

Poster Abstract: Seastar underwater acoustic local area network

Bjørn Kerstens
Naval Postgraduate School
Monterey, CA 93943 USA
bkersten@nps.edu

Joe Rice
Naval Postgraduate School
Monterey, CA 93943 USA
jarice@nps.edu

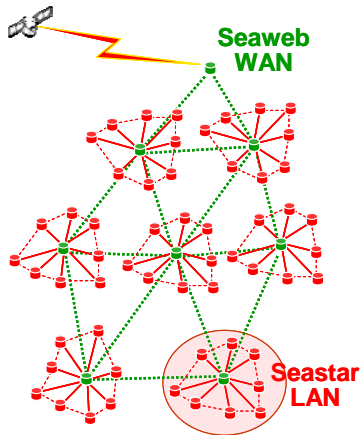


Figure 1. The Seastar concept involves asymmetric, centralized topologies. Relatively simple peripheral nodes (red) report time-series data at high bit-rates to sophisticated central nodes (green), where data fusion is performed for the local area. Peripheral nodes may receive low-bit-rate utility packets from the central node and from their peers. Wide-area communications between central nodes and theater communications through gateway nodes occur via Seaweb networking in a lower band of the acoustic spectrum.

1. Introduction

The Seaweb wide-area network (WAN) concept provides for local-area networks (LANs) having a sophisticated central node that collects and fuses undersea data from a set of relatively simple peripheral nodes, as illustrated in Figure 1. In more general terms, localized clusters of nodes (e.g., sensors, crawlers, divers) assimilate as subnets through the formation of a LAN containing a central node and peripheral nodes distributed in an undersea region up to 1 km². The Seaweb LAN with centralized or star topology is called “Seastar” and is motivated by the desire for an additional tier of local-area communications compatible with and complementary to Seaweb wide-area acoustic communications. The Seastar tier uses a higher-frequency portion of the acoustic spectrum made possible by the shorter ranges and necessitated by the high throughput of the LAN. The baseline Seastar topology is centralized, with axial asymmetry and peer-to-peer capability.

This paper explores candidate Seastar networking strategies and considers link-layer attributes (e.g., RTS/CTS handshake, polling mechanisms, ACK/ARQ/SRQ positive and negative acknowledgments) and physical-layer attributes (e.g., center frequency, bandwidth, baud rate, packet size). The approach consists of a link-budget analysis followed by a bandwidth/capacity calculation resulting in environmental and communications output parameters that drive a network simulation. The analysis assumes an operational range of 500m between peripheral nodes and central node. We also summarize the results of a first prototype Seastar network deployed during AUVFest 2007 in Panama City, FL.

2. Candidate protocols

The three network protocols considered here are TDMA Polling, TDMA Token Ring and a modified version of the Token Ring. The polling protocol has a strong centralized control whereas the token ring protocols only depend on some form of central control in situations of network failure which will be clarified later. Link-layer protocols include some form of selective repeat request (SRQ) but may not necessarily require RTS/CTS and ACK messages. The key idea with all three protocols is that the link between the central node and peripheral nodes has an asymmetric character. This allows the less sophisticated modems to transmit at high data rates but receive control messages at low data rates and perhaps different modulation to keep the complexity of signal processing relatively low.

Polling requires a centralized hub that invites an address to transmit data. All other addresses remain silent and do not have the possibility to interrupt. This results in a single poll round trip time of,

$$T = P / R_p + D / R_D + d \quad (1)$$

where P is the length of the utility packet that contains the poll, D is the length of the data packet, R_p and R_D are the bit rates of respectively the polling message and data packet. The parameter d is the total time of delay

that exists in one cycle necessary for propagation and processing of the data.

The token ring protocol passes a token between the peripheral modems that triggers the transmission of data. The data will only be processed by the central node. This idea diverges from the terrestrial version of the token ring topology in the sense that only the token and not the data is passed from node to node which reduces the round trip time significantly. A single data transmission can be described as,

$$T = D/R_D + d + K/R_K \quad (2)$$

where K is the size of the token packet and R_K represents the token's data rate. The delay d includes a slot that should allow the central modem to respond in case of corrupted packets or network failure.

The modified version of the token ring includes the token in the data packet which reduces d significantly because it removes the additional delay required for network control. Compensation for the absence of this possibility is offered by including the central node in the ring. This allows the "central" node to perform network control once every cycle but it also introduces an additional delay in the form of one more token to be passed. It also results in time late for retransmission of (sub)-packets. A single transmission therefore exists in two forms, one for a peripheral modem (3) and one for the "central" node (4).

$$T = (D + K)/R + d_{reduced} \quad (3)$$

$$T_+ = K/R + d_{reduced} \quad (4)$$

For all three protocols additional delays result from retransmissions or additional protocol features such as RTS/CTS and acknowledgement messages. The total round-trip time for one cycle, which we will further refer to as latency, can now be expressed as

$$T_L = T_+ + \sum_{i=1}^n T_i \quad (5)$$

where n is the number of peripheral modems.

3. Metrics

Trade-offs regarding performance are expressed in terms of channel utilization, latency and information throughput. With these metrics we examine the effects of the various protocols on performance under certain environmental conditions. The metrics are especially

useful for an end-user to identify the opportunities and limitations of the network. To illustrate this, we perform case studies that reflect different network applications.

4. Seastar prototype

During AUVfest 2007 a Seastar prototype was tested in water. The set-up consisted of 1 central node in the form of an anchored Racom gateway buoy and 5 peripheral nodes on the seabed. All nodes were equipped with Teledyne Benthos ATM-885 modems. The protocol tested involved a centralized polling with SRQ enabled, and RTS/CTS and ACK mechanisms disabled. The choice for the polling protocol was driven by the fact that this could readily be developed and integrated using the existing Teledyne Benthos modems and US Navy Seaweb firmware. All modems were uploaded with a standard 2-kbyte test message and the polling message consisted of a 9-byte utility packet. The poll was transmitted at 140 bit/s and the data at 800 bit/s. The single round-trip time was 35s, including some built-in delays.

Although a technical failure with the Racom gateway buoy prevented us from manipulating the network while deployed, useful performance data were obtained. The prototype Seastar proved redundant enough to recover from severe interference from local shipping as well as interference from an adjacent Seaweb network. The average latency matched that observed in the anechoic chamber at the Naval Postgraduate School prior to deployment. The data obtained during AUVfest are being used to calibrate the network simulation.

5. Conclusion

Seastar is a concept that will contribute to an increased communication node and sensor density at affordable cost. It complements the existing Seaweb WAN and is flexible enough for various applications. In order to explore the effects of various topologies and protocols we develop a model that will show trade-offs expressed in terms of latency, information throughput and channel utilization. This should help an end user identify the possibilities and restrictions of present and future Seastar concepts.

6. References

- [1] J. A. Rice, "Seaweb Underwater Networks," *Proc. Acoustics 2005, Australian Acoustical Society Annual Conf.*, ISBN 0-909882-23-1, pp. 25-27, Busselton, Western Australia, November 9-11, 2005