The Introduction of Carrier aggregation

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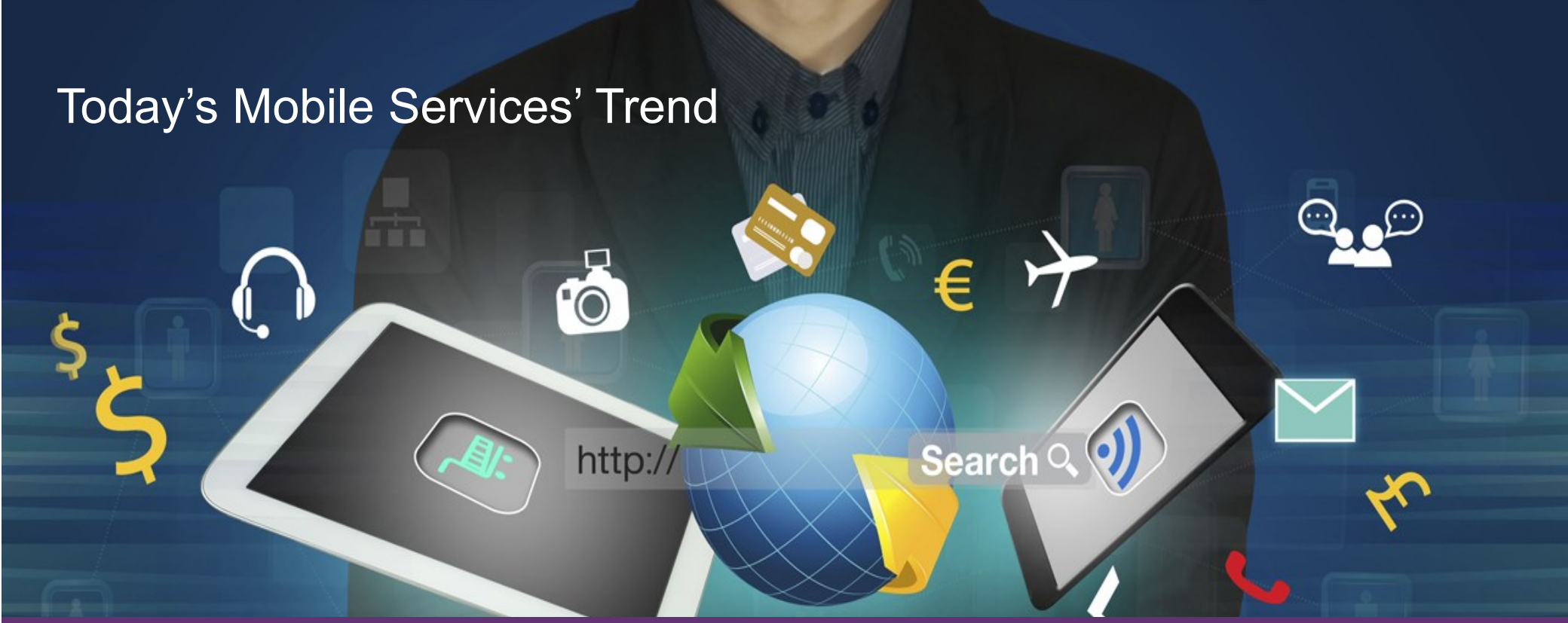
Today's Mobile Services' Trend



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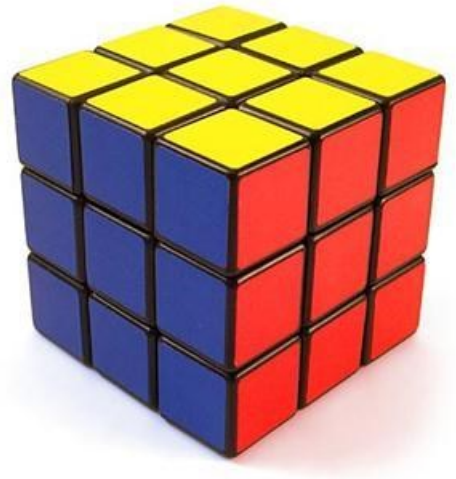
Carrier Aggregation

Introduction, Deployment and Analysis



What is CA?

