5G in Public Safety Networks: Opportunities and Challenges

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Resumo

Este documento aborda as possibilidades abertas pela 5G na área das Redes de Segurança Pública, ou seja, nas redes de comunicação destinadas às autoridades, polícia, protecção civil, bombeiros, infra-estruturas críticas, e a todos os envolvidos em actividades de emergência e segurança. É apresentada a evolução dos terminais e serviços, até aos novos elementos de desgaste; os serviços associados são também abordados, até às realidades aumentadas e virtuais, bio-métricas e monitorização de sinais vitais do corpo, bem como uma melhor precisão de localização. Os aspectos técnicos são abordados numa perspectiva geral, nomeadamente a métrica de implementação de serviços-chave (taxas de dados, latência, fiabilidade e capacidade de conectividade), interface rádio (maior flexibilidade e eficiência dos 4G) e características de rede (virtualização/slicing de redes e arquitecturas de nuvem/edge). As oportunidades e desafios na implementação de 5G especificamente para Redes de Segurança Pública são muitos, os primeiros englobando a utilização de redes comerciais e o salto das actuais redes baseadas em 2G para as 5G, enquanto que os segundos incluem escassez de espectro, implementação das características necessárias e problemas de segurança. Ainda assim, as possibilidades que são abertas por 5G para as Redes de Segurança Pública são infinitas e ninguém pode dar-se ao luxo de ficar de fora.

Keywords: 5G, redes públicas de segurança, terminais, oportunidades, desafios.

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Abstract

This paper addresses the possibilities opened by 5G in the area of Public Safety Networks, i.e., in communication networks aimed at authorities, police, civil protection, fire departments, critical infrastructures, and all of those involved in emergency and security activities. The evolution of terminals and services is presented, up to the new wearables; the associated services are also addressed, up to augmented and virtual realities, bio-metrics and body vital signs monitoring, as well as improved localisation accuracy. Technical aspects are addressed in a general perspective namely key services implementation metrics (data rates, latency, reliability, and connectivity capacity), radio interface (increased flexibility and efficiency of 4G's) and network features (virtualisation/slicing of networks and cloud/edge architectures). The opportunities and challenges on the deployment of 5G specifically for Public Safety Networks are quite many, the former encompassing the usage of commercial networks and the leap from today's 2G based networks to 5G ones, while the latter includes shortage of spectrum, implementation of required features and security problems. Still, the possibilities that are opened by 5G for Public Safety Networks are endless and no one can afford to be left out.

Keywords: 5G, Public Safety Networks, Terminals, Services, Opportunities, Challenges.

Resumen

Este artículo aborda las posibilidades que abre el 5G en el ámbito de las redes de seguridad pública, es decir, en las redes de comunicaciones dirigidas a autoridades, policía, protección civil, bomberos, infraestructuras críticas y todos aquellos que participan en actividades de emergencia y seguridad. Se presenta la evolución de los terminales y servicios, hasta los nuevos wearables; también se abordan los servicios asociados, hasta las realidades aumentadas y virtuales, la biométrica y la monitorización de las constantes vitales del cuerpo, así como la mejora de la precisión de la localización. Los aspectos técnicos se abordan desde una perspectiva general, a saber, las métricas de implementación de los servicios clave (velocidades de datos, latencia, fiabilidad y capacidad de conectividad), la interfaz de radio (mayor flexibilidad y eficiencia de las 4G) y las características de la red (virtualización/corte de redes y arquitecturas de nube/borde). Las oportunidades y los retos del despliegue de la 5G específicamente para las redes de seguridad pública son bastantes, los primeros abarcan el uso de las redes comerciales y el salto de las redes actuales basadas en la 2G a las 5G, mientras que los segundos incluyen la escasez de espectro, la implementación de las características necesarias y los problemas de seguridad. Aun así, las posibilidades que abre el 5G para las redes de seguridad pública son infinitas y nadie puede permitirse quedar al margen.

