LTE Mobility and Traffic Management

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1 Introduction

Mobility and traffic management in a multi-layer network is a complex subject. It involves the interaction of many different features and functionalities, which work together to govern the behavior of the User Equipment (UE) in idle and connected modes. Developing an appropriate mobility strategy necessarily involves a compromise between the competing objectives of maximizing coverage, increasing capacity and improving performance.
The purpose of this document is to provide guidelines on how to understand, design and implement mobility and traffic management strategies for LTE networks. This includes intra-frequency and inter-frequency mobility within LTE, as well as inter-radio access technology (IRAT) mobility with WCDMA and GSM, in both idle and connected modes, for both voice and data. It also covers inter-frequency load balancing, offload, and carrier aggregation, at least to the extent that they impact the mobility and traffic management strategy.

2 Mobility Overview

This section introduces general mobility properties and concepts, which are fundamental to understanding mobility in LTE and are used throughout this document.

Mobility States

Figure 1 shows the LTE mobility states at a high level.

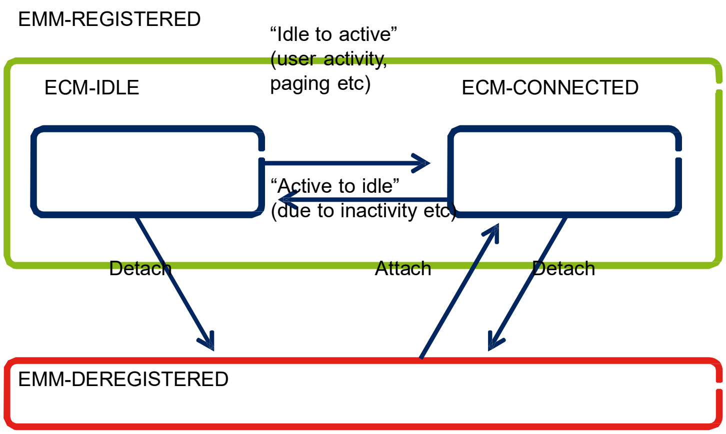


Figure 1 – Mobility States

An EMM-REGISTERED ("attached") User Equipment (UE) is known to the network and can send or receive traffic when required. An EMM-DEREGISTERED UE is not in contact with the network, that is, it is turned off, out of coverage etc.

A UE in ECM-CONNECTED state (“connected mode”) is known to the LTE RBS at a cell level and can send or receive data to the network, and so is consuming radio resources. A UE in ECM-IDLE state (“idle mode”) is not consuming radio resources (other than paging channel) and must transition to ECM-CONNECTED state before sending or receiving traffic.

ECM-IDLE, Idle Mode

To reduce processing and loading in the RBS and UE, all UE related information in the radio network can be released during long periods of inactivity. The MME retains the UE context and information about established bearers during these idle periods, but there is no explicit signaling between the UE and EPC.

However, the UE is still in EMM-REGISTERED state, indicating that it is attached to the network and may transition to connected mode in response to a paging request, user activity or other reason, without having to perform a full attach procedure.

An LTE RBS does not know how many UEs are camped within its coverage area in idle mode. The location of an idle UE is only known within a Tracking Area List, which is a group of Tracking Areas configured in the MME. Idle mode reselection parameters are broadcast in each cell, and an LTE UE is responsible for evaluating nearby cells and camping on the correct cell as determined by these broadcast criteria.

A UE which moves into a cell which is not in the current Tracking Area List must change to connected state to signal this to the network (via a Tracking Area Update), before returning to idle again.

ECM-CONNECTED, Connected Mode

In connected mode the UE makes no mobility decisions and responsibility is transferred to the LTE RAN (an exception to this is the RRC Re-Establishment procedure, where a UE may relocate to a new cell due to a radio link failure while in connected mode).

A UE can be instructed (via RRC Reconfiguration messaging) to report certain mobility events, such as when the serving cell signal drops below a particular level. This, in turn, causes the RBS to take further action, such as instructing the UE to configure further measurements, or perform a handover.

Coordination between the parameters and measurement thresholds is therefore critical, to ensure that the UE idle mode mobility and RBS connected mode mobility behavior is consistent.

Inactivity Timer

The timeout before a UE returns from connected mode to idle mode is configured by setting `tInactivityTimer`. This RBS level parameter influences the amount of time a UE spends in idle mode and hence whether the idle mode or connected mode mobility configuration is dominant. The default setting (61 seconds) can cause smartphone devices to rarely return to idle mode, due to bursty background traffic. A lower setting (typically 10 seconds) allows devices to return to idle mode more often, reducing the demand on system resources and increasing the influence of the idle mode mobility configuration.

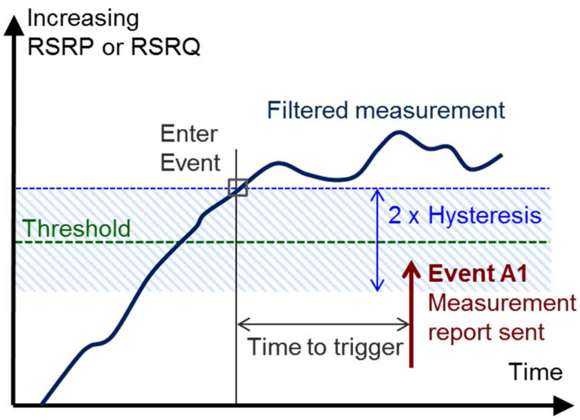
Measurement Events:

Inter and Intra LTE Events

Event A1: Good Coverage, Serving Becomes Better than Threshold

Event A1, shown in **Figure 2**, is used to detect good primary serving cell coverage. It is typically used to exit a search for inter-frequency or IRAT target frequencies for measurement based handover. For this purpose, two parallel A1 measurements can be configured, typically one for RSRP and one for RSRQ. Upon satisfying an Event A1 the UE sends a measurement report informing of good coverage. The RBS considers a UE in good coverage when all configured primary cell A1 events (which could be none, one or two) are satisfied. When this happens, previously configured measurement reports are removed, the UE stops searching for a good enough target and begins searching for poor coverage once more (via Event A2).

Event A1 may also be configured on a secondary cell frequency by the feature *Dynamic SCell Selection for Carrier Aggregation* (as determined by the parameter `sCellSelectionMode`). Such measurements are configured in parallel with any primary cell A1 measurements.



Example of parameters with MCPC
MO: ReportConfigSearch
Threshold: a1a2SearchThresholdRsrp
Hysteresis: hysteresisA1A2SearchRsrp
Time to Trigger: timeToTriggerA1Search

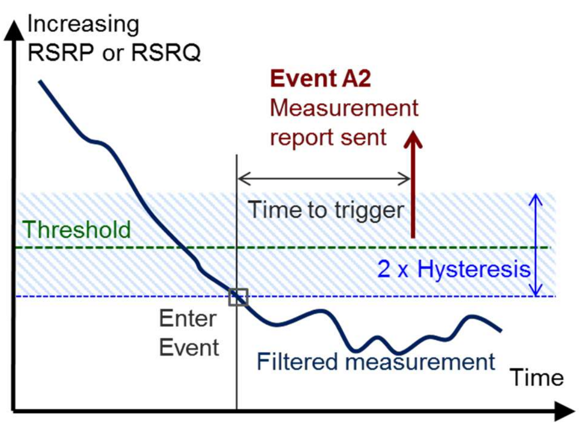
Example of parameters with legacy mobility
MO: ReportConfigA1Prim
Threshold: a1ThresholdRsrpPrim
Hysteresis: hysteresisA1Prim
Time to Trigger: timeToTriggerA1Prim

Figure 2 – Event A1 – Good Coverage, Serving Becomes Better than Threshold

Event A2: Poor Coverage, Serving Becomes Worse than Threshold

Event A2, shown in Figure 7, is used to detect poor primary serving cell coverage. It is typically used to trigger the search for inter-frequency or IRAT target frequencies for measurement based handover. Like Event A1, two parallel A2 measurements can be configured, typically one for RSRP and one for RSRQ. Upon satisfying Event A2, the UE sends a measurement report informing of poor coverage. The RBS considers a UE in poor coverage when either A2 event is satisfied. The reception of an A2 event may trigger either a blind mobility action towards a target frequency, or additional measurement events to detect coverage from the target frequency for handover or redirection. It also triggers configuration of an A1 measurement to detect return to good coverage.

Event A2 can also be configured on a secondary cell frequency by the feature *Dynamic SCell Selection for Carrier Aggregation*. Such measurements are configured in parallel with any primary cell A2 measurements.



Example of parameters with MCPC
MO: ReportConfigSearch
Threshold: a1a2SearchThresholdRsrp
Hysteresis: hysteresisA1A2SearchRsrp
Time to Trigger: timeToTriggerA2Search

Example of parameters with legacy mobility
MO: ReportConfigEUtraBadCovPrim
Threshold: a2ThresholdRsrpPrim
Hysteresis: hysteresisA2Prim
Time to Trigger: timeToTriggerA2Prim

Figure 3 – Event A2 – Poor Coverage, Serving Becomes Worse than Threshold

Event A3: Neighbor Becomes Offset Better than Serving

Event A3, **Figure 4**, is used during handover between intra or, less commonly, inter-frequency LTE neighbor cells (refer to 2.4.3 for guidelines on using A3 for inter-frequency measurements).

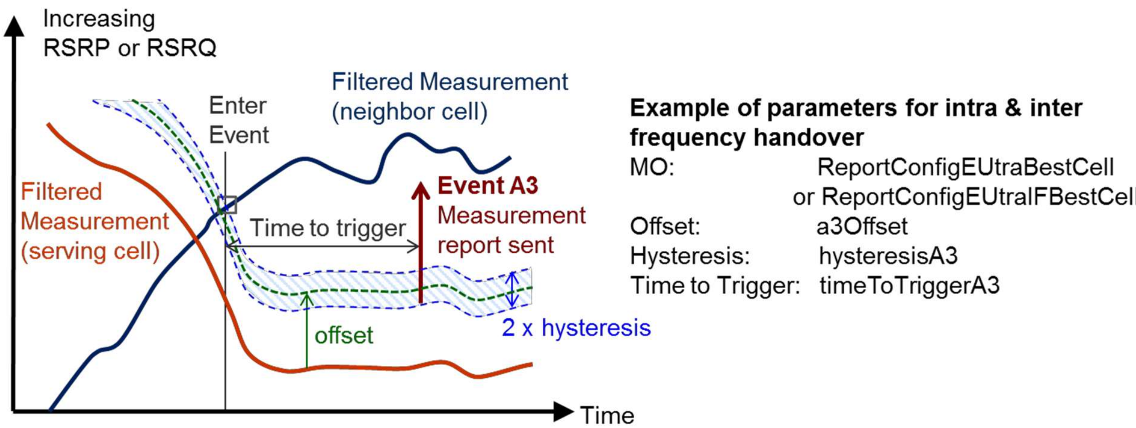


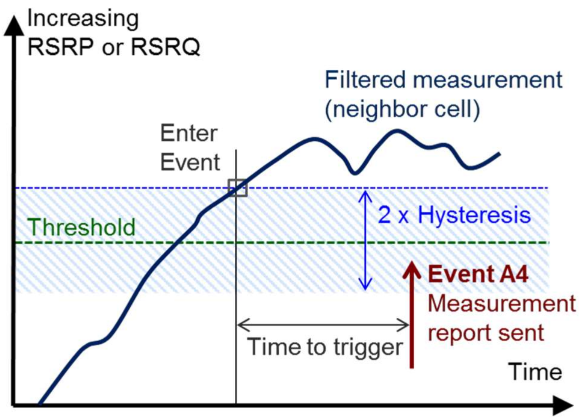
Figure 4 - Event A3 – Neighbor Becomes Offset Better than Serving

A3 requires measurement and filtering of two independent cells (serving and neighbor) and hence changes to filter coefficients may have a larger impact.

Upon satisfying Event A3, the UE sends a measurement report containing the PCI(s) of neighbor cell(s) (typically one) that are now better than the serving cell by a defined amount. If the relevant neighbor relation exists in the source eNodeB, this normally triggers a handover attempt towards the best neighbor cell.

Event A4: Neighbor Becomes Better than Threshold

Event A4, shown in **Figure 5**, was previously (till L13B) used for inter-frequency load balancing. However, it is no longer used for this purpose and A5 is used instead. However, A4 may still be configured for use by the feature *PM-Initiated UE Measurements*, for intra or inter-frequency measurements.



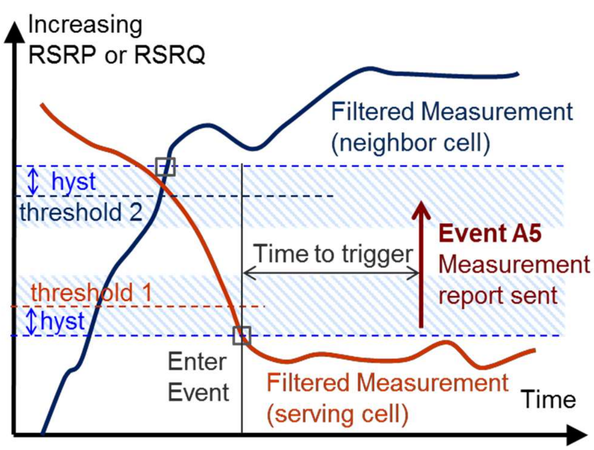
Example of parameters for PMIUM

MO:	ReportConfigEUtraIntraFreqPm or ReportConfigEUtraInterFreqPm
Threshold:	a4ThresholdRsrpPm
Hysteresis:	hysteresisPm
Time to Trigger:	timeToTriggerPm

Figure 5 – Event A4 – Neighbor Becomes Better than Threshold

Event A5: Serving Becomes Worse than Threshold 1 and Neighbor Better than Threshold 2

Event A5, shown in **Figure 6**, is used primarily for coverage triggered inter-frequency handover and inter-frequency load balancing and offload. It differs from Event A3 in that A5 triggering thresholds are absolute rather than relative.



