ERICSSON

4CC DL Carrier Aggregation Extension

Feature Description

277/221 04-LZA 701 6014/1 Uen AD4B

Contents

1 4CC DL Carrier Aggregation Extension Overview

The 4CC DL Carrier Aggregation Extension feature adds the capability to transmit downlink data to a UE on four carriers simultaneously

Access Type:	LTE
Feature Identity:	FAJ 121 4466
Value Package Name:	Carrier Aggregation
Value Package Identity:	FAJ 801 0405
Node Type:	Baseband Radio Node
	DU Radio Node
Licensing:	Licensed feature. One license required for each node.

Summary

The main benefits of the feature are the following:

— Increased downlink speed across the coverage area

— More efficient use of scattered spectrum, making possible to combine four chunks of bandwidth for one UE

— Improved end-user experience by achieving peak throughput based on system configurations, number of component carriers and TX layers

The feature provides support for the new band combination signaling according to 3GPP TS 36.331 and TS 36.101. 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, instead of reporting all the supported carrier aggregation band combinations.

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

The maximum number of MIMO layers that can be configured for the UE depends upon the following:

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

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

For FDD, the maximum number of supported MIMO layers is 16.

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

Table 1 Peak Throughput Based on System Configurations (in Mbps at the Physical Layer)

	Number of TX Layers	64-QAM				256-QAM			
Number of Component Carriers		1CC	2CC	3CC	4CC	1CC	2CC	3CC	4CC
FDD	2	150	300	450	600	201	403	605	807
	4	300	600	899	1198(1)	403	807	1211	1615(1)
TDD UL/DL Configuration 2 (specialSubframe Pattern = 7)	2	110	224	337	449	143	285	428	1145
	4	213	426	639	852(1)	286	572	859	859(1)
TDD UL/DL Configuration 2 (specialSubframe Pattern = 6)	2	108	216	324	432	139	279	418	556
	4	208	416	631	842(1)	279	558	837	1116(1)

(1) Based on 16 layers configuration, with 4CC, 20-MHz bandwidth.

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*

— Carrier Aggregation

— Dynamic SCell Selection for Carrier Aggregation

— 3CC DL Carrier Aggregation Extension

— 4x4 Quad Antenna Downlink Performance Package

— 256-QAM Downlink

— Configurable SCell Priority

— Carrier Aggregation FDD-TDD

- Carrier Aggregation-Aware IFLB
- Supplemental Downlink for Carrier Aggregation
- 3CC DL Carrier Aggregation Extension
- Uplink Carrier Aggregation
- Cross-DU Carrier Aggregation Support
- Multiple Frequency Band Indicators
- Elastic RAN

2 Dependencies of 4 CC DL Carrier Aggregation Extenstion

Table 2 Feature Dependencies

Feature	Relationship	Description
Carrier Aggregation(FAJ 121 3046)	Prerequisite	
Dynamic SCell Selection for Carrier Aggregation(FAJ 121 3063)	Prerequisite	
3CC DL Carrier Aggregation Extension(FAJ 121 3084)	Prerequisite	
4x4 Quad Antenna Performance Package(FAJ 121 3076)	Related	The 4x4 Quad Antenna Downlink Performance Package feature provides support for four transmit antennas resulting in improvements to downlink coverage and capacity, especially in high-quality channel conditions.
256-QAM Downlink(FAJ 121 4422)	Related	256-QAM Downlink is a 3GPP modulation that increases the DL throughput with up to 30%. The system supports dynamic switching between 64-QAM and 256-QAM based on measured quality. To reach higher throughput, 256-QAM Downlink must be used.
Configurable SCell Priority(FAJ 121 4701)	Related	The Configurable SCell Priority feature is an extension to the Dynamic SCell Selection for Carrier Aggregation feature which allows manual prioritization of SCells available for carrier aggregation. To reach the optimal MIMO layer count by prioritizing specific SCells, Configurable SCell Priority must be used.
Carrier Aggregation(FAJ 121 3046)	Related	The Carrier Aggregation feature provides the capability to transmit data to a single UE on two DL bands simultaneously.

