System Performance of Relay-based Cellular Systems in Manhattan-like Scenario

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Information

System Performance of Relay-based Cellular Systems in Manhattan-like Scenario

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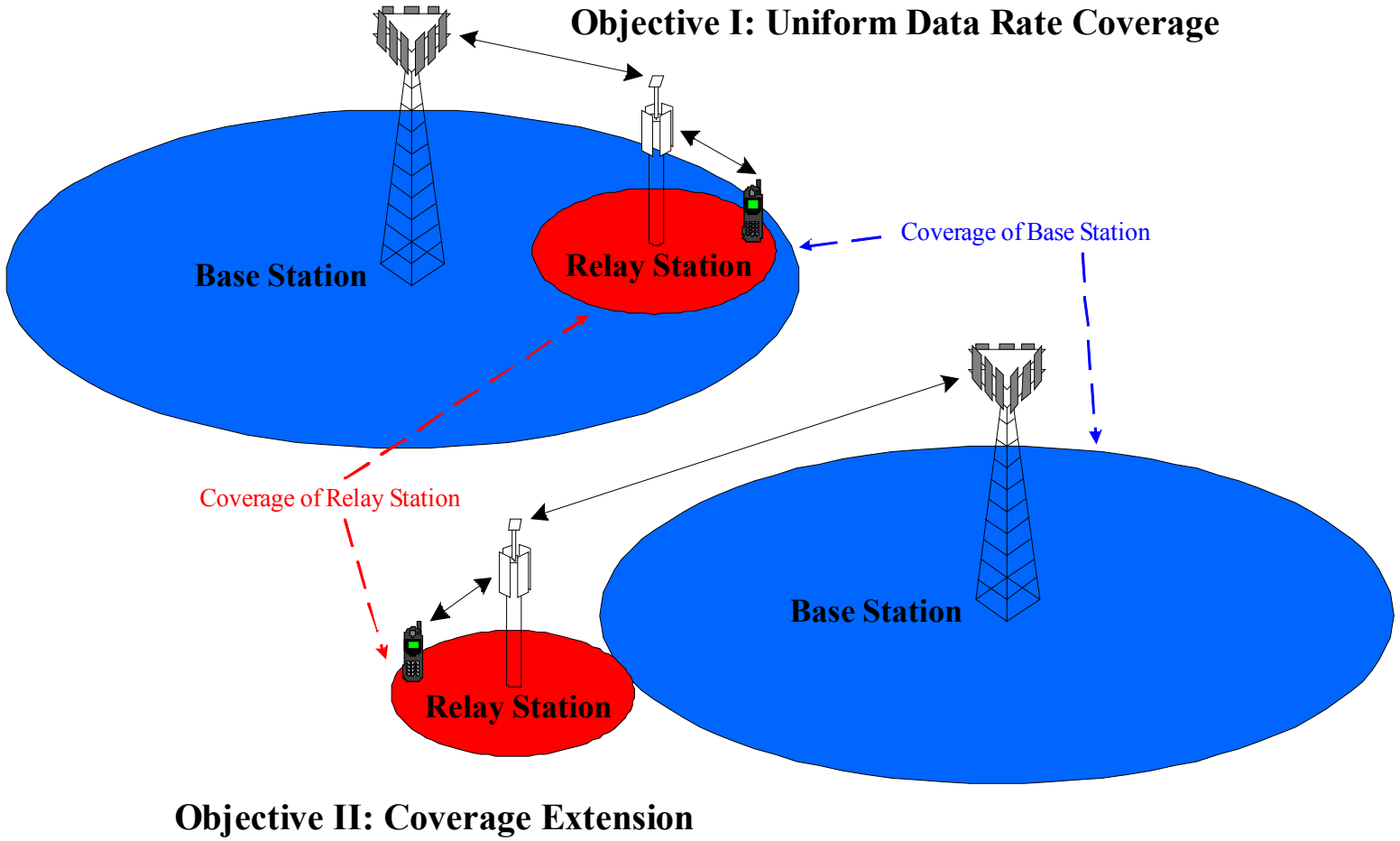
Outline

- **Relay Deployment Scenario**
- **Propagation Models**
- **Simulation Results**
- **Summary**

