ERICSSON

Uplink Carrier Aggregation

Feature Description

172/221 04-LZA 701 6014/1 Uen AB4B

Contents

1 Uplink Carrier Aggregation Overview

Identity:	FAJ 121 4425
Licensing:	Licensed feature. One license per node.
Introduced in:	L16B
Replaces:	N/A
Belongs to:	Carrier Aggregation, FAJ 801 0405

Summary

With UL Carrier Aggregation, the UE can use up to five DL and two UL component carriers at the same time.

A UE is using one cell as PCell and up to four other cells as SCells. The PCell has both a DL and a UL component carrier. The SCells can be supporting either DL and UL or only DL, but not only UL. A cell can be PCell for some UEs and SCell for other UEs.

The main benefits of UL Carrier Aggregation are the following:

— The UE can transmit data on more than one carrier simultaneously

— Up to doubled uplink user throughput

— Increased uplink user average throughput

— Increased app coverage for uplink demanding services

1.1 Additional Information

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

— *3GPP TS 36.101, Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception*

— *3GPP TS 36.213, Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures*

— *3GPP TS 36.321, Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification*

— *3GPP TS 36.331, Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification*

- Carrier Aggregation
- **Feature Description** 3CC DL Carrier Aggregation Extension
- **Feature Description** 4CC DL Carrier Aggregation Extension
- **Feature Description** 5CC DL Carrier Aggregation Extension
- **Feature Description** Dynamic SCell Selection for Carrier Aggregation
- **Feature Description** Cross-DU Carrier Aggregation Support

2 Dependencies of Uplink Carrier Aggregation

Features

Table 1 Feature Dependencies

Feature	Relationship	Description
Carrier Aggregation (FAJ 121 3046)	Prerequisite	Carrier Aggregation must be activated prior to introducing the Uplink Carrier Aggregation feature.
3CC DL Carrier Aggregation Extension (FAJ 121 3084)	Related	The UE is configured to use 3 component carriers. The PCell is always operating with both DL and UL component carriers. Any one SCell can be configured for UL carrier aggregation where the following applies: — The SCell has both DL and UL component carriers. — The SCell has the same frame structure as the PCell. — Both the node and the UE support UL Carrier Aggregation operation.
4CC DL Carrier Aggregation Extension (FAJ 121 4466)	Related	The UE is configured to use 4 component carriers. The PCell is always operating with both DL and UL component carriers. Any one SCell can be configured for UL carrier aggregation where the following applies: — The SCell has both DL and UL component carriers. — The SCell has the same frame structure as the PCell. — Both the node and the UE support UL Carrier Aggregation operation.
5CC DL Carrier Aggregation Extension (FAJ 121 4467)	Related	The UE is configured to use 5 component carriers. The PCell is always operating with both DL and UL component carriers. Any one SCell can be configured for UL carrier aggregation where the following applies: — The SCell has both DL and UL component carriers. — The SCell has the same frame structure as the PCell. — Both the node and the UE support UL Carrier Aggregation operation.
Combined Cell (FAJ 121 3025)	Related	Maximum two sector carriers per SCell are supported for Combined Cell in combination with UL Carrier Aggregation. If more sector carriers are configured per SCell no UL Carrier Aggregation is configured. The sector carriers must not be placed more than 300 meters apart when Combined Cell is used together with UL Carrier Aggregation.
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.

