LTE-Advanced
Release-10 Features Overview

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July 2012

Key requirements of IMT-Advanced

From ITU-R Circular Letter /LCCE/2 on IMT-Advanced requirements

- a high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost efficient manner
- compatibility of services within IMT and with fixed networks as well as capability of inter-networking with other RAT
- high quality mobile services, user-friendly applications, services and equipment
- user equipment suitable for worldwide use and worldwide roaming capability
- enhanced peak data rates (100 Mbit/s for high and 1 Gbit/s for low mobility were established as targets for research)

ITU-R: International Telecommunication Union-Radiocommunicaton
IMT: International Mobile Communications

3GPP LTE-Advanced Requirements

- **LTE-Advanced should evolve from LTE Rel-8, however non-backward compatible element might be considered in case it enables significant benefit achievement**

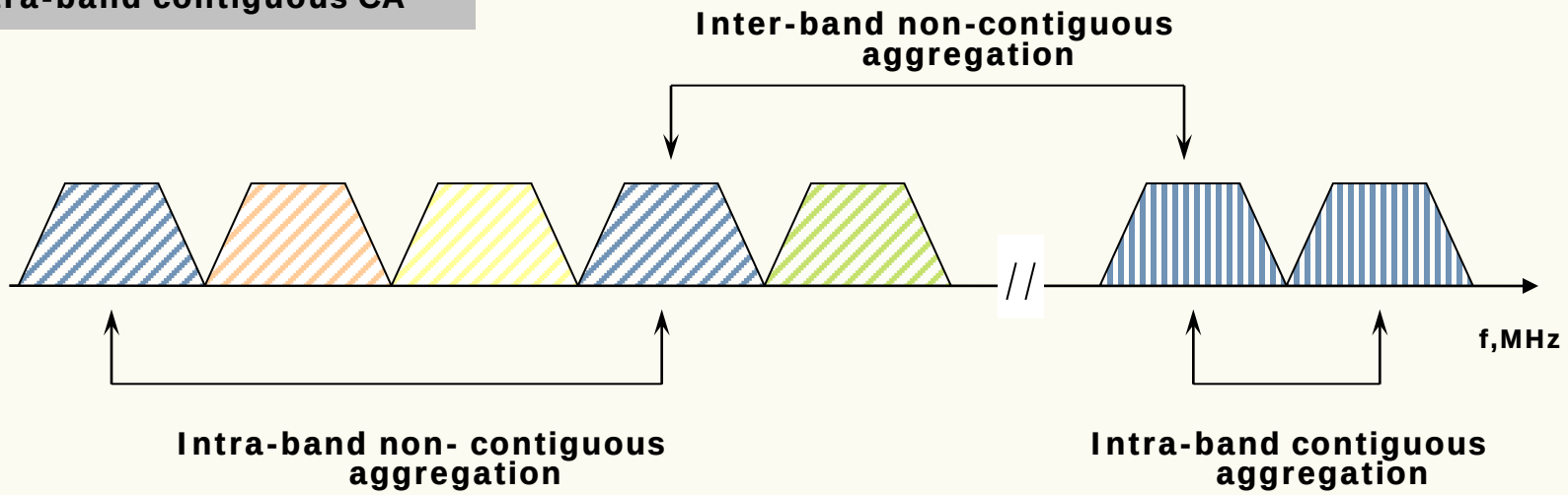
Parameter	LTE Rel8	IMT-Advanced	LTE-Advanced
Maximum bandwidth (MHz)	20	> 40	Up to 100
Peak data rate (Mbps)	>100(DL)/ >50(UL)	1000(low mob)/ 100(high mob)	1000 (DL)/500(UL)
Peak spectral efficiency (bps/Hz) DL/UL	5/2.5	15/6.75	30/15
User plane latency (ms)	10	10	10
Control plane latency (ms)	100	100	50 (idle-active)/ 10(dormant->active)
Average spectral efficiency (bps/Hz/cell) DL/UL	>1.6-2.1/ >0.66-1.0	2.2/1.4	2.6/2.0
Cell-edge user spectral efficiency (bps/Hz) DL/UL	>0.04-0-06/ >0.02-0.03	0.06/0.03	0.09/0.07

LTE-Rel10 - Agenda

- Carrier Aggregation (CA)
- Downlink Transmission Enhancements
- Uplink Transmission Enhancements
- Relaying
- Heterogeneous Networks (HetNet) and Enh. Inter-Cell Interference Coordination (eICIC)
- Self-Organising Networks (SON)
- Minimisation of Drive Tests (MDT)
- MBMS Enhancements
- Outlook beyond LTE-Release 10

Carrier Aggregation (CA) - 1

LTE Rel-10 focuses on Intra-band contiguous CA



Backward compatibility to LTE-Rel8

- LTE Rel-8 carrier numerology is reused for component carrier (CC)
- Max 110 resource blocks (RBs)
- Centre frequencies are multiples of 300 kHz
- Allowed channel bandwidths per CC are 1.4 MHz, 3.0 MHz, 5MHz, 10 MHz, 15 MHz and 20 MHz
- Legacy users access system via one component carrier

Carrier Aggregation (CA) - 2

- **Prioritised Combinations:**
  - Intra-band – initial support of max 2 aggregated carriers
    - 15 MHz and 20 MHz in E-UTRA Band 1
    - 10, 15, 20 MHz in E-UTRA Band 40
  - Inter-band (one CC/Band)
    - 10 MHz in E-UTRA Bands 1&5
    - 10 MHz, in E-UTRA Bands 4&13
    - 10 MHz, in E-UTRA Bands 4&17
    - 10, 15, 20 MHz in E-UTRA Bands 3&7

Carrier Aggregation (CA) - 3

- Each CC has Primary and Secondary Synchronisation Channels (PSS and SSS) and CC-specific System Information (SI)
- **Primary Serving Cell (PCell)** – handles RRC connection, security, NAS mobility info, SI, etc. and provides primary DL and UL CCs (**PCC**)
- **Secondary Serving Cell (SCell)** – is configured later for additional resources provision. It serves secondary DL and UL CCs (**SCC**). Simultaneous connection up to 4 SSCs

