Relay Based Deployments for Wireless & Mobile Systems

Packet Relays: a Disruptive Technology for Future Systems (Panel)

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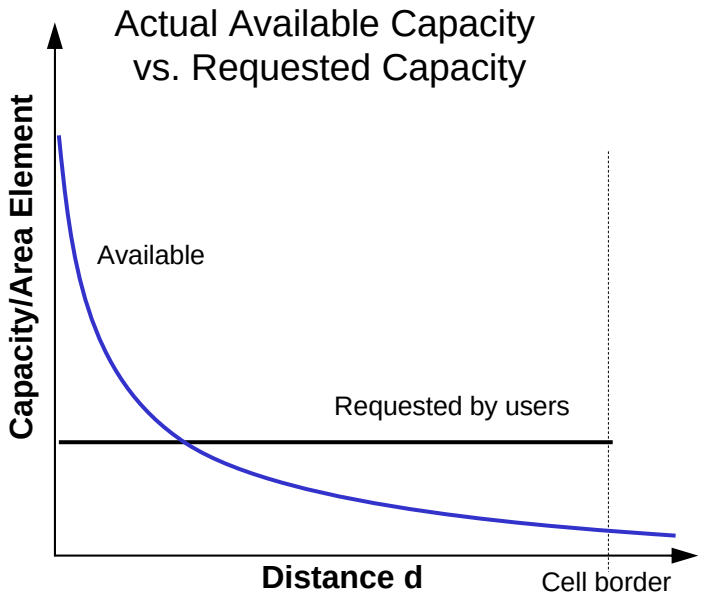
Deployment Studies Motivation

- Range of broadband base stations is limited, owing to
  - high attenuation for high frequency carriers
  - limited transmission power (EIRP limits)
  - Unfavourable radio propagation conditions, e.g., in urban areas

➔ Increasing number of BS needed with increasing carrier frequency to cover a given area
  - ➔ High CAPEX and OPEX
  - ➔ High cost/bit transmitted → hard to attract user

- In high capacity radio cell:
  High data rates available close to AP only
- With constant user density:
  - ➔ Number of users at distance d increases with d
  - ➔ Cell capacity offered per area element substantially differs from capacity requested by users



New Deployment Concepts required to

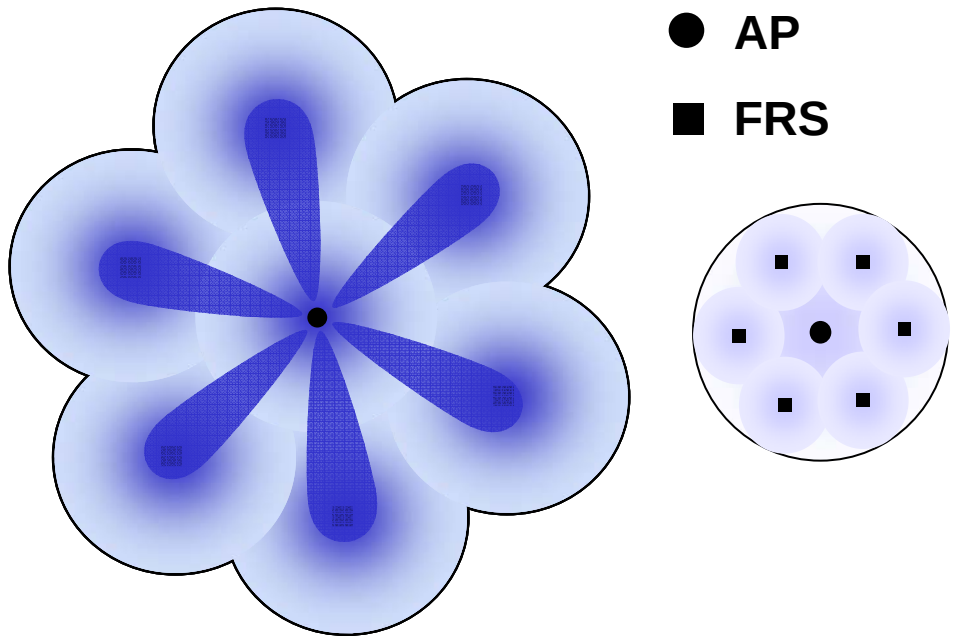
→bring broadband to wider area than possible with one base station in current systems

→Reduce the cost/bit transmitted by 2 to 3 orders of magnitude

Relay Enhanced Cells With Fixed Relay Stations (FRS)

Pros:

- Relays in REC
  - don't need a wired backbone access (lowers CAPEX and OPEX)
  - 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
    - increasing public acceptance
    - Reducing 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

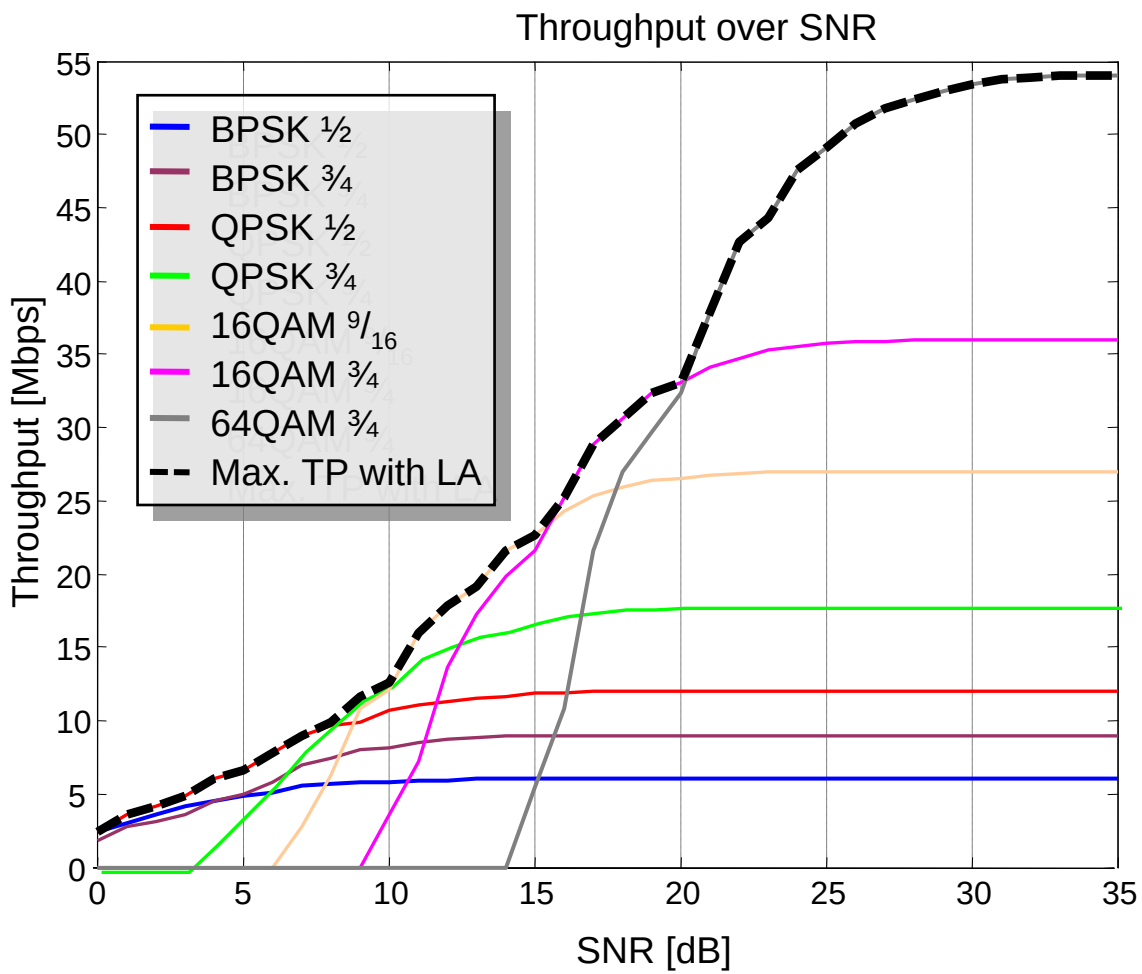
System Parameter

- Link Level Simulation results for HiperLAN/2 OFDM Modem [Ref.: Khun-Jush et al. VTC Spring'99]
- 5 GHz band
- 20 dBm transmission power
- -96 dBm noise
- Perfect Link Adaptation (LA)
- SREJ-ARQ

