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

Invited Presentation at IST Event 2006,
November 23, 2006,
Helsinki, Finland

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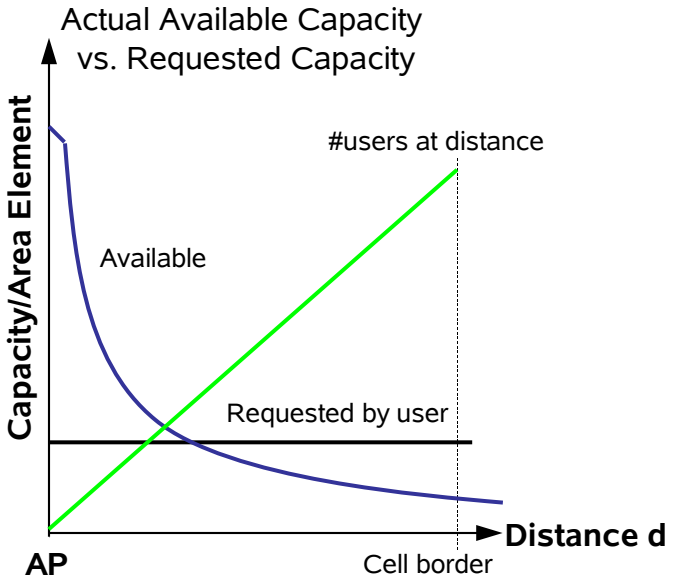
Presentation Overwiew

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



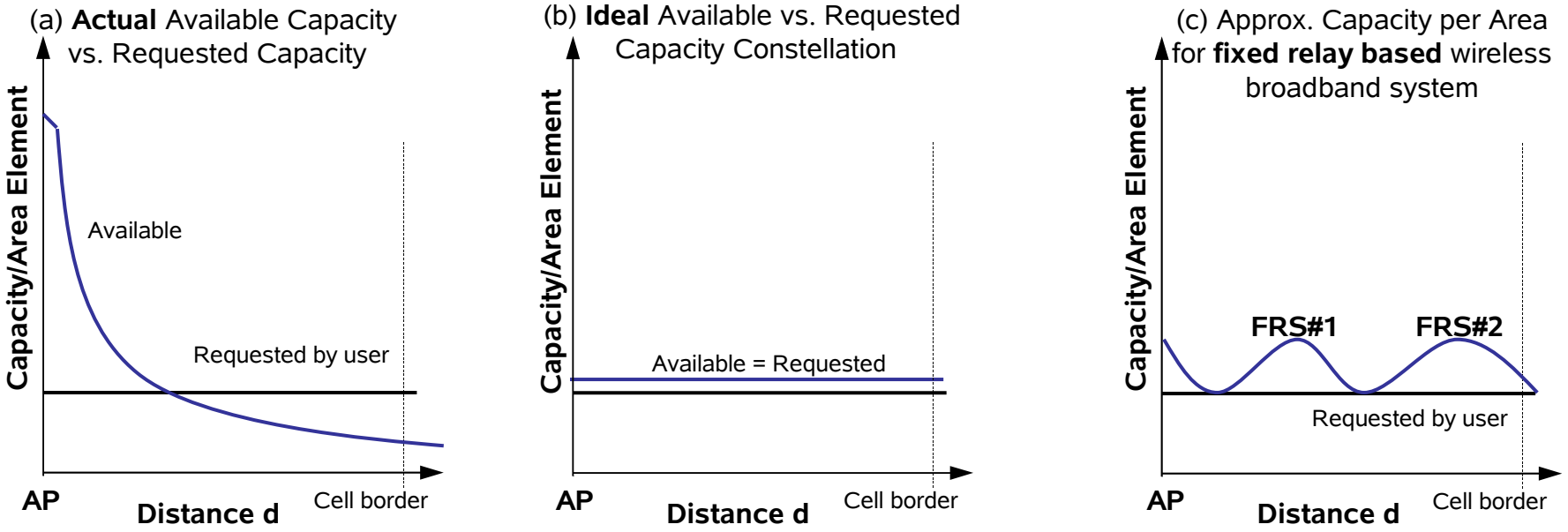
New Deployment Concepts required to

→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:
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

Capacity Distribution in the Cell Area

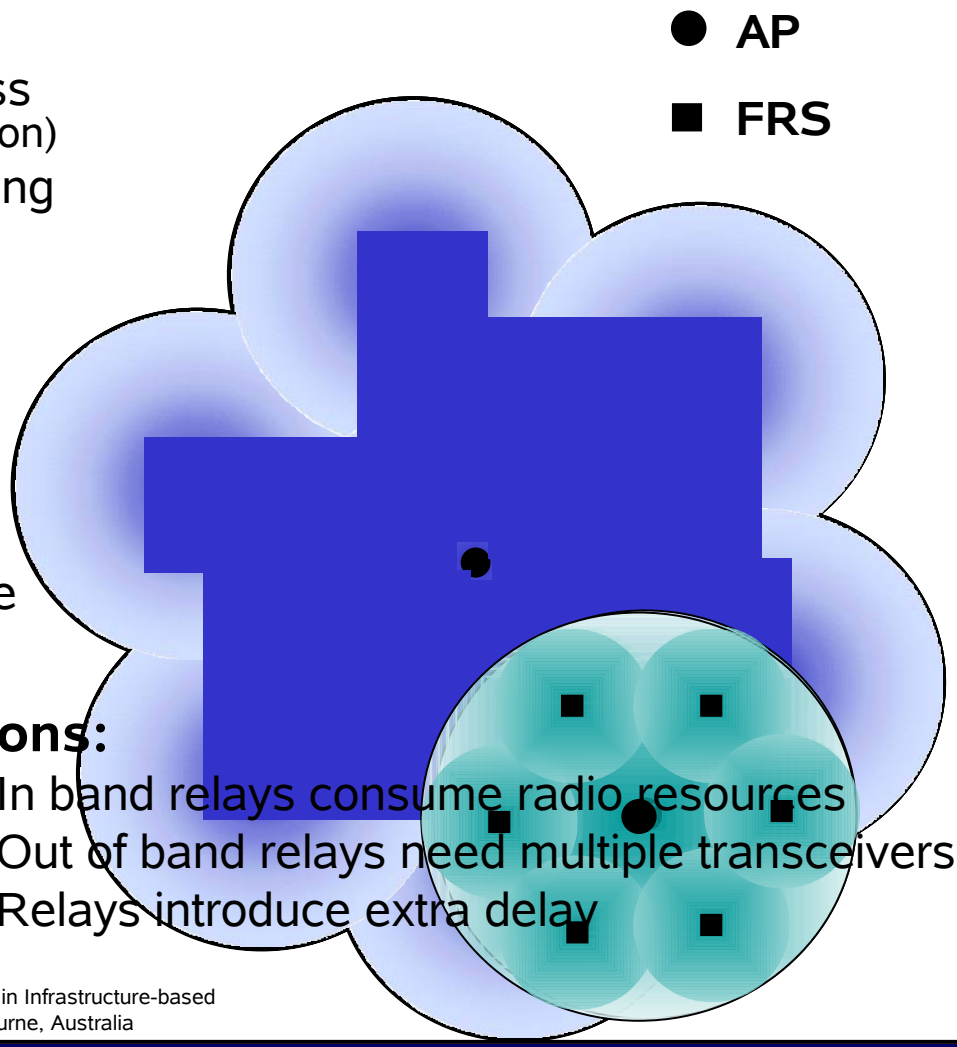


- The **capacity** should be transferred from the AP to outer regions of the cell by means of (Fixed) Relay Stations (FRS)
- AP's capacity should be **distributed** over cell radius like with water filling
- The unfairness in capacity per cell area element can be turned into better **fairness** using 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)

