Throughput Improvements in Micro-Cellular Multi-Hop Networks

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Information

Throughput Improvements in Micro-Cellular Multi-Hop Networks

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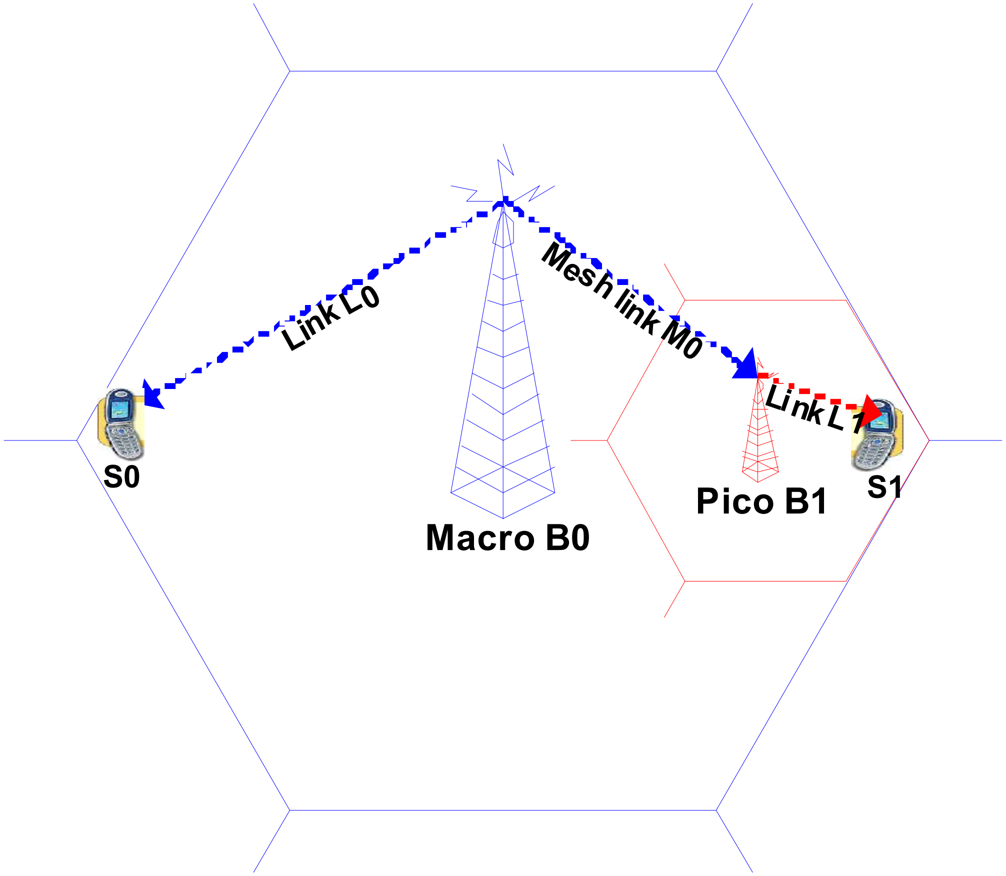
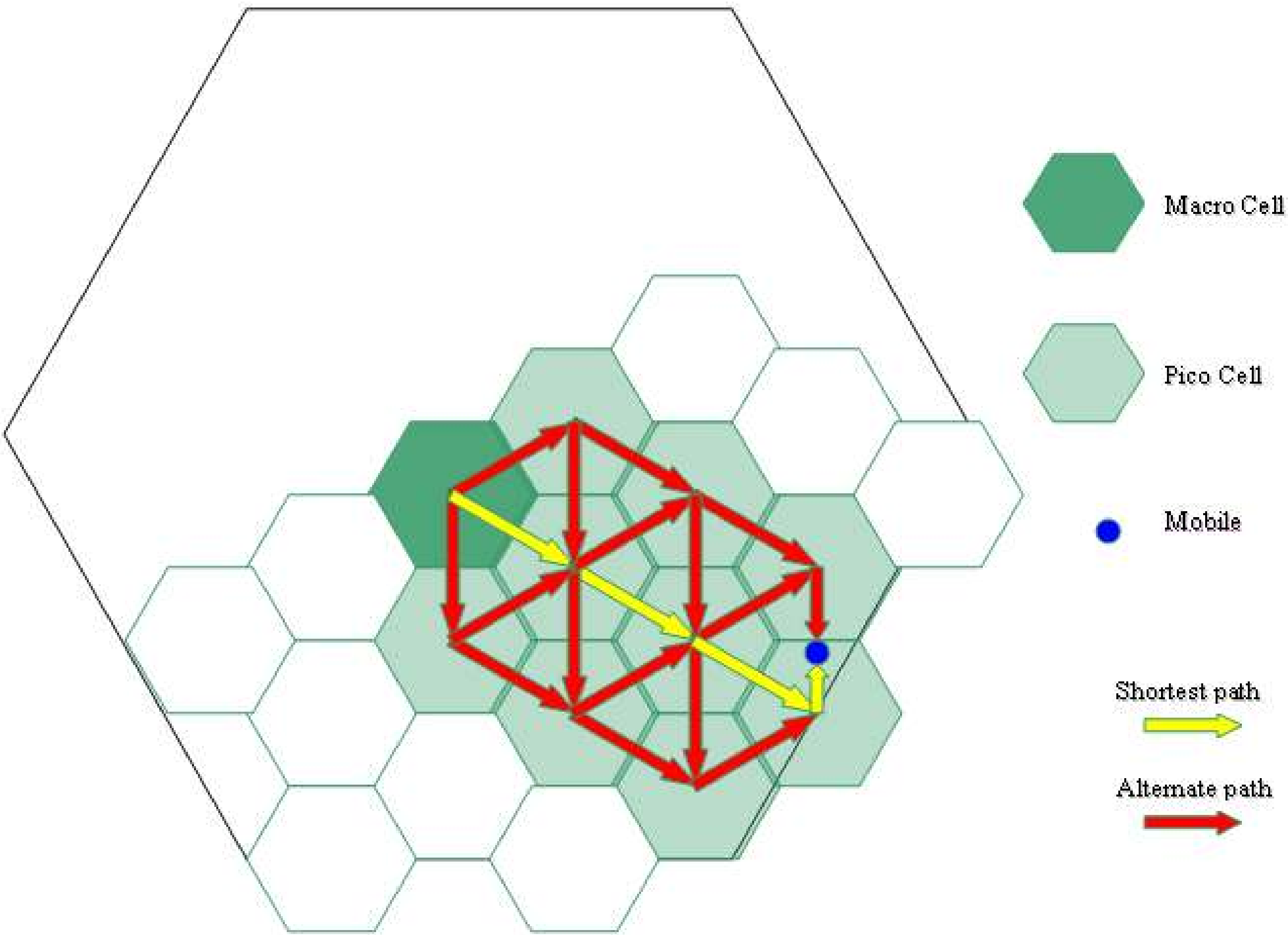
Problem

