RECONFIGURABLE RADIO SYSTEMS FOR PUBLIC SAFETY: NEW GENERATION PUBLIC SAFETY ICT

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ABSTRACT

Reconfigurable Radio Systems (RRS) is a subject which is becoming more and more interesting in that represents an affordable and effective solution for the integration of applications for first responders involved in Public Protection and Disaster Relief (PPDR). These End Users are more and more involved in operations of protection to people environment and properties, addressing a large number of threats both natural and man-made, acts of terrorism, technological, radiological or environmental accidents. Information and Communication Technologies (ICT) have always played an important role in the Public Safety domain. The capability of exchanging information (e.g., voice or data), in particular group calls and situation related data with the required level of security is essential to improve the coordination of Public Safety officers during an emergency crisis and improve their situational awareness. In this paper we focus on the target of interoperability and broadband connectivity in Europe, which are currently the main concerns of Public Safety organizations. This paper explains the specific operational conditions and related main features, the rational for adopting reconfigurable architectures and the level to apply reconfiguration on network components, finally the structure and components of an applicable Business Model is proposed.

I. INTRODUCTION

The definition of Reconfigurable Radio Systems can be considered as a general way of including the better known Software Defined Radio (SDR) which in the last years has attracted the interest of many stakeholders for applications in different market domains. The SDR concept was born in a specific environment, the military domain, in a specific context, the JTRS (Joint Tactical Radio System) program, in a specific country, the USA. Since its inception in early 1997, the JTRS has evolved from a loosely associated group of radio replacement programs to an integrated effort to network multiple weapon system platforms.
This program has already fielded some SDR versions for US military users.

In Europe, the six country ESSOR program aims to the development of a European SDR Architecture based on SCA 2.2.2 recommendations and JTRS public APIs. The ESSOR Program will provide a common architecture, shared by the participating States, that defines radio, platform and security elements.
If we look for other markets in which RRS is deployed, apart from the above military programs, currently real examples can be found in commercial mobile market provided by "SDR like" based Base Stations able to perform multi RAN (Radio Access Network) including 2G/3G/LTE and multiple wireless access technologies including GSM, UMTS, CDMA2000 and WiMAX.

Outside of the above contexts, then also for Public Safety (PS), there is still not a real market exploitation of the SDR capability and relevant knowledge acquired by many companies already involved in military programs, both in US and Europe.

We can find among the reasons of this situation the economic one, in that the deployment of dedicated Public Safety networks is usually very demanding for Public Safety organizations from an economic point of view and its national funding and private investment deserve a suitable support until now not verified. A national or regional network is usually an investment for 10-15 years or more, but a technological innovation like SDR and the Cognitive Radio (CR) should help to minimize the impact of design, development, deployment and functional updating on infrastructures and terminals.
A further reason for this situation is the lack of a real demonstration of the benefits which a RRS can provide so as to allow PS End Users to effectively use ICT infrastructures and services in performing their duties.

Among the PS End Users, first responders include law enforcement, firefighters, emergency medical personnel, and others who are among the first on the scene of an emergency.

PS users need to collect, analyze, distribute and store information among various entities and different contexts. This task requires a set of capabilities, which include resource management, supply chain management and access to relevant data and communication. Communication is an essential element in various operational scenarios and at

different levels of the hierarchy of PS organizations. First responders should be able to exchange information (i.e., voice and data) in a timely manner to coordinate the relief efforts and to improve situational awareness of the environment.

Frequently these capabilities must be provided in a very difficult environment where critical infrastructures (e.g., energy, communications) are degraded or destroyed by the natural disaster, then unplanned events that cause panic conditions in the civilian population and affect existing resources (e.g., transportation), making the task of first responders even more difficult. In large natural disaster, many different PS organizations may be involved, utilising different information management technology and communication systems. These topics have already been experienced in many geographical contexts and, because of this, interoperability among first responders is crucial.

The need for interoperability has been experienced at all level of information flow, both at radio communication level and at procedure and application level. The user applications and the relevant SDR features able to make operative and cost effective the PS ICT evolution could be the key items able to pave the way to the RRS application in the PS market.

There is a growing public awareness of challenges such as terrorism and environmental disasters and therefore increased political support in enhancing the capability and efficiency of Public Safety organizations. In Europe, this is also driven by the progress of the European integration which is aiming for a closer cooperation among Public Safety organizations. As a consequence, there is increasing support at political level to remove interoperability barriers (operational or technical) among national organizations or European member states.

