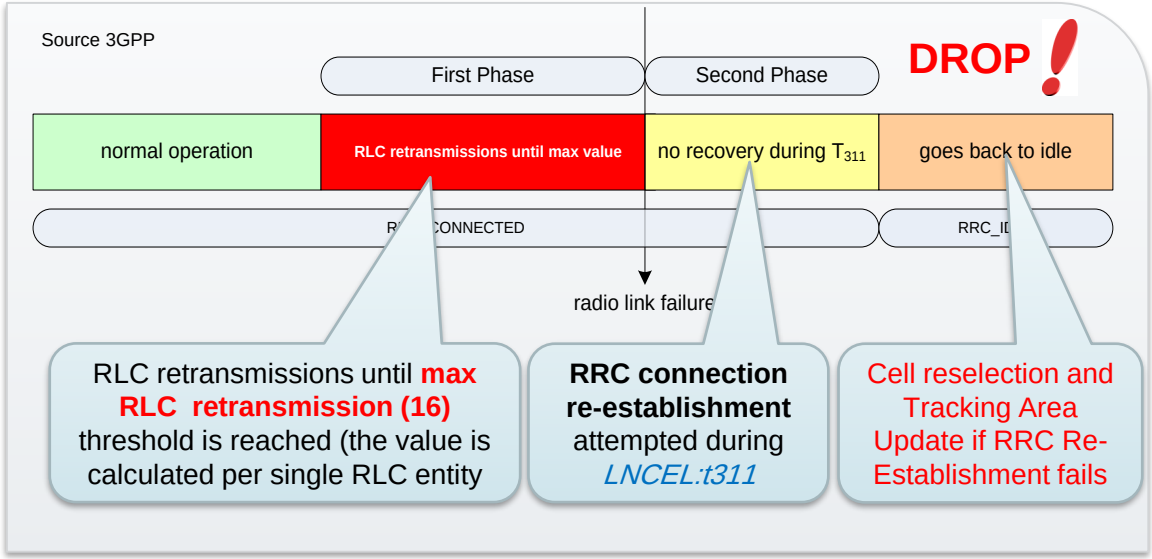
Maximum number of RLC

Main Menu

- Radio link failure can be triggered by UE if maximum number of retransmissions is reached
- That number is defined during call set-up in *RRCConnectionReconfiguration* message
  - Hardcoded to max 16 retransmissions (drbAmMxRtxTh)→ improved robustness

from RRC Connection Reconfiguration:

```
drb-ToAddModList
        drb-ToAddModList value 1
          drb-Identity          : 1
          rlc-Config
            am
              ul-AM-RLC
                t-PollRetransmit        : ms40
                pollPDU                 : p32
                pollByte                : kB25
                maxRetxThreshold        : t16
```



TF_LTE_SFS_BEARERMAN.374; 1219

Call drop reasons

UE detected Radio link problems

- T310 expiry
- Maximum number of RLC retransmissions
- **Handover failure (T304 expiry)**
- Non-HO related random access problem

eNB Detected radio link problems

- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

UE detected radio link problems

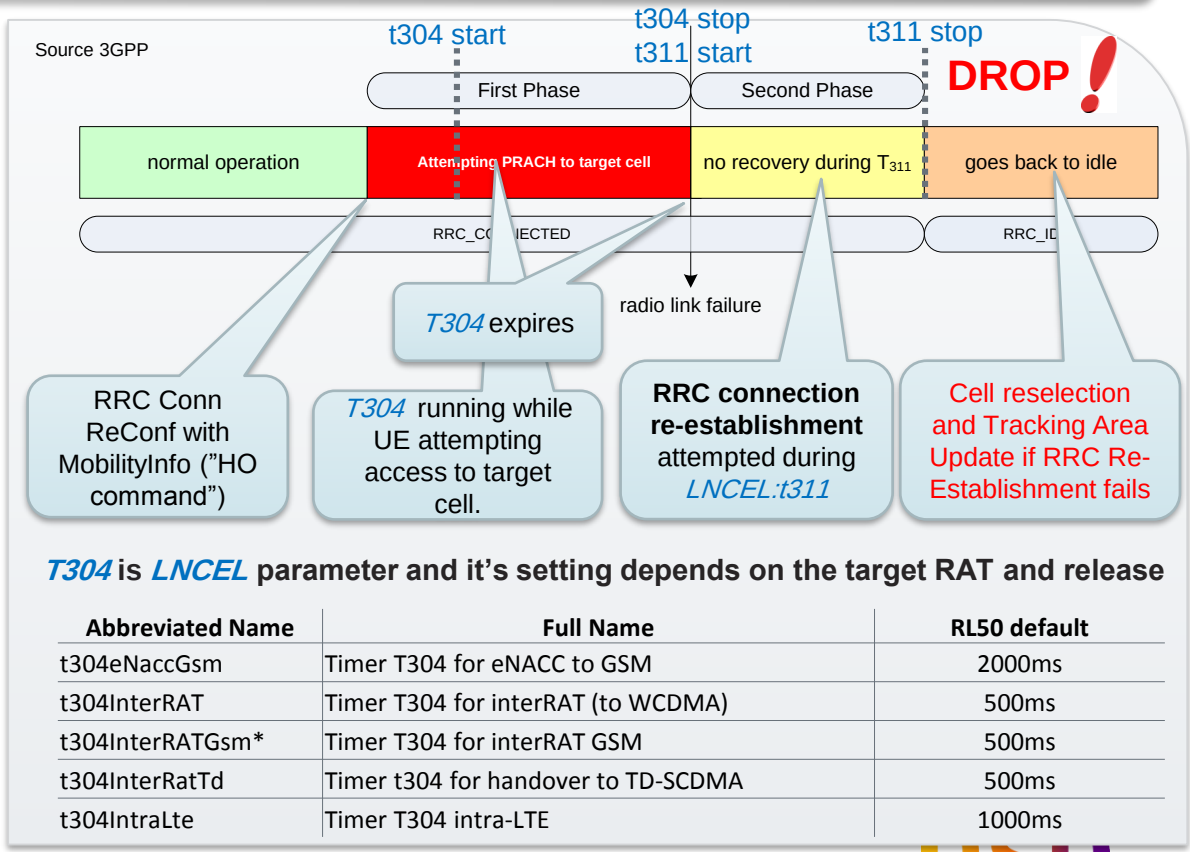
Handover failure (T304 expiry)

Main Menu

- When UE receives ***RRC Connection Reconfiguration*** with mobilityControlInfo IE (i.e, ”handover command”), it starts *timer T304*
- If PRACH procedure to the target cell does not succeed (*RANDOM ACCESS RESPONSE* not received) by the time *T304* expires, handover failure occurs (if air interface security is active)
- UE tries ***RRC Conn Re-establishment*** with re-establishment cause *”handoverFailure”*

from RRC Connection Reconfiguration:

mobilityControlInfo
targetPhysCellId : 33
t304 : ms1000
newUE-Identity
Bin : 14 EB (= 5355)



***T304* is *LNCEL* parameter and it’s setting depends on the target RAT and release**

Abbreviated Name	Full Name	RL50 default
t304eNaccGsm	Timer T304 for eNACC to GSM	2000ms
t304InterRAT	Timer T304 for interRAT (to WCDMA)	500ms
t304InterRATGsm*	Timer T304 for interRAT GSM	500ms
t304InterRatTd	Timer t304 for handover to TD-SCDMA	500ms
t304IntraLte	Timer T304 intra-LTE	1000ms

- To improve the call drop ratio, ***T304*** parameter optimization shall be considered
  - Higher the timer value, longer eNB supervises the HO procedure
    - However in case of failure, UE will longer wait for Re-establishment (critical for voice services)
  - Shorter the timer value, faster the RLF will be triggered (and UE would need to perform RRC Re-establishment).
- Please note that various mobility procedures need different amount of time to succeed (due to e.g. RACH procedure duration and other RAT specifics)
  - Usually procedures should not last more than 50-150 ms
- For detailed procedure time please refer to call flows analysis (LTE Performance SFS chapter 5.2: CP_LTE_SFS_PERF.52)

Abbreviated Name	Full Name	RL50 default
t304eNaccGsm	Timer T304 for eNACC to GSM	2000ms
t304InterRAT	Timer T304 for interRAT (to WCDMA)	500ms
t304InterRATGsm	Timer T304 for interRAT GSM	500ms
t304InterRatTd	Timer t304 for handover to TD-SCDMA	500ms
t304IntraLte	Timer T304 intra-LTE	1000ms

Call drop reasons

UE detected Radio link problems

- T310 expiry
- Maximum number of RLC retransmissions
- Handover failure (T304 expiry)
- **Non-HO related random access problem**

eNB Detected radio link problems

- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

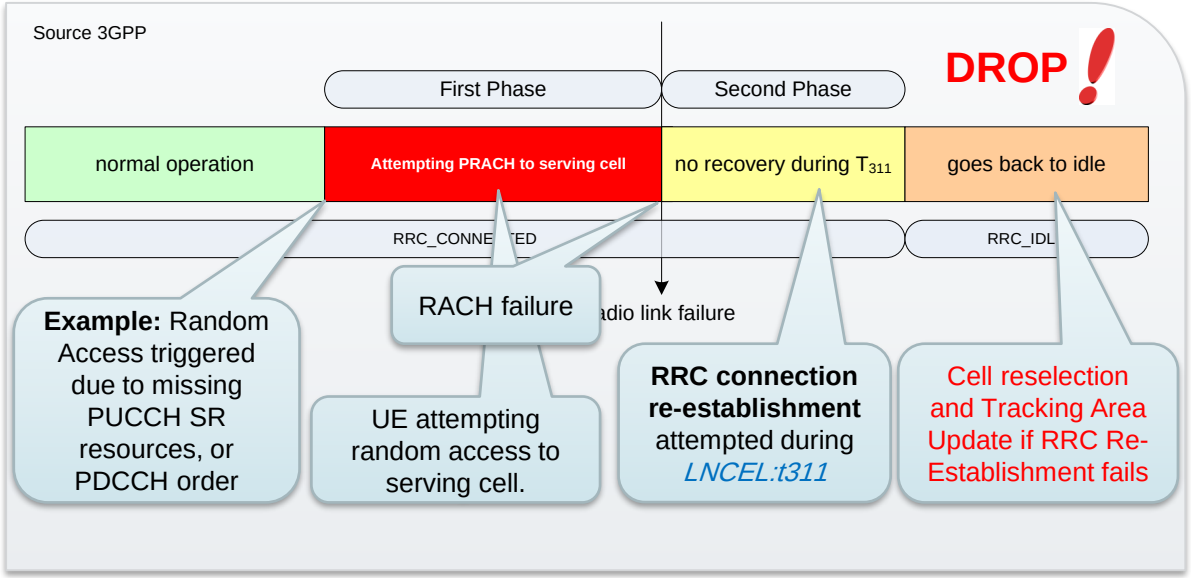
- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

UE detected radio link problems

Non-HO related random access problem

Main Menu

- Radio link failure is indicated also after unsuccessful non-handover related **random access procedure**
- Non-HO related random access refers to
  - PDCCH order triggered RA
    - Timing Alignment re-synchronization
    - For more info on PDCCH order check slide: link
  - Random Access Scheduling Request



eNB Detected radio link problems

- eNB radio link problem detection mechanisms are NSN-internally specified
- Multiple methods (called “link monitors”) are defined to detect a radio link problem in the eNB
- If any of the link monitors detects the problem, the eNB will wait of recovery until T_RLF timer expires

T_RLF = *LNCEL:t310* + *LNCEL:t311*

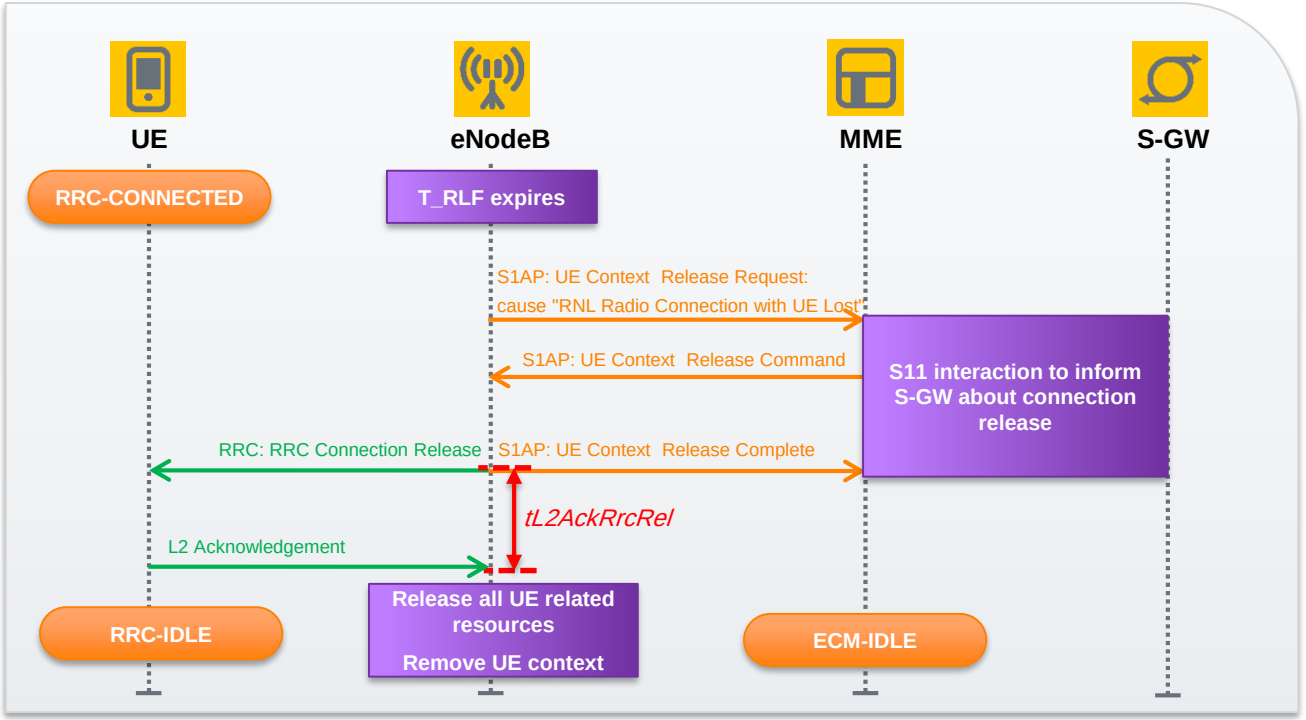
  - **Default: t310 = 2000ms, t311=3000ms**
- Each link monitor has its internal criteria to decide when radio link problem is flagged and de-flagged (radio link recovers)
- If the RLF persists longer than **T_RLF**, RRC+S1 release is triggered
  - i.a. Counter **ENB_INIT_TO_IDLE_RNL** is incremented

Link monitors

- **Uplink PUSCH DTX** detection for scheduled uplink data
- **CQI DTX** detection of periodic CQI reports in PUCCH and PUSCH
- **Uplink Ack/Nack DTX** detection for transmitted downlink data
- **PDCCH Order RLF** (RL30)
- **SRS DTX** detection (RL15TD)

- **RRC CONNECTION RELEASE** message is sent using acknowledged RLC mode on the DCCH (SRB1) mapped to DL-SCH
  - There is no RRC (L3) confirmation for this message, but it requires acknowledgement from L2
  - If the *LNBTS:tL2AckRrcRel* timer expires the eNB release the RRC connection anyway, i.e. it shall behave as if the positive acknowledgement has been received on L2
- After *S1AP: UE Context Release Complete* the connection is released

T_RLF = *LNCEL:t310* + *LNCEL:t311*



Call drop reasons

UE detected Radio link problems

- T310 expiry
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eNB Detected radio link problems

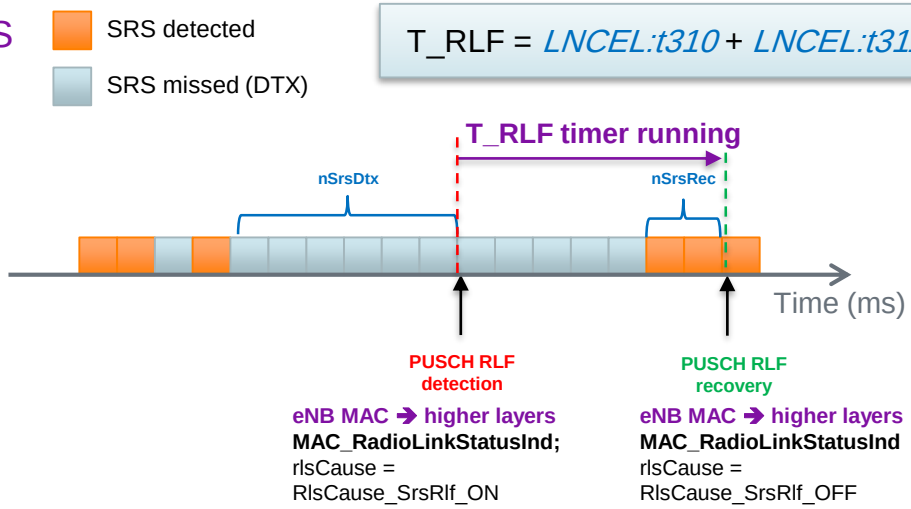
- PUSCH RLF
- CQI RLF
- HARQ RLF
- **SRS RLF**
- PDCCH Order fail

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

Only SRS based link monitor is configurable and used by default in the system, therefore description of other functions is moved to the backup

- **SRS RLF** detection counts consecutive missed SRS transmissions
- When eNB does not receive the SRS (DTX) exactly *LNCEL:nSrsDtx* times, it triggers RLF indication to higher layers
  - High value ➔ slower RLF indication
    - Decreases the probability of SRS RLF triggered call drop
  - Low value ➔ faster RLF indication
    - Increased the call drop probability
- When eNB receives correct SRSs again for *LNCEL:nSrsRec* times, eNB cancels the RLF state
  - Lower the value, faster the recovery of the RLF state
- If the subband configuration for SRS is configured to the minimum value of 4 PRBs, the radio problem detection based SRS can be quite problematic since SRS is not that robust in small SNR regions, e.g. below -5dB



Parameters values

	In this example	RL50.RL35 TD default
*LNCEL:**nSrsDtx***	6	50
*LNCEL:**nSrsRec***	2	2

Call drop reasons

UE detected Radio link problems

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- Maximum number of RLC retransmissions
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- Non-HO related random access problem

eNB Detected radio link problems

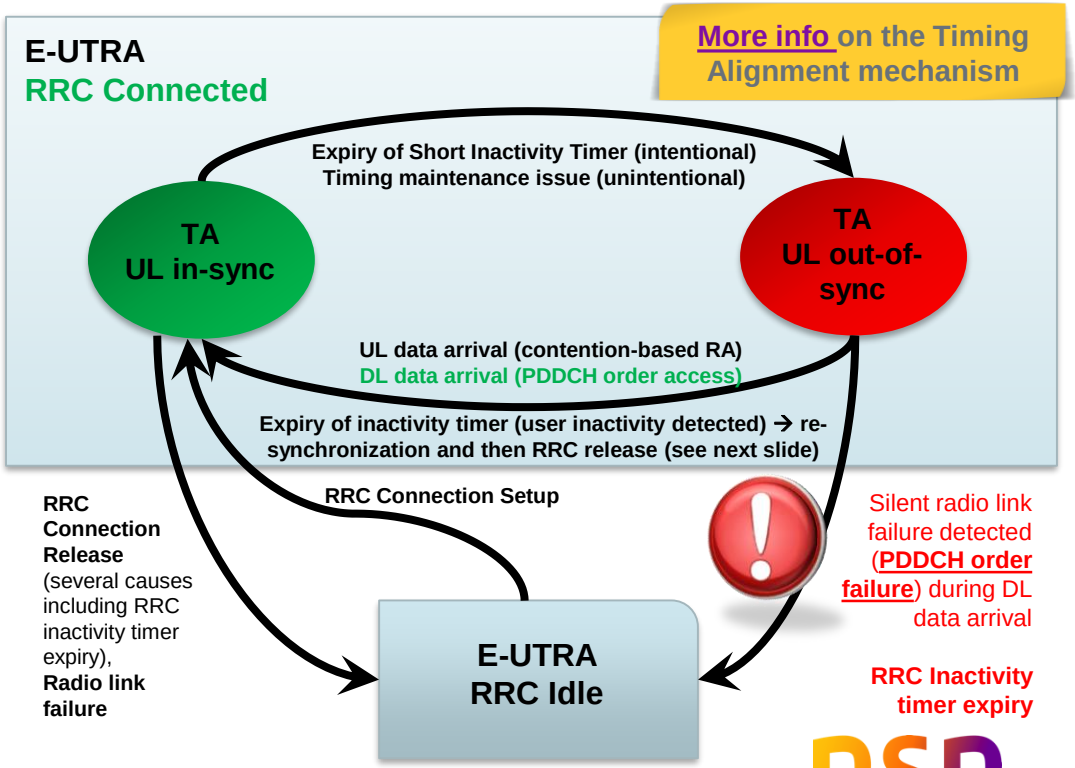
- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- **PDCCH Order failure**

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

- To resynchronize the UE needs to come back into **UL-in-sync** state
  - The procedure includes signaling of dedicated RA preamble (**PDCCH order**) message using DCI format 1A
- In case that PDCCH order fails for a UE (i.e., no transmission of assigned dedicated preamble detected by eNodeB, or no msg3 transmission) the PDCCH order is repeated one time again using the selected preamble and considering DRX status of the UE accordingly
- Final failure of the PDCCH order process is indicated as radio link problem to higher layers with cause “PDCCH order failure”
- It shall be noted that this mechanism exists from RL30 onwards (before, out-of-sync = RRC release → IDLE)

Overview of UE operational stated transitions



eNB initiated release

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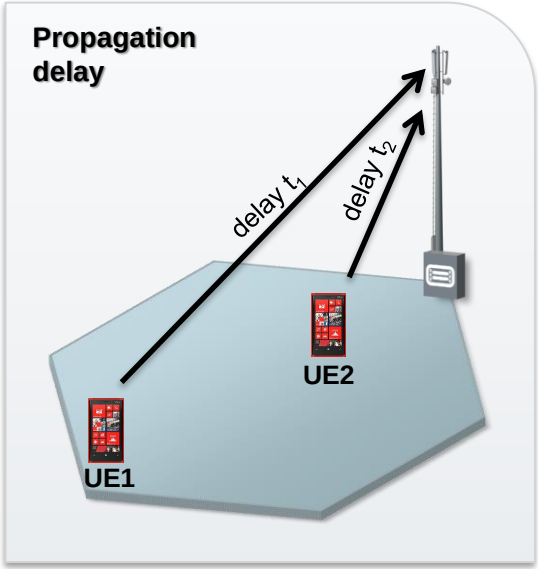
eNB initiated release

- **TA Timer Expiry at UE or eNB**
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

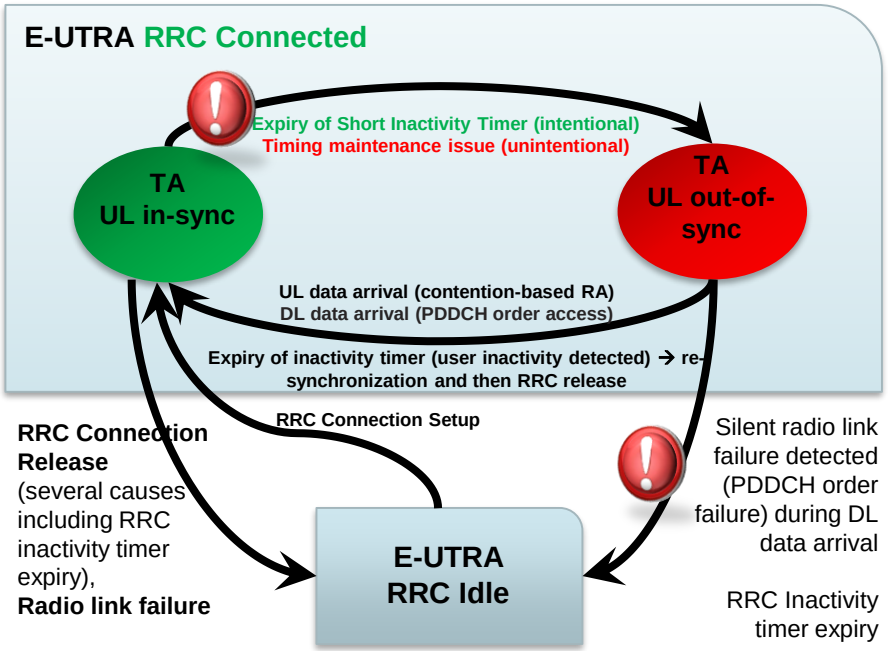
- Due to various length of the transmission paths and UE movement, every UE needs to be separately aligned to subframe timing at network side
- eNB timing alignment mechanism keeps measuring the time difference between PUSCH/PUCCH/SRS reception and eNB subframe
  - The 'Timing Advance' command can be sent to UE to change time UE starts its transmission

  - Timing Advance Command indicates the index value TA (0, 1, 2… 63) used to control the amount of timing adjustment that UE has to compensate
- For the purpose of the Radio link monitoring, the timing alignment is kept at eNB and UE side
  - eNB monitors the delay offset and tries to recover timing alignment for a parameterized period of time
  - UE follows eNB signaling and keeps timer which is used to control how long the UE is considered uplink time aligned



- Identification of UE time alignment with the network is expressed in TA UL sync states
  - **in-sync** UEs have up to date TA command (TA timer is running)
  - **out-of-sync** UEs haven't received/acknowledged TA command for a predefined amount of time (see next slides)
- Out-of-sync UE can be brought back to TA in-sync state by:
  - When DL data arrives ➔ PDDCH order
  - When UL data arrives ➔ UE will trigger contention based RA procedure
- If timing alignment or PDCCH order commands are not successful (no positive response) ➔ Immediate release of RRC and S1 follows

Overview of UE operational stated transitions



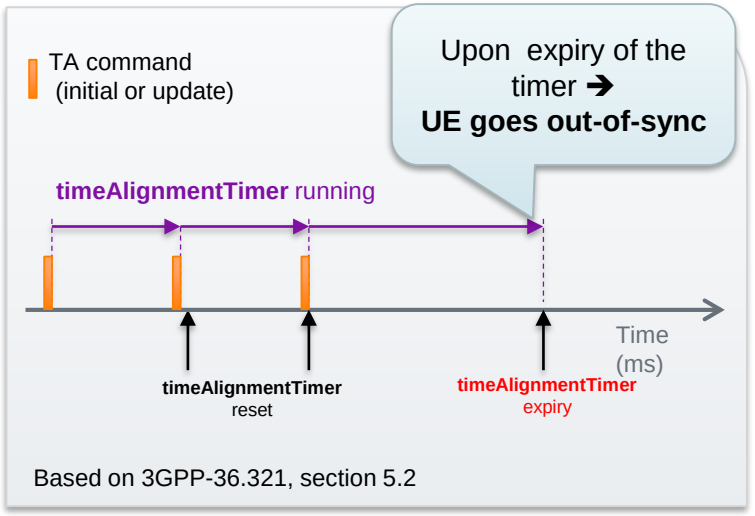
- UE maintains a configurable timer ***timeAlignmentTimer*** which is used to control how long the UE is considered uplink time aligned
  - The length of this timer is the same as in eNB
  - When UE detects Out-of-Sync status using a Timing Alignment Timer, the timer shall be started or restarted whenever an initial TA or a TA update command is received
- RL30: after expiry of the timer UE goes out-of-sync
  - Before RL30, immediate release of RRC and S1 follows

UE MAC [3GPP TS 36.321]

- Flushes HARQ buffers
- Clears any configured downlink assignments and grants
- **Notifies UE RRC layer to release PUSCH/SRS**

UE RRC [3GPP TS 36.331]