- Does breaking up the link L0 into two links M0 and L1 result in a net performance increase?

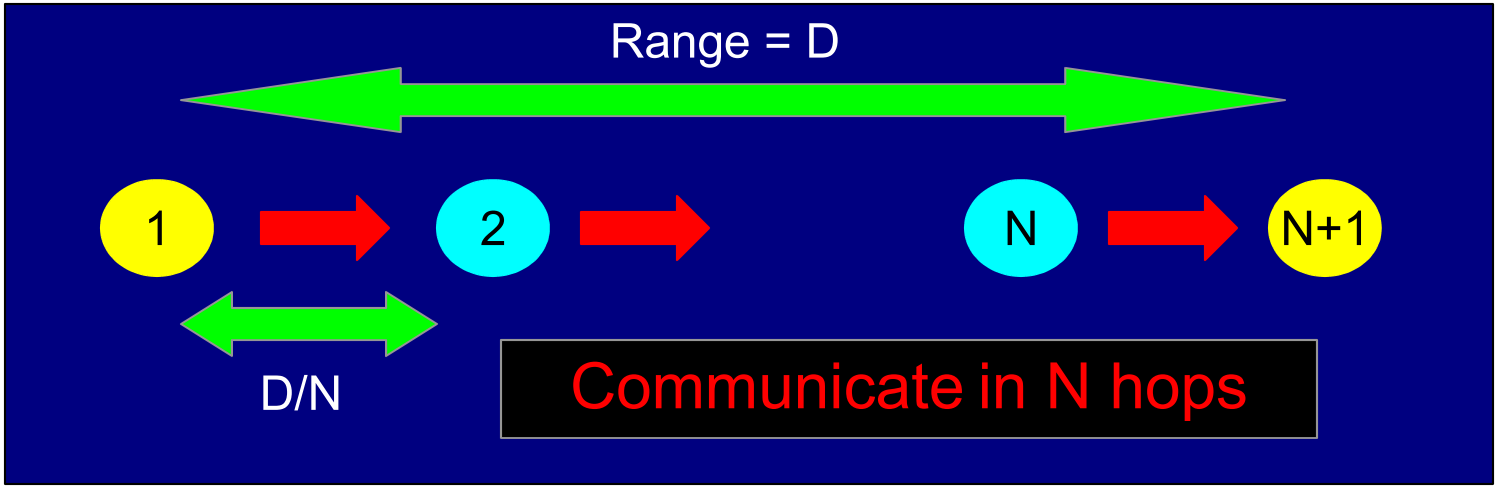


802.16 Micro-Cellular Networks



Objective: Performance analysis of multi-hop wireless

Simple 1D Model



1D-TD Model Assumptions:

- Message of Node 1 hops through all intermediate nodes until it reaches Node N + 1.
- Time-division (TD) based communication model
- Node k only receives from Node k – 1 and transmits to Node k+1

Basic Throughput Analysis

- Only assume path loss:

Received Power: $P_{rec} \quad (D/N)$

- Consider the AWGN channel:

$$C \quad \frac{1}{N} \log 1 \quad P_0 \; D/N$$

Low SNR regime

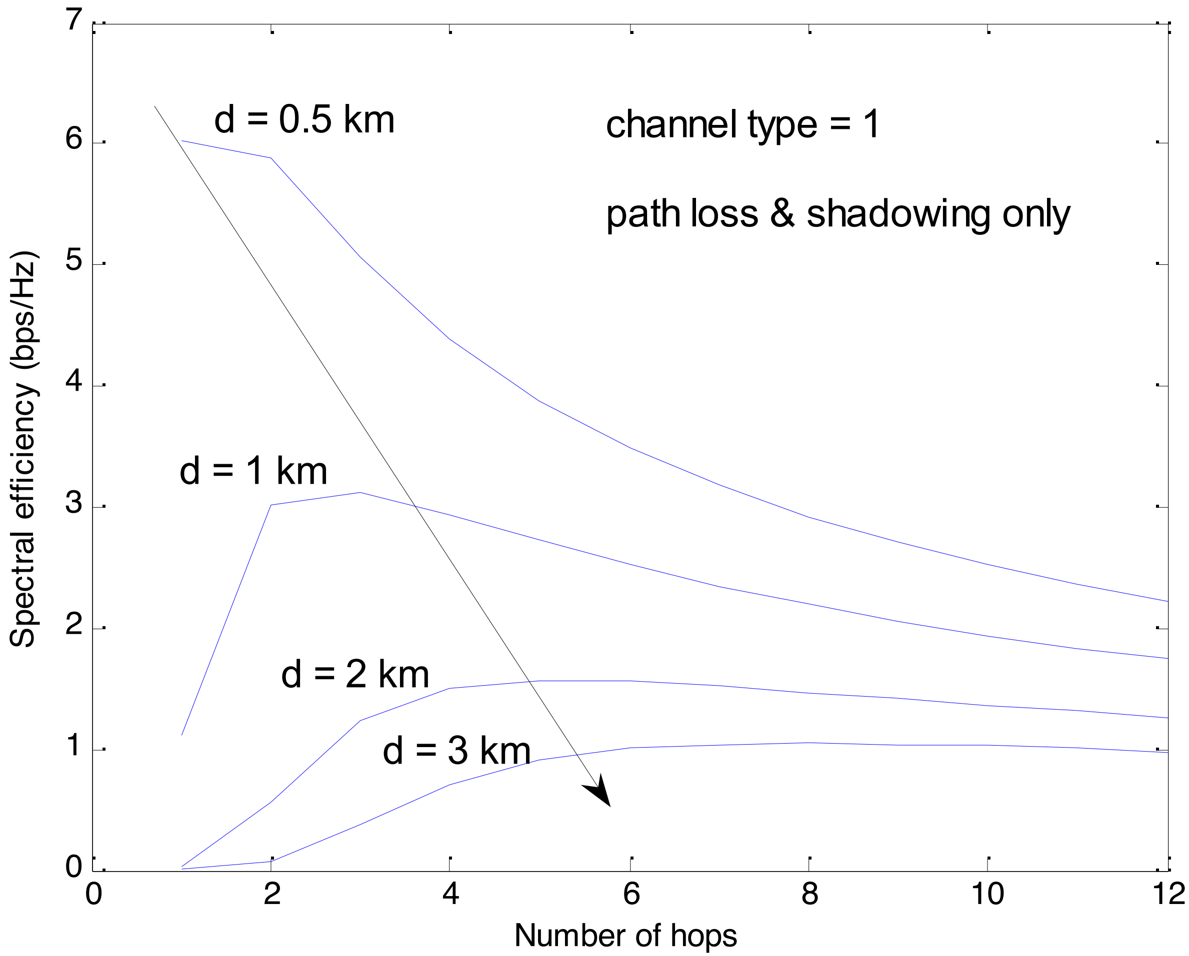
$$C \quad \frac{N^{\quad 1}}{D}$$

High SNR regime

$$C \quad \frac{}{N} \log \frac{N}{D}$$

There exists an optimal number of hops to maximize throughput!

