Multi-Channel MAC for Ad Hoc Networks：Handling Multi-Channel Hidden Terminals Using a Single Transceiver

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Outline

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Introduction

- IEEE 802.11 standard for wireless LAN provides multiple channels available for use.
- Exploiting multiple channels can achieve a higher network throughput than using one channel.
- MMAC is the first protocol that requires only one transceiver per host, but still solves the multi-channel hidden terminal problem

Related Work

- Dynamic Channel Assignment (DCA)
  - Maintain one dedicated channel for control message and other channels for data
  - Each host has two transceivers
  - RTS/CTS packets are exchanged on the control channel, and data packets are transmitted on the data channel
  - It does not perform well in an environment where all channels have the same bandwidth.

Multi-Channel Hidden Terminal Problem(1/2)

- We use a simple multi-channel MAC protocol that does not address this problem.
- The protocol is similar to DCA, except it assumes each node has one transceiver.
- The problem results from the fact that nodes may listen to different channels, which makes it difficult to use virtual carrier sensing to avoid it.

Multi-Channel Hidden Terminal Problem (2/2)

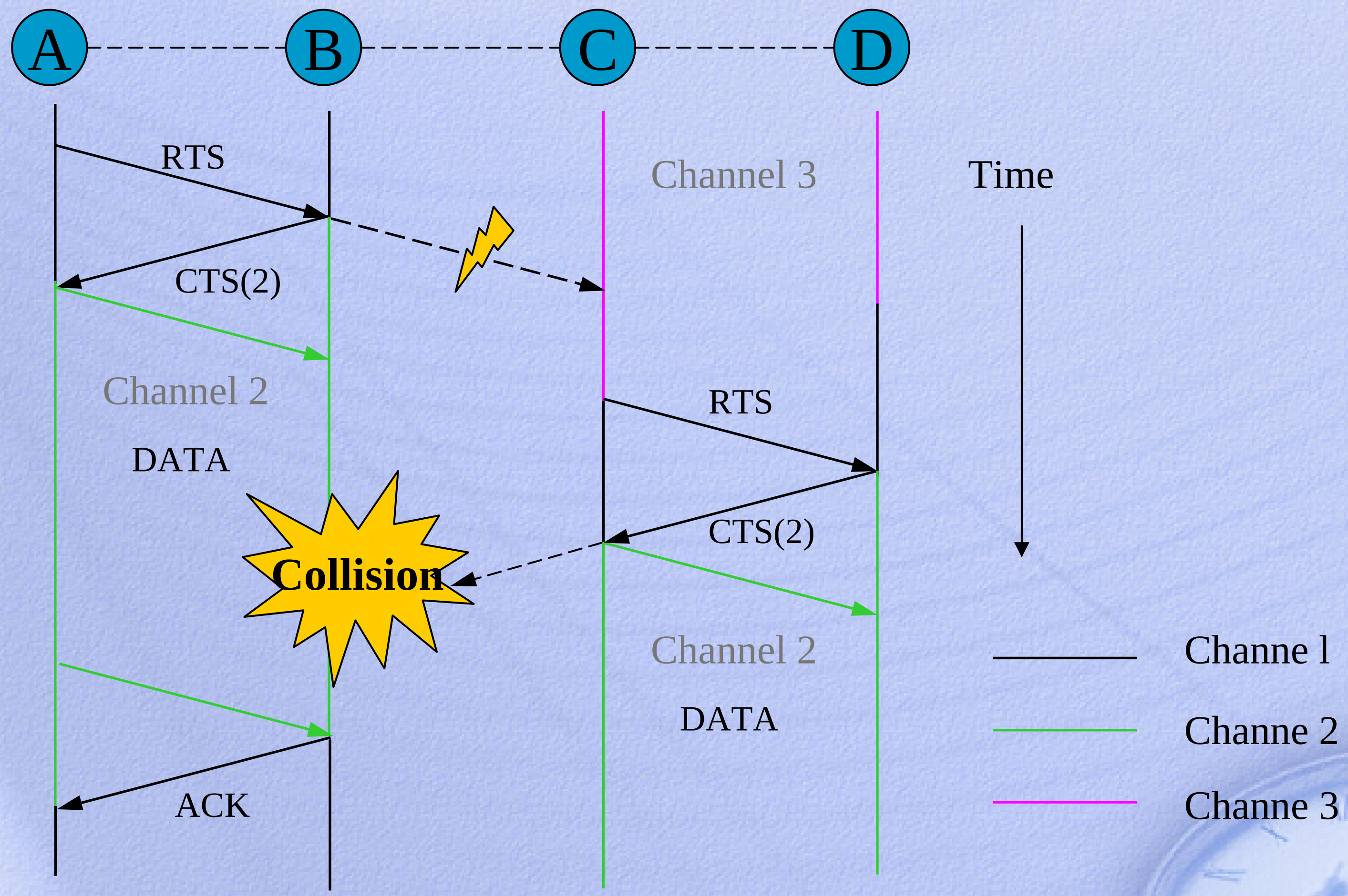


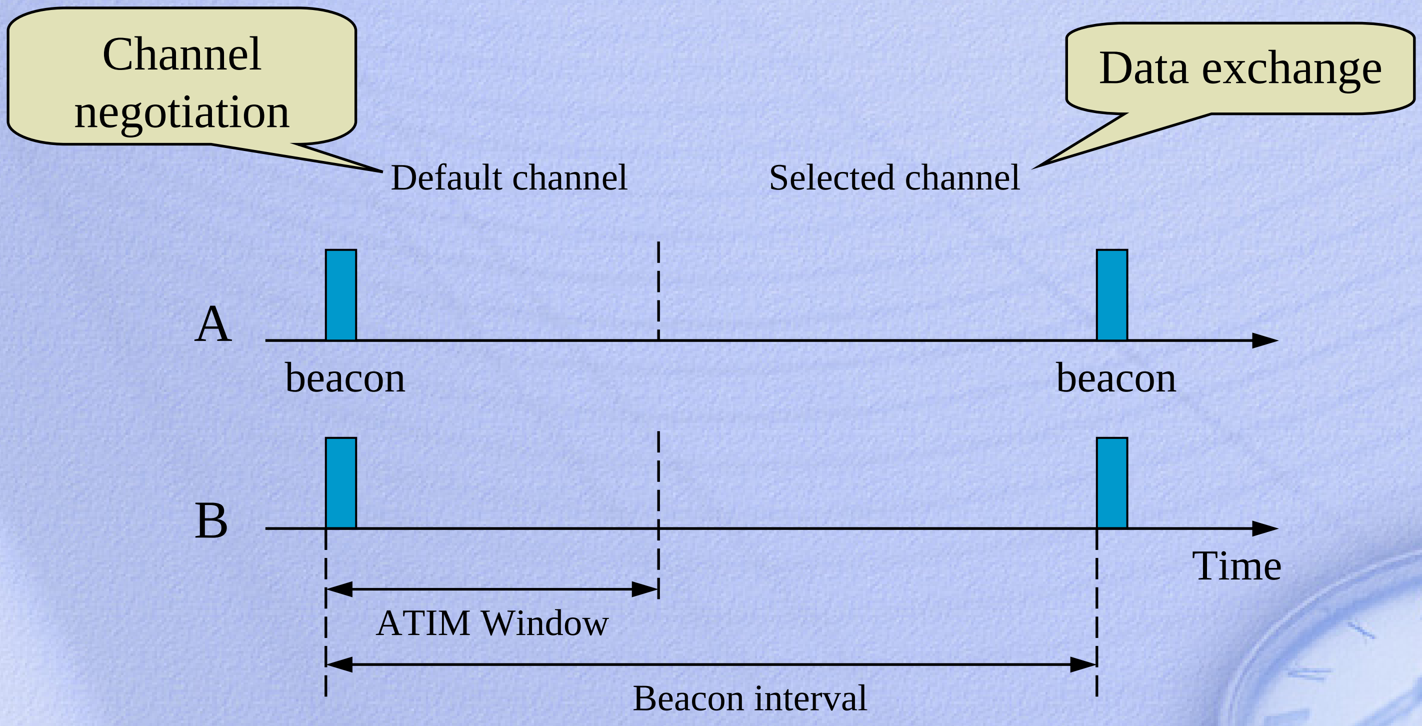
Figure 3

Multi-Channel MAC (MMAC) Protocol (1/7)

- Assumptions :
  - N channels are available for use and all channels have the same bandwidth.
  - Each host is equipped with a single half-duplex transceiver.
  - The transceiver is capable of switching its channel dynamically.
  - Nodes are synchronized, so that all nodes begin their beacon interval at the same time.

