MARINETRAFFIC: DESIGNING A COLLABORATIVE INTERACTIVE VESSEL TRAFFIC INFORMATION SYSTEM

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ABSTRACT
International legislation and current technology provide the tools for better vessel traffic surveillance. Land-based systems are able to collect and process the information transmitted by vessels through the 'Automatic Identification System'. These systems possess a valuable set of information that can be exploited in a variety of useful applications of public interest. The University of the Aegean implemented 'MarineTraffic' as a pilot Vessel Traffic Information System, facing several significant challenges, such as the radio-waves limitations, the establishment and coordination of a large number of stations and the cost-effective processing and storage of a huge amount of collected data. The system design adheres to a set of principles, such as the community efforts to build the stations network, the interactive interfaces and the publicly available information. A large number of interested parties adopted the application, since it exhibits its potential to support many applications, including message notifications, simulation of special scenarios, fleet management, environmental protection and observation of areas of special interest.

Keywords: Automatic Identification System, Vessel Traffic System, Information System, Design, Interaction, Collaboration

1. INTRODUCTION
In line with the European Directive 2002/59 and the regulations of the International Maritime Organization, vessels on the one side and countries on the other side, are requested to support better vessel traffic surveillance.

Aegean and Ionian Seas constitute a unique environment for implementing a large scale shore-based Vessel Traffic Information System (VTIS). A plethora of islands are distributed around the Greek seas, they usually have high mountains and therefore they are ideal for building a network of stations receiving and observing vessels positions. At the same time, millions of passengers are travelling each year around the islands using local ferries, while a very large number of commercial vessels are crossing the Aegean or are entering into the basic commercial ports.

The University of the Aegean is currently designing and implementing a pilot VTIS, initially exploiting the university's own infrastructure, which is distributed on six distant islands in the Aegean Sea. The initial objective of the pilot implementation is to support the research activities of the department of Product and Systems Design Engineering. The public interface of the application is available at http://www.marinetraffic.com/ais/.

The system exploits the benefits of the Automatic Identification System (AIS) which is in fact an active long-range Radio-Frequency Identification (RFID) system. AIS transponders fitted on all vessels with gross tonnage (GT) of 300 tons or more, automatically broadcast information, such as their position, speed, and navigational status, at regular intervals via a VHF transmitter built into the transponder. The information originates from the ship's navigational sensors, typically its global navigation satellite system (GNSS) receiver and gyrocompass. Other information, such as the vessel name and VHF call sign, is programmed when installing the equipment and is also transmitted regularly. Some voyage-related information, such as destination port and Estimated Time of Arrival (ETA) are transmitted as well.

The signals are initially addressed to other vessels, as a supplementary navigation tool and a collision avoidance device, when combined with other means and of course with good seamanship. It is however obvious that land stations (Vessel Traffic Systems – VTS) may also receive and process these signals in order to extract very useful information about vessel traffic in the area. The collected information may be used in a variety of relevant applications, such as traffic simulation, accident or crisis scenarios, fleet management, info-kiosks and personal notifications, as discussed in the present paper.

2. BACKGROUND

2.1. Existing Technology and Limitations
In recognition of the requirement for reporting vessels positions, the AIS Technical Standards (ITU-R M.1371-1) describe the functional specifications for Ship-borne Mobile Equipment that performs the necessary functions. The AIS equipment is categorized in two different classes: Class A equipment complies with the

IMO AIS carriage requirement while the Class B provides capabilities for smaller vessels, not necessarily fully compliant with IMO requirements, but fully compliant with AIS technical standards.

The ITU-R Recommendation M.1371-1 describes the Class A AIS device as "Shipborne mobile equipment intended for vessels meeting the requirements of IMO AIS carriage requirement, and is described above". Class B devices are based on the same technical principles. The main differences from Class A devices are that a) the position reporting rate is slower, b) navigational status is not transmitted, c) the informational fields transmitted are restricted. It is obvious that Class B transponders are designed for 'less critical' applications, giving priority to the information transmitted by larger vessels (Class A fitted).

