Ad Hoc Networks

- Properties
  - Wireless nodes
  - Shared communication
  - Capable of movement
  - Node positions unknown
  - Limited battery life
  - Limited bandwidth
- Considerations
  - Radio power vs. transmission bandwidth (Royer, et al.)
  - Radio power vs. connectivity (Santi, et al.)

An Analysis of the Optimum Node Density for Ad hoc Mobile Networks

E. Royer, P. Melliar-Smith, L. Moser

Increasing Radio Power

Pros

- Reduce path length
- Less load on network

Cons

- A greater proportion of traffic heard by a node is not addressed to it
- A node will be able to transmit less frequently

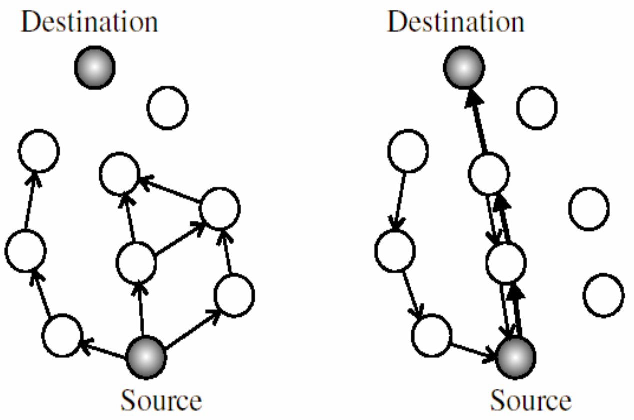
What is optimum radio power/transmission radius?

Motivation

- Kleinrock and Silvester (1978) result:
  - Analytical analysis of tradeoff between transmission radius and bandwidth in static network
  - Adjust transmission radius to include 6 neighbors for optimum result
- This paper:
  - Optimum for mobile nodes?
  - By simulation

Problem Setting

- Mobile Ad hoc network
- AODV routing protocol
- MAC protocol – IEEE 802.11 DCF (CSMA/CA)
- Simulation using GloMoSim
- Radio model
  - Free space propagation ($1/r^2$)
  - Receiver has capture capability
  - Data rate is 2Mb/sec
- 100 nodes in 1km x 1km
- 40 source nodes sending twelve 512 byte packets per second