- Releases periodic CQI reporting configuration, i.e. stops CQI reporting on PUCCH
- Releases Scheduling Request config



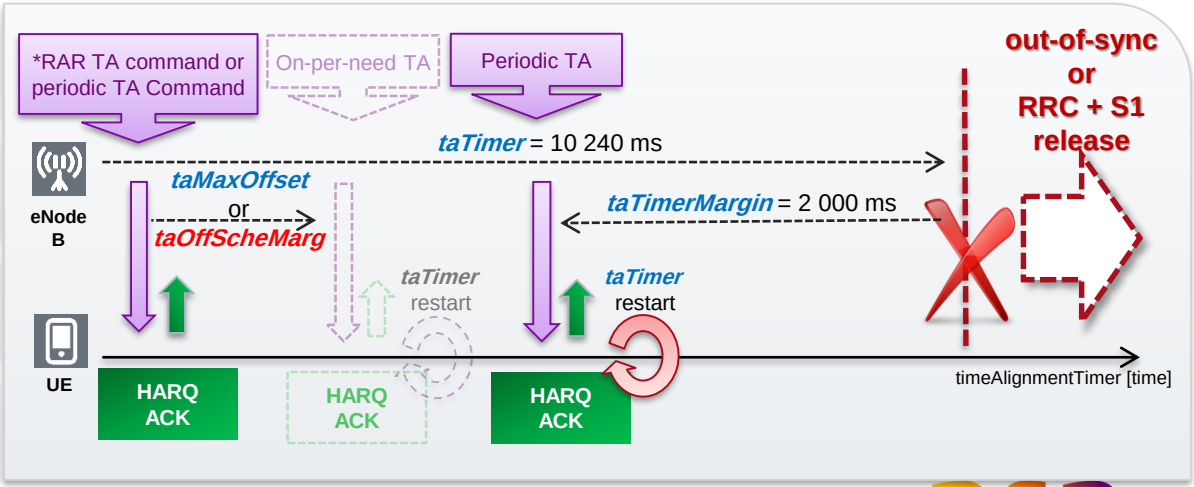
- eNB maintains the timing alignment (***timeAlignmentTimer***) by periodical or per-need TA commands
  - **Periodic UL TA:** triggered by *taTimer* – *taTimerMargin* (~8.2 sec with default settings)
  - **On per-need TA:** triggered if calculated timing alignment is higher than following thresholds before periodic TA is triggered:
    - *taMaxOffset* → 0.52us by default
    - *taOffScheMarg* → Additional timer (vendor parameter), 2us by default. After expiry eNB suspend from UL scheduling
- **timeAlignmentTimer** is started or restarted whenever an initial TA or a TA update command is sent/received

Time alignment timer margin ***LNCEL:taTimerMargin***
unit: subframes [1ms] **hidden**: false
range: 0 … 2560 **default: 2 000 ms**

Time alignment timer ***LNCEL:taTimer***
unit: **subframes [1ms]** **hidden**: false
range: 500(0), 750(1)…10240(6) **default**: 10 240 ms

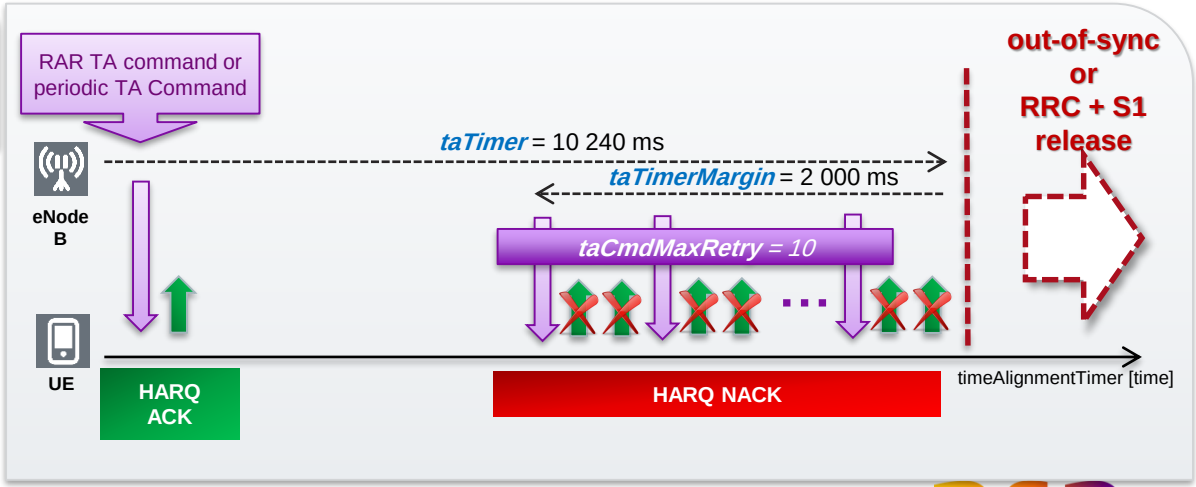
Time alignment maximum offset ***LNCEL: taMaxOffset***
unit: us **hidden**: false
range: 0...5 **default**: 0.52 us

TA offset margin for scheduling ***LNBTS:taOffScheMarg***
unit: us **hidden**: true
range: 1.5...4 **default**: 2 us



- In case the eNB does not receive the ACK response, it send the TA command again
- ***taCmdMaxRetry*** defines the maximum number of TA command retries
- If the maximum number of retries is exceeded or the timing alignment timer has expired, then status UE UL out-of-sync is detected (TatExpiry seen in UDP Log and Emil)
- From RL30 onwards After expiry of the timer UE goes out-of-sync
  - Before RL30, immediate release of RRC and S1 follows (there was no waiting for T_RLF expiry)

Maximum number of time alignment command retries
LNBTS: taCmdMaxRetry
unit: Number **hidden**: true
range: 1...10 **default**: 10



- RL30 introduced DRX feature allowing to reduce power consumption and therefore increase it's battery life time, by usage of Discontinuous Reception/Transmission (DRX/DTX)
- Due to out-of-sync handling timing alignment rules need to be relaxed, so UEs will not be unnecessarily dropped when being in out-of-sync state
- New parameter *LNCEL:applyOutOfSyncState* defines for which UE STIT (Short Term Inactivity Timer) is started on eNB
- RRC inactivity timer shall not be confused with DRX inactivity timers !

extendedDrxOnly (default):
- STIT applied only for UEs that are currently using **drx(Smart)Profile4** or **drx(Smart)Profile5**

allDrx:
- STIT will be applied only for UEs running with DRX Profile, UEs that are currently using **drx(Smart)Profile2 up to drx(Smart)Profile5**.

allUEs:
- STIT will be applied for **all UEs regardless of DRX activation flag** and UE short/long cycle capabilities

Note
When STIT is running, the UE is kept in in-sync state. When STIT expires, UE is allowed to go out-of-sync

- If DRX is not used at all, then setting '***extendedDrxOnly***' should be used

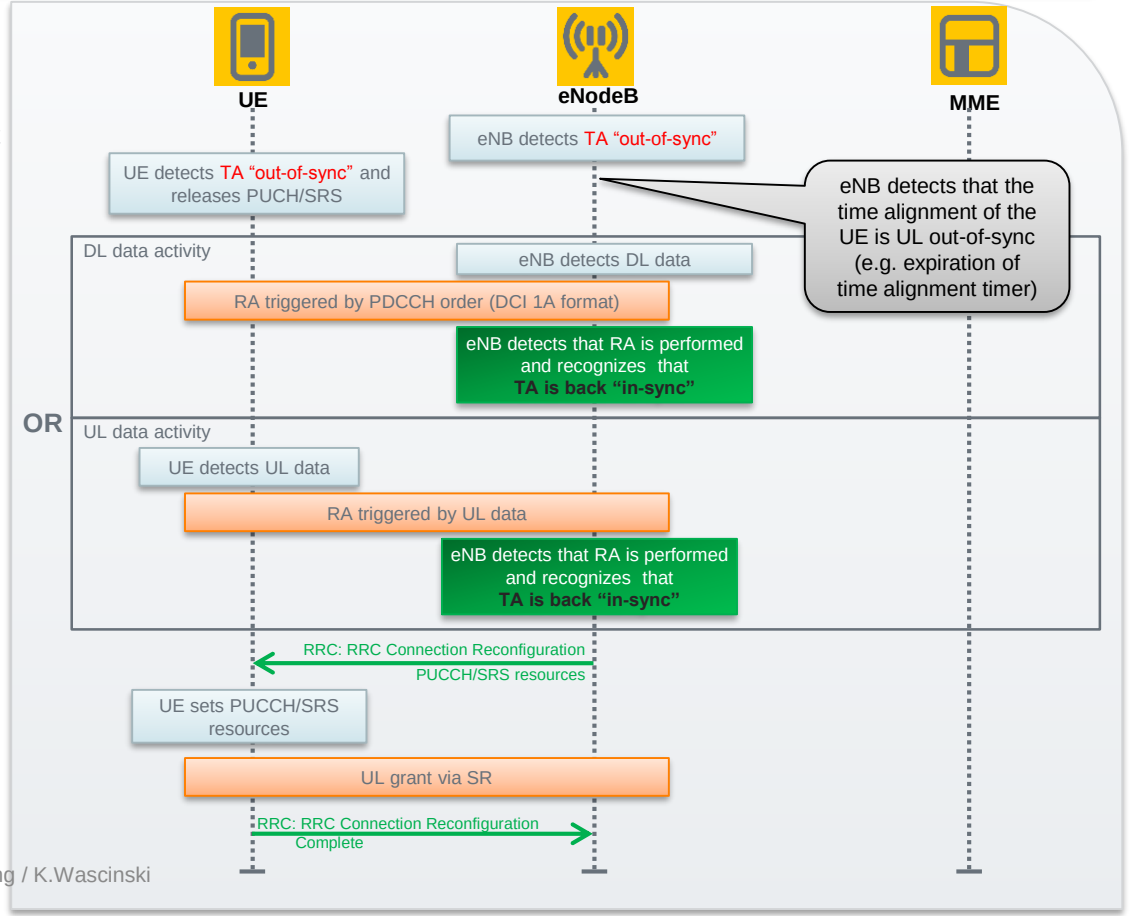
eNB initiated release

TA Timer Expiry at eNB: In-sync normal case

Main Menu

Procedure
Out-of-sync ➔ in-sync -Normal case

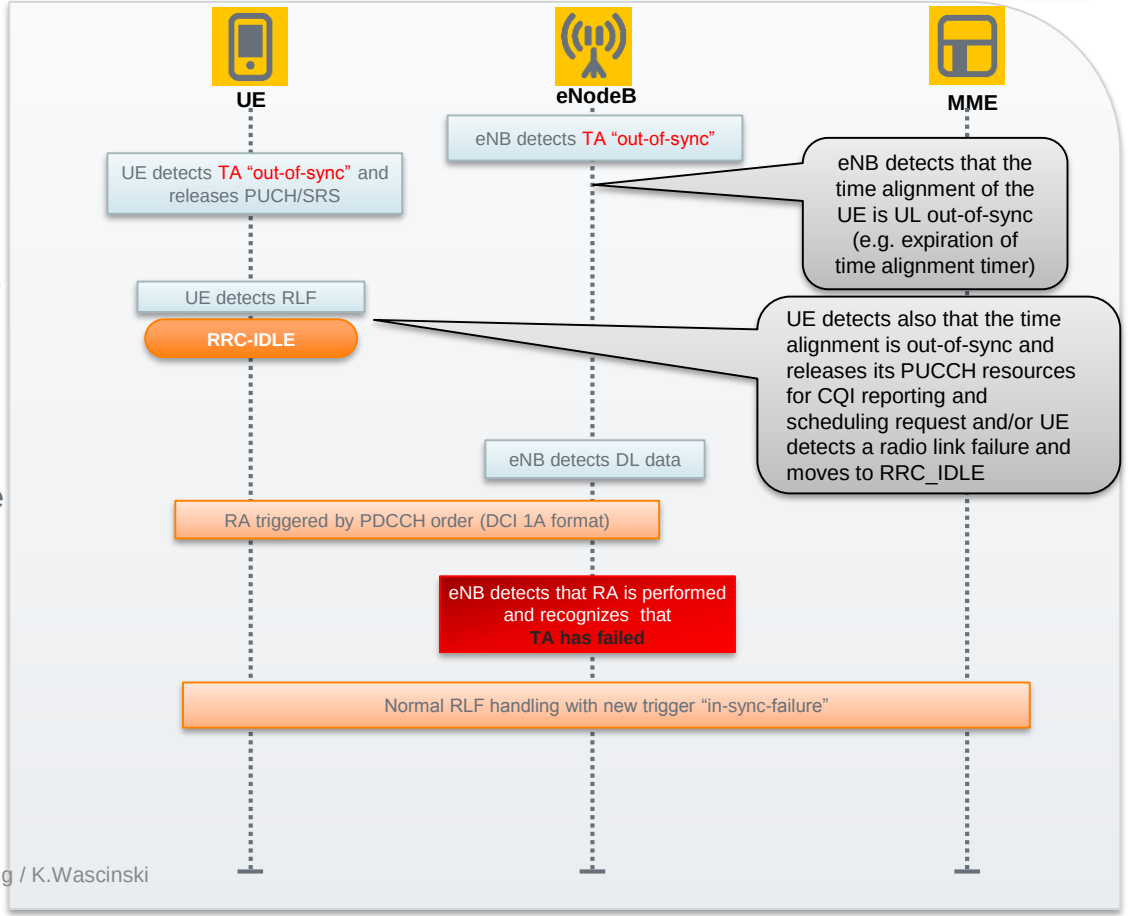
- **eNB detects DL data** (either data traffic or RRC signalling)
  - Then eNB sends a PDCCH order for RA procedure to UE (DCI 1A with specific codepoint; preferably non-contention based RA depending on preamble availability)
  - Procedure may and with PDCCH order failure
- In case **UE detects UL data** (either data traffic or RRC signalling):
  - Then UE starts a random access procedure (contention-based)
- After successful back to TA „in-sync" **eNB triggers** the RRC procedure ***RRC Connection Reconfiguration*** to configure (again) the PUCCH resources for CQI reporting and scheduling request
  - Same PUSCH/SRS resources used for simplification



Procedure
Out-of-sync ➔ in-sync -Failure

- **eNB detects DL data** (either data traffic or RRC signalling)
  - eNB sends a PDCCH order DCI 1A to UE (may include several re-tries)
  - UE will not recognize this PDCCH order because it has gone to RRC_IDLE
  - eNB recognizes that the random access of the UE was not successful (UE does not send any random access preamble) and that the “in-sync” handling has failed
- **This event is handled as a new trigger for the radio link failure procedure**
  - eNB starts a supervision timer T-RLF and triggers UE Context Release after timer expiration

Note
By using the supervision timer (***t311***), UE is able to return to cell via the RRC Connection Reestablishment procedure



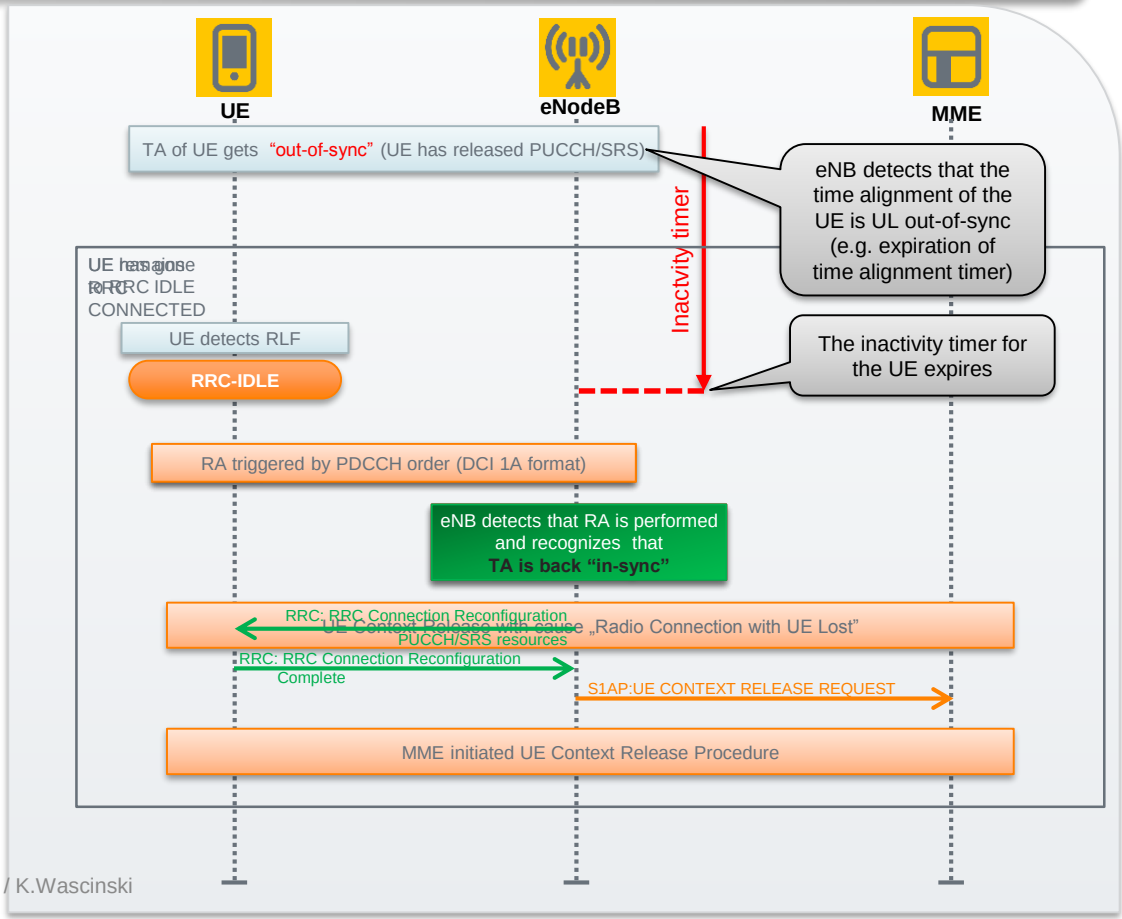
eNB initiated release

TA Timer Expiry at eNB: User Inactivity Detection during out-of-sync

Animated slide | Main Menu

Procedure describes how eNB handles an UE whose time alignment is out-of-sync and whose inactivity timer has expired

- In the meantime, UE may still be RRC_CONNECTED or may have gone to RRC_IDLE silently
- eNB checks the attainability of the UE by sending the PDCCH order (DCI 1A)
- **If eNB does not receive any random access response from UE:**
  - eNB recognizes that this is a normal "user inactivity"
  - eNB sends the *RRCConnectionReconfiguration* to configure PUCCH/SRS resources
  - eNB starts immediately the UE Context Release procedure for RLF
  - eNB sends the message **UE CONTEXT RELEASE REQUEST** to MME with cause *"User Inactivity"*
  - If MME starts the UE Context Release procedure
    - eNB sends the RRC message RRCConnectionRelease to UE and releases the UE context.
  - If MME does not start the UE Context Release procedure
    - eNB keeps the current configuration.
    - Note: this may happen if new DL data arrive - either data traffic or S1AP signalling



Call drop reasons

UE detected Radio link problems

- T310 expiry
- Maximum number of RLC retransmissions
- Handover failure (T304 expiry)
- Non-HO related random access problem

eNB Detected radio link problems

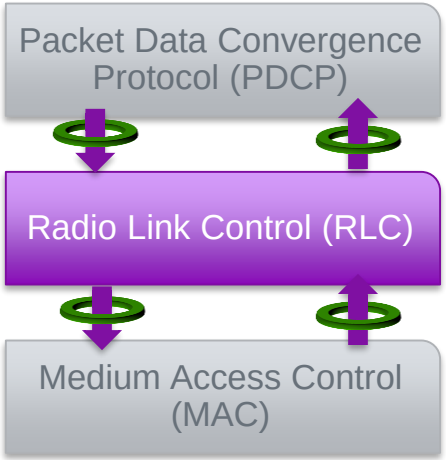
- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

- TA Timer Expiry at eNB or UE
- **Maximum RLC Retransmissions Exceeded at eNB**
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

- One of the functions of the **RLC** (Radio Link Control) protocol is **error detection & recovery**
- A RLC entity is configured (both at UE & eNB) to perform data transfer in one of the three modes: transparent, unacknowledged and acknowledged.

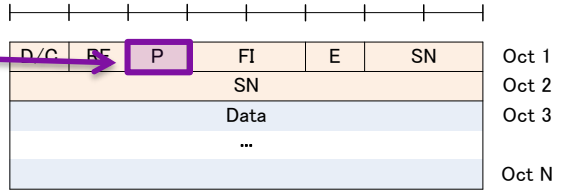
	Transparent Mode (TM)	Unacknowledged Mode (UM)	Acknowledged Mode (AM)
Segmentation and reassembly of RLC SDUs	No	Yes	Yes
RLC header adding	No	Yes	Yes
Delivery guarantee (sequence delivery service)	No	No	Yes
Suitable for	Voice	Streaming traffic	TCP traffic



Source: 3GPP 36.322

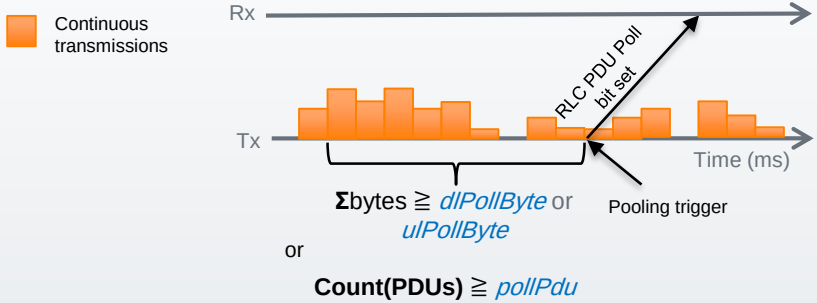
- **RLC layer retransmissions area available only in RLC acknowledged mode**
- Radio Resource Control (RRC) protocol layer is generally in control of the RLC configuration

- To acknowledge the reception in the RLC AM transmitter **requests a *STATUS PDU*** from RLC receiver by setting poll bit on in RLC header triggered when:
  - **Number of bytes transmitted** since previous poll exceeds the value of *ulPollByte* or *dlPollByte*, for the given UE category (currently cat.3)
  - **Number of RLC PDUs** (*pollPdu*) have been transmitted since previous poll
    - Depends on the configured RLC profile *rlcProfIdx* in the current qciTab
  - Or alternatively, in the **last data PDU** in the RLC transmit buffer (end of transmission)



AMD PDU (No LI) (3GPP 36.322)

SRB1 and SRB2 values for RLC configuration are hardcoded (TF_LTE_SFS_BEARERMAN.1219)

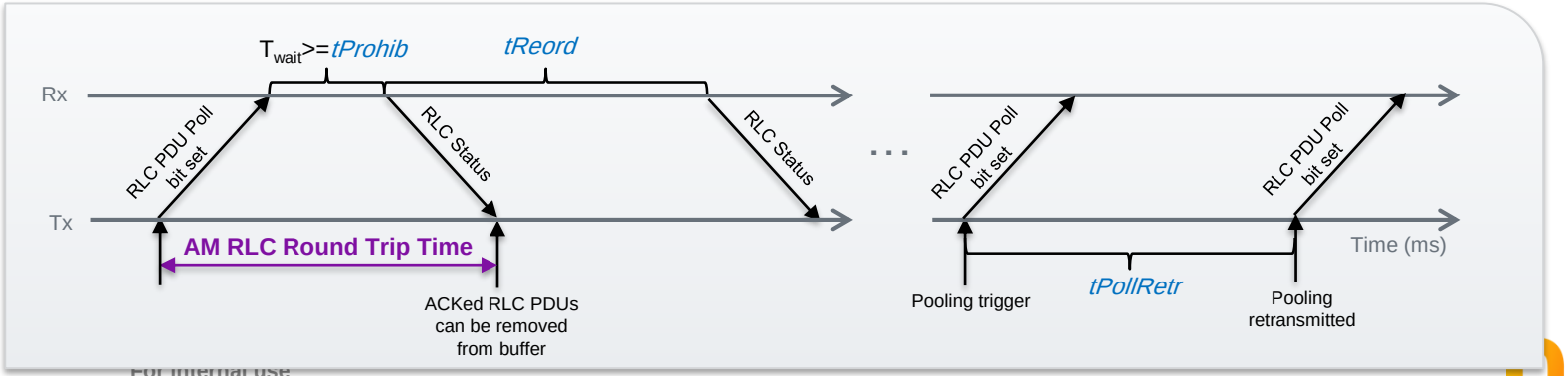


LNBTS → RLC profiles parameters						
	rlcProf1	**rlcProf2**	**rlcProf3**	**rlcProf4**	**rlcProf5**	**SRBs**
pollPdu	infinity	64	64	64	64	Infinity
tPollRetr	120 ms	120 ms	120 ms	120 ms	120 ms	100 ms
tProhib	10 ms	10 ms	10 ms	10 ms	10 ms	0 ms
tReord	10 ms	10 ms	10 ms	10 ms	10 ms	50 ms
LNBTS → AM RLC poll byte tables for DRBs						
	amRlcPBTab1	**amRlcPBTab2**	**amRlcPBTab3**	**amRlcPBTab4**	**amRlcPBTab5**	**SRBs**
dlPollByte	25 kB	25 kB	50 kB	75 kB	125 kB	infinity
ueCategory	1	2	3	4	5	-
ulPollByte	25 kB	25 kB	25 kB	25 kB	50 kB	infinity

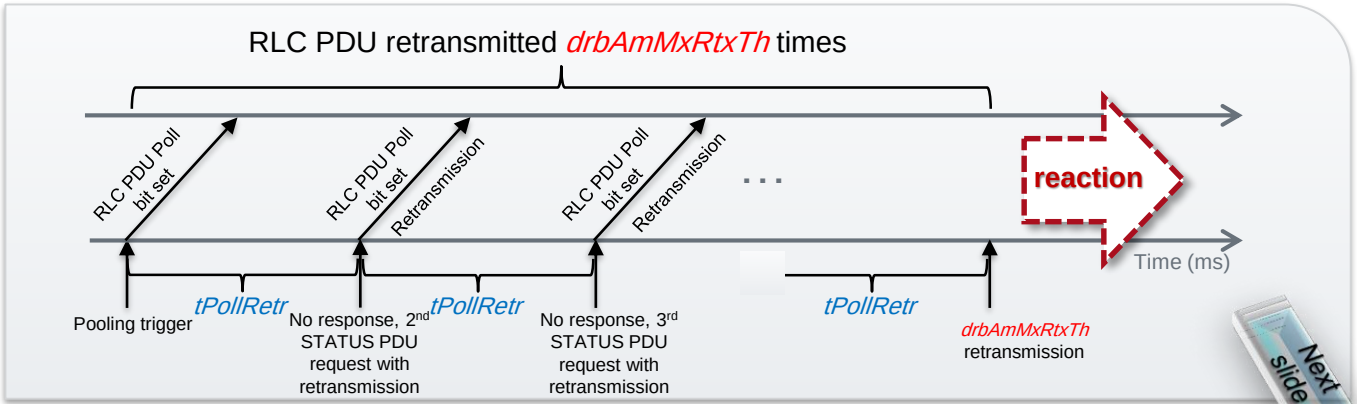
- The RLC AM receiver responds to polling request by **transmitting a *STATUS PDU*** which acknowledges successfully received PDUs and also selectively NACKs unsuccessfully received PDUs
  - RLC receiver also sends *STATUS PDU* if *tReord* timer expires
  - RLC receiver will not send *STATUS PDU* more often than interval defined by parameter *tProhib*
- If RLC transmitter **does not receive** *STATUS PDU* within *tPollretr*, a new poll request along with unacknowledged data will be sent to RLC receiver
- RLC AM window size is fixed to 512 RLC PDUs (segments of an RLC PDU are counted as one PDU)