Optimizing Mesh Throughput



Channel Model

- Path loss (exponent 2-6)

$$PL = A + 10\,\gamma\,\log_{10}(d/d_0) + s \qquad \text{for } d > d_0,$$

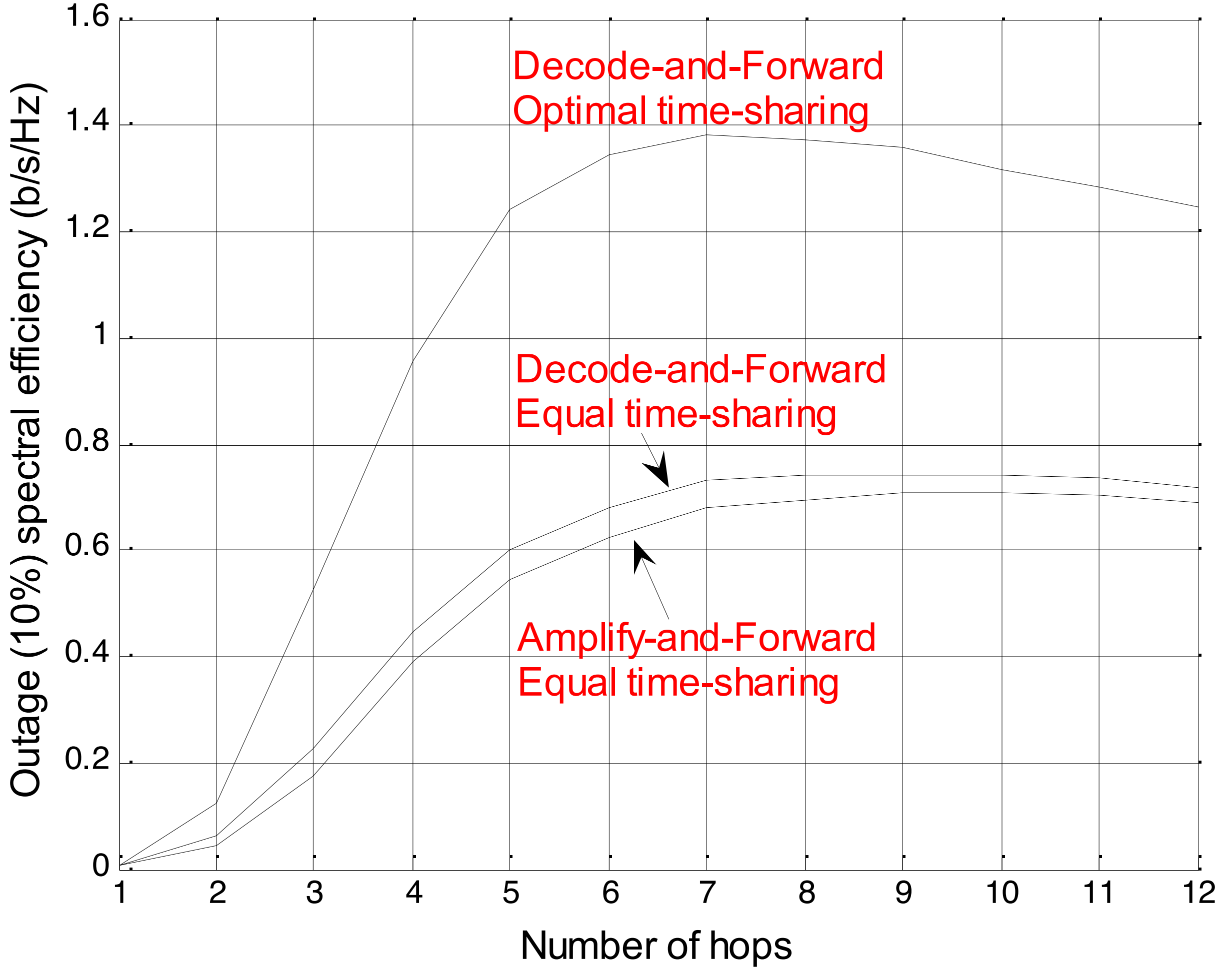
- Lognormal Shadowing (std = 4-8 dB)
- Rayleigh Fading
- Macro BS Power = 41.76 dBm (15 W)
- Micro BS Power = 34.77 dBm (3 W)
- Macro BS Height = 34 m
- Micro BS Height = 12.5 m