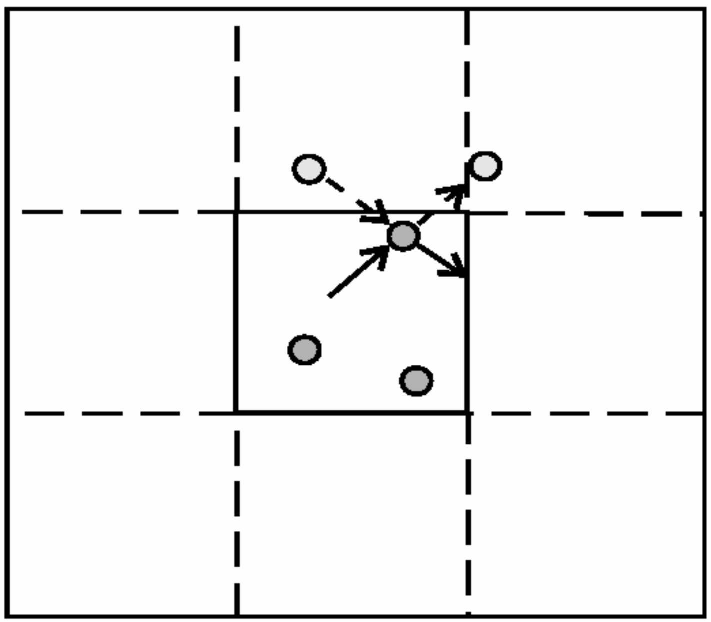


(a) RREQ Propagation

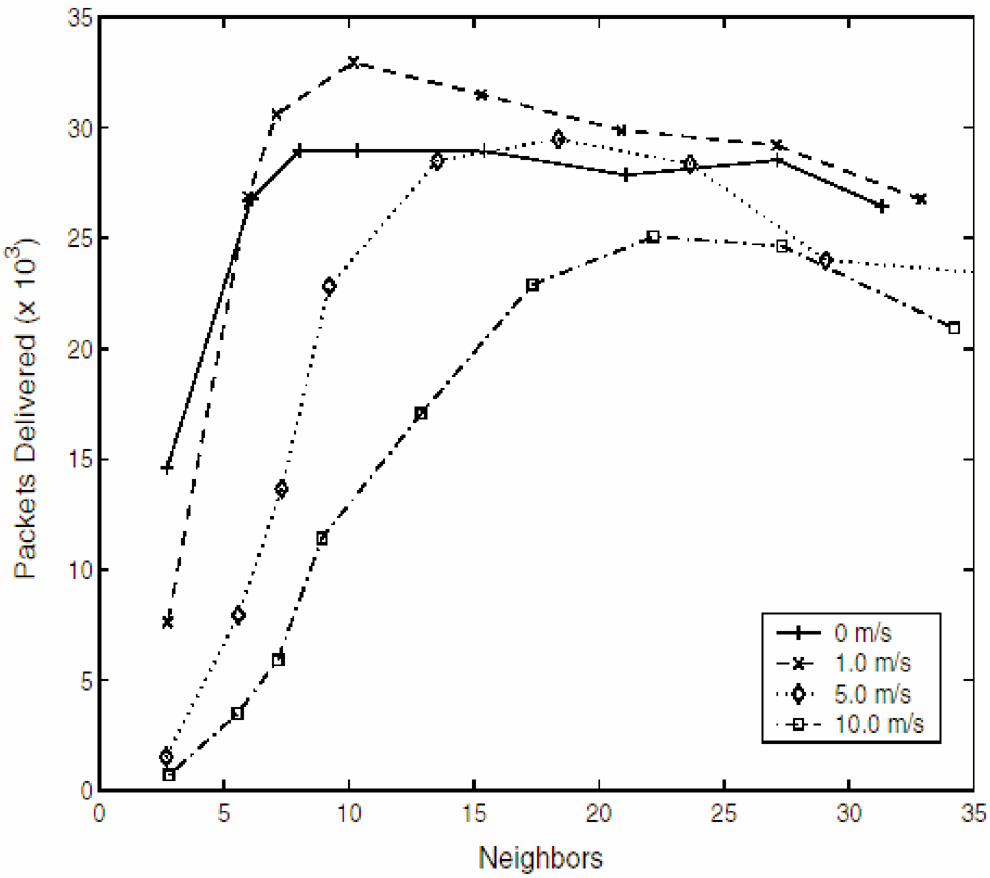
(b) RREPs and Subsequent Data Path

Motion model

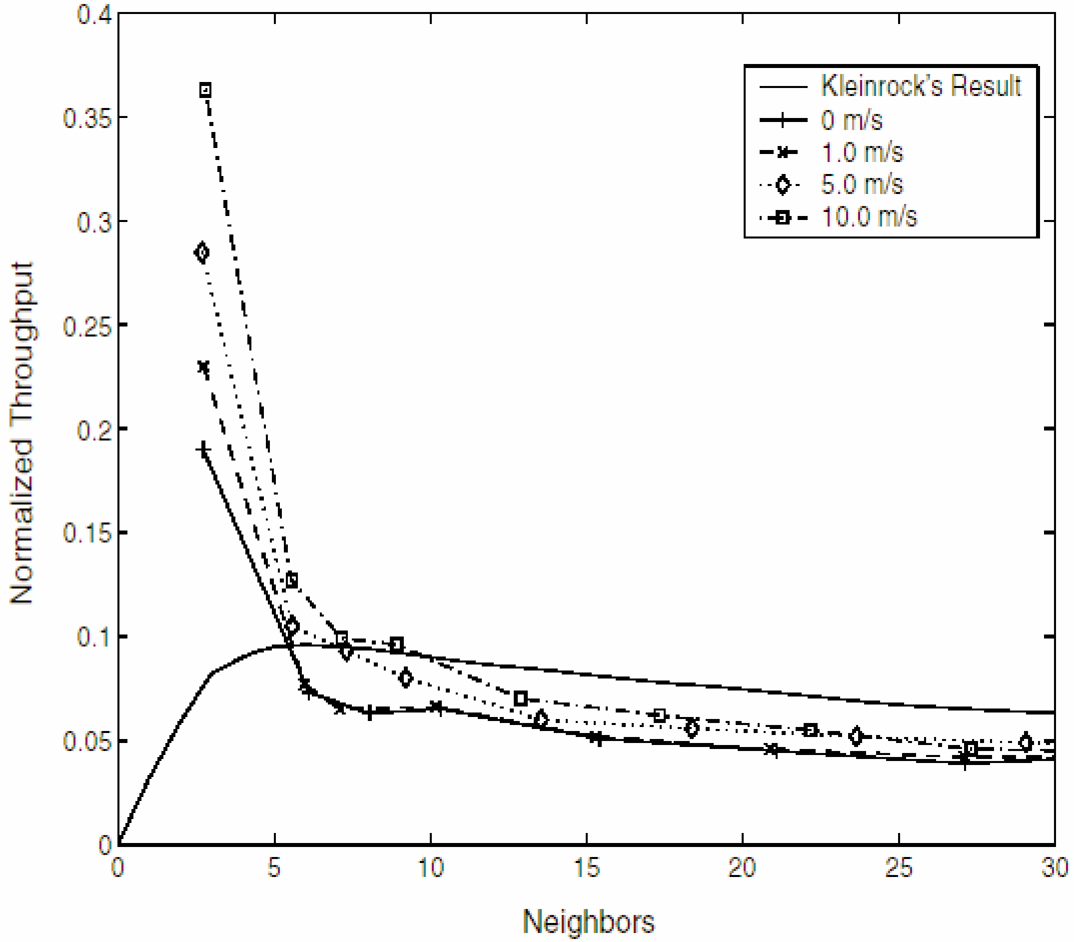
- Random waypoint
- Random direction
- Modified random direction



