Ad Hoc Routing Protocols and Issues

Stefano Basagni
ECE Dept
Northeastern University

Boston, Jan 2003

Ad hoc **(AD-HAHK or AD-HOKE)-Adjective**

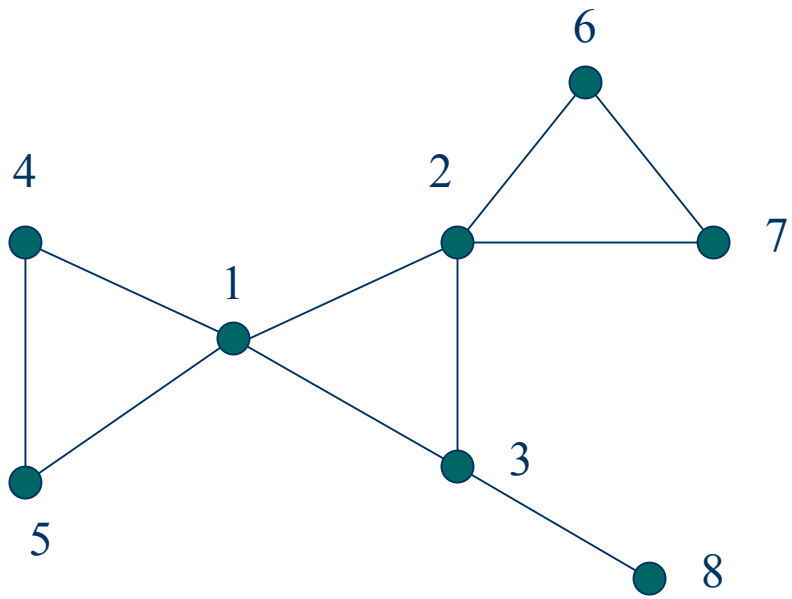
- a) Concerned with a particular end or purpose, and b) formed or used for specific or immediate problems or needs
- Fashioned from whatever is immediately available: improvised

Example sentence: *When the mayor learned that the mill, the town's major employer, was scheduled to close, he assembled an ad hoc committee to address the crisis*

Ad Hoc Networks

- A “Mobile Ad hoc NETwork’’ (MANET) is an autonomous system of mobile routers (and associated hosts) connected by wireless links, the union of which forms an arbitrary graph
- The routers are free to move randomly and organize themselves arbitrarily
- The network’s wireless topology may change rapidly and unpredictably

A Simple Ad Hoc Network



Emerging MANETs

Taxonomy

1. IETF MANETs
2. Bluetooth technology
3. Mobile RFID networks
4. Tactical mutli-hop radio networks

Applications

1. “Ad hoc” emergency services, entertainment assistance
2. Foot-loose, cable free portable computing
3. Ad hoc sensor networks
4. Tactical missions, communication in the battlefield

Ad Hoc Routing

- Point-to-point communication (routing)
  - Adapting solutions for wired networks
  - New proposals to cope with mobility “and stuff”

Ad Hoc Routing

- Multi-hop point-to-point communication
- Internet kind of routing: Every node is a switch (well, if it wants to)
- First attempts: Adapting solutions for wired networks

Routing the Old Way: Link-State Protocols

- Based on broadcast (e.g., OPSF)
- Each node maintains information on the state of the links established between the other nodes
- Very expensive, especially in terms of bandwidth
- Exceptions: Clustering based routing and the STAR protocol (J.J.'s)

Routing the Old Way: Table-Driven or Proactive Solutions

- Each node maintains one or more routing table
- Changes in the network topology are dealt with by propagating updates
- A consistent network view is maintained
- Existing protocols differ in the number of routing table maintained and in updates propagation methods

Proactive Routing: DSDV

- Destination-Sequenced Distance-Vector routing [Perkins+,1994]
- Ad Hoc Bellman-Ford with loop freedom
- Each node maintains a routing table with one entry for each possible destination
- Distance to every other node is kept updated
- Sequence number assigned by the destination

Proactive Routing: WRP

- Wireless Routing Protocol [Murthy+,1997]
- Each node maintains four tables
  1. Distance
  2. Routing
  3. Link-cost
  4. Message Retransmission List
- Loop freedom: Consistency check on the destination's predecessor

Proactive Solutions: Drawbacks

- Updates overhead, especially in presence of high mobility
- Overhead for enforcing loop freedom
- Large routing tables
- Low *scalability*
- ➢ Is it really necessary to maintain a consistent view of the network topology?

