4G Radio Access Key Technologies
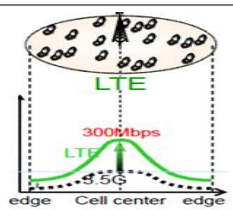
ZHU LONGMING

Chongqing, China
20, October 2016

Part I

Evolution

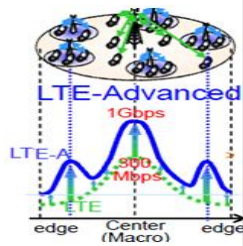# 4G Standard Evolution, LTE-A in 3GPP

LTE (R8/R9)

- DL: 100Mbps, UL: 50Mbps
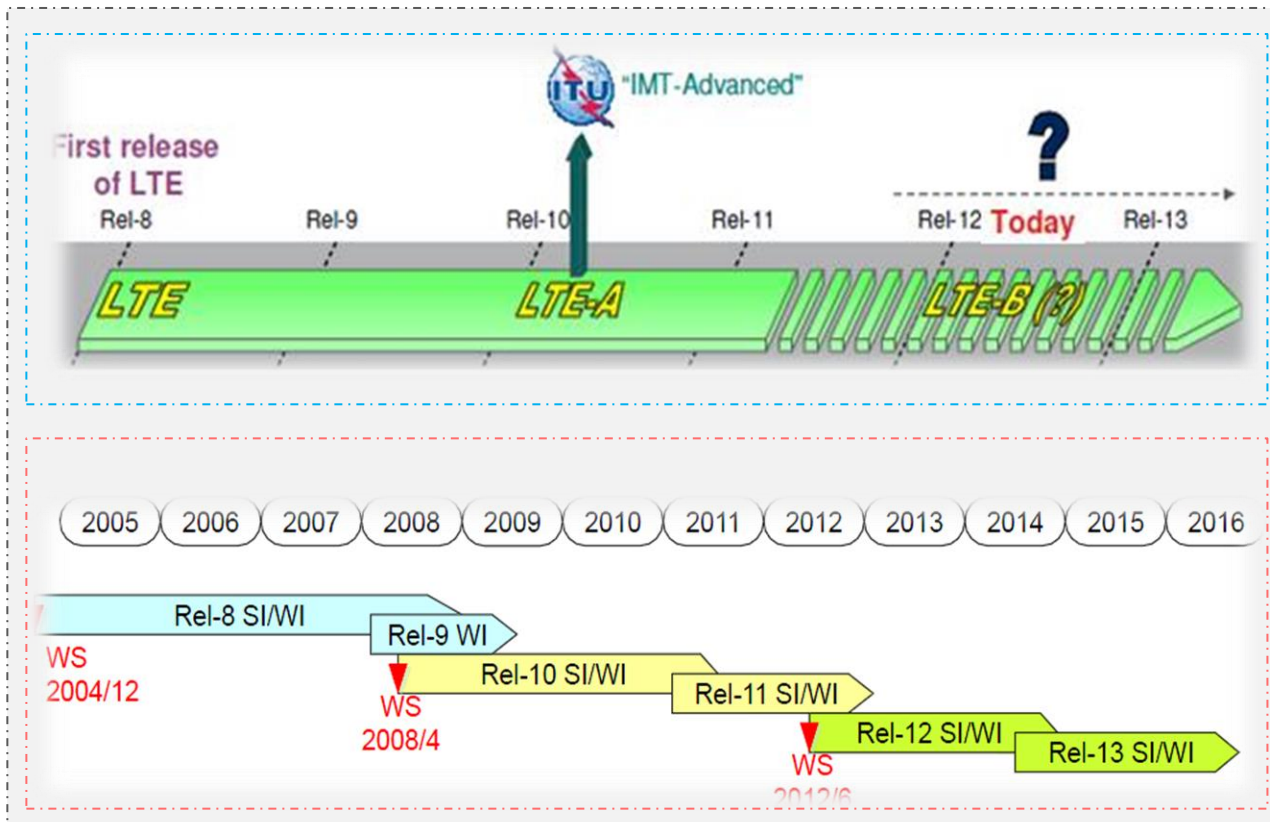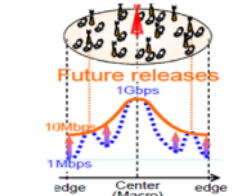- MIMO, BF , LCS, eMBMS

LTE-A (R10/R11)

- DL: 1Gbps, UL: 500Mbps
- CA, Relay, Het-Net
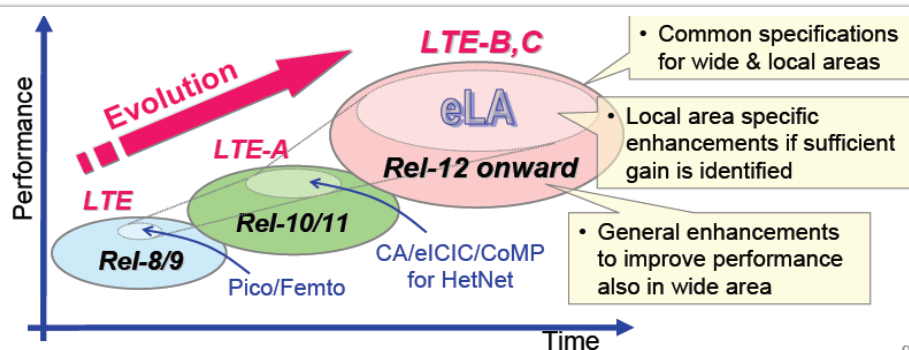- CoMP, eMIMO

LTE-A (R12/R13)

- 256QAM/Small Cell
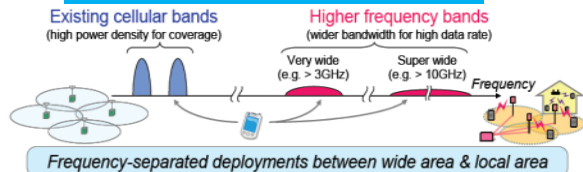- eCA
- LAA

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Update Version of LTE-A, R12

LTE-A Evolution Progress

- LTE-A(R12) was initiated in June, 2012. The 1st Version was released in December of 2014.

- LTE-A(R12) includes eCA, Small Cell and LAA

Performance / Time

Evolution

LTE-B,C

eLA

Rel-12 onward

LTE-A

Rel-10/11

LTE

Rel-8/9

Pico/Femto

CA/eICIC/CoMP for HetNet

- Common specifications for wide & local areas
- Local area specific enhancements if sufficient gain is identified
- General enhancements to improve performance also in wide area

LTE-A(R12) key technologies

Spectrum (>3.5G)

Existing cellular bands (high power density for coverage)

Higher frequency bands (wider bandwidth for high data rate)

Very wide (e.g. > 3GHz) Super wide (e.g. > 10GHz)

Frequency

Frequency-separated deployments between wide area & local area

- 3.5G TDD spectrum application
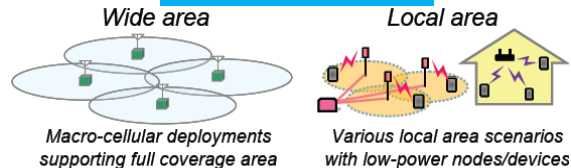- Over 10GHz spectrum application

eCA

Carrier aggregation for continuous carrier

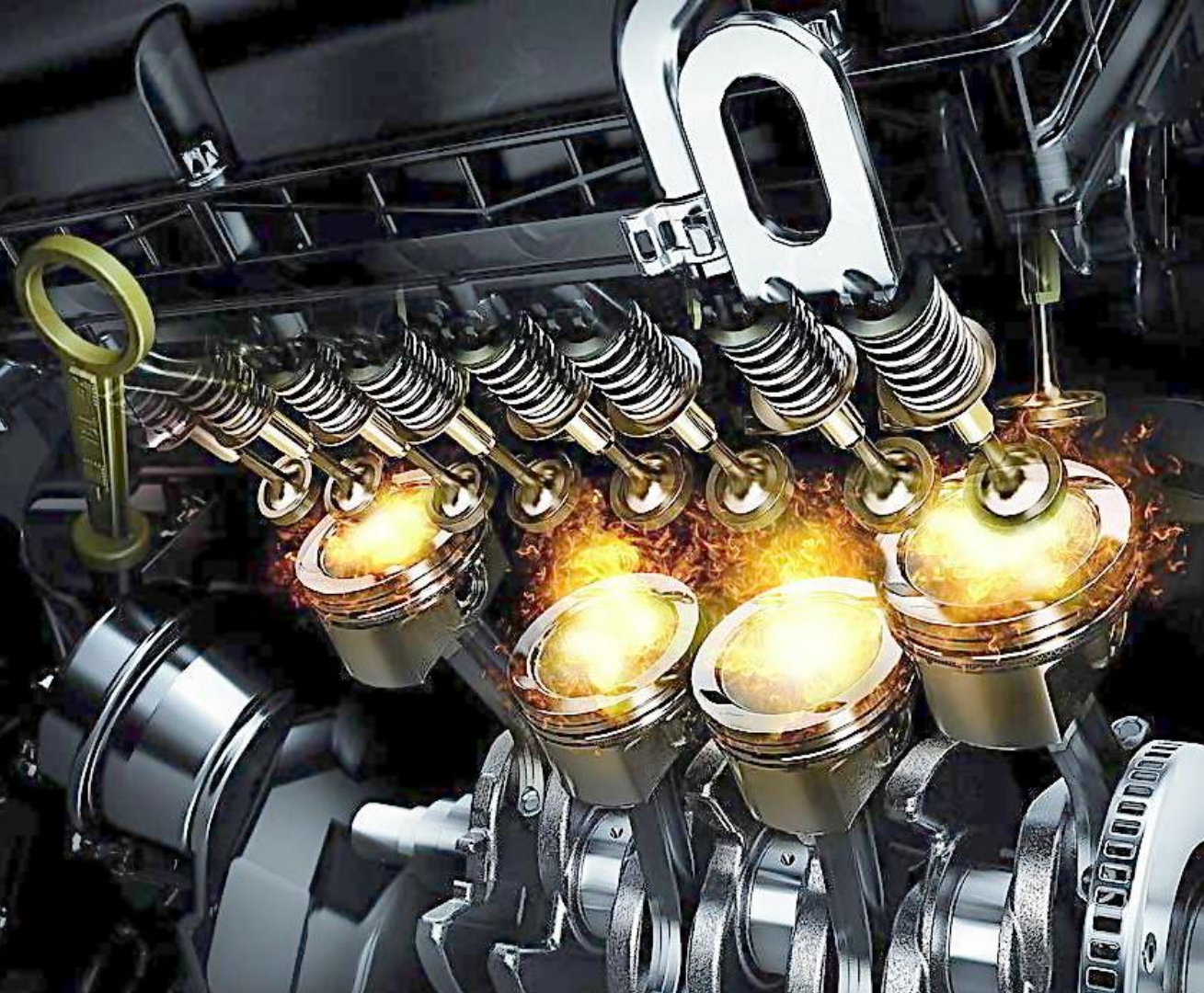Carrier aggregation for non-continuous carrier