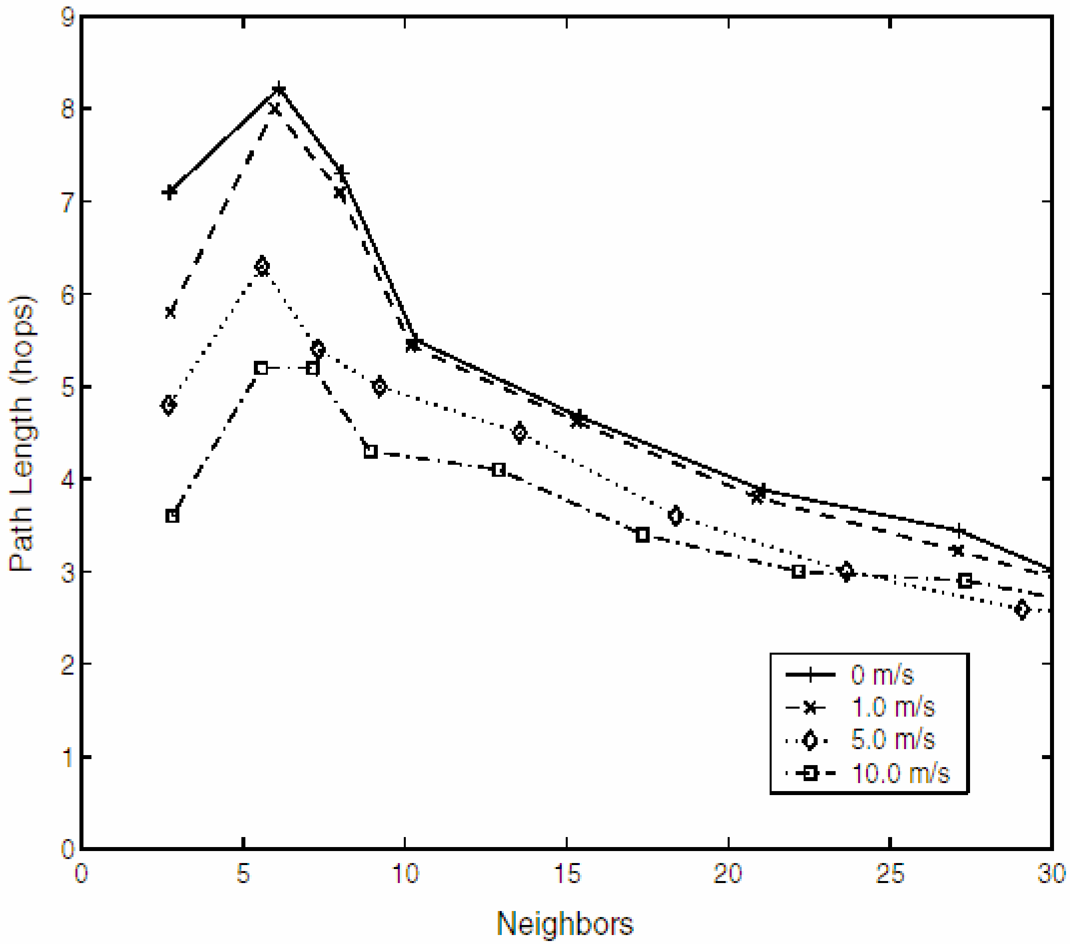
Number of Packets Delivered



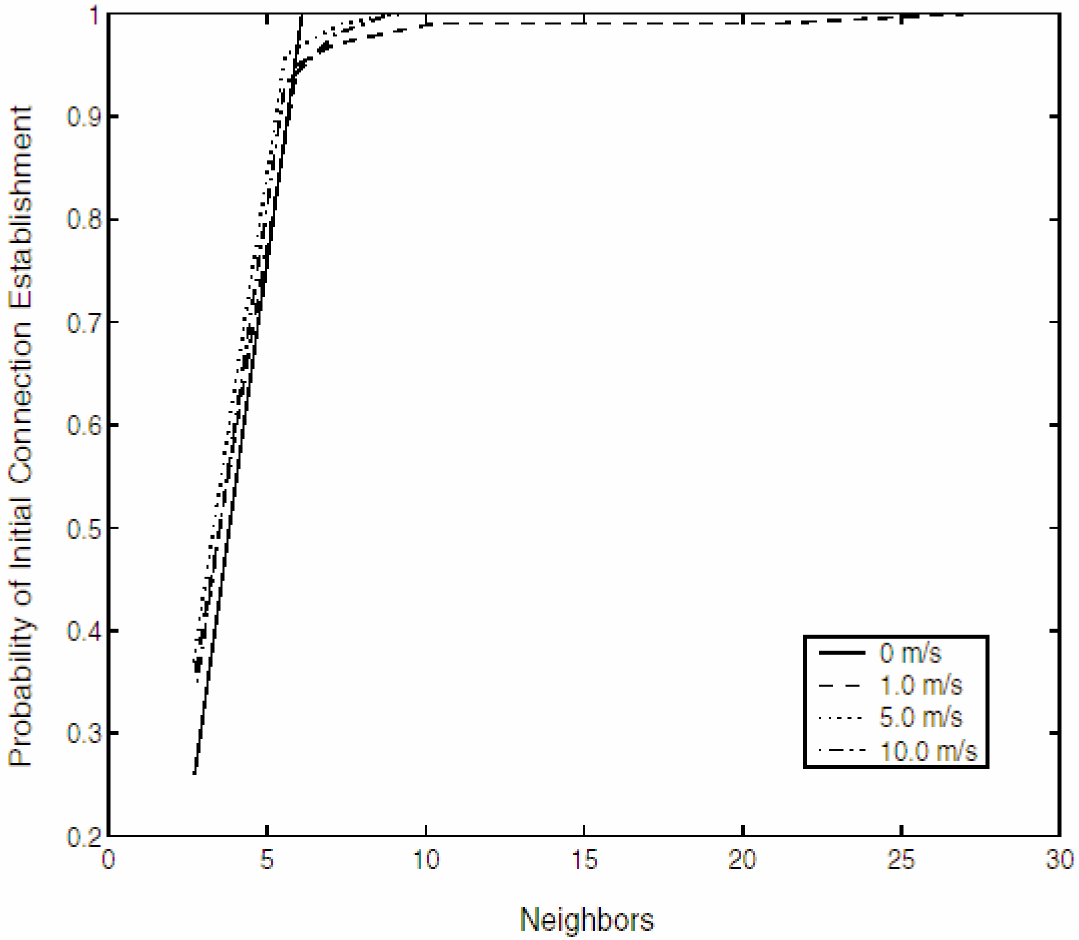
Normalized Throughput



Average path length



Probability of route



A Probabilistic Analysis for the Range Assignment Problem in Ad Hoc Networks

P. Santi, D. Blough, F. Vainstein

Range assignment problem

- Problem of ensuring connectivity while minimizing the transmission range (minimizing the energy consumption)
