

Inter-eNodeB Carrier Aggregation

Feature Description

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Contents

1	Inter-eNodeB Carrier Aggregation Overview	1
2	Dependencies of Inter-eNodeB Carrier Aggregation	3
3	Inter-eNodeB Carrier Aggregation Operation	5
3.1	Feature Operation Sequence Diagram	5
3.2	Supported Bandwidths for Inter-eNodeB Carrier Aggregation	7
3.3	Process Steps	8
4	Network Impact of Inter-eNodeB Carrier Aggregation	10
4.1	LTE Backhaul Network Characteristics	10
5	Parameters of Inter-eNodeB Carrier Aggregation	12
6	Performance of Inter-eNodeB Carrier Aggregation	13
7	Activate Inter-eNodeB Carrier Aggregation	15
8	Deactivate Inter-eNodeB Carrier Aggregation	17
	Appendix A: Feature Change History	18
	Appendix A.a: TDD as ESCell and Inter-eNB Observability Enhancements	18
	Appendix A.b: Inter-eNB CA Usability Enhancements	19
	Appendix A.c: 18.Q3: Software Release Interoperability for Inter-eNodeB Carrier Aggregation	20





1 Inter-eNodeB Carrier Aggregation Overview

Access Type:	LTE
Feature Identity:	FAJ 121 4469
Value Package Name:	Advanced Carrier Aggregation
Value Package Identity:	FAJ 801 0564
Node Type:	Baseband Radio Node
Licensing:	Licensed feature. One license per node.

Summary

The purpose of the Inter-eNodeB Carrier Aggregation feature is to enable DL carrier aggregation between cells not located on the same eNodeB.

The main benefits of the feature are:

- The set of cells considered for use as secondary cells is expanded across multiple eNodeBs. As a result, UEs can find a better set of cells with which to perform carrier aggregation, leading to an increase in overall throughput.
- Allows for an increased utilization of eNodeBs in the network.

Additional Information

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

- *3GPP TS 36.331*
- *3GPP TS 36.211*
- *3GPP TS 36.212*
- *3GPP TS 36.213*
- Carrier Aggregation
- Synchronization
- Fallback from Time and Phase Synchronization
- Dynamic SCell Selection for Carrier Aggregation
- 3CC DL Carrier Aggregation Extension



- Ericsson Lean Carrier
- Uplink Carrier Aggregation
- LTE Broadcast
- Autoconfiguration of LTE Broadcast Subframes
- Characteristics Requirements for LTE Backhaul
- Carrier Aggregation-Aware IFLB
- Elastic RAN
- Carrier Aggregation FDD-TDD
- 4x2 Quad Antenna Downlink Performance Package
- 4x4 Quad Antenna Downlink Performance Package
- 256-QAM Downlink
- Supplemental Downlink for Carrier Aggregation



