Freescale Technology Forum

Design Innovation.

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LTE: MIMO Techniques in 3GPP-LTE

PM101

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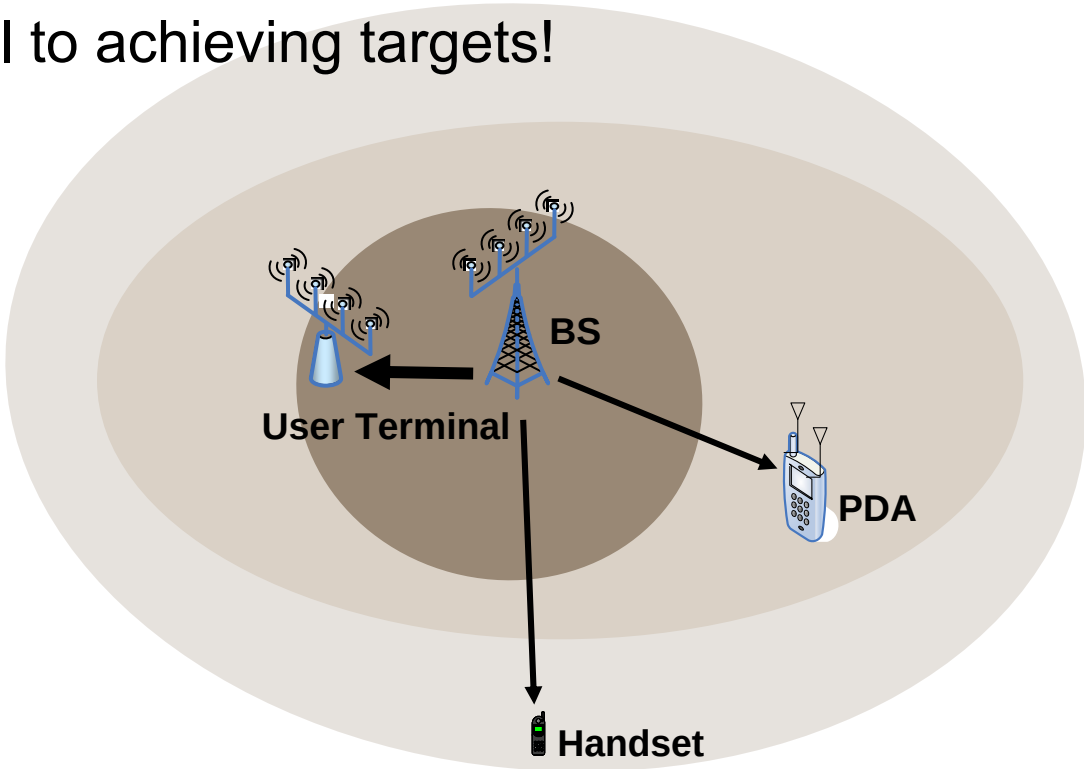
Goals of LTE

- Higher system throughput
- Increasing coverage
- Higher peak data rates
- MIMO critical to achieving targets!



