An IMS-based Interoperable Architecture for Heterogeneous Emergency Services

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Abstract— **Nowadays there is a growing uncertainty about the near future evolution of classical PMR solutions due to spectrum scarcity, digital dividend issues and economic crisis. This paper aims at facing this situation by seizing the existing window of opportunity due to the convergence of the IMS as a predominant enabler for future multimedia networks and the deployment of commercial LTE networks. The paper details an innovative emergency inter-networking system capable of connecting existing first responder communication systems and enabling the integration of next generation mobile networks by defining technology independent standardized interfaces under the umbrella of IMS. Concerning the experimental outcomes, the paper focuses on the reference implementation to interface with the proposed system.**

Keywords—IMS, LTE, TETRA, Emergency, PMR, mobile, 4G, Interoperability.

I. INTRODUCTION

In the current digital world, the users of first responder communication systems are aware of the benefits that the interconnection between different Professional Mobile Radio (PMR) and the integration of new advanced data services could bring to their professional sectors. Considering the current multimedia capabilities of both emergency and general purpose mobile terminals, it is just a matter of time that we see police or fire-fighter units transmitting image-based vital information in real time to central stations or to other mobile units in order to assure quick and expert responses to critical incidents.

In order to satisfy this need for broadband data services, different PMR technologies have tried to improve data transmission capabilities [1]. For example, TETRA Enhanced Data Service (TEDS), standardized with TETRA Release 2 at the end of 2005, has been considered as a suitable alternative for advanced security services, such as video surveillance and extensive image sharing or positioning services. Nearly 5 years later, in May 2010, the world's first big scale TEDS pilot delivered to a customer's network (VIRVE, Finland's nationwide TETRA network) was launched. However, TEDS technology is getting obsolete for the requirements of new security applications and the need for upgrading to broadband is a recognized fact. In fact, despite its potential capabilities, the first wave of TEDS gear coming out will not meet the broadband requirements, due to limited spectrum availability for existing TETRA systems resulting in 50-100 kbps data services (far from theoretical maximum of 540 kbps). Thus, the discussion in the TRA Association has been lately focused on which kind broadband of broadband solution should be adopted: integration of other broadband technologies or evolution of TEDS technology.

At the same time, commercial wireless technologies have been evolving from traditional GSM/GPRS/UMTS services towards more advanced wideband solutions such as WiMAX or LTE, trying to support wider coverage and higher data rates (up to 50-100Mbps). The future of mobile communications seems to be directed towards an all-IP world, which has raised considerable discussion regarding the provision of multimedia services in Public Safety [2]. During 2010, the GSM Association (GSMA) adopted IP Multimedia Subsystem (IMS) as the key driver technology to support voice services over LTE. Thus, IMS can be considered as the candidate for the provision and management of multimedia services of future 4G networks.

On the other hand, in order to incorporate new advanced multimedia services to first responder communication systems, it is compulsory to assure no saturation of the critical communications infrastructure. In such scenario the convergence of both high capacity general purpose mobile systems and PMR systems is emerging as a relevant topic. In fact, several PMR organizations have initiated the use of both technologies providing their professionals with dual terminals, although the use remains separated between critical and non-critical transmissions. A converged scenario will enable those professionals to make the most of both worlds, while assuring an accurate use of critical resources.

GERYON project is a European initiative [3] which aims at facing this situation by seizing the existing window of opportunity due to the convergence of the IMS as a predominant enabler for future multimedia networks and the imminent deployment of commercial LTE networks.

GERYON proposes an innovative emergency inter-networking system capable of connecting existing first responder communication systems and enabling the integration of next generation mobile networks by defining technology independent standardized interfaces and autonomic configuration and adaptation techniques under the umbrella of IMS. Proposed system ensures seamless operation regardless the access technology and take advantage of coverage and

responsiveness of existing PMRs and broadband data services of 4G networks.

GERYON demonstrates both classical (i.e. PTT, MTP and preemptive calls) and enhanced emergency services (i.e. multimedia streaming and data services) over an across-frontier testbed. Furthermore, its capability for including general purpose IMS terminals and GERYON enhanced ones allows an easy access to first responder networks to different groups of users that takes advantage of enhanced services such as the Red Button over general purpose devices.

The rest of the paper is organized as follows Section II provides a brief description of the elementary IMS modules. Section III describes the GERYON ecosystem architecture, introducing the main entities. Section IV describes the multi-domain approach for the IMS compliant GERYON interoperability. Section V describes the GERYON prototype platform along with the signaling path and the offered services.

II. IP Multimedia Subsystem

GERYON proposed architecture is based on a Next Generation Network IMS infrastructure [4] and is fully IMS compliant, composed of modules based on IMS signaling (SIP/SDP) for communication, processing and interaction with the rest IMS modules and interfaces.