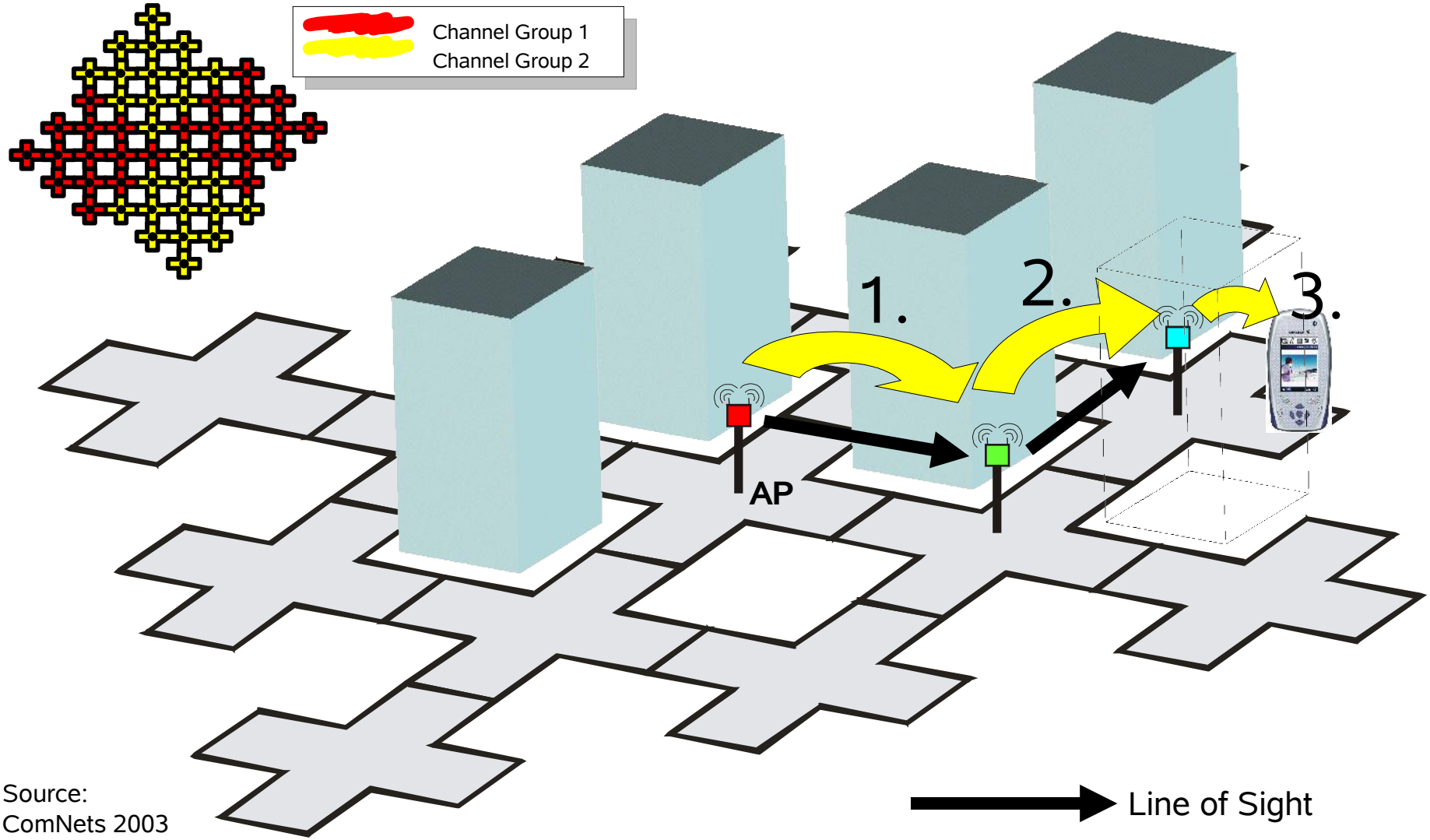


Cons:

- 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

Cellular Multi-hop deployment in high shadowing environment

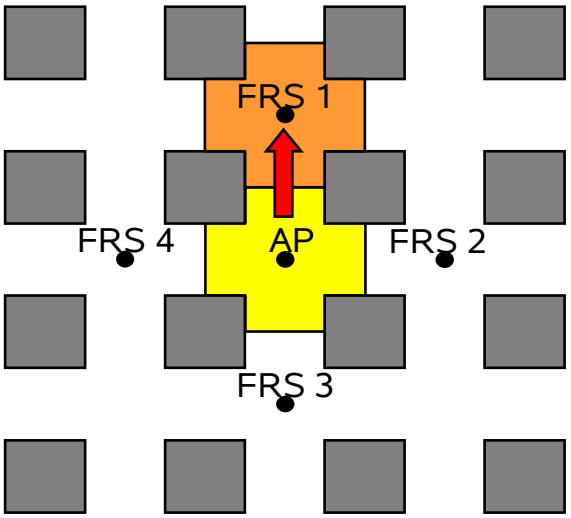


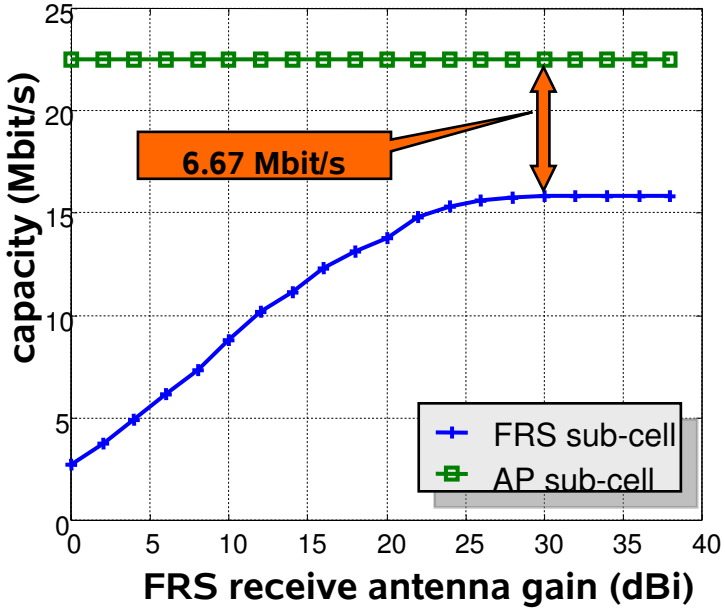
Source:
ComNets 2003

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.