Although AIS has the potential to greatly enhance Vessel Traffic operations, the system has several limitations or potential drawbacks. As a result, a VTS cannot rely solely on AIS data for critical applications related to the safety of navigation. However, this data have a great value for applications of informational nature or applications related to the protection of the environment, to fleet management, port operations, alerting, etc. Some significant limitations follow:

- A Vessel Traffic Information System based on AIS data provides a very 'attractive' picture of vessel traffic. An operator of the VTIS may solely rely on this picture, neglecting to observe additional sources, something that may lead to a dangerous situation. AIS provides only a partial picture of vessels positions, since not all vessels are equipped with AIS transponders or transmission may be weak or erroneous.
- AIS is subject to the problems of VHF-FM radio-wave transmission and propagation, such as interference, distortion and problems caused by physical obstacles in land areas.
- AIS transmission may reach its capacity limits in crowded areas, giving priority to the closest vessels. Again, a VTIS would only receive a partial picture of vessel positions and movements.

2.2. Legal Framework

The international standards and regulations related to vessel traffic surveillance were developed by cooperating international bodies such as IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities), IMO (International Maritime Organization) providing regulatory directions and ITU (International Telecommunications Union) providing technical standards. The practical implementation has been speed up by revision of SOLAS Convention in 2001, Copenhagen Declaration 2001, EU Directive 2002/59 and the EMSA (European Maritime Safety Agency).

Especially in the European Union, in addition to initiatives being taken at national level, EU Directive 2002/59 has been set in place, aiming at the establishment of a Community vessel traffic monitoring and information system. The purpose of this initiative is to ensure that ships in EU waters, and their cargoes, are monitored more effectively than in the past, and that there is a more consistent approach across all EU sea areas. The Directive requires Member States and the Commission to co-operate to establish computerized data exchange systems and to develop the necessary infrastructure. In this direction, data collected by VTIS on a national level, can be distributed in various formats to other interested parties. The combination of data will enable the long-range observation of seas and it will dramatically increase the surveillance capabilities of European countries.

Concerns have been expressed by the IMO in respect to publishing the vessels positions information through public web sites. The concern has to do with the possible consequences on the safety of vessels. It is clear however, that web-based applications are addressed to the public for informational and statistical purposes and they cannot be used for navigation purposes neither for critical safety applications.

Publishing personal or sensitive information is another issue to pay attention to. AIS data does not fall into this case. Vessel's identity and position information are transmitted through open public frequencies and are addressed to anyone possessing a relevant receiver. Additionally, vessels equipped with Class A transponders belong to the public transportation (either commercial or passenger) and do not transmit any kind of personal information. Private vessels equipped with Class B transponders may switch off their device in case they wish to maintain their privacy. The captain of any vessel has also the right to switch off its AIS unit, in case the vessel is sailing in areas subject to piracy and other criminal actions.

3. SYSTEM DESIGN

3.1. Basic Principles

The system design is based on an innovative open and collaborative approach and it adheres to the following principles:

- *The growth of the station network is based on community efforts*. The coverage of large areas is based on terrestrial VHF stations. That means that a large number of stations are necessary to adequately have a good picture of vessel traffic. The community-based model is cost-effective, while it results in quick expansion and in a high level of coverage redundancy.
- *The user interface is highly interactive*. The information related to vessel identities and movements is given interactively to the end-user by means of visual, textual and acoustic

tools, supporting the accessibility through an open web-based application, without the need for additional software.

- *Data collected are convertible and sharable with various interested parties.* The information collected is of interest to port authorities, European agencies, research institutes, content providers, shipping companies and other interested parties. Data are shared toward various destinations, using persistent formats and protocols, such as XML and Web Services.
- *Information is publicly available and not commercially exploited*. The project uses the resources of the University, the contribution of the community and the financial support of sponsors, in order to design, deploy and support the necessary information and communication infrastructure.
- *Mutual data exchange with other Vessel Traffic Information Systems* must be supported in order to have a complete picture of marine traffic around European coasts. This objective can be fulfilled by supporting multiple data exchange protocols based on international standards, such as XML, TCP/IP raw data transmission and Web Services.

A generic picture of the above design principles is given in Figure 1 below. Internet is the main communication medium for all involved parties, taking of course the necessary security measures whenever this is necessary. All involved parties are depicted here: The network of AIS receivers covering different or overlapping areas; the central premises hosting the database, the data collection software and the web applications; other VTS networks mutually exchanging data; other applications receiving data feed in various formats; and finally the end-users consuming the services through the web or through mobile devices.

