

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

IEEE 802.16 Presentation Submission Template (Rev. 8.3)

Document Number:

IEEE C802.16mmr-05/041r1

Date Submitted:

2005-11-15

Source:

I-Kang Fu, Wern-Ho Sheen,
Chang-Lung Hsiao, Rodger Tseng.
NCTU, Department of Communication Engineering
Broadband Radio Access Systems Laboratory
ED922, 1001 TA HSUEH Rd.
Hsinchu, Taiwan 30050, R.O.C.

Voice: +886-3-571-2121 ext. 59237

Fax: +886-3-571-0116

E-mail: apatch.cm91g@nctu.edu.tw

Venue:

IEEE 802.16 Session#40, Vancouver, Canada

Base Document:

None

Purpose:

Information

Notice:

This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release:

The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.

IEEE 802.16 Patent Policy:

The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <<http://ieee802.org/16/ipr/patents/policy.html>>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <<mailto:chair@wirelessman.org>> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <<http://ieee802.org/16/ipr/patents/notices>>.

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

**I-Kang Fu¹, Wern-Ho Sheen¹,
Chang-Lung Hsiao² and Rodger Tseng²**

**National Chiao Tung University¹
ITRI Computer & Communications Research Labs²,
Taiwan, R.O.C.**

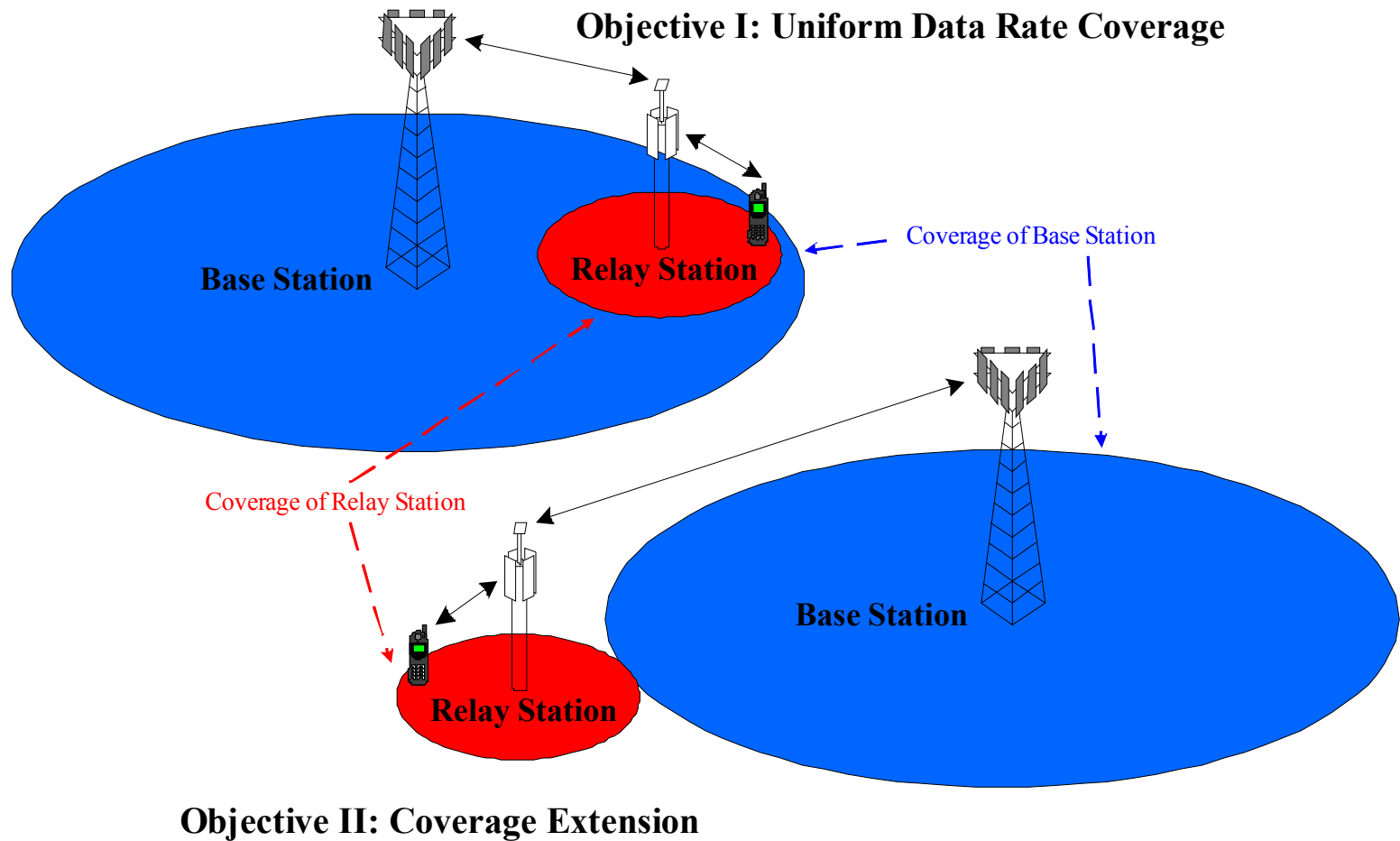
November, 2005

Outline

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

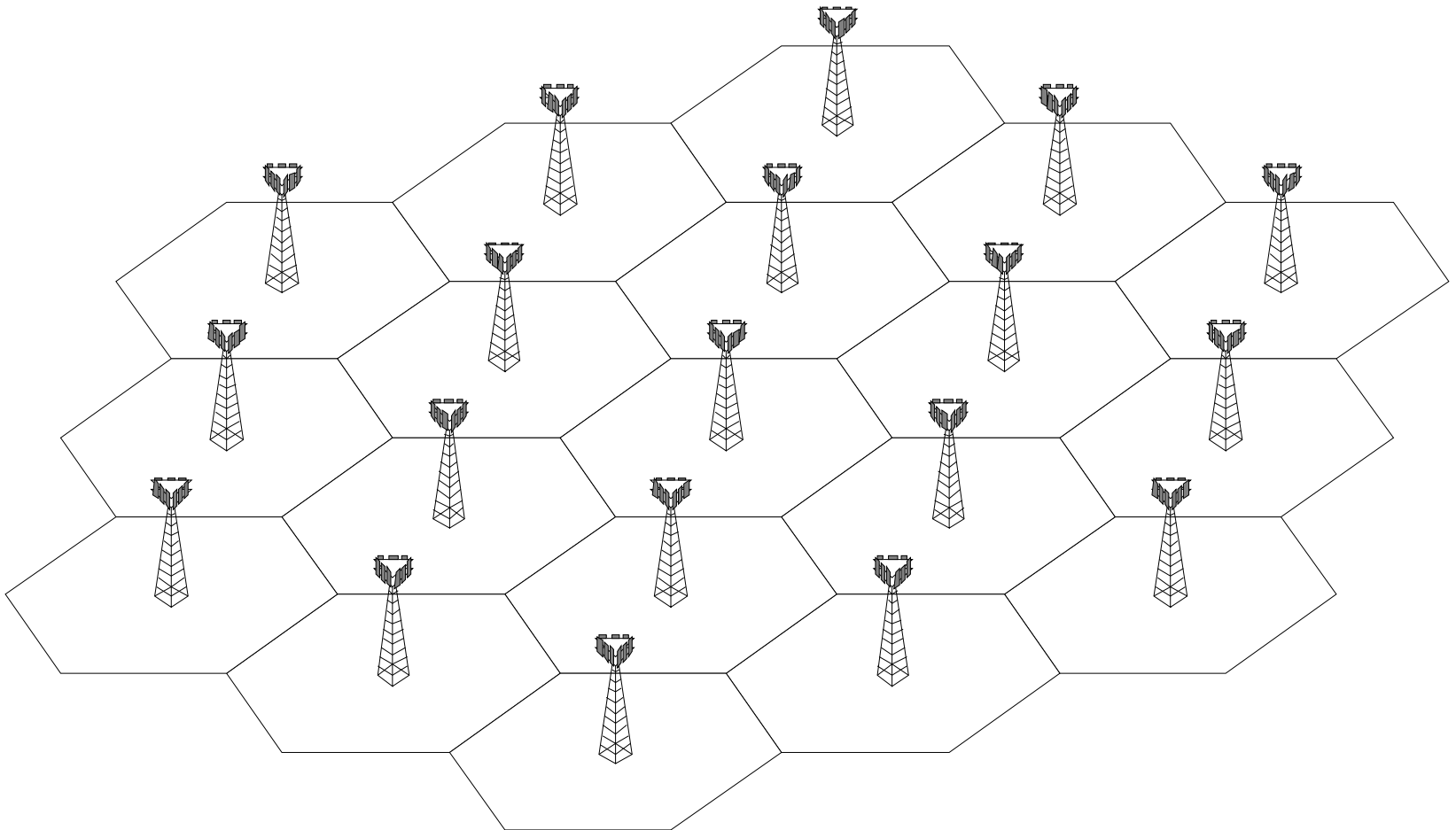
Deployment Scenario

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



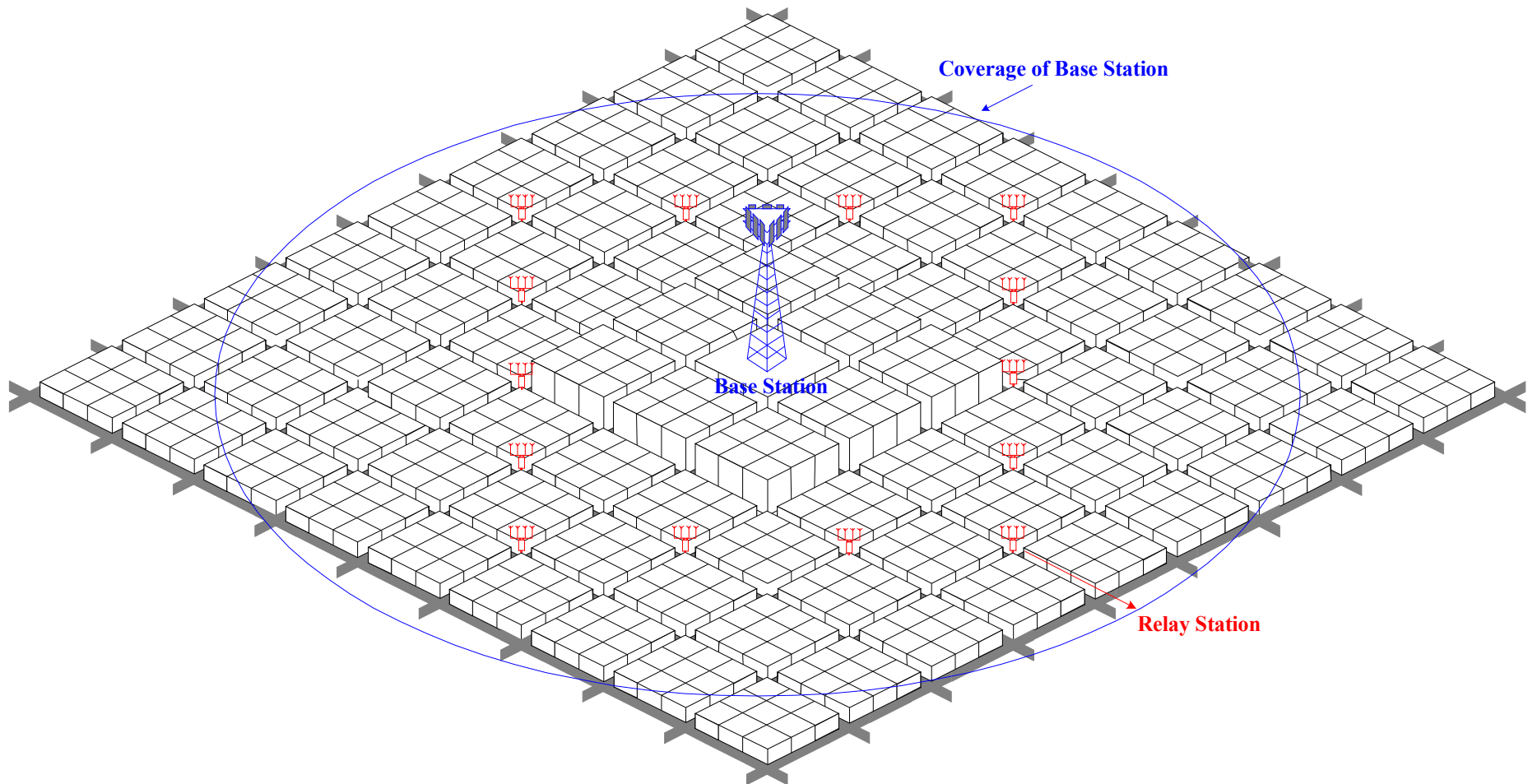
Deployment Scenario

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