- CA between FDD and TDD
- CA between different operators
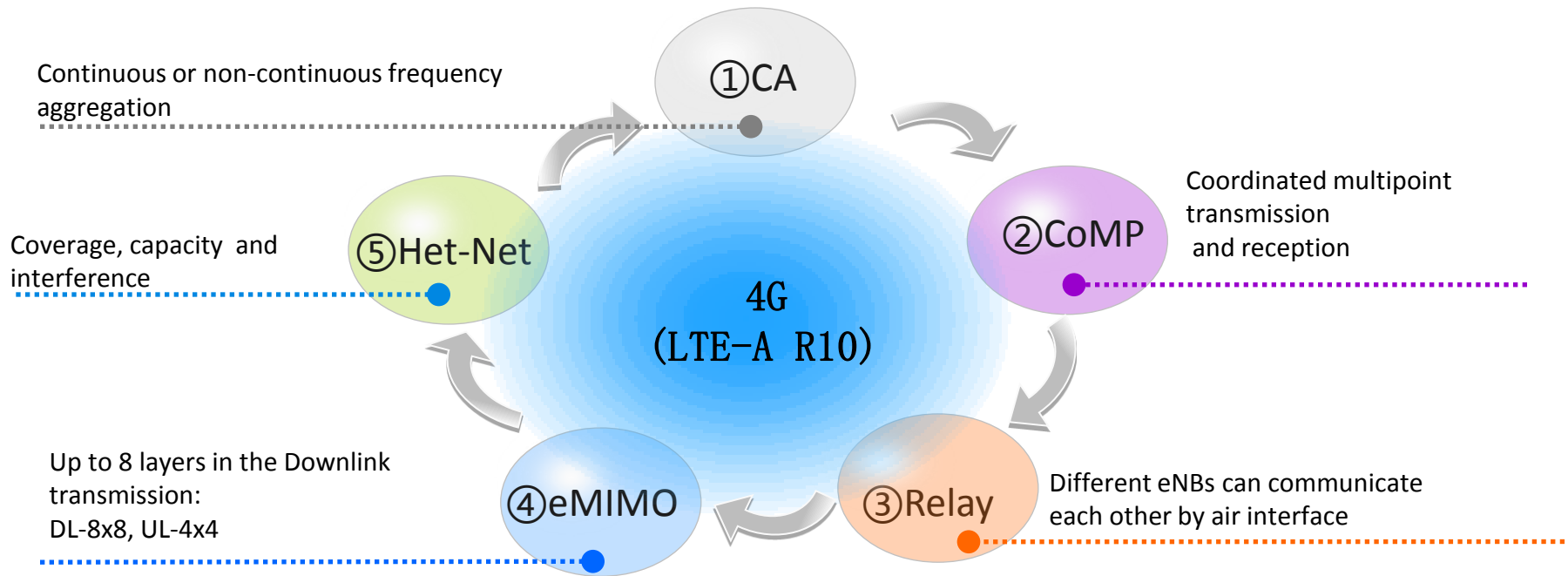- CA between LTE and WiFi ......

Small Cell

Wide area *Local area*

Macro-cellular deployments supporting full coverage area

Various local area scenarios with low-power nodes/devices

- HOM (256QAM)

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Part II

Technologies

(R10)

4G Key Technologies in R10 (LTE-A)

Continuous or non-continuous frequency aggregation

①CA

Coordinated multipoint transmission and reception

②CoMP

Coverage, capacity and interference

⑤Het-Net

4G
(LTE-A R10)

②CoMP

③Relay

Different eNBs can communicate each other by air interface

④eMIMO

Up to 8 layers in the Downlink transmission:
DL-8x8, UL-4x4

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①CA - Carrier Aggregation

Wider bandwidth transmission using carrier aggregation

- Entire system bandwidth up to e.g., 100MHz, is comprised of multiple basic frequency blocks called component carrier (CC)

  → Satisfying the requirements for peak data rate

- Each CC can be configured in a backward compatibility with LTE(R8)

  → Maintaining backward compatibility with LTE(R8)

- Carrier aggregation supports both contiguous and non-contiguous spectrum, and asymmetric bandwidth for FDD

  → Achieving flexible spectrum usage
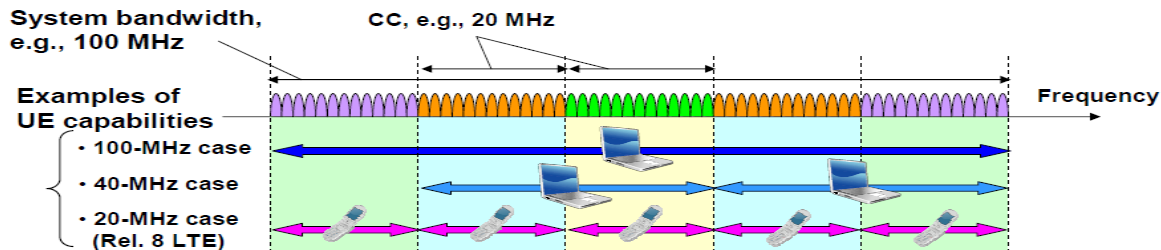
- In R12, the Carrier Aggregation between FDD and FDD was further introduced.

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CA - Downlink

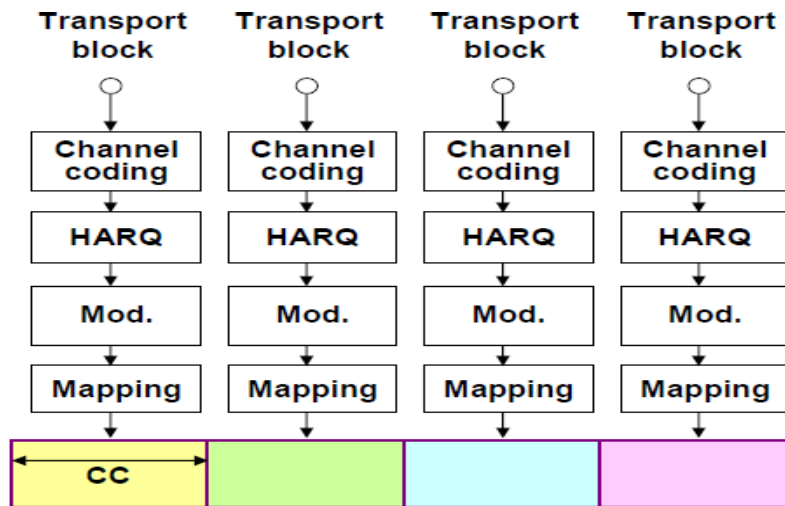**Downlink: base on the structure of CC**

→ Priority given to reusing R8 specification for low-cost and fast deployment

One transport block is mapped within one CC
Parallel-type transmission for multi-CC transmission

Good affinity to Rel. 8 LTE specifications
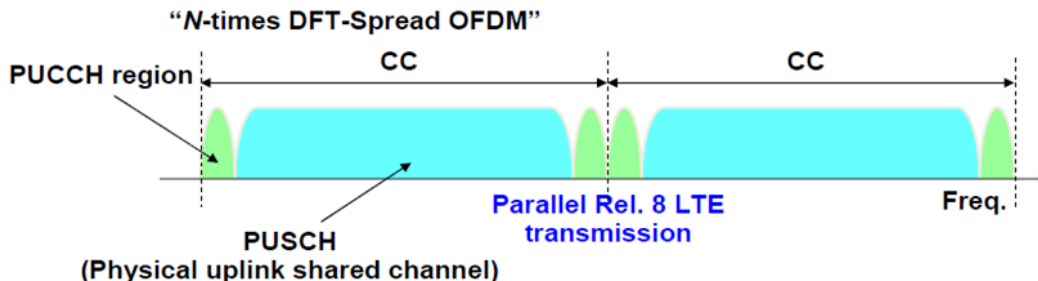
Cross-carrier scheduling is possible:
- PDCCH on one carrier can relate to data on another carrier

Transport block	Transport block	Transport block	Transport block
Channel coding	Channel coding	Channel coding	Channel coding
HARQ	HARQ	HARQ	HARQ
Mod.	Mod.	Mod.	Mod.
Mapping	Mapping	Mapping	Mapping
CC			

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CA - Uplink

Uplink: N x DFT-Spread OFDM

- Realize wider bandwidth by adopting parallel multi-CC transmission

  →Satisfy requirements for peak data rate while maintaining backward compatibility

  → Low-cost and fast deployment by reusing LTE R8 specification

- Support non-contiguous resource allocation

  → Enhanced flexibility and efficiency of resource allocation

- Support PUCCH and PUSCH transmission simultaneously

- Provide independent power control per CC

"N-times DFT-Spread OFDM"

PUCCH region   CC   CC

Parallel Rel. 8 LTE transmission

PUSCH
(Physical uplink shared channel)

Freq.

Non SC-FDMA, Higher PAPR → Not suitable for cell edge users!

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CA - Deployment Scenarios

- F1 and F2 cells are co-located and overlaid, providing nearly the same coverage. and mobility can be supported on both layers.