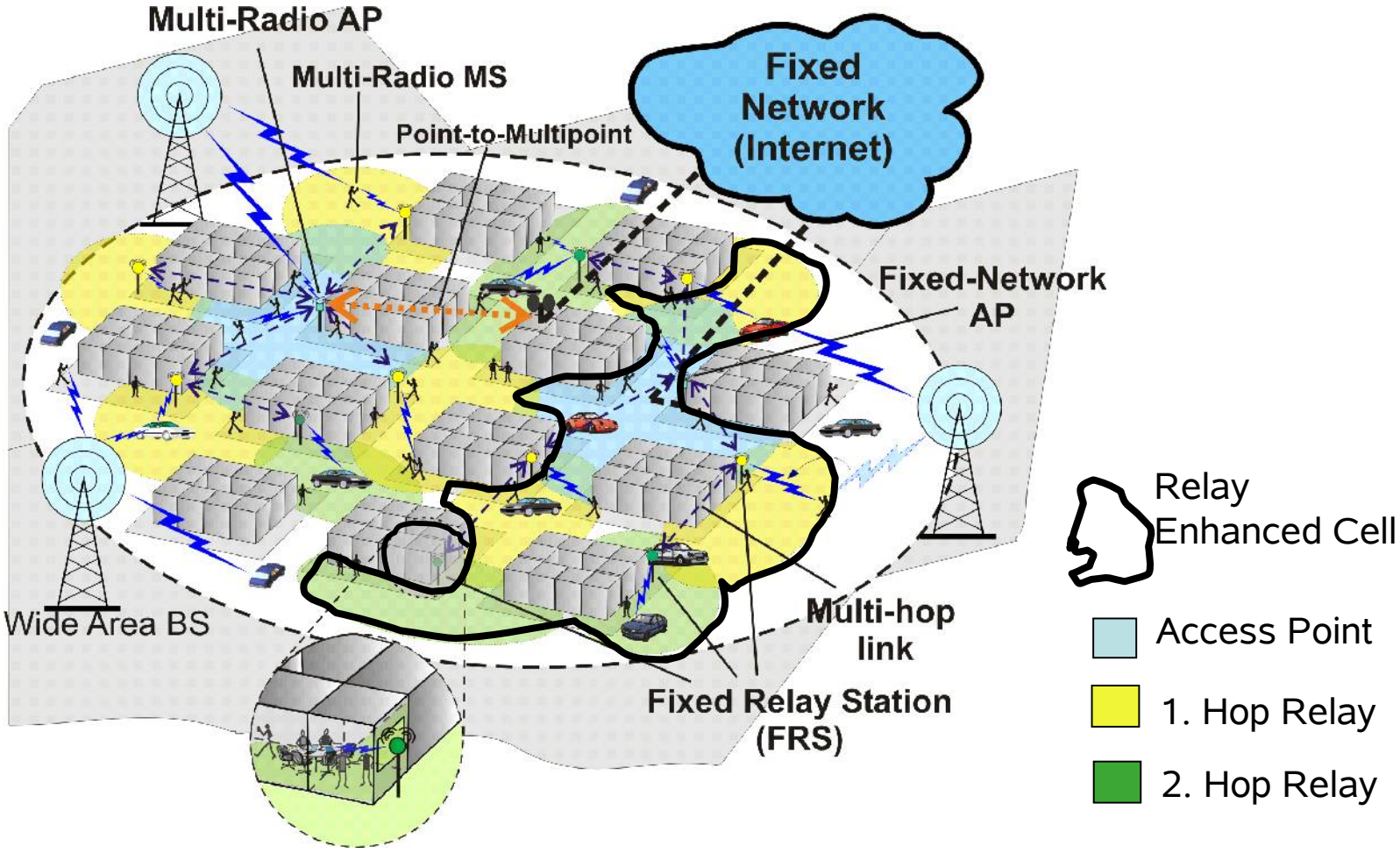
Pabst, Ralf; Esseling, Norbert; Walke, Bernhard: *Fixed Relays for Next Generation Wireless Systems - System Concept and Performance Evaluation*. *Journal of Communications and Networks,* Vol.7, No. 2, p.p. 104-114, Korea, 06/2005: Spectrum capacity can be increased by multi-hop, if some hop is narrow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





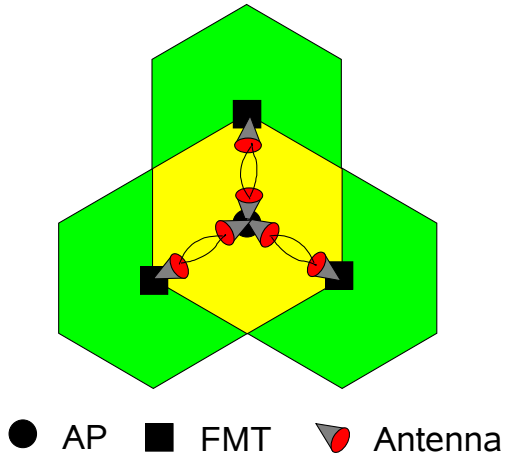
- All AP capacity "transferred" to one FRS sub-cell
- Capacity of FRS rises with antenna gain until highest PHY mode can be applied
- Cost of relaying: 6.67 Mbit/s of AP capacity at 30 dBi gain
  (example: IEEE 802.11a PHY using a WiMax like MAC protocol)

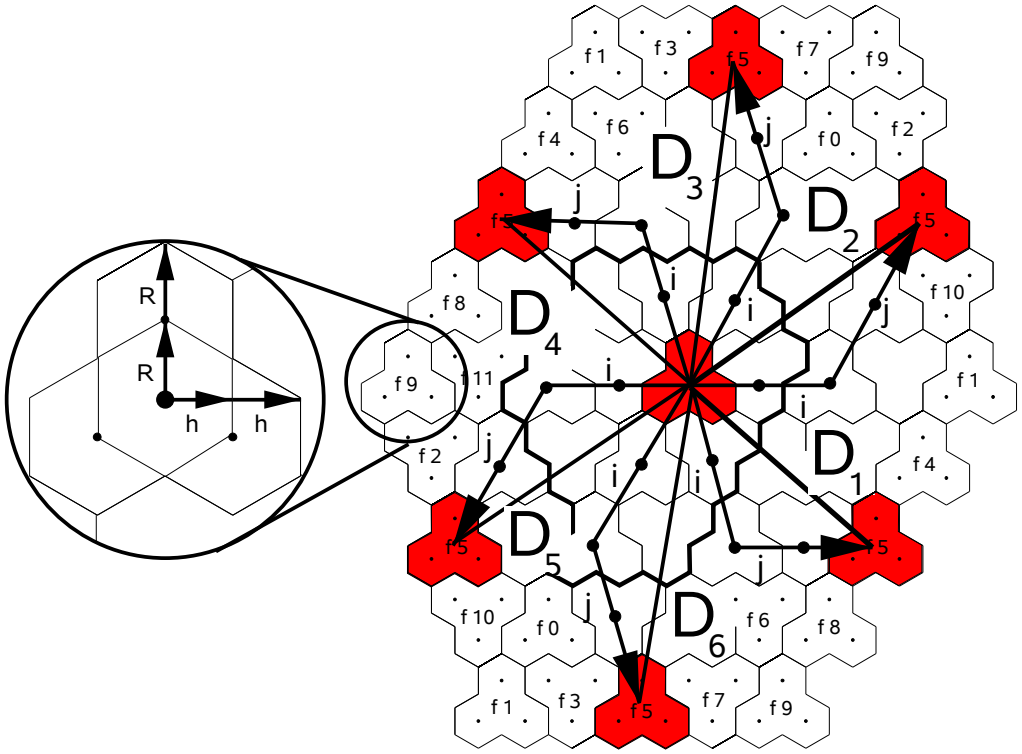
ComNets Vision of a Mobile Low Cost Internet Access: Relay-based Cellular Wireless Mobile Broadband System



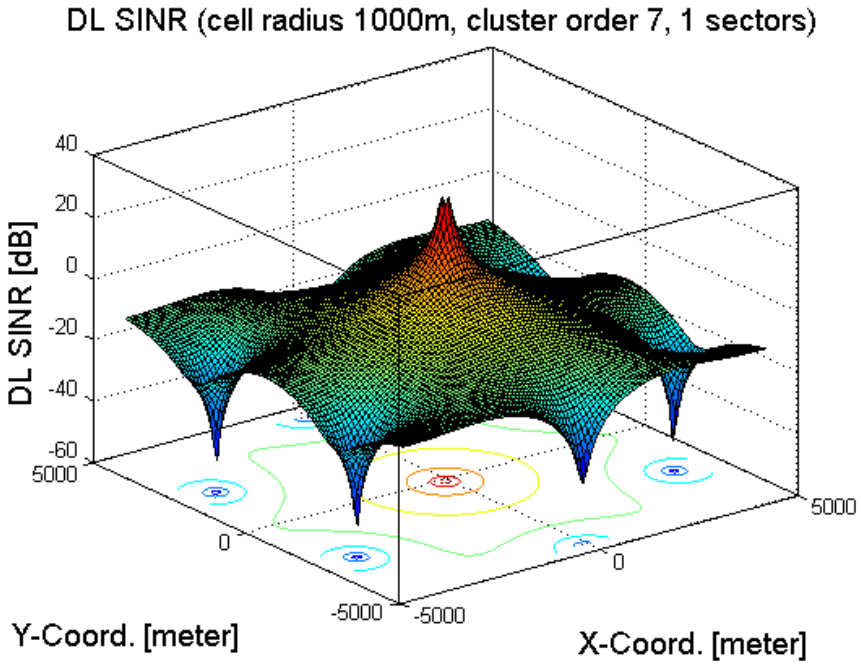
Source: Walke, Bernhard; Pabst, Ralf; Schultz, Daniel C.: *A Mobile Broadband System based on Fixed Wireless Routers*. *Proc. ICCT 2003 Intern. Conf. Comm. Techn.*, 04/2003

