The SWIGacoustic Standard

An acoustic communication standard for the offshore energy community

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***Abstract*—This paper describes industry efforts to develop an underwater acoustic communications standard for the offshore energy community. The Subsea Wireless Group (SWiG), an international oil and gas industry network comprising operators, installers, and technology companies, assessed a variety of potential use cases and possible routes to develop a common standard, culminating in the selection of the JANUS standard as a template. The paper explores typical use cases, the benefits of standardisation for technology developers and users, identification of gaps in the JANUS standard, and current progress in developing the standard.**

Keywords—Underwater Communication, Acoustic; Standards; Interoperability, JANUS

I. Introduction

Underwater acoustic communication has been used in offshore oil and gas for over half a century, initially supporting subsea acoustic positioning systems, and then used increasingly for remote control and data recovery. Most offshore subsea communication systems are tightly integrated with other instrumentation manufactured by specialist acoustics companies serving niche markets. They typically offer packaged products where their acoustic communication technologies can differentiate them from their competitors. As a result there has been little motivation for manufacturers to move towards standardisation.

With the expansion of subsea field developments, deep water intervention by Remotely Operated Vehicles (ROVs), and the increasing use of Autonomous Underwater Vehicles (AUVs) for automated inspection, vessel and vehicle operators need to equip their platforms with a growing range of acoustic systems to cover the various communication tasks. To address the problem of this increasing diversity of systems, the Subsea Wireless Group (SWiG) was formed to promote interoperability between systems and develop open subsea communication standards. Standardisation in subsea communication should reduce costs and lead to faster market growth.

II. Subsea Wireless Group

SWiG is an international offshore industry network that was formed in 2011 to promote interoperability for subsea wireless communications. The scope of the group covers radio frequency, free space optical, and acoustic communication. These technologies are complementary, delivering different functions and performance in different subsea operating environments. Indeed, in time, hybrid systems that utilise more than one technology are likely to offer significant advantages. Members of SWiG include major oil and gas operators, subsea installation and intervention companies, and instrumentation companies including many of the world's leading underwater acoustics pioneers. Members meet quarterly, alternating US and European venues. Working groups then progress agreed work packages between meetings.

As a result of SWiG's efforts, a draft standard for radio frequency underwater communication (SWIGradio) [1], based on wirelessHART, was developed and has recently been submitted to the American Petroleum Institute (API) Standards Subcommittee 17 on Subsea Production Equipment. SWiG's focus then turned to acoustic communication.

The initial methodology for development of an acoustic communications standard was to consult offshore operator, installer and intervention members of SWiG on typical use cases where an acoustic standard would beneficial. The aim was to develop a common set of performance parameters that would serve as a basis for developing the standard. In addition, where possible the intention was to build on existing open standards to support full interoperability between hardwired and wireless systems.

III. Use Cases

SWiG assessed a range of use cases, including Riser Monitoring for motion and stress, AUV communication for several different functions, and Environmental Monitoring using subsea dredge and seep monitoring as detailed examples. Each use case was assessed for a range of performance parameters, including data bandwidth, data volume, transmission range, power requirement, criticality of data,

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security of data, interoperability and conflict with other systems, and local acoustic environment characteristics.

For the AUV communication use case, it became clear that the requirements for acoustic communication vary greatly according to the task in hand, and the stage of the AUV mission. Assuming the vehicle is operating at a range of up to a few thousand metres, status monitoring – the ability to check the basic health and performance of the vehicle – or the issuing of simple mission commands to the vehicle, can still be achieved with a low bandwidth link at tens of bits per second (bps). Sending real-time sensor data from low bandwidth geo-chemical sensors can be achieved at perhaps 100 bps. Higher bandwidth sensors such as current profilers, multi-beam echo-sounders, or laser scanners generating point cloud data demand transmission rates in the order of thousands of bps, while acoustic imaging systems such as side scan sonar and sub-bottom profilers would push the limits of current acoustic communications technology, and any form of video data would far exceed what is currently achievable with acoustics.