- F1 and F2 cells are co-located and overlaid, but F2 has smaller coverage due to larger path loss. Only F1 provides sufficient coverage. Mobility is performed based on F1 coverage

- F1 and F2 cells are co-located but F2 antennas are directed to the cell boundaries of F1 so that cell edge throughput is increased. F1 provides sufficient coverage but F2 potentially has holes, e.g., due to larger path loss. Mobility is based on F1 coverage.

- F1 provides macro coverage and on F2 Remote Radio Heads (RRHs) are used to provide throughput at hot spots. Mobility is performed based on F1 coverage **(DL only for R10)**

- Similar to scenario #2, but frequency selective repeaters are deployed so that coverage is extended for one of the carrier frequencies. It is expected that F1 and F2 cells of the same eNB can be aggregated where coverage overlap**. (DL only for R10)**

F1   F2

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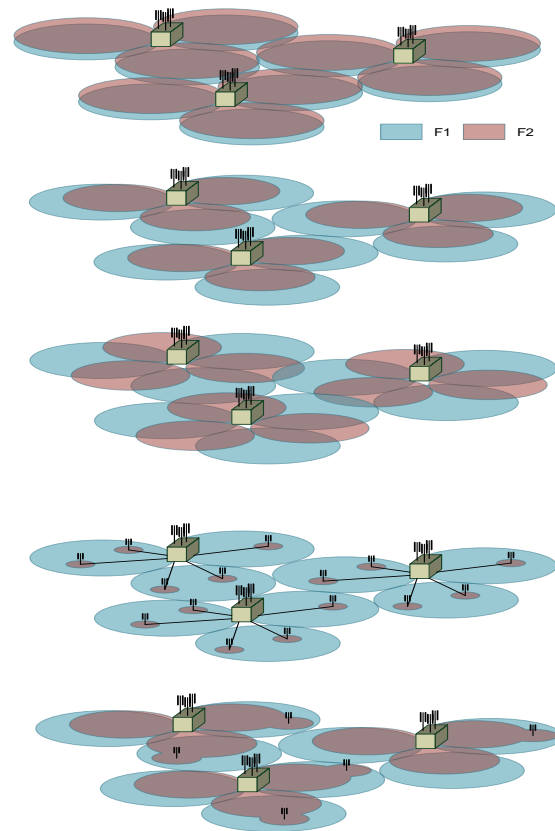
②CoMP

CoMP Scenarios

– **Scenario 1**

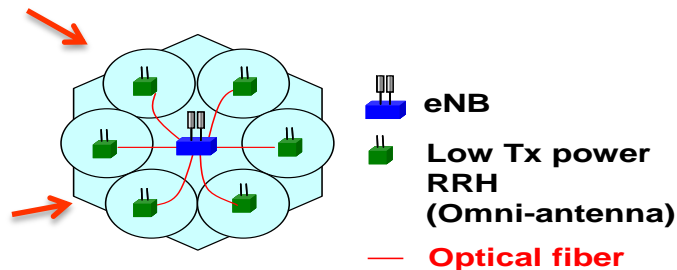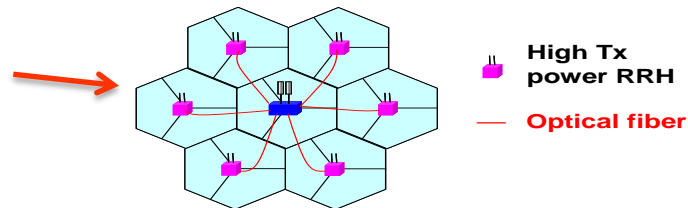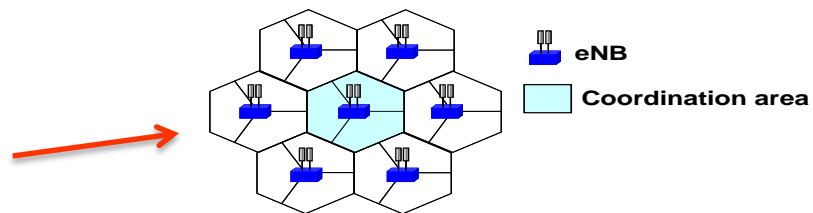Homogeneous network with intra-site CoMP

– **Scenario 2**

Homogeneous network with high Tx power RRHs

– **Scenario 3**

Heterogeneous network with low power RRHs within
the macrocell coverage where the Tx/Rx points created
by the RRHs have different cell IDs as the macro cell

– **Scenario 4**

Heterogeneous network with low power RRHs within
the macrocell coverage where the Tx/Rx points created
by the RRHs have the same cell IDs as the macro cell

eNB

Coordination area

High Tx power RRH

— **Optical fiber**

eNB

Low Tx power RRH (Omni-antenna)

— **Optical fiber**

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CoMP - Downlink

Downlink CoMP Categories

- **Joint Processing (JP)**

  Data for a UE is available at more than one point in the CoMP cooperating set (definition below) for a time-frequency resource.

    - Joint Processing (JP) includes Joint Transmission (JT) and Dynamic point selection (DPS)
    - Joint Transmission (JT): Simultaneous data transmission from multiple points (part of or entire CoMP cooperating set) to a single UE or multiple UEs in a time-frequency resource.

- **Coordinated Scheduling/Coordinated Beam-forming (CS/CB)**

  Data for an UE is only available at and transmitted from one point in the CoMP cooperating set but user scheduling/ beam-forming decisions are made with coordination among points corresponding to the CoMP cooperating set.

Coherent combining or dynamic cell selection

Joint transmission/dynamic cell selection

Coordinated scheduling/beamforming

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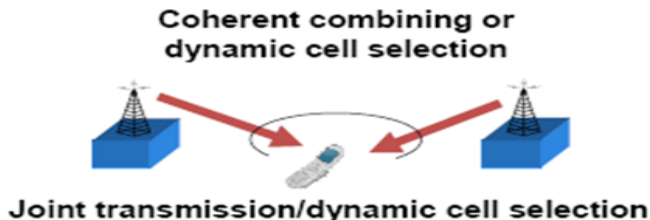
CoMP - Uplink

Uplink CoMP Categories

- **Joint Reception (JR)**

    PUSCH transmitted by the UE is received

    jointly at multiple points (part of or entire

    CoMP cooperating set) at a time,

    e.g., to improve the received signal quality

- **Coordinated Scheduling/Beamforming (CS/CB)**

    The user scheduling and pre-coding selection decisions are made with coordination among points corresponding to the CoMP

    cooperating set. The data is intended for one point only.

Multipoint reception
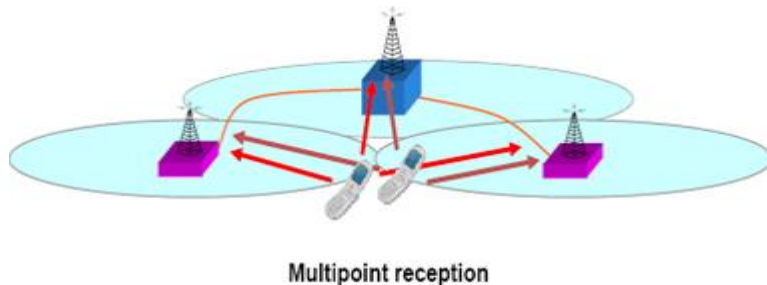
Uplink CoMP has no changes to air interface.

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③Relay

- **Concept**
  - A new node between eNB and UE
  - Wireless backhaul between eNB and RN

- **Benefit**
  - Coverage of high data rates
  - Group mobility
  - Temporary network deployment
  - Cell-edge throughput

- **Category**
  - In-band and out-band
 - Type1(1a and 1b)

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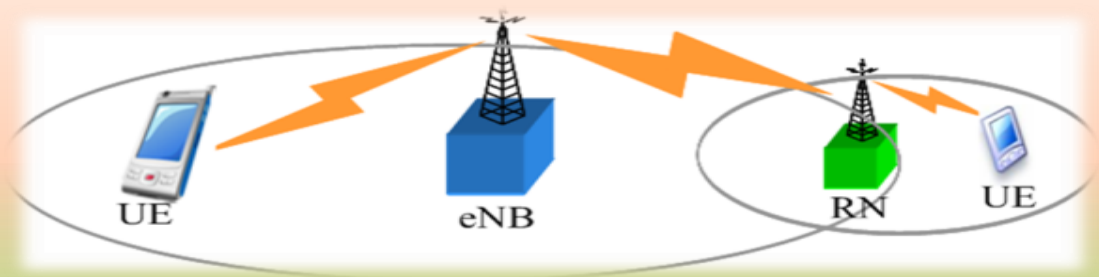
Relay - Type 1

