Ad Hoc Networks: Issues and Routing

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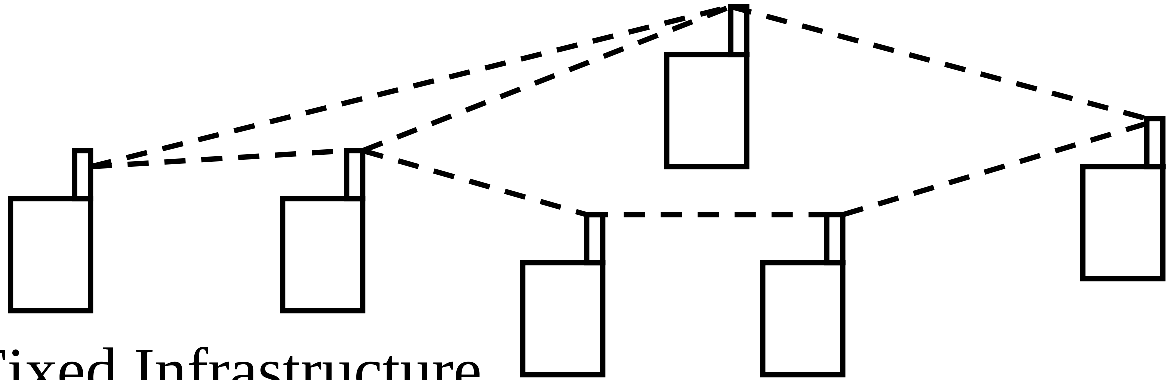
These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse574-06/

- Characteristics, Applications, Issues
- Cellular vs. Ad Hoc
- Routing: Requirements, parameters, classification
- Dynamic Source Routing (DSR)
- Ad Hoc On-demand Distance Vector (AODV)
- Optimized Link State Routing (OLSR)

Ad Hoc Networks: Characteristics



- No Fixed Infrastructure
- Dynamic Topology (Mobility)
- Multi-hopping: Obstacles, spectrum reuse, energy conservation
- Self-Organization: Addressing, routing, clustering, location, power control
- Energy conservation
- Scalability: Thousands of nodes
- Security: Limited
- Bandwidth constrained: Congestion is a norm

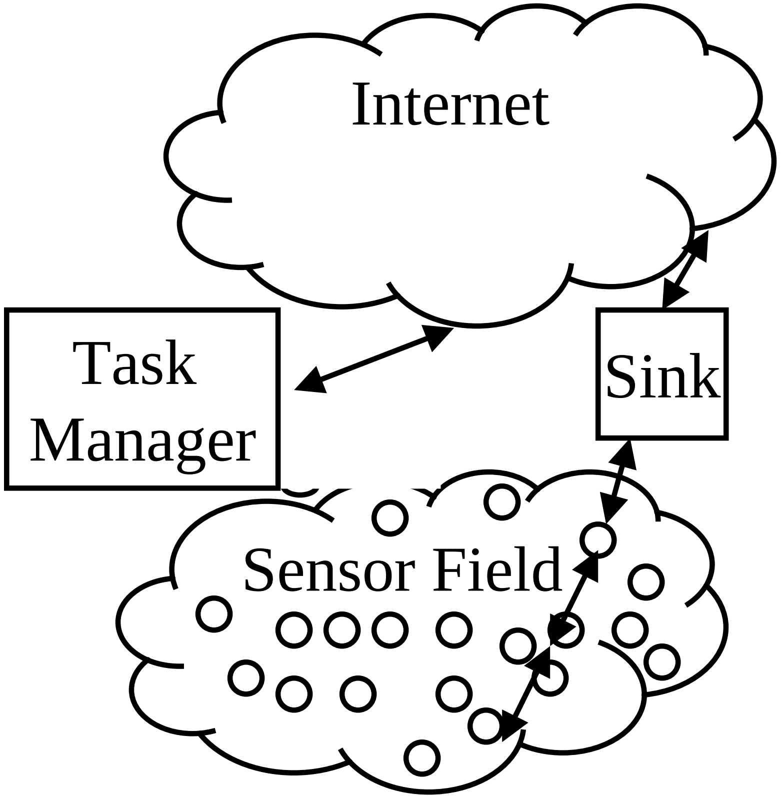
Ref: RFC2501

Ad Hoc Networks: Applications

- Emergency, Disasters
- Wearable computing
- Battlefield: Unmanned ground/airborne/underwater vehicles
- Hybrid: Multi-hop cellular
- Wireless Mesh Networks
- Sensor Networks

