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

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Presentation Overwiew

- Motivation for Relaying Technologies
- Relaying Concepts
- TDD and FDD mode principles
- OFDMA related opportunities

Cell Capacity over Distance is Inverse to the Needs

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:
 - \rightarrow Number of users increases with *d*
 - Cell capacity offered per area element differs from capacity requested by users

Sources:

B. Walke, H. Wijaya, D.C. Schultz: The Application of Relays in Infrastructure-based Future Mobile Radio Network Deployment Concepts VTC 2006, Melbourne, Australia

T. Irnich, D.C. Schultz, R. Pabst, P. Wienert: *Capacity of a Relaying Infrastructure for Broadband Radio Coverage of Urban Areas*. *Proceedings of the 10th WWRF meeting, New York*, 10/2003



New Deployment Concepts required to

Dring 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

Capacity Distribution in the Cell Area



- 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

Source: Walke, Bernhard; Wijaya, Harianto, Schultz, Daniel C.: The Application of Relays in Infrastructure-based Future Mobile Radio Network Deployment Concepts. Submitted: VTC 2006 Spring, Melbourne, Australia AP

FRS

Cellular Multi-hop deployment in high shadowing environment



Capacity at Relay (FRS) with Antenna Gain

P. Gupta and P. R. Kumar: The capacity of wireless networks. *IEEE Transactions on Information Theory*, 46(2):388 - 404, 2000: Multi-hop reduces capacity.

Pabst, Ralf; Esseling, Norbert; Walke, Bernhard: *Fixed Relays for Next Generation Wireless Systems - System Concept and Performance Evaluation. Journal of Communications and Networks*, Vol.7, No. 2, p.p. 104-114, Korea, 06/2005: Spectrum capacity can be increased by multi-hop, if some hop is narrow beam based.





- 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



Source: Walke, Bernhard; Pabst, Ralf; Schultz, Daniel C.: A Mobile Broadband System based on Fixed Wireless Routers. Proc. ICCT 2003 Intern. Conf. Comm. Techn., 04/2003

Cellular End-to-End Throughput (Downlink)



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



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SINR vs Distance in a Cellular Scenario (3G-LTE cellular FDD System)



Throughput of 2-Hop Relay Scenario (3G-LTE cellular FDD System)



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)



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

F-MAC (Frame MAC)

* BroadCast CHannel

•FWR's frame within AP's Frame

The size of FWR's frame can be variable, depending on traffic demand

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F-MAC Source: Esseling, Norbert, Vandra, H.S., Walke,
Bernhard: A Forwarding Concept for HiperLAN/2, Proc.
European Wireless 2000, 13-18, 09/2000 and in
COMPUTER NETWORKS, Vol.37, 25-32, 09/2001
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TDD Relaying: TSWR Concept (H/2, WiMAX)



BCH	FCH	ACH	DL	UL	RCH	BCH	FCH	ACH	DL	UL	RCH	

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

FDD Relaying – full and half duplex



OFDMA MAC Frame Structure for 3G-LTE



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FDD Relaying using OFDMA



Uplink considerations (OFDMA Interference)



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inter/intra cell resource management separation in frequency (OFDMA)



Decentralized resource control here: coordination in time



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!

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