Enabling Technologies for Long Term Evolution (LTE) Advanced

Elias Chavarria Reyes

ECE8863

What is LTE?

- Set of enhancements to 3GPP Universal Terrestrial Radio Acces (UTRA) and optimization to 3GPP's radio access architecture

What is LTE-A?

- Set of FURTHER enhancements to 3GPP LTE to meet the requirements of IMT-Advanced (also called 4G)

"42 LTE networks commitment in 21 countries, 15 LTE networks in service by 2010, 33 LTE networks by end of 2012" GSA Report, Oct 28 '09

Requirements for LTE-A (1)

- Capability
  - Peak data rates
    - 1 Gbps (low mobility)
    - 100 Mbps (high mobility)
- Latency
  - C-Plane:
    - Less than 50ms from idle to connected mode
    - Less than 10ms from “dormant” connected to “active

Requirements for LTE-A (2)

- Spectral efficiency
  - Peak DL: 30 bps/Hz
  - Peak UL: 15 bps/Hz
  - Average [bps/Hz/cell]:
    - UL: (1x2) 1.2, (2x4) 2.0
    - DL: (2x2) 2.4, (4x2) 2.6, (4x4) 3.7

Requirements for LTE-A (3)

- Cell edge throughput (bps/Hz/cell/user)
  - UL: (1x2) 0.04, (2x4) 0.07
  - DL: (2x2) 0.07, (4x2) 0.09, (4x4) 0.12
- Mobility
  - Various mobile speeds up to 350km/h (500 km/h possible)
  - Enhanced for 0 to 10km/h

Requirements for LTE-A (4)

- Spectrum flexibility
  - 450-470 MHz band
  - 698-862 MHz band
  - 790-862 MHz band
  - 2.3-2.4 GHz band
  - 4.4-4.99 GHz

Wider spectrum allocations (up to 100 MHz)

Requirements for LTE-A (5)

- Coexistence and interworking with legacy RATs
  - Handover with legacy RATs
  - Network sharing
- Cost-related
  - Low cost of the infrastructure deployment and terminal
  - Power efficiency, SON

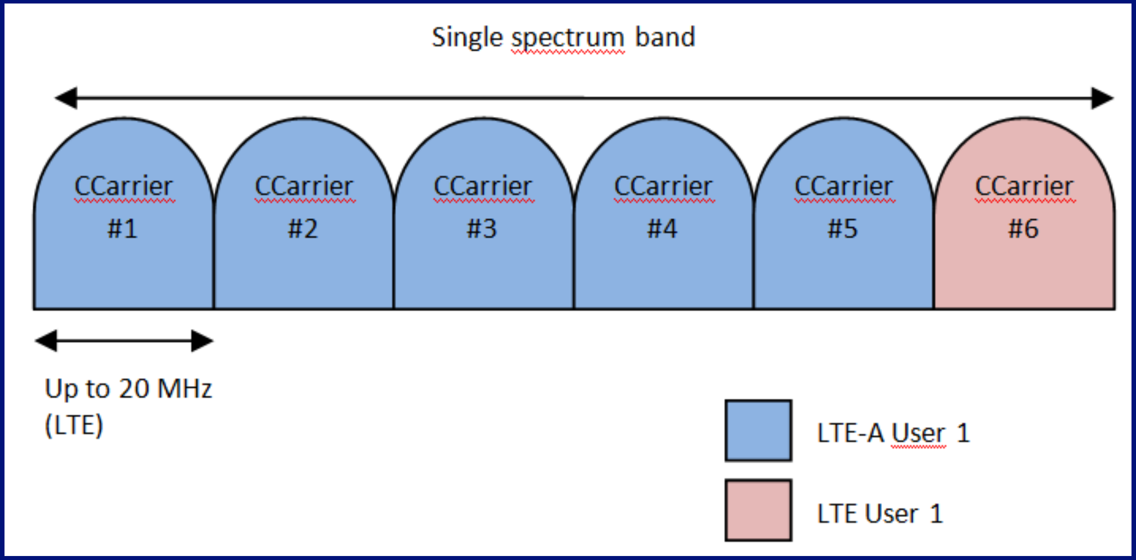
LTE-A current solution Proposals

- Bandwidth aggregation
- Higher order MIMO
- Coordinated Multipoint (CoMP)
- Relaying