Multi-Channel MAC (MMAC) Protocol (2/7)

- The main idea
  - MMAC is similar to the IEEE 802.11's power saving mechanism.



Multi-Channel MAC (MMAC) Protocol (3/7)

- Preferable Channel List (PCL)
  - PCL records the usage of channels inside the transmission range of the node.
  - Counter
    - Record how many source-destination pairs plan to use the channel
  - Categorize into three states :
    - HIGH
    - MID
    - LOW

Channel	State	Counter

Multi-Channel MAC (MMAC) Protocol (4/7)

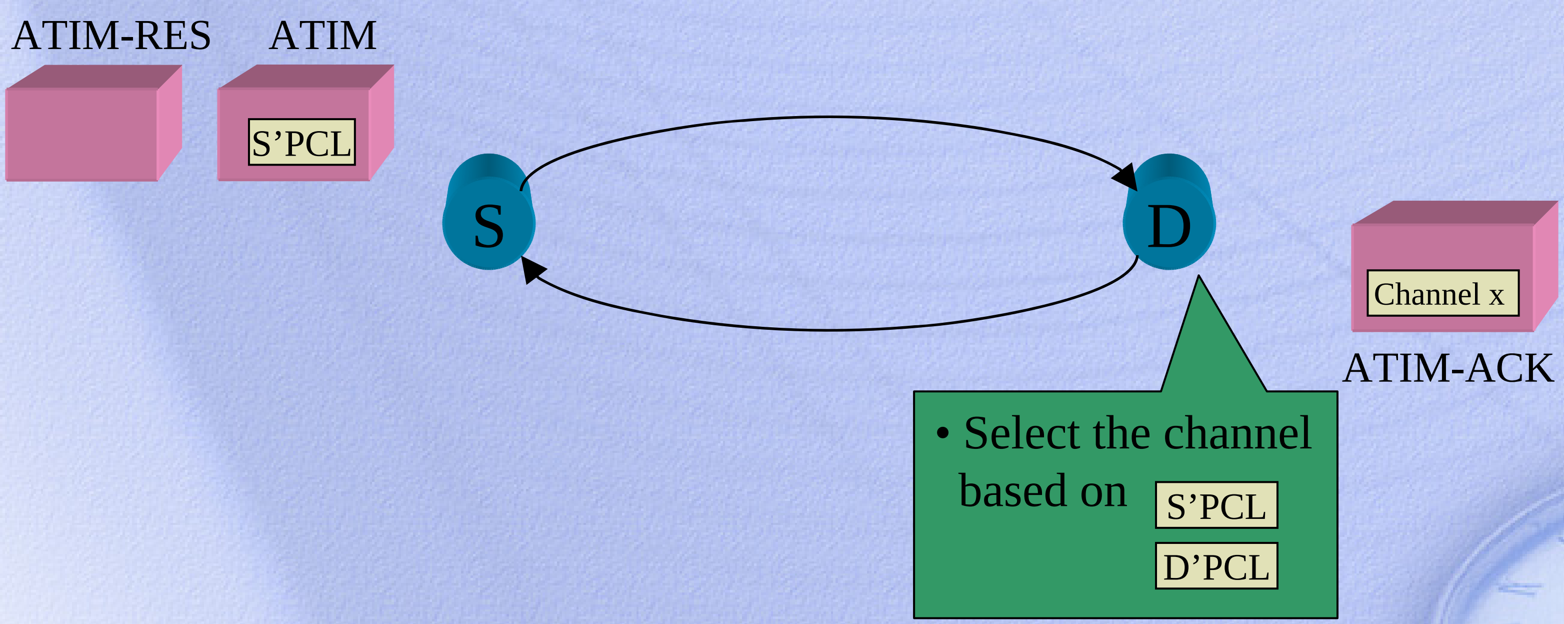
- The channel states are changed in the following way:
  - Reset to MID state when:
    - the node is powered up
    - at the start of each beacon interval
  - If the source and destination nodes agree upon a channel, they both record it to be in HIGH state.
  - Overhear an ATIM-ACK or ATIM-RES