Existing challenges and future trends for broadband connectivity requires new business approaches and technologies for the next generation of PS communications. This paper will evaluate the benefits of new SDR and CR for PS organizations. The following sections explain the specific operational conditions and the related main features, the reasons to adopt reconfigurable architectures and the level to apply reconfiguration on network components as well and, finally the structure and components of an applicable Business Model is proposed.

This paper is organized as follows. Section II describes the operational contexts, essential requirements and challenges for public safety communications with a special focus for interoperability and lack of broadband connectivity. Section III describes the benefits of Reconfigurable Radio technologies. Section IV describes the deployment considerations for Reconfigurable Radio technologies. Section V discusses the business and economical aspects of the introduction of Reconfigurable Radio technologies in the Public Safety domain. Finally Section VI concludes the paper.

II. OPERATIONAL CONTEXTS

Many European programs, both EU (European Union) funded[1] and ETSI managed[2], have proposed a set of documents defining the operational and functional requirements of radio communication for PPDR environment. These programs have also provided results of interaction with End Users aiming to collect requirements and lesson learned from real crisis management experiences. Several EU funded programs[3] performed studies and demonstrations for the application of wideband technologies for PPDR.

The End Users are able to specify the relations among authorities and organizations during emergencies in term of policies or procedures and required services [1]. In order to define the requirements of a PPDR communication network, the operational requirements and the applicable procedures have to be considered.

Interoperability among wireless communication services and functions is a main operational requirement at all the functional layers of information flows and a number of interoperability barriers are present at each level (see Figure 1). The information source in the User Domain encompass contact points and the related hierarchies among PPDR personnel which in turn adopt operational procedures defining “who talks who” and the data format providing the information managed by the Application/Service Domain. At this level an example of diffused protocol is the Common Alerting Protocol (CAP) approved by the OASIS[4] organization [2]. CAP provides a consistent situation picture by means an open, non-proprietary digital message format for all types of alerts and notifications.

Interoperability has to be implemented also at the radio communication infrastructure level able to support the relevant information flow [3]. This infrastructure has to allow every PS first responder to connect to the required services and the ways in which these services are integrated and performed in the deployed network is a sensitive subject.

Already some questionnaire outputs [4]-[5] indicate that the range of applications in demand by PPDR users is extending beyond the traditional core, that’s group-call-based voice and data applications. There is a trend to require access to the same range of applications, services and referenced data bases while in the field as an officer would have in command centre [3].

[1] WINTSEC, EULER, E2R, E3, IMSK, OSASIS, CHORIST, WISECOM, WIDENS

[2] EMTEL, MESA, TC RRS, TC TETRA

[3] FP6 and FP7 (FP = Frame Program)

[4] OASIS (Organization for the Advancement of Structured Information Standards) is a not-for-profit consortium that drives the development, convergence and adoption of open standards for the global information society.

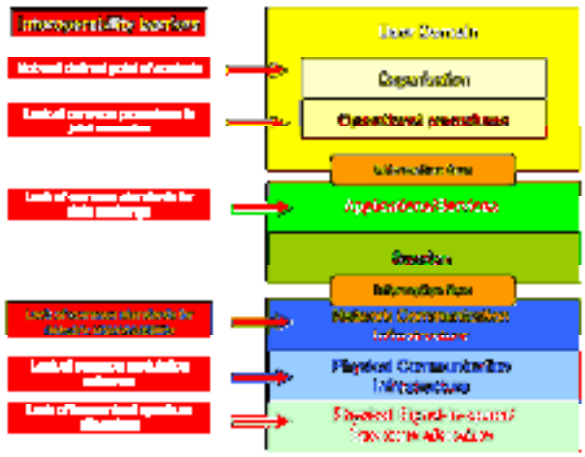

Figure 1- Interoperability levels through information flow

To understand the needs of PS organizations, we have to describe the operational contexts in which they operate. A synthetic description of these contexts is shown in Table 1.

