Future Architectures for Public Warning Systems

Michelle Wetterwald, Christian Bonnet, Daniel Camara
EURECOM, Sophia Antipolis, France
firstname.lastname@eurecom.fr

Sebastien Grazzini
Eutelsat, Paris, France
sgrazzini@eutelsat.fr

Jérome Fenwick
Groupe SYNOX, BALMA, France
jfenwick@groupe-synox.com

Xavier Ladjointe, Jean-Louis Fondere
Thales Alenia Space, Cannes, France
[firststname.lastname]@thalesaleniaspace.com

Abstract— **Natural disasters have often made the headlines in the past years. As a consequence, many actions have been started by the public authorities to reduce the damages and the number of casualties. In that objective, the French project RATCOM aims at developing an alert system in case of coastal tsunami. Its downstream components will propose reliable and efficient communication systems to relay the alert. In parallel to the integration of the existing technologies in the project demonstrator, a survey analysis has been performed to identify the communications technologies and networks which are in preparation but not yet operational, and which will increase the efficiency and quantity of individuals reachable by the future population alert networks. Each of these technologies is not sufficient by itself, but their combination will improve drastically the efficiency of the alerting global system.**

Keywords-tsunamis; alerting; public warning system; broadcasting networks.

I. INTRODUCTION

Natural disasters and the thousand of casualties they usually cause raise a major concern at public authorities' level. A milestone event in this field was the Indian Ocean tsunami that happened in December 2004. This event raised the question of how to improve the protection of the population and prevent so many deaths. In fact, the main answer relies in the fast distribution of the information: information about the best behaviour to adopt in case of a disaster, and more importantly, information about the imminent arrival of a disaster.

The South East part of the French Mediterranean coast has been identified by the experts as the potential location for small-sized tsunamis. These could be caused by major landslides in the underwater area, few kilometres away from the coast. One of these tsunamis occurred in 1979 in front of Nice and made several million euros' worth of damage. As a prevention tool, the RATCOM project [1], started in 2009, aims at developing an alerting system towards the public safety professionals on one hand and the citizens on the other hand. The project is organized around two major components: the upstream component and the downstream component. The upstream component is responsible to monitor the events occurring at the sea and report the risk level to a control centre. The control centre then makes the decision to generate an alert and forwards it to the downstream component which is responsible to disseminate the warning within the shortest time frame possible. The best-known method to broadcast this type of information is by triggering the operation of alert sirens. However, more modern technologies exist nowadays that can help reaching a larger quantity of people. The RATCOM downstream component aims at identifying and setup a network linking these technologies into a single framework. Some of these technologies are currently operational and will be included in the final project demonstration. An additional survey paper activity has been conducted to identify other technologies that are not ready at this point in time, but in the future may become relevant to our warning system. The suitability of these techniques to be included in the project global downstream component has been analyzed. The final objective of this study is to draw up an inventory of the technologies and networks that are not yet operational, but are relevant in the context of a future public warning system.

This paper is organized as follows. The second section considers systems of communication close to their deployment phase, with a probable delay of less than three years, and having the ability to be connected to a warning system in the medium term. Derived from digital broadcast systems, the DVB-SH (Digital Video Broadcasting for Handheld Satellite) uses the coverage capabilities of satellite networks. Satellites offer also the possibility to provide redundant connections and improve the strength of the whole system. WiMAX (Worldwide Interoperability for Microwave Access) is a new technology which can provide service to larger areas than Wi-Fi (or IEEE 802.11), whose concept is somewhat similar. The new capabilities and possibilities of connecting current and upcoming mobile cellular networks are discussed. In the third part are presented prospective technologies that are currently being defined and standardized, but which will be effectively operational in a period longer than five years. They are essentially the Public Warning System integrated in mobile phone networks, broadcast technology in these global networks and Vehicular Networks. Finally, we draw our conclusion to this study in the last section.