Network Capacity

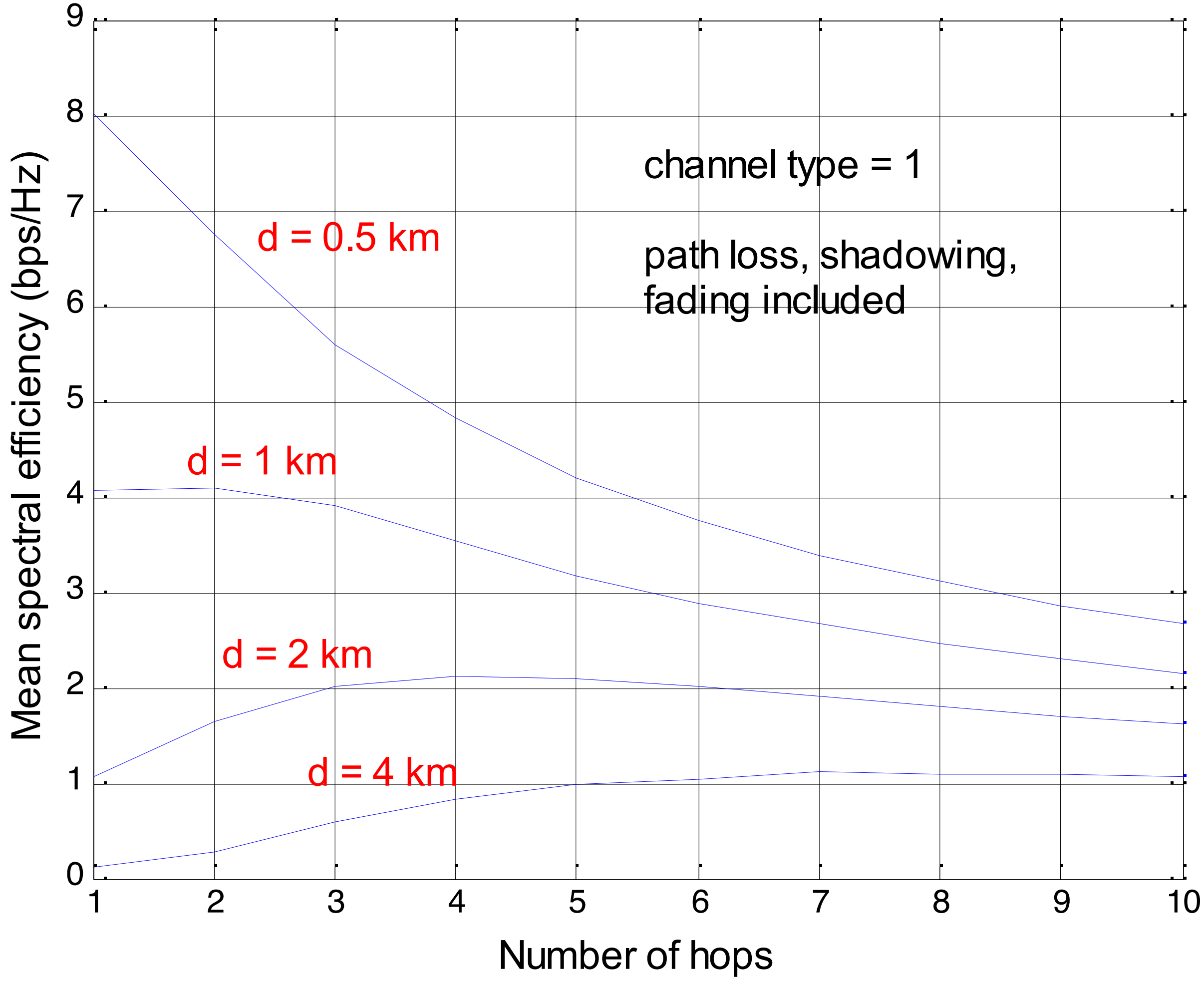
- Let C(i) denote the maximum achievable rate per unit bandwidth during hop i.
- Let lambda_i be the fractional time channel i is used.
- Capacity under time-division

$$C = \max_{\lambda_i : \sum_{i=1}^{N} \lambda_i = 1} \min_i \lambda_i C_i \quad \Rightarrow \quad C = \frac{1}{\sum_{i=1}^{N} \frac{1}{C(i)}}$$