Table 2 Public Safety operational contexts

Operational Context	Description	Features
Urban Area	Emergency crisis in urban environment like large cities or metropolis.	High density of population, different types of PPDR organizations, fast reaction times, network often overloaded.
Cross-Border	Law enforcement activities in border areas among nations or geopolitical regions. This scenario can be based on a blue border (e.g, sea, lake) or green border (e.g., land)	PPDR organizations from different countries and presence of interoperability barriers
Rural Area	Natural disasters in Isolated areas outside towns	Lack of network coverage.
Overlay PMR areas	Crisis and areas where heterogeneous commercial and dedicated networks coexist but security issues require the adoption of private networks	Presence of heterogeneous networks with different security levels.

While commercial networks may be present in the disaster area, Public Safety users are reluctant to use them for a number of reasons including:

1) Public networks do not offer sufficient connection for involved users. Trusted voice and data transfer and the need to avoid traffic constraints make not suitable commercial networks adoption (high levels of network availability and low latency);
2) Public network do not offer sufficient security level. Information protection is required both in the crisis area and for interaction with external users;
3) Public networks in the crisis area may be compromised;
4) Interoperability specific need: Public Safety organizations use various communications systems based on different standards (mainly TETRA + TETRAPOL in Europe, APCO P25 in USA/Canada and DMR across Asia, the Middle East, Europe, North and Latin America, Africa and Australasia);
5) Direct mode (terminal-to-terminal capability) is not provided nor foreseen by commercial network;
6) There is no provision in current commercial networks for pre-emption capabilities or preferential measures which are necessary to provide guarantee services for PS.

III. Benefits Of Reconfigurability In Public Safety Domain

Even a country of limited geographical size like Italy has experienced the need for a radio infrastructure able to meet requirement of fast response for link establishment in situations where the contemporary deployment of LOS (Line Of Sight) and BLOS (Beyond Line Of Sight) radio links are becoming increasingly necessary and with additional wide and broadband capability.

In addition we have to address not only national considerations but also we consider international cooperation. For this purpose a minimum set of radio communication standards could include major radio communications system standards like TETRA, P25, WiMAX or LTE and satellite, typically required on Public Safety applications.

The interoperability requirement has been also experienced in instances in which cooperation with military forces is necessary, given their logistic and technology capabilities. The need for interoperability between military and not-military forces increases within crisis situation caused by terrorist attack and the necessary countermeasures that have to be established. Then a wider-scale vision of interoperability has to consider all the aspects concerning security and to define specific security profiles for specific operations.

Among the recently funded programs by the European Community, EULER has been addressing interoperability including security and radio communications through the deployment of SDR concepts. The EULER solution is depicted in Figure 2, where the RAN is a fast deployable network providing the radio communication infrastructure and a set of centralized services for the different Radio Access Technologies (RAT) and different users. EULER will demonstrate a broadband capable access network amongst SCA (Software Communication Architecture) based BS (Base Stations) and SS (Subscriber Station) SDRs, interoperable with WiMAX COTS products and TETRA professional radio. The deployed SCA based SDRs will run a specific profile of WiMAX standard carried out via full SW implementation.

A PS network deployment like the one EULER program is going to demonstrate has to resolve the following inter-working aspect:

- Physical layer and protocols characteristics matched between the systems (RATs and RAN), including conversion of physical and electrical states, rate adaptation and transmission attributes, in-band signaling conversion, codec and encryption issues, PTT (Push-To-Talk) mode vs. duplexing mode [6];
- IP/TETRA Gateway;
- Mapping service data units with an inter-working protocol, including conversion, filtering and discarding;
- Handle compatibility information and service agreement;
- Provide conversion between numbering or channel allocation plans;
- Information assurance.

Figure 2 – EULER demonstration set-up

There are also other reasons regarding the radio frequency spectrum policies in adopting Reconfigurable architectures.

At European level a real harmonized band exists only for narrow band and currently it is quite difficult to identify new harmonized bands across Europe below 1 GHz. Broadband capable networks have as competing or alternative solutions WiMAX and LTE and no definitive standard seem to be proposed for wideband application. Therefore in summary, the issue concerning "*Best effective adaptation to radio frequency spectrum policies and technologies evolution*" involves the following relevant topics:

- Rugulation fragmentation and delay at European level (only 10 MHz currently harmonized but other national based frequencies ranges are currently used in Europe);
- Different narrowband technologies (FM VHF, TETRA, TETRAPOL);
- Need to capitalize the investment in current technology development allowing for the adoption of modular and incremental new technology insertion moving from the current narrow band solutions to the next wide and broad band technologies (from TETRA/TETRAPOL to TETRA TEDS and WiMAX/LTE);
- There are many candidate broadband technologies but not yet a specific one has been considered as a preferred standard (ex. WiMAX Vs LTE) therefore stressing investments decisions that could be effectively overcome by RRS adoption.