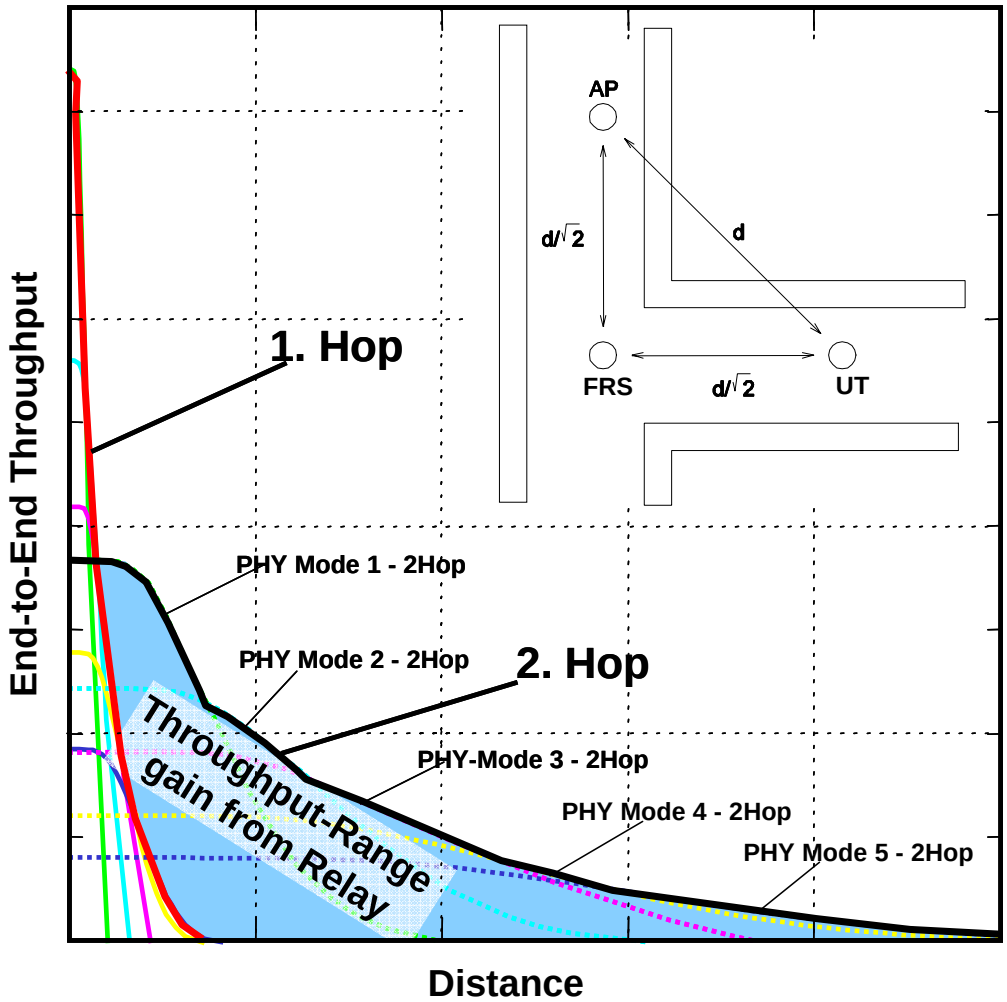
Analysis with simple propagation model:

$$P_R = P_T * g_T * g_R * \left(\frac{\lambda}{4\pi}\right)^2 * \frac{1}{d^\gamma}$$