Sensor Networks

- A large number of **low-cost**, **low-power**, **multifunctional**, and small sensor nodes consisting of sensing, data processing, and communicating components
- Key Issues:
  1. Scalability
  2. Power consumption
  3. Fault tolerance
  4. Data Fusion
  5. Traffic: Low throughput, Delay sensitive



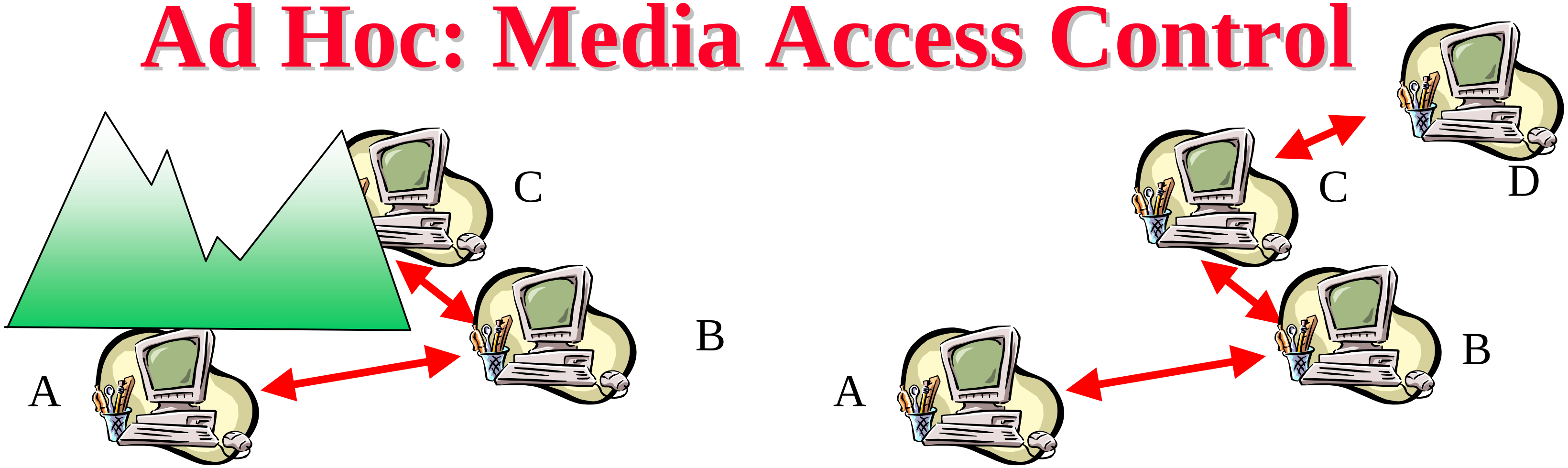
Issues in Ad Hoc Networks

1. **Medium Access**: Distributed, no time sync, directional antennas
2. **Routing**: Route acquisition delay, quick reconfig, loop free
3. **Multicasting**: Common in Ad-Hoc, Emergency/military
4. **Transport Layer**: Frequent path breaks
5. **QoS**
6. **Self-organization**: Neighbor discovery, report link failures
7. **Security**: DoS, jamming, energy depletion
8. **Energy management**: Transmission Power, battery monitoring, processor power
9. **Addressing and Service Discovery**: Global
10. **Pricing Scheme**: Incentives for relaying

Cellular vs. Ad Hoc

Cellular Network	Ad Hoc Networks
Fixed Infrastructure	Infrastructure-less
Single-hop wireless links	Multi-hop wireless links
Centralized routing	Distributed Routing
Base station: Single point of failure	Resilient
Seamless connectivity	Mobility $\Rightarrow$ Frequent link breaks
High cost and long deployment time	Quick and cost effective setup
Commercial sector	Defense, Emergency, Disaster
Simple Mobile, Complex Base	All complexity in Mobile
No forwarding fairness issues	Fairness: own vs other's traffic
Time Sync $\Rightarrow$ TDMA	Time Sync difficult $\Rightarrow$ CSMA
Static frequency reuse (cells)	Dynamic freq reuse $\Rightarrow$ CSMA

Ad Hoc: Media Access Control



- Fully distributed operation. CSMA.
- **Hidden Node**: Reachable from a receiving end of a link but not from the transmitting end.
  A cannot hear C, but can interfere with its transmissions to B
- **Exposed Node**: Other nodes in the vicinity cannot talk.
  When B is talking to A, C cannot talk to D
- Use of Directional Antennas, Steer-able antennas
- Multiple Access Collision Avoidance (MACA): Use RTS/CTS with Binary Back off, e.g., 802.11