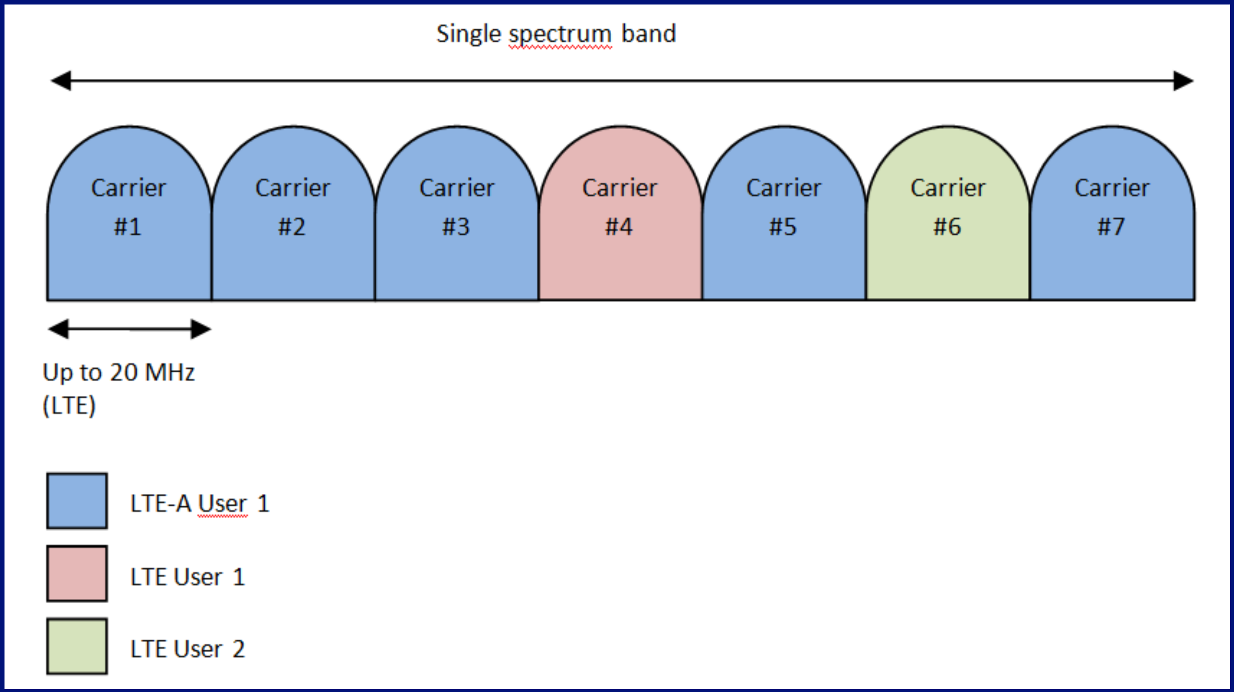
Bandwidth Aggregation

- Objective: Peak data rates
- Types
  - Single Band
    - Contiguous Bandwidth
    - Non-contiguous bandwidth
  - Multiple bands