Five core data flow directions are depicted in this topology:

1. Ship → Public radiofrequencies
2. AIS receiver → Central infrastructure
3. Central infrastructure → web & mobile end-users
4. Central infrastructure → Other specialized applications
5. Bi-directional data exchange with other VTS Networks

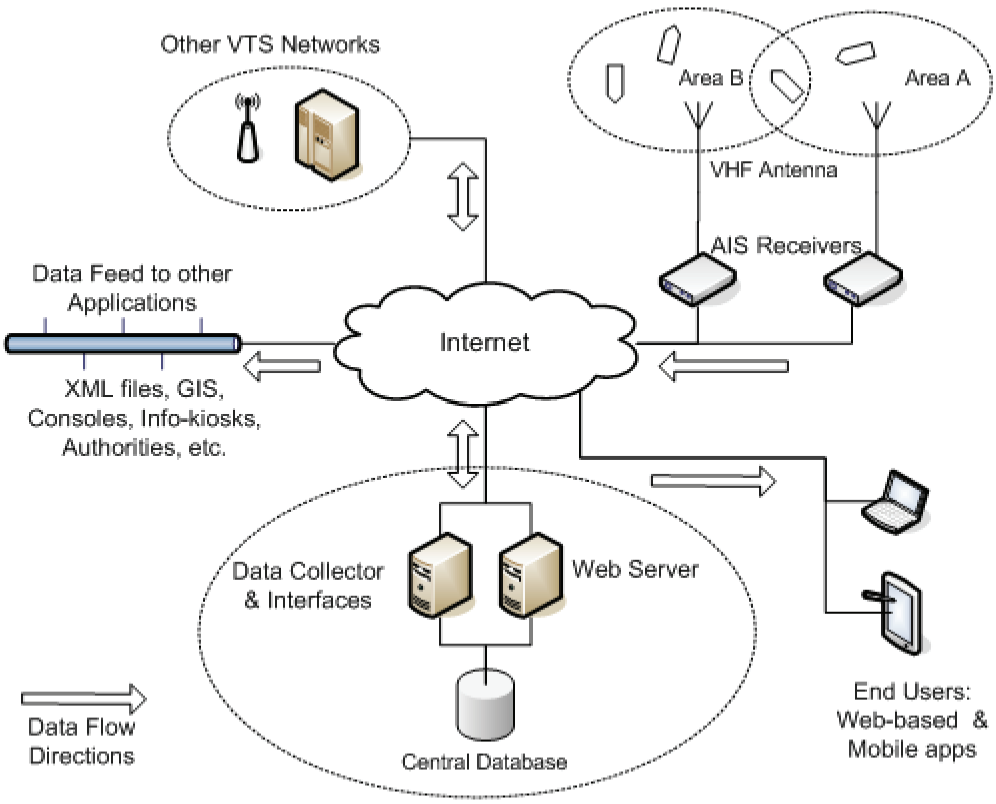

Figure 1: Generic Topology of VTMIS and peripheral equipment and applications

3.2. User Requirements

A brief list of generic user requirements follows, as collected by system designers, citizens, shipping professionals, national authorities, central system administration and other interested parties:

- *Openness and Availability*: Information must be open and available to the public, without constraints, in various visual and textual formats.
- *Data diversity and distribution*: Collected data must be accessible by different heterogeneous parties, in different standard formats, meeting the needs of a variety of applications.
- *Connectivity*: Network connectivity between central facilities and data collectors (receiving stations) must be IP-based in order to support the efforts of the community of individuals. Web services will be supported whenever a strict security policy applies.
- *Efficient processing and storage*: The amount of collected data is expected to grow enormously as the system expands to cover additional sea areas. Data collection, processing, storage and retrieval must be optimized at the best possible level, in order to support heavy vessel traffic, heavy application usage and long back-track of historical data.
- *Alerting*: One of the most useful features that will enhance the benefits of the system is the provision of alerts of various types (arrivals, ETAs, vessel appearance, points of interest and surveillance etc.), through various channels (voice gates, web, email, sms, etc.)
- *Interactive and friendly interfaces*: Interested parties must have a dynamic web-based or mobile environment in order to fully exploit the capabilities of the system. It is therefore necessary to implement multiple diversified levels of data representation and flexible customizable views.
- *Collaboration*: The nature of this system is collaborative. Data collection on the one side (installing remote distributed receiving stations) and data enrichment on the other side (additional information uploaded by users) are necessary to build such a network of stations. Even a vessel's crew is part of this community, since they enter several ship and voyage details into their AIS units, which are then transmitted and uploaded into the central database.

