ERICSSON

Inter-Frequency Load Balancing

Feature Description

83/221 04-LZA 701 6014/1 Uen AJ4B

Contents

1 Inter-Frequency Load Balancing Overview

Access Type:	LTE
Feature Identity:	FAJ 121 3009
Value Package Name:	Multi-carrier Load Management
Value Package Identity:	FAJ 801 0427
Node Type:	Baseband Radio Node DU Radio Node
Licensing:	Licensed feature. One license required per node.

Summary

The purpose of inter-frequency load balancing is to manage uneven distribution of traffic load between different carrier frequencies. It enables efficient use of network resources on multiple carrier frequencies, and achieves similar user experience independent of the carrier in use. Load balancing is achieved by User Equipment (UE) in connected mode is relocated to carriers that are underused in comparison with the carrier in use.

The feature introduces a method to assess traffic load. The method is based on the presence of E-RABs in the cell and the QoS class to which they belong.

The Inter-Frequency Load Balancing feature is realized as a network feature. Neighboring nodes cooperate and perform the traffic load adjustments, without a central node controlling those efforts.

The Inter-Frequency Load Balancing feature can be inter-mode (FDD and TDD) if the Intra-LTE Inter-Mode Handover feature is activated.

The Inter-Frequency Load Balancing feature supports the following:

— An arbitrary grade of coverage overlap between cells

— An arbitrary number of target cells on the same inter-frequency

— An arbitrary number of frequencies and frequency bands

— Load balancing between cells that are co-located and not co-located

— Load balancing between cells in the same and in separate nodes

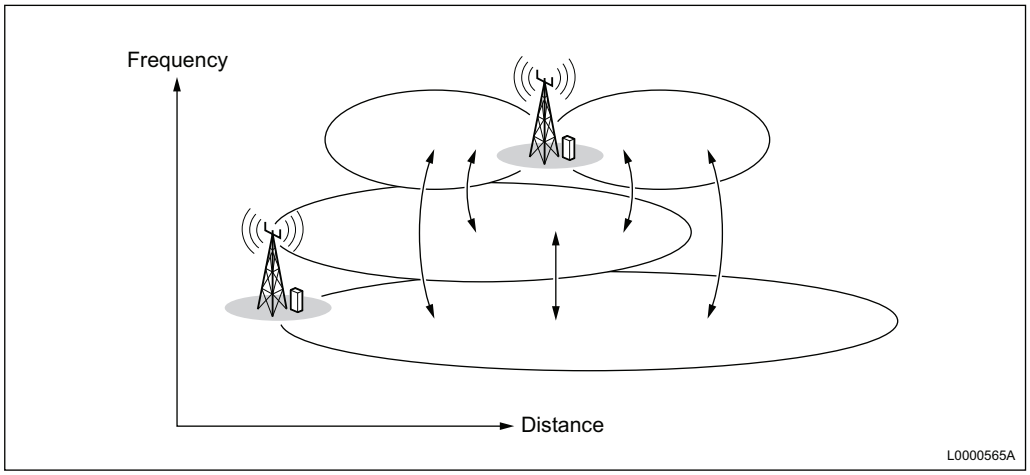


Figure 1 Traffic Moving Between Inter-Frequency Cells Covering a Common Geographical Area Due to Load Balancing

To support load balancing between cells in separate nodes, the feature requires an Ericsson node in both ends.

The feature provides the following benefits:

— Distributes radio traffic load between inter-frequency cells with overlapping coverage.

  For example, lower carrier frequencies can have better coverage and propagation characteristics and attract more traffic than higher frequencies. This can result in the underuse of high frequency carriers. The Inter-Frequency Load Balancing feature distributes radio use evenly over all carriers, which maximizes the availability of radio resources.

— Helps enhance the non-GBR end user experience.

— Reduces the risk of blocking and allows more UEs in an area where multiple carrier frequencies are used.

— Allows the average user throughput to increase linearly when adding new carrier frequencies or increasing the RF spectrum by other means.

— Enhances observability of the traffic load in network on a per cell basis, using subscription ratio.

Additional Information

More information about this feature and related topics can be found in the following documentation:

— *3GPP TS 36.300, Overall description; Stage 2*

— *3GPP TS 36.331, Radio Resource Control (RRC); Protocol Specification*

- *3GPP TS 36.423, X2 Application Protocol (X2AP)*
- Admission-Triggered Offload
- Automated Cell Capacity Estimation
- Best Neighbor Relations for Intra-LTE Load Management
- Best Neighbor Relations for WCDMA IRAT Offload
- Coverage-Adapted Load Management
- Coverage-Triggered Inter-Frequency Handover
- Coverage-Triggered Inter-Frequency Session Continuity
- Dynamic GBR Admission Control
- Idle Mode Support
- Inter-Frequency Offload
- Inter-RAT Offload to WCDMA
- Limited-Uplink-Aware IFLB
- Overlaid Cell Detection
- Radio Bearer Service
- Service Specific Load Management
- Service Triggered Mobility
- Shared LTE RAN
- Subscriber Triggered Mobility
- UE Throughput-Aware IFLB

2 Dependencies of Inter-Frequency Load Balancing

Features

Table 1 Feature Dependencies

Feature	Relationship	Description
Coverage-Triggered Inter-Frequency Handover (FAJ 121 0877)	Prerequisite	Coverage-Triggered Inter-Frequency Handover must be active prior to introducing the Inter-Frequency Load Balancing feature. Handover is triggered based on inter-frequency load balancing.
Admission-Triggered Offload (FAJ 121 3100)	Related	Provides control of the load created by GBR bearers in LTE cells. It offloads the User Equipments (UEs) to other LTE or WCDMA cells when the source cell's GBR usage exceeds the threshold.
Automated Cell Capacity Estimation (FAJ 121 3031)	Related	Provides the function to determine and configure cell downlink capacity automatically.
Automated Neighbor Relations (FAJ 121 0497)	Related	Activating the ANR Detection of Problematic Cells or ANR Whitelist PLMN IDs functionality prevents load balancing on cell relations which are barred for mobility.
Best Neighbor Relations for Intra-LTE Load Management (FAJ 121 3028)	Related	Provides the functions to find and evaluate suitable E-UTRAN relations for Inter-frequency load balancing or offload automatically.
Best Neighbor Relations for WCDMA IRAT Offload (FAJ 121 3065)	Related	Provides the functions to find and evaluate suitable WCDMA IRAT offload neighbor relations for WCDMA IRAT offload automatically.
Carrier Aggregation-Aware IFLB (FAJ 121 3075)	Related	Improves load balancing for CA-capable UEs by distributing them efficiently to cells where the carrier aggregation capability can be utilized in a better way.
Coverage-Adapted Load Management (FAJ 121 3077)	Related	This feature optimizes the load to be transferred to neighboring cells and also the amount of required UE measurements for load balancing purposes. It also allows large numbers of load balancing relations to be handled with better efficiency. This facilitates load balancing towards small cells.
Coverage-Triggered Inter-Frequency Session Continuity (FAJ 121 0797)	Related	Feature providing basic connected mode mobility between frequencies in the LTE network. When the feature is active, the UE can be directed to transfer between frequencies in the LTE network while maintaining the data session.
Dynamic GBR Admission Control (FAJ 121 1748)	Related	Dynamic GBR admission control is performed by monitoring the use of certain system resources, referred to as monitored system resources (MSR), and allowing the setting up of new GBR bearers only if the MSR use by GBR bearers does not exceed a configured threshold.
Idle Mode Support(part of LTE Basic)	Related	This feature is part of LTE Basic. In idle mode, the UE has no active connection to the RAN. The Idle Mode Support feature enables the UE in idle mode to access the network and be reached from the network within acceptable delay.
Inter-Frequency Offload (FAJ 121 3061)	Related	The purpose of this feature is to off-load traffic load above an off-load threshold from an E-UTRAN cell to an Ericsson or non-Ericsson E-UTRAN FDD or TDD cell. This feature uses the method introduced by Inter-frequency Load Balancing for the assessment of traffic load, based on the presence of E-RAB, in the cell and the QoS class to which they belong. This is an alternative feature to IFLB. The main difference to IFLB is that there is no load information exchange between the cells in Inter-Frequency Offload.
Inter-RAT Offload to WCDMA (FAJ 121 3048)	Related	This feature is realized as a network feature. Neighboring LTE and WCDMA cells cooperate and perform the traffic load adjustments, without a central node controlling those efforts. The feature uses the introduced method from Inter-frequency Load Balancing for the assessment of traffic load. Assessment is based on the presence of Evolved Radio Access Bearers (E-RAB) in the cell and the QoS class to which they belong.

Feature	Relationship	Description
Intra-LTE Inter-Mode Handover (FAJ 121 3042)	Related	This feature provides the possibility to initiate a handover from an LTE TDD/FDD cell to an LTE FDD/TDD cell. This is beneficial for operators that have an LTE network where TDD and FDD cells coexist in the LTE RAN.
Limited-Uplink-Aware IFLB (FAJ 121 4406)	Related	This feature adds the limited-uplink awareness to the load balancing to avoid moving UEs to a cell with uplink congestion during load balancing.
Multiple Frequency Band Indicators (FAJ 121 3054)	Related	Inter-Frequency Load Balancing is affected by the Multiple Frequency Band Indicators feature. For more information, see Multiple Frequency Band Indicators.
Overlaid Cell Detection (FAJ 121 3078)	Related	The Overlaid Cell Detection feature optimizes detection of small cells as load balancing relations for load balancing or offload by use of automatic and dynamic identification. This facilitates load management towards small cells and potentially enhances the load balancing performance of the Inter-Frequency Load Balancing.
Radio Bearer Service	Related	This feature is part of LTE Basic. The feature provides the service of establishment, maintenance and release of SRBs and DRBs.
Service Specific Load Management (FAJ 121 3047)	Related	Service Specific Load Management enhances control of the UE selection process for Inter-Frequency Load Balancing, Inter-RAT Offload to WCDMA and Inter-Frequency Offload.
Service Triggered Mobility (FAJ 121 1747)	Related	This feature enables coverage-triggered mobility based on the QoS defined for the UE bearers. The feature applies dynamic levels of coverage thresholds based on the QCI profiles of the bearers.
Shared LTE RAN (FAJ 121 0860)	Related	A core network operator provides its mobile phone services through a PLMN. Conventionally, a PLMN consists of an RAN and a core network, through which only one operator provides services to its subscribers. Subscribers of other operators can receive services as national or international roamers. With the Shared LTE RAN feature, up to six operators that is, with up to six PLMNs, can share an LTE RAN.
Subscriber Triggered Mobility (FAJ 121 1788)	Related	If the RFPM function of Subscriber Triggered Mobility is activated and the UE has a SPID value associated with it, the inter-frequency load balancing is inhibited for that UE. It is inhibited only when the `FreqPrioEUTRA.loadBalancingAllowed` attribute related to the concerned `RATFreqPrio` MO for the concerned target carrier frequency is set to `FALSE`.
TM9 4x2 Using MBSFN Subframes (FAJ 121 4864)	Related	Load balancing actions lead to higher ratio of TM9-capable UEs in cells with feature TM9 Using MBSFN-subframes enabled.
Load-Based Access Barring (FAJ 121 3093)	Conflicting	When Inter-Frequency Load Balancing is used together with automatic access class barring, the following applies. All inter-frequency load balancing processes are disabled in a cell where the access class barring calculation mechanism is triggered. The cell stops broadcasting its load status to other cells, and it is removed from the list of candidates for inter-frequency load balancing to avoid handover to an already overloaded cell.
PLMN-Specific Access Barring (FAJ 121 4916)	Conflicting	
Progressive Access Barring (FAJ 121 4746)	Conflicting	
Virtual Sectors (FAJ 121 4730)	Conflicting	There are differing compatibility issues between Inter-Frequency Load Balancing and Virtual Sectors in various cases, depending on which feature is activated earlier. Inter-Frequency Load Balancing cannot work between virtual sectors. However Inter-Frequency Load Balancing is still possible between a virtual sector and a normal sector.