Feature	Relationship	Description
		— Based on UE measurements and the SCell selection algorithm, the SCell of a UE is dynamically configured or deconfigured.
High Power UE (FAJ 121 4762)	Related	If Uplink Carrier Aggregation is configured for a UE, the UE power class can only be the default 3. Higher output power is not supported with Uplink Carrier Aggregation. At power split, the maximum allowed output power of the UE is taken into account. When determining the priority of all activated component carriers, the UE power class per component carrier is taken into account. When switching to TTI Bundling mode during uplink carrier aggregation, the value of the maximum allowed output power of the UE is passed to the PCell. The maximum allowed output power of the UE is based on the type of downlink carrier aggregation configuration and the UE power class on the PCell.
High Speed UE (FAJ 121 2054)	Related	If High Speed UE is activated and configured in a cell and this cell is selected as SCell then no UL is configured in the SCell. High Speed UE relies on periodic CQI on PUCCH for frequency offset estimation in all component carriers in an UL Carrier Aggregation deployment. CQI on PUCCH is however only available on the PCell.
Psi-Coverage (FAJ 121 4186)	Conflicting	Psi-Coverage must not be configured simultaneously with Uplink Carrier Aggregation.
VoLTE Optimized Carrier Aggregation (FAJ 121 4884)	Related	If the VoLTE Optimized Carrier Aggregation feature is enabled and the MOM attribute `EUtranCellFDD.sCellHandlingAtVolteCall` or `TDD.sCellHandlingAtVolteCall` is set to `DECONF_SCELLS`, `DECONF_UL_SCELLS` or `DECONF_UL_SUPPRESS_DL_SCELLS`, UL SCell which has been configured for the UE is deconfigured during an active VoLTE call.
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.

System Functions

Table 2 System Function Dependencies

Function	Description
Sounding	If the feature Uplink Frequency-Selective Scheduling is enabled and a cell has sounding enabled, CA UEs using this cell as PCell or non-CA UEs are configured for sounding. A CA UE using the cell as SCell is, however not configured for sounding.

3 Feature Operation

This section describes the UL CA feature in more detail, including network configuration requirements and feature specific functionality.

3.1 Network Requirements

UL CA 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 before the feature can be activated and is fully operational:

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

— A cell is an SCell candidate if the attribute `EUtranCellRelation.SCellCandidate` is set to `ALLOWED`.

— To benefit from the feature the network needs to be configured with band and bandwidth combinations allowing UL CA according to 3GPP TS 36.101.

— To benefit from the feature the UE must support UL CA for the applicable band and bandwidth combinations.

— Multiple Timing Alignment values are not supported. It is therefore recommended to only configure UL CA serving cell relations where the inter-antenna distance is less than 300 meters between a Primary Cell (PCell) and an SCell that are both configured with UL and DL.

In addition, some or all of the following features can be required. This depends on the desired number of SCell candidates and the number of carriers to be aggregated in DL.

— 3CC DL Carrier Aggregation Extension. UE support for 3 DL + 2 UL is required in this case.

— 4CC DL Carrier Aggregation Extension

— 5CC DL Carrier Aggregation Extension

— Dynamic SCell Selection for Carrier Aggregation

3.2 Feature Overview

With UL CA, the UE can use up to five DL and two UL component carriers (CC) at the same time.

A UE is using one cell as PCell and up to four other cells as SCells. The PCell has both a DL and a UL component carrier. The SCells can be supporting either DL and UL or only DL, but not only UL. A cell can be PCell for some UEs and SCell for other UEs.

3.3 SCell Configuration

The Uplink Carrier Aggregation feature adds the support to configure an SCell for UL Carrier Aggregation according to the following:

— A UE is evaluated for Carrier Aggregation at initial attach, re-establishment, or incoming handover. What cells are to be configured as SCells is determined by the activated licenses for the following features:

  — Carrier Aggregation

  — 3CC DL Carrier Aggregation Extension

  — 4CC DL Carrier Aggregation Extension

  — 5CC DL Carrier Aggregation Extension

  — Dynamic SCell Selection for Carrier Aggregation

  When an SCell candidate is configured, the eNodeB checks if this cell can also be used for uplink Carrier Aggregation.

— Uplink Carrier Aggregation supports inter-band or intra-band contiguous Carrier Aggregation according to the band and bandwidth combinations defined in *3GPP TS 36.101, Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception*.

— The UE must support the UL band and bandwidth combination for the SCell that is configured for uplink Carrier Aggregation.

