Dr. Rainer Schoenen, ComNets [Prof. Walke],
RWTH Aachen University, Germany

Relay based Access for Cellular:
FDD versus TDD
- An Overview -

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Presentation Overview

• Motivation for Relaying Technologies
• Relaying Concepts
• TDD and FDD mode principles
• OFDMA related opportunities
Range of broadband base stations is limited
- high attenuation at high frequencies
- limited transmission power (EIRP)
- Unfavourable radio propagation conditions, e.g., in urban areas

- Increased # of BS needed with increased carrier frequency to cover an area
- High costs of infrastructure and operation
- High cost/bit transmitted
- High data rate available close to AP only
  - With constant user density:
    - Number of users increases with $d$
    - Cell capacity offered per area element differs from capacity requested by users

New Deployment Concepts required to
- bring broadband to wider area than possible with one base station in current systems
- Reduce the cost/bit transmitted by 2 to 3 orders of magnitude

Sources:
VTC 2006, Melbourne, Australia
The capacity should be transferred from the AP to outer regions of the cell by means of (Fixed) Relay Stations (FRS). AP’s capacity should be distributed over cell radius like with water filling. The unfairness in capacity per cell area element can be turned into better fairness using FRSs compared to current systems. Cell planning will have to be revisited.
Relay Enhanced Cells (REC)  
Using Fixed Relay Stations (FRS)

**Pros:**
- Relays in REC
  - don’t need a wired backbone access (lowers costs of infrastructure & operation)
  - Full flexibility of relays (re-)positioning
- Relays introduced to cell can
  - enlarge the coverage area
  - Increase capacity at cell border
  - balance the capacity/area element
  - reduce transmission power
    - increases public acceptance
    - reduces co-channel interference
- (Movable) Relays support
  - fast network rollout,
  - outdoor to indoor service
  - Exploitation of macrodiversity (co-operative relaying)

**Cons:**
- In band relays consume radio resources
- Out of band relays need multiple transceivers
- Relays introduce extra delay

Cellular Multi-hop deployment in high shadowing environment

Source: ComNets 2003
Capacity at Relay (FRS) with Antenna Gain

- All AP capacity “transferred” to one FRS sub-cell
- Capacity of FRS rises with antenna gain until highest PHY mode can be applied
- Cost of relaying: 6.67 Mbit/s of AP capacity at 30 dBi gain
  (example: IEEE 802.11a PHY using a WiMax like MAC protocol)


ComNets Vision of a Mobile Low Cost Internet Access: Relay-based Cellular Wireless Mobile Broadband System

Multi-Radio AP

Multi-Radio MS

Point-to-Multipoint

Fixed Network (Internet)

Fixed-Network AP

Enhanced Cell

Wide Area BS

Multi-hop link

Fixed Relay Station (FRS)

Single-Hop and Relay Enhanced Cell Throughput Compared (3 FRS in WiMax System)

Increased coverage by 3 relays. This leads to a new 3-hexagon cell. Increased coverage: larger reuse distance -> a better SINR
SINR vs Distance in a Cellular Scenario
(3G-LTE cellular FDD System)

Line of sight or antenna gain gives good SINR at relay position.

Relay is positioned here.

Interferer is positioned here.
Throughput of 2-Hop Relay Scenario
(3G-LTE cellular FDD System)

- Relay is positioned here
- Interferer is positioned here
- Highest Phy Mode here (64QAM-5/6)
TDD multi hop relay principles

Two relay channel access schemes:

2. TD(R) channel access = relays transmit at different times and do not interfere with each other

6. SD(R) channel access = spatially separated relays transmit at the same time
TDD Relaying: F-MAC and HBFSA Concept (H/2, WiMAX)

F-MAC (Frame MAC)
- FWR’s frame within AP’s Frame
- The size of FWR’s frame can be variable, depending on traffic demand


HBFSA (Hierarchical Beacon with Fixed Slot Allocation)
- If AP transmits in the n\textsuperscript{th} frame, then FWR transmit in the (n+1)\textsuperscript{th} frame
- AP and FWR transmit BCCH\textsuperscript{*} (BCH+FCH+ACH) in every MAC frame
- \# MAC frames = \# maximum hops
- FWRs with the same hop level share the same MAC frame

\textsuperscript{*} BroadCast CHannel
TDD Relaying: TSWR Concept (H/2, WiMAX)

To support spatial reuse

- Each FWR has an interference matrix
- Each FWR performs DFS* measurement to locate free MAC frames, on Initialization and periodically

TSWR (Time Sharing Wireless Router)

- Free MAC frames for FWR
- AP and FWRs do not transmit any BCCH when inactive

* Dynamic Frequency Selection
OFDMA MAC Frame Structure for 3G-LTE

TTI = 500 μs (7 x 66.6 μs + 6 x 4.687 μs + 1 x 5.208 μs)

1 chunk = 12x6=72 subsyms

1/6 for pilots

Cyclic prefix

66.6 μs

time slot

(1 OFDMA symbol)

TTI = 500 μs

1200 subchannels

100 chunks

1200 subchannels

100 chunks
FDD Relaying using OFDMA

- BS transmits & receives
- RS transmits & receives
- Guard bandwidth
Uplink considerations (OFDMA Interference)

Parameters: used bw, near (0..-25dB), far (-32dB), far (-50dB)

<table>
<thead>
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<th>Channelization (MHz)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<td>4.75</td>
<td>5.45</td>
<td>9.75</td>
<td>14.75</td>
</tr>
</tbody>
</table>

Residual out-of-band power = interference

OFDMA UPLINK:
- Requires OFDMA bandwidth sharing among different senders
- Requires well synchronized transmitters?
- Requires sharp roll-off filters
- Requires power control (same Rx power)
- Requires OFDM receiver that copes with orthogonality errors
- Excess power leads to interference with parallely transmitted chunks
inter/intra cell resource management separation in frequency (OFDMA)

Resources used in one cell

one TTI frame (500 us)
Decentralized resource control
here: coordination in time

1. beacon  c1  idle
2. beacon  idle  c2  idle
3. beacon  idle  c3

sense for free space
snap into grid in time
breathe ~ traffic
Relay Based Cellular Networks

Conclusion

- Relay enhanced cells provide coverage extension
- RECs provide capacity increase (to the border)
- TDD Relaying: Resources shared in time
- FDD: Time domain relaying (TDR) as well
- Resources in time, frequency and space
- OFDMA: more choice to share resources
- Coordination needed: intra- and inter-cell
- Central vs decentralized coordination possible
Thank you!

rs@comnets.rwth-aachen.de