Ad Hoc Wireless Routing

COS 461: Computer Networks

http://www.cs.princeton.edu/courses/archive/spr14/cos461/

Outline

- What are Ad Hoc Networks?
- Assumptions and Challenges for Routing
- Four Routing Protocols: DSDV, TORA, AODV, and DSR
- How well do these protocols perform?

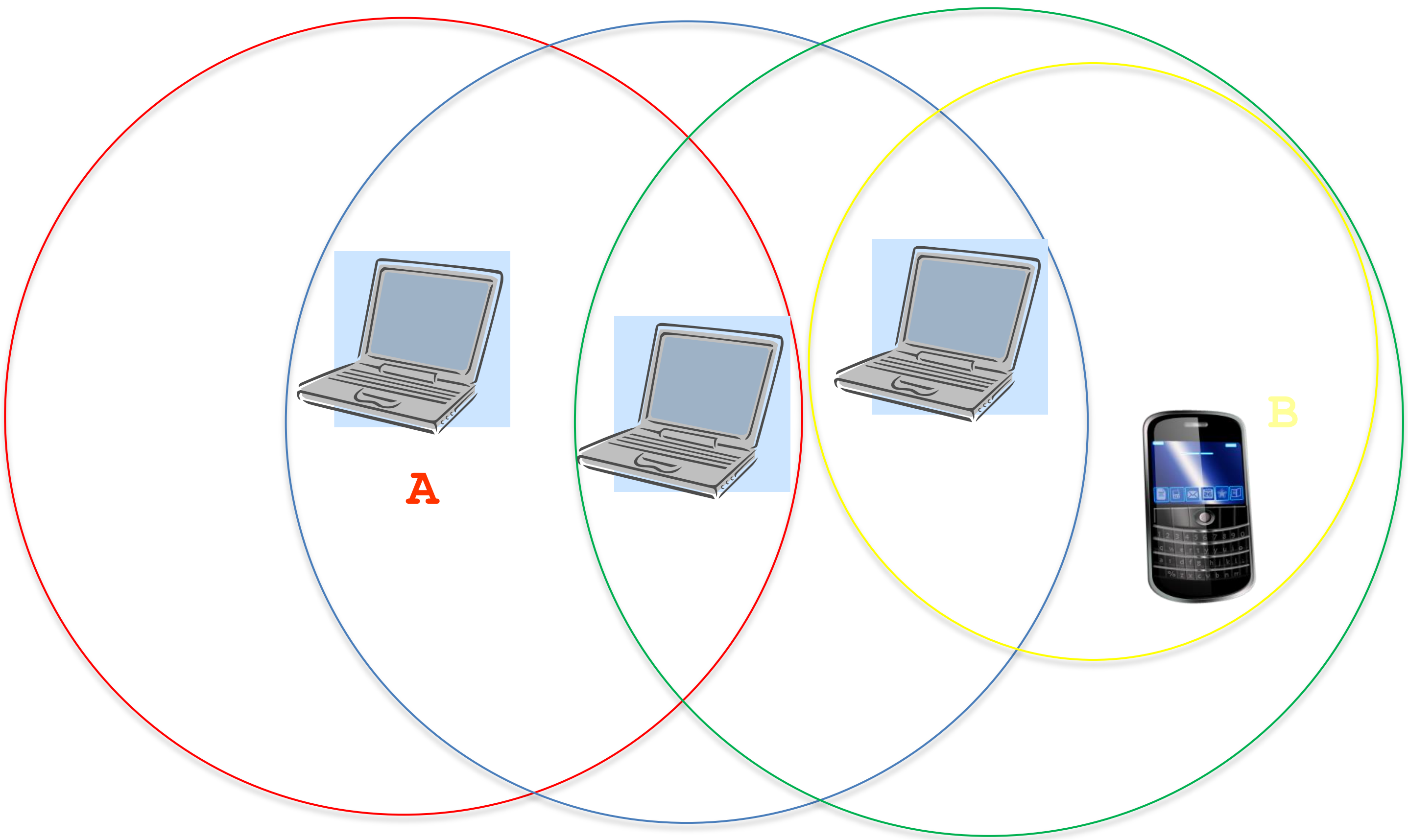
Reference for this lecture: J. Broch, et al. "A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols", *MOBICOMM 1998*: 85-97

Ad Hoc Wireless Network

Infrastructureless: No centralized administration

Nodes move freely within and out of network

Nodes act as hosts and routers



A->B?