The Environmental Monitoring use case assessed several different scenarios, including subsea dredge monitoring and seep control. Dredge monitoring typically has relatively short time frames so instrument autonomy may be as little as one month. Similar sensors to the AUV use case are involved, with both low bandwidth geo-chemical and optical sensors, and higher data rate acoustic sensors such as Doppler current profilers, although these can be configured to provide processed data summaries via lower bandwidth links. Seeps are typically monitored over longer time frames. Low bandwidth geochemical sensors are common, but there is also increasing use of active sonar devices to detect rising plumes of gas or fluid. Without subsea data processing, these would require transmission rates in the order of thousands of bps.

The Riser Monitoring use case examined the current requirements of operators to monitor low frequency dynamic conditions of risers during their operational life. With multiple temperature, load, and motion sensors being sampled at 10 Hz or higher, the net continuous data rate requirement could be several thousand bps per monitoring location, with impractical power demands for data transmission over an asset's life. However, by using adaptive sampling and transmission based on fault conditions, it would be possible to reduce data rates sufficiently to accommodate periodic transmissions of tens to hundreds of bps. Selection of an Acoustic Protocol

During the process of developing use cases and exploring various possibilities for protocol development, SWiG were soon faced with a choice of standardisation approaches. The first scenario would be to develop a ground breaking new approach, pooling the resources of all the technology developers, to achieve a level of performance that would most closely match the stated requirements of the industry. However, with a perceived limited appetite for technology investment from the operators and installers, and no likelihood of the technology companies pooling their most valued intellectual property, a more pragmatic approach was required. The second scenario would be to use an existing standard that could be implemented in a shorter time scale, with relatively little investment. However, would that scenario be so limited in performance that it would be unable to meet any of the use case needs? The third scenario would be to adapt and enhance an existing standard, although this might require some additional intellectual property development.

SWiG felt that the most expedient approach was to work with an existing standard, and then develop this further, subject to sufficient uptake from industry. To address the potential lack of capability of a low data rate standard, it was agreed that the new standard would allow different systems to establish each other's capability using a common interface. If that process established that both systems were capable of communicating on a faster, proprietary protocol, they would be free to do so, but if not, they would at least share a common lower level protocol to carry out basic communications.

Once the decision to work with an existing standard had been made, the only known open acoustic communications standard to choose was JANUS [2], [3], [4], [5]. JANUS was developed by the NATO Centre for Maritime Research and Experimentation (CMRE) and has recently become a NATO standard [6]. The standard evolved from a NATO requirement for communication interoperability between NATO, non-NATO and civilian underwater assets, to share information between all types of underwater platforms, surface vessels, and gateway buoys. The standard was also designed to minimise the changes needed to bring submarine communications equipment such as underwater telephones into compliance, using existing acoustic frequencies and bandwidths.

IV. From JANUS to SWIGacoustic

Once JANUS was selected as the template from which to develop the SWIGacoustic standard, a process began to identify gaps or incompatibilities between the JANUS standard and the SWIGacoustic requirements.

A. Scope

The JANUS standard provides a detailed specification for a Baseline Packet consisting of 64 bits of information. It also specifies how this packet should be encoded into an acoustic transmission, incorporating error correction and detection capabilities, based on a predetermined carrier frequency F_c. The acoustic signal may be preceded by an optional three-tone acoustic wake-up sequence used to alert equipment in a low power operating state that a message is imminent. Further Data Cargo Payload may be appended to the initial Baseline Packet. All frequencies and timings are scaled according to the value of F_c. The NATO standard specifies the initial JANUS band with $F_c = 11520$ Hz.

JANUS defines the encoding in purely mathematical terms. Although the frequencies and timings were selected with real-world hardware and software implementations in mind, no presumptions are made about how the signal should be encoded or transmitted, and the standard does not specify tolerances for the encoding of frequencies or timings. It does not specify how signals should be decoded, nor does it discuss transmitted power, acoustic transducer performance, receiver sensitivity, or channel equalisation. All of these are considered application specific, and for the developer and user to agree upon.

Although JANUS describes the encoding of a 64-bit Baseline Packet and Data Cargo Payload into an acoustic signal, it does not specify how the user should communicate that data to or from a JANUS-compliant modem.