LNBTS → RLC profiles parameters						
	rlcProf1	**rlcProf2**	**rlcProf3**	**rlcProf4**	**rlcProf5**	**SRB**
pollPdu	infinity	64	64	64	64	Infinity
tPollRetr	120 ms	120 ms	120 ms	120 ms	120 ms	100 ms
tProhib	10 ms	10 ms	10 ms	10 ms	10 ms	0 ms
tReord	10 ms	10 ms	10 ms	10 ms	10 ms	50 ms

SRB1 and SRB2 values for RLC configuration are hardcoded (TF_LTE_SFS_BEARERMAN.1219)



- RLC transmitter will retransmit all data that is NACK'ed in the STATUS PDU
- Maximum number of UL and DL RLC retransmissions is defined by hidden vendor parameter *LNBTS:drbAmMxRtxTh*
  - The parameter is set to high value (default=16) to improve robustness in HO scenarios
  - The parameter is on a higher level than ARQ and HARQ
  - For the SRB1 and SRB2 the parameter is hardcoded to the value 16
- Therefore with default values the **"Maximum number of RLC retransmissions"** will be triggered after:
  - **DRB:** *PollRetr* × (*drbAmMxRtxTh*+1) = 120ms × (16+1) = **2040 ms**
  - **SRB1 or SRB2:** *100ms* × (*drbAmMxRtxTh*+1) = 100ms × (16+1) = **1700 ms**

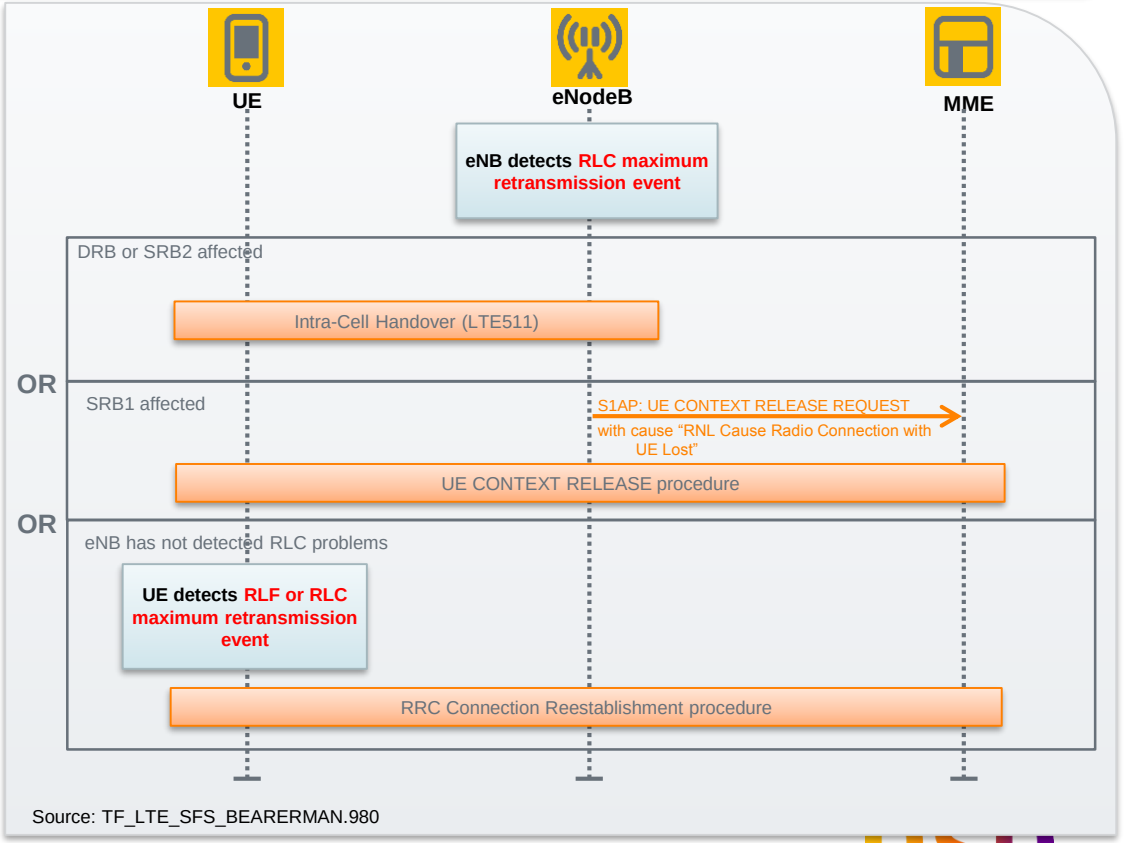


eNB initiated release

Maximum RLC Retransmissions Exceeded at eNB: Max retransmissions reaction

Main Menu

- The reaction on the *"Maximum number of RLC retransmissions"* is aligned with 3GPP and depends on the LTE release
  - **RL10:** Immediate release (RRC + S1)
  - **RL30:** eNodeB waits for the UE to trigger an recovery action when the maximum number of RLC retransmissions would be triggered at UE side
    - If detects maximum number of RLC retransmissions in UL direction it initiates ***RRC Connection Reestablishment***
  - **RL50:** Intra-cell handover is used to unblock the RLC entity (LTE511)
    - If the handover fails, UE CONTEXT RELEASE is triggered instead
    - intra-cell handover cannot be initiated if the event has occurred for SRB1 (the *RRCConnectionReconfiguration* cannot be sent to UE)

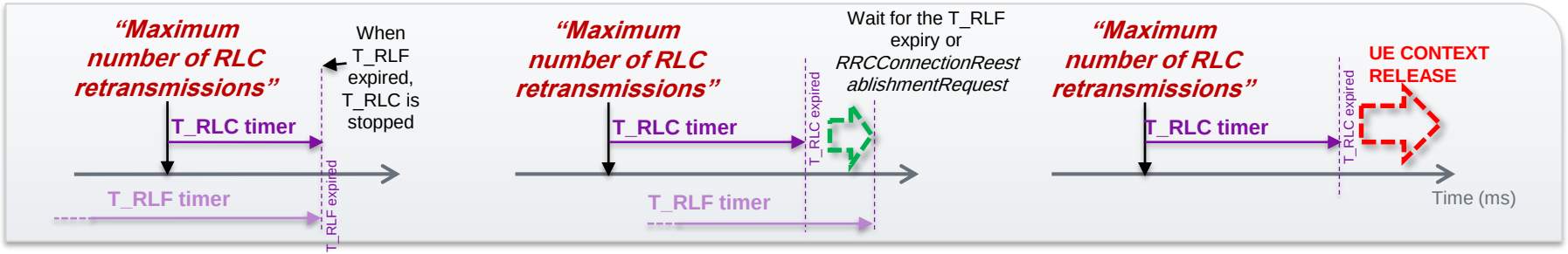


Source: TF_LTE_SFS_BEARERMAN.980

- When **RLC AM entity of a DRB** has reached the event "*Maximum number of RLC retransmissions*" for an
  - eNodeB starts the timer **T_RLC**

T_RLC = *LNCEL:t311*	T_RLF = *LNCEL:t310* + *LNCEL:t311*

  - The timer **T_RLC** is stopped if the eNodeB accepts an RRC message *RRCConnectionReestablishmentRequest* from UE or the **T_RLF** has expired
  - When the timer **T_RLC** expires, eNodeB checks whether the timer **T_RLF** is running:
    - If T_RLF is running, eNodeB ignores all subsequent indications that a problem triggering an RLF has recovered and wait for the expiration of T_RLF or an accepted RRC message *RRCConnectionReestablishmentRequest* from the UE
    - Otherwise eNodeB sends the S1AP message UE CONTEXT RELEASE REQUEST with cause "*RNL Cause Radio Connection with UE Lost*" to MME to initiate the UE release as for the radio link failure procedure



Call drop reasons

UE detected Radio link problems

- T310 expiry
- Maximum number of RLC retransmissions
- Handover failure (T304 expiry)
- Non-HO related random access problem

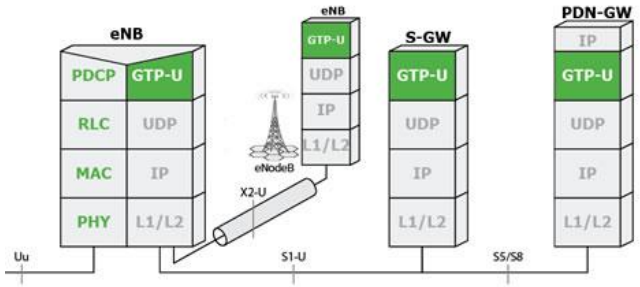
eNB Detected radio link problems

- PUSCH RLF
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- **GTP-U failure at eNB**
- S1 reset
- Lack of DRB ID

- eNodeB may receive a “GTP-U Error Indication” on an active S1 bearer(s) (S-GW has rejected the reception of uplink data packets)
- When single (or all) GBR S1 bearers have failed:
  - eNodeB sends the S1AP message **UE CONTEXT RELEASE REQUEST** with cause “*TNL Cause Transport Resource Unavailable*” to MME
- If one active non-GBR S1 bearer remains:
  - eNB starts an internal triggered E-RAB Release
  - When the E-RAB Release has finished (reception of *RRConnectionReconfigurationComplete*), eNB sends the S1AP message **E-RAB RELEASE INDICATION** to MME
  - Finally the RAC and TAC resources of the released E-RAB become free. Note: TAC allocates only GBR resources



Example

This failure cause happens in X2 handover if S-GW relocation is attempted, or due to non-3GPP compliant UEs

Note

eNB stops sending UL data to S-GW for the affected S1 bearer(s) and waits for a timer (configured by R&D parameter *tWaitForPosDetach*, default 100ms) before starting the described procedure.
This is caused by **non-3GPP-compliant UEs** that continue sending UL data though they have initiated the NAS Detach procedure

Call drop reasons

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- Handover failure (T304 expiry)
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eNB Detected radio link problems

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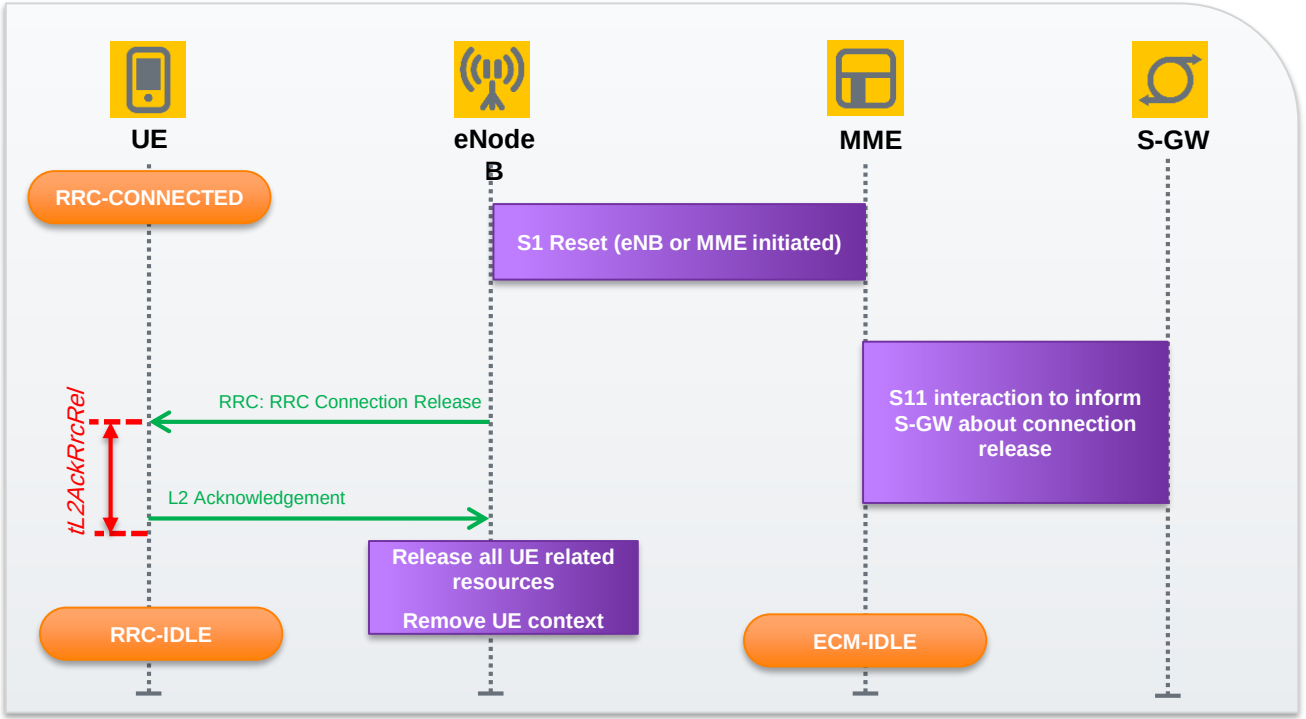
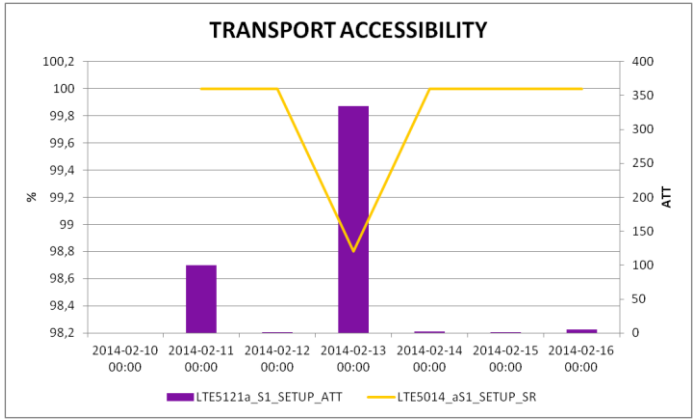
eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- **S1 reset**
- Lack of DRB ID

- S1 Reset (S1AP: RESET) procedure may be used by eNB or MME to recover from erroneous situations
- When the S1 interface is reset either by the eNB or the MME, the eNB releases all affected RRC connections
- Of course, also in this case RAC is informed about the release of the UE as already specified.
- The reset can be triggered for cell center UEs (in area non overlapped by neighboring cells) in case of ***LTE914 Graceful cell shutdown***



- The S1 resets are reflected in the following counters:
  - *S1AP_GLOBAL_RESET_INIT_ENB, S1AP_GLOBAL_RESET_INIT_MME, S1AP_PARTIAL_RESET_INIT_ENB, S1AP_PARTIAL_RESET_INIT_MME*
- Additionally, after the S1 reset the S1 setup attempt follows, which is monitored in the ***LTE_5121a S1 Setup Attempts*** KPI
  - The number of setup attempts may be higher than number of resets → connectivity issues



Call drop reasons

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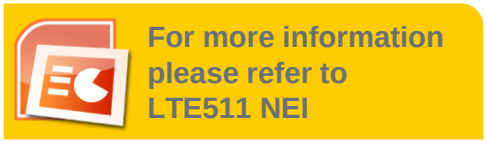
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- **S1 reset**
- **Lack of DRB ID**

- **Up to the RL40** eNB will trigger a UE Context Release if the number of unused drb-Identities is less than the vendor-configurable parameter drbIdThreshold
  - The DRB identity shall never have been in use for a released DRB (since the last update of security keys)
- **From RL50** onwards ***LTE511 intra cell handover*** for key refresh procedure is triggered instead of UE Context Release, so it is expected that the number of call drops will be decreased

- If the number of "unused" drb-Identities is less than the vendor-configurable parameter *drbIdThreshold* (by default set to 2) key-refresh procedure is triggered
  - Because the range of drb-Identities is 0..31 the key-refresh procedure (and former UE Context Release) will be triggered every 31 calls made by the UE
  - The contribution in drop ratio in case intra cell handover is not supported (till RL40)) will be maximum at the level of 1/31 = 3.22% ➔ **negligible impact**



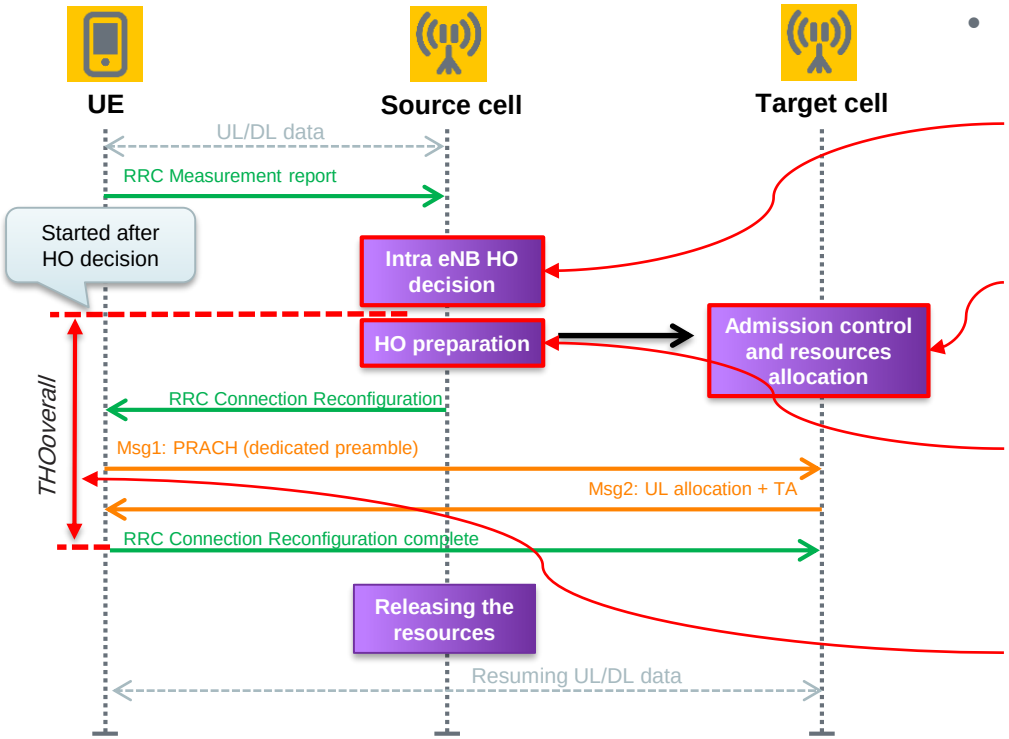
Radio Link Failures and call drop analysis

Table of contents

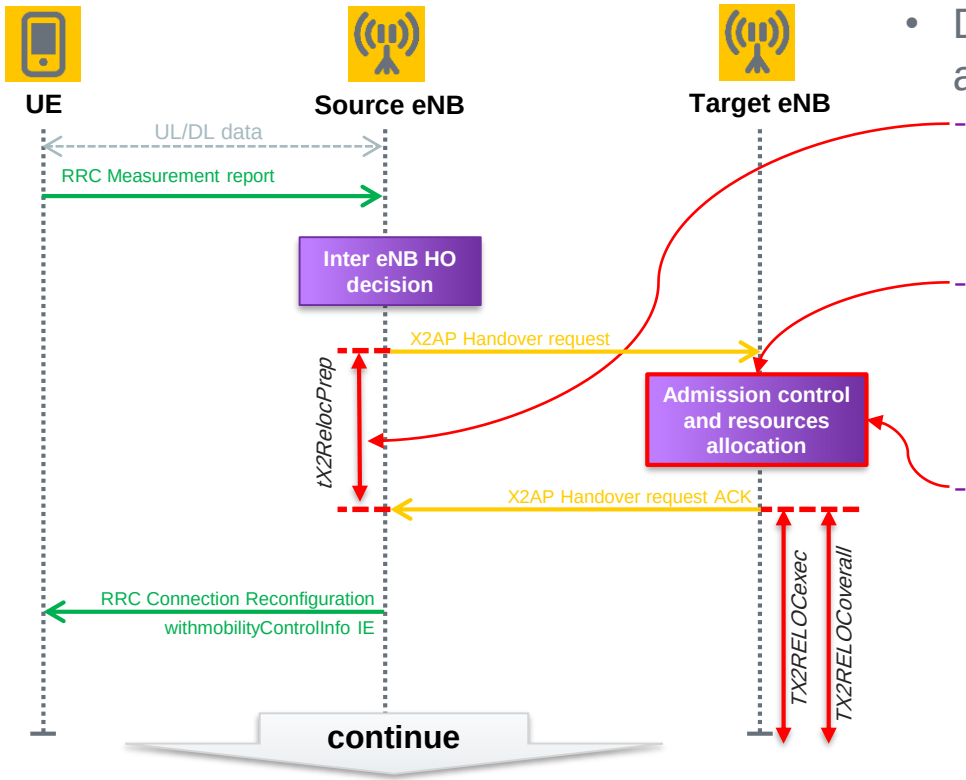
Main Menu

- Handover procedure is usually the main place in which call drops can be observed, due to:
  - Mobility parameterization errors
  - UE movement
  - Discontinuous cell coverage
- Therefore, following types of the mobility are considered within this section:
  - Intra eNodeB handover
  - Inter eNodeB handover
    - X2 example given, the corresponding S1 related counters are given in the PM section
- On the top the **LTE533 Mobility Robustness** feature aims to optimize the mobility thresholds, hence improving the HO success ratio

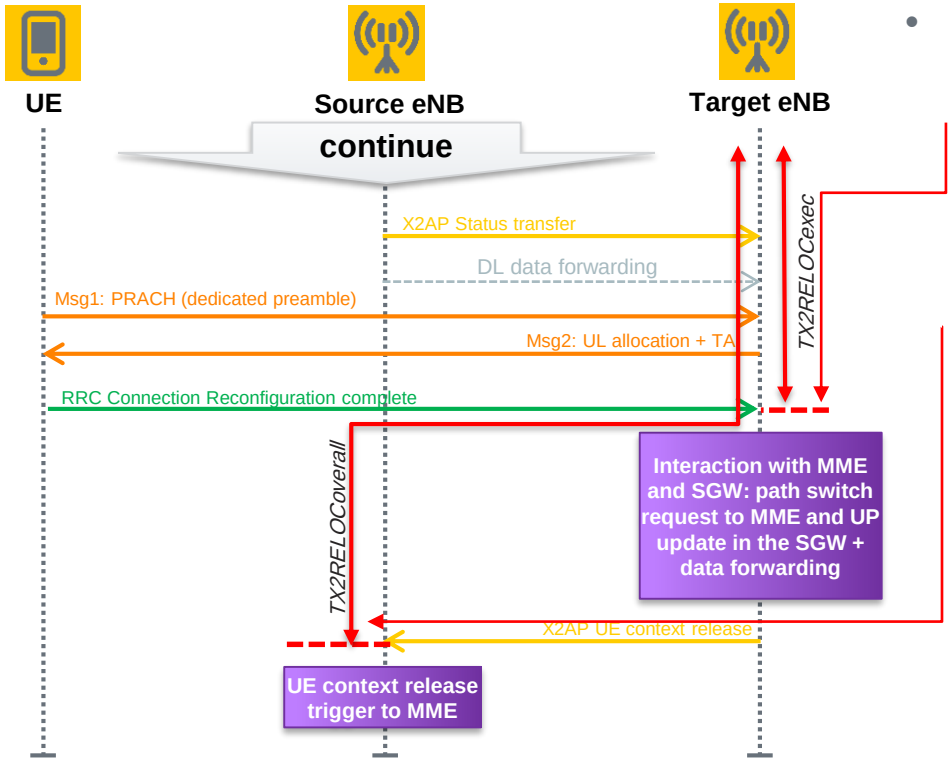
- **Cell level** and **per neighbor** relation counters support the mobility analysis from PM point of view. The details are listed in the PM aspects section



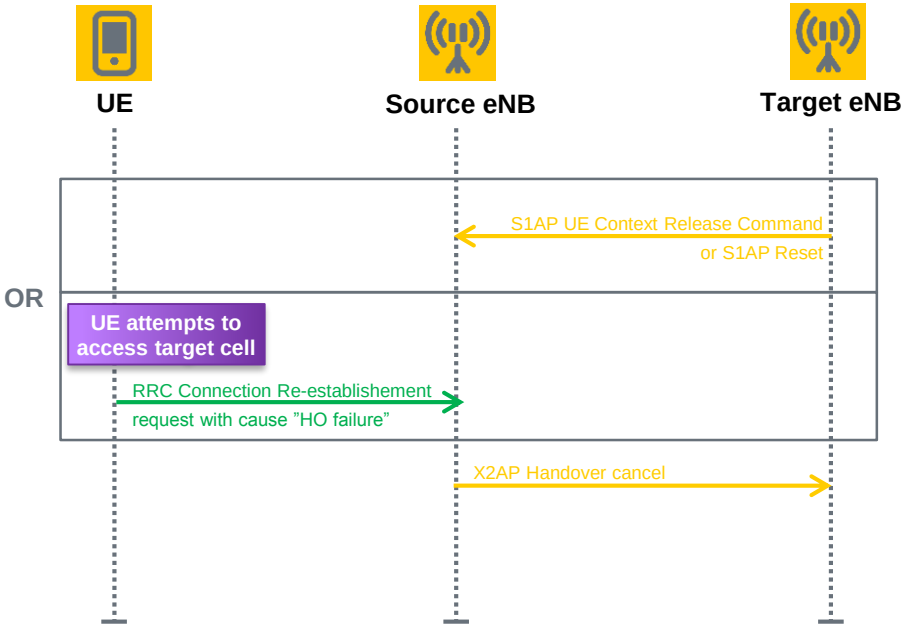
- During the **intra-eNB HO**, there are following monitored fail causes:
  - No intra eNB HO decision
    - Measurement report received but handover not started for some reason
    - Pegged **M8009C0** TOT_NOT_START_HO_PREP
  - Admission control and resources allocation fails on target cell (overload in target cell)
    - Target cell rejects the HO attempt
    - **M8009C3** FAIL_ENB_HO_PREP_AC
  - HO preparation is not triggered
    - RRC connection reconfiguration message is not sent
    - Any other fail, which happens during preparation
    - **M8009C5** FAIL_ENB_HO_PREP_OTH
  - RRC Conn Reconfiguration Complete missing
    - The process is guarded by the timer:
      - ***THOverall*** = = T304 + *t311* + *t301* + *tHoOverallD* timer
    - **M8009C8** ENB_INTRA_HO_FAIL



- During the **inter-eNB HO** preparation, there are following monitored fail causes :
  - Handover request acknowledge missing
    - The process is guarded by the hidden *LNBTS:tX2RelocPrep* timer
    - **M8014C2** FAIL_ENB_HO_PREP_TIME
  - Admission control or resources allocation fails on target eNB
    - Target cell rejects the HO attempt by responding with *X2AP Handover Preparation failure (cause)*
    - **M8014C3** FAIL_ENB_HO_PREP_AC
  - Other failures
    - Any other fail (e.g. X2-HO Path Switch Failure), which happens during the preparation
    - **M8014C5** FAIL_ENB_HO_PREP_OTHER

