A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols

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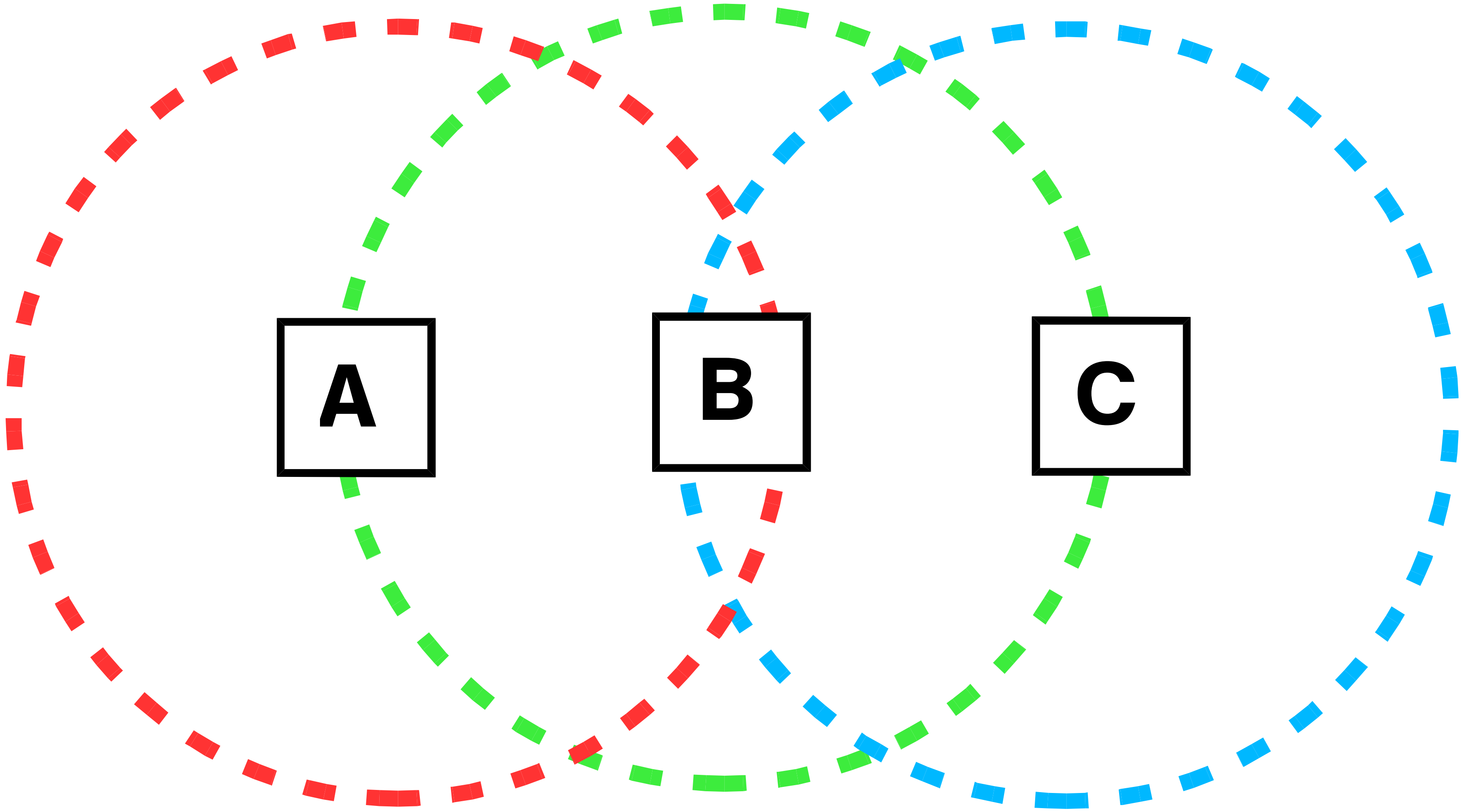
What is ”Ad Hoc”?

- Attributes:
  - collection of wireless mobile nodes
  - dynamically forming a temporary network
  - without the use of any existing network infrastructure or centralized administration
  - multiple hops may be required to cross network

Multi-Hop Motivation



Evaluation Metrics

- What's a "good" ad hoc routing protocol?
  - packet delivery ratio
    - # packets sent by applications *vs.* # packets received
    - describes the "loss rate" seen by transport layer
  - routing overhead
    - determines scalability, performance in low-bandwidth/congested environments, battery consumption...
  - path optimality