2 Dependencies of Inter-eNodeB Carrier Aggregation

Features

Table 1 Feature Dependencies

Feature	Relationship	Description
Carrier Aggregation (FAJ 121 3046)	Prerequisite	Carrier Aggregation must be activated before activating the Inter-eNodeB Carrier Aggregation feature.
Dynamic SCell Selection for Carrier Aggregation (FAJ 121 3063)	Related	The feature is based on the Carrier Aggregation feature and has the following additional functionality: A cell used as PCell can have multiple cells as SCell candidates. Based on UE measurements and the SCell algorithm, the SCell of a UE is dynamically configured or de-configured.
3CC DL Carrier Aggregation Extension (FAJ 121 3084)	Related	The feature is based on Carrier Aggregation feature and has the following additional functionality: Capability to transmit data to a single UE on three carriers simultaneously.
256-QAM Downlink (FAJ 121 4422)	Related	In order for a 256 QAM-capable cell to be selected as external cell, the 256-QAM Downlink feature must be activated in the primary eNodeB.
4x2 Quad Antenna Downlink Performance Package (FAJ 121 3041)	Related	In order to have 4 Tx ports cells selected as external cells, the 4x2 Quad Antenna Downlink Performance Package feature must be activated in the primary eNodeB.
4x4 Quad Antenna Downlink Performance Package (FAJ 121 3076)	Related	In order to achieve 4 layers transmission over 4 ports external cells, the 4x4 Quad Antenna Downlink Performance Package feature must be activated in the primary eNodeB.
Carrier Aggregation-Aware IFLB (FAJ 121 3075)	Related	If an ECell is configured as SCell, it is included as part of the Carrier Aggregation-Aware IFLB assessment with aggregated capacity evaluation.
Elastic RAN (FAJ 121 4608)	Conflicting	
Enhanced PDCCH Link Adaptation (FAJ 121 3051)	Related	If the Enhanced PDCCH Link Adaptation feature is activated, External SCells are deactivated for all UEs engaged in VoLTE calls that have external SCells configured.
Ericsson Lean Carrier (FAJ 121 4471)	Related	If a cell accepts external traffic from other PCells, the Ericsson Lean Carrier feature is automatically switched off while external incoming traffic is present.
Supplemental Downlink for Carrier Aggregation (FAJ 121 3068)	Related	In order for a downlink-only cell to be selected as external cell, the Supplemental Downlink for Carrier Aggregation feature must be activated in the primary eNodeB.
Uplink Carrier Aggregation (FAJ 121 4425)	Related	Uplink Carrier Aggregation is not supported for external cells.
Co-existence of Elastic RAN and Inter-eNB CA (FAJ 121 4609, FAJ 121 4469)	Related	This enhancement allows the simultaneous use of both Elastic RAN and IeNB CA on the same eNB by removing the restriction of coexistence of Elastic RAN and IeNB features on same eNB. Parallel use of both of those features enables more carrier aggregation partners, and improves CA on border areas between two networks. This enhancement also allows to use a single Cell as Elastic RAN and IeNB CA partner at the same time.



Feature	Relationship	Description
IEEE 1588 Time and Phase Synchronization (FAJ 121 1793)	Related	If the time offset values are inconsistently configured between different eNBs with the <code>RadioEquipmentClock.bfnOffset</code> attribute, the performance and services of the Inter-eNodeB Carrier Aggregation feature can be negatively impacted.
Mission-Critical Push-to-Talk (FAJ 121 4929)	Related	When the Mission-Critical Push-to-Talk feature is active, this feature treats mission-critical bearers like it treats VoLTE bearers.
Category M Access (FAJ 121 4658)	Conflicting	A cell that accept traffic from other external PCells must not have Category M Access enabled.

Hardware

No special hardware requirement is expected for this feature.

Limitations

The number of ECells a primary eNodeB can use is limited to maximum 12 per Baseband unit.

The number of Inter-eNodeB Carrier Aggregation X2 tunnel is limited to maximum 12 per Baseband unit.

Network Requirements

No network requirements for this feature.

System Functions

This feature affects no system functions.



3 Inter-eNodeB Carrier Aggregation Operation

3.1 Feature Operation Sequence Diagram

With feature Inter-eNodeB Carrier Aggregation, a UE uses DL transmission resources from partially or fully overlapping cells belonging to different eNodeBs.

In this scenario, the feature Inter-eNodeB Carrier Aggregation can receive downlink data from cells for Rel-10 CA devices. It does not matter if they belong to different eNodeBs or not. The primary eNodeB forwards user-data over the X2 interface to the External eNodeB that has the SCell (ESCell). This enables use of carrier aggregation in scenarios where the cells are not deployed on the same eNodeB.