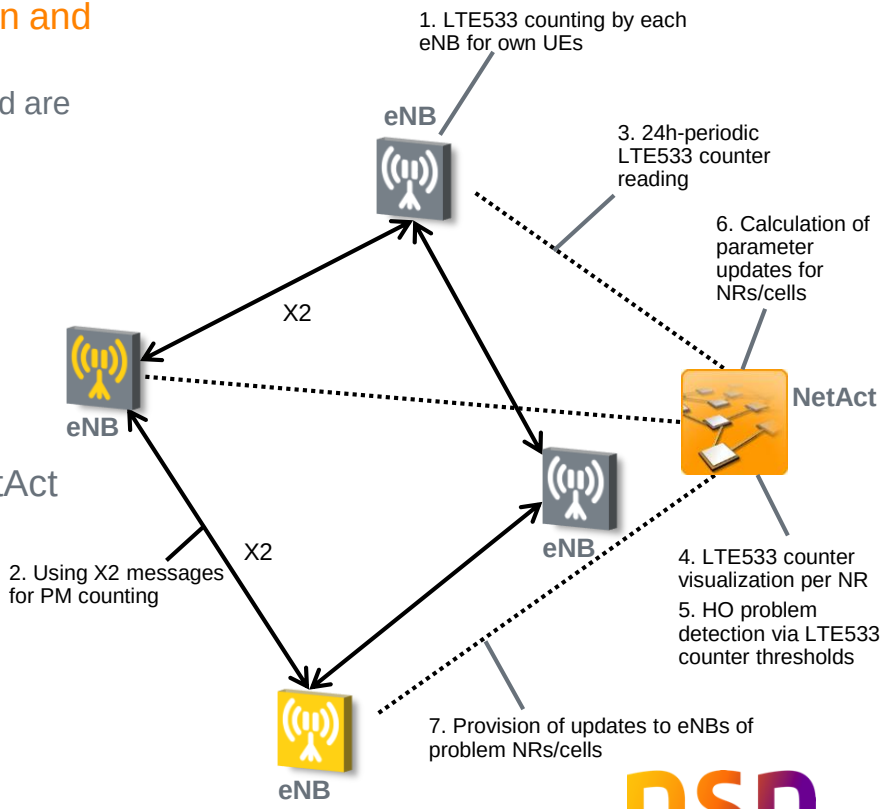


- During the **inter-eNB HO** execution, there are following monitored fail causes :
  - No RRC reconfiguration complete message received in the target eNB
    - The process is guarded by the timer:
      - ***TX2RELOCexec*** = T304 + *t311* + *tX2RelocExcD*
    - **M8007C2** DATA_RB_STP_FAIL (target cell counter)
  - No context release received from target eNB
    - The process is guarded by the timer:
      - ***TX2RELOCoverall*** = T304 + *t311* + *t301* + *tx2RelODelta*
    - **M8014C8** INTER_ENB_HO_FAIL(source cell counter)



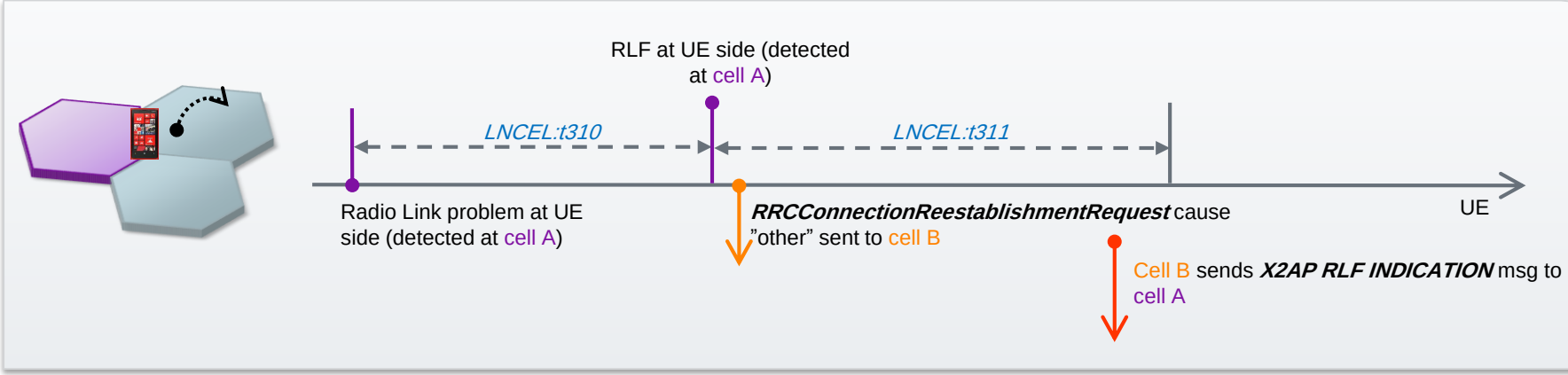
- HO procedure may also be interrupted anytime, by following messages
  - S1AP UE Context Release or S1AP Reset
    - If any of those commands is received, *X2AP Handover Cancel* is triggered and HO fails
    - In case HO cancel is triggered one of the following counters is pegged:
      - Intra-eNB HO: **FAIL_ENB_HO_PREP_OTH**
      - Inter-eNB X2 HO: **FAIL_ENB_HO_PREP_OTHER**
      - Inter-eNB S1 HO: **INTER_S1_HO_PREP_FAIL_OTHER**
    - Check performance section for the detailed explanation
  - RRC Conn Re-Establishment Request
    - If source eNB receives the RRC connection Re-Establishement request from the UE with the cause "HO failure" the *X2AP Handover Cancel* is triggered
    - This type of HO fails is considered in the MRO, by the usage of the counter: **M8021C21** MRO_EARLY_TYPE1_HO
    - See next slides for more information
  - Currently there's no standalone *X2AP Handover cancel* related counter

- Feature **LTE533 Mobility Robustness** enables detection and optimization of selected mobility failure events
  - Mobility failure events represent sequences of RRC events and are partly defined by 3GPP (TS 36.300, TS 36.902)
    - Too Late HO
    - Too Early HO
    - HO to wrong cell
    - Ping-pong HO
- This is an E2E feature spanning functionalities over
  - eNB
  - eNB-NetAct interface
  - NetAct Optimizer
- Due to the fact that the logic (algorithm) is located at NetAct Optimizer, LTE533 is frequently classified as centralized (NetAct) functionality
- Achieved optimization effect is reflected in
  - HO statistics
  - RLF statistics



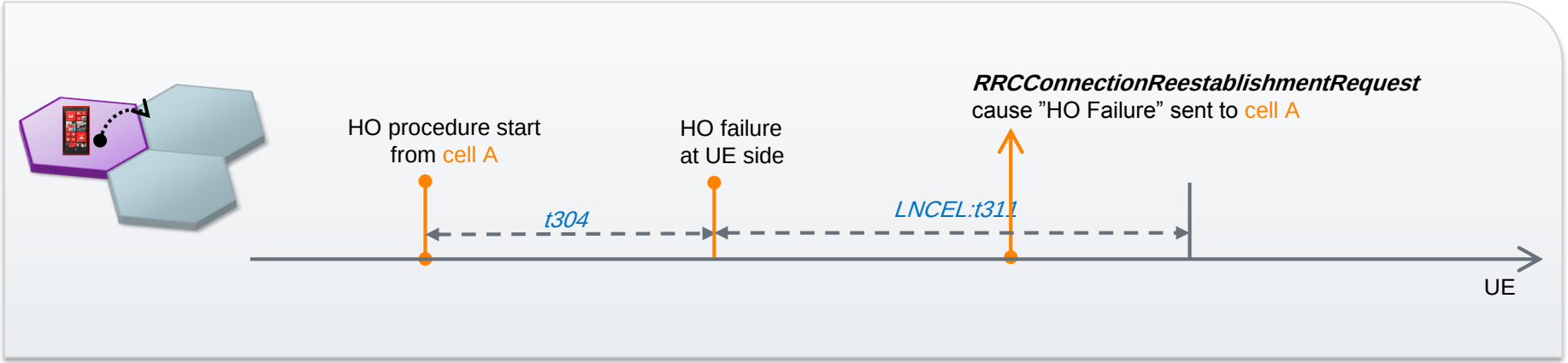
- **Too late HO** occurs when suitable HO target candidate is reported by UE too late, or not at all
  - UE stays too long in HO source cell – degrading cell quality enforces radio link failure on UE side
  - UE re-establishes connection to another cell
  - Could indicate missing neighbors

Related counters (incremented in cell A)
- M8015C16 MRO_LATE_HO_NB
- M8021C20 MRO_LATE_HO



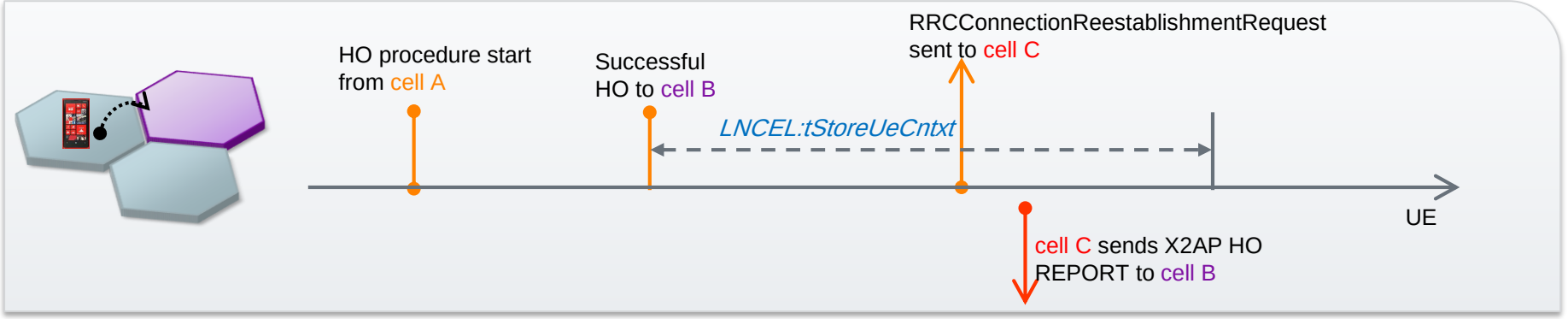
- **Too early HO Type I** occurs when HO triggered too early, UE tries to re-establish to source cell
  - UE tries to enter too early the HO target cell – insufficient cell quality enforces HO failure or radio link failure right after HO completion
  - UE re-establishes connection to HO source cell again
- Similar to this is Ping-Pong HO, which occurs, when UE returns via HO attempt to a cell shortly after leaving this cell via HO attempt

Related counters (incremented in cell A)
- M8015C17 MRO_EARLY_TYPE1_HO_NB
- M8021C21 MRO_EARLY_TYPE1_HO



- **Too early HO Type II** is triggered when handover is executed by UE too early - HO target candidate is reported by UE, while more suitable HO target candidate is becoming available as well
  - UE enters too early the HO target cell – insufficient cell quality enforces HO failure or radio link failure right after HO completion
  - Alternatively, handover is triggered and target cell receives PRACH preamble, but does not receive RRC Reconfiguration CompleteFinally UE re-establishes connection to a third cell
- Event can also be called **short stay**: generalization of Ping-pong HO to a triplet of cell (UE enters 3rd cell instead of returning to 1st)

Related counters (incremented in cell B)
- M8015C18 MRO_EARLY_TYPE2_HO_NB
- M8021C22 MRO_EARLY_TYPE2_HO



- 3GPP specified optional timer dedicated for Mobility Robustness implementation: *LNCEL:tStoreUeCntxt*
- **Start: Upon HO completion;**
  - either as reception of *RRCConnectionReconfigurationComplete* in HO target cell
  - or as reception of *RRCConnectionReestablishmentRequest* in HO target cell
- **Expiration: Upon reaching predefined expiration value;**
  - expiration value is an operator parameter
  - default value is proposed as 2000 ms (simulations)
  - granularity is 100 ms, range is 0-20000 ms
- **Association: UE context-specific, during run time stored with;**
  - PCI of HO source cell (from *X2 HANDOVER REQUEST* of completed HO)
  - ECGI or frequency of HO source cell (from *X2 HANDOVER REQUEST* of completed HO)
  - HO cause (from *X2 HANDOVER REQUEST* of completed HO)
  - C-RNTI assigned in HO target
  - shortMAC-I assigned in HO target
- **Stop: Upon reception of *X2 RLF INDICATION* for corresponding UE context**

The new X2 messages and new timer are the necessary ingredients of all singaling procedures to increment LTE533 counters ...

Radio Link Failures and call drop analysis

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Interdependencies

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Main Menu

Link monitors for RLF triggering

LTE50-a C-Plane exception handling
RL09/RL05TD

LTE50-e Radio Link Failure from HARQ
RL09/RL05TD

LTE50-g Radio Link Failure from CQI
RL09/RL05TD

- These functionalities provide basic mechanism to trigger RLF in case of DTX or desynchronization in UL or DL
- If any of the link monitors detects the problem, the eNB will wait of recovery until T_RLF timer expires (*LNCEL:t310* + *LNCEL:t311*)
- However that features are configurable only by hidden vendor parameters, which default set to the values which practically switches them off
- Included in backup slides

Cell outage

LTE432 Cell Outage Detection **RL10/RL15TD**

LTE502 Cell Outage triggered reset
RL20/RL15TD

LTE914 Graceful cell shutdown **RL20/RL35TD**

- Sleeping cells are special kind of cell outage in which no alarm is triggered and cell is assumed to be available
  - LTE432 & LTE502 provide basic functionality to detect and recover that cells to normal state
  - Due to variety of malfunctions leading to sleeping cell state different situations are expected
  - If UE would try the handover towards sleeping cell it may end with a call drop
- Graceful cell shutdown helps to offload the users to other cells before cell is switched off
  - However it may still happen that some UEs will be dropped

Interdependencies

Related features overview impact on call drops

Main Menu

Mobility

- **LTE533** Mobility Robustness **RL30/RL35TD**
- **LTE56** InterRAT PS handover to WCDMA **RL30**
- **LTE 872 & LTE 873** SRVCC to WCDMA & GSM **RL40/RL45TD**
- **LTE1036 & LTE1407** RSRQ based cell reselection & redirect **RL50/RL35TD**
- **LTE511** Intra cell HO **RL50/RL45TD**
- **LTE1617** RLF triggered handover **RL70/RL55TD**

- All mobility features provide the means to move the UEs between different network layers
- Availability of that features ensures continuity of the service while moving across the network
- In case of poor mobility configuration or lack of proper feature activation, the mobility may be spoiled by non-continuous coverage resulting in call drops

Automatic Neighbor Relationships

- **LTE492** ANR **RL20/RL15TD**
- **LTE782** ANR Intra-LTE, Intra-frequency Fully UE based **RL30/RL25TD**
- **LTE783 & LTE784 & LTE510** ANR InterRAT with O&M **RL30/RL25TD**
- **LTE 771** ANR Optimization of Intra-LTE neighbor relations **RL30/RL25TD**
- **LTE556** ANR Intra-LTE, Inter-frequency - UE based **RL60/RL45TD**
- **LTE908** ANR Inter-RAT UTRAN - Fully UE based **RL70/RL55TD**

- Automatic Neighbor Relationship features support the successful mobility procedures by provision of the relations between the cells
- In case of lack or wrong neighbor relationships, the handover attempt may lead to call drop

Interdependencies

Related features overview impact on call drops

Main Menu

Admission control

- **LTE20** Admission Control **RL09/RL05TD**
- **LTE144** Transport Admission Control **RL30/RL35TD**
- **LTE497** Smart Admission Control **RL40/RL35TD**
- **LTE534** ARP based admission Control **RL40/RL35TD**

- Admission control features protect the limited cell resources against overload
- Then UEs connection attempts may be rejected
- In case UE has no other layer it could connect to and come back to previous cell is impossible, the call drop will be triggered

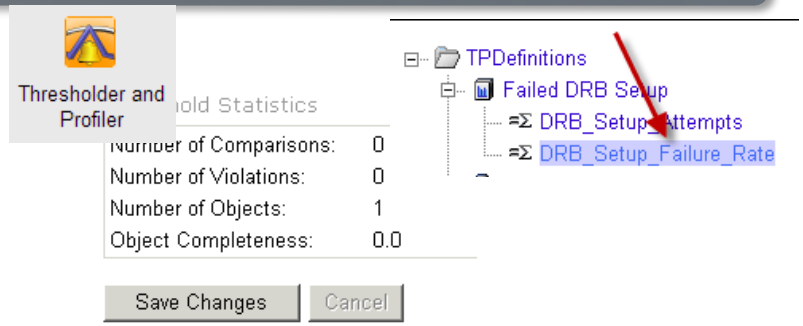
Other features

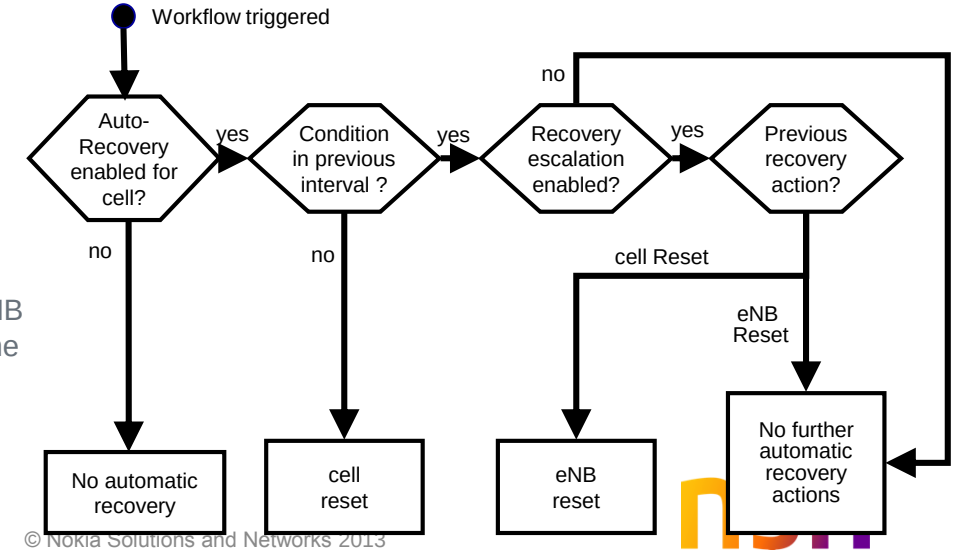
- **LTE735** RRC Connection Re-Establishment **RL30/RL25TD**
- **LTE979** IRC for 2 RX Paths **RL40**
- **LTE980** IRC for 4RX paths **RL50**

- The UE may initiate the RRC connection re-establishment procedure to continue the RRC connection without going to RRC Idle mode when:
  - detecting radio link failure
  - handover failure
  - mobility from E-UTRA failure
  - integrity check failure indication from lower layers
  - an RRC CONNECTION RECONFIGURATION failure
- Interference Rejection Combining features improve the SINR, thus decrease the probability of the call drop in interference limited scenarios

- Call drops may be especially caused by so called “sleeping cells”, which do not respond in UL or DL
  - Sleeping cells are visible to the NetAct as normal cells, however they do not provide the service and spoil CDR

- Basic support of KPI analysis and alarm triggering for this type of malfunction is introduced in the RL10 by the feature LTE432 Cell Outage Detection
  - The feature introduces Thresholder and Profiler NetAct application
  - With its capability (described in the PMO_SFS_Optmize) it is possible to define the KPI thresholds, which violated trigger the alarm
- On the top, LTE502 Cell Outage Triggered Reset will automatically trigger recovery actions, which can either be a cell lock/unlock or a eNB reset
  - NetAct uses plan download to request recovery actions from eNB
  - Two dummy parameters are introduced to control the reset of the cell/eNB reset (dummy → parameter used only to give eNB indication to perform the reset)





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RL09/RL05TD

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RL30/RL35TD

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RL30/RL25TD

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LTE980 IRC for 4RX paths **RL50**

Radio Link Failures and call drop analysis

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- **UE detected radio link problems –** T310 expiry

LNCEL

t310		Timer T310
Range:	0ms (0), 50ms (1), 100ms (2), 200ms (3), 500ms (4), 1000ms (5), 2000ms (6)	Timer T310 supervises the **recovery** from physical layer problems. Higher the value of the parameter, longer the time in which UE can stay in RLF state waiting for recovery. Lowering the value causes faster release → higher drop ratio **The recommended value for cells with high call drop rate is t310=2000ms(6)**
Default:	2000 ms	

t311		Timer T311
Range:	1000ms (0), 3000ms (1), 5000ms (2), 10000ms (3), 15000ms (4), 20000ms (5), 30000ms (6)	Timer T311 supervises the RRC connection re-establishment. Together with T310, the timer increases the time in which UE can try to recover from RLF state. The timer shall be aligned to typical re-establishment procedure time. The longer the value of this parameter, the longer eNB will wait for successful re-establishment. Lowering the value of this parameter can lead to increased drop ratio **The recommended value is t311=3000ms(1)**
Default:	3000 ms	

- **UE detected radio link problems** – T310 expiry

LNCEL

n310		Maximum number of out-of-sync indications
Range:	n1 (0), n2 (1), n3 (2), n4 (3), n6 (4), n8 (5), n10 (6), n20 (7)	N310 specifies maximum number of out-of-sync indications. The number of out-of-sync indications specified by this parameter will trigger the RLF, after which the recovery is attempted. **The recommended value for cells with high call drop rate is n310=n20(7)**
Default:	n10	

n311		Maximum number of in-sync indications
Range:	n1 (0), n2 (1), n3 (2), n4 (3), n5 (4), n6 (5), n8 (6), n10 (7)	Timer T311 specifies the number of in-sync indications. If the number of in-sync indications specified by this parameter will reached during the out-of-sync state, the RLF state will be cancelled. **The recommended value for cells with high call drop rate is n311=n1(0)**
Default:	n1	

- **UE detected radio link problems –** T304 expiry

LNCEL

Abbreviated Name	Range	Full Name	RL50 default
t304eNaccGsm	100ms (0), 200ms (1), 500ms (2), 1000ms (3), 2000ms (4), 4000ms (5), 8000ms (6)	Timer T304 for eNACC to GSM	2000ms
t304InterRAT		Timer T304 for interRAT	500ms
t304InterRATGsm		Timer T304 for interRAT GSM	500ms
t304InterRatTd		Timer t304 for handover to TD-SCDMA	500ms
t304IntraLte	50ms (0), 100ms (1), 150ms (2), 200ms (3), 500ms (4), 1000ms (5), 2000ms (6)	Timer T304 intra-LTE	1000ms

- The timers supervise the successful completion of a handover or cell change to various RATs to guard the procedure during the execution phase
  - The length of those timers is related to specifics of the handover procedures
  - Lowering the value of any of those parameter can decrease the HO success ratio

- **eNB detected radio link problems –** SRS RLF triggered

LNCEL (from RL35TD), LNBTS(to RL25TD)

nSrsDtx		Radio problem indication based on SRS DTX
Range:	0...100	This parameter defines the number of SRS DTX occurrences after which the RLF indication will be triggered for higher layers. • Lower the value of this parameter, faster RLF indication would be triggered. • Higher the value of this parameter, slower RLF indication
Step:	1	
Default:	50	

nSrsRec		Radio problem recovery based on SRS DTX
Range:	1...8	This parameter defines the number of periodic SRS reports after which the RLF indication will be cancelled for higher layers. • Lower the value of this parameter, faster the recovery from the RLF state. **Values higher than 1 and lower than 4 are recommended** • Higher the value of this parameter, slower recovery from the RLF state
Step:	1	
Default:	2	

- **eNB initiated release –** TA Timer Expiry at eNB

LNCEL

taTimer	Time Alignment timer
Range: 500 (0), 750 (1), 1280 (2), 1920 (3), 2560 (4), 5120 (5), 10240 (6) **Default:** 1280	The parameter is used by eNB to maintain the timing alignment (timeAlignmentTimer) by periodical or per-need TA commands. It determines the number of subframes after which a UE assumes it is out-of-sync in UL if no Time Alignment command was received. • Periodic UL TA is triggered by *taTimer* – *taTimerMargin* (~8.2 sec with default settings)
taTimerMargin	**Time alignment timer margin**
Range: 0...2560 **Default:** 89	*taTimerMargin* is used commonly with taTimer to indicate how often periodic Time Alignment should be performed. • Periodic UL TA is triggered by *taTimer* – *taTimerMargin* (~8.2 sec with default settings)
taMaxOffset	**Time Alignment maximum offset**
Range: 0...5 us **Step:** 0,01us **Default:** 0,52 us	*taMaxOffset* is used in On per need basis Time Alignment procedure If eNodeB notes the deviation if calculated TA is higher than taMaxOffset (0.52us by default) the TA cmd (6 bits MAC TA CE command is used).

- **eNB initiated release –** TA Timer Expiry at eNB - DRX

LNCEL

applyOutOfSyncState		Apply UL out-of-sync state
Range:	extendedDrxOnly (0), allDrx (1), allUEs (2)	Determines which UEs shall be actively sent to UL out-of-sync state provided that bearer combination and applied DRX profile allows for this.

Default:	extendedDrxOnly	• **extendedDrxOnly** (default):
		  • Inactivity timer applied only for UEs that are currently using **drx(Smart)Profile4** or **drx(Smart)Profile5**
		• **allDrx:**
		  • Inactivity timer will be applied only for UEs running with DRX Profile, UEs that are currently using **drx(Smart)Profile2 up to drx(Smart)Profile5**.
		• **allUEs:**
		  • Inactivity timer will be applied for all UEs regardless of DRX activation flag and UE short/long cycle capabilities

• eNB initiated release – Maximum RLC Retransmissions Exceeded at eNB

- The RLC configuration is divided into two structures:
  - RLC profiles, which can be assigned to QCI (see next slide)
  - AM RLC poll byte tables, which vary depending on UE category
- SRB1 and SRB2 configuration for RLC is hardcoded

LNBTS → RLC profiles parameters						
	rlcProf1	**rlcProf2**	**rlcProf3**	**rlcProf4**	**rlcProf5**	**SRBs**
pollPdu	infinity	64	64	64	64	Infinity
tPollRetr	120 ms	120 ms	120 ms	120 ms	120 ms	100 ms
tProhib	10 ms	10 ms	10 ms	10 ms	10 ms	0 ms
tReord	10 ms	10 ms	10 ms	10 ms	10 ms	50 ms
LNBTS → AM RLC poll byte tables for DRBs						
	amRlcPBTab1	**amRlcPBTab2**	**amRlcPBTab3**	**amRlcPBTab4**	**amRlcPBTab5**	**SRBs**
dlPollByte	25 kB	25 kB	50 kB	75 kB	125 kB	infinity
ueCategory	1	2	3	4	5	-
ulPollByte	25 kB	25 kB	25 kB	25 kB	50 kB	infinity

SRB1 and SRB2 values for RLC configuration are hardcoded (TF_LTE_SFS_BEARERMAN.1219)

LNBTS RLC profiles (structures):

- rlcProf1
- rlcProf2
- rlcProf3
- rlcProf4
- rlcProf5

Profile parameters
- rlfProfId
- pollPdu
- tPollRetr
- tProhib
- tReord

LNBTS AM RLC poll byte tables for DRBs (structures):

- amRlcPBTab1
- amRlcPBTab2
- amRlcPBTab3
- amRlcPBTab4
- amRlcPBTab5

Poll byte table parameters
- ueCategory
- dlPollByte
- ulPollByte

- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

- All the configured RLC profiles can be assigned to a specific QCI in the QCI tab (e.g. *LNBTS:qciTab1* ➔ *rlcProfIdx*)
- For QCI1-3 there's no possibility to change the RLC mode or RLC profile index
  - They can work only in RLC unacknowledged mode (RLC_UM) with special dedicated profiles
- QCI4 can be assigned with for both RLC_AM and RLC_UM
- QCI5-9 can only work RLC_UM

- Only RLC **profile 1 and 2** are used by default
- QCI9 is usually default bearer

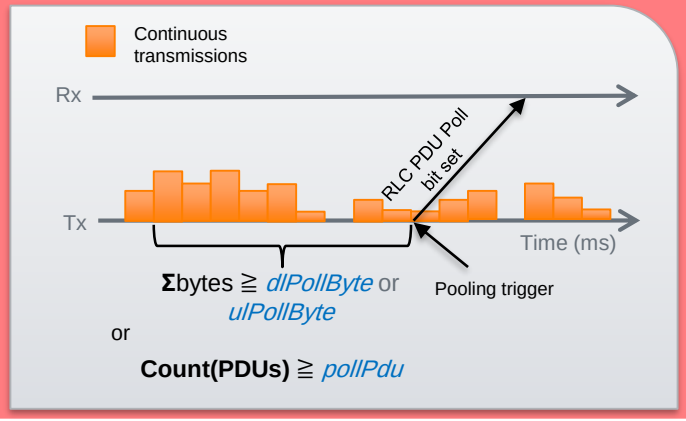
QCI	Resource Type	RLC Mode	RLC Profile Index (default)
1	GBR	RLC_UM	101
2	GBR	RLC_UM	102
3	GBR	RLC_UM	103
4	GBR	RLC_UM, RLC_AM **default: RLC_AM**	104, 1…5 (104 for RLC_UM or 2 for RLC_AM)
5	NON-GBR	RLC_AM	1…5 (1)
6	NON-GBR	RLC_AM	1…5 (2)
7	NON-GBR	RLC_AM	1…5 (2)
8	NON-GBR	RLC_AM	1…5 (2)
9	NON-GBR	RLC_AM	1…5 (2)

TF_LTE_SFS_BEARERMAN.1915, *Table 1915-1: QCITranslationTable in RL60*

- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

LNBTS: rlcProf2 → as an example

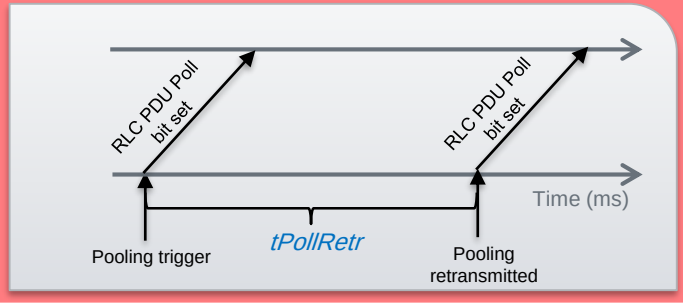
pollPdu	Poll PDU
Range: 4 (0), 8 (1), 16 (2), 32 (3), 64 (4), 128 (5), 256 (6), infinity (7) **Default:** 64 (4)	This parameter defines the behavior of the RLC polling mechanism in the RLC Acknowledged Mode. The RLC PDUs with Poll Bit set to 1 are the PDUs that require the ACK with Status Report to be sent back to the transmitter. This parameter specified how often this polling message is being sent, i.e. how many RLC PDUs separate the occasions at which the polling is transmitted. • The lower the value, the more overhead is introduced (more often *STATUS_PDU* transmissions) but the reliability is increased. • Increasing the value can lead to increased call drop ratio due to RLC retransmissions, due to scarce STATUS_PDU reporting • The value "infinity" means that the polling is not sent.



- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

LNBTS: rlcProf2 → as an example

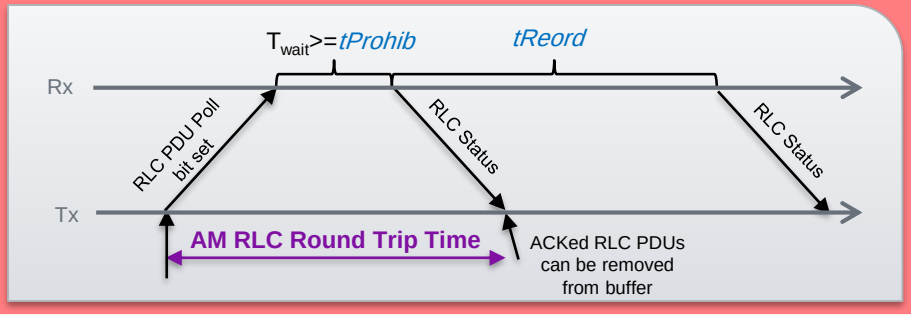
tPollRetr		Timer poll retransmit
Range:	5ms (0), 10ms (1), 15ms (2), 20ms (3), 25ms (4), 30ms (5), 35ms (6), 40ms (7), 45ms (8), 50ms (9), 55ms (10), 60ms (11), 65ms (12), 70ms (13), 75ms (14), 80ms (15), 85ms (16), 90ms (17), 95ms (18), 100ms (19), 105ms (20), 110ms (21), 115ms (22), 120ms (23), 125ms (24), 130ms (25), 135ms (26), 140ms (27), 145ms (28), 150ms (29), 155ms (30), 160ms (31), 165ms (32), 170ms (33), 175ms (34), 180ms (35), 185ms (36), 190ms (37), 195ms (38), 200ms (39), 205ms (40), 210ms (41), 215ms (42), 220ms (43), 225ms (44), 230ms (45), 235ms (46), 240ms (47), 245ms (48), 250ms (49), 300ms (50), 350ms (51), 400ms (52), 450ms (53), 500ms (54)	This parameter defines the behavior of the RLC polling mechanism in the RLC Acknowledged Mode. The RLC PDUs with Poll Bit set to 1 are the PDUs that require the ACK with Status Report to be sent back to the transmitter. This parameter specified how much time shall elapse between sending an original poll and its retransmission in case of not receiving the related Status Report.
Default:	120ms (23)	



- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

LNBTS: rlcProf2 → as an example

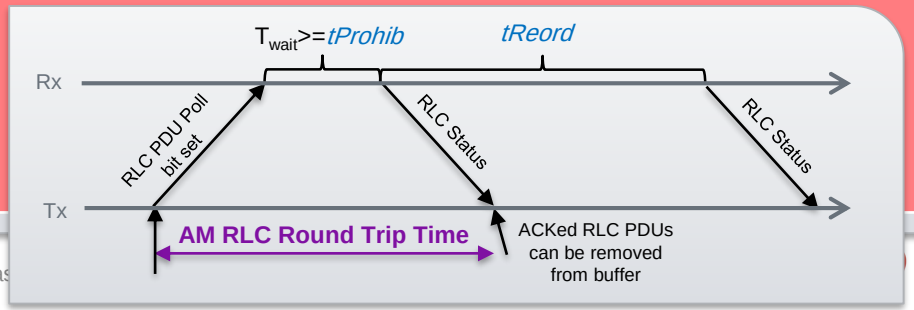
tProhib		Timer status prohibit
Range:	0ms (0), 5ms (1), 10ms (2), 15ms (3), 20ms (4), 25ms (5), 30ms (6), 35ms (7), 40ms (8), 45ms (9), 50ms (10), 55ms (11), 60ms (12), 65ms (13), 70ms (14), 75ms (15), 80ms (16), 85ms (17), 90ms (18), 95ms (19), 100ms (20), 105ms (21), 110ms (22), 115ms (23), 120ms (24), 125ms (25), 130ms (26), 135ms (27), 140ms (28), 145ms (29), 150ms (30), 155ms (31), 160ms (32), 165ms (33), 170ms (34), 175ms (35), 180ms (36), 185ms (37), 190ms (38), 195ms (39), 200ms (40), 205ms (41), 210ms (42), 215ms (43), 220ms (44), 225ms (45), 230ms (46), 235ms (47), 240ms (48), 245ms (49), 250ms (50), 300ms (51), 350ms (52), 400ms (53), 450ms (54), 500ms (55)	This parameter defines the behavior of the RLC polling mechanism in the RLC Acknowledged Mode. The RLC PDUs with Poll Bit set to 1 are the PDUs that require the ACK with Status Report to be sent back to the transmitter. This parameter specified how much time shall elapse between sending an original poll and its retransmission in case of not receiving the related Status Report.
Default:	50ms (10)	



- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

LNBTS: rlcProf2 → as an example

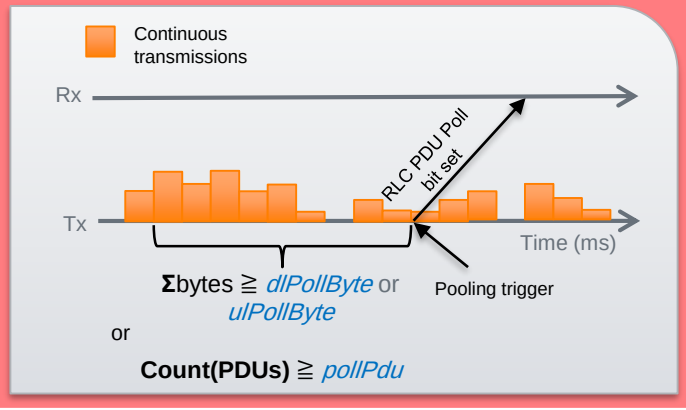
tReord		Timer reordering
Range:	0ms (0), 5ms (1), 10ms (2), 15ms (3), 20ms (4), 25ms (5), 30ms (6), 35ms (7), 40ms (8), 45ms (9), 50ms (10), 55ms (11), 60ms (12), 65ms (13), 70ms (14), 75ms (15), 80ms (16), 85ms (17), 90ms (18), 95ms (19), 100ms (20), 110ms (21), 120ms (22), 130ms (23), 140ms (24), 150ms (25), 160ms (26), 170ms (27), 180ms (28), 190ms (29), 200ms (30)	This parameter defines the behavior of the RLC polling mechanism in the RLC Acknowledged Mode. The RLC PDUs with Poll Bit set to 1 are the PDUs that require the ACK with Status Report to be sent back to the transmitter. Apart from responding to the Poll Bit, the Status Reports are sent in case of detection of a missing PDU. This parameter specifies for how long the receiving side will wait for missing PDU with certain Sequence Number before sending the Status Report. Note that the Status Report will not be sent if less time than defined by time ***LNBTS:tProhib*** elapsed since last transmitted Status Report.
Default:	50ms (10)	



- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

LNBTS: amRlcPBTab3 → UE category 3 (ueCategory = 3) as an example

dlPollByte / ulPollByte	DL poll byte / UL poll byte
Range: 25kB (0), 50kB (1), 75kB (2), 100kB (3), 125kB (4), 250kB (5), 375kB (6), 500kB (7), 750kB (8), 1000kB (9), 1250kB (10), 1500kB (11), 2000kB (12), 3000kB (13), Infinity (14) **Default:** 25kB (0)	This parameter defines the behavior of the RLC polling mechanism in the RLC Acknowledged Mode. The RLC PDUs with Poll Bit set to 1 are the PDUs that require the ACK with Status Report to be sent back to the transmitter. There are several mechanisms defining when the Poll Byte shall be sent. This parameter, defines how much data needs to be sent over RLC layer in the downlink or uplink direction before the Poll Byte is inserted in the uplink PDU requiring the receiving side to sent back the Status Report. This parameter is dependent on UE category (here: UE Category 3). Note that the Status Report will not be anyway sent back if less time than defined by time **LNBTS:tProhib** elapsed since last transmitted Status Report.



- **eNB initiated release –** Maximum RLC Retransmissions Exceeded at eNB

LNBTS: amRlcPBTab3 → UE category 3 (ueCategory = 3) as an example

dlPollByte / ulPollByte		DL poll byte / UL poll byte
Range:	1 (0), 2 (1), 3 (2), 4 (3), 6 (4), 8 (5), 16 (6), 32 (7)	The parameter defines how many retransmissions of any piece of data in RLC Acknowledged Mode are possible before declaring radio link failure. Each AM PDU sent out needs to by acknowledged by the receiving end, therefore all unacknowledged data need to be kept in the transmit buffer until the acknowledgement carrying the appropriate Transmit Serial Number is received. • The parameter is by default set to high value (default=16) to improve robustness in HO scenarios • The parameter is on a higher level than ARQ and HARQ • For the SRB1 and SRB2 the parameter is hardcoded to the value 16 Therefore with default values the **"Maximum number of RLC retransmissions"** will be triggered after: • **DRB**: *PollRetr ×(drbAmMxRtxTh+1) = 120ms ×(16+1) =* ***2040 ms*** • **SRB1** or **SRB2**: *100ms×(drbAmMxRtxTh+1) = 100ms ×(16+1) =* ***1700 ms*** The reaction on the "Maximum number of RLC retransmissions" depends on the LTE release. From RL50 onwards: Intra-cell handover is used to unblock the RLC entity (LTE511) • If the handover fails, UE CONTEXT RELEASE is triggered instead • intra-cell handover cannot be initiated if the event has occurred for SRB1 (the RRCConnectionReconfiguration cannot be sent to UE),
Default:	16 (6)	

Radio Link Failures and call drop analysis

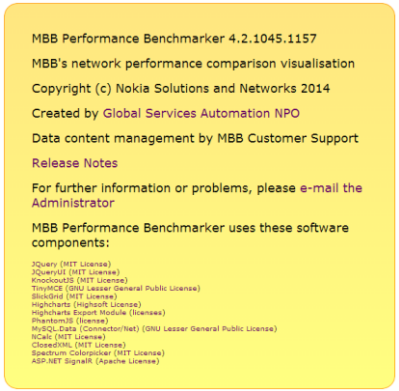
Table of contents

- The call drop performance can be analyzed using **Retainability KPIs**
- Retainability (reliability) KPIs indicate the ability to hold/sustain the call, that is, the **ratio between erroneous or lost data units and the overall number of data units sent**
  - Call drop,
  - Call completion,
  - E-RAB drop,
  - E-RAB normal release,
  - RRC Connection Re-establishment
  - IP incoming traffic error rate
- Additionally, the **Integrity KPIs** can inform about the retransmission rate at RLC level
- Mobility KPIs can be separately analyzed using the existing counters
- This section provides the list of the most important KPI's which can be used to analyze the call drops

Disclaimer

The following slides are based on the MBB Performance Benchmarker data dated on December 2013. For the latest statistics please use the tools.

MBB Performance Benchmarker



- Counters and KPIs are defined in **RISE** and also available from JUMP/NOP (links are given under the IDs)

RISE

- Main tool for storage and maintenance of the PM data
- Contains the most recent information (e.g. counters and alarms descriptions, benchmark KPIs definitions)
- **Only benchmark KPI's (ID > 5000)**
- Includes R&D internal counters
- free of charge

JUMP/ NOP

- **added value information** (e.g. report definitions and all formulas used in the reports)
- **Contains RISE exports, and additional KPI's** (ID <5000)
- **The access to the tool can be obtained for customers with Reporting Suite license**
- Advanced info sharing (counters, parameters, formulas, report definitions), dynamic linking (auto created) and efficient networking (comments) solution

- E-RAB Drop rate is main KPI (LTE_5025) is used to qualify retainability of a LTE network

$$\text{E-RAB Droprate} = \frac{\#\text{of Abnormal E-RAB releases}}{\#\text{of Normal E-RAB releases} + \#\text{of Abnormal E-RAB releases}}$$

  - Number of ABNORMAL E-RAB Releases and number of NORMAL E_RAB releases are impacting Drop rate
  - While number of ABNORMAL releases is an indication of quality, number of NORMAL releases depend a lot on network configuration (e.g. inactivity timers) and on offered service (always connected service)
  - In case of always connected service NORMAL releases might never be triggered. This leads to a very high drops rates, sometimes up to 100%.

- For packet data services E-RAB drop rate is an insufficient performance indicator, therefore **E-RAB Drops per PDCP SDU volume** (LTE_5812b) is introduced
  - For data services the UE can even does not notice that the drop occurred, which will only impact the delay a bit. UE can continue the service after successful Re-establishment.

- **LTE_5025d E-UTRAN E-RAB Drop Ratio, RAN View**
  - The most common drop ratio indicator
  - **KPI describes the ratio of abnormally released (dropped) E-RABs from RAN point of view**
    - Each bearer of the "Bearer to be Released List" IE is counted. RAN point of view means that as abnormal E-RAB drops only those ones initiated by eNB are counted
    - E-RAB releases due to *"No radio resources available"* initiated by eNB are counted as normal releases as they are not real drops resulted from any radio quality problems.
    - "The PRE_EMPT_GBR_BEARER and PRE_EMPT_NON_GBR_BEARER counters provide the total number of released GBR and non GBR E-RABs due to *"Radio resources not available"* despite a pre-emption used in the counter names, respectively
    - In the denominator of the formula normal and abnormal E-RAB releases except the successful intra LTE HO are counted. The E-RAB releases that appear after successful inter RAT HO are counted
    - E-RAB releases due to S1 RESET are not counted at all
  - RL50 KPI target value for optimized network: **LTE_5025< 0.5%** (non optimized 2%)

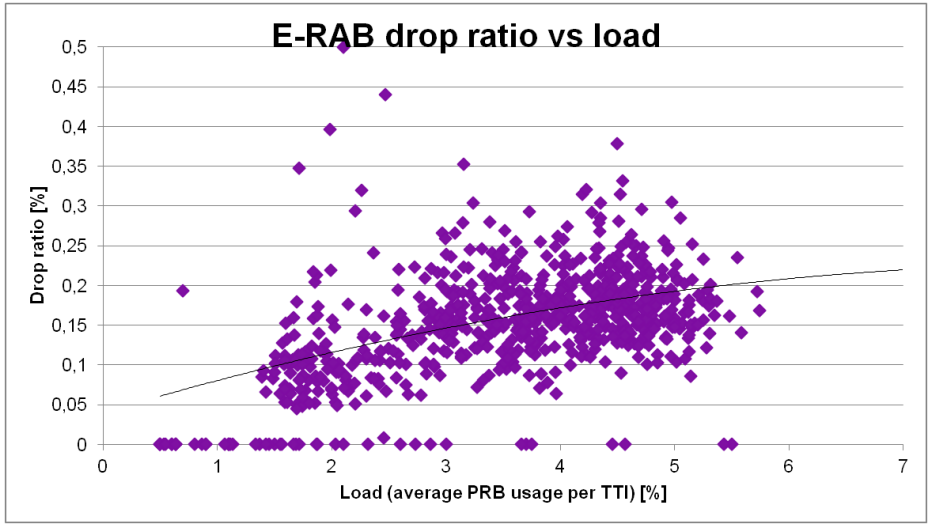
Top 10

Rank	Customer	KPI
1	Customer 221	0.04 %
2	Customer 727	0.05 %
3	Customer 558	0.06 %
4	Customer 639	0.06 %
5	Customer 195	0.11 %
6	Customer 202	0.11 %
7	Customer 357	0.11 %
8	Customer 201	0.12 %
9	Customer 189	0.13 %
10	Customer 419	0.13 %

Source: MBB Benchmarker

$$\text{LTE\_5025d} = \frac{\text{ENB\_EPS\_BEARER\_REL\_REQ\_RNL} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_TNL} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_OTH}}{\text{EPC\_EPS\_BEARER\_REL\_REQ\_NORM} + \text{EPC\_EPS\_BEARER\_REL\_REQ\_DETACH} + \text{EPC\_EPS\_BEARER\_REL\_REQ\_RNL} + \text{EPC\_EPS\_BEARER\_REL\_REQ\_OTH} + \text{ENB\_EPSBEAR\_REL\_REQ\_RNL\_REDIR} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_NORM} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_RNL} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_TNL} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_OTH} + \text{PRE\_EMPT\_GBR\_BEARER} + \text{PRE\_EMPT\_NON\_GBR\_BEARER}} \times 100\%$$

- The probability of the drop is increased in high load scenarios
  - The trend can be verified by correlation with load KPI (e.g. PRB usage)
- When comparing 2 various networks or clusters, the load should be criterion



- **LTE_5812b E-UTRAN E-RAB Drops per PDCP SDU volume, User Perspective (eNB pre-emptions excluded)**
  - KPI describes the amount of E-RAB drops per PDCP SDU volume from user perspective point of view
    - Each bearer of the "Bearer to be Released List" IE is counted
  - For end user it is not relevant how many times a RAB was released in inactivity phase; it is important that data transfer is working without or just very few E-RAB drops
  - The formula indicates how many drops happened per gigabyte

$$\text{E-RAB Drops per end user volume} = \frac{\#\text{of Abnormal E-RAB releases}}{\text{Transfered user data}}$$

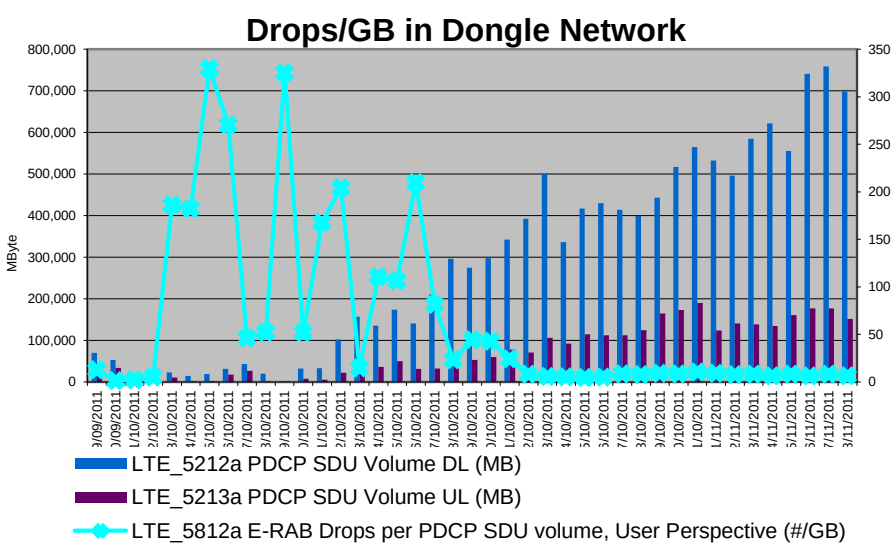
Top 10

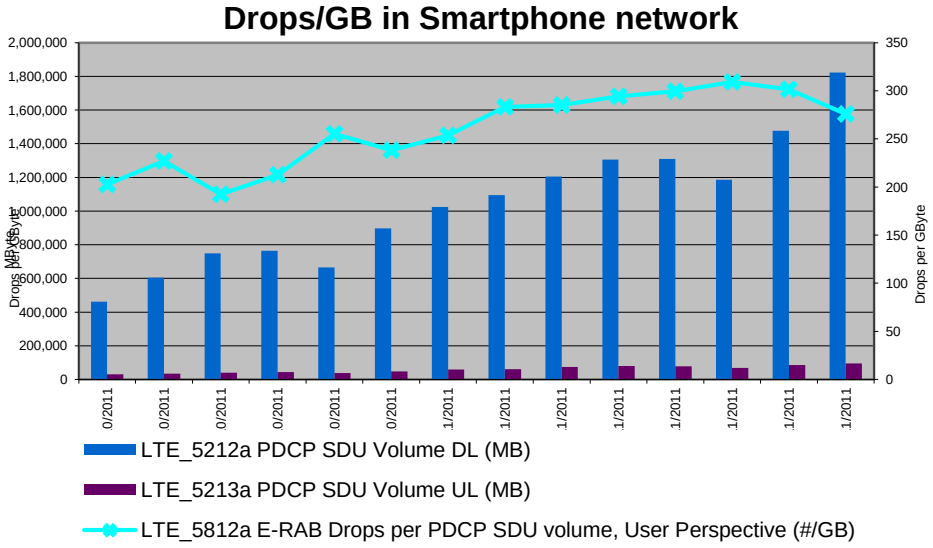
Rank	Customer	KPI
1	Customer 242	0.89 ↓
2	Customer 727	0.90
3	Customer 604	0.92 ↓
4	Customer 606	1.17 ↓
5	Customer 471	1.83 ↓
6	Customer 558	2.52 ↑
7	Customer 477	2.79 ↑
8	Customer 579	3.81 ↓
9	Customer 246	5.64 ↑
10	Customer 197	6.10 ↑

Source: MBB Benchmarker

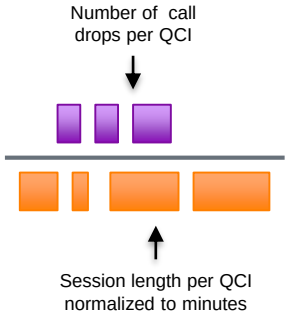
$$\text{LTE\_5812b} = \frac{\begin{array}{l}EPC\_EPS\_BEARER\_REL\_REQ\_RNL + EPC\_EPS\_BEARER\_REL\_REQ\_OTH + \\ ENB\_EPS\_BEARER\_REL\_REQ\_RNL + ENB\_EPS\_BEARER\_REL\_REQ\_TNL + \\ ENB\_EPS\_BEARER\_REL\_REQ\_OTH - \\ PRE\_EMPT\_GBR\_BEARER - PRE\_EMPT\_NON\_GBR\_BEARER\end{array}}{PDCP\_SDU\_VOL\_UL + PDCP\_SDU\_VOL\_DL} \quad [1/GB]$$

- The difference between the E-RAB drops per PDCP volume KPIs in two kind of networks can be observed
  - In dongle dominated network (low mobility, no voice services) the number of drops per GB does not increase too much with increasing data volume
  - In Smartphone dominated network (high mobility, voice services) the drops per GB follow the trend of volume increase, due to additional call drop causes (failed HO, high speed UE etc.)