Ad Hoc Routing: Requirements

- Fully distributed
- Global state (all nodes-all time) maintenance expensive
  $\Rightarrow$ Localized
- Loop-Free routing
- Minimize route acquisition delay: Proactive
- Quick route reconfiguration: Adaptive to Frequent changes. Changes in unrelated parts should not impact a node.
- Energy conservation: Sleep periods
- Unidirectional Link Support
- Minimize:
  - Bits Transmitted/Bits Delivered = Avg hops
  - Control bits/data bits = Overhead
  - Control packets/data packets = Overhead

Classification of Routing Protocols

- **Routing Updates**:
  - Proactive: Before needed
  - Reactive: On-demand
  - Hybrid: Combined. Know neighbors. Others on-demand.
- **Temporal Information**:
  - Past History
  - Prediction:Based on node lifetime, location
- **Topology Organization**:
  - Flat: Global addresses as in 802.11
  - Hierarchical: Geographical or Hop distance
- **Resource Optimization**:
  - Power-Aware: Local or global battery power
  - Geographical info based
  - Efficient Flooding

Murthy and Manoj list 40+ routing schemes for Ad-hoc nets.

Routing in Wired Networks: Review

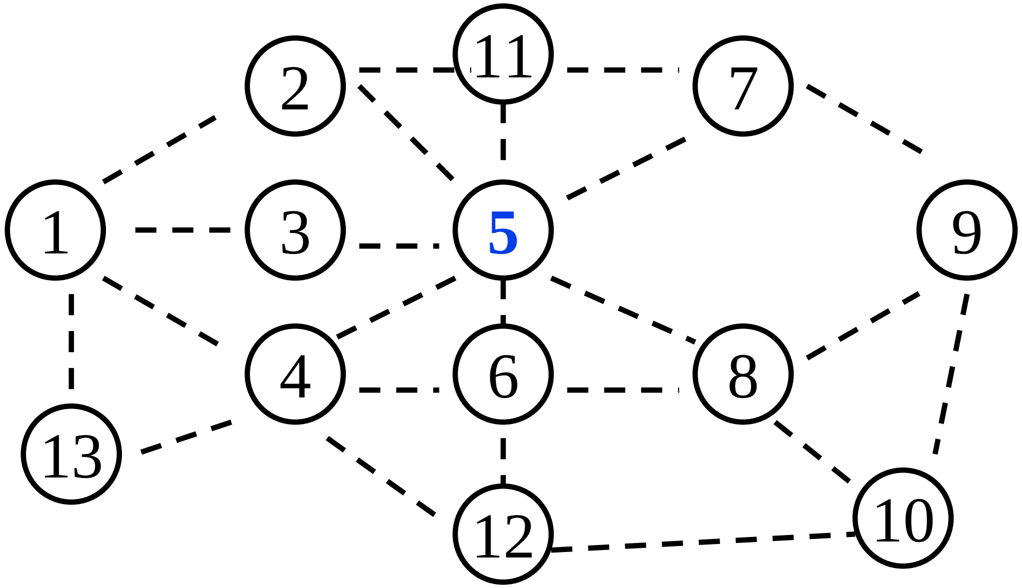
1. **Distance Vector**:
   - Each node sends its complete table (distances to all nodes in the network) to its neighbors
   - Large vectors to small number of nodes
   - Use Dijkstra's algorithm to compute the shorted path
   - Routing Information Protocol (RIP) is a distance vector protocol
2. **Link State**:
   - Each nodes sends its link information (distances to its neighbors) to all nodes in the network
   - Small vectors to large number of nodes
   - Use Bellman-Ford to compute the shortest path
   - Open Shorted Path First (OSPF) is a link state routing protocol

OLSR

- **O**ptimized **L**ink **S**tate **R**outing Protocol
- Proactive ⇒ Routes are prepared before needed
- Optimize ⇒ Min flooding duplication in highly connected nets
- Ask only a subset of your neighbors to forward your link states
  This is subset is your "*Multipoint Relay*" (**MPR**)
- If X is your MPR, you are X's "*MPR selector*"
- Each MPR has a set of MPR selectors
- Each node sends LS to all its neighbors
- MPRs forward LS of their MPR selectors
- Other neighbors use the information to compute routing tables
  But do not forward.
- OLSR significantly reduces the LS control traffic
- Ref: RFC 3626 and draft-ietf-manet-olsr**v2**-01.txt

