Underwater Acoustic Networks

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Outline

- Introduction
- Network Design Principles
- Known Deployments
- Design Example
- Conclusions
- Comments & Discussion

Introduction

- Goal: Long-term Monitoring of selected ocean areas
- Traditional approach: Record & Recover
  - Long lags
  - Loss of all data in case of a failure
- Ideal approach: real-time data acquisition, control and command

Introduction

- Characteristics of Shallow-water acoustic channel
  - Limited bandwidth; dependant on range+freq.
  - Low Propagation speed (5 times lower than that of radio channels)
  - Acoustic signals are subject to time-varying multipath which may result in
    - Severe inter-symbol interference (ISI)
    - Large Doppler shifts and spreads

Network Topologies

- Centralized
  - Suitable for Deep-water UWA Networks
  - Single point of failure
  - Cannot cover large areas
- Fully Connected Peer to Peer
  - Eliminates the need for routing
  - High communication cost for two nodes far from each other
  - Near-far problem
- Multihop Peer to Peer
  - Cover large areas
  - Increasing packet delay

Multiple Access Methods

If many users share a channel

and two or more users transmit packets simultaneously, collision may occur.

To avoid the collision,

suitable access method should be selected.

Multiple Access Methods

- FDMA
  - User fading
  - Possible waste of channel capacity
- TDMA
  - Requires guard time between slots
  - More Flexible (assigning additional slots to a user)
  - Requires Time Synchronization
  - Large idle times & Low throughput
- CDMA
  - Users operate simultaneously over the entire band
  - Resistant to frequency fading due to large BW.
    - A Promising Choice for Shallow-water A.N.
  - Near-far Problem

Media Access Protocols

- ALOHA, Slotted ALOHA
  - Retransmissions to resolve collisions:
    - Power consumption↑ , Lifetime↓
- CSMA
  - Hidden Node Problem
  - Exposed Node Problem
    - Solution: Adding guard time proportional to propagation time
    - Inefficient due to extensive propagation delay in UWA Net

Media Access Protocols (Cntd.)

- MACA
  - Exchange RTS, CTS to detect/avoid collision
  - Automatic Power Control
  - A basis for UWA Net. Media Access protocols
- MACAW
  - Using Ack messages in link layer
    - More gain in throughput than increase in Overhead
  - Throughput of MACAW in Shallow-Water?
  - Throughput of MACAW under Power Control?

Automatic Repeat Request (ARQ)

- Stop & Wait
- Go Back N
  - Needs full duplex links
    - Assigning Freq. bands for Tx and Rx.
    - Dividing the BW → Decrease the data rate
- Selective Repeat
  - The most efficient one
  - Needs full duplex links

Routing

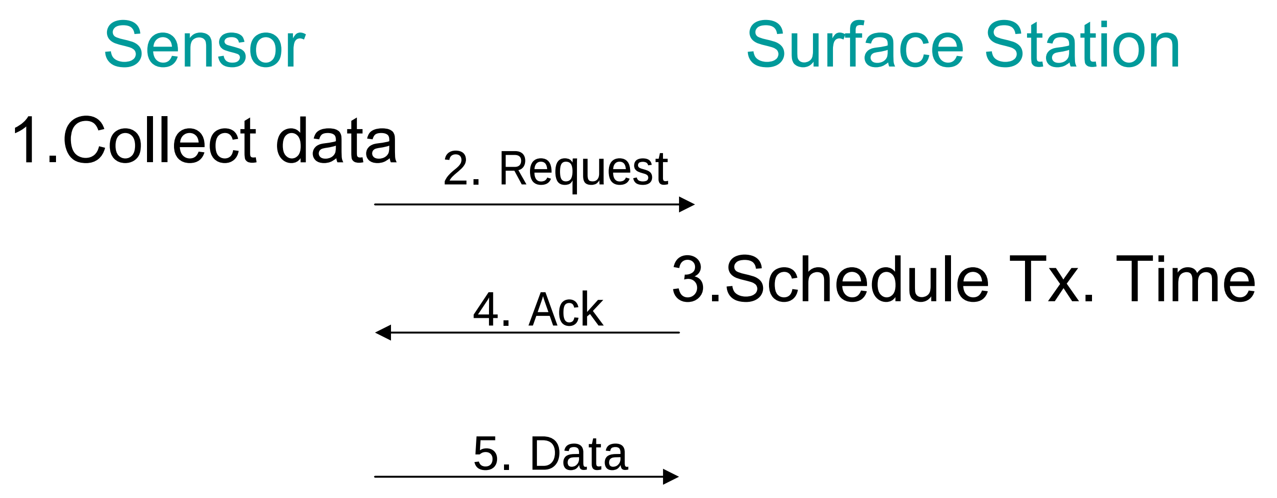
- Routing in ad hoc networks
  - Destination Sequence Distance Vector (DSDV)
    - Maintains a list of *next hops* for each destination in SP.
    - Requirement: Periodic broadcast messages to update routing tables.
  - Temporally Ordered Routing Algorithm (TORA)
    - On demand routing
    - Multiple routes to a destination
    - The route optimality: a second priority
    - Not based on shortest paths

Routing (Cntd.)