Assumptions

- 802.11 MAC with Distributed Coordination Function (DCF)

  Physical carrier sensing

  Virtual carrier sensing (RTS/CTS)

  Link breakage detection

- Address Resolution: ARP

  Broadcasting requests and managing replies harder in this environment.

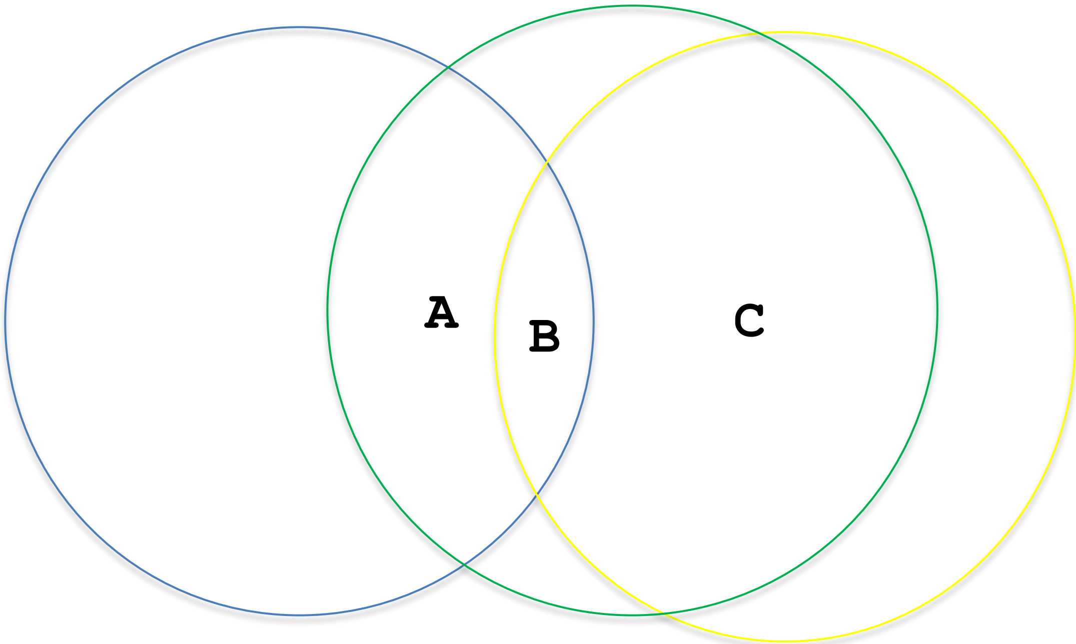
Challenges for Routing

- Dynamic topology

  Node mobility

  Transmission ranges

  Node routing preferences



Challenges for Routing

- Broadcast packets not work as well

  No RTS/CTS exchanged

  Collisions account for loss

  Use random back-off to avoid synchronization

Challenges for Routing

- Managing Queues

  For ARP, pace packets sent to ARP queue or have the space to buffer many packets awaiting ARP reply.

  For transmitting packets, prioritize routing packets in queue followed by ARP and data.

Overview of Protocols

- Bellman Ford variants: DSDV, AODV

  DSDV – avoids loops and count-to-infinity

  AODV - on-demand, no periodic updates

- Link Reversal: TORA

  Loop-free, quick routes, localize changes

- Source Path: DSR

  Packets route themselves; minimize route advertisements and neighbor detection

Destination-Sequenced Distance Vector (DSDV)

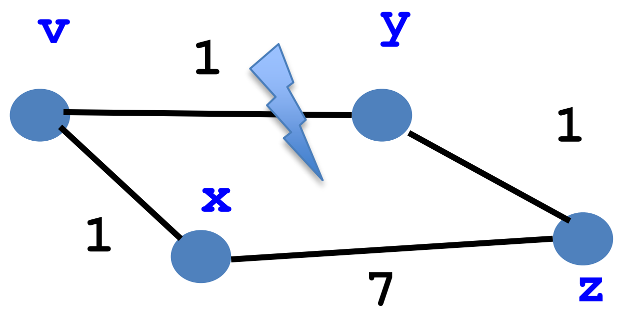
- Bellman-Ford variant
- Each node keeps routing table with next hop to each destination with metric and destination sequence number (SN).
- A route with greater SN is chosen.

