ERICSSON

3CC DL Carrier Aggregation Extension

Feature Description

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1 3CC DL Carrier Aggregation Extension Overview

The 3CC DL Carrier Aggregation Extension feature can transmit data to a single UE on three carriers simultaneously. This leads to increased downlink speed and improved end-user experience.

Access type:	LTE
Feature Identity:	FAJ 121 3084
Value Package Name:	Carrier Aggregation
Value Package Identity:	FAJ 801 0405
Node Type:	Baseband Radio Node
	DU Radio Node
Licensing:	Licensed feature. One license per radio.

Summary

The benefit of the 3CC DL Carrier Aggregation Extension feature is the capability to transmit data to a single UE on three carriers simultaneously.

In addition, support is added for the new band combination signaling according to 3GPP TS 36.331. The new band combination signaling enables UEs supporting more than 128 band combinations to provide all relevant band combinations to the eNodeB. The UE only reports carrier aggregation band combinations for specific bands requested by the eNodeB. This is instead of reporting all the supported carrier aggregation band combinations.

By supporting a higher number of MIMO layers, a higher spectrum efficiency with higher peak downlink throughput can be achieved.

The maximum number of MIMO layers can be configured for the UE up to the following:

— Corresponding capacity and peak rate limitations of the eNodeB DU platform.

— Corresponding capacity and peak rate limitations of the UE capabilities.

Note: To reach peak rate limitations, the UE has to support the system configurations shown in Table 1.

The main benefits of the feature are the following:

— Increased downlink speed across the coverage area.

— More efficient use of scattered spectrum, making it possible to combine three chunks of bandwidth instead of only two.

— Improved end-user experience by achieving peak throughput based on system configurations, number of component carriers and TX layers in unit of Mbps at the physical layer. See details in Table 1.

— For TDD only: Provides clearer information for HARQ-ACK feedback information which leads to lower BLER and more stable and higher downlink throughput.

— A higher number of MIMO layers is also supported on both DUS31 and DUS41. The peak throughput depends on the existing DUS41 capabilities.

Table 1 Peak Throughput Based on System Configurations

	Number of TX Layers	64-QAM			256-QAM		
Number of Component Carriers		1CC	2CC	3CC	1CC	2CC	3CC
FDD	2	150	300	450	195	391	587
	4	300	600	899	391	783	1174
TDD UL/DL Configuration 2 (SSF7)	2	110	220	330	143	285	428
	4	213	426	N/A	286	560	700
TDD UL/DL Configuration 2 (SSF6)	2	108	216	324	139	279	418
	4	208	416	N/A	279	546	700

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*

— *3GPP TS 36.101*

— Dynamic SCell Selection for Carrier Aggregation

— 4x4 Quad Antenna Downlink Performance Package

— 256-QAM Downlink

2 3CC DL Carrier Aggregation Extension Dependencies

The 3CC DL Carrier Aggregation Extension feature has dependencies with other features having an impact on carrier aggregation or downlink capabilities.

Features

Table 2 Feature Dependencies

Feature	Relationship	Description
Carrier Aggregation (FAJ 121 3046)	Prerequisite	The 3CC DL Carrier Aggregation Extension feature requires the Carrier Aggregation (CA) feature to be active. The Carrier Aggregation feature provides the capability to transmit data to a single UE on two downlink bands simultaneously.
Dynamic SCell Selection for Carrier Aggregation (FAJ 121 3063)	Prerequisite	The 3CC DL Carrier Aggregation Extension feature requires the Dynamic SCell Selection for Carrier Aggregation feature to be active. 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 deconfigured.
Scheduler	Related	The Scheduler feature distributes radio interface and RBS resources between various users, and controls data flows requesting transmission in the cell. It gives priority to robust system control signaling and retransmissions over user data. It enables users to be multiplexed and scheduled in time and frequency. Spectral and hardware resources are used efficiently to optimize user throughput and cell capacity.
4x4 Quad Antenna Downlink Performance Package (FAJ 121 3076)	Related	The 4×4 Quad Antenna Downlink Performance Package feature provides support for four transmit antennas. The result is improvements to downlink coverage and capacity, especially in high-quality channel conditions.
256-QAM Downlink (FAJ 121 4422)	Related	The 256-QAM Downlink feature is a 3GPP modulation that increases the downlink throughput up to 30%. The system supports dynamic switching between 64-QAM and 256-QAM based on measured quality.
VoLTE Optimized Carrier Aggregation (FAJ 801 0444)	Related	The VoLTE Optimized Carrier Aggregation provides functions to improve VoLTE retainability during VoLTE calls while UE runs on Carrier Aggregation.

