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A Multihop IEEE 802.11 MAC Protocol for Wireless Ad hoc Networks

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Outline

Multihop Connectivity in Wireless Ad hoc Networks

- Approaches: @ Layer-2 or @ Layer-3
- @ Layer-2: Motivation & Objectives

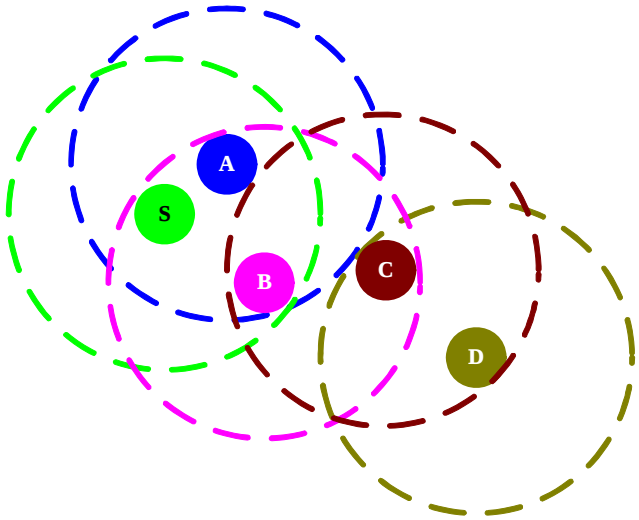
Multihop IEEE 802.11 MAC Protocol

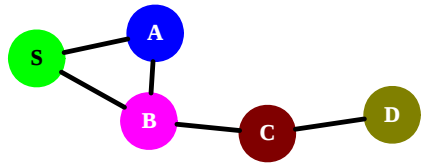
- Protocol Architecture
- Performance Analysis

Conclusions

Multihop Connectivity in Wireless Ad hoc Networks

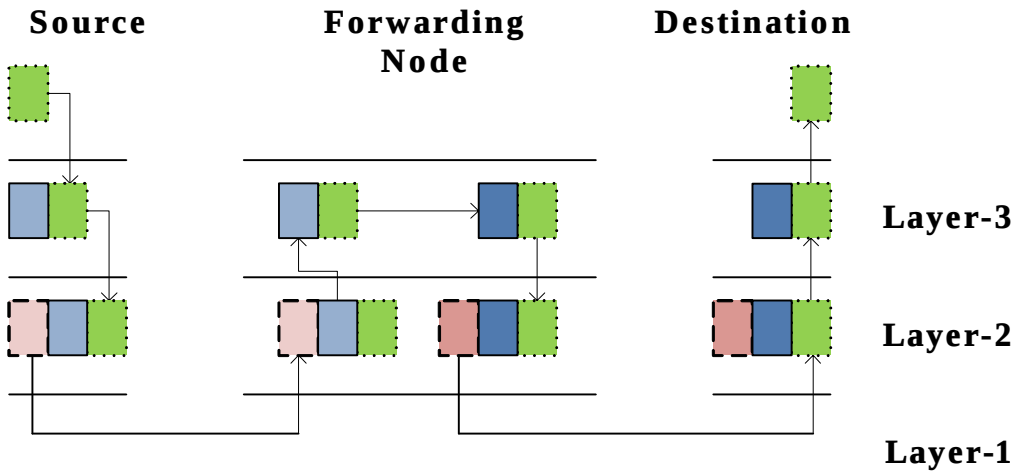
- Nodes can not communicate beyond their radio range
  - Multiple-hops away nodes can not communicate
- Multihop Connectivity
  - Nodes forward messages for each other
  - Can communicate with every other node in the network
    - Beyond their radio range





