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HOW WILL THE NEW SATELLITE NAVIGATION SYSTEMS HELP WITH THE PROVISION OF INFORMATION AND WARNINGS?

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ABSTRACT

HOW WILL THE NEW SATELLITE NAVIGATION SYSTEMS HELP WITH THE PROVISION OF INFORMATION AND WARNINGS?

This paper introduces the concept and benefits of using next generation Global Navigation Satellite Systems (GNSS) such as the Japanese Quasi-Zenith Satellite System (QZSS) for the provision of emergency information and warnings. The Japanese GNSS-based warning system can be tailored to transmit context-sensitive messages according to people's location and situation through GNSS receiver terminal embedded in mobile phones and in-car navigation units. The key advantage of satellite based communication is its high resilience to communication network overload and failure of ground systems and network infrastructure during a disaster. This enables people to obtain necessary information anywhere (outdoor) and anytime during times of disaster. A satellite-based warning system could also be integrated with existing warning services and be used as a complementary technology. This paper describes a collaborative project with Japan on the potential utilisation of QZSS for emergency alerting and warnings in Australia.

INTRODUCTION

A 'warning system' is a means of getting information about an impending emergency, the nature of the threat, communicating that information to those who are likely to be affected by it, and facilitating informed decisions and timely response by people in danger (Mileti and Sorensen 1990). Several studies have shown that functional warning systems can be a highly effective tool for saving lives and reducing property losses (Golnaraghi et al., 2009). The range of Information Communication Technologies (ICT) used by the state and national emergency authorities to disseminate warnings has conventionally involved one-way, top-down communication flows. However, a recent re-examination of hazard warning systems owing to increased global climate variations enhancing natural disaster risk demonstrates a steady progression toward incorporating two-way participatory approaches leveraging new technologies and collaborative information sharing such as the powerful combination of the Internet, mobile, crowd-sourcing and social networking technologies (Keim and Noji 2011; White 2011; Crowe 2012). This marked shift from command to dialogue communication functions reflects the remarkable pace of change within contemporary communication patterns and information sharing systems.

Utilisation of satellite navigation systems for emergency warning and alerting is a relatively new and emerging technology. There has been little research to investigate its feasibility and application. The value of such capabilities could be foreseen in the case of critical situations where ground-based communication channels are limited or unavailable; and the coordination of emergency procedures with location-awareness activities is paramount. In mid-2014, the Japanese and Australian Governments formally agreed to cooperate to promote utilisation of ICT as well as strengthen cooperation for the promotion of geospatial information projects using the Japanese satellite navigation system (Prime Minister of Australia 2014). The Japanese Quasi-Zenith Satellite System or (QZSS) is an example of a satellite-based navigation system. While primarily built for users in Japan, the satellite trajectory design offers significant advantages to neighbouring East Asian countries as well as Australia. This paper introduces the concept of utilising a satellite navigation system in the domain of emergency warning and alerting. The proposed system is capable of providing real-time alerts enhanced with location-based information enabling users to take appropriate risk mitigation actions during events of disaster.

NAVIGATION SATELLITE WARNING SYSTEM

Satellite-based communication is another mode of communication that is used by various countries and organisations around the world to disseminate emergency messages. The Japanese nationwide warning system called J-Alert is an example using Superbird-B2 communication satellite to broadcast warning messages. The International COSPAS-SARSAT[1] Programme is another well-established satellite-based search and rescue (SAR), distress alert detection and information distribution system. It is best known as the system that detects and locates emergency beacons activated by aircraft, ships and backcountry hikers in distress (COSPAS-SARSAT 2014). Satellite communication services are generally robust and can be enhanced with geographical information to specify for which locations the information is relevant. However the use of a satellite phone is not as common as compared to mobile phones. Furthermore, maintenance of satellite communication service and operation are costly for both service providers and users.