DSDV

- If two routes have equal SN, then lower metric route is chosen.
- Each node maintains its own increasing even SN.
- Updates broadcast periodically and upon SN, metric, or topological changes.

DSDV

When topological change discovered:



- V advertised route to Z of cost 2, SN=102
- If V thinks route to Z broken, V advertises route to Z of infinite cost, SN = 103
- X would put infinite metric route in routing table until it gets update from Z with SN > 103

Temporally-Ordered Routing Algorithm (TORA)

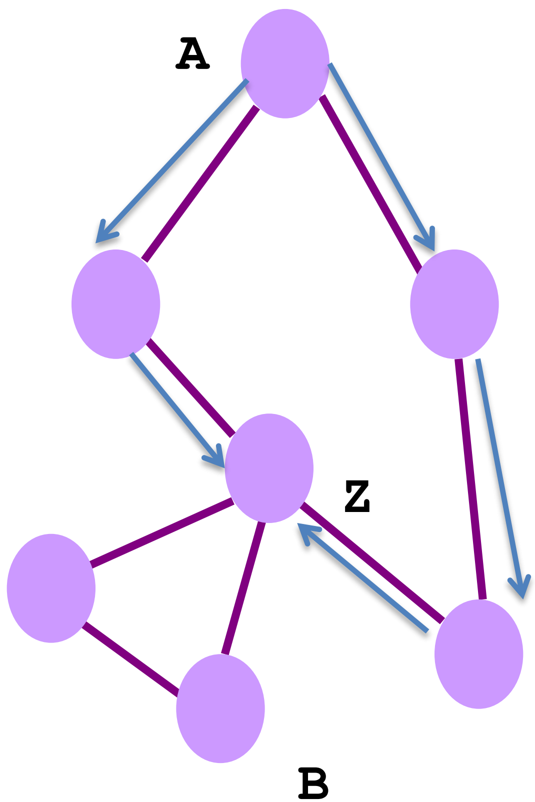
- “Link Reversal Algorithm” – discovers and maintains multiple routes to destination on demand and quickly
- Shortest path not as important

TORA

- Route traffic towards desired destination.
- If a node becomes blocked, pass traffic to its neighbors by setting its height greater than its neighbors.

TORA

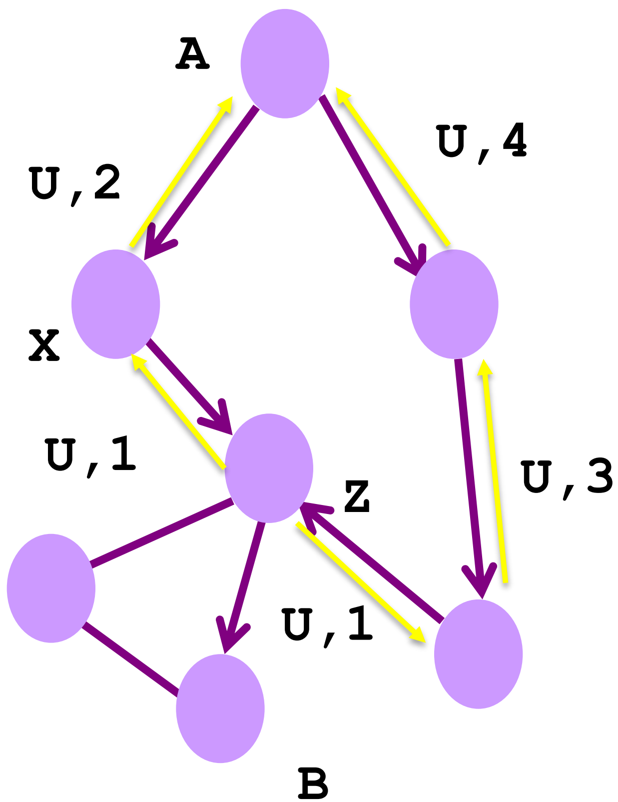
- A needs a route to B



1. A will broadcast a QUERY packet, dest=B
2. B or node with route to B will broadcast UPDATE packet with height from B
3. In this case Z will broadcast UPDATE packet with height of 1 to B