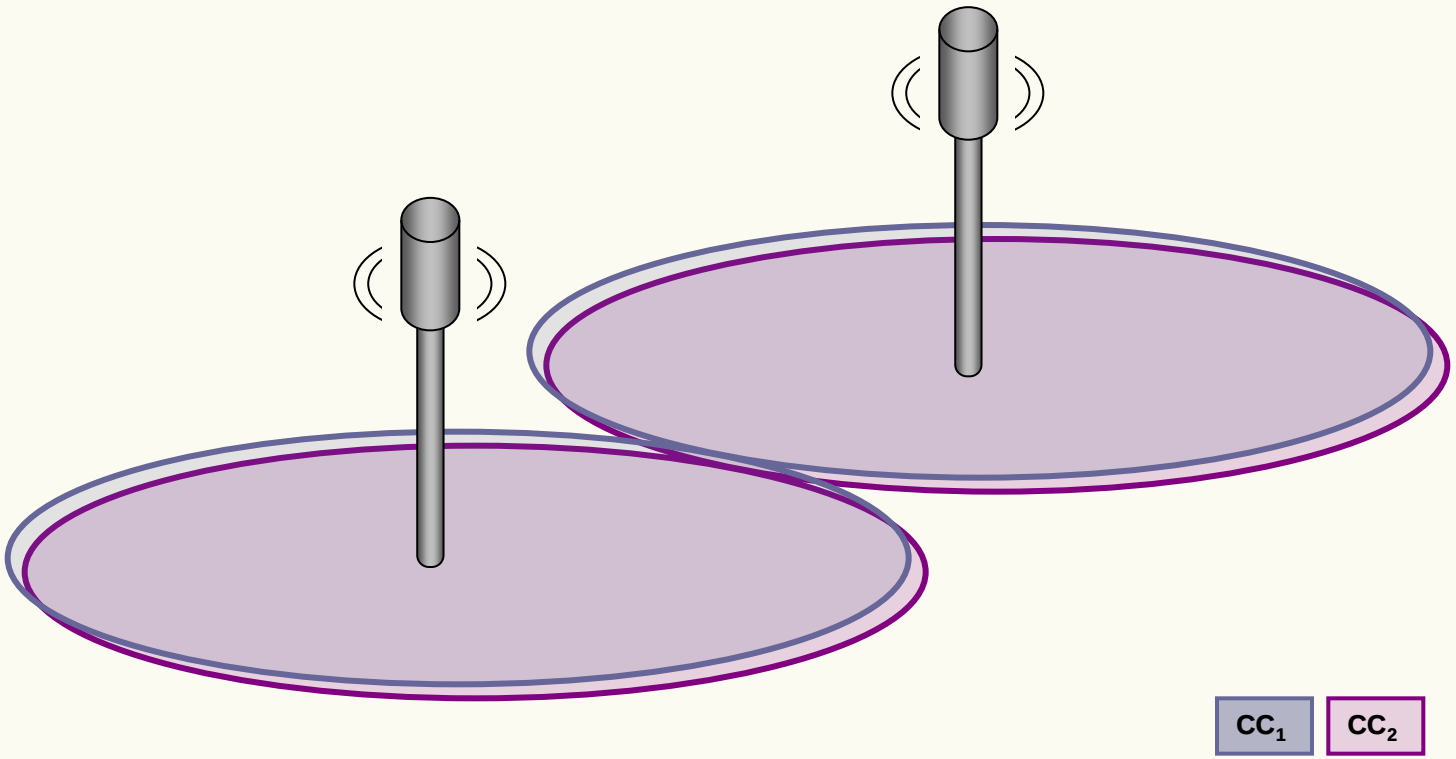
Carrier Aggregation (CA) - 4

- CCs originating from the same eNB may be of different bandwidth
- CC configuration
  - symmetrical, when Ncc_UL = N_cc_DL
  - asymmetrical, when Ncc_UL < Ncc_DL
- CCs originating from the same eNB may provide different coverage
- Different transmit power levels are allowed different CCs in the same band

Carrier Aggregation (CA) - 5

Deployment Scenario 1

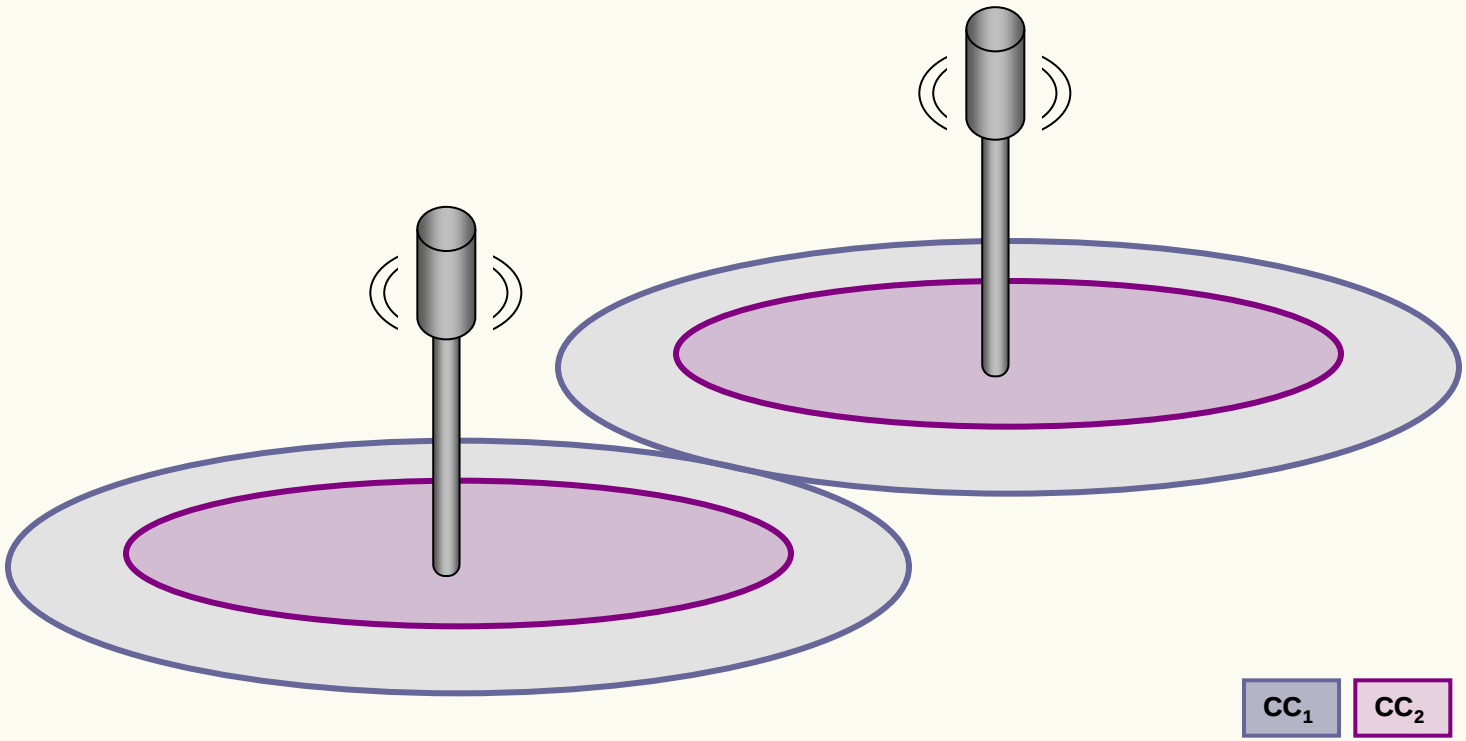
- Smaller frequency separation, likely in the same band
- Nearly same coverage area due to overlaying component carriers
- Mobility support on both component carriers