Feature	Relationship	Description
Carrier Aggregation FDD-TDD(FAJ 121 4252)	Related	The Carrier Aggregation (CA) FDD-TDD feature allows TDD cells to be used as Secondary Cells (SCell) for an FDD Primary Cell (PCell).
Carrier Aggregation-Aware IFLB(FAJ 121 3075)	Related	The Carrier Aggregation-Aware IFLB feature aims to improve average system throughput by efficient distribution of carrier aggregation capable users to cells where the carrier aggregation capability can be utilized, or utilized in a better way. This leads to better throughput for Carrier Aggregation (CA)-capable UEs.
Dynamic SCell Selection for Carrier Aggregation(FAJ 121 3063)	Related	The feature is based on 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 selection algorithm, the SCell of a UE is dynamically configured or deconfigured.
Supplemental Downlink for Carrier Aggregation(FAJ 121 3068)	Related	The main benefits of Supplemental Downlink for Carrier Aggregation are as follows: Spectrum utilization on bands defined as downlink only, for example Band 29 using Carrier Aggregation. Increased downlink User Equipment (UE) peak throughput. Increased aggregated downlink throughput and capacity.
3CC DL Carrier Aggregation Extension(FAJ 121 3084)	Related	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.
Uplink Carrier Aggregation(FAJ 121 4425)	Related	The Uplink Carrier Aggregation feature enables a User Equipment (UE) to transmit data on more than one carrier simultaneously. This means increased uplink throughput across the coverage area, more efficient use of scattered spectrum and higher capacity. The feature is specified by 3GPP.

Feature	Relationship	Description
Cross-DU Carrier Aggregation Support(FAJ 121 3080)	Related	This feature allows carrier aggregation to be used with multi-DU eNodeB configurations where the primary and secondary cells are terminated on different DUs. This can be used to support carrier pooling deployments. Some carriers are terminated on one DU and other carriers on a second DU in a multi-DU configuration, without losing support for carrier aggregation.
Multiple Frequency Band Indicators(FAJ 121 3054)	Related	The MFBI feature will: Simplify frequency band compatibility for operators and UE vendors. Enable the cell to accommodate UE which supports the physical frequency but not the primary band of the cell. Allow efficient use of license spectrum by allowing harmonized 3GPP bands and legacy band in the same cell. Increase the number of UE which are compatible with the operators network, including roaming UE.
Elastic RAN(FAJ 121 4608)	Related	The Elastic RAN feature enables high speed, low latency interaction between eNodeBs, such that eNodeBs can be added as required to increase the capacity and cell interaction scope. Elastic RAN eliminates fixed-sized coordination boundaries and scalability constraints, allowing the sets of cells that can be considered for use as secondary cells to be expanded across multiple eNodeBs.
VoLTE Optimized Carrier Aggregation(FAJ 121 4884)	Related	The VoLTE Optimized Carrier Aggregation feature provides functions to improve VoLTE retainability during VoLTE calls while UE runs on Carrier Aggregation.

Hardware

4CC is supported on DUS 41, Baseband 5216, Baseband 5212, and Baseband 6318.

Limitations

No limitations for this feature.

Network Requirements

This is a licensed feature. This means that for the feature to be operational, a valid license key must be installed and the feature must be explicitly activated by setting a MOM attribute.

The following must also be fulfilled at feature activation:

— A license key for feature Carrier Aggregation must be activated.

— A license key for feature Dynamic SCell Selection for Carrier Aggregation must be activated.

— The cell is a SCell candidate if attribute `EUtranCellRelation.sCellCandidate` is set to `ALLOWED` or `ONLY_ALLOWED_FOR_DL`.

— The UE must support 4CC DL Carrier Aggregation.

— 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 (HOM) and/or 4 layer TX, higher throughput can be achieved.

— To reach 16 MIMO layers, UE category 19 is required.