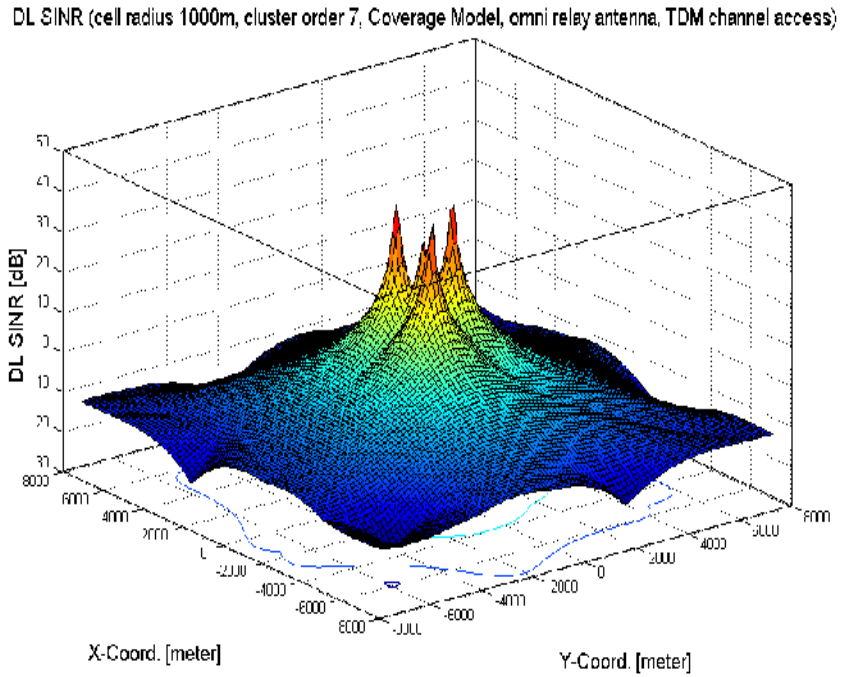
Cellular End-to-End Throughput (Downlink)

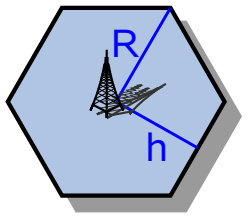




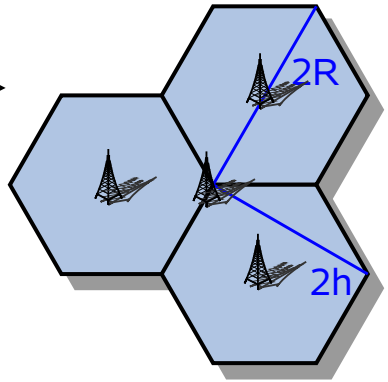
Single-Hop and Relay Enhanced Cell Throughput Compared (3 FRS in WiMax System)





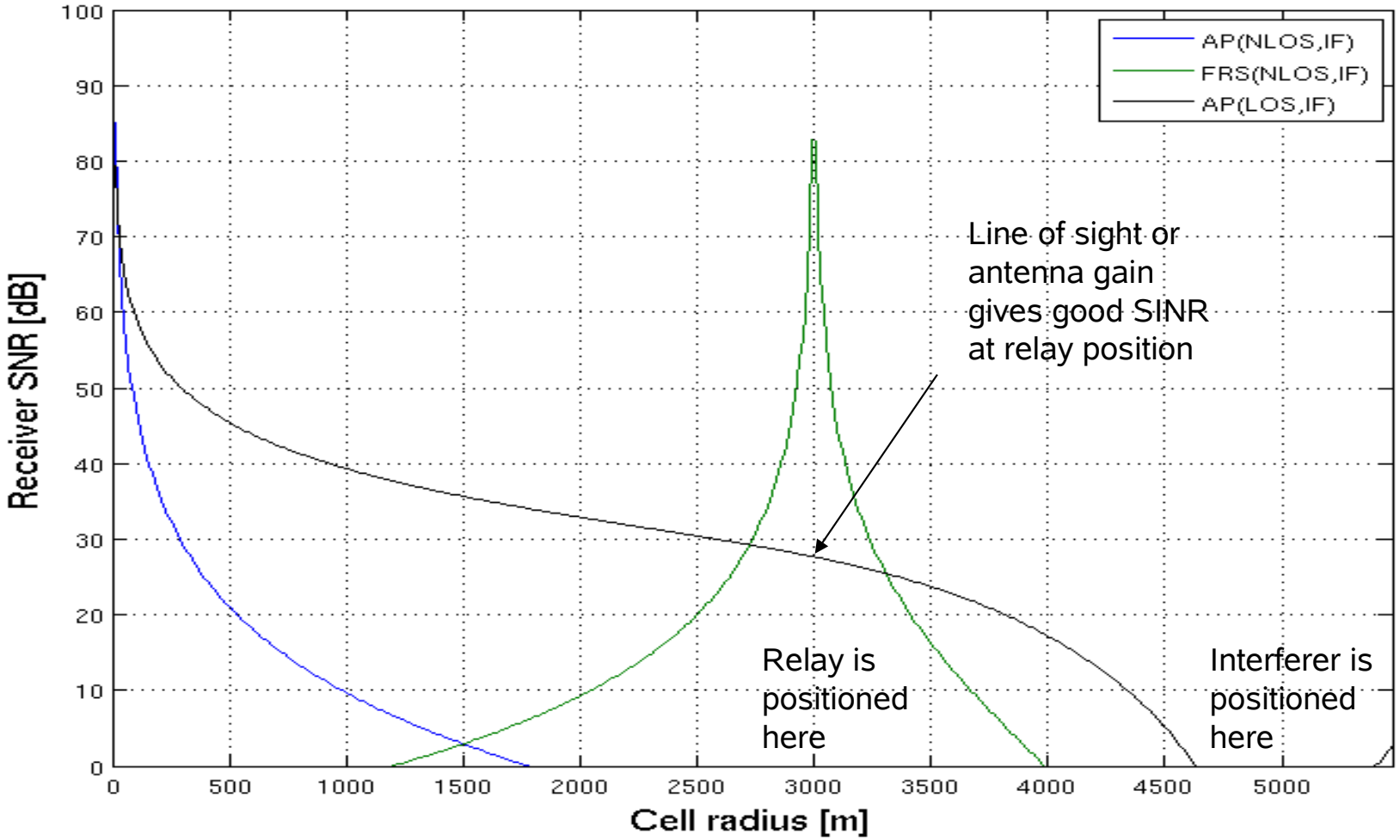


Increased coverage by 3 relays. This leads to a new 3-hexagon cell.