Example of parameters for coverage-triggered handover

MO:	ReportConfigA5
Threshold 1:	a5Threshold1Rsrp
Threshold 2:	a5Threshold2Rsrp
Hysteresis:	hysteresisA5
Time to Trigger:	timeToTriggerA5

Example of parameters for IFLB

MO:	ReportConfigEUtraInterFreqLb
Threshold 1:	a5Threshold1Rsrp
Threshold 2:	a5Threshold2Rsrp
Hysteresis:	hysteresisA5
Time to Trigger:	(in ReportConfigA5)

Figure 6 – Event A5 - Serving Becomes Worse than Threshold 1 and Neighbor Better than Threshold 2

Event A6: Neighbor Becomes Offset Better than SCell

Event A6, shown in **Figure 7**, was introduced in Release-10 for Carrier Aggregation. It is used with *Dynamic SCell Selection for Carrier Aggregation* to trigger a change of SCell. It is similar to event A3, but whereas event A3 is used for primary cell (intra and inter-frequency), event A6 is used for evaluation of new secondary cell candidates amongst neighbor cells within a given frequency layer.

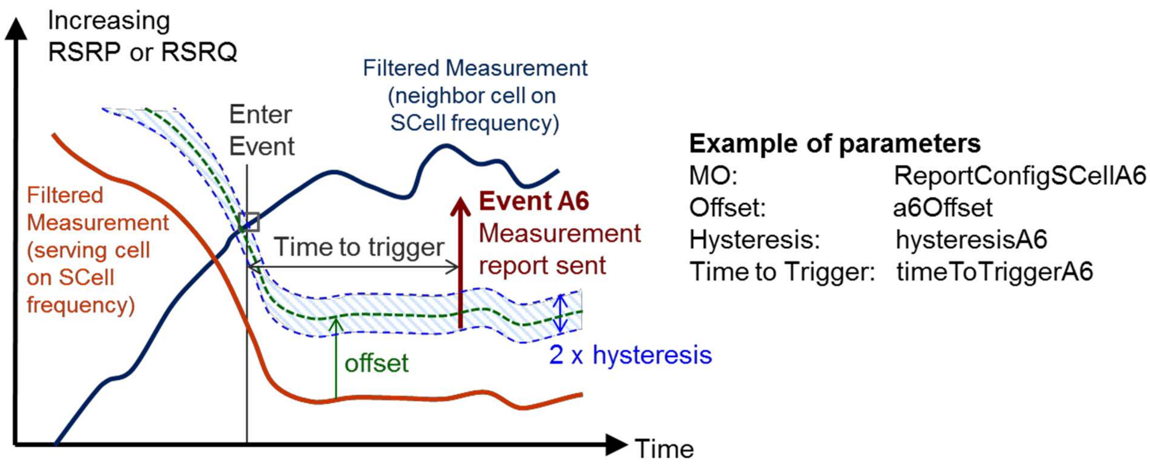


Figure 7 – Event A6

IRAT LTE Events

Event B1: IRAT Neighbor Becomes Better than Threshold

Event B1, shown in **Figure 8**, is used with IRAT offload and measurement-based CS fallback. It is used to ensure that the destination RAT has good coverage before handover or release-with-redirect.

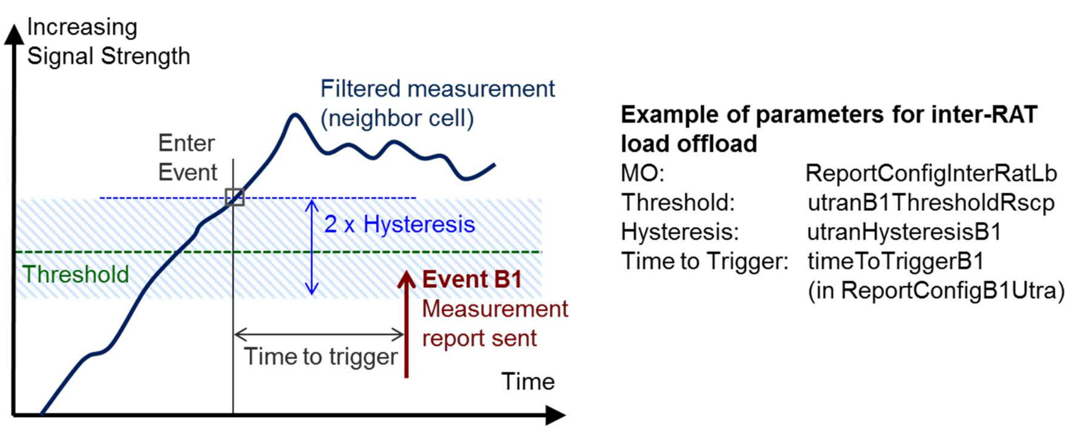
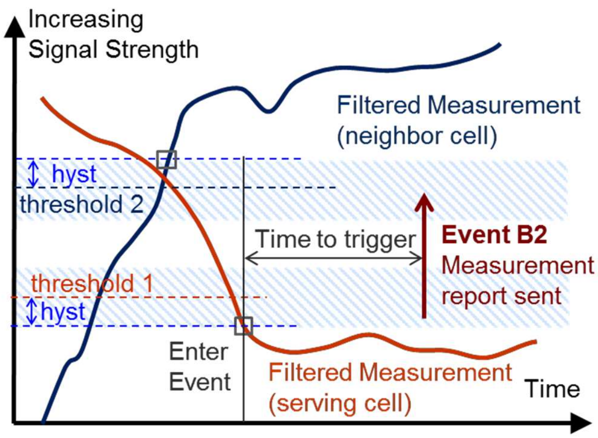


Figure 8 – Event B1 – IRAT Neighbor Becomes Better than Threshold

Event B2: Serving Becomes Worse than Threshold 1 and IRAT Neighbor Becomes Better than Threshold 2

Event B2, shown in **Figure 9**, is the IRAT counterpart to event A5, and is used primarily for coverage triggered IRAT mobility and measurement-based CS fallback. There are several versions of it that can be configured, corresponding to the different target RATs (e.g. GSM, WCDMA, etc). The behavior is similar to Event A5, except that threshold 2 applies to the target RAT and therefore uses the quantity defined for that RAT.



Example of parameters for coverage-triggered handover

MO:	ReportConfigB2Utra
Threshold 1:	b2Threshold1Rsrp or b2Threshold1Rsrq
Threshold 2:	b2Threshold2RscpUtra or b2Threshold2EcNoUtra
Hysteresis:	hysteresisB2
Time to Trigger:	timeToTriggerB2

Figure 9 – Event B2 – Serving Becomes Worse than Threshold 1 and IRAT Neighbor Becomes Better than Threshold 2

Event A3 versus Event A5 for Inter-Frequency Handover

The following features always use Event A5 (rather than Event A3) to evaluate the target frequency:

- *Inter-frequency Load Balancing* (and other load balancing features)
- *Inter-frequency Offload* (and other offload features)
- *Uplink-Triggered Inter-Frequency Mobility*
- *Uplink-Traffic-Triggered Mobility*
- *Cell Soft Lock*
- *Service or Priority Triggered Inter-Frequency Handover*

However, for downlink coverage-triggered inter-frequency handover, the triggering event can be chosen per frequency relation by setting `interFreqMeasType` to `EVENT_A3` or `EVENT_A5`. The key difference is that Event A5 uses two absolute thresholds to evaluate the source and target cells independently, whereas Event A3 uses a single relative threshold, set on the difference between the source and target cells, as show in **Figure 10**.

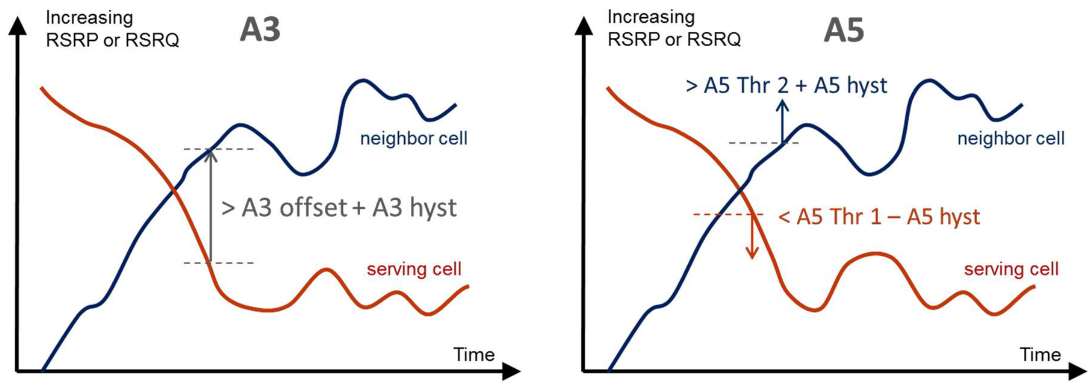


Figure 10 – Event A3 versus Event A5 for Inter-Frequency Handover (Simplified Representation)

This section discusses the pros and cons of A3 versus A5 for inter-frequency handover. Additional information on this topic is also provided in the Coverage Fallback Strategies section of the feature summary for *Mobility Control at Poor Coverage*..

Advantages of EVENT_A5

- When *Mobility Control at Poor Coverage* is active, Event A5, enables the use of the parameter `bothA5RsrpRsrqCheck`, which applies an extended check of both RSRP and RSRQ before inter-frequency handover is allowed.. This advantage was reduced in L18.Q4, which added similar functionality for A3.

- If Event A5 is used, then the thresholds (both source and target thresholds) can be adjusted independently per frequency and QCI using the features *Service-Triggered Mobility* (STM) and *Multi-Layer Service-Triggered Mobility* (MLSTM). For example:

  - Certain frequencies can be prioritized above others by setting a higher A5 Threshold 1, which is met sooner when moving out of serving cell coverage.

  - If a target frequency suffers from known interference, then A5 Threshold 2 can be set higher on this frequency to raise the requirement on the target signal strength or quality.

  - To improve handover robustness for VoLTE, A5 Threshold 1 can be set higher for UEs with a QCI1 bearer to trigger handover in better source cell conditions.

  These A5 advantages were reduced in L18.Q4, which improved A3 functionality by adding control of `a3offset` and `timeToTriggerA3` at the frequency and QCI level in STM and MLSTM.

- Because the Event A5 thresholds are set as an absolute value, they are more easily coordinated with the absolute thresholds used for priority based reselection in idle mode (i.e. `threshServingLow`, `threshXLow`, `threshXHigh`, `threshHigh`, and `sNonIntraSearch`). This is more difficult with A3, which uses a relative threshold.

- Event A5 thresholds are more easily coordinated with the inter-frequency load balancing and offload, as these features also use Event A5.

- a5Threshold1Rsrp and a5Threshold1Rsrq can be set equal to the respective A2 thresholds. This improves the probability of triggering a handover, because it does not require the signal to fall even lower than the A2 to satisfy the A5 Threshold 1. This makes A5 similar to A3 which does not have an absolute requirement on the source cell. Unlike A3 however, this setting also ensures that handover does not occur if the signal strength rises after triggering A2, because in this case the A5 Threshold 1 is not met. This is not the case with A3, where handover can be triggered under rising signal strength (until A1 triggers, which is typically 2 to 4 dB above the A2 trigger point, considering hysteresis). To avoid a similar behavior with A5, do not set A5 Threshold 1 above A2.

- a5Threshold2Rsrp and a5Threshold2Rsrq can be coordinated with the target cell's A2 thresholds to ensure that the UE does not arrive into the search zone of the target cell. This is not possible with A3 which uses a relative threshold which does not prevent the UE from arriving into the search zone. This increases the risk, with A3, of ping-pong handover when both cells are below the A2 thresholds and multipath fading causes the best cell to change frequently. This case is more likely to occur when the site grids of the two frequencies are co-located, and the two signals decrease together. It is less likely to occur for non-co-located cases. Such ping-pong handover could be mitigated by increasing ReportConfigEUtraIFBestCell.hysteresisA3 or ReportConfigEUtraIFBestCell.timeToTriggerA3 but the penalty for this is remaining on a weaker frequency for longer.

Advantages of EVENT_A3

- From L18.Q4 onwards, *Mobility Control at Poor Coverage* provides the parameter bothInterA3RsrpRsrqCheck, which applies an extended check of both RSRP and RSRQ before inter-frequency handover is allowed.
- One of the problems with Event A5 is that the target cell becomes inaccessible below A5 threshold 2. So, if the signal strength of both cells drops rapidly, the target may not qualify for handover even though it is significantly better than the source. This could be a problem if a conservative setting for the serving cell threshold is desired (high value of threshold 1). If threshold 2 is set high as well (to ensure handover to a stronger cell) then there is a danger that both cells fall below the thresholds and prevent handover to a better target at low signal levels. The compromise is to set threshold 2 below threshold 1, but this allows handover to a weaker cell which may not be desirable. This problem is avoided with the relative threshold used by Event A3, which ensures handover only ever occurs to a stronger cell, and allows handover to a stronger cell regardless of the absolute signal strength.