The control layer of the IMS infrastructure consists of nodes for managing call establishment, management and release, which are called Call Session Control Functions (CSCF). The CSCF inspects each SIP/SDP message and determines if the signaling should visit one or more application servers en route to its final destination. More specifically, the CSCF is a distributed entity comprised of three different components:

- The Proxy CSCF (P-CSCF), which acts as the entry point for any service invocation within IMS and grants appropriate access rights after successful user authentication. The P-CSCF is tasked to relay session and therefore is the module with which the PSAP will interact with for the session and call management.
- The Interrogating CSCF (I-CSCF) acts as a topology-hiding gateway between the P-CSCF and the S-CSCF, by determining the S-CSCF or the Application Server (AS) to which an end-user should register. I-CSCF is a contact point within an operator's network for all connections destined to a subscriber of that network operator.
- The Serving CSCF (S-CSCF) is responsible for key routing decisions as it receives all the User Equipment (UE)-originated and UE-terminated sessions and transactions. Therefore it is also responsible for handling registration processes, maintaining session states and storing the service profiles. PSAP will interact with S-CSCF via its interaction with the P-CSCF.
- The Home Subscriber Server (HSS) is the main data storage component for all subscriber and service-related data of the IMS. The main data stored in HSS include user identities, registration information, access parameters and service-triggering information. HSS contains IMS access parameters which include parameters like user authentication, roaming authorization and allocated S-CSCF names.

For the functional needs of the GERYON architecture, the following Application Servers are also required:

- The XML (Extensible Markup Language) Document Management Server (XDMS Server) defines a common mechanism that makes user-specific service-related information accessible to the service enablers (e.g., IM (Instant Messaging), Conferencing, etc.) that need them. Such information is stored in the network at the IMS Application Layer on an XDMS server where it can be located, accessed and manipulated.
- The Presence Server, which supports one of the most well known and used services in today's real time media applications as it has an enabler service role for many applications like Instant Messaging, Push To Talk over Cellular, Video Calls/Conferences and many others by providing the status of the registered users.

III. GERYON Ecosystem Architecture

GERYON supports both professional and 112 emergency communications, creating an ecosystem for interoperability and it should provide access to security services, accepting different organizations and end users. The adopted solution is based on the IMS protocol.

Figure 1 represents the overall network interconnection system of GERYON. It includes internal networking entities and external agents that may take part in emergency communications.

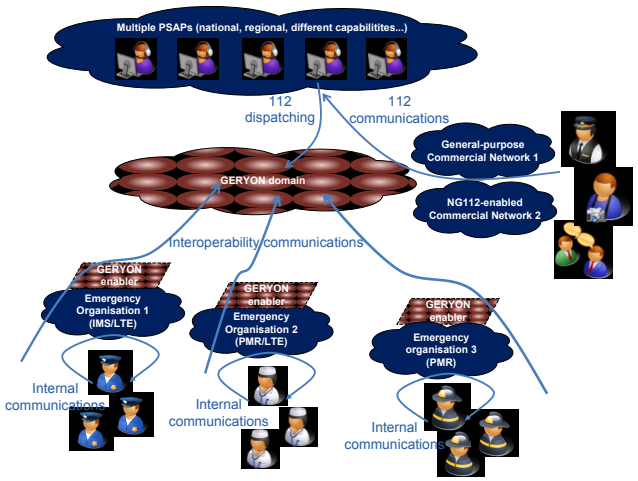

Fig.1 GERYON Overall network system interconnection

GERYON system envisages a standardised domain in order to provide support for interoperability between organisations, so as to ensure suitable operation and communications both on a daily basis and in emergency situations, including the central interoperability IMS domain and the so-called GERYON enablers, which allow different organisations to connect to others through GERYON. Apart from ensuring a correct interoperation, GERYON enablers will also make the provided services available to those organisations, even for internal use.

The main entities of the GERYON system architecture are described below:

A. Top level PSAPs

PSAPs are assumed to be native IMS entities endowed with a well-known set of standardised capabilities for assuring the compatibility of IP-based emergency communications. Besides, it is considered that is PSAP's responsibility to manage the emergency session (e.g. add media types to the session). PSAPs are also able to dispatch citizens' communications to emergency professionals through GERYON system. Top level PSAPs can be high-level operated, managed or subcontracted by governmental organisations.

B. GERYON domain

The GERYON domain represents the overall interoperability enabler and the central management system of the GERYON infrastructure. It offers standardised IMS interfaces to GERYON enablers and will be based on IMS nodes and protocols. Additionally, it provides to the connected users with the basic set of emergency services that nowadays are supported by PMR systems, such as individual voice calls, multiparty-calls, priority calls, push-to-talk calls and location based services. It will be also responsible for deploying configuration and adaptation capabilities, e.g. trans-coding or cross-ciphering, so that users from networks with different characteristics can communicate with each other.