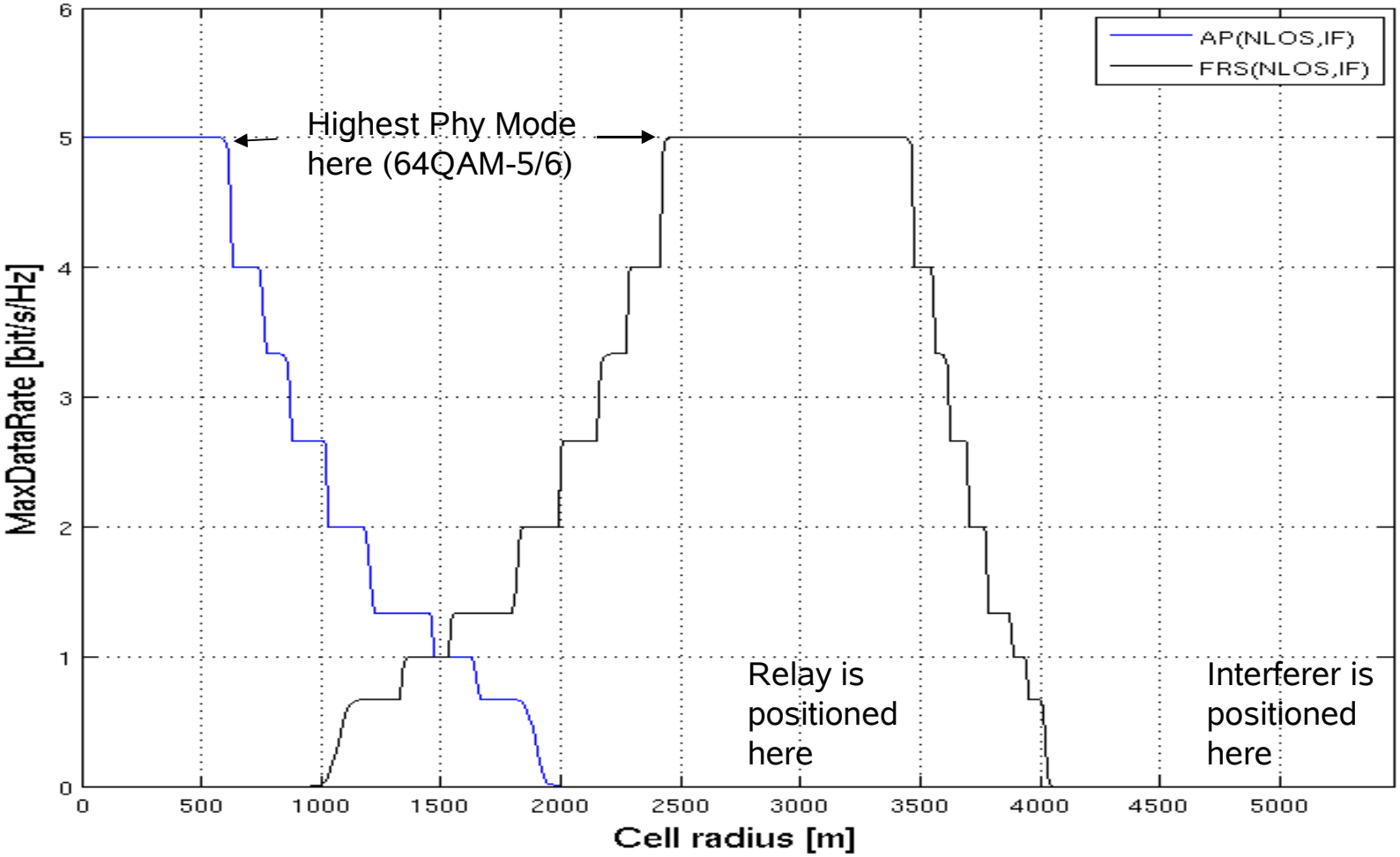


increased coverage: larger reuse distance -> a better SINR

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



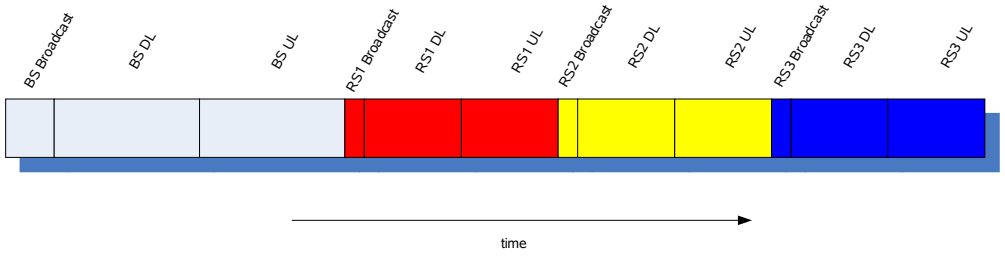
Throughput of 2-Hop Relay Scenario (3G-LTE cellular FDD System)



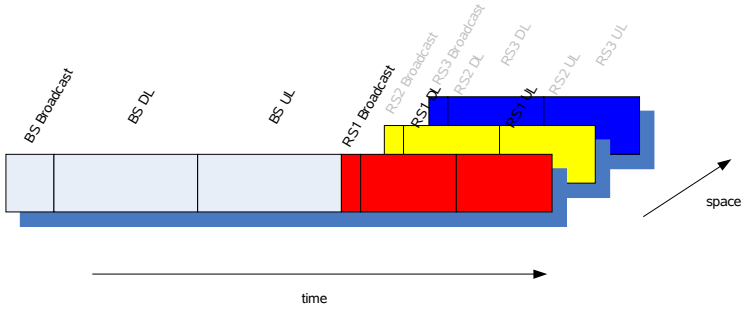
TDD multi hop relay principles

Two relay channel access schemes:

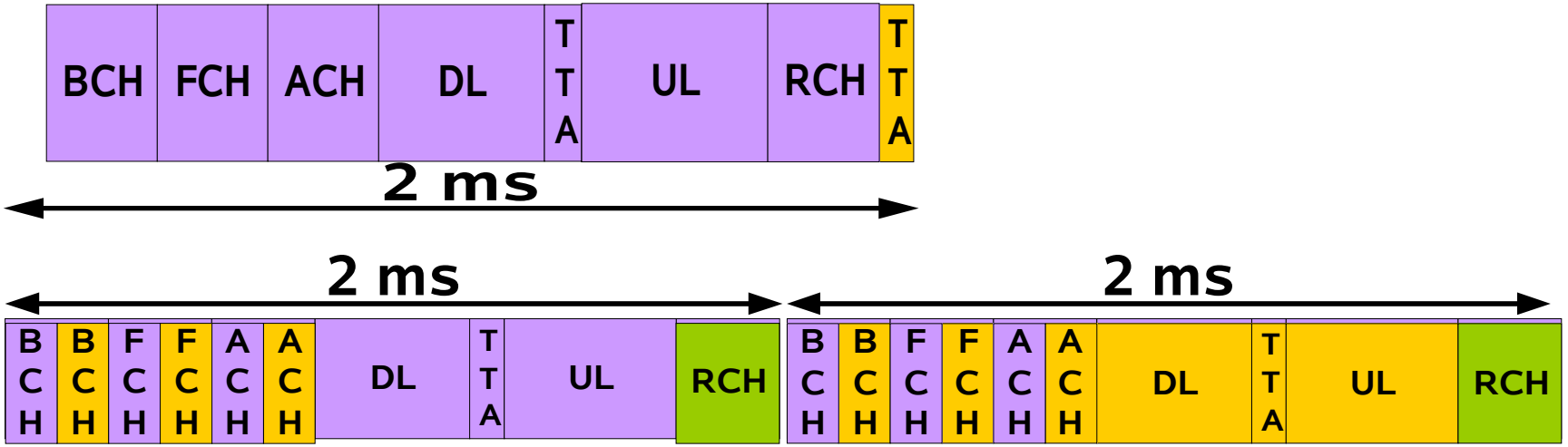
2. TD(R) channel access = relays transmit at different times and do not interfere with each other



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 n^{th} 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

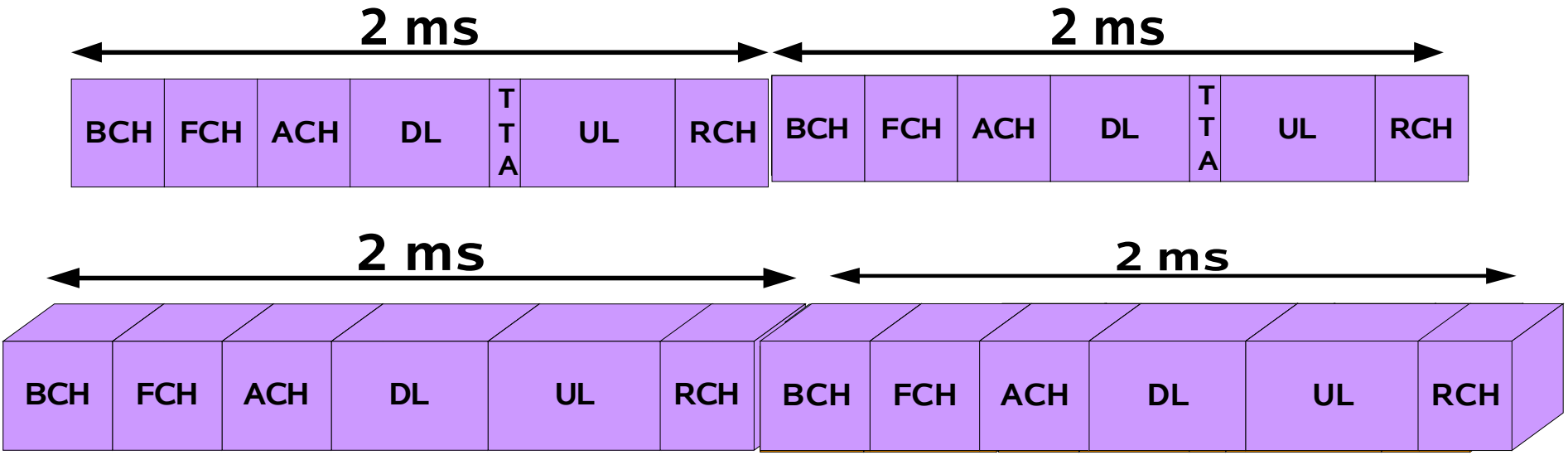
F-MAC (Frame MAC)