- ➢ Type 1 Relay Zone is a different cell from the Donor cell
  - e.g., with different cell ID, RS, Sync signal etc.
- ➢ UE receives/transmits control signals for scheduling and HARQ from/to RN
- ➢ FAKE MBSFN Sub-frames for backhaul partitioning
  - SF #0, #4, #5 and #9 in FDD and #0, #1, #5 and #6 in TDD cannot be configured for downlink backhaul, since system information, paging channels are located
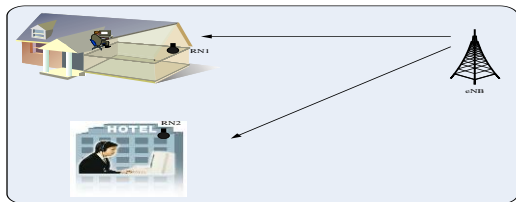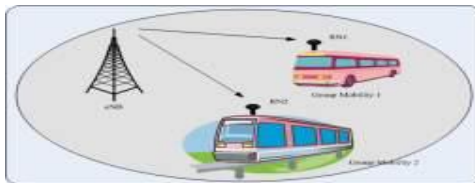 - R-PDCCH has to be defined in LTE R8 PDSCH region
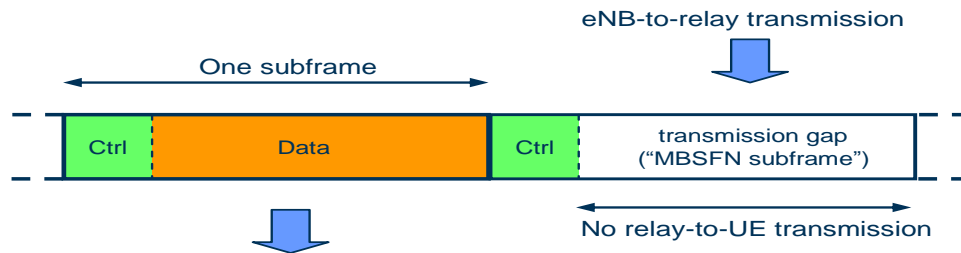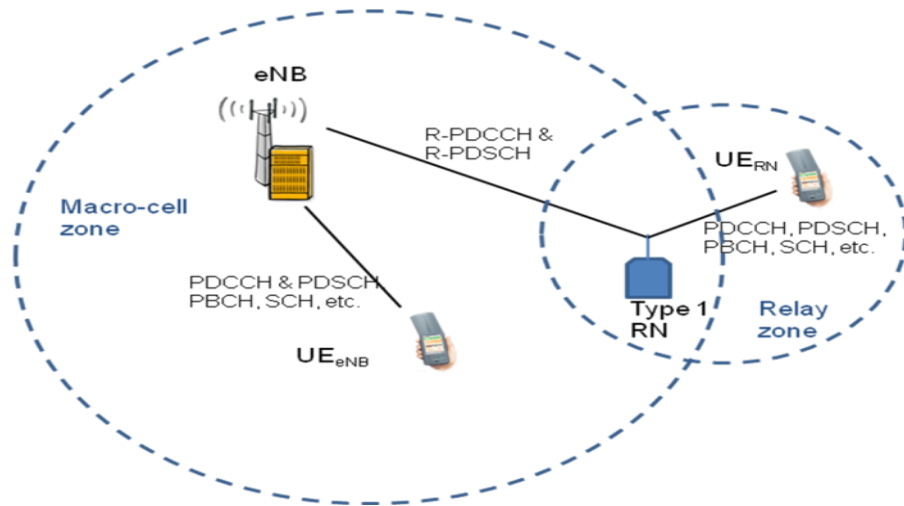
Relay-Application Scenarios
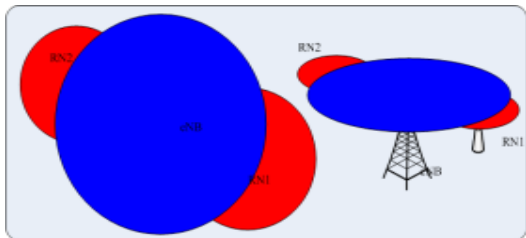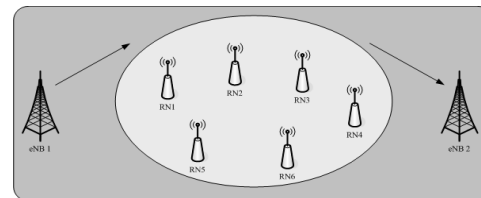

Rural area
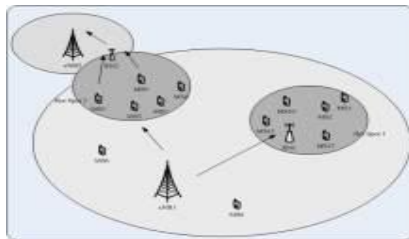
Urban hot spot
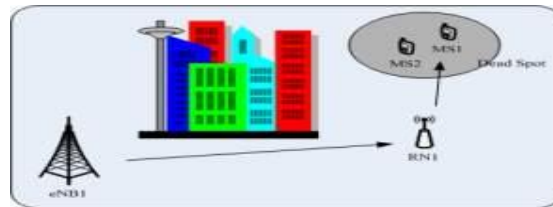
Dead spot
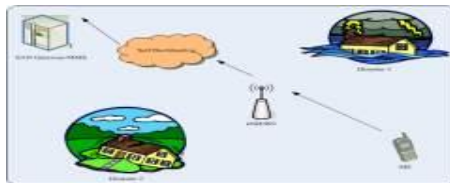

Indoor hot spot

Group mobility

Wireless backhaul only

Emergency or temporary network deployment
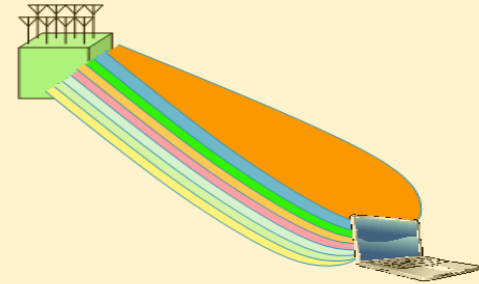
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④Enhanced MIMO
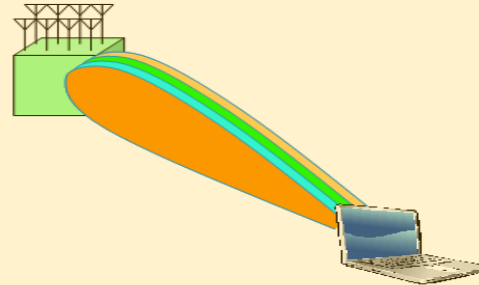
- **DL MIMO**

  - Up to 8Tx in new TM 9
  - SU-MU dynamic switch
  - 8 Tx Codebook
    - Implicit feedback
    - Double codebook design
  - CSI-RS: measurement RS for Rel 10
  - DMRS: pre-coding demodulation RS

- **UL MIMO**

  - PUCCH TxD: SORTD

  - PUSCH SM up to 4Tx/4 layers

8x8 MIMO in DL

4x4 MIMO in UL

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Enhanced MIMO - Uplink

UL transmit diversity for PUCCH

→ Improving signal robustness and cell-edge performance

SU-MIMO up to 4-stream transmission

→ Satisfying the peak spectrum efficiency (e.g. 15bps/Hz)

Signal detection scheme with affinity to DFT-S-OFDM for SU-MIMO

- Turbo-SIC is applied in eNB receiver to achieve higher throughput performance

→ Improving user throughput, while maintaining low cubic-metric signal transmission

Max. 4 streams

SU-MIMO up to 4 streams

ZTE
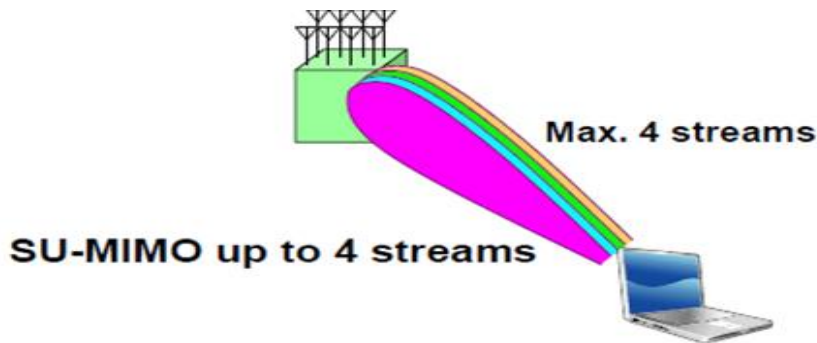
Enhanced MIMO - Downlink

■ Extension up to 8-layer transmission

→ Satisfying the requirement for peak spectrum efficiency (e.g., 30bps/Hz)

■ Additional reference signal (RS) specified

- Channel state information RS (CSI-RS)
  - For downlink channel sounding
  - Sparse, low overhead (configurable)
- UE-specific demodulation RS (DM-RS)
  - UE-specific DM-RS can be pre-coded, supporting non-codebook-based pre-coding
  - DM-RS is only used for the demodulation of PDSCH
  - DM-RS pattern for higher numbers of layers is extended from 2-layer format for TM8 in Rel-9

Max. 8 streams

Baseline

CSI feedback

Enhanced MU-MIMO

ZTE
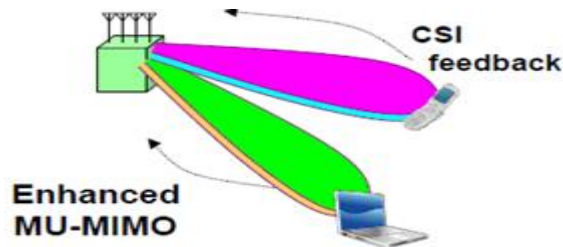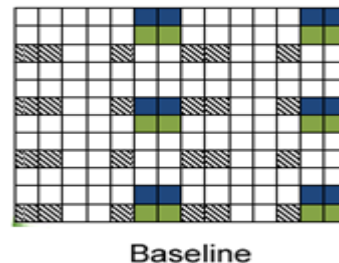
⑤Het Net - Heterogeneous Networks

Het-Net

- Multiple tiers of network of a single RAT
- Low power nodes (LPN) are placed throughout a macro-cell layout (overlaid)

LPN

- RRH
  - Low latency (µs) backhaul to macro, open, planned deployment
- Pico eNB (Hotzone)
  - X2 backhaul, open, planned deployment
- HeNB/Femto
  - No X2; CSG, consumer deployed, indoors
- Relay
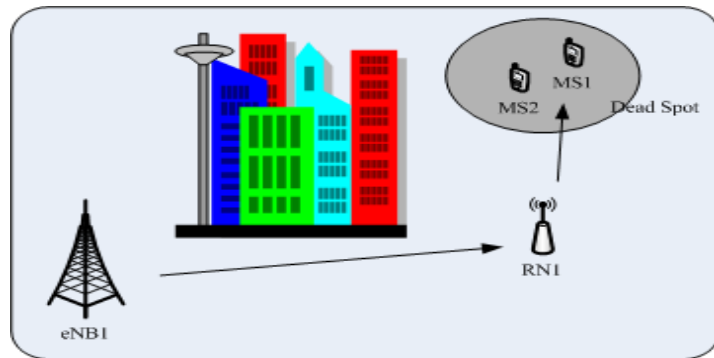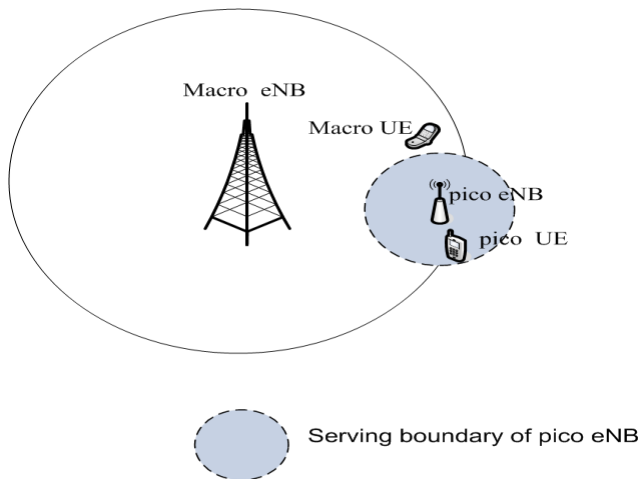 - in-/out-band RN, open, planned deployment