Broadband technologies for PS are already being development by several suppliers but this doesn't mean the current technologies will be immediately replaced. A period of multi RATs including legacy will occur and in order to be ready to face this technology insertion the current interoperability limitation will need to be overcome.

Therefore, with the above operational need and the potential reconfiguration capability applications on PS, an analysis can be carried out concerning the level the reconfiguration should be applied.

IV. Deployment Of Reconfigurable Technologies And Applications

Following the information flow depicted in Figure 1, we can verify the Application/Service Domain, distributed among HQ (Headquarters) local command centers and responders, including applications like emailing, short data/short message sending, data base access for image storage and retrieval [1]-[3]. The current technology already enables incident reporting applications to be integrated into the radio terminal [7], then reducing the responder need to

return to HQ/command centre to access office applications [3] . Currently, the responders and mobile command centers need to connect portable PC running the above applications to radio terminal for network access. Then, existing logical interfaces and protocols have to be applied at waveform and radio services level so as to adapt to new applications, typically designed as web applications.

Now we can already consider and design Smart Radio Terminal(s) (SRT[5]) capable of hosting computer applications. The application can consist of client side with HMI (Human Machine Interface) executed on the terminal, and server side with data gathering executed on the network referred base station. Some Base Stations could temporarily[6] collect sensor data, like images and maps retrieved by remote data bases or sensors, so as to perform most intensive computation and send pre-processed data to the terminals for user management Figure 3.

Emergency related messages based on diffused standards like CAP can be exchanged and locally managed by users directly by means of their SRTs [2],[8]. The standard concerning data exchange is an important issue constraining the applications. In fact, data needed in emergency application, and also in daily operations, may be used by multiple applications. These must be able to share data with one another and present data in a format that is usable by other applications.

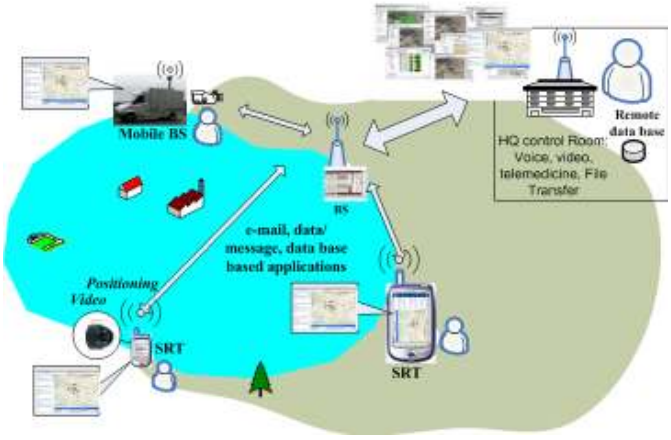

Figure 3 – Applications integration in Smart Radio Terminal

During the initial response hours the PS users need fast deployable and diffused data transfer other than narrowband voice communications. The Italian experience during L'Aquila earthquake demonstrated the effectiveness of suitable coordination which allowed for the fielding of a wide and heterogeneous environment of first responders. The following Table 3 lists the responders involved within the first 48 hours [9].

Table 3 – First responders for L'Aquila earthquake

	24 hours	**48 hours**
Fire fighters	2010	2400
Armed forces	1520	1650
Police	1500	2000
Red Cross	800	800
Volunteers	2000	4300
K9 (rescue dogs unit)	108	134
TOTAL	**7938**	**11284**

Present and future PS applications are dependent on the operational contexts (see Table 2), where PS organizations operate. For example, in the cross-border context, the verification of biometric data is quite important. In this application, Public Safety officers may check the biometric data of potential criminals (i.e. fingerprints) or illegal immigrants and transmit them to their Head Quarters (HQ).

