

# Wireless Mesh and Multi-Hop Relay Networks

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These slides are available on-line at:

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



- ❑ 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

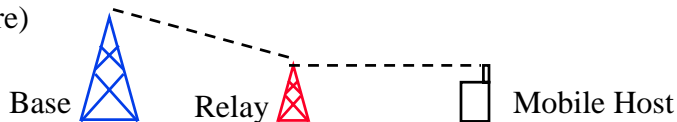
## Multi-Hop Networks

- ❑ **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



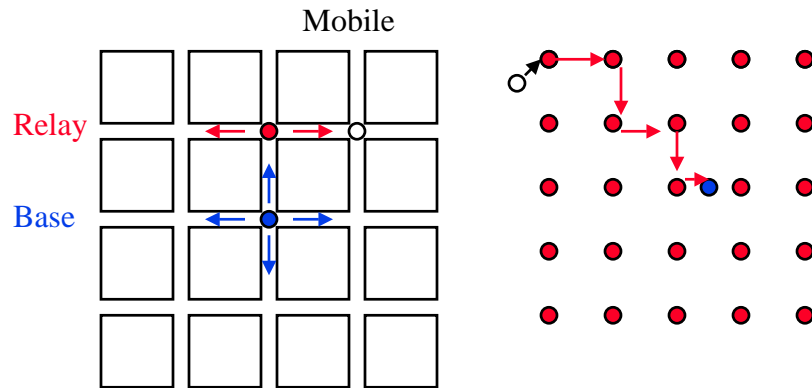
## Multi-Hop Relay Networks

- ❑ Next generation networks need very high data rates
- ❑ Data rate  $\propto 1/\text{distance}$   
 $\Rightarrow$  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)



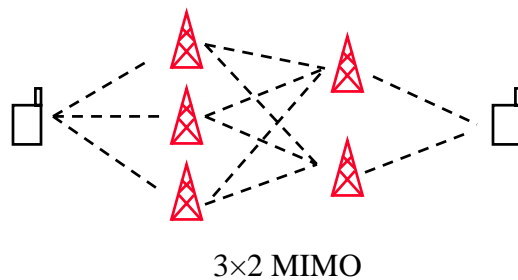
## Coverage Extension

- ❑ 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

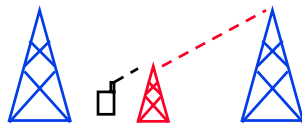
- ❑ Virtual Antenna Arrays
- ❑ Multiple cooperating relays act as distributed MIMO
- ❑ Challenges: Synchronization, Sharing of Channel State Information



3x2 MIMO

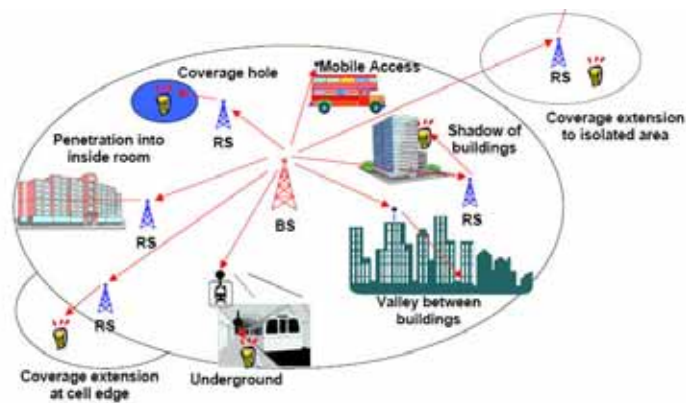
## iCAR

- ❑ 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



## 802.16j Mobile Multi-hop Relay (MMR)

- ❑ 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

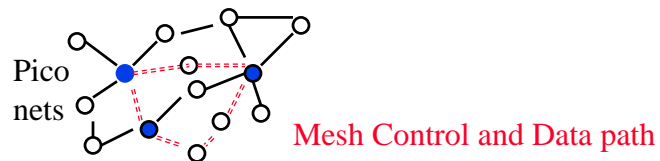
- ❑ Relay concept applies to Cellular Networks and to Wireless Access
- ❑ Relays can help overcome obstacles
- ❑ Relays help improve the capacity by decreasing the distance
- ❑ Relays help decrease the cost since they are much cheaper than base stations
- ❑ Routing with fixed relays is simple
- ❑ Increasing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

