Networking Issues in UWSNs

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Research Challenges

- UnderWater Acoustic (UW-A) channel:
  - Narrow band: hundreds of kHZ at most
  - Huge propagation latency

- Random topology and sensor node mobility (1--1.5m/s due to water current)
  - Existing protocols in terrestrial sensor networks assume stationary sensor nodes;
  - In mobile sensor networks, these protocols weakened

- **Mobility & UW-A channel limitations** open the door to very challenging networking issues

UWSN Protocol Stack

- UWSNs must require:
  - Reliable data transfer (tolerating high error-prone acoustic channels)
  - Efficient data delivery (should be energy-efficient)
  - Localization (for geo-routing or meaningful data)
  - Time synchronization (for sleep cycle schedule, multiple access protocol schedule, etc)
  - Efficient multiple access (sensors are densely deployed)
- Some UWSNs operate in a hostile environment (e.g., submarine warfare, coastal protection etc)
  - Must be protected from attacks
  - Must be tolerate network disconnection
- Objective: **build efficient, reliable, robust, & secure UWSNs**

Secure and Robust Data Delivery

- Consider various attacks
  - Packet delivery vulnerable to wormhole attacks (i.e., traffic jammer)
    - regardless whether static or moving
  - Under water, wormhole attacks are lethal because of large acoustic prop delays
    - due to slow speed of sound
- In case of network disconnection
  - Store data locally and temporarily
  - Re-disseminate data when connected

Reliable Data Transfer

- TCP like end-to-end approach does not work
  - Large propagation delay ➔ large end-to-end delay ➔ large bandwidth x delay product
  - High error-prone acoustic channels ➔ high loss rate
- Pure ARQ type of hop-by-hop approach does not work well
  - Performance degraded because of frequent ACKs
- Possible solution: FEC-based hop-by-hop approach with infrequent ACKs
  - How to design efficient coding schemes

Efficient Multi-Hop Data Routing

- Existing routing protocols in terrestrial WSNs do not work well in UWSNs
  - Node mobility changes node neighborhood
  - *Directed diffusion* requires too frequent route enforcement
- Existing routing protocols in terrestrial ad-hoc networks do not work well in UWSNs
  - Proactive: too much overhead to maintain updated topo
  - Passive: flooding is not efficient, also causes contention
- Possible solution: location-based routing
  - VBF: vector-Based Forwarding (Networking’06)

Localization & Time-Synchronization

- GPS-free and Mobility are the Challenges
- Existing GPS-free localization & time-sync schemes (range-based & range-free)
  - nodes are usually immobile
  - multi-hop schemes usually suffer from
    - poor precision due to high error probability & dynamic network topologies
- Considering underwater GPS-like approach
  - using multiple surface reference points
- Range-based approaches are possible
  - Need dedicated devices to measure distances

Efficient Multiple Access

- Sensor nodes are densely deployed
- Examine existing MAC protocols
  - Scheduled protocols
    - TDMA: ?
    - CDMA: ?
    - FDMA: not feasible, too narrow band in M-UWSNs
  - Random access protocols
    - CSMA/ MACAW: RTS/CTS too much overhead
    - ALOHA/Slotted ALOHA: ?
- Suggest solutions
  - A cluster architecture: CDMA between clusters, TDMA inside clusters
  - ALOHA like approach considering energy efficiency