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LTE Target Review

- OFDMA in Downlink (Unicast and Broadcast)
- SC-FDMA in Uplink

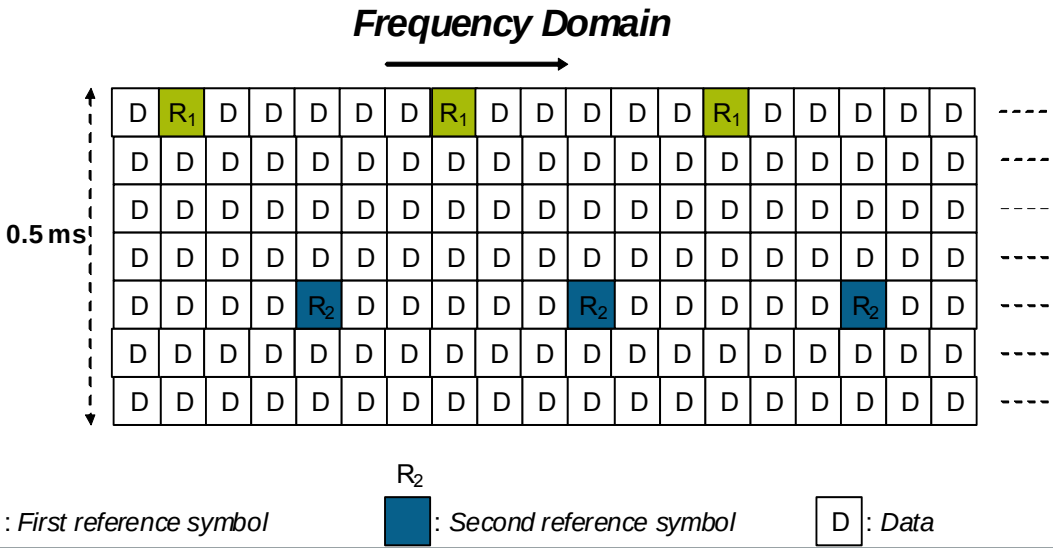
- System performance targets and comparisons of LTE (2x2 and 1x2 baseline in DL and UL) with HSDPA (1x2 and 1x2 in DL and UL)
  - User spectral efficiency: 3 to 4x in DL & 2 to 3x in UL
  - Average spectral efficiency: 3 to 4x in DL & 2 to 3x in UL
  - Cell Edge SE (5% cdf): 2 to 3x in DL & 2 to 3x in UL
  - Mobility: 0-15km(optimized), 15-120km(high), 120-350[500]km (workable)
  - Coverage: 5km, 30km(slight degradation), 100km (not precluded)
  - E-MBMS (broadcast mode): better than HSPA MBMS
  - Feedback overhead (DL is 20-30%) – minimize
  - Minimize the number of modes
  - Minimize complexity

DL Sub-frame Structure

Physical resource block bandwidth and number of physical resource blocks dependent on bandwidth.

Bandwidth (MHz)	1.4	3.0	5.0	10.0	15.0	20.0
Physical resource block bandwidth (kHz)	180	180	180	180	180	180
Number of available physical resource blocks	6	15	25	50	75	100

- 14 OFDM symbol sub-frame
- Control bits in a max of first three OFDM symbols
- Reference symbols and control bits used for channel estimation, CQI measurement and cell search & initial acquisition.
- Localized and distributed RBs



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LTE Technologies Overview

- Multiple access in the frequency domain – localized and distributed resource blocks – scheduling gains
- Link adaptation – adaptive modulation and coding
- Hybrid ARQ
- MIMO
- Interference management
- Power control

Sometimes competing technologies for the same gain pool – study of interaction of these is critical to optimize the system