The GERYON domain will take advantage of additional support from GERYON enablers in order to implement advanced capabilities for emergency communications such as location based services, multicast transmissions or QoS management, according to the Next Generation EENA 112 guidelines [5].

C. GERYON enablers

The GERYON enabler acts as the interface for the different GERYON user groups across network boundaries with the GERYON domain, connecting several networks together and providing interoperability between users residing in networks based on different technologies. It may reside in organisations' premises and will be responsible for ensuring that the different organisations comply with GERYON communication requirements, performing adequate translations and operations.

These are some functionalities that need to be implemented by GERYON enablers in order to ensure a correct cooperation:

- feed GERYON domain with information related to dynamic user activity.
- ensure suitable operation and orchestration of inter-organisation emergency communications.

D. Top level operators

Top level operators are personnel trained to manage communications within each organisation, with decision making capabilities. They are normally organisations' operators and responsible staff, who may configure GERYON-related information (e.g. operate GERYON enablers).

E. GERYON users

Different types of users interact with the GERYON infrastructure, depending on their nature, the network where they are located or their terminal capabilities. Among GERYON users we can distinguish the following:

- Professionals belonging to organisations who are selected (by their organisation's operator) as enabled for communicating with external organisations through GERYON domain
- PSAPs, who may connect to GERYON-associated emergency professionals from any organisation
- Citizens who contact emergency services via 112 service.
- Users with special needs (GERYON Red Button users) who access emergency services through specially designed terminals or applications.

IV. A MULTI-DOMAIN IMS ECOSYSTEM

In [6], the foundations of this interoperability system are analyzed. First, the key requirements of the Public Safety users are identified from an organizational standpoint. From these requirements, a series of design principles are derived. Additionally, the main pillars of the general interoperability system are set up based on IMS concepts as key enablers.

GERYON interoperates different PMR technologies with each other and with commercial mobile terminals. So the involved access networks may be totally heterogeneous in terms of technology, management and signaling and GERYON system plans to offer network neutrality and interoperability in this heterogeneous environment.

Therefore GERYON ecosystem consists of heterogeneous networks which will be interoperated and managed by GERYON Management System (GEMS), which is build on top of IMS and is used for all the basic signaling needs of the ecosystem. Considering that IMS is considered mandatory for the signaling of the overall GERYON ecosystem, it is clear that the following discrimination should be done between the types of the access networks that are IMS and non-IMS enabled. GERYON overall architecture considers that in order both of these networks (IMS and non-IMS) to be compatible, appropriate modules, systems and sub-systems need to be able to communicate with GEMS, the central management entity of GERYON overall architecture.

Considering a layered approach of a typical case of an IMS-enabled access network (e.g. a mobile operator with LTE and IMS access network), as depicted in the Figure 2, at the lower layer (i.e. the Network Layer) are located all the Access Network (AN)-relevant modules and systems (i.e., PDN-GW, SGW, RAN and GMLC), which perform the actual e.g. bearer establishment and management. This plane would be closely related to the underlying technology (thus, technology dependent). Moving up to the management plane (i.e. the IMS plane), a respective mapping is performed with the relevant

IMS Core and Support nodes, which are responsible for managing and handling the performance and tasks of the Network Plane modules (i.e. the management of the LTE infrastructure).

GERYON domain is built upon IMS plane and is based on the exploitation of the management capabilities that the IMS domain offers for handling the LTE Access Network, which is summarized by the IMS core modules, the IMS Identity Management Repositories and other support nodes for policy enforcement and location retrieval (e.g. PCRF and LRF). In this multimodal IMS plane, the relevant Application Servers (ASs) are also located, which offer all the necessary services needed in order PMR-grade Services to be offered within this single Emergency Communication Domain.

The mapping between the Network and the IMS planes is specific and standard with scope the management and exploitation of the PDN-GW by the IMS Core modules, which are responsible for the routing of the intra-domain user requests and the establishment of the bearers between the two ends.