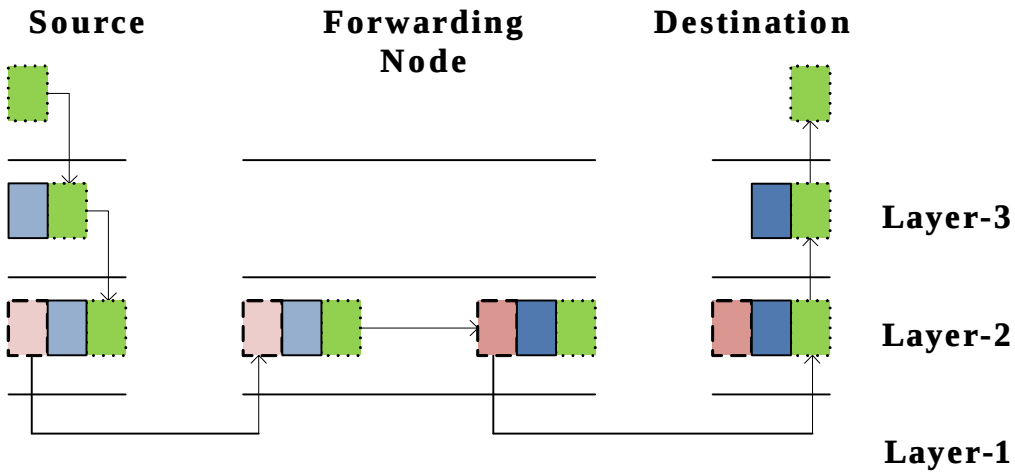
Multihop Connectivity Approaches: @ Layer-3

- Routing: forwarding performed at Layer-3
  - Based on Layer-3 (IP) addresses
- A very common/popular approach
  - Extensively researched
- Adaptation of routing in wired networks
- AODV, DSR, OLSR, TORA etc.



Multihop Connectivity Approaches: @ Layer-2

- Relaying
  - Forwarding performed at Layer-2
    - Based on MAC addresses
  - Not a widely used/researched approach
  - For example: Bluetooth, HiperLAN/1



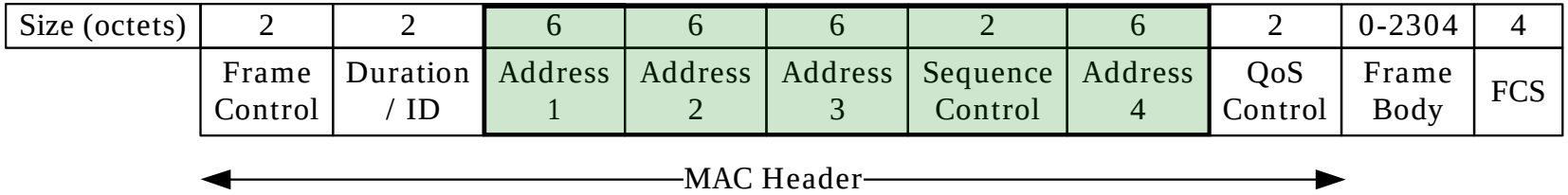
Motivation for Relaying

- Layer-2 support is inevitable in routing
  - For example: AODV, DSR, ABR, SSA etc. have
    - Link layer feedback, beacon frames etc.
    - In order to reduce response time or overhead
  - Signal strength, neighbor connectivity etc. are available at Layer-2

- Collision Avoidance MAC Protocols
  - Control messages (RTS/CTS/ACK) used quite often
    - Can help in topology learning, no special messages required

Why IEEE 802.11 MAC?

- Most widely used wireless MAC in consumer scenarios
- Collision Avoidance MAC
- Four address fields in MAC frame header
  - End-to-end addressing requires at least three address fields
- Fragmentation/Reassembly Option
- Frame sequence numbers



Related Work

- Different suggestions to introduce relaying in 802.11 networks
  - As an additional scheme
  - Complex approaches, require major modifications
  - Proactive approaches
  - Have limitations
  - Examples:
    - IEEE 802.11 Ad hoc bridge
    - A Bridging Method for Mobile Ad hoc Networks
    - DCMA : Data Driven Cut-through Multiple Access
    - LUNAR: Lightweight Underlay Network Ad-hoc Routing Protocol

