OUTLINE

Series of two seminars

I. Part I
- Introduction to 3GPP LTE (Advanced)
- Interference Management
  - Inter-system Interference
  - Intra-LTE Interference
    - Inter-Cell Interference
    - Inter-Cell Interference Coordination (ICIC)

II. Part II
- Cell-autonomous schemes
- Coordinated Schemes
  - Interference Management for Heterogeneous Networks
    - Control Channels
    - Data Channels
PHYSICAL RESOURCE

- One frame (10 ms)
- One subframe (1 ms)
- One slot (0.5 ms)
- One resource element
- 12 sub-carriers

ARCHITECTURE

› Core network evolved in parallel to LTE
  – EPC – Evolved Packet Core

› Flat architecture, single RAN node, the eNodeB
  – Compare HSPA, which has an RNC
SUMMARY FROM PREVIOUS SEMINAR

› Intercell interference situation within 3GPP LTE Advanced
  – Collisions
    › Collision cost
    › Trade-off
  – Comparison between full reuse vs 3 reuse case
  – Conclusion
    › Cost for collision avoidance higher than cost of collision
WHAT IS THIS RESULT OF THIS TRADE-OFF?

Downlink: 2X2, Maximum Ratio Combining (MRC)  
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Uplink: 1X1, Single Input Single Output (SISO)  
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Avoiding a collision results in higher loss in radio resource usage than the gain in interference reduction
HOW CAN THE EFFECTS OF A COLLISION BE MINIMIZED? - 1

› Radio Resource Management (RRM)
  - Scheduling
  - Fractional Frequency Reuse (FFR)

  - Fractional Power Control (FPC)

› Coordinated RRM
  - Joint scheduling
  - Joint power control
HOW CAN THE EFFECTS OF A COLLISION BE MINIMIZED? - 2

› Advanced Receivers, e.g.
  - Interference Rejection Combining (IRC)
  - Coordinated RRM Combined with Advanced Receivers aka Coordinated Multipoint Transmission & Reception (COMP)
    - IRC
    - Successive Interference Cancellation (SIC)

Weighted signals combined to maximize SINR (reject interference and amplify desired signal)
“COST” FOR REDUCING THE EFFECTS OF A COLLISION

› Advanced receivers
  – Hardware complexity, higher processing power, cost

› Coordinated schemes
  – Hardware complexity, higher processing power
  – Backhaul cost
    › Requirements on
      - Latency
      - Capacity
ICIC ALGORITHMS
AUTONOMOUS-COORDINATED SCHEMES

- ICIC schemes can be either:
  - cell autonomous or
  - Coordinated between eNBs (aka "X2-based")

- Cell autonomous schemes
  - No coordination between neighbor cells

- Coordination schemes
  - exchanging scheduling information between cells
    - time scale of information exchange depends on the backhaul latency
AUTONOMOUS ICIC

EXAMPLE OF AUTONOMOUS ICIC ALGORITHMS
STARTING OFFSET-BASED

- Offset based allocation order
  - Random Start index
    - Starting PRB selected randomly

Offset based allocation order

Well performing schemes @ low loads
ICIC BASED ON FFR

- Cell edge user determined by averaged geometry
- Predefined resources for cell edge users
REL. 8-9 SUPPORT FOR ICIC
UPLINK ICIC

- Overload Indicator – OI ("Reactive" mechanism)
  - Bit map per resource block sent over X2 to neighbor cells
  - Signals if cell experiences low, medium, or high interference

- High Interference Indicator – HII ("Proactive" mechanism)
  - Bit map per resource block sent over X2 to neighbor cells
  - Indicates intention to schedule cell edge users in specific bands

- OI: high interference observed on RBs \{y_i\}
- HII: intends to schedule cell-edge UEs on RBs \{x_i\}
- Avoids scheduling on RBs \{x_i\} to avoid interference from cell A
- Reduces activity on RBs \{y_i\} to reduce interference to cell A
DOWNLINK ICIC

› Less beneficial compared to uplink
  – Enough power available also for wide bandwidth transmission
  – Cost in DL data rate from power limitation

› Relative Narrow band TX Power Indicator (RNTPI)
  – Own intention to limit DL TX power in e.g red subband (per RB)
  – Soft intention that can be broken in case if needed
RELEASE 10 FEATURES

HETEROGENEOUS NETWORKS
HETEROGENEOUS NETWORKS

- Refer to deployments of a mixture of cells with different characteristics, mainly in terms of output power, operating (partially) on same set of frequencies
  - “Low power nodes are placed throughout a macro-cell layout”
WHY HETEROGENEOUS NETWORKS?

› Higher data rates ➔ need denser infrastructure
  – …but user distribution and traffic density is often non-uniform

› Alt 1 – Denser "macro cells"
  – Not cost efficient (in case of non-uniform traffic)
  – Issues with rapidly moving users – frequent handovers

› Alt 2 – Heterogeneous Networks
  – Macro for coverage, pico for capacity
  – Semi-static, or dynamic, sharing of resources across macro - pico layers
HOW DO THEY DEFER FROM EXISTING TYPES OF NETWORKS?

› In its simplest form similar to Hierarchical Cell Structures (HCS)...

› ...but
  - LTE offers/will offer tools for efficient macro-pico/femto resource sharing and interference coordination
  - Different types of small base stations

› Open Access (OA)
  - "Any user" can connect to the small (pico) cell

› Closed Subscriber Group (CSG)
  - Only a subset of users can connect to the small (femto) cell (e.g. home eNodeB)

  - Possibly mixing open access and closed subscriber group small base stations in the same spectrum
Significant imbalance in the DL Tx powers of macro eNB & low power NBs

Scenario: Open Access Picos, No Extended Range, No Interference Management
  - Similar interference situation as within homogeneous networks
    > Sometimes more pronounced UL interference to pico eNBs

Scenarios with pico cells using extended range or with CSG low power nodes
  - Interference problems on DL Control Channel Region
  - New interference management mechanisms needed
LTE – DL PHYSICAL CHANNEL STRUCTURE

- Transmitted within first 1-3 OFDM symbols of each DL subframe
  - Transmission over all system bandwidth

- Layer 1 control signaling
  - UL/DL channel allocations
    - Physical Dedicated Control Channel (PDCCH)
  - Format of the L1 control signaling channel
    - Physical Control Format Indicator Channel (PCFICH)

Physical Control Channel Transmission with QPSK modulation

INTERFERENCE MANAGEMENT FOR HETEROGENEOUS NETWORKS
"SAME-CARRIER" APPROACH

- L1 Control signaling (PDCCH, PCFICH)
  - interference avoidance only in time domain
    - Almost blank subframes (ABSF)
      - One layer does not transmit L1 control signaling within given subframes
ALMOST BLANK SUBFRAMES (ABSF)

- During certain subframes
  - no L1 control signaling is transmitted
  - CRS are still present

- Data not transmitted during ABSF (neither DL or UL)
  - Resources not fully utilized

- Cross subframe scheduling might improve this non-efficient use of resources
SUMMARY

› Interference Management Mechanisms
  – Based on
    › RRM
    › Advanced Receivers
    › Coordination between neighbor base stations
    › Combination of the above
  – Deployments of heterogeneous networks challenging for interference management techniques