Many PS applications require reconfiguration capability. At PS user level the terminal allows for the activation of group-calls with the capability of sharing information output via situation awareness applications locally executed and providing a common operating picture. The reconfiguration capability of the terminal shall concern the applications and also the applicable policies. These include procedures that should be followed for data sharing (whom and how), common formats, spectrum policies adoption according to pre-set plans or dynamic management. All involved terminals have to adopt policies tailored for the specific operation among those ones defined in section 2 (Table 2) and sometimes agreed among users of different nations. All that could require the policies up-dating and the support to the dynamic creation of multi-services teams connected across multiple networks ([1] paragraph 5.3.1.2). Then the reconfigurable terminals shall be able to load standard based common policies and update their applications suite in order to meet the PS users need evolution.

Hence the applications distribution and integration model above described can be implemented by well-designed reconfigurable devices adopting suitable SW and HW solutions. Logical interfaces adopted by the devices have to allow for the installation of new applications and interoperable data management. These interfaces should be standardized in order to make technology independent new application installation (Figure 4).

[5] Here with terminal we mean both vehicular and handheld.

[6] Some information could be sensitive and not suitable to be stored in unmanned base stations.

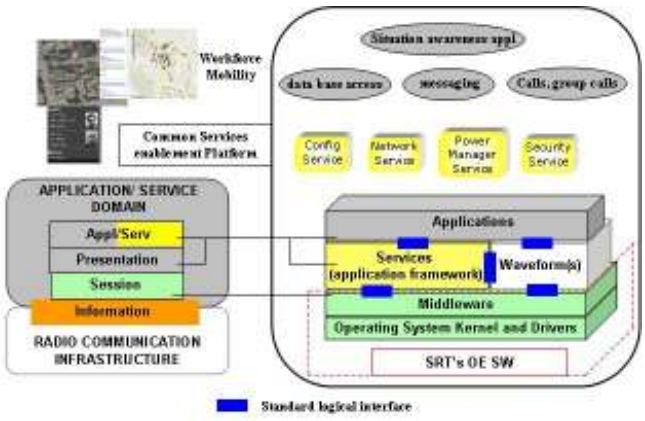

Figure 4 – SW Environment for applications distribution and integration model

The adoption and installation of new applications have not to be constrained by the RATs they relay on to transfer their data. This technology transparency should be provided also with respect the intrinsic mechanisms offered by some standards like TETRA[7], in order to perform basic services, like group-calls and short message sending contemporary to voice connections [10]. This relationship, also including policies, is quite relevant for BS performing multi RATs eventually installed in it. We can suppose an initial set of applications will be gradually deployed and then the SRT capabilities will be gradually update. These applications will adopt "web-based" like mechanisms and will have to rely on the services framework in turn adopting standard protocols using a common markup language suitable to exchange heterogeneous information. This "application centric" approach, already experienced on PC based solutions and recently in smart phones seized applications, is the main issue of ICT based new generation Public Safety interoperability.

Interoperability concerns also specific topics involving security mechanisms. The BS protects unauthorized access to data transport services by enforcing encryption of associated link level transport services across the network (e.g., service flows for WiMAX). In addition, in order to protect from "denial-of-services" attacks, the encryption is generally applied so as to protect the network signaling. This is an additional issue that rises at higher level of complexity in heterogeneous or multi-RAT networks (see Figure 5). This condition will goes on again for many years because the legacy technologies will be not replaced at short time.

[7] TETRA, like other PMR complying with Schengen European Police forces, includes supplementary call services (SCHENGEN Police Telecom Group, already replaced by Public Safety Radio Communication Group – PSRG, adopted TETRA for pan-European police communications).

New RAT insertion in deployed PPDR networks would have to be carried out without constraining or limiting the applications available to the users making the PS application environment more and more "infrastructure independent".

Figure 5 – Heterogeneous or multi-RAT networks (PMN = Professional Mobile Network)

PS network components at node level and higher one support services in different ways. BSs providing radio access support for group connections involve sometime multiple geographic units then supporting group services across multiple networks. BSs can perform all the functions of the radio communications infrastructure, allowing for physical and logical connections between remote user groups including authorization verification and sensitive data protection. These subjects mainly concern network interoperability for effective cross-border cooperation. In Europe this subject has been faced from 1990 when the standardization of TETRA Air Interface and Inter-System Interface (TETRA ISI) began. TETRA ISI addresses cross-border communications between independently owned and operated TETRA networks and its following relevant features provide an important area of ICT solutions application:

- Allow terminals to use a foreign 'independent' network when required;
- Allow users in one network to communicate with users in another 'independent' network (individual call, group call);
- ISI Gateway (GW) to control the system's access policy regarding foreign users;
- Basic services such as Group Call, Individual Call and Telephony services including status and short data service;
- Provide "roaming" capability for terminals moving from one network to another (i.e., cross border roaming).