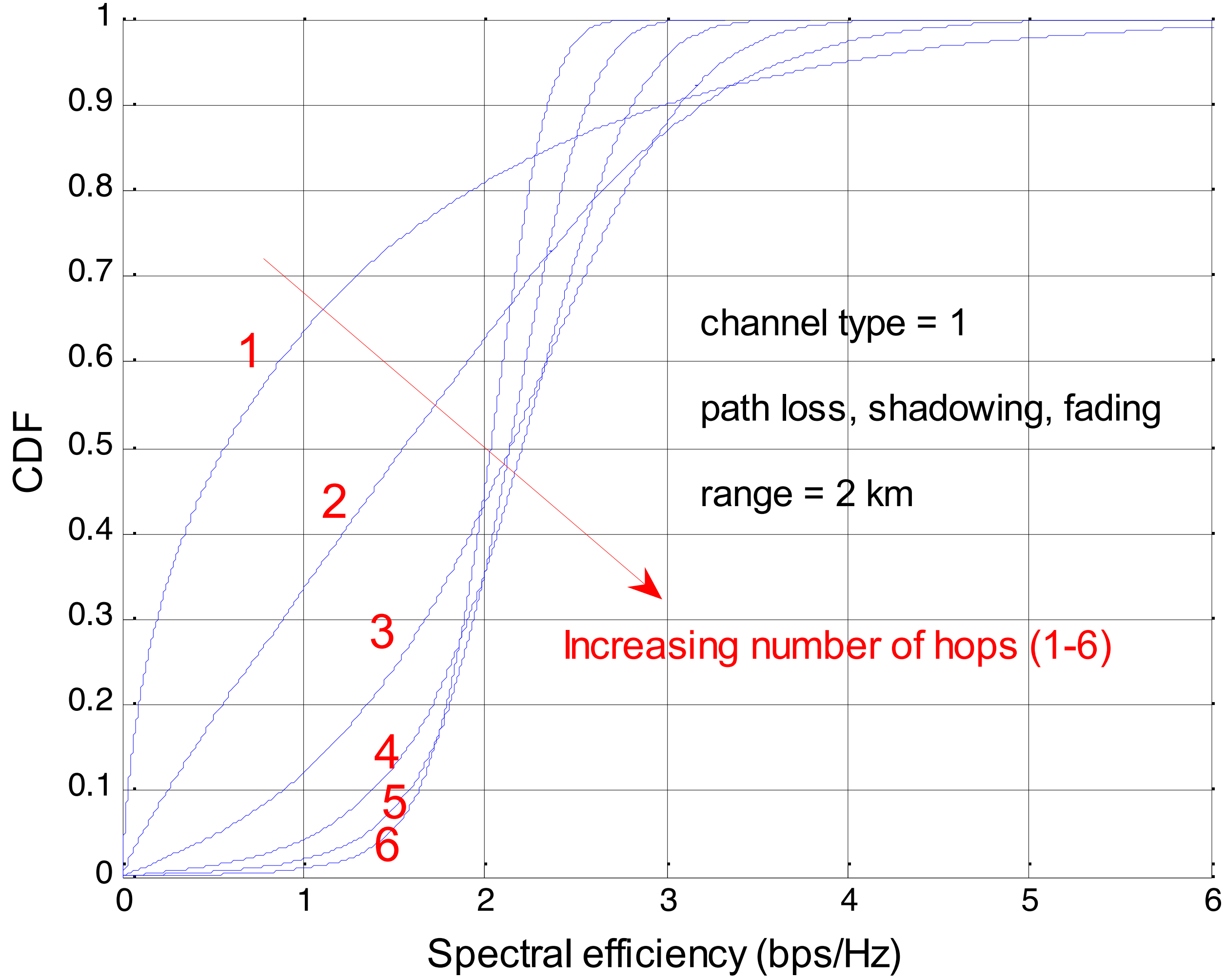
Per-link adaptation is better than worst link adaptation



