Priority Communications for Critical Situations on Mobile Networks

Autor: Salvador Díaz Sendra

Director: Jose F. Monserrat Del Rio

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Objetivos

Esta tesina de máster se contextualiza en el marco del proyecto Europeo PROSIMOS. El principal objetivo de la tesina es diseñar mecanismos de priorización de llamadas en sistemas públicos de comunicaciones móviles y realizar una prueba de concepto acerca de la idoneidad de estas redes, mucho más baratas de mantener que las redes privadas, para garantizar la comunicación de los cuerpos y fuerzas de seguridad y emergencias en situaciones críticas.

Metodología

Esta tesina de máster ha contemplado cuatro fases. (1) Analizar los sistemas de comunicaciones que los equipos de rescates están utilizando en la actualidad así como sus necesidades de comunicación. (2) Profundizar en el estado del arte respecto a la priorización y gestión de la congestión en redes públicas. (3) Estudiar los mecanismos de priorización y selección existentes en los distintos estándares de comunicaciones móviles celulares. (4) Utilizar herramientas de simulación para evaluar distintas alternativas de control del acceso y priorización de llamadas. En esta última fase será fundamental tener en cuenta escenarios realistas que incluyan modelos de tráfico y de acceso fidedignos.

Desarrollos teóricos realizados

No aplican en esta tesina de máster.

Desarrollo de prototipos y trabajo de laboratorio

Se han evolucionado las capacidades de un simulador de acceso radio GPRS/EDGE y HSDPA programado en C++ que permite evaluar la calidad de servicio (QoS) de los usuarios de dichos sistemas. Para ello se ha desarrollado una entidad de gestión de recursos común para todas las tecnologías, además de implementar las funciones propias de gestión de cada una de ellas por separado (RRM). El CRRM/RRM permite estudiar el comportamiento y la calidad de cada usuario, por lo que se puede caracterizar al detalle lo ocurrido en una hipotética situación de emergencia. Para una correcta simulación, también se han implementado todas las características físicas asociadas a la comunicación como por ejemplo: características de las estaciones base (altura, tilt, ancho de haz de antenas, etc), modelos de propagación, características de la modulación, simulación de canal, etc.

Resultados

Los resultados demuestran que con un sistema adecuado de priorización de llamadas es posible dar servicio de voz a los cuerpos de seguridad en redes públicas. En cambio, no todas las tecnologías cumplen los requisitos mínimos. Mientras que HSDPA puede dar el servicio en cualquiera de los escenarios, GSM no lo consigue. Las simulaciones se han llevado a cabo considerando que sólo una tecnología cubre el escenario. Esto, evidentemente, no es una situación realista pero es la metodología adecuada para comprobar cuál es el límite de cada tecnología.

Con los resultados obtenidos podemos concluir que, utilizando los mecanismos de priorización y control de la congestión diseñados en la tesina, todo el tráfico de voz de usuarios en los distintos escenarios de uso planteados en el proyecto PROSIMOS podría cursarse utilizando la tecnología HSDPA. HSDPA no sólo cumple todos los requisitos planteados por un sistema de emergencia sino que, además, permite la realización de vídeo-llamadas y la consulta de datos a elevadas tasas binarias. Por otra parte, en una situación de emergencia, el tráfico civil podría limitarse a tráfico de voz sobre GSM pudiéndose aplicar técnicas conocidas, como por ejemplo half-rate, para aumentar al máximo la capacidad de la red.

Líneas futuras

En este proyecto se ha comprobado que es posible cursar, sobre una red de comunicaciones móviles pública, todo el tráfico de voz generado por los cuerpos de seguridad y emergencias en una situación crítica. Pero además, la tecnología actual permite la utilización de nuevos servicios y aplicaciones como videoconferencias o transferencias de datos a alta velocidad. Este tipo de tráfico debería ser, en primera instancia, simulado y analizado para ver cómo se afectaría su uso a calidad de voz. Las técnicas de priorización y control de acceso y de congestión deberían aplicarse en un sistema real y realizar un test con equipos reales en la que se compruebe que todos los datos obtenidos de la simulación concuerdan con un sistema real. También sería deseable realizar una extensión de los resultados obtenidos a las redes de última generación, como LTE y WiMAX.

Publicaciones

Esta tesina de máster ha dado lugar a las siguientes publicaciones:

- PROSIMOS A Tool for identifying business cases in the implementation of a priority communications systems for first responders in Public Mobile Networks, ServiceWave 2010 Conferences, Ghent, Belgium, 2010. -- ISBN / ISSN: 978-3-8396-0295-9 -- 07/09/2011.
- Simulator for PROSIMOS (PRiority communications for critical SItuations on MObile networkS) service, 6th Future Security, Security Research Conference, Berlin, Germany, 2011 -- ISBN / ISSN: 9783642176937.

Abstract

En la actualidad, las redes públicas de comunicación están ampliamente desplegadas en todo el territorio. Como las redes públicas no contemplan un uso priorizado de los recurso, los cuerpos de seguridad tienden a utilizar redes privadas de uso específico. Estas redes privadas satisfacen los requisitos marcados pero, a cambio, los costes de despliegue y mantenimiento son muy elevados, lo cual limita su despliegue y disponibilidad. Además, la interconexión entre distintas redes privadas no siempre es posible, lo que supone un gran problema cuando la emergencia se produce en zonas fronterizas. Estos grandes inconvenientes justifican un estudio minucioso sobre nuevos mecanismos de priorización en la gestión de recursos radio que permitan hacer uso de las redes públicas por parte de los cuerpos de seguridad y emergencias. Para ello se ha analizado el marco tecnológico actual, se ha contactado con distintos cuerpos de seguridad para averiguar los requisitos de comunicación actuales y los deseables. Caracterizado el sistema, se han definido distintos escenarios realistas utilizados en simulación masivas para finalmente demostrar cómo una red pública es capaz de cursar todo el tráfico que actualmente cursa una red privada en una situación de emergencia.

Autor: Díaz Sendra, Salvador, email: saldiase@iteam.upv.es
Director: Monserrat Del Rio, Jose F., email: jomondel@iteam.upv.es
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References

[1]	http://www.comdes.gva.es/
[2]	http://www.elperiodic.com/noticias/43492_consell-culmina-emergencias-ambiciosa-espaa-permite-cobertura-cien-cien-territorio.html
[3]	http://www.tetrapol.com/web/pdfs/tetrapol-features-and-functionality.pdf
[4]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) General System Design. ETSI TR 102 398 V1.1.2 (2008-05)
[5]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Conformance testing for the Digital Mobile Radio (DMR); Part 1: Protocol Implementation Conformance Statement (PICS) proforma. ETSI TS 102 362-1 V1.3.1
[6]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Conformance testing for the Digital Mobile Radio (DMR); Part 2: Test Suite Structure and Test Purposes (TSS&TP) specification. ETSI TS 102 362-2 V1.3.1
[7]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Conformance testing for the Digital Mobile Radio (DMR); ETSI TS 102 362-2 V1.3.1. ETSI TS 102 362-2 V1.3.1
[8]	Electromagnetic compatibility and Radio spectrum Matters (ERM); Peer-to-Peer Digital Private Mobile Radio using FDMA with a channel spacing of 6,25 kHz with e.r.p. of up to 500 Mw. ETSI TS 102 490 V1.6.1
[9]	http://www.etsi.org/WebSite/Technologies/DigitalMobileRadio.aspx
[10]	Technical Specification Group Core Network and Terminals; enhanced Multi-Level Precedence and Pre-emption service (eMLPP). 3GPP TS 23.067 V9.0.0
[11]	Technical Specification Group Core Network and Terminals; Voice Group Call Service (VGCS). 3GPP TS 43.068 V9.0.0
[12]	CMT Telecommunication Industry Statistics – 2010
[13]	http://spectrum.ieee.org/telecom/wireless/why-haitis-cellphone-networks-failed/
[14]	Dynamic half-rate connections in GSM, Erik M.M. Winandsa, Jeroen Wielandb and Bart Sandersb, November 2005
[15]	
[16]	European Telecommunication Standard “Digital Cellular Telecommunications System (Phase 2+); Half Rate Speech; GSM 06.20 06.20 Version 5.1.1”, May 1998
[17]	3GPP TS 43.022 v9.0.0, Functions related to Mobile Station (MS)in idle mode and group receive mode. December 2009
[18]	3GPP TS 22.011 V9.3.0. Service Accessibility
[19]	3GPP TS 22.067 V9.0.0. enhanced Multi Level Precedence and Pre emption service
[20]	3GPP TR 22.950 V9.0.0. Priority Service feasibility study
[21]	3GPP TS 48.008 v9.1.0. Mobile Switching Centre - Base Station system (MSC-BSS) interface
[22]	3GPP TR 22.952 v9.0.0. Priority service guide
[23]	3GPP TS 25.331 v9.1.0. Radio Resource Control (RRC); Protocol specification
[24]	Threshold-Based Congestion Control for the SS7 Signaling Network in the GSM Digital Cellular Network. Ramesh Nagarajan. March 1999
[25]	Radio network planning and optimisation for UMTS, Second Edition. Jaana Laiho, Achim Wacker, Toma´ sˇ Novosad. 2006 John Wiley & Sons Ltd
[26]	3GPP TS 25.304 v9.0.0, User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode. December 2009

[27]	3 GPP TS 25.413. UTRAN Iu Interface RANAP Signalling
[28]	3GPP TS 23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".
[29]	Providing congestion control in the Iub Transport Network for HSDPA. Szilveszter Nádas, Sándor Rácz, Zoltán Nagy, Sándor Molnár. IEEE GLOBECOM 2007
[30]	Preventive and Reactive based TNL Congestion Control Impact on the HSDPA Performance. Thushara Weerawardane, Andreas Timm-Giel, Gennaro C. Malafronte, Durastante Gianluca, Stephan Hauth, Carmelita Görg. 2008 IEEE
[31]	Impact of the Transport Network Layer Flow Control for HSDPA Performance. T.L. Weerawardane, A. Timm-Giel, C. Görg, Thomas Reim. IEEE conference, Sep. 2006
[32]	Impact of the Transport Network Congestion Control on the HSUPA Performance. Weerawardane, T.; Zaki, Y.; Timm-Giel, A.; Malafronte, G.C.; Hauth, S.; Gorg, C.; Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th
[33]	Congestion Control Strategies in Multi-Access Networks. X. Gelabert, J. Perez-Romero, 0. Sallent, R. Agusti. 2006
[34]	Performance Evaluation and Analytical Modeling of Novel Dynamic Call Admission Control Scheme for 3G and Beyond Cellular Wireless Networks. Salman A. AlQahtani, Ashraf S. Hassan Mahmoud and A. Alshanyour. IEEE 2007
[35]	S. AlQahtani and A. Mahmoud ," A Prioritized Uplink Call Admission Control Algorithm for 3G WCDMA Cellular Systems with Multi-Services" ,Proceedings of 6th IEEE International Conference on 3G & Beyond (3G 2005), London, UK, pp. 173-178, 5-7 Nov. 2005
[36]	Implementation of call admission control scheme in next generation mobile communication networks using particle swarm optimization and fuzzy logic systems. Chenn-Jung Huang, Yi-Ta Chuang, Dian-Xiu Yang. 2007 Elsevier Ltd
[37]	http://www.swarmintelligence.org/
[38]	Joint call admission control algorithms: Requirements, approaches, and design considerations. Olabisi E. Falowo, H. Anthony Chan. ScienceDirect, computer communications. November 2007
[39]	Radio Access Congestion in Multiaccess/Multiservice Wireless Networks. Xavier Gelabert, Oriol Sallent, Jordi Pérez-Romero and Ramon Agustí. IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 58, NO. 8, OCTOBER 2009

1 Introduction

1.1 Objectives

In a crisis situation, the ability to communicate is a vital capability. This capability is needed for authorized users who are involved in the prevention, mitigation or resolution of the emergency situation. Furthermore, all the civilian population inside the affected area wants to establish a communication.

The communication needs of priority users can be regarded as essential and will be needed at the same time as the public will be attempting an increased number of calls during the period when the public communications networks may be restricted due to damage, congestion or faults.

In order to protect their territory and citizens most of countries have started to develop National Priory Plans for Communications which include important regulations concerning Public Telecommunications Networks.

Up to now, emergency bodies have largely relied on private networks for its communications. The most used systems for Private Mobile Radio by emergency bodies are TETRA (ETSI Standard; Terrestrial Trunked Radio) and TETRAPOL (EADS development), which present among other the following drawbacks:

- Expensive deployment
- Expensive maintenance
- Lack of compatibility among the different PMR

A remarkable inconvenience appears in small regions or villages because they cannot afford the purchase of a PMR system, while Public Mobile Networks have ubiquitous almost everywhere in Europe.

In addition, one of the main inconvenient of private networks is the radio equipment. Usually, professional equipment’s only supports one technology whereas commercial mobile devices work with different Radio Access Technology (RAT). But during emergencies, public networks become overloaded to the point that emergency workers have trouble getting critical calls through. Here is where this master thesis comes to solve this issue of having prioritized communications in crisis situations for emergency bodies. Public mobile networks have to be considered then as the primary candidate for the introduction of priority services due its ubiquity and pervasiveness.

1.2 Wireless priority communications in Spain

Spanish administration is highly decentralized resulting, in case of emergency and security services, that most of the responsibility is being handled by regional or even local authorities. There are also cases as nationwide scope polices or military where the state deals with communication services. In this context we find a great number of local and regional scope police, fire brigades or ambulances with emergency communication services provided by their local or regional authorities.

For the nationwide security services as national police or military, Spanish government has deployed a nationwide communications network based on digital TETRAPOL technology. It is mainly used by national polices, but it is open to be used by other regional or local security or emergency services. Anyway only two regional governments have subscribed to this network for regional emergency communication services.

In some cases, regional governments have driven initiatives to unify the emergency communication services within the region, deploying their own emergency oriented digital communication systems, principally TETRA. The local government of several big cities, like Madrid, Zaragoza or Seville, has also deployed their own wireless digital emergency networks for local use. In other regions and cities is still common the use of analogue radio systems like Professional Mobile Radio (PMR) and trunking for local and regional emergency communication purposes.

As a result of these policies, we find a heterogeneous distribution of emergency communication systems and technologies, even within a region itself. Communication interoperability between emergency agencies using different networks, even if the communication technology is the same, is very limited, forcing emergency agencies to use public mobile or wireline phone systems to communicate each other. It is also a great economic charge for local and regional governments to deal with the deployment and maintenance of these private telecommunication systems.

The communication technologies most commonly used in Spain to provide emergency wireless communication services are traditional analogue two way radio services (PMR or Trunking) and, when these networks have been deployed recently, digital radio systems oriented to emergency services as TETRA, TETRAPOL or DMR.

