COPE-MAC: A Contention-based Medium Access Control Protocol with Parallel Reservation for Underwater Acoustic Networks

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Outline

- **Overview**
- Motivations
- Previous work
- COPE-MAC
- Simulation results
- Conclusions

Underwater Sensor Networks

- Underwater Sensor Networks (UWSNs)
  - Forming sensor networks in underwater environments

- UWSN has a wide range of applications
  - Environment monitoring
  - Persistent surveillance
  - Oil/gas industry
  - Transportation
  - Fishery
  - …

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Motivation

- Acoustic modems are getting faster
  - higher data rate: 80bps ~ 10kbps
  - Transmission delay is decreasing
- Long propagation delay slows down the network communication
  - Could easily go to a few seconds
  - High costs limit the number of sensor nodes
  - Distance between two nodes would be very long
  - Propagation delay will still be very long, no matter how modem technology improves
  - Old handshaking methods would be less efficient

Objectives

- Improve the efficiency of medium access control (MAC) protocol
- Increase the throughput of the underwater network
- Reduce energy overheads

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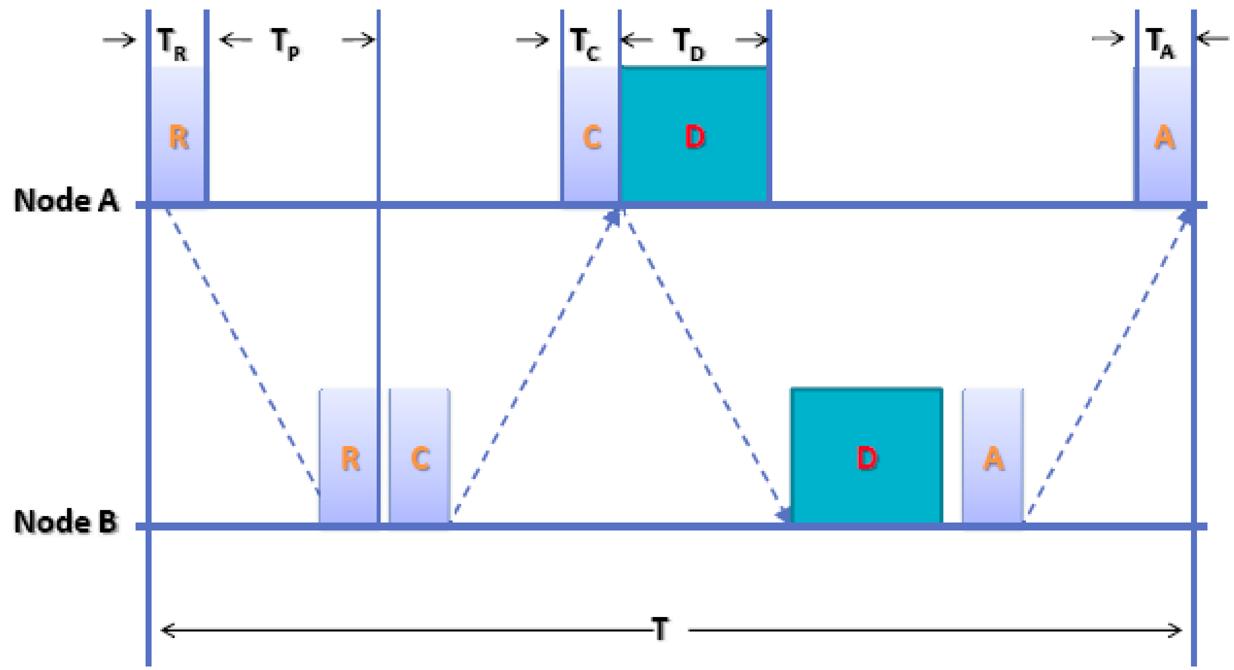
Typical RTS/CTS approach

- Use RTS/CTS/DATA/ACK to establish one connection
- Channel utilization

$$\eta \leq \frac{T_D}{T} \leq \frac{T_D}{T_D + 4 \times T_P} = \frac{1}{1 + 4 \times \alpha}$$

- T_R: control frame delay
- T_D: data frame delay
- T_P: propagation delay



Limitations of previous protocol

- In UWSN, one round of RTS/CTS could be longer than DATA
- Only one connection can be established with one handshake
- Low channel utilization
- Nodes are suppressed when receiving CTS/RTS messages
- Unable to establish connections when neighbors are handshaking