- Optimum solution in polynomial time in 1d
- NP-hard in 2d and 3d

Problem Setting

- Homogeneous assignment r
- Node positions unknown
- n nodes are distributed in d dimensional cube of side length L
- Deterministic solution: $r = L * \mathrm{sqrt}(d)$
- Probabilistic solution?

a.a.s.

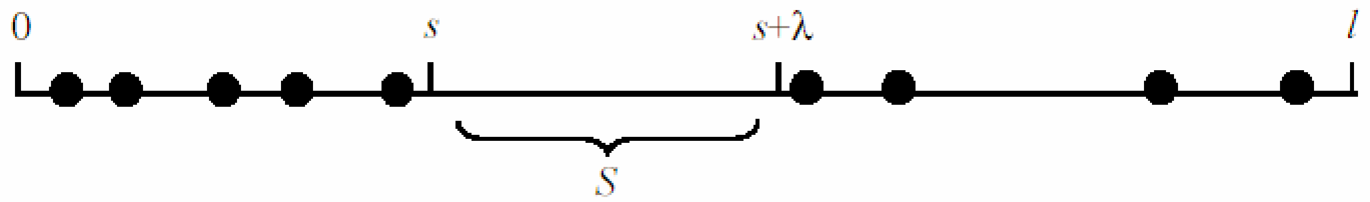
- Asymptotically almost surely:
  - $P(\text{Event}_L) \rightarrow 1$ as $L \rightarrow \infty$