- The above point makes Event A3 an attractive alternative for handover between frequencies on non-co-located site grids. In this case A2 can be set to a higher level, knowing that a HO occurs only if a better target is found.

- A3 is recommended for handover between carriers with overlapping spectrum. In this case it is very important for the UE to be on the strongest cell to mitigate interference

UE Behaviors

The success of a mobility strategy depends on knowledge of UE behavior. Some observations that may impact a deployment are:

- Some early UE implementations may provide increasingly optimistic RSRP measurements as DL SINR degrades. At the cell edge, this can cause a UE to incorrectly camp on an LTE cell due to an overestimate of the signal strength. If an attempt is made to connect to the cell, this may fail completely due to the higher than expected path loss.

- Most smartphones are WiFi capable, and may automatically move to WiFi if available. This is not controlled by the network and so understanding of potential WiFi deployments, particularly around airports, shopping centers, public transport etc. may indicate which locations to target for optimization.

- A UE only has support for a limited number of bands and RATs. If support for a particular LTE band is limited in the UE population, this may require a stronger prioritization of that band to ensure that utilization is not low.

- UEs may not support all LTE features. For instance: Release 8 LTE UEs do not support Release with system information procedures, some UEs do not support event A4, A6 and/or event B2 measurements (or only have partial support), and UEs have different requirements for measurement gaps.

- The number of measurement events configured in parallel is limited and may impact the UE capability to service any particular event quickly. This is especially true when measurement gaps are required to measure inter-RAT or inter-frequency neighbors.

- The number of frequency layers to monitor in parallel is limited and may also impact the UE capability to find best cells on a particular frequency layer quickly.

- When a UE is released to a legacy RAT in a blind redirect, but cannot find coverage, the behavior can vary between different models. Some UEs search for other potential cells or carriers on the target RAT first, others “prefer” a particular RAT, for instance, UMTS over GSM.

3. Scenario: Single Layer LTE with WCDMA and GSM

Scenario description

In this scenario, a single LTE carrier is deployed over legacy GSM and WCDMA carriers, interworking with both. The following inputs are available: • A single low band LTE carrier (e.g. 800 MHz) is deployed as a mobile broadband coverage layer, providing both data and Voice over LTE (VoLTE) services. • Legacy networks are high band WCDMA (e.g. 2100 MHz) and low band GSM (e.g. 900 MHz), providing both data and voice services. • Coverage from WCDMA is present in most of the LTE footprint, however there are holes where only GSM is available. • WCDMA is preferred target for coverage fallback and CS fallback from LTE for UEs not capable of VoLTE. The primary focus of this scenario is IRAT mobility

Strategy Overview

LTE packet performance is expected to be superior to both WCDMA and GSM when LTE coverage is good. However, where LTE coverage is poor WCDMA may be better, so idle mode re-selection should allow reselection to WCDMA in such cases.

Figure 11 summarizes the mobility actions. Note that only the main cases are shown, and some actions are omitted for clarity.

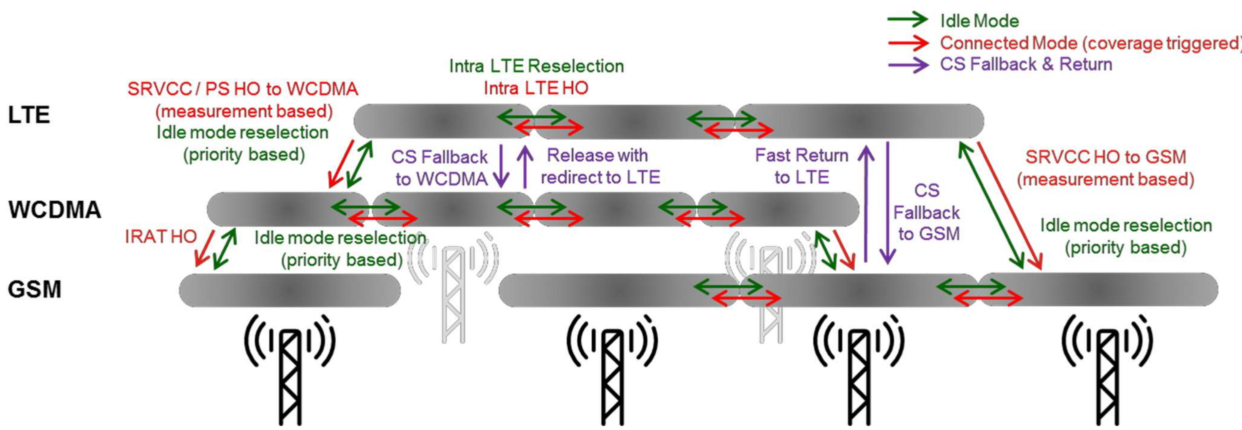


Figure 11 – Mobility Actions

In idle mode, priority ranking is used to ensure that devices reselect from GSM (lowest priority) to WCDMA (middle priority) to LTE (highest priority) as coverage is available. In connected mode, connections are maintained in LTE as long as possible, to reduce connected mode IRAT transitions.

If poor LTE coverage is encountered, the feature *Mobility Control at Poor Coverage* (MCPC) is used to search for alternative coverage on another RAT. For connections with a voice (VoLTE) bearer, both WCDMA and GSM are searched as both can support voice connections well. However, for PS only connections, only WCDMA is searched because even poor LTE coverage is considered better than GSM for PS. If a WCDMA target is found, PS and/or voice services are handed over. If a GSM target is found, only the voice service is handed over. Handover to WCDMA is prioritized over HO to GSM by setting the serving cell handover threshold for WCDMA 3dB higher than that for GSM. If no target is found, PS only connections are released with redirect to WCDMA when the serving coverage becomes critical. However, if a voice bearer (VoLTE) is present then this release does not occur, and the voice call continues in LTE until a target is found, or coverage improves or the call drops. This strategy is illustrated in **Figure 12**.

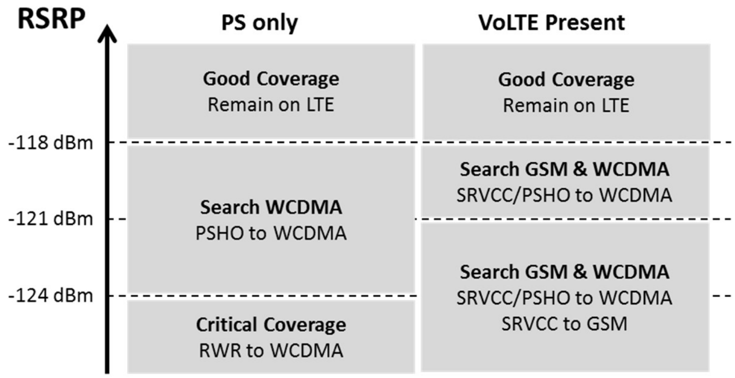


Figure 12 – SRVCC and PSHO Strategy

Circuit Switched Fallback (CSFB) is used to provide voice services to UEs not capable of VoLTE. The feature *Measurement-Based CSFB Target Selection* is used to search for a suitable WCDMA target first or, if this fails, fallback to GSM.

The features *Redirect with System Information* (in LTE), *Fast Return to LTE* (in GERAN), *SRB on HSDPA* (in UTRAN) and *Release with Redirect to LTE* (in UTRAN) are used to improve the user experience for CS Fallback and speed the return to LTE.

Connected mode interworking is also required between GSM and WCDMA but is not covered here. Network edge LTE sites need to be tuned to match existing coverage to prevent fallback attempts where coverage from another RAT does not exist.

Figure 13 highlights the main IRAT mobility actions and related thresholds relevant to this scenario. Parameters are listed adjacent to the network layer in which they are set.

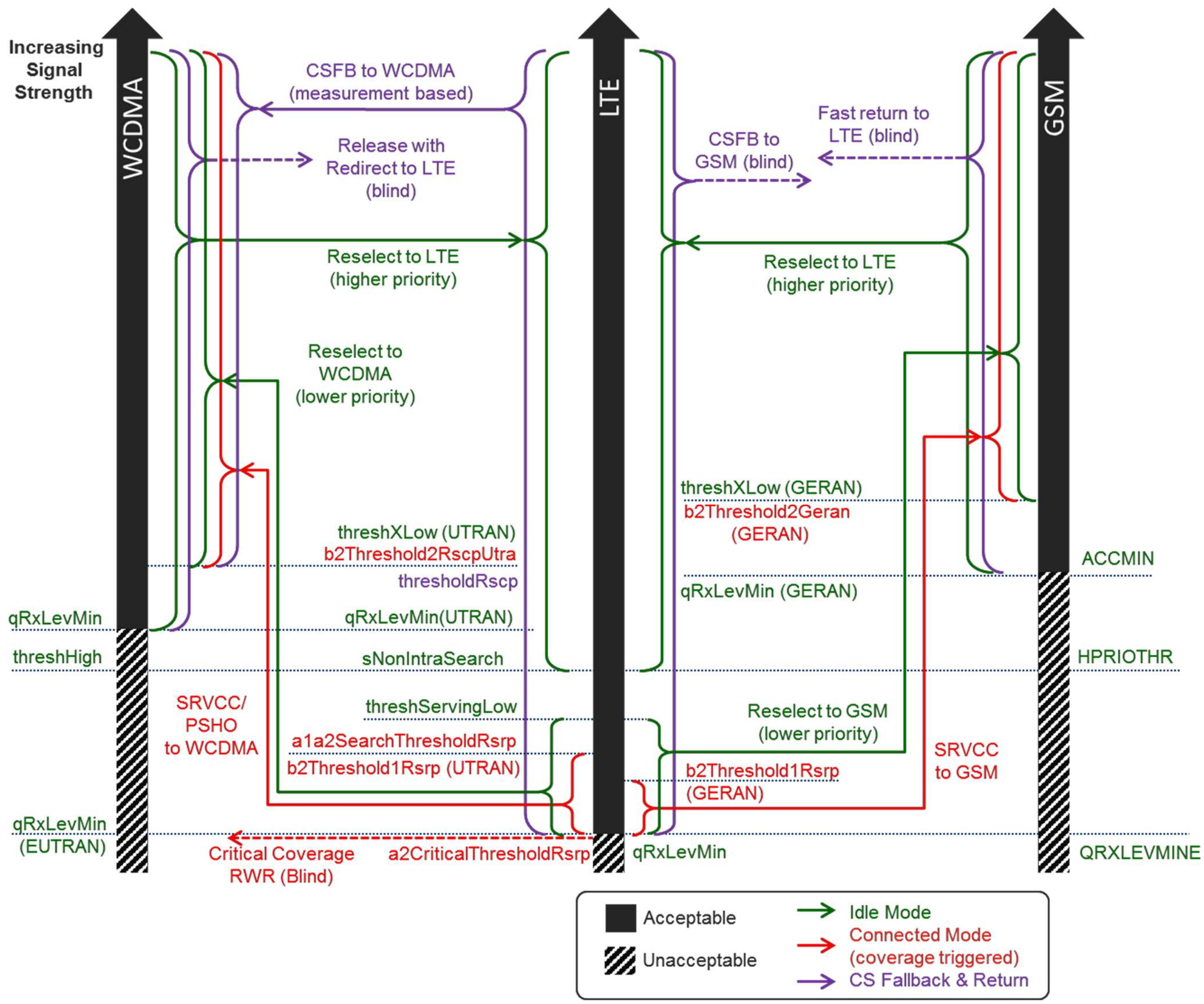


Figure 13 – IRAT Mobility Actions and Key Thresholds

Idle Mode Mobility

Idle mode mobility (intra-frequency, inter-frequency and inter-RAT) is covered in detail in the feature summary for *Idle Mode Support* . Familiarity with that content is assumed, and this section is limited to additional information which is relevant for this scenario. Explanations of idle mode behavior are given with respect to `qRxLevMin` alone, assuming that cell and frequency specific offsets are zero.

For intra-frequency mobility on LTE, the recommendations are provided in **Table 1**.

Table 1 – Intra-frequency Idle Mode Parameters

Parameter	Value	Comment
`qRxLevMin`	-124 dBm	Nominal value.

Parameter	Value	Comment
`qHyst`	4 dB	Aligned with the connected mode `a3offset` and `hysteresisA3` values to ensure equal cell size in idle and connected modes. This decreases the risk of immediate handover after RRC connection setup.
`tReselectionEutra`	2 s	Default value
`sIntraSearch`	62	Maximum value. Measurements are required when serving RSRP is below -124+62 = -62 dBm (neglecting cell and frequency specific offsets). Ensure that the UE always camps on the best serving cell.

In this scenario idle mode reselection is configured between all combinations of RATs, that is LTE ↔ GSM, LTE ↔ WCDMA, WCDMA ↔ GSM. Another possible design choice is to limit reselection to LTE ↔ WCDMA ↔ GSM only, with no direct LTE ↔ GSM reselection. In this case, such an approach is unsuitable due to the uncertainty of WCDMA coverage. Idle mode reselection based on absolute priorities is used,– Priority Carrier Configuration". Idle mode priorities are set via `cellReselectionPriority` per frequency relation as illustrated in **Figure 14**. In GERAN the relevant parameter is `RATRIO`. Note that the own-frequency relation must also be assigned a priority.