II. Using State of the Art Technologies

In this chapter some technologies that are still in their early phase of deployment or will be in the next two or three years are described. The section focuses only on the technologies which seem to be relevant for the broadcast of warning messages to the public. These technologies (satellite systems, WiMAX and CBS / LTE) have the ability to quickly reach a greater proportion of the population, including people on the move. They constitute a part of the population who could not be informed by more traditional methods such as the television. For each of the technologies is presented a fast description then an analysis of why it is relevant for the public warning and for the interconnection with our alert distribution system is performed.

A. Satellite systems

Satellite systems can be used in two different manners: first manner consists in broadcasting directly information to handheld devices. This is the DVB-SH technology. The second manner consists in strengthening the whole system by operating connections redundantly with terrestrial links which may be at risk.

The DVB-SH is a standard derived from the DVB-H standard to distribute broadcast video, audio and data to mobile devices such as mobile phones. Mobile TV is definitely set to become the next major media market of tomorrow. The publication in November 2004 of the DVB-H standard, seen by analysts as a possible solution for providing mobile television, was the starting point of a series of work on this new mode of television programs consumption. While DVB-H is designed primarily for use in the UHF terrestrial broadcasting only, the DVB-SH tries to exploit the S band, where there are opportunities for Mobile Satellite Services (MSS). Thus, this standard, created specifically for distributing content via satellite in mobility situation, makes a major innovation in the telecommunications world by satellite: it enables the addition of a network of terrestrial repeaters, called CGC (Complementary Ground Component) to complement the satellite coverage.

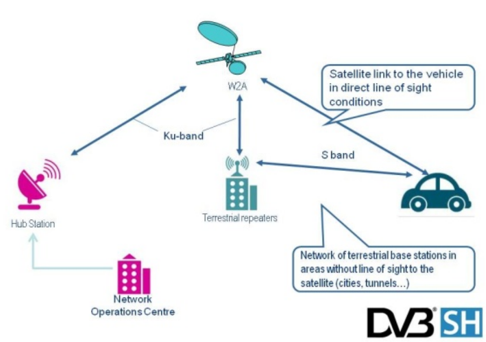

Figure 1. DVB-SH broadcast network architecture

One of the major problems in terms of warning systems is to quickly reach a large number of people, whether they are in a mobility situation or not and, if possible, at a reduced cost. The DVB-SH broadcast network meets these criteria through the variety of devices able to receive the signal (mobile phones, vehicular terminals, etc.) as well as through the possibility of sharing the same flow between a large number of people via the satellite. Accordingly, it becomes quite interesting to interface our alerting network and demonstrate the potential offered by hybrid broadcast architecture. Three warning systems are considered in the framework of this study: first, the broadcast of video / audio warning on TV / Radio mobile satellite devices, second, the broadcast of a detailed report about the alert to the TV / Radio mobile satellite devices for interested people and finally the triggering via the satellite of fully autonomous and easily installable alerting peripherals (e.g. on beaches).

The first two cases are closely related; they actually consist in stopping the Radio / TV programs to replace them with the tsunami warning. The procedure is very similar to what exists for the abduction alerts on TV but would be applied to mobile TV. The major innovation lies in the fact that, simultaneously with the program stop, an alert is sent as data traffic and the user can view this bulletin with the same device. This bulletin can be updated to indicate, for example, the end of the alert. The third case is the satellite triggering of alerting fully autonomous and of easy maintenance devices. Indeed, with DVB-SH, it is possible to receive the signal with a small omnidirectional antenna and one can imagine devices (sirens, billboards...) independent of terrestrial communications networks that can be triggered remotely via a satellite signal. This new type of installation would benefit from reduced costs because no wired connection would have to be planned and its assembly and disassembly in urban areas would be simplified. The positioning of the devices would be defined only by taking into account the risk factor and not the availability of a terrestrial network. This freedom enables an improvement of the efficiency of the devices. Moreover, such a warning system would benefit from a complete independence from terrestrial communications networks which can be damaged by natural disasters.