P – power ; g – antenna gain;
γ - pathloss coefficient

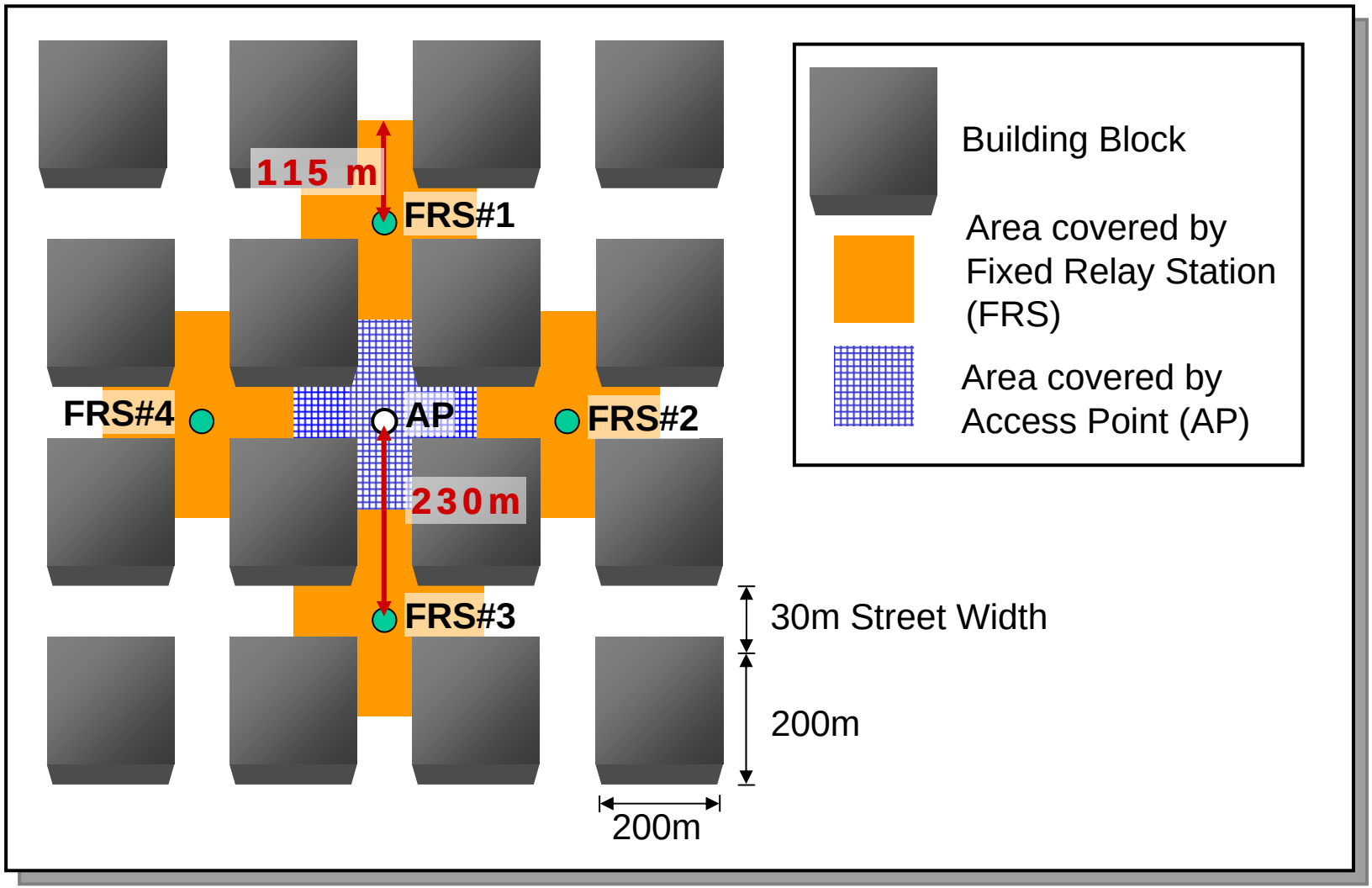


L2-Relays are useful to bring coverage to shadowed areas



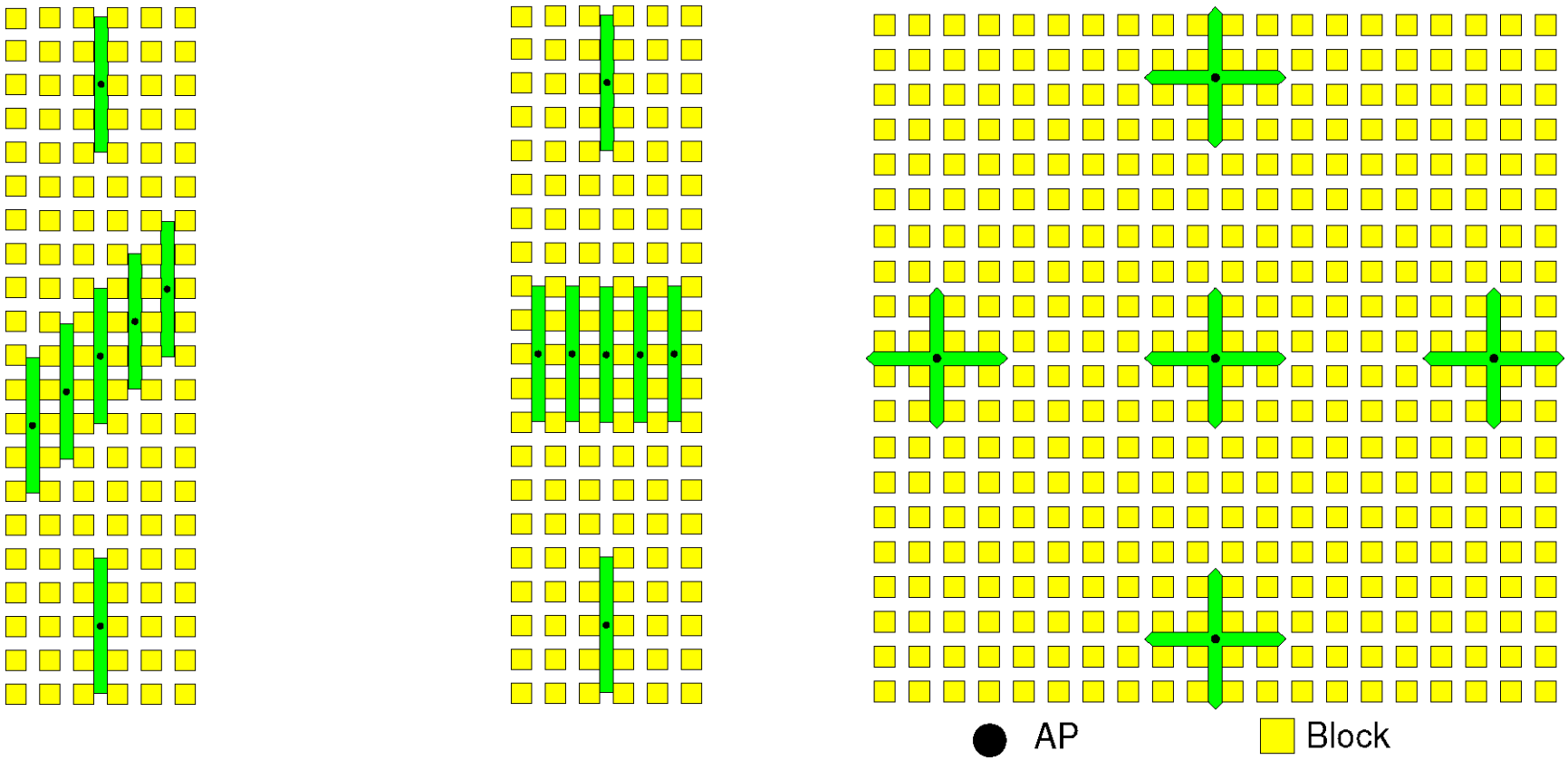
Maximum End-2-End throughput over distance for 1- and 2-hop links with S-ARQ