Carrier aggregation (CA) was introduced in Release-10 of the 3GPP specifications

Carrier aggregation (CA) – is a core capability of LTE-Advanced

CA permits LTE to achieve the goals mandated by IMT-Advanced while maintaining backward compatibility with Release-8 and 9 LTE.

Release-10 CA permits the LTE radio interface to be configured with any number (up to five) carriers, of any bandwidth, including differing bandwidths, in any frequency band.

Carrier aggregation can be used for both FDD and TDD.

Types of CA

Possibility to configure carriers in UL and DL independently (UL cannot exceed DL) for FDD.

For TDD the number of CCs as well as the bandwidths of each CC will normally be the same for DL and UL.

Each aggregated carrier is referred to as a component carrier, CC.

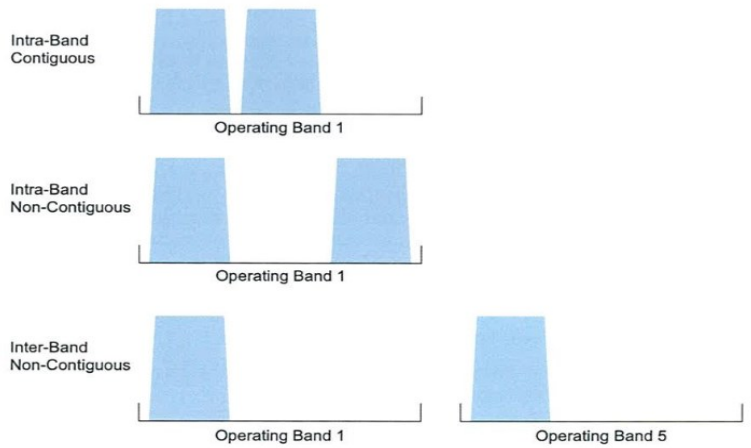
The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz.

With a maximum of five component carriers, the maximum aggregated bandwidth is 100 MHz.

3 types of allocation have been defined in 3GPP to meet different operator's spectrum scenario.

These are defined as:

- Intra-Band Contiguous
- Intra-Band Non-Contiguous
- Inter-Band Non-Contiguous



Intra-Band Contiguous

When aggregation is in the same operating band using contiguous component carriers – it is called intra-band contiguous

Not used currently as most operators do not have contiguous bands of more than 20 MHz

The spacing between center frequencies of contiguously aggregated CCs is a multiple of 300 kHz to be compatible with the 100 kHz frequency raster of Release-8/9 and preserving orthogonality of the subcarriers with 15 kHz spacing.

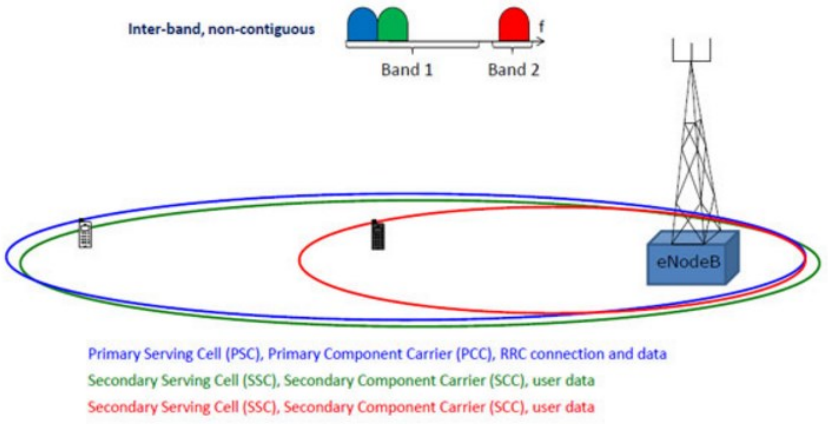
Intra and Inter-Band Non-Contiguous

To counter the problem of non-contiguous spectrum allocation, intra and inter-band non-contiguous CA is introduced