— In initial simultaneous SCell selection, if several SCells are capable of uplink Carrier Aggregation, the SCells to be configured for both DL and UL Carrier Aggregation can be determined by the priority as configured with the `ulSCellPriority` attribute in MO class `EUtranCellFDD` or `EUtranCellTDD`.

  The selection can be further influenced by the `caPreference` attribute. Setting this attribute to `DL` ensures that UL Carrier Aggregation is only configured for SCells if the total number of possible component carriers is not reduced. The total number is based on eNodeB configuration and UE capabilities.

  The default value of the `caPreference` attribute is `NONE`, which means that whenever possible, UL Carrier Aggregation is configured on selected SCells without regard to the impact on the number of configured DL or UL component carriers. This behavior is the same as it is for initial sequential SCell selection.

Note: If the High Power UE feature is used, the following applies:

When determining the priority of all activated component carriers, the UE power class per component carrier is taken into account.

A cell is not capable as an UL Carrier Aggregation SCell for a UE, if any of the following applies:

— The cell has the MO attribute `EUtranCellRelation.SCellCandidate` set to `ONLY_ALLOWED_FOR_DL`.

— The cell is located in a different node than the PCell for the same UE.

Note: UL Carrier Aggregation can be combined with Cross-DU Carrier Aggregation Support for DL.

— The cell is using another frame structure type (FDD, TDD) than the PCell for the same UE.

— The cell is a Combined Cell with more than two sector cells.

— The cell has the High Speed UE feature enabled.

— The cell is a DL only cell.

Power Splitting

The total maximum output power of a UE is independent of the number of active uplink component carriers, so it is split between the used component carriers, and PUSCH transmission power is scaled down.

Note: If the VoLTE Optimized Carrier Aggregation feature is enabled and the MOM attribute `EUtranCellFDD.sCellHandlingAtVolteCall` or `TDD.sCellHandlingAtVolteCall` is set to `DECONF_UL_SCELLS`, the UL power split of the UE can be avoided during VoLTE calls by deconfiguring the UL SCell.

The available UE output power is divided between the component carriers based on the relative radio conditions in each component carrier.

Note: If the High Power UE feature is used, the maximum allowed output power of the UE is taken into account at power split.

Remove or Configure the Uplink Aspect of an SCell

A new threshold is introduced to allow UL not to be configured in an SCell in the higher attenuation regions. Some UEs are unable to dedicate their maximum power to a single carrier when two UL carriers are configured. This can lead to potential UL power budget degradation for such UEs, and the possibility of associated connection loss.

The threshold that triggers the removal or configuration of the UL aspect of an SCell is a1a2ThresholdRsrpBidir. When the RSRP falls below the configured value a1a2ThresholdRsrpBidir - hysteresisA1A2RsrpBidir, the UL aspect is removed. When the RSRP is above the configured value a1a2ThresholdRsrpBidir + hysteresisA1A2Rsrp, the UL aspect is configured in addition to the DL direction.

The expected drop in UL power on the PCell when the SCell is configured for UL has to be determined to calculate the recommended value of a1a2ThresholdRsrpBidir.

For example, a UE with 5 MHz PCell (25 PRBs) and 20 MHz SCell (100 PRBs) might experience a drop of 10*log10(125/25)=7.0 dB. UEs can have other values of loss.

The ReportConfigSCellA1A2.a1a2ThresholdRsrpBidir attribute is recommended to be set to the sum of the power drop and the ReportConfigSCellA1A2.a1a2ThresholdRsrp attribute (both in dB and dBm).

When a1a2ThresholdRsrpBidir is less than a1a2ThresholdRsrp, the capability to add or remove UL Carrier Aggregation without removing DL is disabled.

Note: The triggerQuantity attribute under the ReportConfigSCellA1A2 MO has to be set to 0 (RSRP) in so that the a1a2ThresholdRsrpBidir and hysteresisA1A2RsrpBidir attributes work as described above. Only thresholds corresponding to the a1a2ThresholdRsrq and hysteresisA1A2Rsrq attributes are configured in the UE if the triggerQuantity attribute is set to 1 (RSRQ).