Result 1: Bound for not a.a.s. connected (in 1,2,3d)

- $r^d n$ in $O(L^d)$, not a.a.s. connected
- $r^d n << L^d$, a.a.s. disconnected
- Short outline:
  - P(Connected) = 1 – P(Disconnected)
  - P(Disconnected)>=P(IsolatedNode(i))
  - So if P(IsolatedNode(i)) $\rightarrow \varepsilon > 0$ as $L \rightarrow \infty$, then P(Connected) does not approach 1 and network is not a.a.s. connected

Result 2: Probability of connected in 1d

- P(Connected) >= $1 – (L-r)(1-r/L)^n$
- Short outline:
  - Compute upper bound of P(Disconnected)
  - P(Connected) >= 1 – upper bound of P(Disconnected)

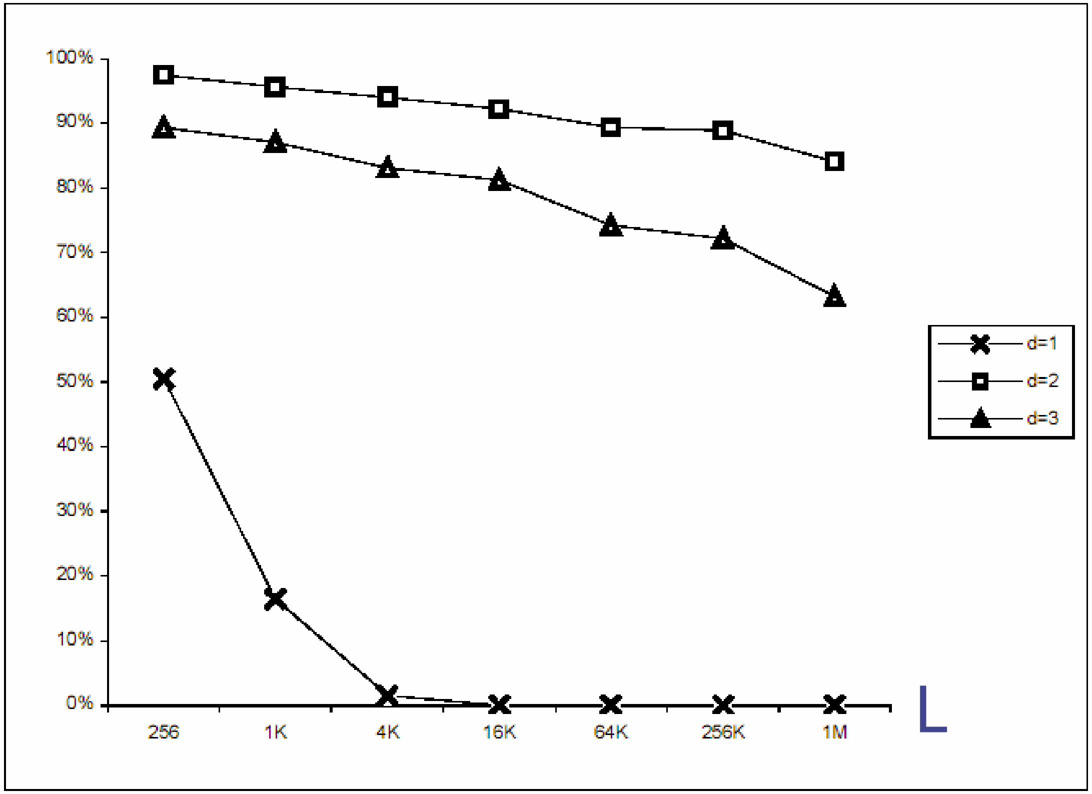


Result 3: Bound for a.a.s. connected in 1d

- Assume $r << L$
- If $rn \in \Omega(L \log L)$, then a.a.s. connected
- Short outline
  - $P(\text{Connected}) >= 1 - (L-r)(1-r/L)^n$
  - Apply l'Hopital's rule