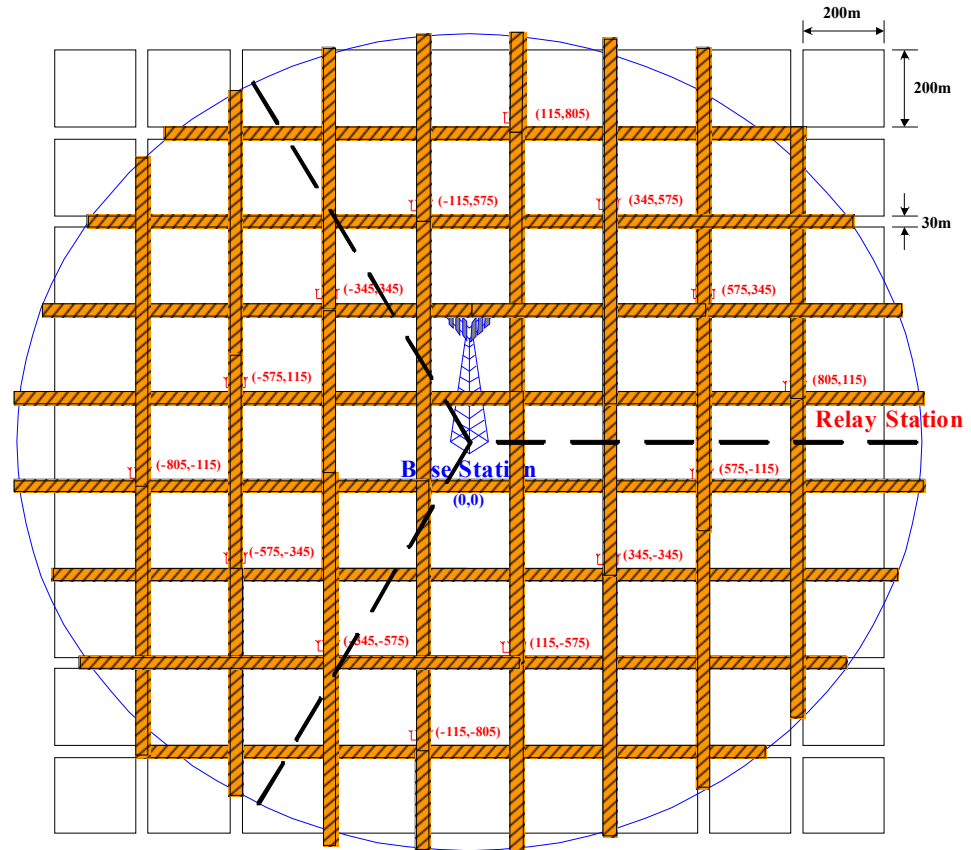
Deployment Scenario

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



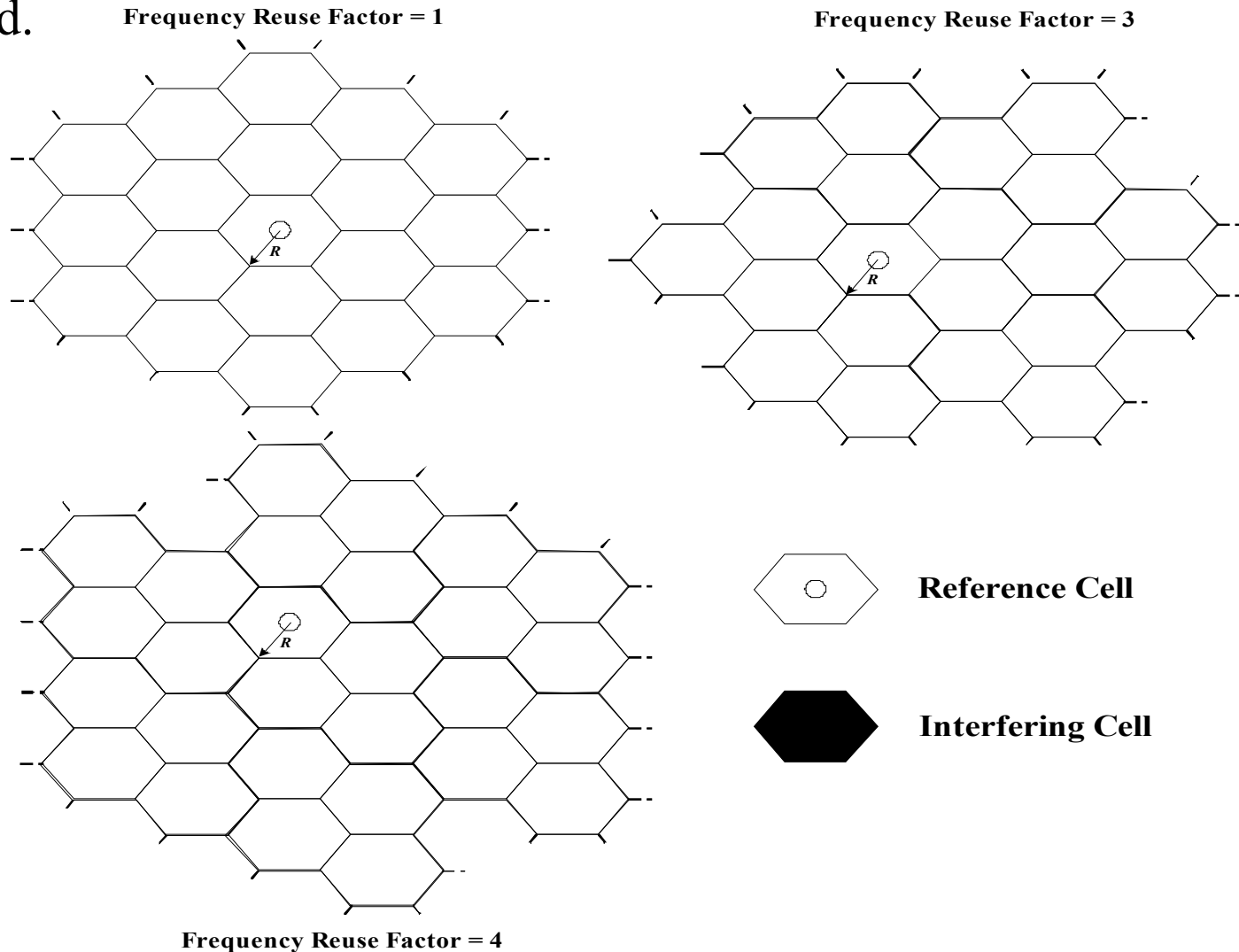
Deployment Scenario

- 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
- Propagation Models
- Simulation Results
- Summary

Propagation Models

- The link between BS and MS

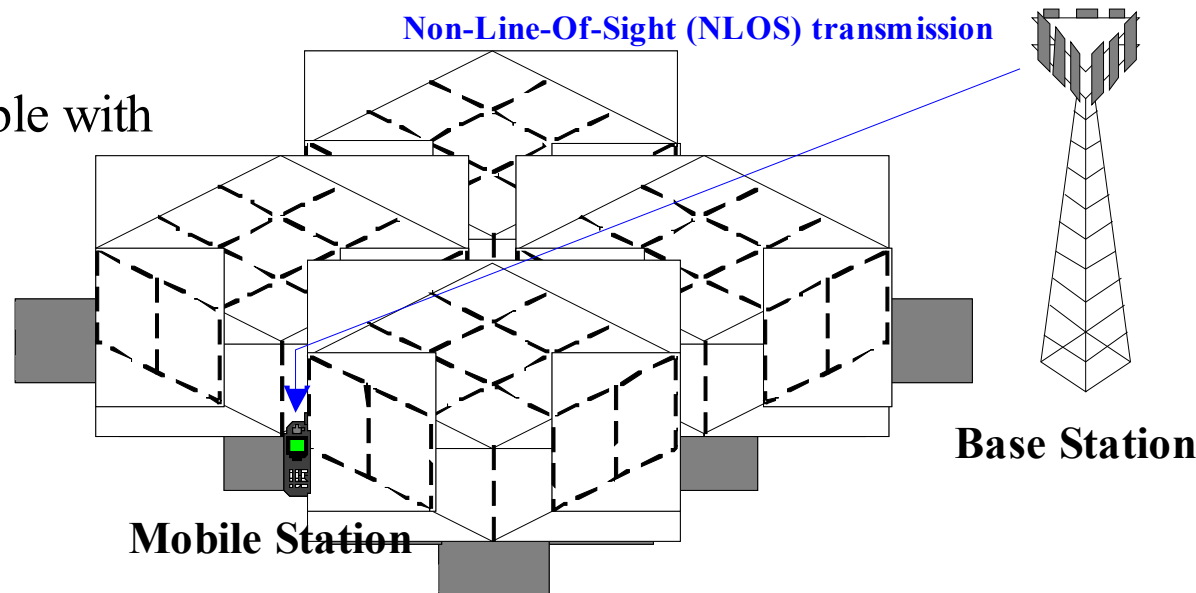
$$Pathloss[dB] = 38.4 + 35 \log_{10}(d) + 20 \log_{10}(f_c/5)$$

f_c carrier frequency (GHz)

d distance between BS and MS (meters)

