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ESABALT Improvement of Situational Awareness in the Baltic with the Use of Crowdsourcing

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ABSTRACT: This paper presents the key assumptions and preliminary research on an integrated system called ESABALT, for enhancing maritime safety, which incorporates the latest technological advances in positioning, e-Navigation, Earth observation systems and multi-channel cooperative communications. The most novel part of the ESABALT concept, however, is a focus on user-driven crowdsourcing techniques for information gathering and integration. The system will consist of a situational awareness solution for real-time maritime traffic monitoring via utilizing various positioning technologies; an observation system of the marine environment relevant to transportation and accidents including assessing the sea ice, oil spread, waves, wind etc.; and a methodology for context-aware maritime communication with cooperative, multi-channel capabilities. The paper presents the intelligent, novel, user-driven solution and associated services developed in ESABALT for enhancing the maritime safety in the whole Baltic area.

1 INTRODUCTION

In 2010 the European Union launched a new research and development program to protect the Baltic Sea worth EUR 100 million over the period 2010-2017, called Baltic Organizations Network for Funding Sciences EEIG (BONUS). BONUS (EU 2015) is considered as the first model case for the development of science-based management of the European regional seas by bringing together the research communities of marine, maritime, economical and societal research to address the major challenges faced by the Baltic Sea region.

2 PROJECT ASSUMPTIONS

The project *Enhanced Situational Awareness to Improve Maritime Safety in the Baltic* (*ESABALT*) (FGI et al. 2015) is a research and development (R&D) project funded by the BONUS program for studying the feasibility of a novel system for enhancing maritime safety, focusing on the Baltic Sea as a test-bed for the system and service concept. The partners in the ESABALT consortium include the Finnish Geospatial Research Institute (FGI), Furuno Finland Oy, SSPA Sweden, and Maritime University of Szczecin (MUS), Poland.

The term situational awareness refers to the concept of being aware of one's current or developing situation. In the maritime context, a vessel's crew must maintain good situational awareness in order to safely and efficiently operate the vessel. This includes awareness about the environment (e.g. developing weather conditions), the maritime traffic surrounding the ship, and the condition of one's own vessel and crew. Especially in the case of an emergency, situational awareness may also include information about the condition of other ships in the vicinity, such as a damaged ship whose navigational ability has been jeopardized.

The Baltic Sea is a very busy waterway, and although relatively safe as compared to other seas, presents certain unique challenges to maritime safety (Brunila & Storgård 2014), (Häkkinen & Posti 2014), (Sztobryn 2012). In the past, major efforts to increase safety at sea have been initiated and driven by governmental authorities or supranational agencies, such as the International Maritime Organization and United Nations (UN 2015). In addition, several development and research projects such as EfficienSea (EfficienSea 2015), MARSUNO (MARSUNO 2015), BaltSeaPlan (BaltSeaPlan 2015), Baltic Master II (Baltic Master II 2015), MONALISA (MONALISA 2015) and GMES Polar View (GMES Polar View 2015), were initiated for addressing maritime spatial planning, safety of transport and environment in the Baltic Sea Region. However, studies show that in addition to improved maritime safety regulations, voluntary activities of companies and sailors can also be one the most effective way to improve maritime safety in the future (Lappalainen et al. 2013).

ESABALT aims to increase the safety of all vessels operating in the Baltic Sea by providing tools and services which enhance situational awareness. This is achieved using the latest technological advances in sensing, positioning, e-Navigation, Earth observation systems, and multi-channel cooperative communications. In addition, ESABALT aims to facilitate crowdsourcing of relevant information from a multitude of users. That is, by reporting information to a central repository, all end-users will be able to achieve a greater level of collaborative situational awareness than they would by acting independently. The various elements of the ESABALT concept are depicted in Figure 1.

Therefore, the overall objective of ESABALT is to assess the feasibility of providing an enhanced situational awareness solution for all ships operating in the Baltic, including real-time maritime traffic monitoring and a marine environment observation system relevant for maritime transportation and accident prevention. This solution will include information for assessing sea ice, oil spread (in the case of an oil spill), wave heights, currents, as well as wind speed and direction. In addition, three specialized services will be studied in addition to the situational awareness solution, including intelligent marine navigation and routing information, efficient emergency response, and environmental monitoring and reporting with emphasis on cross-border functionality.

