Signaling, Routing, Physical Layer Access, Protocols

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Creating the necessary signaling, routing, physical layer access and protocols for the SWiG standard presents many challenges. The wide range of applications, generally extremely low bit rates, poor signal reliability all make undersea acoustic communications a fraught enterprise.

Some pre-conditions further complicate the effort:

- requirement for backward compatibility with SWiG standards for modulation
- strong desire for little or no hardware changes required to comply with the new standard
- flexibility to support applications with very few nodes
- flexibility to support applications with many nodes
- support for moving platforms

The author has conducted a literature survey of methods used in RF wireless networks as well as undersea networks. Greatest attention was focused on networks that have operated successfully in undersea environments similar to those required for SWiG.

Because of the extremely low bit rates (110 bits per second for SWiG Level 1 full-bandwidth), the standard must support the simplest possible messages. If a single configuration message requires 10 kBits, then transmission of that message alone requires over a minute and a half.

The SWiG standard is expected to cover the mid-frequency band around 20 kHz. Typically, messaging systems lose approximately 5% of packets in this band, even at close range, due to channel multipath, time-varying fade, interference, etc. The packet loss rate rises higher as distances increase because signals are attenuated, and channel coherence times fall. This implies that the protocol must be resilient to much higher packet loss rates than are expected in RF networks.

The packet loss rate and low bit rate make most RF networking methods inappropriate for undersea acoustics.

Signaling

SWiG FHSS modulation support is a requirement. While the SWiGAcoustic Level 1 standard is written as a single-access modulation method, the waveforms themselves are quite capable of being used for simultaneous multiple access. The SWiG waveform is less sensitive to multiple access interference (MAI) than typical CDMA-BPSK waveforms. That robustness is tempered by a strong susceptibility to failure should two messages collide when both are in the preamble section. While the current SWiG standard does not permit of simultaneous access, the author believes that simultaneous access is quite appropriate and feasible.

Much of the literature focuses on either single access methods (OFDM, QPSK, etc.). These methods can be employed most readily when the network is extremely well-behaved, making these more appropriate to the HD high-bit-rate channel, rather than the FD low-bit-rate-many-user channel.

CDMA methods have achieved some level of success in simultaneous-multiple-access undersea networks. Several SWiG members manufacture DSSS modems, so this is an appropriate choice for the FD channel. In the simulation, this is modeled as genericDSSS. The generic DSSS modem is characterized by SNR power spectral density requirement and interference power spectral density requirements. It is presumed to have a training preamble. It permits options of full-duplex and CSMA access.

Physical layer access (MAC)

Many MAC methodologies have been tried for undersea networks. TDMA, CSMA, ALOHA. TDMA has met with great success when networks have no moving nodes, though it is fraught due to requirements of timekeeping synchronization. Clocks drift and are difficult to correct when equipment sits on the bottom of the ocean for months at a time. TDMA also fails when moving nodes are introduced. CSMA and ALOHA are far more appropriate for modulation methods that do not permit simultaneous multiple access. They are incorporated, regardless, in case fallback is required.

Generally, unrestricted transmission (i.e. transmit when needed, provided you are not in the process of receiving a message directed at you) is assumed, but CSMA has also been modeled for comparison.

TDMA design has been required by some members. This will require additional input and assistance from SWiG to ensure that it meets the stakeholder requirements.

Routing

Standard wired and RF networks use TCP or UDP. These are not appropriate to the undersea FD channel. The overhead of TCP (and even UDP) makes them impractical at such low bit rates. UDP fails completely, since at best, any link is roughly 95% reliable.

Routing data within a packet must be kept to an absolute minimum, and is to include source ID, destination ID and hop ID (needed for mesh networking). To keep these fields small, it is envisioned that no more than 255 nodes will be individually addressable.

Any of the ad hoc networking standards imposed far too much overhead and latency to seem workable. Hundreds of bits of data need to be transferred to all nodes many times over to configure the network. Numerical experiments failed to yield any practical outcome. This area will require assistance and advice from SWiG.