It is also possible to allow UL not to be configured in an SCell by a new feature. The feature that triggers the removal or configuration of the UL aspect of an SCell is VoLTE Optimized Carrier Aggregation.

When the VoLTE Optimized Carrier Aggregation feature is enabled and a voice bearer request is received at initial context setup, incoming handover, or RRC connection re-establishment, the SCell candidate list for the UE is removed or modified depending on the following values of the attribute EUtranCellFDD.sCellHandlingAtVolteCall or TDD.sCellHandlingAtVolteCall:

— If the attribute EUtranCellFDD.sCellHandlingAtVolteCall or TDD.sCellHandlingAtVolteCall is set to DECONF_SCELLS, all SCell candidates are removed. All UL and DL SCells are reconfigured for the UE when the voice bearer is released.

— If the attribute EUtranCellFDD.sCellHandlingAtVolteCall or TDD.sCellHandlingAtVolteCall is set to DECONF_UL_SUPPRESS_DL_SCELLS, UL component carriers in SCell are deconfigured during VoLTE calls.

— If the attribute EUtranCellFDD.sCellHandlingAtVolteCall or TDD.sCellHandlingAtVolteCall is set to DECONF_UL_SCELLS, UL SCell

candidate is changed to DL SCell. And UL SCell is reconfigured for the UE when the voice bearer is released.

When the VoLTE Optimized Carrier Aggregation feature is enabled and a voice bearer request is received at E-RAB Setup, the SCell is deconfigured depending on the following values of the attribute `EUtranCellFDD.sCellHandlingAtVolteCall` or `TDD.sCellHandlingAtVolteCall`.

— If the attribute `EUtranCellFDD.sCellHandlingAtVolteCall` or `TDD.sCellHandlingAtVolteCall` is set to `DECONF_SCELLS`, all SCells which have been configured for the UE are deconfigured. And all SCells are reconfigured for the UE when the voice bearer is released.

— If the attribute `EUtranCellFDD.sCellHandlingAtVolteCall` or `TDD.sCellHandlingAtVolteCall` is set to `DECONF_UL_SUPPRESS_DL_SCELLS`, UL component carriers in SCell are deconfigured during VoLTE calls.

— If the attribute `EUtranCellFDD.sCellHandlingAtVolteCall` or `TDD.sCellHandlingAtVolteCall` is set to `DECONF_UL_SCELLS`, UL SCell which has been configured for the UE is deconfigured. And UL SCell is reconfigured for the UE when the voice bearer is released.

3.4 Dynamic SCell Activation and Deactivation

In addition to the activation and deactivation conditions applicable with downlink carrier aggregation features, an SCell can also be activated and deactivated based on buffer occupancy in the UE. Activation and deactivation of an SCell in the UE is done at the same time for DL and UL.

For operator configurable thresholds related to the activation and deactivation, see Feature Configuration Parameters on page 11.

3.5 Uplink Data Transmission on Multiple Carriers

UL data can be transmitted over both the PCell and the SCell when a UE has an activated SCell.

3.5.1 Interactions with VoLTE

Enhanced PDCCH Link Adaptation

VoLTE transmissions are scheduled only on the PCell when VoLTE is used together with the features UL CA and Enhanced PDCCH Link Adaptation. No scheduling resources are allocated on the SCell when VoLTE is scheduled.

VoLTE Optimized Carrier Aggregation

If the VoLTE Optimized Carrier Aggregation feature is enabled on Carrier Aggregation, by setting `sCellHandlingAtVolteCall` to value 2, the UL component carriers in the SCell are deconfigured and dynamic SCell selection is suppressed during VoLTE call.

3.5.2 Interaction of Uplink Carrier Aggregation with TTI Bundling

3GPP TS 36.331 does not allow simultaneous RRC configuration of Uplink Carrier Aggregation and TTI Bundling.