Hardware

No special hardware requirement is expected for this feature.

Limitations

No limitations for this feature.

Network Requirements

The cell relations where load balancing is desired must be configured to allow load balancing actions and reporting, by setting attribute `EUtranCellRelation.loadBalancing`.

Load balancing between cells in different nodes requires an X2 connection between the nodes.

System Functions

Table 2 System Function Dependencies

Function	Description
Inter-frequency measurements	The number of inter-frequency measurements increases when the Inter-Frequency Load Balancing feature is activated. The increase depends on the number of inter-frequency handovers required to keep traffic load in balance.
Inter-frequency handover	The number of inter-frequency handovers increases when the Inter-Frequency Load Balancing feature is activated. The increase depends on the number of inter-frequency handovers required to keep traffic load in balance.
X2 signaling	X2 signaling is required for the exchange of traffic load information if the Inter-Frequency Load Balancing feature is applied between cells located on separate nodes.
Added E-RAB Establishment Success Rate	When the Inter-Frequency Load Balancing feature is activated, the accessibility success rate can slightly decrease for end-user services. This is carried by E-RABs included in the E-RAB setup procedure.

Hardware

No special hardware requirement is expected for this feature.

EPC Feature Dependencies

Packet Core Network-controlled RAN Load Balancing based on Mobility-Based Policy and RAN feature Inter-Frequency Load Balancing may have interoperability issues. This can cause unwanted behavior in the RAN or Packet Core Network, or both. See *Mobility-Based Policy* in the SGSN-MME CPI documentation for more information.

2.1 Compatibility of Load Balancing and Automatic Access Barring

During ongoing automatic access class barring calculation mechanism, inter-frequency load balancing for incoming handover is disabled in the cell.

When automatic access class barring is used together with Inter-Frequency Load Balancing, disabling inter-frequency load balancing is necessary to prevent incoming handover to an overloaded cell.

Subscription ratio measurements, hence inter-frequency load balancing are disabled in a cell when the automatic access class barring calculation mechanism is triggered.

Inter-frequency load balancing is enabled in the cell when the barring probability reaches 0.

Note: If the Preferential Traffic Management solution is enabled—by `ENodeBFunction.zzzTemporary56` being set to `0`—and the cell is configured as priority cell, triggering of the access class barring calculation mechanism does not disable subscription ratio evaluation, inter-frequency load balancing, and inter-frequency offload.

A cell is configured as priority cell, if any of the following is true:

- `PrefTrafficMgmt.atoAllowedFrom` = true
- `PrefTrafficMgmt.highLoadPlmnReservedEnabled` = true
- `PrefTrafficMgmt.sendStopIncomingIflbEnabled` = true
- `PrefTrafficMgmt.sendInhibitIMPrioritizationEnabled` = true

Example 1 Automatic Access Class Barring Disables Load Balancing

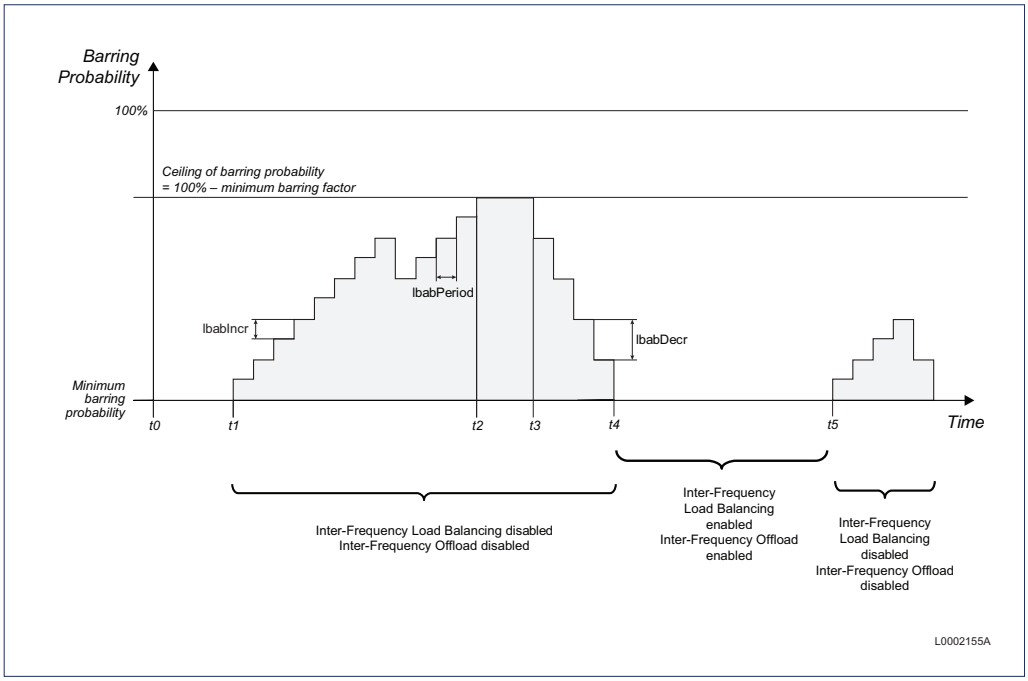


Figure 2 Inter-Frequency Load Management Disabled by Automatic Access Barring

Before t1, inter-frequency load balancing can be enabled.

At t1, these load balancing functions are disabled, and automatic access class barring calculation is enabled.

Between t1 and t4, until the automatic access class barring calculation is enabled, the load balancing functions remain to be disabled.

At t4, the barring probability reaches its minimum, value 0. Inter-frequency load balancing can be enabled again.

At t5, inter-frequency load balancing is disabled again.

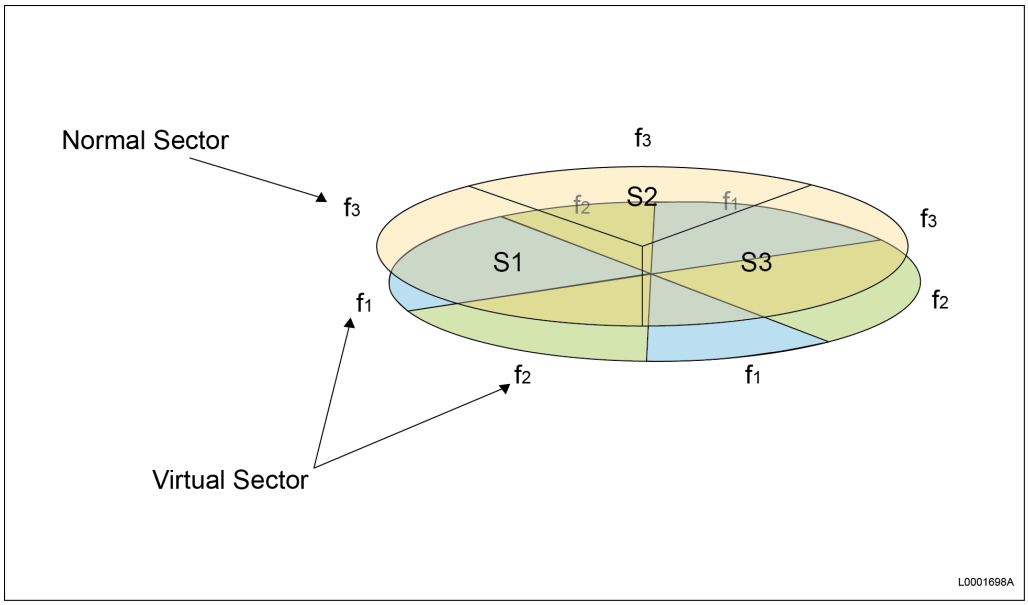
2.2 Compatibility of Inter-Frequency Load Balancing and Virtual Sectors

In the following cases there are compatibility issues between features Inter-Frequency Load Balancing and Virtual Sectors:

— When Inter-Frequency Load Balancing is activated after Virtual Sectors, the SCell candidate relations must be set to the overlapping virtual sectors.

— When Inter-Frequency Load Balancing is activated before Virtual Sectors, Inter-Frequency Load Balancing cannot work. However the Inter-Frequency Load Balancing configuration between these virtual sectors can be kept. Turn off the license for Virtual Sectors to use Inter-Frequency Load Balancing again.

— Inter-Frequency Load Balancing cannot work between virtual sectors. However Inter-Frequency Load Balancing is still possible between a virtual sector and a normal sector.



There are three carriers per radio. One carrier (f3) covers the full physical sector and the other two carriers (f1 and f2) cover the virtual sectors.

Figure 3 Compatible Configuration for Carrier Aggregation or Inter-Frequency Load Balancing

3 Inter-Frequency Load Balancing Operation

The Inter-Frequency Load Balancing feature is a continuous process that tries to balance the traffic load between carrier frequencies. Load balancing relations are configured between overlapping inter-frequency cells. The cells communicate information about traffic load and use it to regulate the load balancing algorithm. This allows the feature to operate autonomously in each cell without a central node. This is beneficial to the scalability of the feature.