- **LTE_5581a E-UTRAN E-RAB Retainability Rate, RAN View, RNL Failure with UE Lost**
  - **KPI provides how often an end-user abnormally looses E-RAB due to RNL failure with UE lost cause an E-RAB during the time the E-RAB is active**
    - The KPI unit is number of drops per minute
    - **Denominator counters are updated** when user data are buffered (UL/DL) for an E-RAB with various QCI characteristics and the "S1AP UE Context Release Request" message is sent by eNB to the MME with the release cause "RNL Radio Connection with UE lost“
    - The release is initiated by the eNB due to radio connectivity problems



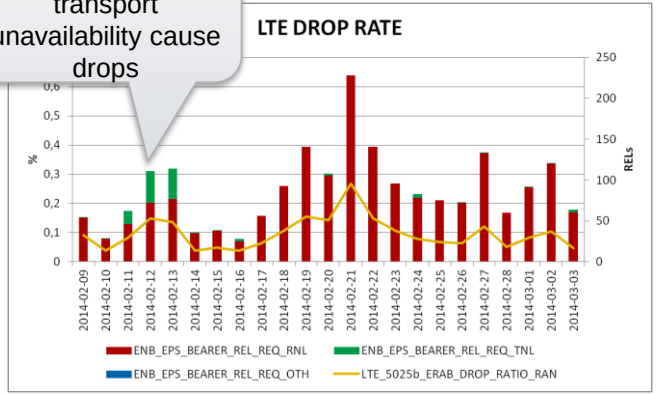
$$\text{LTE\_5025d} = \frac{ERAB\_REL\_ENB\_ACT\_QCI1 + ERAB\_REL\_ENB\_ACT\_QCI2 + ERAB\_REL\_ENB\_ACT\_QCI3 + ERAB\_REL\_ENB\_ACT\_QCI4 + ERAB\_REL\_ENB\_ACT\_NON\_GBR}{(ERAB\_IN\_SESSION\_TIME\_QCI1 + ERAB\_IN\_SESSION\_TIME\_QCI2 + ERAB\_IN\_SESSION\_TIME\_QCI3 + ERAB\_IN\_SESSION\_TIME\_QCI4 + ERAB\_IN\_SESSION\_TIME\_NON\_GBR) / 60} \quad [\#/min]$$

- **LTE_5570c E-UTRAN E-RAB active drop ratio with data in the buffer due to RNL Radio Connection with UE Lost**
  - **KPI describes the drop ratio of E-RABs with data in the buffer due to RNL Radio Connection with UE Lost cause initiated by eNB**
    - Each bearer of the "Bearer to be Released List" IE is counted excepting the formula LTE_5570b and LTE_5571a (QCI1) where as abnormal releases only those E-RABs with data in any buffer are counted
    - There is an overlapping in the abnormal E-RABs counted within the LTE_5090a and LTE_5570b but from network planning and optimization point of view it is mandatory to have also an own indicator dealing with active E-RAB drops with data in the buffer only
    - In the denominator of the formulae normal and abnormal E-RAB releases except the successful intra LTE HO are counted. The E-RAB releases that appear after successful inter RAT are counted.

$$\text{LTE\_5570c} = \frac{\text{ERAB\_REL\_ENB\_ACT\_QCI1} + \text{ERAB\_REL\_ENB\_ACT\_QCI2} + \text{ERAB\_REL\_ENB\_ACT\_QCI3} + \text{ERAB\_REL\_ENB\_ACT\_QCI4} + \text{ERAB\_REL\_ENB\_ACT\_NON\_GBR}}{\text{EPC\_EPS\_BEARER\_REL\_REQ\_NORM} + \text{EPC\_EPS\_BEARER\_REL\_REQ\_DETACH} + \text{EPC\_EPS\_BEARER\_REL\_REQ\_RNL} + \text{EPC\_EPS\_BEARER\_REL\_REQ\_OTH} + \text{ENB\_EPSBEAR\_REL\_REQ\_RNL\_REDIR} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_NORM} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_RNL} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_TNL} + \text{ENB\_EPS\_BEARER\_REL\_REQ\_OTH} + \text{PRE\_EMPT\_GBR\_BEARER} + \text{PRE\_EMPT\_NON\_GBR\_BEARER}} \times 100\%$$

- **LTE_5090b E-UTRAN E-RAB Drop Ratio per Cause RNL**
  - **KPI describes the ratio of a specific E-RAB drop (abnormal release) cause related to all E-RAB release commands**
    - Numerator of this KPI is triggered with transmission of an S1AP:UE CONTEXT RELEASE REQUEST message from the eNB to the MME in case this message is sent due to a detected Radio Link Failure (RNL cause "Radio Connection with UE lost")
    - All released E-RABs are counted
  - Besides the RNL cause also the TNL and OTH causes exist, however their impact on the on the drop rate is marginal
    - TNL present

Only during massive eNB resets transport unavailability cause drops



$$\text{LTE\_5090b} = \frac{ENB\_EPS\_BEARER\_REL\_REQ\_RNL}{EPC\_EPS\_BEARER\_REL\_REQ\_NORM+EPC\_EPS\_BEARER\_REL\_REQ\_DETACH+EPC\_EPS\_BEARER\_REL\_REQ\_RNL+EPC\_EPS\_BEARER\_REL\_REQ\_OTH+ENB\_EPSBEAR\_REL\_REQ\_RNL\_REDIR+ENB\_EPS\_BEARER\_REL\_REQ\_NORM+ENB\_EPS\_BEARER\_REL\_REQ\_RNL+ENB\_EPS\_BEARER\_REL\_REQ\_TNL+ENB\_EPS\_BEARER\_REL\_REQ\_OTH+PRE\_EMPT\_GBR\_BEARER+PRE\_EMPT\_NON\_GBR\_BEARER} \times 100\%$$

- **LTE_5571b E-UTRAN E-RAB QCI1 with data in the queue drop ratio, RAN View, RNL Failure with UE Lost**
  - **KPI describes the drop ratio of QCI1 E-RABs with data in the buffer due to RNL Radio Connection with UE Lost cause initiated by eNB**
    - Each bearer of the "Bearer to be Released List" IE is counted excepting the formula **LTE_5570b** and **LTE_5571b** (QCI1) where as abnormal releases only those E-RABs with data in any buffer are counted
    - This formula is needed to monitor the VoIP Call Drop Ratio (more information on the VoLTE performance monitoring ➔ link)
    - In the denominator of the formulae normal and abnormal E-RAB releases except the successful intra LTE HO are counted. The E-RAB releases that appear after successful inter RAT HO are counted
    - E-RAB releases due to S1 RESET are not counted at all
    - E-RAB releases due to *"No Radio Resources Available"* initiated by eNB are counted as normal releases as they are not real drops resulted from any radio quality problems.
    - The PRE_EMPT_GBR_BEARER and PRE_EMPT_NON_GBR_BEARER counters provide the total number of released GBR and non GBR E-RABs due to "*Radio Resources not Available"* despite a pre-emption used in the counter names, respectively.
    - This KPI may provide slightly worse results as the E-RAB releases due to *"No Radio Resources Available"* initiated by eNB are not counted in denominator of the formula
  - Similar KPIs exist also for other QCIs

$$\text{LTE\_5571b} = \frac{ERAB\_REL\_ENB\_ACT\_QCI1}{EPC\_EPS\_BEAR\_REL\_REQ\_N\_QCI1+EPC\_EPS\_BEAR\_REL\_REQ\_D\_QCI1+EPC\_EPS\_BEAR\_REL\_REQ\_R\_QCI1+ EPC\_EPS\_BEAR\_REL\_REQ\_O\_QCI1 + ENB\_EPS\_BEAR\_REL\_REQ\_RD\_QCI1+ ENB\_EPS\_BEAR\_REL\_REQ\_N\_QCI1 + ENB\_EPS\_BEAR\_REL\_REQ\_R\_QCI1 +ENB\_EPS\_BEAR\_REL\_REQ\_T\_QCI1 +ENB\_EPS\_BEAR\_REL\_REQ\_O\_QCI1} \times 100\%$$

- **LTE_5575a E-UTRAN Total E-RAB Active Time**
  - **KPI provides the aggregated in-session activity time in minutes for all E-RABs**
    - The E-RAB is said to be "in-session" if any user data has been transferred in UL or DL direction within the last 100msec
    - All released E-RABs are counted
  - It is always important to check this KPI, whenever the call drop ratio increases, to make sure that there were enough sessions in the statistics. **Small value of this KPI may indicate low number of sessions which can spoil drop ratio**
  - **The respective KPI can be drilled down to specific QCI class:**
    - LTE_5576a E-UTRAN E-RAB Active Time QCI1
    - LTE_5577a E-UTRAN E-RAB Active Time QCI2
    - LTE_5578a E-UTRAN E-RAB Active Time QCI3
    - LTE_5580a E-UTRAN E-RAB Active Time nonGBR

$$\text{LTE\_5575a} = \frac{ERAB\_IN\_SESSION\_TIME\_QCI4+ERAB\_IN\_SESSION\_TIME\_QCI3+ERAB\_IN\_SESSION\_TIME\_QCI2+ERAB\_IN\_SESSION\_TIME\_QCI1+ERAB\_IN\_SESSION\_TIME\_NON\_GBR}{60} \quad [min]$$

- **LTE_5150b E-UTRAN Graceful Cell Shutdown Drop Rate**
  - **KPI describes the ratio of the number of released UE context due to S1AP Partial Resets to the total number of UEs before start of graceful cell shutdown.**
    - The KPI is related to LTE914 Graceful cell shutdown which is used to empty the cell from UEs whenever the cell of an eNodeB shall be deactivated e.g. to execute service tasks
    - The UEs are motivated to leave the cell by stepwise reduction of the eNodeB cell TX power. After the power reduction procedure is completed the eNB will execute a **S1 Partial Reset**. Then the remaining UE connections (e.g. located in the center of the cell) will be released.
  - High value of this KPI could spoil the overall, drop rate as long as E-RABs are also dropped
  - Poor performance is subject for further LTE914 optimization (e.g. slower shutdown)

$$\text{LTE\_5150b} = \frac{ACT\_UE\_CONT\_REL\_INIT\_ENB + ACT\_UE\_CONT\_REL\_INIT\_MME}{SUM\_ACTIVE\_UE\_ENB / DENOM\_ACTIVE\_UE\_ENB} \times 100\ \%$$

- **LTE_5043b E-UTRAN Total HO Success Ratio, intra eNB**
  - KPI describes the total intra eNB HO Success Ratio from HO preparation start until successful HO execution
    - It is worth to observe the SR with HO preparations to include the HO blocking due to AC, or unnecessary HO triggers (mobility parameterization)
    - Despite the FAIL_ENB_HO_PREP_OTH counter indicate the number of failed handover preparations due to other reasons in fact the counter provides the number of handover cancellations, i.e. number of times the Handover Preparation procedure has been cancelled due to either eNB initiated UE Context Release procedure (due to user inactivity, RLF, etc) or EPC initiated UE ContexRelease procedure or Release procedure due to reception or S1AP RESET or X2AP RESET, which are removed from the number of handover preparations provided with the counter INTRA_ENB_HO_PREP
  - Low value of this KPI may indicate bad HO configuration leading to HO failures → bad HO SR

Top 10

Rank	Customer	KPI
1	Customer 605	100.00 % ↑
2	Customer 705	100.00 % →
3	Customer 197	99.92 % ↓
4	Customer 470	99.88 % ↑
5	Customer 419	99.86 % ↓
6	Customer 639	99.86 % ↑
7	Customer 221	99.85 % ↓
8	Customer 357	99.83 % ↓
9	Customer 370	99.83 % ↑
10	Customer 516	99.82 % ↑

Source: MBB Benchmarker

$$\text{LTE\_5043b} = \frac{SUCC\_INTRA\_ENB\_HO}{INTRA\_ENB\_HO\_PREP - FAIL\_ENB\_HO\_PREP\_OTH} \times 100\ \%$$

- **LTE_5058c E-UTRAN Total HO Success Ratio, inter eNB X2 based**
  - KPI describes the total inter eNB X2 based HO Success Ratio from HO preparation start until successful HO execution
    - It is worth to observe the SR with HO preparations to include the HO blocking due to AC, or unnecessary HO triggers (mobility parameterization)
    - Despite the FAIL_ENB_HO_PREP_OTHER counter indicate the number of failed handover preparations due to other reasons in fact the counter provides the number of handover cancellations, i.e. number of times the Handover Preparation procedure has been cancelled due to either eNB initiated UE Context Release procedure (due to user inactivity, RLF, etc) or EPC initiated UE Context Release procedure or Release procedure due to reception or S1AP RESET or X2AP RESET, which are removed from the number of handover preparations provided with the counter INTER_ENB_HO_PREP
  - Low value of this parameter may indicate bad HO configuration leading to HO failures → bad HO SR

Top 10

Rank	Customer	KPI
1	Customer 558	99.78 % ↑
2	Customer 221	99.55 % ↑
3	Customer 189	99.50 % ↑
4	Customer 370	99.45 % ↑
5	Customer 243	99.32 % ↑
6	Customer 419	99.01 % ↓
7	Customer 195	98.95 % ↓
8	Customer 451	98.49 % ↓
9	Customer 196	98.35 % ↑
10	Customer 470	98.33 % ↑

Source: MBB Benchmarker

$$\text{LTE\_5058c} = \frac{SUCC\_INTER\_ENB\_HO}{INTER\_ENB\_HO\_PREP - FAIL\_ENB\_HO\_PREP\_OTHER} \times 100\ \%$$

- **LTE_5084b E-UTRAN Total HO Success Ratio, inter eNB S1 based**
  - KPI describes the total inter eNB S1 based HO Success Ratio from HO preparation start until successful HO execution
    - It is worth to observe the SR with HO preparations to include the HO blocking due to AC, or unnecessary HO triggers (mobility parameterization)
    - Despite the INTER_S1_HO_PREP_FAIL_OTHER counter indicate the number of failed handover preparations due to other reasons in fact the counter provides the number of handover cancellations, i.e. number of times the Handover Preparation procedure has been cancelled due to either eNB initiated UE Context Release procedure (due to user inactivity, RLF, etc) or EPC initiated UE Context Release procedure or Release procedure due to reception or S1AP RESET or X2AP RESET, which are removed from the number of handover preparations provided with the counter INTER_ENB_S1_HO_PREP
  - Low value of this parameter may indicate bad HO configuration leading to HO failures → bad HO SR

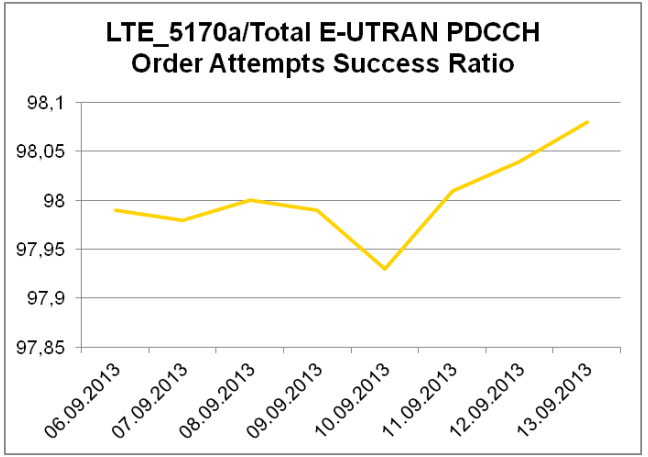
Top 10

Rank	Customer	KPI
1	Customer 189	97.7 % ↑
2	Customer 606	97.6 % ↑
3	Customer 661	95.8 % ↑
4	Customer 357	94.8 % ↓
5	Customer 419	93.7 % ↓
6	Customer 705	93.0 % ↓
7	Customer 443	92.7 % ↑
8	Customer 196	85.5 % ↑
9	Customer 221	84.0 % ↑
10	Customer 382	81.8 % →

Source: MBB Benchmarker

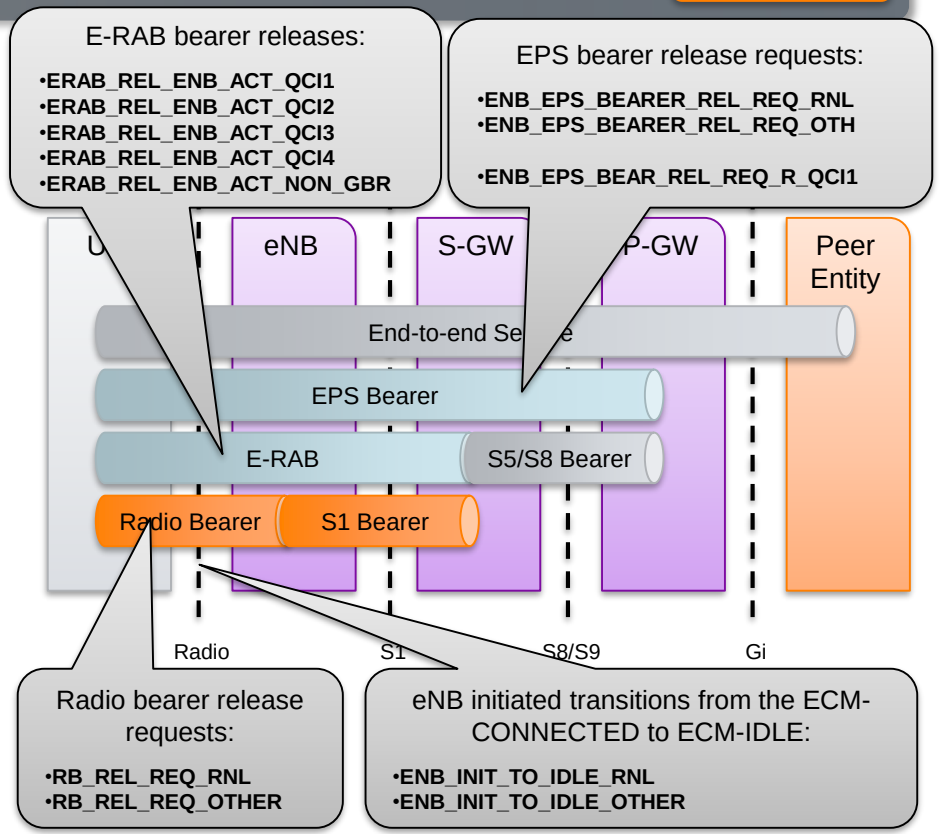
$$\text{LTE\_5084b} = \frac{\text{INTER\_ENB\_S1\_HO\_SUCC}}{\text{INTER\_ENB\_S1\_HO\_PREP - INTER\_S1\_HO\_PREP\_FAIL\_OTHER}} \times 100\ \%$$

- **LTE_5170a E-UTRAN PDCCH Order Attempts Success Ratio**
  - **KPI can be used to monitor fruitfulness of the resumption of the downlink traffic for a UE with considering the unavailability of dedicated preamble**
    - KPI counts only initial PDCCH order transmissions (no repetitions)
  - Final failure of the PDCCH order process is indicated as radio link problem to higher layers with cause “PDCCH order failure” followed by UE Context Release
  - Low value of this KPI may indicate high amount of PDCCH order failures (UE goes to RRC IDLE)
    - The KPI target for loaded networks is ~98-99%

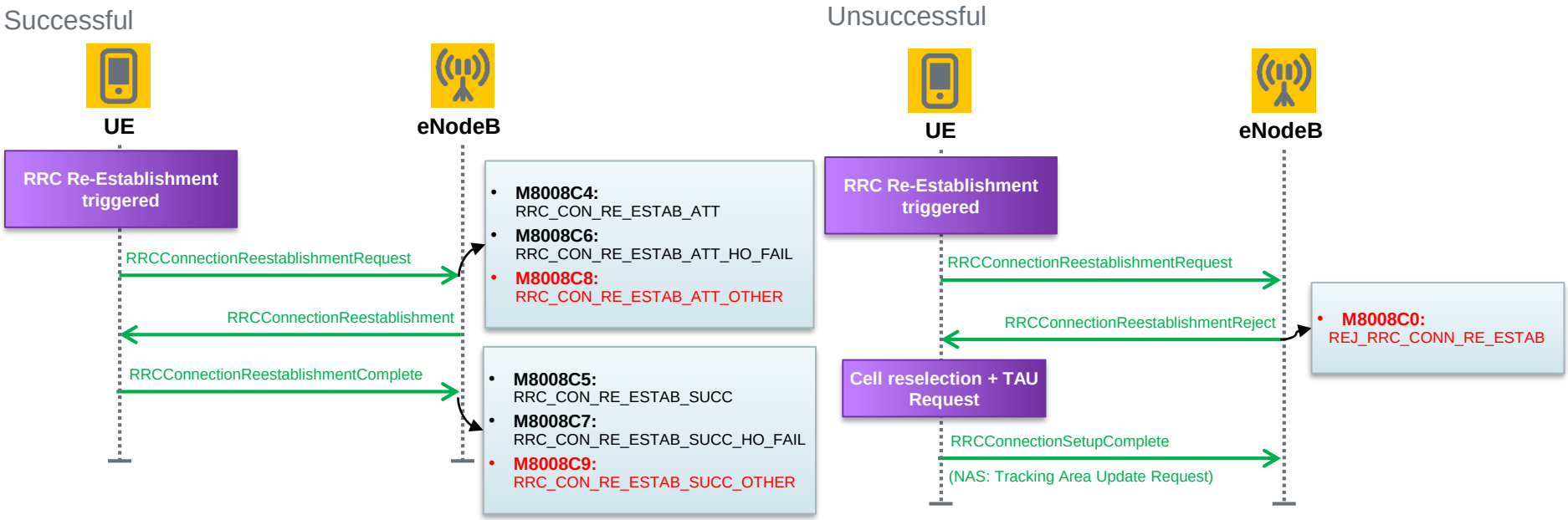


$$\text{LTE\_5170a} = \frac{PDCCH\_ORDER\_SUCCESS}{PDCCH\_INIT\_ORDER\_ATT + D\_PREAMB\_PDCCH\_UNAVAIL} \times 100\ \%$$

- S1AP UE context release request (eNB → MME) triggers the release of all established bearers and increment of related counters on various levels
  - Radio Bearer
  - EPS Bearer
  - E-RAB
  - eNB initiated transitions from the ECM-CONNECTED to ECM-IDLE
- Two release causes are distinguished by the counters:
  - Cause: *"Radio Connection with UE Lost"* ➔ **_RNL**
    - Main counters → contain majority of the call drops
  - Other causes than *"User Inactivity", "Redirect" or "Radio Connection with UE Lost"* ➔ ***_OTH***

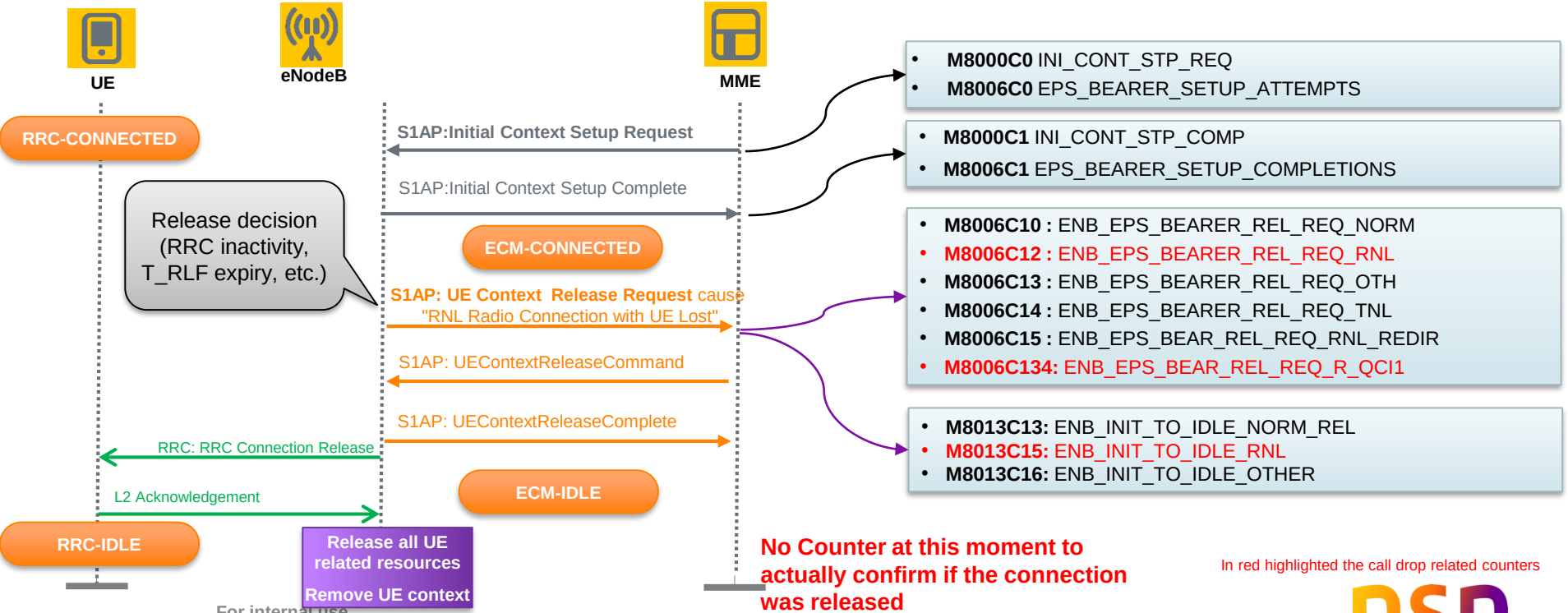


- RRC Conn Re-Establishment procedure (for i.e. UE initiated RLF recovery)



In red highlighted the call drop related counters

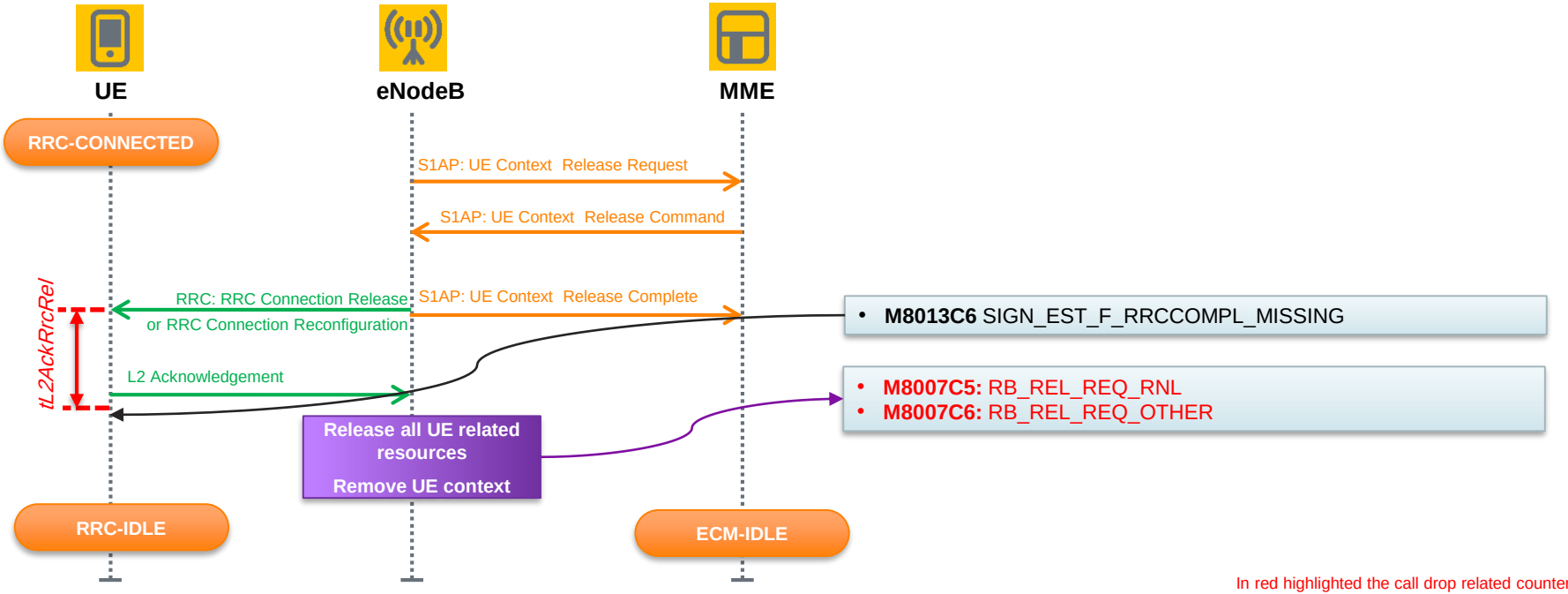
- S1 and RRC Release Signaling: ECM Connected to ECM Idle (eNB initiated)



No Counter at this moment to actually confirm if the connection was released

In red highlighted the call drop related counters

- Abnormal DRB Release (after RRC release)



In red highlighted the call drop related counters

- The call drop causes can be roughly connected with following counters and parameters
  - Underlined main counters/parameters which can be used for evaluation

RLF cause	Counter trigger	Related counters and KPIs	Related parameters
UE detected RLF: • T310 expiry	Expiry of the T310 timer	No counters available	•*t310* •*t311* •*n310* •*n311*
UE detected RLF: • Handover failure	PRACH procedure to the target cell does not succeed (*RANDOM ACCESS RESPONSE* not received) by the time *T304* expires	LTE_5569a E-UTRAN RACH Setup Completion Success Rate → should be close to 100% (impacted only by eNB load). → Applicable only for intraLTE HO (measured at target cell)	•*t304eNaccGsm* •*t304InterRAT* •*t304InterRATGsm* •*t304InterRatTd* •*t304IntraLte*

- For eNB detected RLF, always the group of counters is pegged:
  - ENB_INIT_TO_IDLE_RNL, RB_REL_REQ_RNL, ENB_EPS_BEARER_REL_REQ_RNL, ENB_EPS_BEAR_REL_REQ_R_QCI1, ERAB_REL_ENB_ACT_QCI{1-4},

RLF cause	Counter trigger	Related counters and KPIs	Related parameters
eNB detected RLF: • T_RLF (T310 + T311) timer expiry due to either: ○ PUSCH RLF ○ CQI RLF ○ HARQ RLF ○ SRS RLF	RNL Radio Connection with UE Lost sent within the UE Context Release Request message from eNB to MME	• ENB_INIT_TO_IDLE_RNL + other see above There are no dedicated counters to check which cause triggered the T_RLF expiry and call drop	•*t310* •*t311* •*nSrsDtx* •*nSrsRec*
eNB detected: • PDCCH order failure	PDCCH order fails for a UE (i.e., no transmission of assigned dedicated preamble detected by eNodeB, or no msg3 transmission) by second time.	• ENB_INIT_TO_IDLE_RNL + other see above • LTE_5170a Total E-UTRAN PDCCH Order Attempts Success Ratio	No related parameters available with direct impact, however the **TA timer expiry parameters impact the PDCCH order attempts indirectly**

- For eNB initiated RLF, always the group of counters is pegged:
  - ENB_INIT_TO_IDLE_RNL, RB_REL_REQ_RNL, ENB_EPS_BEARER_REL_REQ_RNL, ENB_EPS_BEAR_REL_REQ_R_QCI1, ERAB_REL_ENB_ACT_QCI{1-4},

RLF cause	Counter trigger	Related counters and KPIs	Related parameters
eNB initiated: • max RLC retransmissions has been reached	•RNL Radio Connection with UE Lost sent within the UE Context Release Request message from eNB to MME or •RRC connection Re-establishment attempt or •Intra eNodeB HO	• ENB_INIT_TO_IDLE_RNL + other see above • RRC_CON_RE_ESTAB_ATT	•*tPollretr* •*t311* •*drbAmMxRtxTh*
eNB initiated: • eNB initiated Release due to UE being out-of-sync (TA timer expiry)	RNL Radio Connection with UE Lost sent within the UE Context Release Request message from eNB to MME	• ENB_INIT_TO_IDLE_RNL + other see above • CELL_LOAD_UL_OUT_SYNC_100_INF → part of the "UE UL-Out-Of-Sync time" histogram. High percentage of this counter in the histogram could indicate this RLF cause	•*taTimer* •*taTimerMargin* •*taMaxOffset* •*applyOutOfSyncState*

- The call drop causes can be roughly connected with following counters and parameters
  - Underlined main counters/parameters which can be used for evaluation

RLF cause	Counter trigger	Related counters and KPIs	Related parameters
eNB initiated RLF: • "GTP-U Error Indication"	TNL Transport Resource Unavailable sent within the UE Context Release Request and E-RAB Release Indication message from eNB to MME in case all non-GBR S1 bearers of an UE have failed and one active non-GBR S1 bearer remains active, respectively	• RB_REL_REQ_OTHER • ENB_EPS_BEARER_REL_REQ_TNL • ENB_EPS_BEAR_REL_REQ_T_QCI1 • ENB_INIT_TO_IDLE_OTHER • This kind of drop is rare → majority is caused by RNL	No related parameters available.
eNB initiated RLF: • S1 reset	Partial on full S1 reset initiated by eNB or by MME	• S1AP_GLOBAL_RESET_INIT_ENB • S1AP_GLOBAL_RESET_INIT_MME • S1AP_PARTIAL_RESET_INIT_ENB • S1AP_PARTIAL_RESET_INIT_MME	• *enableGrflShdn*

- Call drop related counters during the Intra-eNB handover procedure
  - For parameter reference, please refer to the NEI slides in NEDC NEI corner

HO type	Counters	Counter trigger
Intra-eNodeB handover	**TOT_NOT_START_HO_PREP**	**Updated:** The reception of an RRC Measurement Report message sent by the UE to eNB and of the RRM decision not to execute a handover. Updated to the source cell.
	FAIL_ENB_HO_PREP_AC	**Updated:** An internal eNB trigger. The eNB MM receives a list with the target cells from the RRM. The MM or RRM AC decides not to execute an Intra-eNB Handover. Updated to the source cell.
	FAIL_ENB_HO_PREP_OTH	**Updated:** when the Intra-eNB Handover Preparation procedure at the source eNB is cancelled because of the following reasons: - eNB initiated UE Context Release procedure (caused by user inactivity, RLF, and other causes) - EPC initiated UE Context Release procedure - Release procedure caused by reception of S1AP RESET - Release procedure caused by reception of X2AP RESET
	ENB_INTRA_HO_FAIL	**Updated:** The counter is updated to the source cell when timer **THOoverall** expires.

