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Research Article

Alternative On-board Communication Systems Enhancing the Operation Efficiency of Vessel Traffic Services

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ABSTRACT:

The European Integrated Maritime Policy aims to improve the sustainable development of the maritime economy and better protect the marine environment. It is well understood, that cooperation among all entity participants crossing different sectors and borders should be facilitated. The cellular network communications, the radio frequency identification techniques and the high-level communication protocols are in fact all modern technologies complementary to each other. The article considers and makes comparison between traditional ways for GPS tracking and modern LoRa WAN devices, utilized in coastal waters. The utilization of such devices onboard of small leisure crafts or fishing vessels could be vital to support the operation of vessel traffic services. Cellular trackers have also the advantage to send distress alerts. Measurements of signal strength and quality have been presented to decide whether to utilize cellular network signal for emergency alerting and position reporting. So far, on the Bulgarian coast, the IoT gateway infrastructure might be insufficient but the growth rate is sufficiently high. The potential solution, presented in this article, could serve to improve the operational efficiency of marine traffic control.

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Introduction

In order to prevent accidents, protect borders and effectively respond to accidents, it is necessary to maintain maritime domain awareness. This means that the vessel traffic services must have real-time knowledge of the location and intention of vessel and small craft operating in coastal waters as well as other background information for weather changes, temperature, tides and currents. This type of awareness requires access to alternative sources of data, including visual observations, long range vessel tracking information, weather predictions and data provided by shipborne transponders. The integration of data sources could provide a common picture of coastal activities shared by shore-side facilities, ships and small crafts. This would form the basis of the future plans to deploy vessel traffic service (VTS) assets wisely and cost effectively in order to improve safety and security in the transportation system. Considering vessel tracking services, the automatic identification system (AIS) is the concept introduced in 2002 in order to provide for safety of navigation and have full picture of the vessel traffic and maritime awareness. The updates are as often as every two seconds. Hence this system is complicated and expensive for small seagoing crafts and leisure boats, the article aims to suggest alternative ways to follow the movement and activity of such boats or yachts in the coastal areas.[10, 11]

Currently, research considering comparison between conventional means for tracking and alternative communication systems for small crafts is very limited. Different technologies have been used during years to help the process of following small ships in harbours and coastal areas. The movement of ships can be monitored by radar or automatic identification system. Unfortunately, the small vessels have weak radar signature and could be missed. About 10 years ago, there appeared research studies concerning tracking of small vessels. Some of them consider implementation of autonomous low-complexity acoustic sensors.[13] Examining the hydro-acoustics nature, their algorithm utilized the sound level while extracting the amplitudes of the harmonic frequencies due to propeller movement. Such systems have limiting factors as network topology, additional noises and multiple reading errors. Localization of small boats could be done through acoustic data fusion of hydrophone arrays. These proved effectiveness in shallow-water harbour environment localization. Small errors in hydrophone elevation causes a significant error in positioning at short range. That algorithm proved effectiveness in lower speeds through water.[14] Some studies consider application of frequency modulated continuous wave with digital beam forming. Such systems are in use and provide promising performance. Hardware is expensive and classification should be refined with other observation options.

Options for implementation of position reporting devices

Historical overview includes shipboard radar display showing a symbol for every significant ship within radio range, having its velocity vector (indicating speed and heading). The symbol can depict the actual size of the ship, with its position to GPS or differential GPS accuracy. The “target” contains name, course and speed, classification, call sign, registration number, MMSI, as well as other information. The proposed devices below are much simpler but details about identification, transport vehicle activity from the accelerometer, as well as position and additional sensor data could be obtained with great success. Vessel traffic services could utilize different new and developing technologies to assist in the analysing process of maritime awareness. The authorities continue to conduct oversight of critical security issues with the goal to provide the highest level of safety and security possible that does not impede the efficient flow of maritime commerce activities or interrupt employment opportunities in the maritime sector.

