Digital Voice Communication in the Maritime VHF Band

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Abstract

Today's and future communication systems in maritime rely on digital data communication between the ship and transceivers that are either on land, in air (satellite) or on sea. Analog voice communications is not an integrated part of future maritime communication system proposals. However, it is in general preserved in its functionality according to future maritime communication system proposals. In recent years parts of the dedicated voice spectrum was already reallocated for digital non-voice communication systems. Within this paper, we focus on the possible usage of digital voice communications in the maritime VHF frequency band regarding its technical feasibility, benefits, and challenges.

I. Introduction

The current voice communications in maritime is only based on analog communication technologies in the very high frequency (VHF) band, e.g. in Channel 16 on 156.8 MHz – also Channels 6 and 13 [1], [2]. Other channels are allocated in advance according to the position of the vessel. Within the maritime VHF band (156.025 to 162.025 MHz) there exist already several digital services:

- Digital Selective Calling (DSC) for sending pre-defined distress message as core part of the Global Maritime Distress Safety System (GMDSS) on Channel 70 (156,525 MHz) [3];
- Digital Automatic Identification System (AIS) on Channel 87B (161.975 MHz) and 88B (162.025 MHz), e.g., for tracking and collision avoidance;
- Recently, satellite AIS was introduced towards Channel 75 and 76 [4].

Data exchange between shore to ship and ship to shore exists within the VHF band in various regions. For example, it is described in the ITU-R Recommendation to address the characteristics of VHF radio systems for digital systems on diverse VHF channels [5]. Also digital voice communications is already mentioned and envisioned in the Maritime Communication Radio Plan of IALA but without any detailed specifications [6].

As seen in all areas of society, the use of voice communication shifted from pure analog to digital, except in the maritime and aeronautical world. This paradigm shift towards digital communication could have benefits in many fields for maritime:

- efficiency of spectrum usage;
- co-existence of existing (legacy) communications system with future systems;
- increase of security towards undesired listeners;
- enabling a dynamic channel planning along coast lines and high traffic areas to avoid interference;
- more possibilities towards text/content messaging reducing voice misunderstanding in distress;
- speech codec optimization for typical maritime communications;
- realtime translation of the different voices to ensure broader and better understanding;

Driven by these benefits, focus should be given towards the technical feasibility of digital voice communications in the maritime VHF band. Furthermore, reallocation happens currently for digital non-voice communication maritime systems in this band (e.g., satellite AIS, VHF digital exchange (VDE), etc.) reducing the analog VHF capacities and raising the need for more spectrum efficient voice communication

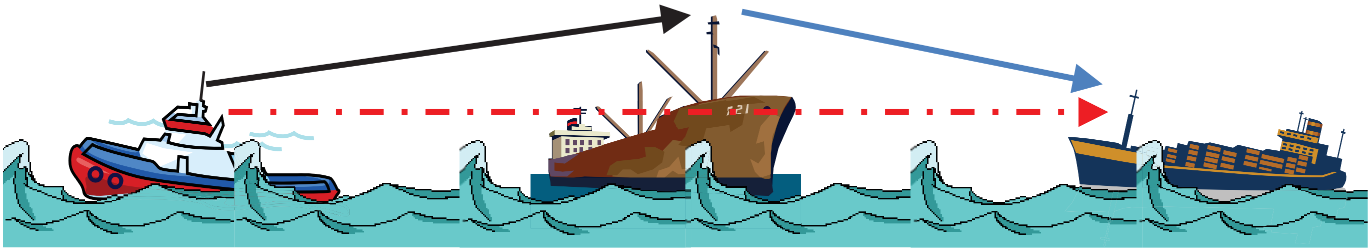

Fig. 1. The middle ship acts as relay to overcome the blockage it is causing, and to reduce the needed transmit power on the left ship. Special care needs to be addressed to latency caused by the relay for voice traffic.

in the long term. Nevertheless, at least the common distress channels has to be conserved for analog voice due old communication equipment during possible distress in all areas of the world.