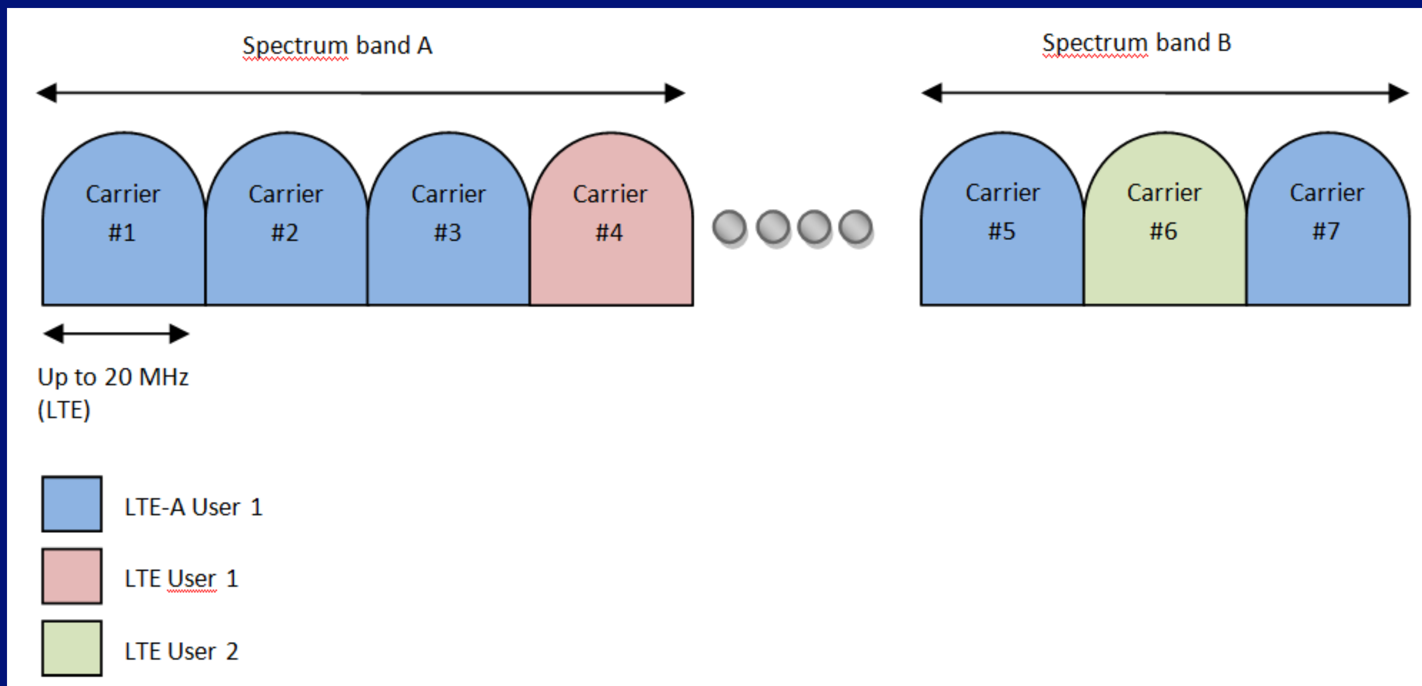
Single Band – Contiguos Bandwidth



Single Band – Noncontiguous Bandwidth



Multiple Bands – Noncontiguous Bandwidth



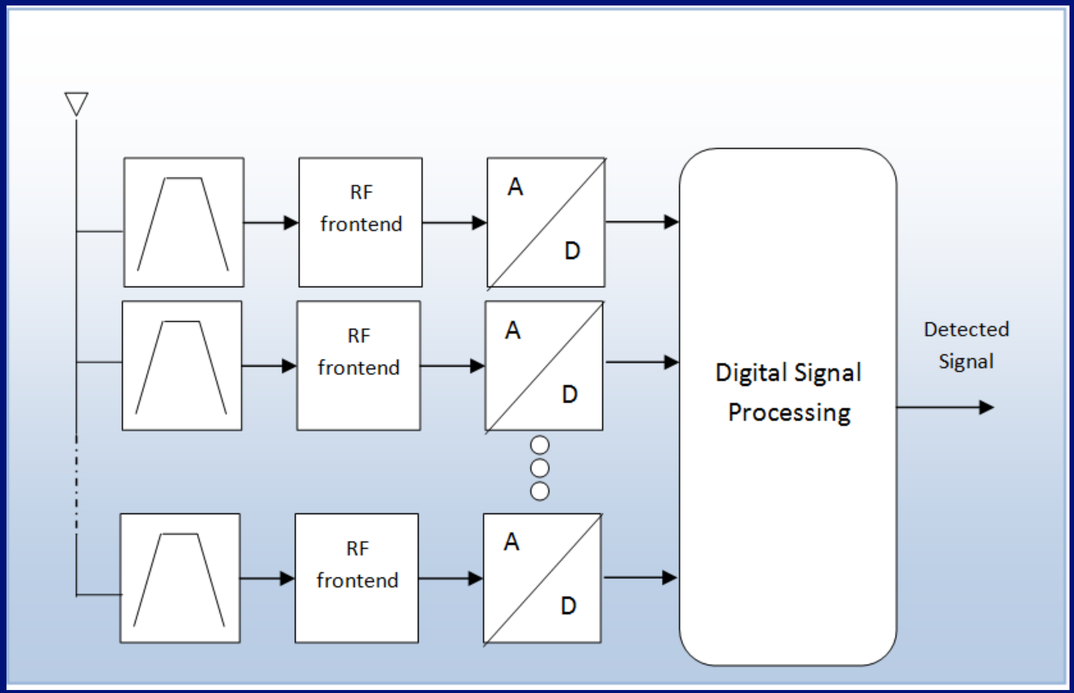
3GPP - Initial deployment scenarios

Scenario No.	Deployment Scenario	Transmission BWs of LTE-A carriers	No of LTE-A component carriers	Bands for LTE-A carriers	Duplex modes
A	Single-band contiguous spec. alloc. @ 3.5GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Contiguous 2x20 MHz CCs DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD
B	Single-band contiguous spec. alloc. @ Band 40 for TDD	100 MHz	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD
C	Multi-band non-contiguous spec. alloc. @ Band 1, 3 and 7 for FDD	UL: 40 MHz DL: 40 MHz	UL/DL: Non-contiguous 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD
D	Multi-band non-contiguous spec. alloc. @ Band 39, 34, and 40 for TDD	90 MHz	Non-contiguous 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8GHz) Band 34 (2.1GHz) Band 40 (2.3GHz)	TDD