Interplay of Technologies – Examples

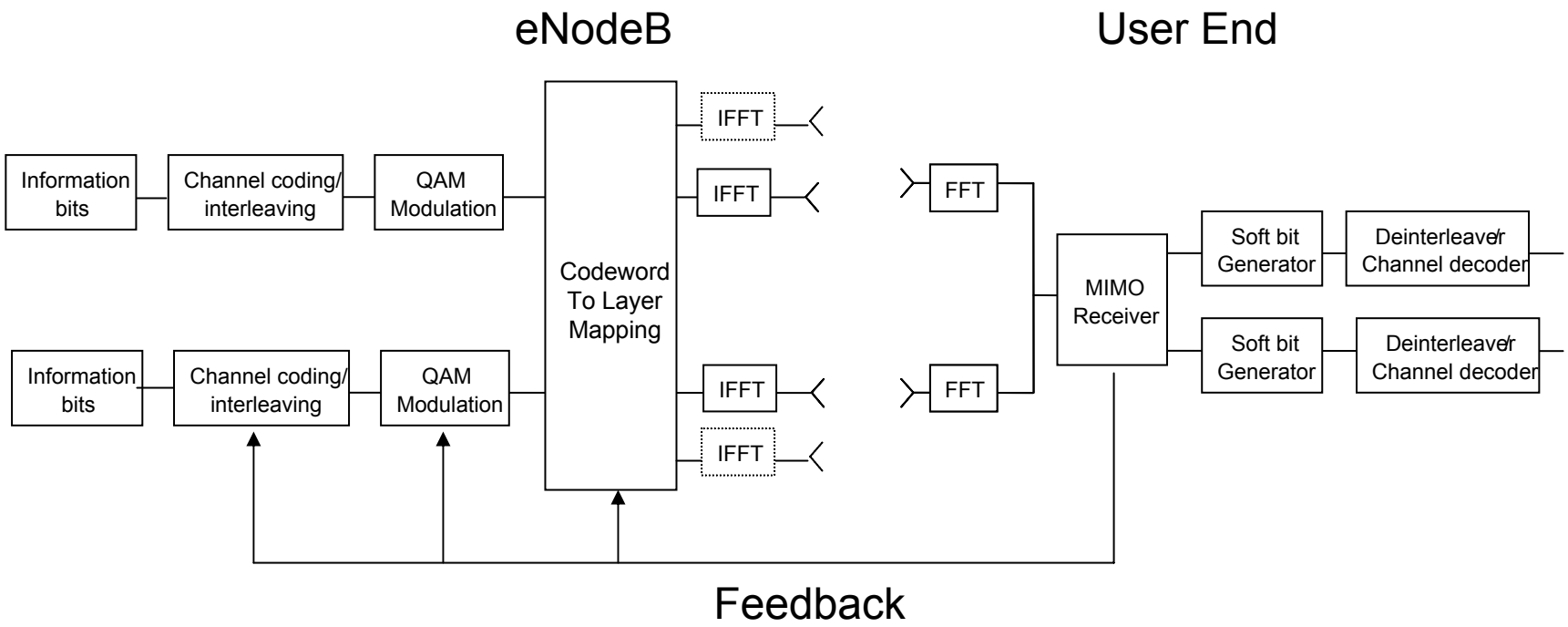
- Multi-antenna diversity vs. scheduling
- Frequency selectivity (LRB or DRB) vs. scheduling
- Interplay of different diversity (time-freq-space) gains due to HARQ, scheduling, channel coding, transmit diversity and space-time coding

Multiple Antenna Schemes in LTE

- Open loop – for control and data channels (higher Doppler)
  - Spatial multiplexing
  - Space-time codes / transmit diversity
  - Cyclic delay diversity
- Closed loop – for data channels, low Doppler
  - Linear pre-coding
  - Rank adaptation
- Multi-user MIMO – SDMA – closely spaced antennas
- Virtual MIMO - uplink
- MIMO in E-MBMS

LTE MIMO PHY DL Architecture

- Multiple transmit antennas at BS/eNodeB – 1,2 or 4
- Multiple receive antennas at user end – 2



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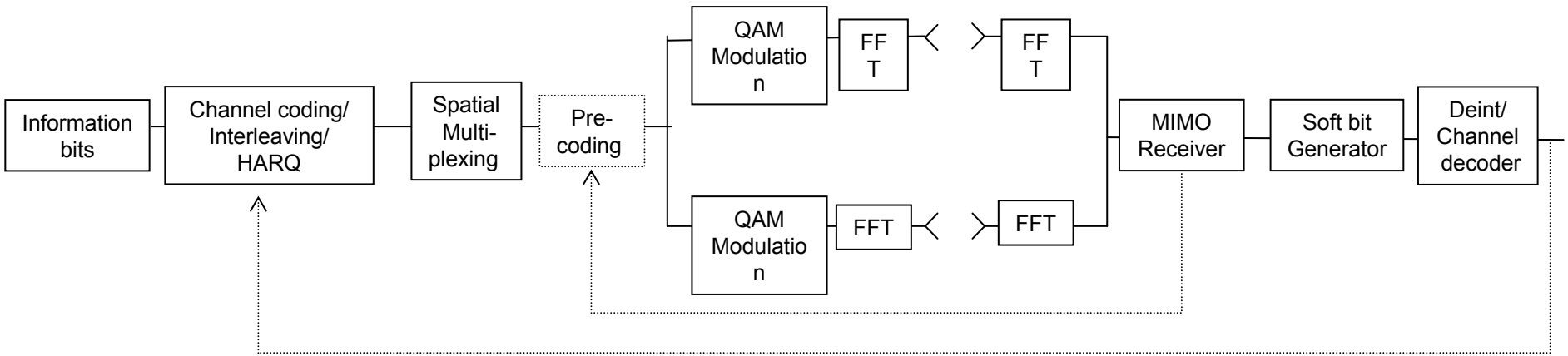
2 x 2 Pre-coded MIMO Simplified System Block Diagram