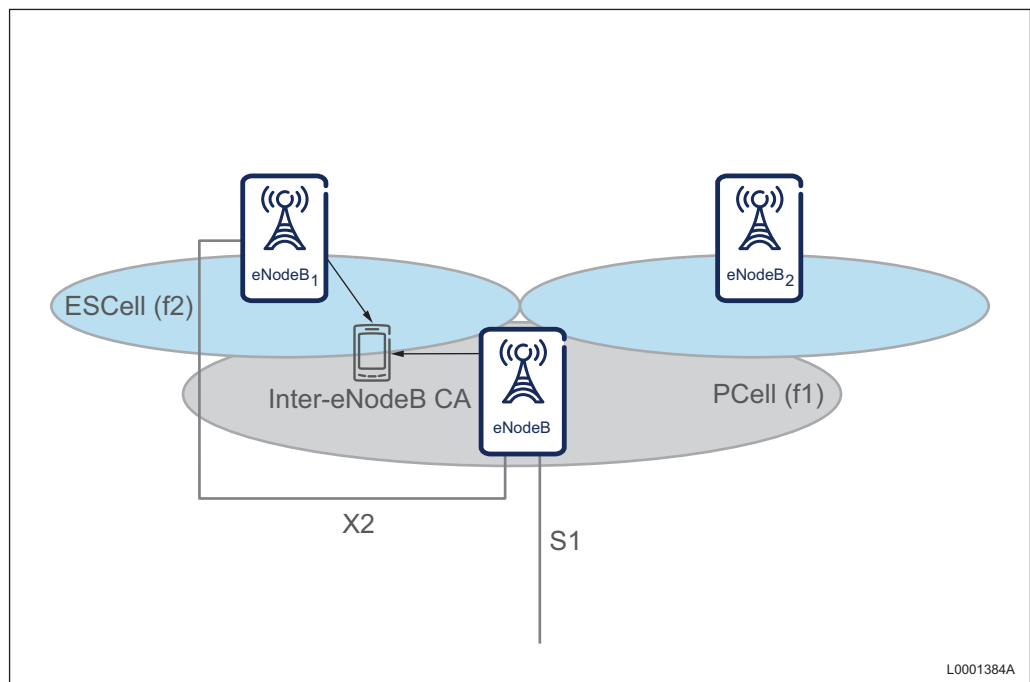
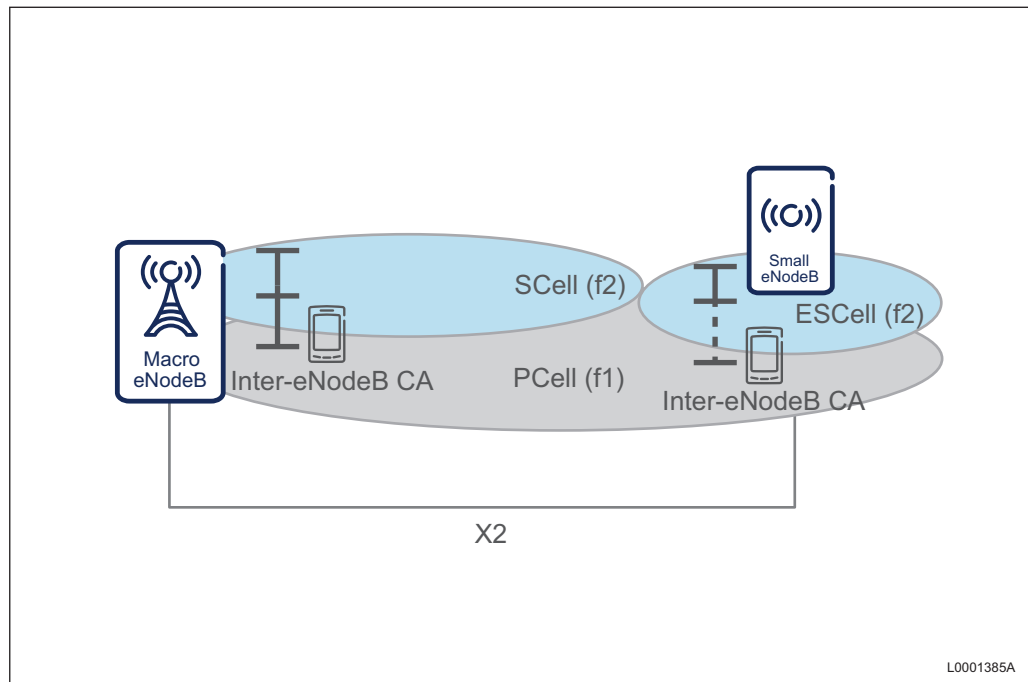


Figure 1 Example of UE Resource Use by Cells Belonging to Different eNodeBs

In another typical scenario, a small E-Cell belonging to a small eNodeB is deployed in the coverage area of a macro P-Cell (typically fully overlapping) in addition to an existing S-Cell. In this case it is possible to perform Inter-eNodeB Carrier Aggregation so as to utilize bandwidth from both the small E-Cell and macro P-Cell simultaneously for subscribers that are within the coverage of the small E-Cell. For subscribers that are within the coverage of the P-Cell and S-Cell, Inter-eNodeB Carrier Aggregation can be performed as if the cell were local.