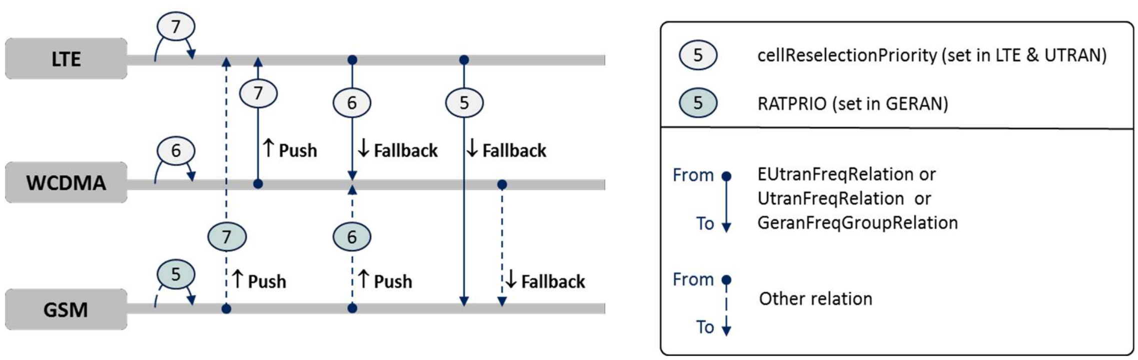


Figure 14 – cellReselectionPriority and RATPRIO Settings

The following figure illustrates the idle mode reselection thresholds. The heavy black (LTE), green (WCDMA) and blue (GSM) arrows in the diagram represent decreasing signal strength measured by the UE. In a similar way the colors of the parameters indicate the layer in which they are set. The brown arrows show the mobility behavior of the UE in response to the configured thresholds: diagonal as it moves within a cell from good to poor coverage, and vertical as it reselects to a different RAT. Only RSRP thresholds are shown here.

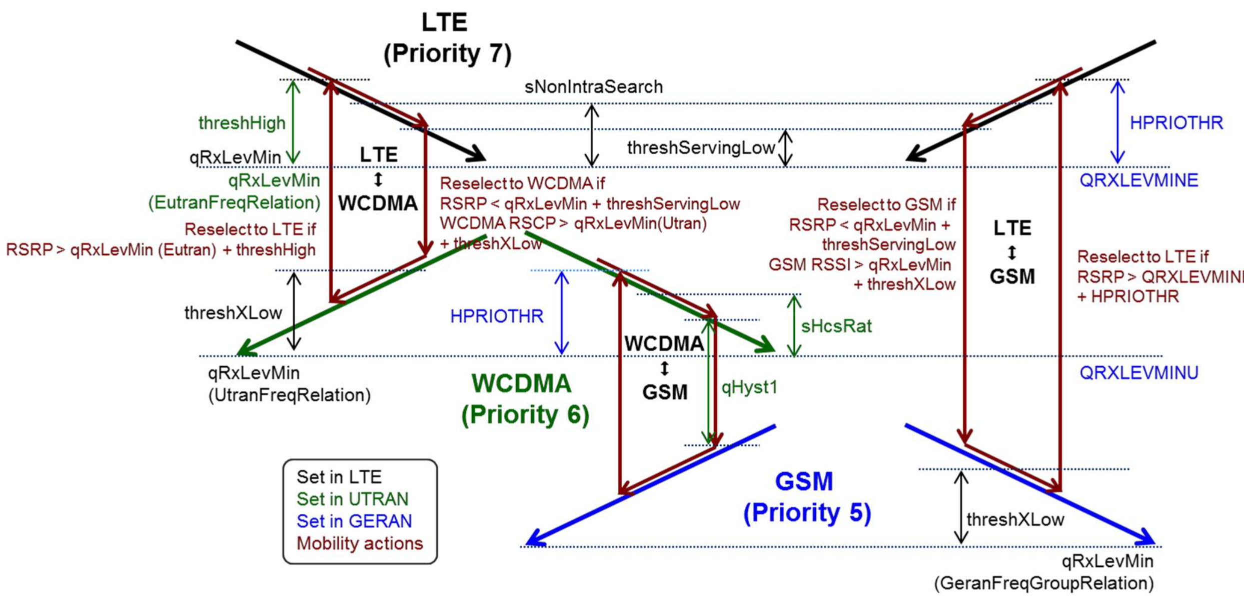


Figure 15 – Idle Mode Mobility Actions and Thresholds …

LTE is broadcast as the highest priority RAT in all three technologies, followed by WCDMA, and then GSM. Reselection to a lower priority RAT occurs only when the destination coverage is expected to be "better".

A UE reselects from LTE to a lower priority RAT when both the following criterion are met:

- RSRP < qRxLevMin (E-UTRAN) + threshServingLow
- RSCP / RSSI > qRxLevMin (UTRAN/GERAN) + threshXLow

The values chosen for `threshServingLow` and `threshXLow` to GERAN and UTRAN should ensure that the performance when arriving in the target RAT is at least comparable to, or preferably better than, the performance when leaving LTE. The optimal values depend on many factors and should be confirmed with drive test data.

When a UE is camped on WCDMA it always measures LTE, and reselects when the RSRP exceeds `threshHigh + qRxLevMin`. Set `threshHigh` a few dB above `threshServingLow` to prevent cyclic reselection and continuous inter-RAT measurement. However, setting this value too high makes it more difficult to reselect LTE, causing UEs to stick to the WCDMA unnecessarily.

When UE is camped on GSM, it reselects to LTE when the RSRP exceeds `QRXLEVMINE + HPRIOTHR`. As with threshHigh for WCDMA, set `HPRIOTHR` above `threshServingLow`. A UE on GSM reselects to WCDMA when the WCDMA RSCP exceeds `QRXLEVMINU + HPRIOTHR`.

In WCDMA, a UE measures GSM neighbor cells when either of the following is fulfilled:

- CPICH RSCP < qRxLevMin + sHcsRat
- CPICH EcNo < qQualMin + sRatSearch

To prevent the case where a UE reselects to WCDMA, then immediately reselects to GSM, configure threshXLow (LTE to WCDMA) ≥ sHcsRat (WCDMA to GSM), although reselection may still trigger on the CPICH Ec/No requirement. In a network where there is no direct reselection from LTE to GSM, this recommendation does not apply.

The IRAT idle mode recommendations:

- Reselection to a lower priority RAT occurs only when the destination coverage is expected to be better
- Use drive test data to compare the performance of the three technologies and assist in setting the thresholds
- Set threshXLow to the minimum value to simultaneously meet the following criteria:
  - At least 3 dB, to ensure some margin above the minimum cell selection criterion on the target
  - Greater than the UTRAN sHcsRat parameter if GSM is also broadcast as a lower priority RAT in UTRAN, to prevent fall-through
  - As required to ensure there is an advantage in reselecting another RAT
- Set qRxLevMin + threshServingLow equal to or greater than thresholds used in connected mode, to prevent immediate mobility after an idle to connected mode transition
- Reselection from a lower priority RAT towards LTE (set by HPRIOTHR and threshHigh) should allow some hysteresis (typically a few dB) above reselection from LTE back to the lower priority RAT (set by threshServingLow).

Parameter Recommendations

Values to be used in this scenario are listed below.

Table 2 – IRAT idle mode parameters

Parameter	System	Value	Comment
cellReselectionPriority (EUtranFreqRelation)	LTE / UTRAN	7	LTE is the highest priority RAT
cellReselectionPriority (UtranFreqRelation)	LTE	6	WCDMA is middle priority
cellReselectionPriority (UtranCell)	UTRAN	6	WCDMA is middle priority
cellReselectionPriority (GeranFreqGroupRelation)	LTE	5	GSM is lowest priority
RATPRIO	GERAN	7, 6, 5	7 for LTE frequencies, 6 for WCDMA frequencies and 5 for the GSM cell
qRxLevMin (EUtranCellFDD/TDD)	LTE	-124 dBm	Nominal value.

Parameter	System	Value	Comment
sNonIntraSearch (EUtranCellFDD/TDD)	LTE	8 dB	The UE begins searching for IRAT cells at RSRP < -116 dBm
threshServingLow (EUtranCellFDD/TDD)	LTE	6 dB	Reselection towards WCDMA or GSM is allowable when RSRP < -118 dBm
tReselectionUtra (EUtranCellFDD/TDD)	LTE	2 s	Default value
qRxLevMin (UtranFreqRelation)	LTE	-115 dBm	Nominal value, from the WCDMA radio network design.
threshXLow (UtranFreqRelation)	LTE	6 dB	A WCDMA cell is considered for reselection when RSCP > -109 dBm
qRxLevMin (EUtranFreqRelation)	UTRAN	-124 dBm	UTRAN parameter. From the LTE radio network design.
threshHigh (EUtranFreqRelation)	UTRAN	12 dB	UTRAN parameter. Implies that reselection towards LTE occurs when RSRP > -112 dBm
sHcsRat (UtranCell)	UTRAN	2 dB	UTRAN parameter. From the WCDMA radio network design.
tReselectionGeran (EUtranCellFDD/TDD)	LTE	2 s	Default value
qRxLevMin (GeranFreqGroupRelation)	LTE	-107 dBm	Nominal value, from the GSM radio network design.
threshXLow (GeranFreqGroupRelation)	LTE	10 dB	A GSM cell is considered for reselection when RSSI > -97 dBm

Mobility Threshold Design

The thresholds for mobility in this scenario are best designed holistically, considering idle and connected modes together. The design should ensure, for example, that inwards mobility is not immediately followed by outwards mobility or that idle and connected mode transitions do not work in opposition. This section focusses on this task.

A good approach is to start with the extreme edge of coverage and work inwards, setting the triggering levels relative to each other and allowing appropriate margins at each step. This approach is illustrated in **Figure 17** and the accompanying notes in **Table 4**. The order of the notes in the figure and the table illustrates the logic flow of the design. When setting thresholds, it is convenient to adopt a two-stage approach: first design the effective triggering levels and then translate them into the relevant threshold, hysteresis and offset parameter values.

In **Figure 17** the arrows pointing to the right represent the RSRP range over which mobility into LTE occurs, due to adequate RSRP. The arrows pointing to the left represent mobility out of the frequency, due to inadequate RSRP. The main controlling parameter is shown for each transition. The color represents the mobility type: green for idle mode and red for coverage-triggered connected-mode.