Results and visualization

This article shows results received after implementation of a GPS cellular tracker and a LoRa 868MHz tracker. The traditional methods include well-known GPS trackers using SIM card and sending data via the public land mobile network operator (PLMN). Such conventional system is for example a popular tracker ST-901 which uses global packet radio services - GPRS, 3G, 4G LTE technology. It sends data at pre-programmed regular intervals as well as messages containing its coordinates when interrogated. These devices incorporate also an accelerometer that alerts when craft is blown or other impact is registered. Control is carried remotely via SMS or an Android smartphone application. It is also possible to interface the tracker with other restraint systems onboard.[2] The traffic normally costs 2 EUR per month for the volume of 250 MB but such device spends actually not more than 30MB for monthly position reporting. In the coastal areas, the coverage is up to 3 km from the shore. The GPS tracker ST-901 utilizes the Sinotrack web platform and features GPS, GSM and GPRS technologies. The incorporated battery is rated 150mAh and lasts for several hours of operation. The device operates in the temperature range between -20o and +55o C. The operating humidity is between 5% and 95% non-condensing. The ST-901 is quad band and operates in GSM 850/900/1800/1900 MHz. The GPS sensitivity is -162dB and the location accuracy is 10 meters. The accuracy is 1 microsecond time synchronization of satellite time. The device has both SMS and GPRS working mode. If the operator would prefer to monitor the tracker online in real time and to utilize the installed tracker data for years, one should choose GPRS mode. This is set using control commands over the air. The operator could get location also by phone call to the SIM card. It will reply the location with a Google link. There are several Android applications that helped the authors to evaluate the coverage of cellular operators in the bay of Varna. The software shows the serving cells and the parameters as power and the quality of the reference signal.[12] Figure 1 shows the sectors of a site, as calculated by the Cell Mapper web application. This represents the coverage of VIVACOM mobile operator. Research continues to determine the reliability of signal coverage for the other two large national operators – Telenor BG and A1. Besides data position reports the terminal could connect its users with the national emergency call system 112. The maps on Figure 1 depicts the signal strength of the Bulgarian mobile operator VIVACOM. Considering A1 mobile operator coverage, for the days of this research, there is a small gap between 43°10'05.8"N 27°57'02.9"E and 43°08'32.3"N 27°59'59.3"E.

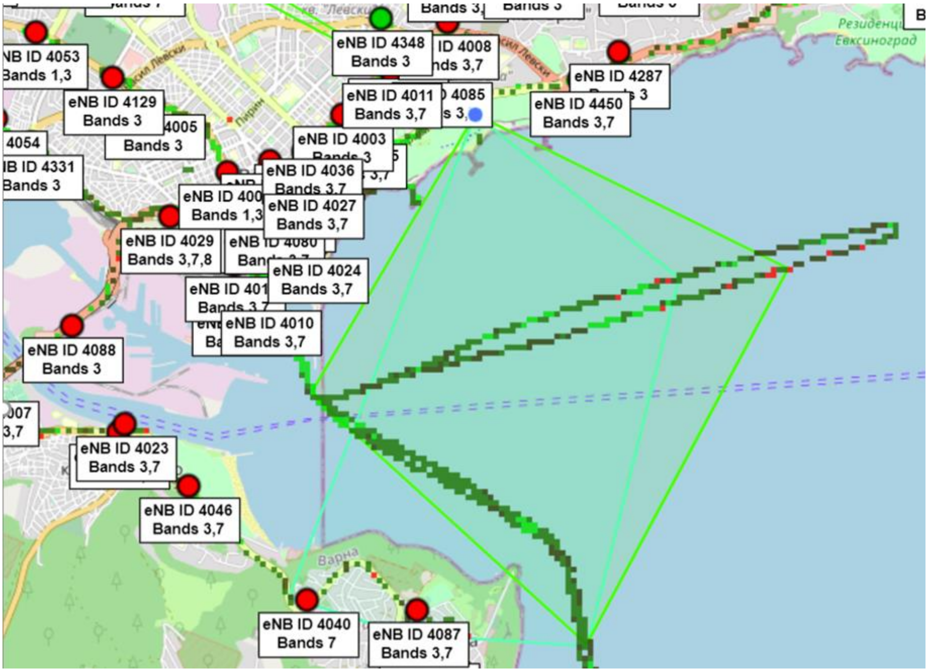

Figure 1: Coverage of Varna bay provided by VIVACOM mobile operator. The color trails show the measurements of signal strength.

The signal changes down to GSM 2G with interruptions during handover with levels of -114dBm. The coverage of Telenor BG is mostly oriented towards the beach. So according to Figure 2, not more than three or four handover candidate sites could be in service. The signal quality is good but the coverage is limited.

The other proposed device GAT2038 is an inexpensive long range (LoRa) sensor tracker and is a wireless remote positioning solution based on LoRA+GPS nRF52832 chip.[1, 2] It also includes temperature and humidity sensor. The circuit uses LoRaWAN 1.0.2 protocol and supports LoRaWAN working mode, allowing customers conveniently to link to the IoT network. The user can utilize MQTT nodes to receive the data published by Everynet. To make it even easier, Everynet has written custom nodes for Everynet integration. Having in mind the duty cycle of the system, 1% and 0.1% are both acceptable for the mentioned project purpose. Thus, the vessels could be followed in an area between two