Different component carriers can be planned to provide different coverage

In the case of inter-band carrier aggregation the component carriers will experience different path-loss

In the example shown in figure 3 carrier aggregation on all three component carriers can only be used for the black UE, the white UE is not within the coverage area of the red component carrier. Note that for UEs using the same set of CCs, can have different PCC:



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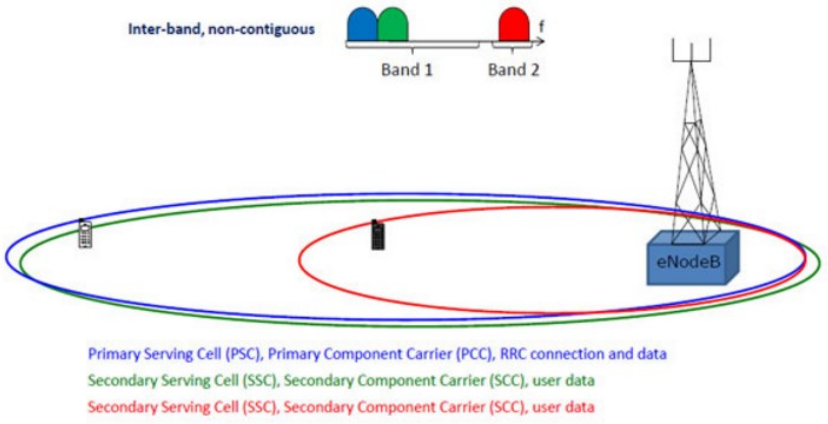


New Definitions 3GPP 36.808

To understand CA, 3GPP definitions must be understood:

Aggregated Channel Bandwidth: The RF bandwidth in which a Base Station transmits and receives multiple contiguously aggregated carriers. The aggregated channel bandwidth is measured in MHz.

Highest Carrier: The carrier with the highest carrier center frequency transmitted/received in a specified frequency band.

Lowest Carrier: The carrier with the lowest carrier center frequency transmitted/received in a specified frequency band.

CA bandwidth class: indicates a combination of maximum ATBC and maximum number of CCs. In R10 and R11 three classes are defined:

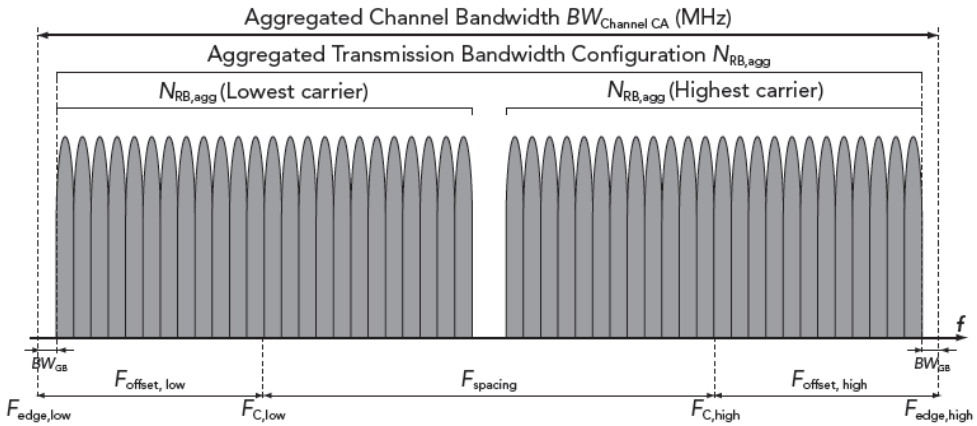
- Class A: ATBC ≤ 100, maximum number of CC = 1
- Class B: ATBC ≤ 100, maximum number of CC = 2
- Class C: 100 < ATBC ≤ 200, maximum number of CC = 2

- Aggregated Transmission Bandwidth Configuration (ATBC): total number of aggregated physical resource blocks (PRB).