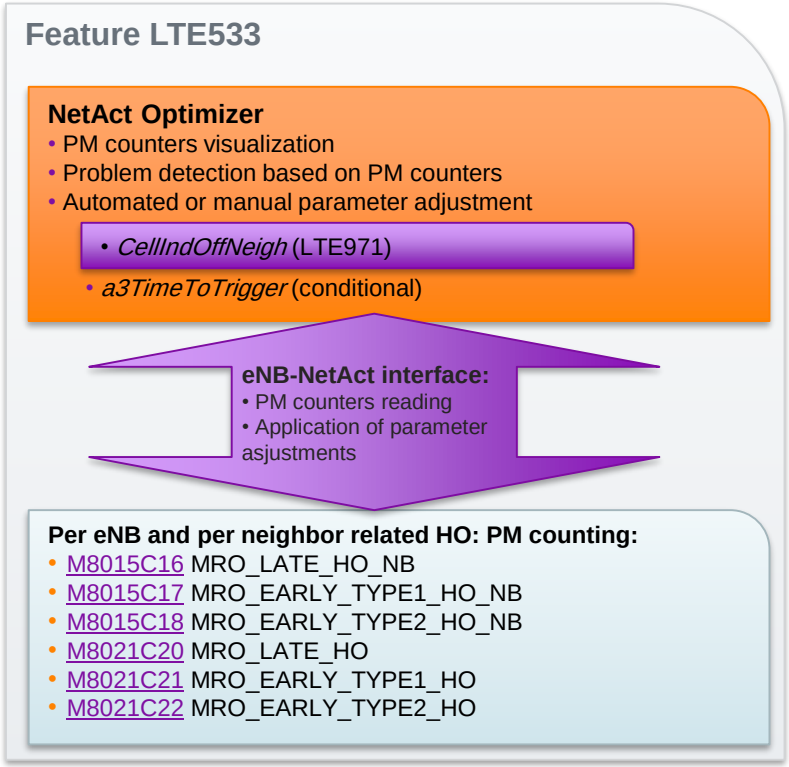
- Call drop related counters during the Inter-eNB handover procedure – X2 based
  - For parameter reference, please refer to the NEI slides in NEDC NEI corner

HO type	Counters	Counter trigger
X2 based Intra-eNodeB handover	**FAIL_ENB_HO_PREP_TIME**	The expiration of timer TX2RELOCprep
	FAIL_ENB_HO_PREP_AC	Reception of an X2AP: Handover Preparation Failure message from the target eNB.
	FAIL_ENB_HO_PREP_OTHER	Updated: When the Inter-eNB X2-based Handover Preparation procedure at the source eNB is cancelled because of the following reasons: - eNB initiated UE Context Release procedure (caused by user inactivity, RLF, and other causes) - EPC initiated UE Context Release procedure - Release procedure caused by reception of S1AP RESET - Release procedure caused by reception of X2AP RESET
	INTER_ENB_HO_FAIL	The expiration of timer TX2RELOCoverall

- Call drop related counters during the Inter-eNB handover procedure – S1 based
  - For parameter reference, please refer to the NEI slides in NEDC NEI corner

HO type	Counters	Counter trigger
S1 based Intra-eNodeB handover	**INTER_S1_HO_PREP_FAIL_TIME**	The expiration of timer TS1RELOCprep
	INTER_S1_HO_PREP_FAIL_NORR	Reception of an S1AP: HANDOVER PREPARATION FAILURE message from MME to source eNB with cause **"No Radio Resources Available in Target Cell"** if this message is received in response to the preparation of an Inter eNB Handover
	INTER_S1_HO_PREP_FAIL_OTHER	Updated: when the Inter-eNB S1-based Handover Preparation procedure at the source eNB is cancelled because of the following reasons: - eNB initiated UE Context Release procedure (caused by user inactivity, RLF, and other causes) - EPC initiated UE Context Release procedure - Release procedure caused by reception of S1AP RESET - Release procedure caused by reception of X2AP RESET
	INTER_ENB_S1_HO_FAIL	The expiration of timer TS1RELOCoverall

- LTE533 Mobility robustness introduces new counters which can be used to validate the HO performance
- NetAct Optimizer application uses that counters in the feature algorithm to optimize cell individual handover offsets
- Additionally the HO statistics may be visualized

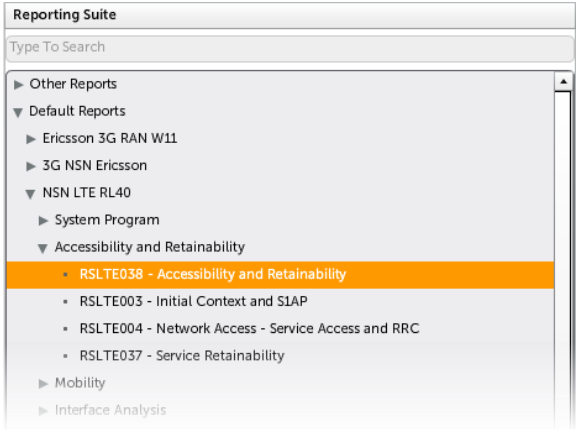


- Due to low number of the PM counters only high level analysis for the RLF can be performed in the NetAct

- The KPIs listed in this presentation can be found in the Reporting Suite and NPM (Network Performance Manager) in the **RSLTE038 Accessibility and Retainability** report

- On top of that report, the counters listed on the previous slide may be observed to verify the abnormal bearer release ratio in contrary to the normal releases

- Please note that detailed call drop analysis aiming to find exact call drop reason require deep dive into BTS logs (Emil tool)



- **For the complete reference material on the LTE Performance Measurement counters please refer to:**

LTE performance management NEI Complex

- RL50 updated list of all measurement counters per category
- PM counters in message flow charts
- Key features brief explanations
- KPI listing, new KPI proposals
- PM Configuration management aspects

Field experience

Call drop issue investigation for VoLTE [7]

- Due to call drop decrease in customer network, the optimization activity was launched
- Following steps were performed to optimize the QCI1 drop ratio:

Step1	Step2	Step3	Step4	Step4_Addition	Step5
• Clear LNREL for 850MHz & LTE1383 – Cell-specific neighbor relation & PCI handling • Cleanup of wrong and missing NR	• QCI5 tab – Change *resourceType* to SIGNALLING • Increase stability for QCI5	• **CLPC – PUCCH SINR window** • To overcome PUCCH interference	• CLPC – P0NomPUCCH, PUCCH RSSI window • To reduce PUCCH interference	• PUCCH SINR window (additional increase) • To further reduce PUCCH interference	• IRC (2RX) – TOP w/o PhaseSync, GPS w/o PhaseSync (FSMF only) • To add the gain from IRC on the sites without GPS sync

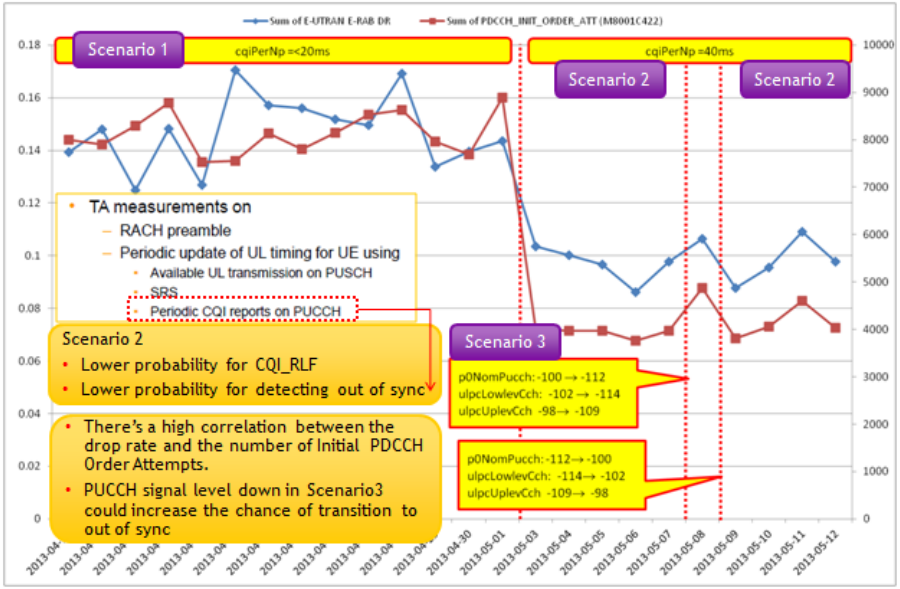
- The most critical from network POV was the change of the PUCCH power control settings

- **eNB KPIs**
  - **VoLTE CDR improved as 29% by Step4 & 31% by Step4_add [eNB KPI]**
  - **UE Tx power for PUCCH has been reduced 3.7dB by Step4 & 2.4dB by Step4_add (Cluster level)**
- **Drive test**
  - **VoLTE CDR improved as 40% by Step4_add [LQMS KPI]**

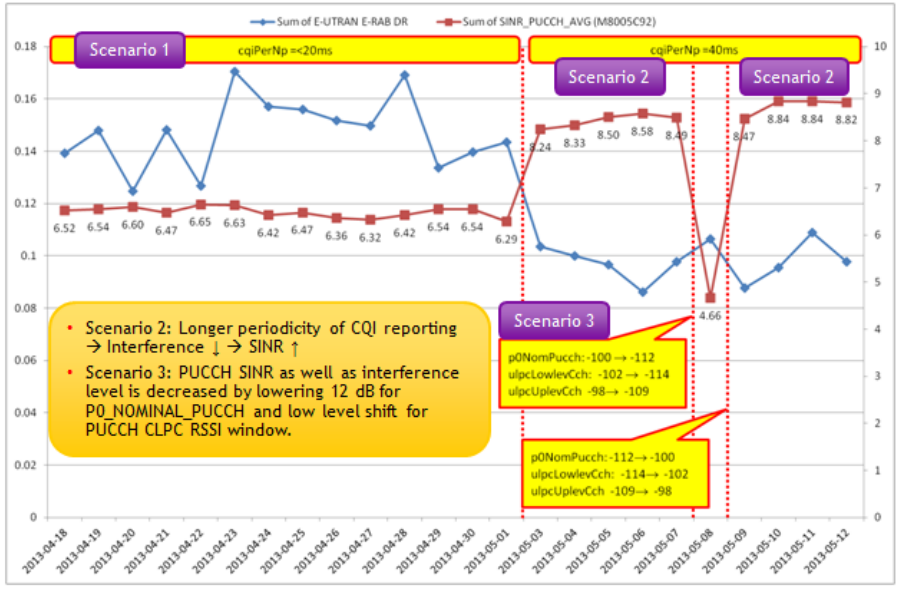
- Handover Decision ratio has been improved after clearing LNREL & ANR
- **Step4_Add** PUCCH PC parameterization is recommended

Managed object	Abbreviated name	Parameter name	RL50 Default	Step3	Step4	Step4 Addition
LNCEL	p0NomPucch	Nominal power for UE PUCCH TX power calculation	-116	-100	-109	
LNCEL	ulpcLowlevCch	Lower RSSI threshold for PUCCH power command decision	-118	-103	-111	
LNCEL	ulpcLowqualCch	Lower SINR threshold for PUCCH power command decision	-1	6		9
LNCEL	ulpcUplevCch	Upper RSSI threshold for PUCCH power command decision	-113	-98	-108	
LNCEL	ulpcUpqualCch	Upper SINR threshold for PUCCH power command decision	2	8		11

KPI>> Drop Rate & PDCCH Order Attempts [Daily]



KPI>> Drop Rate & Avg. PUCCH SINR [Daily]



Based on experience of May, 2013, CQI_RLF has been improved due to CQI reporting period adjustment.
Longer CQI reporting period causes less PUCCH RSSI & higher SINR and CDR has been improved.
But when P0NomPUCCH & RSSI window were set to low value then PUCCH SINR has been reduced by half and CDR has been increased a bit.

[UE Problem]
- There was massive call drop from Single UE during daytime
- Based on LQMS log, UE has sent TAU request without completion of TAU (couples of time per second)
- It seems that there are some UE causing similar problems

[UL interference]
- Based on KPI analysis, NSN has visited field with signal analyzer
- Obvious UL interference has been observed and it will impact KPIs surrounded area
- Troubleshooting for interference should be done after VoLTE CDR activity

[Handover problem]
- Based on KPI analysis, there were also sites with handover problems
- Handover problem sites should be further investigated for troubleshooting

Field experience

High drop rate issue analysis [8]

FiVe comparison b/w 2T4R(OL2x2MIMO) and 4T4R(CL4x2MIMO)

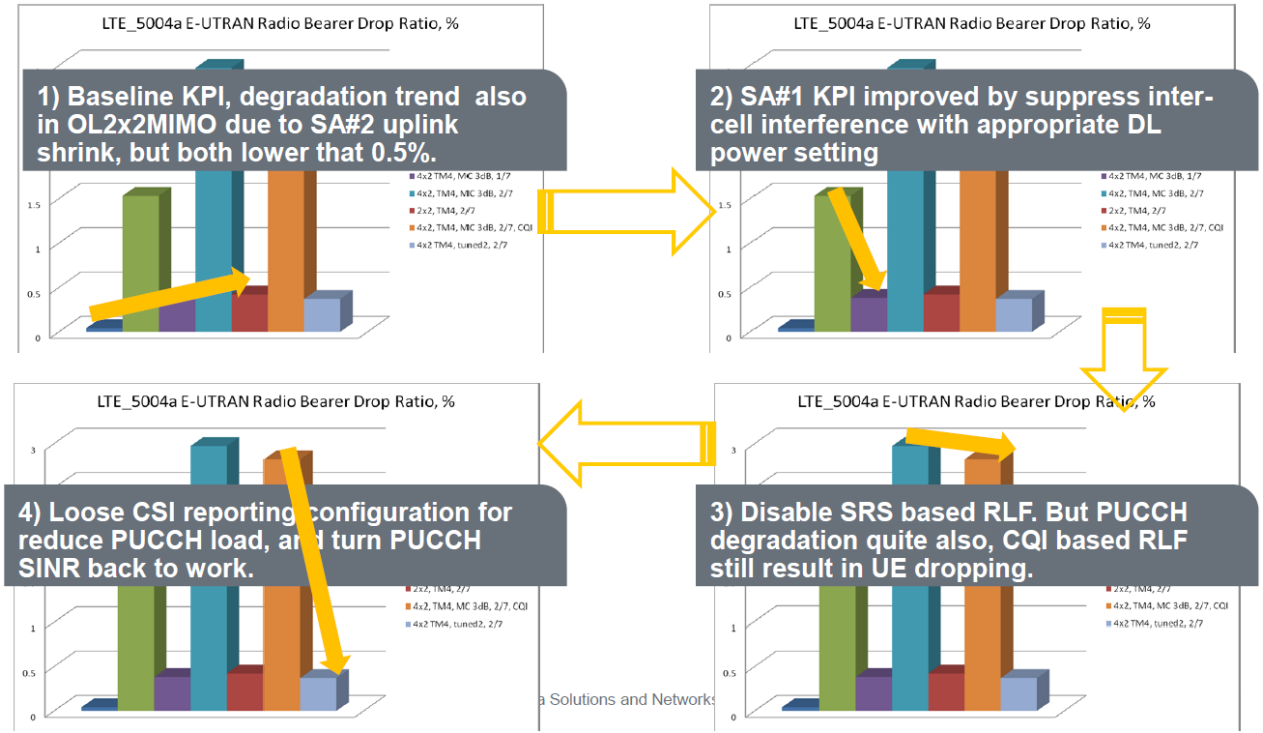
March 7, 2014

- Due to high call drop ratio in TDD customer network, optimization activities aimed to mitigate that situation

DL power setting adjustment

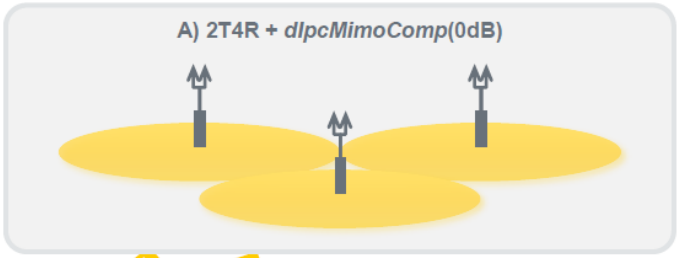
SRS based RLF deactivation

PUCCH performance improvement



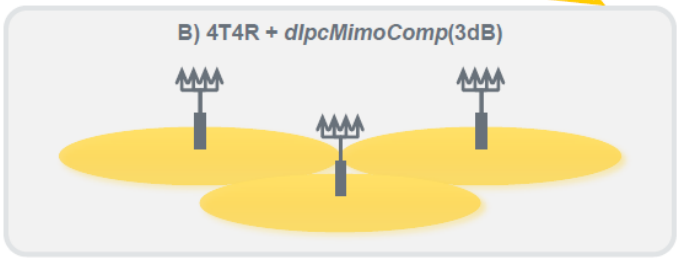
❑For upgrade case, ISD(inter-site distance) already planned for 2T4R, then reduce 4T4R per Tx antenna power adapt to not re-planned ISD.

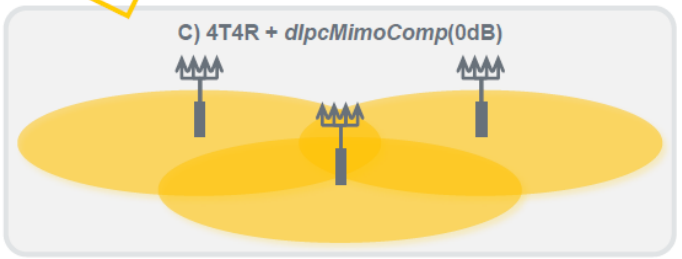
❑For new deployment case, setting DL power according to planned cell coverage that usually limited by uplink budget.



❑If 4T4R halved per antenna power (*dlpcMimoComp* as 3dB) to keep same DL coverage from DL power aspect. I
❑Inter-cell interference optimized as 2T4R

❑If 4T4R keep same per antenna power (*dlpcMimoComp* as 0dB), doubled DL aggregated power introduce inter-cells interference.
❑Cell edge UEs suffer in inter-cell interference especially in high load, and drop as consequence





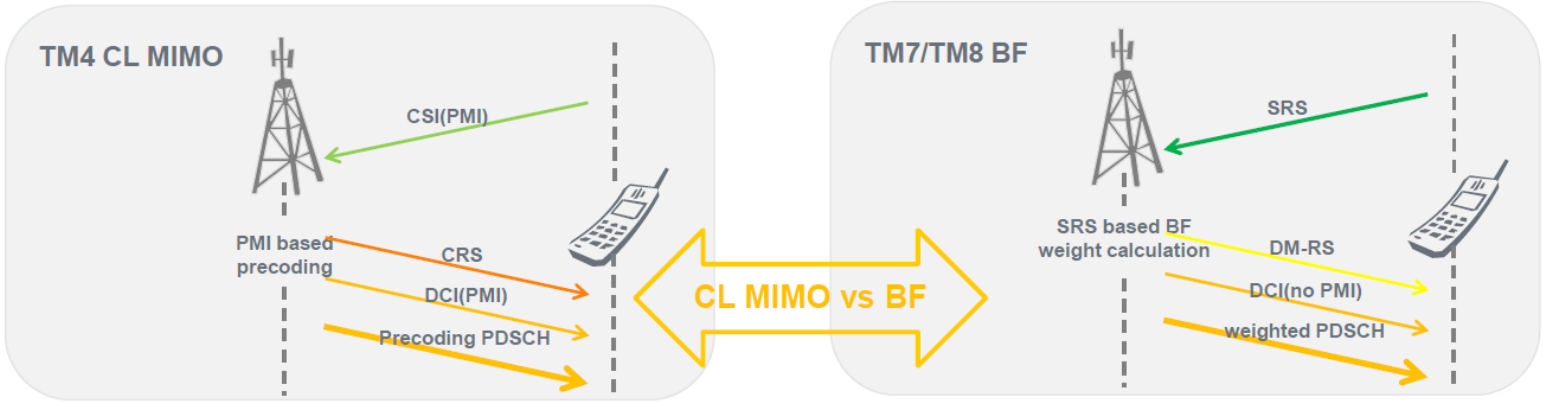
After make DL power right, SRS based RLF become major reason of UE dropping.

Workaround

- Totally disable SRS based RLF detection(*nsrsdtx* as 0) with consideration that SRS not so critical for CL MIMO solution

Issue and Solution – further investigation required

- Is too restrict for SRS DTX threshold? Anyway should not be restrict than PUCCH's, and not be bottleneck of RLF release
- SRS not used for DL precoding in MIMO solution, but meaningful to UL measurement that contribute to UL-Scheduler, UL-AMC and Time Alignment calculation.

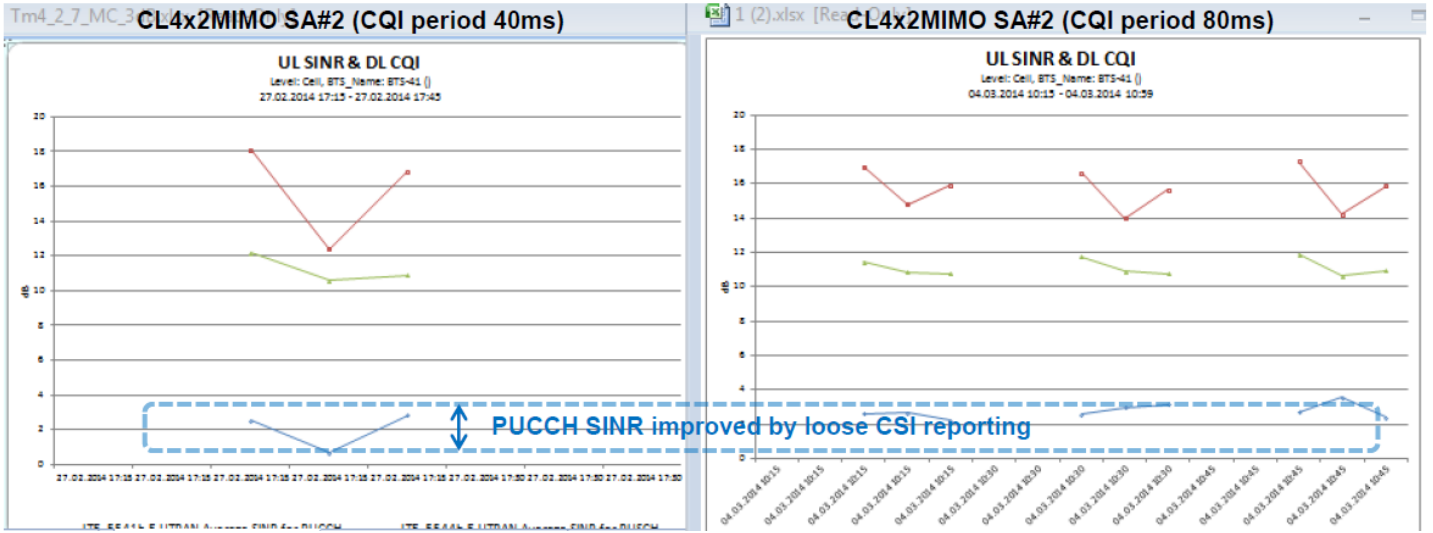


PUCCH performance degradation is bottleneck of drop rate issue

- **SA#2 uplink budget shrink**(major reason) and **CL4x2MIMO increase bits**(minor reason) result in PUCCH performance critical challenge in SA#2 + CL4x2MIMO configuration. PUCCH degradation result in UE dropping.

Short term solution

- Loosing CSI reporting period for reduce PUCCH load, and turn PUCCH SINR back to work. Work as below.



What's penalty of short term solution by loose CSI reporting period (*cqiPerNp* as 80ms)

- As Close Loop MIMO gain performance requite rely on timely updated CQI.
- If Aperiodic CSI reporting not available, with loose periodic CSI reporting, CL4x2MIMO pre-coding gain not available especially in driving scenario(fast fading) and SA#2 configuration that adjacent RI&PMI impossible due to no continuous UL transmission available.
- But in most traffic model, Aperiodic CSI reporting possible due to UL traffic. So no additional penalty of ST solution.