Regarding the technologies incorporated into this concept, real-time traffic situations will be detected with satellite and terrestrial navigation sensors, while the sea environment will be identified with images from Earth observation satellites, local vessel sensors, fixed sensor stations and deployable sensor stations. The developed context-aware communication solutions will be implemented based on various satellite and terrestrial technologies, optimizing the communication channels based on available technologies and in terms of costs and capabilities.

ESABALT differs from traditional navigation information systems, as it is a user-driven system and learns from users' navigation experiences to provide route plans and real-time navigational updates. Issues of information integrity can be regulated directly by the user community without active oversight of authorities. With ESABALT users can report accidents, local ice-status and weather conditions, route plans, navigational issues, and other ships and boats. ESABALT also helps users find energy efficient routes and speeds due to prognoses from statistics and other ESABALT users. In addition, ESABALT will have the ability to use freely available navigational information, such as AIS-data, to support the information provided by the users. ESABALT is planned to be open so that commercial ships as well as pleasure boats can use and provide information to the system.

The following Sections describe the ESABALT concept and its constituent modules in more detail. Section II describes the concept of crowdsourcing as applied to the maritime domain. Section III lists the various stakeholders and users of ESABALT. Section IV presents the system architecture and interdependencies between the constituent modules. Section V describes some of the services and functionalities of ESABALT. Finally, Section VI describes the expected impact of the ESABALT concept and system on the maritime domain.

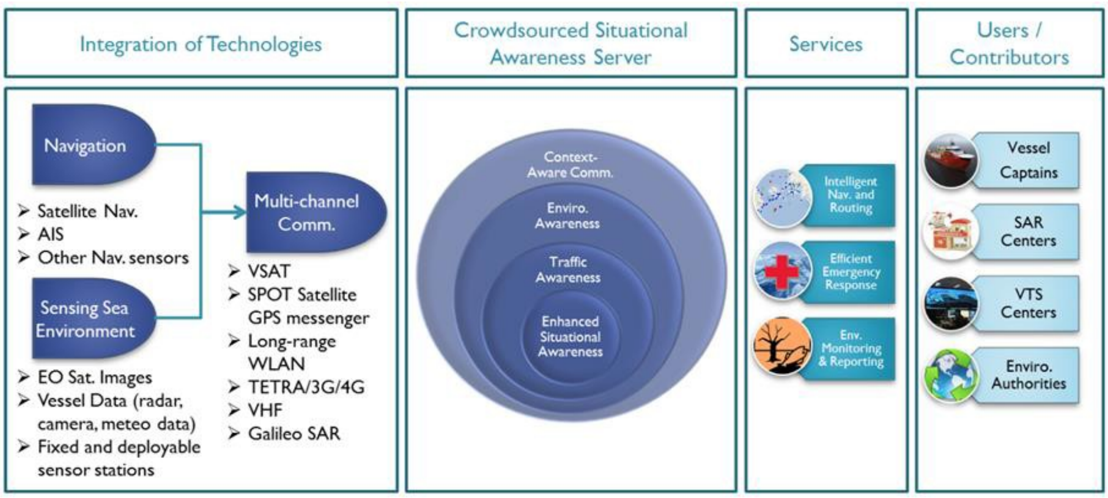

Figure 1. ESABALT integrates relevant maritime technologies through a dedicated situational awareness server, providing innovative services to end-users and stakeholders in the Baltic Sea region.

3 CROWDSOURCING IN THE MARITIME SCENARIO

Crowdsourcing means the use of an undefined network of people for collecting information to be used for a certain purpose (Franzoni & Sauermann 2014). One of the most known examples is Wikipedia. Based on (Gao et al. 2011), the use of crowdsourcing data for safety applications has the advantage that the distribution of the data is fast, that data are provided from multiple sources and with various forms, and that the data are automatically geo-tagged. However, its defects are: (1) it is difficult to coordinating the use of the data, (2) verification of the accuracy and reliability of the data is challenging, and (3) the security as well as privacy issues of transmitting the data must be carefully considered.

In the case of transportation, crowdsourcing would be beneficial for providing the user with improvements and corrections for existing maps, or in the most extreme case providing maps in the areas where none are available. Also, due to the fast nature of crowdsourcing, the users could be warned about dangers and accidents nearby almost in real-time. Crowdsourcing applications for enhancing transportation safety are only slowly moving from the research stage into implementation, probably due to the above mentioned challenges.