Hardware

No specific hardware requirement is expected for this feature.

Limitations

No limitations for this feature.

Network Requirements

No network requirements for this feature.

3 3CC DL Carrier Aggregation Extension Feature Operation

The 3CC DL Carrier Aggregation Extension feature enables the UE to use up to three downlink component carriers and one uplink component carrier at the same time. This alters the behavior of dynamic SCell selection and also impacts the activation and deactivation of SCells.

Feature Operation Sequence Diagram

With the Carrier Aggregation feature, a UE uses resources from multiple cells. With 3CC DL Carrier Aggregation Extension, the UE uses up to three downlink component carriers (CC) and one uplink component carrier at the same time.

Note: In case VoLTE Optimized CA feature is enabled on Carrier Aggregation, by setting `sCellHandlingAtVolteCall` to value 2, the selection, configuration and de-configuration of DL SCells is disabled and UL component carriers are de-configured, during VoLTE calls.

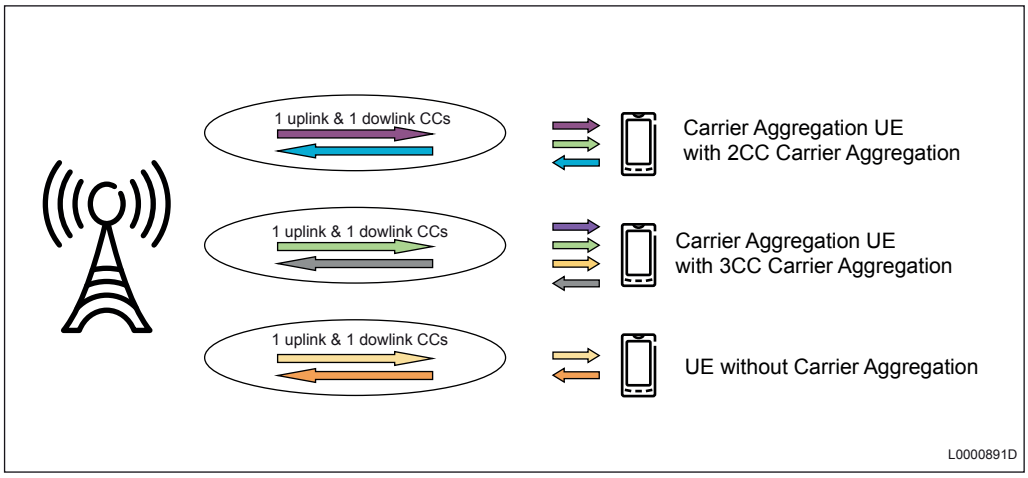

Figure 1 3CC DL Carrier Aggregation Extension

Process Steps of Dynamic Secondary Cell Configuration and Deconfiguration

When the 3CC DL Carrier Aggregation Extension feature license is enabled, dynamic SCell selection behaves as follows:

— A UE is evaluated for Carrier Aggregation at initial attachment, re-establishment, or incoming handover.