The ISI GW will make interoperable different national system solutions adopting different channels management and related end-to-end encryptions.
This transparency will be applied also to services level allowing a mobile terminal to access to home network services and, following the roaming phase, to the services available in the host network (TETRA migration) maintaining the same user interfaces and related facilities.
The TETRA ISI standard content is partially defined[8] [11]-[12] and it is still not in operation today. After first trials faced by Motorola and EADS concerning a subset of necessary services, a full set will have to be agreed at wide extension in Europe. In the last years this subject has been discussed [13] claiming a solution adopting IP packet switched concept being already it a subject of EU FP7 funded programs like SECRICOM [14]. Then TETRA-ISI is a chance for adopting reconfigurable solutions able to make compatible and interoperable a suitable minimum set of basic services that can be aligned and standardized across national systems at Switching and Control node level (see Figure 6). This is a chance for integrating new services and to allow new suppliers to be involved in the business and relevant value chain.

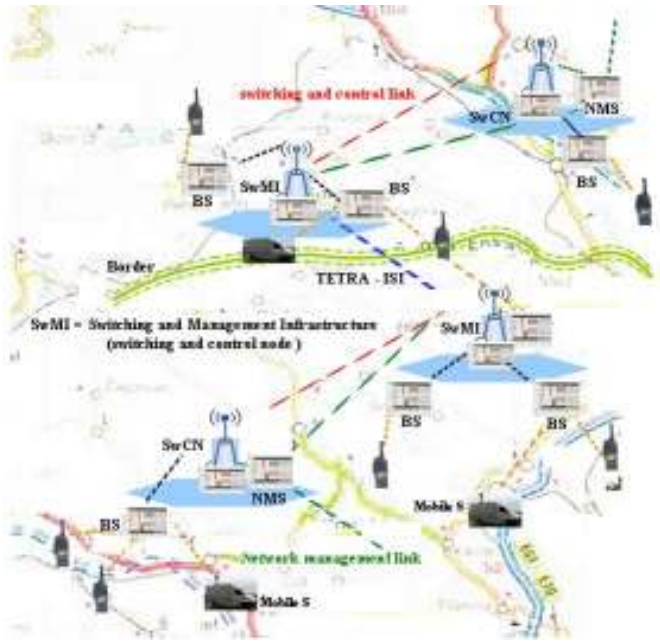

Figure 6 – Cross border TETRA interface

[8] Progress has been made over recent years to complete the ETSI standards, TETRA Interoperability Profiles (TIP) and Test Plans for the features that comprise two phases. More recently, the Group Call specification and test plan has now been completed. Functionality described as Phases 3 & 4 remains incomplete, with some elements not yet agreed within ETSI. The first proof-of-concept testing was completed successfully in March 2009 and witnessed by the independent test house. The functionality tested was individual call and short-data.

In the frame of European harmonization of frequency bands for the implementation of digital radio communication for Public Safety, reconfigurable technologies could also provide important benefits.
In the future, the allocation of harmonized spectrum bands at European level for public safety will become increasingly difficult, especially in the lower frequency bands (below 500 MHz) where the majority of the existing public safety networks are operating. The reference [15] presents a detailed analysis of the current PS spectrum assignments and potential solutions to support wideband (up to 1 Mbits/s) and broadband applications (greater than 1 Mbits/s).
As a consequence, there is a need for new approaches and new technologies for overcoming the current spectrum deadlock and for exploiting the capability allowable by future harmonised additional spectrum where that one proposed by TC-TETRA community is a candidate (see [15]). A potential solution is to adopt dynamic spectrum management (DSM) where utilization of spectrum bands is flexible on the basis of the context of the availability of spectrum bands. For example, in the cross-border context, a reconfigurable device could use different spectrum bands depending on the location. In another example, in a rural area hit by an earthquake, commercial infrastructure could be degraded or destroyed in the aftermath of the disaster and PS equipment could operate in the commercial bands, which would not be otherwise used in the disaster area.

Regardless of the adopted solutions, the future spectrum policies the European Parliament will set in the medium term[9], the spectrum management will be an issue to face and the relevant solutions will require reconfigurable devices for network components.