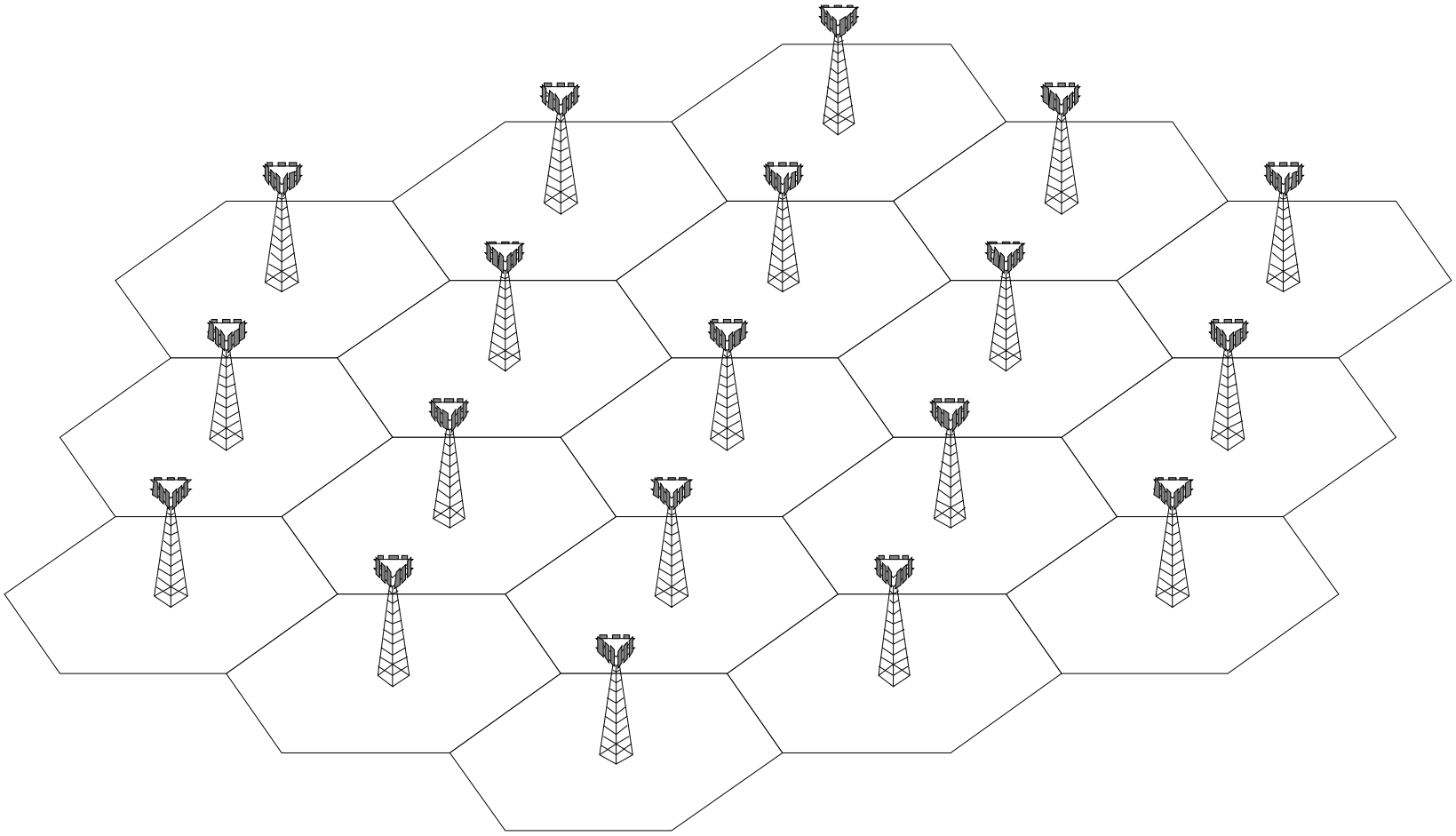
Deployment Scenario

- Two typical objectives for relay deployment:
  - Relay deployment for objective I is considered in this research



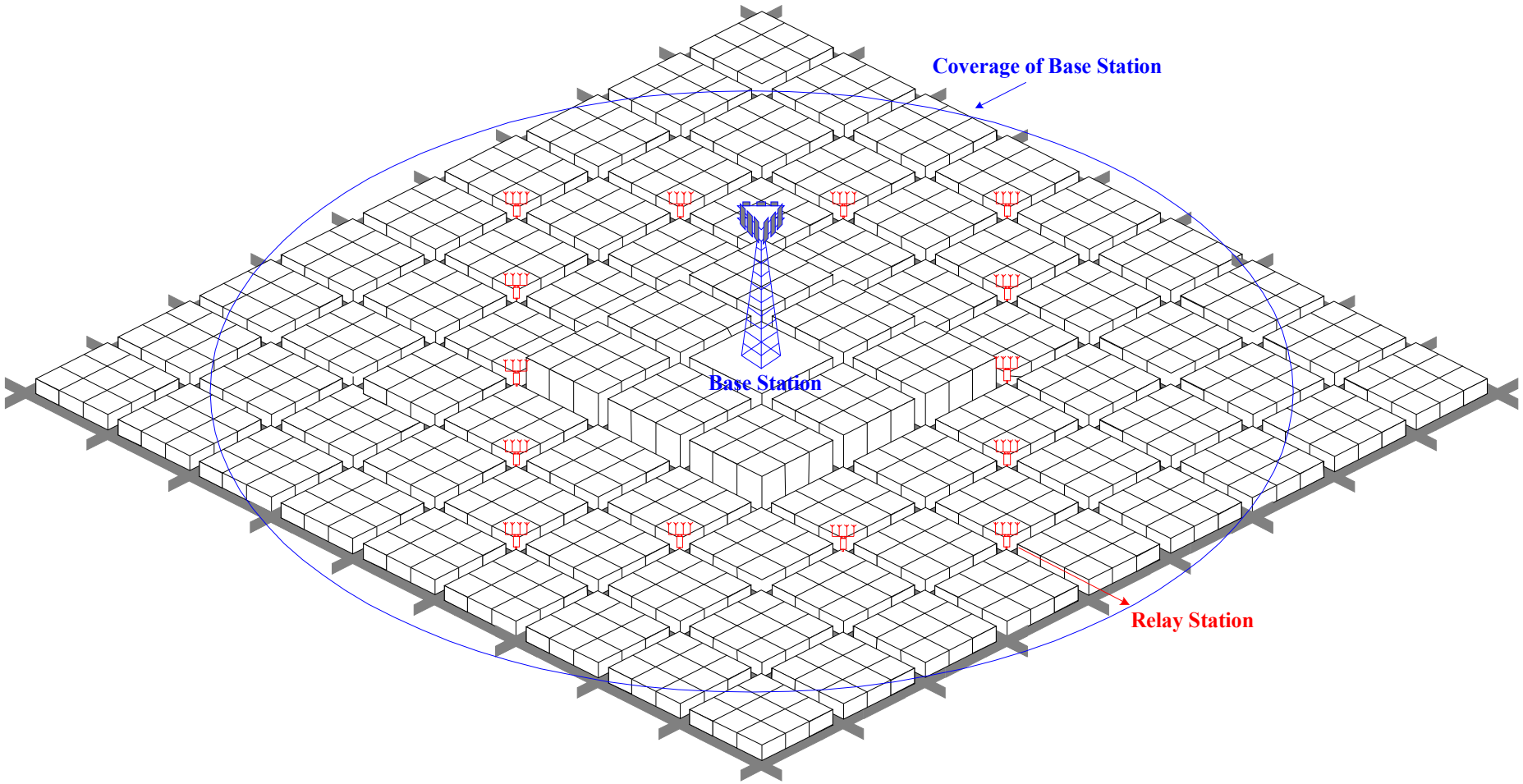
Deployment Scenario

- For objective I, it is reasonable to consider an cellular network with well-planned coverage has already been exist.



