Mobile and Sensor Systems

Lecture 3: Infrastructure, Ad-hoc and Delay Tolerant Mobile Networks
Prof Cecilia Mascolo
In this lecture

• In this lecture we will describe the difference in infrastructure and ad hoc networks and we will introduce ad hoc routing protocols.

• We will also introduce disconnected ad hoc networks and delay tolerant routing protocols.
Infrastructure-based sv Ad-hoc

• Wireless communication can be organized in two different fashions:
  – This might depend on the application and on the network set up.
Infrastructure-based

- Infrastructure mode
  - base station connects mobiles into wired network
  - handoff: mobile changes base station providing connection into wired network
Ad-hoc

ad hoc mode
- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves
802.11 - MAC layer (recap)

- Priorities
  - defined through different inter frame spaces
  - no guaranteed, hard priorities
  - SIFS (Short Inter Frame Spacing)
    - highest priority, for ACK, CTS, polling response
  - PIFS (PCF IFS)
    - medium priority, for time-bounded service using PCF
  - DIFS (DCF, Distributed Coordination Function IFS)
    - lowest priority, for asynchronous data service

- medium busy
  - SIFS
  - DIFS
  - PIFS
  - contention
  - next frame

- direct access if medium is free ≥ DIFS
802.11 – competing stations

- **Station 1**
  - 0: DIFS (idle)
  - 1: packet arrival
  - 2: bo_e, bo_r (backoff)
  - 3: busy

- **Station 2**
  - 0: busy

- **Station 3**
  - 0: busy

- **Station 4**
  - 0: bo_e, bo_r (backoff)
  - 1: busy

- **Station 5**
  - 0: bo_e, bo_r (backoff)
  - 1: bo_e, busy
  - 2: bo_e, bo_r (backoff)

**Legend:**
- **Busy**: medium not idle (frame, ack etc.)
- **bo_e**: elapsed backoff time
- **bo_r**: residual backoff time
- **Packet arrival at MAC**: packet arrival at MAC
Synchronization using a Beacon (infrastructure)

• Nodes need to keep a tight synchronized clock with the access point: this is useful for power management and coordination of frequency hopping or contention slots.
• Beacons are sent semi-periodically \([ei \text{ when the medium is not busy}]\)
Synchronization using a Beacon (ad-hoc)

• In ad hoc mode each station transmits a beacon after the beacon interval [semi periodic again]
• Random backoffs are applied to beacons too: all station adjust clock to beacons received and suppress their beacon for the beacon interval
Power saving with wake-up patterns (infrastructure)

TIM interval

DTIM interval

access point

medium

station

T TIM
D DTIM

p PS poll

B broadcast/multicast

d data transmission to/from the station

awake

t

TIM: list of stations for which there will be data in the slot
DTIM Interval indicates the delivery traffic indication map: for broadcast and multicast frames. It’s a multiple of TIM
Power saving with wake-up patterns (ad-hoc)

ATIM is the transmission map for ad hoc traffic: all stations stay awake for this slot.
Examples of Multi-hop Ad hoc Networks
A schematic of an ad hoc network

Note that this is a static snapshot: the network will be reconfiguring when nodes move.
Examples of Ad-hoc Networking

• Destination Sequenced Distance Vector (DSDV) Routing.

• Proactive: routes are maintained also when not needed. Each node maintains a table with a route to every node.

• Each entry of the table has a sequence number assigned by the destination.

Dest. Next Hop, Hops Required, Dest. Seq. number.
# DSDV: Routing Table for Node D

<table>
<thead>
<tr>
<th>Dest</th>
<th>Nexthop</th>
<th>Hops</th>
<th>SequenceN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>2</td>
<td>406</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>1</td>
<td>128</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td>2</td>
<td>564</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>0</td>
<td>710</td>
</tr>
<tr>
<td>E</td>
<td>F</td>
<td>2</td>
<td>392</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>1</td>
<td>076</td>
</tr>
<tr>
<td>G</td>
<td>F</td>
<td>2</td>
<td>128</td>
</tr>
<tr>
<td>H</td>
<td>F</td>
<td>3</td>
<td>050</td>
</tr>
</tbody>
</table>
DSDV Routing Updates

- Each node periodically transmits updates.
- Includes its own sequences number, routing table updates.
- Nodes also send routing table updates for some incremental link changes.
- When two routes to a destination received from two different neighbors, choose the one with greatest destination sequence number.
- If equal (when would they be equal?), choose the smaller metric (hop count).
DSDV: When a new link appears (ie a node moved closer)

- When K joins it
  - Transmits routing table <K,K,0,101>
  - Node A receives it and inserts in routing table: <K,K,1,101>
  - Node A propagates the new route to neighbours.
  - Neighbours of A update table with <K,A,2,101> and continue propagation.
DSDV: When a link breaks (ie a node moves away)

• The link between D and F breaks (the two nodes move apart or the wireless link has no connection for other reasons).