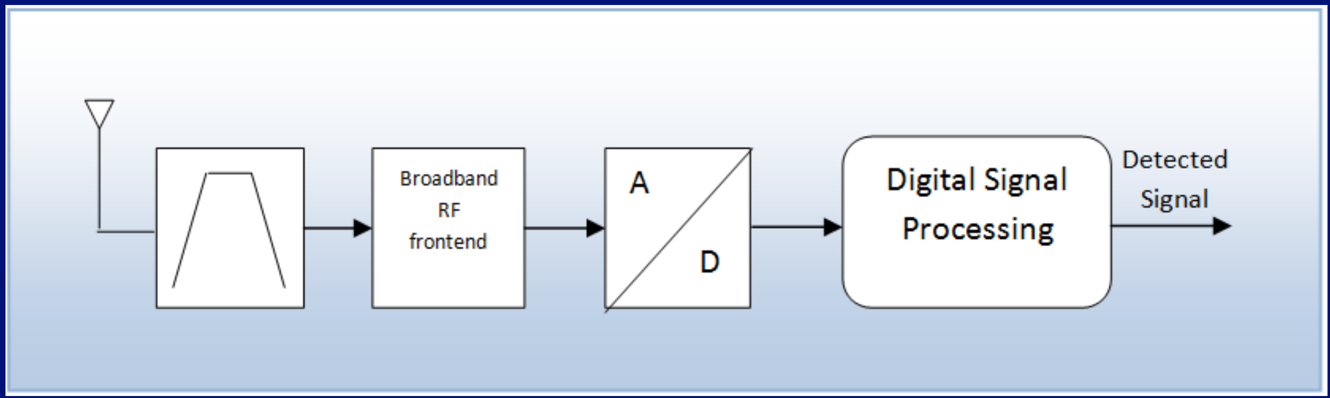
Challenges

- Transceiver Design
  - Multiple single-band transceivers
  - Wideband transceiver
- Increased FFT Size
- Spectrum decision & Scheduling
- Retransmission Control & Error Correction

Transceiver Design (1)
Multiple single-band transceivers



Transceiver Design (2)
Wideband transceiver



Transceiver Design (3) Constraints

- Frequency dependent path loss
- Doppler Frequency and spectrum
- Effective noise power
- Receiver input signal
- Nonlinearities in Analogue Receiver components
- Reciprocal mixing
- Filters
- Sampling frequency, resolution and Dynamic Range

Transceiver Design (4)
Existing Design approaches

- **Bandpass sampling**
  - Advantages:
    - Receives signals from multiple bands without the need of a full transceiver for each band
    - Sampling frequency is proportional to the signal bandwidth and no to the RF carrier
  - Disadvantages
    - Design constraints could increase the sampling frequency considerably
    - It requires the ADC to be able to accommodate the RF carrier, even if the sampling frequency is lower
    - Considers aggregating only TWO frequency bands

Transceiver Design (5)
Existing Design approaches

- Common IF stage, oscillator and filter stage
  - Advantage:
    - Reduces the number of required elements after LNA to half by sharing components
  - Disadvantage:
    - Considers aggregating only TWO frequency bands

Transceiver Design (6)
Research areas

- Design of multiple single-band transceiver with common point as near as possible to antenna
- New designs of wideband transceivers that
  - Use current technologies
  - OR require less perfomance improvement in current technologies
- Design of new RF components that support the multiple widebands
  - Note: Designs should consider the aggregation of more than 2 CCs

Increased FFT Size

- LTE utilizes up to 20MHz bandwidth, for which it requires a 2048 FFT
- LTE-A, a bandwidth of 100MHz requires an FFT of increased size
- If we follow the trend in LTE of FFT size vs. bandwidth, for 100 MHz would be needed an FFT size of 10240
- Issues: Memory size, power consumption, processing power