In another typical scenario, a small ESCell belonging to a small eNodeB is deployed in the coverage area of a macro PCell (typically fully overlapping) in addition to an existing secondary cell (SCell). In this case it is possible to perform Inter-eNodeB Carrier Aggregation so as to utilize bandwidth from both the small ESCell and macro PCell simultaneously for subscribers that are within the coverage of the small ESCell. For subscribers that are within the coverage of the PCell and SCell, Inter-eNodeB Carrier Aggregation can be performed as if the cell were local.

Figure 2 Example with a Small Cell Deployed in the Coverage Area of a Macro Cell

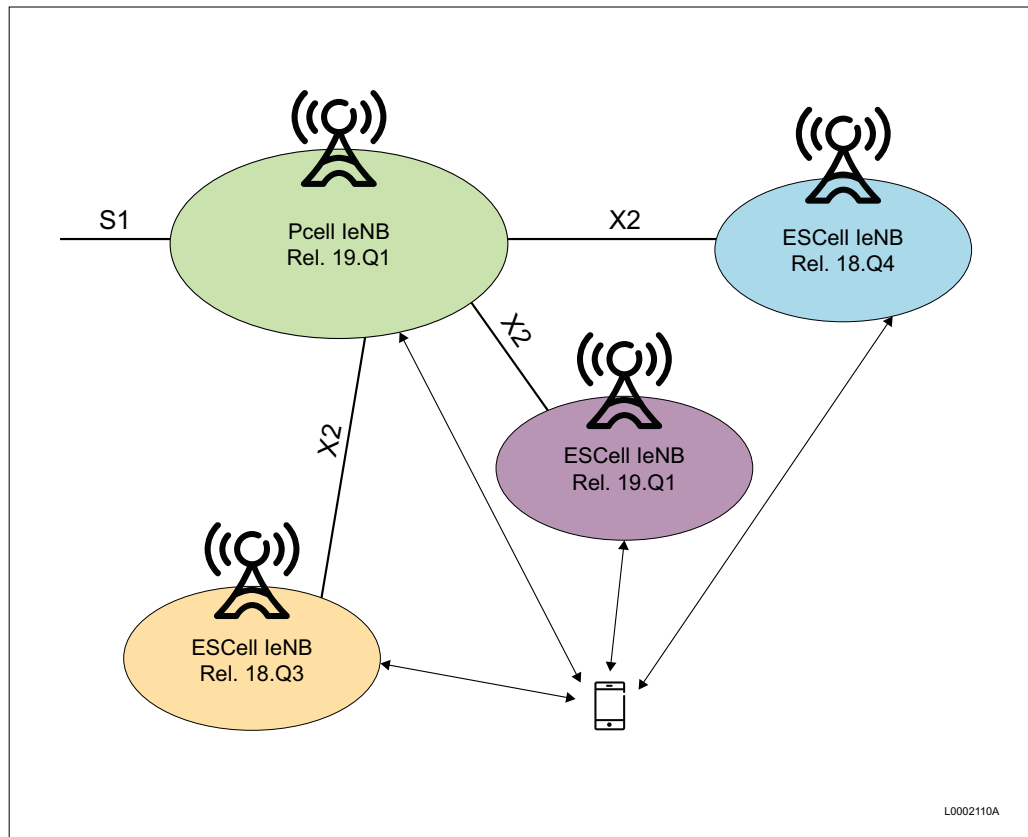


Figure 3 Inter-eNodeB Carrier Aggregation between

The Inter-eNodeB Carrier Aggregation feature is capable of operating across different software versions. In other words the feature makes it possible to have active inter-eNodeB tunnels with different software versions. Figure 3 shows a scenario where a UE employs DL transmission resources from cells belonging to different eNodeBs by means of Inter-eNodeB Carrier Aggregation. In this specific example, the PCell and one ESCell are running software release 19.Q1 whereas the other two ESCells are running software releases 18.Q3 and 18.Q4 respectively. As a result Software Release Interoperability for Inter-eNodeB Carrier Aggregation enhancement, the DL transmission to the UE is seamlessly integrated regardless of the different software releases among eNodeBs. At minimum, the feature is backwards compatible with up to three major software releases. For more information regarding software release interoperability, see the Release Notes.