Feature Operation Sequence Diagram

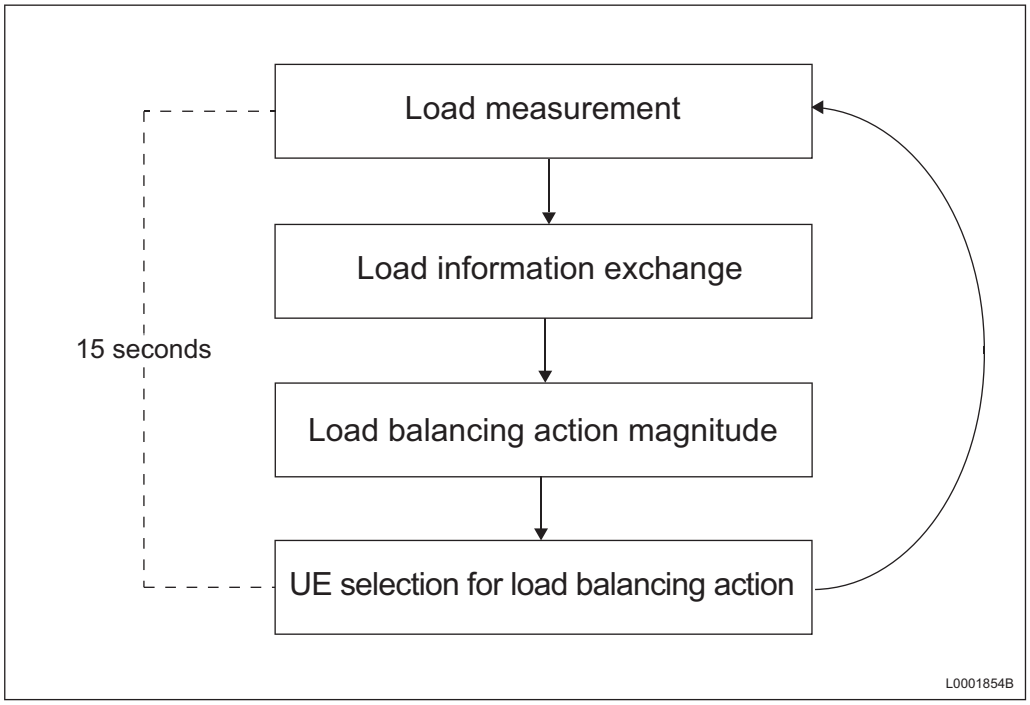


Figure 4 Load Balancing Operation

Process Steps

1. The traffic load in a cell is assessed repeatedly in certain intervals of a load balancing cycle.

   The current subscription ratio of the cell is calculated. The QCI subscription quanta values (`QciProfilePredefined.qciSubscriptionQuanta` and `QciProfileOperatorDefined.qciSubscriptionQuanta`) of all E-RABs (both GBR and non-GBR services) present in the cell are added. The sum is divided by the cell subscription capacity that is the value of `EUtranCellFDD.cellSubscriptionCapacity` or `EUtranCellTDD.cellSubscriptionCapacity` attributes.

The subscription ratio is input to the load information exchange and used to determine further load balancing actions in the cell.

2. Cell load information is exchanged between cells. Each cell can receive load reports from one or more other cells in the same node or in a remote node. The exchange of load information only takes place if load balancing is configured between the related cells.

   Load information exchange between cells in remote nodes is performed over X2 private messages, in an asynchronous process.

   Information exchange is only possible between Ericsson nodes.

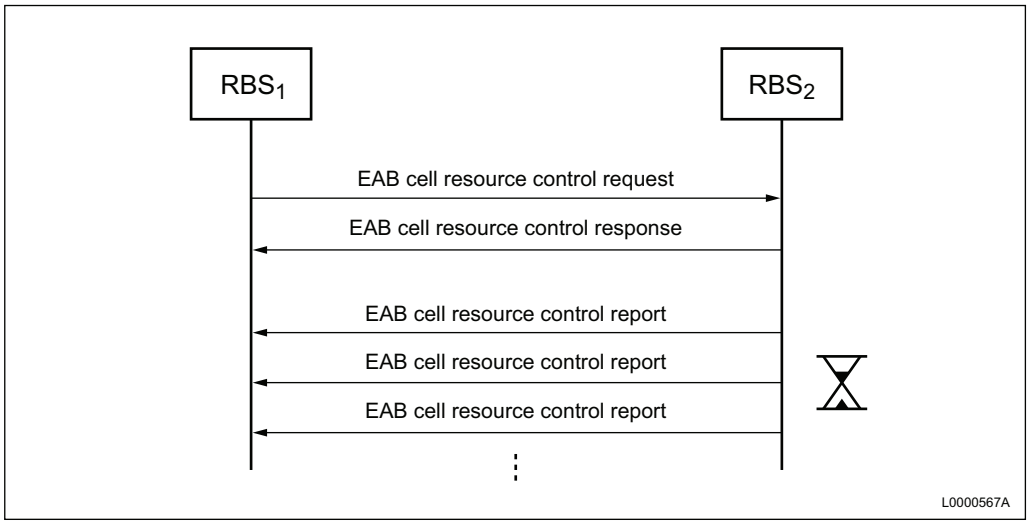


Figure 5 Load Information Exchange between Nodes

   The selection of target cells is controlled with parameter `EUtranCellRelation.loadBalancing`.

3. Based on the load information received from other cells, each source cell determines the traffic load that is to be handed over to each target cell to balance the load differences.

   This is done based on the following:

   - Load difference to each target cell
   - Minimum load difference to trigger load balancing action, set by `LoadBalancingFunction.lbThreshold`
   - Total offload from the source cell
   - Maximum load difference, `LoadBalancingFunction.lbCeiling`, taken into account in one round of load-balancing action

   If multiple target cells exist, the total offload is split between these cells.

Normally, load balancing targets equal subscription ratios in the source and target cells. However, when traffic is low, load balancing can allow rate offset. The rate offset is pronounced at very low subscription ratios and gradually decreases as traffic grows. The rate offset is removed at a subscription ratio of `LoadBalancingFunction.lbRateOffsetLoadThreshold` or higher, where load balancing targets equal subscription ratio.

4. UEs that are suitable for offload are selected.

   In the UE selection process, the UEs perform inter-frequency Event A5 measurements on the target frequency. This ensures that the UE has acceptable coverage in a target cell. Only those UEs are selected which support the target frequency band and trigger an Event A5 measurement report on the target cell.

   Note: Event A5 is also enables load balancing actions for UEs that are configured for Carrier Aggregation.

   There is a maximum allowed number of measurements started for load balancing purposes during a 15-second period of load balancing cycle. This number depend on the DU or Baseband hardware type and the number of cells.

   Table 3 Maximum Allowed Measurements Started

DU Type	Number of Cells	Maximum Allowed Number of Measurements
DUS 41	0-3	120
	4-6	60
	7-12	30

   Note: A UE in connected mode is selected to perform a measurement on a target frequency for load balancing purposes at most once for each load balancing cycle.

5. The execution of load balancing actions is performed by handover of the selected UEs to the target cells.

   The handover of UEs is performed using the following normal inter-frequency handover procedures:

   — X2 Handover Preparation

   — S1 Handover Preparation

   — RRC Connection Reconfiguration

   Handover to a target cell is inhibited in the following cases:

   — The `EUtranCellRelation.isHoAllowed` attribute for the target cell is set to `FALSE`.

— The cell is listed as forbidden in a HRL provided for the UE. For more information on the support of HRL, see Shared LTE RAN.

— The RFPM function of the Subscriber Triggered Mobility feature is used. The `FreqPrioEUTRA.loadBalancingAllowed` attribute related to the `RATFreqPrio` MO for the target carrier frequency is set to `FALSE` for matching UE SPID.

Note: If the Preferential Traffic Management solution is used, to inhibit inter-frequency offload for load balancing relations is inhibited. It can be achieved by setting the `EUtranCellRelation.loadBalancing` attribute to `IFO_AND_IFLB`, and the `FreqPrioEUTRA.offloadAllowed` attribute must also be set to `FALSE`.

Otherwise, if the `FreqPrioEUTRA.loadBalancingAllowed` attribute is set to `TRUE` or there is no matching UE SPID, load balancing to the target cell for the UE is allowed.

For more information on the support of SPID use, see Subscriber Triggered Mobility.

If the solution Preferential Traffic Management is enabled and appropriate configuration is set, the following applies:

Inter-frequency load balancing can be stopped for some cell relations—to priority cells with high traffic load from non-prioritized cells. This allows the priority band to be used primarily to serve prioritized users, and ensures access for prioritized UEs in high traffic load situations.

For more information, see Preferential Traffic Management Guidelines.

3.1 Load Balancing Cycle

The load balancing cycle is the time interval between two successive evaluations of traffic load balancing status. It is the time frame for the actions attempting to restore the traffic load balance.

Load balancing between cells is done repeatedly in successive load balancing cycles of 15 seconds.

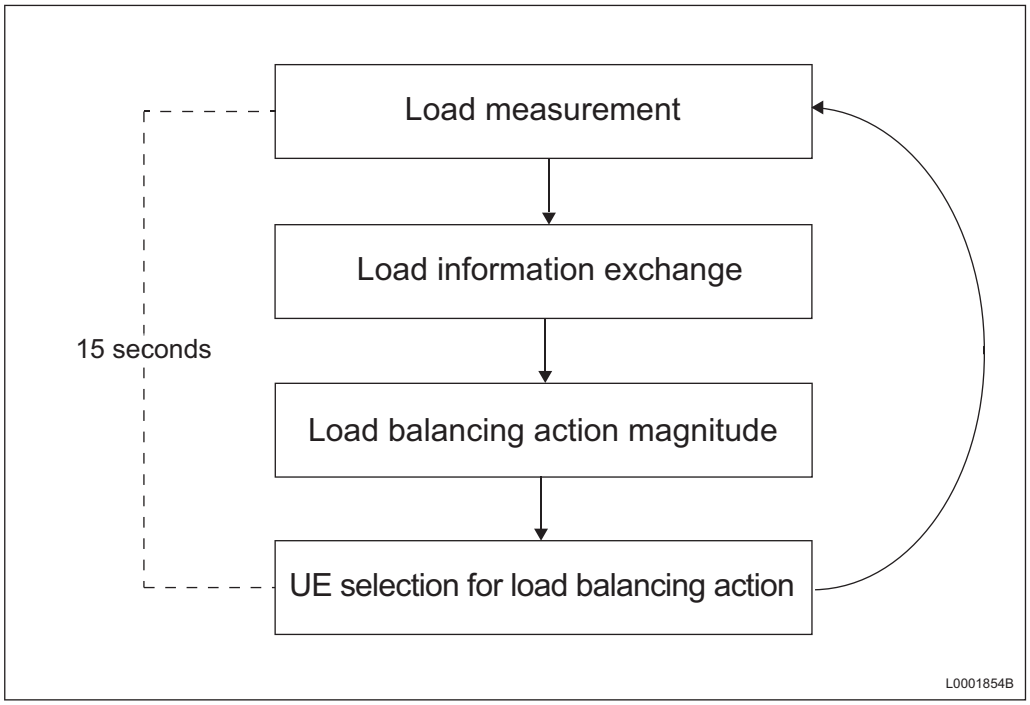


Figure 6 Load Balancing Cycle

Load Measurement

The load of each cell is estimated.

Load Information Exchange

Load information is exchanged between source and target cells.

For inter-eNodeB load exchange, X2 messages are used.

Load Balancing Action Magnitude

The amount of offloading required to manage load between cells is determined.

Higher loaded cells select some UEs as candidates for load balancing. The selected UEs are configured for Event A5 inter-frequency measurement.