Deployment Scenario

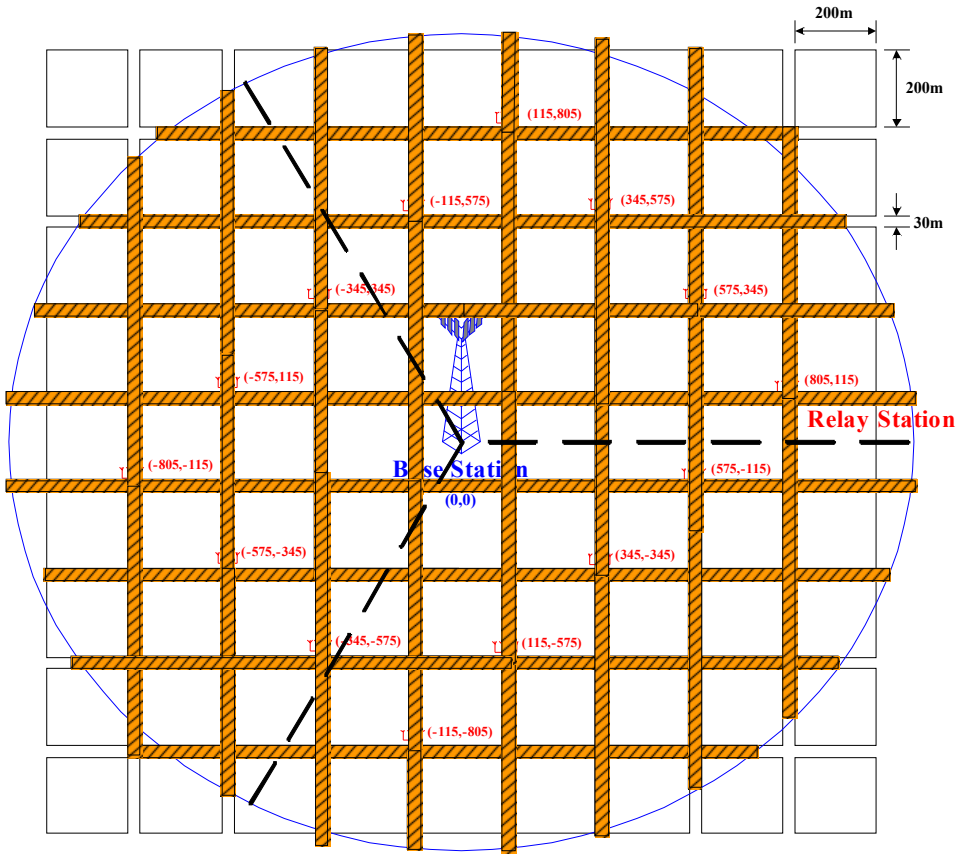
- Fixed Relay Stations (FRS) are deployed within the coverage of base station (BS)
  - Enhance the data rate uniformity of existing cellular network



Deployment Scenario

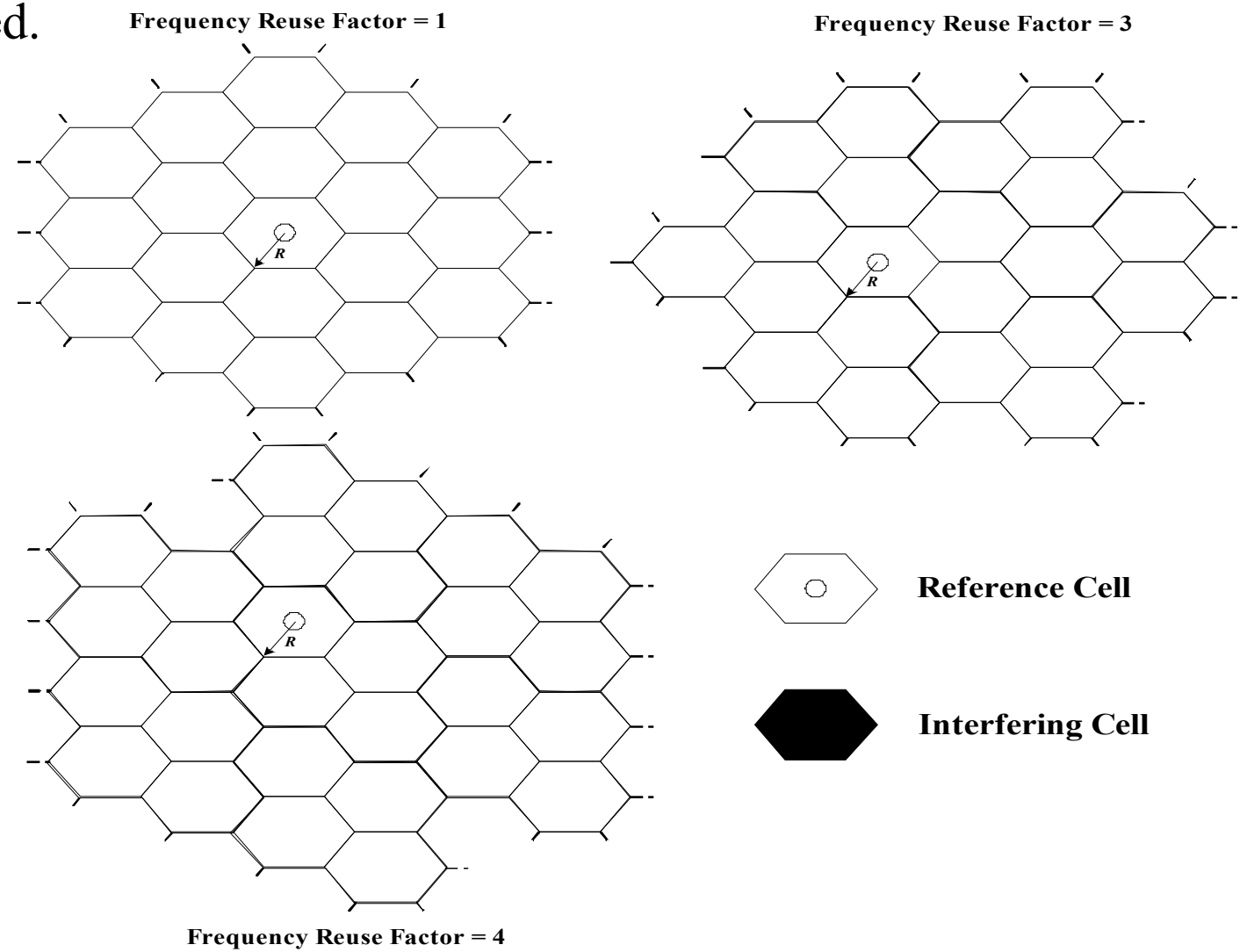
- Positioning of FRS is highly dependent on the traffic distribution
  - Hot spot
  - Homogeneous

- In this research, homogeneous traffic distribution is considered, and FRSs are deployed to provide full coverage within each cell.