2-Hop Cell in Manhattan Scenario



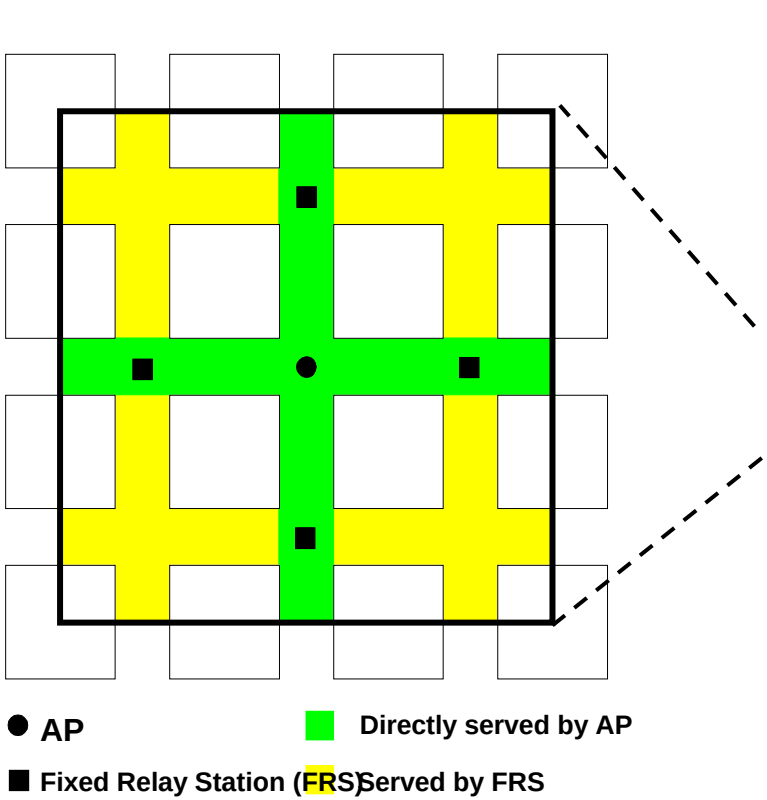
Different Deployment of Co-Channel APs

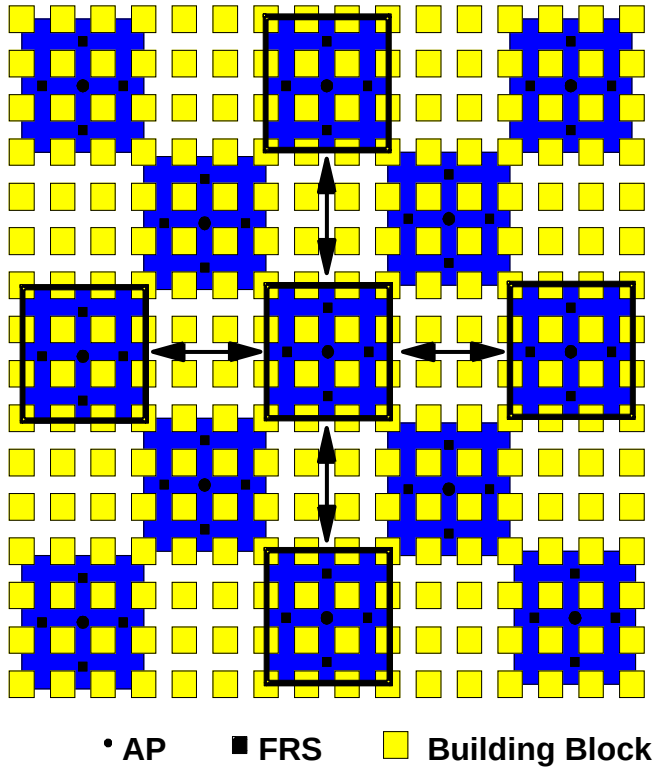
Single-Hop – Manhattan



(a) UMTS 30.03 AP Placement (b) APs at equal y-Coords (c) APs on street-crossings

Relay Enhanced Cell (REC) in Manhattan Scenario





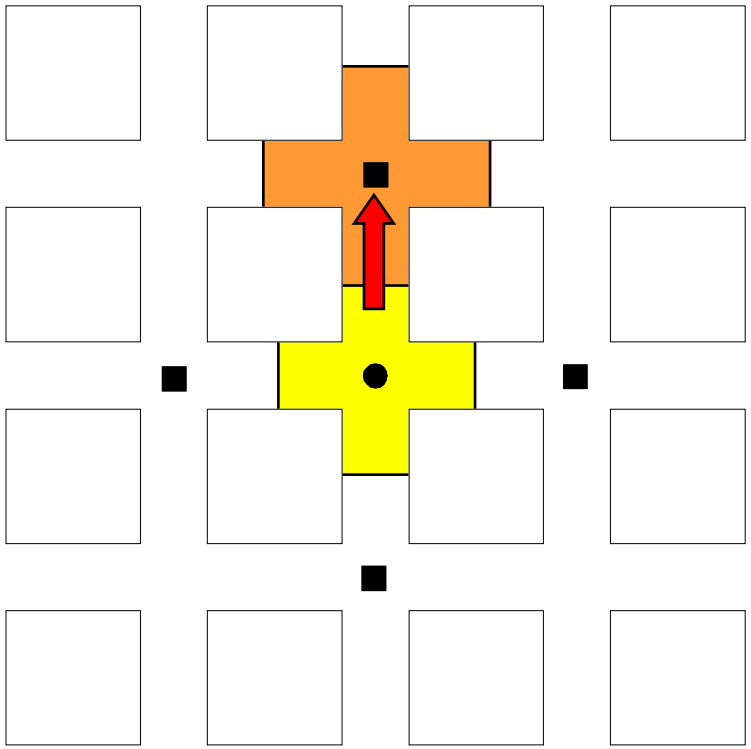
Cluster order N=2

FRS serve to

- extend coverage of AP
- increase cell capacity

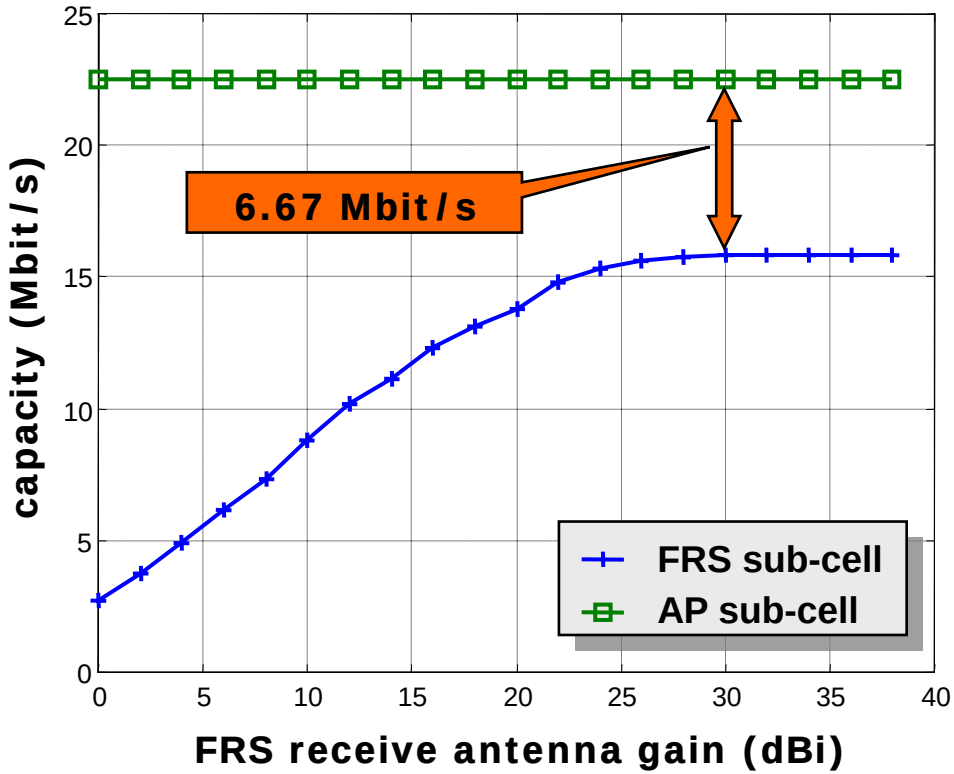
- AP + 4 FRSs form a "Relay Enhanced Cell"

FRS sub-cell Capacity



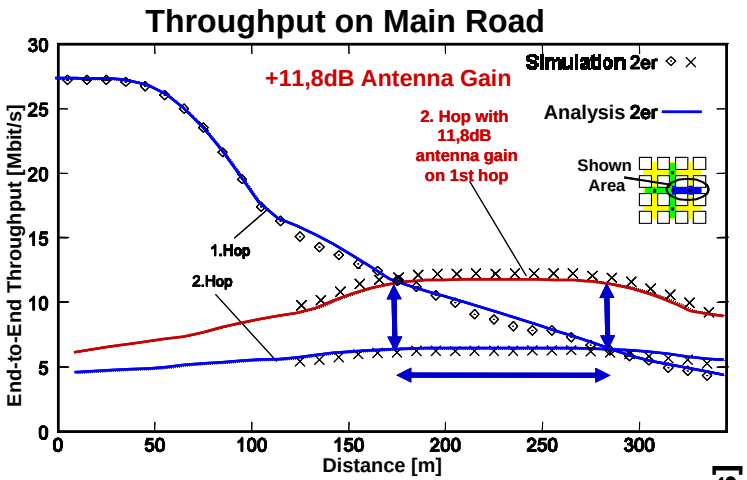
● AP

■ Fixed Relay Station (FRS)