The Multihop IEEE 802.11 MAC

- Provide relaying service at MAC layer in ad hoc mode
- No routing protocol at Layer-3

- Reactive approach
- A simple extension of existing MAC protocol
- No dependency on previously stored topology information
- No route discovery
  - Exploits MAC address resolution by ARP

Protocol Architecture (1)

- Forwarding Table (FWT)
  - Destination MAC address, Next hop MAC address, Used bit
  - No route cost, a fresh route is always preferred

Size (bits)	48	48	1
	Destination MAC Address	Next hop MAC Address	Used

- End-to-End Addressing: four address fields
  - Address 1: Recipient (RA)
  - Address 2: Transmitter (TA)
  - Address 3: Destination (DA)
  - Address 4: Source (SA)

Size (octets)	2	2	6	6	6	2	6	2	0-2304	4
	Frame Control	Duration / ID	Address 1 **RA**	Address 2 **TA**	Address 3 **DA**	Sequence Control	Address 4 **SA**	QoS Control	Frame Body	FCS

MAC Header

Protocol Architecture (2)

- Learning
  - Learning topology, FWT maintenance
  - Entries for SA/TA are updated whenever a frame is received
    - SA information in old frames is not used
- Forwarding
  - Originating/forwarding frames
  - Unicast if FWT has an entry for the destination, else broadcast
- Repair
  - Route error and loop detection/correction
    - Maintain FWT & broadcast the frame

Performance Analysis (1)

- Comparison with AODV
  - Is multihop 802.11 MAC a feasible idea?
- Performance metrics
  - Packet Delivery Ratio: Success in data delivery
  - MAC overhead: Cost incurred
  - Throughput: Amount of data delivered
  - End-to-end delay of data packets
  - Normalized Throughput: Cost efficiency of delivered data

Performance Analysis (2)

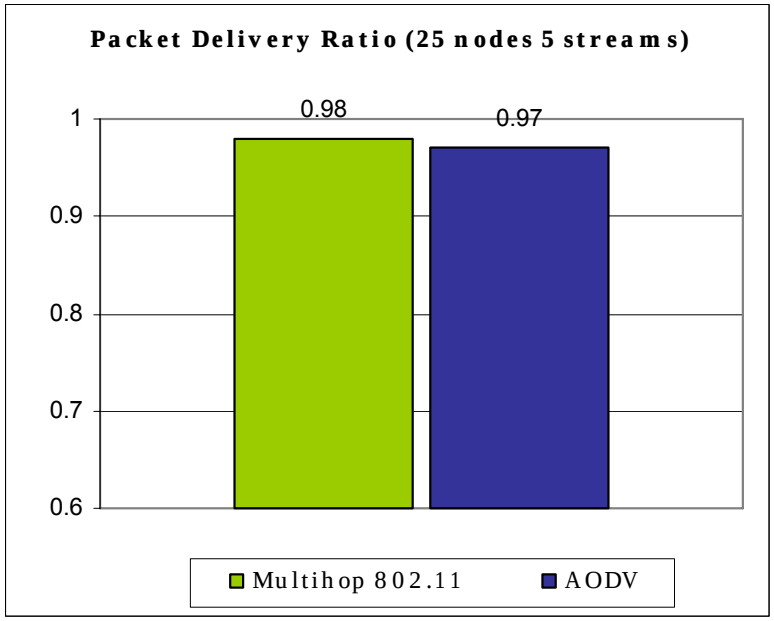
- OPNET Modeler
  - manet_station node model
  - Random way point mobility
- Simulation scenarios with varying
  - Network size
  - Data streams
  - Mobility parameters