previous	after
HIGH	HIGH
MID	LOW
LOW	LOW

Counter +1

Multi-Channel MAC (MMAC) Protocol (5/7)

- Channel negotiation during ATIM window
  - If S can not select the same channel as D, it does not send an ATIM-RES to D.



Multi-channel MAC (MMAC) protocol (6/7)

- Rules for selecting the channel
  - Select the “best” channel

    - the channel with the least scheduled traffic
  - This algorithm attempts to balance the channel load as much as possible, so that bandwidth waste is reduced.

High

PCL	State
B	HIGH
A	HIGH
A and B	MID
A or B	MID
1. Add the counters 2. Select the least count	

Low

Multi-Channel MAC (MMAC) Protocol (7/7)

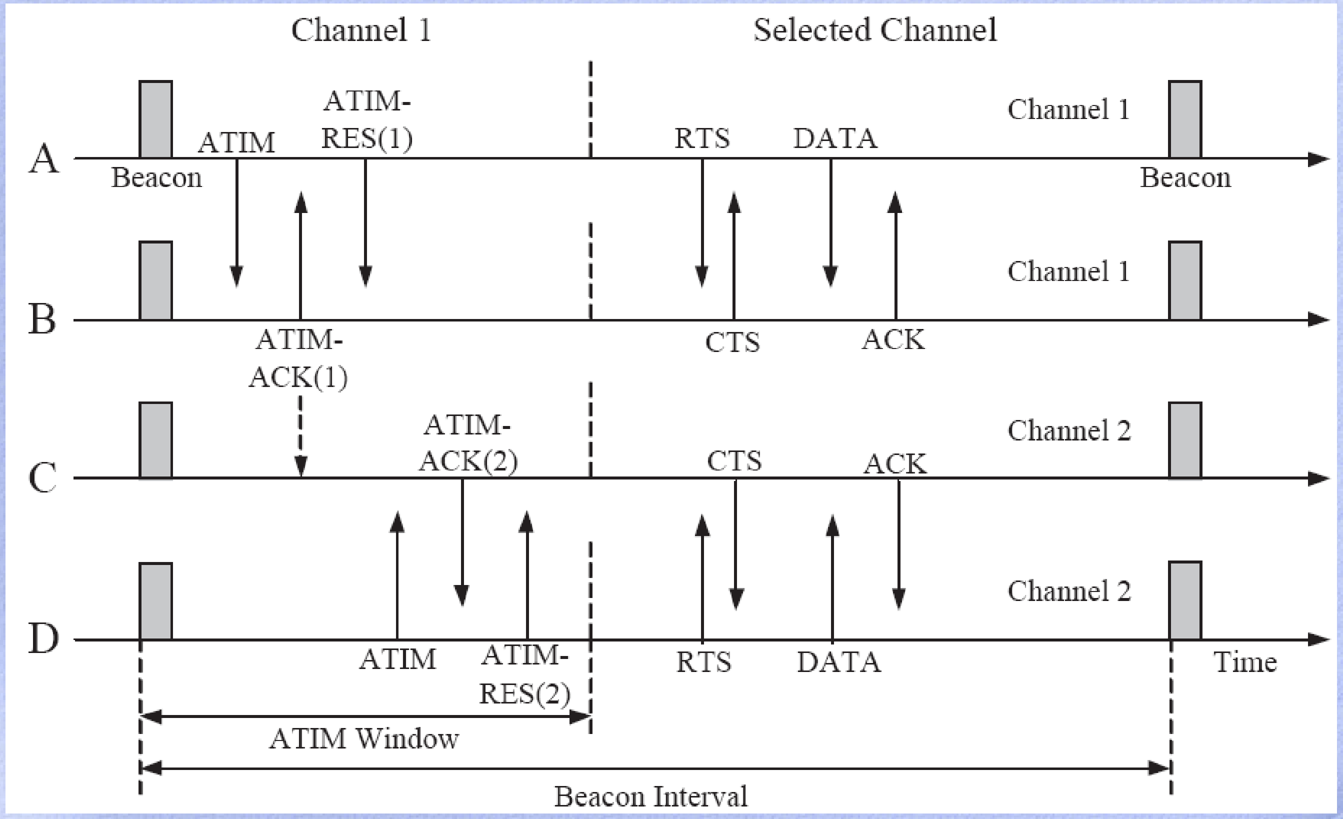


Figure 4: Process of channel negotiation and data exchange in MMAC

Performance Evaluation(1/7)

- Compare with IEEE 802.11, and DCA protocol
- Two metrics :
  - Aggregate throughput over all flows in the network
  - Average packet delay over all flows in the network

Performance Evaluation (2/7)

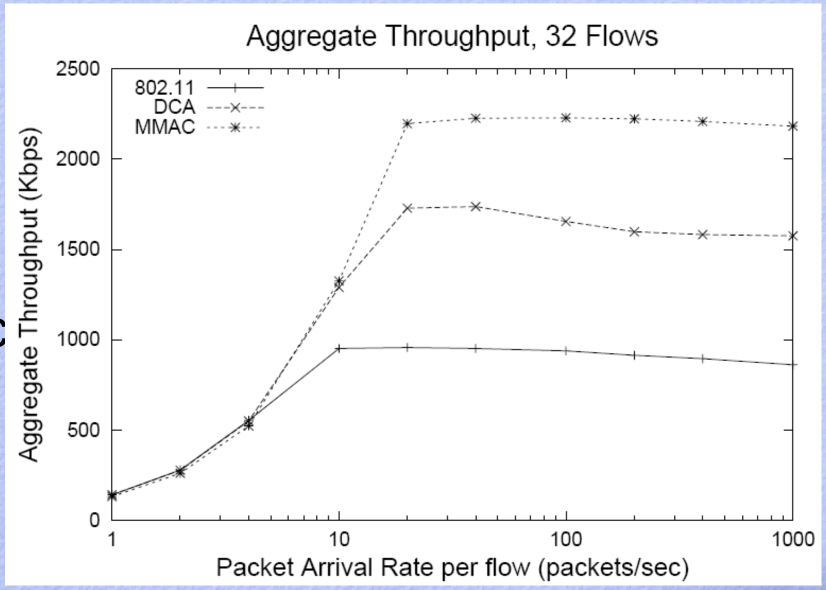
- Simulation model
  - Ns-2
  - Two network scenarios
    - Wireless LAN
    - Multi-hop network
  - Transmission range : 250m
  - Beacon interval : 100ms
  - 3 channels
  - Packet size : 512 bytes
  - ATIM window : 20ms

