

# Towards a Connectivity-Based, Reliable Routing Framework

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# A Cross-Layer Perspective of Routing

How to get from A to B?

Underlying question:

- what are the ways to get from A to B?
  - not given
  - vary over time

Select Good Routes

Neighbor management

- keep the good ones

Discover & characterize connectivity

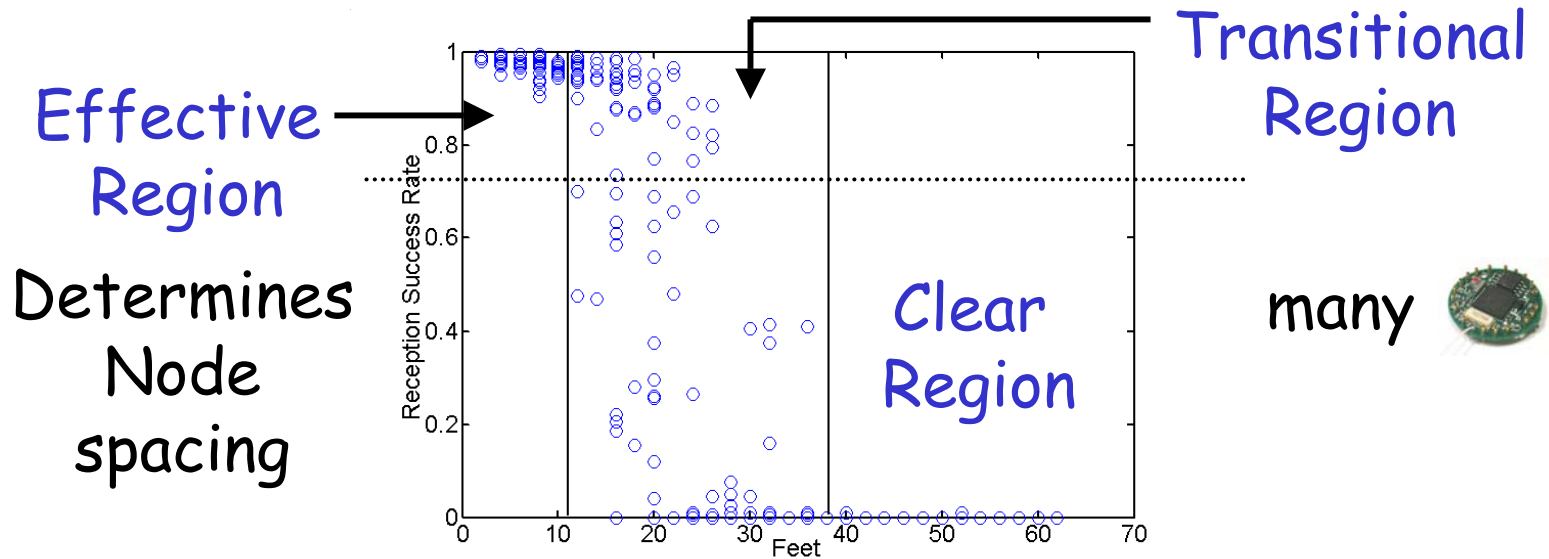
Each layer is a distributed, local process.

Combine  Yield global properties

- End-to-end success rate
- Routing topology
- Stability

# Underlying Connectivity

- 3 regions and transitional region is *large*



- Communication range?
  - Discover connectivity = link estimation
- How to define a "neighbor"?

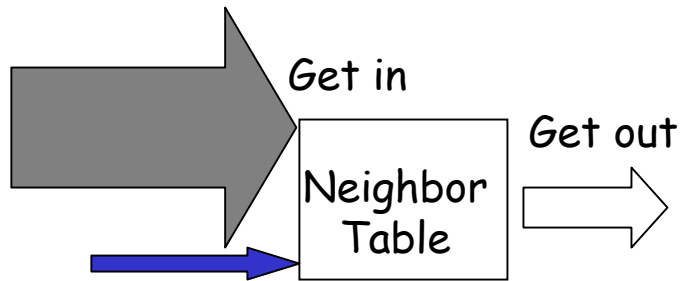
Zhao (Sensys '03)  
SCALE (Ucla)