Good crowdsourcing examples may be found from other means of transportation, mainly land transportation, where the use of crowdsourced data is evolving from improving the user experience to enhancing safety. Waze is one of the few already implemented crowdsourcing based transport services (Waze 2015). It is a mobile navigation application that passively collects, e.g. location data from users, as well as receives and distributes crowdsourced data from other users, e.g. reports from accidents or police inspections. The service also includes an active community of people updating the maps. (Aubry et al. 2014) study the use of traffic offence reports made by the service users for improving the immediate safety of the road users as well as providing a tool for the authorities for traffic planning. (Zambonelli 2011) suggests the use of crowdsourcing for improved situational awareness making, e.g. private parking spaces or cars available for other users when they are not reserved by the owner, as well as for enabling more efficient car-pooling. The technological implementation aspects of the crowdsourcing based services are discussed actively in different scientific publications, e.g. (Ali et al. 2012) and (Gorin et al. 2014). Also, the safety of pedestrians may be increased by producing collective emotion maps, as implemented in an EMOMAP pedestrian navigation system (Klettner et al. 2013), alarming the user about unsafe places in a city pinpointed by crowdsourcing.

Applications addressing the use of crowdsourcing for other transportation means are still more immature. A study for getting a better understanding about the behavior of the Dutch Railways (NS) customers was carried out in 2011 (Van der Wees 2011). The research envisioned that in the future the crowdsourced data could also be used for detecting technical problems of trains by collecting the user perceptions of, e.g. abnormal noises. (Omokaro & Payton 2014) discuss the use of crowdsourcing for improving the aviation comfort and safety by, e.g. collecting information about the in-flight air pressure and noise levels using relevant sensors which already exist even in smartphones to some extent. The research also suggests that the passengers could be seen as additional black boxes in the case of an emergency, if their perceptions of, e.g. weather conditions or ambient sounds would be collected by crowdsourcing during the flight.

Maritime transportation, as well as aviation, has very stringent safety requirements and therefore the use of crowdsourcing is even more complex than for land transportation purposes. Also, the different roles of information users have to be taken into account. A lesson learned from the MARSUNO pilot project, aiming to achieve better interoperability among maritime monitoring and tracking systems between the authorities of different countries, was that there are issues even on the data collected by the officials of different countries controlling the sea areas the vessels are crossing (MARSUNO 2011). Due to the sensitive nature of maritime transportation, so far the use of crowdsourcing has been limited, and mainly only authoritative data with verified status and provenance have been employed.

However, crowdsourcing has been seen as a useful tool for some maritime operations, as the authority's data have issues with currency and coverage. The possibility to ensure good quality of user-provided data has been studied (Chilton & Mason 2013). One of the maritime crowdsourcing systems already in use is called Argus (Van Norden et al. 2013). It is a crowdsourcing bathymetry system which provides the users with depth data collected using GPS and depth-finding systems of multiple vessels with different sizes. Argus is in use in the United States an the Intracoastal Waterway (ICW), and in addition to the depth data it provides the users with information about navigation hazards like misplaced buoys overlaid on chart displays. Crowdsourcing would be feasible also for addressing the lack of data from inland lakes, as investigated in a project carried out in Denmark for bathymetric data (Vedel & Hansen 2012).

OpenSeaMap is a project addressing the need for easily accessible nautical charts including also navigation data (e.g. beacons, buoys, port information), by aiming to create comprehensive nautical charts by crowdsourcing (OpenSeaMap 2015). OpenSeaMap is a subproject of OpenStreetMap aiming at creating a free map of the whole world (OpenStreetMap 2015).

Use of crowdsourcing for creating ice awareness would improve the safety of vessels especially in Arctic areas. At present, ice monitoring is done by interpreting radar data and using crew's visual perception. (Reid et al. 2014) suggests an ice-aware system using multispectral sensing by a combination of LIDAR, radar, and video. The resulting data are georeferenced with GNSS measurements and distributed to all vessels nearby.

Figure 2 describes the use of crowdsourcing for service delivery based on Econom's blog (Econom 2015). Crowdsourcing is compared to the concepts outsourcing, namely buying services from other service providers outside the client organization, and to insourcing, namely providing the service inside the organization in need. The main benefits of crowdsourcing are that the cost for the service is very low compared to outsourcing and insourcing, while the time to value, namely the fastness of receiving the need data, is high. Also, when the number of crowdsourcing participants is high, the breadth of the solutions is high, e.g. maps, barometry data, and ice awareness. One of the key challenges of maritime-related crowdsourcing is, therefore, attracting a large number of participants.