Switching from Uplink Carrier Aggregation to TTI Bundling

In case uplink Carrier Aggregation is configured for the UE and the radio conditions trigger the UE to use TTI Bundling, then TTI Bundling has priority over uplink Carrier Aggregation.

When radio conditions trigger the UE to use TTI Bundling the UE is configured to use TTI Bundling with an `RRC Connection Reconfiguration` message which does the following:

— Deconfigures the SCell or SCells.

— Configures the SCell or SCells with downlink and no uplink.

— Configures TTI Bundling in the PCell.

If the High Power UE feature is used, the following applies:

When switching to TTI Bundling mode during uplink carrier aggregation, the value of the maximum allowed output power of the UE is passed to the PCell. The maximum allowed output power of the UE is based on the type of downlink carrier aggregation configuration and the UE power class on the PCell.

Switching from TTI Bundling to Uplink Carrier Aggregation

When TTI Bundling is to be deconfigured in the UE, and there is at least one configured SCell that can be configured with uplink for the UE, the following is done with one `RRC Connection Reconfiguration` message:

— Deconfigures the SCell or SCells.

— Configures the SCell or SCells with downlink and one SCell with uplink. If more than one SCell is configured with uplink, the eNodeB selects an SCell randomly.

— Deconfigures the use of TTI Bundling in the PCell.

4 Parameters

4.1 Feature Configuration Parameters

The following table describes parameters used to configure this feature.

Table 3 Feature Configuration Parameters

Parameter	Description
sCellActDeactUlDataThresh	If the minimum time needed to transmit all bits in all priority queues in UL of a UE is higher than sCellActDeactUlDataThresh, activation of one or more secondary cells is considered.
sCellActDeactUlDataThreshHyst	If minimum time needed to transmit all bits in all priority queues in UL of a UE is less than sCellActDeactUlDataThresh minus sCellActDeactUlDataThreshHyst, deactivation of one component carrier is considered.
ulSCellPriority	Relative priority in initial SCell selection for cells that can be configured with UL Carrier Aggregation. Lowest value has highest priority. The parameter is available in the following MO classes: —EUtranCellFDD —EUtranCellTDD
networkSignallingValueCa	The parameter (Enum) is available in the following MO classes:(Enum) CA Network Signalling value CA_NS_XX according to TS 36.101. This literal value corresponds to additional spectrum emission requirements for intra-band contiguous aggregation on E-UTRA band XX. —EUtranCellFDD —EUtranCellTDD

Parameter	Description
a1a2ThresholdRsrpBidir	RSRP threshold value for events A1 and A2 below which UL CA is not configured.
hysteresisA1A2RsrpBidir	(Enum) CA Network Signalling value CA_NS_XX according to TS 36.101. This literalHysteresis value for RSRP in event A2 measurements below which UL CA is not configured.
caPreference	Sets the preference between DL and UL Carrier Aggregation. Setting the preference to DL direction ensures that the number of configured Component Carriers is not limited by UL direction. For example, if there is a choice between configuring 2 DL CC + 2 UL CC or 3 DL CC + 1 UL CC, setting the value to DL results in a 3 DL CC + 1 UL CC configuration.

4.2 Affected Parameters

The implementation of this feature affects no parameters.

4.3 Parameters Affecting the Feature

describes parameters that affect this feature.

Table 4 Parameters Affecting the Feature

Parameter	Description
sCellCandidate	Under normal circumstances sCellCandidate is set to ALLOWED for the cells that are aggregated. If a cell is aggregated only for DL, the parameter can be set to ONLY_ALLOWED_FOR_DL. For example, the inter-cell distance is larger than 300 meters.

5 Network Impact

5.1 Capacity

Each Carrier Aggregation UE with configured SCell consumes the memory of two connected users in the system. As a result, the maximum total number of `RRC_CONNECTED` users decrease by the number of Carrier Aggregation UEs connected.