New Definitions 3GPP 36.808

CA configuration: indicates a combination of E-UTRA operating band(s) and CA bandwidth class(es), to exemplify the configuration CA_1C indicates intra-band contiguous CA on E-UTRA operating band 1 and CA bandwidth class C, CA_1A_1A, indicates intra-band non-contiguous CA on band 1 with a one CC on each side of the intra-band gap, finally CA_1A-5B indicates inter-band CA, on operating band 1 with bandwidth class A and operating band 5 with bandwidth class

Type of CA and duplex type	CA configuration	Maximum aggregated bandwidth (MHz)	Max number of CC
Intra-band contiguous FDD	CA_1C	40	2
	CA_7C	40	2
Intra-band contiguous TDD	CA_38C	40	2
	CA_40C	40	2
	CA_41C	40	2
Inter-band FDD	CA_1A_5A	20	1 + 1
	CA_1A_18A	35	1 + 1
	CA_1A_19A	35	1 + 1
	CA_1A_21A	35	1 + 1
	CA_2A_17A	20	1 + 1
	CA_2A_29A	20	1 + 1
	CA_3A_5A	30	1 + 1
	CA_3A_7A	40	1 + 1
	CA_3A_8A	30	1 + 1
	CA_3A_20A	30	1 + 1



New Definitions 3GPP 36.808

Carrier Aggregation catergories cells as follows:

Pcell

Scell 1, 2, ….

Pcell = Primary Cell

The cell on which the UE performs the initial connection

Primary cell can be changed during handover

Each connection has a single Pcell

A PDCCH order to initiate Random Access Procedure can only be received on Pcell

PRACH Preambles can only be sent on Primary cell

New Definitions 3GPP 36.808

Scell = Secondary Cell

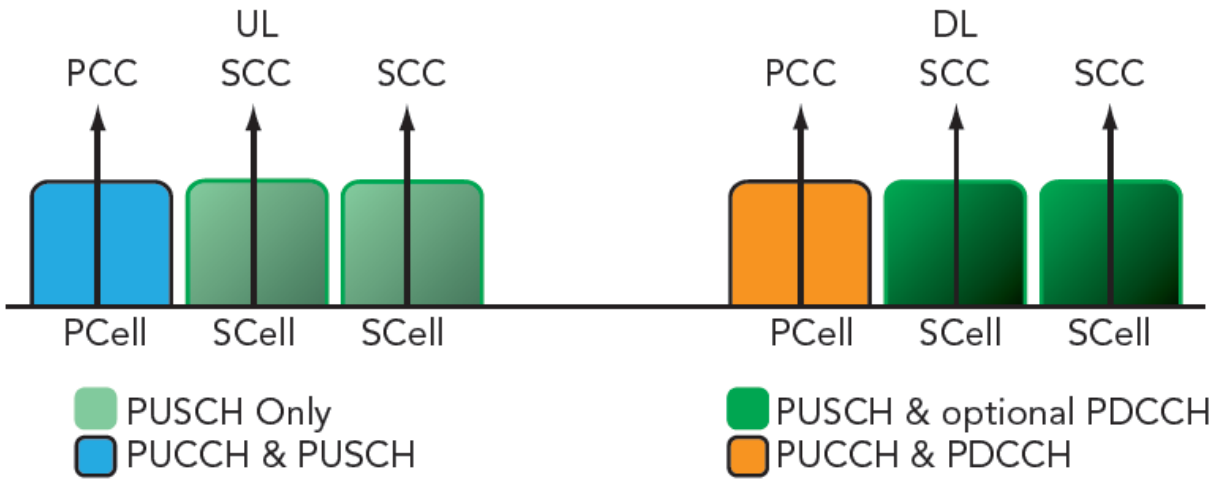
A cell which has been configured to provide additional radio resources after connection establishment