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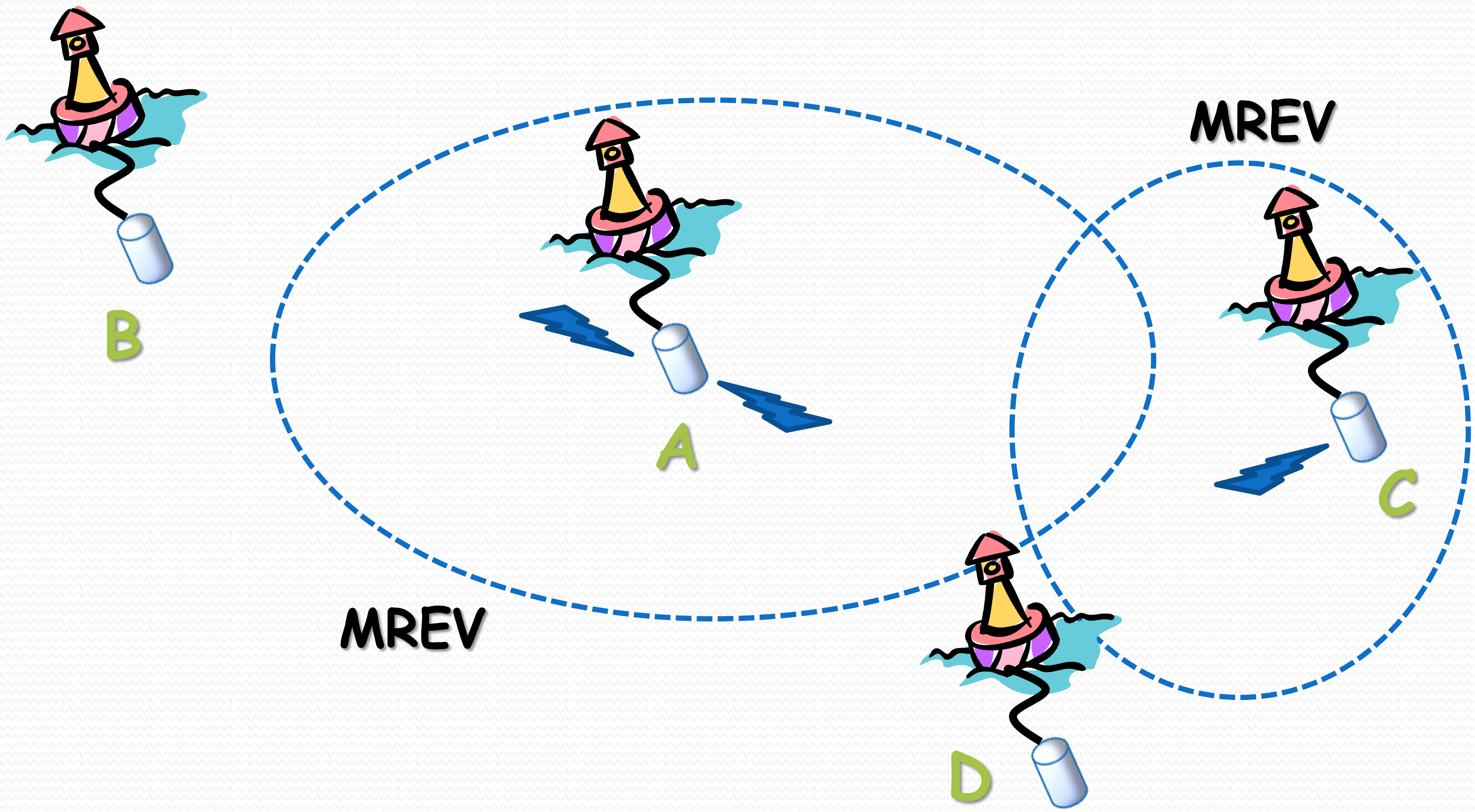