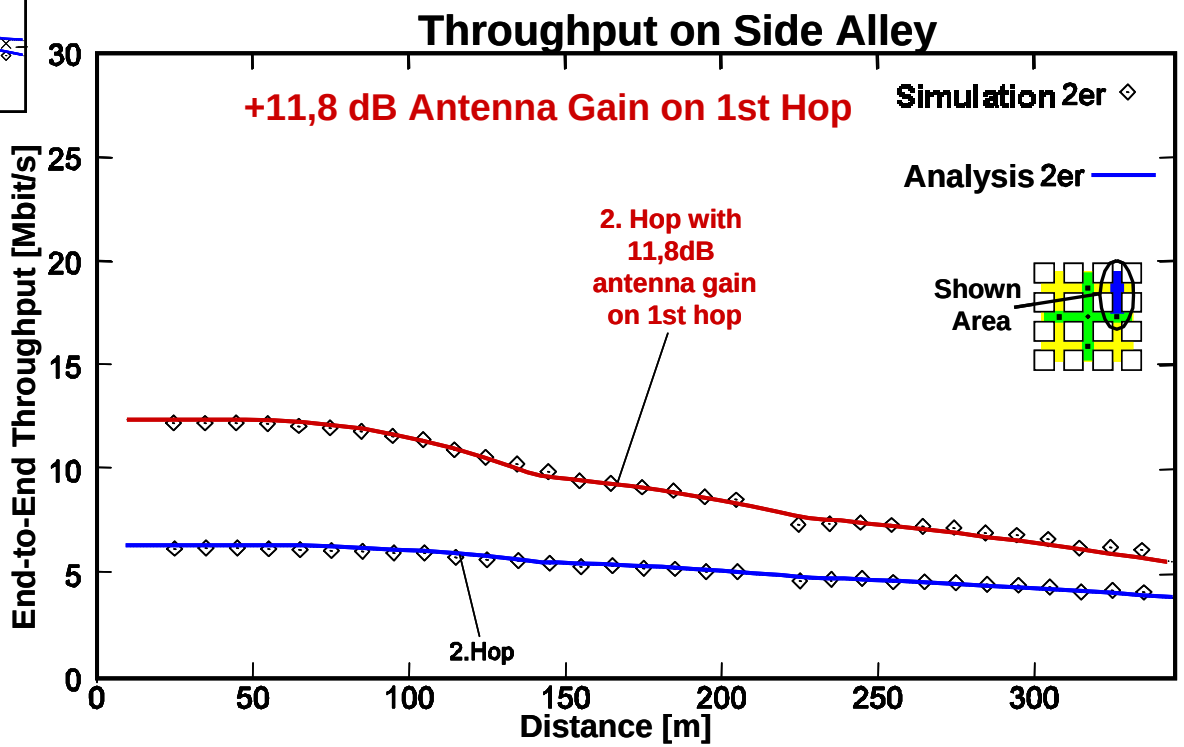


- All AP capacity “transferred” to one FRS sub-cell
- Capacity of FRS rises until antenna gain allows using highest PHY mode without packet errors on first hop
- Relaying costs 6.67 Mbit/s of AP capacity at 30 dBi gain

Simulation Results vs. Analysis
Two-Hop C/I and E-2-E Throughput: Manhattan

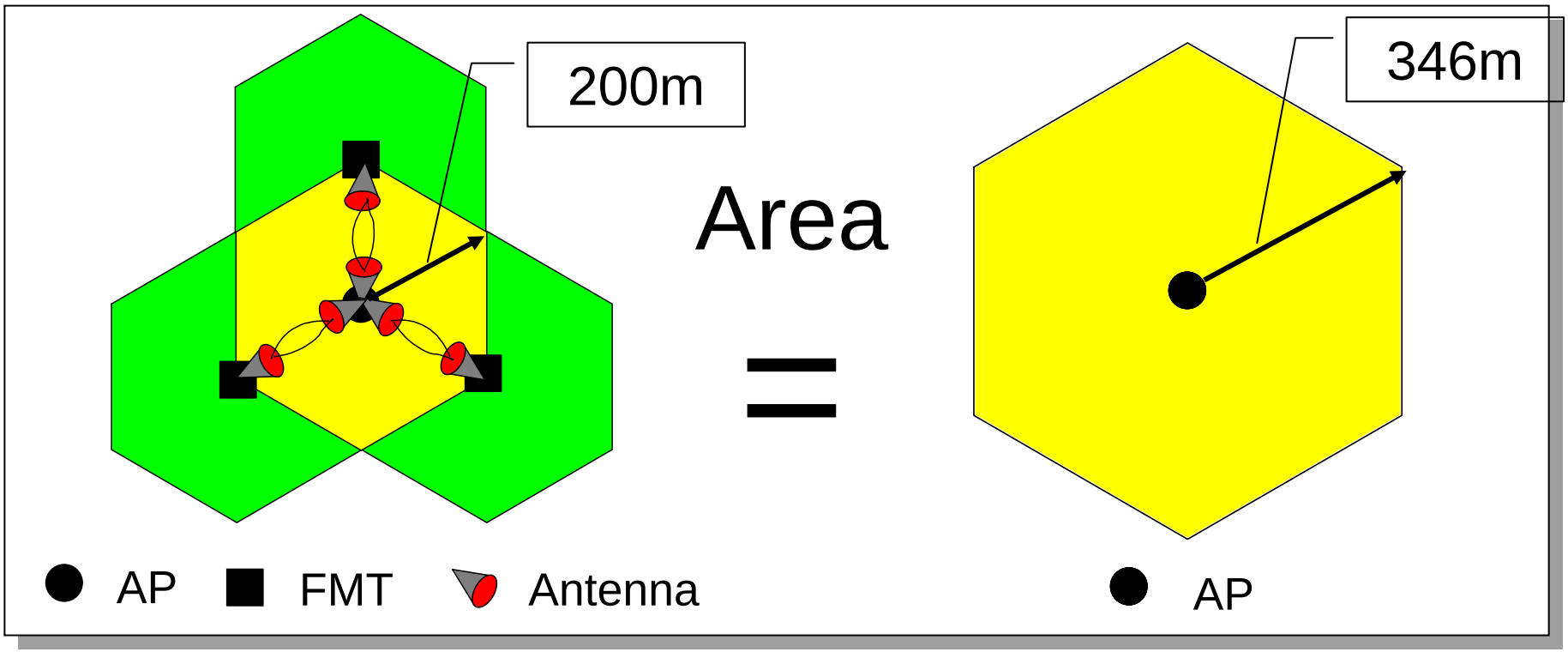


- The results are based on MAC frame based system, e.g. WiMax/IEEE802.16e



[1]More detailed results in Esseling, N.; Walke, B. and Pabst, R.: “Performance Evaluation of a Fixed Relay Concept for Next Generation Wireless Systems”; In *Proceedings of PIMRC 2004*, p. 9, pp. 9, Barcelona, Spain, 09/2004