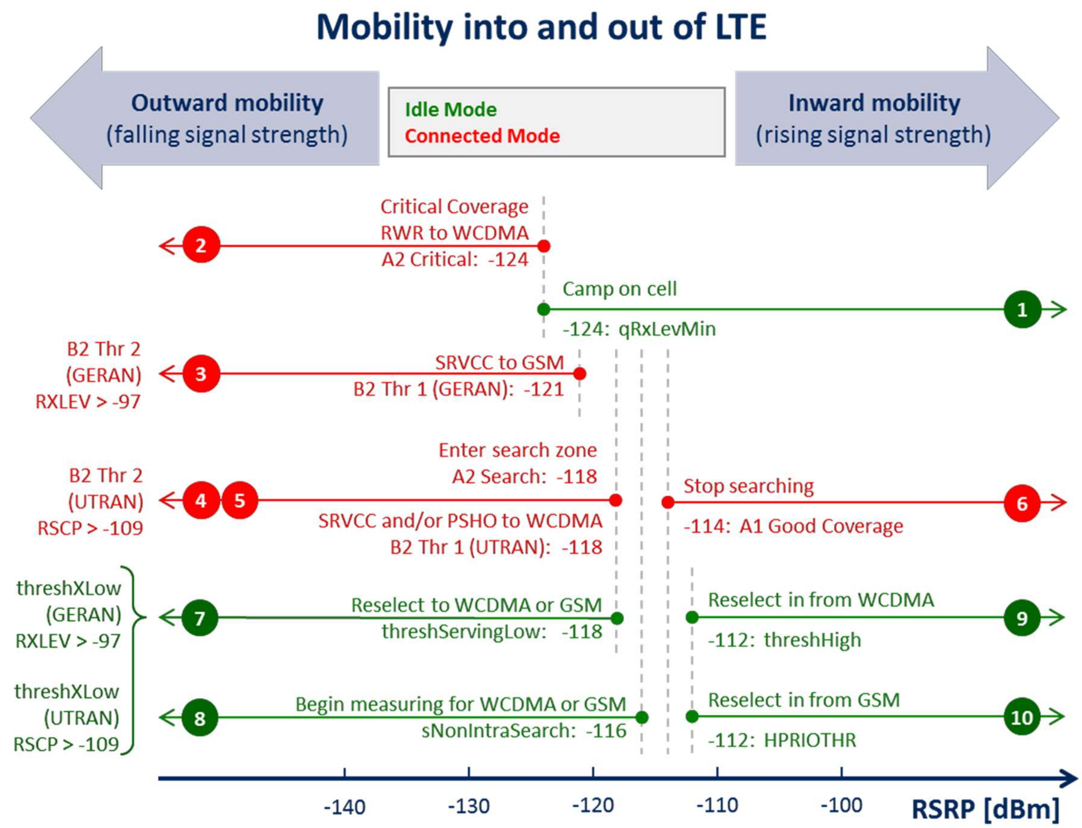


Figure 17 – Thresholds for Mobility into and out of LTE

Table 4 – Mobility Thresholds

Threshold Description	Comment	Setting
Note 1 Purpose: Idle coverage limit on LTE (`qRxLevMin`) Set on: LTE Measured on: LTE Mode: Idle	Nominal value. Depends on several factors. -124 is reasonable for `crsGain` = 3dB. For `crsGain` = 0 dB could lower to -126 or -128 dBm.	Effective level: -124 dBm Parameter values: `qRxLevMin` = -124 dBm
Note 2 Purpose: Coverage-triggered blind release from LTE to WCDMA (A2 critical coverage) Set on: LTE Measured on: LTE Mode: Connected	Remain on LTE as long as possible if WCDMA or GSM is not found by measurements. Align with idle mode cell boundary.	Effective level: -124 dBm (same as `qRxLevMin`) Parameter values: `a2CriticalThresholdRsrp` = -123 dBm `-hysteresisA2CriticalRsrp` = 10 (1 dB)
Note 3 Purpose: Coverage-triggered SRVCC HO from LTE to GSM when voice is present. (Event B2) Set on: LTE Measured on: LTE, GSM Mode: Connected	Allow a margin between SRVCC handover to GSM and critical coverage release.	Effective level: Source < -121 dBm (3 dB above A2 critical coverage) Target > -97 dBm Parameter values: `b2Threshold1Rsrp(GERAN)` = -120 dBm `-hysteresisB2` = 10 (1 dB) `b2Threshold2Geran` = -98 dBm `+hysteresisB2` = 10 (1 dB)
Note 4 Purpose: Coverage-triggered PS or SRVCC handover from LTE to WCDMA. (Event B2) Set on: LTE Measured on: LTE, WCDMA Mode: Connected	Prioritize WCDMA handover over GSM handover by setting threshold for WCDMA 3dB above the equivalent threshold for GSM.	Effective level: Source < -118 dBm (3 dB above GSM B2_Thr1) Target > -109 dBm Parameter values: `b2Threshold1Rsrp(UTRAN)` = -117 dBm `-hysteresisB2` = 10 (1 dB) `b2Threshold2RscpUtra(UTRAN)` = -110 dBm `+hysteresisB2` = 10 (1 dB)
Note 5 Purpose: Enter search zone and begin searching for coverage from alternative RAT (A2 search) Set on: LTE Measured on: LTE Mode: Connected	Avoid searching without the possibility of handing over, so set the same as B2 threshold 1 for WCDMA. A higher setting may be beneficial in the case of fast moving UEs.	Effective level: -118 dBm (align with B2_Thr1 for WCDMA) Parameter values: `a1a2SearchThresholdRsrp` = -116 dBm `-hysteresisA1A2SearchRsrp` = 20 (2dB)
Note 6 Purpose: Enter good coverage and end searches (A1A2 good coverage) Set on: LTE Measured on: LTE Mode: Connected	Stop searching for WCDMA and GSM when UE re-enters good coverage.	Effective level: -114 dBm (A1 is 4dB above A2) Parameter values: `a1a2SearchThresholdRsrp` = -116 dBm `+hysteresisA1A2SearchRsrp` = 20 (2 dB)

CS Fallback scenario1

In this scenario, UEs not capable of VoLTE are provided with voice services via Circuit Switched Fallback (CSFB) to GSM or WCDMA. Section 5.1.17 presents general information on the features available for CSFB and recommendations on their use. This section presents additional information relevant to this particular scenario.

WCDMA is the preferred target for CSFB, due to the superior data performance in the case where a PS bearer is also involved. However, since the coverage from WCDMA cannot be guaranteed in this scenario, CSFB to GSM must also be possible. Measurements are used to search for WCDMA, and if it is not found then CSFB to GSM occurs as second preference. The feature *Measurement-Based CSFB Target Selection* is used for this purpose, building on the basic feature *CS Fallback to GERAN and UTRAN*. The feature *PSHO-Based CS Fallback to UTRAN* is not used in this scenario, on the assumption that the WCDMA network does not support the feature *SRB on HSDPA*, which is required for optimal call setup times. Blind release-with-redirect….

Given this use of features, CSFB to both WCDMA and GSM occur via a release-with-redirect, based on measurements in the case of WCDMA and blind in the case of GSM. On sites where WCDMA coverage is ensured, blind release-with-redirect to WCDMA can be used instead of measurement-based, by disabling *Measurement-Based CSFB Target Selection*. This leads to faster call setup times. To discover whether WCDMA coverage is good enough for blind release, configure measurements first and then examine the CSFB statistics to determine what proportion end up on WCDMA.

The priority settings required to achieve this behavior are shown in **Table 3**.

Table 5 – CSFB Priority Settings

Parameter	GSM relation	WCDMA relation
`csFallbackPrio`	-1	4
`altCsfbTargetPrio`	3	-1

To facilitate the prompt return of UEs to LTE following a CSFB event,

Fast Return to LTE after Call Release (GERAN feature)

As explained in the feature summary for CSFB, to minimize the call setup delay involved with CSFB it is important that coverage of each TA list is completely contained within the coverage of a single LA on the target RAT. In this scenario it is assumed that the LAs used in WCDMA and GSM are different and that the LA boundaries of the two do not necessary align. Note, however, that is possible to configure common LAs between 2G and 3G and this eases the TA to LA mapping requirements. Since the preferred target for CSFB in this scenario is WCDMA, it is best to align the TA boundaries with the WCDMA LA boundaries rather than with the GSM LA boundaries. In most cases this results in the UE being registered in the correct LA for CSFB.

Where holes in WCDMA coverage exist, however, GSM becomes the target for CSFB. **Figure 18** presents two possible options to deal with this.

For smaller holes, and for ease of managing configuration data, measurement-based CSFB are used to measure WCDMA first, with fallback to GSM in where no WCDMA target is found. The penalty when falling back to GSM is longer call setup times, firstly due to the time spent measuring WCDMA and secondly due to the requirement for an LAU on GSM.

If WCDMA is unavailable in larger areas (many sites), LTE TAs are defined to cover these areas. In these TAs, measurement-based CSFB is disabled and direct release- with-redirect to GSM is used (by setting `csFallbackPrio` to a higher priority on the GSM relation than on the WCDMA relation). In addition, the TA to LA mapping in the MME is changed to GSM, rather than WCDMA.

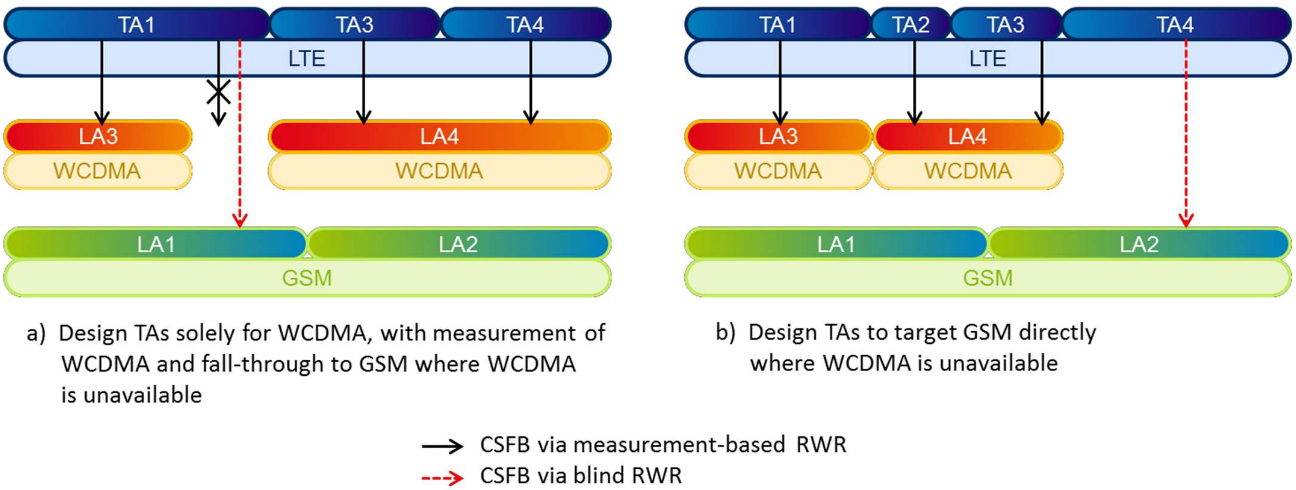


Figure 18 – CSFB Strategies

The feature *Redirect with System Information* is used to reduce the call setup time associated with CSFB. It does this by providing the UE with system information for a limited number of potential target cells, allowing the UE to connect more quickly when it arrives in the target network. The `coverageIndicator` parameter is used to prioritize the co-sector cells on WCDMA (and/or GSM where appropriate) for RIM associations.

Parameter Recommendations

The recommended CSFB parameter settings for this scenario are provided in **Table 6**.

Table 6 – CSFB parameters

Parameter (MO)	Value	Comments
`csFallbackPrio` (`UtranFreqRelation`, `GeranFreqGroupRelation`)	-1 (GERAN) 4 (UTRAN)	Prioritizes this target frequency for CSFB. 0 is lowest, 7 is is highest, -1 is excluded. Set to 4 on `UtranFreqRelation` to allow measurements on this frequency. Set to -1 on `GeranFreqGroupRelation` to disallow measurements on this frequency. If the UE does not support the WCDMA band then blind release to GSM occurs instead of measurement-based release, which is preferable.

Parameter (MO)	Value	Comments
altCsfbTargetPrio (UtranFreqRelation, GeranFreqGroupRelation)	3 (GERAN) -1 (UTRAN)	Sets the alternative priority for CSFB when the feature *Measurement Based CSFB Target Selection* is active and the measurement has timed out or the handover preparation has failed. 0 is lowest, 7 is is highest, -1 is excluded. Set to -1 on UtranFreqRelation to exclude this frequency and to 3 on GeranFreqGroupRelation to allow this frequency.
mobilityActionCsfb (UtranFreqRelation, GeranFreqGroupRelation)	RELEASE_WITH_REDIRECT_NACC	Sets the preferred mechanism for CSFB to RELEASE_WITH_REDIRECT_NACC on both WCDMA and GSM.
coverageIndicator (UtranCellRelation, GeranCellRelation)	OVERLAP (co-sector cells) NONE (other cells)	Set to OVERLAP on co-sector WCDMA and GSM cells to prioritize those cells for RIM associations.
csfbHoTargetSearchTimer (UeMeasControl)	500 ms	Length of time the eNodeB waits for reports from B1 or B2 measurement on WCDMA. After this expires a RWR to GSM is initiated. Timer is extended if measuring more than one frequency (e.g. 900 ms for two frequencies).
csfbMeasFromIdleMode (ENodeBFunction)	true	Set to true. When CS Fallback is requested for a UE in idle mode this parameter controls if measurements must be performed. If the parameter is set to false a blind release-with-redirect is performed.
thresholdRscp (ReportConfigCsfbUtra)	-109	The RSCP threshold for CSFB to UTRAN. Align with b2Threshold2RscpUtra for SRVCC, namely -109 dBm.

Automated Neighbor Relations

In this scenario, the feature Automated Neighbor Relations (ANR) is used to manage both intra-frequency LTE and inter-RAT neighbor relations. Section 5.1.16 presents general information on configuring ANR, and that should be read before proceeding with the scenario-specific information in this section.

One of the key functions of managing neighbor relations is detecting unknown cells. To detect unknown cells, ANR can potentially use UE measurements of three types: mobility-initiated event-based measurements, ANR-initiated event-based measurements and ANR-initiated periodic measurements. As a general principle, it is good to minimize unnecessary measurements. With this in mind, the recommendations for this scenario are:

Mobility-Initiated Event-Based Measurements

Intra-frequency LTE: Because MCPC is enabled in this scenario, ANR can use mobility-initiated intra-frequency A3 measurements for the discovery of unknown LTE cells throughout the entire cell area, even when the reports occur in poor coverage (i.e. A2 has been triggered). These mobility-initiated measurements are sufficient for intra-frequency ANR, and no additional ANR-initiated measurements are required.

WCDMA: Since mobility-initiated B2 reports on WCDMA cannot contain unknown cells, these measurements are of no use to ANR for discovering unknown cells. ANR-initiated measurements must be used instead.

GSM: ANR can use mobility-initiated B2 measurements on GSM to discover unknown GSM cells. This is sufficient for coverage-triggered mobility at LTE cell edge. However, additional ANR-initiated measurements are required to discover unknown GSM cells which are not at LTE cell edge.

ANR-Initiated Event-Based Measurements

Intra-frequency LTE: Because mobility-initiated measurements are used to discover intra-frequency LTE cells, ANR-initiated measurements are not required and are disabled in this scenario.

ANR-Initiated Periodic Measurements

WCDMA: These measurements are enabled to discover unknown WCDMA cells, because mobility-initiated measurements cannot be used for this purpose.

GSM: These measurements are enabled as they are required to discover unknown GSM cells which are not at LTE cell edge. Relations to such cells may be needed for the feature *Redirect with System Information* (used in association with CSFB).

ANR also includes functionality for dealing with problematic cells which is useful in this scenario:

Detection of Problematic Cells: provides the possibility to detect and bar for mobility cell relations with low handover execution success rate.

ANR PCI Handling of Problematic Cells: provides the possibility to detect unknown neighboring cells with the same PCI by triggering extra CGI measurements. Additionally, for relations involved in a PCI conflict, an extra CGI measurement is used to select the correct cell for handover.