Deployment Scenario

- If frequency reuse factor (K) > 1, additional radio bandwidth is needed.



- Relay Deployment Scenario
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Propagation Models

- The link between BS and MS

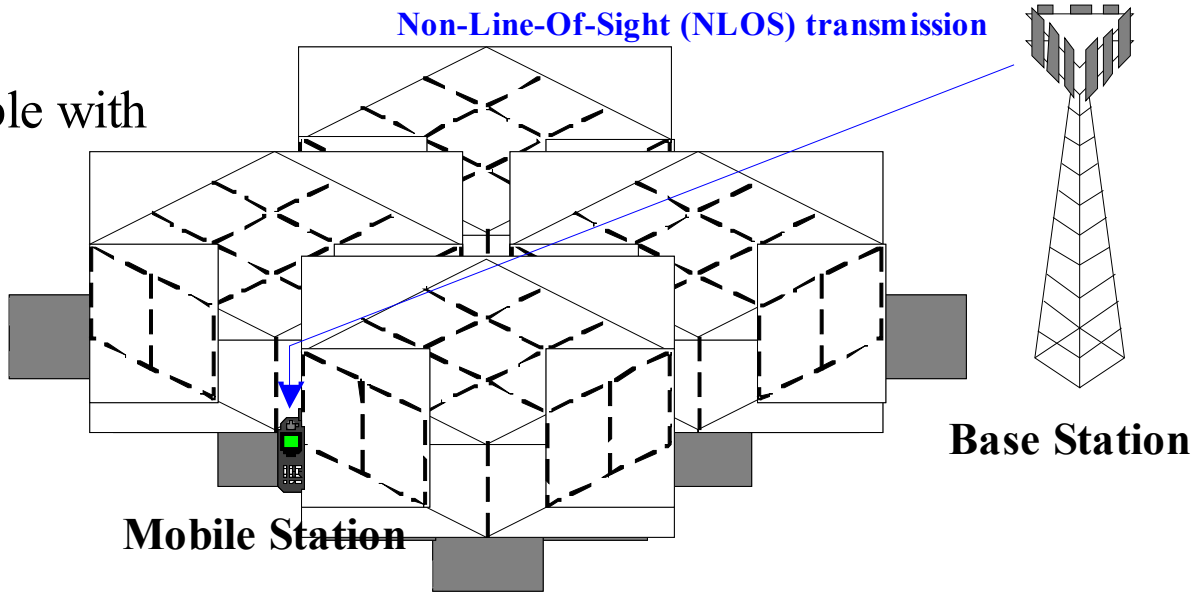
$$Pathloss[dB] = 38.4 + 35\log_{10}(d) + 20\log_{10}(f_c/5)$$

f_c carrier frequency (GHz)

d distance between BS and MS (meters)

Shadow fading :

log-normal random variable with standard deviation 8 *dB*



IST-2003-507581 WINNER D5.4 v.1: Scenario C2
online available - https://www.ist-winner.org/

Propagation Models

- The link between <u>BS and FRS</u>

$$Pathloss[dB] = 36.5 + 23.5\log_{10}(d) + 20\log_{10}(f_c/2.5)$$

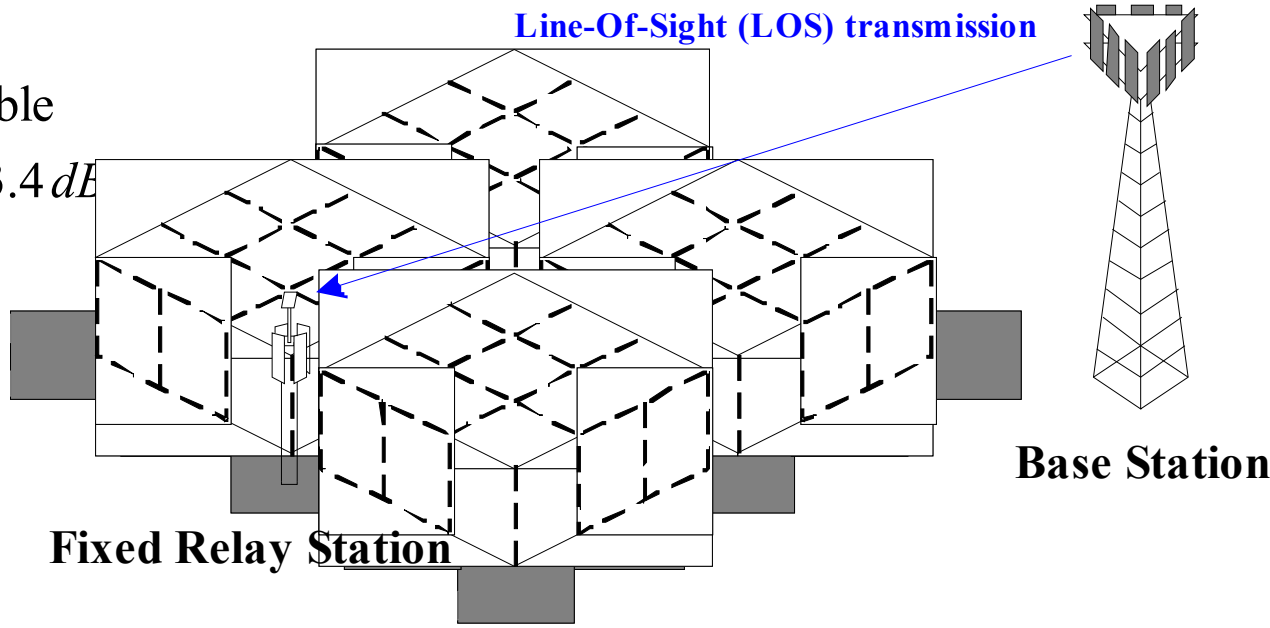
f_c carrier frequency (GHz)

d distance between BS and FRS (meters)