3 Feature Operation

3.1 Feature Operation Sequence Diagram

With Carrier Aggregation (CA), a UE uses resources from multiple cells. With 4CC DL Carrier Aggregation Extension, the UE uses up to four downlink (DL) component carriers (CC) at the same time, as shown in Figure 1.

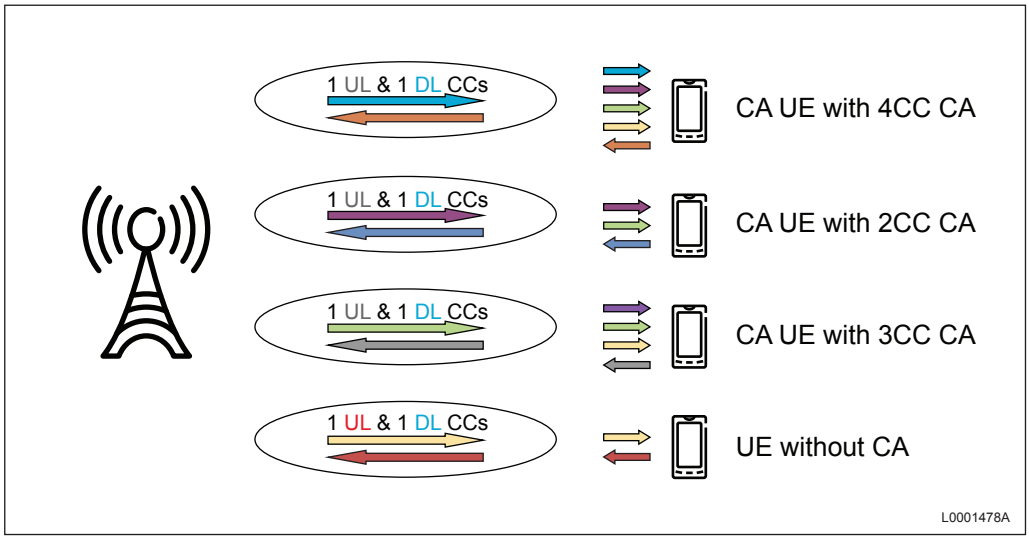

Figure 1 4CC DL Carrier Aggregation Extension

3.2 Process Steps

3.2.1 Dynamic Secondary Cell Configuration and Deconfiguration

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 deconfigured, during VoLTE calls.

— A UE is evaluated for carrier aggregation at initial attach, re-establishment, or incoming handover.

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

- If `sCellSelectionMode` is set to `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 as being in coverage and the third SCell is only selected once the second SCell has been concluded as being in coverage.

- If `sCellSelectionMode` is set to `ACK_SIMULTANEOUS_SCell_SELECTION`, three SCells are selected and configured simultaneously. A1 is configured per SCell to confirm the coverage.

- If `sCellSelectionMode` is set to `UN_ACK_SIMULTANEOUS_SCell_SELECTION`, three SCells are selected and configured simultaneously. This mode assumes SCells to have good coverage. To reduce RRC overhead no A1 measurements are configured.

For the initial SCell selection of the first, second and third SCell, please see Dynamic SCell Selection for Carrier Aggregation.

Note: In simultaneous SCell selection modes, the SCell UL CA evaluation is made by means of the attribute `caPreference`. For more information on UL CA functionality, see Uplink Carrier Aggregation.

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

— All three SCells are implicitly deconfigured upon release of the UE.

— All three 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 (indicated by A2 report) or there is a better SCell candidate in the same frequency (indicated by A6 report) . Also, it is triggered separately for the first, second, and third 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, second, and third SCell.

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

3.2.2 Dynamic Secondary Cell Activation and Deactivation

The SCell activation and deactivation triggers are the following:

— Need based:

- Activate/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 evolved Multimedia Broadcast Multicast Service (eMBMS) start or stop.

— Up to two SCells are deactivated based on poor PCell UL Channel condition. To avoid deactivation of the third SCell it is recommended to set:

```
CarrierAggregationFunction.sCellDeactOutOfCoverageTimer >=
 MAX(160, 2 *CarrierAggregationFunction.sCellDeactProhibitTimer + 80) ms
or:
CarrierAggregationFunction.sCellDeactOutOfCoverageTimer = -1
```

— Activation based on buffer occupancy triggers activation of one, two or three SCells.

