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:
  - COnstention based Parallel rEervation MEdium Access Control
- Based on RTS/CTS
- Parallel Reservation
- Cyber Carrier Sensing
COPE-MAC example
COPE-MAC example

B
MREV-ACK

A
MREV-ACK

C

D
MREV-ACK
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”
  - No propagation delay
  - Detect collision by scanning the virtual channel in “cyber space”
States of a COPE-MAC node

- **Start MREV accumulation timer**
- **App. DATA received**
- **Start MREV-ACK accumulation timer**
- **Construct MREV**
- **Construct MREV-ACK**
- **Receive DATA-ACK**
- **Receive MREV**
- **Receive MREV-ACK**
- **Start DATA-ACK accumulation timer**
- **Start Data sending timer and update REV Queues**
- **Send DATA**
- **DATA sent**
- **Data TX timeout**
- **Receive DATA-ACK**
- **Cancel the DATA retransmission Timer and delete the DATA**
- **Construct DATA-ACK**
- **DATA-ACK sent**
- **Timeout**
- **Network DATA received**
- **MREV sent**
- **Timeout**
- **DATA sent**
- **DATA TX timeout**
- **Timeout**
- **MREV sent**
- **Receive MREV-ACK**
- **MREV-ACK sent**
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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 m²
  - $\lambda$ range: 0.02 to 0.24

- **Scenario II**
  - Average neighbor distance: 500 to 900 meters
  - $\lambda$ is fixed at 0.1
Scenario I
Scenario II
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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?