Navigation satellites emergency system combines the strengths of both mobile telecommunication services and satellite-based communication. Global Navigation Satellite System (GNSS) is a standard term for satellite-based navigation systems, which include the U.S. GPS, Russia's GLONASS, and several other new and emerging constellations such as Europe's Galileo and China's BeiDou systems. These systems provide precise position in three dimensions, timing, and velocity using radio navigation signals. GNSS is generally a one-way system: the receivers receive the signals and there is no interaction from the receiver to the satellites. There are also regional navigation satellite systems and Satellite Based Augmentation Systems (SBAS) like the U.S. WAAS, Europe's European Geostationary Navigation Overlay Service (EGNOS) and India's GAGAN, which aim to augment GNSS.

The GNSS receiver embedded in smartphones providing information of the users' position could be used to correlate messages sent from the satellite based on the message geographical criteria. This makes the information relevant to intended users at a specific point in time and within the defined geographical area. GNSS could be used to supplement and enhance exiting warning systems. Europe has been working on emergency message services since 2005 using the EGNOS and Galileo satellite navigation systems with the introduction of the ALIVE (Alert interface via EGNOS) Concept (Mathur et al. 2005). Since then there were follow on projects investigating technical and non-technical benefits as well as advantages of utilising GNSS satellites for disaster alerting (Dixon and Haas 2008; Wallner 2011; Domínguez et al. 2013).

1 SARSAT is an acronym for Search and Rescue Satellite-Aided Tracking. COSPAS is an acronym for the Russian words "Cosmicheskaya Sistyema Poiska Avariynich Sudov", which means "Space System for the Search of Vessels in Distress".

The Japanese Quasi-Zenith Satellite System (QZSS) is another example of an SBAS developed by Japan Aerospace Exploration Agency (JAXA). When fully deployed in 2018, it will consist of three QZSS satellites placed in Highly Inclined Elliptical Orbits (HEO) and one geostationary satellite providing 24 hours coverage. The orbit configuration of these QZSS satellites provides continuous coverage at a high elevation angle, providing improved satellite navigation in areas of Japan that challenge traditional GNSS satellite positioning capabilities, such as central city areas. While intended primarily for users in Japan, the orbit design offers significant advantages to neighbouring East Asia countries and Australia. Figure 1 shows the footprint of QZSS satellite. The first QZSS satellite was launched on 11 September 2010.

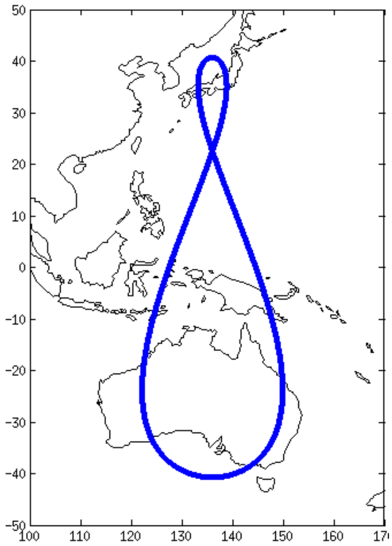

FIGURE 1: GROUND TRACK OF QZS-1 ORBIT.

One unique feature of QZSS is that in addition to the standard GNSS navigation signals used for Position, Navigation and Timing (PNT), QZSS also has the capability of sending short emergency messages. The messages can be received directly from the satellite by a GNSS/GPS receiver embedded in mobile phone or in in-car navigation systems. An application software or app would interpret and display the information. Given that mobile phones use and in-car navigation systems are becoming near-universal, with almost everyone involved, the potential coverage and reach of warnings sent to these personal devices is likely to be much greater than the current approaches could achieve.

Another feature of the QZSS provision for alert messaging is that in addition to the wide area coverage provided by the satellite system, the receivers also provide, through their embedded GNSS/GPS capabilities, precise position information. In this way, alert messages can be sent to a specific area depending on the type and content of the disaster information, and only those receivers within the specific area will be activated. Knowing the area of the possible disaster location, the intended users could then be warned, while those outside the disaster area would not be alerted.