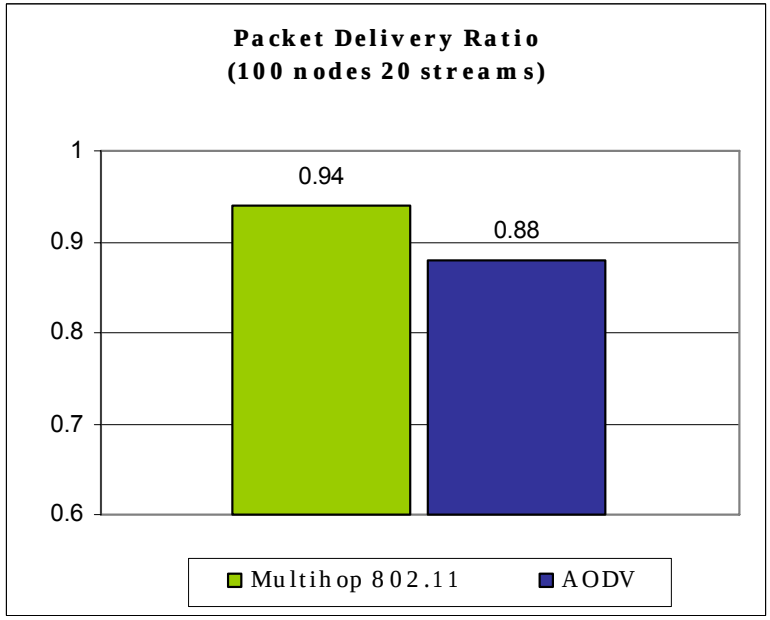
Mobility Parameters			
Variation of	**Pause Time (seconds)**	**Node Speed (m/sec.)**	**Data Packet Rate (packets/second)**
Pause Time	0, 30, 60, 300, 900, 1800	1	4
Node Speed	0	1, 2, 5, 10, 25	4
Packet Rate	0	1	1, 2, 5, 10, 20

Network Parameters			
Nodes	**Area**	**Data Streams**	**Active Nodes**
25	800 m X 800 m	5	8
		20	20
100	2000 m X 500 m	20	30
		80	85

Simulation Results (1)

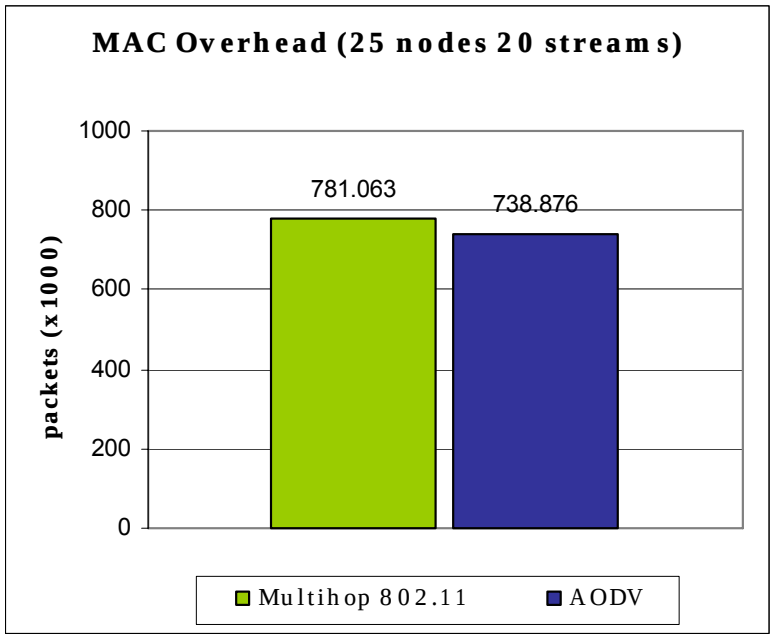
- Better packet delivery ratio
  - Up to 6% high
  - Immediate and local recovery (broadcast)
  - AODV requires a new route discovery (at point of failure or source)