Each connection can have multiple secondary cells

Serving Cell

Both secondary and primary are considered as serving cells

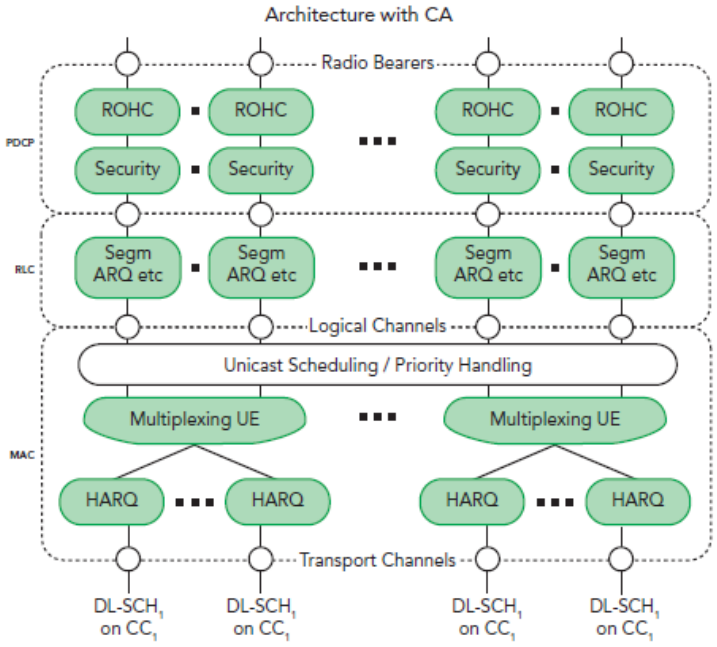
One HARQ per serving cell

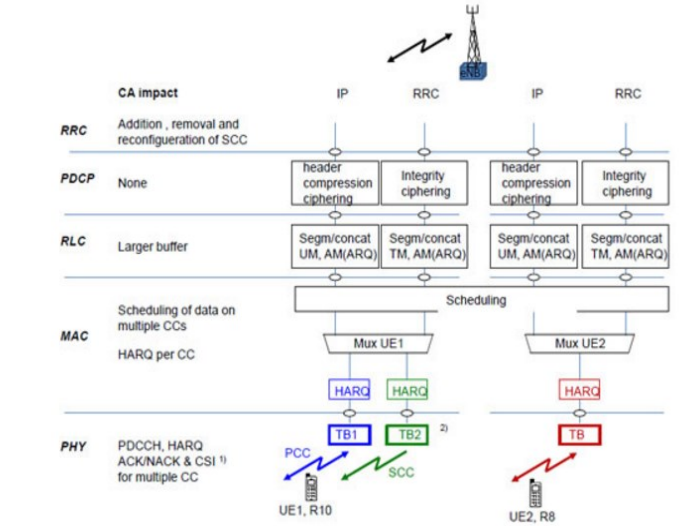


Impact of Carrier Aggregation on Signaling

Key procedures like Key exchange and mobility are carried by the Primary Cell

UE RLC Buffer sizes have to be increased to support the higher data rates





MAC layer plays the role of multiplexing these aggregated carriers

Each MAC entity will provide its corresponding CC its own physical layer, data modulation, HARQ and channel coding