Performance Evaluation (3/7)

- Simulation results
  - Wireless LAN

    - Can not achieve 3 times throughput compared to IEEE 802.11, because of it's overhead

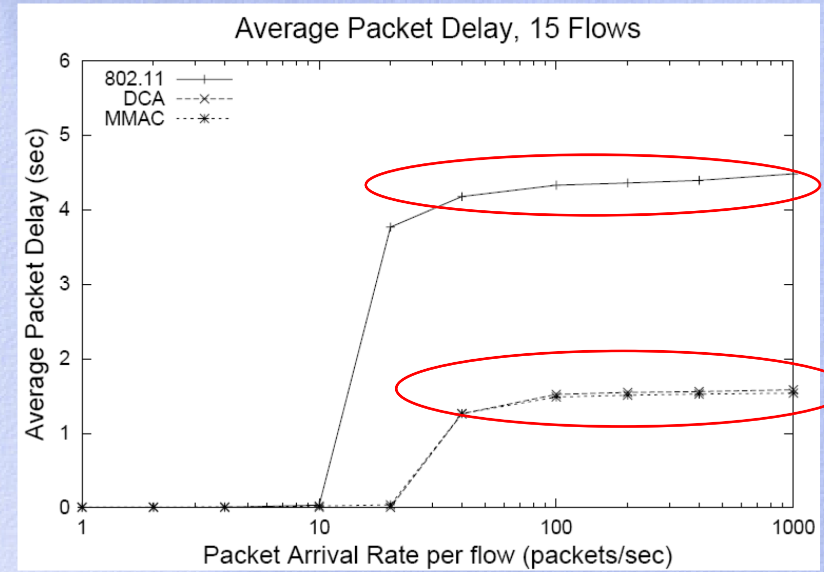
    -The overheads are periodic beacon transmission and ATIM packets.



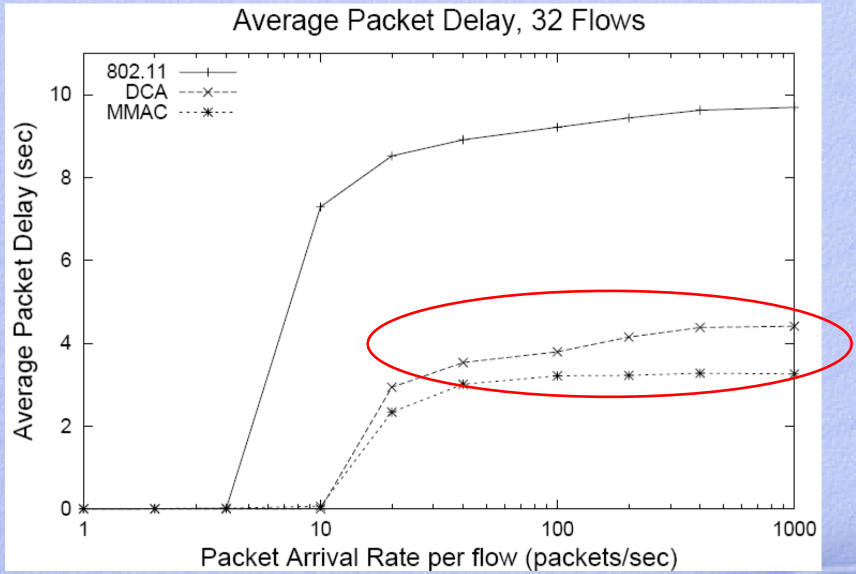
64 nodes

Figure 5: Aggregate throughput vs. Packet arrival rate

Performance Evaluation (4/7)