Shadow fading :

log-normal random variable

with standard deviation 3.4 *dB*



IST-2003-507581 WINNER D5.4 v.1: Scenario B5a
online available - https://www.ist-winner.org/

Propagation Models

- The link between FRS and MS

$$Pathloss[dB] = \begin{cases} 41 + 22.7\log_{10}(d) + 20\log_{10}(f_c/5) & if\ LOS \\ 0.096 \cdot d_1 + 65 + 20\log_{10}(f_c/5) & \\ \quad + (28 - 0.024 \cdot d_1)\log_{10}(d_2) & if\ NLOS \end{cases}$$

Shadow fading :

log-normal random variable with standard deviation s

$$s = \begin{cases} 2.3dB & if\ LOS \\ 3.1dB & if\ NLOS \end{cases}$$

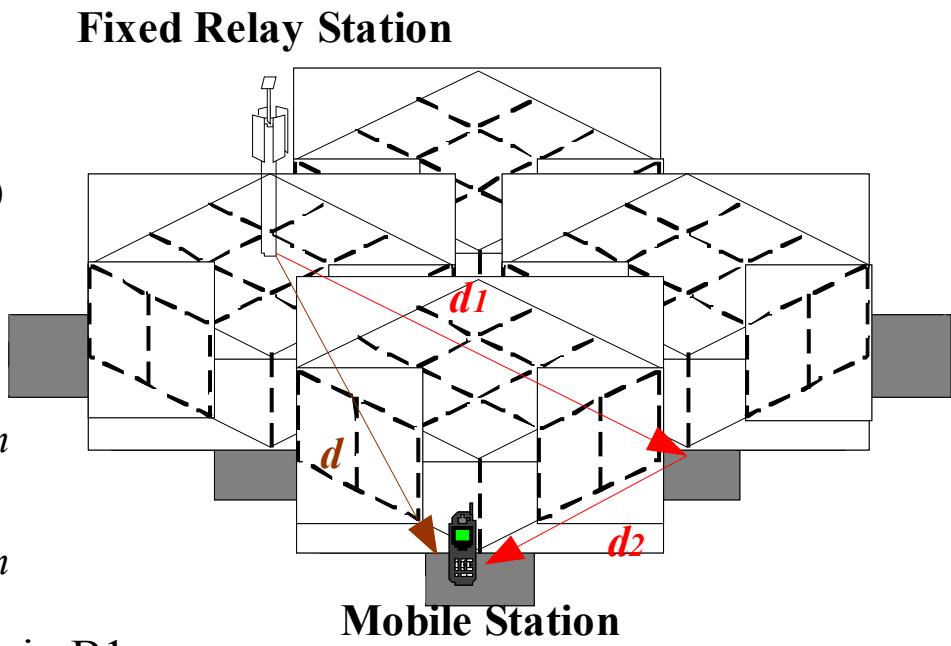
f_c carrier frequency (GHz)

d distance between FRS and MS (meters)

d_1 distance along main street (meters)

d_2 distance along perpendicular street (meters)

$$P_{LOS}(d) = \begin{cases} 1 & d \le 15m \\ \left(1 - \left(1.56 - 0.48\log_{10}(d)\right)^3\right)^{\frac{1}{3}} & d > 15m \end{cases}$$



IST-2003-507581 WINNER D5.4 v.1: Scenario B1
online available - https://www.ist-winner.org/

- Relay Deployment Scenario
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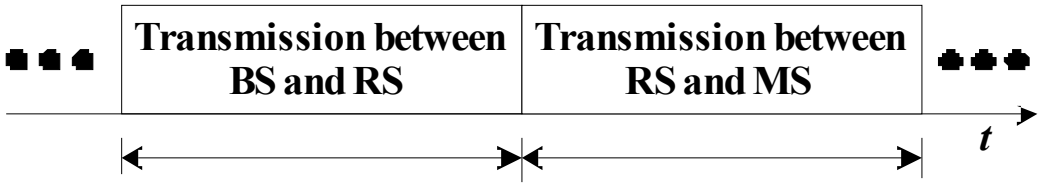
Simulation Parameters

- Base Station (BS)
  - The coverage (1km) is planned by link budget
  - 3 sectors in each cell
  - PUSC or FUSC permutation applied within each sector
    - If FUSC is applied, each sub-channel can be reused within each sector to achieve SDMA(Spatial Division Multiple Access)
- Fixed Relay Station (FRS)
  - FRSs are deployed to provide full coverage within each BS cell
    - Transmit power and coverage along main street (600m) is planned by link budget
    - 4 directional antennas are equipped by FRS toward each main street direction
  - Time domain relaying within the same radio bandwidth