— Both the first and the second SCell are configured using blind-selection. The initial selection and configuration of SCells depends on the `CarrierAggregationFunction.sCellSelectionMode` attribute:

CarrierAggregationFunction.sCellSelectionMode Value	Configuration
ACK_SEQUENTIAL_SCell_SELECTION	SCells are selected and configured in sequence. A1 is configured per SCell to confirm the coverage. The second SCell is only selected once the first SCell has been concluded to be in coverage.
ACK_SIMULTANEOUS_SCell_SELECTION	Two SCells are selected and configured simultaneously. A1 is configured per SCell to confirm the coverage.
UN_ACK_SIMULTANEOUS_SCell_SELECTION	Two SCells are selected and configured simultaneously. Since this mode assumes SCells have good coverage, no A1 is configured to reduce RRC overhead.

Note: In simultaneous SCell selection modes, the SCell uplink carrier aggregation evaluation is made by means of the `CarrierAggregationFunction.caPreference` attribute. For more information, see Uplink Carrier Aggregation.

— For the initial SCell selection of the first and second SCell, SCell selection priority can be used to determine which SCell candidate, within a given frequency, is preferred.

  - The prioritization is enabled by setting the `EUtranCellRelation.coverageIndicator` attribute to indicate cell overlap. The priority is then based on what type of overlap the cells have. The priority order is as follows where the default value `0` means no prioritization is applied:

    — `1` (`COVERS`)

    — `2` (`OVERLAP`)

    — `3` (`CONTAINED_IN`)

    — `0` (`NONE`)

  - To use the `EUtranCellRelation.coverageIndicator` attribute with value 1 (`COVERS`) for SCell selection prioritization without also enabling blind handover, blind handover must be manually disabled. Otherwise it becomes enabled for the cells where the `EUtranCellRelation.coverageIndicator` attribute is set to value 1 (`COVERS`) . The disabling is done by setting the `EUtranCellFDD.covTriggerdBlindHoAllowed` or `EUtranCellTDD.covTriggerdBlindHoAllowed` attribute to `FALSE`.

— The maximum TX layers that both the eNodeB and UE can support are reconfigured on each component carrier. If the maximum TX layers are changed on a component carrier due to another SCell being added or removed, they are reconfigured at the same time along with SCell reconfiguration.

— Both SCells are implicitly deconfigured upon release of the UE.

— Both SCells are deconfigured at incoming handover. However, the UE is configured with one or more SCells in the target cell following the same procedure as at initial access.

— An SCell is deconfigured when the UE has poor coverage (A2) or there is interference (A6) from another cell. Also, it is triggered separately for the first and second SCell.

— An SCell is deconfigured at SCell change (A6) and an SCell candidate cell with stronger signal is configured as the new SCell. Also, it is triggered separately for the first and second SCell.

For more details, see Dynamic SCell Selection for Carrier Aggregation.

Process Steps of Dynamic Secondary Cell Activation and Deactivation

The SCell activation and deactivation triggers are the following:

— Need based:

  • Activate or deactivate, based on buffer occupancy.

— Coverage based:

  • Deactivate, based on poor SCell coverage.

— Prohibit timer to avoid ping-pong effect.

— SCell is deactivated as a result of cell lock or eMBMS start or stop.

— When both SCells are configured, the SCell with highest SCell index is deactivated based on poor PCell Uplink Channel condition.

— Activation based on buffer occupancy triggers activation of one or two SCells:

  • The SCell which has the lowest SCell index is activated first.

— Deactivation, based on buffer occupancy triggers deactivation of one SCell at a time:

  • The SCell which provides the lowest potential throughput is deactivated, or

  • The SCell which is located at a different DU from PCell is deactivated.

— Potential throughput:

  • Calculated based on bandwidth, number of code words and channel condition. These are only used for deactivation decision as CQI is only reported for activated SCells.

For more details, see Carrier Aggregation.

4 3CC DL Carrier Aggregation Extension Network Impact

With the feature allowing up to two configured SCells per UE, the loading limit is reached by fewer UEs. By stopping SCell configuration before the limit is reached, carrier aggregation UEs cannot block new UEs from attaching to the system, therefore the system capacity is increased.