— 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 Parameters

4.1 Feature Configuration Parameters

The following parameters are used to configure this feature:

- `CarrierAggregationFunction.caPreference`
- `EUtranCellFDD.noOfPucchFormat3PrbPairs`
- `EUtranCellTDD.noOfPucchFormat3PrbPairs`

4.2 Affected Parameters

The implementation of this feature affects no parameters.

5 Network Impact

5.1 Capacity

A UE configured with an SCell consumes more resources than a UE connected only to a PCell. For each additional SCell configured a new resource is allocated at PCell. However, it is counted as one from a connected UE license perspective. As the 4CC DL Carrier Aggregation Extension feature allows up to three configured SCells per UE, the loading limit is reached by fewer UEs than previously, with 2CC, or 3CC.

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, section Limiting the number of CA Users.

Additional resources are required on Physical Uplink Control Channel (PUCCH) for transmission of SCell downlink Hybrid Automatic Repeat Request (HARQ) Acknowledgements (ACK). For more information, see Control Channel Dimensioning.

5.2 Coverage

The feature does not have any impact on coverage.

5.3 Mobility

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

6 Performance

6.1 Key Performance Indicators

The main Key Performance Indicators (KPI) associated with the 4CC DL Carrier Aggregation Extension feature are the same as for the Carrier Aggregation feature. For more information, see Carrier Aggregation and Key Performance Indicators.

6.2 Counters

The following counters are associated with this feature:

- EUtranCellFDD.pmCaCapableDlSum
- EUtranCellTDD.pmCaCapableDlSum
- EUtranCellFDD.pmCaConfiguredDlSum
- EUtranCellTDD.pmCaConfiguredDlSum
- EUtranCellFDD.pmCaActivatedDlSum
- EUtranCellTDD.pmCaActivatedDlSum
- EUtranCellFDD.pmCaScheduledDlSum
- EUtranCellTDD.pmCaScheduledDlSum
- EUtranCellFDD.pmCaActivatedDlFddTddSum

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

6.3 PM Events

Table 3 lists PM events related to this feature:

Table 3 Events

Event	Event Parameter
INTERNAL_EVENT_UE_CAPABILITY	EVENT_PARAM_UE_CAP_CATEGORY
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 4CC DL Carrier Aggregation Extension

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.

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 =FourDlCarrierAggregation`
Baseband Radio Node	`FeatureState =CXC4011980`

After This Task

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

8 Deactivate 4CC 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 attribute `featureState` to DEACTIVATED in the applicable MO instance, depending on node type:

Node Type	License Control MO
DU Radio Node	`OptionalFeatureLicense =FourDlCarrierAggregation`
Baseband Radio Node	`FeatureState =CXC4011980`

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 4CC and 5CC DL Carrier Aggregation Extension

Access Type:	LTE and Multi-Standard RBS
Hardware Platform:	For 4CC, the following platforms are supported: All Baseband products
	For 5CC, the following platforms are supported: Baseband 5216, Baseband 6630, Baseband 6318
Licensing:	4CC DL Carrier Aggregation Extension, FAJ 121 4466
	5CC DL Carrier Aggregation Extension, FAJ 121 4467
Introduced in:	17.Q4

The feature improvement enables the 4CC DL Carrier Aggregation Extension and 5CC 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 acknowledge mode) in the downlink direction, with a time interval applicable to the volume measurement.

pmCounter	Description
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 acknowledge mode) in the downlink direction, 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 two carriers, 2x2 MIMO on two carriers and 256 QAM for 4CC DL Carrier Aggregation Extension

— 4x4 MIMO on one carrier, 2x2 MIMO on four carriers and 256 QAM for 5CC DL Carrier Aggregation Extension

— 5CC UE needs to support 16-bit RLC SN

— UE needs to support downlink category 18

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.