TORA

- A needs a route to B



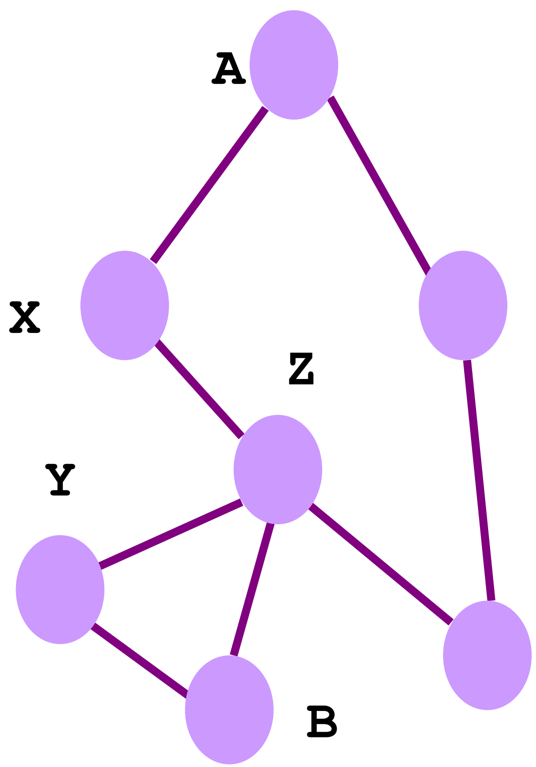
1. Z broadcasts update creating directed link between itself and B.
2. All nodes receiving UPDATE packets set height to B to be greater than in received update.
3. Nodes broadcast UPDATE to source of QUERY
4. UPDATEs create directed links from A to Z and a directed acyclic graph, DAG, with B as sink

TORA

- If route to destination no longer valid, nodes will set height to maximum value of its neighbors and UPDATE.
- If no new route is found, node will send CLEAR packet to remove invalid routes.
- Internet MANET Encapsulation Protocol (IMEP): for routing control messages and notification for broken/created links (BEACON/HELLO)

Dynamic Source Routing (DSR)

- Source based: Packet headers contain complete route of nodes to traverse in order.

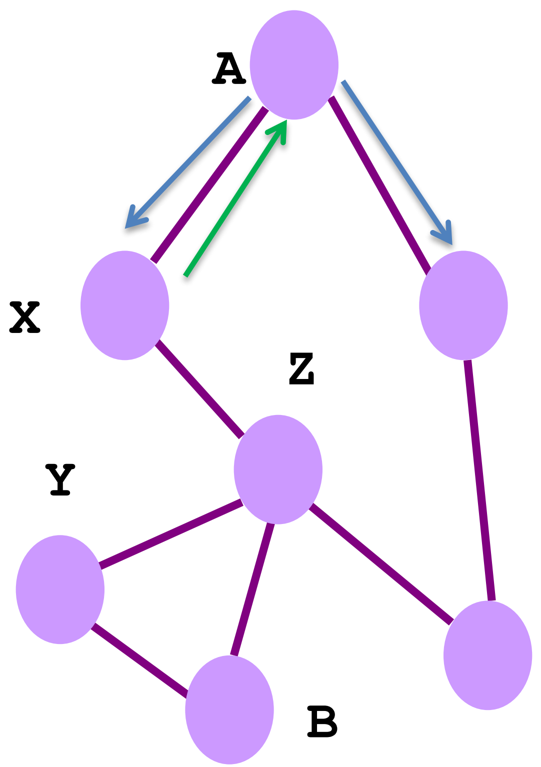


Within DSR source route option header in IP payload, before data:

IP address of X
IP address of Z
IP address of Y
IP address of B

DSR Route Discovery

- A needs a route to B



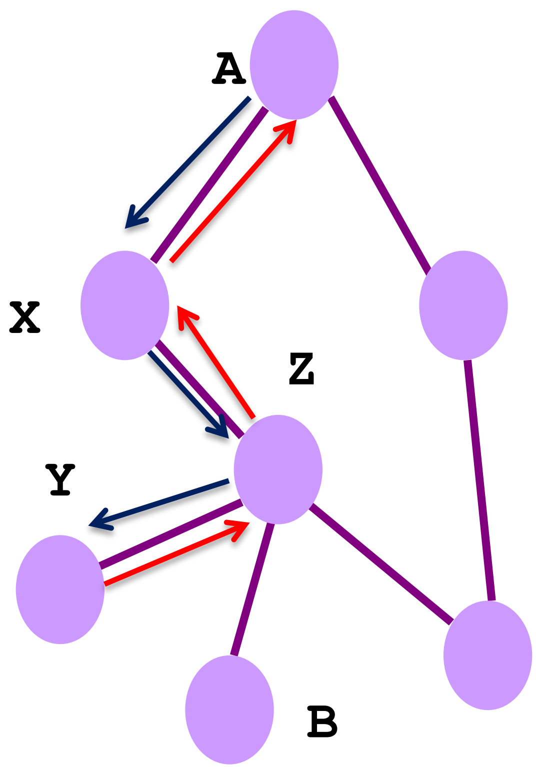
1. A broadcasts a ROUTE REQUEST, packet, dest=B using hop limit to limit propagation
2. If hop limit = 0, neighbor replies with ROUTE REPLY if it is B or has route to B
3. If no neighbor replies, A will send another request with greater hop limit to propagate the request.
4. In this example, X replies with a ROUTE REPLY to A.

DSR Route Maintenance

- Caching
- Nodes maintain cache of routes from route discovery and eavesdropping.
- Nodes will return ROUTE REPLY if cache contains shorter path.
- If forwarding packets and route broken, node will attempt to fix broken path from cache and retransmit before dropping.

DSR Route Maintenance

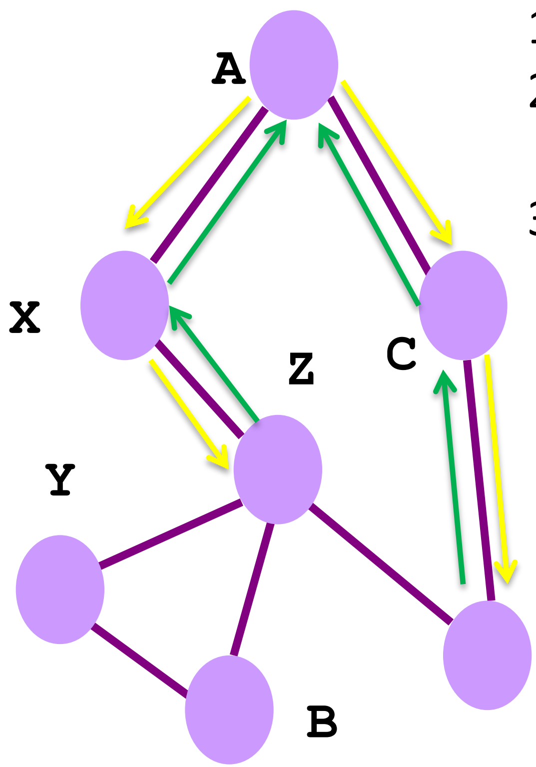
ROUTE ERROR packets: A sending data to B



1. A unicasts data to B on path discovered
2. Y discovers link to B is broken.
3. Y unicasts ROUTE ERROR packet to Z.
4. ROUTE ERROR packets indicate broken link.
5. ROUTE ERROR packets are propagated back to A.
6. Each node receiving ROUTE ERROR packet removes routes using the Y<->B link from its cache.