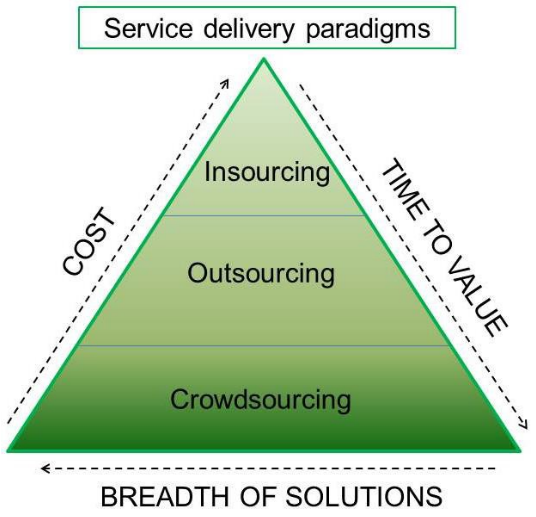

Figure 2: Comparing three service delivery paradigms: insourcing, outsourcing, and crowdsourcing (Econom 2015)

4 ESABALT STAKEHOLDERS

The concept of ESABALT aims to raise awareness of dedicated stakeholders. To do this the stakeholders involved in maritime sector processes, especially in maritime transport processes, were identified and analysed taking into account different stakeholder classification criteria. Stakeholder in ESABALT was assumed as an individual or an organization having a right, share, claim or interest in a system or in its possession of characteristics that meets their needs and expectations, while user of the system was assumed as any party interacting (input into and/or extract information) with the system including operators and maintainers.

In the first approach partners of the project identified stakeholders involved in in maritime sector processes. Four classification criteria for extensive description were proposed:

1 Stakeholder levels
2 Stakeholder roles
3 Stakeholders breakdown by location
4 Stakeholders breakdown by interest

For each classification criteria several groups of stakeholders were identified. For instance for first criteria – by level following groups were proposed:

– supranational organizations,
– international organizations,
– regional organizations,
– national organizations and states,
– branch/ industry,
– users.

In second step parties involved in in maritime information exchange processes were identified. This task was done in order to point potential users of ESABALT system. Three classification criteria were proposed:

1 Stakeholders breakdown byinformation needs in relation to time (time horizon)
2 Stakeholders breakdown by information need types
3 Stakeholders by breakdown by information service types

Again for each classification criteria several groups of stakeholders were identified. For instance for relation to time criteria following groups were proposed:

– operational data user,
– tactical data user,
– historical data user.

Finally system users involved in maritime information exchange processes were identified. Users were divided into two main groups: basic user and assigned system users. All users were analysed and described with breakdown by their description, characteristic and expected needs. Thirty three potential ESABALT system users and six groups of potential basic users. Basic users consist of:

– main users
– additional users
– support users
– administration users
– educational users
– others.

The group of main users includes seamen, fishermen, offshore, emergency management center, nonprofessional users (i.e. leisure boats). This group will use the system in the widest level, provide and use most of the information primarily the local weather and navigation information as well as warnings about potential hazards.

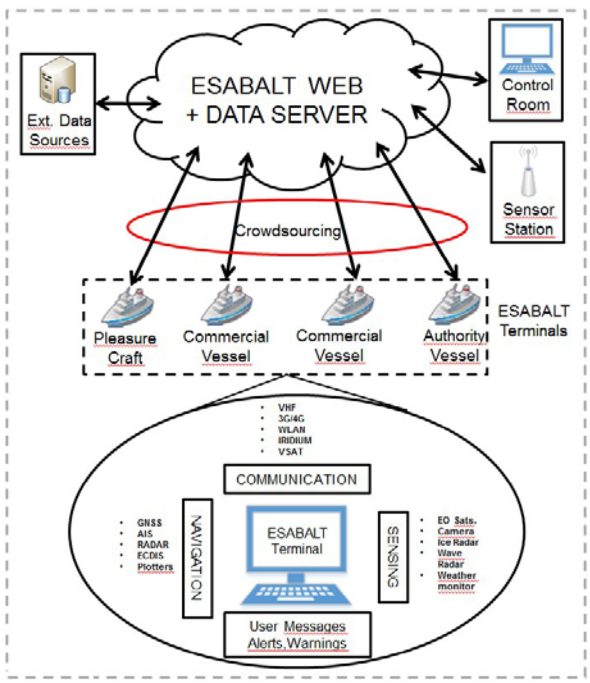

Figure 3. ESABALT system architecture showing the different modules, the central position of the server, and the four primary sources of crowdsourcing data to the terminal.