3.2 Supported Bandwidths for Inter-eNodeB Carrier Aggregation

The Inter-eNodeB Carrier Aggregation Feature supports the following bandwidths:



- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

3.3 Process Steps

3.3.1 Inter-eNodeB Tunnel Setup

For the purpose of coordinating scheduling between cells and for relaying transport blocks between the PCells and ECells, proprietary tunnels are automatically set up between eNodeBs hosting the PCell and ECells over the X2 interface.

The tunnels are automatically set up upon the initial activation of the Inter-eNodeB Carrier Aggregation feature provided that at least one cell has the state UNLOCKED or ENABLED on the same LBMId as the tunnel.

Note: Subsequent activations of the feature after the initial activation do not automatically set up the tunnels. In this case, to set up the tunnels again, it is necessary to set the `TermPointToENB.administrativeState` attribute under the desired `ExternalENodeBFunction` MO instance to LOCKED and then to UNLOCKED.

As a result of a successful tunnel creation, a `TermPointToLbm` MO instance is created under `TermPointToENB`.

3.3.2 Cleaning up Inter-eNodeB Tunnels

When the last cell relation using a tunnel becomes inoperable, the tunnel is removed automatically and the corresponding `TermPointToLbm` MO instance is deleted. Also tunnels can be removed manually by locking the `TermPointToENB` MO. For tunnel removal, at least one cell has to have the state UNLOCKED or ENABLED on the same LBMId as the tunnel. After unlocking the `TermPointToENB` MO, if the conditions for Inter-eNodeB Carrier Aggregation are met, the tunnels are created again.

Note:

Tunnels are not removed automatically by deactivating the feature. To permanently remove the tunnels, lock and then unlock all `TermPointToENB` MO instances representing the applicable X2 interfaces.



3.3.3 Dynamic External Secondary Cell Selection

To achieve dynamic selection of an ESCell for carrier aggregation, the `EUTranCellRelation.esCellCaConfigurationAvail` attribute must be set to `ENABLED`. This attribute is automatically enabled only if the following conditions are met:

- The `ExternalEUTranCellFDD.remoteCellState` or `ExternalEUTranCellTDD.remoteCellState` attribute of a related MO instance is set to `ENABLED`.
- An X2 tunnel is set up between the two eNodeBs.
- The Inter-eNodeB Carrier Aggregation feature is activated.
- The Carrier Aggregation FDD-TDD feature must be activated.

Note: The `EUTranCellRelation.esCellCaConfigurationAvail` attribute is used to identify that configured ESCell is available for the Carrier Aggregation-Aware IFLB feature. For more information, see document `Carrier Aggregation-Aware IFLB`.

3.3.4 Secondary Cell Configuration and Deconfiguration

The Secondary Cell Configuration and Deconfiguration algorithm does not distinguish between local or external SCells. This is described in `Dynamic SCell Selection for Carrier Aggregation and 3CC DL Carrier Aggregation Extension`.

3.3.5 Secondary Cell Activation and Deactivation

The SCell activation and deactivation algorithm is the same as for local or external SCells described in `Dynamic SCell Selection for Carrier Aggregation and 3CC DL Carrier Aggregation Extension`.

The Inter-eNodeB Carrier Aggregation, LTE Broadcast, and Autoconfiguration of LTE Broadcast Subframes features can be used together. However, UEs with ESCell configured at the time of any eMBMS service change in this cell will have their ESCell deactivated for the duration of current UEs connection.



4 Network Impact of Inter-eNodeB Carrier Aggregation

Capacity and Performance

UEs using External SCells consume similar resources as UEs using local cells. PCells get additional overhead when forwarding transport blocks over the X2 interface to External eNodeBs.

Note: As a limitation, the DU-based throughput can degrade significantly, if the following settings and functions are used together:

- Inter-eNodeB Carrier Aggregation is used together with 256-QAM DL in a 4 layer transmission mode.
- The PCell is on a Baseband-based node.
- The SCell is on DU-based node.