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Het Net - Architecture
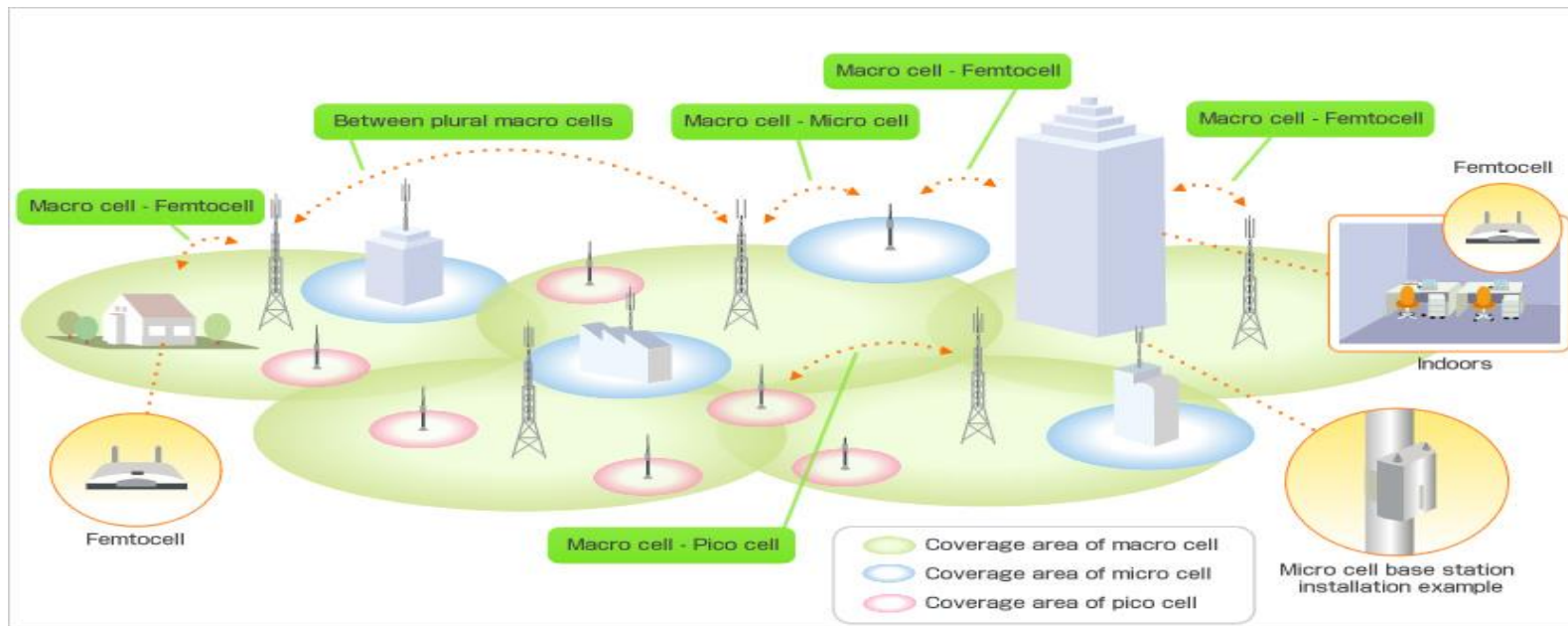
Het Net - Application Scenario 1

Scenarios 1: **coverage**

- Seamless coverage for rural area or cell edge, lower CAPEX
- e.g., fixed RN/pico

- Blind spot
- e.g., RN or micro/pico

Macro eNB
Macro UE
pico eNB
pico UE

Serving boundary of pico eNB

MS1
MS2
Dead Spot
RN1
eNB1

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Het Net - Application Scenario 2

Scenarios 2: **capacity**

- Hot spot/zone
- e.g. high density UEs in a small area

- Indoor: improving capacity and providing coverage
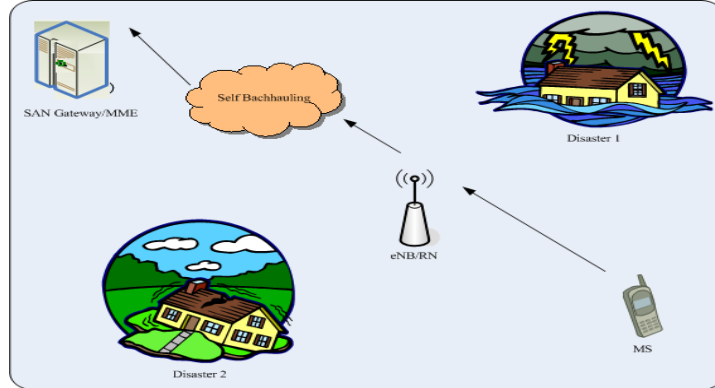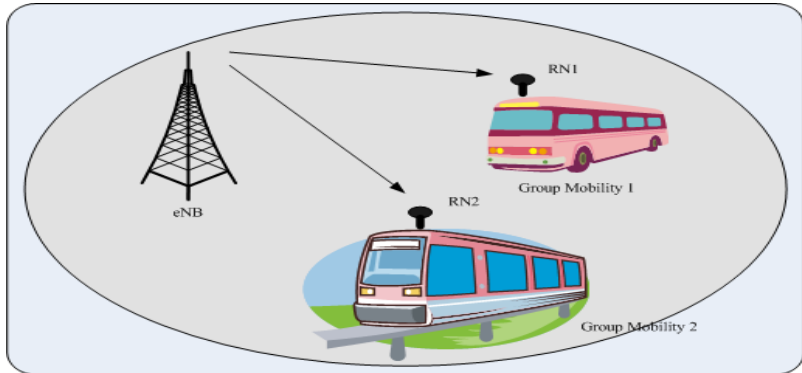- e.g., femto

ZTE
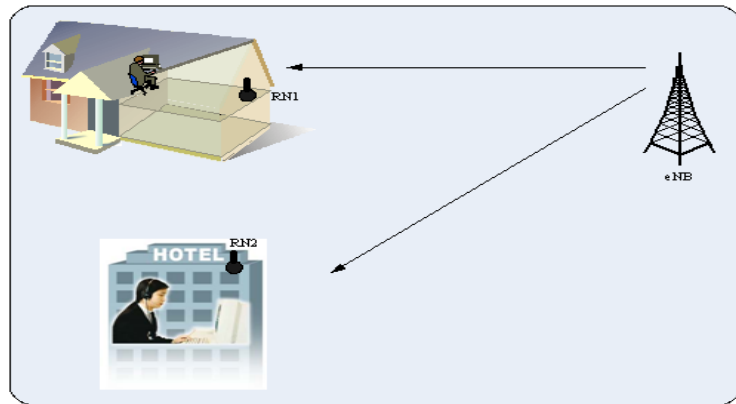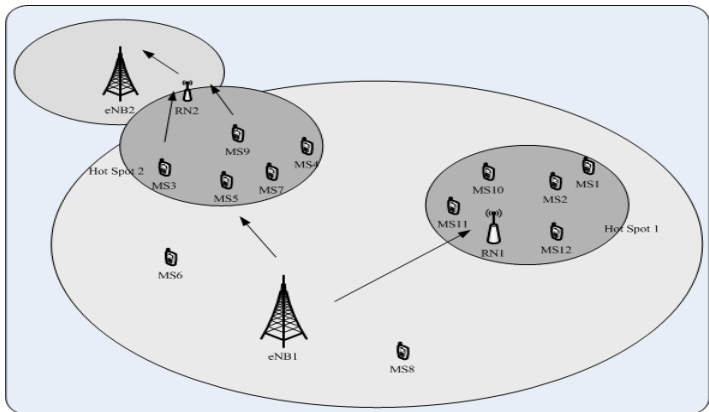
Het Net - Application Scenario 3

Scenarios 3: others

- Group mobility
- e.g., mobile RN

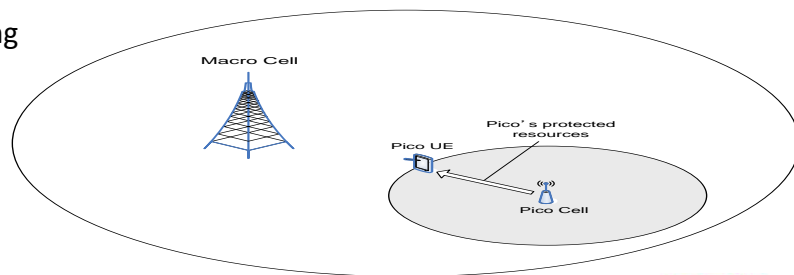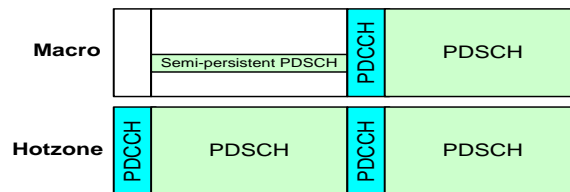- Emergency or Temporary Network Deployment
- e.g., RN

Het Net - eICIC based on ABS

- Het-Net co-deployment problem: interference!