OLSR: Example

- Node 5 has selected 4, 8 as MPR
- Node 5 sends a LS to 2, 3, 4, 6, 7, 11
- Nodes 5, 7, 8 use the info but do not forward
- Nodes 4 uses the info and forwards it to 1, 12, 13
- Node 8 uses the info and forwards it to 9, 10



Selection of MPR

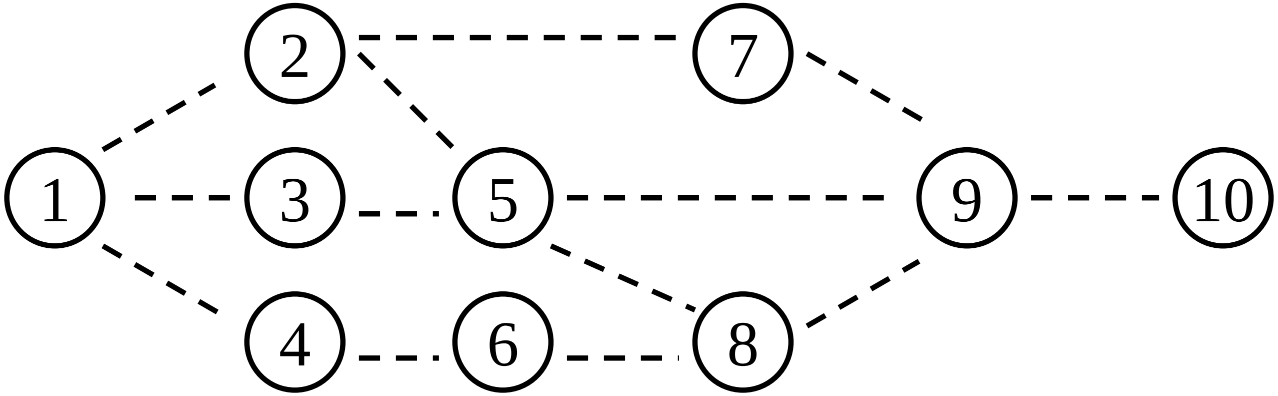
- Selection of MPR is arbitrary
- You can select all your neighbors as MPR
  $\Rightarrow$ Lots of duplication $\Rightarrow$ no optimization
- Optimal $\Rightarrow$ Min set such that all 2-hop neighbors get your LS
- Finding optimal MPR is NP-complete
- Heuristics:
  - N1(x) = 1-hop neighbors
  - N2(x) = 2-hop neighbors not covered
  - MPR(x) = MPRs of x = empty initially
  - From N1(x)-MPR(x), Select the node that has maximum connectivity to uncovered nodes
  - Add that node to MPR(x)

Dynamic Source Routing (DSR)

- On-Demand routing using "Source Route“
  On-demand ⇒ Reactive ⇒ Construct a route when needed
- Source Route = List of routers along the path.
  Strict source route, Loose source route
- **Routing database**: Complete route to recent destinations
- If a source-route is not available, send "*route request*" to all neighbors
- Each neighbor adds it self to the route in the request and forward to all its neighbors (only first receipt)
- If a node knows the route it appends the rest of the route and returns the "*route reply*"
- If a transmission fails, link error is sent to the source. All routes with that link are truncated.
- Disadvantage: Not suitable for high-mobility environments. Source-route overhead in each packet.
- Ref:draft-ietf-manet-dsr-10.txt

DSR: Example

- Node 1 sends RREQ to 2, 3, 4:
  "*Any one has a route to 15"*
- Nodes 2, 3, 4 send RREQ to 5, 6, 7
- Node 3 has 3-5-8-9-10
- Node 4 has 4-6-8-10
- Both nodes 3 and 4 respond.



