Mobile Communications

Ad-hoc and Mesh Networks

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What is an ad-hoc network?

What are differences between layer 2 and layer 3 ad-hoc networks?

What are the differences between an IEEE mesh network and an IETF MANET network?

What are the differences between a mobile network and a mobile terminal?

How to support a moving network?
♦ MANET – Ad-hoc Networks
  » AODV, OLSR

♦ Mesh networks
  » 802.11s

♦ Mobile Networks
  » IETF NEMO
  » MANET support for mobile networks
Basics on ad-hoc networks

♦ What is an ad-hoc network?

♦ What are the differences between and ad-hoc wireless network and a wired network?

♦ What are the characteristics of the most important ad-hoc routing protocols?
Ad-Hoc Network (Layer 3)

- Auto-configurable network
- Working over wireless links
- Nodes are mobile ➔ dynamic network topology
- Isolated network, or interconnected to Internet
- Nodes forward traffic
- Routing protocol is required
IETF MANET - Mobile Ad-hoc Networking

Mobile Router

Mobile Devices

Fixed Network

Manet

Mobile IP, DHCP

Router

End system
Route calculation in wired networks

- **Distance vector**
  - Messages exchanged periodically with neighbours
  - Message indicates reachable nodes and their distance
  - Algorithm takes long time to converge
  - Eg. RIP

- **Link state**
  - Router informs periodically the other routers about its links state
  - Every router gets information from all other routers
  - Lots of traffic
  - Eg. OSPF
Route calculation in Ad-Hoc Networks - Characteristics

Ad-hoc network

» Dynamic topology
  – Depends on node mobility

» Interference
  – Radio communications

» Asymmetric links
  – Received powers and attenuation unequal in the two directions
Routing in Ad-hoc Networks

♦ Conventional routing protocols
  – Built for wired networks → whose topology varies slowly
  – Assume symmetric links

♦ In Ad-hoc networks
  » Dynamic topology → information required to be refreshed more frequently
    – energy consumption
    – radio resources used for signaling information
  » Wireless node may have scarce resources (bandwidth, energy) …

♦ New routing strategies / protocols for ad-hoc networks
  – 2 type : reactive e pro-active
To think about

- How can we avoid a large signaling overhead (number of routing messages) in ad-hoc networks
AODV – A needs to send packet to B
AODV – A sends RouteRequest
AODV – B replies with RouteReply
AODV - Characteristics

» Decision to request a route
» Broadcast of *Route-request*
» Intermediate nodes get routes to node A
» *Route-reply* sent in *unicast* by same path
» Intermediate nodes get also route to node B
» Routes have *Time-to-live*, in every node
» Needs symmetric graph
**Pro-active routing protocols**

- Routes built using continuous control traffic
- Routes are maintained

- Advantages, disadvantages
  - Constant control traffic
  - Routes always available

- Example – OLSR (RFC 3626)
  - OLSR - Optimized Link-State Routing protocol
**OLSR – Main functions**

- Detection of links to neighbour nodes
- Optimized forwarding / flooding (MultiPoint Relaying)

| Bits: | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 |
| OLSR header: | Packet Length | Packet Sequence Number |
| Message: | Message Type | Vtime | Message Size |
| | Originator Address |
| Time To Live | Hop Count | Message Sequence Number |
| MESSAGE |
| Message: | Message Type | Vtime | Message Size |
| | Originator Address |
| Time To Live | Hop Count | Message Sequence Number |
| MESSAGE |
**OLSR – Detecting links to neighbour nodes**

- Using *HELLO* messages
- All nodes transmit periodically *HELLO* messages
- *HELLO* messages group neighbour by their state
OLSR – MultiPoint Relaying (MPR)

- MultiPoint Relaying (MPR)
  - Special nodes in the network
  - Used to
    - Limit number of nodes retransmiting packets
    - Reduce number duplicated retransmissions

- Each node selects its MPRs, which must
  - Be at 1 hop distance
  - Have symmetric links

- MPR set selected by a node
  - Must be minimum
  - Must enable communication with every 2-hop-away nodes

- Node is MPR if it has been selected by other node
**OLSR – Link State**

- In wired networks, OSPF
  - Every node floods the network
  - With information about its links state

- OLSR does the same, using 2 optimizations
  - Only nodes associated to MPR are declared in link state message
    - Reduced message length
  - Only the MPR nodes send link state messages
    - Smaller number of nodes sending messages
**OLSR – Link state, example**

- Messages which declare the links state
  - “Topology Control Messages”
The IEEE 802.11 mesh networks

- How will the 802.11s Mesh Network work?
Note: This set of slides reflects the view of a 802.11s draft standard.
IEEE 802.11s - Main Characteristics

- Network topology and discovery
- Inter-working
- Path Selection and Forwarding
- MAC Enhancements
Elements of a WLAN Mesh Network

- **MP** - Mesh Point
  - establishes links with neighbor MPs
- **MAP** - Mesh AP
  - MP + AP
- **MPP** - Mesh Portal
- **STA** – 802.11 station
  - standard 802.11 STA
**L2 Mesh Network - Emulates 802 LAN Segment**

- **Broadcast LAN**
  - Unicast delivery
  - Broadcast delivery
  - Multicast delivery

Support for connecting an 802.11s mesh to an 802.1D bridged LAN
- Broadcast LAN (transparent forwarding)
- Learning bridge
- Support for bridge-to-bridge communications: Mesh Portal participates in STP
To think about

- Suppose A sends a frame to B (MAC layer). What MAC addresses are required for the frame transmitted between the two Ethernet switches?