- eICIC solutions - ABS
    - Time domain: Almost Blank Subframes (ABS)
    - ABS Contains no data but may have essential signals for legacy support (PSS/SSS, PBCH, CRS, Paging, SIB1 etc.)
    - In ABS, very low interference to UEs of neighbor cells
    - Macro cell(s) utilizing ABS to protect the corresponding pico cell's subframes
    - Pico cell schedules serving UEs correspondingly considering received ABS pattern(s) from other cell(s)
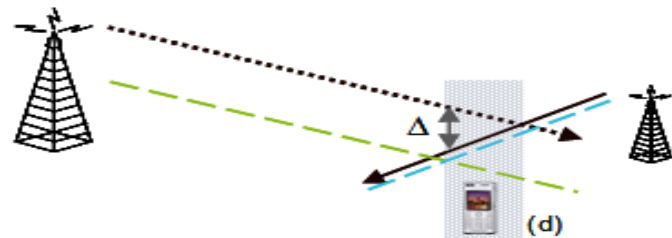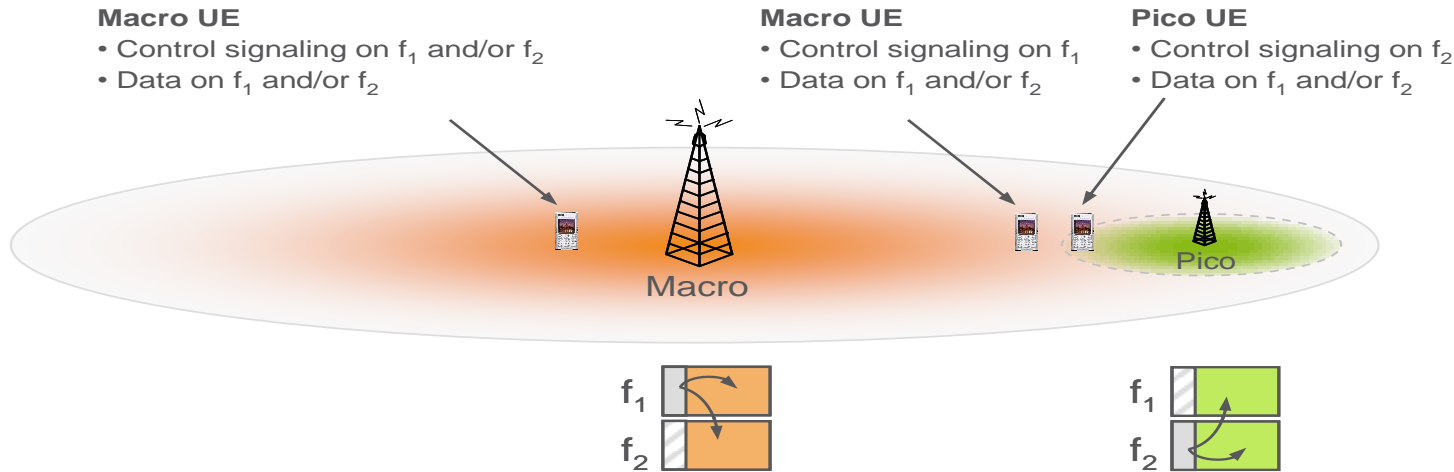

Rx power (solid, dotted->macro), 1/pathloss (dashed)

Het Net – eICIC based on CA

CA applies to heterogeneous deployments

Macro UE
- Control signaling on f_1 and/or f_2
- Data on f_1 and/or f_2

Macro UE
- Control signaling on f_1
- Data on f_1 and/or f_2

Pico UE
- Control signaling on f_2
- Data on f_1 and/or f_2

Macro

Pico

f_1 f_2

f_1 f_2

Cross-carrier scheduling →
Downlink control channel interference avoidance!

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Part III

Technologies

(R12)

4G Enhanced Features in R11(LTE-A)

- **Carrier aggregation (CA) enhancements**
  - Different TDD UL/DL configuration on different band
  - Multiple timing advances for UL CA
- **Enhanced downlink control channel (E-PDCCH)**
  - Enhanced DL control channel to support increased
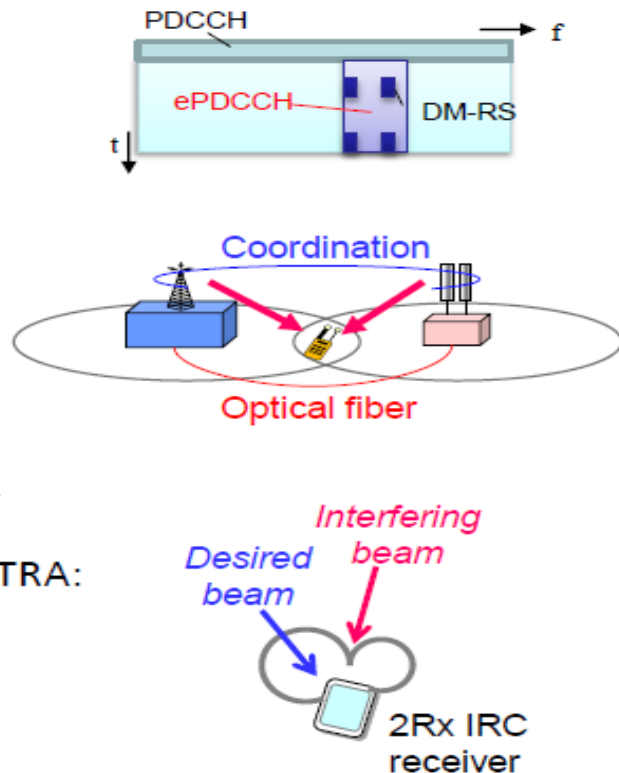 - control channel capacity, freq. domain ICIC, beamforming and/or diversity
- **CoMP transmission and reception**
  - CoMP for Homogeneous/Heterogeneous NW
    - Enhancement on DL/UL reference signal, control signal
    - Channel state information feedback and measurement
- **Further enhanced inter-cell interference coordination (FeICIC)**
  - Interference cancelation technique for UE (e.g., CRS canceller from Macro-cell)
- **Improved minimum performance requirements for E-UTRA: Interference rejection**
  - Interference rejection combining (IRC) UE receiver

PDCCH

ePDCCH DM-RS

f

t

Coordination

Optical fiber

Interfering beam

Desired beam

2Rx IRC receiver

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4G New Features in R12 (LTE-A)

- **Study Item**
  - Small Cell Enhancement
  - 3D-channel model for Elevation Beamforming and Full Dimension-MIMO
  - Network-Assisted Interference Cancellation and Suppression
  - Device to Device (D2D) Proximity Services
    - Discovery/Communication
  - Enhanced Coordination Multi-Point (CoMP) Transmission/Reception
- **Work Item**
  - New Carrier Type (NCT)
    - Stand alone NCT/Non-stand alone NCT
  - Further enhancements to TDD for DL/UL Interference Management and Traffic Adaptation (eIMTA)
  - Further DL MIMO Enhancement
  - Low cost & enhanced coverage MTC UE
    - Low cost MTC
    - Coverage enhancement
  - TDD-FDD Carrier Aggregation
 - Coverage Enhancements

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①Small Cell

Application Scenarios

- **The evolution of LTE technology**
- **In order to meet the demand of hot spot and indoor coverage scenario**

Advantages

- **Ultra high speed**
- **Can management and control**
- **The current version of LTE terminal can access to the new system**

| 2/3G Small Cell	LTE Small Cell	Small Cell Enhancement
Pico	**Pico**	Small Cell
Femto	**Femto**	

ZTE
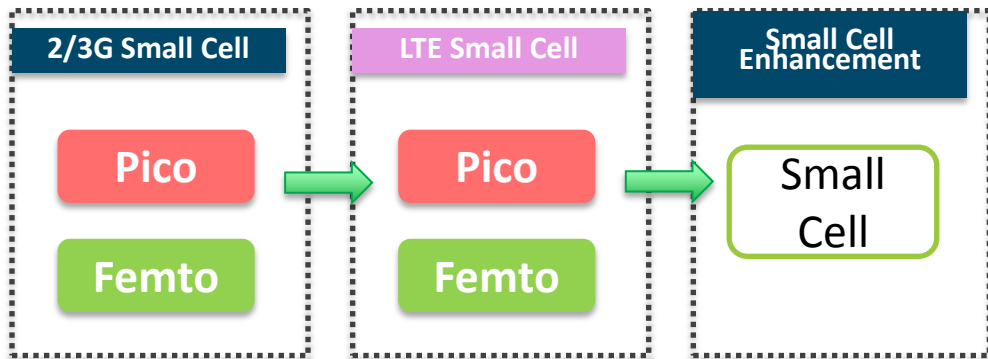
Small Cell - Enhancement


- **Objective**
  - **Spectrum efficiency improvements**
    - Higher order modulation (e.g., 256QAM)
    - Overhead reduction, control signaling enhancement
  - **Efficient small cell operation**
    - Interference avoidance and coordination
    - Small cell ON/OFF, load balancing/shifting, et al.
    - Efficient small cell discovery
    - Radio Interface-based sync.
  - **Physical layer study for higher-layer aspects**
    - Dual connectivity to macro and small cell layers
    - Mobility enhancements
- **Study will be closed and specification works for identified technologies will start in Sep. 2013**

