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Integrating Future Communication Technologies for the Downstream Component of Public Warning Systems

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***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 aimed at developing an alert system in case of coastal tsunami due to underwater landslides. Its downstream component combines 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 improves drastically the efficiency of the alerting global system. This paper presents the RATCOM architecture, focusing mainly on its downstream component. For each candidate technology, it analyses how it can satisfy the requirements and improve the efficiency of the public alerting system. The final demonstration of the project is also described, as it assesses the feasibility of the system and how the overall impact on the alert dissemination is improved by the design of this new architecture.**

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

I. INTRODUCTION

Natural disasters and the thousands 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 and ended in June 2011, aimed at developing and confirming the feasibility of an evolved alerting system towards the public safety professionals on one hand and the citizens on the other hand. The project has been 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. Mainly the downstream component is addressed by this paper.

The best-known method to broadcast alert messages 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 combining these technologies into a single framework. Some of these technologies are currently operational and have been included in the final project demonstration. To complete this setup, an additional survey paper activity has been conducted to identify other technologies that are not ready to be included in the demonstrator, but may become relevant to this warning system in the future. Their suitability to be included in the project downstream component has been analysed. The final objective of this study, which is reported in this paper, is to draw up an inventory of the technologies and networks that are not yet operational, but are relevant to be used in the context of a future public warning system. Understanding what these technologies can bring and how they can be included in the system architecture that combines them as much as possible is an important step for the definition of future systems. This study has provided the core of [2], which is extended here to provide more details on the RATCOM objective and architecture, the prospective technologies, and a presentation of the feasibility demonstration that was performed at the end of the project.

The rest of the paper is organized as follows. Section II describes the RATCOM architecture and its expected impact on the alert dissemination. The third 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 Satellite Handheld) 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. The Alert System Architecture

Following the tsunami that occurred in December 2004 in the Indian Ocean, the French government ordered a risk analysis covering the French coast which highlighted that the south-eastern part ran a small risk, possibly triggered by large underwater landslides. Willing to develop activity and competence in this area, the government decided to launch a project aiming at the feasibility study for an end-to-end system addressing that challenge, i.e., short range local tsunamis, somehow different from the earthquake and tsunami monitoring systems deployed in the Pacific Ocean for example, which address long range threats.

Providing an end-to-end architecture, from seismic or pressure sensors to public warning, the RATCOM project has been organized according to two main components. The upstream component monitors the threat, while the downstream component disseminates the alert. Both are linked through a terrestrial or Alert Elaboration Centre, also called Control Centre. These components are pictured in Figure 1. The upward component has the objective to deploy sensors in the sea or on the coastal ground, and to provide an enhanced automated aggregation and analysis of their outputs, in order to help making the alert decision, while eliminating the risk of false alarm.

This processing is performed in the Control Centre and, when relevant, launches the alert towards two different groups: firstly the local and administrative authorities through a highly secured specialized network, secondly the concerned population (mentioned as citizens in the figure), through a public warning network organized around a centralized and intranet-like network called SecuNet. Even though it would have been interesting to describe the whole chain in details, this paper targets the study that was performed to enhance the public warning system with modern communication technologies, in order to extend the impact of the alert on the largest number of people possible and comply with a requirement of an alert dispatched in a few seconds timeframe.