Carrier Aggregation (CA) - 6

Deployment Scenario 2

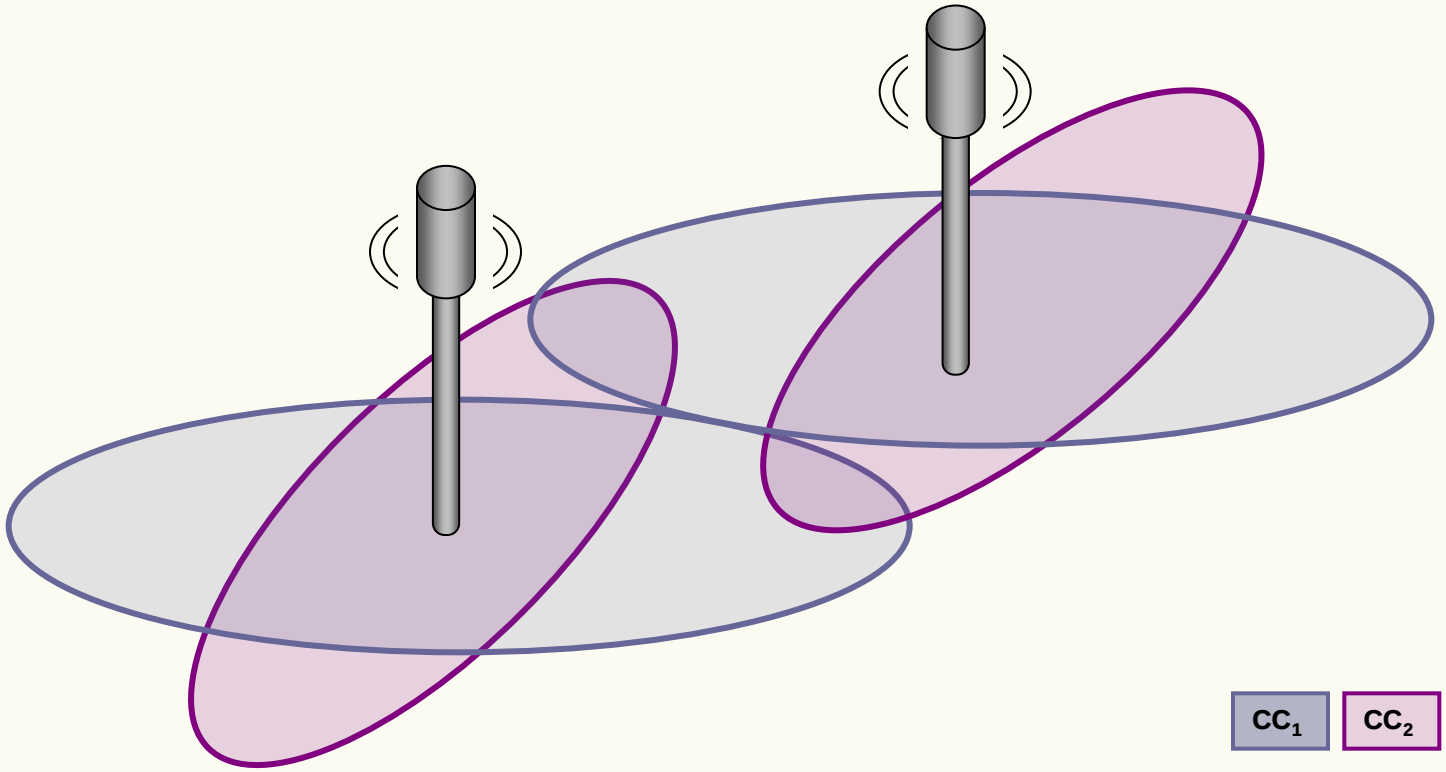
- Larger frequency separation, likely in different bands
- Higher frequencies have smaller coverage area than lower ones
- Mobility support is based on coverage of CC_1



Carrier Aggregation (CA) - 7

Deployment Scenario 3

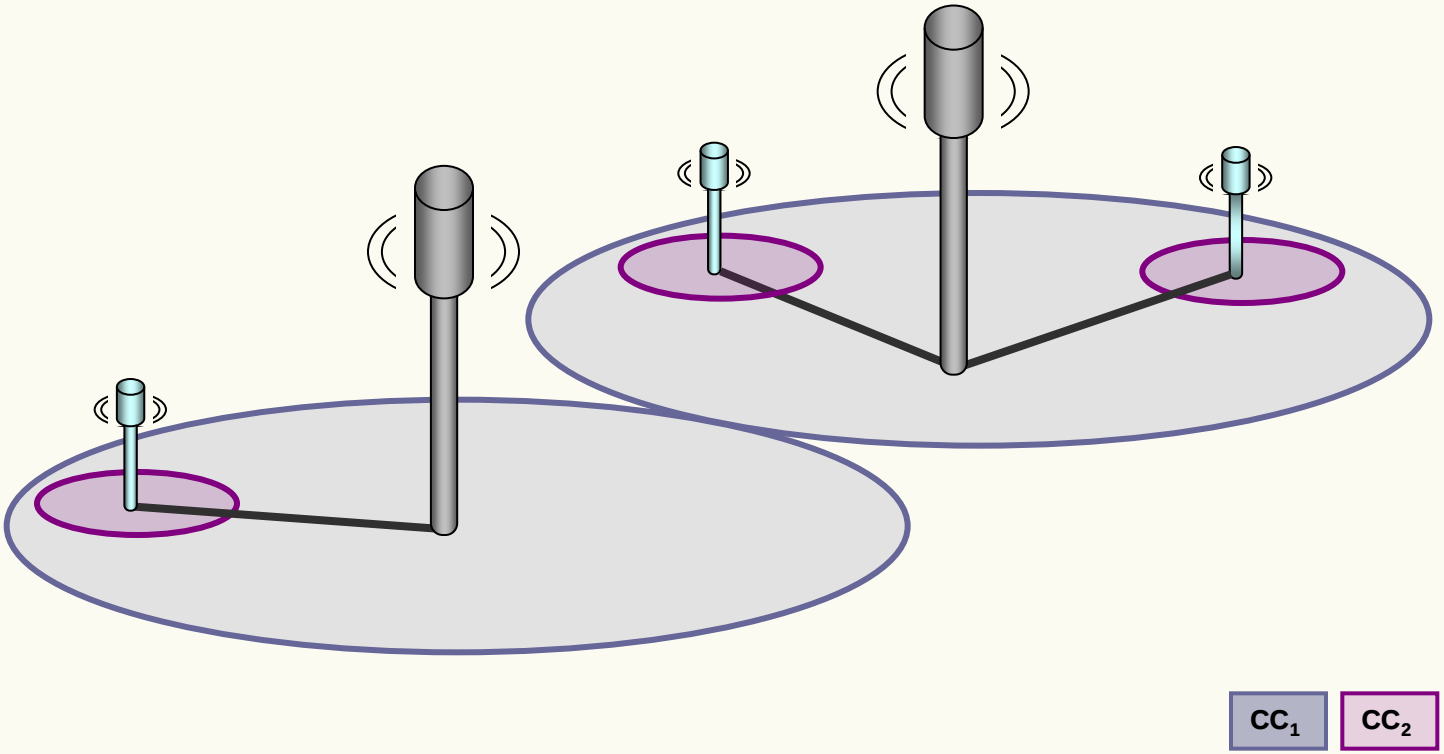
- Larger frequency separation, likely in different bands
- Antennas of higher frequency CC_2 are directed to the coverage boundaries of CC_1
- Mobility support is based on coverage of CC_1