30 nodes



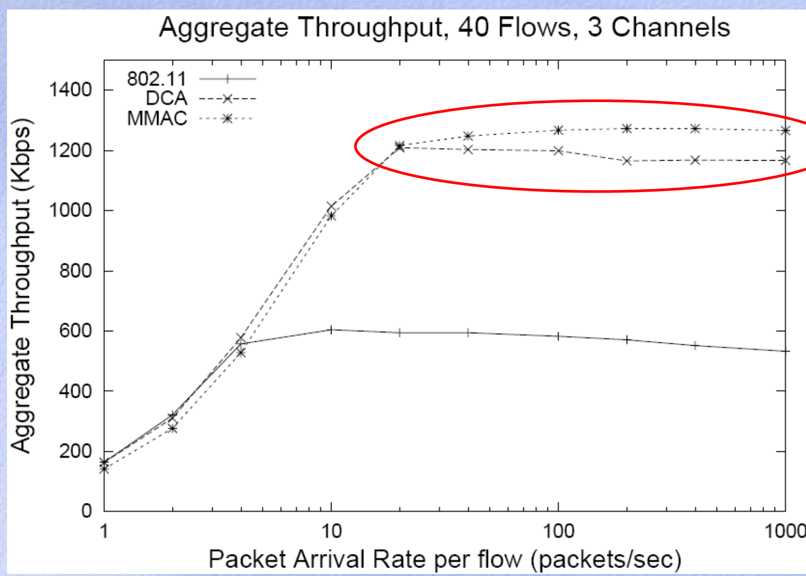
64 nodes

Figure 6: Average packet delay vs. Packet arrival rate

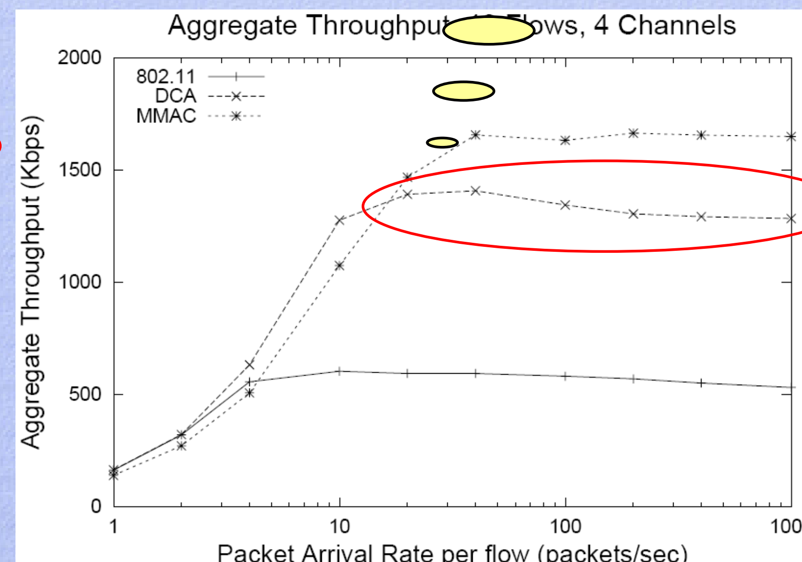
Performance Evaluation (5/7)