- FWR's frame within AP's Frame
- The size of FWR's frame can be variable, depending on traffic demand

** BroadCast CHannel*

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

TDD Relaying: TSWR Concept (H/2, WiMAX)



To support spatial reuse

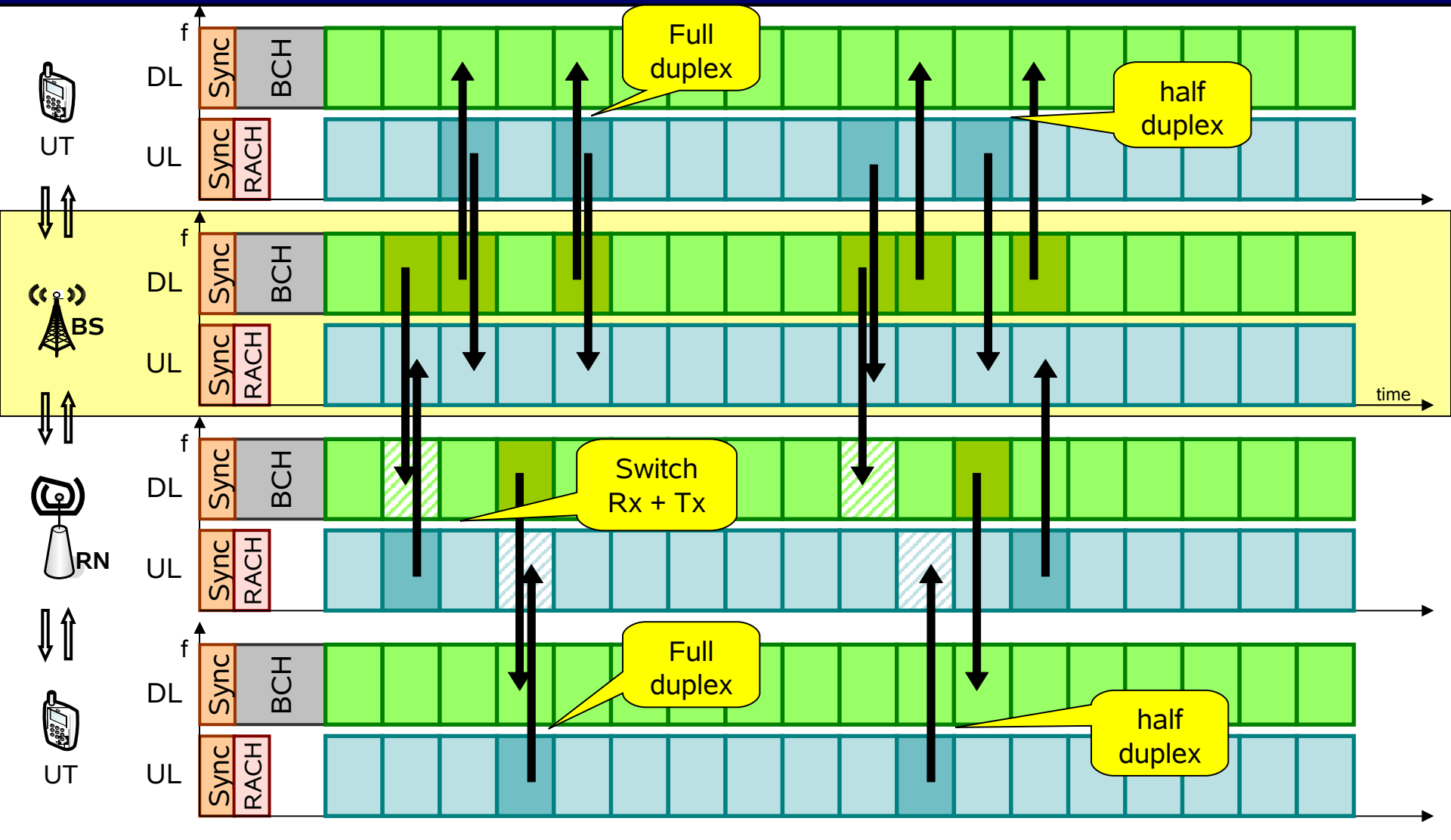
- Each FWR has an interference matrix
- Each FWR performs DFS* measurement to locate free MAC frames, on Initialization and periodically

TSWR (Time Sharing Wireless Router)

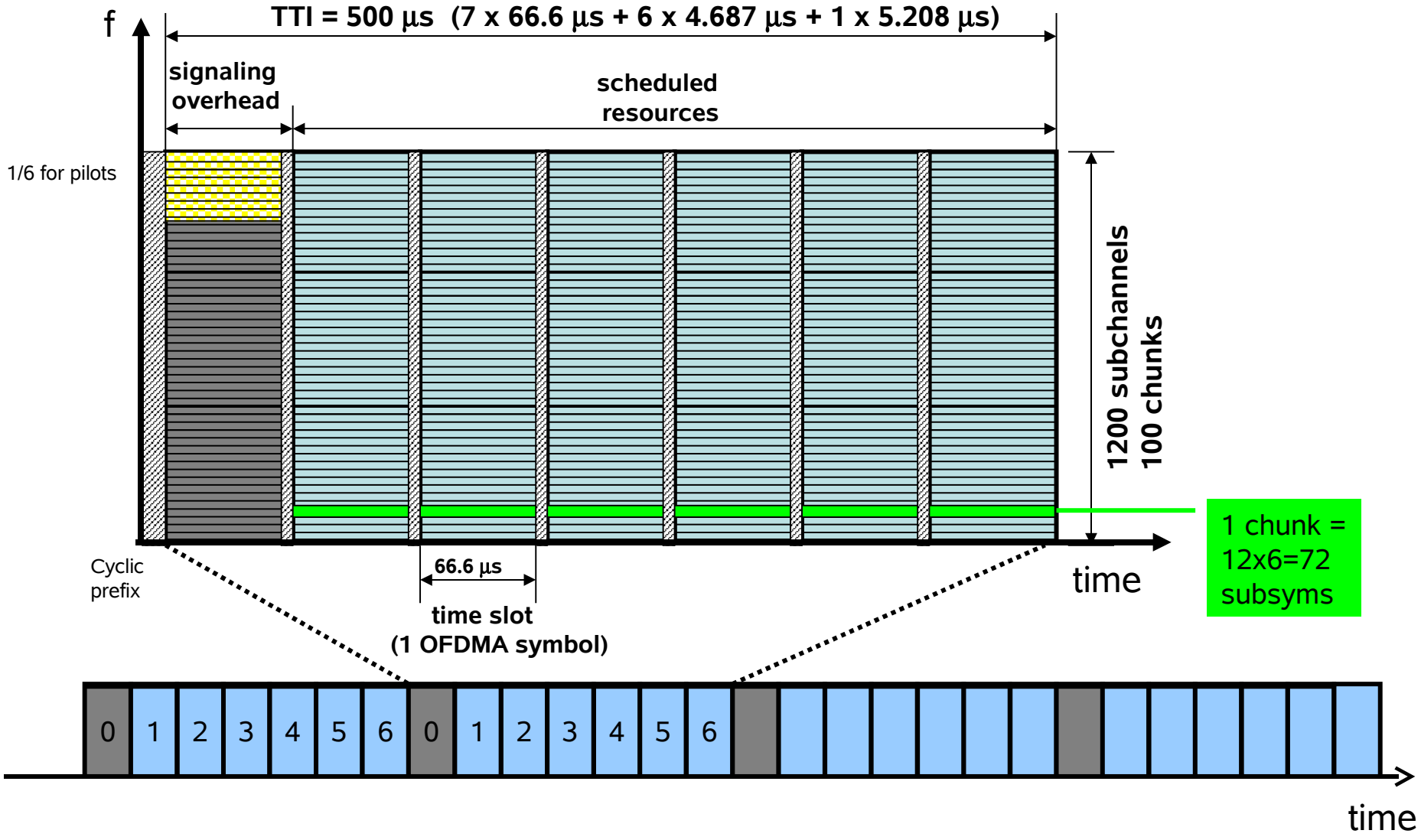
- Free MAC frames for FWR
- AP and FWRs do not transmit any BCCH when inactive