UE Selection for Load Balancing Action

The UEs suitable for offload are selected. The suitable UEs are those that reported to the source cell that they detected sufficient coverage in a target cell.

Some suitable UEs are moved to detected target cells by inter-frequency handover.

3.2 Load Balancing Relation

The load balancing relation is the logical relation between a load balancing source and a target cell. Load balancing relations are controlled with the `EUtranCellRelation.loadBalancing` attribute.

For load balancing features to steer traffic from one source cell to a target cell, a relation must be defined in the source cell. This relation is defined to the target cell using the `EUtranCellRelation` MO. The `EUtranCellRelation.loadBalancing` attribute controls whether load balancing, or offload, or both are allowed.

Note: Each defined load balancing relation is unidirectional.

3.3 User Experience Dependency on Traffic Load

The influence of traffic load on the user experience is different for GBR services with guaranteed performance and non-GBR services of best effort type.

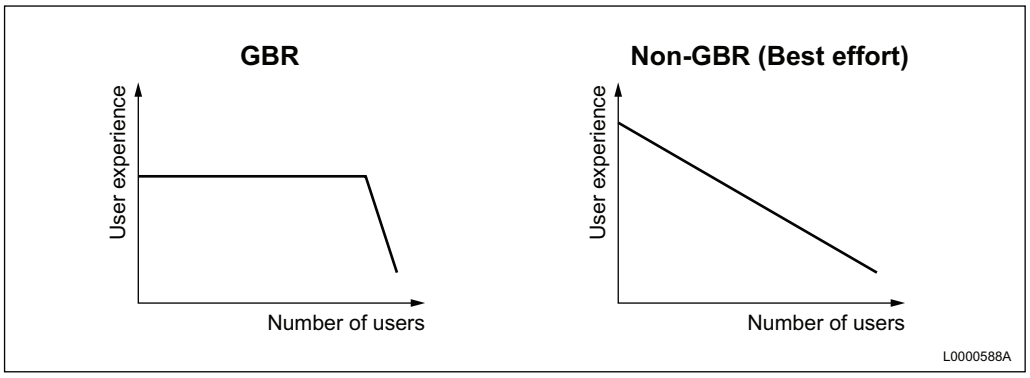


Figure 7 Influence of Number of Users on User Experience for GBR and Non-GBR Services

The user experience of a GBR service is essentially unaffected by an increase of traffic load. This is up to the point where LTE RAN is unable to grant additional users into the network. Above that point, LTE RAN may deny access and the user experience drops rapidly for users with difficulties to gain access.

The user experience of non-GBR services gradually decreases by an increase of traffic load. The grade of service is characterized by qualities like achievable bit rate and packet delay. The achievable bit rate for the individual user decreases and packet delay tends to increase. This is because shared transmission resources are used in LTE RAN with an increasing traffic load.

The LTE RAN provides both GBR and non-GBR services. Of the total transmission resource in the network a certain amount is employed to satisfy the GBR services. This reduces the resources available for non-GBR services. Therefore, the number of both GBR and non-GBR users affects the non-GBR user experience. The GBR

user experience, on the other hand, is to a high degree unaffected by the number of non-GBR users.

Note: Admission thresholds for GBR services may be used to ensure a minimum resource available for non-GBR services. For this, the Dynamic GBR Admission Control feature can be used.

3.4 GBR Traffic Load

GBR traffic is characterized by a relatively persistent E-RAB that generates a steady data stream. For example, an E-RAB for a voice call typically lasts for one or a few minutes. During the voice call, a stream of voice packets is transferred at a nearly constant rate.

Therefore, the number of E-RABs for GBR traffic present in a cell is a good basis for the assessment of the GBR traffic load.

3.5 Non-GBR Traffic Load

Non-GBR traffic is typically characterized by short but frequent data transactions. The individual data transactions can range from a few data packets to the transfer of large files. Many data transactions are completed within a short time, often less than a few seconds.

Non-GBR traffic has the following pattern:

1. The UE enters connected mode.
2. The E-RABs are established.
3. The data transaction, or a sequence of data transactions proceeds.
4. The UE is released after a period of inactivity.

This pattern is repeated, but each RRC connection and each E-RAB for the node is unique. The node is unable to correlate the different RRC connections generated by a UE.

Non-GBR traffic patterns are difficult to predict because they change often and quickly. The activity of an individual UE or E-RAB does not necessarily give much information about the activity a few seconds ahead. The number of E-RABs presented by the UEs to the LTE RAN can be used to assess the non-GBR traffic load generated by the UE groups. This applies for a UE group camped in a cell.

3.6 Subscription Ratio

Subscription ratio is a relative traffic load measure. It is the ratio between the total QCI subscription quanta of all E-RAB instances currently configured in a cell and the cell subscription capacity of the cell.

It takes a value between zero and one for an under-subscribed cell. Values greater than one indicate an over-subscribed cell.

$$SubscriptionRatio = \frac{\sum qciSubscriptionQuanta}{cellSubscriptionCapacity}$$

Figure 8 Subscription Ratio

The configuration of the following values has to obtain the required load balancing behavior:

— `qciSubscriptionQuanta` (in MOs `QciProfilePredefined` or `QciProfileOperatorDefined`)

— `cellSubscriptionCapacity` (in MOs `EUtranCellFDD` or `EUtranCellTDD`)

This enables load balancing between cells with different UE groups, and cells with different traffic capacities.

Configuration of the assessment model offers control of the load balancing objectives in LTE RAN and opportunity for further changes.

The subscription ratio can be used to monitor the traffic load in a cell.

3.7 Cell Subscription Capacity

Cell subscription capacity is the nominal traffic handling capacity of a cell. Its value is an estimate of the total amount of QCI subscription quanta values the cell is expected to accommodate at full system load. Cell subscription capacity defines the target for load balancing to divide the traffic load between overlaid cells within the network. It can be configured with one of the following MOM attribute:

— `EUtranCellFDD.cellSubscriptionCapacity`

— `EUtranCellTDD.cellSubscriptionCapacity`

3.8 QCI Subscription Quanta

QCI subscription quanta is the representation of the anticipated or typical traffic handling capacity required for an E-RAB with certain QCI.

QCI subscription quanta is configured for a QoS class by setting the `QciProfilePredefined.qciSubscriptionQuanta` or `QciProfileOperatorDefined.qciSubscriptionQuanta` attribute.

3.9 Rate Offset

Rate offset is traffic load balancing offset, shifting the traffic load with a bias towards cells with high traffic handling capacity. This offers anticipated better performance during periods of low traffic.

Normally, load balancing targets equal subscription ratios in the source and target cells. However, when traffic is low, load balancing can allow higher subscription ratios in high capacity cells, as those provide better user performance in sparsely loaded LTE RAN. The effect is called rate offset. The rate offset is pronounced at very low subscription ratios and gradually decreases as traffic grows. The rate offset is completely removed at a subscription ratio of `LoadBalancingFunction.lbRateOffsetLoadThreshold` and higher, where load balancing targets equal subscription ratio.

3.10 Load Management and MP Load Control

The objective for the load management functions in the eNodeB is to balance or offload load when possible. However, the focus is on the air interface load. During the execution of load management functions the MP processor load may increase. To not affect general traffic handling, the load management functions are temporarily paused if the MP load control state is higher than `NOT HIGH`. For more information, see Basic Load Management.

3.11 Sticky Carrier

The Sticky Carrier configuration is used to confine UEs in idle mode to the carrier frequency of the current serving cell. This is suitable in a network deployment where good coverage can be expected across large areas on two or more carrier frequencies.

The technique is shown in Figure 9. It takes advantage of the CRPs of the carrier frequencies. The CRP settings are included in the System Information Broadcast in each cell. In the Sticky Carrier configuration, the CRP of the serving carrier frequency is set higher than the CRP of the other carrier frequencies used in the network.

In this way, a UE in idle mode is confined to the carrier frequency of the current serving cell. This is beneficial because the UE tends to remain on the carrier

frequency where it is released to idle mode. The effect of load balancing actions in connected mode may then sustain periods in idle mode. The effect remains the next time the UE connects to the network. It reduces the need for load balancing action to compensate for idle mode mobility between the carrier frequencies.

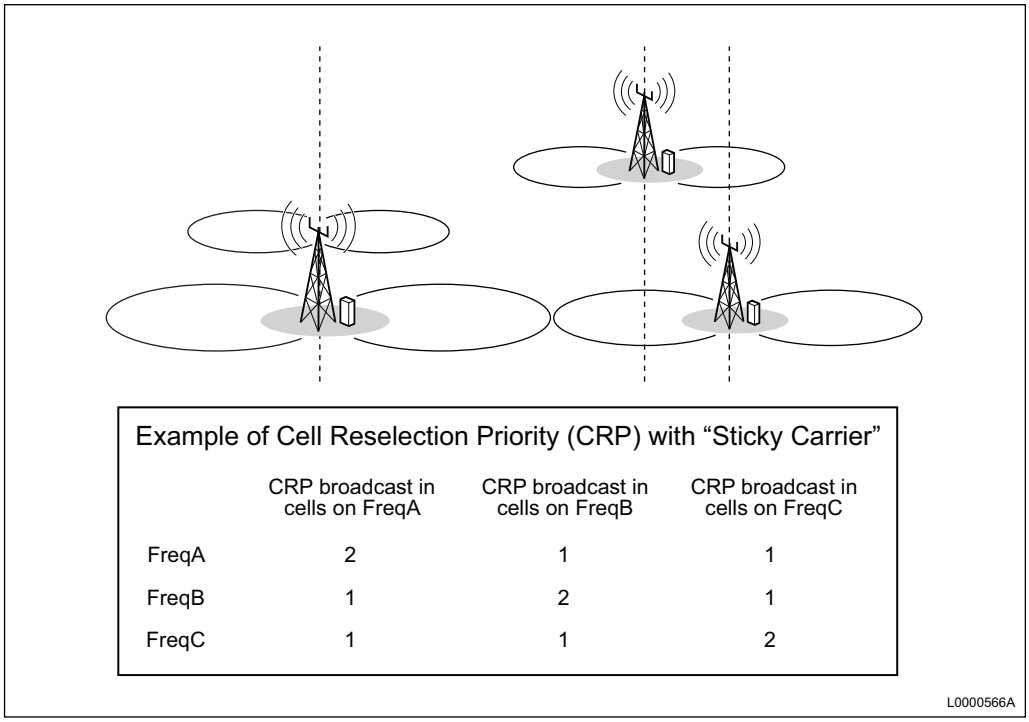
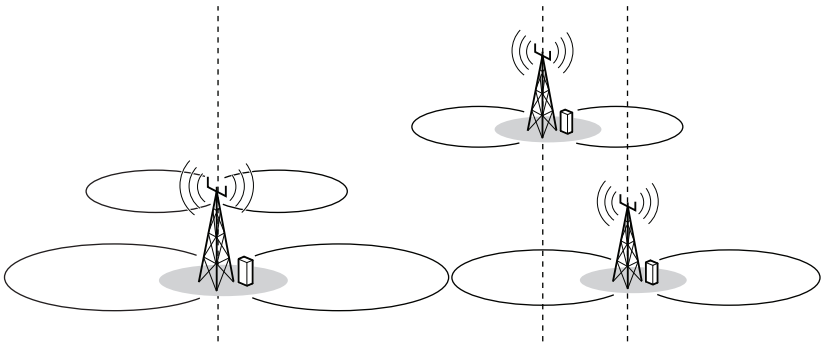


Figure 9 Example of Cell Reselection Priority with Sticky Carrier

3.12 Priority Carrier

The Priority Carrier configuration is used to direct UEs in idle mode to a particular carrier frequency. It is suitable for deployment in networks where the cells on one or more carrier frequencies are small and do not provide continuous coverage. In those cells, UE camping frequently runs into poor coverage. As a result, UEs are required to reselect cells on other carrier frequencies. This configuration supports the Inter-Frequency Load Balancing feature to find a sufficient number of UEs in connected mode suitable for relocation back to the priority carrier cells. Using the idle mode mobility to bias the UE population towards the priority carrier can then be a useful complement.