4.1 LTE Backhaul Network Characteristics

The following aspects must be considered before attempting to deploy this feature:

Considerations about congestion

Inter-eNodeB Carrier Aggregation requires a congestion-free transport path between the primary eNodeB and secondary eNodeB. Congestion typically leads to an increase in delay, delay variation, and possibly packet loss.

Considerations about packet loss

Inter-eNodeB Carrier Aggregation user data traffic destined to the External Cell uses Backhaul Transport Network resources, increasing resource consumption over the X2 path between the PCell and external SCell eNodeBs. User packets lost in the X2 backhaul network result in wasted radio resources and can result in retransmission by the PCell eNodeB over the backhaul network, further increasing the network traffic.

Control traffic for Inter-eNodeB Carrier Aggregation requires a congestion-free, low-loss backhaul transport network. Control packets that are lost result in an order of magnitude loss (waste) in radio resources.



Considerations about packet reordering

Inter-eNodeB Carrier Aggregation requires a transport path between the primary eNodeB and secondary eNodeB that does not introduce packet re-ordering. If re-ordering occurs, it will have the same effect as packet loss.

Considerations about Inter-eNodeB delay

Inter-eNodeB Carrier Aggregation requires a relatively low-delay transport path between the primary eNodeB and secondary eNodeB. Recommended maximum delay is less than 9 ms. Packets experiencing a delay of 9 ms or more are discarded.

Delay Variation in the LTE backhaul network

Inter-eNodeB Carrier Aggregation requires a relatively low delay variation transport path between the primary eNodeB and secondary eNodeB. The maximum acceptable delay variation is 0.5 milliseconds for each second.

Considerations about detecting failures in the transport network

For optimal detection of transport network failures when Inter-eNodeB Carrier Aggregation is activated, set the following MO attributes to a 2 seconds value:

DU Radio Node:	Sctp.heartbeatInterval
Baseband Radio Node:	SctpProfile.heartbeatInterval



5 Parameters of Inter-eNodeB Carrier Aggregation

Feature Configuration Parameters

- `ENodeBFunction.interEnbCaTunnelDscp`
- `ENodeBFunction.timePhaseMaxDeviationIeNbCa`
- `ENodeBFunction.interNodalProtVersions`
- `EUtranCellRelation.sCellCandidate`
- `EUtranCellRelation.esCellCaConfigurationAvail`
- `ExternalEUtranCellFDD.lbmId`
- `ExternalEUtranCellFDD.remoteCellState`
- `ExternalEUtranCellFDD.uniqueCellId`
- `GtpuApplicationTunnel.gtpuApplicationTunnelId`
- `TermPointToENB.interEnbSwCompatibilityState`
- `TermPointToENB.interEnbCaProtVerActive`
- `TermPointToLbm.termPointToLbmId`
- `TermPointToLbm.operationalState`

Affected Parameters

The implementation of this feature affects no parameters.



6 Performance of Inter-eNodeB Carrier Aggregation

KPIs

The following KPIs are associated with this feature:

- Average DL PDCP UE Throughput
- Total DL PDCP UE Throughput
- Average DL PDCP UE DRB Throughput per QCI
- Total DL PDCP UE DRB Throughput per QCI
- Average DL PDCP UE Throughput for Carrier Aggregation
- Average DL UE Latency
- Average DL UE PDCP DRB latency per QCI

Counters

The following counters are associated with this feature:

- ExternalENodeBFunction.pmEenbPktTransDlCa
- ExternalENodeBFunction.pmEenbPktRecDlCa
- ExternalENodeBFunction.pmEenbPktLostDlCa
- ExternalENodeBFunction.pmEenbPktDiscDlCa
- ExternalENodeBFunction.pmEenbPktLateDlCa
- EUtranCellFDD.pmCaActDlIeNbSum
- EUtranCellTDD.pmCaActDlIeNbSum
- EUtranCellFDD.pmCaScheduledDlIeNbSum
- EUtranCellTDD.pmCaScheduledDlIeNbSum
- EUtranCellFDD.pmRadioThpVolTxDlSCell
- EUtranCellTDD.pmRadioThpVolTxDlSCell