The use of cellular telephone and satellite voice or data communication is normally a complementary option to emergency communication services described before. Public wireless networks are also used for high rate data transmission since emergency networks do not provide this service.

The use of public mobile networks for emergency communication services is limited by the lack of priority schemes implementation and other services required by emergency agencies (for example group and broadcast call, short call setup time, specific terminal options in terms of size and roughness, etc.) that are fulfilled by mentioned emergency communication systems but not by actual public mobile networks.

At this time, there are not governments or institutional initiatives oriented to implement these services necessary for emergency communications over public networks. The main initiatives in this field have been taken in standardization partnerships like 3GPP and focus on next generation technologies like LTE or WiMAX.

1.3 Comunidad Valenciana

Valencia Community has deployed a TETRA digital communications network to provide priority communications to emergency services depending of regional government and also to be used by local security and emergency agencies. This network is internally called COMDES [1], [2] (red de COmunicaciones Móviles De Emergencia y Seguridad) – Emergency and Security Mobile Communications Network.

The network uses about 110 base stations, and provides communications to over 8000 users, including local polices, fire brigades and civil protection services. It also provides coverage to Valencia underground.

Elche town has deployed its own TETRA digital network communications system to provide priority communications to local dependent security and emergency services.

2 Wireless Communication Systems

At this section, it is done a brief description of public and private wireless communication systems, existing and being used in Spain by services handling emergency issues.

2.1 Conventional PMR (Public / Private Mobile Radio) Systems

Traditional radio communication systems used for professional purposes and by emergency services consisted of a base station that distributed voice communication between radio terminals (portable and mobile). Users who wanted to talk each other had to select the same frequency channel in order to establish a communication.

Using DTMF signalling, some improvements were introduced, like selective calls. Thereby, more than one user group could share the same frequency channel, increasing the potential number of user of radio systems.

The use of repeaters in order to increase coverage is possible but problematic as this is not a centralized control system and needs an exhaustive planning of the use of frequency channels to avoid conflicts and interferences.

Disadvantages of these systems are the lack of security in communications, interference exposure and the difficulty of extending coverage to wide zones or in complex urban environments. It is also difficult for these systems to be handle communications of a number of groups of users higher than the maximum number of voice channels available in the system, especially in frequent communications operation mode.

Interoperability with other telecommunication networks using different communication protocols (i.e. analogue or digital trunking systems) requires for external integration devices (usually audio matrix systems) that provide a limited interconnection between both networks.

2.2 Analogue Trunking Systems

Trunking systems have a centralized control of channel using. This means that the radio users do not select the frequency channel they are using, but the system itself selects the most appropriated channel available in each moment, optimizing the use of system resources and increasing the performance of the whole system.

Here, n user groups can communicate using k frequency channels, being $n>k$. System assigns a physical communication channel only when a radio is involved in a communication (transmitting or receiving). In a conventional system, each user group has a static assignment of frequency channels, and a radio of a user group can’t transmit if another user group with the same frequency channel assignment is already communicating, even if the rest of the frequency channels available in the network are free.

Trunking access comprises the following steps:

- Radio informs through uplink system control channel that it is going to begin a transmission.
- System automatically assigns an available physical channel to the conversation
- System notifies the radio through downlink control channel which physical channel must use for its transmission
- Radio begins communication through assigned voice channel

Trunking systems are designed to offer coverage to wide zones by connecting repeaters to a central switching node that facilitates extending system coverage in a more simply way than conventional radio systems do. Therefore, the deployment of a network can begin with a small number of channels and repeaters which can increase its capacity (number of channels) and coverage (number of repeaters). These systems also provide data communications (status data or data through radio modems).

Interoperability with networks of different types (analogue PMR or digital trunking networks) requires intermediate integration devices connected to both systems that perform intercommunication between networks in a limited way.

Security is one of the weaknesses of analogue networks, as these systems, generally, do not encrypt communications. To provide a higher security level and assure that confidential communications are not intercepted, it is necessary the use of additional end to end encryption systems, usually connected to radio terminals. These encryption systems imply an additional increase in the price of the communication equipment.

2.3 Digital Trunking Systems

Worldwide digital two-way radio markets can be roughly divided into three categories: Commercial, Professional and Public Safety. Digital trunking systems are conceptually similar to analogue trunking systems, but the voice is digitally codified before being transmitted. These are cellular systems that provide voice and data services and have been developed having as basis specific requirements of traditional user of emergency communication systems.

Additional services like data handling, system APIs for application development, etc., are usually allocated in other subsystems connected to the network switching node.

Site controllers are in charge of assigning physical channels to voice communications and of communicating base stations with the central switching node. Communications between site controllers and switching nodes have evolved to IP, contributing to standardize switching centres towards widely extended IP switching devices.

Trunking digital systems are designed to be used at the same time by a wide range of different user groups, but isolated between them. So, these groups of user never interact between them, as the system establishes different communication scopes for different user groups, just as virtual private networks do in the field of data communication networks.

It is also possible to define and limit the resources of the systems available for each user group. Therefore, in a network with national extension, a users group might have permission to use only part of the base stations of the whole network, being capable of having communication services only inside a specific geographic zone.

2.3.1 TETRA

TETRA is a European standard for digital trunking radio communications developed by ETSI (European Telecommunication Standard Institute). Its functional requirements have been collected from traditional radio users and professional radio suppliers: public safety, transportation, utilities, government, military, PAMR, commercial & industry, oil & gas.

The air interfaces, network interfaces as well as the services and facilities are specified in sufficient detail to enable independent manufacturers develop infrastructure and radio terminal products that would fully interoperate with each other. For example, radio terminals from different manufacturers can operate on infrastructures from other manufacturers.

The ability for full interoperability between different manufacturer's products is a distinct advantage of open standards developed by ETSI. TETRA standard is supported by several independent manufacturers. This increases competition, provides second source security and allows a greater choice of terminal products for specific user applications.

TETRA signal medium access is gained through TDMA (Time Division Multiple Access) and digital modulation is made using π/4 DQPSK.

Interoperability between terminals is guaranteed by the standard but system interoperability is limited, and interconnection of network from different suppliers is not always easy. There is a functionality described in the standard called ISI (Inter System Interface) whose function is to provide TETRA terminals interoperability in two different networks (i.e. TETRA systems at both sides of a borderline), the same way than international roaming is handled in mobile telephone networks. ISI has been implemented first in real systems in 2009 and can be a key functionality for emergency communication users who have mobility between different TETRA networks.

As the rest of radio systems described in this document, TETRA interoperability with different type radio networks needs of intermediate intercommunication elements. The case of interconnection with telephone networks is different, as this type of service is defined in the standard, and infrastructures can perform this interoperation without the need of more equipment. Terminals have also integrated the function of telephone interoperability as defined in the standard. The system allows performing full duplex calls from a TETRA terminal to a phone and also the inverse way.

Because TETRA standard has been specifically developed to meet the needs of a wide variety of traditional PMR user organizations, it has a scalable architecture allowing economic network deployments ranging from single site local area coverage to multiple site wide area or national coverage. Besides meeting the needs of traditional PMR user organizations, the TETRA standard has also been developed to meet the needs of Public Access Mobile Radio (PAMR) operators.

Anyway, it is not always possible to increase the capacity of a small TETRA network maintaining the same infrastructure devices, as it is not nowadays available the possibility of joining some networks of the same or different suppliers in a one wider network with increased coverage.

A second version of TETRA was released at the end of 2005. TETRA 2 modifies some codifying aspects to provide increased data capacity and to extend the maximum distances of coverage of base stations.

2.3.2 TETRAPOL

TETRAPOL is an EADS proprietary digital trunking radio network system. It is conceptually very similar to TETRA, provides practically the same voice and data service than TETRA does and their slight differences are in the field of physical interfaces to radio access. The main difference between both systems is that TETRAPOL is not a standard, and EADS is the only supplier of infrastructure and terminal equipment for this system.

TETRA and TETRAPOL use different schemas of signal modulation and codifying, which implies terminal of both systems being not compatible. Medium access in TETRAPOL is gained using FDMA (Frequency Division Multiple Access) and signal digital modulation is made using GMSK. TETRAPOL in Europe uses the 380 – 400 MHz emergency communications reserved bandwidth.

Security in communications is a requirement of the conception of TETRAPOL, as it is in the case of TETRA. This system provides user authentication capabilities and air interface encryption plus end to end encryption.

TETRAPOL has good scalability features, as there is only one infrastructure supplier there’s no risk of incompatibility between different systems. TETRAPOL system is designed to grow in capacity and coverage just adding more TETRAPOL network elements.

TETRAPOL specifications [3] include interfaces for interconnection with other networks (TETRAPOL, TETRA, PMR, telephone networks and data networks).

2.3.3 DMR (Digital Mobile Radio)

Digital Mobile Radio (DMR) is a recent European standard (2005), produced by ETSI, defining a direct digital replacement for analogue PMR. DMR is a scalable system that can be used in unlicensed mode (in a 446.1 to 446.2 MHz band), and in licensed mode, subject to national frequency planning.

This technology promises improved range, higher data rates, more efficient use of spectrum, and improved battery. Significantly, DMR has been designed to fit into existing licensed PMR bands, meaning that there is no need for rebinding or relicensing, thus aiding the transition from analogue to digital. The new standard poses no fundamental changes in the architecture of either conventional or trunked systems. The focus is on a change in the over-the-air protocol that will facilitate the use of applications that are beyond the capability of analogue schemes.

Features supported include fast call set-up, calls to groups and individuals, short data and packet data calls. The communications modes include individual calls, group calls, broadcast calls and a direct communication mode among the mobiles. Other important DMR functions such as emergency calls, priority calls, full duplex communications, short data messages and IP-packet data transmissions are supported.

For business users, DMR may be seen as a commercially attractive alternative to TETRA, particularly for those users who do not need (or cannot afford) the complexity of this highly-successful digital technology. Many existing digital radio protocols suffer reduced radio coverage so a swap-out from analogue FM to digital is not possible. DMR has been specifically designed to offer at least the same range as 12.5 kHz channel analogue FM so a direct replacement or upgrade from analogue to DMR is a practical proposition.

ETSI Technical Report TR 102 398 [4] provides a useful introduction to DMR. Technical Specification TS 102 362 parts 1 to 3 [5]-[7] covers DMR protocol conformance testing and test suites, and Technical Specification TS 102 490 [8] defines the narrow-band or 'digital PMR' protocol.

System Reference Documents produced by ETSI have enabled the European frequency administrations to agree on the harmonized license-free use of digital PMR 446 (meaning that the same frequencies are, or will be made, available in all European countries). The System Reference Documents are ETSI Technical Report TR 102 335-1 (Tier 1 DMR) and TR 102 335-2 (licensed). [9]

2.4 Mobile Communications Networks

3GPP workgroup (3rd Generation Partnership Project), in charge of defining technical specifications that must be accomplished by new generation mobile networks, include in its requirements some aspects demanded by emergency communication users, as priority handling of calls and handovers (3GPP TS 23.067 [10]) or group and broadcast calls (3GPP TS 43.068 [11]). The implementation of these services in next generation (4G – LTE) Networks would be a key factor for their possible use as emergency communication networks.

However, in real deployed mobile telephone networks these kinds of services are rarely available. Vodafone and Movistar have offered PoC (Push to talk over Cellular) service for group calls between phone terminals. This service uses the packet data service (GPRS) of the mobile network to distribute the voice between the call participants. The maximum number of users involved in a group call is limited and it is also limited the number of models of mobile phone terminals that support this kind of service.

In the field of call priority and pre-emption capabilities, mobile phone operators have not offered this kind of service. It is a key service to guarantee QoS of emergency communications in cases of network congestion. The only priority service working in Spanish mobile phone networks nowadays is the 112 call (General Telecommunications Law 32/2003, from 3rd November), a service for citizen to emergency service communication, not between emergency actors.

Emergency attention services demand their communication calls to be processed in all situations, receiving maximum priority in the system, and pre-emption capability to have the call processed even if all voice traffic channels are busy.

Although mobile telephone networks rarely offer these services, they are widely used by emergency services, in most cases as a complementary communication system to other private wireless telecommunication networks. The optimum coverage and the general knowledge of the operation of mobile telephony system make possible the great acceptance and introduction of this element in all sectors of emergency services.

2.5 Satellite Communications for Emergencies

Mobile communication networks have a coverage limited to populated and transit zones, as they are developed for day to day communications. In almost any countries there are low populated areas without wireless phone network or emergency radio network coverage.

The impact of a big disaster (earthquake, flood, volcano, war…) can also result in the inoperativeness of existing wireless or wireline communication networks. In these cases it is possible to use portable base stations to extend coverage of existing networks or to deploy local networks to give limited communication facilities. Nevertheless, the simplest way to establish communications is using existing satellite communication services.

Anyway, satellite communication systems are a complementary service to emergency communication networks, as their capacity is lower and the call cost much higher than in the case of terrestrial communication networks.

3 Candidate Public Technologies

In Spain and most European countries, a multitude of emergency situations occurs every day and the rescue teams mainly use private networks as TETRA or TETRAPOL technology – or other Private Mobile Radio (PMR) technologies – to support the communications between them. However, being a private network entails several inconveniences: each association, team or company has to deploy, support and maintain its own network. Besides, this self-management represents a potential problem in the community boundaries where different rescue teams operate which different private networks due to interferences.

On the other hand, in a European country like Spain the public network covers more than the 99% of the territory with more than 50 millions [12] of clients for a total population of 47 million. Precisely the massive market penetration is one of the main strength of the public network but also, at same time, this is one of the main disadvantages because, immediately after an emergency situation, public networks are collapsed. A clear and recent example of what happens after a natural disaster is the case of Haiti earthquake [13]. The public wireless network was completely collapsed caused by the punctual load increase. The goal of this master thesis is to solve this disadvantage, developing a system where a specific user or group of users has priorities at each moment and under any situation trying to reach the main advantages of TETRA but using public networks. The rest of the section analyses capabilities of current mobile communication systems that could be applied to tackle this drawback.

3.1 GSM/GPRS

GSM was initially designed to support voice and when the need to transmit data appeared, the 3GPP standardized GPRS. Currently in Spain, all 2G networks are deployed with GSM/GRPS coverage. GPRS supports voice and data up to 144 kbps.

3.1.1 GSM differential aspects and services

Global System for Mobile communication [14] (GSM) uses a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) as multiple access scheme. The FDMA scheme divides the GSM frequency band into a number of carrier frequencies, which in their turn are split up into time slots by means of a TDMA scheme. A frame consists of a number of consecutive time slots. The time slots in a frame are then assigned to individual users (for a more detailed description see [15]).