The technique of Priority Carrier is shown in Figure 10. The carrier frequency C is configured as the priority carrier, whereas a sticky carrier configuration is applied between carrier frequencies A and B. Strictly higher CRP is configured for C, the priority carrier frequency, compared with A and B, the other carrier frequencies.



Example of Cell Reselection Priority (CRP) with “Sticky Carrier” and “Priority Carrier”

	CRP broadcast in cells on FreqA	CRP broadcast in cells on FreqB	CRP broadcast in cells on FreqC
FreqA	2	1	1
FreqB	1	2	1
FreqC	3	3	3

L0000574A

Figure 10 Example of Cell Reselection Priority with Priority Carrier

UEs in idle mode are directed to the priority carrier cells when entering their coverage. The Inter-Frequency Load Balancing feature then has an easier task to find suitable UEs in connected mode for load balancing action towards those cells. This can be beneficial, in particular if the priority carrier cells only cover a small number of the UEs on the other carrier frequencies.

4 Parameters for Inter-Frequency Load Balancing

Feature Configuration Parameters

- EUtranCellFDD.cellSubscriptionCapacity
- EUtranCellTDD.cellSubscriptionCapacity
- EUtranFreqRelation.lbA5Thr1RsrpFreqOffset
- EUtranCellRelation.loadBalancing
- LoadBalancingFunction.lbCeiling
- LoadBalancingFunction.lbRateOffsetCoefficient
- LoadBalancingFunction.lbRateOffsetLoadThreshold
- LoadBalancingFunction.lbThreshold
- QciProfileOperatorDefined.qciSubscriptionQuanta
- QciProfilePredefined.qciSubscriptionQuanta
- ReportConfigEUtraInterFreqLb.a5Threshold1Rsrp
- ReportConfigEUtraInterFreqLb.a5Threshold2Rsrp
- ReportConfigEUtraInterFreqLb.a5Threshold2Rsrq
- ReportConfigEUtraInterFreqLb.hysteresisA5

Affected Parameters

Table 4 Affected Parameters

Parameter	Description
UeMeasControl.sMeasure	Serving cell RSRP threshold controlling whether the UE is required to perform measurements The parameter should be disabled in cells where load balancing is applied.

Parameters Affecting the Feature

Table 5 Parameters Affecting the Feature

Parameter	Description
FreqPrioEUTRA.loadBalancingAllowed	If the RFPM function of Subscriber Triggered Mobility is activated and the UE has a SPID value associated with it, the inter-frequency load balancing is inhibited for that UE. It is inhibited only when the FreqPrioEUTRA.loadBalancingAllowed attribute related to the concerned RATFreqPrio MO for the concerned target carrier frequency is set to FALSE.
ENodeBFunction.zzzTemporary56	These parameters are used to enable and configure the Preferential Traffic Management solution. With appropriate configuration, inter-frequency load balancing can be stopped for some cell relations—to priority cells with high traffic load from non-prioritized cells. For more information, see Preferential Traffic Management Guidelines.
PrefTrafficMgmt.lbStopIncomingIflbThreshold	
PrefTrafficMgmt.sendStopIncomingIflbEnabled	
PrefTrafficMgmt.stopOutgoingIflbEnabled	

5 Network Impact of Inter-Frequency Load Balancing

Capacity and Performance

The Inter-Frequency Load Balancing feature adjusts uneven distribution of traffic load between carrier frequencies. The ability to fully use the traffic capacity on all the available carrier frequencies is improved. The feature is beneficial for the system throughput and the number of UEs and E-RABs the LTE RAN is able to handle. It allows the system capacity to increase proportionally when new carrier frequencies are added and the available RF spectrum thereby increases.

The feature relies on UE inter-frequency measurements to identify UEs suitable for load balancing action. The RRC signaling associated with inter-frequency measurements and the handover-related signaling may increase. At steady state, when traffic load is nearly in balance, the increase is small compared with other signaling of similar kind.

Mobility

The Inter-Frequency Load Balancing feature redistributes users in connected mode between inter-frequency cells by means of traffic load triggered inter-frequency handover. The number of inter-frequency handover increases with this feature. The handover is typically performed in good radio conditions.

The outgoing handover cause code value for the Inter-Frequency Load Balancing feature is set depending on the value of the attributes `LoadBalancingFunction.lbCauseCodeS1SourceTriggersOffload` and `LoadBalancingFunction.lbCauseCodeX2SourceTriggersOffload` for S1 and X2 handovers respectively. It is important that Inter-Frequency Load Balancing and Inter-Frequency Offload use different cause codes. Therefore the selected cause code for Inter-Frequency Load Balancing is set by the node depending on the value of the parameters.

Table 6 Cause Code for Outgoing S1 Handover

lbCauseCodeS1SourceTriggersOffload	Cause Code
`REDUCE_LOAD_IN_SERVING_CELL`	Resource Optimization Handover
`RESOURCE_OPTIMISATION_HANDOVER`	Reduce Load In Serving Cell

Table 7 Cause code for Outgoing X2 Handover

lbCauseCodeX2SourceTriggersOffload	Cause Code
REDUCE_LOAD_IN_SERVING_CELL	Resource Optimization Handover
RESOURCE_OPTIMISATION_HANDOVER	Reduce Load In Serving Cell
LOAD_BALANCING	Resource Optimization Handover

The following sub-counters are introduced to distinguish inter-frequency load balancing handover from other types of inter-frequency handover:

— pmHoPrepAttLteInterFLb

— pmHoPrepSuccLteInterFLb

— pmHoExeSuccLteInterFLb

6 Performance of Inter-Frequency Load Balancing

KPIs

The table lists the main KPIs associated with the feature, and the expected impact.

Table 8 Key Performance Indicators

KPI	Description
Mobility Success Rate	The Mobility Success Rate KPI includes both the preparation of the target cell resources and the move from the source cell to the target cell.

Counters

The following counters are associated with the Inter-Frequency Load Balancing feature:

- EUtranCellFDD.pmLbSubRatioSamp
- EUtranCellTDD.pmLbSubRatioSamp
- EUtranCellFDD.pmLbSubRatioSum
- EUtranCellTDD.pmLbSubRatioSum
- pmLbMeasRepUe
- pmLbQualifiedUe
- pmHoPrepAttLteInterFLb
- pmHoPrepSuccLteInterFLb
- pmHoExeAttLteInterFLb
- pmHoExeSuccLteInterFLb
- pmHoPrepAttNonMob
- pmHoPrepSuccNonMob
- pmHoExeAttNonMob
- pmHoExeSuccNonMob

More information about counters can be found in Managed Object Model (MOM).

Events

Table 9 Events

Event	Event Parameter	Description
INTERNAL_EVENT_LB_SUB_RATIO	EVENT_PARAM_SUB_RATIO	Average subscription ratio for a cell during a load reporting period. Default time is 15 sec.
X2_PRIVATE_MESSAGE	ASN.1 encoded content is part of the pmEventHeader	X2 messages used to subscribe and exchange load information between RBSs.
INTERNAL_EVENT_LB_INTER_FREQ	EVENT_PARAM_NEIGHBOR_CGI	CGI of target cell that participates in load balancing if it is available.
	EVENT_PARAM_LB_DIFF	Load difference (in subscription ratio) between source and neighbor cells.
	EVENT_PARAM_LB_DIFF_INT_SIGN	Unsigned integer value of EVENT_PARAM_LB_DIFF. The value can be positive or negative.
	EVENT_PARAM_LB_AMOUNT	Load balancing amount (in subscription quanta) to be moved from source to target cell.
	EVENT_PARAM_LB_SOURCE_RATIO	Subscription ratio of source cell.
	EVENT_PARAM_LB_TARGET_RATIO	Subscription ratio of target cell.
	EVENT_PARAM_LB_RATE_OFFSET	Rate offset applied to offset the load balancing towards a cell with higher capacity, if the general traffic load level is low.
	EVENT_PARAM_LB_OFFSET_INT_SIGN	Unsigned integer value of EVENT_PARAM_LB_RATE_OFFSET. The value can be positive or negative.
INTERNAL_EVENT_UE_LB_MEAS	EVENT_PARAM_FREQ	Target frequency
	EVENT_PARAM_TRIGGERING_FUNCTION	Indicates the function that has triggered UE measurement. Can be one of the following: —Load Balancing —Carrier Aggregation Triggered Redirection (CATR) —Best Neighbor Relation (BNR) for Load Balancing —Admission-Triggered Offload (ATO)
	EVENT_PARAM_UE_CA_CABABLE	Indicates whether or not the UE selected for load balancing related measurements is CA-capable.
	EVENT_PARAM_NEIGHBOR_CGI	CGI of neighbor target cells for which UEs fulfilled event A5 criteria.
	EVENT_PARAM_TRAVERSED_UES	Number of UEs checked and discarded before choosing this UE for load balancing related measurements.
INTERNAL_EVENT_UE_LB_QUAL	EVENT_PARAM_NEIGHBOR_CGI	CGI of neighbor target cells for which UEs fulfilled event A5 criteria.