- Multi-hop network
  - Packet size is 512 bytes

Control channel saturation



3 channels



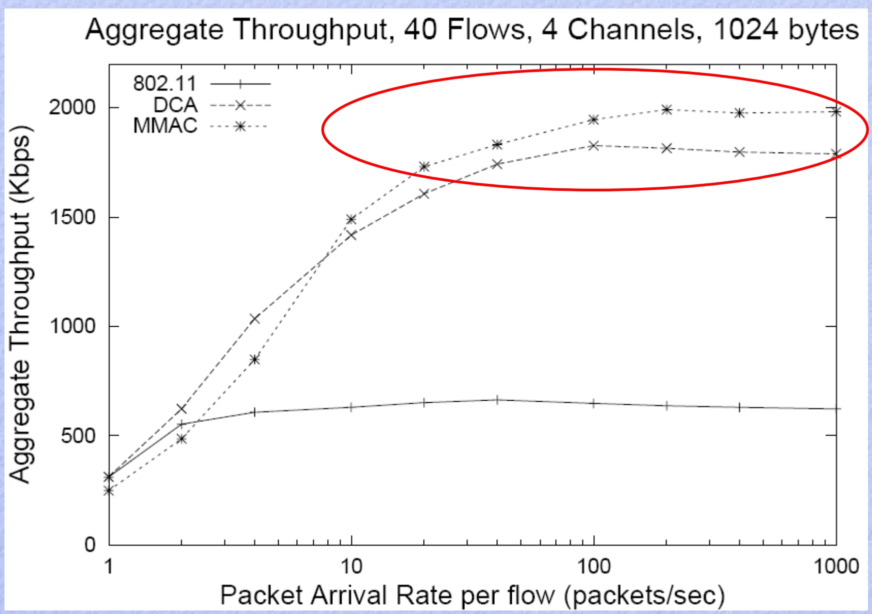
4 channels

Figure 7: Aggregate throughput vs. Packet arrival rate

Performance Evaluation (6/7)

- Packet size is 1024 bytes

  - the impact of control channel saturation can be reduced, because less control message are needed to transmit the same amount of data



4 channels

Figure 8: Aggregate throughput vs. Packet arrival rate

Performance Evaluation (7/7)

- The ATIM window size affects the throughput of MMAC protocol
- The optimal ATIM window size depends mainly on the number of flows in the beacon interval.
  - Flow ↑ ATIM window ↑
  - Flow ↓ ATIM window ↓

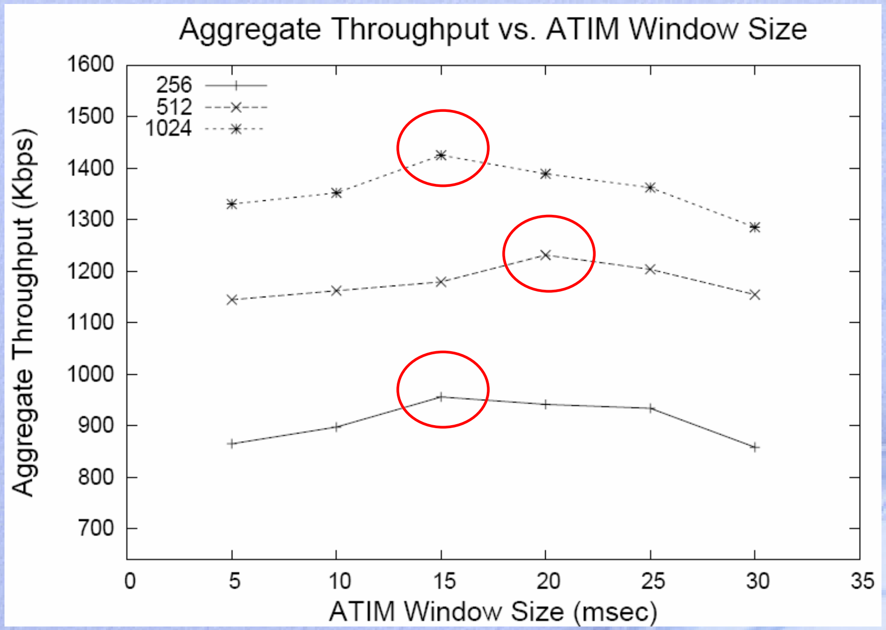


Figure 10: Aggregate throughput vs. ATIM window size

Conclusion And Future Work

- The advantage of MMAC
  - Exploit multiple channels to improve total network throughput over IEEE 802.11 single channel
  - Perform better or at least comparable to DCA in most cases
  - Require only one transceiver per host
    - Can be implemented with hardware complexity comparable to IEEE 802.11
  - IEEE 802.11 PSM can be integrated with MMAC for energy efficiency, without further overhead
- Future work
  - Change the size of ATIM window dynamically, based on the traffic cindition

THE END