GSM/GPRS has a radio access interface divided in timeslots. For the voice service, each user employs a single slot while GPRS uses the maximum number of slots predefined by the operator or available in the cell at that moment. The number of available timeslots is directly related with the number of radio bearers mounted in the base station. One GSM/GPRS radio bearer has 8 slots and these 8 radio timeslots are grouped into a TDMA frame. Therefore, for each radio bearer installed in a base station it is possible to support up to 8 users simultaneously without considering the slot that must be reserved in the first radio bearer for the control broadcast information.

A system based on timeslots is easily managed because the operator knows the maximum number of users supported in a cell and, hence, load control mechanisms can be easily adjusted.

3.1.2 Mechanism in GSM/GPRS for traffic prioritization

According to the standard, to solve the congestion different techniques can be used. There are a huge number of studies trying to give an optimal combination of such mechanism. This subsection summarizes the most important ones giving a brief explanation of them. Among these techniques we can differentiate frame restructuring using Half-Rate [16], a set of explicit 3GPP specifications – TS 43.022 [17], TS 22.011 [18], TS 22.067 [19], TR 22.950 [20], TS 48.008 [21], TR 22.952 [22] and TS 25.331 [23] – and some papers among which we have selected [24].

3.1.2.1 Half-Rate

Half Rate (HR or GSM-HR or GSM 06.20) is a speech coding system for GSM, developed in the early 1990s. Since the codec, operating at 5.6 kbit/s, requires half the bandwidth of the Full Rate codec, network capacity for voice traffic is doubled, at the expense of audio quality. It is recommended to use this codec when the battery is low since it saves 30% more energy.

HR could be used as a congestion mechanism: when congestion exceeds a certain threshold the HR is activated thus allowing a higher number of users since capacity is automatically doubled. The only limitation is that not only the network has to support the HR but also the devices. However, this is not a major problem since conventional devices support it.

HR should be the first technique because the network supports it without the necessity to do any modification.

3.1.2.2 3GPP TS 43.022 v9.0.0

The user uses a path loss criterion, named C1, to determine whether a cell is suitable to camp on. C1 depends on 4 parameters:

- The received signal level.
- The parameter RXLEV_ACCESS_MIN, which is broadcasted as system information, and that can be modified per cell in order to give more or less coverage at any cell.
- The parameter MS_TXPWR_MAX_CCH, which is also broadcasted as system information, and is the maximum power that an MS may use when initially accessing the network.
- The maximum power of the MS.

In order to optimize cell reselection, additional cell reselection parameters can be broadcasted as system information of each cell. The cell reselection process employs a parameter C2 which depends on these parameters.

- CELL_RESELECT_OFFSET, which can be again used to control cell priorities.
- PENALTY_TIME. When the user places the cell on the list of the strongest carriers it starts a timer which expires after the PENALTY_TIME. This timer will be reset when the cell is taken off the list. For the duration of this timer, C2 is given a negative offset. This will tend to prevent fast moving users from selecting the cell.
- TEMPORARY_OFFSET: negative offset described above.

Note that with the combination of C1 and C2 the system could make some cell unreachable by some users, at least in the cell selection phase. These cells could be employed to handover certain calls from congested cells to free cells ready to give service to emergency calls.

3.1.2.3 3GPP TS 22.011 v9.3.0

This technical specification defines a set of different priority access levels in the wireless network [18]. All User Equipments (UE) are randomly allocated to one out of ten mobile populations groups, defined as Access Classes 0 to 9. The Access Class is stored in the SIM/USIM. In addition, UEs may be members of one or more of the different 5 special categories (Access Classes 11 to 15), also held in the SIM/USIM. These last 5 categories specify high priority users as follows:

- Class 15 - PLMN Staff;
- Class 14 - Emergency Services;
- Class 13 - Public Utilities (e.g. water/gas suppliers);
- Class 12 - Security Services;
- Class 11 - For PLMN Use.

The enumeration does not mean priority order. Previous values are checked by the mobile device using the information sent by the network in the broadcast channels. When the network operator correctly activates these values, it can control the load and congestion in the network because preventing “normal” users to consume resources in priority cells. Therefore, this technique allows reducing in a considerable way the congestion in specific zones.

In order to activate the control on priority access methods and cell reselection restriction some parameters must be sent through the broadcast channels. These parameters are CELL_BAR QUALIFY and CELL_BAR ACCESS.

The next table shows the values of these parameters to achieve a specific goal in GSM:

CELL_BAR QUALIFY	CELL_BAR ACCESS	Cell selection priority	Status for cell reselection
0	0	Normal	Normal
0	1	Barred	Barred
1	0	Low	Normal
1	1	Low	Normal

Table 1 Parameters affecting cell priority for cell selection in GSM

The parameter to be modified in the broadcast channels for a GPRS system is CELL_BAR_ACCESS_2. The table below shows these values:

CELL_BAR ACCESS_2	Cell selection priority	Status for cell reselection
0	Normal	Normal
1	Barred	Barred

Table 2 Parameters affecting cell priority for cell selection and re-selection in GPRS

3.1.2.4 3GPP TS 22.067 v9.0.0

This document specifies the stage 1 description of the enhanced Multi-Level Precedence and Pre-emption Service (eMLPP) [19]. This service has two parts: precedence and pre-emption. Precedence involves assigning a priority level to a call in combination with a fast call set-up. Pre-emption involves the seizing of resources that are used by a call of a lower precedence by a higher level precedence call in the absence of idle resources. Pre-emption can also involve the disconnection of an ongoing call of lower precedence to accept an incoming call of higher precedence.

The eMLPP service is provided as a network operator's option, not of mandatory implementation. The eMLPP can be applied in the whole network or in a subset of the network. Moreover, the eMLPP service is applicable to all mobile stations with subscription assigning precedence.

Finally, eMLPP provides different levels of precedence for call set-up and for cell reselection in case of handover. The maximum precedence level is set by the service provider.

There are three classes of set-up time performance:

- class 1: fast set-up → 1-2 s
- class 2: normal set-up → < 5 s
- class 3: slow set-up → < 10 s

The eMLPP shall be invoked automatically by the network at call set-up. Calls with a high priority requiring a class 1 set-up may not require authentication at call set-up nor confidentiality on the radio link.

The network operator can allocate set-up classes and resource pre-emption capabilities to each priority level Table 3 presents an example for the assignment of priority levels and the corresponding parameters.

Priority level	Set-up time	Pre-emption	Examples
A	class 1	yes	VBS/VGCS emergency applications
B	class 2	yes	Operators calls
0	class 2	yes	112 Emergency calls
1	class 3	yes	Premium rate calls
2	class 3	no	Standard rate calls
3	class 3	no	Default for no eMLPP subscription
4	class 3	no	Low tariff calls

Table 3 Example on eMLPP service composition

Note that, in public networks, the capability to pre-empt an on-going 112 call (emergency call) shall be subject to national regulations.

Interworking of the eMLPP service with other networks shall be provided based on the MLPP service specified in ITU-T Recommendation I.255.3

3.1.2.5 3GPP TR 22.950 v9.0.0

This document presents the results of the Feasibility Study on Priority Service [20]. The intention of this Feasibility Study is to assess the ability of 3GPP specifications to meet high-level requirements identified for Priority Service.

Primary 3GPP capabilities were identified to support Priority Service:

- Service Accessibility.
- Enhanced Multi-Level Precedence and Pre-emption (eMLPP).
- Subscriber Identity Module (SIM) Specifications.
- Priority Information Element.

The following table summarizes the mapping of the high-level requirements to 3GPP Specifications, where NS means Not Supported, VS means Vendor Specific, PS means Partially Supported and √ means Supported:

High-level Requirement	Specification			
	3G TS 22.011, Service Accessibility	3G TS 22.067, 23.067, 24.067, eMLPP	3G TS 11.11, SIM	3G TS 08.08 (GSM), 25.413 (UMTS), PIE
Priority Call Origination	√	√	√	√
Priority Call Termination	√	√	√	√
Priority Progression	NS	√	NS	NS or VS
Priority Radio Resource Queuing	NS	PS	NS	√
Priority Level	PS	PS	PS	VS
Invocation on Demand	NS	√	PS	VS
Applicability to Telecommunications Services	√	√	√	√
Authorization	√	√	√	VS
Priority Service service code	NS	PS	NS	VS
Roaming	PS	√	PS	NS/VS
Handover	NS	PS	NS	√
Priority Service charging data record	NS	√	NS	VS
Priority Trunk Queuing	NS	NS	NS	NS
Coexistence with eMLPP	NS	NS	NS	NS

Table 4 High-level Priority Service Requirements to 3GPP Specifications

3.1.2.6 3GPP TS 48.008 v9.1.0

This specification defines the format with the specific fields used in the broadcast channels [21] to inform about the eMLPP priority level. An assignment request message is sent from the MSC to the BSS via the relevant SCCP connection – control connection – in order to request the BSS to assign radio resource following the priority level definition. Inside the Assignment Request, it is especially relevant the message Priority, defined at point 3.2.2.18 of this document. The message specifies 4 bits for the priority level, so it is possible to define 15 different levels. Furthermore, with one bit the request may pre-empt or not an existing connection and with another bit it is indicated if the connection might be or shall not be pre-empted by another allocation request.

3.1.2.7 3GPP TR 22.952 v9.0.0

This document addresses the Service Aspects (Service Description), Network Aspects (Call Flows), and Management Aspects (Operations, Administration, Maintenance, and Provisioning) of Priority Service, based on existing 3GPP specifications [22].

Table below shows an example of the values for the USA emergency system over a public network. There is not available information about the configuration in Spain.

Service User Priority Assignment	Access Class(es)	eMLPP Priority Level	48.008 Priority Level	48.008 qa Value	Precedence Level in ISUP Precedence Parameter
1 (highest)	14 and 13 and 12	B	2	1	0
2	14 and 13 and 12	0	3	1	1
3	13 and 12	1	4	1	2
4	13 and 12	2	5	1	3
5 (lowest)	12	3	6	1	4
	0-10	4	Implementation dependent, in the range of 7-14	Implementation Dependent	

Table 5 Mapping of Priority Indicators

3.1.2.8 Threshold-Based Congestion Control

This paper [24] considers the congestion control scheme for the SS7 signalling network. This congestion control scheme is based on monitoring the SS7 link buffer occupancy. In this scheme, a congestion onset message is sent to the user parts of the SS7 network when the buffer occupancy exceeds a certain threshold, and, subsequently, a congestion abatement message is sent when the buffer occupancy goes below another threshold. This paper primarily proposes appropriate choice of throttles and an algorithmic procedure to size the thresholds so as to yield good performance during congestion.

Detection is the first step to reach in a congestion control system but when it is detected, is possible to active and manage the necessary protocols. Not only is important detect the congestion but it is important to do it accurately because detect it before or latter it occurs can cause quality service degradation. This document details how is possible to calculate the accurate thresholds.

3.2 UMTS

UMTS is the technical evolution of GSM. At early 2000, before the .COM bubble exploits, UMTS standard, more commonly known as 3G, was foreseen to replace GSM completely. However, the reality was quite different and it has not been until 2007 when 3G experiments a real increase of use coinciding that launch with the appearance of the smart-phones and the 3G USB modems for laptops.

UMTS was designed to be compatible with GSM. In fact the core network was initially the same being substituted by an all-IP network in the late 2008. Since UMTS has a completely different radio access interface based on code instead of time division, 3G devices are usually back-compatible with GSM.

Nowadays, 3G networks covers most of the European territories and the new 3G releases – more known as High Speed Packet Access (HSPA) or 3G+ –, which provide higher data rates, are implemented in the major cities where data traffic is growing exponentially. In Spain the number of data users has been triplicate between 2007 with 500mil users and 2009 with 1’5 millions [12]. These numbers come from users using only data services without considering voice services.

3.2.1 UMTS differential aspects

UMTS uses Wideband Code Division Multiple Access (WCDMA) and supports a maximum theoretical data rate of 21 Mb/s (with HSDPA). At the moment, users in deployed networks can expect a data rate not higher than 384 kb/s for R99 handsets, and 7.2 Mb/s for HSDPA handsets in the downlink. This is still much higher data rate than the 9.6 kb/s of a single GSM circuit switched data channel.

UMTS standard specifies the UMTS Terrestrial Radio Access Network (UTRAN), which consists of multiple base stations or NodesB. As explained before, UMTS and GSM/GPRS can share the Core Network (CN), making UTRAN an alternative radio access network to GERAN (GSM/EDGE RAN), and allowing a transparent switching between both RANs according to available coverage.

The set of properties related to a specific data transmission is called Radio Bearer (RB). This set of properties determines the maximum transmitted data per time slot or Transmission Time Interval (TTI). The characteristics of the RB can be changes dynamically, most of all in case of HSPA where granularity is around 2 ms.

In 3G networks is important to keep the air interface load under predefined thresholds because an excessive load can drive the network into an unstable condition causing a reduction in the coverage area [25]. Besides a higher load entails a reduction in capacity and a degradation in QoS. Three mechanisms are defined in the standard to tackle these inconveniences:

- Admission Control (AC): Handling all new incoming traffic. It checks whether a new packet or circuit switched RAB can be admitted to the system and produces the parameters for the newly admitted RABs.

- Load Control (LC): Managing the situation when system load has exceeded the threshold(s) and some countermeasures have to be taken to get the system back to a feasible load. On Table 6 at point 3.2.1.1 is summarized how the system must execute the load control in a 3G network.

- Packet Scheduling (PS): This handles all the NRT traffic, for example, packet data users. Basically, it decides when a packet transmission is initiated and the bit rate to be used.

Nevertheless, the establishment of the optimal threshold to know if the UMTS system is being congested is one of the biggest challenges to be solved. This is due to the soft capacity of 3G networks, highly dependent on interference level. For a better understanding of the problem, the following point explains how congestion control is performed in 3G networks.

3.2.1.1 Congestion control

Section 4.4 of [25] explains how a PS network executes the admission control. The following table shows how different systems act to execute the inter-working actions of admission control:

Load	Admission Control	Package Scheduler	Load Control
Overload state	No new Rab Drop RT bearers	Decrease bit rates NRT bearers to FACH Drop NRT bearers	Overload actions
Preventive state	only new RT bearers if RT load below PrxTarget/PtxTarget	No new capacity request scheduled Bit rates not increased	Preventive load control actions
Normal state	AC admits RABs normally	PS schedules packet traffic normally	No actions

Table 6 inter-working actions of admission control [25]

The Admission Control (AC) and the Package Scheduling (PS) are preventive techniques that are intended to avoid overload in the network. Of course, when the users' demands are too high the system becomes inevitability congested. Therefore, load control techniques are necessary to drop and/or pre-empt calls in order to reduce the total traffic in the network.

