Simulation of a Wireless CDMA Ad Hoc Network

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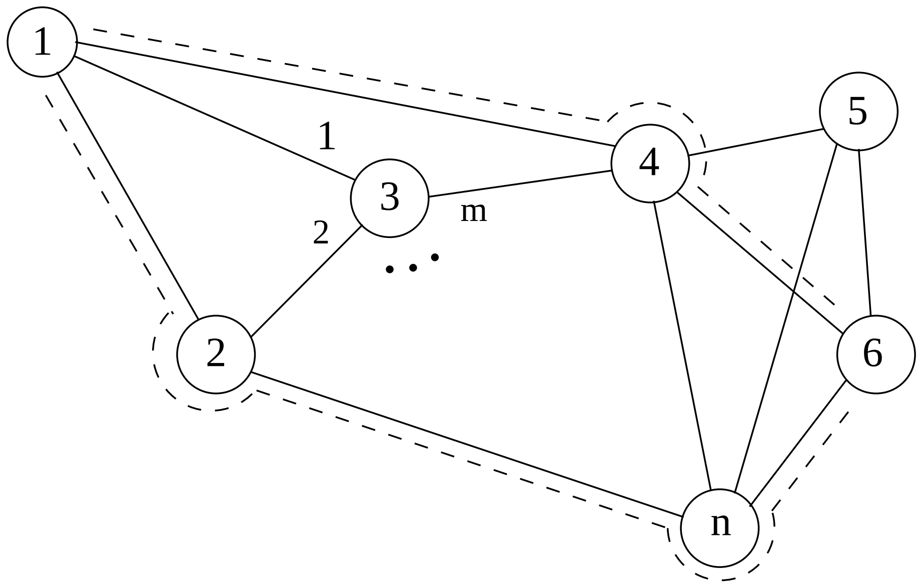
Network Model



- Ad hoc network
- n randomly distributed nodes
- Multipoint-to-multipoint communication
- Redundant paths
- Each node has a neighbor set of m nodes

Network Model (2)

- DS-CDMA communication channels
- Each connection has its own CDMA code
- Completely asynchronous CDMA
- Connections used concurrently and continuously
- Transmission range large enough
- Transmit power is adjusted to the farthest node
- Received signal level is proportional to the square of distance

$\boxed{\text{Questions}}$

- Is completely asynchronous CDMA feasible in ad hoc networks?
- Impact of multiuser interference?
- Improvement through multiuser interference reduction (MUIR)?
- Amount of required hardware?

CDMA Receive Signal

- $R_{\text{no interf.}}(i,j) = l * A(i,j)$

  l ... chip length (chips per bit)

  A ... receive amplitude

- If $R(i,j)$ negativ $\rightarrow$ logical 1
- Fully asynchronous CDMA
- Cross-correlation $X_{(x \rightarrow y)}^{(i \rightarrow j)}$

$$R_{\text{interf.}}(i,j) = l * A(i,j) + \sum_{(x,y) \neq (i,j)} X_{(x \rightarrow y)}^{(i \rightarrow j)} * A(x,j)$$

CDMA Receive Signal (MUIR)

- Incoming and outgoing connections are known
- Eliminate known connections with MUIR
- Assume perfect MUIR

$$R_{\text{interf.}}(i,j) = l * A(i,j) + \sum_{\{(x,y) | x \in N \setminus \{j\} \text{ and } y \in M_x \setminus \{j\}\}} X_{(x \to y)}^{(i \to j)} * A(x,j)$$