** Dynamic Frequency Selection*

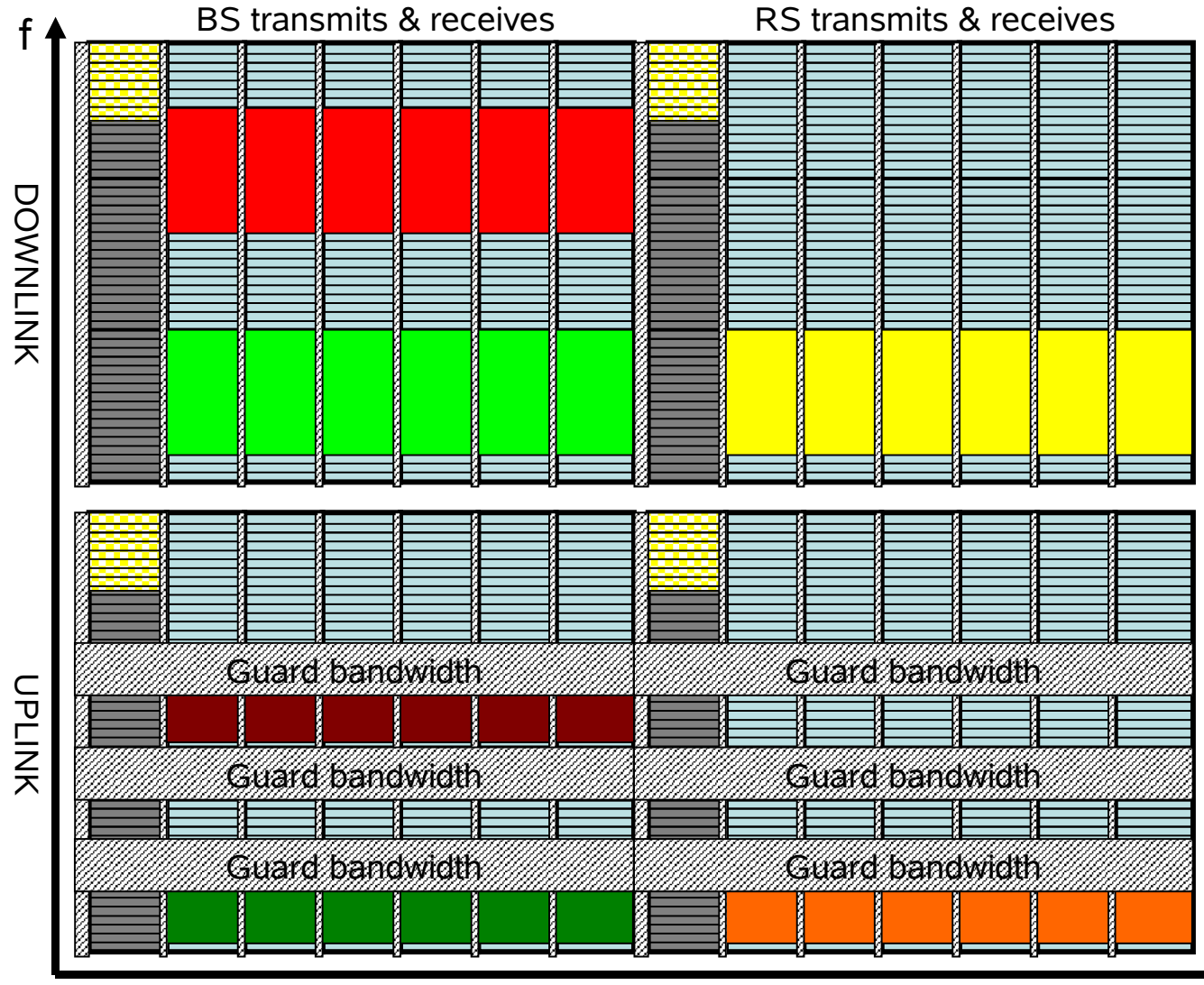
FDD Relaying – full and half duplex

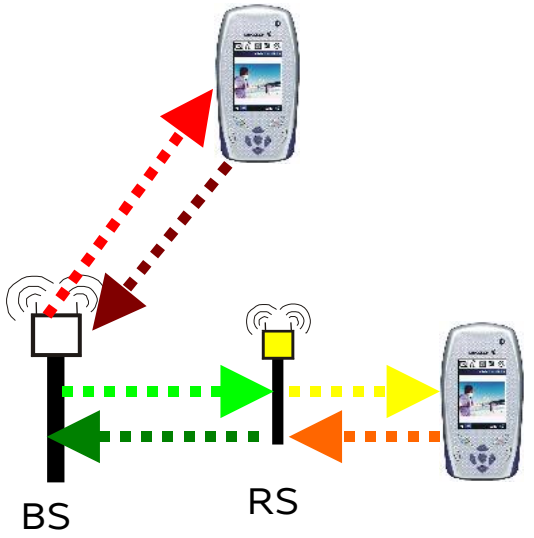


OFDMA MAC Frame Structure for 3G-LTE

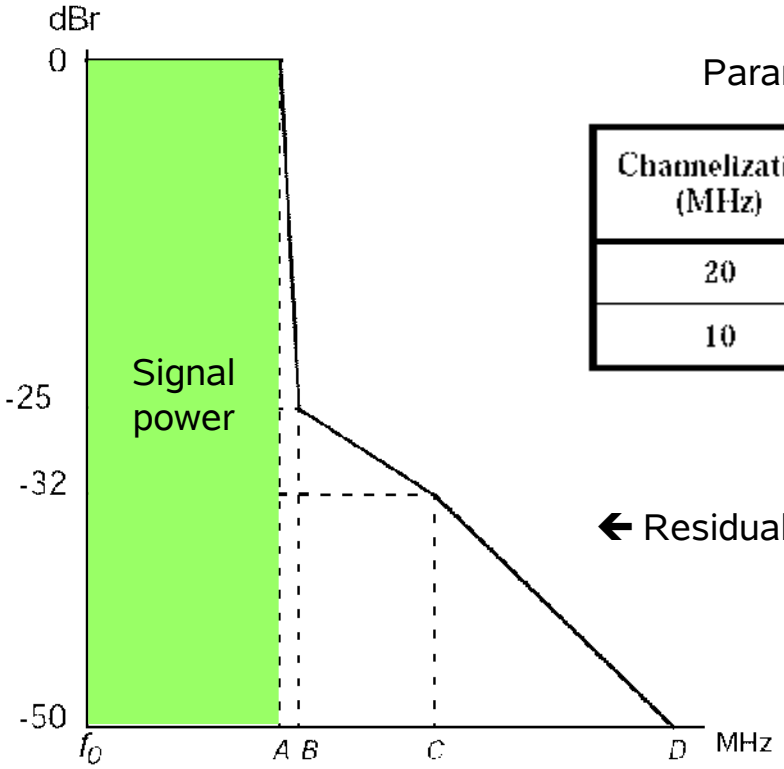


FDD Relaying using OFDMA





Uplink considerations (OFDMA Interference)