AC determines whether an incoming call is admitted or not according to the predicted load and the defined threshold, both in the uplink and downlink. The AC will use thresholds produced during radio network planning and the uplink interference and downlink transmission power information received from the wideband channel. The radio bearer service covers all aspects of radio interface transport. How to calculate the wideband power-based admission control is explained in [25]. Furthermore, each threshold is associated to a particular throughput, and also this throughput is calculated.

Packet Scheduling (PS) methods follow the principle of load distribution in WCDMA cells, which Radio Resource Management (RRM) functionality controls. In wideband power-based RRM the uplink total Received Signal Strength Indicator (RSSI) and downlink transmitted carrier power are the quantities measured by the Node B that are planned to be below the target values. If the system load exceeds the load thresholds that are set during radio network planning then an overload situation occurs and LC actions are applied to return the load to an acceptable level.

PS decides the bit rate and length of the allocation to be used. Several PS approaches can be utilized in UMTS. Figure 4.17 of [25] illustrates two basic approaches, which are time division scheduling and code division scheduling

In time division scheduling the available capacity is allocated to one or very few radio bearer or bearers at a time. HSPA is based on this principle. Usually all codes are allocated to the same user changing this allocation in a TTI-basis. In code division scheduling the available capacity is shared between a large number of radio bearers, allocating a low bit rate simultaneously for each user. Circuit switching in UMTS is based on code division and is today used for voice and video call services.

Finally, the Load Control (LC) has two functionalities: controls that the network is not overload and when it occurs, it reduces the overload as soon as possible. In order to control the load of the network, the LC uses AC and PS. There are several projects trying to improve both techniques because they are critical to fulfil the QoS in the system. When both techniques fail, it is necessary to reduce the load of the system. The LC actions can be located in the Node-B or in the RNC, and also can be executed both in uplink and downlink.

3.2.2 Mechanism in UMTS for traffic prioritization

3.2.2.1 3GPP TS 25.304 v9.0.0

In [26] UMTS specifications explain two methods to reserve and restrict cell access. Therefore, [26] allows prioritizing traffic when needed. The first mechanism uses a set of cell status indicators to prevent users from getting connected. Besides, the UMTS standard reserves some slots for this control of cell selection and re-selection procedures. The second mechanism, referred to as Access Control, shall allow preventing selected classes of users from sending initial access messages for load control reasons. Both methods allow defining when new users can connect or not to a cell depending on their priority level. Besides, they make possible to control each cell individually, so that it is possible to enclose the coverage area where the access control is restricted. In [26] the complete methodology to do this task is carefully described.

3GPP TS 22.011 v9.3.0, 3GPP TR 22.950 v9.0.0, 3GPP TR 22.952 v9.0.0 and 3GPP TS 25.331 v9.1.0 are the same technical reports that have been previously explained.

This document specifies the Radio Resource Control protocol for the UE-UTRAN radio interface [23]. It is of great interest the Cell Access Restriction parameters defined there. There are several values but only two are relevant for this master thesis. These two values are included in the next table:

Information Element/Group name	Need	Type and reference	Semantics description
Intra-frequency cell re-selection indicator	CV-Barred	Enumerated(not allowed, allowed)	
Tbarred	CV-Barred	Integer (10,20,40,80,160,320,640,1280)	3GPP TS 25.304

Table 7 Restrictions to cell access [26]

Tbarred details can be found in TS 25.304 [26]

3.2.2.2 3GPP TS 25.413 v9.1.0

In UMTS the RAB assignment request to the RNC may also include the priority level and pre-emption capability of the connection as defined in this document [27]. The MSC maps the eMLPP priority on these priority levels. In addition, the eMLPP priority shall be explicitly indicated to the RNC in the RAB assignment request. The RNC shall store the priority level in order to decide on later actions.

The Subscriber Profile ID IE for RAT/Frequency Selection Priority is used to define camp priorities in idle mode and to control inter-RAT/inter-frequency handover in Active mode. A complete description about how the core network should work, mainly the Allocation and Retention Priority (ARP), is gived in [28].

IE/Group Name	Presence	IE type and reference
Subscriber Profile ID for RAT/Frequency Priority	Mandatory	INTEGER (1..256)

Table 8 Subscriber Profile ID for RAT/Frequency priority

3.2.2.3 UMTS Congestion Control Projects

Several papers focus on the congestion control in 3G networks. In [29] authors propose a Flow Control (FC) system with Dynamic Delay Detection (DDD) for the congestion control over the Iub interface. Without any control, the number of retransmissions is too high to be acceptable but applying FC together with DDD it is possible to maintain the data frame delay constant and with low rate. The article [30] explains how to detect congestion on the Iub Interface (interface between the Node-B and the RNC).In order to do this the detection mechanism identifies the congestion upon detection of packet losses at the transport network. Since the Transport Network Layer (TNL) uses the ATM as the transport technology between Node B and RNC, small cell losses can occur when the system is overloaded. The preventive congestion detection is in charge of detecting Iub packet losses before they occur, and hence before the congestion occurs. This way it is possible to take the necessary actions to try to avoid it. The proposal of this paper mixed with [31] allows reaching remarkable results: the throughput is increased twice using this congestion control techniques, with a 77% reduction of the FP average delay at the transport network layer. The paper [32] is focused on preventing the congestion in the Iub interface. In this paper, there are two simulations: based on worst ftp traffic model and based on 3GPP ftp traffic model. The result of the worst ftp traffic simulation is that without LC the number of lost packages is very high while the TCP delay is 1.5 times higher without LC. The result of 3GGP ftp traffic simulation shows that the number of lost packages is even higher than before while the TCP delay is similar with a difference of 1.4.

3.3 Other procedures for admission and congestion control

Different techniques are studied in order to analyse the admission and congestion control techniques where different RATs are considered as a single one [33]- [39]. These studies have the advantage to analyse the problem globally avoiding the congestion in a single RAT because it is possible to distribute the traffic using the others. However, the studies will be simulated just in case the previous techniques do not reach the expected goals.

4 Use cases

At previous section we have reviewed different radio mobile technologies and it is demonstrated that there are several methods to provide precedence and pre-emption in radio mobile public networks.

This section is focused on describing several realistic scenarios to analyse how a public network works under catastrophic situation if it implements the proposed techniques.

4.1 Context and Scope

Communications are critical for proper management and coordination in an emergency situation. Fig. 1 shows some target emergency situations, including natural disasters, environmental risks, terrorist attacks and any other incident representing a critical situation at either European, national or regional level. A great number of people involved in such situations make communications a complex issue. Furthermore, since First Responders (FR) as a rule belong to different groups, i.e. different emergency bodies, or different levels in the hierarchy for commanding the emergency, or others, it is essential that communications become a suitable tool that help manage an emergency efficiently.

The master thesis solution is framed in a generic emergency situation in Europe in which all emergency bodies take part and public communication networks may become congested because of being used not only by the emergency bodies but for all the people in the surroundings. Priority communications rights will be allocated to certain users such as e.g. FR – fire fighters, security forces, medical service, and other specialized emergency units – and Emergency Coordinators, whereas other users may get their ongoing communications overridden.

All these situations can be schematically split into three areas (see Fig. 1) that will have different communication requirements, roles and responsibilities. The definition of these areas is based on the level of risk as described below:

- Hot Area: Where only fire brigades, special Police Brigades or military in full PPA (Personal Protective Equipment) may enter.
- Warm Area: Where the mobile command posts, medical and decontamination services are located.
- Cold Area: Where the Back Offices of the different FR units are located. Back Offices should be in constant communication with Command Posts.

In this context, the selected technology on which the solution is based may be any Public Mobile Networks (PMN). Prioritization of communications for certain actors will be enabled in the network, i.e. certain actors will have communication capability whenever it is required and other users may have their communications interrupted or unavailable as a consequence.

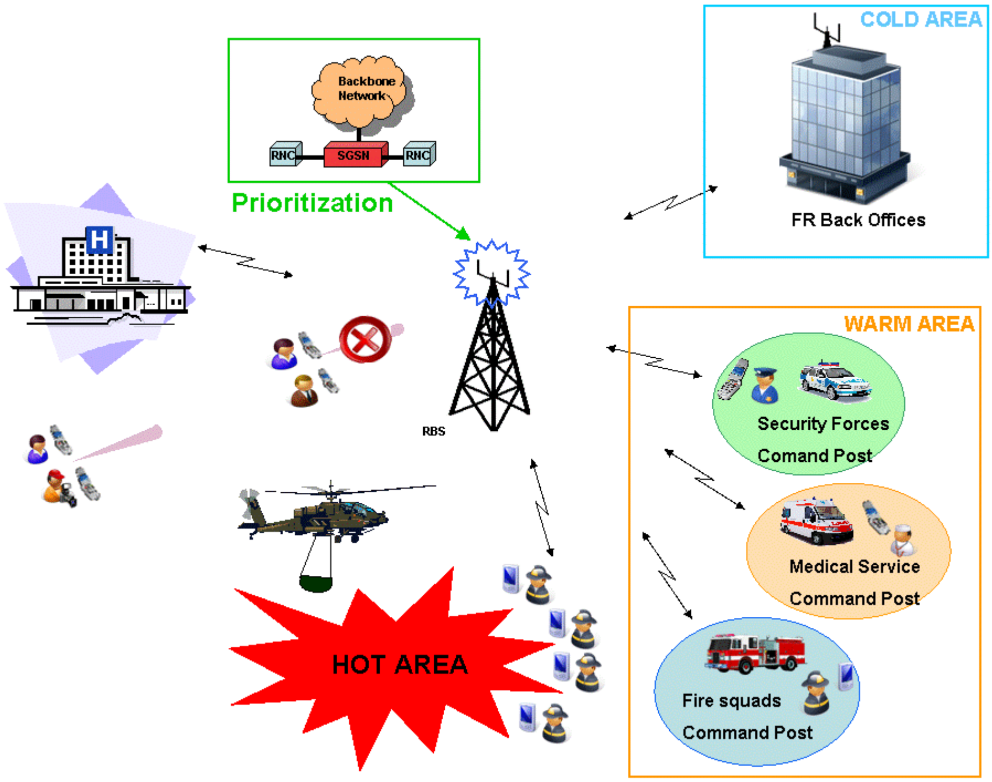

Fig. 1. Generic emergency situation – prioritization

This master thesis covers critical situations since emergency procedures are activated until the emergency status is ended. Besides critical situations, this study also covers certain non-critical situations in which first responders, security bodies or other potential users may need priority rights for their communications through public mobile networks.

4.2 Roles and Responsibilities

To better understand the operational concept described in this section, a set of generic roles and responsibilities have been defined. It must be noted that the operational scenarios created in the master thesis as well as eventual use cases and business models may use variations of the definitions here provided along with additional definitions.

- First Responder (FR) at the hot area: Its role is to act directly in an incident area according to the mission of the emergency body it belongs to; it is responsible for mitigating the risks of the subjects involved in the incidents.
- Squad Commander. Its role is to coordinate the FR at the hot area which belong to the squad under its command, as well as to communicate with the back office; it is positioned at the warm area and is responsible for the actions performed by the FR under its command and for informing the Mobile Command Post Coordinator and the back offices about the situation.
- Mobile Command Post Coordinator- Its role is to coordinate all brigades in the incident area and, in case a fixed command post existed, it is the point of contact of the incident area; it is

responsible for the proper coordination and management of the different brigades operating in the incident area and of informing power entities such as Government, Military, or others.

- Back Office Emergency Coordinator. Its role is to manage the emergency units' resources (personnel, vehicles, terminals, etc.) of the emergency corps it belongs to; it is responsible for allocating appropriate resources, as far as these are available, for the emergency operation.
- Prioritization Manager. Its role is to manage priority communications rights and levels; it is responsible for the correct allocation of prioritization.

4.3 Scenario 1: Incident in a critical infrastructure (Metro)

4.3.1 Scenario definition

An incident in a metro tunnel is broached in this scenario. A metro wagon derails and catches on fire with 40 victims entrapped within the wagon structure. The metro security guards alert about the situation calling 112 which is connected to the back office and the following emergency bodies are sent immediately to the disaster area: Fire Brigade, in charge of rescuing the victims and extinguish the wagon fire; Police Brigade, who delimit the intervention area around the metro exits and inside the metro stations; and Medical Services, in charge of health attendance to victims and injured FRs. It is assumed that there are also some civilian in the Metro stations located at both exits of the tunnel.

4.3.2 Players involved

Taking into account the type of Public Safety operation (PP2) and assumed emergency level 2, Madrid Civil Protection has suggested an approach of the players and vehicles to be sent to a similar disaster area. The emergency number per vehicle has been set up, following regular operational modes.

Fire Brigade is present with 4 squads comprised of 8 members each. Civil Police has 6 patrol units deployed around both Metro exits with 2 policemen in each patrol unit. Medical Services send 4 ambulances and 2 Intensive Care Units (ICUs), also deployed around both Metro exits (warm area) with 3 members each: doctor, nurse and driver. Each emergency group (Civil Police, Fire Brigade and Medical Service), has one mobile Command Post which behaves as a dispatcher to relay information and coordinate their operations.

Players involved in the metro incident			
	MEMBERS PER VEHICLE	*PERSONNEL*	*VEHICULAR UNITS*
Fire brigade	8 per regular vehicle. 3 per CP	35	5
Police	2 per regular vehicle. 3 per CP	13	6
medical services	3 per regular vehicle. 3 per CP	18	6
Total units deployed	-	**62**	**16**

Table 9 Players involved in metro incident

Although emergency units deployed in the disaster area can dynamically change as time passes, numbers above have been set as constant in this scenario. On the other hand, depending on their roll and on the emergency phase they will be located in a certain security zone.

4.4 Scenario 2: Natural disaster in a rural area (Forest Fire)

4.4.1 Scenario definition

A medium level forest fire is detected in a remote area. The uncontrolled fire has rapidly spread over 200 hectares. Non civil victims are considered. Forest guards alert about the situation calling 112, which is directly connected to the nearest Regional Emergency Back Office. This BO sends emergency units of the three Public Safety Agencies to the disaster area: Fire Brigade, in charge of rescuing the victims and fire extinction; Police Department, who delimit the intervention area; and Medical Services, in charge of health attendance to victims and possible injured FRs.

Another smaller forest fire centre of 3 hectares is detected 5 kilometres away from the previous one located near an urban area. The corresponding emergency units are set up in hot and warm areas of this second fire centre.