• Node D notices the break (eg lack of table update from F):
  – Updates hop count to F to infinity.
  – Increments the sequence number for F,E,G,H
  – Then:
DSDV: When a link breaks (ie a node moves away)
– Then Node D sends updates with new route information:
  • \(<F, -, \infty, 077>\)
  • \(<E, -, \infty, 393>\)
  • \(<G, -, \infty, 129>\)
  • \(<H, -, \infty, 051>\)
DSDV: Limitations

- Circulating and maintaining table updates is expensive for the network.
  - Especially if this is battery powered.
- If the network changes a lot then these updates might be worthwhile but only if all nodes need to communicate to all others
  - Why would a node need to keep updates of routes to nodes it does not need to communicate with?
Another Ad-hoc routing example
Dynamic Source Routing (DSR)

• DSR is a reactive protocol: routes are searched only when communication with a node is needed.
• When a node needs to communicate it sends a route request packet.
• Nodes receive it and add themselves to the path and propagate the request to their neighbours.
• Eventually the destination node is found and the path is sent back to the source (how?).
DSR example

- Node A needs to communicate with F. Sends request \(<A,F,[-],101>\).
- Node B receives the request and forwards:
  - \(<A,F,[B],101>\).
- Node D receives it and forwards:
  - \(<A,F,[B,D],101>\).
- Node F receives it and \(\ldots\) (continued).
DSR example (continued)

• Node F receives it and:
  – If links are symmetric sends the path back following the indicated inverse route.
  – Or, if it has cached a path to A uses it.
  – Otherwise it sends a route request for A.
DSR Comments

• Sequence numbers are used to avoid routing loops.
• Routes are cached for some time to avoid frequent route requests by intermediate nodes.
• Low mobility and low traffic are the best scenarios for this protocol.
Hybrid Solutions

Zone Routing Protocol (ZRP)

• Zone routing is a hybrid protocol which combines proactive with reactive approaches.
• A zone around node N is maintained where routes are collected proactively.
• Beyond the zone an inter zone protocol is responsible to determine the routes in a reactive way.
Disconnected Ad-hoc Networks

• The protocols we have seen until now only work when there is a “connected path” among the communicating nodes
• I.e. no storage on intermediate nodes is allowed.
• The protocols do not work when this is not the case.
Connected vs Disconnected Ad-hoc Networks

Connected: there is a connected path among each couple

Disconnected: not all links are present at the same time
Delay Tolerant Networks and Protocols

• These protocols do not assume a temporally connected path among the nodes.
• Nodes can accept a packet and deliver it later, after some time storing it.
Example: Epidemic Routing

• A flooding protocol which allows nodes to store packets before forwarding.
• A node accepts a packet, moves while carrying the packet and then forwards at a different time to a different neighbourhood.
• Flooding is always expensive (many transmissions, large buffers needed)
Example
Example continued
Can we do better?

- Exploit the knowledge on the mobility of the nodes
- Is the mobility deterministic (i.e., Always on the same path at same times like busses)? Maybe we can even control the mobility of some of the nodes!
- If not fixed, is it at least predictable?
- If not predictable, random…
When mobility is predictable

• Prediction of mobility techniques need to be applied unless you want to use “epidemic”.
• Instead of blindly forwarding packets to all or some neighbors, intermediate nodes estimate the chance, for each outgoing link, of eventually reaching the destination.
• Based on this estimation, the intermediate nodes decide whether to store the packet and wait for a better chance, or decide to which nodes (and the time) to forward.
Context Aware Routing (CAR)

• A node chooses the best carrier to reach a specific node. How is the best carrier neighbour chosen?
  – Host mobility, host colocation with destination node, battery.
  – A utility function which weights these aspects
  – Kalman Filter is used to predict future host colocation with destination based on previous history.

• The approach is based on local knowledge only.
Reference