Ad Hoc On-Demand Distance Vector (AODV)

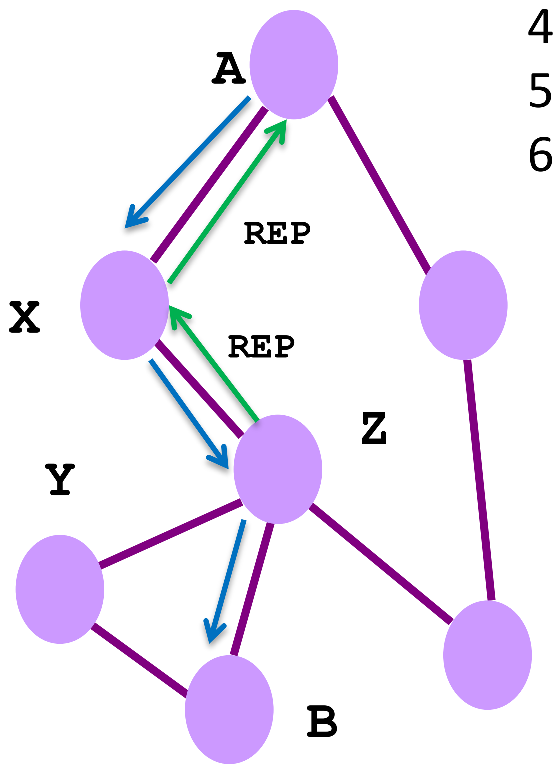
- Bellman Ford variant like DSDV uses SN
- Like DSR, on demand route discovery: A->B



1. A broadcast ROUTE REQUEST, dest=B, SN=102
2. X and C broadcast forward the REQUEST and create reverse route to A
3. Z has a route to B of 1 hop and SN = 104.

AODV

- Route Discovery: A->B



4. Z will unicast ROUTE REPLY on the reverse route.
5. This creates the forward route for data.
6. A will accept route since it has greater SN.

AODV Route Maintenance

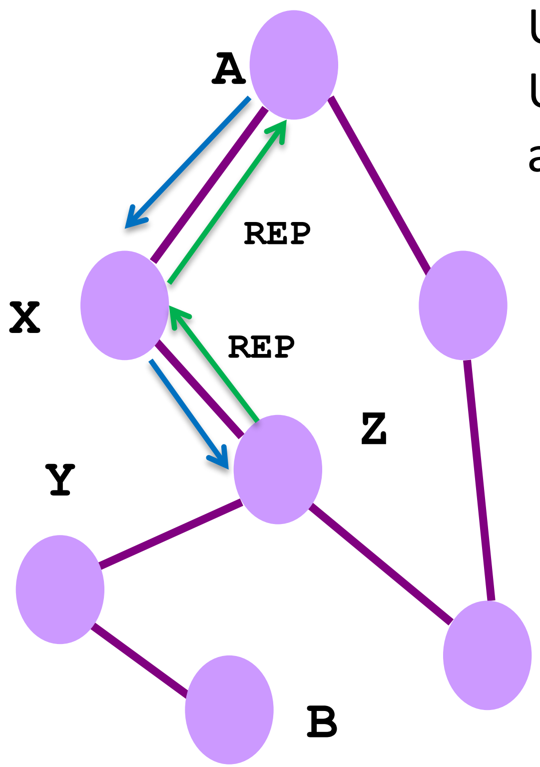
- No cache and no full routes
- Only routing table entries for reverse path and forward path next hops
- Routing table entries have timeouts

AODV Link Detection

- Periodic HELLO messages for maintaining neighbors
- If don’t hear from neighbor in 3s, assume broken link

AODV Broken Link

- UNSOLICITED ROUTE REPLY



Upon discovering Z->B link is down, Z sends an UNSOLICITED ROUTE REPLY with infinite metric to all nodes that used the forward path.

Performance?

- Depends on the metric

1. *Packet delivery ratio*: ratio of packets sent/packets received between application layers
2. *Routing overhead*: total number of routing packets sent
3. *Path optimality*: how close to shortest path

- Depends on how quickly the topology of network is changing

Packet Delivery Ratio

- Assume same number of nodes and constant mobility. Rank the algorithms from best to worst packet delivery ratio:

DSDV 4

TORA 3

DSR 1

AODV 2

Routing Overhead

- Assume same number of nodes and constant mobility. Rank the algorithms from best to worst routing overhead:

DSDV 2

TORA 4

DSR 1

AODV 3

Path Optimality

- Assume same number of nodes and constant mobility.
- Which two algorithms have best path optimality?

DSDV, DSR

- Which two algorithms have the worst?

TORA, AODV