4.4.2 Players involved

This scenario is a Public Safety operation (PP2) and approximately corresponds to emergency level 3. Members per vehicle are the same considered in previous scenario but number of units deployed is significantly higher. The players and vehicles (CP included) finally deployed in each fire centre are summarized in Table 10.

Players involved in forest fire scenario					
		200 HA FIRE CENTRE		*3 HA FIRE CENTRE*	
Public safety agencies	members per vehicle	Personnel	Vehicles	Personnel	Vehicles
Fire brigade	8 per regular vehicle 3 per CP	163	21	75	10
Police	2 per regular vehicle 3 per CP	23	11	13	5
medical services	3 per regular vehicle 3 per CP	18	6	24	8
Total units deployed		**200**	**35**	**103**	**23**

Table 10 Players involved in forest fire scenario

4.5 Scenario 3: Aircraft crash in an airport

The critical situation presented in this section is caused by an aircraft crash against the terrain inside the airport borders. Although flying is the safest mean of transport, statistics show that most aircraft accidents occur in the landing or in the initial climbing phases, thus normally in populated areas. The risk the situation involves for passengers and crew requires an immediate reaction from the airport first responders and the other usual emergency services. Due to the fact that the airport is a delimited and highly secured area, the transport of resources to the hot area is one of the first steps in the emergency attention, and it relies on the marshallers and handling agent's staff. While the search and rescue is taking place, it is necessary also to establish other measures to prevent risks to surrounding aircraft and to pay attention to the affected passengers' relatives.

4.5.1 Scenario description

This scenario addresses an accident of an aircraft departing from an airport. Due to unexpected events, the aircraft misses control and crashes against the terrain just after take-off, when still inside the airport limits.

The Control Tower (TWR) of the airport is the first actor in noticing the situation, since the flight is being monitored during take-off. The TWR alerts the emergency services about the accident, first pushing the fire fighters alarm which is built-in in the controller's console and, after passing the location information to the fire fighters' supervisor, calling the Airport Management Centre (AMC). The AMC immediately establishes the Airport Back Office for the emergency, contacts the central emergency coordination centre (112) of the region and sets the emergency status in the airport and the surrounding airspace.

The 112 alerts the emergency services back offices (BO) and informs about the magnitude of the disaster. Emergency units (fire fighters, security forces and medical service) are sent to the disaster area. Emergency units of the airport are the first ones in arriving at the hot area and they set up the Advanced Command Post (ACP). When the region emergency units arrive, they set their command posts at the ACP to coordinate the different groups.

An unusual peak in the demand of traffic through the PMN is produced by many different users: emergency services; staff of the airport, press and population of the surrounding areas, passengers in airport terminal buildings and relatives of the affected passengers.

Due to the similarity of the usual emergency services response with the previous scenarios, in this case the description puts the stress on the setup of the emergency status at the airport, and the communications needs of this new subset of personnel.

4.5.2 Players involved

The main players of this scenario are the emergency services already analyzed in scenarios 1 and 2 (fire fighters, police, and medical service) and the actors at the airport. The latter are briefly described in the following paragraphs, from an emergency response point of view:

- The Control Tower (TWR): priority 1.
- The Airport Management Centre (AMC): priority 1.

- The Airport Crisis Room: priority 2.
- The Airport First Responders: priority 2.
- Other Airport Teams: priority 3.
- Number of airport players:

Airport Players involved in the airporT crash		
EMERGENCY SERVICE	*PERSONNEL*	*VEHICULAR UNITS*
Fire fighters	24	8
SECURITY	35	5
medical services	16	4
AMC	7	-
Advisory committee	20	-
Control tower	2	-
Airport marshallers	3	3
Airlines and handling agents	111	10
Airport services staff	4	-
Technical Unit	5	1
Total units deployed	**225**	**31**

Table 11 Players involved in Scenario 3

4.6 Scenario 4: Major Event management (Football match)

A major event management that corresponds to PP2 operation classification cannot be characterized clearly as an emergency or disaster. Approximately, considering number emergency users required, it could be assumed that this scenario belongs to emergency level 3 although the operational period usually remains under the range 8-48 hours.

Police finds prioritization solution functional not only for several daily work security incidents, but also in major events which involve large number of citizens, and thus, mobile telephony currently fails during certain periods.

In addition to those services, they currently use they consider video surveillance from the field, situation pictures transmission, ID cars scanning on the field, etc, extremely useful applications that, as opposed to current narrowband technologies, PMN can provide.

4.6.1 Scenario definition

In this scenario, the master thesis solution will be applied in a major sport event such as a crucial football match. Extra security measures are needed before, meanwhile and after this kind of football matches where a number of City Police, National Police units, Civil Guards, emergency units and private security guards from football clubs and the stadium may be present.

Specifically, police forces shoulder public safety responsibility. They are in charge of controlling spectator's entrance and exit confiscating dangerous objects, covering stadium areas reserved for the hooligan supporters, patrolling stadium surroundings or targeting illegal alcohol sales, among other activities.

Several data has been collected related to Santiago Bernabeu 80,354-seat stadium of Real Madrid Football club that can give guidelines of players involved in this kind of events. This stadium can join approximately 65,000 spectators in a crucial football match, which can mobilize 400 riot police from National Police, 120 Civil Police, 230 private security guards and 700 stewards to protect the public health, welfare, and safety of the public. Security forces confiscate approximately 2000 dangerous objects susceptible to be thrown or become airborne and inspecting bags, cloths, etc. Santiago Bernabeu counts on more than 350 security cameras controlled by its advanced control centre UCI (literally, Integrity Control Unit), which monitors and regulates illumination, lifts, escalators or heating, and not all stadiums have such a site available.

For the purposes of this master thesis, it will be considered that just three Public Safety Agencies are present, (National Police, Civil Police and Medical Services) as listed in Table 11.

Players involved in major event scenario		
PUBLIC SAFETY AGENCY	*PERSONNEL*	*VEHICULAR UNITS*
Police	100 Civil police 300 National police	40
medical services	60 Red cross 10 civil protection	6 ambulances 6 ICU
Total units deployed	**470**	**46**

Table 12 Players involved in Scenario 4

5 Results

Several international proposals for prioritization calls system have been studied, being finally selected the technique described in [18] due to its special relevance and simplicity for implementation in actual systems. The scope of this section is to analyse the performance of GSM and HSPA networks when using this load congestion method.

The approach of this section is:

- Define the test environments.
- Analyse the performance of GSM and HSPA.

The section is divided in four subsections, each dealing with the corresponding use case. Actors are divided into four categories, depending on the role played inside the scenario:

- P1 users: users with maximum priority. Users those are located inside the hot area and also the coordination personal
- P2 users: users with the second maximum priority. These users are inside the warm area
- P3 users: priority users with the minimum level of priority. Users located at cold area.
- P4 users: civilians. Not involved in the emergency action

5.1 Incident in a critical infrastructure (Metro)

An incident in a metro tunnel is broached in this scenario. A metro wagon derails and catches on fire with 40 victims entrapped within the wagon structure. From the point of view of the simulation, it runs with the supposition that each stage of the metro is covered with several microcells, so users of one stage are covered only with microcells of this stage. The accident occurs on the second underground stage between two platforms. The consequence is that only the civilian users inside these metro wagons are covered with the same BS as the First Responders. The hot area is covered by the BS1 and the BS2.

At ground level, the rescue teams are covered by 2 BS. The Figure 2 shows that these BS are BS3 and BS4. The First Responders are covered only by one beam.

The accident occurs too deep, for that reason the hot area does not have coverage with the BS3 and the BS4. The simulation has to be divided into an indoor and an outdoor scenario.

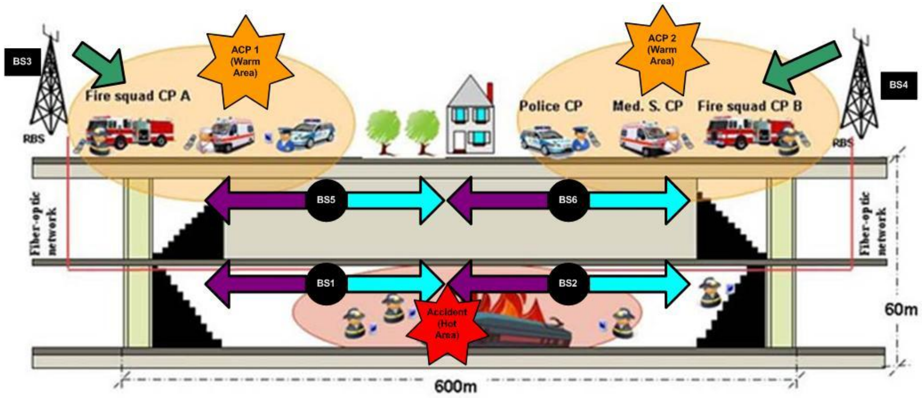

Fig. 2. Metro station

5.1.1 GSM

The most important users, that are users with maximum and medium priority, reach a percentage of successful calls higher than 95%. Besides, civil users almost reach this value. Only when the scenario is simulated with a high number of civilians, the system cannot accept all the connections attempts for this group. However, even in this situation, the percentage of denied is lower than 1%.

The main reason of these good results is the call rate per user defined in the scenario. The network under study, with 23 timeslots and a duration call around 15 seconds, is ready to support 1 call per second. If call duration decreases then the call rate supported by each cell increases. This means that network performance improves if call duration per user is reduced, what seems reasonable. Comparing the traffic generated by the users with the traffic supported by the network, it is possible to conclude that with the GSM network the traffic originated by the accident could be perfectly supported.

As explained before, users without priority can be dropped to keep the QoS requirements of the other priority users. Despite this load control, percentage of dropping is less than 5%, which results affordable for a congested situation. Note that in most cases drops are due to lack of coverage that happens in a part of the metro scenario. This cannot be controlled with any load control algorithm.

Finally, the required maximum time to establish a call is perfectly achieved.

5.1.2 HSDPA

HSDPA is a package switch system and consequently the load depends on the traffic type and cannot be calculated like GSM.

The system configuration is defined at Section 4.3. **¡Error! No se encuentra el origen de la referencia.** shows the results of the simulated scenario using the highest thresholds for different users' types. The P1 users reach a percentage of successful around the 92%, which is a bit lower than the results get for the GSM scenario. The reason is that the coverage at 2100 MHz is worse than at 900MHz and therefore the black holes are bigger in this second technology. Besides, priority users are who mainly occupy these areas and are the most affected by the lack of coverage, as demonstrated in the results. Anyway, for users with coverage the probability of satisfaction is similar to the GSM case, and identical conclusions can be drawn.

Metro scenario GSM			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	24	24	24
Number_Users_P2	51	51	51
Number_Users_P3	0	0	0
Number_Users_P4	60	180	300
Call_Generation_Rate_User	0,004	0,004	0,004
Number_tentative_calls_P1	171	160	170
Number_tentative_calls_P2	363	352	361
Number_tentative_calls_P3	0	0	0
Number_tentative_calls_P4	211	862	1057
Number_BS	4	4	4
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	96,533176	95,939683	95,660734
Prob_Succ_Call_P2	95,382722	94,619544	96,291421
Prob_Succ_Call_P3	0	0	0
Prob_Succ_Call_P4	96,640137	95,667049	95,706323
Prob_Drop_Call_P1	3,466824	4,060317	4,339266
Prob_Drop_Call_P2	4,617278	5,380456	3,708579
Prob_Drop_Call_P3	0	0	0
Prob_Drop_Call_P4	3,359863	4,332951	4,293677
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	0	0	0
Max_wait_time_call_establ_ms	162,561856	178,022744	108,112577

Table 13 Results of the metro scenario using GSM

The time call establishment is 10 times lower using HSDPA than using GSM. This time is much better than the 300 milliseconds required in TETRA.

5.1.3 Conclusions

The GSM network provides a good rate of successful calls, more than 90% of the calls, for users with the maximum priority, P1 users, and users with high priority, P2 users. Moreover, HSDPA technology achieves similar results. The percentage of drops for P1 is higher for HSDPA than for GSM. The GSM network achieves percentages around 3.5% while HSDPA gets 8%.

Nowadays, all the devices are dual and automatically commute between GSM and HSDPA. Therefore, the conclusion is that the applied technique performs well in this scenario.

Metro scenario HSDPA			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	24	24	24
Number_Users_P2	51	51	51
Number_Users_P3	136	136	136
Number_Users_P4	60	180	300
Call_Generation_Rate_seconds	0,004	0,004	0,004
Number_tentative_calls_P1	143	170	156
Number_tentative_calls_P2	347	322	321
Number_tentative_calls_P3	0	0	0
Number_tentative_calls_P4	200	811	949
Number_BS	4	4	4
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	91,98541	91,468521	90,6547
Prob_Succ_Call_P2	97,458452	96,211452	95,111202
Prob_Succ_Call_P3	0	0	0
Prob_Succ_Call_P4	96,232354	96,221522	94,221545
Prob_Drop_Call_P1	8,01459	8,531479	9,3453
Prob_Drop_Call_P2	2,541548	3,788548	4,888798
Prob_Drop_Call_P3	0	0	0
Prob_Drop_Call_P4	3,767646	3,778478	5,778455
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	0	0	0
Max_wait_time_call_establ_ms	10,444	10,653	10,991

Table 14 Results of the metro scenario using HSDPA

5.2 Natural disaster in a rural area (Forest Fire)

5.2.1 GSM

The probability of successful call is a bit lower than 90% for P1 users. There are not denied calls, but there are a 10% of unsuccessful calls caused by drops. The reason of these drops is the non-satisfaction of the minimum QoS. The same happened in the metro scenario. P2 users have a successful call probability of 70%. In order to provide more QoS to the ongoing calls, 12% of calls are denied, independently of the number of civilian users. During all the busiest hour, the whole system is occupied by P1 and P2 users. The civilian calls drop because new most priority calls must be served. While the load of civilians is low, percentage of drops is around 90%, the other 10% has the access to the network denied. When the civilian load increases, the number of drops decreases and the reason is that the number of denied increases. The thresholds of the system keep the minimum QoS.