V. BUSINESS AND LIFE-CYCLE CONSIDERATIONS

As already positively experienced on 3G market, the application centric view has been and it's the driver of the mobile commercial market as it has been changing the old first generation mobile phone to the current smart devices. Then, the applications and the services they rely on are the key by means of we can find common topics rather than contrasting elements between PS and commercial markets. The environment of PS is a fertile area where to apply an application-centric approach being it not concentrated and limited on the cost optimisation of fixed functions and RATs related devices.

[9] On 9 December 2010, the European Parliament's Committee on Industry, Research and Energy (ITRE) discussed the "Proposal for a decision establishing the first radio spectrum policy program" (RSPP), adopted by the European Commission in September 2010. The ITRE Committee will vote on the report on 12 April 2011. The expected date for the vote in the plenary is 9 May 2011. More information is available at: http://www.europarl.europa.eu/oeil/FindByProcnum.do?lang=2eprocnum=COD/2010/0252.

Of course this requires an initial investment unlikely to be accepted, mainly in this period of economic crisis. In order to provide help in this phase, the EU has been funding R&D, mainly for SME (Small and Medium Enterprise), by means of the EC funded FP6/7 programs, with respect relevant themes named Security, ICT and IST (Information Society Technologies). The ideal target is to fund projects able to output user applications prototypes fielded, tested and validated by first responders. An example of this effective path is the FP6 REACT[10] program executed in the time range 1/9/2006-28/2/2009. The topic of REACT was aims at reducing risks to citizens and the environment by enhancing the interactivity of citizens with Emergency Services and by providing added value to integrated information coming from disparate sources. REACT has supported existing emergency systems by providing an interoperable multimedia Enhanced Emergency Call Service. An interoperable system prototype CAP/TSO based (see [2],[8]), output of REACT was tested in the final phases of the program. Thanks to the one month trials carried out in Venezia (Italy), CNVVF[11] operators were also able to test the improvements on their daily-work in a live environment [16]. Updated and specialized version of the above prototype was used during L'Aquila earthquake emergency. The company in charge of developing the prototype was able to exploit its work done for the prototype realization so as to achieve a product suite which consists of XML based web applications.

Other FP6/7 programs have offered a chance to develop new technologic solutions and relevant products [17] and the FP7 Security theme still proposes specific topics concerning technical solutions for interoperability between first responder communication systems [18].

Among these topics TETRA and TETRAPOL standards and also TETRA-ISI are involved.

This concerns also the cost drivers and relevant reference to the initial costs that couldn't be effectively sustained by means of short term local strategies due to national governments. Then a medium and long term strategy effective to start new business cases can be managed only at European level. International cooperation between end-users, as required to occur in every PS related EC funded program, is mature. General ISI topic and relevant involved user applications set are subjects which can foster the business at medium term rather than be a limit. As a consequence a reconfigurable architecture for the network components will offer an effective way to allow additional services and additional suppliers to be integrated in the business model and relevant value chain.

According to this model there is a chance to take in the PS market new stakeholders, currently aimed mainly in commercial or military markets. These technology experiences, currently applied to PC based platforms, could be the basis for the development of embedded versions as the programmable devices technology already now allows for deploying the applications in such low power portable devices. The experiences collected on web-services applications can be exploited in all the components of the PPDR network. Security features and services access protocols could be effectively replicated. These experiences allow for making ready an environment of application SW suppliers already able to design and develop PS related products as these suppliers know PS operators needs and constraints.

We could also see in this phase a chance to develop civil-military synergies following a trend already occurred some tenths years ago. In the past the military budget reduction and the increasing R&D activity in the civil applications have moved the trend of ICT innovation. This moving was even funded by private stakeholders. Evident signals of this trend can be found also in US Army with the adoption of ruggedized versions of commercial tablet computers [19] and, recently a combination of smartphones plugged into tactical radios included in the equipment of small Army units [20].

Of course, in order to avoid making ineffective the sustained effort, this virtuous approach will have to get the best but affordable technologies for the PS market. In fact Public Safety market is much smaller in comparison to the commercial market (in volumes of equipment) and military (in budget). This aspect has an impact on the final cost of the equipment as high volumes of network units are required to provide an adequate return on investment and to lower the final cost for each unit. Synergies among the three different markets can be used to reduce the equipment cost in the Public Safety domain. These synergies have to be found not only among technologies and R&D funding but also allowing the coming of new players, among them that ones specialized on developing and selling of functional and application software.