Shadow fading :

log-normal random variable with
standard deviation 8 dB



Propagation Models

- The link between BS and FRS

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

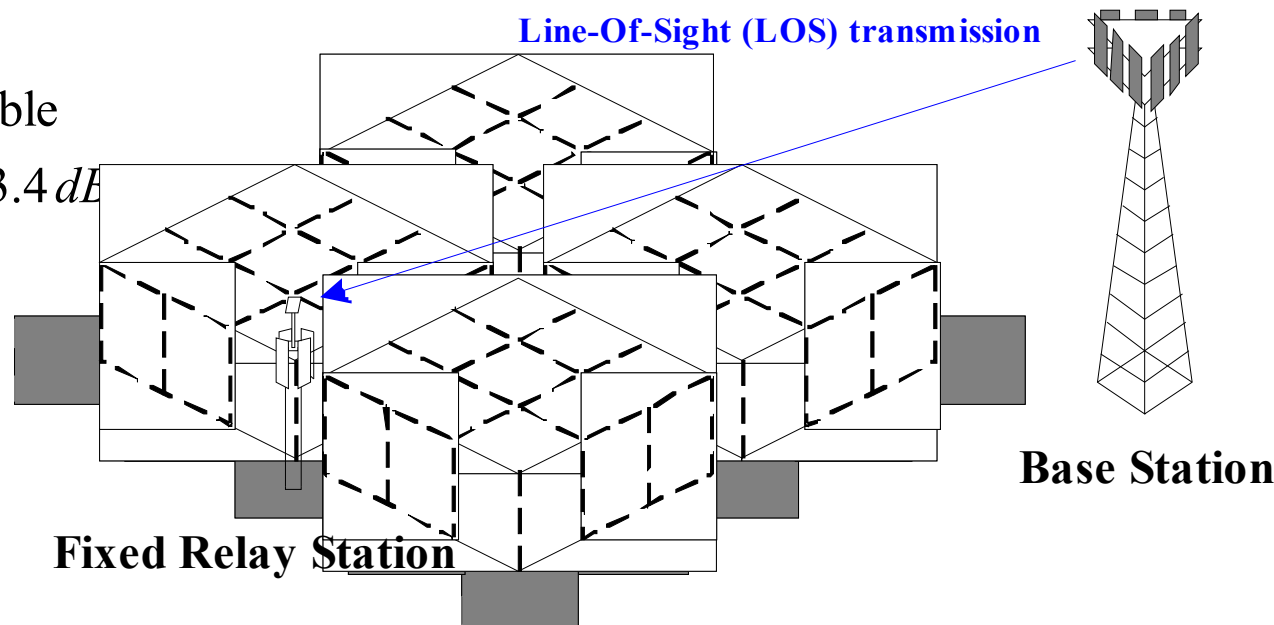
f_c carrier frequency (GHz)

d distance between BS and FRS (meters)

Shadow fading :

log-normal random variable

with standard deviation 3.4 dB



Propagation Models

- The link between FRS and MS

Shadow fading :

log-normal random variable
with standard deviation σ

$$Pathloss[dB] = \begin{cases} 41 + 22.7 \log_{10}(d) + 20 \log_{10}(f_c/5) & \text{if LOS} \\ 0.096 d_1^{1.65} + 20 \log_{10}(f_c/5) & \text{if NLOS} \\ 28 + (28 - 0.024 d_1) \log_{10}(d_2) & \text{if NLOS} \end{cases}$$

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

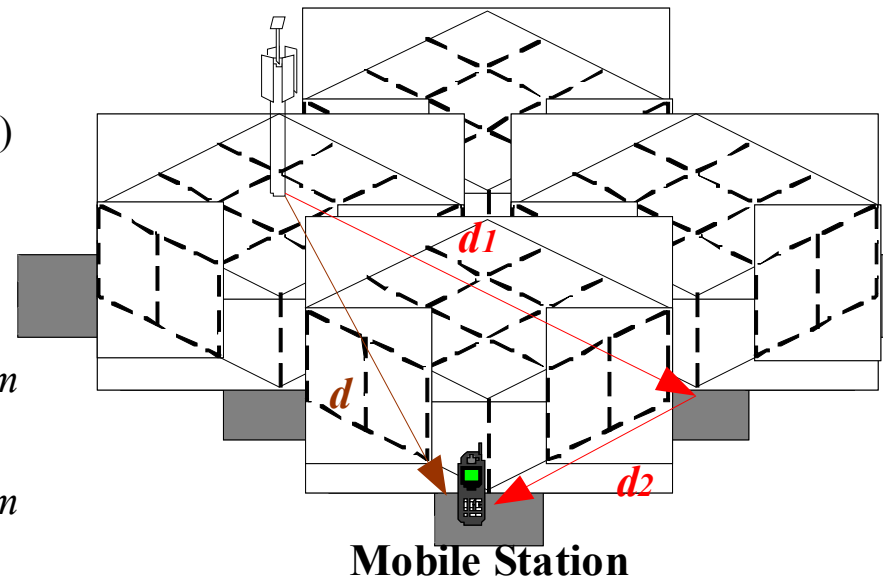
f_c carrier frequency (GHz)

d distance between FRS and MS (meters)

d_1 distance along main street (meters)

d_2 distance along perpendicular street (meters)

Fixed Relay Station

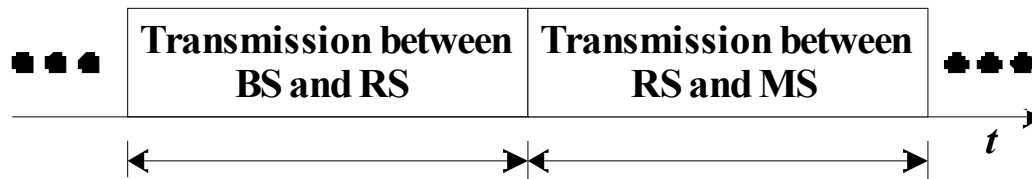


$$P_{LOS}(d) = \begin{cases} 1 & d \leq 4.5m \\ \left(1 - (1.56 - 0.48 \log_{10}(d))^3\right)^{\frac{1}{3}} & d > 15m \end{cases}$$

