CS551
Ad-hoc Routing

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Mobile Routing Alternatives

- Why not just assume a base station?
  - good for many cases, but not some (military, disaster recovery, sensor nets)
- Why not just use regular Internet routing?
  - completely different assumptions about stability, hierarchy
  - but might work well for fixed wireless
- Why not just flood the data to all nodes?
  - best choice for rapid movement, but doesn't work for many nodes and much traffic

Ad-hoc Routing Goals

- Paths should be:
  - multi-hop paths
  - loop-free
  - inexpensive to set up
  - robust to node movement
- System should autoconfigure, adapt to movement
- Low memory, bandwidth, energy required
  - scalable with numbers of nodes
  - localize effects of link failure
- Multicast?
  - not here :-)

Problems With Traditional Approaches

- Periodic (a priori) routing or LS updates are expensive
- Dynamic topology problems:
  - frequent LS updates
  - algorithm must converge very quickly to avoid blackholes
- Many "links" in wireless (many nodes can hear each other)
  ⇒ large routing tables/msgs
- Not studied in the context of realistic radio propagation models, MAC layers and mobility patterns

Ad Hoc Routing

- Create multi-hop connectivity among set of wireless, possibly moving, nodes
  - typically trustworthy (more or less)
  - want low energy consumption
  - implications: cannot use hierarchical addressing, assume things will change
- Mobile, wireless hosts act as forwarding nodes as well as end systems
- Need routing protocol to find multi-hop paths
  - Needs to be dynamic to adapt to new routes, movement
  - Interesting challenges related to interference and power limitations

Problems Using DV or LS

- DV protocols may form loops
  - very wasteful in wireless: bandwidth, power
  - loop avoidance sometimes complex
- LS protocols: high storage and communication overhead
- More links in wireless (e.g., clusters) - may be redundant
  ⇒ higher protocol overhead

..Problems

- Periodic updates waste power
  - tx sends portion of battery power into air
  - reception requires less power, but periodic updates prevent mobile from "sleeping"
- Convergence may be slower in conventional networks but must be fast in ad-hoc networks and be done without frequent updates

Proposed Protocols

- A priori protocols (DSDV, TORA) pre-compute routing tables
  - Destination-Sequenced Distance Vector (DSDV)
    - hbh, DV protocol w/periodic routing update broadcasts
  - Temporally-Ordered Routing Algorithm (TORA)
    - on demand creation of hbh routes based on link-reversal
- On-demand protocols (DSR, AODV) compute routes *lazily* (only when needed)
  - *Dynamic Source Routing (DSR)*
    - on demand source route discovery
  - Ad Hoc On-Demand Distance Vector (AODV)
    - combination of DSR and DSDV: on demand route discovery with hbh routing

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Dynamic Source Routing in Wireless Networks
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Key Ideas

- Ad-hoc routing: routing in multi-hop networks of mobile nodes
  - no base stations
- Note that this goes way back: DARPA packet radio in the early '70s

DSR

- Components:
  - route discovery
  - route maintenance
- Route discovery - basic idea
  - S floods route-request to D
  - each node forwards request by adding own address and re-broadcasting
  - requests propagate outward until target is found

Route Requests (RREQ) and Replies (RREP)

- A request (w/new hop) is forwarded if:
  - not a duplicate
  - node is not the destination (if D, then send RREP reply)
  - node not already listed in recorded source route (loop suppression)
- Replies at D are returned to S via
  - source route from D's cache
  - invert source route (not preferred because of potential asymmetry)
  - piggy-backed on another route request from D to S

Route Maintenance

- Several options to detect broken "links":
  - use link-level info (if present)
  - passive ACKs (listen for data to be forwarded)
  - end-to-end

Route Cache

- Keep all source routes in route cache (reuse if possible)
- Can short-circuit RREQs if it matches the cache
  - just generate a reply
  - but make sure you don't step on your neighbors
- Can eavesdrop to pre-fill route cache

Other Optimizations

- Piggybacking
  - Data messages on the initial route request
  - Reply messages on the reverse route request
  - Need to do this carefully
    - ... interacts with route cache optimization
- Hop short-cuts
  - If a node notices that the packet has skipped a hop, it can send an unsolicited route reply
- Optimized error handling
  - Rate limiting requests: need to worry about partitions
  - Snooping error messages

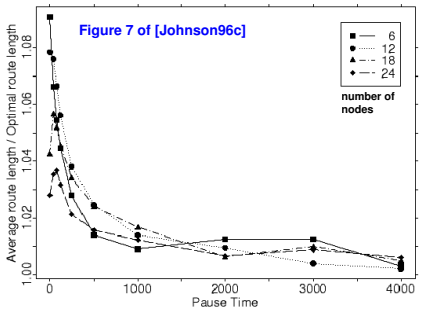
Sending Data

- Check cache for route to D
- If route exists then
  - if reachable in one hop
    - send packet
  - else insert routing header to D and send
- If route does not exist, buffer packet and initiate route discovery

Performance Evaluation

- Models for
  - traffic: random pairs sending pseudo-CBR
  - mobility: random waypoint
  - node placement: random
- Metrics
  - path-length relative to optimal
  - message count relative to optimal

Mean Route Length vs. Movement



Discussion

- Source routing is good for on-demand routes instead of a priori distribution
- Route discovery protocol used to obtain routes on demand
  - Caching used to minimize use of discovery
- Periodic messages avoided
- But need to buffer packets

Discussion

- Context
  - Ad-hoc networks was in its early stages of development
- Impact
  - Showed that these networks needed a differrent routing architecture
- Discussion
  - Good, clean design
  - Simple and useful performance optimization tricks
- Other comments
  - The field is still looking for non-military applications

Other Observations?

- What do people use ad hoc routing today?
  - sensor nets
  - cars on highways (mostly single-hop)
  - military/disaster recovery applications
  - mesh networking (at places where there is no infrastructure)
  - small-scale sharing with workgroups could use it, but today most people use floppy/zip disks or CD-RW
  - vs. most laptop users today use basestations
- What are alternatives?