6 Performance

6.1 Key Performance Indicators

The following Key Performance Indicators (KPI) are associated with this feature:

— Average UL PDCP UE Throughput for Carrier Aggregation

— UL PDCP UE Throughput Distribution

— Mean UL PDCP UE Throughput

— Average UL PDCP Cell Throughput

— Average UL MAC Cell Throughput

For more information about KPIs, see Key Performance Indicators.

6.2 Counters

The following counters in MO classes `EUtranCellFDD` and `EUtranCellTDD` are associated with this feature:

— `pmCaCapableUlSum`

— `pmCaConfiguredUlSum`

— `pmCaScheduledUlSum`

— `pmRadioThpVolUlSCell`

— `pmUeThpVolUl`

— `pmUeThpTimeUl`

— `pmRadioThpVolUl`

— `pmUeThpVolUlCa`

— `pmUeThpTimeUlCa`

— `pmUeThp2UlDistr`

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

6.3 PM Events

The following table lists amended PM events for which the listed event parameters are added for the UL CA feature.

Table 5 Related PM Events

Event	Event Parameter
INTERNAL_PER_CELL_TRAFFIC_REPORT	EVENT_PARAM_SCELL_RADIOTHP_VOL_UL EVENT_PARAM_SCELL_RADIOTHP_RES_UL EVENT_PARAM_PER_SCELL_SCHED_ACTIVITY_UE_UL EVENT_PARAM_SCELL_HARQ_UL_SUCC_QPSK EVENT_PARAM_SCELL_HARQ_UL_FAIL_QPSK EVENT_PARAM_SCELL_HARQ_UL_SUCC_16QAM EVENT_PARAM_SCELL_HARQ_UL_FAIL_16QAM EVENT_PARAM_SCELL_HARQ_UL_SUCC_64QAM EVENT_PARAM_SCELL_HARQ_UL_FAIL_64QAM EVENT_PARAM_PER_SCELL_MAC_DTX_UL_QPSK EVENT_PARAM_PER_SCELL_MAC_DTX_UL_16QAM EVENT_PARAM_PER_SCELL_MAC_DTX_UL_64QAM
INTERNAL_PER_UETR_CELL_TRAFFIC_REPORT	EVENT_PARAM_SCELL_RADIOTHP_VOL_UL EVENT_PARAM_SCELL_RADIOTHP_RES_UL EVENT_PARAM_PER_SCELL_SCHED_ACTIVITY_UE_UL EVENT_PARAM_SCELL_HARQ_UL_SUCC_QPSK EVENT_PARAM_SCELL_HARQ_UL_FAIL_QPSK

	EVENT_PARAM_SCELL_HARQ_UL_SUCC_16QAM EVENT_PARAM_SCELL_HARQ_UL_FAIL_16QAM EVENT_PARAM_SCELL_HARQ_UL_SUCC_64QAM EVENT_PARAM_SCELL_HARQ_UL_FAIL_64QAM EVENT_PARAM_PER_SCELL_MAC_DTX_UL_QPSK EVENT_PARAM_PER_SCELL_MAC_DTX_UL_16QAM EVENT_PARAM_PER_SCELL_MAC_DTX_UL_64QAM

7 Activate Uplink Carrier Aggregation

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=UplinkCarrierAggregation`
Baseband-based Node	`FeatureState=CXC4011973`

After This Task

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

8 Deactivate Uplink Carrier Aggregation

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=UplinkCarrierAggregation`
Baseband-based	`FeatureState=CXC4011973`

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: Support for 3-Carrier, 2-Band Combinations for UL CA

Access Type:	LTE
Hardware Platform:	All
Licensing:	Uplink Carrier Aggregation
	FAJ 121 4425

With this enhancement, a UE can run 3CC DL and 2CC UL simultaneously in both a 3-band and a 2-band combination in the case of Inter-Band Carrier Aggregation.

Capacity and Performance

No impact.

Operation

No impact.

Interfaces

No impact.

Other Network Elements

No impact.