Mobile Backhaul and Synchronization for Heterogeneous Networks

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HETEROGENOUS NETWORKS......

... PROVIDING SEAMLESS USER EXPERIENCE—EVERYWHERE
WHAT IS A HETEROGENEOUS NETWORK?

SEAMLESS USER EXPERIENCE - EVERYWHERE

Densify macro

Add small cells

Required Capacity

Current Capacity

Improve macro
BACKHAUL IMPLICATIONS

1. Improve Macro
   Backhaul modernization and capacity upgrades

2. Densify macro
   Backhaul expansion and densification

3. Add Small Cells
   Additional low power nodes
   Backhaul ↔ coordination
WHEN TO DEPLOY SMALL CELLS?
WHY IS RADIO COORDINATION NEEDED?

› To improve uplink **coverage**
  – i.e. cell edge throughput

› To increase **capacity**
  – Capacity improves as coverage improves

› Offload congested macro cells

› Interference coordination between macro and small cells will
  – Boost coverage
  – Boost capacity

**Small cells for coverage and capacity**
DIFFERENT DEGREES OF MACRO-SMALL CELL COORDINATION

› No coordination
  – Example: Uncoordinated deployment with femtos in a macro network

› Moderate to tight coordination
  – Example: Coordinated deployment of pico RBSs in a macro network
  – SON, Mgmt, Transport, Radio

› Very tight coordination
  – Example: Main/remote radio network with joint scheduling (air interface) using CPRI
SMALL CELLS
- ARCHITECTURE OPTIONS

DISTRIBUTED BASEBAND ARCHITECTURE
- ‘NORMAL’ BACKHAUL MACRO-SMALL RBS

› Backhaul: As for macro S1/X2/IuB
› Performance potential: Good
› Coordination: Moderate / Tight

COMMON BASEBAND ARCHITECTURE
- CPRI INTERCONNECTING RADIO UNITS AND BASEBAND

› Backhaul: As for macro S1/X2/IuB
› CPRI: Primarily Dedicated Fibre
› Performance potential: Best
› Coordination: Very Tight

ADDRESSES DIFFERENT
DEPLOYMENT SCENARIOS
“WHAT IS COMP?”
- RADIO COORDINATION USING COORDINATED MULTIPoint (COMP) SCHEMES

› Multiple schemes and possibilities, often used in combination
  - Coordinated scheduling
  - Coordinated beamforming (null forming)
  - Dynamic point selection
  - Joint transmission/reception
  - …
TRANSPORT REQUIREMENTS
- FROM RADIO COORDINATION FEATURES

SYNCHRONIZATION

DEMANDS ON THE BACKHAUL

LATENCY

BANDWIDTH

TYPE OF BACKHAUL?
# Transport Requirements - Radio Coordination Features for LTE

<table>
<thead>
<tr>
<th>Type of Radio Coordination</th>
<th>Absolute time accuracy</th>
<th>Latency (1-way)</th>
<th>Feature Bandwidth Requirements</th>
<th>Likely Deployment Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Tight Co-ordination</td>
<td>+/- 1.5 us</td>
<td>&lt; 0.5 ms</td>
<td>Up to 1Gbps/antenna (internal RBS interface)</td>
<td>› CPRI case only</td>
</tr>
</tbody>
</table>
| Tight Co-ordination       | +/- 1.5 us              | 1-10 ms¹         | Medium..Low                    | › CPRI case             
|                            |                         |                  |                                | › Small Cell RBS, only if low latency + time alignment needs are supported |
| Moderate co-ordination    | +/- 5 us                | None²            | Low                            | › CPRI case             
| (time alignment needed)   |                         |                  |                                | › Small Cell RBS, only if time alignment needs are supported |
| Moderate co-ordination    | None³                   | None²            | Low                            | › CPRI case             
| (no time alignment)       |                         |                  |                                | › Small Cell RBS         |

**Note1:** Performance benefit larger with lower latency

**Note2:** No special requirements for coordination features
EXAMPLE 1: MODERATE COORDINATION

- ICIC - ENHANCED ICIC

- Macro cell avoids scheduling in “protected” subframes
  - Capacity loss in macro layer and pico layer
  - Reduced interference from macro cell in “protected” subframes
- Advanced Rx in Ue required for range expansion
- Cell size: Dense urban environment
- Time alignment: +/-5us required between macro and small cell
- Latency: No special demands
- Bandwidth Needs: Low

Unprotected subframes

Protected subframes

UES in macro cell scheduled in non-protected subframes only

UES in range expansion zone scheduled in protected subframes only

UES in inner part of pico cell scheduled in any subframe

TIME ALIGNMENT NEEDED
EXAMPLE 2: TIGHT COORDINATION

DOWNLINK COORDINATED SCHEDULING

› Share information.
› Based on received information, perform coordinated scheduling
› **Cell size**: Dense urban environment
› **Time alignment**: +/-1.5us required between macro and small cell
› **Latency**: 1..10ms – the lower the latency, the better the cell edge gain
› **Bandwidth**: Up to 20Mbps, per coordinated cell pair
Example 3: Very Tight Coordination
UL Joint Reception (UL L1 Comp)

- Schedule UE:s.
- Receive transmitted data.
- Share received data and jointly process it
  (Communicate back ACK/NACK to BS responsible to certain UE.)
- Cell size: Dense urban environment
- Time alignment: +/-1.5us required between cells
- Latency: <0.5ms one way
- Bandwidth: 1Gbps per antenna, internal RBS interface
- No impact on mobile backhaul

Time Alignment, High BW & Very Low Latency => Baseband Internal Only
Some radio coordination features require Time Alignment between radio subframes

CoMP features:
- Optional, radio coordination features
- Cost of deployment vs actual gain must be considered

Radio coordination features with very stringent synchronization, BW and latency demands realistically will be run only over CPRI

CPRI is an internal RBS interface, not part of mobile backhaul

TIME ALIGNMENT OF <+/-5US OVER X2 FOR SOME FEATURES
ACRONYMS

› **CPRI**: Common Public Radio Interface
› **CoMP**: Coordinated Multipoint
› **eICIC**: Enhanced Inter Cell Interference Coordination
› **EPC**: Evolved Packet Core
› **RRU**: Remote Radio Unit
› **UE**: User Equipment
› **X2**: Standardized interface between LTE RBSs
› **S1**: Standardized interface between LTE RBS and EPC
› **SON**: Self Optimizing Networks