Event	Event Parameter	Description
	EVENT_PARAM_HO_SOURCE_OR_TARGET_TYPE	Indicates the RAT of the source for incoming handover and for target for outgoing handover cell.
	EVENT_PARAM_LB_CANCELLED_REASON	Indicates the reason for not proceeding with a load balancing (LB) or CATR when a measurement report has been received from the UE : — CA criteria not met — Reported cell is not a valid load balancing target — Reported cell is a valid target, but lbAmount is already satisfied for the cell — Service Specific Load Management (SSLM) related restrictions — RSRQ of target cell is lower than configured threshold — UE has signalled interest in Multimedia Broadcast Multicast Service (MBMS) on serving frequency — UE has signalled interest in Multimedia Broadcast Multicast Service (MBMS) and UE is MBMS on SCell capable (mbms-SCell-r11 = 1, 3GPP 36.331) — UE has an ongoing Voice over IP (VoIP) call and does not support Single Radio Voice Call Continuity (SRVCC) — Admission-Triggered Offload (ATO) related restrictions
	EVENT_PARAM_TRIGGERING_FUNCTION	Indicates the function that has triggered the UE measurement. Can be one of the following: — Load Balancing — CATR — BNR for Load Balancing — Admission-Triggered Offload (ATO)
INTERNAL_PROC_HO_EXEC_X2_OUT	EVENT_PARAM_PROC_HO_EXEC_OUT_ATTEMPT_CAUSE	The cause of the procedure for HO Execution. — Circuit Switched (CS) — Carrier Aggregation (CA) — Service or Priority-triggered Inter-Frequency Handover (SPIFHO) — Admission-Triggered Offload (ATO)
INTERNAL_PROC_HO_EXEC_S1_OUT	EVENT_PARAM_PROC_HO_EXEC_OUT_ATTEMPT_CAUSE	The cause of the procedure for HO Execution. — Circuit Switched (CS)

Event	Event Parameter	Description
		—Carrier Aggregation (CA) —Service or Priority-triggered Inter-Frequency Handover (SPIFHO) —Admission-Triggered Offload (ATO)
INTERNAL_EVENT_UE_MOBILITY_EVAL	EVENT_PARAM_MOBILITY_TRIGGER	Indicates the trigger for performing a mobility evaluation. —Circuit Switched (CS) —Carrier Aggregation (CA) —Service or Priority-triggered Inter-Frequency Handover (SPIFHO) —Admission-Triggered Offload (ATO)

7 Activate Inter-Frequency Load Balancing

Prerequisites

— The license key is installed in the node.

— Continuous Cell Trace Recording (CCTR) is activated since at least one week. This ensures there is troubleshooting data available if something goes wrong.

— The Coverage-Triggered Inter-Frequency Handover feature is activated.

Steps

1. Set the attribute `featureState` to ACTIVATED in the applicable MO instance, depending on node type:

Node Type	License Control MO
DU Radio Node	`OptionalFeatureLicense=InterFrequencyLoadBalancing`
Baseband-based Node	`FeatureState=CXC4011319`

After This Task

Let the CCTR be active for one week, for continued collection of troubleshooting data.

8 Deactivate Inter-Frequency Load Balancing

Prerequisites

Continuous Cell Trace Recording (CCTR) is activated since at least one week. This ensures there is troubleshooting data available if something goes wrong.

Steps

1. Set the attribute `featureState` to DEACTIVATED in the applicable MO instance, depending on node type:

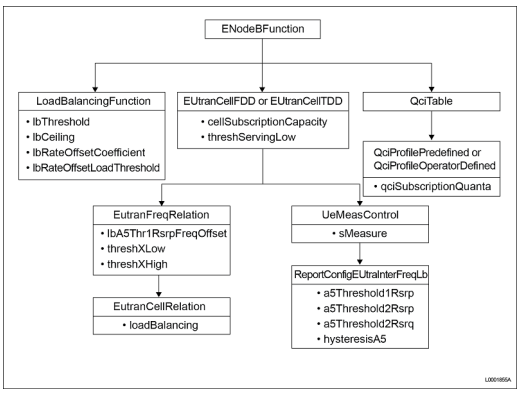
Node Type	License Control MO
DU Radio Node	`OptionalFeatureLicense=InterFrequencyLoadBalancing`
Baseband-based	`FeatureState=CXC4011319`

After This Task

Let the CCTR be active for one week, for continued collection of troubleshooting data.

9 Engineering Guidelines for Inter-Frequency Load Balancing

For information on configuration, click on the attribute.



9.1 Configuration of Load Balancing Relation

Load balancing relations are configured in the source cell towards each target cell, by setting the EUtranCellRelation.loadBalancing attribute.

Table 10 Configuration of Load Balancing Relation

MO Attribute	Value	Description
EUtranCellRelation.loadBalancing	NOT_ALLOWED	Setting the EUtranCellRelation.loadBalancing attribute to NOT_ALLOWED deactivates Inter-Frequency Load Balancing and Inter-Frequency Offload to the related target cell, in one direction.
	ALLOWED	Setting the EUtranCellRelation.loadBalancing attribute to ALLOWED activates Inter-Frequency Load Balancing to the related target cell, in one direction.
	OFFLOAD	Setting the EUtranCellRelation.loadBalancing attribute to OFFLOAD activates Inter-Frequency Offload to the related target cell, in one direction.
	IFO_AND_IFLB	Setting the EUtranCellRelation.loadBalancing attribute to IFO_AND_IFLB activates both Inter-Frequency Load Balancing and Inter-Frequency Offload to the related target cell, in one direction. **Note:** The IFO_AND_IFLB value can only be used if Preferential Traffic Management is enabled and configured, because the operation depends on the setting of the PrefTrafficMgmt.lbStopIncomingIflbThreshold attribute.

The EUtranCellRelation.loadBalancing attribute can be configured in one direction, from the source cell to the target cell.

To apply the same configuration in both directions between two cells, EUtranCellRelation.loadBalancing must be set to the same value in both directions. This allows both cells to act as source cells to each other.

The EUtranCellRelation.loadBalancing attribute also controls the exchange of load information. When set to ALLOWED or IFO_AND_IFLB, the source cell requests the target cell to provide traffic load reports.

Other mobility functionality is not affected by the EUtranCellRelation.loadBalancing attribute.

Note: Inter-Frequency Load Balancing does not consider and may override restriction of connected mode mobility at coverage-triggered session continuity. Coverage-Triggered Inter-Frequency Session Continuity describes the configuration of the connected mode mobility restrictions.

The `EUtranCellRelation.loadBalancing` attribute can be determined and configured automatically by the Best Neighbor Relations for Intra-LTE Load Management feature.

—— RELATED INFORMATION —

3.2 Load Balancing Relation on page 15

9.2 Configuration of Subscription Parameters

The operation of the Inter-Frequency Load Balancing feature requires that QCI subscription quanta and cell subscription capacity are configured. QCI subscription quanta can be the `QciProfilePredefined.qciSubscriptionQuanta` or `QciProfileOperatorDefined.qciSubscriptionQuanta` attribute. The cell subscription capacity can be the `EUtranCellFDD.cellSubscriptionCapacity` or `EUtranCellTDD.cellSubscriptionCapacity` attribute.

Configuration of QCI Subscription Quanta

The `QciProfilePredefined.qciSubscriptionQuanta` or `QciProfileOperatorDefined.qciSubscriptionQuanta` attributes are configured in proportion to the typical traffic load an E-RAB of the specific QoS class represents in LTE RAN at high load. The general recommendation is to choose values for these attributes in proportion to the expected downlink bit rates (in kbps) under those conditions.

Note: The `qciSubscriptionQuanta` attribute does not influence the scheduling of the E-RAB, nor is it used for admission control. It is used solely to express the typical traffic load an E-RAB of the specific QoS class imposes on LTE RAN.

In case of combination with the Automated Cell Capacity Estimation feature, the principle of configuring `qciSubscriptionQuanta` is changed. For more information, see the document Automated Cell Capacity Estimation.

For a GBR type of E-RAB, the `qciSubscriptionQuanta` parameter is chosen in proportion to the typical guaranteed downlink bit rate (in kbps) for the particular QCI.

Table 11 Recommendations to Configure qciSubscriptionQuanta for GBR E-RABs

QCI	Recommendation
1 (conversational voice)	The value depends on the typical voice codec in use.

QCI	Recommendation
Other (2..4, ...)	The value depends on the type of streaming media.

For a non-GBR type of E-RAB, the `qciSubscriptionQuanta` parameter is chosen in proportion to what is considered an acceptable downlink bit rate (in kbps) for a UE in connected mode in LTE RAN at high load.

Table 12 Recommendations to Configure qciSubscriptionQuanta for Non-GBR E-RABs

Type of E-RAB	Recommendation
Default non-GBR types	The default non-GBR types of E-RAB are activated whenever the UE enters connected mode, irrespective if they are going to be used. Conservative values are chosen, reflecting an expected low or moderate duty rate on these E-RABs. In particular, the inactivity timer configured in the cell must be considered. A reduction of the inactivity timer may reduce the UE time spent in connected mode, whilst the UE data consumption is unaffected. The value of the `qciSubscriptionQuanta` attribute is increased to reflect the typical increase in average bit rate. If the inactivity timer is increased, the value of `qciSubscriptionQuanta` should be decreased. **Note:** The document Radio Bearer Service describes the configuration of the inactivity timer.
IMS signaling (default QCI = 5)	The expected bit rate is typically low (not exceeding 3 kbps).
Default ISP E-RAB	A suitable value can be based on the typical UE data consumption. This consumption is over a longer period of time in relation to the time spent in connected mode over the same period of time. The value has to focus on the conditions in LTE RAN at high load.
On-demand non-GBR type	Values have to be chosen based on the typical minimum QoS

Type of E-RAB	Recommendation
	requirements of the intended applications.

The default E-RAB can be distinguished on different QCIs for users of separate categories, for example, for users with different types of UE devices. It offers a way to differentiate the `qciSubscriptionQuanta` attribute values among users of different categories. This can be useful if there are user categories with widely different QoS demand.

Note: A separation of user categories on separate QCIs requires support from the core network. This is not a feature of LTE RAN.

Configuration of Cell Subscription Capacity

At high load in LTE RAN, the `cellSubscriptionCapacity` (in MOs `EUtranCellFDD` or `EUtranCellTDD`) is configured in proportion to the achievable traffic capacity in the cell.

The achievable traffic capacity is typically proportional to the RF bandwidth of the cell, but can also depend on other factors, including the following:

— Inter-site distances and the presence of radio interference from neighbor cells.

— How the cell antenna is configured. For example, whether MIMO is applied.

— How the UE group in the cell is distributed between the cell center and the cell edge.

Note: If Inter-Frequency Load Balancing is used in combination with the features Automated Cell Capacity Estimation and Limited-Uplink-Aware IFLB, the function of the `cellSubscriptionCapacity` attribute can be replaced by these features. This determines and configures the cell capacity automatically. In this case, the principle of configuring `qciSubscriptionQuanta` is changed. For more information about the configuration, see the documents Automated Cell Capacity Estimation and Limited-Uplink-Aware IFLB.

It is recommended to choose a value of the attribute `cellSubscriptionCapacity` in proportion to the achievable downlink bit rate (in kbps) in the cell, considering the factors affecting the capacity. In a typical LTE RAN deployment, without advanced antenna configurations, the achievable spectrum efficiency at high load is usually in the proximity of 2 Mbit/MHz (bit rate for each RF bandwidth).