The satellite based system offers a number of advantages for real-time disaster alerts over current approaches to sending warnings via personal devices. A disadvantage is that at present the signal is not generally received indoors due to the low signal strength (GPS signals do not typically pass through solid objects). Advantages include:

1) GNSS with location-based information can be used during an emergency. This provides the ability to indicate high priority and targeted messages for specific areas and groups;

2) The service can cover a wide area simultaneously – e.g. the whole of Australia – because of its wide area broadcast footprint, and within the broadcast area, there is no limit to the number of people who can be warned simultaneously;

3) The messages can still be received even when terrestrial communications infrastructure is damaged or not available. This allows for redundancy; and

4) As the system is independent of mobile phone coverage it would reach people wherever they are, regardless of the existence of mobile phone coverage.

QZSS RED RESCUE PROJECT

The Red Rescue Project (for real-time disaster response using small-capacity data packets from the ubiquitous environment) was funded by the Japanese Ministry of Education, Culture, Sports, Science and Technology. It is a real-time disaster response solution, which sends emergency messages through the L1-SAIF signal from QZSS satellites to government, relevant authorities as well as the general public through smartphone equipped with GNSS chips during times of emergencies. The project commenced in 2009 as a three-year project and has recently run trials in Japan, Thailand and Malaysia for tsunami warnings. The core members of the project consist of system design specialists from Graduate School of System Design and Management in Keio University, Asia Air Survey on panoramic navigation, Pasco on disaster management and NTTDATA on disaster information systems. NTTDATA Corporation (a Japanese system integration and data company) has developed several governmental IT infrastructures for disaster management (Buist et al. 2013; Iwaizumi and Kohtake 2013; Iwaizumi et al. 2014).

The emergency message is sent to the user from the QZSS satellite using the L1-SAIF (Submetre-class Augmentation with Integrity Function) signal. This signal is broadcasted on the L1 frequency band (1575.42 MHz). The advantage of the L1 signal is that it is the most widely used signal by the mass-market GNSS/GPS receivers. All GNSS/GPS receivers are able to track and acquire this signal for positioning. The L1-SAIF signal, as the name implies, is designed to transmit precise navigation messages and integrity data with the intention to augment positioning accuracy to decimetre-level and transmit integrity information for mission critical applications. The L1-SAIF signal has a data rate of 250 bits per second (bps) and the 212 bits data area in between the navigation message could be used to deliver emergency messages. At 212 bits, each emergency message is very short, but a number of messages can be combined to produce a longer message. Figure 2 shows a schematic diagram of the QZSS alert messaging transmission system. The system consists of three parts: the Transmission, Satellite and User Segments (Iwaizumi et al. 2014).

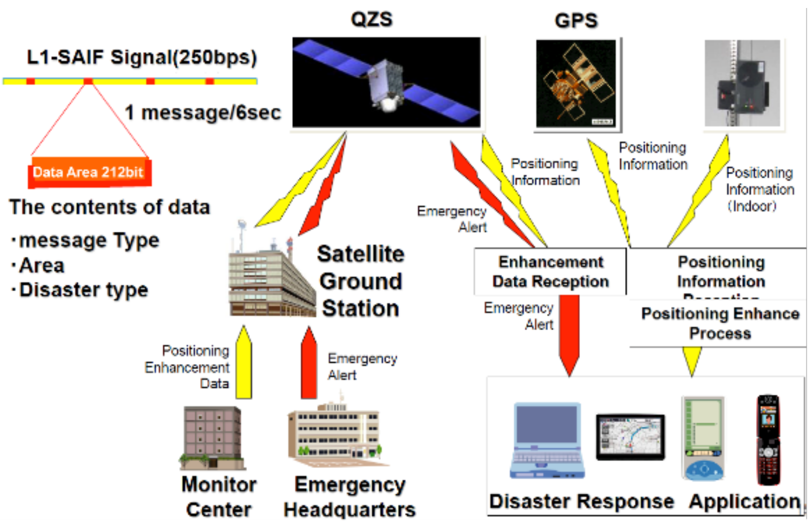

FIGURE 2: QZSS ALERT MESSAGING TRANSMISSION SYSTEM.

