QinetiQ Inc

2 Channel Protocol – Detailed WBS

Contract: C-01892

1. Protocol Requirements Definition

This will be accomplished in a series of technical teleconference meetings with the SWiG membership to ensure goals and requirements are achievable and agreed to.

1.1. Determine network requirements. Completed
- 1.1.1. Create & distribute survey to SWiG members to gain perspective on operations.
  - 1.1.1.1. Desired number of nodes
  - 1.1.1.2. Desired geometry (i.e. range, distribution within range)
  - 1.1.1.3. Messaging requirements for command/status:
    - 1.1.1.3.1. Number of payload bits
    - 1.1.1.3.2. Number of messages per node per minute/hour/day
    - 1.1.1.3.3. Destinations of messages
    - 1.1.1.3.4. Active acknowledgement required?
  - 1.1.1.4. Messaging requirements for large data transfer (if needed)
    - 1.1.1.4.1. Fraction of nodes with this requirement for TX
    - 1.1.1.4.2. Fraction of nodes with this requirement for RX
    - 1.1.1.4.3. Fraction of nodes with this requirement for TX/RX (i.e. high speed required in both directions)
    - 1.1.1.4.4. Number of payload bits
    - 1.1.1.4.5. Number of messages per node per minute/hour/day
    - 1.1.1.4.6. Destinations of messages
    - 1.1.1.4.7. Active acknowledgement required?
  - 1.1.1.5. Special needs
    - 1.1.1.5.1. Mesh network has been requested.
    - 1.1.1.5.2. Store/forward requirements?
    - 1.1.1.5.3. Broadcast requirements?
    - 1.1.1.5.4. Large, blank area for special requirements
    - 1.1.1.5.5. Special waveform or MIMO requirements for HD channel

1.2. Establish modem requirements, system performance requirements. (Ongoing. Pending 1.2.4.3)
- 1.2.1. System performance requirements
- 1.2.2. Throughput estimates
  - 1.2.2.1. Determine estimates of mean, median and peak throughput requirements for each node for
    - 1.2.2.1.1. command/status
    - 1.2.2.1.2. active acknowledgment
    - 1.2.2.1.3. large data transfer
  - 1.2.2.2. Determine estimates of mean, median and peak throughput requirements for overall network for

1.2.2.2.1. command/status
1.2.2.2.2. active acknowledgment
1.2.2.2.3. large data transfer
1.2.3. Determine network loading based on throughput estimates for:
1.2.3.1. Full FD bandwidth
1.2.3.2. ¾ FD bandwidth
1.2.3.3. ½ FD bandwidth
1.2.3.4. ¼ FD bandwidth
1.2.4. Determine collision rates
1.2.4.1. Determine simultaneous collision rates -- determines how many simultaneous receptions may be needed for simultaneous multiple access (SMA)
1.2.4.2. Determine simultaneous collision rates with preamble overlap -- determines how many failures to decode even with simultaneous reception – also useful to define unique hop sequences. This is useful to determine if the same hop sequences can be used by all nodes, or if we need to individually assign hop sequences, and when.
1.2.4.3. Determine throughput in the presence of sporadic, large broadband interference (pending).

1.3 Identify ideal modem functionality and capability to be simulated. Completed
Ideal modems will be specified generically (i.e. spectral efficiency, bandwidth, number of simultaneous users).

1.3.
1.3.1. Legacy – no modifications
1.3.2. Legacy – capable of multiple simultaneous receive.
1.3.3. Half-duplex, full-capability
1.3.4. Full-duplex, full-capability

1.4. Identify available modem functionality and capability to be implemented for verification of simulation. (Activity Removed from 2021 scope. This can be performed in the next phase when available modems to be part of the first test have been selected)
1.4.1. Modem survey
1.4.2. Modem select/characterize

1.5. Deliverable - Agreed on Requirements Documentation. Pending agreement with SWiG
1.5.1. Survey summary, conclusions
1.5.2. Modem requirements and trade-offs
1.5.3. Network band-splitting architecture
1.5.4. Network throughput estimates
1.5.4.1. Full legacy
1.5.4.2. Legacy modified for SMA
1.5.4.3. Half-duplex full-capability
1.5.4.4. Full-duplex