The amount of E-RABs the cell can accommodate is ultimately a trade-off with respect to the achievable QoS level. Increasing the amount of E-RABs has the following effects:

— Reduced throughput and increased packet delay for individual (non-GBR) E-RABs

— Increased subscription ratio, with a given configuration of the `qciSubscriptionQuanta` and `cellSubscriptionCapacity` attributes

— Declined user experience, yet a still operable cell

Therefore, the subscription ratio can be used as an indicator of the user experience in the cell.

The Inter-Frequency Load Balancing feature can handle load balancing also at subscription ratio levels greater than 1.0 (normally conceived as a mark of high load). The upper limit of the subscription ratio is 16. If the upper limit is reached, the load balancing can stall, because traffic load differences between cells above the limit are not perceptible. The value of the `cellSubscriptionCapacity` attribute should be chosen large enough to keep a margin with respect to this limitation.

—— RELATED INFORMATION ——

3.6 Subscription Ratio on page 17

3.7 Cell Subscription Capacity on page 17

3.8 QCI Subscription Quanta on page 18

3.4 GBR Traffic Load on page 16

3.5 Non-GBR Traffic Load on page 16

9.3 Tuning of Subscription Parameters

In addition to the basic recommendations to configure load balancing, further tuning of the QCI subscription quanta and cell subscription capacity is possible to improve the load balancing behavior.

The QCI subscription quanta can be the `QciProfilePredefined.qciSubscriptionQuanta` or `QciProfileOperatorDefined.qciSubscriptionQuanta` MO attribute. The cell subscription capacity can be the `EUtranCellFDD.cellSubscriptionCapacity` or `EUtranCellTDD.cellSubscriptionCapacity` MO attribute.

For example, if a high E-RAB density of certain QoS class tends to cause the QoS level to decline. Then an increase of the corresponding `qciSubscriptionQuanta` attribute can help to reduce the number of UEs in the cells where that type of E-RAB is frequent.

The load balancing process does not consider the absolute level of `qciSubscriptionQuanta` and `cellSubscriptionCapacity`. The relations are important between these parameters.

Relation Between qciSubscriptionQuanta Values for Different QCIs

The relations between `qciSubscriptionQuanta` values for different QCIs determine how UEs with different E-RAB configuration can be exchanged in the load balancing process.

Increasing the `qciSubscriptionQuanta` attribute value for one QoS class tends to relocate UEs from cells with high density of this type of E-RAB to cells with lower density. The opposite is also true.

Relation Between cellSubscriptionCapacity Values of Different Cells

The relations between the `cellSubscriptionCapacity` values of different cells determine how the UE group is divided between cells where load balancing is allowed.

Increasing the value of the `cellSubscriptionCapacity` attribute for one cell attracts UEs to that cell. The opposite is also true.

Relation Between cellSubscriptionCapacity and qciSubscriptionQuanta Values

The overall relation between the values of `cellSubscriptionCapacity` and `qciSubscriptionQuanta` attributes determines the absolute level of the subscription ratio in the cell.

Increasing the overall ratio between the values of attributes `cellSubscriptionCapacity` and `qciSubscriptionQuanta` requires a higher number of UEs in the cell to reach the same subscription ratio.

—— RELATED INFORMATION ——

9.2 Configuration of Subscription Parameters on page 33

3.7 Cell Subscription Capacity on page 17

3.8 QCI Subscription Quanta on page 18

9.4 Configuration of Load Balancing Action on Node Level

The load balancing sensitivity and the maximum rate of load balancing actions are configured with parameters `LoadBalancingFunction.lbThreshold` and `LoadBalancingFunction.lbCeiling`. These attributes are defined at node level and apply to all load balancing relations within the node and towards target cells

in other nodes. In many deployments, the default values of these attributes can be used.

Increasing the value of `lbThreshold` can reduce the rate of load balancing actions back and forth between cells as a result of random variations of the traffic load up and down. However, a certain degree of UE shuffling between the cells can be useful, as it reduces the risk of UE segregation due to differences in traffic behavior.

An increase of the value of `lbThreshold` can also increase the burstiness of load balancing actions. This means that load balancing occurs all at once rather than as a sequence of small steps.

Reducing the value of `lbCeiling` can help to distribute a sudden large amount of load balancing actions over a period of time. However, care is required to ensure that `lbCeiling` is configured large enough to outbalance any systematic drift in the load balance. For example, due to poor coverage-triggered mobility or due to mobility between neighbor cells on particular carrier frequencies.

Attribute `lbThreshold` can be configured greater than attribute `lbCeiling`. The effect can be that the load gap between the cells is not entirely closed.

9.5 Configuration of Measurements for UE Selection for Load Balancing Action

Inter-frequency Event A5 measurement reporting in the UE selection for load balancing action is configured for each source cell using the following attributes:

— `ReportConfigEUtraInterFreqLb.a5Threshold1Rsrp`

— `ReportConfigEUtraInterFreqLb.a5Threshold2Rsrp`

— `ReportConfigEUtraInterFreqLb.hysteresisA5`

For inter-frequency Event A5 measurement reporting, `ReportConfigEUtraInterFreqLb.lbA5Thr1RsrpFreqOffset` can be applied to `a5Threshold1Rsrp` to support a flexible `a5Threshold1Rsrp` between frequency relations.

To ensure that the UE can stay in the target cell after a load balancing action, configure `a5Threshold2Rsrp` attribute with a value higher than the Event A2 Poor Coverage threshold in the target cell. If QCI-dependent thresholds are applied in the target cell, parameter `a5Threshold2Rsrp` must be configured with a value higher than the maximum of these thresholds. The documents Coverage-Triggered Inter-Frequency Session Continuity and Service Triggered Mobility describe the configuration of poor coverage thresholds.

Attribute `ReportConfigEUtraInterFreqLb.a5Threshold1Rsrp` can be used to exclude UEs in a good radio environment from load balancing.

Attribute `ReportConfigEUtraInterFreqLb.a5Threshold1Rsrp` can also be used in a priority carrier configuration.

Attribute `ReportConfigEUtraInterFreqLb.a5Threshold2Rsrq` is configured for the source cell. It is used to set the RSRQ threshold for the target cell. The reporting quantity for Inter-Frequency Load Balancing is set to RSRP, so the RSRQ check is made at reception of an Event A5 measurement report. The load balancing action is ended if the reported RSRQ falls lower than the threshold.

Note: In a source cell where the Inter-Frequency Load Balancing feature is active, the `UeMeasControl.sMeasure` attribute must be set to disable the s-Measure threshold in the cell. Otherwise, the UE cannot perform the measurements required for the UE selection process.

QCI-dependent UE selection criteria can be configured for the individual E-UTRAN frequencies if the Service Specific Load Management feature is activated. For more information, see Service Specific Load Management.

9.6 Configuration of Rate Offset for Load Balancing

Attributes `LoadBalancingFunction.lbRateOffsetCoefficient` and `LoadBalancingFunction.lbRateOffsetLoadThreshold` are used to configure the rate offset mechanism for load balancing.

Attribute `lbRateOffsetCoefficient` controls the impact of the rate offset mechanism. The higher the value, the more biased load balancing is towards high capacity cells at low load. To switch off the rate offset mechanism, attribute `lbRateOffsetCoefficient` must be set to value `0`. Otherwise, it is recommended to use the default value.

Attribute `lbRateOffsetLoadThreshold` controls up to which subscription ratio the rate offset is to have effect. The effect gradually decreases as the average subscription ratio increases and disappears at an average subscription ratio of `lbRateOffsetLoadThreshold`. The default value corresponds to an average subscription ratio of `0.5` and it is not recommended to go below this value.

—— RELATED INFORMATION ——

3.9 Rate Offset on page 18

9.7 Idle Mode Mobility Aspects for Inter-Frequency Load Balancing Configuration

When the Inter-Frequency Load Balancing feature is used, consideration of the UE mobility in idle mode is recommended. The load balancing can be improved by appropriate configuration of the UE idle mode mobility. The appropriate configuration depends on the type of network deployment and cell topology.

Coverage-Triggered Inter-Frequency Session Continuity and Idle Mode Support provide additional information regarding the configuration of idle mode mobility.

9.7.1 Configuration of threshServingLow and threshXLow in Sticky Carrier or Priority Carrier Configuration

The recommendations to configure thresholds `threshServingLow` and `threshXLow` are the same for a cell deployment where the sticky carrier configuration is used and where priority carrier configuration is applied.

threshServingLow

Attribute `threshServingLow` (`EUtranCellFDD.threshServingLow` or `EUtranCellTDD.threshServingLow`) is used to set a threshold for the inter-frequency cell reselection at poor coverage. The recommendation is to configure `threshServingLow` attribute at the same level as the Event A2 Poor Coverage threshold in the cell. Event A2 Poor Coverage threshold configuration is described in document Coverage-Triggered Inter-Frequency Session ContinuityIdle Mode Support describes the configuration and function of idle mode mobility..

The `sNonIntraSearch` attribute in struct `SIB3` for the E-UTRAN cell needs to be set to a value greater than or equal to `threshServingLow` attribute. In this case, the idle mode inter-frequency mobility operates sufficiently towards carrier frequencies with low CRP.

Note: The idle mode mobility thresholds, like `threshServingLow`, are defined relative to the required minimum RSRP of the respective cell.

The Event A2 Poor Coverage threshold is defined in absolute RSRP.

threshXLow

For a UE to reselect a cell on a carrier frequency with lower CRP, the RSRP of the target cell must exceed a threshold the `EUtranFreqRelation.threshXLow` attribute defines for that frequency. The recommendation is to configure `threshXLow` threshold with a small margin above `threshServingLow` threshold used in the cells on the target frequency.

Note: The `threshServingLow` parameter can be configured differently on different carrier frequencies. This must be taken into account when configuring the corresponding `threshXLow` attributes.

—— RELATED INFORMATION —

3.11 Sticky Carrier on page 18

3.12 Priority Carrier on page 19

9.7.2 Configuration of threshXHigh in Priority Carrier Configuration

For UEs to reselect a cell on a carrier frequency with higher CRP, the RSRP of the target cell must exceed a threshold that attribute `EUtranFreqRelation.threshXHigh` defines for that frequency. The recommendation is to configure threshold `threshXHigh` with at least a small margin higher than parameter `threshServingLow` used in the cells on the target frequency.

The value of threshold `threshXHigh` can be further increased to reduce the probability for UEs to select lower CRP carrier frequencies. This can be useful if the priority carrier cells are large enough to be selected by significant number of UEs. In this way, the bias achieved in the idle mode UE distribution can be moderated to a suitable level. The Inter-Frequency Load Balancing feature can then be applied to tune the UE distribution on top of that.

The possibility to exclude UEs in a good radio environment from load balancing can also be beneficial in a priority carrier configuration like the one shown in Figure 11.

The F2 frequency has higher CRP than the F1 frequency. This means that all UEs within the dotted lower circle perform idle mode cell reselection to the higher cell on frequency F2. There is a high risk that such UEs are load balanced back to the lower cell if the higher cell is more loaded than the lower cell. Avoid this by setting `ReportConfigEUtraInterFreqLb.a5Threshold1Rsrp` parameter so that only UEs outside the coverage area are subject to load balancing. Coverage are is defined by `threshXHigh` attribute.