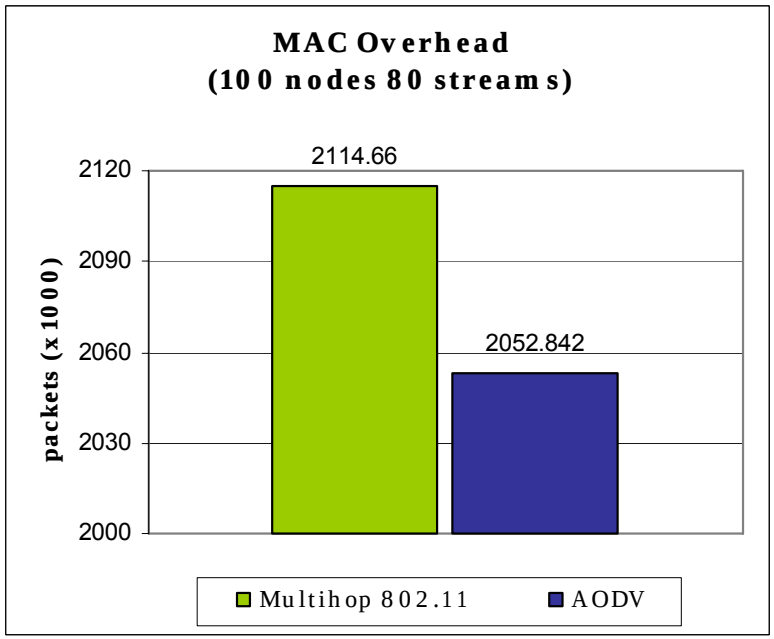




Simulation Results (2)

- Higher MAC overhead
  - Up to 10% high
- Undelivered packets ??
  - Lost while traveling
  - Lost at the source: never transmitted





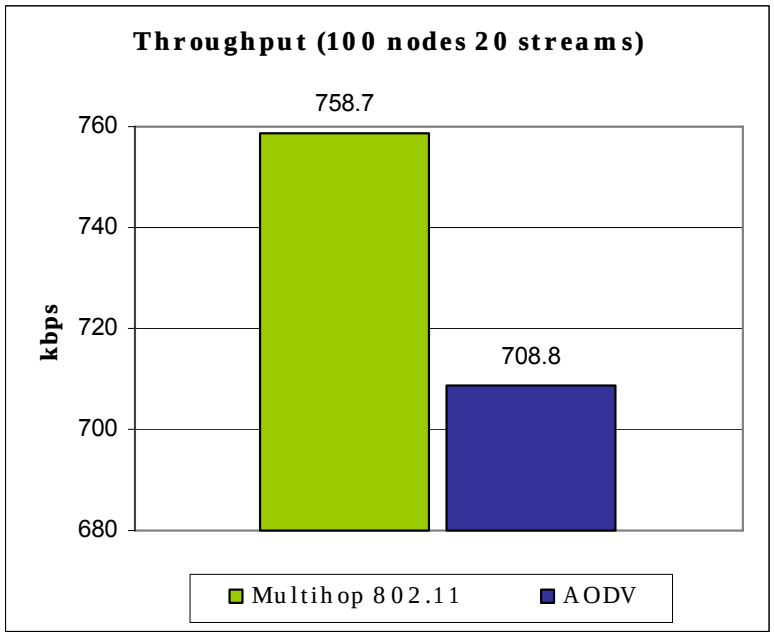
Simulation Results (3)

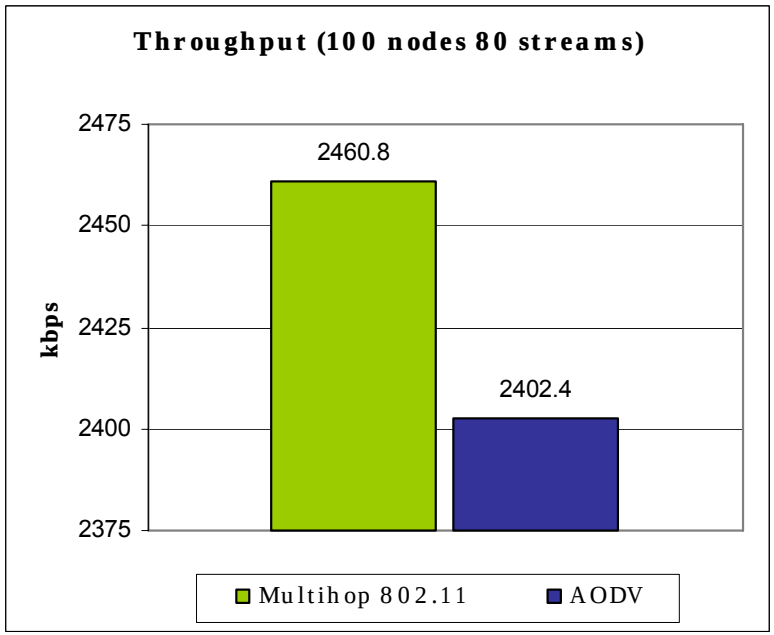
- AODV: up to 48% of undelivered packets are not transmitted
  - The effect of connection failure goes back to the data source
- Multihop 802.11: up to 38% only
  - Heuristic approach does not overload data sources