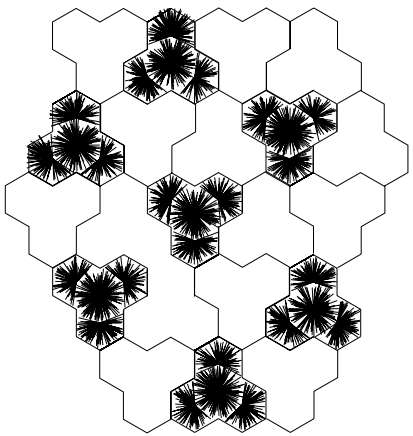
Wide Area Comparison Cases



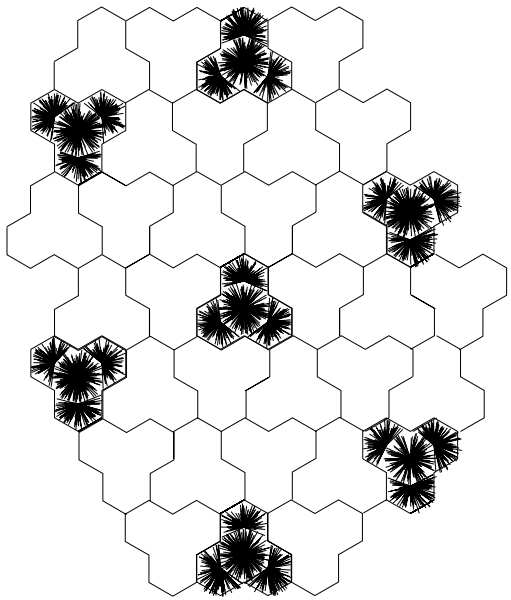
One-hop cell with R=346m is equivalent in coverage area to a two-hop cell with 3 FRSs, where each subcell has the radius R=200m

