UE Role in LTE Heterogeneous Networks

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• **Target coverage with macro eNBs for initial deployments**

• **Pico cells, Home eNBs and Relay nodes added for incremental capacity growth, richer user experience and in-building coverage**
  – These low power nodes can offer flexible site acquisition
  – Relay nodes provide coverage extension with no incremental backhaul expense

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**Deployment Model Vision: Heterogeneous Networks**

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**Need for Flexible and Low-Cost Network Deployment Using Mix of Macro, Pico, Relay, RRH and Home eNBs**
Heterogeneous Networks: Goals

• **Maximize gains from the addition of new nodes to macro-network**
  – Looking for cell-splitting gains
    • More servers providing service to same UE population
  – Enough UE population needs to be associated with new low power nodes
  – Performance metrics of interest: mean vs. median throughput

• **Enable self-configuration / self-adaptation to**
  – Different densities of new nodes
  – Distribution of UEs in the network
    • Number of UEs close to hot-zones, etc.
HetNets Deployment choices: co-channel

- **High power nodes (macro cells) and low power nodes (picos, HeNBs, relays) share the same resources**
  - Co-channel deployment
  - Large power disparity between high power and low power nodes
    - Could have a 30x power disparity (30W vs. 1W)
      - Low power nodes in disadvantage
  - The capacity gain offered by the deployment of low power nodes is limited
    - Very few terminals will associate with the low power nodes
HetNets Deployment choices: resource partition

- **Macro cells limit their transmissions to some set of (time/frequency) resources: S1**
  - Macro cells “give away” some resources with the expectation that there will be a net network capacity gain
  - Resources given away by macro cells experience no interference from macro network and become “prime” resources for low power layer
  - Effectively expands the coverage of low power nodes: **cell range expansion**
    - Shift to the right of the geometry distribution of low power layer

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![Diagram showing the resource partition and cell range expansion](image-url)

- No macro tx on resource set S2 reduces interference and increases coverage of Pico layer on these resources
How can the resources be partitioned?

- **FDM of different power class nodes (multi-carrier)**
  - f1: for macro cells, f2: for pico cells
  - Note that an additional carrier could be required for femto/CSG cells to avoid coverage holes
  - FDM (multi-carrier) approach characteristics:
    - Coarse granularity
    - Semi-static in nature

- **TDM of different power class nodes (time-domain partition)**
  - Set 1 of subframes: for macro cells, Set 2 of subframes: for pico cells
    - Use of Set 1 of subframes for pico cells also permitted (limited gain)
  - Femto/CSG cell operation may require exclusive resources to avoid coverage holes
  - TDM approach characteristics:
    - Does not require multiple carriers
    - Finer granularity: Can adapt to different partitioning more easily
    - Requires network time synchronization
Issues to resolve with TDM approach

- **Hearibility: initial acquisition, regular control and data reception**
  - Need to enable acquisition, measurement and reporting of weak cells

- **Association: serving cell determination**
  - Best DL SINR may not be the best association technique
    - Smallest pathloss minimizes interference on UL
  - Handover biasing providing the network the ability to offload traffic to low power nodes
    - How aggressive the biasing can be depends on UE capability (discussed later)

- **Resource specific UE feedback**
  - Channel quality on different subframes can change considerably

- **Resource partition: what subframes are given to each power class**
  - Adaptive resource partitioning
    - For different/changing densities of low power nodes across the network
    - For different UE distributions across the network or over time
    - Resource partitioning and association techniques interact with each other
Small Caveat…

• **Due to UE legacy support issues subframes can not be blanked out**
  – Therefore, we have *almost blank subframes* (ABS)

• **Taking a closer look almost blanks subframes are not that blank:**
  – The following signals are transmitted to ensure backward compatibility
    • CRS (pilot signal)
    • PSS/SSS (synchronization signals)
    • SIB1/MIB (broadcast information)
  – CRS/PSS/SSS/SIB1/MIB still cause strong interference
  – In a ABS, no unicast data or control is transmitted
Small Caveat...

Primary synchronization signal (PSS)
Secondary synchronization signal (SSS)
Physical broadcast channel (PBCH)

Subframe, 0
Subframe, 1,2,3,4,6,7,8,9
Subframe, 5

System bandwidth 6 resource blocks
Slot
Subframe
Resource block

Data resource element (subcarrier)
Control resource element (subcarrier)
CRS antenna port 0 resource element (subcarrier)
CRS antenna port 1 resource element (subcarrier)
Implications of ABS

- **The fact that ABS subframes are not really empty poses new challenges**
  - The interference caused by the transmission of legacy signals affects the reception of weak signals in ABS
    - Limited cell range expansion regime unless this interference is removed at the UE
- **A UE can convert an ABS subframe into blank by cancelling the interference**
  - This becomes the main role of the UE for HetNets
- **How aggressive the handover biasing can be at the network depends on how well the UE can cope with the interference from legacy signals**
  - This determines the cell range expansion regime
  - 3GPP recently agreed on 9dB handover bias for which UE performance requirements will be standardized as part of Rel-11
Conclusions

• **Heterogeneous Networks are a cost effective approach to significantly enhance capacity of LTE cellular networks**
  – Macro cells ensure broad coverage and low power nodes provide additional capacity

• **Three design features are crucial for HetNets**
  – **Interference management** as severe interference limits the coverage area of low power nodes
  – **Cell range expansion** through adaptive resource partitioning as it enables traffic load balancing between high and low power cells (traffic offloading)
  – **Interference cancellation** receiver in the terminal as it ensures that weak cells can be detected and legacy transmissions can be removed

• **All three components together are needed to exploit the full potential of HetNets**
Annex (some simulation results)
Throughput Gains by CRS IC – Colliding RS

CRS IC Gains for colliding RS in non-MBSFN ABS

9 dB Gain
Throughput Gains by CRS IC – Non-colliding RS

- CRS IC Gains for Non-colliding RS in non-MBSFN ABS

Throughput Gains by CRS IC – Non-colliding RS

3.5 dB Gain
Reliability of PBCH with PBCH IC

ETU90, SFBC, interference cell geometry=16dB, Cell ID=0, 21

SINR=-18dB
Simulation Assumptions
- Hotspot scenario with two pico cells per macro cell randomly placed
- 2/3 of the UEs located within 40m radius of the two pico cells
- User arrivals follow Poisson process
- 1 Mbytes download file size
- Cell range expansion of SIR = -18 dB by CRS/PSS/SSS/PBCH IC
- Served throughput = total amount of data for all users / total amount of observation time / number of cells

Gains up to 130% at 75% load achievable by aggressive cell range expansion, adaptive ABS allocation and advanced receivers