AODV

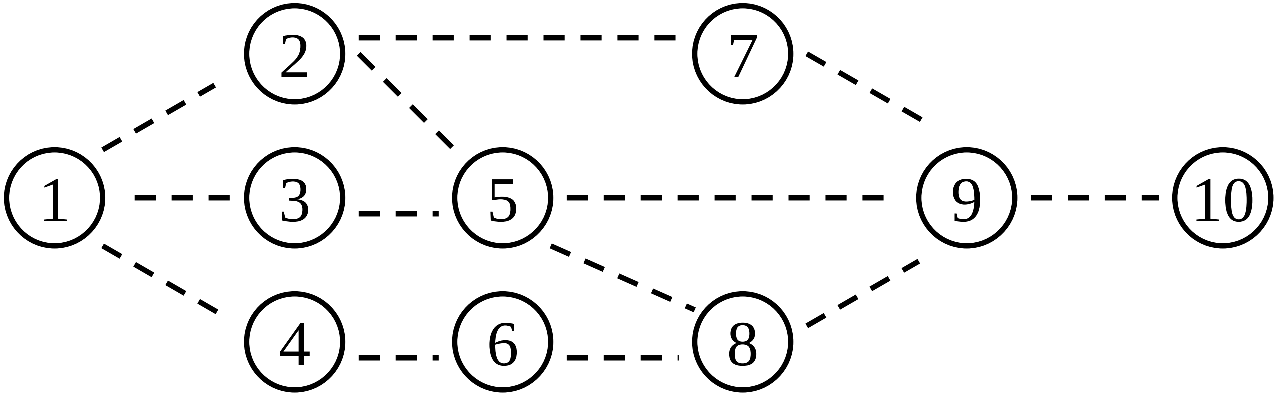
- **A**d-hoc **O**n-demand **D**istance **V**ector Routing
- **Routing Table**:
  - Entry = <destination, route, "sequence #" (timestamp)>
  - Each source keeps a "broadcast ID" counter
- **Path Discovery**: Flood a route request (RREQ) to all neighbors. Neighbors broadcast to their neighbors
- Each RREQ has the source address, source's broadcast ID, destination, source's sequence # for the destination
- Intermediate nodes can reply to RREQ only if they have a route with higher sequence #
- Intermediate nodes record node from which the first copy was received $\Rightarrow$ the reverse path

AODV (Cont)

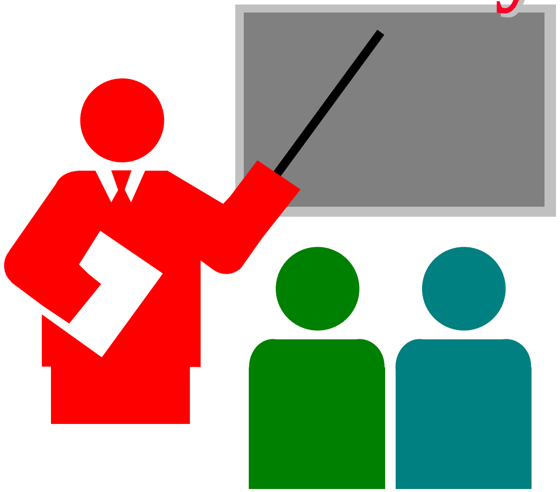
- *Route reply* comes back on the reverse path
  $\Rightarrow$ Intermediate nodes update their forwarding tables
- Old entries are timed out
- AODV supports only symmetric links
- If a source node moves, it must reinitiate RREQ
- If an intermediate node moves, all upstream nodes broadcast a *link failure* to their upstream neighbors until source nodes is reached
- Disadvantage: Intermediate nodes may send more up-to-date but still stale routes.
- Ref: RFC3561

AODV: Example

- Node 1 sends RREQ to 2, 3, 4:
  "*Any one has a route to 15 fresher than 3. This is my broadcast #10*"
- Nodes 2, 3, 4 send RREQ to 5, 6, 7
- Node 3 has 3-5-8-9-10 Sequence #1
- Node 4 has 4-6-8-10 Sequence #4
- Node 4 responds. Node 3 does not respond.



Summary



- Ad Hoc = No Infrastructure $\Rightarrow$ Resilience
  Useful in military and emergency
- Multi-hop wireless
- Routing: Proactive, Reactive, Hybrid
- AODV is reactive DV, DSR is reactive DV
  OLSR is proactive LS

Reading Assignment

Text Book:

- Murthy and Manoj: Chapter 5, Sections 6.1-6.4, Sections 7.1-7.3

RFCs:

- RFC 2501: MANET Routing Protocol Performance Issues and Evaluation Considerations
- RFC 3561: Ad Hoc On Demand Distance Vector (AODV) Routing
- RFC 3626: Optimized Link State Routing Protocol (OLSR)

Optional Reading

RFCs:

- RFC 3684: Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)

Internet Drafts:

- The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR), *draft-ietf-manet-dsr-10.txt*
- Dynamic MANET On-demand (DYMO) Routing, *draft-ietf-manet-dymo-04.txt*
- Simplified Multicast Forwarding for MANET, *draft-ietf-manet-smf-02.txt*
- The Optimized Link-State Routing Protocol version 2, *draft-ietf-manet-olsrv2-01.txt*
- Generalized MANET Packet/Message Format, *draft-ietf-manet-packetbb-00.txt*

Homework

- Find optimal MPR set for node 5.