The SWiG group decided that the low bandwidth offered by the JANUS protocol did not easily lend itself to networking for the initial draft of the SWIGacoustic standard. The group are aware of community efforts on network protocol stacks, including the SUNSET framework [7]. Furthermore, recommendations were made during an earlier NATO Industry Advisory Group study [8] on how networking might be incorporated into a future revision of JANUS. Having chosen to make only small adaptations to the JANUS standard, in developing a SWIGacoustic specification, the 7-layer OSI model [9] has been considered (Table 1). From this, three layers (Transport, Data Link, and Physical) are addressed in the first draft of the SWIGacoustic standard.

TABLE I. OSI MODEL AND SWIGACOUSTIC

OSI Layer	SWIGacoustic
Application	User interface to a SWIGacoustic modem, absent from JANUS – to be defined in next revision of standard
Presentation	Not addressed
Session	Not addressed
Transport	To handle retransmissions and packet acknowledgment protocol, absent from JANUS
Network	Not addressed
Data Link	Best use of the baseline and data payload packets – SWIGacoustic to modify JANUS
Physical	The main focus of JANUS – SWIGacoustic to optimise F_c

B. Physical Layer

JANUS is essentially a Physical and Data Link Layer specification. To make the best use of the JANUS standard, SWiG decided only to review the carrier frequency F_c. The initial JANUS band defined by the NATO standard has a carrier frequency of 11520 Hz. This should provide good range performance (up to perhaps 6000 m), but with a low data rate of 80 bps or less. A commercial consideration in selecting a carrier frequency is that acoustic communication systems with $F_c < 20$ kHz or $F_c > 60$ kHz are generally subject to export licence restrictions. Given that many offshore applications are now taking place in water depths exceeding 3000 m, Selecting F_c at or slightly above 20 kHz would give the optimum data rate performance at an acceptable maximum range, while remaining licence free. A baseline packet with fixed preamble comprises 176 chips of duration 26/Bw. For Fc of approximately 20 kHz, the bandwidth is approximately Fc/3, so the packet would take around 700 ms to transmit, and a typical 64-bit data cargo packet of 144 chips would therefore be transmitted at a little over 110 baud.

C. Data Link Layer

For efficient data communications at low data rates, it is important to make the best use of the available data. This includes optimising data transfer to use Data Cargo Payload packets where practical, to avoid a large protocol overhead.

For messages that can be contained within a JANUS Baseline Packet, the availability of data cargo is very limited. The configurable data within the packet comprises 8 bits that define User Classes allocated to countries, specific organisations, and special purposes, 6 bits that define different types of message per User Class, and 34 bits of Application Data. There was concern that the 8 bits defining User Classes were driven by specific NATO demands that did not necessarily reflect the requirements of a multi-purpose acoustic link, consuming one sixth of the available configurable data. In a future revision there would be an argument for reallocating these bits..

JANUS includes a carrier detection Media Access Control (MAC) collision avoidance protocol that was probably included to ensure compatibility and prioritisation for use with conventional underwater telephones. As this works by progressively backing off from channel access with timeouts that can be unfeasibly large, this feature will not be implemented as described. Indeed, thanks to its frequency-hopped nature, JANUS has the capability of supporting multiple coincident messages through a form of Frequency-Division Multiple Access, provided a receiver is able to run multiple decoding threads, so a primitive carrier detection MAC would limit this capability. However, for simple systems, the SWiG group have suggested that an ALOHA-based MAC could be used. This is likely to be reserved for a later revision of the standard.

D. Transport Layer

JANUS includes error correction (convolutional encoding) but does not have a strategy for dealing with a transmission that is received with uncorrected errors, nor with one that is expected but not received. There is no limit on the data cargo payload, which places the burden on dealing with potentially large numbers of failed transmissions on the receiver. The transport layer should address these issues and include some arrangement for packet acknowledgment and retry.

V. NEXT STEPS

At the time of writing, the first draft of the SWIGacoustic standard is in preparation, with an anticipated submission to API Standards Subcommittee 17 by the end of 2016. The first draft should be based strongly on JANUS but with a new F_c, and likely enhancements to the Data Link and Transport layers to reflect the needs of the offshore oil and gas community. The next priority will be the development of an Application Layer interface, likely to be based on an existing open standard.

In practical terms, further progress will depend on uptake by the oil and gas community, including the willingness of offshore operators and installers to allow technology developers to deploy and test SWIGacoustic solutions in offshore applications.

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