Spectrum decision & Scheduling

- LTE-A can use contiguous and noncontiguous CC from one or multiple spectrum bands
  - How many bands a UE will need?
  - What bands should be assign to each UE?
    - Notes: Take into account QoS requirements (delay, jitter, rate, reliability, suscription cost, mobility) and constraints (interference coordination, power consumption, coverage)
    - Research should take into account, but not limit to, initial 3GPP scenarios
    - Scheduling and interference cancellation are implementation independent, making them attractive for innovative approaches without conflicting with standards

Error correction and retransmission control

- LTE uses ARQ and hybrid ARQ (LTE-A will also used both)
- How to achieve 1Gbps (low mobility) and 100 Mbps (high mobility)? => low error rate (at least on TCP) (lightweight TCP which can cope with very high speed data rates)
- Will the current scheme of ARQ and hybrid ARQ be enough to support the target data rates?
  - If not, what modifications or new approaches can be used to sustain the expected target data rates?

Next Steps for Bandwidth aggregation research

- Investigate current research in spectrum decision and scheduling => Close spectrum aggregation section (look at CRNs spectrum decision, scheduling: usable in LTE-A?)

LTE-A current solution Proposals

- Bandwidth aggregation
- Relaying
- Higher order MIMO
- Coordinated Multipoint (CoMP)

Relaying

- Objective: Performance, cell-edge performance, coverage

Relay Classification (1)

- According to connection to 'donor cell'
  - Inband: network-to-relay link shares the same band with direct network-to-UE links within the donor cells
  - Outband: network-to-relay link does not operate in the same band as direct network-to-UE links within donor cell
- According to the knowledge in the UE:
  - Transparent: UE is not aware of whether or not it is communicating with the network via a relay
  - Non-Transparent: UE is aware whether or not is is communicating with the network via a relay

Relay Classification (2)

- According to the relaying strategy, a relay may
  - Be part of the donor cell
  - Control cells of its own
- According to the layer:
  - L1: repeaters (amplify & forward)
  - L2: decode and forward
  - L3: self backhauling
  - Cooperative Relaying

What is the optimum number of relays? What is the optimum location/ layout?

What is the optimum transmission/reception schedules with UE/BSs?

What is the optimum/maximum number of hops? => multi-hop relay

What type of relay should be used in different scenarios?

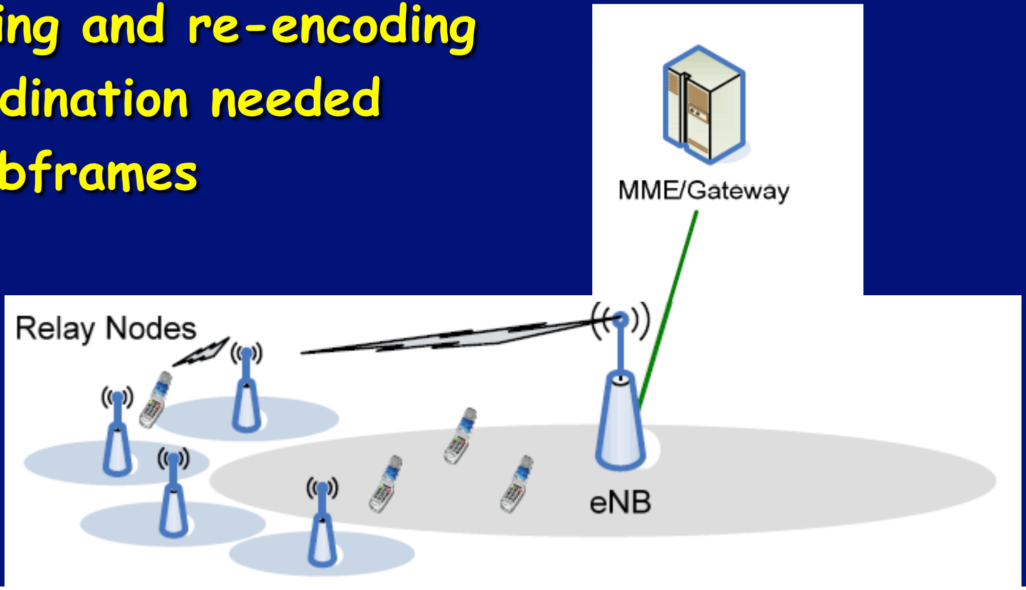
L1 – Repeater

- Amplify-and-forward devices based on analog signal
  - Desired signal can't be separated
    - Interference and noise amplified as well
  - Immediate forwarding is done (within the CP length)
    - Neglectable delay, looks like multipath
  - Strong RF isolation required to minimize leakage
- Alternatively signal can be forwarded at other frequency

L2 – Decode and Forward

- Relay nodes (RN) are introduced at cell edges
- Rx and Tx times require some multiplexing
  - TDD or FDD
  - Coordination/Cooperation among nodes required
- Decoding, scheduling and re-encoding
- Interference coordination needed
- Delay of a few subframes

- Is there any clear benefit compared to L1?