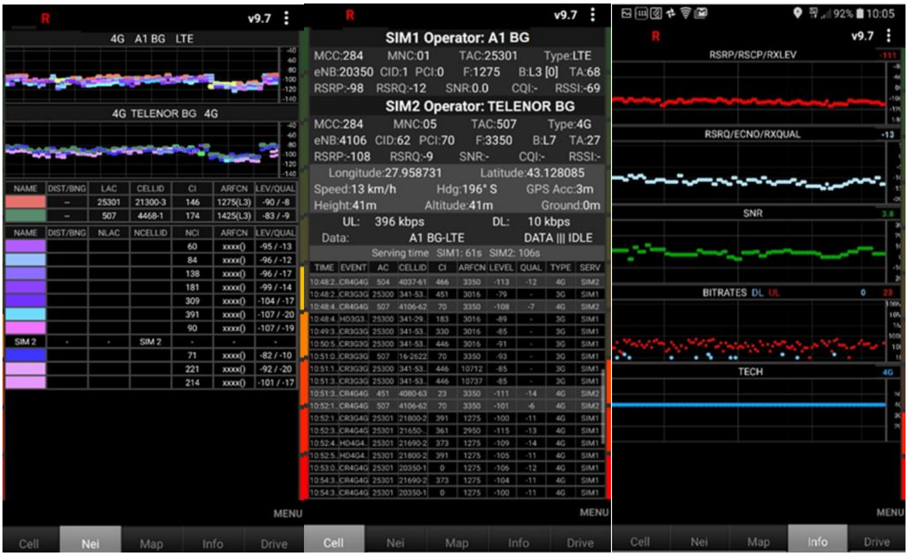

Figure 2: Details showing the signal power and quality readings for A1 and Telenor BG.

And five km from shore. The traffic the device generates comes up to 3.5 EUR per year for one-way uplink traffic sending 7-100 reports per day.

As per the manufacturer's decision, there are separate channels for each "service". Channel 1 is allocated for GPS data, channel 2 is the data from the accelerometer, channel 3 is the temperature data, channel 4 is the data coming from the humidity sensor (See Table 1). An online service like Cayenne makes it easy to integrate with Everynet, but one can also integrate with own software using message queueing telemetry transport (MQTT) protocol. The data from GAT2038 in this article is compatible with Cayenne Mydevices platform. Cayenne My devices is a solution to build applications based on platforms as Arduino, Raspberry Pi, ESP8266 and Serial devices, WiFi, LoRa devices, which also include a MQTT client API.[4] The GAT2038 LoRa tracker utilizes AcSIP S76G [1] and is registered as Cayenne low power payload (Cayenne LPP).[7] The Table 1 shows the data entering the visualization platform. On Table 2 below is given a comparison between known utilized technologies, considered in this article. The hydroacoustic network utilized for detection and classification in busy environments use correlation algorithms in order to determine the difference between several targets.[15] Enhancement to GSM technology suitable for maritime surveillance is also implementation of small radar cross section techniques.[16]

Table 1. Data entering the visualization platform.

Timestamp	Chan	Sensor ID	Data	Values
2019-08-08 12:55:14	3	17b8c3a0-b9b3-11e9-879f-4ff2bd1b7688	Temp	42
2019-08-08 12:55:14	2	17cdab30-b9b3-11e9-b6c9-25dbdbf93e02	Accel	-16.132,24.576,-24.572
2019-08-08 12:55:04	3	17b8c3a0-b9b3-11e9-879f-4ff2bd1b7688	Temp	41
2019-08-08 12:54:43	1	9457de80-b9b0-11e9-80af-177b80d8d7b2	GPS	43.1918,27.9215
2019-08-08 12:53:42	1	9457de80-b9b0-11e9-80af-177b80d8d7b2	GPS	43.1912,27.921
2019-08-08 12:53:53	2	17cdab30-b9b3-11e9-b6c9-25dbdbf93e02	Accel	-16.382,-16.384,16.638
2019-08-08 12:48:52	3	17b8c3a0-b9b3-11e9-879f-4ff2bd1b7688	Temp	46
2019-08-08 12:45:32	1	9457de80-b9b0-11e9-80af-177b80d8d7b2	GPS	43.1936,27.9208

Table 2. Comparison between the considered technologies.

Technology	Hydroacoustic	GPS Cellular	LoraWAN
Performance	Medium	High	Medium
Reliability	Medium	High	Medium
Cost	High	Medium	Low

Conclusions

Traditional methods for tracking are the cellular devices that incorporate GPS receiver. A small extension to these devices is the possibility to interrogate them and have backward information coming from additional sensors if connected. Configuration of these devices is also possible over the air still having in mind the restrictions in coverage. Having collected and post processed data from Varna Bay, it is clear that traditional GPS trackers could be widely utilized as the coverage though having some small gaps extends up to 20 nautical miles. If small vessels and leisure crafts are equipped with inexpensive trackers, accidents could be avoided and alerting could be initiated in due time. The idea to utilize inexpensive cellular or LoRa trackers in coastal areas will definitely improve in effective way the risk evaluation process, consideration of the circumstances and predict the actions for accident prevention. The LoRa WAN option is modern and advanced. The devices are cheap and tiny, but its coverage is still limited. The growth rate is promising and the future will favour their implementation as communication fees are minimal on a yearly basis. Such solution will be both cost effective and meets the need of waterway users, VTS and stakeholders. Furthermore, the collected measurements concerning the maritime environment – temperature, humidity and accelerator readings could be of help for the oceanographic research in Black Sea coast areas. Protection projects will be a large investment but will lead to responsible shipping and healthy coastal community and environment. Considering leisure boat accidents each year, more than 90 percent of the casualties were not wearing personal floating or alerting devices.

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