3.3. Challenges

A wide area VTIS which publishes the collected information through the web or through other channels, has to face several challenges, such as:

- *Morphology of Terrain*. Covering seas around island and continental areas, especially in Greece, poses several problems due to mountains and other obstacles.
- *AIS Limitations*: The AIS protocol is designed to use a minimal set of data, in order to support the communication of a large number of vessels using a very restricted bandwidth. Some details are missing, while the length of existing content is very restricted.
- *Coordination of a large network of stations*: Sufficient coverage of the Greek archipelago requires a large number of base station installations (>30). The number significantly increases when the coverage is to be expanded in other countries. For such a large network of devices, proper monitoring, alerting and supporting is necessary. Additionally, data may be received by different stations for the same overlapping areas, requiring proper filtering and synchronization.
- *Combination with other sources* of data, such as port details, shipping databases and scheduled itineraries. For example, in order to forecast port arrivals and other moves, it is necessary to combine data derived from scheduled itineraries databases, port geographical data and historical data of similar vessels moves.
- *Inconsistencies in transmitted data*, such as: Erroneous or obsolete content entered by crew, Errors in positioning details, Participation of boats (smaller boats or boats navigating in closed waters do not carry AIS transponders)
- *A cost-effective processing and storage* of a large amount of data, in order to preserve the history of vessels traffic for long periods.

4. IMPLEMENTATION

4.1. A Community-based system to build infrastructure and collect data

High cost in building base stations, in providing data lines and especially in supporting the infrastructure in remote isolated locations, pose significant difficulties in establishing a large network of stations. On the other hand a VTIS has no value unless vessels can be monitored in long-range itineraries. Additionally, base stations must cover overlapping areas, in order to provide the necessary redundancy.

Deploying and supporting tens or hundreds of base stations would require a substantial investment in money, time and human resources. MarineTraffic would never come alive, unless we kept the system open and we called any interested party to participate, by just installing an antenna and using any existing Internet connection. This approach shows great success until now. We recorded a very high interest from people wishing to support their area in vessel monitoring, from professionals, from authorities and from radio-amateurs just wishing to experiment with equipment, antennas and radio-frequency reception.

In return, the public site acknowledges the participation of third parties, while the participants feel the power of a large-scale social network, combining a huge amount of data. The system is also open to the public to upload additional information, such as vessels' and ports' photographs. The University of the Aegean hosts and supports the central facilities to collect process and publish the data and it provides technical support for the remote sites sharing their data.

4.2. An Interactive web-based Interface

One of the major objectives of the project is to provide an attractive interactive and accessible web-based interface, supporting the usability for every interested party. The public website combines the Asynchronous JavaScript and XML (AJAX) technology and the server side scripting with a wide range of optical, textual and sound content. It exploits the dynamic map APIs, such as the one provided by Google at no cost for non-commercial applications.

The interactive environment has been designed so as to support a variety of usages, depending on the potential users and their needs. Local authorities may wish to monitor vessel traffic in a specific port in real time. Passengers usually want to have an estimation of the arrival time of a ship, or even better to be alerted when their ship is approaching the port. Furthermore, they may wish to observe the weather conditions during their trip, as well as the route that their ship will be following. Finally, a ship owner company may be interested in tracking the exact position of their ships at any time and in observing their route.

In order to fulfill these user needs, the web-based interface provides layered, customizable information presentation and a number of functions that aim to assist users in navigating the map and viewing the required information. Concerning map navigation, the environment allows users to track the position of a specific ship by selecting it from a list of all ships that have been identified and inserted in the database, and to focus on a specific port from the list of all major ports in the Aegean Sea. Concerning information presentation, users can adjust the layers of information that they wish to be displayed on the map, such as specific vessel types, ports and vessel names. Furthermore, by selecting a specific vessel, users can view vessel details, such as name, flag, dimensions, etc. and they can also visualize its route on the map.

Besides the map visualizations, the system provides an additional number of useful services. For any given port, it presents a list of ships that have been recently arrived and of those that are expected to arrive along with their estimated time of arrival. It also provides statistical data on arrivals, departures and distribution of vessel types. Finally, it can generate sound alerts and send e-mails to the interested users concerning vessel arrivals and departures and estimated times.