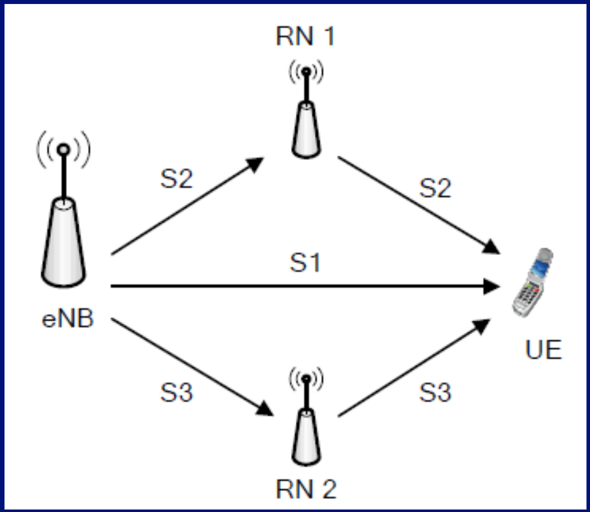


L3 – Self Backhauling

- No new nodes defined, but new cells are created
- Backhaul via LTE
- Same/different spectrum could be used
- High spectral efficiency for backhaul
- Spatial coordination with beams possible
- Signalling overhead from encapsulation
- Relay as complex as Home NB

Other open issues in Relay Comm

- Efficient strategies which cope with entering or leaving mobile nodes
- Relaying shcemes in the presence of multiple distributed relays
  - Simple with L1 relays
  - Tight coordination for L2 & L3



LTE-A current solution Proposals

- Bandwidth aggregation
- Relaying
- Higher Order MIMO
- Coordinated Multipoint (CoMP)

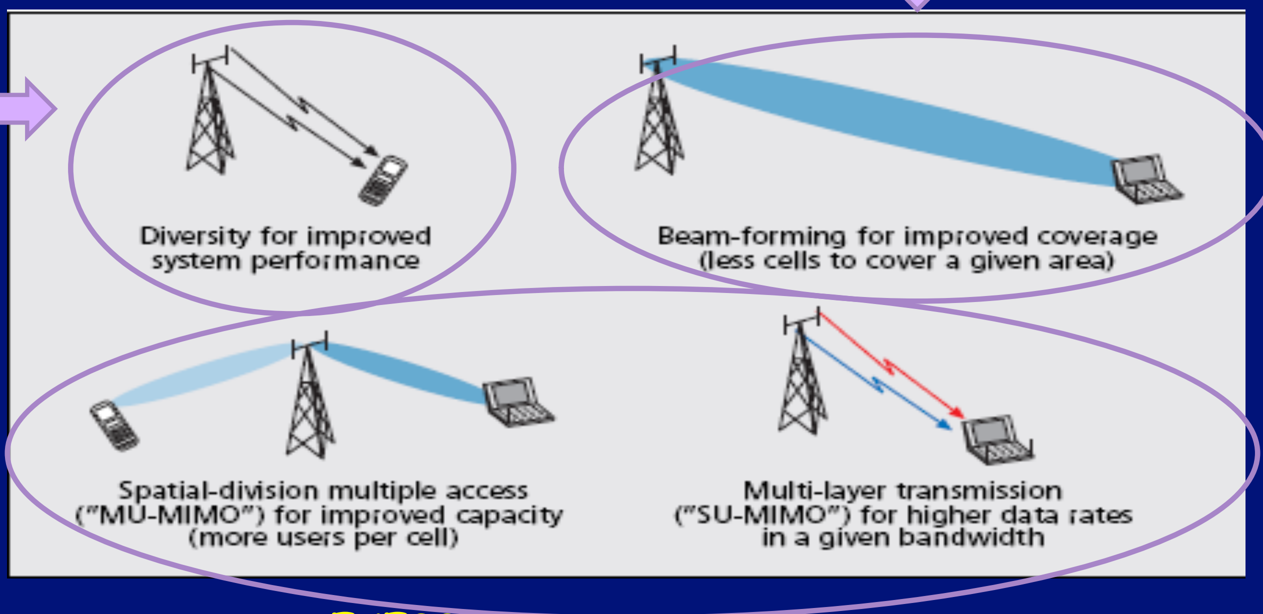
LTE MIMO Review

Downlink (I)