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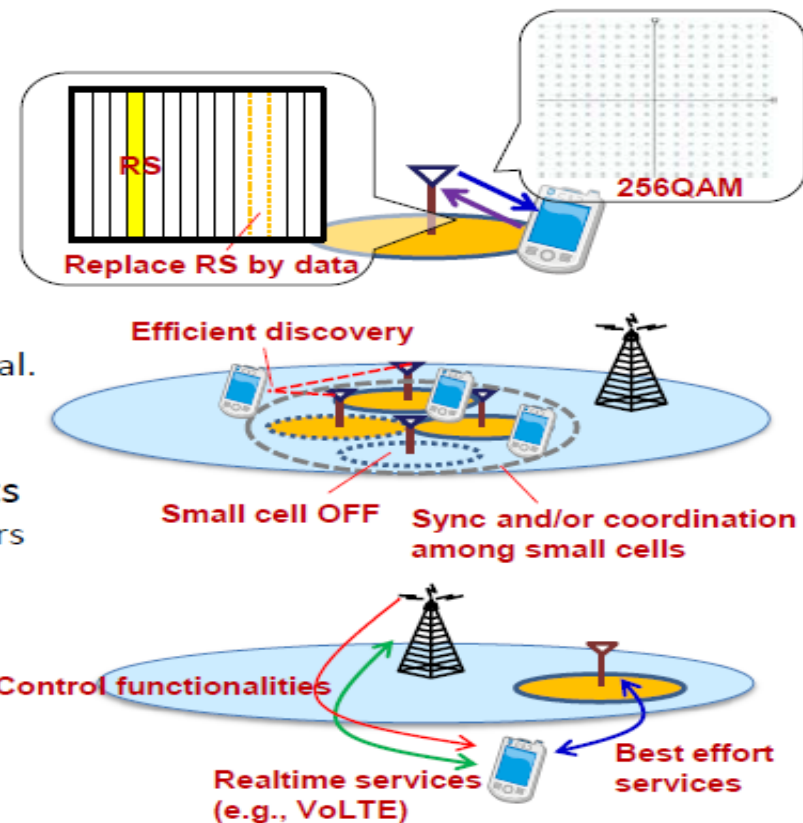
②Enhance MIMO – Evolove to 3D MIMO

Rel-10 MIMO
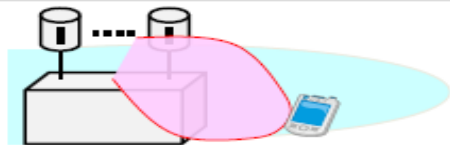
- Max. 8-Tx (Max. 4-Tx for FDD)
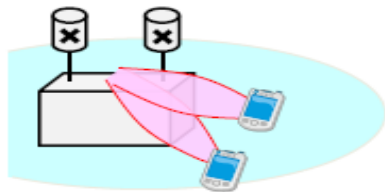- Achieves beamforming in azimuth angle

Optimization for realistic environment

Beamforming in azimuth/elevation angle

Enhancement of the number of antennas

Rel-12 MIMO

2D MIMO enhancement

- 4-Tx codebook enhancement
- Feedback enhancement for MU-MIMO
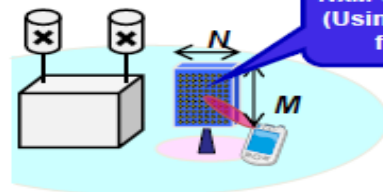
3D MIMO using active antenna system

Study of 3D channel model (3D UE distribution, 3D pathloss, fast fading, etc

Elevation beam forming

- Max. 8-Tx
➔ Beam gain and interference reduction using 3D beam

Full dimension-MIMO

NxM antennas (Using higher freq.)

- More than 8-Tx (e.g., 16, 32, …)
- Higher freq. (e.g., 3.5 GHz-)
➔ Progressive capacity enhancement in hotspot area

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③NW-Assisted Interference Cancellation and Suppression

	Rel. 11 Advanced receiver	Rel. 12 Advanced receiver
Target for receiver	Interference limited areas, i.e., cell edge	All areas including cell edge

■ **Target for Advanced receiver**

Inter-UE interference for MU-MIMO

Inter-cell interference at cell edge

Severer interference for other scenarios
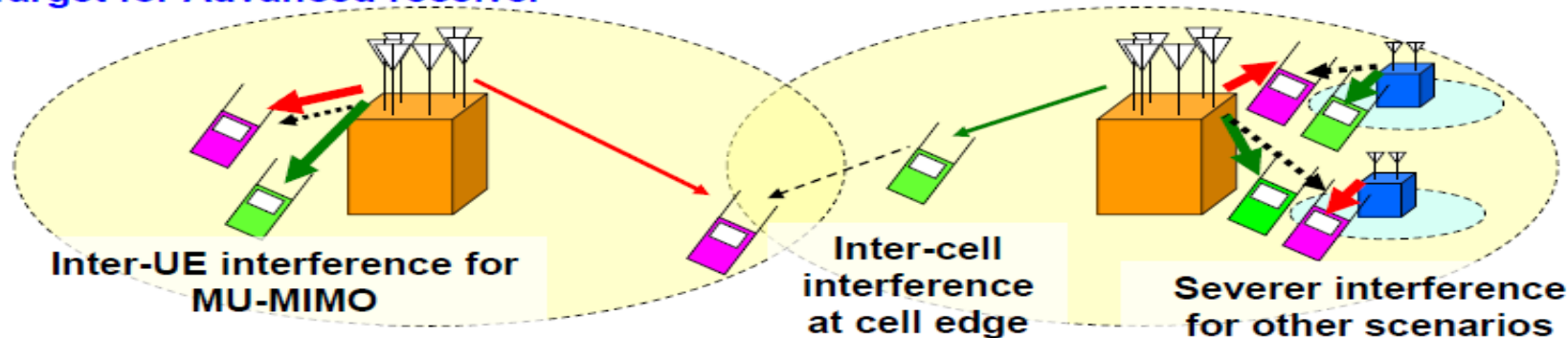
Study on a variety of receiver types and need of interference information (NW-assisted receiver)

- Interference suppression: Enhancement of Rel-11 receiver
- Interference cancellation: Subtraction of interference replica from received signal, e.g., SIC

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④eIMTA (Dynamic TDD)

Further enhancements to LTE TDD for DL-UL Interference Management and Traffic Adaptation

Objective

- TDD UL-DL reconfiguration for traffic adaptation
- Interference mitigation with TDD UL-DL reconfiguration

Topics under discussion

- Reconfiguration mechanism
- Interference mitigation scheme

DL-to-UL interference

UL-to-DL interference

Cell 1

Cell 2
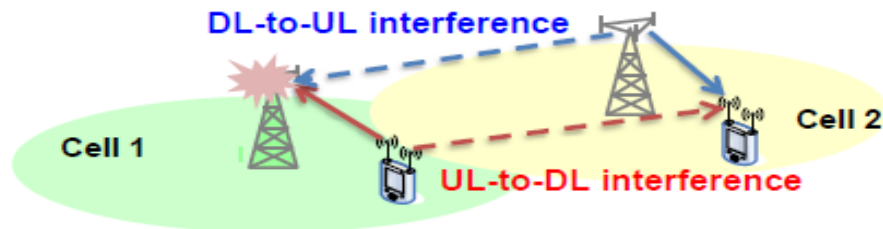
✓ **Interference mitigation schemes**

| Scheme 1	Scheme 2
Cell clustering	Scheduling enhancement
Scheme 3	**Scheme 4**
Interference mitigation based on (F)eICIC	Interference suppressing and mitigation

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⑤TDD+FDD Dual connectivity

Application Scenarios

- **Implement the aggregation of resources between different network system**

- **Suitable for FDD and TDD joint deployment**

- **None ideal backhaul transmission scenario**

- **Deployed in between two different base station , Interface standard open , Different vendors base station can be realized**

Mode 1 Cell
Mode 1 Data
Mode 2 Data
Mode 2 Cell
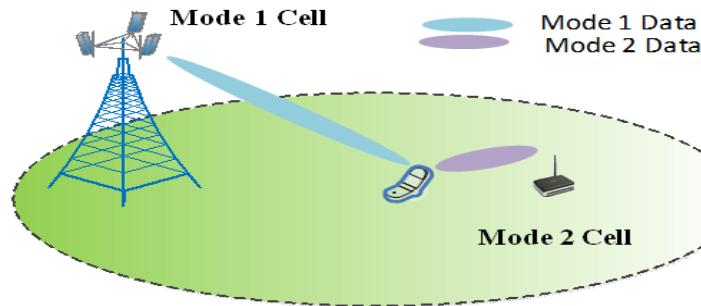
Advantages

■Improve the peak rate of users
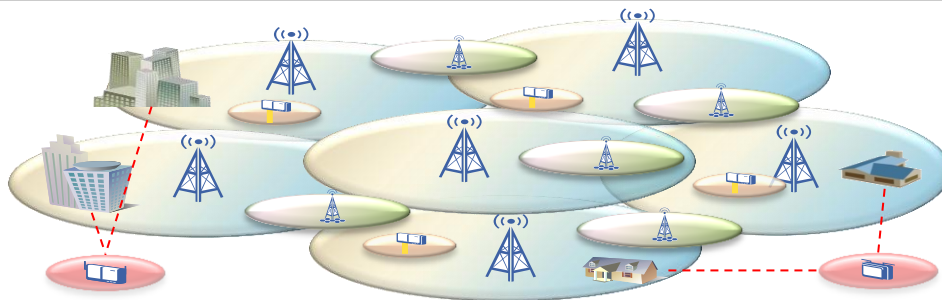■For TDD + FDD operators , FDD macro covering and TDD micro covering can achieve high capacity covering in hot point

FDD
TDD
Capacity Requirement
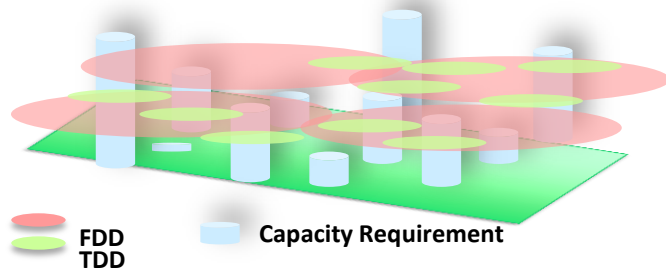
Implement the aggregation of resources between different network system,improve user peak velocity

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⑥256QAM

- **Outdoor Small cell network scenarios**
- **Indoor higher user rate demand scenario**
- **Cat11~12 to support**