As the second manner to use this technology, the Ku band satellite connection systems or VSAT (Very Small Aperture Terminal) serve redundant network nodes or quickly connect fixed subscribers or isolated alert networks. These systems make use of satellite dishes with a diameter less than 3 meters and terminals (or modem) that allow bidirectional communications. They provide the following intrinsic advantages: a minimum ground infrastructure, an immediate area covering several alert networks from one or several countries at the same time and a simple and rapid deployment. With a satellite link, it is possible to connect either a comprehensive warning system, in which case we preferably connect via the satellite the control node responsible for the warning broadcast on this network, or a specific node of the warning network, such as a siren, a VMS (Variable-Message Sign) or any other equipment that would require redundancy or that just needs to be connected to the network. Such a node can be a warning system sharing the same satellite link or a single important subscriber connected to the satellite endpoint.

The choice of the satellite as the transmission system component on the downstream component is justified by the desire, first, to avoid congestion or interruption of the terrestrial networks which can become harmful in case of a tsunami, and, secondly, to be able to quickly connect a warning system or a single isolated but important subscriber. In this case, the satellite will thus be used for the redundancy of critical network nodes (connected to a warning system or a subscriber of critical importance in the decision process), to connect the system to an existing warning network, or just to quickly connect a siren or isolated warning sign.

B. WiMAX networks

The WiMAX technology is standardized by the IEEE (Institute of Electrical and Electronics Engineers) under IEEE 802.16 and addresses several objectives: fixed mobile convergence, higher flow rates, compliance with quality of service constraints, etc. Compared with the architecture of conventional cellular systems such as EDGE (Enhanced Data rates for GSM Evolution) or UMTS (Universal Mobile Telecommunications System), the architecture of a WiMAX network is based on components that are intended to remain close to the Internet standards, as pictured in Figure 2.

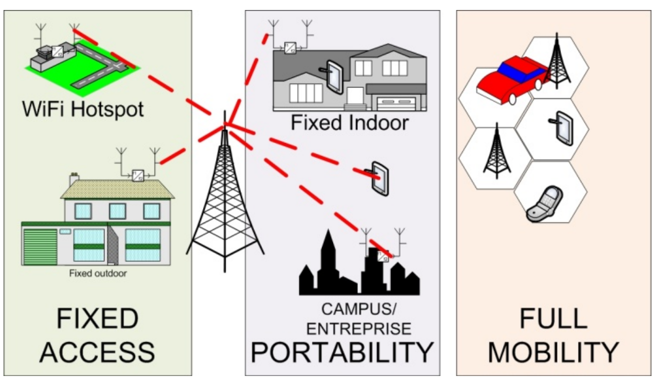

Figure 2. WiMAX Mobile Environment

The standard provisions various types of communications. For point to point transmission, it aims to link transmission points separated by a few dozens kilometres for the multiplexing of IP traffic with the support of differentiation and service guarantee. This type of application is similar to radio-relay transmission while it provides the spectral efficiency and intelligent management of IP traffic. It comes in support of network deployments that would not be economically viable if done in wire line technologies. The systems for point to multipoint transmissions without mobility provide the Internet IP traffic from a connection point of the wired network to a group of buildings or homes through the radio interface. User equipments within the buildings are basically PCs that receive a service equivalent to an ADSL (Asymmetric Digital Subscriber Line) access. This standard thus targets to address the so-called "white areas" in which a typical deployment of ADSL based on a wired infrastructure would be too expensive to setup. In the point to multipoint transmission with mobility version, the WiMAX radio signal terminates directly on the terminal of the final user. This system can accommodate the wireless ADSL users, but also PC terminals (usually laptops) for a mobile Internet access.

The WiMAX offers a continuous connection for the transfer of IP packets. Accordingly, it can support any type of warning system based on data transmission. An interesting feature is its ability to support a Broadcast / Multicast mode called MCBCS (Multicast and Broadcast Services). In the same perspective as the 3GPP MBMS (Multimedia Broadcast/Multicast Service) technology, the WiMAX plans to provide broadcast services in geographical areas managed by the system. In a Multi-BS (MBS) system, several BSs located in the same geographical area, called MBS_ZONE, can transmit the same broadcast / multicast messages simultaneously on a single radio channel. It should be noted that a BS may belong to several MBS_ZONEs. A mobile terminal that registers for an MBS service can receive information from all the BSs of the MBS_ZONE without having to register with a specific BS of the area. In addition, it can receive the MBS signals from several BSs simultaneously for an improved reception quality. This broadcast service enables the usage of the WiMAX technology as a potential support for public alerting messages.