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

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

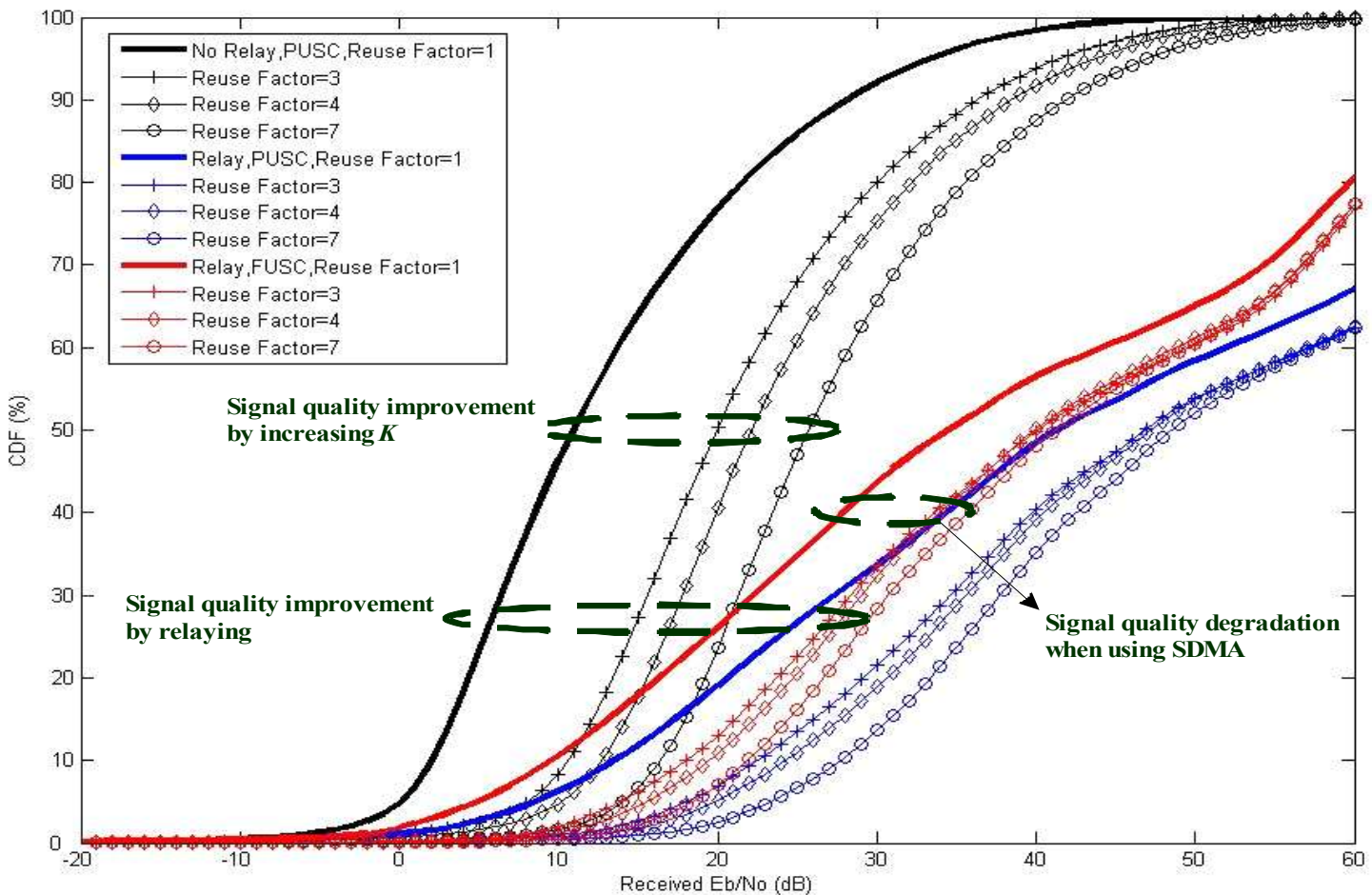
- Reference System: IEEE 802.16e OFDMA mode
 - Radio bandwidth: 6MHz
 - Total number of sub-carriers: 2048
 - Carrier frequency: 3.5GHz
 - Number of sub-channels in each sector: 32(FUSC), 20(PUSC)
 - Number of sectors: 3
 - Max. transmit power of each BS: 50W
 - Max. transmit power of each FRS: 5W
 - 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)