Advantages

- ■ **Improve throughput**
- ■ **Improve the single user peak rate**

Downlink peak speed increase
3*20MHz CA，2*2 MIMO

**600Mbps
Cat 11/12**

**450Mbps
Cat 9/10**

64QAM　　　　**256QAM**

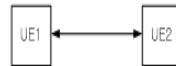**256QAM can promote downlink peak rate, suitable for small cell scenario**
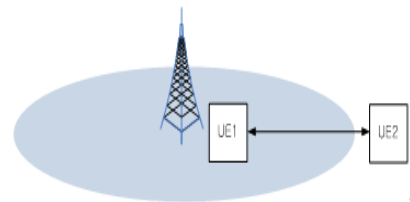
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⑦D2D(Device to Device)

- **Close communication between the social network**
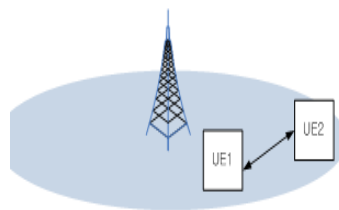- **Public security areas: lack of infrastructure network support**

Advantages

- **Hop gain**
- **Reuse gain**
- **Extremely high data rate**
- **low delay**
- **low power consumption due to the proximity of UEs**
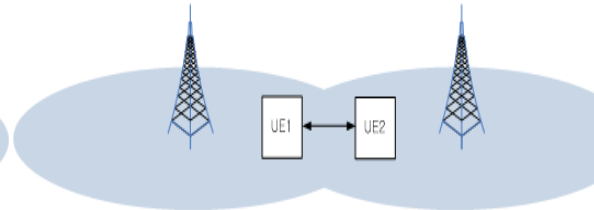

(a) Scenario 1A

(b) Scenario 1B

(c) Scenario 1C

(d) Scenario 1D

Indispensable to the future communications technology
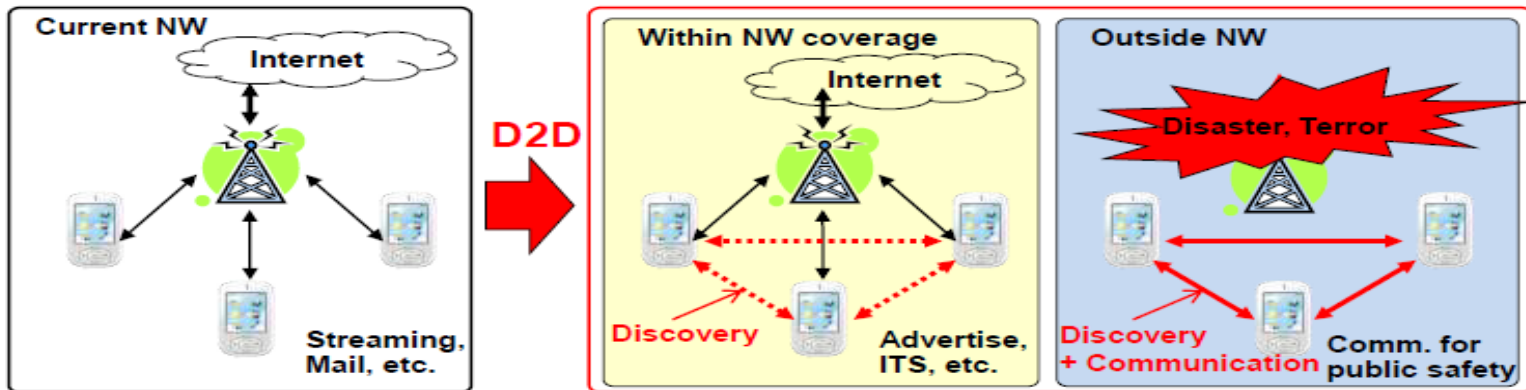
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D2D: Proximity Service

- Two kinds of objective
  - Commercial use with NW coverage
  - Public safety/critical communication with/without NW coverage
- Two kinds of technical topics
  - D2D discovery
  - D2D communication

	With NW coverage	Without NW coverage
Discovery	Required both for public safety & non-public safety	Public safety only
Commu-nication	Required at least for public safety	Public safety only

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⑧LAA - LTE Solution in Unlicensed Band

Un-licensed spectrum
•Co-site with licensed spectrum
• Non-collocated but with ideal transmission

LTE secondary carrier

Carrier Aggregation

LTE primary carrier

Licensed spectrum

LTE primary carrier

Dual Connectivity

LTE secondary carrier

Un-licensed spectrum
•New small cell, non-collocated
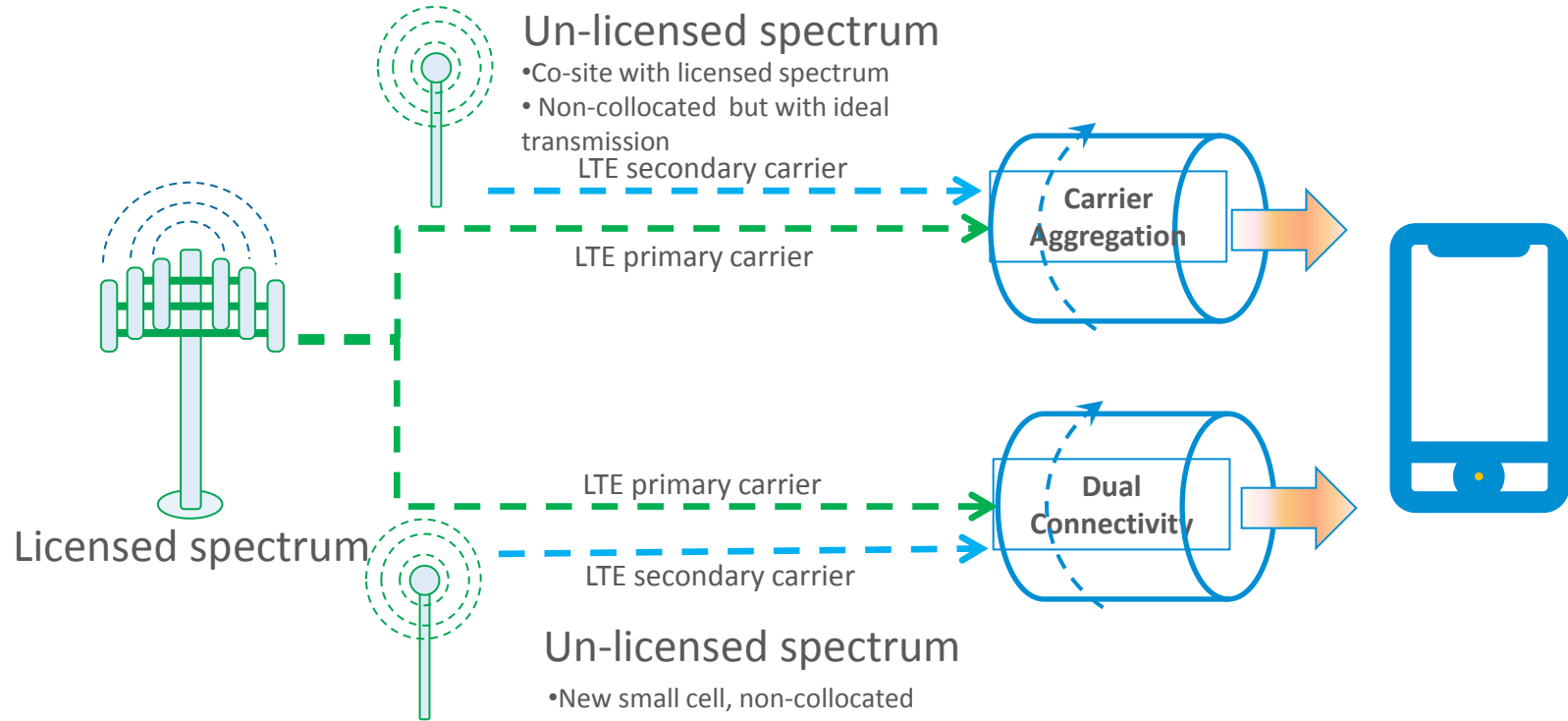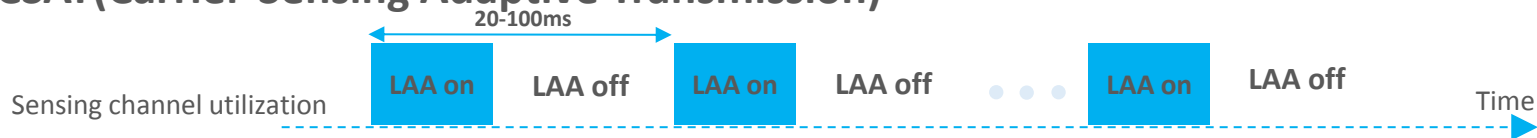
LAA - Key Regulations & Technologies

■**R10/11/12: for early deployment in USA, China, Korea, India, etc.**

① **DFS(Dynamically Frequency Selection)**

Select clear channel

Unlicensed 5GHz band 20M ... 20M Frequency
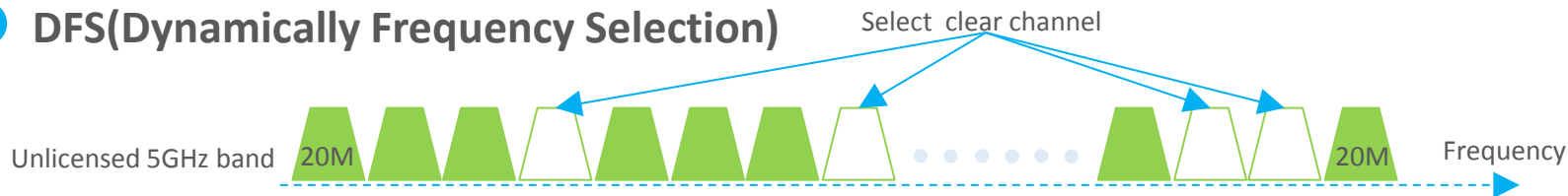
② **CSAT(Carrier-Sensing Adaptive Transmission)**

20-100ms

Sensing channel utilization LAA on | LAA off | LAA on | LAA off ... LAA on | LAA off Time

■**R13: for deployment in Europe, Japan and beyond**

③ **LBT(Listen Before Talk)**

1-10ms burst

Sensing channel utilization Time

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Thank you