- Routing in ad hoc networks
  - Dynamic Source Routing (DSR)
    - Includes route of each packet in its header
    - Best Performance in terms of reliability, routing overhead and path optimality
  - *Ad hoc* On-demand Distance Vector (AODV)
    - On demand routing like TORA
    - Maintenance characteristics of DSR
    - Periodic updates

Known Deployments

- A deep-water acoustic LAN deployed in CA
- Ocean Monitoring
  - Ocean-bottom nodes: Sensing
  - Surface deployed station: Command, Control and Collecting gathered data



Known Deployments (Cntd.)

- Surface station schedules the transmission time based on round-trip propagation delay.
- Errors in estimation of transmission time causes:
  - Retransmission
  - Prolonged Idle time
- Request, Ack and Data Tx. are carried out in different frequency bands.

Known Deployments (Cntd.)

- Store-and-Forward Protocol
- To be employed in ALAN
- Uses three separate channels
  - To Tx.
  - To Rx. packets from its predecessor
  - To Rx Ack from its successor
- Effective Go-Back-N
- Dynamic route establishment such that a node is not used for two simultaneous Tx's.

Known Deployments

- A “peer-to-peer” communication protocol for UWA communication
- CSMA
- Highly reliable
- Low throughput due to the extra idle time between transmissions

Design Example: A Shallow Water Network

- General Settings
  - Depth of Water: 50m-100m
  - Nodes mounted on the bottom
  - Maximum Distance Between Two Nodes: 10km
  - Transmission: rate=100 b/s, Mode: half-duplex
  - Available Frequency Band: 8-15 kHz
  - Packet Size: 256 bits
  - Maximum Rate Allowed per Node: 5 Packets/hour
  - Battery Powered Acoustic Modems
  - Sleep/Active Modes of Operation

Network Topology and Energy Consumption

- Network Topology
  - Node locations are not determined
  - Uniform node distribution to provide best area coverage
  - Simplified scenario: N nodes and a master node in a line segment of length r.
    - Distance of each two adjacent node: r/N
- Analyze energy consumption for two topologies:
  - Fully connected peer to peer topology
  - Multi-hop peer to peer topology

Energy Consumption

- Assumption: required quality of reception is achieved if the received power level is P0.
- Transmitter power needs to be $A(x)P_0$
- A(x) is the attenuation.
- To transmit a data packet over N hops when transmission duration is T:

$$E = TNP_0 A(r / N)$$

Energy Consumption

- When each of the nodes has a packet to send to the master node, the total energy consumed for packet relaying is
  - In Direct Access Scenario

$$E = P_0 TA(r / N) + P_0 TA(2r / N) + ... + P_0 TA(Nr / N)$$

  - In Multihop Peer-to-Peer Scenario

$$E = P_0 TA(r / N) + 2P_0 TA(r / N) + ... + NP_0 TA(r / N)$$

Energy Consumption (Comparison of two scenarios)

- Direct Access
  - More energy consumption
  - Adding a node increases the total energy consumption
- Multihop peer-to-peer
  - Less energy consumption
  - Adding a node decreases the total energy
    - The additional node acts as an additional relay
  - More delay
  - Needs a sophisticated communication protocol

Design Example: A Shallow Water Network

- Multiple Access Strategy
  - Both FDMA and CDMA applicable
- Media Access Protocol
  - Variation of MACA
  - WAIT command added to inform nodes whose RTS's are declined
  - Give priorities to packets directed toward the master node to avoid possible deadlocks
- ARQ Scheme
  - Stop & Wait

Design Example: A Shallow Water Network

- Initialization & Routing
  - Initialization: establishing preliminary connections
    - Per node “neighbor table” is created
    - Neighbor tables are collected by the master node
    - Master node forms the routing tree and sends primary routes to the nodes
    - Process repeated in case of (apparent) failures/performance degradation

Conclusions

- Paper discusses design issues of reliable UWA networks
- Major challenges:
  - Severe limitations of power & bandwidth
  - Channel characteristics:
    - Long propagation delays
    - Multipath & signal fading effects
- Provide insights on how well known schemes fit into UWA design

Comments & Discussion

- Efficiency of ad hoc routing schemes in UWN's
- Comments on the provided example
  - Centralized approach
    - Practical and easy to deploy
    - Robustness
    - Scaling
    - Overhead
    - Energy consumption & lifetime
    - Mobility
- Other solutions?
  - Our suggestion: adaptive distributed multi-hop routing
  - Your suggestion?