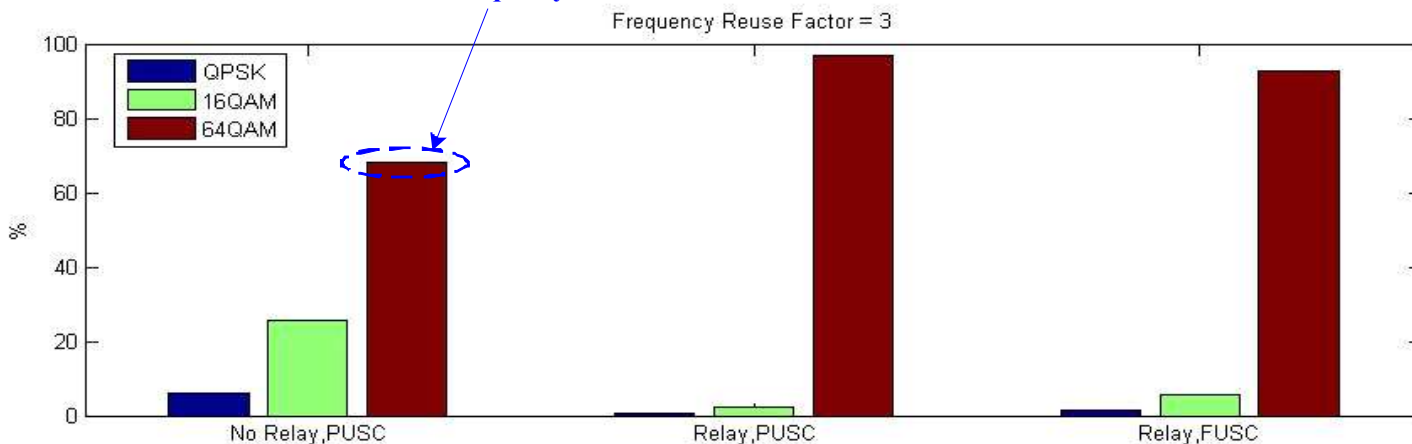
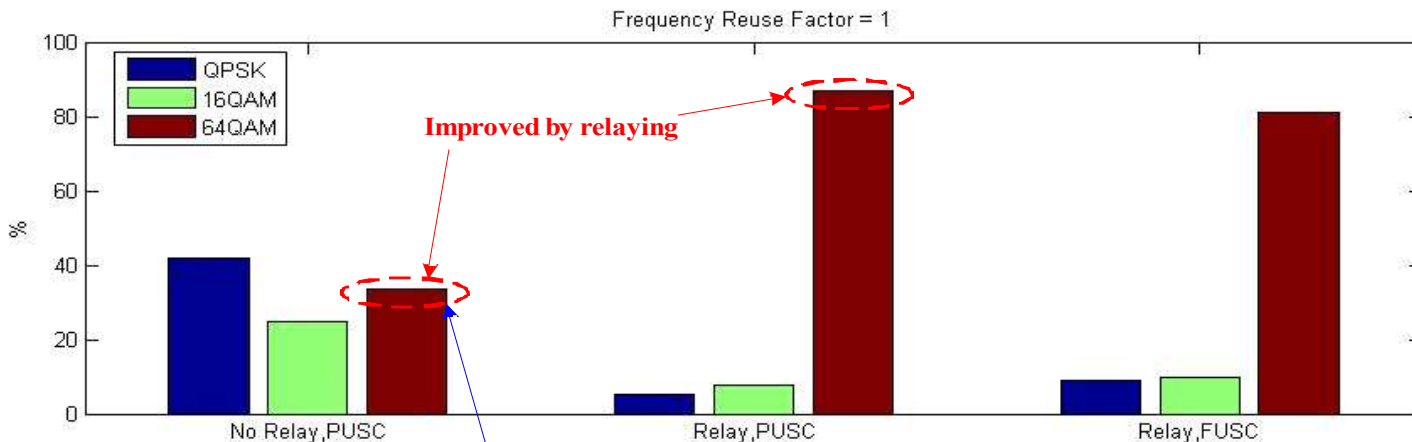
Simulation Results

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

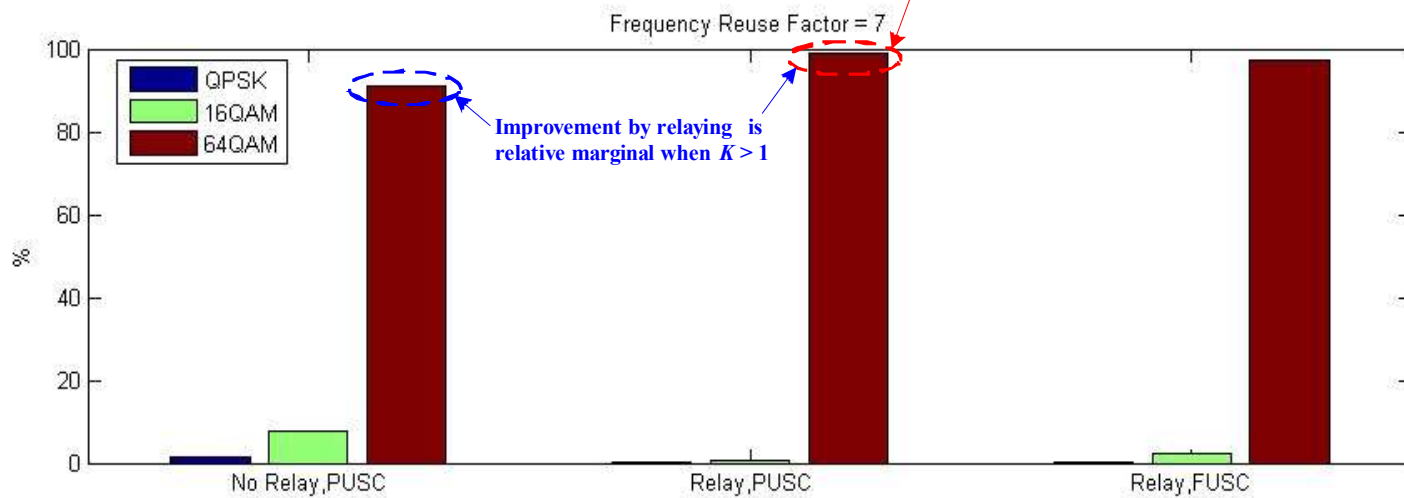
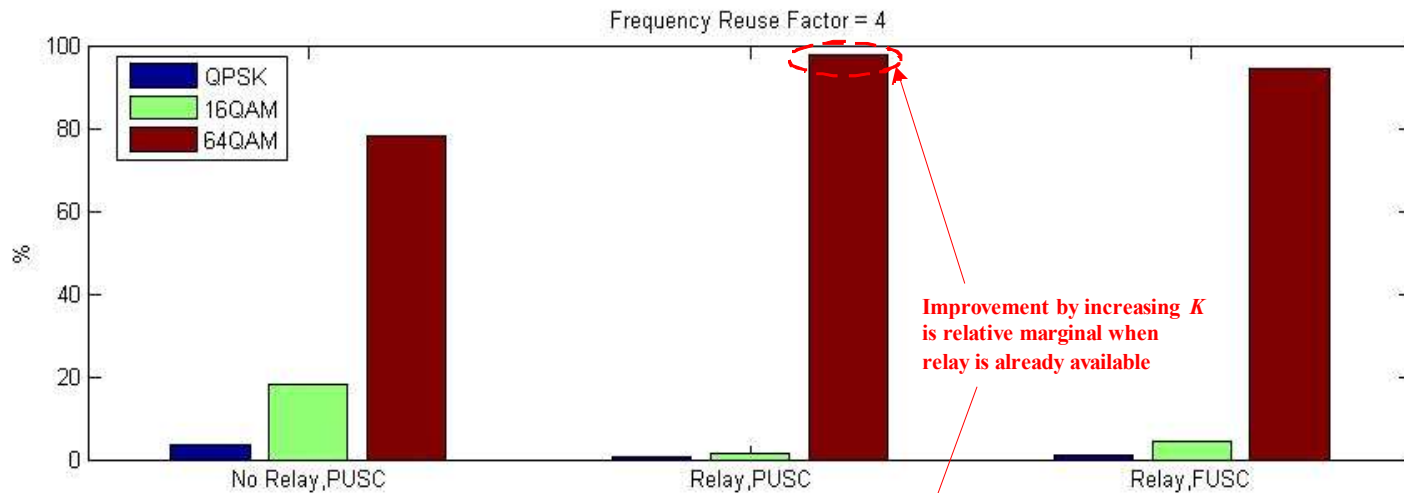