Simulation: $r^d n = L^d$ verify Result 1

Percentage of connected



We expect not a.a.s. connected

$n = L^{1/2}$

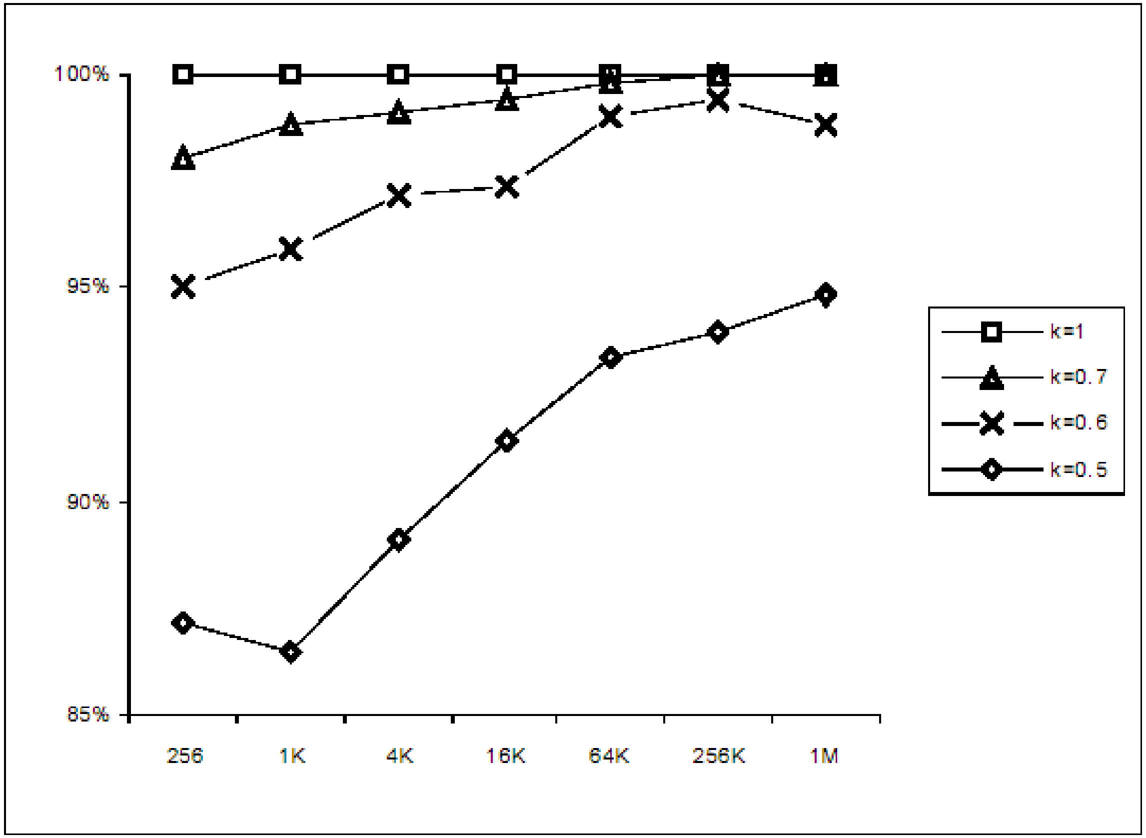
$r = c_d L^{(d-1/2)/d}$

$c_1 = 3,$

$c_2 = 2,$

$c_3 = 1,5$

Simulation: rn=L log L for 1d verify Result 3