The Answer: Reactive Solution

- A route to a destination is sought for only when needed (on-demand routing)
- Route discovery process
  - A probe is sent (flooded) to discover a path to the destination
  - Upon receiving the probe the destination sends the probe back to the source
  - The probe “accumulates” the route

Reactive Solutions: AODV

- Ad hoc On-Demand Distance Vector routing [Perkins+, 1999]
- Based on DSDV
- Operations:
  - Check is valid route to destination is available
  - If not, path discovery via flooding RREQ
  - Loop freedom is based on destination sequence numbers

AODV, Cont.

- RREQ needs to reach the first node in the way to the destination that has a “fresh route” to it
- This implies route maintenance
  - Link failure notification messages toward the source
- For local topology maintenance nodes use “hello” messages or listen for retransmissions

Reactive Protocols: DSR

- Dynamic Source Routing [Johnson+, 1996]
- Based on “route caches” that store routes to destinations
- Caches are updates as soon as new routes are learned
- Two main phases
  - Route discovery
  - Route maintenance

DSR, Cont.

- Route discovery is via the broadcasting of a Route request packet that accumulates the route as it travels to the destination
- Route reply is sent either by the destination or the first node that has a cached route to the destination
- A Routing Record stores the hops in the route and it is then piggibacked to the data packet by the source

DSR, Cont.

- Route maintenance is based on Route Error packets and acknowledgments
- Route Error packets are triggered by MAC transmission errors
- Reception of a transmission error “cleans” the caches

Reactive Protocols: TORA

- Temporally-Ordered Routing Algorithm [Park+,1997]
- Based on the concept of Link Reversal
- Route creation is based on the creation of a DAG “rooted” at the destination

Reactive Protocols: Drawbacks

- The discovery phase introduces long delays
- Route discovery and maintenance is very sensitive to node mobility
- Route caching is memory greedy
- The size of the header of a data packet can become cumbersome (no scalability)
- ➢ Is the dependency on the network topology avoidable?

The Answer: GPS-Enabled Ad hoc Routing

- Nodes are equipped with positioning system devices (e.g., Global Positioning System receivers) that make them aware of their position
- This enabled “directional” routing
- Possible solutions differ on how the location information of the destination nodes is achieved

GPS Routing: DREAM

- Distance Routing Effect Algorithm for Mobility [Basagni+, 1998]
- A proactive, effective way to spread location information based on:
  - "Distance effect"
  - Mobility
- Robust and resource efficient

GPS Routing: LAR

- Location Aided Routing [Ko+, 1998]
- The location of a destination is sought for in an on-demand fashion (broadcast)
- Once the destination is found, the data packet is sent in the geographic area where the destination is supposed to be found

GPS Routing: Drawbacks

- Needs extra hardware
- Depends on the extra hardware limitation (and resource requirements)
- Scalability is an issue

Ad Hoc Routing: Some Issues

- Extensive comparisons are available for proactive and reactive protocols
- Comparisons are based only on numerical results (simulations)
- Comparisons regard mainly (avg.): Routing delays, “robustness,” throughput, message complexity, and, lately, energy consumption

Ad Hoc Routing: Some Issues, Cont.

- Lack of analytical results
- Scalability: Existing solutions do not deal well with increasing number of nodes (> 200 is already a problem)
- Energy-conserving solutions: Vague metrics
- Multicast: Several solutions but lack of comparisons and meaningful metrics

Ad Hoc Routing: Some Issues, Cont.

- Security
- Interaction with and influence of MAC protocols
- Location and tracking of user/resource
- Sensor Networks: transport networks with a very large number of nodes

Ad Hoc Routing: Some Issues, Cont.

- Personal area networks: Bluetooth, Hyperlan2 and IEEE 802.11
- Need to define meaningful “scenarios”
- Node addressing
- Topology discovery: Active (HELLO), passive, MAC aided?

A possible solution for scalability: Clustering

- Hierarchical organization of ad hoc networks
- We will see possible solutions tomorrow
- “To Go:” Think of some basic requirements for clustering ad hoc networks, e.g., in terms of:
  - Diameter of cluster
  - Cluster formation (distributed?, centralized?)
  - Mobility
  - Etc.