Simulation Results

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

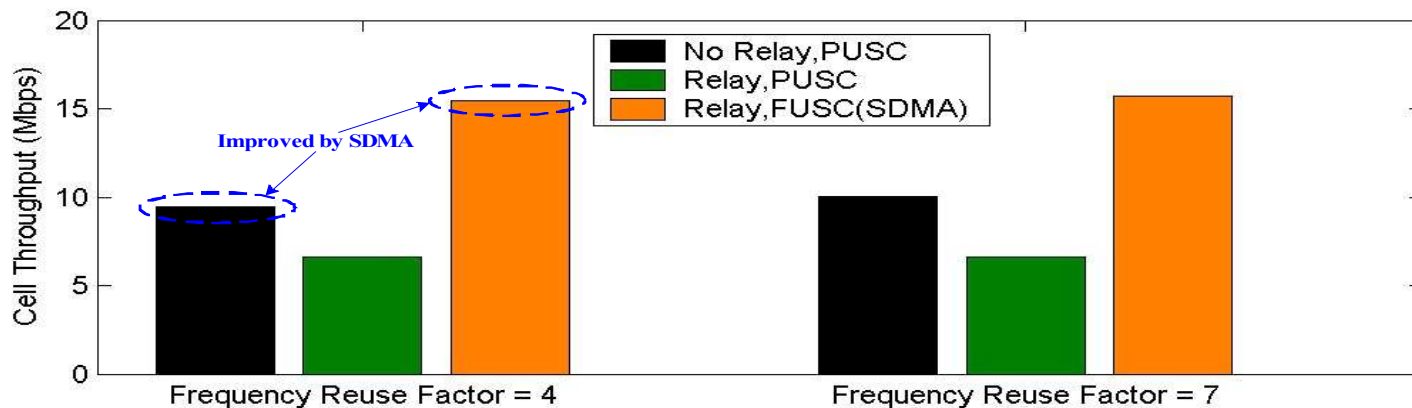
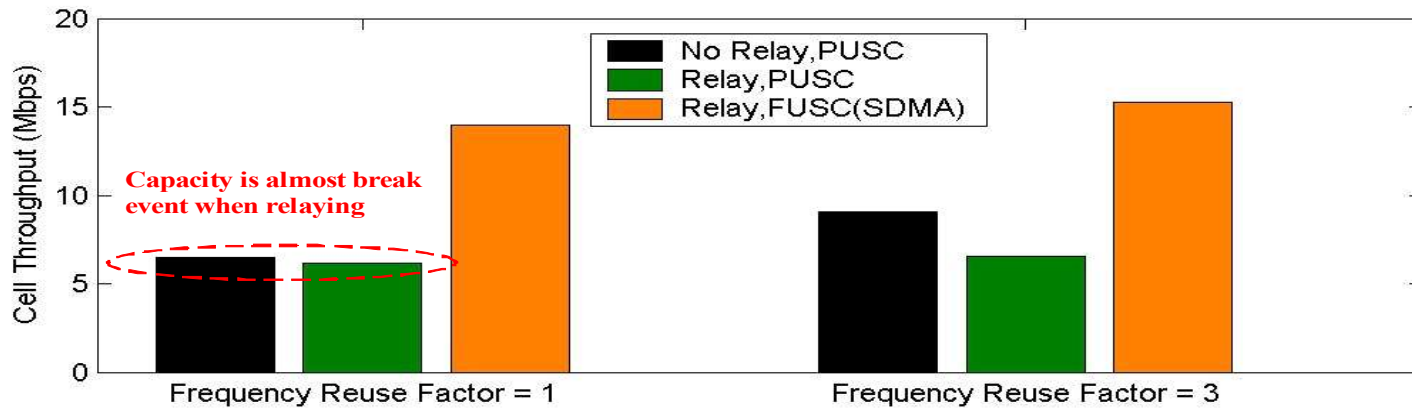


Simulation Results



Simulation Results

- Averaged cell capacity
 - When using time domain relaying, the capacity will be degraded by sharing time domain resources for the links BS \leftrightarrow FRS and FRS \leftrightarrow 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% |

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

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