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

Effective Region
Determine Node spacing

Communication range?
- Discover connectivity = link estimation

How to define a “neighbor”?
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

Get in
Neighbor Table
Get out

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

Grid Y Coordinate

Grid X Coordinate

Basestation
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

Application

Application Dispatch

Intelligent Broadcast
Other Routing
Reliable Routing

Active Message

Neighbor Management

Link Estimator

List of neighbors, neighbor preference

(Stability, Prefer Parent, Min rate)