The Transmission Segment consists of the Disaster Management Centre, the Monitor Centre, and the Satellite Ground Control Station. The transmission segment transmits disaster messages to the satellite segment in the following order: First, the Disaster Management Centre gathers the relevant information. Second, the Disaster Management Centre converts the information into an emergency message for transmission by QZSS. The Disaster Management Centre decides the distribution schedule for providing the information and transmits the emergency message to the Satellite Ground Control Station. Third, the Ground Control Station collects the Monitor Centre's results and generates (enhanced) navigation messages for broadcast on the L1-SAIF signal, which will be used by the user to derive precise position information The Ground Control Station uplinks both the navigation message and the emergency message to the QZSS satellites.

The *Satellite Segment* consists of both the QZSS and other GNSS satellites like GPS and QZSS. The L1-SAIF signal with the enhanced navigation message and the superimposed emergency message are transmitted to the users.

The *User Segment* (or receiving segment) receives the L1-SAIF signal and position information from QZSS as well as position information from other GNSS satellites on their GNSS receivers. The enhanced navigation message is used to provide an accurate position of the users. The L1-SAIF signal contains the emergency messages that are decoded by the users' device in order to acquire the disaster information. Once these messages are received, it triggers the app, which then provides guidance to users to take appropriate risk aversive actions, for example an evacuation route for the user at a specific location and other relevant information. Here we assume the use of smartphones with GNSS/GPS capability and other geospatial tools such as maps for evacuation guidance.

For the QZSS alert messaging system, two receiving modes are being developed: One is the wide-area broadcast mode, which can send emergency messages simultaneously over a large area; the other is the area-selected broadcast mode, which can send messages to a specified area (Iwaizumi et al. 2014). The area-selected mode delivers several emergency messages to provide disaster information for all areas depending on the type and content of the disaster information. Therefore, the user segment of this system provides the disaster information to the users by selecting the information of the area corresponding to the location of the user from the received emergency messages (Iwaizumi et al. 2014).

CONCLUSION

Australia's vast landmass presents a significant operational and practical challenge for the government to provide an emergency warning mechanism that can disseminate time critical safety information 'wherever to whomever it is necessary' during events of disaster. It would require massive investment in establishing the network and underlying infrastructure, which may not be economically viable. The provision of safety information through a GNSS-based system is feasible as it combines the strengths of both mobile telephone-based service and satellite communications, while it overcomes their weaknesses. The key advantage of satellite based communication is its high resilience to communication network overload and failure of ground systems and network infrastructure during a disaster. It also provides scalability of coverage for mass public warning and its operation is potentially more cost effective compared to other warning systems.

In spite of pervasive presence of GNSS based technologies, application of GNSS in emergency warning and alerting in Australia is still in its infancy. To a large extent, research into the viability and implications of GNSS technology within the national emergency warning apparatus is scarcely limited. This boils down to the partial immaturity of the satellite-based warning technology which soon will change with the advent of new GNSS satellites and augmentation systems. The challenge remains in thinking beyond the immediate barriers, identifying technical and non-technical requirements and understanding operational context in which the technology can be used as 'added value' to existing warning systems.

The Japanese satellite system or QZSS has the capabilities of delivering warning messages to people's personal mobile devices. The devices could be tailored to receive location-based emergency warnings at a specific point in time and within a defined geographical area. It has the potential to therefore address some of the shortcomings of the traditional warning services. A GNSS-based warning system is not likely to replace existing systems, but it can augment and strengthen them by providing an independent means of sending location-based warnings. There is a constant need to build effective warning systems that evolve over time by embracing newer technologies. As other GNSS systems such as Galileo and BeiDou continue to mature and be equipped with emergency alert capability, Australia will have an opportunity, by virtue of the geographical location of the continent relative to all of these global navigation satellite systems, to be an excellent test ground for GNSS-based emergency services and be first to innovate with new tools and products.

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