Deployment Scenario and Possible Frequency Plans

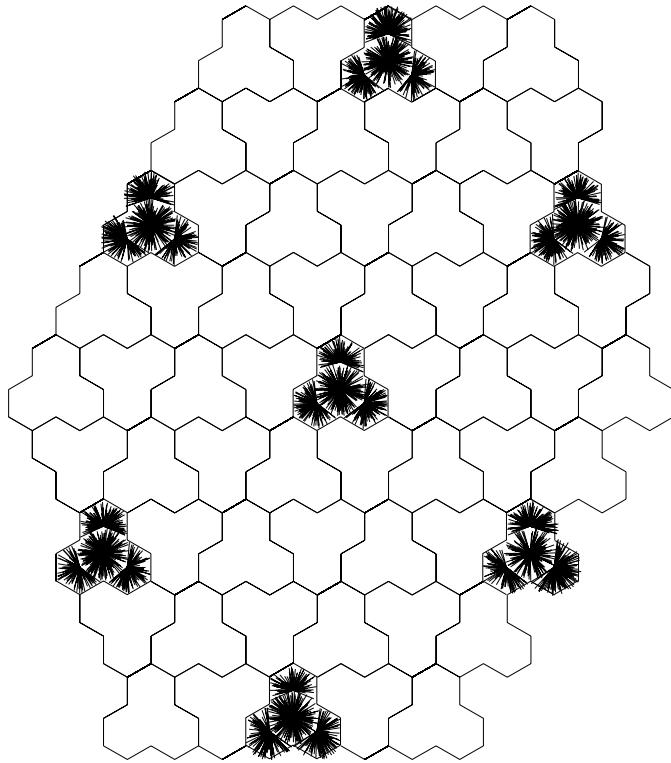
Two-Hop – Wide Area



(a) Cluster Size N=3



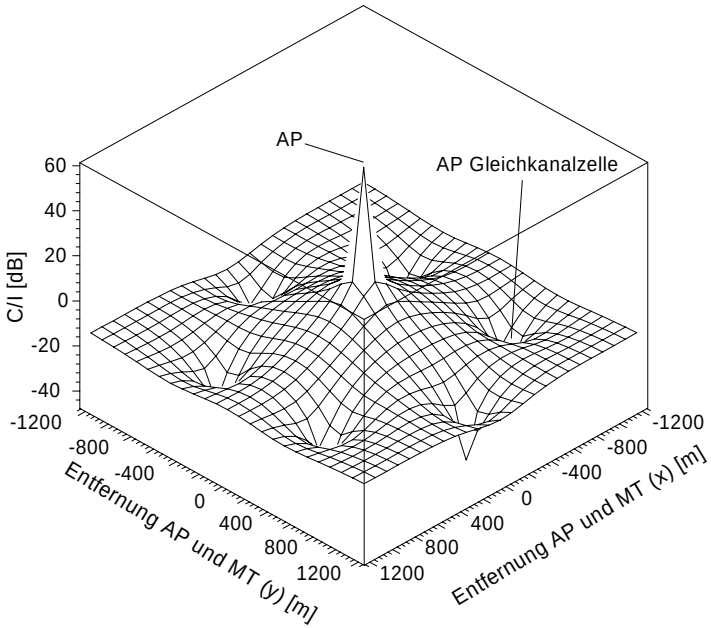
(b) Cluster Size N=7



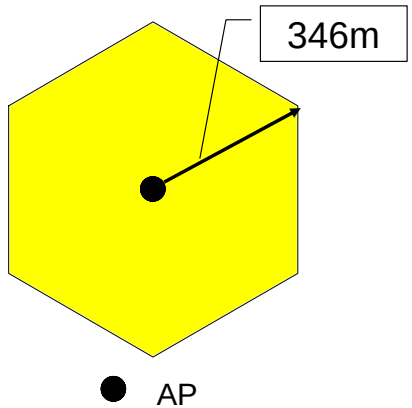
(c) Cluster Size N=12

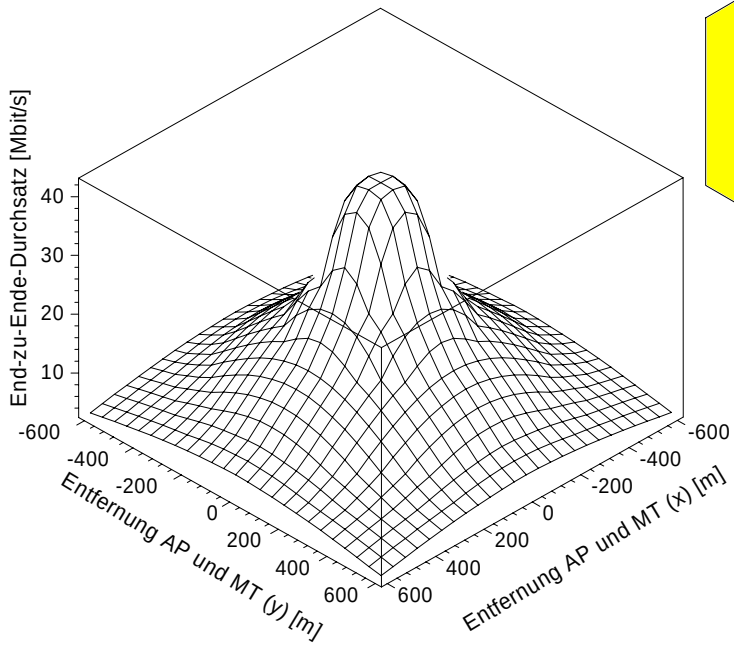
Single Hop – Cluster Size N=7

- C/I in a Scenario with 1st “Ring” of co-channel interferers visible



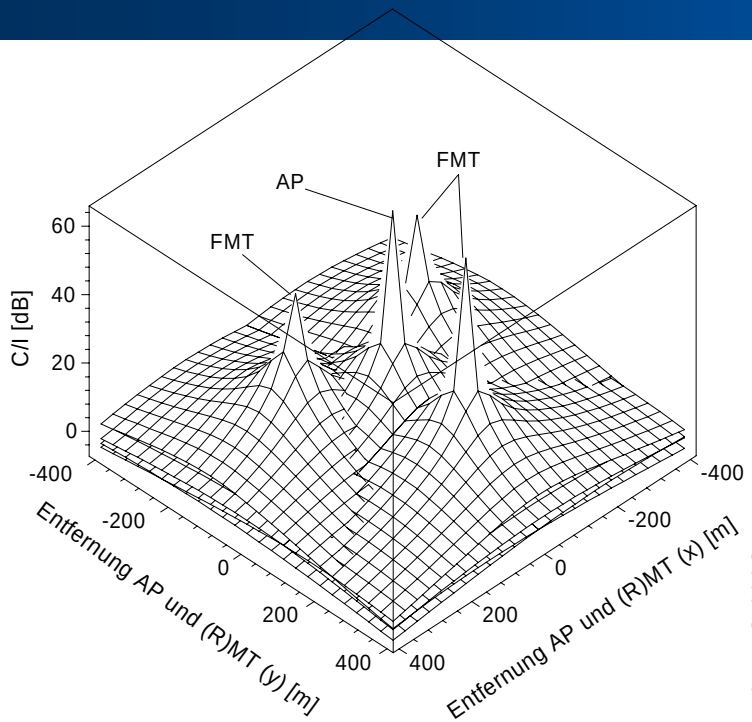
Cell type:



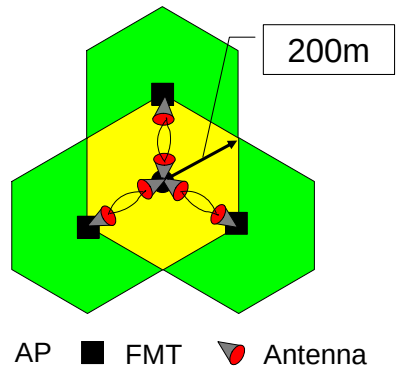


- Max. End-to-End throughput in a celll

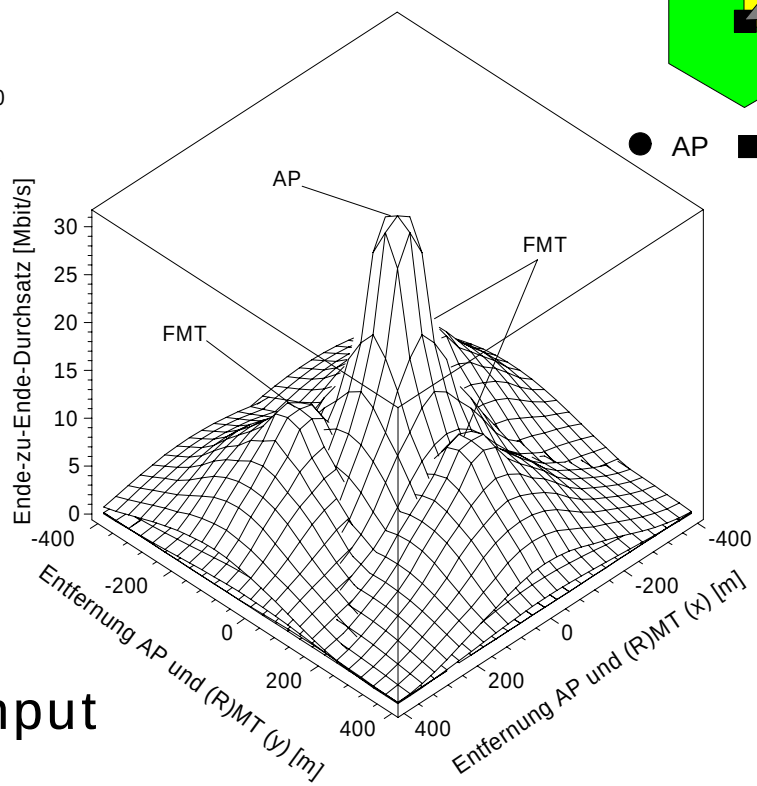
2-Hop – Cluster Size 7 – 11.8dB Gbain Antennas



Cell type:

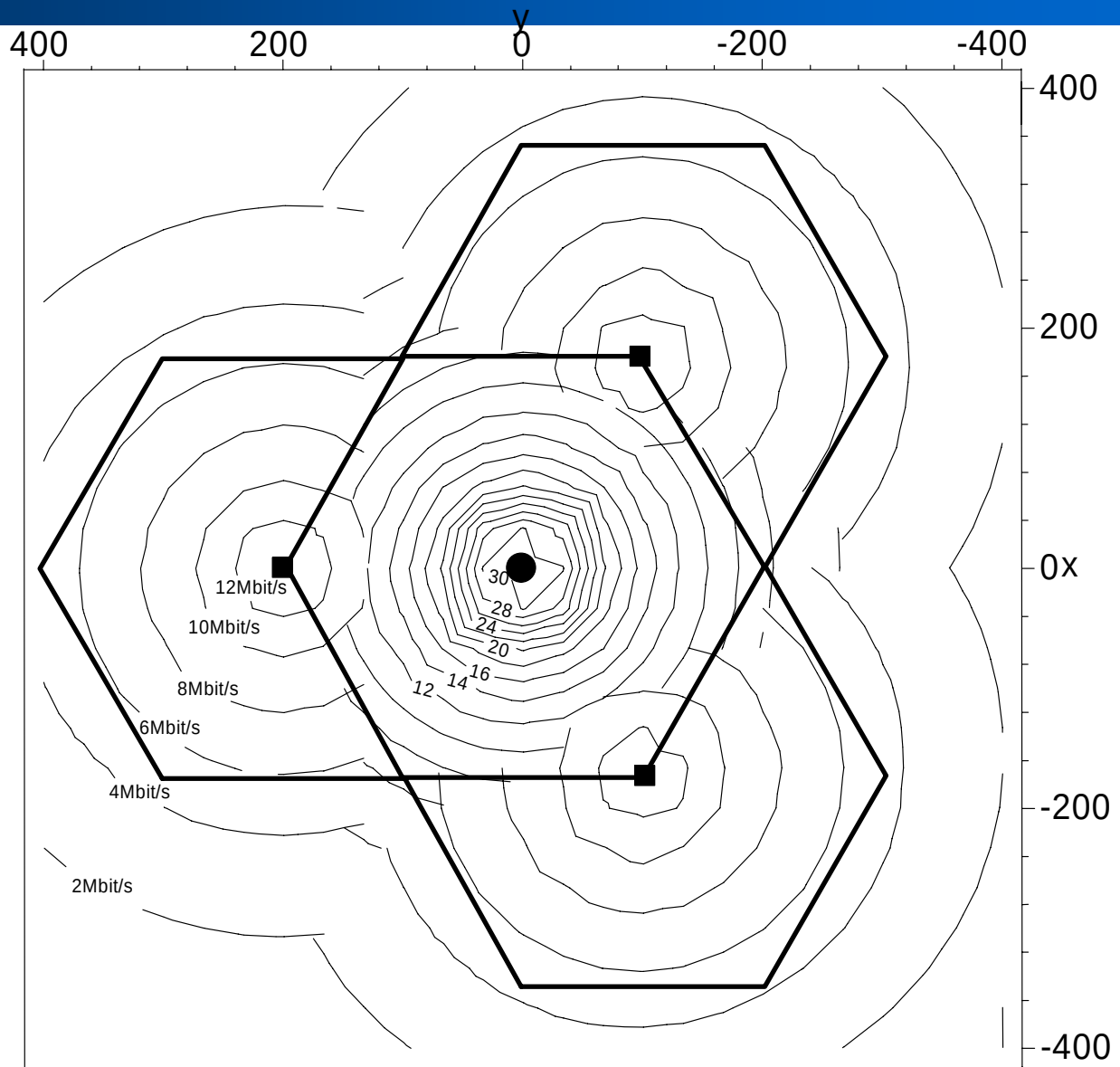


- C/I over cell area



- Max. End-to-End throughput in a cell

2-Hop – Cluster Size N=7 – 11.8dB gain Antennas on 1st Hop



Spectral Efficiencies[1]