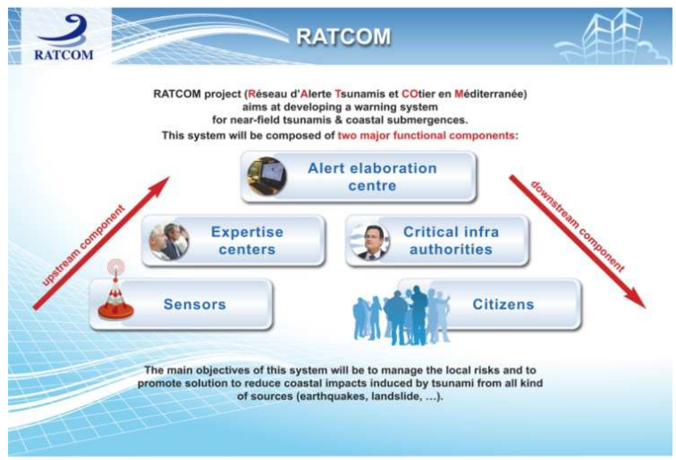

Figure 1. RATCOM project components

When studying existing alerting systems, including in France, a varied set of mechanisms can be found, addressing diverse types of population. Moreover, they are usually not correlated, lacking thus the benefits of an integrated system. Finally, they often rely on old technologies like sirens or direct voice communications, obviously not benefiting from the more recent technologies brought by satellites, mobile cellular networks or, in the future, vehicular communications. The impact of the integrated system highly depends on the combination of technologies used for the alerting system. It varies also according to the density and location of the population in the target area. The same beach in August or in November would not host the same number of people. It's even more difficult to evaluate if we include the first ten meters of coast where people would or would not be swimming. Some parts of the coast offer beaches; others are sided by roads, where people are driving their cars, or railways with frequent trains. The objective and novelty of the RATCOM downstream component is thus to federate a large amount of communication and warning system in order to become more adaptive to the conditions under which the alert has to be broadcasted. Next section will analyse how the state of the art technologies are suited to be federated under the SecuNet umbrella, while Section IV will evaluate the relevance of future upcoming technologies.

III. Using State of the Art Technologies

In this section, 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 that seem to be relevant for the broadcast of warning messages to the public. These technologies (satellite systems, WiMAX and cellular systems) 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 [3] is a standard derived from the DVB-H (Digital Video Broadcast-Handheld) standard to distribute broadcast video, audio and data to mobile devices such as mobile phones. Mobile TV (television) 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, as shown in Figure 2, where there are opportunities for Mobile Satellite Services (MSS). Thus, this standard, created specifically for distributing content in mobility situation, makes a major innovation in the satellite telecommunications world: it enables the addition of a network of terrestrial repeaters, called CGC (Complementary Ground Component) to complement the satellite coverage. This is displayed with the terrestrial repeater in the middle of the figure.

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).

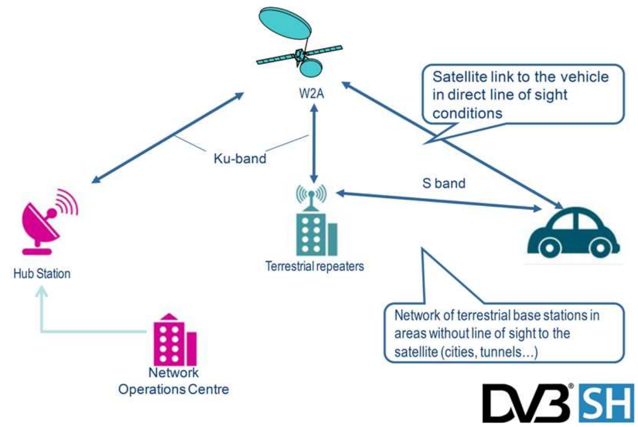

Figure 2. DVB-SH broadcast network architecture

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, etc.) 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 the satellite technology, the Ku band connection systems or VSAT (Very Small Aperture Terminal) serve redundant network nodes or quickly connect fixed subscribers or isolated alert networks. This is illustrated in Figure 3. 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.

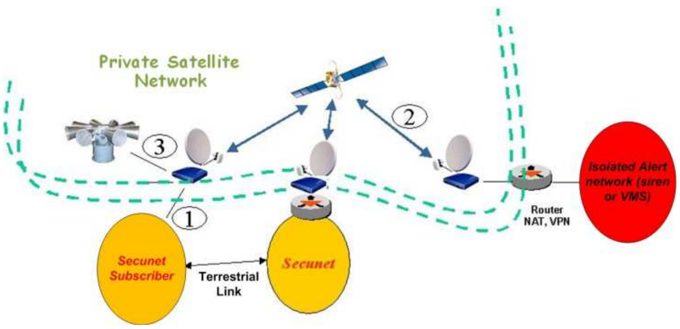

Figure 3. Ku Band Satellite Connection Systems

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 for [Global System for Mobile communications] 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 4.