Carrier Aggregation (CA) - 8

Deployment Scenario 4

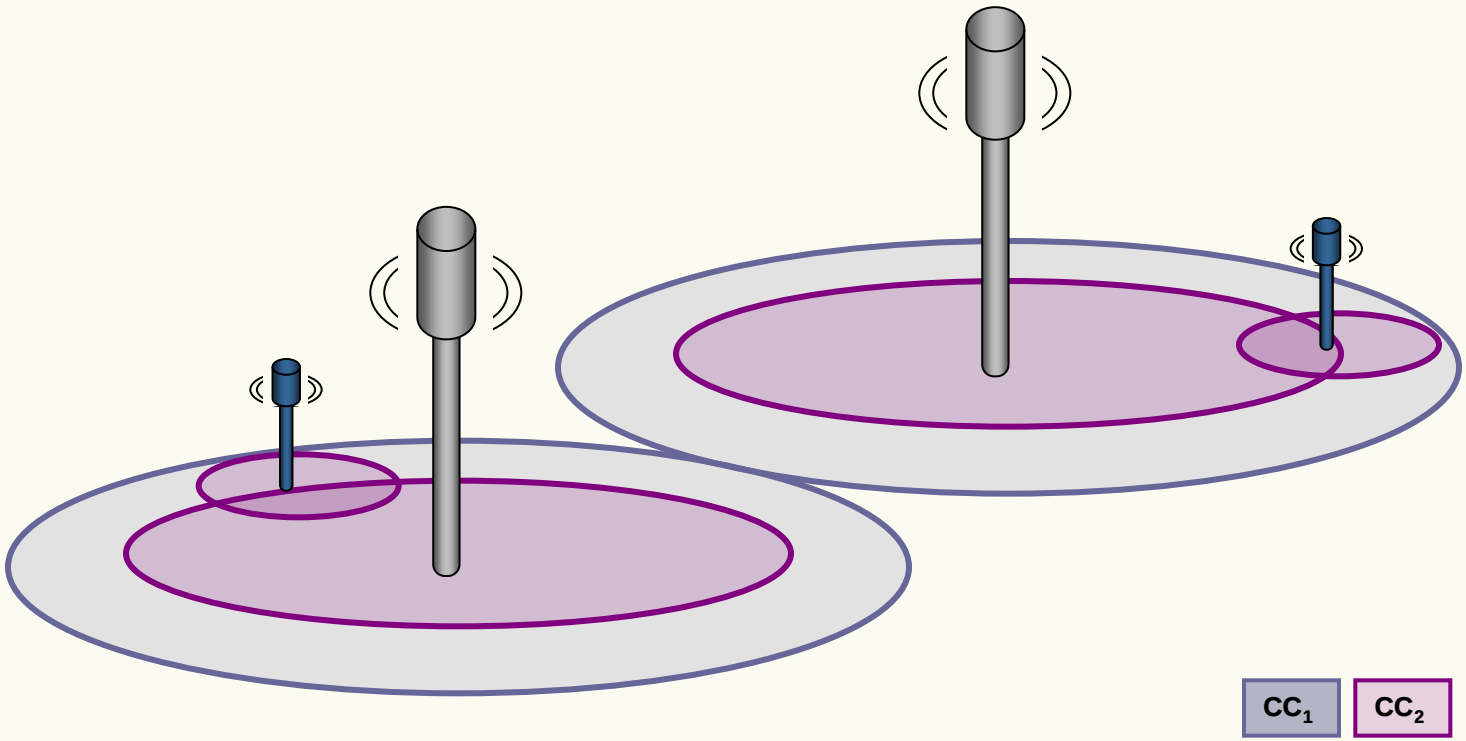
- Macro coverage on CC_1
- CC_2 on Remote Radio Heads (RRHs)
- Mobility support is based on coverage of CC_1



Carrier Aggregation (CA) - 9

Deployment Scenario 5

- Macro coverage on CC_1
- CC_2 on frequency selective repeaters
- Mobility support is based on coverage of CC_1

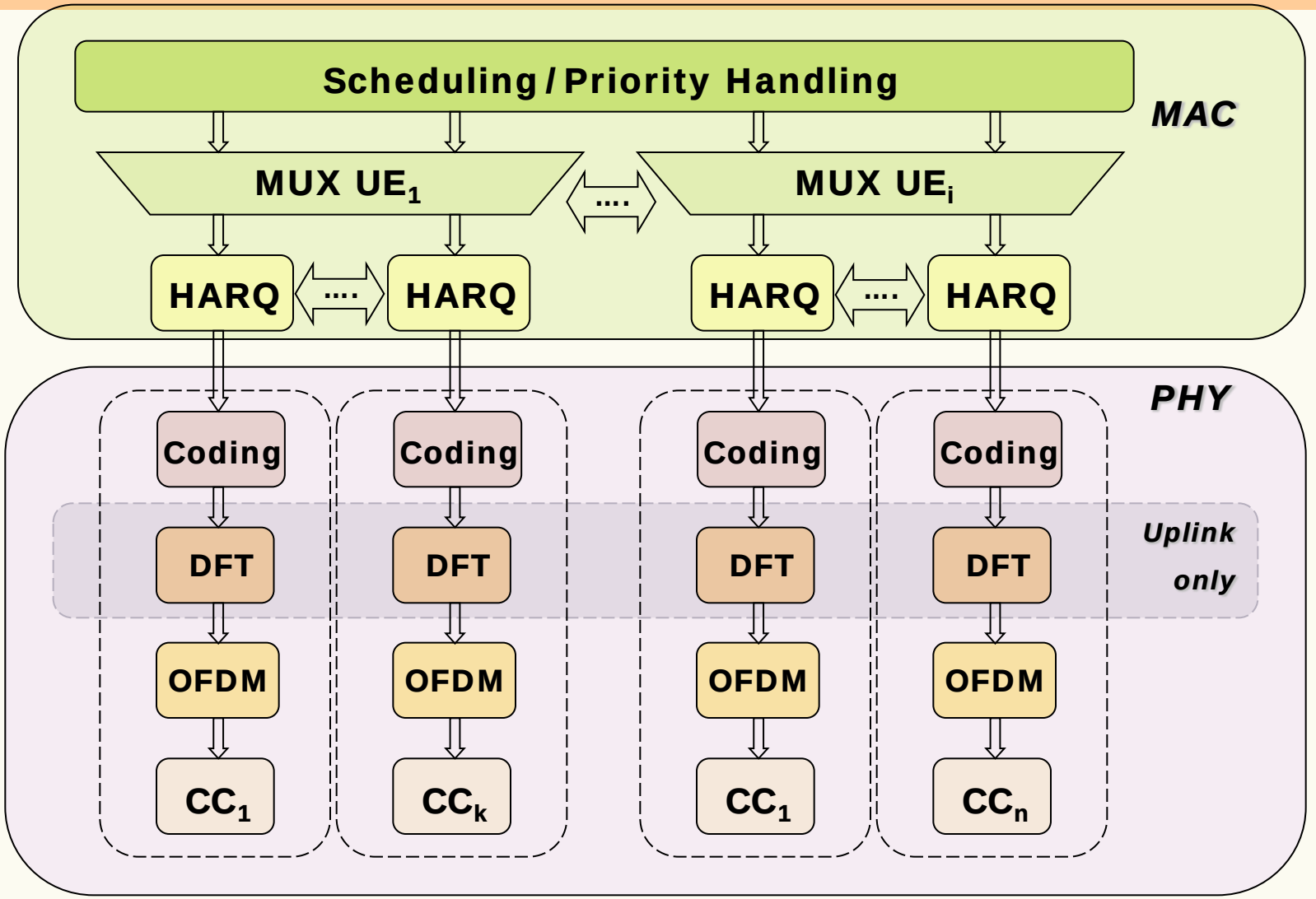


Carrier Aggregation (CA) – 10

- **User plane**
  - Unaffected remain
    - PDCH
    - RLC
  - Modifications to MAC required
    - Common schedule for all CCs, while separate HARQ per single CC
  - Rel-8 compliant HARQ features
- **Control plane**
  - Specific system information on each CC (Rel-8 relevant and possible LTE-A extensions)
  - Only one RRC connection, single C-RNTI
  - Measurements for any CC are configurable
  - Rel-8 idle mode mobility procedures