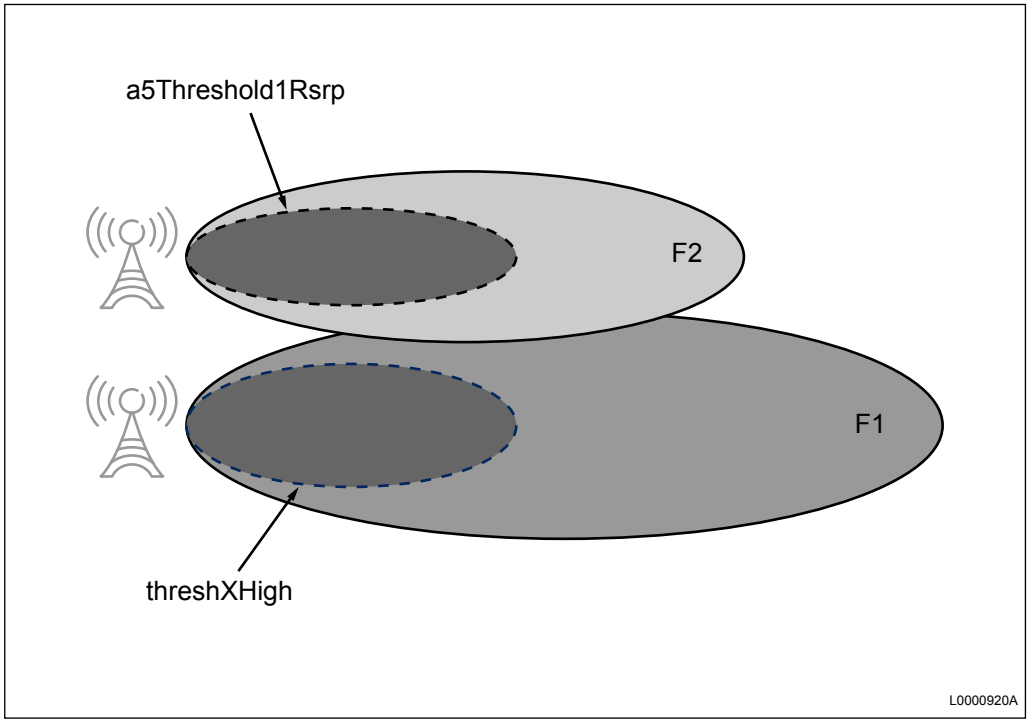


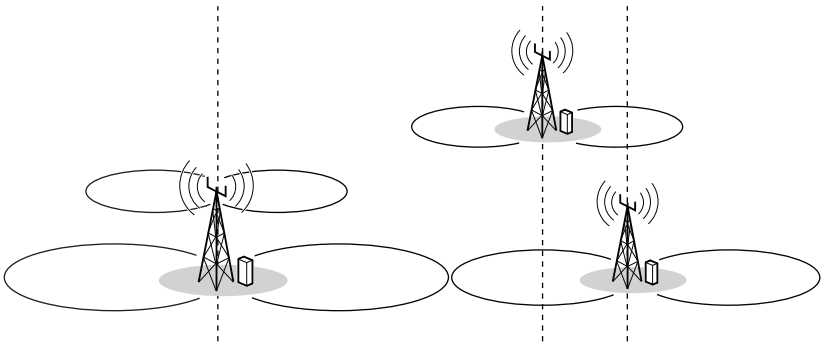
Figure 11 Example of Managing UE Load Balancing in a Priority Carrier Configuration

—— RELATED INFORMATION ——

3.12 Priority Carrier on page 19

9.7.3 Combination of Idle Mode Mobility

The sticky carrier and priority carrier configurations can be combined in a multi-carrier network (one with more than two carrier frequencies).



Example of Cell Reselection Priority (CRP) with "Sticky Carrier" and "Priority Carrier"

	CRP broadcast in cells on FreqA	CRP broadcast in cells on FreqB	CRP broadcast in cells on FreqC
FreqA	2	1	1
FreqB	1	2	1
FreqC	3	3	3

L0000574A

Figure 12 Combination of Sticky Carrier and Priority Carrier Configurations

The sticky carrier configuration is typically applied between carrier frequencies with similar coverage properties. The priority carrier configuration is suitable for carrier frequencies with substantial loss of UEs. The loss can occur because areas have poor coverage or have large coverage gap, and in areas where cells that are small compared to the cells on other carrier frequencies.

The way to configure the idle mode mobility can alternate between different locations within the network, depending on the local conditions.

Other principles for the configuration of the idle mode mobility are also possible. The Inter-Frequency Load Balancing feature is not restricted to particular configurations of UE idle mode cell reselection.

—— RELATED INFORMATION ——

3.11 Sticky Carrier on page 18

3.12 Priority Carrier on page 19

Appendix A: Feature Change History

This section lists changes that affected this feature and the impact it had on network.

Appendix A.a: Preferential Traffic Management

Access Type:	LTE
Hardware Platform:	All
Licensing:	Admission-Triggered Offload, FAJ 121 3100
	Best Neighbor Relations for Intra-LTE Load Management, FAJ 121 3028
	Inter-Frequency Load Balancing, FAJ 121 3009
	Subscriber Triggered Mobility, FAJ 121 1788
Value Package:	Service-Based Mobility, FAJ 801 0433
	Multi-Carrier Load Management, FAJ 801 0427
	LTE Base Package, FAJ 801 0400

The Preferential Traffic Management solution offers the operator the possibility to efficiently use an LTE network, deployed on several frequency bands, with one frequency band used primarily for prioritized users. The solution enables the following functions:

— To use the priority band for both prioritized and non-prioritized users as long as co-existence rules allow it

— To use the priority band exclusively for prioritized users in intended traffic situations

— To use the non-prioritized bands for both non-prioritized and prioritized users, both as coverage bands and bands to offload prioritized traffic when the priority band is overloaded

The load management policies used depend on the current traffic load level. Traffic load states in the solution are defined by configurable load threshold parameters.

The solution is developed for existing commercial RAN infrastructure with a designated band used as priority band, using an MOCN architecture. The solution is achieved by a collection of extensions in existing licensed features, configured to work together.

Capacity and Performance

The solution introduces one new parameter EVENT_PARAM_TRAFFIC_LOAD_STATE for PM Event INTERNAL_EVENT_LB_SUB_RATIO. The parameter captures current traffic load state by monitoring load report.

Operation

The Preferential Traffic Management solution is activated on node level using MO attribute ENodeBFunction.zzzTemporary56.

If the solution is enabled and appropriate configuration is set, the following applies:

Table 13 Affected Features

Feature	New Configuration MOs	Description
Admission-Triggered Offload, FAJ 121 3100	—PrefTrafficMgmt.atoAllowedFrom	Admission-Triggered Offload can be enabled per cell in a node to given target frequencies for UEs configured with an SPID.
Best Neighbor Relations for Intra-LTE Load Management, FAJ 121 3028		New value IFO_AND_IFLB is introduced for attribute EUtranFreqRelation.lbBnrPolicy, to allow automatic configuration of inter-frequency offload and inter-frequency load balancing for the cell on the given frequency relation.
Inter-Frequency Load Balancing, FAJ 121 3009	—PrefTrafficMgmt.lbStopIncomingIflbThreshold —PrefTrafficMgmt.sendStopIncomingIflbEnabled —PrefTrafficMgmt.stopOutgoingIflbEnabled	Inter-frequency load balancing can be stopped for some cell relations—to priority cells with high traffic load from non-prioritized cells. This allows the priority band to be used primarily to serve prioritized users, and ensures access for prioritized UEs in high traffic load situations.
Subscriber Triggered Mobility, FAJ 121 1788, RFPM function	—PrefTrafficMgmt.inhibitIMPrioritizationEnabled —PrefTrafficMgmt.inhibitIMPrioritizationInterval —PrefTrafficMgmt.inhibitSpidList —PrefTrafficMgmt.sendInhibitIMPrioritizationEnabled —FreqPrioEUTRA.offloadAllowed	Idle mode prioritization can be inhibited between some cells—to priority cells with very high traffic load from non-prioritized cells. This ensures that priority cells are not overloaded, so prioritized UEs have access in very high load traffic situations. A new MO attribute is introduced to allow or disallow inter-frequency offload for UEs with SPID to a target frequency: FreqPrioEUTRA.offloadAllowed.

Handover of UEs with certain PLMN IDs and SPID to a target cell can be blocked. This occurs when the PLMN ID of the UE is "reserved for operator use" in the target cell. It can be reserved, because the cell has very high traffic load—subscription ratio or MSR usage. It is also required that the SPID of the UE is configured in attribute PrefTrafficMgmt.spidBlacklistHo.

This function is controlled by the following new parameters:

— PrefTrafficMgmt.highLoadPlmnReservedEnabled

— PrefTrafficMgmt.plmnResOpUseMsrUsageThreshold

— PrefTrafficMgmt.plmnResOpUseSRatioThreshold

— PrefTrafficMgmt.plmnsToReserveAtHighLoad

— PrefTrafficMgmt.plmnUnresOpUseMsrUsageThreshold

— PrefTrafficMgmt.plmnUnresOpUseSRatioThreshold

— PrefTrafficMgmt.spidBlacklistHo

The following attributes are affected by the solution:

Table 14 Affected Parameters

Parameter	MO Class	Description
lbBnrPolicy	EUtranFreqRelation	New value IFO_AND_IFLB is introduced for attribute EUtranFreqRelation.lbBnrPolicy, to allow automatic configuration of inter-frequency offload and inter-frequency load balancing for the cell on the given frequency relation. **Note:** The IFO_AND_IFLB value can only be used if Preferential Traffic Management is enabled and configured. To operate properly, the PrefTrafficMgmt.lbStopIncomingIflbThreshold attribute must be set.
loadBalancing	EUtranCellRelation	New value IFO_AND_IFLB is introduced for the attribute, to allow inter-frequency offload and inter-frequency load balancing for the cell. **Note:** The IFO_AND_IFLB value can only be used if Preferential Traffic Management is enabled and configured, because the operation depends on the setting of the PrefTrafficMgmt.lbStopIncomingIflbThreshold attribute.
loadBalancingAllowed	RATFreqPrio In FreqPrioEUTRA struct of attribute RATFreqPrio.freqPrioListEUTRA.	Offloading behavior can be controlled by FreqPrioEUTRA.offloadAllowed, if loadBalancingAllowed is set to FALSE. **Note:** The parameter has any effect for cell relations EUtranCellRelation.loadBalancing set to IFO_AND_IFLB. It requires also that Preferential Traffic Management is enabled.

Interfaces

This change affects the following interfaces:

— X2

New private information element for traffic load state of a cell is added to cell resource status report messages.

Other Network Elements

No impact.