# Discovering Connectivity

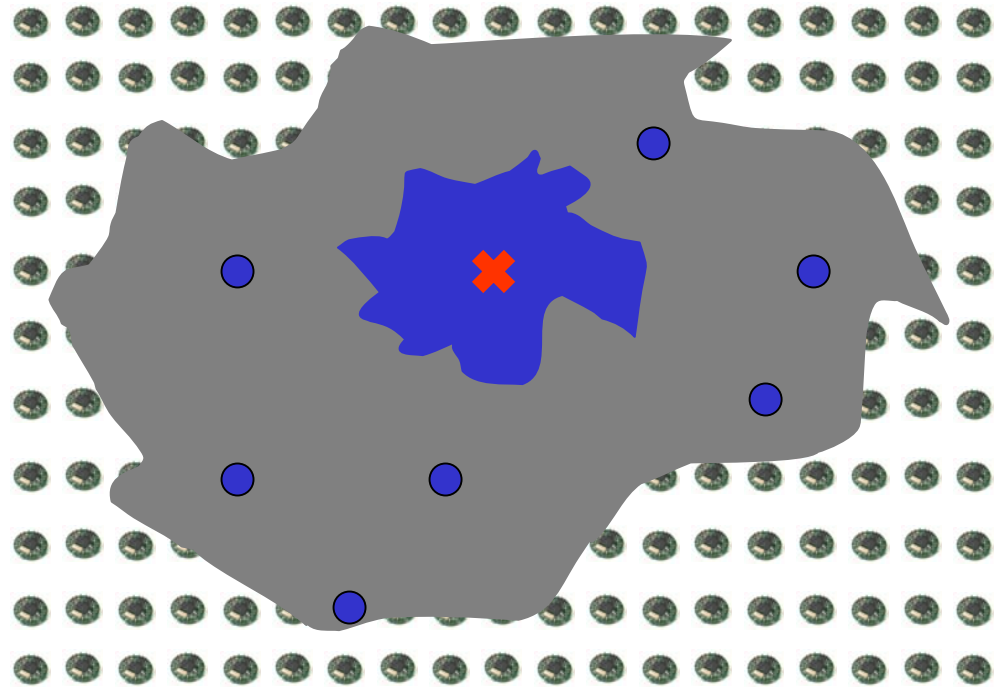
- Link estimation
  - History-based estimator, software process (Link)
    - DSDV (Intel), Tiny Diffusion (UCLA), GPSR (USC)
    - 802.11 networks (DeCouto 03)
    - Worst case: a  $|10\%|$  error takes 100 message time to settle
  - Hardware-based process (Physical)
    - Link quality indicator
      - ChipCon 2420, 802.15.4 standard
- A minimum link data rate
  - A need to maintain connectivity estimation

# Neighborhood Management

- Hear
  - Many potential neighbors
  - Few good nodes (blue)
- Potential neighbors > available table-size



- Cannot est. which neighbor is "good"
- On-line process to maintain good neighbors