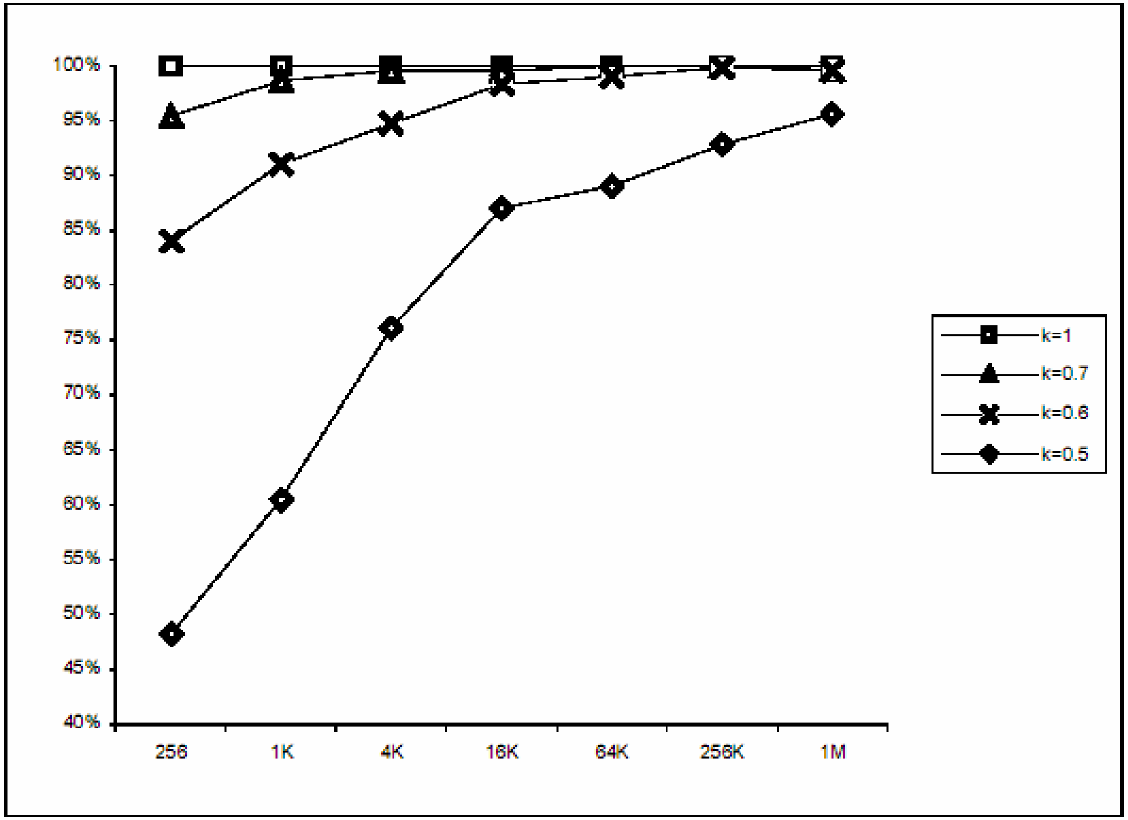


$n = L^{1/2}$

$r = k\, L^{1/2} \log L$

We expect a.a.s. connected

Simulation: $r^d n = L^d \log L$ for 2d

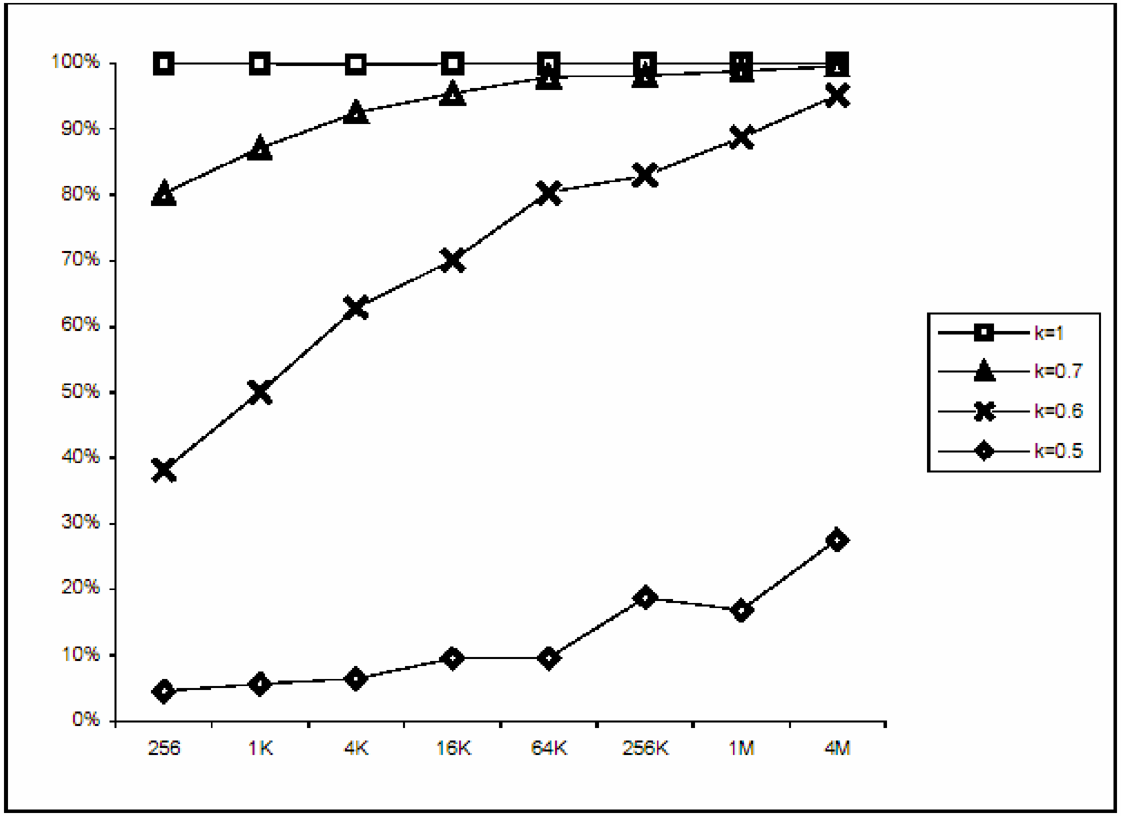


$n = L^{1/2}$

$r = kL^{3/4}(\log L)^{1/2}$

a.a.s. connected?