Design Assumptions

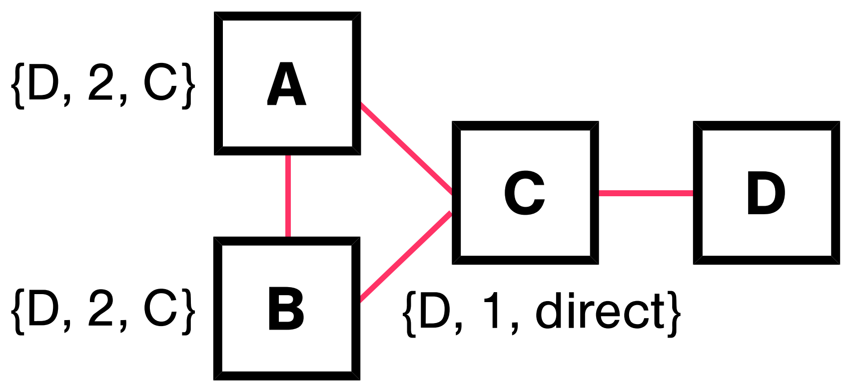
- What is your physical environment?
  - how many nodes?
  - do nodes move?
    - how often?
    - how quickly?
  - radio attenuation model? (*e.g.*, r^{-2}–r^{-4})
    - “reference distance” (*e.g.*, 100m)
    - free space propagation, 2-ray ground reflection, ...

Design Assumptions
(continued)

- Medium Access Control
  - carrier sense (physical, virtual)
  - acknowledgement mechanism
- Packet Buffering
  - how long can a node wait before *sending?*
  - how long can a node wait before *forwarding?*

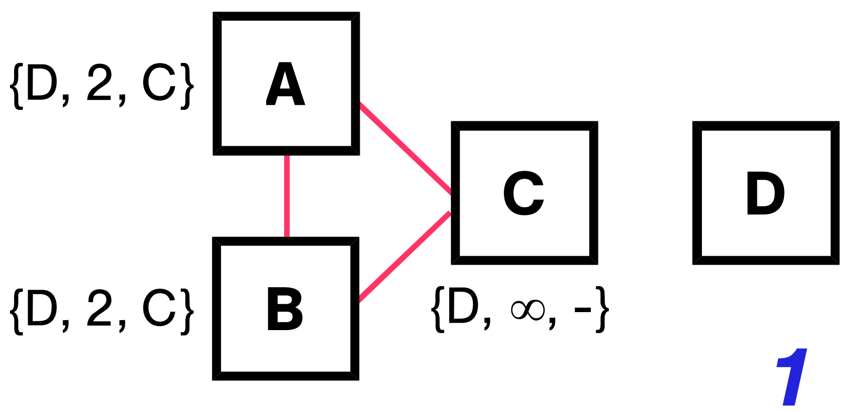
Destination Sequenced Distance Vector

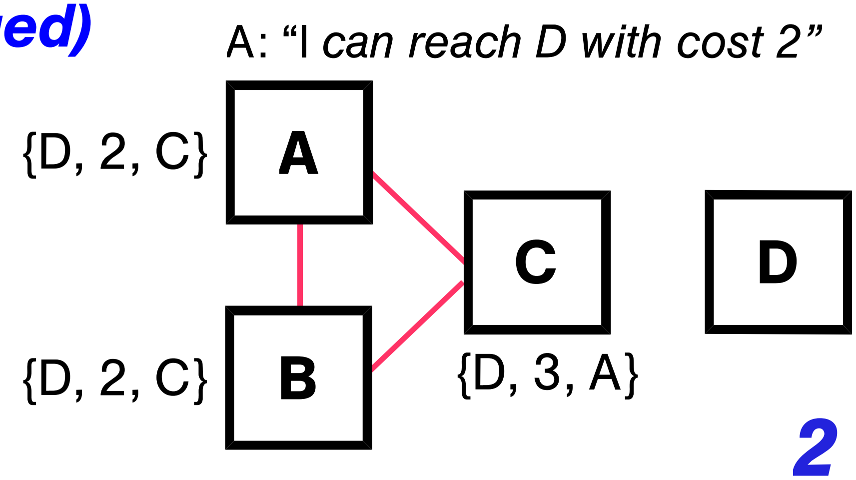
- *Distance Vector*
  - every node maintains a table of {*destination, distance, next_hop*} entries for all destinations
    - periodically test link to each immediate neighbor
    - broadcast entire table of least-cost estimates
  - count-to-infinity