Some stakeholders require reliable message delivery for certain messages. There seems to be consensus that most messages do not require reliable delivery, and that small loss rates are acceptable for these. Because the number of messages requiring reliable delivery is expected to be small, the overhead must also be small. Therefore, a simple ARQ mechanism is employed, with timeout-based retry. Because the standard method of communication failure is full packet loss rather than packet corruption, NAK is unused.

The most reliable undersea acoustic networks to date have been the Seaweb trials. These networks are generally preconfigured with each node having connectivity to just a few nearby nodes, with store-and-forward at all nodes. Store-and-forward is supported, using fixed routing tables.

Mesh networking is a requirement for some SWiG stakeholders. The simplest form of mesh infrastructure has been implemented, with fixed designation for infrastructure nodes. Routing tables are simple client list/next-hop format – again to minimize the number of bits required for transmission.

Fixed routing at configuration time has been implemented. Dynamic and AI-based routing mechanisms must be studied and modeled. This will require assistance from SWiG members.

Protocols

Much of the messaging protocol is already defined in the SWiG Level 1 standard, as well as the new table of commands (SWiG work in progress for the main document) . New commands have been implemented to perform the following functions:

- The modem will be responsible for mapping between user packets and modem physical layer packets. User packets that are larger than modem physical layer packets shall be encoded using forward redundant vanDerMonde coding.
- Configure node modem type for FD channel. Each node is assumed to have multiple waveform capability, and selection of active waveform is done via index into a list of waveforms (i.e. SWiG FHSS, genericDSSS, QPSK, etc.)
- Configure node modem for bandwidth and center frequency. Running the HD channel generally requires the FD modems to lower bandwidth and change center frequency within their nominal band to make room in the spectrum for the HD channel on a temporary basis
- Configure scheduling for network reconfiguration. Specifies time to begin operation of HD channel, and time to relinquish HD channel, as well as source, destination, modulation type, center frequency and bandwidth for the HD channel.

Simulator

The simulator is written in Matlab. Classes are used for simulating nodes, modulator/demodulators and packets. The simulator as-written provides great flexibility in network configuration and testing. It is easy to do a full peer-to-peer network as well as a single-point exfiltration network. Store-and-forward nodes are simple to configure, as are mesh infrastructure nodes.

Software structure has been carefully set up to make it easy to extend functionality via class inheritance methods.

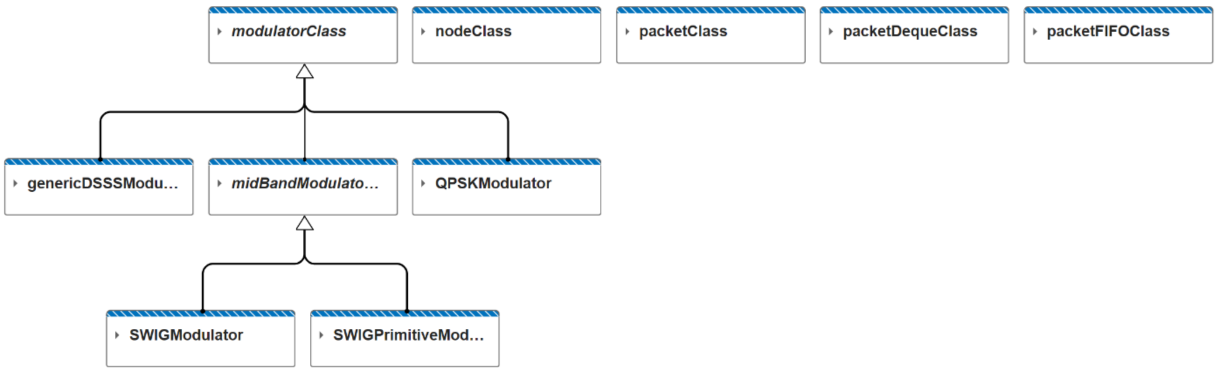

Figure 1: Class diagram for Simulator

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