Packets left at the source / Undelivered packets		
	AODV	**Multihop 802.11**
25 nodes 5 streams	0.047	0.022
25 nodes 20 streams	0.153	0.069
100 nodes 20 streams	0.288	0.081
100 nodes 80 streams	0.476	0.378

Simulation Results (4)

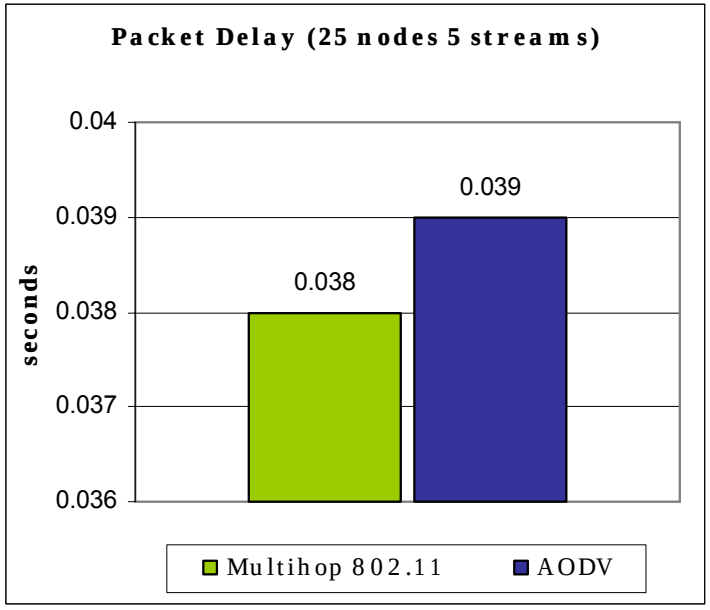
- Higher Throughput
  - A linear relation of packet delivery ratio

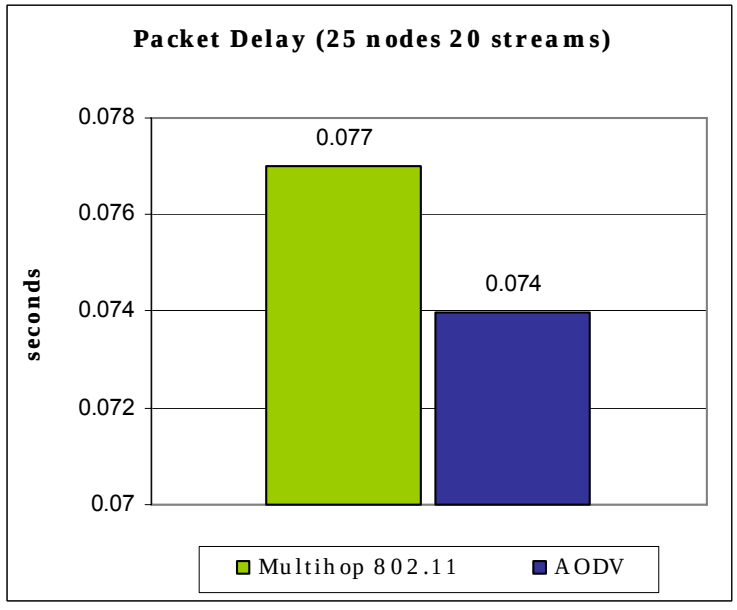




Simulation Results (5)