Refer to the feature summary for ANR for more details.

Parameter Recommendations

The parameters required to implement this strategy are provided in the following tables.

Table 7 – General ANR parameter recommendations

Parameter (MO)	Value	Comment
maxNoMeasReportsInact (UeMeasControl)	1 report (default value)	Maximum number of reports that any UE must provide for ANR-initiated periodical measurements.
cellRelHoAttRateThreshold (AnrFunction)	10 attempts	Controls creation of EUtranCellRelation MOs and conversion to candidates. Increasing this causes stricter requirements for relations to be created, and increases conversion of relations to candidate relations, which may be necessary if too many relations are being created.
removeNrelTime (AnrFunction)	7 days	The maximum time that a neighbor relation can fall short of the cellRelHoAttRateThreshold before MO is removed from the MOM. Reduce to 3 to remove unwanted neighbors more quickly and so reduce the burden on PCI planning.
removeNcellTime (AnrFunction)	1 day	The length of time that neighbor cells without any neighbor relations remain in the RBS.
removeNenbTime (AnrFunction)	1 day	The length of time that neighbor RBSs without any neighbor cells remain in the RBS. RBSs without any neighbor cells remain in the RBS.

Table 8 – Intra-Frequency ANR Parameter Recommendations

Parameter (MO)	Value	Comment
anrIntraFreqState (AnrFunctionEUtran)	1 (ACTIVATED)	Activate ANR for intra-frequency LTE.
anrMeasOn (EUtranFreqRelation)	true (default value)	Enable ANR measurements and ANR triggered CGI reading on this frequency relation. If false, ANR does not add relations on this frequency.
anrUesEUtraIntraFMax (AnrFunctionEUtran)	0	Set to zero to turn off ANR-initiated event-based intra-frequency measurements.
anrUesEUtraIntraFMin (AnrFunctionEUtran)	0	Set to zero to turn off ANR-initiated event-based intra-frequency measurements.

Table 9 – UTRAN ANR Parameter Recommendations

Parameter (MO)	Value	Comment
anrStateUtran (AnrFunctionUtran)	ACTIVATED	Activate ANR for UTRAN

Parameter (MO)	Value	Comment
anrMeasOn (UtranFreqRelation)	true	Enable ANR measurements and ANR triggered CGI reading on this frequency relation. If false, ANR does not add relations on this frequency.
anrUtranMeasReportMax (AnrFunctionUtran)	100 (10 reports/hr, default value)	Defines the maximum target number of periodical measurement reports per hour for each relation.
anrUtranMeasReportMin (AnrFunctionUtran)	5 (0.5 reports / hr, default value)	Defines the minimum target number of periodical measurement reports per hour for each relation.
anrUtranMeasReportDecr (AnrFunctionUtran)	1 (0.1 reports / hr, default value)	Defines the decrease in the target number of periodical measurement reports for each relation each time an Automated Neighbor Relations (ANR) UTRAN measurement report is received with only known neighbor cells.
anrUtranMeasReportIncr (AnrFunctionUtran)	10 (1 report / hr, default value)	Defines the increase in the target number of periodical measurement reports for each relation each time an Automated Neighbor Relations (ANR) UTRAN measurement report is received with unknown neighbor UTRAN cells.
anrUtranMeasReportAcIncr (AnrFunctionUtran)	20 (2 reports / hr, default value)	Defines the increase in the target number of periodical measurement reports for each relation each time a PCI measurement report is received with known cell but the corresponding LAC or RAC missing.
cellAddRscpThresholdUtranDelta (AnrFunctionUtran)	-1 (-1 dB, default value)	Added to b2Threshold2RscpUtra to determine the threshold for adding a UTRAN cell as a neighbor in response to ANR-initiated periodical reports.
cellAddEcnoThresholdUtranDelta (AnrFunctionUtran)	-10 (-1 dB, default value)	Added to b2Threshold2RscpUtra to determine the threshold for adding a UTRAN cell as a neighbor in response to ANR-initiated periodical reports.

Table 10 – GERAN ANR Parameter Recommendations

Parameter (MO)	Value	Comment
anrStateGsm (AnrFunctionGeran)	ACTIVATED	Activate ANR for GSM
anrMeasOn (GeranFreqGroupRelation)	true	Enable ANR measurements on this frequency group relation.
anrGeranMeasReportMax (AnrFunctionGeran)	100 (10 reports/hr, default value)	The maximum target number of measurement reports per hour for each relation.
anrGeranMeasReportMin (AnrFunctionGeran)	5 (0.5 reports/hr, default value)	The minimum target number of measurement reports per hour for each relation. Default value

Parameter (MO)	Value	Comment
anrGeranMeasReportDecr (AnrFunctionGeran)	1 (0.1 reports/hr, default value)	The decrease in the target number of measurement reports per relation each time an ANR GERAN measurement report is received with only known neighbor cells.
anrGeranMeasReportIncr (AnrFunctionGeran)	10 (1 report/hr, default value)	The increase in the target number of measurement reports per relation each time an ANR GERAN measurement report is received with unknown neighbor GERAN cells or an unknown cell is found in GERAN a mobility report.
anrGeranMeasReportRacIncr (AnrFunctionGeran)	20 (2 reports/hr, default value)	Defines the increase in the target number of measurement reports for each GeranFreqGroupRelation each time a PCI measurement report is received with known cell but the corresponding RAC missing.

Connected Mode – Carrier Aggregation

it is likely that Carrier Aggregation (CA) is deployed on some, or all, sites, to exploit the combined spectrum assets of the LLow and LHi carriers. With CA, the UE can use resources on more than one cell simultaneously, with one cell being designated the primary cell (PCell), and the other one or more cells being secondary cells (SCells). The mobility and traffic management features which are the focus of this document are responsible for the allocation of the PCell. The allocation SCell and the scheduling of data over the PCell and SCell(s) are managed by the CA features, and do not impact PCell mobility. For this reason, most of the concepts discussed in this document apply regardless of whether carrier aggregation is activated or not.

CA has a load balancing effect by allowing UEs to use resources on more than one carrier. However, this does not reduce the importance of good primary cell load management. Some aspects to consider are:

- In practice, only a relatively small fraction of user data ends up being scheduled on secondary cells. The fraction depends upon UE capability, multi-carrier configuration and coverage, and the intensity of user activity (how much is full buffer) but values of less than 10% are common. Given this low use of CA, the impact on load balancing is limited.

- CA does not schedule signaling transmissions (e.g. RRC signaling) on secondary cells, and so has no load balancing effect for this traffic.

- Standalone VoLTE doers not trigger activation of an SCell, due to the small data buffer size of QCI1 not meeting the minimum data threshold for SCell activation. If data bearers are used in parallel with VoLTE calls, an SCell can be activated. VoLTE is then scheduled on the carrier with best radio conditions; this could be the PCell or an SCell. Semi-persistent scheduling is only supported on the PCell.

- CA is less likely to be used when IFLB is working well. This is because UEs are more likely to be located on layer which can deliver the best throughput, and less likely to build up enough data in the DL buffer to trigger SCell activation.

- CA increases UE battery consumption because the UE is required to monitor the configured SCells; therefore, avoid the use of CA, and the activation of SCells in particular, if it does not bring a performance benefit.

The mobility strategy is responsible for the selection of the PCell, and therefore has an impact on the performance of CA, particularly when a large proportion of the UE population is CA capable. Some aspects to consider are:

- In the case of downlink only CA, it is the PCell which provides the uplink. A sufficient uplink quality is required to make full use of the potential aggregated downlink resources. This is particularly the case at cell edge, where the uplink throughput is limited by the maximum UE power capability. Which carrier has the stronger uplink depends on the network. In some cases, LLow may have a stronger uplink, due its lower pathloss and is therefore a better choice for the PCell. However, if LLow suffers significant uplink interference, either network or externally generated, LHi may be the better choice for the PCell.

- If the PCell is located on LHi then it is likely that a suitable SCell is always available on LLow (see UE1 in **Figure 20**). In this case the A1 measurements which are used to detect good SCell coverage can be disabled by setting `sCellSelectionMode = 1` (UN_ACK_SIMULTANEOUS_SCELL_SELECTION). This reduces RRC signaling and speeds up CA setup. However, if the PCell is located on LLow then a suitable SCell on LHi is not guaranteed, and A1 measurements should then be enabled (see UE2 in **Figure 20**) by setting `sCellSelectionMode = 0` (ACK_SEQUENTIAL_SCELL_SELECTION) or `2` (ACK_SIMULTANEOUS_SCELL_SELECTION).

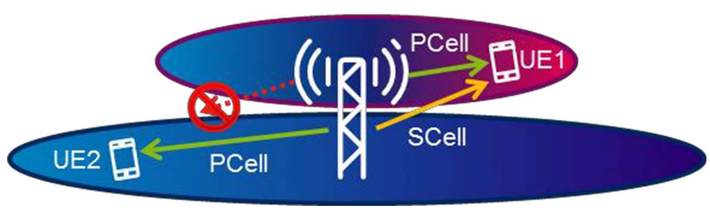


Figure 20 – Carrier Aggregation

CS Fallback scenario2

In this scenario, UEs not capable of VoLTE are provided with voice services via Circuit Switched Fallback (CSFB) to WCDMA. general information on the features available for CSFB and recommendations on their use. This section presents additional information relevant to this particular scenario.

To provide a contrast with the other scenarios, the features PSHO-Based CS Fallback to UTRAN and Measurement-Based CSFB Target Selection are not used in this scenario. Instead only the CS Fallback to GERAN and UTRAN feature is used, enabling CSFB via a blind release-with-redirect. As two potential target WCDMA frequencies with similar coverage are available, various configuration options are possible, . In this case both WCDMA carriers are configured as targets from both LTE carriers, and the eNodeB round-robin-releases UEs to the configured targets, distributing the load. This is achieved by setting csFallbackPrio = 6 on all frequency relations from LTE to WCDMA.

The feature *Release with Redirect to LTE* is used to speed the return of UEs from WCDMA to LTE after CSFB. The UMTS release-with-redirect message can include several targets, and their priority is set by the parameter `redirectionOrder`, with lower values being listed first in the RRC Connection Release message. The UE prioritizes based on the order. In this scenario, LHi is prioritized over LLow by giving it a lower `redirectionOrder`). This is consistent with the idle mode reselection priorities. Note, however, that standards do not mandate that the UE follows the `redirectionOrder` priority.

Figure 21 – CSFB Settings

the feature *Redirect with System Information* is used to reduce the call setup time associated with CSFB. It does this by providing the UE with system information for a limited number of potential target WCDMA cells, allowing the UE to connect more quickly when it arrives in the target network. The `coverageIndicator` parameter is used to prioritize the co-sector cells on WCDMA for RIM associations.

Parameter Recommendations

The parameter recommendations for CSFB are as follows:

Table 18 – CSFB Parameter Recommendations

Parameter (MO)	Value	Comments
`csFallbackPrio` (`UtranFreqRelation`)	6	Same priority for all WCDMA frequencies on all LTE cells. Results in round robin allocation.
`mobilityActionCsfb` (`UtranFreqRelation`)	RELEASE_WITH_REDIRECT_NACC	Sets the preferred mechanism for CSFB to RELEASE_WITH_REDIRECT_NACC on both WCDMA and GSM.
`coverageIndicator` (`UtranCellRelation`, `GeranCellRelation`)	OVERLAP (co-sector cells) NONE (other cells)	Set to `OVERLAP` on co-sector WCDMA and GSM cells to prioritize those cells for RIM associations.

Parameter (MO)	Value	Comments
maxNoCellsNaccCsfb (ENodeBFunction)	4	Allow 4 cells for RIM associations

Automated Neighbor Relations

In this scenario, the feature Automated Neighbor Relations (ANR) is used to manage both intra-LTE and inter-RAT neighbor relations.

One of the key functions of managing neighbor relations is detecting unknown cells. To detect unknown cells, ANR can potentially use UE measurements of three types: mobility-initiated event-based measurements, ANR-initiated event-based measurements and ANR-initiated periodic measurements. As a general principle, measurements should be minimized. With this in mind, the recommendations for this scenario are:

Mobility-Initiated Event-Based Measurements

Intra-frequency LTE: Because MCPC is enabled in this scenario, ANR can use mobility-initiated intra-frequency A3 measurements for the discovery of unknown LTE cells throughout the entire cell area, even when the reports occur in poor coverage (i.e. A2 has been triggered). These mobility-initiated measurements are sufficient for intra-frequency ANR, and no additional ANR-initiated measurements are required.

Inter-frequency LTE: As with intra-frequency measurements, MCPC enables ANR to use mobility-initiated, inter-frequency A5 measurements in the search zone for the discovery of unknown LTE cells. These are sufficient to discover unknown cells for the purposes of coverage-triggered mobility. In a similar way, the measurements initiated by IFLB and BNR can be used to discover unknown cells for the purposes of inter-frequency load balancing. No additional ANR-initiated inter-frequency measurements are required.

WCDMA: Since mobility-initiated B2 reports on WCDMA cannot contain unknown cells, these measurements are of no use to ANR for discovering unknown cells. ANR-initiated measurements must be used instead.

ANR-Initiated Event-Based Measurements

Intra-frequency LTE: Because mobility-initiated measurements can be used to discover intra-frequency LTE cells, these measurements are not required and are disabled in this scenario.

