Wireless Mesh and Multi-Hop Relay Networks

Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@cse.wustl.edu

Audio/Video recordings of this lecture are available at:
http://www.cse.wustl.edu/~jain/cse574-08/
Overview

- Multi-Hop Relay Networks
- 802.16j Mobile Multi-hop Relay (MMR)
- 802.15.5 WPAN Mesh Networking
- 802.11s Mesh Networks: Applications
- Wi-Fi Mesh Products
Multi-Hop Networks

- **Relay**: Dedicated *carrier owned* infrastructure, Tree based topology. One end of the path is the base station.
- **Mesh**: Routing by *subscriber* equipment, Multiple connections, mesh topology.
Multi-Hop Relay Networks

- Next generation networks need very high data rates
- Data rate $\propto 1/distance$
  $\Rightarrow$ High density of cell towers $\Rightarrow$ High cost
- Multi-hop Networks have fixed infrastructure
  $\Rightarrow$ Do not complex routing techniques
- Relays are low-cost low transmit power and have no connection to wired infrastructure
- More capacity due to shorter distances and frequency reuse
- Goal: High capacity and coverage (not absence of infrastructure)
Coverage Extension

- Side streets can be covered by relays
- A series of relays can be used to forward traffic to base
- Relaying either in time domain or frequency domain
Throughput Enhancement

- Virtual Antenna Arrays
- Multiple cooperating relays act as distributed MIMO
- Challenges: Synchronization, Sharing of Channel State Information

3×2 MIMO
iCAR

- Integrated Cellular and Ad-Hoc Relaying System
- Relaying stations are used to divert traffic from congested cells to nearby lightly loaded cells
- Even existing calls can be moved
  ⇒ Secondary relaying
Three types of Relays: Fixed, Nomadic (special events, Indoor), Mobile Relays (Trains)
802.16j Technical Issues

- Centralized vs. distributed control:
  Functional division between Base and Relay
- Scheduling
- Radio Resource management
- Power Control
- Call Admission and Traffic Shaping Policies
- QoS: Network wide load balancing,
  Congestion control
- Security
- Management

Note: Routing is not an issue with fixed relays
Multi-Hop Relay Networks: Summary

- Relay concept applies to Cellular Networks and to Wireless Access
- Relays can help overcome obstacles
- Relays help improve the capacity by decreasing the distance
- Relays help decrease the cost since they are much cheaper than base stations
- Routing with fixed relays is simple
- Increasing delays
  ⇒ Number of hops must be limited to two or three
- Distributed MIMO ⇒ Improvement in data rates
Mesh Networks

- WPAN Mesh: 802.15.5
- WLAN Mesh: 802.11s
802.15.5 WPAN Mesh Networking

- Goal: Range Extension, Routing Redundancy
- Issues:
  - Handle Multiple Master devices
  - Handle multiple super frame coexistence
  - Fair sharing of channel time
  - Minimal changes to 802.15.3 and 802.15.4

Mesh Control and Data path
802.11s Mesh Networks: Applications

**MSOs/ CLEC/ Municipal**

- CMTS
- Internet
- 10/100/1000 Mbps

**Enterprise Campus**

- 100/1000 Mbps

**Emergency Response**

**Home Networks**
802.11s Device Classes

- Stations (STA): Non-mesh capable station
- Mesh Points (MP): Mesh capable station
- Mesh AP (MAP): MP + AP
- Mesh Portal (MPP): Entry/exit to wired network. Support transparent bridging, address learning, and bridge-to-bridge communication (spanning tree etc).
- Root Portal: MPP configured for topology building. Elected to become the root of the default forwarding tree
802.11s Hybrid Wireless Mesh Protocol

- Two Configurations: With Root Portal and Without Root Portal

Route Discovery:

- W/O Root Portal:
  - On-demand *Radio Metric* AODV (RM-AODV)
    Cost = Amount of air time consumed per packet transmission
  - Radio Aware OLSR Path Selection Protocol (Optional)
    Frequency of LS forwarding is reduced with hops
    (Fish eye state routing)

- W Root Portal: Most of the traffic is to the root.
  - Proactive. Tree based distance vector routing.
Common Channel Framework

- All stations use a single control channel
- Stations dynamically select the data channel
- They announce it on the common control channel using RTX/CTX (Not RTS/CTS) packets
802.11s Examples

4->9
4 sends RREQ
9 sends RREP

4->X
4 sends RREQ
No Resp
⇒ 4 forwards to MPP 1
4->X
4 forwards to MPP1
MPP1 sends to X

4->9
4 forwards to MPP1
MPP1 sends to 9
9 Issues RREQ
4 sends RREP
Wi-Fi Mesh Products

- **LocustWorld.com**
  - Allows computers to act as wireless routers.
  - Uses AODV protocol. Problem of false DVs.
  - MeshBox: Complete hw/sw package
  - MeshBox 2 or MexBox: Uses two Wi-Fi radio modules. Successive routers could share a channel, e.g., 1+2, 2+3, 3+1 among three routers.

- **FireTide Network:**
  - HotPort 4.9 GHz Public Safety Mesh Nodes,
  - HotPort Indoor Mesh Nodes,
  - HotPort Outdoor Mesh Nodes.
  - Uses MANET (Topology Broadcast based on Reverse Path Forwarding (TBRPF) protocol
Wi-Fi Mesh Products (Cont)

- Tropos Networks, [www.tropos.com](http://www.tropos.com)
- PacketHop Communications, [www.packethop.com](http://www.packethop.com)
- Proxim Wireless, [http://www.proxim.com/can/index.html](http://www.proxim.com/can/index.html)
- Nortel Networks, [http://www2.nortel.com/go/solution_content.jsp?segId=0&catId=0&parId=0&prod_id=47160&locale=en-US](http://www2.nortel.com/go/solution_content.jsp?segId=0&catId=0&parId=0&prod_id=47160&locale=en-US)
- WaveWireless, [www.wavewireless.com](http://www.wavewireless.com)
Multi-Hop Relay Networks are designed for coverage extension and throughput enhancements.

802.16j Mobile Multi-hop Relay (MMR) standard allows for fixed, nomadic, and mobile relays.

802.15.5 WPAN Mesh is being designed for routing redundancy and range extension.

802.11s Mesh Networks use RM-AODV and RA-OLSR for on-demand routing along with pro-active tree based routing.
References

- Murthy and Manoj, Chapter 13