C. 3G and LTE cellular networks

The CBS technology allows sending through the GSM (Global System for Mobile communications) network one or more small messages to all the mobile phones located within a specific area covered by one or several broadcasting Base Transceiver Stations (BTS). The information can be broadcast over several channels, possibly one per language used for the broadcast message. The user must first select the channels to which he wants to subscribe. This technology allows broadcasting a mass message without network performance problems. However, setting the terminal requires an adequate communication plan to the population associated with a technical support team able to assume the setup on heterogeneous consumer devices, in the best case when they are compatible, since the CBS feature has been removed from many terminals in favour of more vending features. In any case, this technology has been selected by the standards to carry the messages of the Public Warning System (PWS), as will be explained in Section IIIB.

The LTE is a project led by the 3GPP standards body for the publication of the technical standards of the future fourth generation mobile telephony. It enables data transfer at very high speed, with a longer range, a higher number of calls per cell and lower latency. For the operators, the LTE involves changing the core network and the radio transmitting stations. New compliant mobile terminals must also be developed. Considering the limitations of the current solutions in terms of deployment and performance, the LTE generation allows, with continuous connections, to be able to alert all the terminals almost simultaneously in a specific area, using dedicated short messages. The question of the

 ISBN: 978-1-61208-133-5

penetration rate of terminals with 4G subscriptions is an important element in the relevance of the solution for an alerting system. The number of users accessing the 3G services has been increasing sharply since the latest developments of devices such as the iPhone, Android, BlackBerry or Windows phones and the commercialization of unlimited flat rate packages. The population currently reached with 3G mobile subscriptions will probably evolve to the upcoming 4G systems rapidly due to the effect of device renewal.

III. USING ENHANCED UPCOMING TECHNOLOGIES

This analysis has been completed a prospective study of networks currently in the phase of definition and standardization, and which are of interest for the future population warning systems. In a first step are introduced the future vehicular networks, whose deployment is planned for the second half of the decade. The advantage of such networks is that, in addition to being able to reach the drivers, they operate in a cooperative mode. As a result, these networks are resilient to the possible destruction of the communications infrastructure. In a second step are presented the future developments of broadcast technology for mobile cellular networks (CBS and MBMS) and their integration in terms of standards into warning systems. The presented techniques were initially developed for a tsunami warning network in Japan and subsequently generalized to a more comprehensive Public Warning System (PWS). The CBS technology is used here again. This standard is part of the GSM, UMTS-3G and future LTE operational standards. Its advantage is that it allows the global broadcast of short messages (SMS-type) and thus overcomes the limitations due to network overload when targeting a large population. It also contains features that allow to "wake up" idle mobile phones and select the geographical coverage for the broadcast, making it particularly suitable for a connection to a global alerting system. However, it is somehow questioned since its deployment differs according to operators and countries.

A. *Vehicular Communications*

This new mode of communication from vehicle to vehicle is based on the new standards for Intelligent Transport Systems (ITS). Here we introduce the ETSI TS 102 636-3 standard [3], which is under development for ITS and GeoNetworking. The most interesting feature of this standard is the definition of a set of methods to distribute, and route messages in specific geographical areas. For example, in the advent of an emergency situation, the message is sent to the vehicles concerned by this emergency in the destination area. It would, in this way, reach only the concerned vehicles, not disturbing drivers outside the target region. The communication among entities may be between Vehicle to Vehicle (V2V), Infrastructure to Vehicle (I2V), Vehicle to Infrastructure (V2I), Infrastructure to Infrastructure (I2I) and all the concatenation of these basic scenarios. In the GeoBroadcast communications, the same message is forwarded to all the ITS stations in the defined area, as shown in Figure 3.