Simulation: $r^d n = L^d \log L$ for 3d

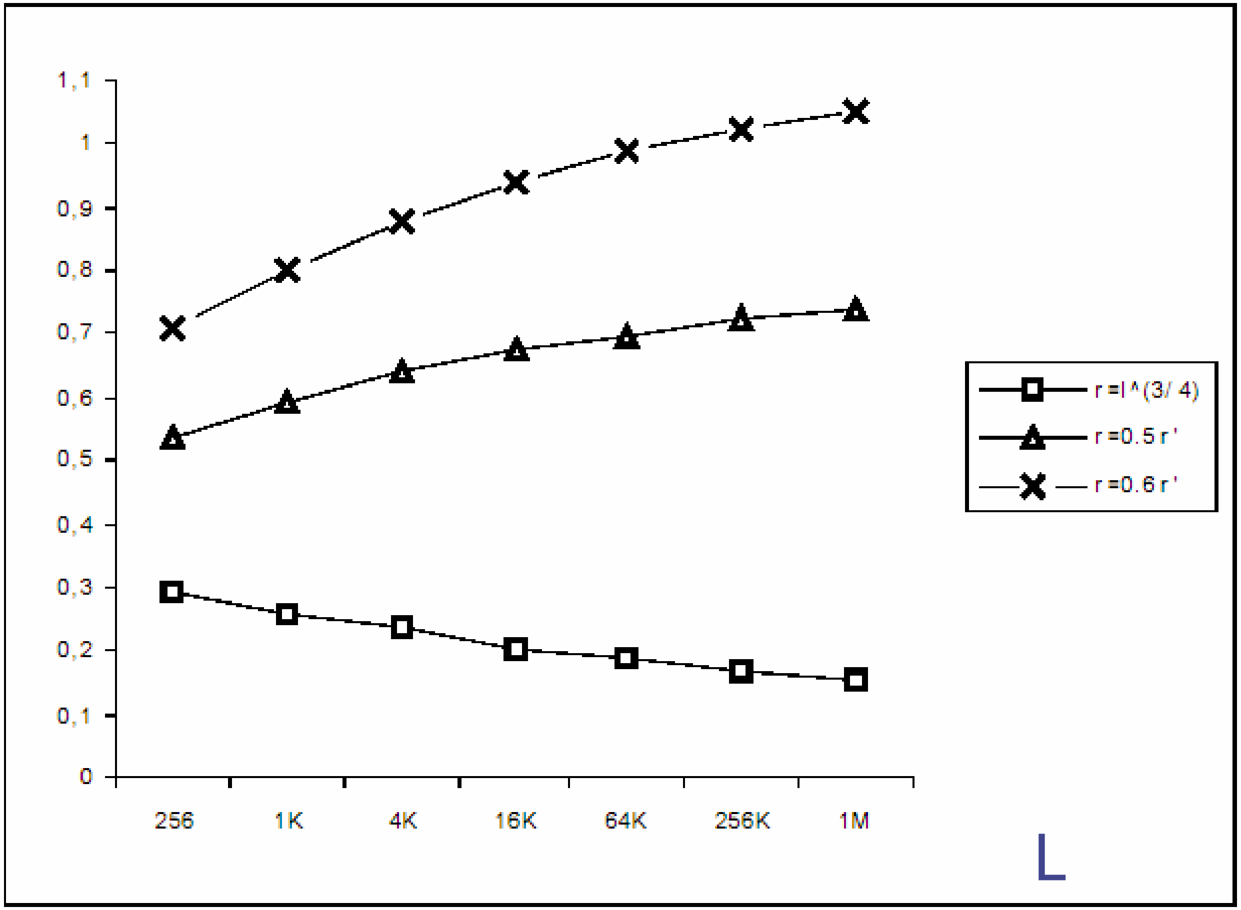


$n = L^{1/2}$

$r = kL^{5/6}(\log L)^{1/3}$

a.a.s. connected?

Num. Neighbors/log L in 2d



$n = L^{1/2}$

$r' = L^{3/4}(\log L)^{1/2}$

Summary/Discussion

- Optimum transmission radius is an important problem
- Many quantities to optimize for:
  - Bandwidth/Throughput
  - Connectedness
  - Energy
  - Lack of holes in the network