C-RNTI: Cell Radio Network Temporary Identifier

Carrier Aggregation (CA) – 11



Carrier Aggregation (CA) – 12

- **Downlink Control Signalling:**
  - Reused Rel-8 structure for PCFICH, PDCCH and PHICH
  - Resource assignments – per carrier scheduling grant
    - Same carrier scheduling – reuse of Rel-8 DCI formats
    - Cross-carrier scheduling – with carrier indicator field (CIF) extended Rel-8 DCI format, allows dynamical load balancing

DCI: Downlink Control Information

Carrier Aggregation (CA) – 13

- **Uplink Control Signalling:**
  - PUCCH format 3
    - FDD: 10 ACK/NACK bits (5CCs MIMO)
    - TDD: 20 ACK/NACK bits
  - 1 Scheduling Request (SR) bit is appended at the end of ACK/NACK bits
  - Primary Component Carrier (PCC) for PUCCH transmission
  - Support up to 5 DL CCs on Rel-10 PUCCH
  - Periodic CSI on PUCCH for up to 5 DL CCs
  - Transmission of ACK/NACK HARQ on PUCCH in absence of PUSCH transmission
  - Semi-statically mapping of scheduling requests on PUCCH
  - Uplink Control Information (UCI) simultaneously on PUCCH and PUSCH

MIMO: Multiple-Input Multiple-Output

LTE-Rel10 - Agenda

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Downlink Transmission Enhancements - 1

- **Physical channel mapping**
  - Unused MBSFN subframes are utilised for PDSCH transmission
  - Same CP (cyclic prefix) for both control and data
  - CP length relation between normal and MBSFN subframe in the control region is the same as for LTE Rel-8

MBSFN: Multimedia Broadcast Single Frequency Network

Downlink Transmission Enhancements - 2

- **Spatial Multiplexing**

  - Support of up to **8** layers spatial multiplexing per CC
  - New PDSCH **Transmission Mode 9**
  - Up to **2 TBs** transmission in a subframe per DL CC to a scheduled UE
  - Codeword-to-layer mapping of max 2 codewords
  - Freedom of precoding matrix choice

Downlink Transmission Enhancements - 3

- **To support higher-order spectral efficiency in LTE-Advanced existing DL reference signalling had to be also extended**

Rel-8 DL Reference Signals	LTE Advanced DL Reference Signals
Cell-specific (common) – phase reference for DL control channels demodulation	Introduced new type of cell-specific RS – for Estimation of Channel State Information (CSI-RS) to assist precoding in eNB by providing a feedback on a channel state for up to x8 antenna ports
UE-specific (DeModulation, DE-RSs) – embedded in UE's PDSCH to derive channel estimation for data demodulation. Extended in Rel-9 to support x2 spatial layers	Extension to precoded UE-specific RS to support up to x8 spatial layers. Orthogonal multiplexing is needed to avoid inter-layer RS interference

RS: Reference Signals

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Uplink Transmission Enhancements - 1

- **Spatial Multiplexing**
  - **SU-MIMO** (Single User) with up to **4** layers spatial multiplexing
  - Up to **2 TBs** in a sub-frame per uplink component carrier can be transmitted from a scheduled UE
  - Configuration of SU spatial multiplexing transmission with or without **layer shifting**
  - Precoding **codebooks** with 3-bit or 6-bit precoding depending on number of antennas used

Uplink Transmission Enhancements - 2

- **Uplink multiple access**
  - DFT-precoded OFDM for PUSCH transmission
  - Both frequency-contiguous and frequency-non-contiguous resource allocation on CCs
  - Simultaneous transmission support of control signalling and data
  - Clusters of subcarriers may be used for uplink transmission

Uplink Transmission Enhancements - 3

- **Uplink transmit diversity**
  - Single antenna mode
    - Compatible with the LTE Rel-8 PUSCH transmission, support of non-contiguous spectrum possible
    - **Default** operation mode till eNB gets aware about UE Tx antenna configuration
    - Spatial Orthogonal-Resource Transmit Diversity (**SORTD**) mode for UL control information transmission on Rel-8 PUCCH formats 1/1a/1b
  - Multi-antenna mode
    - Applicable for UEs with two and four transmission antennas

Uplink Transmission Enhancements - 4

- **Reference Signals (RS)**
  - Demodulation RS (**DM-RS**)
    - Multiplexing via cyclic shift
    - Same precoding as for PUSCH
  - Sounding RS (**SRS**)
    - LTE Rel-8 multiplexing scheme
    - Non-precoded, antenna specific

Uplink Transmission Enhancements - 5

- **Uplink power control**

  - Closed loop- CC specific UL power control for contiguous and non-contiguous CA

  - Open loop – in cases when $Ncc_{DL} >= Ncc_{UL}$

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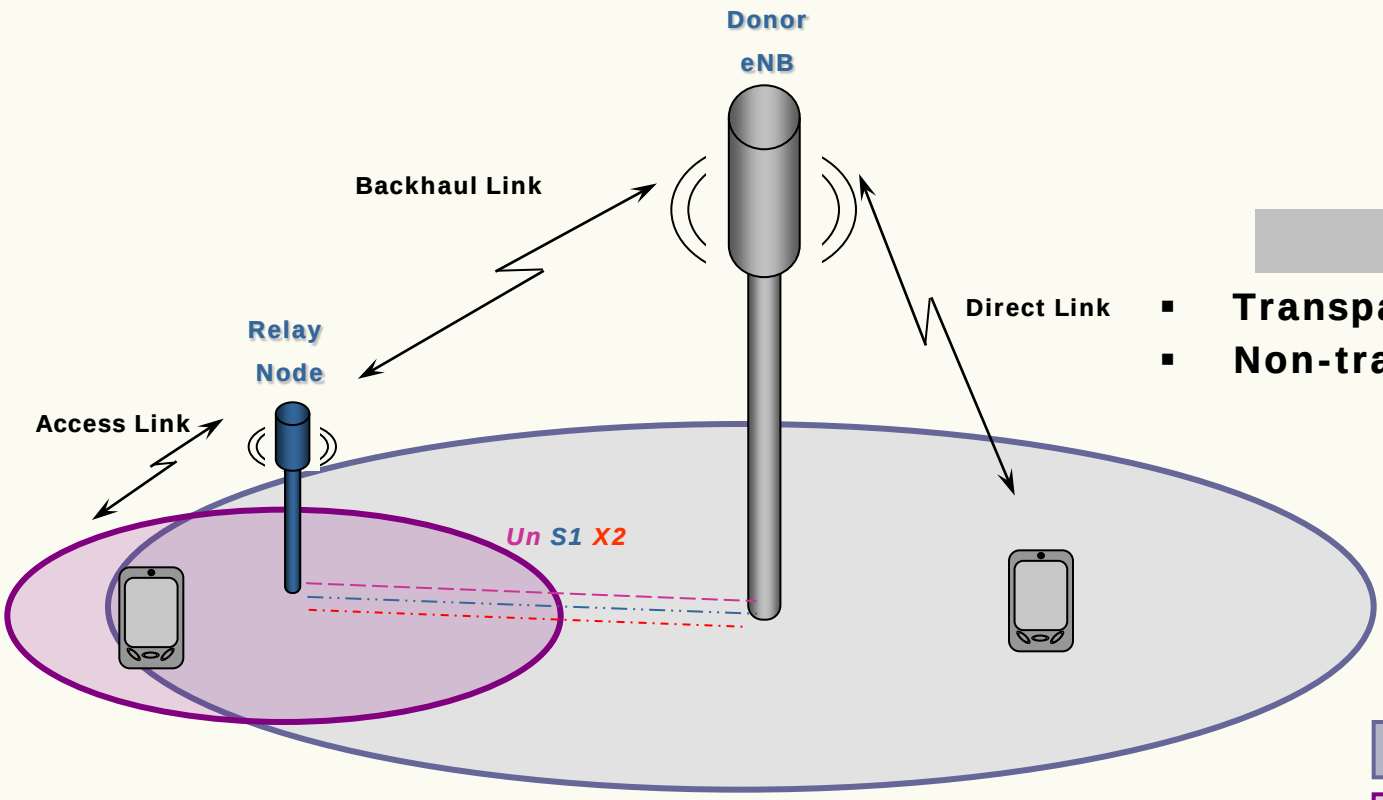
Relaying - 1