Simulation Parameters

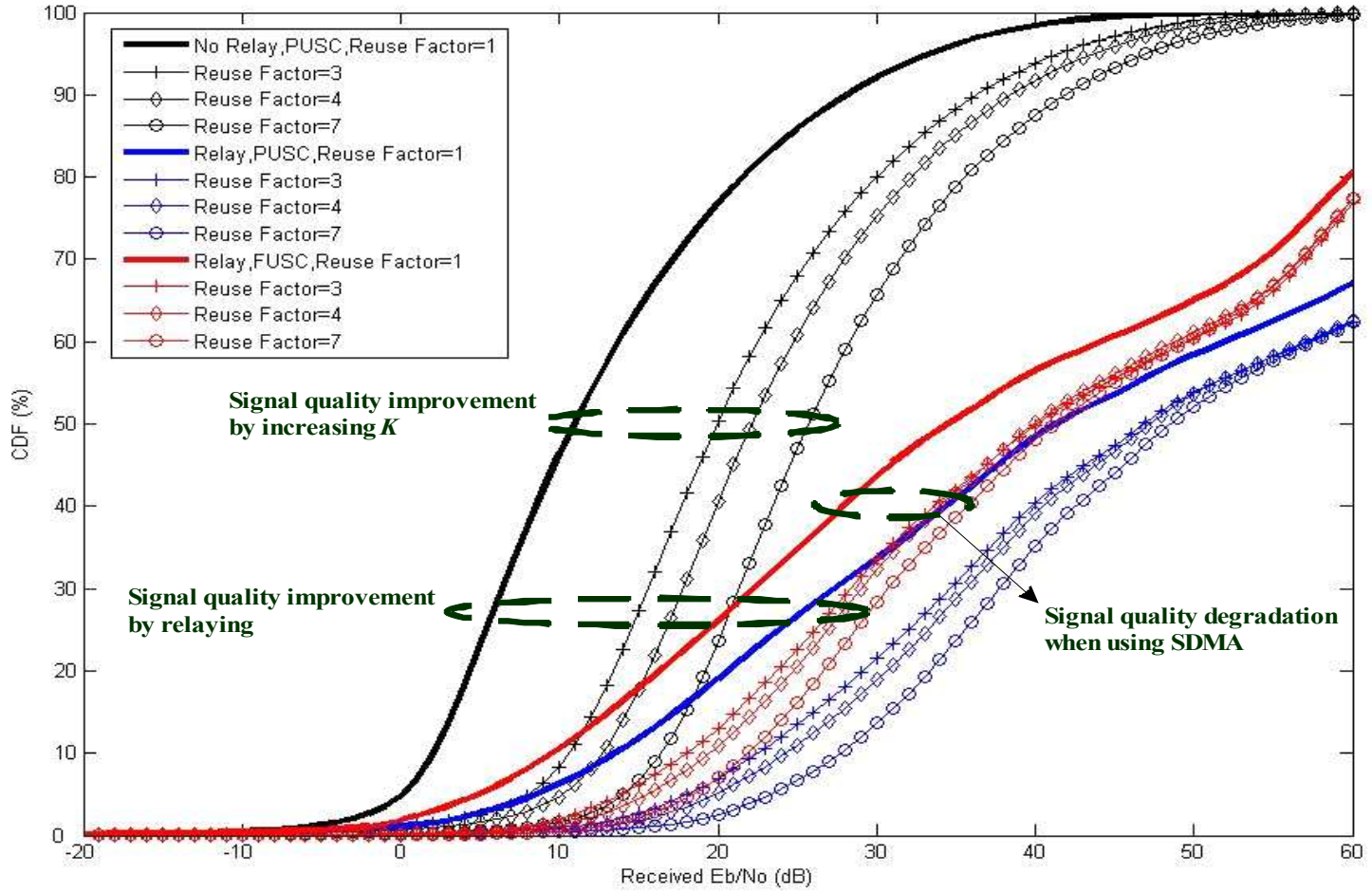
- Reference System: IEEE 802.16e OFDMA mode
  - Radio bandwidth: 6MHz
  - Total number of sub-carriers: 2048
  - Carrier frequency: 3.5GHz
  - Number of sub-channels in each sector: 32(FUSC), 20(PUSC)
  - Number of sectors: 3
  - Max. transmit power of each BS: 50W
  - Max. transmit power of each FRS: 5W
  - Antenna height of BS: Above rooftop (35m)
  - Antenna height of FRS: Above / below rooftop (to BS / MS)
  - MS speed: 30km/hr
  - Prob. of changing direction at intersection: 50%
  - MS arrival: Poisson process
  - Handoff type: hard handoff

Simulation Results

- System configurations
  - Case I
    - No Relay
    - PUSC permutation for each cell
  - Case II
    - Fixed Relay
    - PUSC permutation for each cell
  - Case III
    - Fixed Relay
    - FUSC permutation for each sector
      - Spatial Division Multiple Access (SDMA)