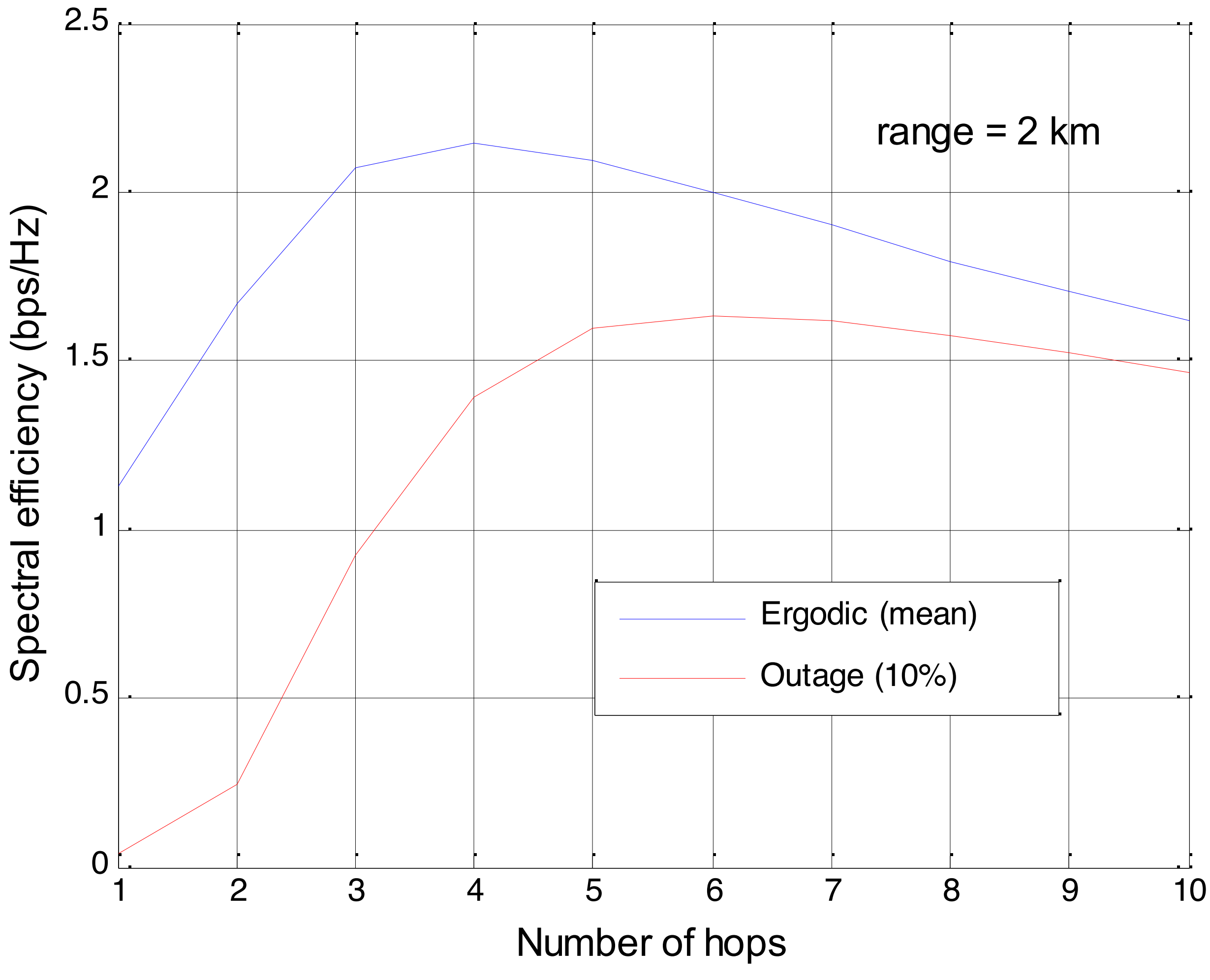
Throughput at Different Ranges



Hop More at Outage - I



Hop More at Outage - II



Throughput Results Summary

- We observed that for any given range there exists an optimal number of hops to maximize end-to-end throughput.

- Optimal number of hops increases for longer range

  ⇒ There exists an **optimal hop distance**.

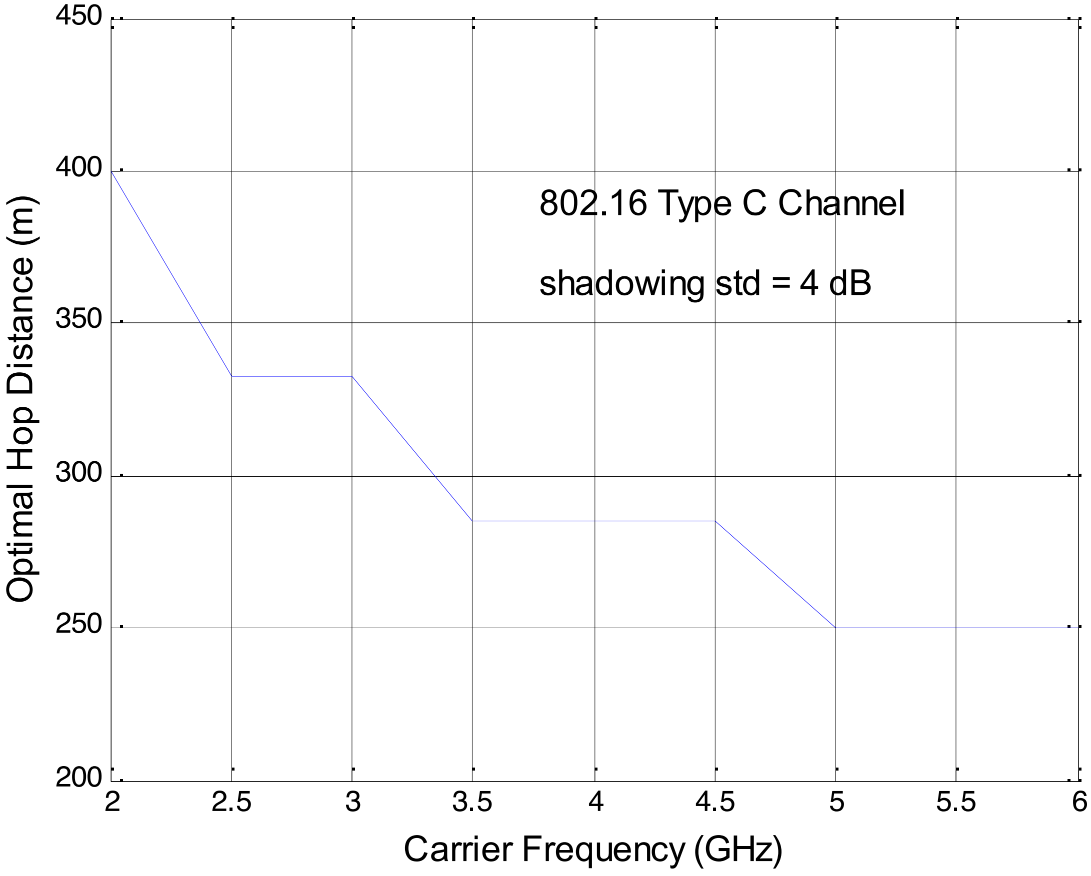
- Under fading, we showed that hopping can be an additional source of diversity over other forms of diversity (space, time or frequency).