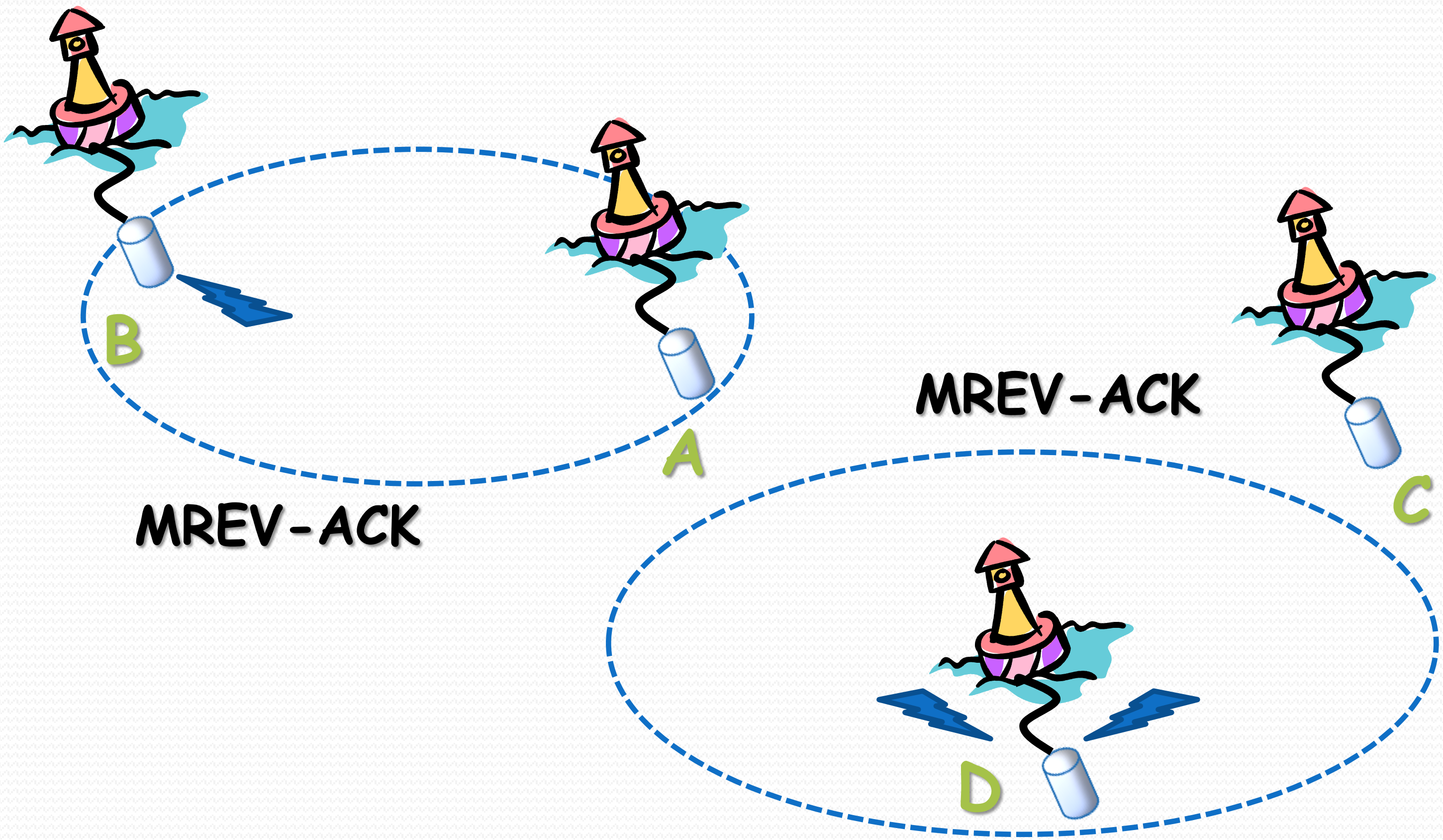
COPE-MAC Overview