- And what MAC addresses are required for the frame transmitted between the two MAPs? Why are the 2 cases different?

I) A — ethernet switch — ethernet switch — B

II) A — MAP — MAP — B
Mesh Data Frames

- Data frames
  - based on 802.11 frames - 4 MAC address format
  - extended with: 802.11e QoS header, and new Mesh Control header field

- Mesh Control Field
  - TTL – eliminates possibility of infinite loops (recall these are mesh networks!)
  - Mesh E2E Seq
Topology Formation

♦ Mesh Point discovers candidate neighbors
  » based on beacons, which contain mesh information
    – WLAN Mesh capabilities
    – Mesh ID

♦ Membership in a WLAN Mesh Network
  » determined by (secure) association with neighbors
Mesh Association

1. MP X discovers Mesh *mesh-A* with profile *(link state, …)*

2. MP X associates / authenticates with neighbors in the mesh, since it can support the Profile

3. MP X begins participating in link state path selection and data forwarding protocol

**Capabilities:**
Path Selection: distance vector, link state

**One active protocol in one mesh but alternative protocols in different meshes**
Interworking - Packet Forwarding

Destination inside or outside the Mesh?

- Portal forwards the message
- Use path to the destination
**Hybrid Wireless Mesh Protocol (HWMP)**

Combines

- on-demand route discovery
  - based on AODV

- proactive routing to a mesh portal
  - *distance vector routing tree* built and maintained rooted at the Portal
**HWMP Example 1:**

*No Root, Destination Inside the Mesh*

- Communication: MP4 → MP9
- MP4
  - checks its forwarding table for an entry to MP9
  - If no entry exists, MP4 sends a broadcast RREQ to discover the best path to MP9
- MP9 replies with unicast RREP
- Data communication begins
**HWMP Example 3:**

*No Root, Destination Outside the Mesh*

- Communication: MP4 → X
- MP4
  - first checks its forwarding table for an entry to X
  - If no entry exists, MP4 sends a broadcast RREQ to discover the best path to X
  - When no RREP received, MP4 assumes X is outside the mesh and sends messages destined to X to Mesh Portals

- Mesh Portal that knows X may respond with a unicast RREP

[Diagram of mesh network with nodes labeled 1 to 10 and routes marked with arrows indicating on-demand path.]
HWMP Example 2:

**Root, Destination Inside the Mesh**

- Communication: MP 4 → MP 9
- MPs learn Root MP1 through **Root Announcement** messages
- MP 4 checks its forwarding table for an entry to MP9
- If no entry exists, MP4 forwards message on the proactive path to Root MP1
- When MP1 receives the message, it forwards on the proactive path to MP9
- MP9, receiving the message, may issue a RREQ back to MP 4 to establish a path that is more efficient than the path via Root MP1
**HWMP Example 4:**

**Root, Destination Outside the Mesh**

- Communication: MP4 → X

- MPs learn Root MP1 through **Root Announcement** messages

- If MP4 has no entry for X in its forwarding table, MP4 may forward the message on the proactive path toward the Root MP1

- When MP1 receives the message, if it does not have an active forwarding entry to X it may assume the destination is outside the mesh

- Mesh Portal MP1 forwards messages to other LAN segments
Radio Aware OLSR (RA-OLSR)

- OLSR may be used in alternative to AODV
- RA-OLSR proactively maintains link-state for routing
MAC Enhancements for Mesh

- Intra-mesh Congestion Control
- Common Channel Framework (Optional)
Need for Congestion Control

- Mesh characteristics
  - Heterogeneous link capacities along the path of a flow
  - Traffic aggregation: Multi-hop flows sharing intermediate links

- Issues with the 802.11 MAC for mesh
  - Nodes blindly transmit as many packets as possible, regardless of how many reach the destination
  - Results in throughput degradation and performance inefficiency
Intra-Mesh Congestion Control Mechanisms

♦ Local congestion monitoring (informative)
  » Each node actively monitors local channel utilization
  » If congestion detected,
    notifies previous-hop neighbors and/or the neighborhood

♦ Congestion control signaling
  » Congestion Control Request (unicast)
  » Congestion Control Response (unicast)
  » Neighborhood Congestion Announcement (broadcast)
Common Channel

- Common channel
  - Unified Channel on which MPs jointly operate
  - Using RTX, the transmitter suggests a destination channel
  - Receiver accepts/declines the suggested channel using CTX
  - The transmitter and receiver switch to the destination channel
  - Data is transmitted
  - Then they switch back
Control Frames

- Request to Switch (RTX) Frame

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<tr>
<th>Frame Control</th>
<th>Duration/ID</th>
<th>RA</th>
<th>TA</th>
<th>Destination Channel Info.</th>
<th>FCS</th>
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- Clear to Switch (CTX) Frame

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