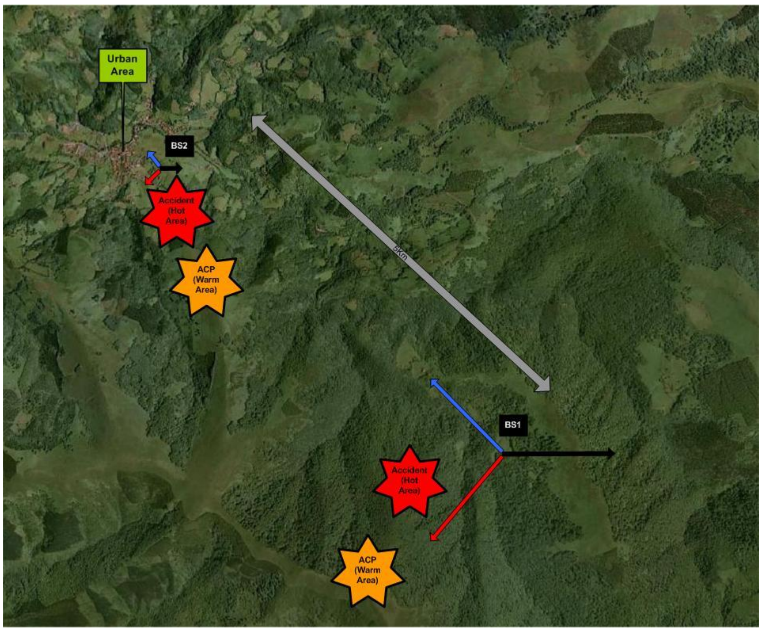

Fig. 3. Forest scenario over a map

Forest scenario GSM			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	174	174	174
Number_Users_P2	169	169	169
Number_Users_P3	0	0	0
Number_Users_P4	20	60	100
Call_Generation_Rate_seconds	0,015	0,015	0,015
Number_tentative_calls_P1	1245	1209	1210
Number_tentative_calls_P2	1164	1142	1135
Number_tentative_calls_P3	0	0	0
Number_tentative_calls_P4	366	768	1590
Number_BS	4	4	4
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	88,76003	89,054794	88,545384
Prob_Succ_Call_P2	67,597952	68,513884	66,632398
Prob_Succ_Call_P3	0	0	0
Prob_Succ_Call_P4	1,814314	0	0
Prob_Drop_Call_P1	11,23997	10,945206	11,454616
Prob_Drop_Call_P2	20,371818	20,117211	21,77
Prob_Drop_Call_P3	0	0	0
Prob_Drop_Call_P4	89,427524	52,465725	31,867011
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	12,03023	11,368904	11,597602

Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	8,758161	47,534275	68,132989
Max_wait_time_call_establ_ms	130,124633	147,092335	123,048816

Table 15 Results of the forest scenario using GSM

5.2.2 HSDPA

Unlike GSM, the HSDPA network can perfectly manage the traffic originated by P1 and P2 users. Besides, civilians can fulfil their requirements when the non-priority load is low or medium. When the civilian load is high, the successful probability decreases below 50%. A mobile HSDPA station should be deployed to support the civilian calls.

The establishment time for calls is really good and lower than the minimum required by specifications.

Forest scenario HSDPA			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	174	174	174
Number_Users_P2	169	169	169
Number_Users_P3	0	0	0
Number_Users_P4	20	60	100
Call_Generation_Rate_User	0,015	0,015	0,015
Number_tentative_calls_P1	1224	1248	1241
Number_tentative_calls_P2	1178	1174	1173
Number_tentative_calls_P3	0	0	0
Number_tentative_calls_P4	258	784	1522
Number_BS	4	4	4
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	96,599571	97,800845	97,922833
Prob_Succ_Call_P2	98,400712	97,891259	98,011053
Prob_Succ_Call_P3	0	0	0
Prob_Succ_Call_P4	94,351515	83,622543	47,586519
Prob_Drop_Call_P1	3,400428	2,199155	2,077167
Prob_Drop_Call_P2	1,599288	2,108741	1,988947
Prob_Drop_Call_P3	0	0	0
Prob_Drop_Call_P4	5,648485	8,917455	2,62594
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	0	7,460002	49,78754
Max_wait_time_call_establ_ms	10,023	10,262	10,374

Table 16 Results of the forest scenario using HSDPA

5.2.3 Conclusions

The GSM network configuration reveals that the maximum call rate supported by each BS is 1 call per second. The P1 users defined in the scenario have a maximum call rate of 2 calls per seconds. The users' distribution for the simulation causes that this rate decreases to 0.015 calls per user. Using the parameters for the simulation, the results are as follows.

For GSM, the percentage of success for P1 users is around 89% while for HSDPA this is close to 98%. The P2 users have a successful percentage around 70% using GSM but, using HSDPA, the percentage is increased until 98%. The civilians cannot talk if the system is GSM but if they use HSDPA the probability of correct access depends on the load. With low load levels 95% of non-priority users can talk. With a medium load, the percentage decreases to 83%. Finally, when the load is high, less than 50% can access the system.

After the analysis of this scenario, the emergency users can only talk without problems if the area has HSDPA coverage. Furthermore, the P1 users have good service even if only GSM covers the area but P2 and non-priority users experience bad quality unless HSDPA is used. A mobile station, with one transponder, will be needed to ensure the quality of P2 users. Additionally, another optional mobile station will be required to serve the civilians if there is not HSDPA coverage.

5.3 Aircraft crash in an airport

The full scenario is described in section 4.5.1. The accident is 3km far away from the passengers' terminal so there are not static or pedestrian civilian users inside the hot and warm area. The figure below describes the scenario.

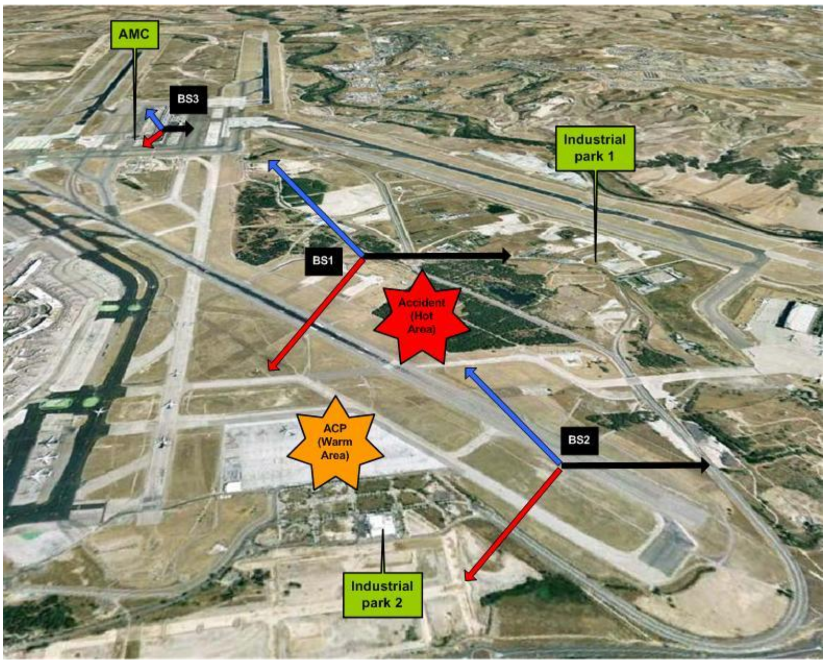

Fig. 4. Analysis of the airport scenario

5.3.1 GSM

With the GSM network configuration, the maximum call rate supported by the BS is 1 call per second. The maximum call rate defined in the scenario is less than this value and hence the network GSM can manage the PROSIMOS users' traffic without additional transponders. The percentage of successful calls is close to 93%.

Civilian users do not reach percentages of successful calls higher than 65%. The calls are dropped because the system is overloaded causing poor QoS. The solution is easy, increase the number of transponders that cover the terminals in order to support more traffic. In this specific scenario, this action does not affect PROSIMOS users because the accident is far away from the terminals. If the accident was closer to the terminals, the results for civilians will change completely, decreasing the successful calls drastically.

Airport scenario GSM			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	29	29	29
Number_Users_P2	66	66	66
Number_Users_P3	136	136	136
Number_Users_P4	80	360	720
Call_Generation_Rate_User	0,0037	0,0037	0,0037
Number_tentative_calls_P1	48	49	34
Number_tentative_calls_P2	136	133	98
Number_tentative_calls_P3	300	315	218
Number_tentative_calls_P4	86	439	666
Number_BS	9	9	9
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	92,547209	89,418568	90,038951
Prob_Succ_Call_P2	91,490764	90,770934	89,670989
Prob_Succ_Call_P3	92,099765	91,159797	86,515395
Prob_Succ_Call_P4	61,406634	40,76896	28,529717
Prob_Drop_Call_P1	7,452791	10,581432	9,961049
Prob_Drop_Call_P2	8,509236	9,229066	10,329011
Prob_Drop_Call_P3	7,880871	8,614785	10,077807
Prob_Drop_Call_P4	38,593366	46,474841	36,022116
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0,019364	0,225418	3,406799
Prob_Denied_Call_P4	0	12,756199	35,448167
Max_wait_time_call_establ_ms	157,852506	123,728358	145,884883

Table 17 Results of the airport scenario using GSM

5.3.2 HSDPA

The higher capacity of HSDPA as compared with GSM and the low call rate, makes that the percentage of successful calls for all groups will be higher than 98%. There are not denied calls and 1% of drops is caused by an insufficient QoS during the call. The maximum time to establish a connexion is perfectly reached.

Airport scenario HSDPA			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	29	29	29
Number_Users_P2	66	66	66
Number_Users_P3	136	136	136
Number_Users_P4	80	360	720
Call_Generation_Rate_Users	0,0037	0,0037	0,0037
Number_tentative_calls_P1	51	49	49
Number_tentative_calls_P2	143	144	139
Number_tentative_calls_P3	313	317	313
Number_tentative_calls_P4	106	493	991
Number_BS	9	9	9
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	99,476342	98,656926	99,367573
Prob_Succ_Call_P2	98,265352	98,468963	98,271418
Prob_Succ_Call_P3	98,591572	98,035353	98,818427
Prob_Succ_Call_P4	99,454828	99,112254	99,107769
Prob_Drop_Call_P1	0,523658	1,343074	0,632427
Prob_Drop_Call_P2	1,734648	1,531037	1,728582
Prob_Drop_Call_P3	1,408428	1,964647	1,181573
Prob_Drop_Call_P4	0,545172	0,887746	0,892231
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	0	0	0
Max_wait_time_call_establ_ms	10,481	9,943	10,178

Table 18 Results of the airport scenario using HSDPA

5.3.3 Conclusions

The maximum call rate defined at this scenario is caused by the most priority PROSIMOS users, P1, is set to 0.15 calls per second. If all the P1 users remain at the same BS, the maximum call rate per user will be 0.005 calls per second. Considering the users' distribution, the call rate decreases to 0.0037 calls per second per user. This rate is approximately a 25% lower than the maximum.

The percentage of successful calls for PROSIMOS users is higher than 90% when they use GSM, and higher than 98% if they use HSDPA. With these percentages of successful calls, it is possible to conclude that with the additional techniques it is possible to cover an emergency situation like the accident in the airport.

5.4 Event Management - Football Match

The following scenario occurs every weekend in stadiums where teams of the football season play. This project analyses a possible scenario defined at section 4.6.

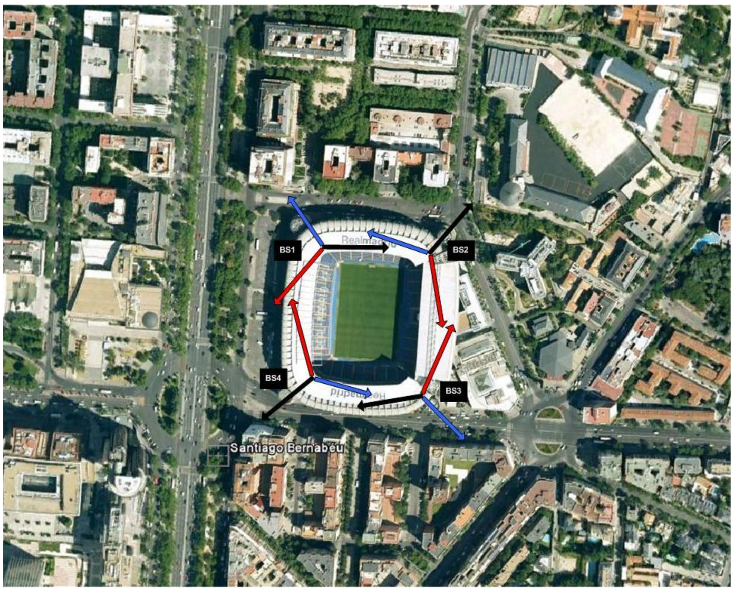

Fig. 5. Deployment of microcells

5.4.1 GSM

The following table summarizes the result considering the best configuration of the congestion control algorithms. The medium threshold is set to 85% but, given that there are not high PROSIMOS users, this medium threshold has not a real effect. The percentage of successful calls for medium users is around 80% depending on the number of civilian users. Unfortunately, the civilians cannot call with satisfied QoS during the match. This is mainly due to the high number of calls made by the rescue and security teams.

The Erlang-B analysis is as follow: the Erlangs of the P2 users is 37.5 Erlang. With block probability of 2% it gives that the minimum channels to support this traffic is 48. This is the reason why P2 users only attain the 80% of successful calls while the P4 cannot call. The system is designed with 32 channels and a block probability of 2%. With these parameters it is possible to support up to a voice call per user during the busiest hour.

Football scenario GSM			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	0	0	0
Number_Users_P2	480	480	480
Number_Users_P3	0	0	0
Number_Users_P4	600	900	1200
Call_Generation_Rate_User	0,037	0,037	0,037
Number_tentative_calls_P1	0	0	0
Number_tentative_calls_P2	983	970	929
Number_tentative_calls_P3	0	0	0
Number_tentative_calls_P4	791	1345	2108
Number_BS	12	12	12
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	0	0	0
Prob_Succ_Call_P2	82,540323	81,755999	77,38582
Prob_Succ_Call_P3	0	0	0
Prob_Succ_Call_P4	0,462963	0	0,42735
Prob_Drop_Call_P1	0	0	0
Prob_Drop_Call_P2	17,459677	18,244001	22,61418
Prob_Drop_Call_P3	0	0	0
Prob_Drop_Call_P4	97,705535	90,771713	68,295814
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	1,831502	9,228287	31,276836
Max_wait_time_call_establ_ms	195,716695	148,537565	180,028047

Table 19 Results of the football match scenario using GSM

Football scenario HSDPA			
PARAMETERS	*LOW LOAD*	*MEDIUM LOAD*	*HIGH LOAD*
Number_Users_P1	0	0	0
Number_Users_P2	480	480	480
Number_Users_P3	0	0	0
Number_Users_P4	600	900	1200
Call_Generation_Rate_seconds	0,037	0,037	0,037
Number_tentative_calls_P1	0	0	0
Number_tentative_calls_P2	1000	975	941,6667
Number_tentative_calls_P3	0	0	0
Number_tentative_calls_P4	808,3333	1600,6667	2565
Number_BS	12	12	12
Traffic_model	ITU-R M.2135	ITU-R M.2135	ITU-R M.2135
Prob_Succ_Call_P1	0	0	0
Prob_Succ_Call_P2	100	99,537037	100
Prob_Succ_Call_P3	0	0	0

Prob_Succ_Call_P4	99,666667	100	99,537384
Prob_Drop_Call_P1	0	0	0
Prob_Drop_Call_P2	0	0,462963	0
Prob_Drop_Call_P3	0	0	0
Prob_Drop_Call_P4	0,333333	0	0,462616
Prob_Denied_Call_P1	0	0	0
Prob_Denied_Call_P2	0	0	0
Prob_Denied_Call_P3	0	0	0
Prob_Denied_Call_P4	0	0	0
Max_wait_time_call_establ_ms	10,096	10,124	10,501

Table 20 Results of the football match scenario using HSDPA

5.4.2 HSDPA

Using HSDPA technology, all the users involved in the scenario are well covered. Thanks to the higher capability of the networks system can support the huge load generated by priority users.