- COPE-MAC:
  - **CO**ntention based **P**arallel r**E**servation **M**edium **A**ccess **C**ontrol
- Based on RTS/CTS
- Parallel Reservation
- Cyber Carrier Sensing

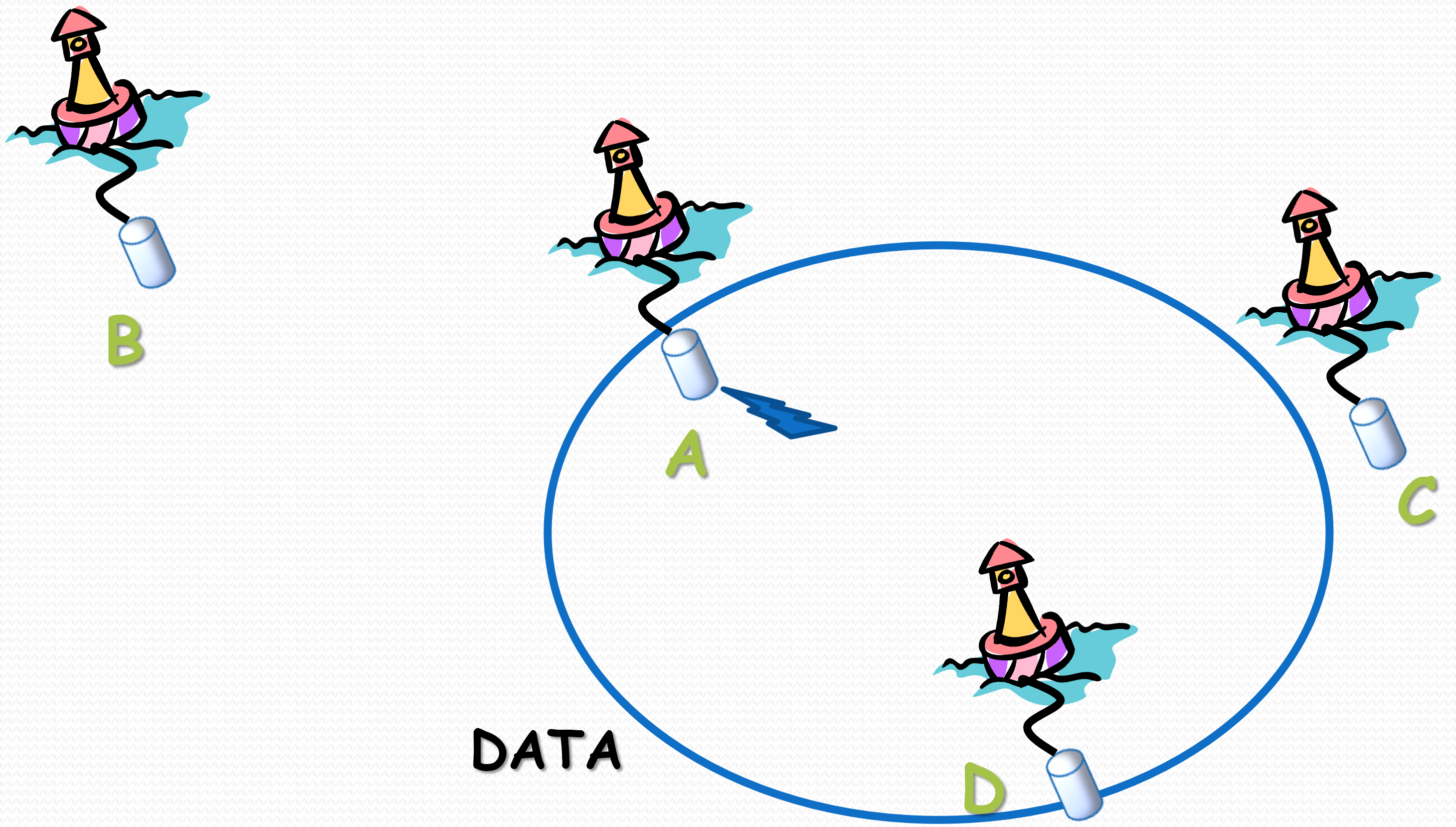
COPE-MAC example



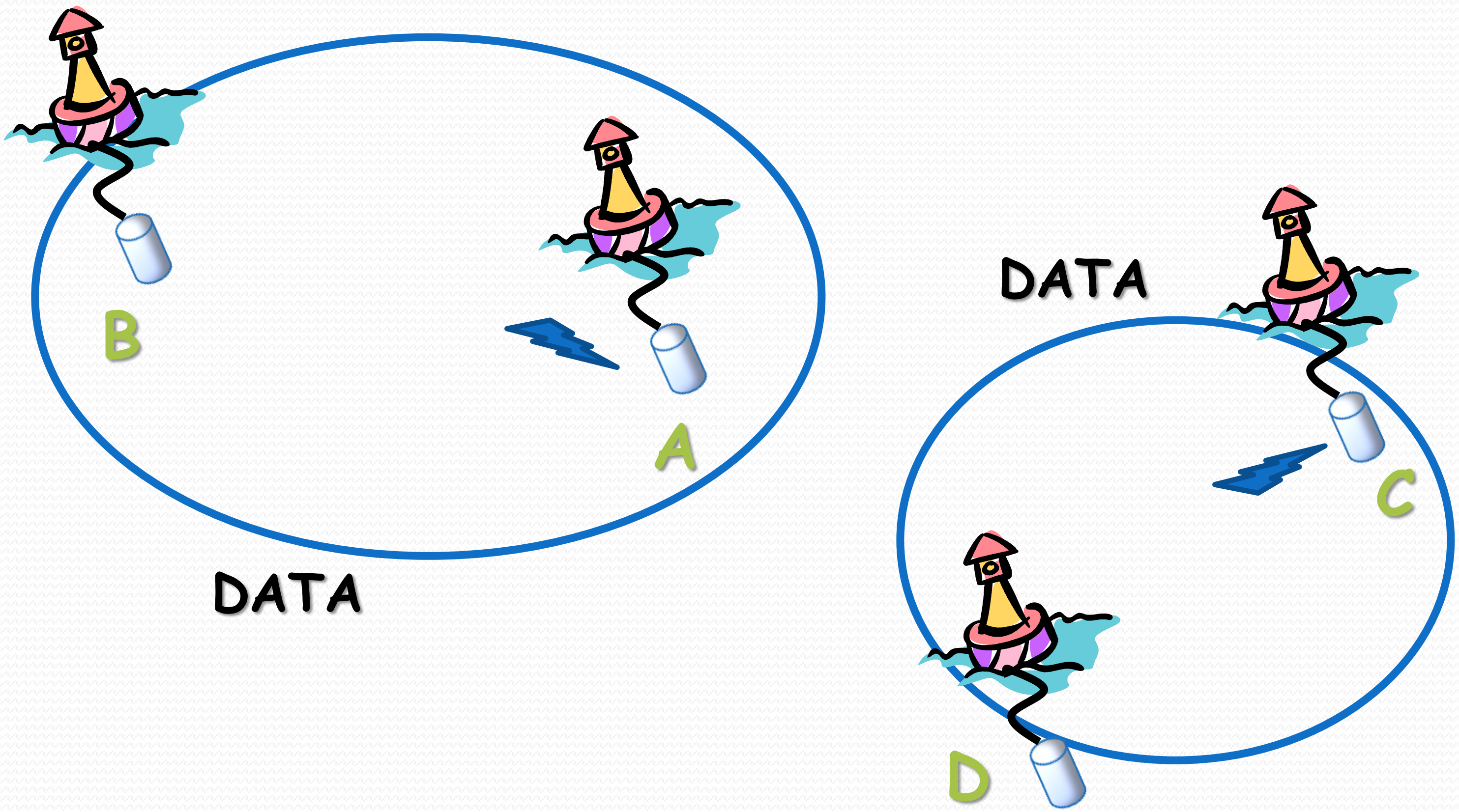
COPE-MAC example



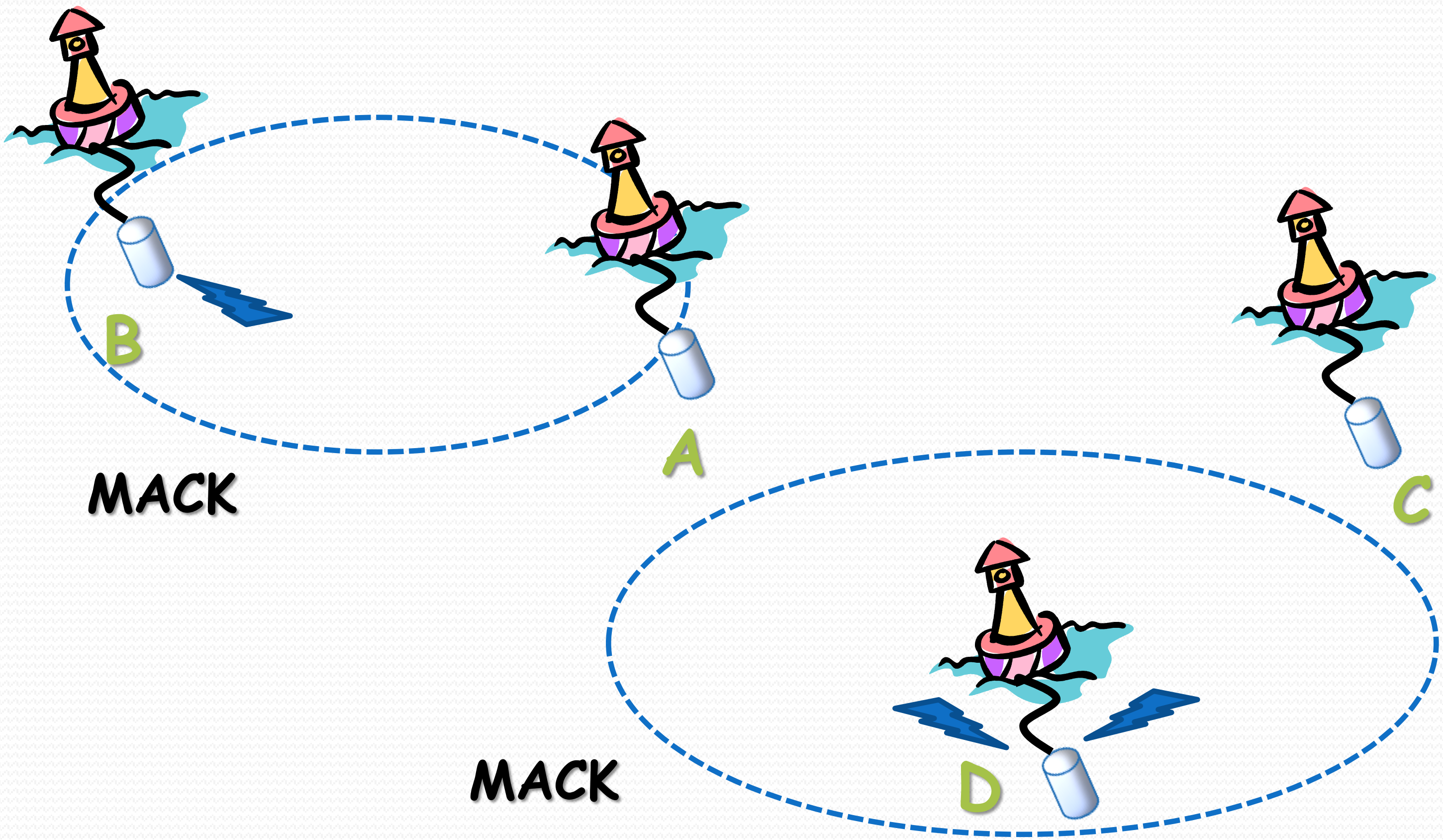
COPE-MAC example



COPE-MAC example



COPE-MAC example



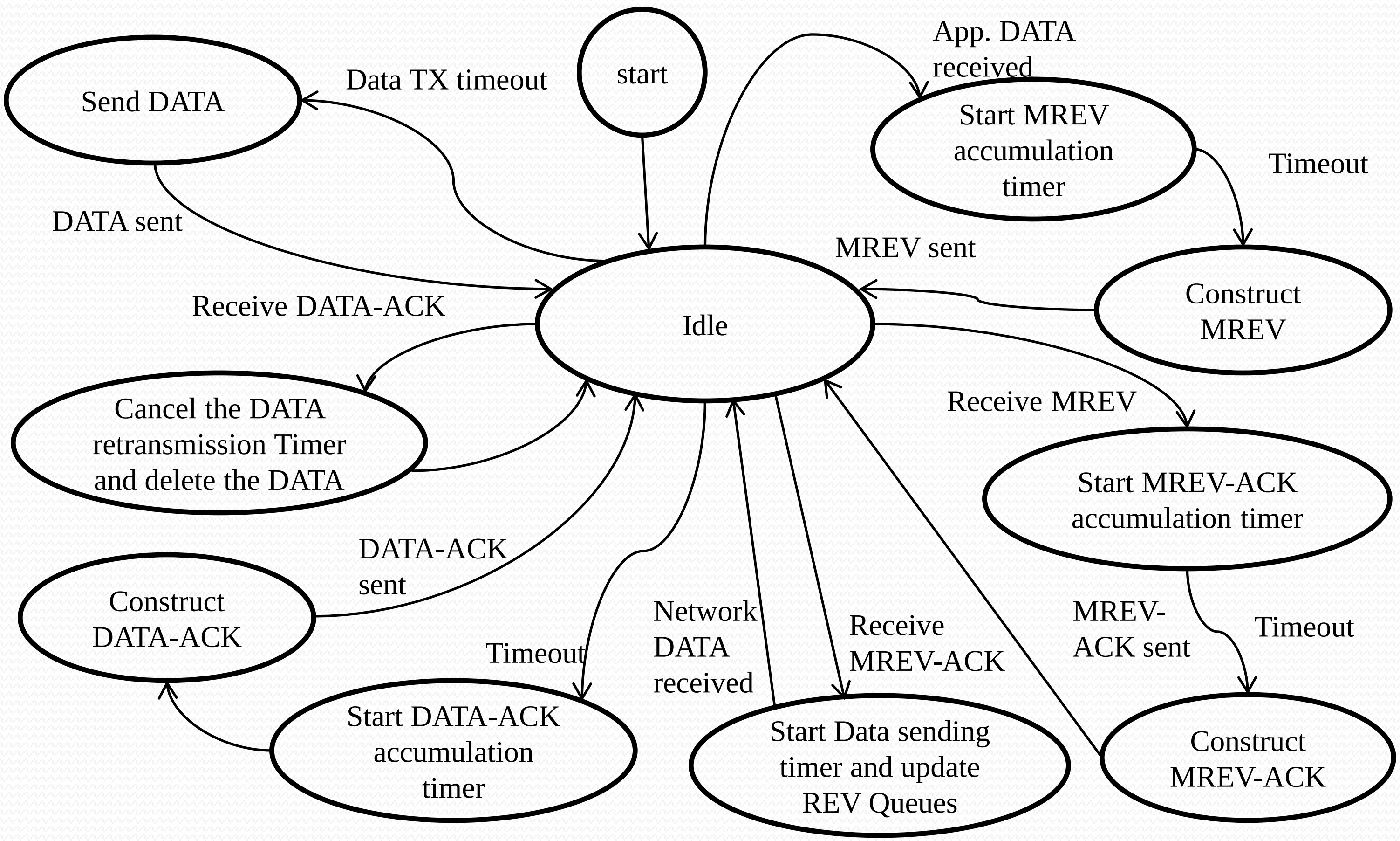
Parallel Reservation

- Parallel reservation
  - Schedule packet transmissions in the near future
  - Schedule packet transmissions to multiple destination
- Multicast RTS/CTS/ACKs
  - Can contain multiple source, destination addresses
  - One RTS can request for sending data to multiple neighbors at different time
  - One CTS can establish connections to different nodes
  - One ACK can acknowledge Data from multiple nodes

Cyber carrier sensing

- Carrier sensing
  - Full-duplex channel
  - Avoid collision by detecting a carrier wave
  - Example: CSMA/CD in 802.3 Ethernet
- Virtual carrier sensing
  - Half-duplex channel
  - Avoid collision by detecting control packets
  - Example: CSMA/CA in 802.11 with RTS/CTS
- **Cyber carrier sensing**
  - Half-duplex channel
  - Control messages include local "schedule"
  - Construct a virtual channel
    - Map neighbors' time to "local time"
    - <u>No propagation delay</u>
  - <u>Detect</u> collision by scanning the virtual channel in "cyber space"