Palabras-clave: 5G, redes públicas de seguridad, terminales, oportunidades, retos

I. Introduction

The new 5th generation of mobile communications systems, 5G, has started its implementation in many countries worldwide. Many expectations have been created around this new system, especially because some of the new features associated with it will enable the deployment of new services, promising a revolution in the way that businesses, and organisations in a more general perspective, may develop new products and services, reduce costs, and ultimately communicate with their members, collaborators, customers and everyone else. The reason for these expectations come from the fact that 5G brings new ways of establishing communications in the networks. Contrary to previous generations, the main users of this new system will not be just consumers with their smartphones but rather businesses and organisations with their generalised IoT (Internet of Things) implementations, because the new features are really targeting the latter.

This paper addresses the possibilities opened by 5G in the area of Public Safety Networks, i.e., in communication networks aimed at authorities, police, civil protection, fire departments, critical infrastructures, and all of those involved in emergency and security activities. The paper is structured into 5 more sections, besides the current one. Section II presents an evolution of mobile communication systems, and of private ones in particular, giving the framework for the current status. Section III addresses the evolution of terminals and services, providing also a perspective of the terminals and services that one can envisage for 5G. Section IV gives a general overview of the technical aspects, i.e., key services implementation metrics, radio interface and network features. Section V presents the opportunities and challenges on the deployment of 5G, specifically for Public Safety Networks. Finally, conclusions are drawn n Section VI.

II. The Evolution of Systems

Mobile communications systems started some decades ago, at the end of 1970s, with the 1st Generation, based on analogue technologies, providing voice. At the time, many companies in many countries developed their own system, not only for commercial operation, but also for Public Safety Networks. Since then, technology has evolved a lot, and every decade one has witnessed the emergence of a new generation of mobile communications systems, along with their consolidation via standardisation (while there were more than half dozen systems in the

1st Generation, the 4th and 5th Generations already have only a single one). Table I shows an overview of the systems evolution. The 2nd Generation is already based on digital technologies, enabling voice and data connections, so the evolution on the following generations has been on increasing data speed transmission, until 5G.

Table I – Evolution of commercial mobile communications systems and generations.

Generation / System		**Start**	**Country**
1G	NAMTS	1978	JP
	NMT	1981	NO, SE, FI
	AMPS	1983	US
	C	1985	DE
	…	…	…
2G	GSM	1991	EU
	D-AMPS	1991	US
	PDC	1995	JP
	cdmaOne	1996	US
3G	UMTS	2002	EU, JP
	CDMA2000	2003	US
4G	LTE	2010	SE, NO
5G	NR	2019	KR, US

But this evolution in commercial systems does not have a parallel in Public Safety Networks. Although the change to the 2G systems has been done almost in parallel, together with standardisation efforts, some of them based on commercial ones (e.g., GSM-R for railway communications and TETRA for Public Safety Networks, based on GSM), no further generation systems have been developed, Table II. As a consequence, current advanced commercial systems do not have counterparts for usage as Public Safety Networks and 2G systems are still in use, which leads to awkward situations, e.g., users of these systems needing to use a mobile phone in a commercial network to send data, which are subject to congestion in emergency situations, may not have a proper coverage in certain locations and lack additional security features, among other problems; this is a direct consequence of the most advanced version of TETRA enabling just a few 100 kbps, while 4G provides 300 Mbps, which makes a huge difference when transmitting large volumes of data.

Table II – Evolution of systems for Public Safety Networks.

Generation / System		Country
1G	LTR	USA
	MPT1327	UK
	Motorola	USA
	Ericsson	SE
	…	…
2G	EDACS	SE
	GSM-R	EU
	P25-APCO	USA
	iDEN	USA
	TETRAPOL	FR
	TETRA	EU
	CDMA450	USA
	…	…

The emergence of 5G, and the fact that its radio interface is based on 4G's one, has enabled that the development of a 4G/5G Public Safety Network standard is taking place, in the Mission Critical Communications version. It is expected that during the current decade, a slow handover between the old 2G systems and the new 5G ones will occur, enabling all users of Public Safety Networks to experience in this type of networks the features they are used to in their personal mobile phones, and many more.