- EUTRANCellFDD.pmRadioThpVolD1SCellExt
- EUTRANCellTDD.pmRadioThpVolD1SCellExt

Events

Table 2 Events

Event	Event Parameter
EVENT_PARAM_ESCELL_RADIOTHP_VOL_DL_SCELL_EXT	pmRadioThpVolD1SCellExt
EVENT_PARAM_ESCELL_RADIOTHP_VOL_TX_DL_SCELL_EXT	pmRadioThpVolTxD1SCellExt
EVENT_PARAM_ESCELL_RADIOTHP_VOL_TX_DL_SCELL	pmRadioThpVolTxD1SCell
EVENT_PARAM_NO_ESCELL_CONFIGURED	pmCaConfiguredD1IeNbSum
EVENT_PARAM_ONE_ESCELL_CONFIGURED	pmCaConfiguredD1IeNbSum
EVENT_PARAM_TWO_ESCELL_CONFIGURED	pmCaConfiguredD1IeNbSum
EVENT_PARAM_THREE_ESCELL_CONFIGURED	pmCaConfiguredD1IeNbSum
EVENT_PARAM_FOUR_ESCELL_CONFIGURED	pmCaConfiguredD1IeNbSum
EVENT_PARAM_CA_ACT_DL_IENB_0	pmCaActD1IeNbSum
EVENT_PARAM_CA_ACT_DL_IENB_1	pmCaActD1IeNbSum
EVENT_PARAM_CA_ACT_DL_IENB_2	pmCaActD1IeNbSum
EVENT_PARAM_CA_ACT_DL_IENB_3	pmCaActD1IeNbSum
EVENT_PARAM_CA_ACT_DL_IENB_4	pmCaActD1IeNbSum
EVENT_PARAM_CA_SCHEDULED_DL_IENB_0	pmCaScheduledD1IeNbSum
EVENT_PARAM_CA_SCHEDULED_DL_IENB_1	pmCaScheduledD1IeNbSum
EVENT_PARAM_CA_SCHEDULED_DL_IENB_2	pmCaScheduledD1IeNbSum
EVENT_PARAM_CA_SCHEDULED_DL_IENB_3	pmCaScheduledD1IeNbSum
EVENT_PARAM_CA_SCHEDULED_DL_IENB_4	pmCaScheduledD1IeNbSum
EVENT_PARAM_PER_IENB_X2_PACKET_TX	pmEenbPktTransD1Ca
EVENT_PARAM_PER_IENB_X2_PACKET_RX	pmEenbPktRecD1Ca
EVENT_PARAM_PER_IENB_X2_PACKET_RX_LOST	pmEenbPktLostD1Ca
EVENT_PARAM_PER_IENB_X2_PACKET_RX_000	pmEenbPktDiscD1Ca
EVENT_PARAM_PER_IENB_X2_PACKET_RX_LATE	pmEenbPktLateD1Ca



7 Activate Inter-eNodeB Carrier Aggregation

Prerequisites

- The license key is installed in the node.
- CCTR is activated at least for a week. This ensures that troubleshooting data is available if something goes wrong.
- Only FDD cell is allowed to be configured as PCell.
- The Carrier Aggregation feature is activated on both eNodeBs.
- The eNodeBs configured for Inter-eNodeB Carrier Aggregation must be time and phase synchronized using either GNSS (GPS) or IEEE 1588 Time and Phase Synchronization. The clock source is configured as described in [Synchronization and Fallback from Time and Phase Synchronization](#).

Note: The Inter-eNodeB Carrier Aggregation feature remains enabled regardless of any time and phase synchronization availability or deviation. If the time and phase synchronization deviation exceeds the limit as defined in [FDD and TDD on same eNodeB](#) feature, TDD ECells are disabled and not available for Inter-eNodeB Carrier Aggregation.

- Attribute `TermPointToENB.interEnbSwCompatibilityState` is set to `COMPATIBLE` indicating that the version check is passed. There are no Inter-eNodeB Carrier Aggregation for any two eNodeBs running `INCOMPATIBLE` versions.
- Attribute `EUtranCellRelation.sCellCandidate` is set to `ALLOWED` for the intended ECell candidate.
- Attribute `ExternalEUtranCellFDD.remoteCellState` is set to `ENABLED`.