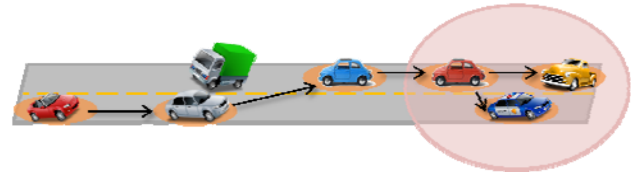

Figure 3. GeoBroadcast type of V2V communication

Some additional research has been conducted on the propagation of public safety warning messages using GeoBroadcast and Delay Tolerant Networks (DTN) techniques [4]. The main purpose of such work is to increase the coverage of the existing network to reach more people in a faster way. People in vehicles usually do not watch TV and may not be listening to the radio. In the future, cars will be equipped with devices helping to increase road safety that will be constantly active to provide the drivers with the information about the road conditions. The work described in [4] proposes that the vehicles act as virtual roadside units (vRSUs) and help on the spreading of the warning messages in case of an emergency. The intention is to decrease the “last mile” information access problem. The evaluations show that the mechanism is robust and efficient even over different disaster scenarios. Thus the use of vRSUs is an effective way to distribute warning messages to vehicles in a region.

B. *Cellular Communications*

Some new technologies and actions have recently been introduced in the 3GPP standardization for cellular systems which are relevant to public warning systems. The first part describes the two candidate technologies that can comply with the broadcasting requirements in case of a major event. Both technologies offer a global broadcast capability, which means that a message is sent only once and received at once by all the target terminals. The CBS has been part of the standards since the early GSM, even if not always deployed by operators, so it is technically compliant with all the existing enabled mobiles in the market. It permits to broadcast unacknowledged messages to all the receivers within some particular defined geographical areas known as cell broadcast areas. A CBS page is comprised of 93 characters and up to fifteen pages may be concatenated to form a message. Messages are broadcast cyclically at a frequency and for a duration agreed with the information provider. Mobiles can selectively display only the messages chosen by the Mobile user. In addition, a message that has been formerly successfully received is not displayed a second time. The second technology, the MBMS is an enhancement of the 3G systems which provides a point-to-multipoint capability for Broadcast and Multicast Services [5], allowing resources to be shared in the network. Since it is more recent, it has more constraints, but it also brings the capability to disseminate multimedia information (video, audio, pictures) in addition to the text messages. As the LTE is enhancing the capacity and efficiency of the cellular networks, the MBMS is evolving and adapted to benefit from these improvements.

 ISBN: 978-1-61208-133-5

Some actions have recently been taken in the 3GPP standardization groups to implement public notification warnings. Japan launched the first step with the ETWS (Earthquake and Tsunami Warning System), delivering Warning Notifications specific to Earthquake and Tsunami simultaneously to many mobile users located in Warning Notification Areas who should evacuate from an approaching Earthquake or Tsunami. An ETWS warning may be required in a very urgent timeframe (down to 4 seconds for the primary notification or initial alert) and is characterized by the capability to provide a very short notification period. A secondary notification can be delivered afterwards, carrying a larger amount of information such as text, audio or graphics to instruct what to do and where to get help, or a valid route from present position to an evacuation site. In a further release, this system has been generalized into the PWS (Public Warning System) [6] which targets worldwide objective, including the CMAS (Commercial Mobile Alert System) in the USA or the support of European requirements.

Some early technical studies considered both some variants of the CBS and MBMS broadcasting technologies for the PWS. Since the CBS is more mature from a standardization point of view, it is the solution that has been adopted. However, because the MBMS will be part of the future LTE systems and can convey larger amount of data, it is still an interesting candidate to support future alerting systems. One of its drawbacks, though, is that it lacks the geo-localization feature of the CBS system. An enhanced system has been proposed in [7] to extend the MBMS by developing cross-layer cooperation where the networking protocol and the cellular system collaborate to improve the efficiency of the geographical radio coverage. It enables a more precise and efficient delivery of the broadcast information, taking advantage of the comprehensive knowledge of the infrastructure and network topology by the mobile operator. Only the base stations located in the target zone participate in the distribution of the message, as shown in Figure 4.