III. The Evolution of Terminals and Services

Terminals, which up to now have been mostly mobile phones, have also evolved a lot along these last decades. From the 1G 5 kg voice only phones to current 5G 100 g multimedia ones, many changes have occurred and many new features have been added. In the last years, one has witnessed the appearance of new types of terminals, ranging from personal computers to tablets, but encompassing spectacles, wrist watches and bracelets. The arrival of 5G and the inclusion of many Internet of Things (IoT) features in it will certainly lead to many more changes: the world of sensors and actuators is being brought to mobile communications systems, and with this, many other types of terminals will start to appear commercially (they already exist in a prototype form). More than a decade ago, new types of terminals started to emerge embedded in clothes, shoes and other objects, e.g.: Burton and Motorola manufactured a winter jacket with an FM radio receiver [Outside, 2006]; Nike made shoes with a connection to Apple's iPod [Apple, 2006]; Ermenegildo Zegna manufactured a solar-powered jacket [Luxury, 2008]; Voltaic Systems launched a solar-powered backpack [Voltaic, 2011]; and Google has done a first attempt for multimedia glasses [CNET, 2013].

It is clear then that 5G will bring the possibility for Public Safety Network's users to have a wide variety of terminals, in many shapes and forms, associated to uniforms ("smart clothes") and their gear as well as to wearable devices. One can mention, among others:

- the already existing external video-cameras and communications equipment (voice and video-telephony), which will be embedded,
- enhanced communications devices (e.g., spectacles), namely for augmented and virtual realities,
- navigation devices (using GPS, mobile communications networks, WiFi and Bluetooth),
- bio-metric sensors (fingerprints, facial and iris recognitions, but considering others, e.g., body posture),
- body vital signs transmitters (e.g., temperature, heartbeat, blood pressure and breathing rate),
- detectors of smoke and hazardous substances,
- solar panels to charge devices.

All these features will enable a vast number of services and applications, that will extend much further than the usual current ones. Besides the usual services of voice and video communications, together with web browsing, file transfer and email (just to name a few), one can think of many others that will take the experience of users of 5G Public Safety Networks to a much higher level:

- augmented and virtual realities will enable the deployment of services like the visualisation of the indoor of buildings unknow to users;

- increased navigation capabilities and accuracy of users, making it possible to have an accurate location of users by a central dispatch;
- bio-metrics for the authentication of users, which can be extended to the usage of other devices (e.g., firearms);
- body vital signs for the monitoring of users' health conditions, detection of fatigue and many other situations;
- and remote control of devices and equipments.

These services and applications can definitely improve the professional conditions for the users of Public Safety Networks.

IV. Some Technical Aspects

5G offers advanced features for the services along three axes that are significantly better (at least 10 times) than current ones:

- EMMB (Enhanced Mobile Broadband), i.e., increased data rates that can go up to 10 Gbps (Giga bit per second);
- URLLC (Ultra-High Reliability Low Latency), i.e., reduced latency down to 1 ms and increased availability up to 99.999%;
- MMTC (Massive Machine-Type Communications), i.e., increased connectivity capacity up to 1 000 000 devices/km^2.

The radio interface of 5G is an improved and more flexible version of 4G's, being still based on OFDMA (Orthogonal Frequency-Division Multiple Access). It may adapt carrier frequency, use carrier aggregation, provide more flexible data rates, increase the numerology level, use more efficient and higher capacity modulation and coding schemes, and make use of active antennas with beam forming and beam steering, among other aspects. On the network side, 5G presents a totally new perspective, by introducing virtual networks / slicing and cloud / edge networking.

Although these features will benefit the way that consumers communicate and live, still, one cannot really take advantage of these "extreme" values for a human usage. In fact, it will be up to businesses and organisations to make use of these new features: by implementing ways for the improvement of efficiency in their internal processes, and by developing new services and products.

Furthermore, Public Safety Networks require services that are not available in commercial networks, namely: one-to-many and many-to-many calls; highly encrypted communications; trunking (TMO) and direct (DMO) (with relay) modes operation; fast call set up (less than 1 s); and emergency calls with priority.