5.4.3 Conclusions

Table 18 and Table 19 summarise simulations results. GSM has a percentage of successful calls for PROSIMOS users around 80% but it does not work fine for civilian users, where almost no one can talk. On the other hand, HSDPA technology behaves perfectly well for all the users involved in the scenario. The maximum establishment time is lower than the time required in the specifications.

HSDPA has not problems to serve all the users but not GSM. A possible solution to improve the GSM results for civilians is that the PROSIMOS users use HSDPA for their communications. With this solution, the load in the GSM network will decrease and civilians will use it to talk.

6 Future works

This master thesis is the first step to prove that it is possible to change private calls over private networks to public networks during emergencies. Previously, we have shown that we can do it, but this work requires more actions to validate the results. These actions imply to contact with mobile operators and entities that use private networks. With all actors playing their role, it will be possible to deploy a real test that validates the simulated data.

The most important future lines of development are:

- Test the solution in a real environment in order to check the simulations
- Simulate a system where GSM and HSDPA collaborate with the purpose of analysing how video-calls, data services as database queries, personal tracking and continuous monitoring of vital constants work over a public network at the same time that it supports traffic from civilians
- Analyse 4G technologies and select the appropriate techniques to provide enhance and pre-emption over a public network
- Test the 4G technology with the previous techniques in a real environment

Additionally, device's manufacturers should adapt their equipment for emergency situations.

ANNEX A

Título del proyecto: Priority Communications for Critical Situations on Mobile Networks (PROSIMOS)

Entidad financiadora: Comisión Europea

Duración desde: 01/01/2010 **Hasta:** 01/03/2011

Investigador principal: Diego Giménez Pérez (ISDEFE)

Importe de la subvención (UPV): 70.623 **Nº total investigadores del proyecto (UPV):** 4

ANNEX B

Simulator for PROSIMOS (PRiority communications for critical SItuations on MObile networkS) service

[1]Roberto Gimenez, [1]Inmaculada Luengo, [1]Anna Mereu, [2]Diego Gimenez, [2]Rosa Ana Casar, [2]Judith Pertejo, [3]Salvador Díaz, [3]Jose F. Monserrat, [3]Vicente Osa, [4]Javier Herrera, [4]Maria Amor Ortega, [4]Iñigo Arizaga

[1] HI-iberia Ingenieria y Proyectos {rgimenez, iluengo, amereu}@hi-iberia.es
[2] ISDEFE {dgimenez, racasar, jpertejo}@isdefe.es
[3] Universidad Politecnica de Valencia, iTEAM {saldiase, jomondel, viosgi}@iteam.upv.es
[4] ROBOTIKER-Tecnalia {jherrera, mortega, inyigo}@robotiker.es

Abstract. Public Mobile Networks (PMN) are at the very heart of nowadays communications. They are not only used by individuals, but also by a large number of Agencies committed to Security and Safety. This will be even more common in near future, when cities become crowded with real time sensors scattered in every corner of our lives. The ability from this data (and others from First Responders teams) to reach its assigned Command and Control Centers in time can be determinant in a large number of incidents. PROSIMOS project aims at researching on business cases for the implementation of a priority communications system on public mobile networks (PMN). The objective of this system is to enable critical users to communicate during emergency situations, in a time when PMN services may be restricted due to damage, congestion or faults. The scope of the project is to identify the best business case to be adopted to cope with this requirement, guaranteeing its short term implementation in Europe. In order to accomplish this goal a Business Model Simulator has been designed including both economical and network performance features. In this paper we present the Simulator that has been designed in order to identify the most suitable business model and technology to be adopted for the implementation of PROSIMOS service. When taking into consideration enabler technologies for EMSOA PROSIMOS is a not to be missed one.

Keywords: EMSOA Enabler Technology, Priority Communications, Wireless Emergency Communications, Business Models.

Disclaimer. PROSIMOS project has been funded with the support of the Prevention, Preparedness and Consequence Management of Terrorism and other Security-related Risks Programme of the European Commission - Directorate-General Home Affairs". This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

1. Introduction

Private Mobile Radios (PMR) like TETRA, TETRAPOL and many other constitute the backbone of nowadays First Responders' Communications. This realization under the shape of different private networks entails, however, several inconveniences: high deployment and maintenance costs and interoperability problems are the most notorious ones.

On the other hand, Public Mobile Networks (PMN) have a penetration ratio superior to 99% of EU territory, interoperability always guaranteed. Nevertheless its public conception has, so far, discouraged its usage during emergencies, since day-to-day experience has shown how, after a catastrophe, increase in service demand brings PMN to default due to the dramatic increase in service demand.

Some countries have been working on how to make available to First Responders Priority Services in their PMN. It is in United States where most serious advances have been made with the implementation of WPS: Wireless Priority Service, introduced in 2002, for public mobile networks. But, other countries such as UK, Peru, Canada, and Sweden have also taken steps in this direction.

In the use case of Spain analyzed in PROSIMOS, priority communications through PMNs are neither available nor planned in the short-term. Communications for safety issues are handled through a plethora of PMR, deployed at national, regional or local scope, with the aforesaid problems of cost and interoperability.

Fig. 1 PMR maze in Spain

The idea of implementing priority services in public mobile networks for First Responders may overcome some of these problems. Even more, now with the hot controversy going on about net neutrality, PROSIMOS concept is to be born in mind. But in order to become a reality, a deep analysis of user requirements, cost and associated business models is erstwhile needed.

This paper introduces a Business Model Simulator (BMS), for addressing this problem, that is being at present moment developed in the frame of the PROSIMOS Project. It does not only include an economical simulator but also a traffic network one to evaluate the technological aspects like congestion side-effects leading to calls drop and maximum network capacity. The BMS takes into account an extensive set of variables basically belonging to three different domains: User Requirements, considered Scenarios, CAPEX and OPEX costs and applicable Radio Access Technologies (RATs).

2. User Requirements and Scenarios

First phase in PROSIMOS project requires a correct definition of user requirements. After in-depth inquires with several First Responders Agencies, PROSIMOS project has been able to sift major needs and translate them into technical understandable parameters. Prioritization (prioritization mechanisms permanently activated, levels of priority, automatic authorized users set-up…), interoperability, high network resilience, availability, trust and ruggedized terminals are the most remarkable ones. These requirements have been reflected into input variables to the BMS. This consideration will allow end-users to verify the fulfillment level of their requirements among the thousands of possible realizations of PROSIMOS.

Also a definition of use cases and emergency scenarios has been performed. For the sake of the project simplicity, four synthetic test scenarios for the validation of PROSIMOS BMS have been defined. These scenarios are: Incident in a Critical Infrastructure (Metro); Natural disaster in a rural area (Forest Fire); Aircraft crash in an airport and a mass gathering event (like a football match).

3. CAPEX and OPEX costs

In order to estimate the economical impact that the implementation of PROSIMOS service could have on PMN Operators, First Responder Agencies and Government, a deep study of non-recurrent (CAPEX) and operating (OPEX) costs has been needed; in particular, the estimation of these costs in Spain has been performed.

CAPEX costs are mainly (60%) constituted by the update or replacement of the mobile network equipment, that is Mobile Switching Centers (MSC) and Home Location Registers (HLR). In order to compute these costs, the following information is necessary for each mobile operator: number of total MSC and HLR; number of network component that have to be updated on the basis of their lifetime; components unit cost. This information is not available for the public; hence, it has been estimated starting from the information of total number of mobile users, approximate MSC and HLR user capacity and update/replacement costs, and market share of each PMN.

Other CAPEX costs are the following: design and engineering tasks (that cover the cost of consultants); transport, installation and configuration; costs of management and control platform for call priority, that have been estimated starting from other mobile portability platforms; costs of the management and control platform website for user registration and other functionalities for First Responders.

On the other hand, OPEX costs can be classified into fixed and variable costs. Fixed OPEX costs are the structural, personnel and allowance costs related to the new departments founded, and costs related to the operation and maintenance concept. They are the following: priority service management department, that cover the structural and personnel costs; priority service information and training department costs, that cover the structural, personnel and allowance costs; hosting and O&M (Operation and Maintenance) of management and control platform website.

Variable OPEX costs depend on the priority calls routed by the service, in fact it is composed of the quantity: Gross per-minute cost * Priority call length * Number of priority calls: the latter element is quite difficult to estimate at emergency scenario level, but above all, it is difficult to estimate at annual level. One of the goals of the simulator is also the estimation of this quantity.

4. Radio Access Technologies

The ability of PMN to support Priority Services is basic enabler in PROSIMOS. Foundation pillars for this ability are Call Admission Control (CAC) and Congestion Control (CC). CAC is used to control the users' access. CC methods are used to manage the network load in order to ensure the minimum required QoS.

At PROSIMOS considered RAT are GSM/GPRS/EDGE Radio Access Network (GERAN), Universal Mobile Telecommunication System (UMTS) and Long Term Evolution (LTE) technologies. The reason is that the actual public radio technologies deployed in Europe are GERAN and UMTS, while LTE is now considered as the next step forward in the development of 3G networks and its massive roll-out is expected during 2011.

With respect to GERAN RAT and PROSIMOS, three different 3GPP specifications can be used as possible CAC solutions: TS 43.022, TS 22.011 and TS 22.067. The CAC proposed for UMTS are TS 25.304, TS 25.33, TS 22.011 and TS 22.06. Finally, the CAC proposed for LTE is TS 22.011.

When considering CC, one of the first challenges to be solved is determining when the system is overloaded to counteract this state. First step is to know, in average, the load introduced by one user depending on the service. Identifying this load in a GSM system is simple neither for UMTS or LTE. Second, it is important to know the maximum load supported by the network with a specific configuration.

The knowledge of users load is attained thanks to system simulations, conducted to extract the main behavior of users. Extensive simulations have been run in different scenarios and with increasing system loads. Concerning maximum load, this will depend on the business model and the levels of QoS that the operator specifies. PROSIMOS has studied different solutions for the CC implementation in a range of load thresholds that act as inputs for the business simulator described in following section.

In order to determine the technical aspects of the business models, PROSIMOS makes use of a standalone RAT simulator, SPHERE. SPHERE is a novel, ambitious and scalable radio simulation platform for heterogeneous wireless developed in the framework of PROSIMOS. The platform currently integrates five advanced system level simulators, emulating the GERAN, HSDPA, WLAN and LTE RATs.

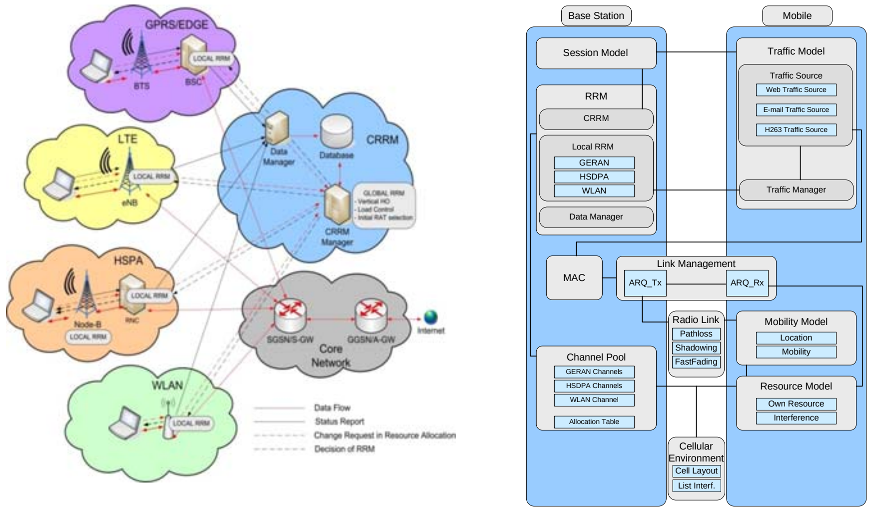

Fig. 2 SPHERE heterogeneous scenario and logic structure

SPHERE is a unique simulation platform that emulates all five RATs in parallel and at the packet level, which enables an accurate evaluation of the final user perceived QoS through the implementation of novel Congestion Radio Resources Management (RRM) and RRM mechanisms. The radio interface specifications of these five technologies have been faithfully implemented in the SPHERE simulation platform, which works with a high time resolution. This modeling approach validates the capability of the SPHERE simulation platform to dynamically and precisely evaluate the performance of RRM/CRRM techniques devised in PROSIMOS.

An example of SPHERE simulator results is depicted in Figure 3. We can see that different network performance indicators are shown in correspondence of different Base Station, and then the overall performance. The indicators are: probability of successive calls, probability of dropped calls, probability of denied calls, call establishment time, etc…, for the different priority class. Note that three priority levels have been defined for First Responders, whereas the fourth level is the one assigned to civilians.

These parameters corresponding to the different emergency scenarios, RAT technologies and user requirements, are then given as input to the Business Model simulator.