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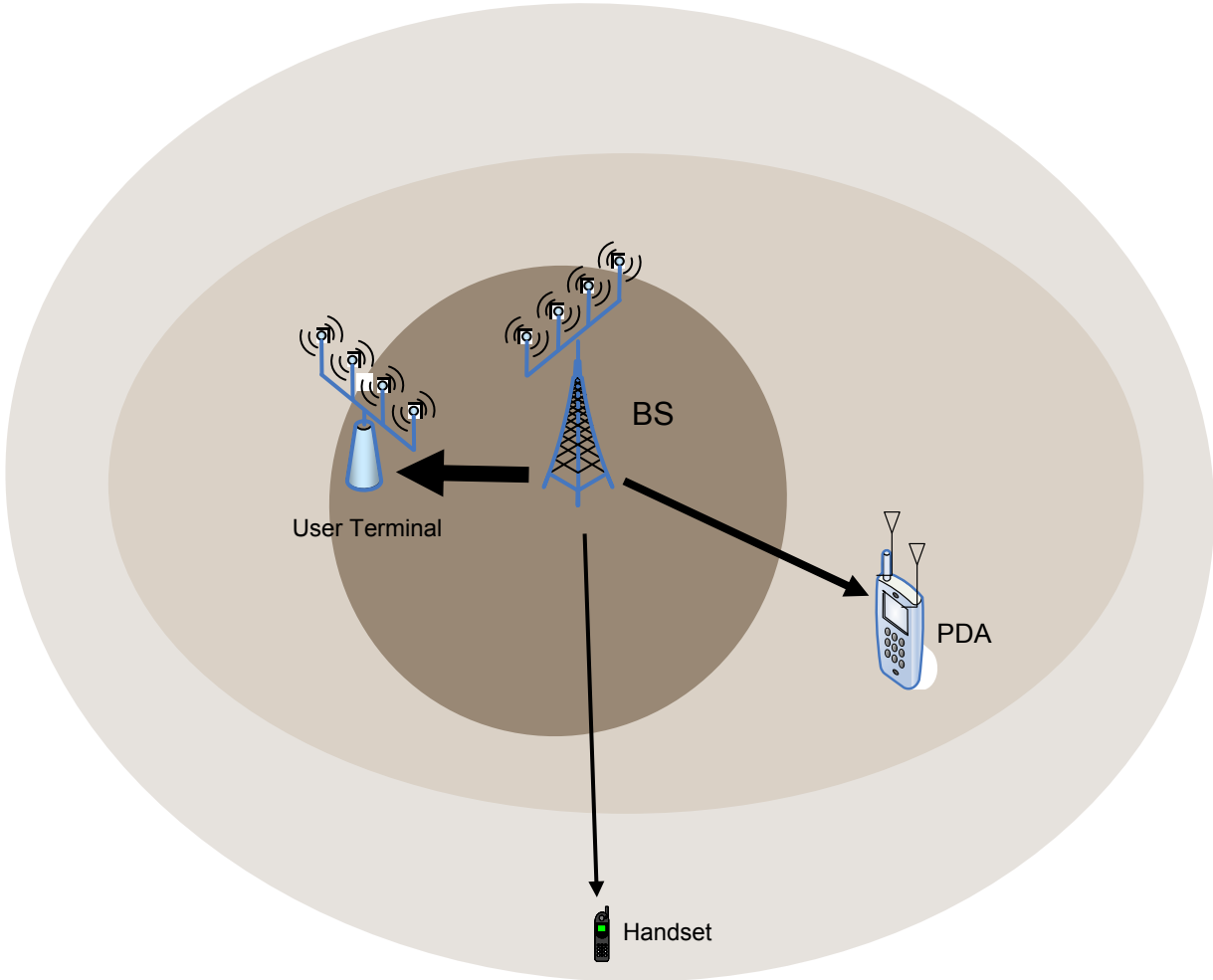
Rank Adaptation