The standard provisions various types of communications. For point to point transmission, it aims to link transmission points separated by a few dozen 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 traffic from a connection point of the wired network to a group of buildings or homes through the radio interface. User devices within the buildings are basically PCs (Personal Computers) 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.

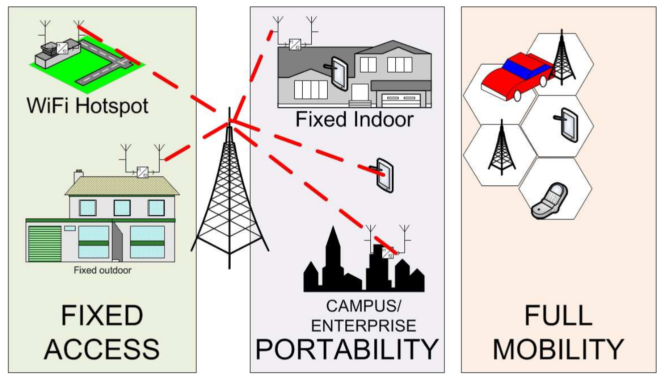

Figure 4. WiMAX Mobile Environment

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 (Base Stations) 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 (Cell Broadcast Service) technology allows sending through the GSM 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), as pictured in Figure 5. 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 disseminating 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.

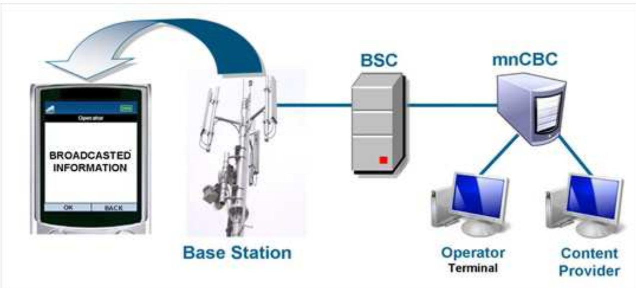

Figure 5. Using 3G and LTE (4G) Cellular Networks

The LTE (Long Term Evolution) 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 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.

IV. USING ENHANCED UPCOMING TECHNOLOGIES

This analysis has been completed with 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, which 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 [4], which specifies the GeoNetworking operation in the ITS environment. 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. Vehicular communication is becoming a huge research area and one of the most crucial aspects into this new research field is the data forwarding problem. Data forwarding is related to how to transmit a packet from one node to another, trying to reach the destination. Usually, in the context of vehicular networks, nodes forward data through geocast, where the position of the nodes defines the way the data will be transferred. There are basically three types of data forwarding schemes: geographical unicast, geographical broadcast and topologically scoped broadcast. Figure 6 (a) shows an example of geographical unicast, where multi-hop data transfer is used to connect the origin and the destination. Only one copy of the message is present at each time in the network. In geographical broadcast, Figure 6 (b), the message is distributed by unicast until a delimited region, where the nodes rebroadcast the message using flooding. In topologically scoped broadcast, Figure 6 (c), the nodes rebroadcast the messages for a predefined number of hops from the origin. Propositions and techniques, linked to data forwarding, range from the use of torrent-based communications to propagate messages, to the seamless connection to the network and the use of Delay Tolerant Networks (DTNs).

As a work on seamless connectivity, we can highlight BATMAN [5], a distance vector based routing protocol that performs channel selection between vehicular and roadside mesh. On BATMAN, each node has its own forwarding strategy to find the best next hop and reach the destination. The proposed solution shows to be more efficient than some of the most popular routing protocols for mesh and ad hoc networks.