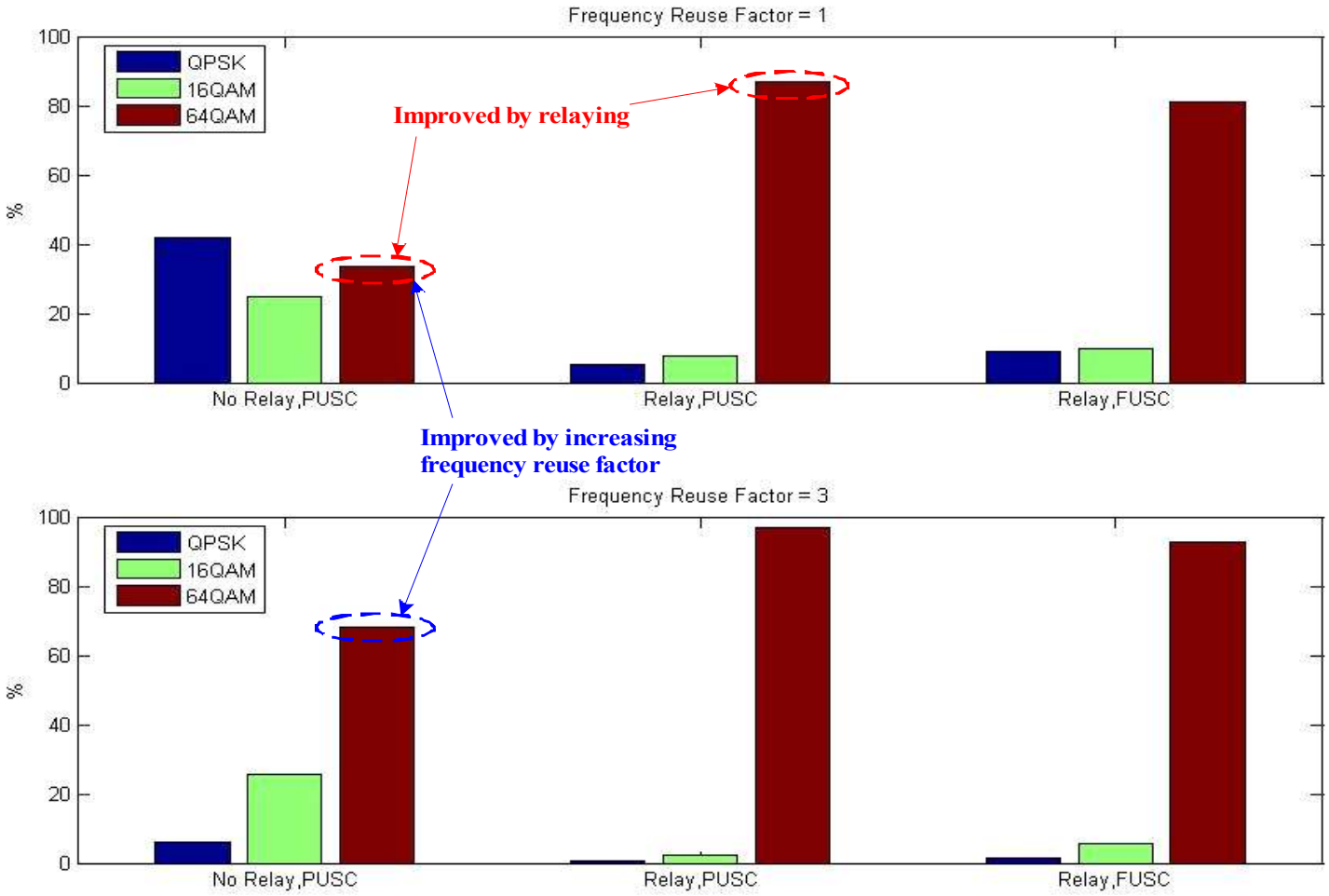
Simulation Results

- CDF (Cumulative Distribution Function) of received E_b/N_0
  - Relaying provides substantial improvement on received signal quality

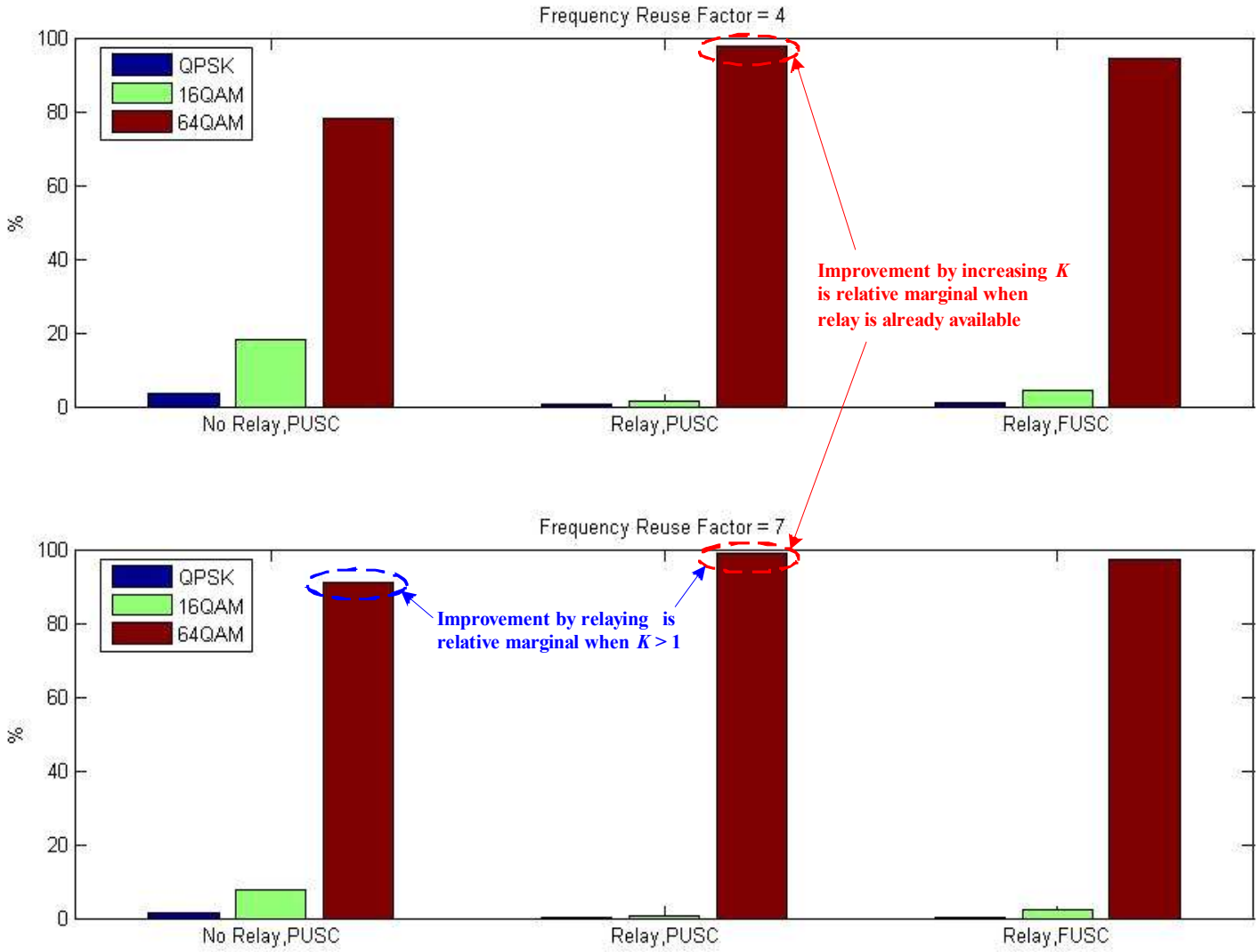


Simulation Results

- Distribution of each modulation scheme chosen by MS
  - Percentage of highest data rate is substantially increased by relaying