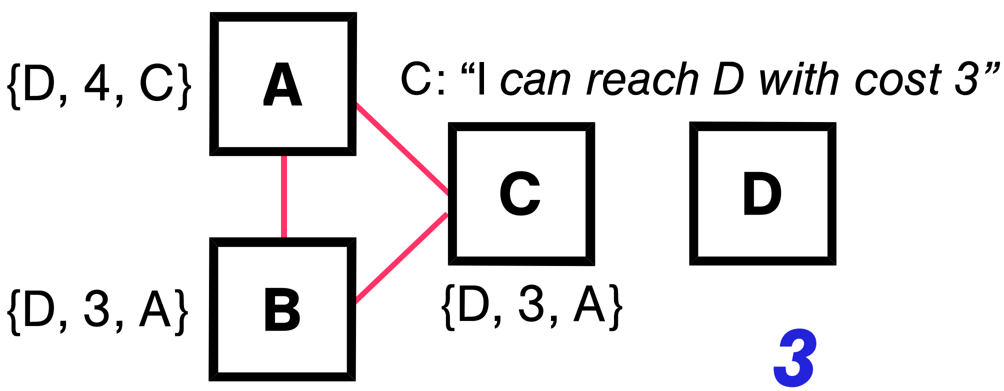


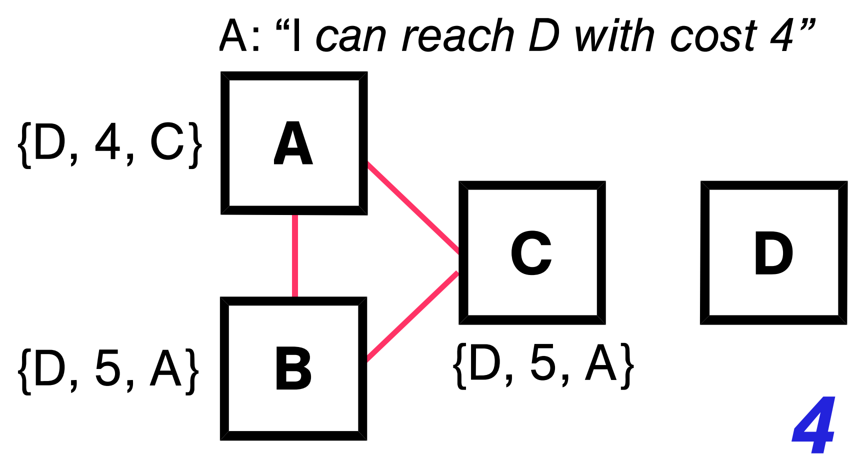
(all links have unit cost)

DSDV
(continued)









DSDV

(continued)

- How to deal with count-to-infinity?
  - split horizon, split horizon with poisoned reverse
  - sequence numbers
    - normal updates have even sequence numbers
    - in case of link failure, use odd sequence number
      - prevents ”stale” information from clobbering ”fresh” info
      - would have stopped **A** at step 2 in the example

Performance of DSDV

- Simulation results
  - fails to converge if nodes don't pause for at least 300 seconds during movement
    - 70%-92% delivery ratio at higher rate of mobility
    - lost packets due to stale routing entries
  - routing overhead is constant with respect to mobility rate (periodic protocol)
  - nearly optimal path selection

Dynamic Source Routing

- Problems with traditional routing protocols
  - large, periodic updates are wasteful
    - redundant information
    - waste bandwidth
    - waste battery power
  - topology changes may involve more than link status
  - routes may not be bi-directional

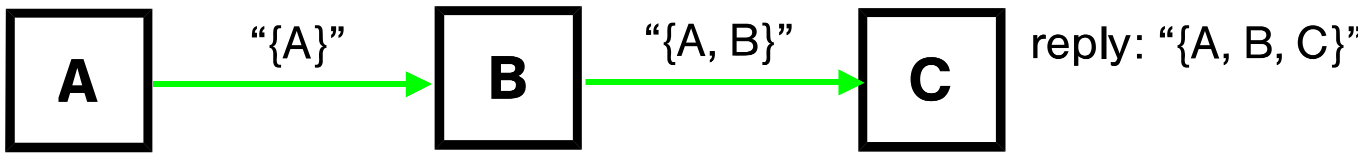
(source: *Ad Hoc Wireless Networking Using Dynamic Source Routing*, David B. Johnson, Spring 1997 15-839A)

DSR
(continued)

- Source Routing
  - each packet contains a complete, ordered route
  - intermediate nodes do not need to maintain up-to-date routing information
  - on-demand protocol
    - eliminates periodic route advertisement
    - eliminates neighbor detection protocols

DSR
(continued)

- Route Discovery
  - flood *route request* message through network
  - request answered with *route reply* by:
    - destination
    - some other node that knows a path to the destination



  - nodes remember/overhear routes
    - maintain route cache
    - use cache to limit propagation of route requests

DSR
(continued)

- Route Maintenance
  - if 2 nodes listed next to each other in route move out of range
    - return *route error* message to sender
    - sender can use another route in its routing cache
    - sender can invoke Route Discovery again

Performance of DSR

- Simulation results
  - packet delivery ratio is independent of traffic load (greater than 95%)
  - incremental cost of adding new sources decreases as sources are added
    - can re-use information about other routes
    - scoping of route requests via route cache
  - nearly optimal path selection

Results

- DSDV performs predictably
  - delivers virtually all data packets...
  - ...for low node mobility rate & movement speed
  - fails to converge for increased mobility
- DSR
  - performs well at all mobility rates & movement speeds
  - increased number of routing overhead bytes per datagram

Questions

- What scenarios fit this communications model?
  - lots of peer nodes with processing & bandwidth
  - take advantage of snooping & caching?
  - variable latency in delivery?
  - communication with the “outside world” may not be instantaneously available