The first and leading interface is for the PS customer the initial supplier that's the System Integrator or OEM (Original Equipment Manufacturer). By means of partnerships among OEM, user applications developers and sub-assembly providers a modular value chain could be created in order to provide the best but affordable solution (see Figure 7).

The RRS concept moves the lifecycle concept application from the overall terminal or base station down to the single subassembly, application and waveform. The lifecycle concept for the RRS terminal can be applied from the technological point of view in order to increase processing performances or to manage the obsolescence.

[10] REACT = Reaction to Emergency Alerts using voice and Clustering Technologies

[11] CNVVF = Corpo Nazionale dei Vigili del Fuoco (National Fire Brigade)

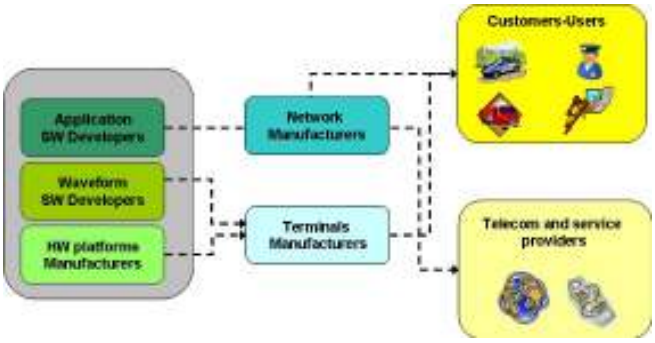

Figure 7 – Value chain stakeholders

The Life Cycle costs and Radio System Cost Model are two subject already faced by the WIF (Wireless Innovation Forum) (see respectively [21], [22] and [23]). Here we can refer to these references correlating them to the specific topics described in this paper.

The impact of some cost drivers are lowered with the use of RRS/SDR technology, but someone could still see others costs may be increased. But, as already foreseen in the previous analysis (i.e. WIF), the continuous evolution of the technologies and the growing need of PS users have pushed the supplier to remove some limits again considered just some years ago. The processing overhead due to "hardware independent" architecture like SCA based SDR has been quite reduced with both the technology evolution and the experiences (see [24]-[25]). Additional overhead reduction can be also obtained with "light architecture" based SDR, like the current SCA next foresees [26][12]. The upfront cost due to the training on Software Defined (SD) architecture development has been faced by many manufacturers as the SD versions of terminals and BS functionalities are already applied, as some manufacturers operating in military or commercial markets have proved. As for the commercial sector, for PS a suitable SD profile can be selected and adopted in order to design RRSs able to effectively reduce the operational life costs including the user training, the maintenance and the upgrading. The latter cost driver is the more sensitive for the users as they can positively accept the application upgrading capability allowed by RRS.

VI. CONCLUSIONS

Some world wide diffused opinions are shared among the PS operators. First of all, the interoperability has to be at every level involved by the information flow, from the hierarchy level to the RAT, including the inter-system level.

[12] SCA next includes lightweight SW components and CORBA neutral models. The Full SCA Profile is a superset of the Medium SCA Profile, which is a superset of the Lightweight SCA Profile. Each profile may be overlaid with additional functionality.

At application level the interoperability concerns a set of required user applications, more and more evolving, as the result of the evaluations provided by studies and field experiences. The current envisaged applications set already is as wide as to match the need of many PS domains involving PS users in their day-by-day operations or crisis recovery missions. The framework of ICT based user applications and relevant RRS features able to make operative and cost effective the PS ICT evolution could be the key item able to pave the way to the RRS application reviving the PS market.

As already experienced in the past for the commercial market, now the application centric view can leverage the intrinsic technology capabilities of RRS for PS.

It's up to every country, at regional or national level, to involve the relevant stakeholders so as to make efficient and effective the economic effort. At European Union level, relevant authorities are setting the strategy for activate policies, dual use technologies applications and the coordination.

Finally, to complete this paper, a consideration is worth to be done. A lot of publications, among which some references mentioned in this paper, consider the public safety sector a niche market. This is the current situation. But if we think about all the natural disasters occurred in the last ten or more years, also including the terrorist attacks, then we would think about the number of first responders involved all over the world.

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