- **Key new feature in LTE Rel-10**
- **Repeaters (signal amplifiers) already used in UMTS and LTE Rel-8. Drawbacks:**
  - Noise is amplified along with the signal
  - Due to independent operation separate O&M functionality is required
- **Relay Nodes (RNs) advantages:**
  - Operate under full control of RAN
  - Process the signal before forwarding it

Relaying - 2

Relaying strategy

- RN is a part of a donor cell – no cell ID, split of RRM
- RN controls cells of its own – each cell with unique cell ID



From UE sight

- Transparent
- Non-transparent

Donor cell

Relay Cell

RN: Re

Relaying - 3

- **Use cases**
  - Cell coverage extension
  - Indoor coverage enhancement
  - Boost of capacity in hotspots
  - Overcoming of shadowing troubles
  - Temporary deployments (emergency, events)
  - In-vehicle deployments for group mobility

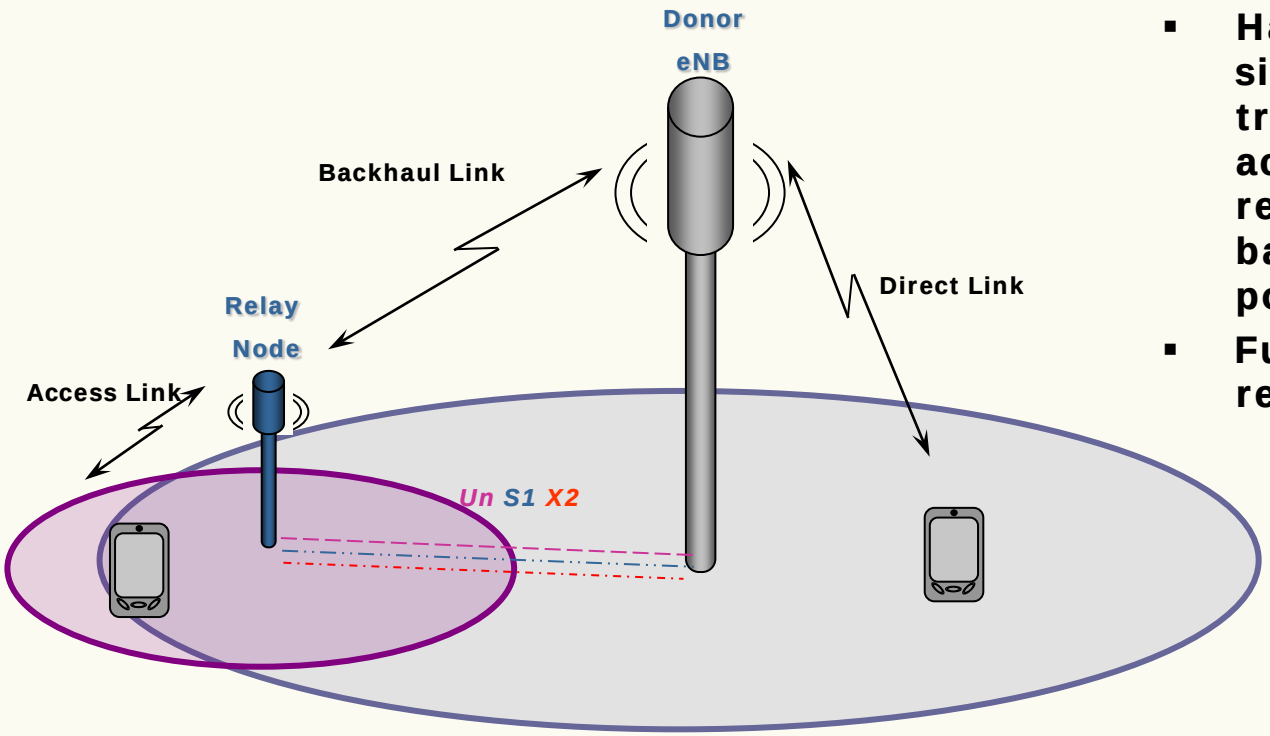
Relaying - 4

Protocol functionality categorisation	
Layer 1 Relay Nodes (L1)	Only RF processing, like Forward Error Correction (FEC) or simple repeaters (amplify-and-forward)
Layer 2 Relay Nodes (L2)	Support of MAC functions and possibly RLC functions, optional implementation of Physical Cell-ID (PCI)
Layer 3 Relay Nodes (L3)	Support of protocols up to RRC in control plane and up to PDCP in user plane, mandatory PCI presence

Relaying - 5

RF Channel Assignments

- Inband, backhaul link and access link use the same carrier frequency
- Outband, different carrier frequencies are used



Operation Mode

- Half-duplex, simultaneous transmission on access link and reception on backhaul link is not possible
- Full-duplex, no restrictions

Donor cell

Relay Cell

Relaying - 6

	Type1	Type2
Cell control	Own cells “appear” as separate cells, distinct from the donor cell	Does not create/control any own cells
Physical Cell ID	Each controlled cell has its own PCI as defined in LTE-Rel-8	No, relay ID only
Compatibility with Rel-8 UEs	Is seen by Rel-8 UE as Rel-8 eNB	Transparent to Rel-8 UEs
Compatibility with LTE-A UEs	Appears different than Rel-8 eNB thus allowing further enhancements	Conformable with Rel-10 UEs
Transmitted channels	PDSCH as well as own synchronisation channels and reference symbols	PDSCH, at very least does not transmit CRS and PDCCH
Control information processing	Scheduling and HARQ feedbacks from RN, it also processes UE’s control channels (SR/CQI/ACK)	Control information is being forwarded from/to donor cell
Spectrum usage	Type 1 – inband, half-duplex Type1a – outband, half-duplex Type1b – inband, full-duplex	Inband
Examples	L3 Relay (Self-Backhauling)	L2 Relay
Advantages	Less design impact on eNB	Better signal quality and better link performance
Disadvantages	More overhead that Type2 relay	Hardship for HARQ