## Mesh Networks

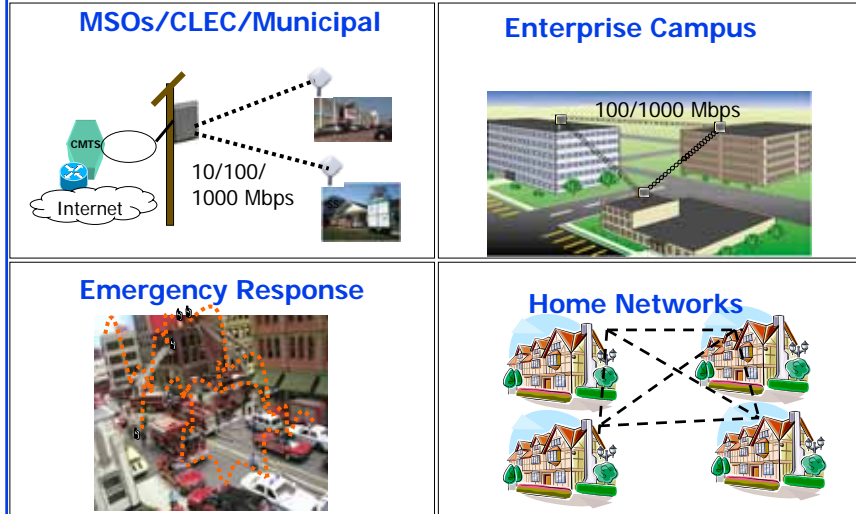
- ❑ WPAN Mesh: 802.11.5
- ❑ WLAN Mesh: 802.11s

## 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 15.5.3 and 15.5.4



## 802.11s Mesh Networks: Applications



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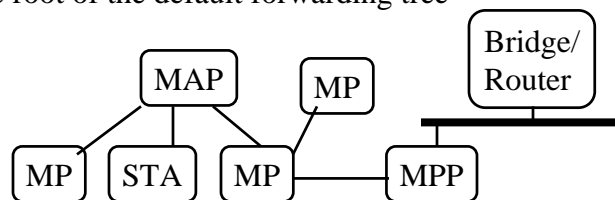
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## 802.11s Device Classes

- ❑ 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



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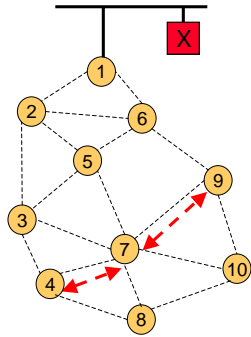
## 802.11s Hybrid Wireless Mesh Protocol

- ❑ 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.

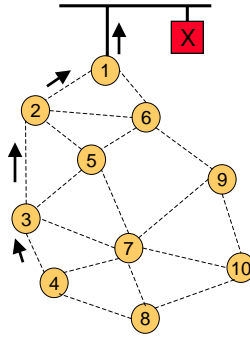
## Common Channel Framework

- ❑ 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

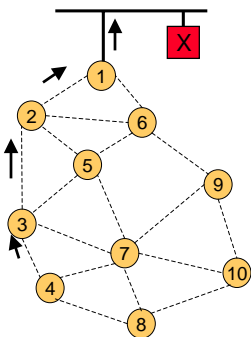


4->9  
4 sends RREQ  
9 sends RREP

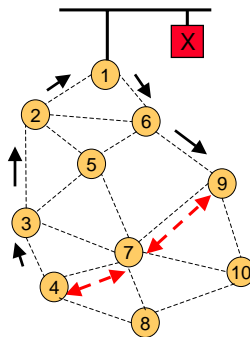


4->X  
4 sends RREQ  
No Resp  
⇒ 4 forwards to MPP 1

## 802.11s Examples



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

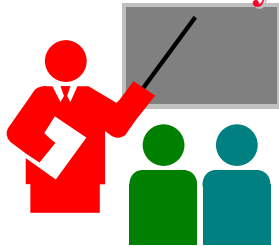
## Wi-Fi Mesh Products

- ❑ **LocustWorld.com**
  - MeshAP S/W: Freeware from 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)

- ❑ Motorola Mesh Networks, <http://www.motorola.com/mesh/index.htm>
- ❑ Tropos Networks, [www.tropos.com](http://www.tropos.com)
- ❑ PacketHop Communications, [www.packethop.com](http://www.packethop.com)
- ❑ MeshDynamics, <http://www.meshdynamics.com/index.html>
- ❑ SkyPilot Networks, <http://www.skypilot.com/>
- ❑ Proxim Wireless, <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)

## Summary



- ❑ 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

- ❑ R. Tafazolli (ed), "Technologies for the Wireless Future," Wiley, 2005, 576 pp., ISBN: 0470012358
- ❑ Murthy and Manoj, Chapter 13
- ❑ G. Held, "Wireless Mesh Networks," Auerbach Publications, 2006, ISBN:0849329604
- ❑ I. F. Akyldiz, et al, "Wireless Mesh Networks: A Survey," Computer Networks, 2004, [www.ece.gatech.edu/research/labs/bwn/mesh.pdf](http://www.ece.gatech.edu/research/labs/bwn/mesh.pdf)