5 SYSTEM ARCHITECTURE

The overall system architecture has been envisioned as a distributed network, where different user and data source groups are connected via the internet, as shown in Figure 3. This includes small boat systems (i.e. pleasure boats), ship systems (i.e. professional vessel systems) and authorities' vessel systems, as well as ESABALT sensor station systems and the authorities onshore based control center system. ESABALT sensor station system may be a fixed shore based station or a vessel-based mobile system which is performing a specific task in a defined location. External data sources (eg. satellite data) are connected to ESABALT server via the network. Different communication protocols can be used to link these different nodes in the system, such as standard TCP/IP, IVEF, and secure connections utilizing SSL/TLS, such as OpenVPN.

Next, the nodes connecting to the network may themselves have different architectures, depending on the type of vessel or user, its capabilities, and its role in the overall system. "Small boat systems" are expected to have less capabilities and especially intended to be used by pleasure boat navigators.

As an example, in the small boat system the user interface may be a tablet-based application that is connected to an ESABALT gateway via a wireless router. This gateway can then connect to the ESABALT server through one of a number of different communication interfaces. Since these small vessels are expected to stay mainly in coastal waters, one possibility is that they would use existing 3G/4G mobile networks to connect to the internet. ESABALT application would transmit boat own position data and other specified crowd sourcing type of information relevant to small boat navigators. Received ESABALT added value information close to boat and it's route is displayed in tablet GUI.

6 ESABALT SERVICES & FUNCTIONALITIES

The different functionalities of the ESABALT system aim to satisfy the following three overarching services: (1) intelligent marine navigation and routing, (2) efficient emergency response, and (3) environmental monitoring and reporting with emphasis on cross-border functionality.

6.1 *Intelligent Marine Navigation and Routing*

Currently, marine navigation and routing is comprised of a relatively manual set of tasks, involving the use of a navigation system, radar, and ECDIS (or ECS), as well as paper charts, which are increasingly used as only a back-up source. In addition, navigators must manually integrate weather information and operational constraints into their duties. In winter conditions, navigators must independently decide the safest and most efficient route through ice infested waters, as well as coordinate their possible assistance from ice breakers.

The ESABALT system will investigate the feasibility of creating an intelligent marine navigation and routing service that will take into account many different factors related to the maritime traffic situation, weather situation, and (during wintertime) the ice conditions. As much as possible, the service should aim to automate the route planning functions, while still offering the navigators alternative routes to choose from. Also, the service should provide periodic updates concerning the traffic and weather situations, including ice conditions, during the course of a voyage.

6.2 *Efficient Emergency Response*

ESABALT system users are logically classified into pleasure craft, commercial vessels and authority vessels. Vessels have compulsory onboard emergency response equipment required by IMO. The majority of pleasure boats, however, do not have any emergency response equipment on board. In emergency situations, a mobile phone is often the device used. In emergency situations, events may happen very rapidly, and telephone numbers where to call are not always immediately available. This is the background where ESABALT could give benefits especially in small boats' emergency reporting.

The ESABALT GUI for small boats could include easy-to-use reporting mechanisms for different type of emergency situations, e.g. engine failures, lack of gasoline, man overboard, vessel groundings, etc. In emergency situations, information could be forwarded to authorities, volunteer-based civil organizations, or to other vessels close to the boat, in order to initiate different types of responses. ESABALT automatic mechanisms might be used in the forwarding processes.

Also, the ESABALT vessel system might have the same kind of response mechanisms available, although it is not the intention to build any parallel systems to the ship's own emergency response equipment. External data sources might provide information concerning ship emergencies automatically to the ESABALT system. Value-added information related to an emergency situation, such as the assisting vessels' route and status could be forwarded to the ESABALT system.

6.3 *Environmental Monitoring and Reporting*

Annex VII of the Helsinki Convention requires signatories to "request masters or other persons having charge of ships and pilots of aircraft to report without delay and in accordance with this system on significant spillages of oil or other harmful substances observed at sea. Such reports should as far as possible contain the following data: time, position, wind and sea conditions, and kind, extent and probable source of the spill observed." ESABALT can facilitate this type of environmental monitoring and reporting by providing the interfaces and automatic forwarding of reports to the appropriate authorities. In particular, many operators of small boats may not be aware of the requirements or guidelines regarding reporting of observed pollution. Therefore, ESABALT can play a key role in encouraging these users to report observed pollution. This is especially relevant to the coastal areas of the Baltic, where comprehensive and timely reporting of environmental pollution is critical to ensuring a rapid and effective response from the appropriate environmental authorities.