- Rx Diversity (2 or 4 antennas)
- Open-loop Tx Diversity with SFBC

- Only for one user

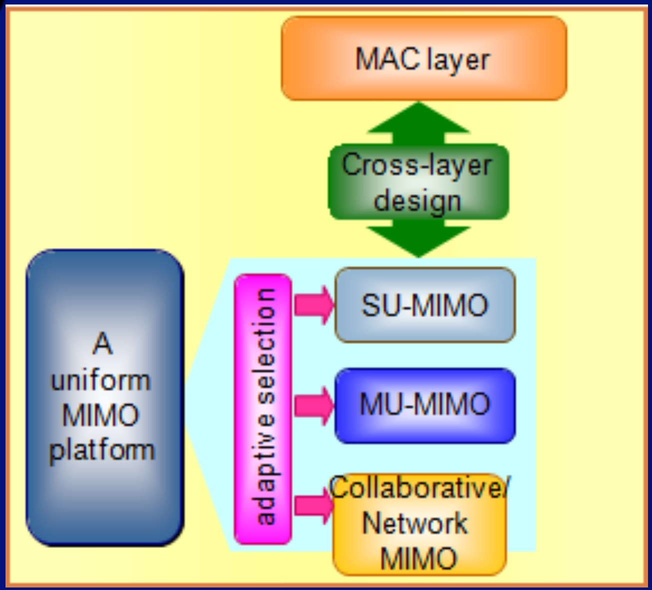
- Closed loop (PMI) → Codebook-based precoding



MIMO in LTE-A

Multimode Adaptive MIMO

- Accomodation of demand for higher data and wider coverage by switching scheme:
  - SU-MIMO for high peak rates
  - MU-MIMO for average rate enhancement
  - Collaborative MIMO for cell edge user data rate boost



Single-Site MIMO in LTE-A

- Some challenges
  - Increased power cosumption/cost
  - Physical space → Virtual MIMO?
  - Reference signals design
    - Cell-specific vs UE specific

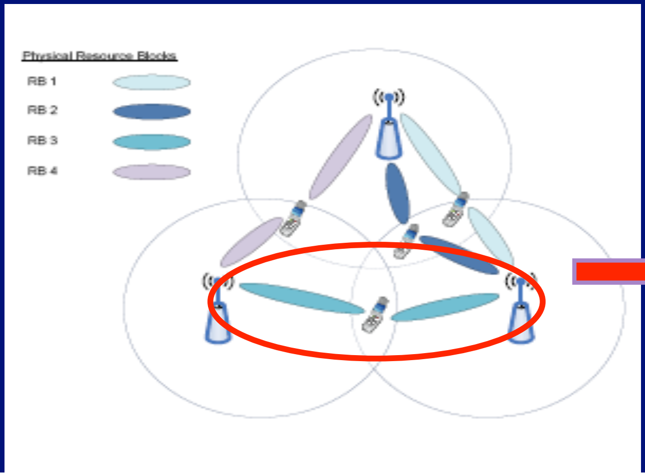
      CSI-RS: Channel State Information

      DM-RS: enables enhanced non-codebook-based MU beamforming.
  - Optimized codebooks for antenna weights
  - Feedback design needs to be revisited

Multiple-Site MIMO

- Downlink
  - Leverage throughput through SMUX.
  - **Network** MIMO & **Collaborative** MIMO
  - Network MIMO for DL only in TDD mode
  - For FDD: collaborative+MU MIMO+SU MIMO

- UE Sync to more than one cell and Network Sync.
- Increased feedback signaling



- Same resources are used for each UE

MIMO Issues in LTE-A

- Identify decision rules to shift between different MIMO schemes
- Backhaul Bandwidth, channel estimation overhead, closed/open loop MIMO