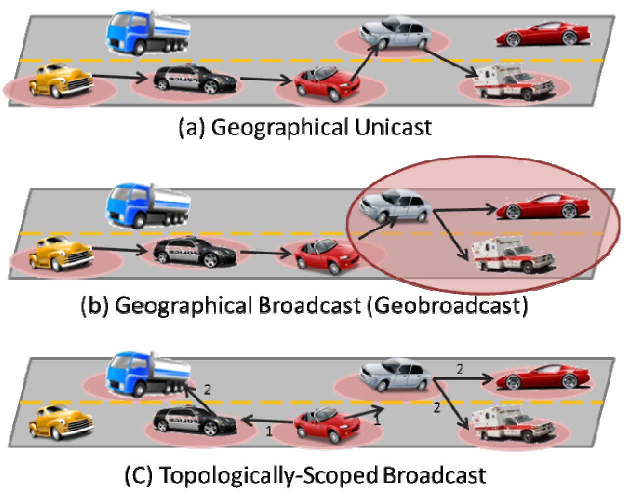

Figure 6. Types of V2V communication, (a) geographical unicast (b) Geobroadcast (c) Topologically-scoped broadcast

Some additional research has been conducted on the propagation of public safety warning messages using GeoBroadcast and Delay Tolerant Networks techniques [6]. 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 [6] 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. One of the greatest advantages of this kind of epidemic approach is its efficiency. Remembering that the target scenario for this work is the propagation of public safety warning messages, i.e., extremely important data. vRSU, even considering disaster scenarios can redistribute a warning message to all nodes into an area of 15x9 kilometres in about six to seven minutes.

B. Future Cellular Technologies

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, which has already been pointed out above (Section IIC) as a potential existing technology, 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 [7], allowing resources to be shared in the network. Figure 7 shows the network reference model with the infrastructure design of the MBMS, as defined in the 3GPP standards for cellular network. Since it is more recent than CBS, 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.

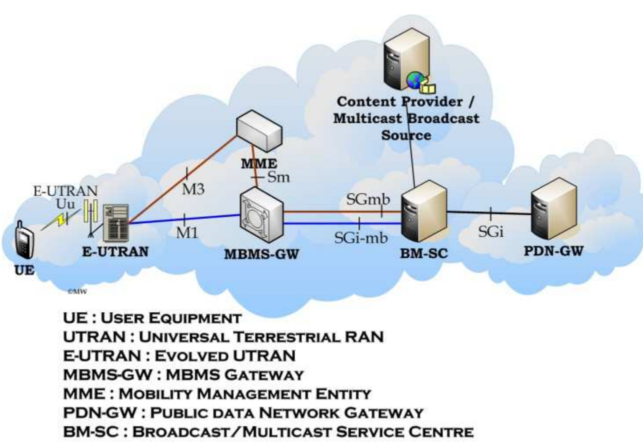

Figure 7. MBMS model in the LTE system

Public notification warnings have recently been implemented by the 3GPP standardization groups. 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, typically a distribution of cells, who should evacuate from an approaching Earthquake or Tsunami. The architecture and notification hierarchy of the ETWS is shown in Figure 8. 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) [8], which targets worldwide objective, including the CMAS (Commercial Mobile Alert System) in the USA or the support of European requirements. The minimum functionalities to be supported by warning providers are activation of the notification delivery, its update and its cancellation. This notification must be delivered without any user interaction, even if it targets a terminal in sleeping mode. On the contrary, a manual action is mandatory to suppress the message, increasing the potential impact of the method.

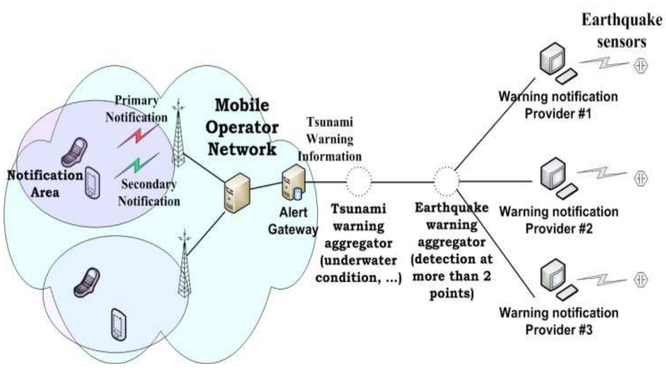

Figure 8. Global view of the Earthquake and Tsunami Warning System

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 EPS (Evolved Packet Systems), which will replace the current mobile networks, 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 [9] 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 9.