- Adapt number of streams to SNR and spatial scattering
- Higher SNR – more streams possible
- Cell edge – single stream pre-coding (transmit beamforming gain)



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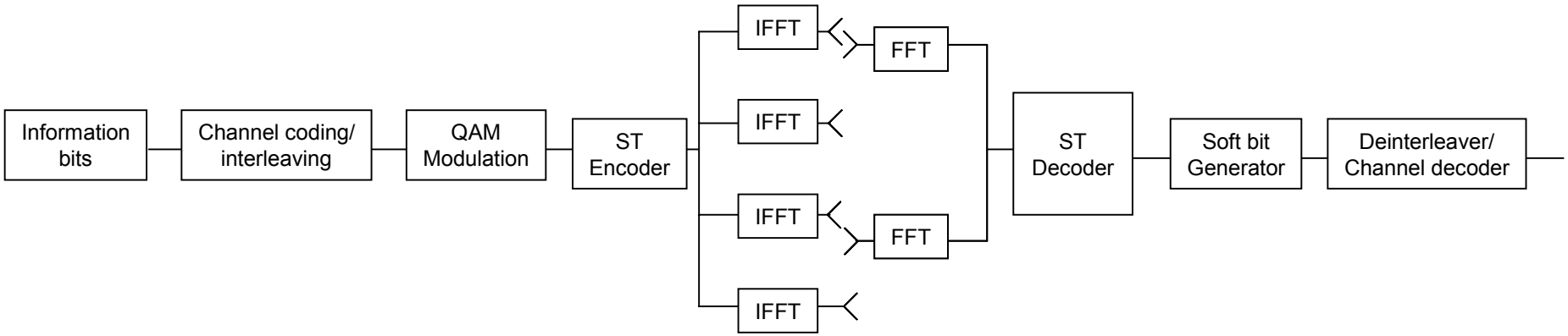
CQI Feedback

- UE feeds back
  - Channel quality information (CQI) => preferred modulation and coding rate
  - Preferred Rank
  - Preferred precoding matrix index (PMI)
  - Groups of resource blocks = subbands => CQI/PMI feedback is on a per subband basis (not per RB basis) due to overhead constraints.
    - Example - 20 MHz has 100 RBs – overhead is prohibitive on per RB basis

- CQI/PMI feedback types – configurable by Node B
  - Wideband – One CQI/PMI value for entire band
  - Best-M – One CQI/PMI value for best M subbands
  - Per Subband – One CQI/PMI value for each subband
  - Rank – One value for any CQI/PMI feedback type