6.4 *Further Development of Associated Services*

The functionality of the system is designed to be modular, enabling easy addition of new functionality or removal of unwanted ones without disturbing the overall system. The ESABALT terminal onboard ships and in the Control Room is based on the ECS (electronic chart system) using standard S57 charts and utilizing GUI for added value ESABALT services. ESABALT terminal has own profiles and functions to each user groups: small boats (pleasure craft), commercial ships and authorities vessels. The ESABALT terminal is designed to integrate (rather than supplement) the existing maritime electronic systems onboard vessels. The number of devices that are integrated with the terminal determines the number of functions it is able to perform.

Following is a list of ESABALT software modules which enable it to offer the expected functionality and associated services:

1 System registration and log-in
2 Display vessel position and submit to ESABALT server
3 Display vessel route and submit to ESABALT server
4 Display position and information about nearby ships
5 Display route of nearby ship(s)
6 Report an unidentified vessel
7 Route optimization request to ESABALT server and submit the selected route
8 Make an update to vessel route and submit to ESABALT server
9 Display situational awareness reports – weather, sea ice, pollution etc.
10 Report situational awareness – sea ice, pollution, oil spill, violating ship etc.
11 Report and display ship(s) violating maritime rules
12 Submit vessel radar tracks to ESABALT server
13 Submit messages/warnings/alarms to ESABALT server
14 Display messages/warnings/alarms from ESABALT server
15 Speed-reporting of emergency situations for pleasure craft

7 EXPECTED IMPACT FROM THE ESABALT SYSTEM

By reporting information to a central repository, all end-users will be able to achieve a greater level of situational awareness than they would by acting independently. A guiding tenet of the ESABALT concept is that all maritime users in the Baltic Sea can operate more safely and effectively by collaboratively building and maintaining situational awareness. Features of the system can be summarized in three categories; increased information sharing, increased number of users and aggregated information overview.

7.1 *Increased information sharing*

Early in the project a web based survey on feasibility and interest in crowd sourcing in the maritime was conducted. Of the 166 answers from maritime industry professionals, 86.4% answered that they would participate in crowdsourcing of maritime information if given the chance and/or technical possibility. Maritime services such as AIS and navigational warnings already incorporate crowd sourcing principles. In addition, other information such as sea-state, ice conditions and planned route are included in the communication.

7.2 *Increased number of users*

A majority of survey responses considered other ships as one of the main hazard for ships in the Baltic. Some participants explicitly answered; congested waters and pleasure crafts in summer time. The commercial fleet and relating organizations have established means for communication. Yet many small national passenger vessels or inshore pleasure boats lack such communications equipment. Harmonization, through increased availability of the system e.g. as smartphone application, will lead to a larger amount of users and hence, increased amount of data.

7.3 *Aggregated information overview*

By gathering the information to a central display, an aggregated information overview is obtained. The user will know where to find the information. In addition to the targeted purpose, the ESABALT system could have other unexpected effects. Big data of this type could be valuable from an operational as well as historical point of view. For instance, statistically significant echo sounding data gathered through ESABALT could form the basis for decision to conduct a further hydrographical survey or as an operational decision support for a pleasure craft visiting an unmeasured place. Other possible applications could be land based monitoring of real time and historical maritime traffic and environmental conditions and data.

8 CONCLUSION

This paper introduces the concept and system architecture of the ESABALT platform for enhanced situational awareness in the Baltic Sea. The first stage in the implementation of this platform is a feasibility study to ensure its utility under current maritime operating scenarios. The primary motivation for this system is to improve maritime navigation and safety of sea transportation. Primary technologies incorporated in this platform are eNavigation, Earth Observation and Communication. An innovative addition is the use of information crowdsourcing from the users of ESABALT for overall situational awareness at sea.

We have identified stakeholders and their requirements for such a system based on which a system architecture is proposed. The ESABALT services include intelligent marine navigation and routing, efficient emergency response and environmental monitoring and reporting, which are further described using fifteen functionalities. The ESABALT platform is expected to bring increased information sharing among the maritime community in the Baltic Sea region leading to an overall improvement in international cooperation and ultimately maritime safety.

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