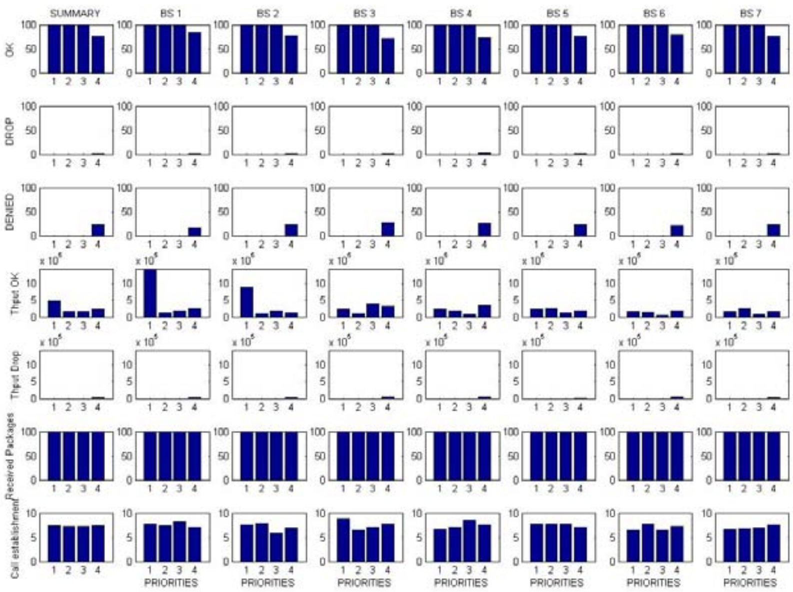

Fig. 3 SPHERE results

5. Business Models

PROSIMOS project outcome is expected to foster the development and favorable regulatory for a set of new services for First Responders across Europe. In order to reach this point it is necessary, however, that the corresponding business models are defined. The basic starting point is the costs analysis, since it will impact the whole business model chain. In PROSIMOS different schemes can be applied in order to translate non-recurrent (CAPEX) and operating (OPEX) cost to the three actors that are considered to be economically supporting the system: Government, First Responder Agencies and finally PMN Operators. In following lines we will produce the three business models that have been considered in PROSIMOS. It has to be noted that these Business Models have been produced after an extensive analysis and synthesis of the different implementation of PROSIMOS service worldwide (in USA, UK, Peru…).

In the first approach it is considered that countries Governments should be responsible for providing needed infrastructure for PROSIMOS, covering CAPEX costs (which in the Spanish case tot up to 48 million-odd Euros), while network operators should take care of OPEX costs. A further step in this line of though considers the share of the OPEX costs among the different mobile operators on their market position. This first type of business model has been named Model OnlyOp, thus referring to the fact that mobile operators only have to cover OPEX costs.

In the second solution we consider what happens when the customer (First Responder agencies) actively takes part in the cost distribution. This means that both CAPEX and OPEX costs can be divided in different ways and percentages between country Government, mobile operators and First Responders agencies. Also in this case all the mobile operators owning a private infrastructure are induced to implement PROSIMOS service. This second type of business model has been referred as Model 3Shared, implying that in this case three entities participate to the distribution of costs.

Finally, the third considered business model encompasses the complex procedures of Public Authorities, bringing up into discussion the issue of public open contests calls for service provision, with the objective of selecting which mobile operator would (on a sole/joint venture basis) implement PROSIMOS service. Only those mobile operators interested in deploying the service would apply to the call (needed appealing of the business model). Decision award criteria would have then to consider the distribution of the costs among the three parties and also the associated operational gain. This third business model has been called Model Exc, thus referring to the fact that in this case an exclusive agreement between a customer segment and a mobile operator according to free market practices is to be reached. As can be seen, each Business Model represents an evolution in complexity from previous ones.

The proposed models vary also from the point of view of the different revenue sources that can be applied (subscription fees, call per minute costs, flat rates, etc…) and they can be further differentiated in other variants that we will not describe here for brevity.

In order to validate the Business Model, a specific Simulator is being developed (in final stage at present moment) in the frame of the project, limited to the Spanish use case, as aforesaid mentioned: the simulator will perform an estimation of costs and incomes for the different business models thus allowing to better understand the most suitable one to be adopted.

It is not indeed straightforward the identification of the best business model for PROSIMOS service without the support of a simulator. This difficulty mainly arises from the fact that several actors take part on the business process. Rather than being a trivial customer/suppliers matter, where companies aim at reaching the maximum profit guaranteeing the satisfaction of the customers' needs, it is a public interest matter where also government and First Responder have to pay a key role in order to foster the implementation of the service. For this reason, we think that business models including a participation of government and emergency agencies in the distribution of costs will probably turn out to be the most suited one.

At this point, an important point must be raised. It is that PROSIMOS Business Models and associated Simulator are considering, at present moment, only voice communications. Although the network simulator (SPHERE) is able of providing information about data traffic behavior, the complexity of already performed work and the foreseen load associated to defining the corresponding BM for data traffic and holistic (voice and traffic) ones have strongly suggested to limit research at this stage only to voice capabilities, providing then the uppermost quality results.

PROSIMOS BMS will help future entities involved in PROSIMOS service to evaluate the performance of the service as well as the implementation costs and the type of revenue sources that are most suitable to refund the investment.

Concerning the BMS, it is composed of three main parts, one committed to the web interface, that will provide a friendly user interface, another one to the specific MATLAB business model simulator development and a third one comprised by auxiliary elements (MySQL database and the SPHERE simulator previously presented).

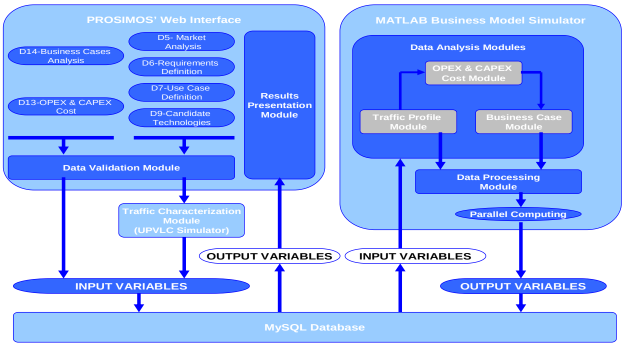

Fig. 3 Business Model Simulator Architecture

Previous input parameters are fed to the BMS through PROSIMOS' Web Interface (certain simplification is applied). Then BMS processes the input variables extracted from the database, through the different Data Analysis Modules. The obtained results are passed to the Data Processing Module in order to calculate the final outcomes, as for example, call cost or CAPEX and OPEX distribution. Finally, all output variables stored in the database are shown in the PROSIMOS Web Portal in an aggregated and understandable way. Examples of output variables are Internal Rate of Return, Gross Profit, Net Profit, Incomes (for Mobile Operators); number and type of prioritized calls (First Responders) carried out along the incident, etc.

6. Conclusions and current progress of work

Prioritization of First Responder communications in Public Mobile Networks will be an essential service in close future for some specific uses cases. PROSIMOS can be then regarded as an enabler "technology" for EMSOA. Conducted research has so far proposed both the technical business models approaches. Both of them will be validated in the simulation phase and are expected to provide important conclusions and recommendations for subsequent steps. At present moment the development of the BMS is in its final stage, and the simulation phase is expected to start in short time. It is expected that the BMS will be available through the project webpage (www.prosimos.eu) to authorized users and general public (under request).

References

PROSIMOS project public deliverables, available at www.prosimos.eu.

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6TH FUTURE SECURITY
SECURITY RESEARCH CONFERENCE
BERLIN, SEPTEMBER 5TH – 7TH, 2011

PROGRAM

GENERAL INFORMATION

REGISTRATION AND OPENING HOURS

The registration desk is open and entry to the conference venue is possible during the following times:

Monday, September 5th:	9.00 - 21.00
Tuesday, September 6th:	8.00 - 19.00
Wednesday, September 7th:	8.00 - 17.00

CONFERENCE FEES

Regular	714,00 €
Students (only with certificate)	357,00 €
Ministries and subordinate agencies	238,00 €

These fees include coffee breaks and lunch buffets, the welcome reception and the conference dinner.

CONFERENCE LANGUAGE

The conference language is English.

CONFERENCE PROCEEDINGS

The conference proceedings will be published on CD under ISBN 978-3-8396-0295-9 by Fraunhofer Verlag. Every participant will get a free CD at the registration desk.

TIMETABLE

MONDAY 5TH SEPTEMBER			
Time	Atrium	Europasaal	Saal Rheinland
11:00-11:20 11:20-13:00		**Welcome and Opening** **Plenary Session**	
13:00-14:00	*Lunch Break*		
14:00-15:40		**A.1** **Sensor Technology for Security**	**B.1** **Crisis Managment I**
15:40-16:10	*Coffee Break*		
16:10-17:30		**A.2** **Supply Chain Security (invited)**	**B.2** **Crisis Managment II**
17:30-21:00	**Poster Session and Welcome Reception**		

TUESDAY 6TH SEPTEMBER			
Time	Atrium	Europasaal	Saal Rheinland
09:00-10:20		**A.3** **Detection of Hazardous Material**	**B.3** **Video Surveillance (invited)**
10:20-10:50	*Coffee Break*		
10:50-12:30		**A.4** **Maritime Security**	**B.4** **Social Dimension of Security**
12:30-13:50	*Lunch Break*		

14:00 15:40 B.1 CRISIS MANAGMENT I

Chair: Christopher Schlick (Fraunhofer FKIE, Germany)

Automated Planning in Evolving Contexts: an Emergency Planning Model with Traffic Prediction and Control
Florence Aligne, Pierre Savéant (Thales Research and Technology, France)

Highly Efficient Event and Action Processing for Emergency Management in Large Infrastructures
Rüdiger Klein (Fraunhofer IAIS, Germany)

Coordinating Ambulance Operations
Thomas Remmersmann, Kellyn Rein, Ulrich Schade (Fraunhofer FKIE, Germany)

PROSIMOS a Tool for Identifying Business Cases in the Implementation of a Priority Communications Systems for First Responders in Public Mobile Networks
Javier Herrera Lotero (Tecnalia-Sistemas de Innovación, Spain)

An Integrated and Integrating Airport Security Management Concept
Torben Hecker, Nunzio Lombardo, Holger Pansch (EBS European Business School gGmbH, Germany)

PROSIMOS A Tool for identifying business cases in the implementation of a priority communications systems for first responders in Public Mobile Networks

Authors

Roberto Gimenez, HI-iberia Ingenieria y Proyectos, Spain
Inmaculada Luengo, HI-iberia Ingenieria y Proyectos, Spain
Anna Mereu, HI-iberia Ingenieria y Proyectos, Spain
Diego Gimenez, ISDEFE, Spain
Rosa Ana Casar, ISDEFE, Spain
Judith Pertejo, ISDEFE, Spain
Salvador Diaz, Universitat Politècnica de València, Spain
Jose F. Monserrat, Universitat Politècnica de València, Spain
Vicente Osa, Universitat Politècnica de València, Spain
Javier Herrera Lotero, Tecnalia, Spain
Iñigo Arizaga, Tecnalia, Spain

Abstract

This article presents the research activities and the results that have been obtained during the PROSIMOS (PRiority communications for critical SItuations on MObile networkS) project. The aim of this project was to investigate the feasibility both technologically and economically of a wireless priority telecommunications service for emergency agencies that relies on Public Mobile Networks (PMNs). The challenge was technological since the system performance with respect to the traditional Private Mobile Networks had to be verified and the advantages and limitations needed to be clearly determined; moreover, it was also a challenge from the point of view of the economical feasibility of the implementation of PROSIMOS service at European level. The project has reached both objectives allowing to clearly identify the most suited technological solution and the best business model to be adopted for the development of PROSIMOS service.

1 Introduction

Effective crisis management is the key factor for guaranteeing an efficient handling of emergency situations and for assuring the security of critical infrastructure and urban areas. In order to accomplish this goal, communications between the personnel of the emergency agencies have to be ensured. Nowadays, these communications mainly rely on dedicated radio telecommunications systems, called Private Mobile Radios (like TETRA, TETRAPOL and others). However, the usage of these private networks entails several drawbacks: high deployment and maintenance costs and interoperability problems are the most notorious ones.

On the other hand, Public Mobile Networks (PMN) are at the very heart of nowadays communications since they are not only used by individuals, but also by a large number of agencies committed to security and safety. Nevertheless, its public nature has traditionally discommended its usage during emergencies. Indeed, day-to-day experience has corroborated how, after a catastrophe, increase in service demand brings PMN to collapse.

The idea of implementing priority services for first responders in PMN may solve some of these problems. In this sense, similar solutions have already been addressed in USA, UK, Canada, Sweden and other Countries. PROSIMOS project has researched on business cases for the implementation of a priority communications system on PMN. The objective of this system is to enable critical users to communicate during emergency situations, in a time when PMN services may be restricted due to damage, congestion or faults. The scope of the project has been to identify the best business case to be adopted to cope with this requirement, guaranteeing its short term implementation in Europe. In order to accomplish this goal a complete simulator has been designed including both economical and network performance features. For this reason, the simulation tool comprises two modules: a network and a business one.

The network simulator is a scalable radio simulation platform for heterogeneous wireless networks. It is

SCENARIO	GSM	HSDPA
METRO	Better results than HSDPA. All priority success, calls rates above 94%.	Success rates above 91%.
FOREST	Poor service results: • P1 less than 90% • P2 less than 70% • No service for non priority users.	P1 & P2 successful rates over 95%. Non-priority users have low access.
AIRPORT	Prioritized users above 90%. Non-priority users reach 60% only if low load.	Both prioritized and non-prioritized users reach 98%.
FOOTBALL MATCH	Very poor results for all users (due to high network load)	Excellent results for all type of users above 99%.

Figure 6 Comparison of QoS parameters for the 4 scenarios

Simulations have helped to find the most efficient economical schemes to implement PROSIMOS service, taking into account Mobile Operators profit and expenses that customers may be willing to pay. Simulation results pointed out 3Shared Variant A as the most efficient business model where CAPEX and OPEX costs are to be shared among Country Government, Customer Segments and Mobile Operators. In addition, duration based revenue sources is the most adequate scheme to refund the expenses keeping high profits for all the operators with lower costs for customers since they present better results than charging a transaction fee per each call plus a cost per minute to the customers. To sum up, results confirmed the service feasibility for the end-users as well as the market opportunity for the operators and industries.

7 Conclusions

The main objective of PROSIMOS was to extract which business model should be selected when implementing PCPMN in terms of rational economic and service efficiency. The results of the project have allowed the definition of the most suited technological solution to implement PROSIMOS service and also the identification of the best business model to be adopted for the service development. In addition, this activity answered several additional issues from the point of view of end-users, some related to the costs comparison between using private networks or prioritization services over the public mobile networks, others related to the most suitable and affordable revenue sources and others related to the technology that provide best performance in QoS terms. Important research activity has been also performed in order to situate PROSIMOS service within the European and worldwide regulatory framework. Concrete results lead to the conclusion that prioritization service over PMN is more beneficial for the users than the deployment and maintenance costs of private network, using HSDPA technology, 3Shared Variant A business model and duration based revenue sources. These results have shown the PROSIMOS service importance and feasibility to the end-users as well as the market opportunity for the operators and industries betting for these leapfrogging technologies over PMNs.
Further research in this field will consider business models for high speed data traffic and next generation networks (LTE) support for PPDR operations.

Disclaimer. PROSIMOS project has been funded with the support of the Prevention, Preparedness and Consequence Management of Terrorism and other Security-related Risks Programme of the European Commission - Directorate-General Home Affairs". This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

References

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