A Frugal Time-Division MAC Protocol for Underwater Acoustic Networks

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Motivation

Time-division MAC protocols adapted from RF perform poorly in underwater acoustic networks (UWANs) due to:

- Large guard times ≈ propagation delay
- Tight time synchronization requirements

These constraints are not necessary, but RF networks typically use them since they have negligible cost

Contributions

- Argue against exclusive access MAC protocols for UWANs
- Clarify guard time definition for acoustic networks
- Show a time-division scheme can achieve high utilization
- Method for precisely communicating transmission slots without tight clock synchronization
- Ideas for a frugal time-division MAC protocol

Exclusive Access?

- In RF networks, exclusive access is needed
- In UWANs, two nodes can transmit concurrently and receive each other's transmissions
- See example schedule for other examples of nodes transmitting concurrently, and one node transmitting while another is receiving (e.g. packets #2 and #6).
- Pipelined UWAN protocols show promise [Gui et al., 2007]
- Exclusive access does not make sense for UWANs

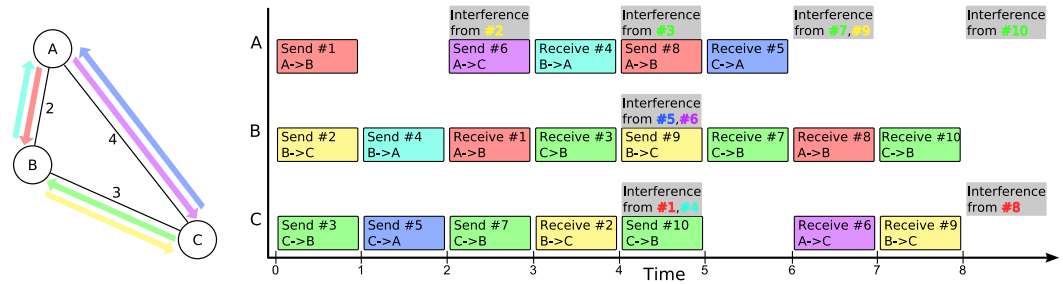
Clarifying Guard Times

- In RF, fixed guard time separates consecutive transmissions to account for propagation delay, etc.
- In UWANs, no exclusive access, separation must only occur at receiver between reception of desired transmission and any interference
- Guard times in UWANs should only prevent collisions due to clock skew, and short-term *variation* in propagation delay
- Guard times are then much smaller than propagation delay
- Collisions due to propagation delay itself need to be considered individually during scheduling

Protocol Overview

- Split time into cycles as in TDMA
- Slots can have any length and start at any offset
- Large "established" period of cycle, and much smaller "experimental" period of cycle, boundaries agreed upon to within 1 propagation delay [Syed et al., 2006]
- Nodes monitor channel, mark portions of established period in which interference is received based on local clock – **no tight synchronization needed**
- Nodes contend for new slots in experimental period
- Successfully used slots become owned & are used in subsequent cycles for transmission of data to same receiver
- Once schedule is determined, can re-use for long periods with little cost and few collisions

Example Schedule



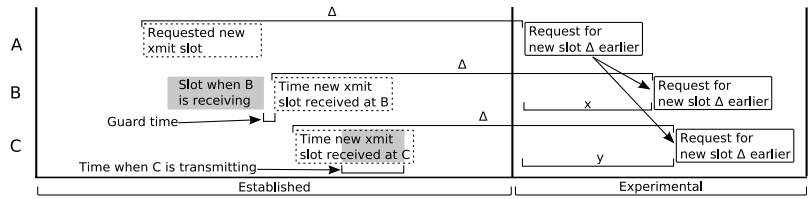
Example of one possible transmission schedule when exclusive access is not required

- Transmit delay is 1 time unit, propagation delays for each link are shown on left, small guard times
- Nodes may transmit concurrently and while channel is busy at source and/or destination
- 10 transmissions sent/received in approximately 8-9 time units, high utilization

Requesting a New Slot

Example where node A would like to transmit to B and does not own a slot

1. Node A chooses a new slot to acquire
2. Node A transmits Δ value at random time in several experimental periods - Δ is time difference between new slot and request
3. Each node which receives A's request uses Δ and the time the request is received to individually determine when a transmissions in the requested new slot will be received (the propagation delays, x and y, are unknown)
4. Nodes check for conflicts:
   i. No conflict exists at C because C is only transmitting during overlap
   ii. At B, one guard time separation between B's existing reception slot and new slot
   iii. At B, one guard time separation between any interference and new slot
   iv. No conflict exists at B even though A will transmit while B is receiving
5. If conflicts exist, nodes send rejection message during next experimental period and suggest alternate Δ's which do not conflict
6. Process repeats until no conflicts occur



(times not drawn to scale)

Discussion and Future Work

- Time-division protocols can be practical for UWANs
- Our protocol efficiently uses bandwidth and energy
- Need to investigate impact of fragmentation:
  - In RF networks, we have found that our protocol has negligible fragmentation
  - Possible to design network topology to reduce probability of collisions and fragmentation?
- Working on QualNet simulation model for UWANs

Thanks

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