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

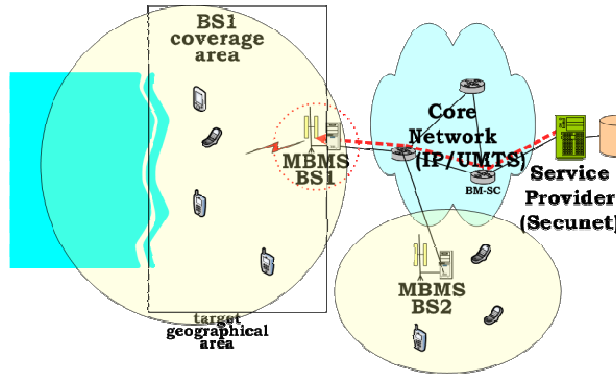

Figure 9. RATCOM Application Scenario with MBMS

C. *Software Defined Networks*

In many contexts, Public Safety Networks (PSN) rely on multi-hop transmissions to deliver the information. This makes the discussion about wireless capacity and efficient use of the spectrum as a central topic for these networks. Some works, such as Tenoc [10], try to reduce the volume of data transmitted into a wireless network using software defined networks or network coding. Network coding [11] is a technique that permits a sensible reduction into the number of data transmissions. We believe that this kind of technique will have a huge impact on the data forwarding in the future. Network coding is a packet dissemination strategy that aims to improve the throughput and increase the robustness of wireless networks. Network coding implements a store, code and forward paradigm, where each node stores the incoming packets in a temporary buffer and at each transmission time, the node sends a combination of the stored data. To successfully decode N packets a node has to collect N independent combinations of packets. Reducing the number of packet transmission to deliver data to multiple destinations is an effective strategy to increase the network throughput.

V. FEASABILITY EXPERIMENTATION

Administrative officials were invited to a system feasibility demonstration at the end of the project [12]. The experimentation featured the downstream component built according to the planned administrative hierarchy, as described below. It concluded the validation phase of the project, which targeted the feasibility and successful operation of the integrated system only, leaving performance analysis for future work. In the setup shown, the Control Centre is directly interconnected with a professional alerting system (for firemen or rescue teams, for example), the SECUNET network, which also hosts a relay allowing to access the various technologies listed in the previous sections of this paper, using either commercial or experimental equipment. The layout of the demonstrator is pictured in Figure 10.

The initial alert is encoded as an XML (Extensible Markup Language) message, whose template is stored in the Alerting Gateway. This server contains a network manager which is made of plug-ins that allows transferring the message to the various technologies through mail, file transfer or web service, whichever is the adequate format for the technology. When the alert is triggered by the Control Centre, it is first re-formatted by each plug-in and then forwarded to all the relevant networks.