5G enables the deployment of private networks, which can be Public Safety Networks, since an organisation can contract a network slice to an operator and use it for its own purposes and/or for the provision of services to its users. The use of virtual networks / slicing will enable isolation, the same physical infrastructure being used to share virtual networks for commercial and public safety usages, and to provide communications to Public Safety Networks to both different groups in a complete isolated way and to all of them in a fully global way. Cloud / edge networking should be used for a hierarchy of communications in operational and non-operational scenarios, taking service differentiation into account and enabling the integration of base stations with cache nodes at different levels of the network.

Security is another major issue that cannot be neglected. It includes various aspects, ranging from access to the network and the miming of nodes to access to and change of information flowing in the network. The increasing softwarisation of the network creates also new challenges for the security of the network and of the information.

V. Deployment Perspectives

The difference between the current situation and 5G is that the set of characteristics enabled by the latter allow for an effective implementation of new services: the high data rate, the high capacity of connected devices and the low latency enable to serve terminals with the required service characteristics that are not possible these days.

One can expect that many economic sectors (both public and private) and Public Safety Networks, which are general to all countries, will include the full extent of 5G in their products and services, e.g.:

- transportation, where vehicles tracking and routes optimisation can be taken to a much higher level, but where services to passengers can be improved immensely (not only in terms of internet access but also entertainment for long-distance travel);
- health care, where the usage of clothes with sensors enable to monitor patients (from chronical diseases to early post-surgery recovery at home), and where extended remote

services can be provided (including remote surgery and much more effective teleconsultation);

- police forces, fire departments and civil protection, where many of the devices and services aforementioned can make a huge difference in the safety of their users in certain operational scenarios.

There is the also the need/opportunity to take advantage of 5G to implement effective communications for critical infrastructures, an example being railways: currently, in Portugal the railway network is not entirely covered by a mobile communications system, and the existing one is based on a 2G system (GSM-R), which is quite limited and does not enable a proper transmission of data at rates required for the implementation of many of the services that should be deployed. Additionally, the communications system for polices, fire departments, civil protection and critical infrastructures (designated as SIRESP) is also based on 2G technology (TETRA), hence, suffering from the same problems as the railways one; again, an upgrade to 5G is imperative in this area.

But, there are barriers in the uptake of 5G. The generalised usage of 5G IoT needs to have very low-cost terminals with sensors and actuators (given the scale with which they will be used), and the very diversified application areas will be an obstacle for the mass production of general devices. Reaching the many different businesses and organisations with appropriate solutions will be very much different from selling smartphones to the consumer market.

Specifically for Public Safety Networks, there are other aspects to be taken into account, e.g.: lack of enough dedicated spectrum, jeopardising a proper deployment of all available features; some lack of standardisation at the world level (by comparison with commercial networks), although many efforts are being done in this direction; the need of specific communication features (as those previously mentioned), which are not common to the mass market, hence, delaying and raising the cost of networks and terminals.

Public Safety Networks must be faced as critical infrastructures, i.e., enabling secure communications, providing coverage "everywhere", having a better degree of redundancy and allowing direct communications among entities, among other aspects.

VI. Conclusions

This paper addresses 5G in Public Safety Networks, starting with a brief introduction that gives their usage framework. The evolution of mobile communication systems, and of private ones in particular, is presented, where one can see that while commercial mobile communications systems have a cycle of a decade for each new generation, the development of Public Safety Networks has basically stopped in 2G. The evolution of terminals and services is also presented, ranging from the basic mobile phones to the new wearables, such as spectacles and wrist watches; the associated services are also addressed, ranging from today's common voice and video-telephony communications to future enabled ones, which include augmented and virtual realities, bio-metrics and body vital signs monitoring, as well as improved localisation accuracy.

Technical aspects are also addressed in a general perspective, namely key services implementation metrics (data rates, latency, reliability, and connectivity capacity), radio interface (increased flexibility and efficiency of 4G's) and network features (virtualisation/slicing of networks and cloud/edge architectures). The opportunities and challenges on the deployment of 5G specifically for Public Safety Networks are quite many, the former encompassing the usage of commercial networks and the leap from today's 2G based networks to 5G ones, while the latter includes shortage of spectrum, implementation of required features and security problems.

Still, the possibilities that are opened by 5G for Public Safety Networks are endless and no one can afford to be left out.

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