Inter-frequency LTE: Because mobility-initiated measurements can be used to discover inter-frequency LTE cells, these measurements are not required and are disabled in this scenario.

ANR-Initiated Periodic Measurements

WCDMA: These measurements are enabled to discover unknown WCDMA cells, because mobility-initiated measurements cannot be used for this purpose.

CS Fallback scenario 3

In this scenario, UEs not capable of VoLTE are provided with voice services via Circuit Switched Fallback (CSFB) to WCDMA. general information on the features available for CSFB and recommendations on their use. This section presents additional information relevant to this particular scenario.

To provide a contrast with the other scenarios, in this scenario CSFB is configured with the following features activated:

- *CS Fallback to GERAN and UTRAN*
- *PSHO-Based CS Fallback to UTRAN*
- *Measurement-Based CSFB Target Selection*

This provides CSFB with faster voice call setup time and lower interruption time for PS services, assuming that the feature *SRB on HSDPA* is active in the target WCDMA network. To spread the load between the two WCDMA carriers, and to provide an alternate target in case the measured frequency is not found, the priorities are configured as shown in **Figure 22**. Setting different priority levels for WLow1 and WLow2 ensures only one frequency is measured for CSFB (the one with the highest `csFallbackPrio`, unless the UE does not support measurements on that frequency). If a suitable cell is not found then a release-with-redirect occurs to the frequency with the highest `altCsfbTargetPrio`.

Figure 22 – CS Fallback Priority Settings for Scenario 3

To ensure that the UTRAN neighbor relations required for the PSHO-based CSFB are defined, ANR is configured with periodic UTRAN measurements to detect unknown WCDMA cells and create UTRAN cell relations.

Mobility Control at Poor Coverage

Mobility Control at Poor Coverage (MCPC) builds on the legacy Session Continuity features to provide more control over mobility when poor coverage is encountered. The impacts when MCPC is enabled are discussed. The remainder of this section with focus on the functionality of MCPC itself.

MCPC improves control by dividing the cell into concentric zones, in which progressively more actions are taken to find good coverage. The zones are: good coverage, search zone (optionally further divided into inner and outer search zones) and critical coverage. Transition between the zones is triggered by A2 and A1 measurement reports configured in the UE. Measurements can be configured based on RSRP, RSRQ or both.

When in the search zone(s), the UE searches for good enough coverage from other frequencies, potentially both inter-frequency LTE (using A3 or A5 measurements) and other RATs (using B2 measurements). If the search zone is divided into inner and outer, then the UE searches for only high priority frequencies in the inner search zone, and both high and low priority frequencies in the outer search zone. If a valid target is reported, handover or release-with-redirect occurs. In critical coverage, blind handover or release- with-redirect occurs, potentially to a different frequency from those previously searched. Without this feature, a combination of blind and measurement-based release to different targets is not possible. The release-with-redirect actions can be inhibited if a QCI1 bearer is in use, in which case the UE continues searching for other frequencies.

Figure 23 shows the case where inner and outer search zones are configured.

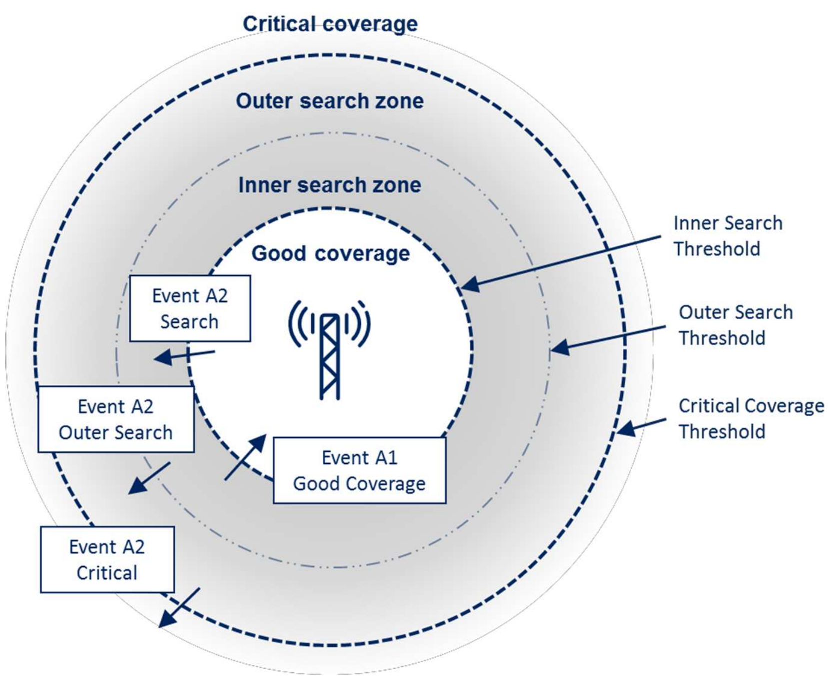


Figure 23 – Mobility Control at Poor Coverage, with Inner and Outer Search Zones

Transitions between the zones are triggered by measurement reports configured in the UE. The measurements can be based on RSRP, RSRQ or both, as determined by `inhibitA2SearchConfig` which can be set to `0` (`NOT_INHIBIT`), `1` (`INHIBIT_A2SEARCH_RSRQ`) or `2` (`INHIBIT_A2SEARCH_RSRP`). When both RSRP and RSRQ are configured, they act independently.

For example, the UE could be in the inner search zone for RSRP and the outer search zone for RSRQ. In this case the UE is configured with all of the following measurements:

- **Event A1 Good Coverage** (RSRP) - to detect good coverage from serving cell
- **Event A1 Good Coverage** (RSRQ) - to detect good coverage from serving cell
- **Event A2 Outer Search** (RSRP) - to detect the outer search in serving cell
- **Event A2 Critical** (RSRQ) - to detect critical coverage in serving cell
- **Event A3/A5/B2 Target Good Enough** (RSRP) - to detect good enough coverage from valid high priority targets on other frequencies or RATs
- **Event A3/A5/B2 Target Good Enough** (RSRQ) - to detect good coverage from valid targets, both high and low priority on other frequencies or RATs
- **Event A3** (RSRP) - to trigger intra-frequency handover

The above behavior is illustrated in a simplified form in **Figure 24**. Assuming that the UE has entered the search zone at t = 0, the subsequent actions are displayed, depending on the RSRP and/or RSRQ.

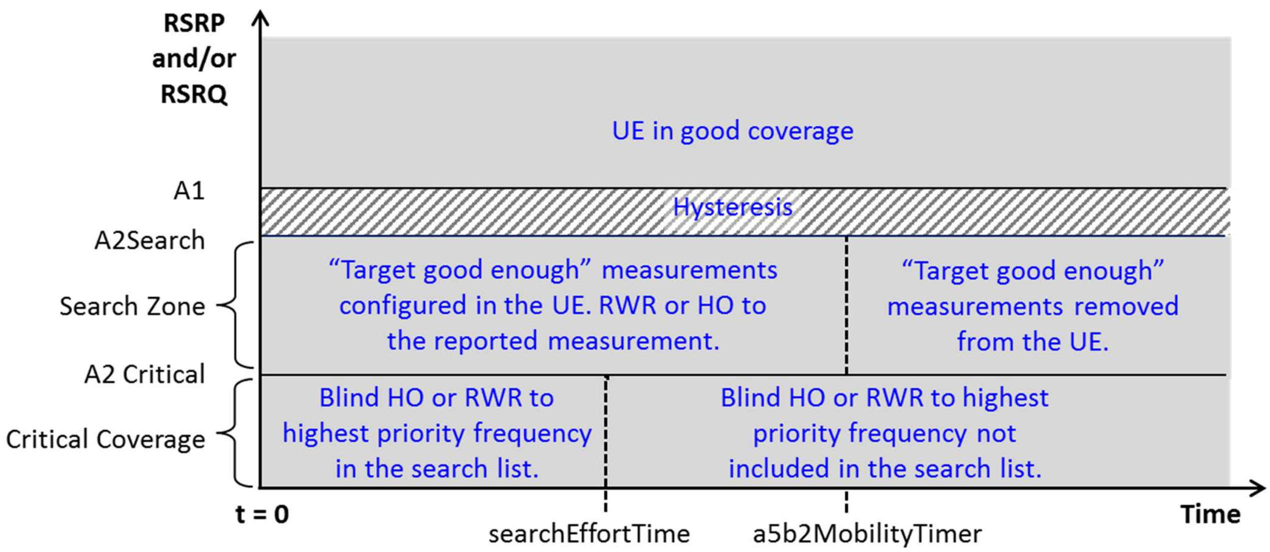


Figure 24 – Timer Behavior with MCPC

Coverage Fallback Strategies

In a multi-layer network, designing a coverage fallback strategy with MCPC involves choosing how to configure both handover and the critical coverage action. **Figure 25** presents three cases, and the following notes describe the recommendation in each case.

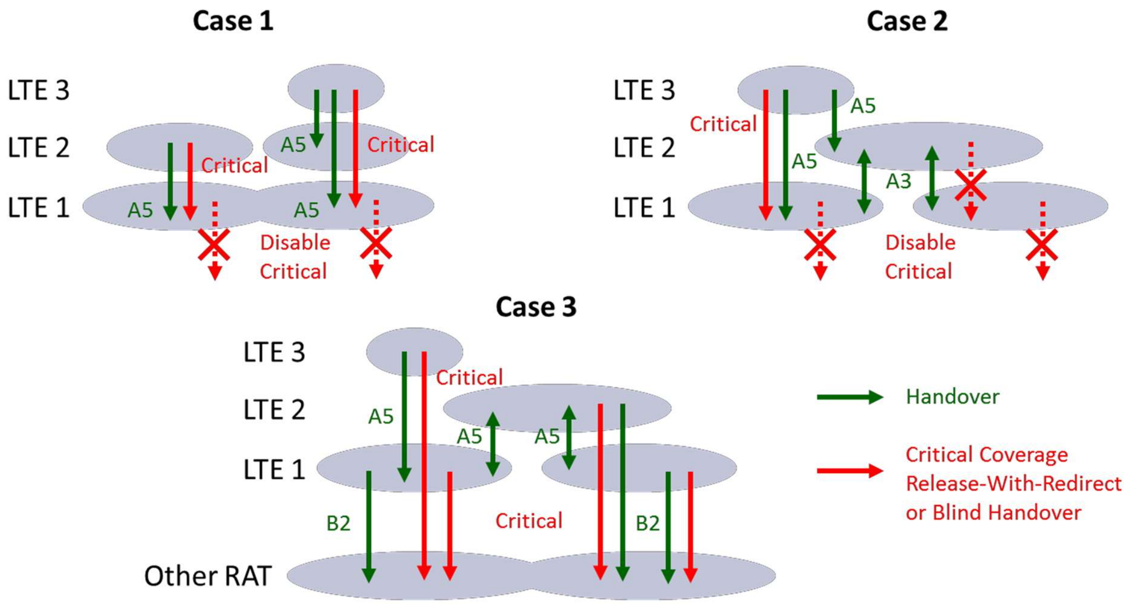


Figure 25 – Critical coverage strategy examples

<u>Case 1 – LTE Only, Definite Best Coverage Layer</u>

In this case there is no other RAT and there is a definite "best coverage" LTE layer, namely LTE 1. From LTE 3 and LTE 2, configure handover to LTE 1. Using Event A5 for this handover has multiple benefits, as described in "Section 2.4.3 - Event A3 versus Event A5 for Inter-Frequency Handover". From LTE 3 and LTE 2 configure the critical coverage target to be LTE 1. On LTE 1, however, disable the critical coverage action by setting the `a1a2SearchThresholdRsrp` to -140 dBm. This prevents an RWR occurring to an LTE layer with worse coverage.

Case 2 – LTE Only, No Definite Best Coverage Layer

In this case there is no other RAT and also no definite “best coverage” layer on LTE. Either LTE 1 or LTE 2 may provide the best LTE coverage. In this case use Event A3 for handover between LTE 1 and LTE 2. Unlike Event A5, this allows the UE to handover to the best available coverage even when the signal strength is very low. Disable the critical coverage action on both LTE 1 and LTE 2 by setting the `a1a2SearchThresholdRsrp` to
-140 dBm. This prevents an RWR occurring to an LTE layer with potentially worse coverage.

Case 3 – LTE with Other RAT with Better Coverage

In this case there is another RAT with better coverage but there is, once again, no definite “best coverage” LTE layer. Use Event A5 for handover between the two “best coverage” layers. This ensures that inter-frequency handover only occurs when the LTE target is above an absolute threshold, set to ensure reasonable performance and prevent ping pong handover. Below this level it is preferable to fall back to the other RAT via a handover or a critical coverage RWR if necessary. Configure B2 handover to the other RAT above the critical coverage release.

Implementing Mobility Control at Poor Coverage

This section explains the benefits of *Mobility Control at Poor Coverage* (MCPC), how it impacts mobility behavior and how to control the impacts. The term “legacy mobility” is used to refer to the case where MCPC is not enabled (but the relevant session continuity and handover features are enabled).