- Multi-hop diversity is especially useful at low outage levels.

Channel Sensitivity

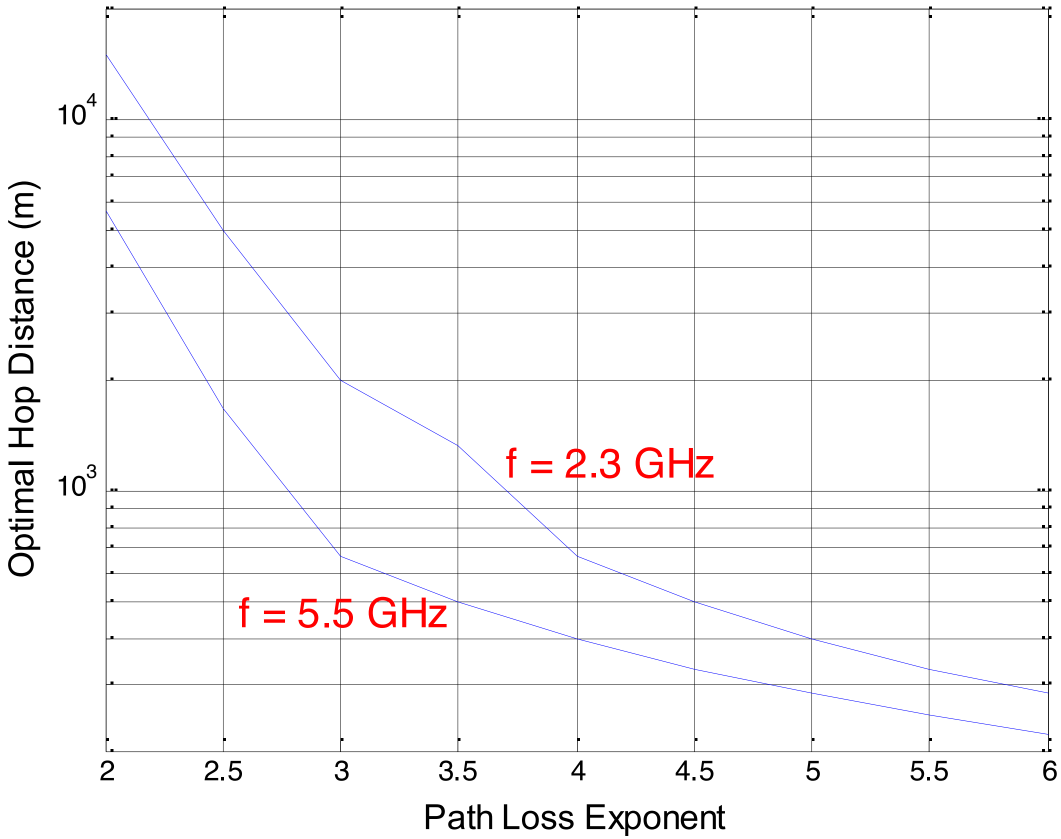
- Next step: Verification of channel models
- Current models: COST, ITU, Erceg-Greenstein
- How sensitive are the multihop gains to different propagation environments?
- Key variables: Antenna heights, carrier frequency, hop distance, shadowing std, LOS / NLOS path loss exponent

Sensitivity to Carrier Frequency



Optimal hop distance varies drastically with carrier frequency!

Sensitivity to Path Loss Exponent



Optimal hop distance varies drastically with different path loss exponents!

Conclusions

- We characterized the end-to-end throughput performance of multihop relaying and showed significant gains over direct transmissions.
- Throughput-optimal design of multihop networks is very sensitive to the channel behavior.
- One necessary step into MMR design is to decide on appropriate channel models.
- The performance improvements of multihop relaying also allows better range extension.