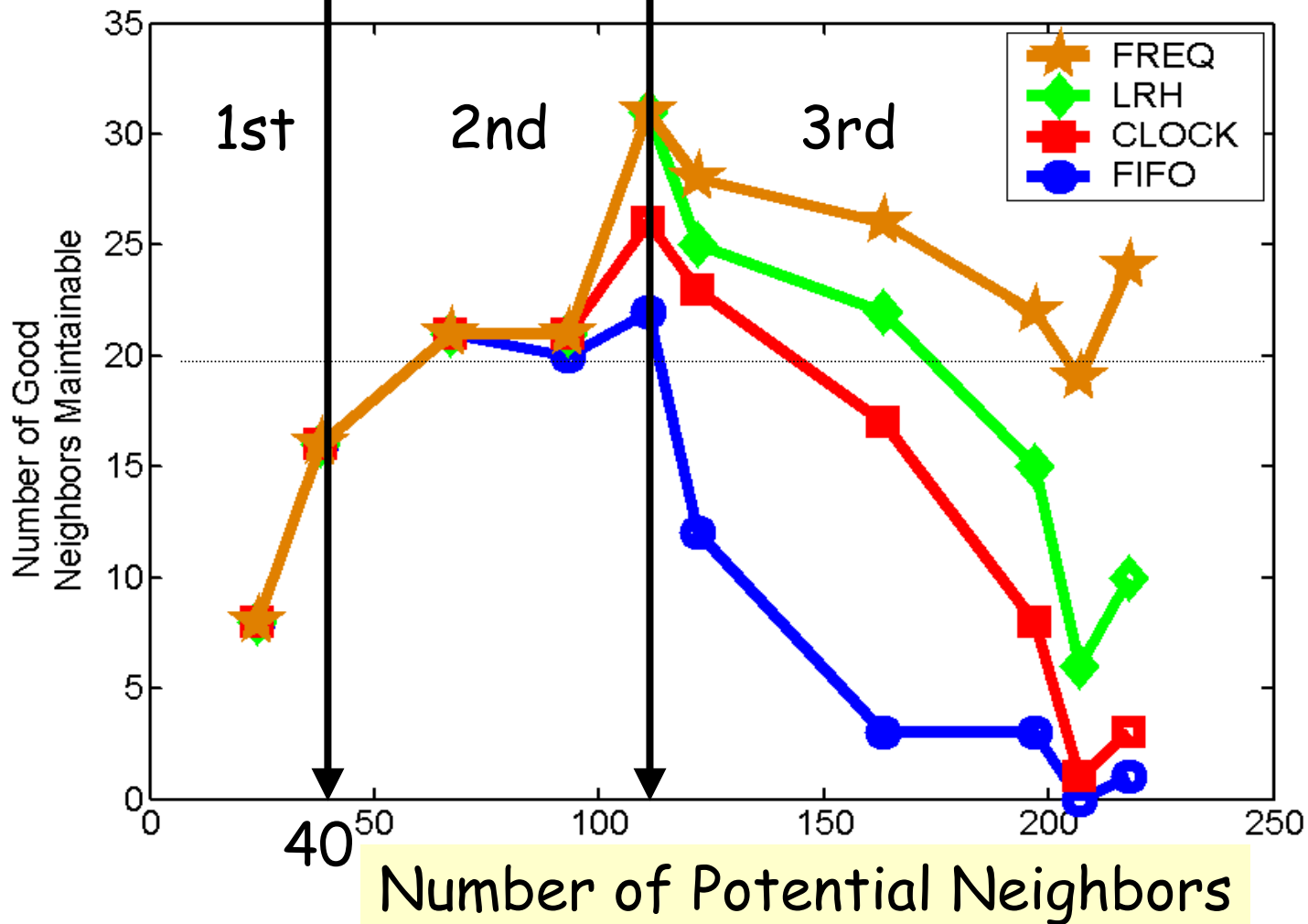


General solution:

- down-sample to suppress gray nodes
- maintain frequent nodes

# Cache Policies vs. Freq Algorithm

- Fixed-size table as cell density increases

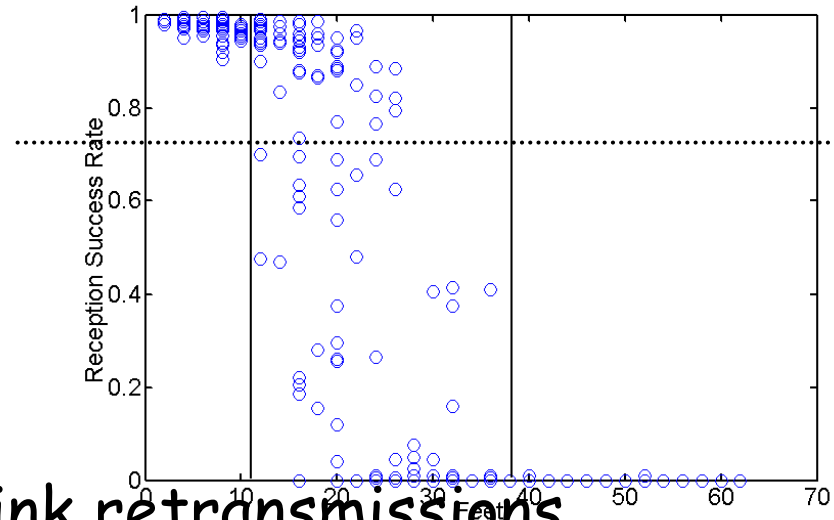


# Good neighbors > Table size

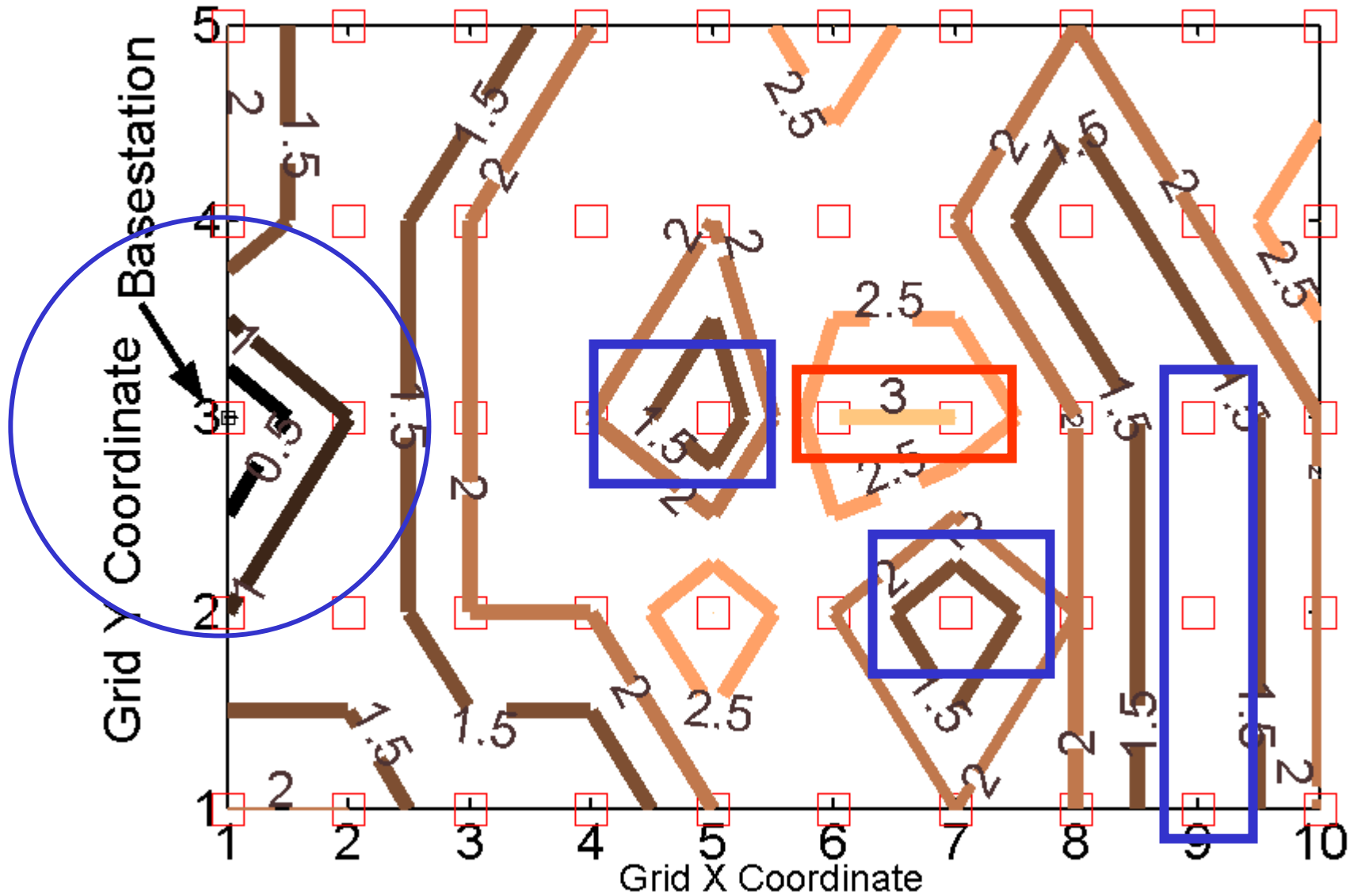
Freq always maintains 50% or more good neighbors in table

# Distributed Tree Building

- Connectivity based rather than hop based
  - Operate over link estimator and neighbor management
  - node sends route messages periodically (min rate)
    - Carry "cost" to tree root
    - Piggyback link estimations
- Shortest path with hard threshold
  - Instability
  - Network partition
- Min. Exp. Transmissions
  - Non-threshold based
  - Tradeoff long hops with link retransmissions



# Average Hop-Count Contour Plot



# Topology Stability

- In-networking processing prefers stability
  - Unlike mobile computing
  - Robustness
  - Tradeoff link quality for topology stability
- Techniques
  - Route dampening
  - Parent switching threshold
  - Higher-layer informed routing

# Caveats

- Congested traffic
  - Link quality drops under traffic load
    - Hidden-node and other issues
    - Put congested traffic over tree built based on low-data rate can be problematic
  - Neighborhood and connectivity estimation under high traffic load

# Broadcast-Based Routing Revisit

- Improvement in July NEST demo
  - Additional "back off" above the MAC
    - Idle means "no broadcast" has been heard for  $T$  sec
  - signal-strength filtering
  - "strong-first" shadowing
- Routing tree is fairly reliable
  - 36 nodes spread over Woz. Lounge
  - Parent = shortest-hop parent above the signal-strength threshold
  - Built a 2-hop tree once and run for 3 hours
    - 96% end-to-end success rate with 0.3 retransmission on average along the entire path

# Potential Routing Framework