2. Protocol Development (ongoing)

2.1. Develop protocol – handling strategies for re-queuing and dealing with legacy hardware.
- 2.1.1. Review existing standards for appropriateness, with an eye to low bit rate high failure rate
  - 2.1.1.1. JANUS
  - 2.1.1.2. ZIGBEE
  - 2.1.1.3. Bluetooth
  - 2.1.1.4. Others (see *Underwater Acoustic Networks,* IEEE JOURNAL OF OCEANIC ENGINEERING, VOL. 25, NO. 1, JANUARY 2000)
- 2.1.2. Design media access control layer
  - 2.1.2.1. Decide if network is *ad hoc* or pre-configured based on requirements from Swig.
    - 2.1.2.1.1. If *ad hoc*, borrow numbering scheme(s) from appropriate pre-existing standards, if possible.
    - 2.1.2.1.2. If not *ad hoc*, design configuration method and how to designate master(s).
  - 2.1.2.2. Design hop sequences for FD channel reduced bandwidth conditions (i.e. when HD channel overlaps full FD channel). Decide whether hop sequences should be orthogonal
  - 2.1.2.3. Determine access methods for legacy systems. These take priority, as they are not capable of simultaneous multiple receive.
  - 2.1.2.4. Determine access method(s) for systems capable of simultaneous multiple receive. This must also include capabilities permitting legacy nodes.
- 2.1.3. Determine routing and acknowledgment protocols. This will depend heavily on the decision whether network is *ad hoc* or preconfigured. The routing protocol is likely to deal differently with control messages and data messages.
  - 2.1.3.1. Literature search and survey of appropriate protocols.
  - 2.1.3.2. Literature search and survey of failed underwater acoustic protocols, so we can learn from others' errors
  - 2.1.3.3. Design routing method(s) – paying particular attention to permitting varying levels of guaranteed delivery.
  - 2.1.3.4. Create list of control messages
  - 2.1.3.5. Design scheme for distributing control messages.
    - 2.1.3.5.1. Network-wide critical control messages, such as allocating FD channel. This must involve
    - 2.1.3.5.2. Node-critical control messages, such as configuration and addressing, querying capabilities.
    - 2.1.3.5.3. Less critical control messages.

2.2. Meeting with SWiG to review protocol (Pending)

2.3. Modify protocol as per consensus.

2.4. Protocol Definition Report (Preliminary Definition to be discussed with SWiG)

2.5. Simulate protocol for evaluation and development for the ideal modem. Preliminary Simulations performed to be completed in 2022
- 2.5.1. Build simplified modem models – based on behavior rather than implementing them. These will be Matlab or Simulink models. Modeled behaviors include:
  - 2.5.1.1. Multiple simultaneous message tolerance (zero to many, depending on modem)
  - 2.5.1.2. Near/far sensitivity
  - 2.5.1.3. Sensitivity to timing – i.e. modems using the JANUS protocol could, theoretically, receive from multiple sources simultaneously, provided there is not strong overlap between preambles
  - 2.5.1.4. Sensitivity to broad-band interferences
  - 2.5.1.5. Signal strength considerations as parameter set for full-duplex modems
- 2.5.2. Build protocol simulation diagram in Simulink
- 2.5.3. Build simulation of message contents and timing for modems to send
- 2.5.4. Run simulation under several scenarios typical from SWiG survey.
  - 2.5.4.1. Number of nodes
  - 2.5.4.2. Message type/frequency
  - 2.5.4.3. HD channel simulation for point-to-point
  - 2.5.4.4. Appropriate model of broad-band interference
- 2.5.5. Determine minimum decoupling/cancellation requirements needed for protocol
- 2.5.6. Identify key parameters for protocol compliance and initial requirements for compliance testing.

2.6. Simulate protocol for available modem.

(Activity Removed from 2021 scope. This can be performed in the next phase when available modems to be part of the first test have been selected)
- 2.6.1. Select available modem for simulation
- 2.6.2. Construct model of available modem
- 2.6.3. Repeat earlier simulations

2.7. Protocol Definition-Standard Documentation and Simulation Report Final delivery to be completed in 2022
- 2.7.1. MAC layer definition in IEEE standard format
- 2.7.2. Routing layer definition in IEEE standard format
- 2.7.3. Simulink or Matlab code for simulation, with documentation
- 2.7.4. Statistical simulations for
  - 2.7.4.1. Legacy hardware only
  - 2.7.4.2. Mixed half-duplex compliant hardware with legacy nodes
  - 2.7.4.3. Mixed half-duplex compliant hardware
  - 2.7.4.4. Full-duplex hardware mixed with half-duplex and legacy
  - 2.7.4.5. Full-duplex hardware