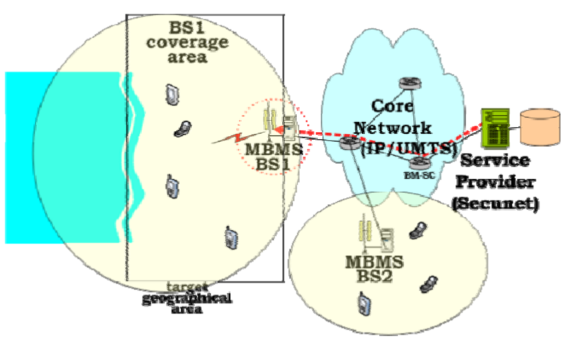

Figure 4. RATCOM Application Scenario with MBMS

Users located outside of their coverage do not have to filter out the un-necessary information, increasing the efficiency of the system.

IV. CONCLUSION

In this paper were presented several technologies to be deployed in the medium to long term. Some are completely new (WiMAX, DVB-SH or vehicular networks), others are the future evolution of existing communication networks (Ku band satellite networks, cellular mobile telephony).

Each of these technologies offers specific characteristics and particular interest for the broadcast of warning messages. The DVB-SH satellite broadcast network reaches a large number of users by stopping the radio and TV programs received on fixed or mobile devices, and replace them by the alert bulletin. It does not require the availability of a terrestrial network and therefore does not run the risk of being damaged by a natural disaster. The Ku band satellite network connections can also serve as redundancy to the existing network nodes in the case of failure due to a major problem, enabling the safe operation of critical network nodes or connecting a subnet that was isolated. The WiMAX technology, which is in its early deployment, is based on features close to the Internet. It offers the ability to support a Broadcast / Multicast mode and thus to provide broadcast services in geographical areas that cannot be easily connected with a legacy wired network. The CBS is based on existing cellular networks and deployable at medium term. In countries like Japan, CBS is used for mass message broadcast, even if its setting is somehow problematic. It will be advantageously replaced by the LTE that will achieve permanent connections towards all the terminals with a 4G subscription. Vehicular Networks will allow the broadcast of information from car to car in a specific geographical area. The advantage of this technology lies in the fact that it requires no infrastructure and can reach people while they are travelling. The future evolution of cellular networks is still being defined. With CBS and MBMS technologies, it is possible to broadcast a single message to many users, so at a lower cost from the point of view of radio resources, while capitalizing on a network and a massive penetration rate. The PWS systems take advantage of these features to provide a comprehensive model of early warning network. A proposal to extend the geographical feature of MBMS and increase its efficiency has also been introduced.

All these technologies can reach in a very limited time a significant number of users and are particularly relevant to a potential connection to the downstream component of a future public warning system. The availability of these technologies in the near or longer future depends mainly on their commercial success, according to business models and the return on investment expected from their deployment. Nevertheless, it is the administrative authorities who ultimately may decide on the development and promote the implementation of the functionalities needed to connect them to a global safety system.

 ISBN: 978-1-61208-133-5

REFERENCES

[1] RATCOM project http://ratcom.org, last accessed on 15.01 2011.

[2] ETSI TS 102 585 V1.1.2 : "System Specifications for Satellite services to Handheld devices (SH) below 3 GHz"

[3] ETSI TS 102 636-3: "Intelligent Transportation System (ITS); Vehicular Communications; GeoNetworking; Part 3: Network architecture".

[4] D. Camara, C. Bonnet, and F. Filali, Propagation of Public Safety Warning Messages, IEEE WCNC 2010, pp 1-6, Sydney, Australia

[5] 3GPP TS 23.246, “MBMS; ARCHITECTURE AND FUNCTIONAL DESCRIPTION”, V8.3.0 (03-2009)

[6] 3GPP TR 22.268; “Public Warning System (PWS) Requirements”; V9.2.1 (06-2009)

[7] M. Wetterwald, A case for using MBMS in geographical networking, ITST 2009, pp 309-313, October 2009, Lille, France.