Transmit diversity

4 x 2 MIMO Simplified System Block Diagram



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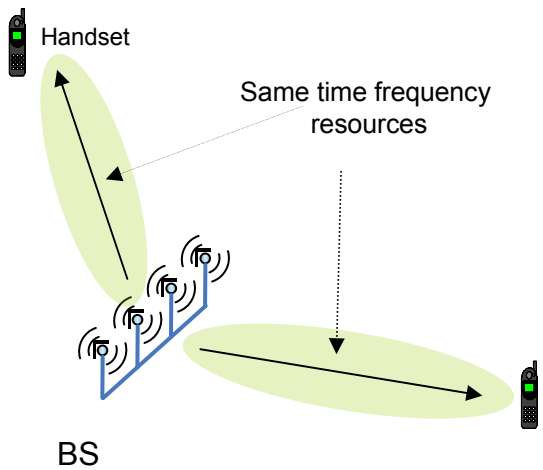
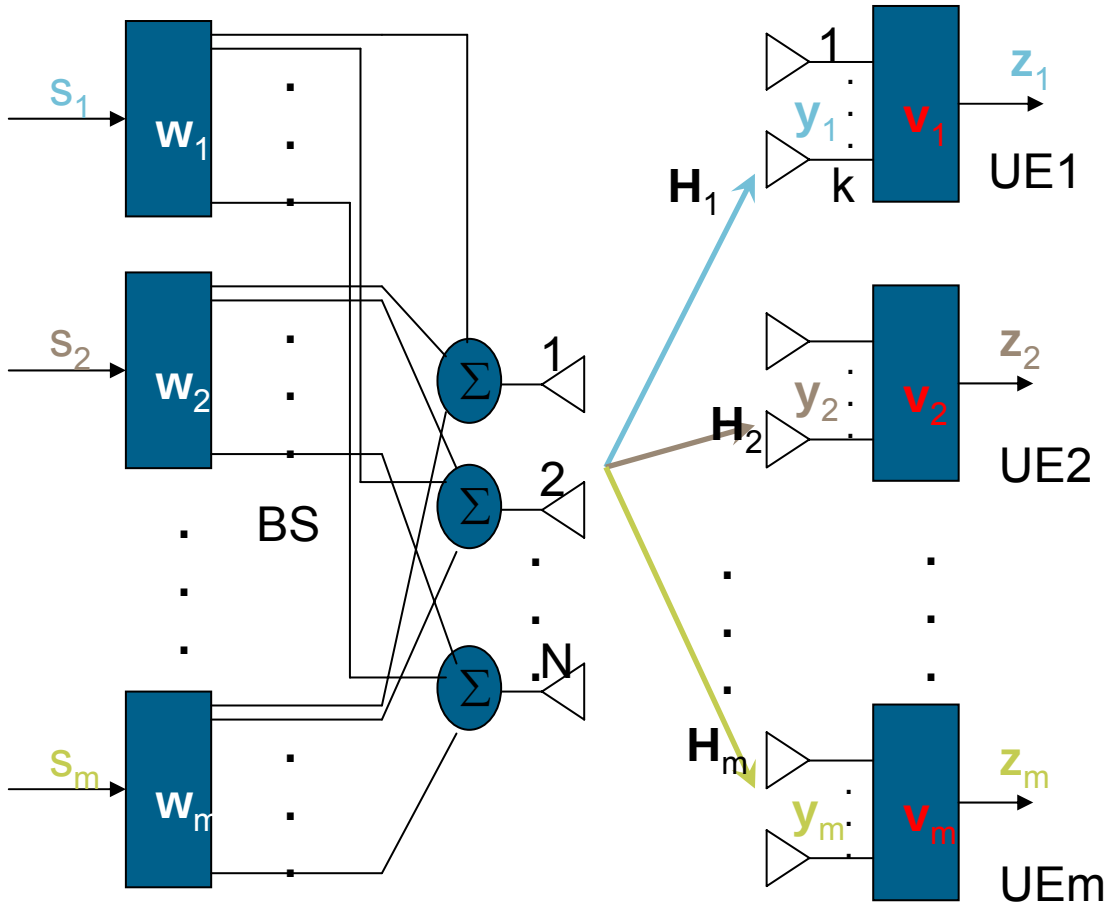
Multi-user MIMO - SDMA

- Multiple users share same time-frequency resources
- Users separated in spatial domain





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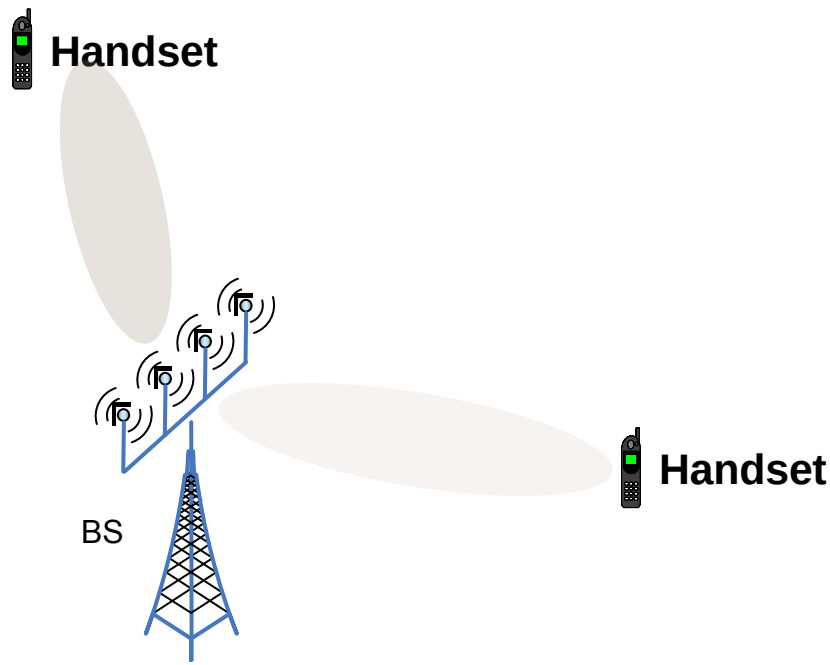
Downlink Beamforming