eNodeB scheduler needs to have knowledge of all CC

Impact of Carrier Aggregation on Signaling

The activation of an additional CC is done through MAC control element

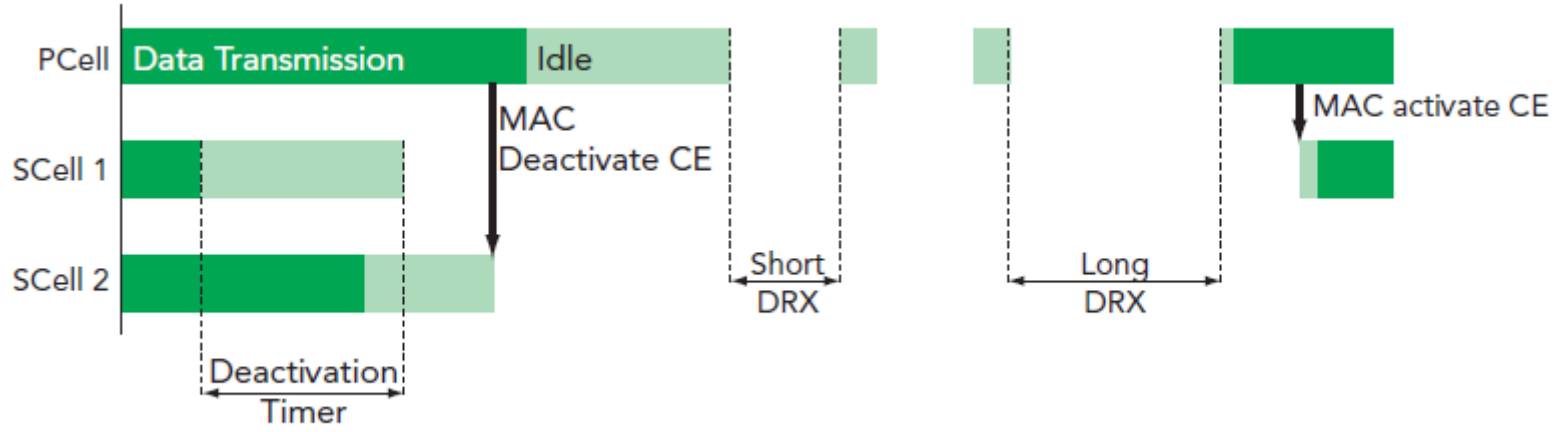
Additional CC is activated for a given subframe, the actual resource for scheduling is available 8 subframes later (8 ms)

At this point, a new timer called sCellDeactivationTimer-r10 will also start, if no scheduling information is provided by the PDCCH within this timer, the SCell will be deactivated at the MAC layer.

The RRC Configured timer is the same timer for all Scells

The deactivation of a given SCell can also be controlled by the network using MAC header control elements

Even with no traffic a PCell will always be active or in DRX mode



Downlink Channel Quality

CQI and downlink HARQ ACK/NACK indicators and other information, is reported to the base station via the uplink control information (UCI) IE

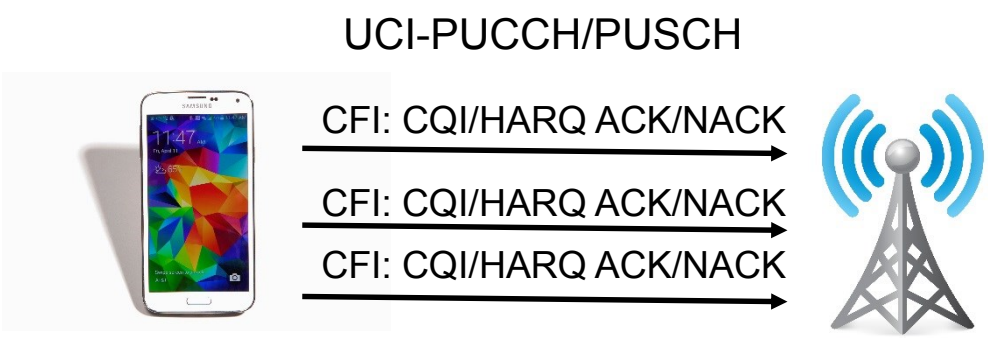
There is exactly one PUCCH and it is on the PCell regardless of the number of CCs

The UCI for each CC should be reported via this PUCCH if the terminal does not have a PUSCH configured

In order to distinguish which UCI belongs to a given CC, the header of the UCI contains a carrier indicator field (CIF)

UE report CQI periodically. UEs do not necessarily support simultaneous transmission of PUCCH and PUSCH, CQI also could be reported on the PUSCH, if the PUSCH happens to be active at the time of a periodic reporting instance

In the context of CA, this means that CQI could be transmitted on an SCell if an SCell uplink burst is ongoing while a PCell burst is not.



Uplink Channel Quality

Uplink control signaling carried by the single PUCCH

the terminal does not have a valid scheduling grant, had to be changed to support the increase HARQ Acknowledgements of the additional carriers.

The Release-8 PUCCH known as format 1b with was only defined to support up to 4 bits, can only support a maximum of 2 CCs.