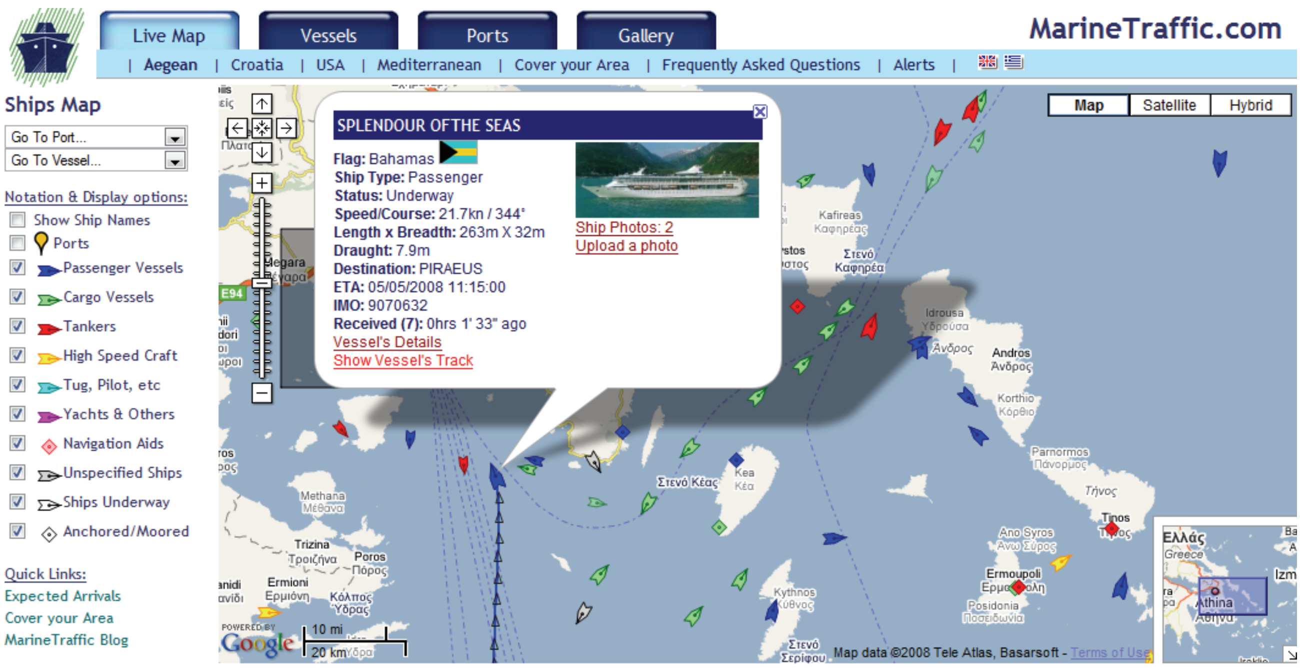

Figure 2: The Interactive web-based environment

4.3. Technical Solution

Each one of the base stations transmits the received raw AIS data directly to a central server, through any Internet connection. No data processing takes place at the station side, in order to avoid extra overhead and software maintenance. The bandwidth requirements are very low. Even in areas crowded by vessels, the bandwidth consumption is estimated at no more than 10 Kbits/second due to the intrinsic design of AIS data transmission protocol which has to support more than one thousand vessels in a restricted area, transmitting data within a very narrow time-span.

At the server side (Database) the collected raw data is decoded into structured information i.e. position, identity and voyage-related records. A data 'clean-up' is necessary at the first stage of the processing, since:

- Duplicate data may be received by different station in overlapping areas
- Amount of data is huge, since a moving vessel may transmit its position information several times a minute and hundreds of vessels may appear within the system's range at each time. The processing software ignores records received sooner than one minute for the same vessel. The one-minute interval is adequate for this application, since it is designed for informational and not for navigation safety reasons
- Erroneous data are often received, due to GPS glitches or, rarely, due to erroneous AIS data encoding and transmission. Detection of erroneous data is based on heuristic methods, i.e. based on logical checks and on the comparison with other existing information and previously recorded positions.

A second server (Listener) provides the connectivity and the interfaces to open networks, for both collecting and presenting previously stored data.