States of a COPE-MAC node



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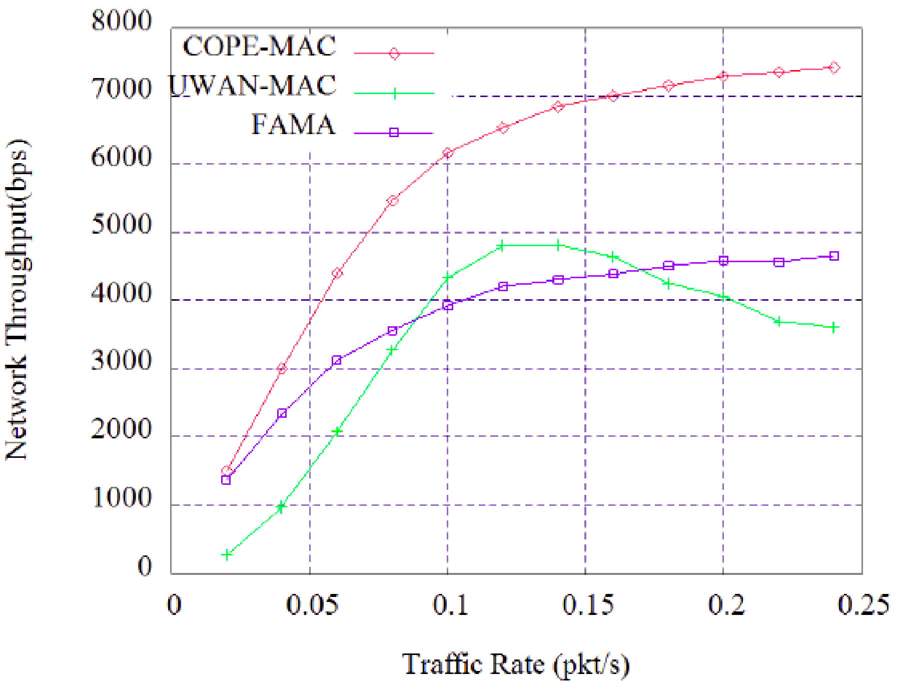
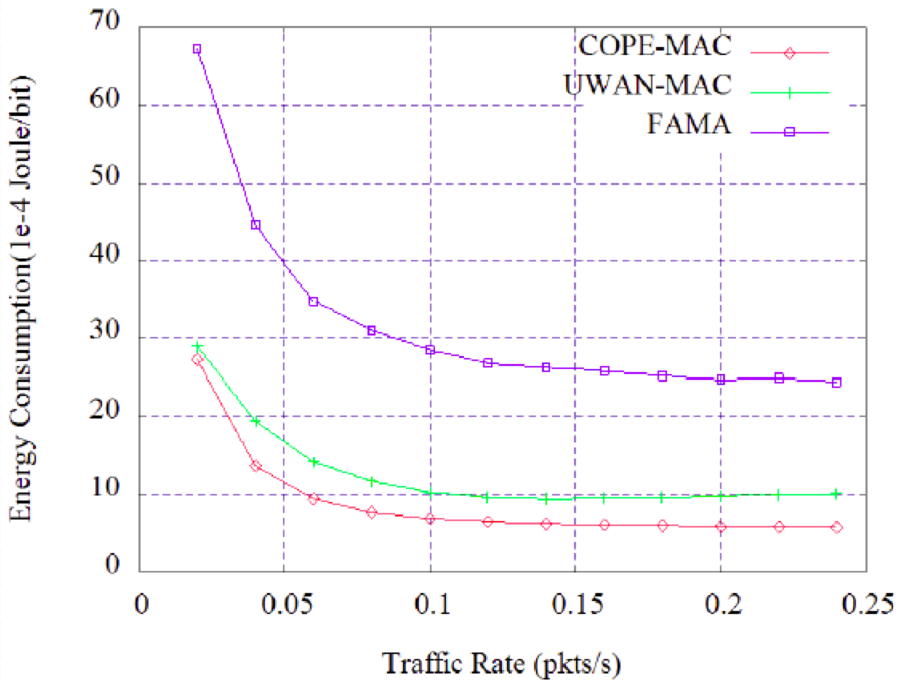
Simulation Results

- Simulation settings
  - Number of nodes: 50
  - Packet arrival mode: Poisson
  - Simulation time: 1000 seconds
  - Number of runs: 100
- Scenario I
  - Network size: 5500 x 5500 m^2
  - λ range: 0.02 to 0.24
- Scenario II
  - Average neighbor distance: 500 to 900 meters
  - λ is fixed at 0.1