- Transmit beamforming weights to antennas
- Increases coverage – higher received SNR during focused beam transmission
- User end unaware of number of transmit antennas used for DL beamforming – appears as single antenna transmission
- Targeted for rural deployments – larger cells



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Multi-antenna Channels in LTE

- PDCCH – Transmit diversity
- PBCH - Transmit diversity (Blind Antenna detection)
- PDSCH – Closed loop pre-coding, open loop spatial multiplexing, transmit diversity

Receiver Design

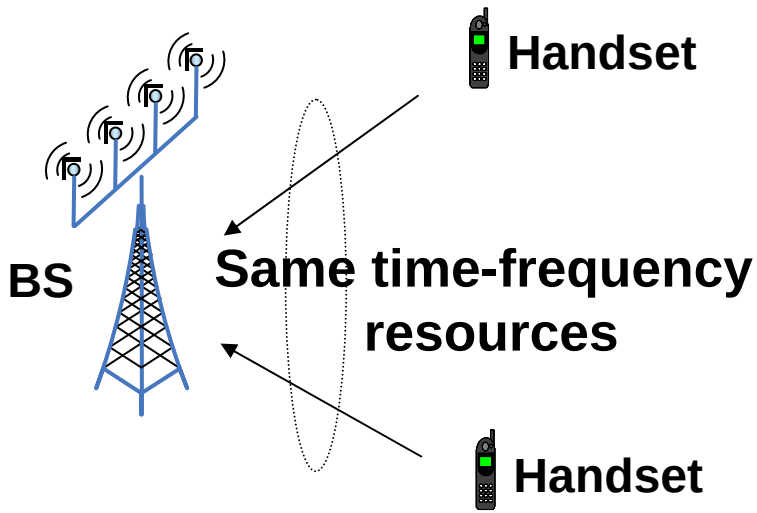
- **MMSE Receiver**
  - Low complexity
  - Good performance
  - Interference rejection capabilities
- **Maximum Likelihood Detectors**
  - Highest complexity
  - Optimal performance
- **Near ML Detectors**
  - QR-MLD
  - Higher complexity
  - Performance closest to MLD
- **Successive Interference Cancellation Receivers**
  - High complexity
  - Performance between MMSE and ML detectors

Uplink Multi-Antenna Techniques

- No uplink single user MIMO
  - Lack of time to finish spec – but does not lack motivation
- Antenna selection
  - Selects “best antenna” for transmit
  - Needs only one RF chain
  - Needs extra duplexer – cost prohibitive

Virtual MIMO

- Virtual MIMO
  - Two users form a “virtual” multi-antenna transmission
  - BS separates the transmitted user streams
- Increased uplink spectral throughput