Capacity and Performance

A UE configured with an SCell consumes more resources (one for the PCell and one for each configured SCell) than a UE having only a PCell. However, it is still counted as one connected UE from a connected UE license perspective. As the 3CC DL Carrier Aggregation Extension feature allows up to two configured SCells per UE, the loading limit is reached by fewer UEs than previously.

Existing mechanisms with the right configuration ensure that SCell configuration is stopped before the loading limit is reached. By doing this, carrier aggregation UEs are prevented from blocking attachment of new UEs into the system. For more information, see Carrier Aggregation.

Additional resources are required on PUCCH for transmission of SCell downlink HARQ ACK. For more information, see Control Channel Dimensioning.

Mobility

The feature has no impact on mobility since mobility is based on PCell coverage.

Other Network Elements

The UE must support 3CC DL Carrier Aggregation Extension. To benefit from the new band combination signaling according to 3GPP TS 36.331, the UE needs to have the corresponding support. If UE supports higher order modulation or 4 layer TX, or both, higher throughput can be achieved.

5 3CC DL Carrier Aggregation Extension Parameters

Feature Configuration Parameters

`CarrierAggregationFunction.waitForAdditionalSCellOpportunity`

Affected Parameters

The implementation of this feature affects no parameters.

6 3CC DL Carrier Aggregation Extension Performance

The 3CC DL Carrier Aggregation Extension feature is associated with performance management entities measuring downlink and uplink capabilites.

KPIs

The following KPIs are associated with the feature:

— Downlink Latency, Downlink Latency per QC

— Average downlink PDCP UE Throughput for Carrier Aggregation

— Average uplink PDCP UE Throughput for Carrier Aggregation

— Downlink PDCP UE Throughput Distribution

— Uplink PDCP UE Throughput Distribution

— Mean downlink UE PDCP Throughput

— Mean uplink UE PDCP Throughput

Counters

The following counters are associated with the 3CC DL Carrier Aggregation Extension feature:

— `EUtranCellFDD.pmUeCategoryDistr`

— `EUtranCellTDD.pmUeCategoryDistr`

— `EUtranCellFDD.pmUeCategoryDlUlCombDistr`

— `EUtranCellTDD.pmUeCategoryDlUlCombDistr`

For a full list with detailed information about counters, see the list files in the *List Files* library folder.

Events

Table 3 Events

Event	Event Parameter
`INTERNAL_EVENT_UE_CAPABILITY`	`EVENT_PARAM_UE_CAP_CATEGORY`

Event	Event Parameter
INTERNAL_PER_CELL_TRAFFIC_REPORT	EVENT_PARAM_CA_PF3_ASSIGNED_1..12
INTERNAL_PER_UETR_CELL_TRAFFIC_REPORT	EVENT_PARAM_CA_PF3_ASSIGNED_1..12

For a full list with detailed information about PM events, see the list files in the *List Files* library folder.

7 Activate 3CC DL Carrier Aggregation Extension

Prerequisites

— The prerequisite features of the 3CC DL Carrier Aggregation Extension feature are activated.

— The cell must be an SCell candidate by setting the `EUtranCellRelation.sCellCandidate` attribute to `ALLOWED`.

— 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.

Steps

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

Node Type	License Control MO
DU Radio Node	`OptionalFeatureLicense=ThreeDlCarrierAggregation`
Baseband-based Node	`FeatureState=CXC4011714`

After This Task

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

8 Deactivate 3CC DL Carrier Aggregation Extension

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

Node Type	License Control MO
DU Radio Node	`OptionalFeatureLicense=ThreeDlCarrierAggregation`
Baseband-based Node	`FeatureState=CXC4011714`

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: 1.2 Gbps DL Enhancement for 3CC DL Carrier Aggregation Extension

Access Type:	LTE and Multi-Standard RBS
Hardware Platform:	All Baseband products
Licensing:	3CC DL Carrier Aggregation Extension, FAJ 121 3084
Introduced in:	17.Q4

The feature improvement enables the 3CC DL Carrier Aggregation Extension to reach a higher spectrum efficiency with a peak downlink throughput of near 1.2 Gbps by using 12 MIMO layers.