LTE-A current solution Proposals

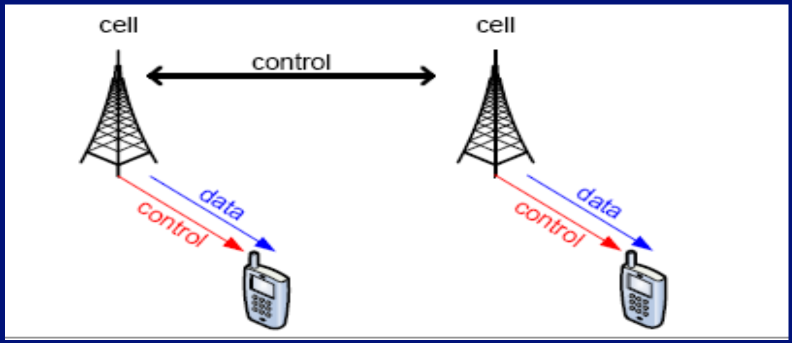
- Bandwidth aggregation
- Relaying
- Higher Order MIMO
- Coordinated Multipoint (CoMP)

Coordinated Multipoint (CoMP)

- Objective: Spectral efficiency, cell-edge performance & coverage

CoMP in DL

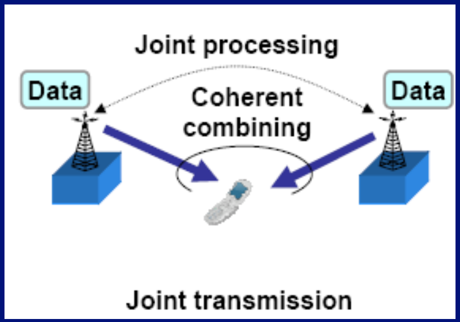
- Coordinated scheduling/beamforming

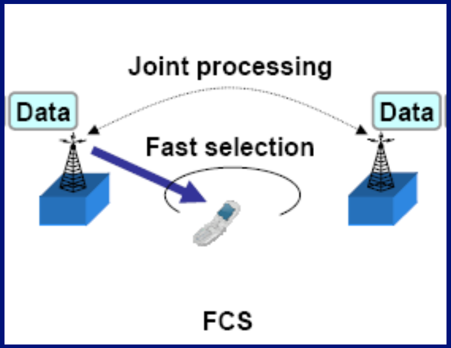


  - Dynamic multi-site scheduling Coordinated precoder design and beam allocation
  - Each payload data transmitted only from one cell
  - No carrier phase coherence requirement
  - No impact on radio; only X2 interface

CoMP in DL

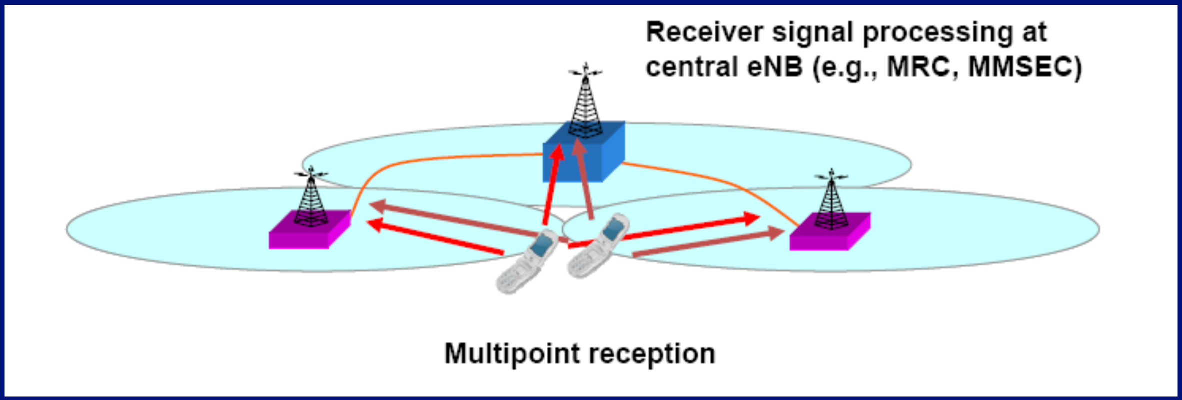
- Joint processing (soft Handover)
  - Multiple nodes Tx
  - Tight synchronization
  - High speed symbol-level link
  - UE specific reference signals
  - X2 interface will be probably used
  - Explicit/Implicit joint CSI feedback
  - Two strategies:





CoMP in UL

- Less advanced: impossible to ensure data sharing
- Data received at multiple eNBs
- **Scheduling is coordinated to reduce interference**
- **Does not require changes in radio interface**
- Increases cell edge user rate



Other topics for further enhancement of LTE-A

- Advanced Radio resource management (ARRM)
- Femtocells (already considered in LTE)
- Self-Organizing Networks
- Frequency-[non] adaptive transmission
- P2P and network coding
- Advanced packet scheduling