Manhattan Scenario

Scenario	Used # of Freq.	Cell Size [m^2] / 10^3	Cell Capacity [Mbit/s]	Spect. Efficiency [$bit \cdot s^{-1} \cdot Hz^{-1} \cdot m^{-2}$]
1-Hop (APs on cross.)	8	53,4	20,24	2,37
2-Hop N=2, +11,8 dB	2	116,0	10,72	2,31

Wide Area Scenario

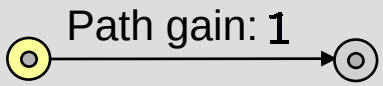
Scenario	Used # of Freq.	Cell Size [m^2] / 10^3	Cell Capacity [Mbit/s]	Spect. Efficiency [$bit \cdot s^{-1} \cdot Hz^{-1} \cdot m^{-2}$]
1-Hop Standard 346m	3	311	6,53	0,35
2-Hop 3 FRS, +11,8 dB	3	311	7,44	0,40

In comparable deployments (APs / Relays on crossings), the relay-based system offers the same spectral efficiency as the conventional system, with the advantage of considerably lower deployment efforts[2]

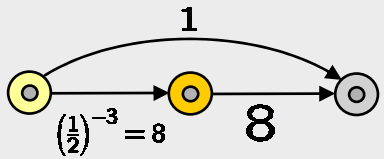
[1]R. Pabst, N. Esseling, B. Walke: "Performance Evaluation of a Fixed Relay Concept for Next Generation Wireless Systems," EW2005b

Cooperative Relaying – Idea

Direct



Single-Path Relaying



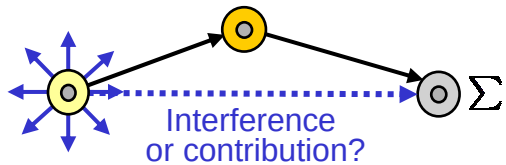
At layers 2, 3

Example: ODMA

\+ Pathloss savings

– Need two phases

Cooperative Relaying



\+ Exploits broadcast nature of wireless medium

\+ Spatial diversity

- Additional path via relay
- Can emulate arrays → "virtual antenna arrays"

Point–to–point coding → Network coding

Implementations of Relay based Deployments

A: Homogeneous Relay

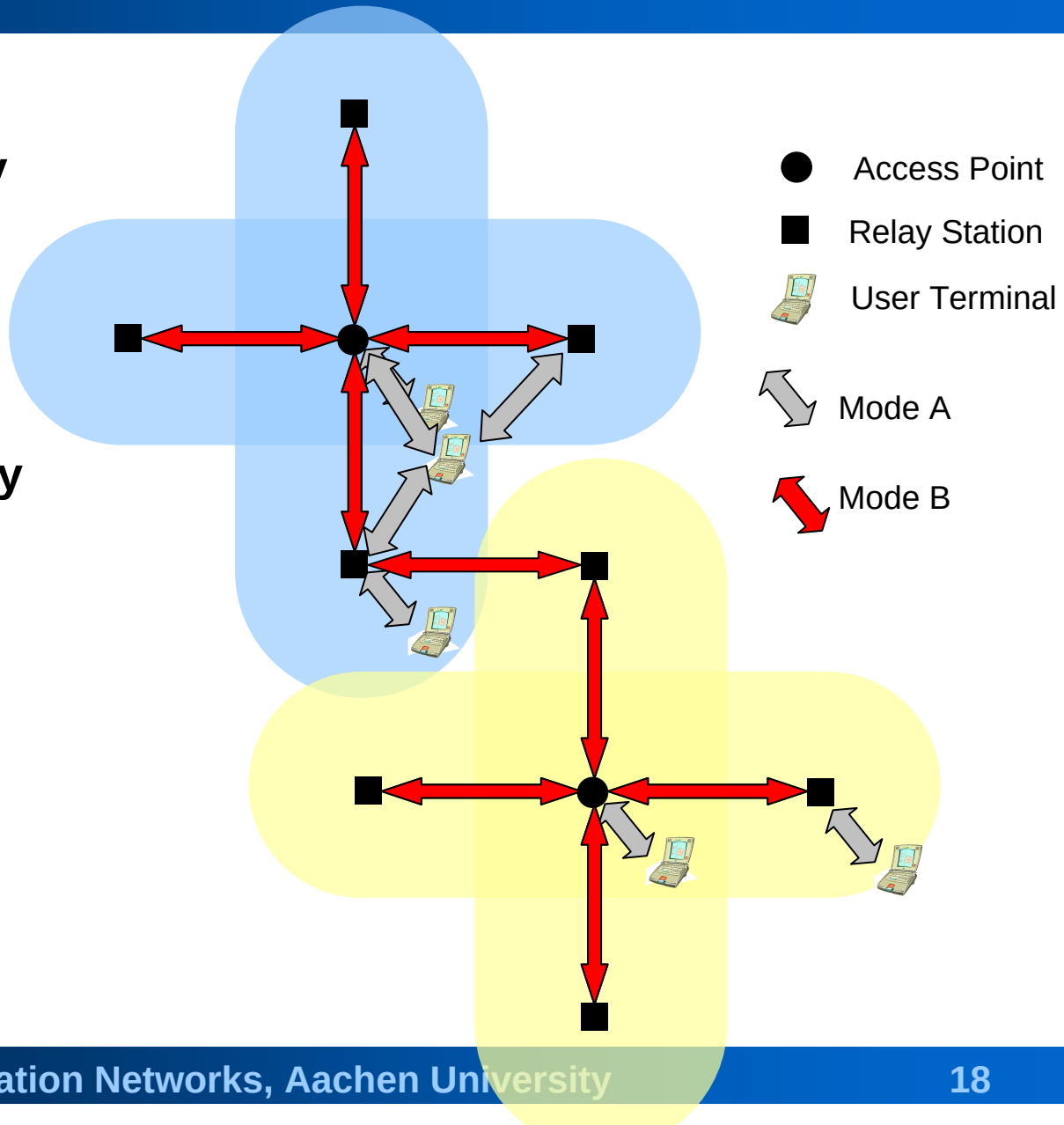
- AP-FRS (intra RAP) connection in **Mode A**
- RAP – UT connection in Mode A

B: Heterogeneous Relay

- AP-FRS (intra RAP) connection in **Mode B**
- RAP – UT connection in Mode A

Additional

- Mesh network to increase network resilience
- Cooperative Relaying



Conclusions

- Relays are a disruptive technology. Relay can
  - Extend the coverage range of an AP
  - Increase substantially the capacity of a cell
  - Cover areas otherwise shadowed from the AP
  - Reduce transmission power levels (when used to increase capacity)
- Relays & Smart Antennas offer opportunities to exploit spatial diversity
- Mesh networks may improve reliability