5. ADDITIONAL APPLICATIONS AND RESEARCH AREAS

5.1. Simulation

The massive collection of vessel position data can be analyzed and used as input in simulation models in order to conduct research concerning traffic and safety in the Aegean Sea. Mainly, we are planning to develop an interactive analysis and simulation environment, which will process past ship routes stored in the database and acquire critical information. The system is an early design stage and the expected functionality is the following:

- *Detection of dangerous waterways*: based on the traffic analysis of the recorded ship routes and the average weather conditions, the system may estimate places considered dangerous using a number of metrics, such as: high traffic, frequent storms, difficult to access, etc.
- *Detection of congestions and delays in ports*: being a country with high tourism, congestions and delays have been noticed in popular ports of Greece, especially during high-traffic seasons (July - August). The system may detect and perform statistical analysis of such occurrences, in order to assist experts in proposing solutions.
- *Simulation of what-if scenarios*: using hypothetical scenarios, such as an oil leak or emergency evacuation of a ship, in user-defined position and time of the year in the Aegean Sea, the system may estimate the availability of nearby ships and the time needed to approach the emergency area.
- *Simulation of alternative ship routes*: the system may allow an interactive modification of ship routes in order to propose alternative scenarios aiming to minimize sea danger and to avoid port congestions..

5.2. Alerting

Several categories of alerts or notifications may be generated and distributed through various channels (e.g. email, visual and sound notification through web-pages, SMS to mobile devices, interactive TV, voice gates). The generated alerts fit into one of the following categories:

- *Position alerts*: Sent whenever a vessel arrives/departs in/from a port, whenever it reaches a specific waypoint or whenever it goes in or out of the range of the system.
- *Estimation alerts*: Sent periodically, whenever a prediction of the time of arrival at a specific port or waypoint, is possible.
- *Special situation alerts*: Sent whenever a special, application-specific situation occurs. A special situation may include but not limited to: A vessel attempting to anchor at an area with underwater cables; a candidate vessel which is possibly the origin of a detected pollution; moving vessels in a very close proximity.

5.3. Fleet Management

Fleet Management is an essential function which allows shipping companies to efficiently observe their vessels, to minimize costs by better coordinating port approaches, to organize bunkering, to ideally adjust vessel's speed and consumption, and to improve their overall productivity.

The services provided by MarineTraffic may be easily personalized in order to meet the special requirement of a shipping company, by providing surveillance of a specific subset of vessels. Current positions, routes, port reaches and estimated times of arrivals are valuable information for a shipping company wishing to better organize its fleet and to maximize its efficiency and cost-effectiveness. Personalization of services can be offered through the web-based application, giving the possibility to the operations department to have a full and accurate picture of the fleet, at any place and at any time, as an outsourced information service.

5.4. Other application & research areas

We plan to investigate the added-value that the implemented system provides to a variety of research areas. Our future work will include:

- Study of radio-waves propagation. Hundreds of vessels around a base station, distributed in large areas, provide an ideal collection of transmitters that can be observed in terms of signal quality and propagation.
- Research models on the detection of the origin of a pollution or the observation of illegal fishing and other criminal actions
- Combination of vessels itineraries with weather conditions
- Observation of areas of special interest, such as underwater cables, places with archaeological interest or environmental-sensitive areas.
- Examination of the necessary assumptions and amendments that must be made in order to exploit the collected data in more safety-critical applications.

6. CONCLUSIONS

A Vessel Traffic Information System collecting vessels data through the 'Automatic Identification System", which also combines this information with other sources, may become a very powerful tool for maritime surveillance and for other special applications.

A careful design of a pilot system, such as the "MarineTraffic", has to face several challenges and has to respond to specific user requirements. An effective implementation must include a large number of base stations collecting data and to process a huge amount of information. As such, it would only come into operation if a considerable investment was made or if the community helped. The second option applies to our case, which proved to be rather successful and efficient.

The interface presenting the data is web-based and highly interactive, in order to attract all interested parties and to be able to respond to the needs of the shipping industry. By analyzing user needs, we conclude that there is a large number of useful application areas where the system may be used as a tool. There are significant potentials in evolving the pilot system to support important applications, such as Notification and Alerting, Simulation of special scenarios, Tracking the origin of a pollution, Fleet management, Study of radio-wave propagation and many others.

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