To enable terminals capable of more than two downlink component carrier and 4 bits of acknowledgement,

a new PUCCH known as “format 3” in Release-10 has been defined.

It enables a full range of ACK/NACK to be transmitted bits:

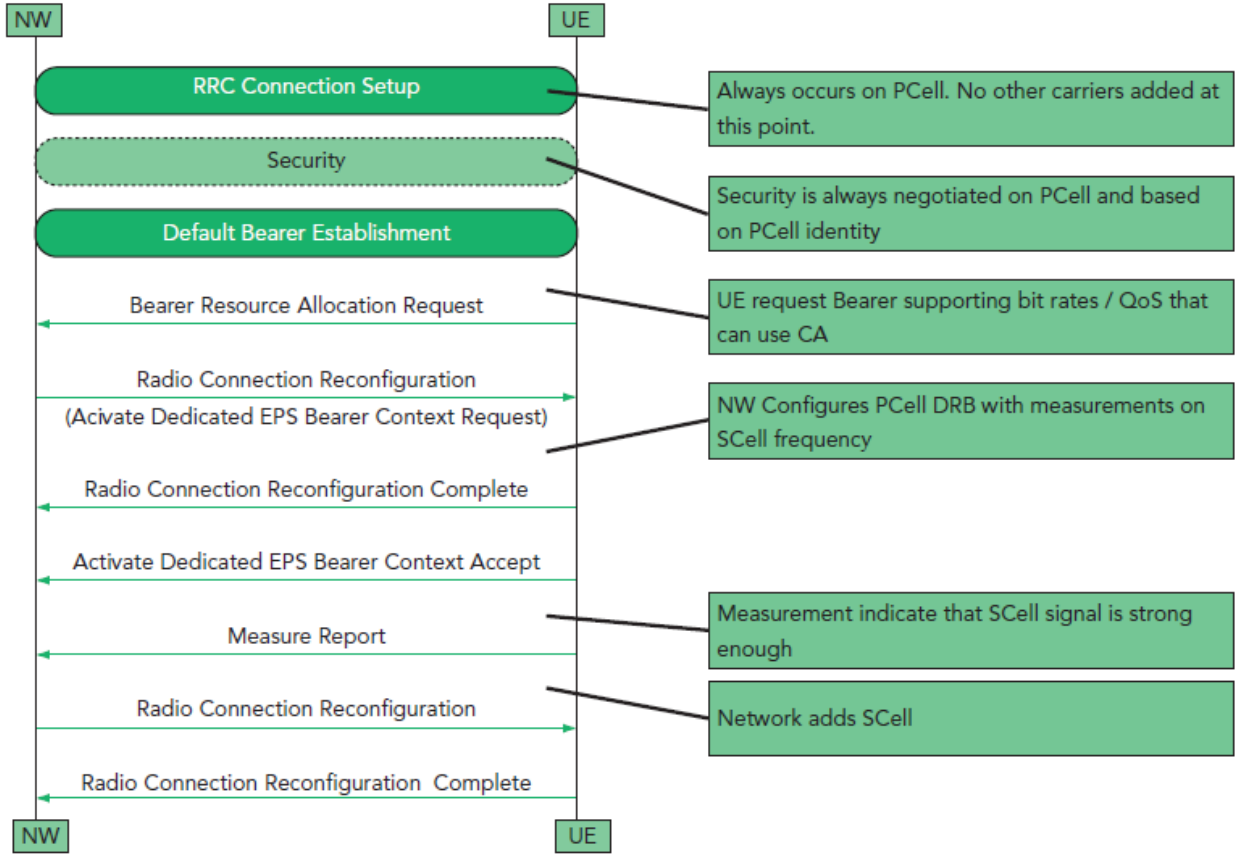
Up to 10 ACK/NACK bits for FDD and Up to 20 ACK/NACK bits for TDD.

Instead of using Zadoff-Chu sequences as other PUCCH format it uses similar to PUSCH transmissions (DFT-S-OFDM).

The HARQ are concatenated with Scheduling bit request, block coding is applied, followed by cell specific scrambling.