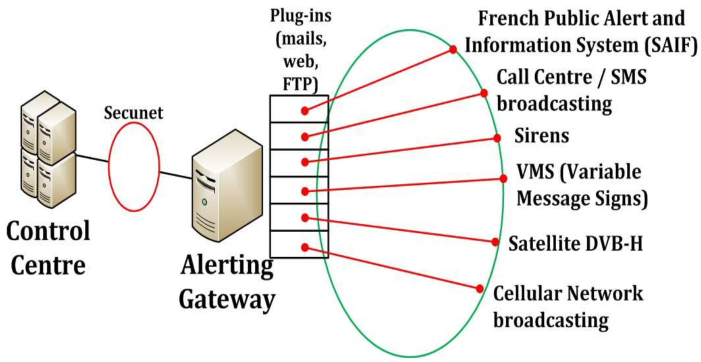

Figure 10. Demonstration of the public Alerting System

During the demonstration, a simulated alert was launched and led within a few seconds to the simultaneous ringing of *(i)* phones registered at the call centre, *(ii)* satellite phones or *(iii)* geographically-scoped mobile phones receiving SMS (Short Message Service). In addition to these existing technologies, the demonstrator was connected to an experimental test setup, showing the operation of multicast over LTE network and virtual Road Side Units, which were described in Section III. The layout of this setup is pictured in Figure 11 and described in more details in [13]. Figure 12 shows that it consisted mainly in laptop computers, running the LTE OpenAirInterface [14] software platform under Linux. When the alert was triggered at the Control Centre, an email was sent to the Alerting Application at the Cellular Network Gateway, appearing on the bottom right of Figure 10 or as “backhaul” in Figure 11. It resulted in the appearance of a pop-up window in each of the end user terminals. This demonstration concluded that existing state of the art and future technologies are capable to be combined in an integrated alerting system, enhancing its effect and efficiency.

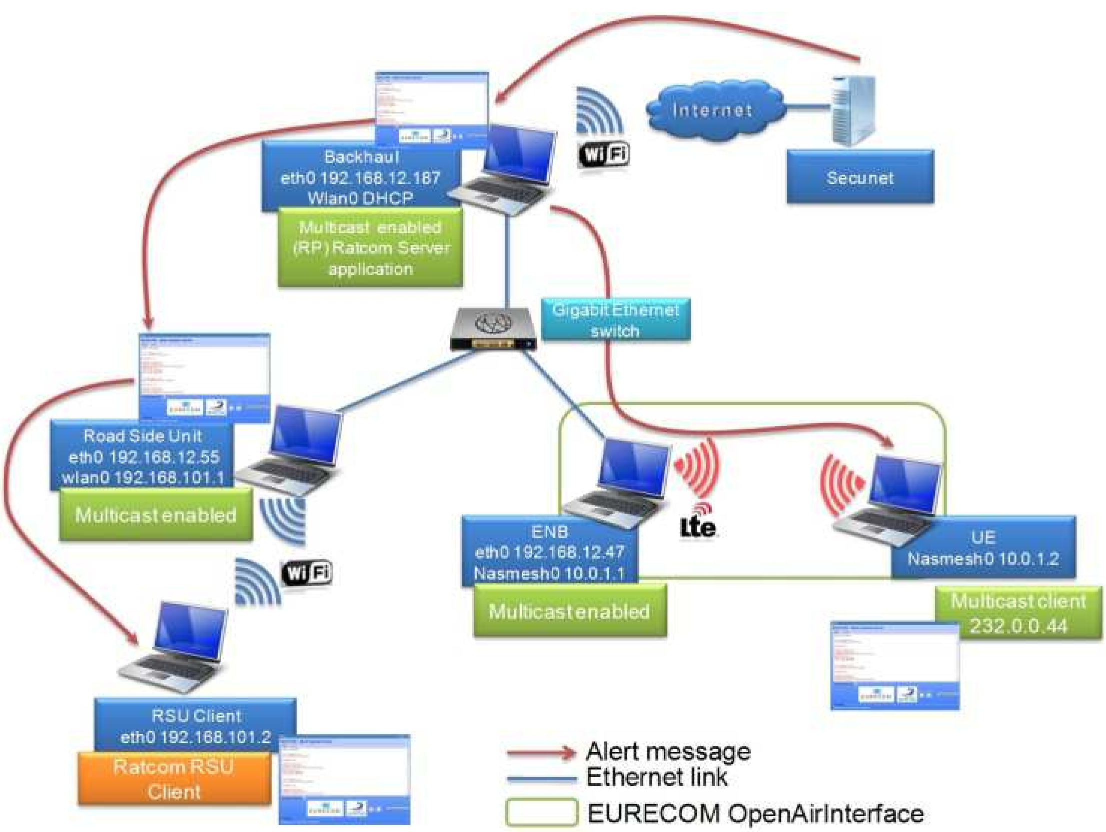

Figure 11. Experimental testbed setup for the demonstration

Figure 12. Picture of the experimental setup during the demonstration

VI. 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 alert 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. Finally, the successful demonstration held at the end of the project and showing the downstream public alerting system has been described.

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, enhancing its overall efficiency. 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.

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