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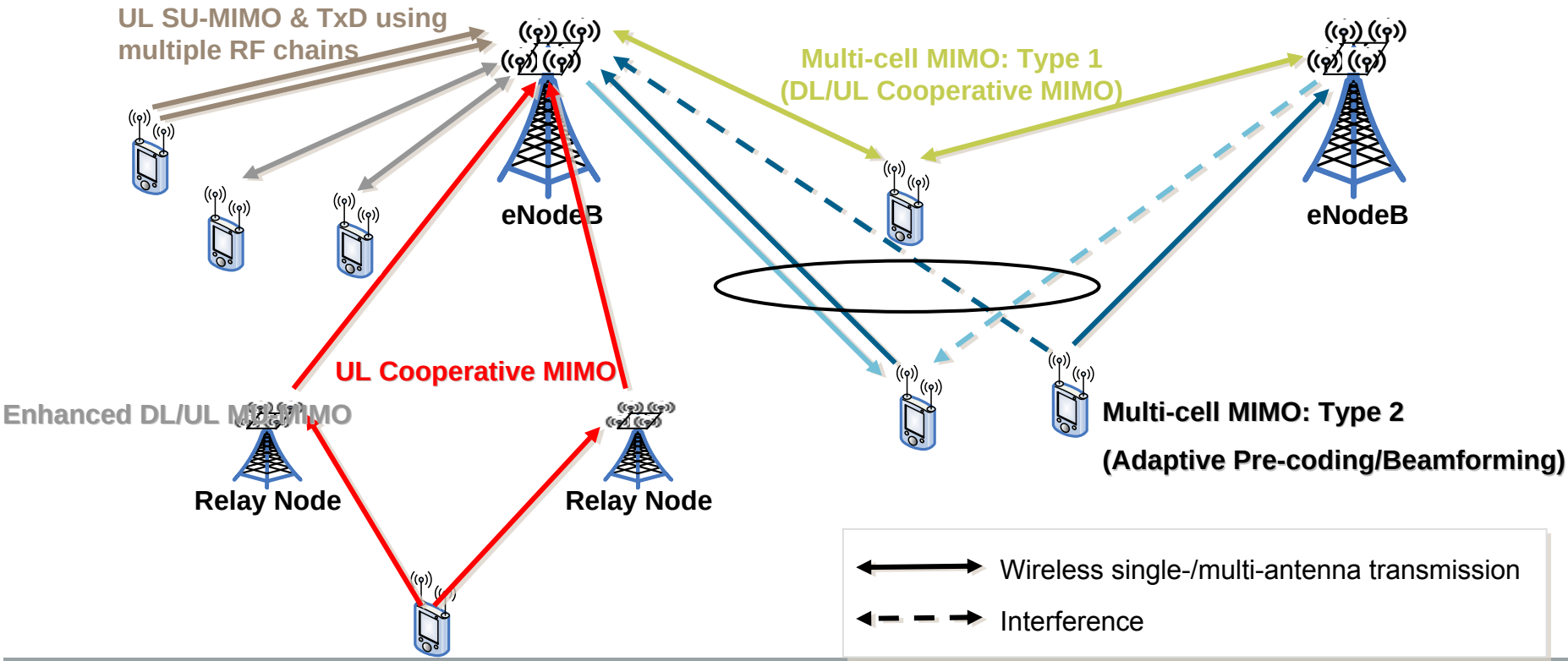
Proposed LTE-Advanced MIMO Enhancements

- Improvement of DL/UL peak & cell spectral efficiency
- Improvement of DL/UL cell edge user throughput by applying an enhanced MIMO transmission considering multi-cell situation



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LTE Advanced: MIMO Everywhere

- **More complex antennas configurations**
  - 8x8 MIMO DL; 4x8 UL MIMO - spectral efficiency gains
  - Improvement of UL peak & cell spectral efficiency
    - Antenna power balancing
    - Low and uniform per-antenna PAPR
- **Network MIMO**
  - Multi-cell/site MIMO transmission and reception
    - Downlink/uplink cooperative MIMO
    - Pre-coding based dual-cell unicast transmission
  - Evolved DL/UL MIMO for inter-cell interference mitigation
    - Network Coordinated Interference Allocation and pre-coding
    - Enhanced DL/UL single-user MIMO
    - Enhanced DL/UL multi-user MIMO
  - Improvement of DL/UL cell edge user throughput as well as cell spectral efficiency
- **Cost effective design for DL/UL control signaling**

Related Session Resources

Session Location – Online Literature Library

http://www.freescale.com/webapp/sps/site/homepage.jsp?nodeId=052577903644CB

Sessions

Session ID	Title
PM104	LTE: Downlink Physical-Layer Overview and Throughput Simulation Results

Demos

Pedestal ID	Demo Title

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