Layer 3 Signaling

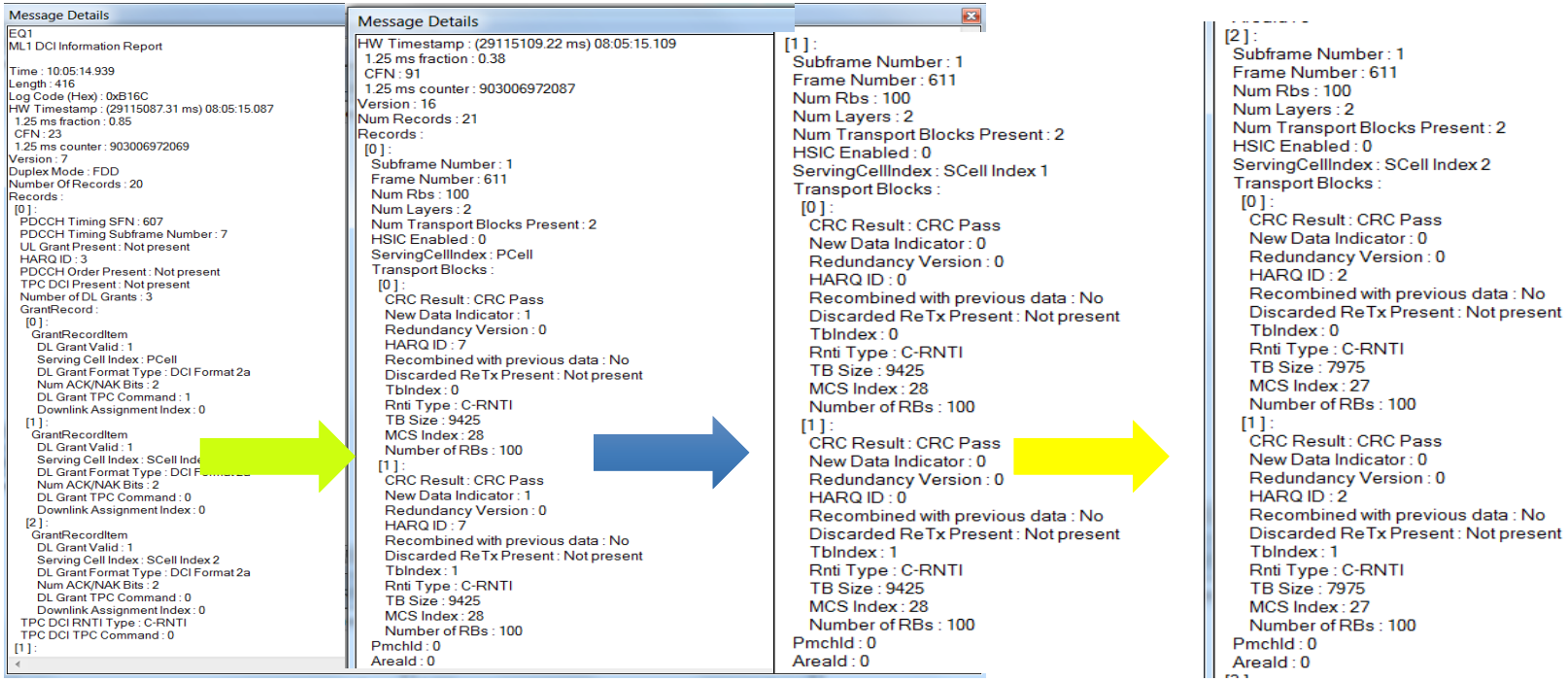
The layer 3 signaling for Carrier Aggregation is shown and explained below:



TEMS Investigation and Discovery

ASCOM in keeping with its trend of remaining at the cutting-edge of the technology can decode 3-CC information from the UE

A typical setup of 3CC and decode by TEMS Investigation is shown below:



ASCOM supports 3CC in TEMS Discovery with different reports and throughput calculations to allow its customers to optimize and troubleshoot 3CC

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THANK YOU