The main benefits of MCPC are:

- Improved flexibility for defining the radio conditions which constitute poor coverage
- Increased control of the potential targets to be searched when poor coverage is entered or RWR targets if critical coverage is encountered
- Improved measurement handling in ANR

The evolution from legacy mobility to MCPC impacts the following areas:

- Detection of poor coverage (A1 and A2)
- Trigger quantity for A3, A5 and B2 measurements (RSRP or RSRQ)
- Trigger times for A3, A5 and B2 measurements
- Activation of inter-frequency and inter-RAT measurements

- Selection of target frequencies and RATs for target good enough search
- Critical coverage and the a5B2MobilityTimer
- Offsets for service-triggered mobility
- *Automated Neighbor Relations* (ANR) functionality

Detection of Poor Coverage (A1 and A2)

With legacy mobility, Events A1 and A2 are configured using two sets of triggers, primary and secondary. There is no inherent difference between the primary and secondary triggers; they run in parallel and use the same evaluation process. By default the trigger types are RSRP for primary and RSRQ for secondary, but his can be changed and they can even be set the same. If RSRP is chosen for a particular trigger, then the RSRQ threshold for that trigger is ignored, and vice versa. The end result is just two A2 triggers: two RSRP, or two RSRQ, or one of each. The trigger types for A1 follow those selected for A2. The relevant MOs and parameters are shown in **Table 12**.

Table 12 – MOs and Triggers for Events A1 and A2 with Legacy Mobility

MO	Parameter

`ReportConfigEUtraBadCovPrim`	`a2ThresholdRsrpPrim`
	`a2ThresholdRsrqPrim`
	`hysteresisA2Prim`
	`timeToTriggerA2Prim`
	`triggerQuantityA2Prim`

`ReportConfigEUtraBadCovSec`	`a2ThresholdRsrpSec`
	`a2ThresholdRsrqSec`
	`hysteresisA2Sec`

`ReportConfigA1Prim`	`a1ThresholdRsrpPrim`
	`a1ThresholdRsrqPrim`
	`hysteresisA1Prim`
	`timeToTriggerA1Prim`

`ReportConfigA1Sec`	`a1ThresholdRsrpSec`
	`a1ThresholdRsrqSec`
	`hysteresisA1Sec`
	`timeToTriggerA1Sec`

MCPC replaces these parameters with a new set defined in the MO ReportConfigSearch, as shown in **Table 13**. These parameters effectively create up to six A2 triggers, being: inner search zone RSRP and RSRQ, outer search zone RSRP and RSRQ and critical coverage RSRP and RSRQ. These six triggers are set by the first six parameters in Table
38., the RSRP and RSRQ triggers run in parallel and are independent of each other. Although there are up to six triggers for A2, there are only two

triggers for A1 and they are used to detect the return from the search zone into good coverage. They are set by applying the hysteresis to the a1a2 thresholds.

Table 13 – MOs and Triggers for Events A1 and A2 with MCPC

MO	Parameter
ReportConfigSearch	a1a2SearchThresholdRsrp a1a2SearchThresholdRsrq a2OuterSearchThrRsrpOffset a2OuterSearchThrRsrqOffset a2CriticalThresholdRsrp a2CriticalThresholdRsrq hysteresisA1A2SearchRsrp hysteresisA1A2SearchRsrq hysteresisA2CriticalRsrp timeToTriggerA1Search timeToTriggerA2Critical timeToTriggerA2OutSearch timeToTriggerA2OutSearchRsrq timeToTriggerA2Search timeToTriggerA2SearchRsrq

When MCPC is enabled, the legacy behaviour cannot be maintained exactly. One reason is that in the legacy case the final release-with-redirect is triggered by expiry of the a5B2MobilityTimer, whereas with MCPC it is triggered by the RSRP or RSRQ falling below the critical thresholds. Enabling MCPC therefore involves deciding how to map the two legacy A2 thresholds into the search and critical thresholds used by MCPC. One option is to set the MCPC search entry and exit points at the legacy A2 and A1 levels respectively, and then set the critical thresholds a few dB below those levels, with the outer search zone remaining unused. This is achieved as follows (assuming that the legacy primary and secondary triggers are RSRP and RSRQ respectively):

- Set a1a2SearchThresholdRsrp equal to the average of the primary A1 and A2 RSRP levels:
- a1a2SearchThresholdRsrp =
  ```
  ((a2ThresholdRsrpPrim - hysteresisA2Prim/10) +
   (a1ThresholdRsrpPrim + hysteresisA1Prim/10))/2
  ```
- Set a1a2SearchThresholdRsrq equal to the average of the secondary A1 and A2 RSRQ levels:
- a1a2SearchThresholdRsrq =
  ```
  ((a2ThresholdRsrqSec - hysteresisA2Sec/10) +
   (a1ThresholdRsrqSec + hysteresisA1Sec/10))/2
  ```
- Set hysteresisA1A2SearchRsrp equal to half the distance between the primary A1 and A2 levels:

- `hysteresisA1A2SearchRsrp =`
```
        ((a1ThresholdRsrpPrim*10 + hysteresisA1Prim) -
         (a2ThresholdRsrpPrim*10 - hysteresisA2Prim))/2
```

- Set `hysteresisA1A2SearchRsrq` equal to half the distance between the secondary A1 and A2 levels:

- `hysteresisA1A2SearchRsrq =`
```
        ((a1ThresholdRsrqSec*10 + hysteresisA1Sec) -
         (a2ThresholdRsrqSec*10 - hysteresisA2Sec))/2
```

- Set `a2CriticalThresholdRsrp` 3 dB below the A2 search level (noting that a further 1 dB is added by `hysteresisA2CriticalRsrp`, giving a total of 4 dB)

- `a2CriticalThresholdRsrp =`
```
        a1a2SearchThresholdRsrp -
        hysteresisA1A2SearchRsrp/10 - 3
```

- Set `a2CriticalThresholdRsrq` 2 dB below the A2 search level (noting that a further 1 dB is added by `hysteresisA2CriticalRsrq`, giving a total of 3 dB)

- Set `hysteresisA2CriticalRsrq = 10` (1 dB)

- Set `timeToTriggerA1Search = timeToTriggerA1Prim`

- Set `timeToTriggerA1SearchRsrq = timeToTriggerA1Sec`

- Set `timeToTriggerA2Search = timeToTriggerA2Prim`

- Set `timeToTriggerA2SearchRsrq = timeToTriggerA2Sec`

- Set `timeToTriggerA2Critical = timeToTriggerA2Prim`

- Set `timeToTriggerA2CriticalRsrq = timeToTriggerA2Sec`

If the above formulas result in a non-allowed value, then choose the closest allowed value. This is just one example of how to map the parameters. An alternative is to set the MCPC critical thresholds at the legacy A2 levels, and to set the search levels a few dB above them. Similar formulas are used to map the values.

Finally, note that the parameters `filterCoefficientEUtraRsrp`, `filterCoefficientEUtraRsrq`, and `sMeasure` still apply with MCPC.

Trigger Quantity for A3, A5 and B2 Measurements (RSRP or RSRQ)

With legacy mobility, the trigger quantities used by A3, A5 and B2 for LTE measurements are determined by the parameters in **Table 14**.

Table 14 – Trigger Quantities with Legacy Mobility

MO	Parameter	Values
`ReportConfigA5`	`triggerQuantityA5`	`RSRP, RSRQ`
`ReportConfigEUtraIFBestCell`	`triggerQuantityA3`	`RSRP, RSRQ`
`ReportConfigB2Utra`	`triggerQuantityB2*`	`RSRP, RSRQ`
`ReportConfigB2Geran`	`triggerQuantityB2*`	`RSRP, RSRQ`

* Applies to B2 Threshold 1 only.

Note that these triggering quantities are statically configured to either RSRP or RSRQ. They therefore do not necessarily match the A2 triggering quantity, which can be configured for both RSRP and RSRQ. For example, if A2 is triggered by RSRQ but A5 is statically configured to RSRP, then the UE may be asked to measure when it has no chance of satisfying the A5 Threshold 1, because the serving RSRP is not low enough. This is a problem when trying to use both RSRP and RSRQ triggers in legacy mobility.

This problem is solved by MCPC, where the trigger quantity for A3, A5 and B2 measurements matches the preceding A2 trigger quantity; RSRP upon entering the RSRP search zone, and RSRQ upon entering the RSRQ search zone. The trigger quantities shown in **Table 14** are ignored when MCPC is enabledOffsets for RSRQ Measurements

MCPC introduces the following additional offset and hysteresis parameters, which are never used by legacy mobility. Details of how these offsets are applied are provided in Section 5. To match legacy behavior, leave these parameters set at their default value of zero.

Table 15 – A3, A5 and B2 RSRQ Offset and Hysteresis Parameters for MCPC

MO	Parameter
`ReportConfigEUtraIFBestCell`	`a3RsrqOffset`
`ReportConfigEUtraIFBestCell`	`hysteresisA3RsrqOffset`
`ReportConfigA5`	`hysteresisA5RsrqOffset`
`ReportConfigB2Utra`	`hysteresisB2RsrqOffset`
`ReportConfigB2Geran`	`hysteresisB2RsrqOffset`

Minimization of Drive Tests

The *Minimization Of Drive Tests* feature (MDT) provides a simpler, cheaper, and remote method to use for troubleshooting or verification of the radio network, instead of using traditional drive tests. The feature provides a tool to optimize network planning with the Minimization Of Drive Tests measurement data including location information. The feature can configure an M1 RSRP and RSRQ measurement in the UE. The report can contain detailed location information optionally if available in the UE.

MDT can be used to survey a frequency without also enabling idle or connected mode mobility to that frequency; for example, when benchmarking a competitor's network.

- To enable MDT measurements on a frequency, set `EUtranFreqRelation.mdtMeasOn` = `true`.

- To prevent a frequency from being used for idle mode cell reselection and *Load Based Distribution at Release* set `cellReselectionPriority` to -1 in the relevant frequency relation. This prevents the frequency from being broadcast in SIB5 and from being included in the IMMCI messages used by LBDAR

- To prevent a frequency being used for connected mode, coverage-triggered mobility set `connectedModeMobilityPrio` and `voicePrio` to -1.

- To prevent a frequency being used for connected mode, load-triggered mobility (by IFLB) set `eutranFreqToQciProfileRelation.lbQciProfileHandling` to 1 (FORBIDDEN) on the QCI values used for MBB (e.g. QCI 9) and VoLTE (QCI 1).

- To disable ANR measurements on a frequency, set `EUtranFreqRelation.anrMeasOn` = `false`.

Best Neighbor Relations for WCDMA IRAT Offload

The purpose of the feature is to automatically and dynamically configure the suitable cell relations for WCDMA IRAT offload. It is used in combination with Inter-RAT Offload to WCDMA to identify the suitable WCDMA target load balancing relations to be used for WCDMA IRAT Offload.

Automatic configuration is crucial in network deployments with several frequency layers and different cell grids. It reduces the need for manual configuration of load management relations.

Dynamic configuration of load management relations improves load management efficiency. By considering suitable targets and removing unsuitable targets, the load balancing relation list is optimized and is used to determine the amount of traffic load that must be handed over to each target cell. Additional unsuitable target cells in the list reduce the chance of utilizing the suitable targets and can also increase the number of unnecessary UE measurements.

Release Inactive UE at High Load Handover

This licensed feature improves performance in high load networks by allowing inactive UEs to be released with a redirect rather than performing an intra or inter-frequency handover. This improves accessibility in high load networks and reduces inter-cell interference at cell borders, particularly in handover-intense areas.

A release-with-redirect is performed rather than a handover when:

- The MP load level exceeds `releaseInactiveUesMpLoadLevel`
- All UE bearers are inactive, and have been so for `releaseInactiveUesInactTime`

UTRAN Features

This section covers features which are implemented in UTRAN nodes, but are relevant to inter-RAT mobility with LTE. In addition to the feature summaries presented here, more information can be found in WCDMA CPI Inter-Radio Access Technology.

GERAN Features

This section covers features which are implemented in GERAN nodes, but are relevant to inter-RAT mobility with LTE.

Fast Return to LTE After Call Release

In areas with both LTE and GSM coverage, the CS Fallback procedure can be used to enable CS calls for LTE users by moving them to GSM where the CS call is established.

When Fast Return to LTE after Call Release is active, the GSM network sends a list of LTE cells or frequencies to the mobile at call release in GSM. Using this list the mobile selects a LTE cell that it connects directly to after the call is released. The

RA update procedure in GSM is thereby avoided and the user can quickly resume data services in LTE. The list is included in the Information Element “Cell selection indicator after release of all TCH and SDCCH”, which has been added to the 3GPP standards for this purpose.

Without this feature, the normal procedure is that the user stays in GSM after the CS call has been released and perform normal idle-mode mobility. Typically, the mobile, after a while, also measures LTE quality and decides to perform cell re-selection to LTE. However, this is a process that may take in the order of 10-15 seconds, during which the mobile use GPRS/EDGE connectivity for the data services. Once LTE is selected, data buffers are discarded in GSM, leading to TCP timeout which cause additional delay to the data services.

GSM-LTE Cell Reselection

GSM-LTE Cell Reselection covers cell reselection in idle and packet transfer modes without the network taking part in the decisions of which cells to select. The GSM network broadcasts system information and defines neighbor lists needed for cell reselection. The feature enables LTE capable terminals to detect LTE access and perform a cell reselection to LTE.

With this feature it is possible to set priority between GSM, WCDMA and LTE cells. The operator can configure which system terminals prefer in different areas.

The estimated application level outage during the GSM to LTE cell reselection is approximately six seconds including effects from TCP slow start and radio bearer establishment.

Note that users engaged in a CS call do not move to LTE since it is BSS that is then in control and the normal CS mobility is applied.

Thank you