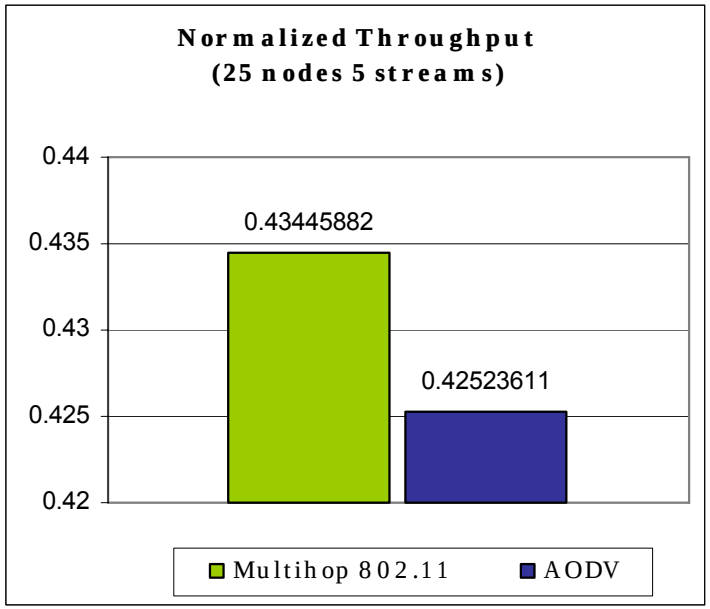
- End-to-end packet delay
  - High-Low
  - Measured only for delivered packets
  - Multihop MAC delivers more packets

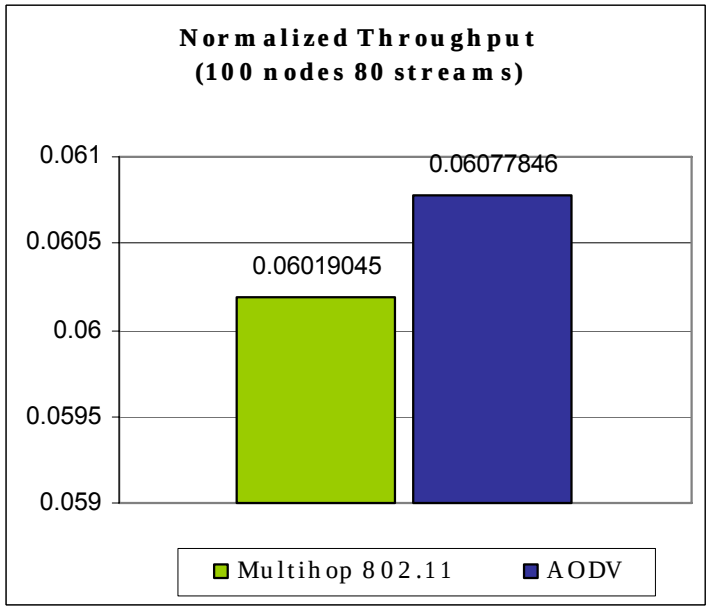




Simulation Results (6)

- Normalized Throughput : high-low
  - Similar cost/overhead efficiency
  - Data packets delivered / MAC packets transmitted
    - AODV transmits less packets





Conclusions

- Relaying seems more suitable in wireless ad hoc networks
  - Can provide a self-dependent and flexible solution
- Multihop IEEE 802.11 MAC protocol is feasible
  - Simpler in implementation
  - Can perform equally or even better than AODV

Future Options

- Refine the design of Multihop IEEE 802.11 MAC protocol
  - Explore the possibility of multihop channel reservation
  - Introduction of accessibility awareness

- Possibility of relaying in other wireless MACs for ad hoc or sensor networks

Thank you very much for your attention

Questions/Comments/Suggestions