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HetNet and eICIC - 1

- **Heterogeneous Network (HetNet) in LTE is a network consisting of high power macro nodes and low power micro nodes of different capabilities**

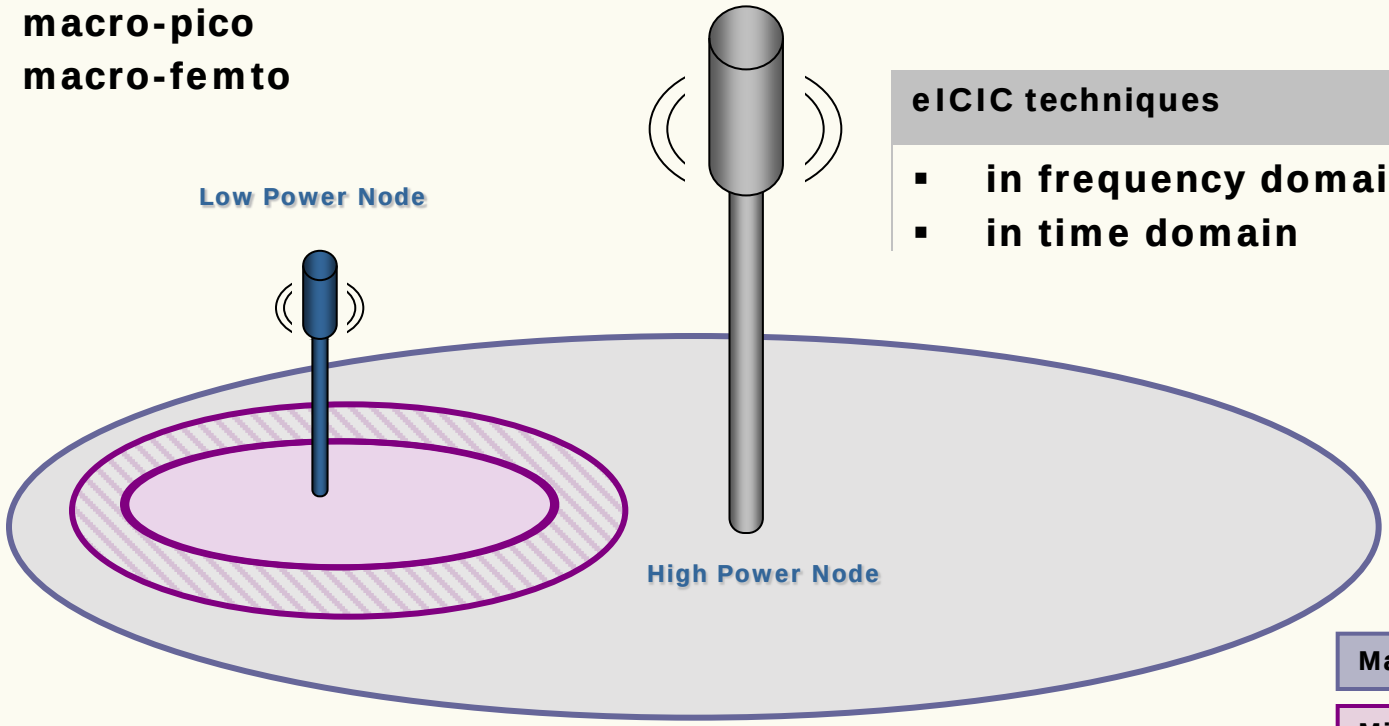
Types of Nodes	Tx Power	Coverage area	Backhaul link
Macro	46 dBm	Up to few km	S1
Pico	23-30 dBm	< 300 m	X2
Femto	<23 dBm	< 50 m	IP
Relay	30 dBm	Up to few km	Un

HetNet and eICIC - 2

Main aim of HetNET is to improve data rates for the edge-cell users

General deployment scenarios

- macro-pico
- macro-femto



eICIC techniques

- in frequency domain
- in time domain

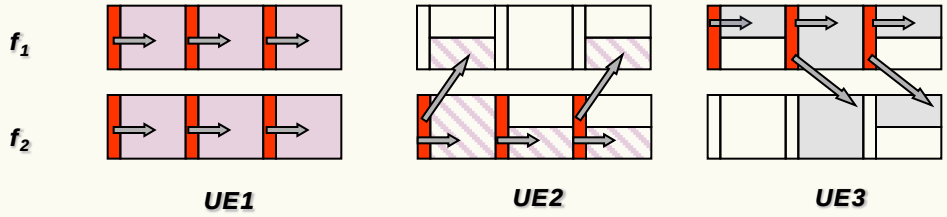
HetNet: Heterogeneous Networks
eICIS: enhanced Inter-Cell Interference Coordination