Long term solution

- TDD SA specific GMC, take both performance and capacity into account. Accumulated works/experiences at GMC
- PUCCH receiver performance improvement migrate SA#2 drawback,
  - Any improvement possible with exist IRC/MRC? Extended PUCCH receive bandwidth?
  - Uplink CoMP for PUCCH?
- Any improvement possible at RF?
- *… more ideas appreciated*

Tracing capabilities

Call drops monitoring via cell trace interface

- Starting from LTERLCR-1947 **RLF cause codes added to cell trace,** the cell trace interface is able to precisely identify the call drop cause, i.e:
  - RLF(radio link failure) cause codes are added to cell trace content as part of Radio Link Status Indication by eNB:

Failure Code Failure code description
0 Out-of-Sync detected
1 In-Sync detected
5 DL HARQ failure detected
6 DL HARQ failure cleared
8 Permanent Out-Of-Sync state
9 CQI report failure detected on PUCCH or PUSCH
10 CQI report failure cleared
11 UL transmission failure detected on PUSCH
12 UL transmission failure cleared
15 SRS failure detected (WMP TDD only)
16 SRS failure cleared (WMP TDD only)

The following cause values are still not supported via this CRL (listed for information only):
2 Timing alignment timer expiry (only DCM - so not applicable)
3 Radio Link Failure (reserved value for future use)
4 RA Scheduling Request failure
7 RA procedure completion (only DCM – so not applicable)
13 Change mode to TTI Bundling.
14 Change mode to no TTI Bundling.
17 report Timing Advance type 2 fro the reception of RACH Msg3 indicating BSR for LCG0 which increase the signaling between FAN and MAC.
18 SRS Upgrade (WMP FDD only)
19 SRS Downgrade (WMP FDD only).
20 TM switch to TM3 (TDD only).
21 TM switch to TM7 (TDD only).

- The NSN **trace analyser** as NetAct **TraceViewer** and L3DC with L3DA needs to consider the additional information.
  - Please note that external trace analyser partners may not to be informed about update via the trace interface specification update

Thank you for your attention!

Radio Link Failures and call drop analysis

Table of contents

- This section concludes additional material which can be useful, however its impact on call drops is low, due to fact that:
  - Parameters are hidden
  - Default parameter values practically disables that features

eNB Detected radio link problems - backup

Call drop reasons

UE detected Radio link problems

- T310 expiry
- Maximum number of RLC retransmissions
- Handover failure (T304 expiry)
- Non-HO related random access problem

eNB Detected radio link problems

- **PUSCH RLF**
- CQI RLF
- HARQ RLF
- SRS RLF
- PDCCH Order failure

eNB initiated release

- TA Timer Expiry at eNB or UE
- Maximum RLC Retransmissions Exceeded at eNB
- GTP-U failure at eNB
- S1 reset
- Lack of DRB ID

- **PUSCH RLF** is declared when eNB cannot detect the signal from the UE (DTX) for a given period
  - DTX is when the UE was scheduled for PUSCH, but eNB didn't received the transmission on the scheduled PRB's
  - NOTE: The case where UL transmission is received but it fails CRC check is not DTX (it's a NACK)
- DTX PUSCH indication is provided by the UL physical layer
- The result is received by LTE MAC in *reliableULtransmissionFlag* parameter (which can be seen in UL TTI trace)

- Up to RL30EP2 PUSCH RLF could be counter or timer-based(2 parameters), but from RL40 onwards only counter based solution is possible

PUSCH RLF detection

- Timer-based (*LNBTS:rlpDetMaxTUl*)
- Counter-based (*LNBTS: rlpDetMaxNUl*)

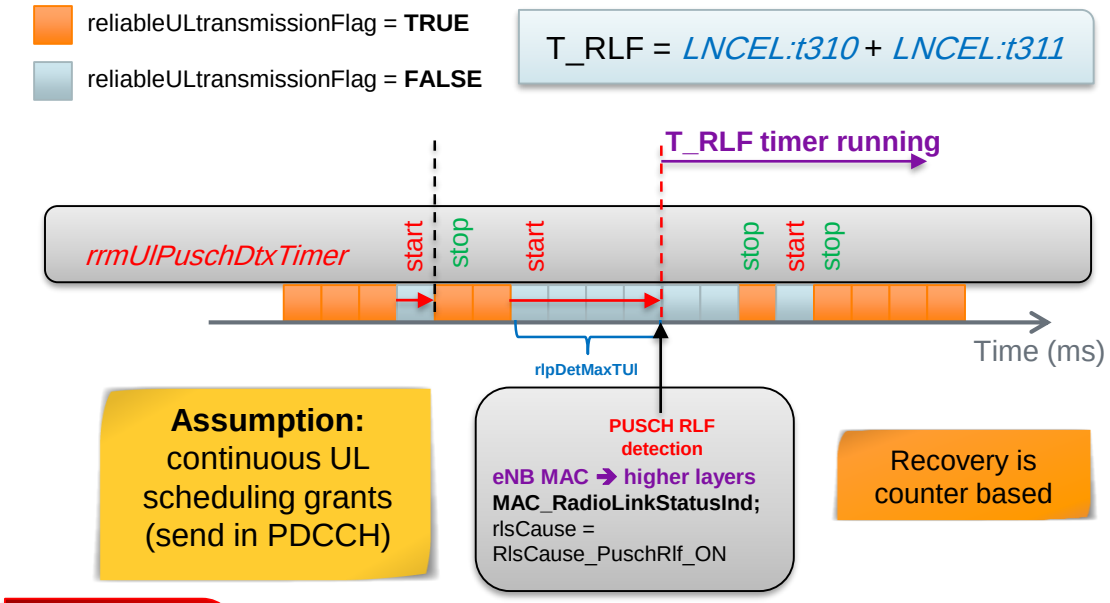
Recovery from RLF

- Counter-based *(LNBTS: rlpDetEndNUl*)

- Timer-based **PUSCH RLF** detection uses ***rrmUlPuschDtxTimer*** *eNB* internal timer

- The timer is started with first *reliableULtransmissionFlag=FALSE* occurrence
- The timer is stopped with *reliableULtransmissionFlag=TRUE*

- If the counter for the UE reaches *LNBTS:rlpDetMaxTUl* value, eNB indicates RLF to higher layers



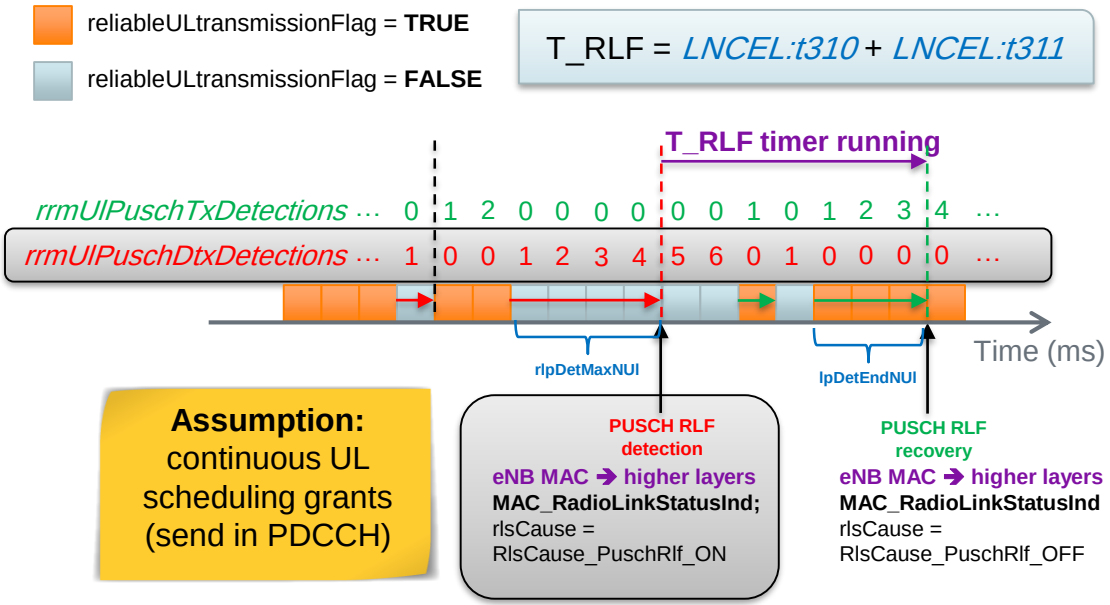
Parameter values

	In this example	RL30 default
Hidden *LNBTS:**rlpDetMaxTUl***	4	0 (switched off)

- Counter-based **PUSCH RLF** detection uses ***rrmUlPuschDtxDetections*** *eNB* internal counter

- The counter is started when *reliableULtransmissionFlag=FALSE*
- The counter is reset with every *reliableULtransmissionFlag=TRUE*

- If the counter for the UE reaches *LNBTS:rlpDetMaxNUl* value, eNB indicates RLF to higher layers



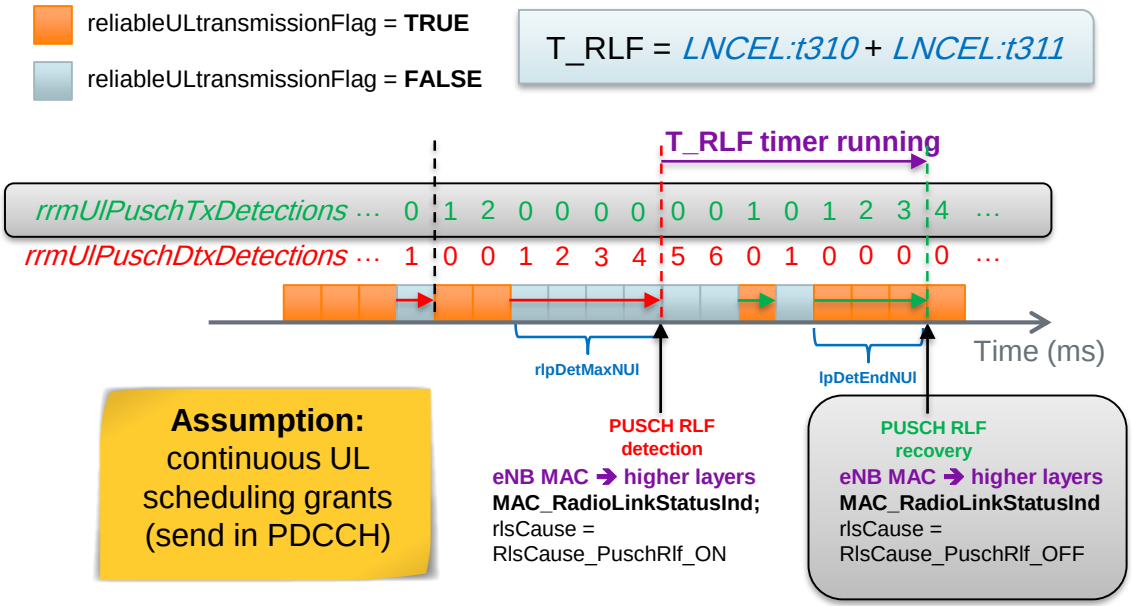
Parameters values

	In this example	RL50 default
Hidden *LNBTS:**rlpDetMaxNUl***	4	1000
Hidden *LNBTS:**rlpDetEndNUl***	3	3

- Counter-based **PUSCH RLF** recovery uses ***rrmUlPuschTxDetections*** *eNB* internal counter

- The counter is started when *reliableULtransmissionFlag=TRUE*
- The counter is reset with every indication of *reliableULtransmissionFlag=FALSE*

- If the counter for the UE reaches *LNBTS:rlpDetEndNUl* value, eNB indicates RLF cancellation to higher layers



Parameters values

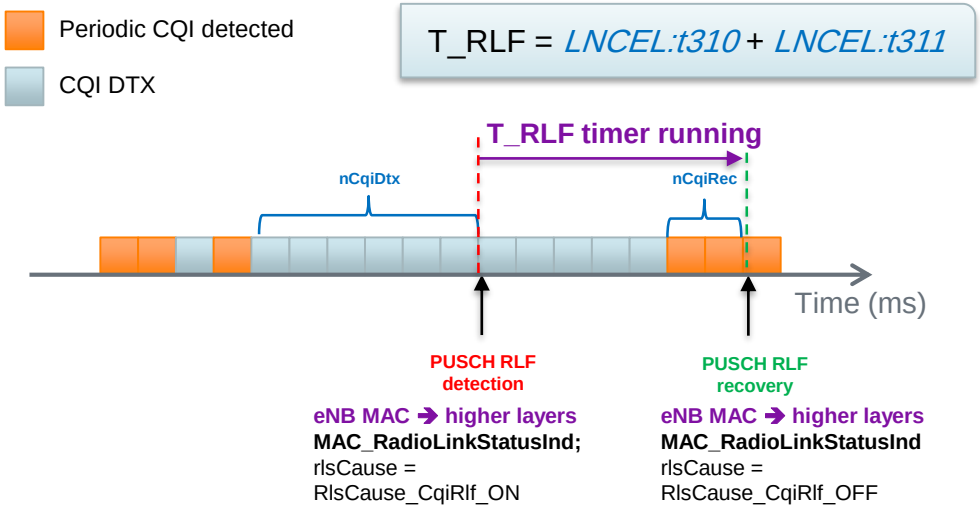
	In this example	RL50 default
Hidden *LNBTS:**rlpDetMaxNUl***	4	1000
Hidden *LNBTS:**rlpDetEndNUl***	3	3

Call drop reasons

UE detected Radio link problems	**eNB Detected radio link problems**	eNB initiated release
• T310 expiry • Maximum number of RLC retransmissions • Handover failure (T304 expiry) • Non-HO related random access problem	• PUSCH RLF • **CQI RLF** • HARQ RLF • SRS RLF • PDCCH Order failure	• TA Timer Expiry at eNB or UE • Maximum RLC Retransmissions Exceeded at eNB • GTP-U failure at eNB • S1 reset • Lack of DRB ID

- **CQI RLF** detection counts consecutive missed CQI transmissions

- When eNB receives CQI DTX exactly *LNBTS:nCqiDtx* times, it triggers RLF indication to higher layers
- When eNB receives correct CQIs again for *LNBTS:nCqiRec* times, eNB cancels the RLF state



Parameters values

	In this example	RL50 default
Hidden *LNBTS:**nCqiDtx***	6	50
Hidden *LNBTS:**nCqiRec***	2	2

Call drop reasons

UE detected Radio link problems	**eNB Detected radio link problems**	eNB initiated release
• T310 expiry • Maximum number of RLC retransmissions • Handover failure (T304 expiry) • Non-HO related random access problem	• PUSCH RLF • CQI RLF • **HARQ RLF** • SRS RLF • PDCCH Order failure	• TA Timer Expiry at eNB or UE • Maximum RLC Retransmissions Exceeded at eNB • GTP-U failure at eNB • S1 reset • Lack of DRB ID

- **HARQ RLF** is declared when eNB cannot detect the ACK/NACK response from the UE who was scheduled for transmission

- Both PUSCH and PUCCH received HARQ responses are counted
- For the purpose of RLF detection, ambiguous HARQ are interpreted as NACK
- The mechanism considers DRX settings
- In RL50 two HARQ RLF methods are available: counter or timer-based (2 parameters)
  - However for the Carrier Aggregation UE, only counter-based method is applicable

HARQ RLF detection

- Timer-based (*LNBTS:rlpDetMaxTimeDl*)
- Counter-based (*LNBTS: rlpDetMaxNoDl*)

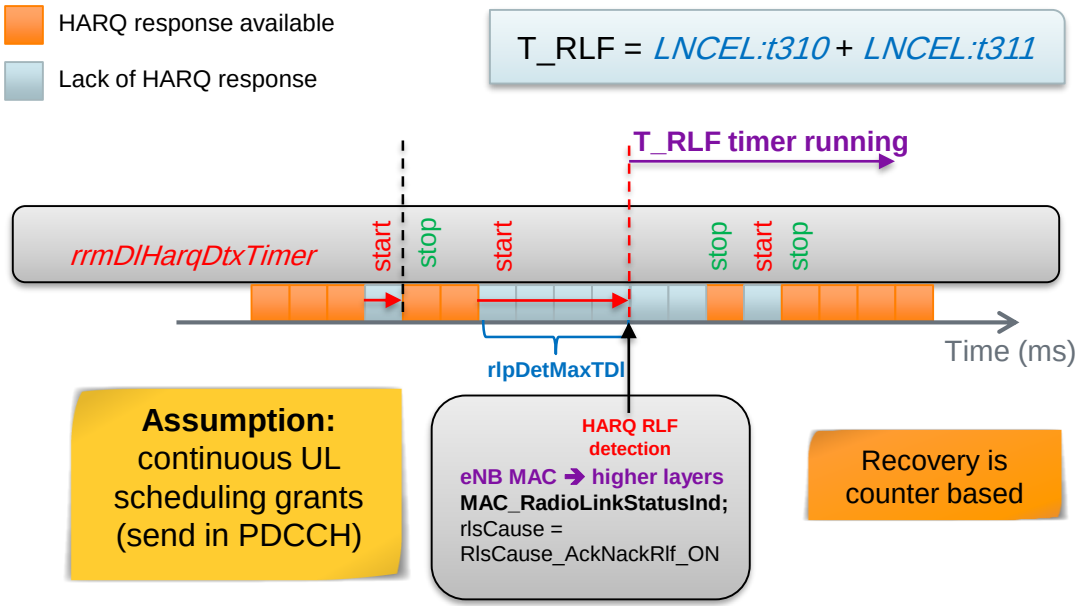
Recovery from RLF

- Counter-based (*LNBTS: rlpDetEndNoDl*)

- Timer-based **HARQ RLF** detection uses ***rrmDlHarqDtxTimer*** *eNB* internal timer

- The timer is started with first *HARQ DTX* occurrence
- The timer is stopped with the first occurrence of the ACK/NACK response

- If the counter for the UE reaches *LNBTS:rlpDetMaxTimeDl* value, eNB indicates RLF to higher layers



Not used with Carrier Aggregation

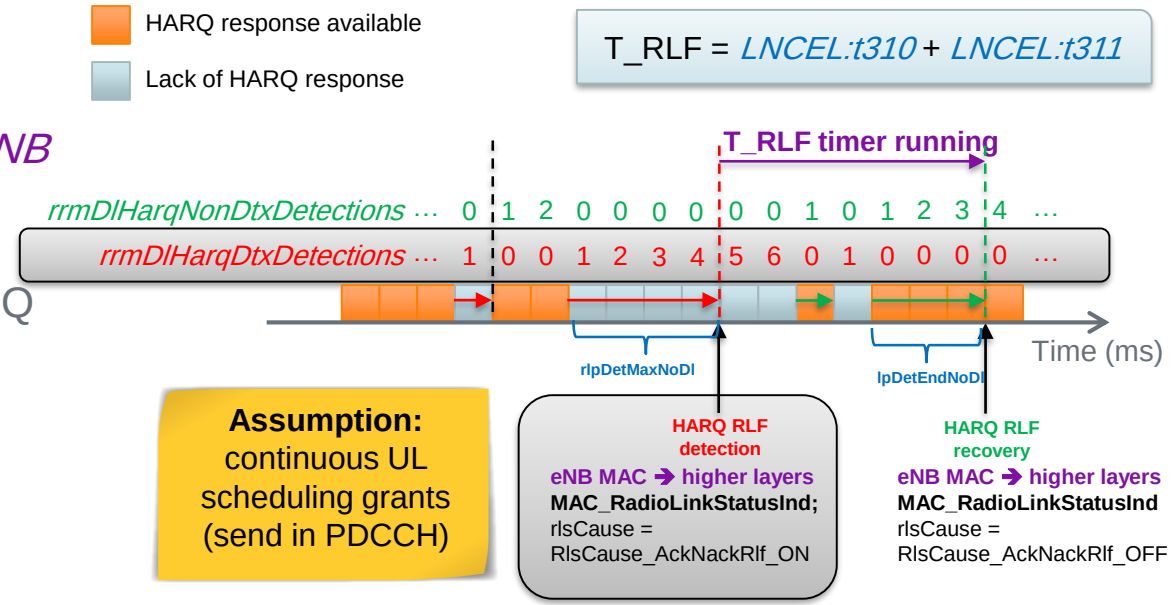
Parameter values

	In this example	RL30 default
Hidden *LNBTS:**rlpDetMaxTimeDl***	4	0 (switched off)

- Counter-based **HARQ RLF** detection uses ***rrmDlHarqNonDtxDetections*** *eNB* internal counter

- The counter is started when HARQ response is not available
- The counter is reset with the first occurrence of the ACK/NACK response

- If the counter for the UE reaches *LNBTS:rlpDetMaxNoDl* value, eNB indicates RLF to higher layers



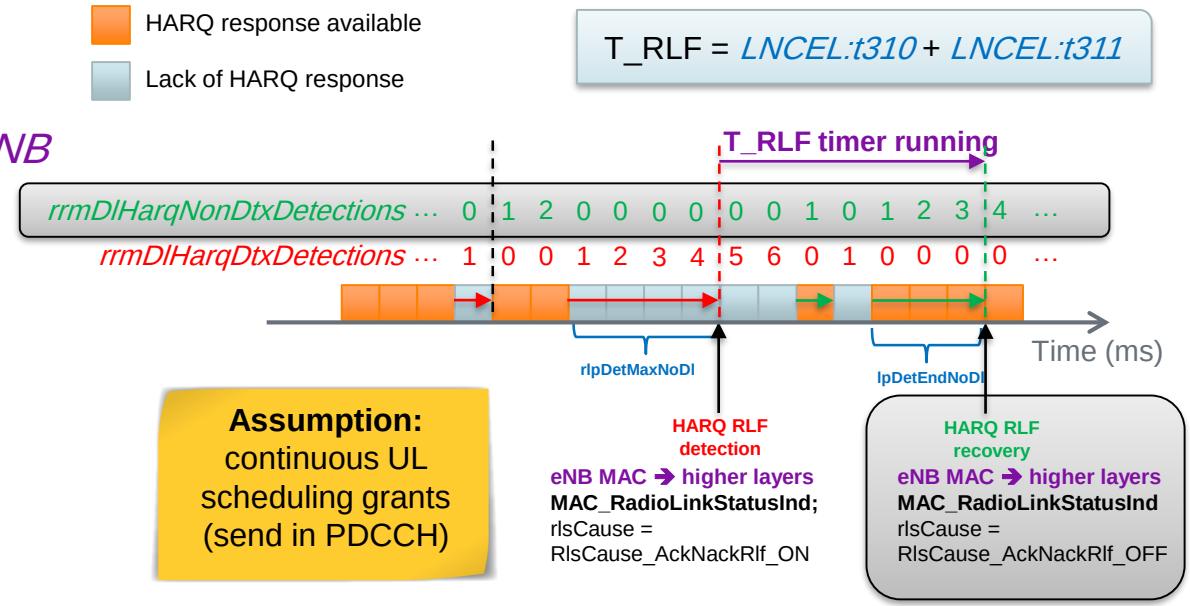
Parameters values

	In this example	RL50 default
Hidden *LNBTS:**rlpDetMaxNoDl***	4	1000
Hidden *LNBTS:**rlpDetEndNoDl***	3	3

- Counter-based **HARQ RLF** recovery uses ***rrmDlHarqNonDtxDetections*** *eNB* internal counter

- The counter is started with the occurrence of the ACK/NACK response
- The counter is reset when HARQ response is not available

- If the counter for the UE reaches *LNBTS:rlpDetEndNoDl* value, eNB indicates RLF cancellation to higher layers



Parameters values

	In this example	RL50 default
Hidden *LNBTS:**rlpDetMaxNoDl***	4	1000
Hidden *LNBTS:**rlpDetEndNoDl***	3	3

Parameters - backup

- **eNB detected radio link problems** - CQI RLF triggered

LNBTS

nCqiDtx		Radio problem indication based on CQI DTX
Range: **Step:** **Default:**	0...100 1 50	This parameter defines the number of CQI DTX occurrences after which the RLF indication will be triggered for higher layers. • Lower the value of this parameter, faster RLF indication would be triggered. • Higher the value of this parameter, slower RLF indication

nCqiRec		Radio problem recovery based on CQI DTX
Range: **Step:** **Default:**	1...8 1 2	This parameter defines the number of periodic CQI reports after which the RLF indication will be cancelled for higher layers. • Lower the value of this parameter, faster the recovery from the RLF state. **Values higher than 1 and lower than 4 are recommended** • Higher the value of this parameter, slower recovery from the RLF state

- **eNB detected radio link problems –** PUSCH HARQ RLF triggered

LNBTS

rlpDetMaxNUI		Number of PUSCH DTX detections for radio link problem
Range:	1...1000	The number of PUSCH DTX occurrences after which the RLF indication will be triggered for higher layers.
Step:	1	• By default the parameter is increased to maximum, i.e. it has almost not chance to trigger the RLF
Default:	1000	• Lower the value of this parameter, faster RLF indication would be triggered.
rlpDetMaxTUI		**Time of PUSCH DTX detections for radio link problem**
Range:	20...5000	The time after first PUSCH DTX occurrence with consecutive PUSCH DTX indications after which the RLF will be triggered for higher layers.Lower the value of this parameter, faster the recovery from the RLF state. **Values higher than 1 and lower than 4 are recommended**
Step:	1 ms	
Default:	0 ms (off)	• Higher the value of this parameter, slower recovery from the RLF state
rlpDetEndNUI		**Number of PUSCH detections to end radio link problem**
Range:	1...20	The number of PUSCH TX (ACK/NACK) occurrences after which the RLF indication will be cancelled for higher layers.
Step:	1	• Lower the value of this parameter, faster the recovery from the RLF state. **Values higher than 1 and lower than 4 are recommended**
Default:	3	• Higher the value of this parameter, slower recovery from the RLF state

Deleted in RL40/RL25TD

- **eNB detected radio link problems –** PDSCH HARQ RLF triggered

LNBTS

rlpDetMaxNDl		Number of failed PDSCH transmissions
Range:	1...1000	The number of PUSCH DTX occurrences after which the RLF indication will be triggered for higher layers. • By default the parameter is increased to maximum, i.e. it has almost not chance to trigger the RLF • Lower the value of this parameter, faster RLF indication would be triggered.
Step:	1	
Default:	1000	

rlpDetMaxTimeDl		Timeframe for failed PDSCH transmissions
Range:	20...5000	The time after first HARQ DTX (lack of NACK/ACK response) occurrence with consecutive HARQ DTX indications after which the RLF will be triggered for higher layers. • Lower the value of this parameter, faster RLF indication would be triggered.
Step:	1 ms	
Default:	0 ms (off)	

rlpDetEndNoDl		Number of successful PDSCH transmissions
Range:	1...20	The number of consecutive HARQ responses (ACK/NACK) after which the RLF indication will be cancelled for higher layers • Higher the value of this parameter, the lower recovery time from the RLF state. **Therefore it is recomended to keep this value lower than 5**
Step:	1	
Default:	3	

- **eNB initiated release –** TA Timer Expiry at eNB

LNBTS

taOffScheMar	Time alignment offset margin for scheduling
Range: 1.5...4 us **Default:** 2 us	Parameter determines the time alignment offset limit for the uplink scheduler to stop considering the UE for scheduling. It is used by **On per-need TA** triggered if calculated timing alignment is higher than thresholds before periodic TA is triggered

taCmdMaxRetry	Maximum number of time alignment command retries
Range: 0...2560 **Default:** 89	The number of times the timing advance command is retried before the LTE MAC assumes that the UE has gone out-of-synch. It is used by **On per-need TA** triggered if calculated timing alignment is higher than thresholds before periodic TA is triggered The *taCmdMaxRetry* parameter is used if eNB transmit of a TA command and if the TA transmission fails - eNB will retry it by *taCmdMaxRetry* times.

- LTE502 Cell outage triggered reset feature has two related parameters which trigger the reset in erroneous situations:
  - ***LNCEL:cellResetRequest***
    - Value has no meaning for eNB
    - Change of parameter triggers Automatic cell lock/unlock feature (LTE830)
    - Parameter have human readable format, indicating time stamp at which reset was requested
  - ***LNBTS:btsResetRequest***
    - Change of parameter triggers BTS reset
- Both are dummy parameters, which are only used by NetAct to trigger the reset of the eNB, therefore they shouldn't be used by the customer nor changed manually