Within this paper, possible digital voice communication technologies for the maritime VHF band will be investigated. Existing digital VHF systems will be evaluated if digital voice communications can be integrated. Due to the given fundament of shore to ship and ship to shore communication without any fixed terrestrial infrastructure, the underlying transmission technologies need to be self-organized. Already in the aeronautical domain, a self-organized transmission technology, namely the VDL Mode 4 standard [7], was introduced for data communication. Applying such a technology in the maritime area requires the investigation of the system towards the different impacting factors. This paper focuses on transmission ranges, radio channel characteristics, state-of-the-art speech decoders, influence of the used access schemes, velocity of ships, possible encryption and channel coding techniques and interference towards other systems.

II. Gap and System Analysis

We split the maritime environment into two different zones. One is the open sea and the other one are coastal and inland areas, such as harbors. At the open sea dedicated routes or water-highways are used by large vessels to comply with the most recent maps about the water depth. The routes next to the coast are close enough to interact with the national coastal communication centers. The communication links between vessels, and vessel and landstation depends on the condition of the sea.

In an ad-hoc network changes in the topology may result in disconnected links because of out-of-range, blockages or interferers (e.g. new mobile vessels appear). In the maritime network the changes are slow proceeding in long bursts of packet loss. Furthermore, the changes are expectable due to the geographic information of large vessels that is broadcast via the Automatic Identification System (AIS). In addition to the current position the heading and the velocity is exchanged and could be used to adapt the needed changes in the topology in advance. In non-delay sensitive services the packets could be queued and stored in a buffer and retransmitted in case the connection is re-established. However, in a delay sensitive service as voice communication long bursts in the order of multiple seconds will be silenced and then consequently result in a dropped call [8]. Figure 1 shows the principle of a relay that adds path diversity which would help to overcome the packet loss and avoid a dropped call. However, the relay adds delay into the reception of the packets transmitted via the wireless network. Therefore, they need to be considered at the receiver to avoid severe echo effects and additional jitter.

Our focus is on voice communications. The ITU has defined a desired maximum delay of 150 ms as an acceptable target for voice communications. The delay depends on the distance between transmitter and receiver. In a relay network additional delay results by the signal processing of the relay stations. Figure 2 shows the different delays that besides land-line communications are experienced and accepted by users. Satellite phone connections cause a rather high delay depending on which system is used. The LEO

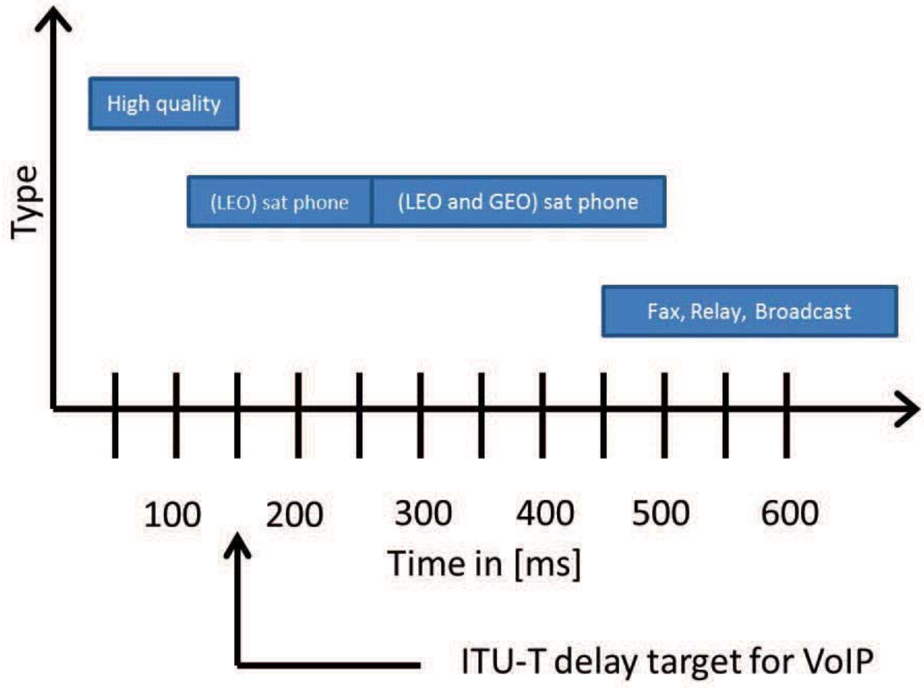

Fig. 2. The different types of delay for different voice related communication channels. High quality indicates the typical delay in land-line voice communications.