Macro cell

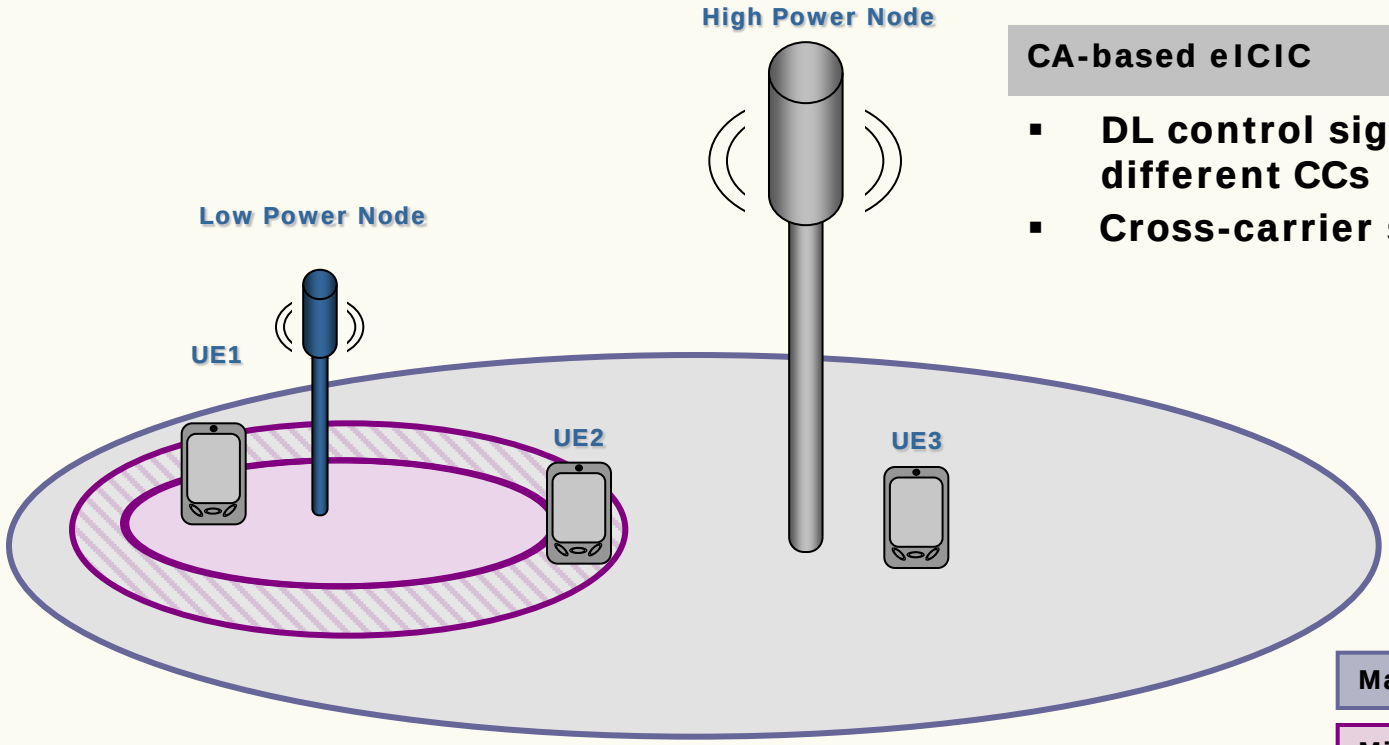
Micro Cell

Cell Range Expansion

HetNet and eICIC - 3



Data scheduling example



CA-based eICIC

- DL control signalling on different CCs
- Cross-carrier scheduling

Macro cell

Micro Cell

Cell Range Expansion

HetNet and eICIC - 4

- **Almost Blank Subframes (ABS) – subframes with reduced downlink transmission power configured to transmit only legacy broadcast signals and channels**
  - all ABS contain common reference signals CRS
  - PSS/SSS/PBCH/SIB1/Paging/PRS are transmitted in the ABS with associated PDCCH when the SIB1/Paging are transmitted
  - ABS pattern signalling to neighbouring eNB over X2
  - Advanced Receiver for cancellation of ABS signal from interfering nodes
- **Channel State Information CSI-RS enhancements**
- **Resource specific CQI**

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Self Organising Networks (SON)

- **SON** are networks for which such tasks as planning, configuration, management, optimisation and healing can be run at most automatically

- Rel-10 enhancements:
  - Coverage and Capacity Optimization (**CCO**)
  - Mobility Load Balancing (**MLB**)
  - Mobility Robustness Optimization (**MRO**)

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Minimisation of Drive Tests (MDT)

- **Two modes are specified in Rel-10**
  - **Logged** MDT – measurements performed by UE in idle mode and reported at some later point in time
  - **Immediate** MDT – measurements performed by UE in connected mode
- **MDT can define a geographical area (cell(s) / tracking area / whole PLMN) where measurements should be performed**
- **UE measurement may be linked with time stamps and location information**

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MBMS Enhancements

- **There are two enhancements to existing MBMS features introduced in Rel-10**

  - Counting, to supervise number of UEs receiving or interested in receiving particular MBMS service
  - Allocation and Retention Priority (**ARP**) – prioritisation of MBMS bearers

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Future Developments - 1

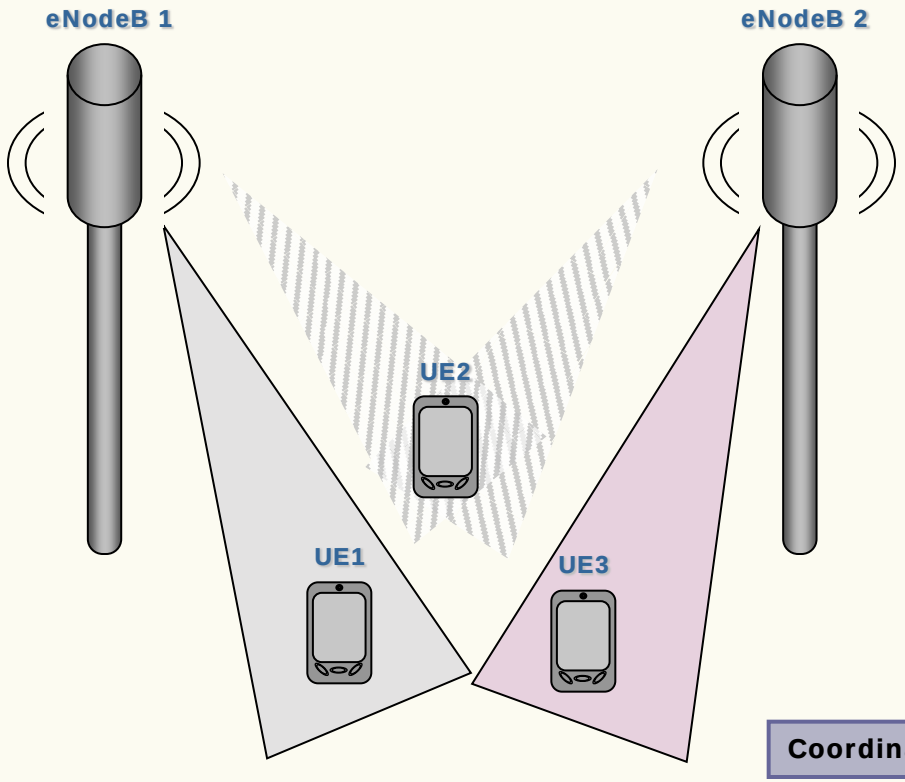
- **Global goals**
  - Increase of system capacity and spectrum utilisation efficiency
  - User throughput growth
  - Improvement of the cell-edge user throughput
  - Cost/bit reduction
  - Energy saving for environmental and operational targets

Future Developments - 2

- **Further enhancements**
  - Coordinated Multipoint Transmission/ Reception (**CoMP**)
  - DL and UL MIMO enhancements
  - CA enhancements
  - Further ICIC enhancements
  - SON, MDT enhancements
  - Machine-Type Communications (**MTC**)

Co-ordinated Multi-Point Transmission (CoMP) - 1

Cell-edge UE combines signals received from multiple cells
Its own transmissions may also be received at multiple cells



Possible Scenarios

- **inter-site**
- **intra-site**

Coordinated beamforming, eNB1 is Serving Cell

Coordinated beamforming, eNB2 is Serving Cell

Joint processing

Co-ordinated Multi-Point Transmission (CoMP) - 2

- **CoMP Support types:**
  - Joint Processing
    - Joint transmission/Joint reception JT/JR
    - Dynamic cell selection (DL-only)
  - Co-ordinated scheduling/beamforming (CBF)
    - Centralised
    - Distributed

Co-ordinated Multi-Point Transmission (CoMP) - 3

- **Impacts on radio-interface specs:**
  - Feedback & measurement mechanisms from UE
    - Explicit channel feedback
    - Implicit channel feedback
  - Joint pre-processing prior to transmission & control signalling
  - Reference signal design
- **Additional requirements for the Rel-8 LTE modifications are**
  - Synchronous operation of eNBs
  - Cell specific pilots for multi-cell CSI estimation
  - Reduction of overhead caused by channel feedback /channel state information

References:

- Overview of **3GPP Release 10 V0.1.4 (2012-03),** http://www.3gpp.org/ftp/Information/WORK_PLAN/Description_Releases/
- **3GPP TS 37.320 V10.4.0 (2011-12) -** Radio measurement collection for Minimization of Drive Tests (MDT); Overall description; Stage 2 (Release 10)
- **3GPP TR 36.912 V10.0.0 (2011-03)** - Feasibility study for Further Advancements for E-UTRA (LTE-Advanced)(Release 10)
- **3GPP TS 36.300 V10.7.0 (2012-03)** - Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2
- Stefania Sesia, Isaam Toufik,Matthew Baker – **LTE-The UMTS Long Term Evolution**, Wiley, 2011
- Stefan Parkvall, Erik Dahlman, George Jöngren, Sara Landström and Lars Lindbom **- Heterogeneous network deployments in LTE**, Ericsson Review 2011-03