Scenario I

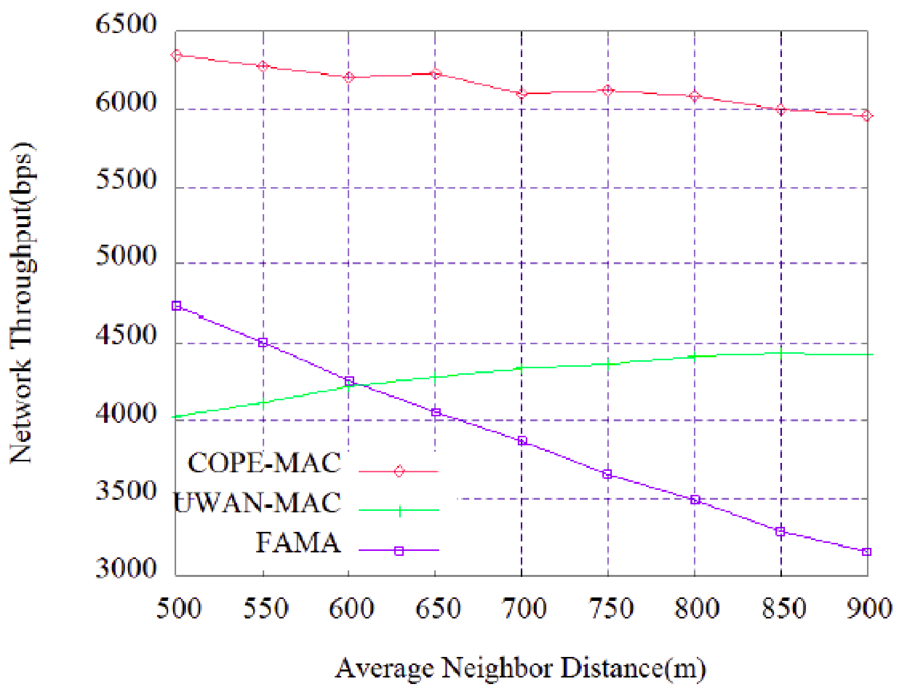


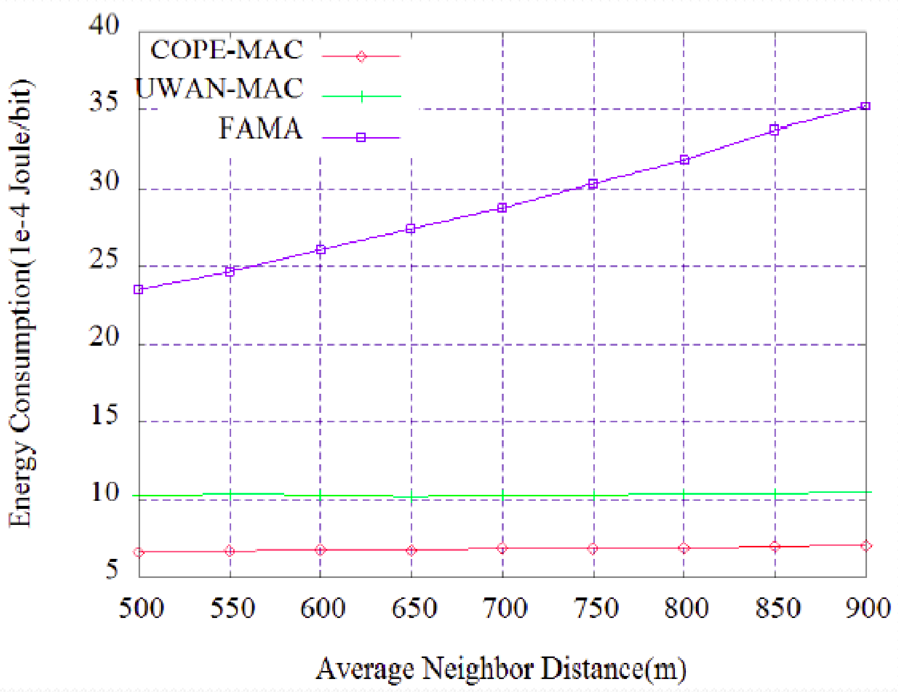
Network Throughput(bps)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.05
0.1
0.15
0.2
0.25
Traffic Rate (pkt/s)
COPE-MAC
UWAN-MAC
FAMA



Energy Consumption(1e-4 Joule/bit)
70
60
50
40
30
20
10
0
0
0.05
0.1
0.15
0.2
0.25
Traffic Rate (pkts/s)
COPE-MAC
UWAN-MAC
FAMA

Scenario II


6500
6000
5500
5000
4500
4000
3500
3000
500 550 600 650 700 750 800 850 900
Network Throughput(bps)
Average Neighbor Distance(m)
COPE-MAC
UWAN-MAC
FAMA


40
35
30
25
20
15
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5
500 550 600 650 700 750 800 850 900
Energy Consumption(1e-4 Joule/bit)
Average Neighbor Distance(m)
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Conclusions

- COPE-MAC
  - Key features:
    - Parallel reservation
    - Cyber carrier sensing
  - Performance:
    - High network throughput
    - Better energy efficiency

- Future work
  - Field test with real environment
  - Study the effects of concurrency on network performance

Thanks!

Questions
&
Comments?