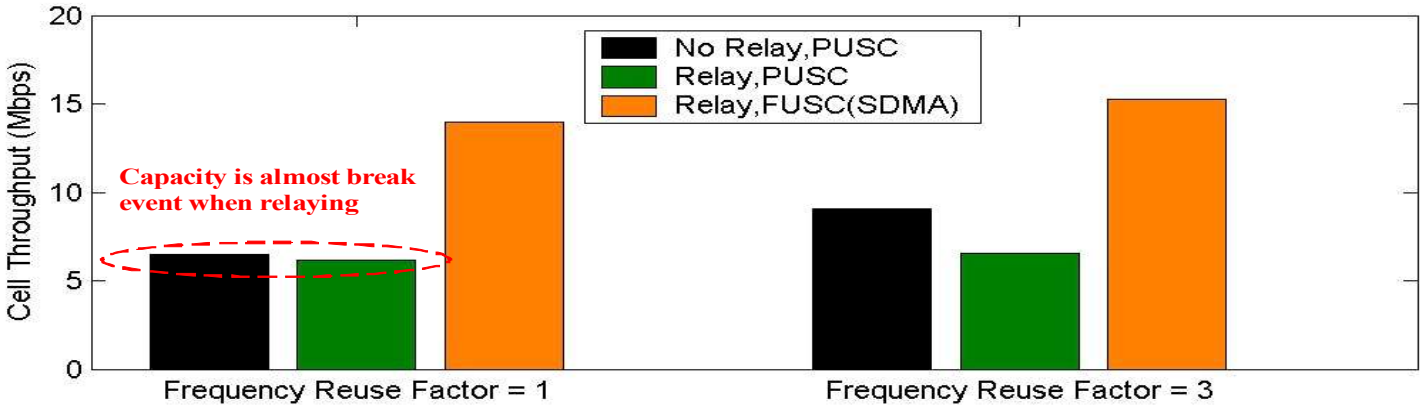


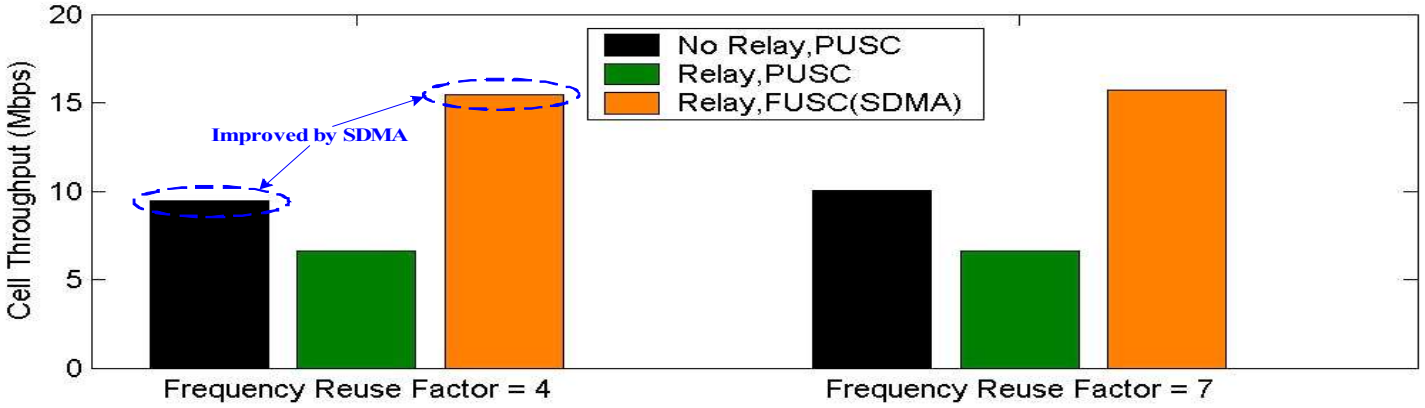
Simulation Results



Simulation Results

- Averaged cell capacity
  - When using time domain relaying, the capacity will be degrade by sharing time domain resources for the links BS ↔ FRS and FRS↔MS. Meanwhile, the capacity can be improved by better signal quality and higher order modulation.





Simulation Results

Reference case: No relay, PUSC permutation, frequency reuse factor (K) = 1

- Either using relay or increasing frequency reuse factor can enhance the uniformity of highest data rate coverage
- When increasing K, the increment on cell capacity is not proportional to the cost on additional spectrum.

	Relay, PUSC, K=1	No Relay, PUSC, K=3	No Relay, PUSC, K=4	No Relay, PUSC, K=7
Cost on Spectrum	100%	300%	400%	700%
Cost on Relay Deployment	Yes	No	No	No
Average Received E_b/N_0	+29.25dB	+8.61dB	+10.8dB	+14.4dB
Percentage of Highest Data Rate	+159.43%	+103.63%	+133.58%	+172%
Cell Capacity	**-4.81%**	**+40.13%**	**+46.13%**	**+55.38%**

Simulation Results

- When the relay has already been deployed, improvement by increasing *K* seems to be marginal in Manhattan-like environment.
  - By properly positioning the FRSs to make MS has LOS condition to serving FRS and NLOS to interfering FRS, the interference from other FRS is usually kept in low level no matter adjacent use the same bandwidth or not.

	Relay, PUSC, K=1	Relay, PUSC, K=3	Relay, PUSC, K=4	Relay, PUSC, K=7
Cost on Spectrum	100%	300%	400%	700%
Cost on Relay Deployment	Yes	Yes	Yes	Yes
Average Received E_b/N_0	+29.25dB	+34.29dB	+34.88dB	+36.27dB
Percentage of Highest Data Rate	+159.43%	+188.7%	+191.75%	+195.14%
Cell Capacity	-4.81%	+1.4%	+1.99%	+2.66%

Simulation Results

- By using the relay and SDMA, both coverage uniformity of the highest data rate and cell capacity can be outperformed.

	Relay, SDMA, K=1	Relay, SDMA, K=3	Relay, SDMA, K=4	Relay, SDMA, K=7
Cost on Spectrum	100%	300%	400%	700%
Cost on Relay Deployment	Yes	Yes	Yes	Yes
Average Received E_b/N_0	+23.84dB	+28.77dB	+29.04dB	+30.18dB
Percentage of Highest Data Rate	+141.87%	+176.7%	+182.15%	+190.09%
Cell Capacity	**+116.4%**	**+135.89%**	**+138.84%**	**+142.45%**

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Summary

- Appropriate propagation model is very critical to indicate the path-loss gain for relay deployment
  - Otherwise, incorrect conclusion may be obtained.
- Relay provides significant enhancement on data rate coverage uniformity
  - Additional cost on relay deployment is required
  - Performance on cell capacity is almost break event to the case without relaying when universal frequency reuse
- Inter-FRS interference can be mitigated by appropriate relay positioning in Manhattan-like environment
  - To make MS has LOS condition to serving FRS but NLOS to interfering FRS
- SDMA can outperform the performance on cell capacity with little cost on received signal quality degradation