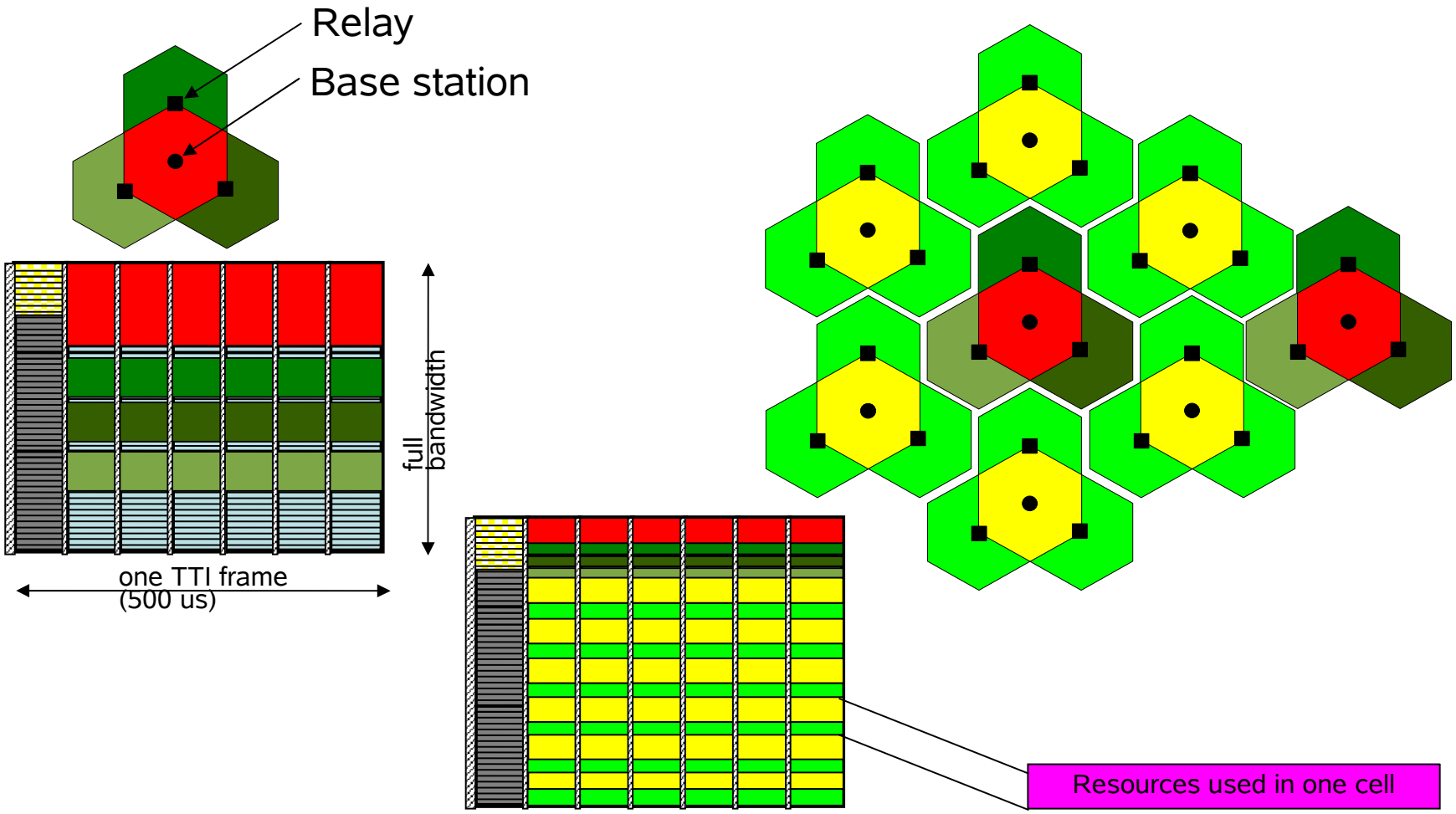
Parameters: used bw, near (0..-25dB), far (-32dB), far (-50dB)

Channelization (MHz)	A	B	C	D
20	9.5	10.9	19.5	29.5
10	4.75	5.45	9.75	14.75

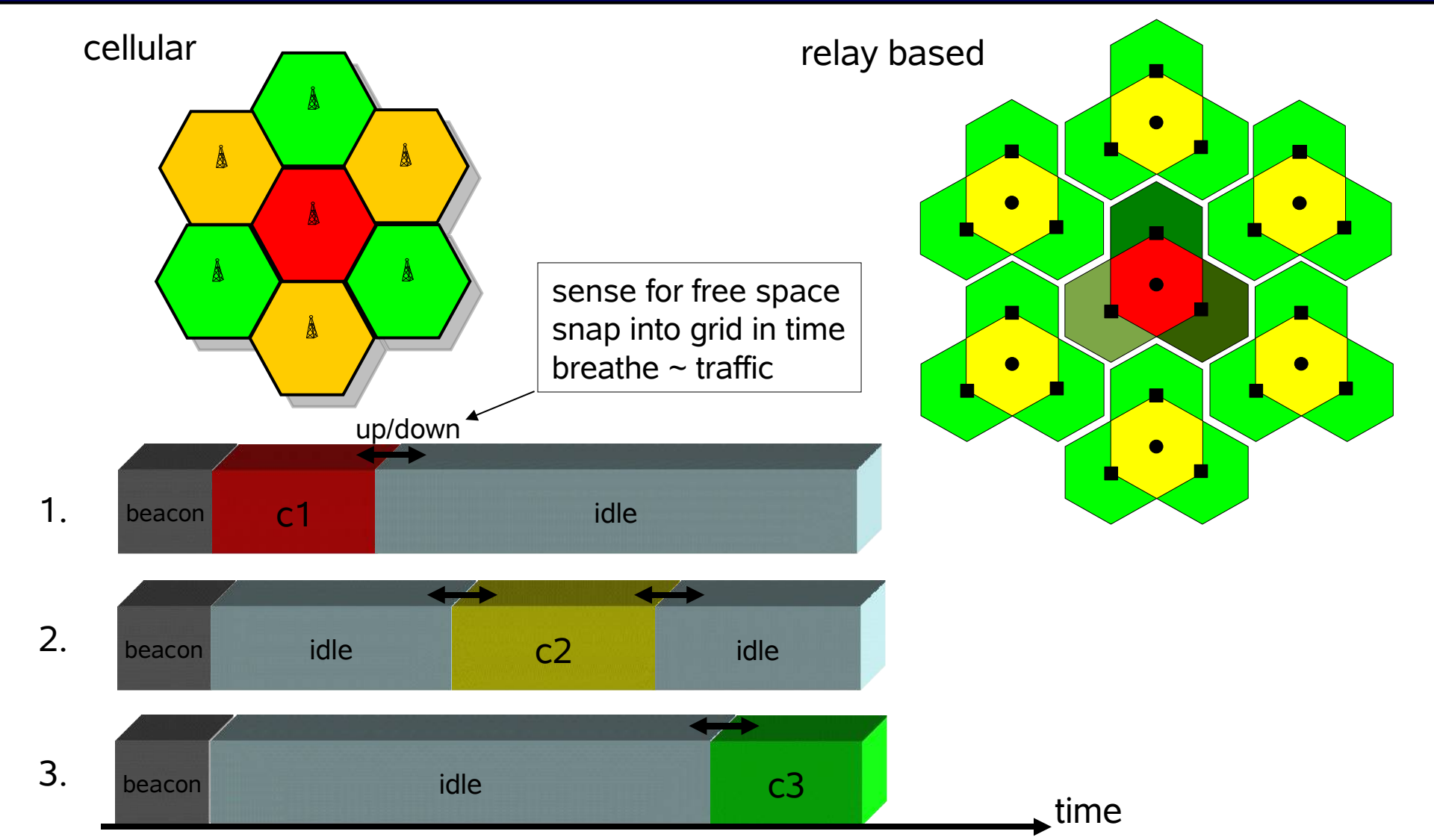
← Residual out-of-band power = interference

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)



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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