Capacity and Performance

The UE downlink throughput is expected to increase for UEs that are in very good channel condition.

Operation

Table 4 Updated pmCounters

pmCounter	Description
`pmUeCategoryDlUlCombDistr`	Distribution of supported combinations for UE capability parameters `ue-CategoryUL` and `ue-CategoryDL` for established UE contexts, according to 3GPP TS 36.306 Table 4.1A-6.
`pmUeThpDlDistr`	Distribution of the downlink UE throughput. One downlink UE throughput sample is obtained by dividing the total volume (PDCP SDU) on Data Radio Bearers per UE, that is transferred (unacknowledged mode and acknowledged mode) in the downlink direction, with a time interval applicable to the volume measurement.
`pmUeThp2DlDistr`	Distribution of the downlink UE throughput. One downlink UE throughput sample is obtained by dividing the total volume (PDCP SDU) on Data Radio Bearers per UE, that is transferred (unacknowledged mode and acknowledged mode) in the downlink direction,

pmCounter	Description
	with a time interval applicable to the volume measurement.

The following pmEvents are also updated:

— INTERNAL_EVENT_UE_CAPABILITY

— LOCAL_PER_BB_UE_ON_CELL_LEVEL_EVENT

— LOCAL_PER_BB_UE_ON_CELL_LEVEL_EVENT

— LOCAL_PER_BB_UE_ON_CELL_LEVEL_EVENT

— INTERNAL_TESTEVENT_BB_RB

— INTERNAL_PROC_ERAB_SETUP

— INTERNAL_PROC_ERAB_RELEASE

— NTERNAL_PER_RADIO_UE_MEASUREMENT

— INTERNAL_PROC_HO_EXEC_S1_OUT

— INTERNAL_PER_UE_TRAFFIC_REP

— INTERNAL_PER_UE_RB_TRAFFIC_REP

— INTERNAL_PER_UE_LCG_TRAFFIC_REP

— INTERNAL_PROC_UE_CTXT_RELEASE

— INTERNAL_PROC_INITIAL_CTXT_SETUP

— INTERNAL_EVENT_UE_MOBILITY_EVAL

— INTERNAL_PER_UETR_UE_TRAFFIC_REP

— INTERNAL_PER_UETR_UE_RB_TRAFFIC_REP

— INTERNAL_PER_UETR_UE_LCG_TRAFFIC_REP

Interfaces

No impact.

Other Network Elements

To fully benefit from the change, the node requires support from the following network elements:

— 4x4 MIMO on all carriers and 256 QAM for 3CC DL Carrier Aggregation Extension

— UE needs to support downlink category 18

Limitations

3/4/5 CC with 12 layers MIMO is available in 17.Q4 GA release with the following limitations:

— System verification of performance has not been completed due to late availability of UE that supports 12 layers MIMO.

— IODT verification of 5CC with 12 layers MIMO has not been performed since commercial support for UE capable of 5CC with 12 layers MIMO is not available.

Appendix A.b: Cross DU Support for 12 Layers MIMO

Access Type:	LTE
Hardware Platform:	DUS 31 and DUS 41
Licensing:	3CC DL Carrier Aggregation Extension, FAJ 121 3084
	4CC DL Carrier Aggregation Extension, FAJ 121 4466
Introduced in:	18.Q1

With this enhancement, cross DU for 12 MIMO layers is supported with features 3CC DL Carrier Aggregation Extension and 4CC DL Carrier Aggregation Extension. This means that operation with 12 MIMO layers is verified on both DUS 31 and DUS 41.

Capacity and Performance

The peak downlink throughput depends on the existing capabilities of DUS 41.

Operation

No impact.

Interfaces

No impact.

Other Network Elements

No impact.