Steps

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

Node Type	License Control MO
DU-based	<code>OptionalFeatureLicense=InterENBCarrierAggregation</code>
Baseband-based Node	<code>FeatureState=CXC4011983</code>



After This Task

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



8 Deactivate Inter-eNodeB Carrier Aggregation

Prerequisites

CCTR is activated at least for a week. This ensures that troubleshooting data is 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-based	<code>OptionalFeatureLicense=InterENBCarrierAggregation</code>
Baseband-based	<code>FeatureState=CXC4011983</code>

After This Task

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



Appendix A: Feature Change History

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

Appendix A.a: TDD as ECell and Inter-eNB Observability Enhancements

Access Type: LTE
 Hardware Platform: All
 Licensing: Inter-eNodeB Carrier Aggregation, FAJ 121 4469

It is now possible for External Secondary Cell (ECell) to be a TDD cell.

Also introducing PM counters to replace previously temporary counters, used to monitor X2 traffic packet statistics, and adding new ENIQ counters for ECell statistics.

Capacity and Performance

No impact.

Operation

Temporary counters have been replaced as follows:

Table 3 Inter-eNodeB pmZtemporary Replacements

Temporary Name	New Name
pmZtemporary153	pmEenbPktTransDICa
pmZtemporary154	pmEenbPktRecDICa
pmZtemporary155	pmEenbPktLostDICa
pmZtemporary156	pmEenbPktDiscDICa
pmZtemporary157	pmEenbPktLateDICa

The following new ENIQ counters are added for ECell-specific configuration and deconfiguration statistics:

Table 4 Inter-eNodeB ENIQ Counters

Counter Name	Description
pmCaConfiguredAtt	The total number of SCell configuration attempts.



Counter Name	Description
pmCaConfiguredSucc	The total number of SCell configuration successes.
pmCaDeconfigured	The total number of SCell deconfigurations.

Interfaces

No impact.

Other Network Elements

No impact.

Appendix A.b: Inter-eNB CA Usability Enhancements

Access Type: LTE

Hardware Platform: All

Licensing: Inter-eNodeB Carrier Aggregation, FAJ 121 4469

The enhancement includes the following changes:

GTP-U Unused Tunnels Removal

It is possible to automatically or non-intrusively remove inter-Baseband tunnels that are no longer used. This increases the number of potential Inter-eNB relations as the number of simultaneously supported tunnels is finite.

eMBMS Restriction Removal

With this change, cells that function as ESCells can be configured with eMBMS subframes.

Interworking between Inter-eNB CA and Elastic RAN

Inter-eNB Carrier Aggregation and Elastic RAN cannot be operated at the same time in a Baseband Radio Node (Elastic RAN is not available in DU Radio Nodes). If both features are turned ON, the system operates the feature that was turned ON first. The `featureState` of the other feature is ignored and has no effect.

Capacity and Performance

No impact.

Operation

No impact.



Interfaces

No impact.

Other Network Elements

No impact.

Appendix A.c: 18.Q3: Software Release Interoperability for Inter-eNodeB Carrier Aggregation

This enhancement provides support for carrier aggregation between eNodeBs across multiple software releases.

Feature Name:	Inter-eNodeB Carrier Aggregation
Feature Identity:	FAJ 121 4469 R3
Value Package Name:	Advanced Carrier Aggregation
Value Package Identity:	FAJ 801 0564 R5
Node Type:	Baseband Radio Node
Access Type:	LTE

This enhancement enables Inter-eNodeB Carrier Aggregation to operate across different software versions. It provides the ability to have active inter-eNodeB tunnels with different software versions.

Capacity and Performance

Performance can vary depending on the releases involved, so it is recommended for users to inter-operate with short release time gap loads. Software interoperability is supported with at least three previous software versions. For more information regarding supported software versions and interoperability type, see the Release Notes.

Operation

This enhancement introduces the following new attributes:

- `TermPointToENB.interEnbCaProtVerActive`
- `ENodeBFunction.interNodalProtVersions`

Interfaces

- No impact.

Hardware

No special hardware requirements.



Other Network Elements

No impact.