(low Earth orbit) satellites are e.g. within distances of 780 km and cause an acceptable delay especially compared to geostationary satellites that are 36000 km above the Earth.

A. state of the art

In [9] voice over internet protocol (VoIP) and the relevant factors that impact its performance are discussed in detail. The advantages of digital systems are manifold:

- dynamic channel planning;
- reduce interference management increases total capacity for other services;
- prioritization of voice traffic handover between different VTS is possible;

A mobile ad hoc network (Manet) is a continuously self-configuring infrastructure-less network of mobile devices [10], [11]. This means it is non-guaranteed network structure. Therefore, the adaptive scheme needs to consider this in the choice of the voice codec, modulation and channel coding (especially interleaver), and required protocol overhead. Compared to digital data a key focus in voice communications is too maintain the call and not necessarily to keep the quality of the call stable. Therefore, path diversity as presented in the beginning could support the maintenance of the call by different means.

The typical voice communication between ships is expected to be rather short compared to private chatty talks. This can be expected from the history and how nowadays the analog system is used. This has to the authors knowledge not yet been considered, but could optimize the expected delay and the jitter by the voice codec and the medium access protocol.

B. Maritime Digital Non-Voice Communication Systems

The Automatic Identification System (AIS) system offers non-voice compatible delays in its MAC protocol. However, the AIS system provides the coordinates of the different vessels and could be used to build up the MANET in a coordinated way by awareness of where different vessels inside the range of the whole MANET are. Such a case could be relevant for conference or group calls to coordinate rescue cases or joint operations even via relaying the voice data through other vessels.

C. Requirements for Voice Communication in the VHF band

The VHF band offers channels with a spectrum bandwidth of 25 kHz. Low bit rate codec, such as G.729[12], encodes speech of 10 ms with 8 kBits/s (fixed bit rate). There are extensions of this codec that address also silence detection and the complexity of the algorithm itself. The 25 kHz bandwidth support today at least four voice channels by applying time division multiple access (TDMA). Depending on the network structure even more voice channels could be allocated. Furthermore, to increase the robustness of the network frequency diversity could be integrated to distribute the voice channels on different carrier frequencies as well as by using mobile vessels as relay.

III. Commercial Off-The-Shelf Solutions for Voice Communications on Sea

Different systems today offer digital voice communications. In the VDL mode 3, which operates in the VHF band, a centralized voice communication is integrated. This system is standardized and ready, but not commercially in use as planned by parts of the aeronautical community.

Cellular mobile radio networks operate well in our daily life inland. They also operate close to the coastal areas, but on the open sea the coverage is limited. It is also a centralized system and requires an operator who controls the interaction between the mobile and the base station. There is no peer-to-peer mode possible, but this changes with LTE-direct. Alternative solutions without a cellular mobile network operator build their own network by using of the shelf open source GSM base stations. Such networks could allow other vessels to connect to each other by normal mobile phones.

Finally, wireless LAN or WiFi networks offer an ad hoc link for indoor as well as for vehicular communications. Latter is discussed also for maritime communications, but operates in the upper 5 GHz band and uses direction antennas between transmitter and receiver. Such a system could use the relevant position information broadcasted by the AIS transmitter to inherently find the counterpart.

IV. Conclusion

In this short paper we presented the problem of the missing voice component in future digital maritime communications. We sketched several existing solutions for different scenarios that show similarities to easily consider them for a future digital voice communication system.

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