N ... set of all nodes

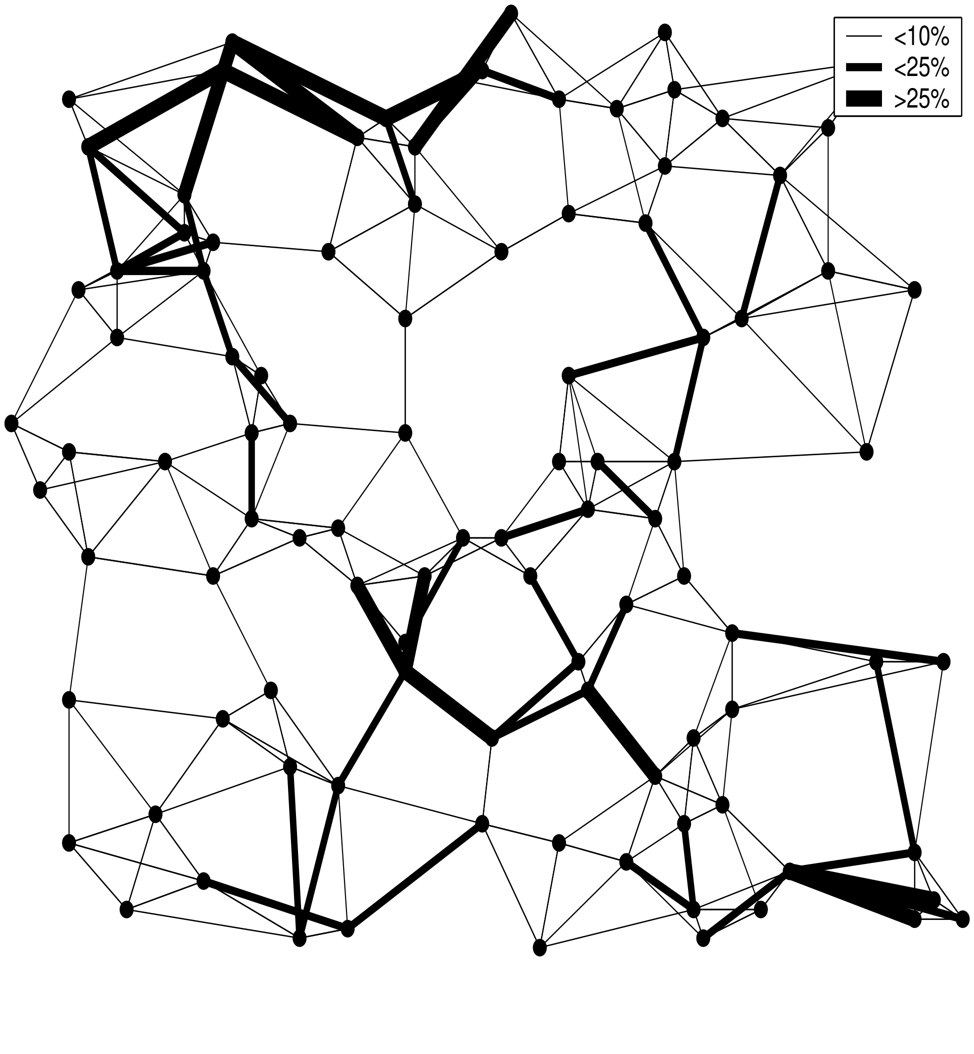
M_x ... neighbor set of node x

Simulation

- Gold codes, with trivalent cross-correlation function
- X is simulated with a random function
- Pre-assigned CDMA codes
- 100 random data bits for each connection
- Bit error rate (BER) is our measure of quality
- Each node chooses the nearest m nodes
- No external interference (e.g. noise)

Example

$n = 100$; $m = 4$; unidirectional; $l = 1023$; $d > 3$;
100×100 plane



- No partitions
- High BER close together and at boundaries

Simulation Overview

1. Uni- vs. bidirectional connections
2. Minimum distance
3. Number of nodes
4. Connections per node
5. Chip length
6. Signal propagation
7. Power management
8. Multiuser interference reduction

1. Uni- vs. Bidirectional

Unidirectional:

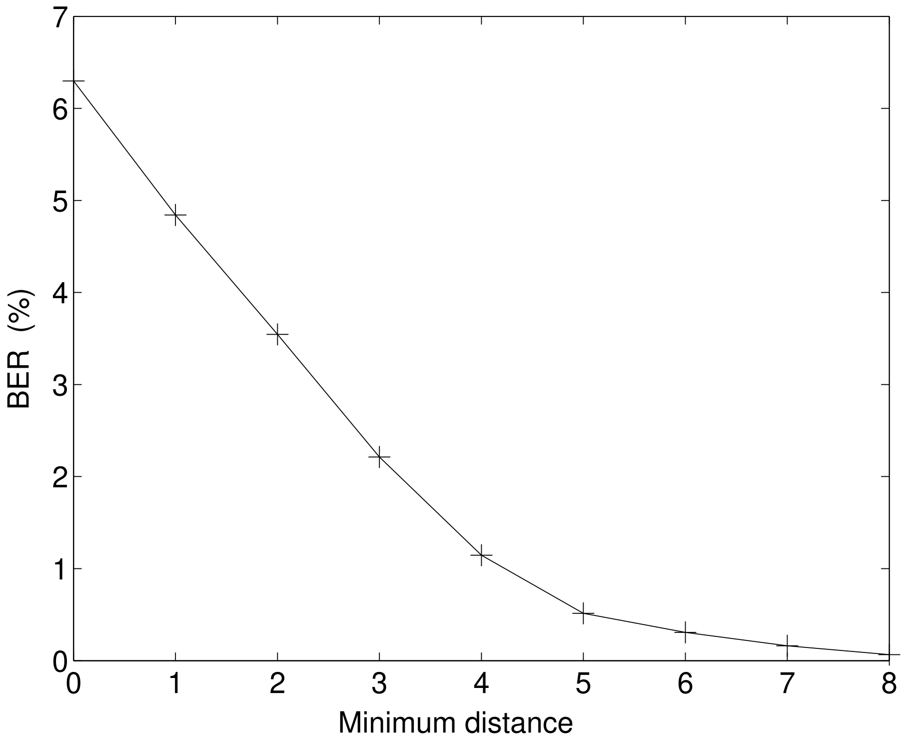
- Each node chooses the nearest m nodes

Bidirectional:

- Iterated in random order
- Each node selects the corresponding outgoing connection for each incoming connection
- Remaining connections filled up with the nearest nodes

	unidirectional	bidirectional
average BER	2.21%	8.93%

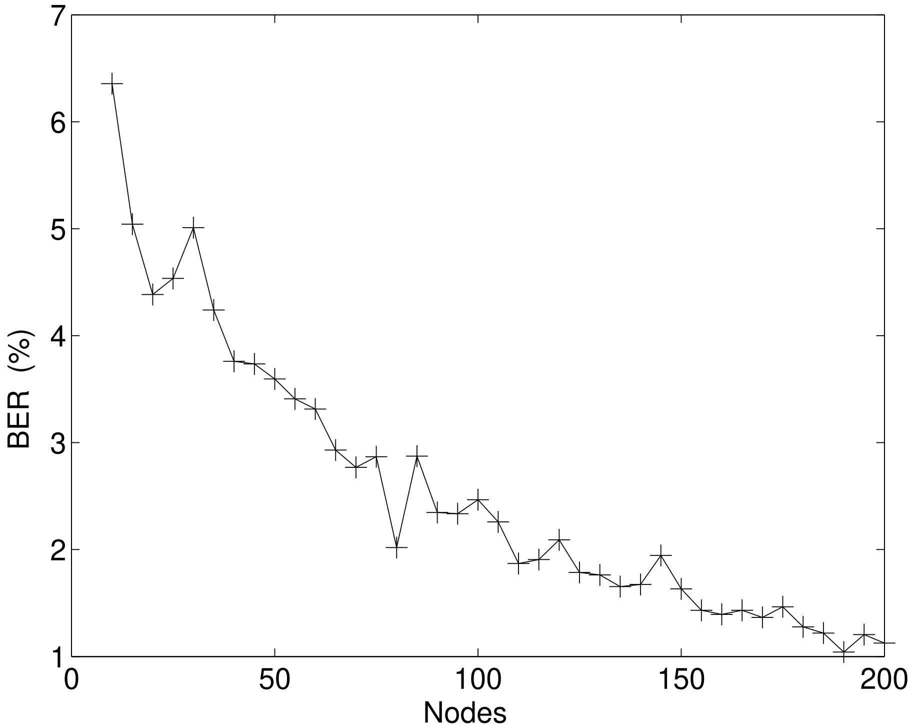
2. Minimum Distance



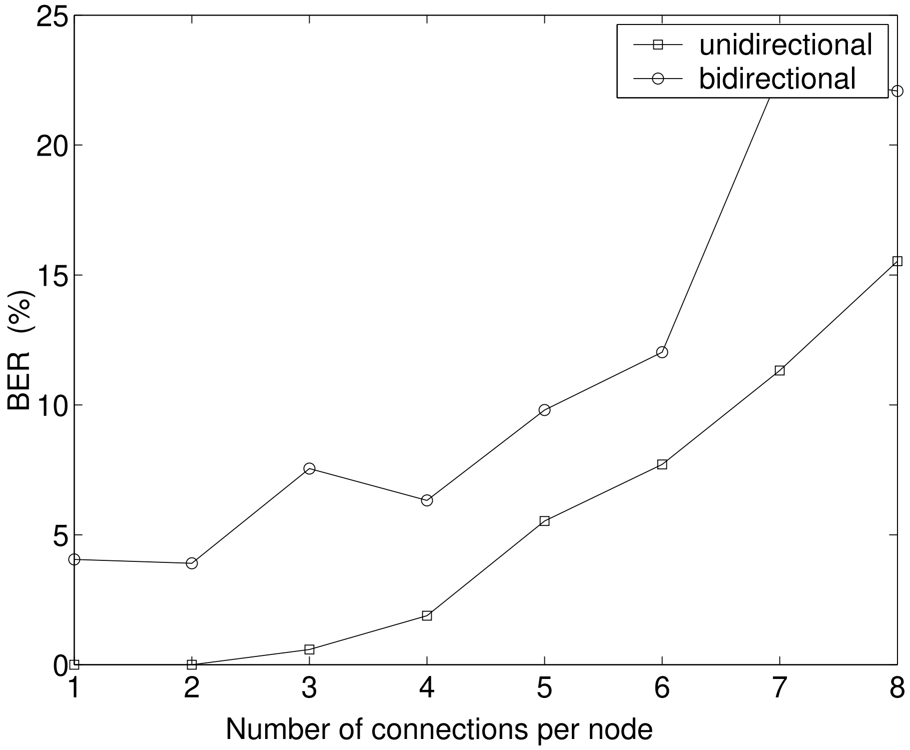
Options:

- Influence on placement: keep minimum distance
- No influence: coordinate transmissions

3. Number of Nodes

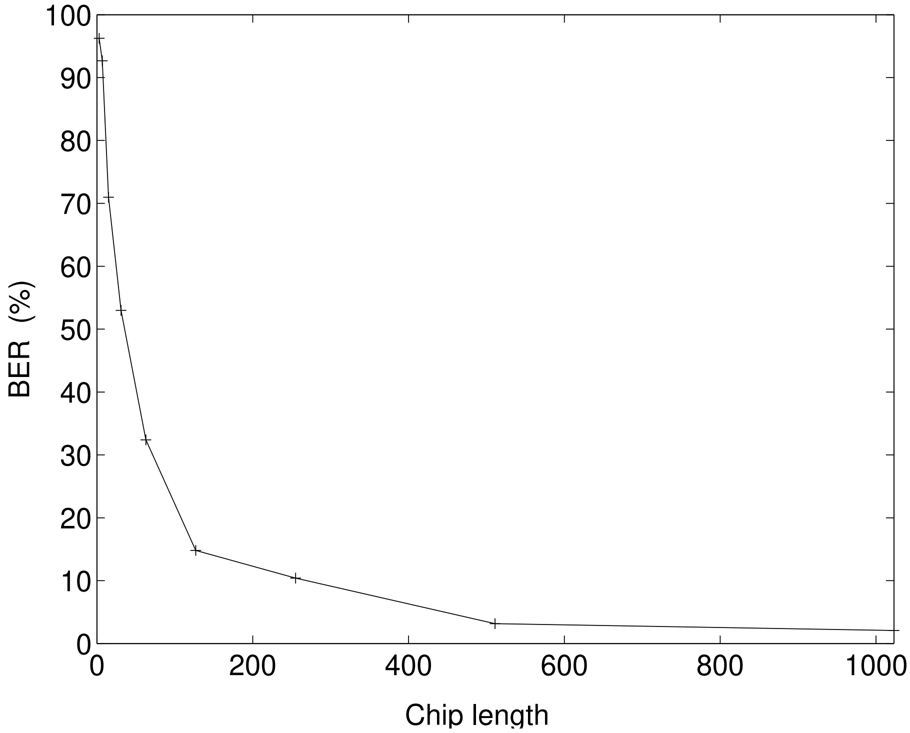


4. Connections per Node



Tradeoff: fault tolerance through connection redundancy or increasing BER

5. Chip Length

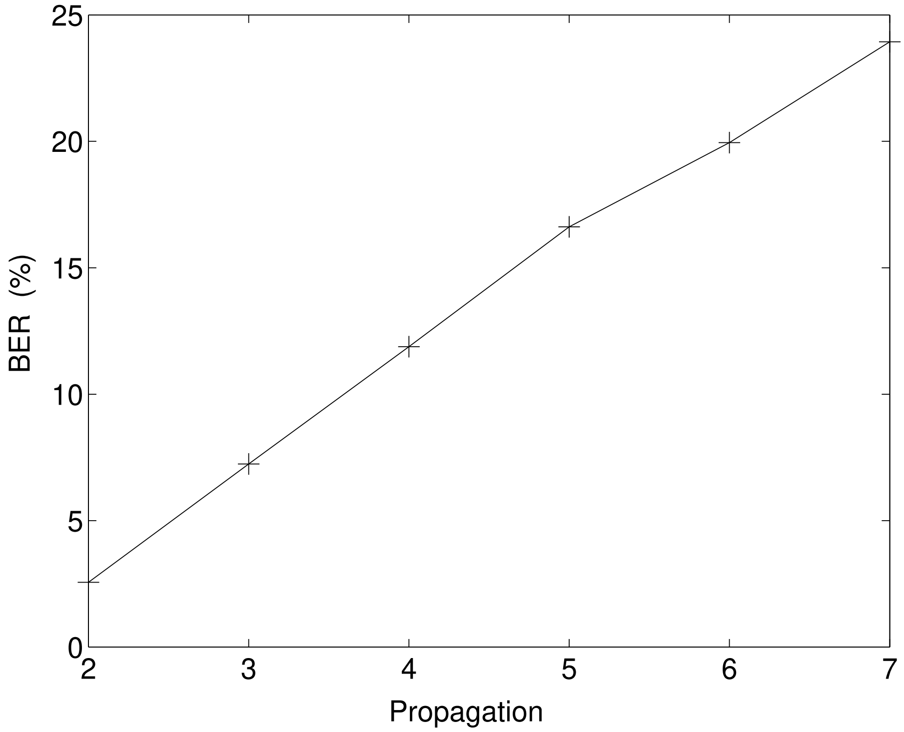


Applicable for any asynchronous code family

6. Signal Propagation

Outdoor:

- Different homogeneous signal propagations



Indoor:

- Path loss for a connection equally distributed between distance^{-2} and distance^{-6}

average BER	17.78%

7. Power Management

Strategy 1:

- Same signal amplitude on all links
- Farthest neighbor receives with amplitude of 1

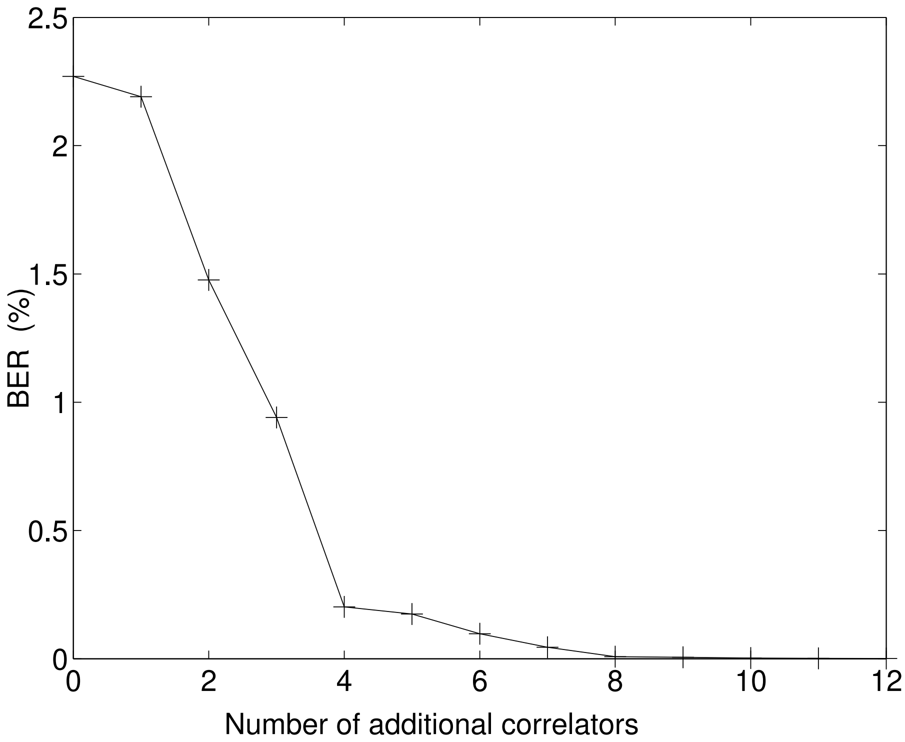
Strategy 2:

- Adjust transmission power for each connection
- Each incoming connection is received with amplitude 1

	strategy 1	strategy 2
average BER	2.16%	2.69%

8. Multiuser Interference Reduction

- Cancel the influence of the heavily interfering connections
- Additional correlators with successive interference cancellers (SIC)



Conclusions

Questions:

- CDMA-based communication in a homogeneous wireless ad hoc network possible?
- What topology constraints?
- What effect has MUIR?
- What hardware requirements?

Results:

- Unidirectional network
- Demand a minimum distance
- High node number but few connections per node
- A few additional correlators are sufficient for significant improvement

Future Work

Improving simulation:

- More low level details (data block communication, modulation, external interference, no perfect SIC)

Theoretical analysis:

- Combine results of *E. Sousa and J. Silvester's* work: "Optimum transmission ranges in DS SS multihop packet radio network" with our multiuser interference concept