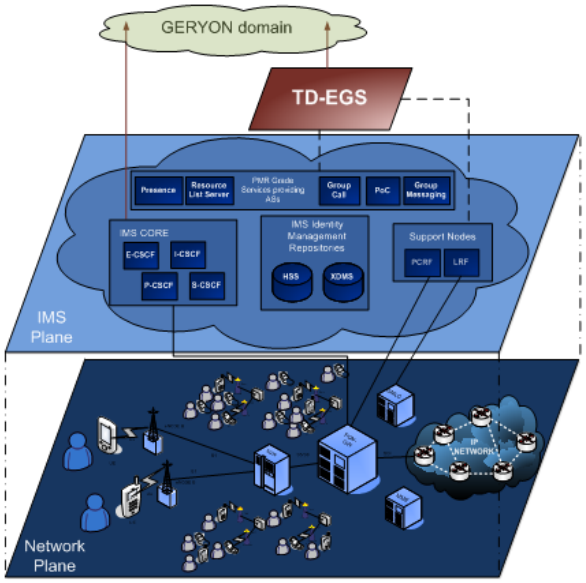

Fig.2 GERYON IMS and Network Plane at LTE side

Considering that the GERYON overall objective is to provide interoperable support of PMR-grade services across multi IMS-enabled domains, it is necessary to further enhance the IMS capabilities with a centralized management system (i.e. GEMS), which will be responsible for bridging the user and session management across different IMS-enabled domains. For these reasons, the Technology Dependent Enhanced GERYON Services (TD-EGS) management module is considered for each IMS-enabled domain, which aims to interface the intra-domain IMS signaling with the GERYON GEMS management module. By this way, the GEMS will act as a common interfacing management entity for all the IMS-enabled domains, creating a common node, where all the entities involved in the GERYON ecosystem are interfacing via their TD-EGS management modules.

Thus, the overall design for the case of interoperating IMS-enabled domains via the GERYON domain is based on i) the interaction of the IMSs of the different domains with the IMS of the GERYON domain for session signalling handling and forwarding/routing across the different domains and ii) the interaction of the TD-EGS, which acts as an enhanced management module of the standard IMS management capabilities of each IMS domain in order to grand management rights to GEMS central entity, reassuring by this way an inter-domain and multi-user management of all the IMS-enabled domain.

Thus, the GERYON domain, by exploiting the main characteristic of IMS, which is the Access Network independency (i.e. network neutrality), provides the interoperable bridge across different IMS-enabled domains. Moreover, via the GEMS and the AS enablers –that are provided by the ESMM-, all the users of the domains can gain access to basic and enhanced PMR-grade services.

Another type of Access Network, which is non-IMS and is strongly involved in the GERYON ecosystem is the PMR TETRA network.

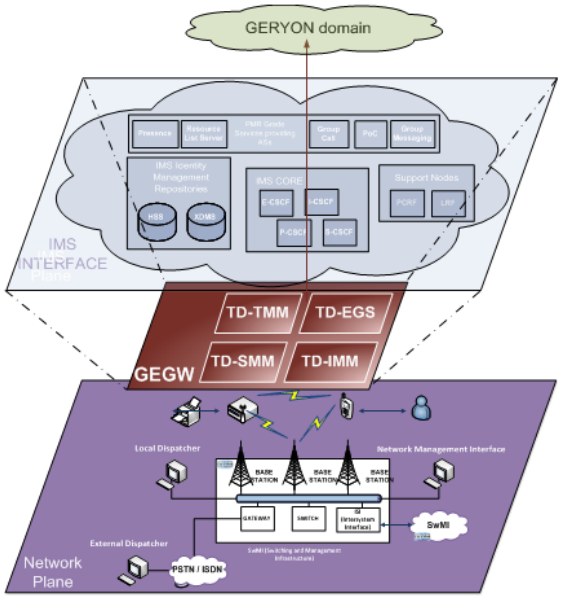

Fig.3 GERYON IMS and Network Plane at TETRA side

The PMR network is not an IMS-enabled one, so there are two incompatibilities that should be covered in order to reassure interoperability with the GERYON domain, namely: i) the IMS signalling (the GERYON domain is IMS enabled), ii) the GERYON signalling, which is performed via the TD-EGS when the IMS-enabled domain is also missing.

Therefore, the respective Gateway that will be provided by the GERYON project in order to connect the PMR network with the GERYON domain should be able to perform both the aforementioned interoperability related signalling requirements (i.e. the IMS signalling with the GERYON IMS Domain) and the GERYON signalling (i.e. with the GEMS management module). In this framework, the GERYON project proposes, designs and implements the GERYON GateWay (GEGW) that supports both the basic IMS and the supplementary enhanced interoperable GERYON signalling. As can be observed in Figure 4, the GEGW will provide an IMS interface towards the

GERYON domain, including inside all the IMS functionalities available in the pure IMS/LTE infrastructure.

V. GERYON PROTOTYPE

Figure 4 illustrates the GERYON testbed deployed for the functional and technical validation tests. As can be observed, the testbed is made up of a core GERYON domain based on IMS, and two different professional domains.

The first one is based on a traditional PMR infrastructure (TETRA in this case) with the required elements to enable IMS-compliance. The second domain is an IMS-driven network, which supports a variety of radio access technologies. WiFi connectivity is natively supported for local users. Additionally, users may connect to the IMS domains through commercial radio technologies such as UMTS/HSPA, LTE or external WiFi networks. The three geographically dispersed domains are interconnected through a VPN infrastructure.

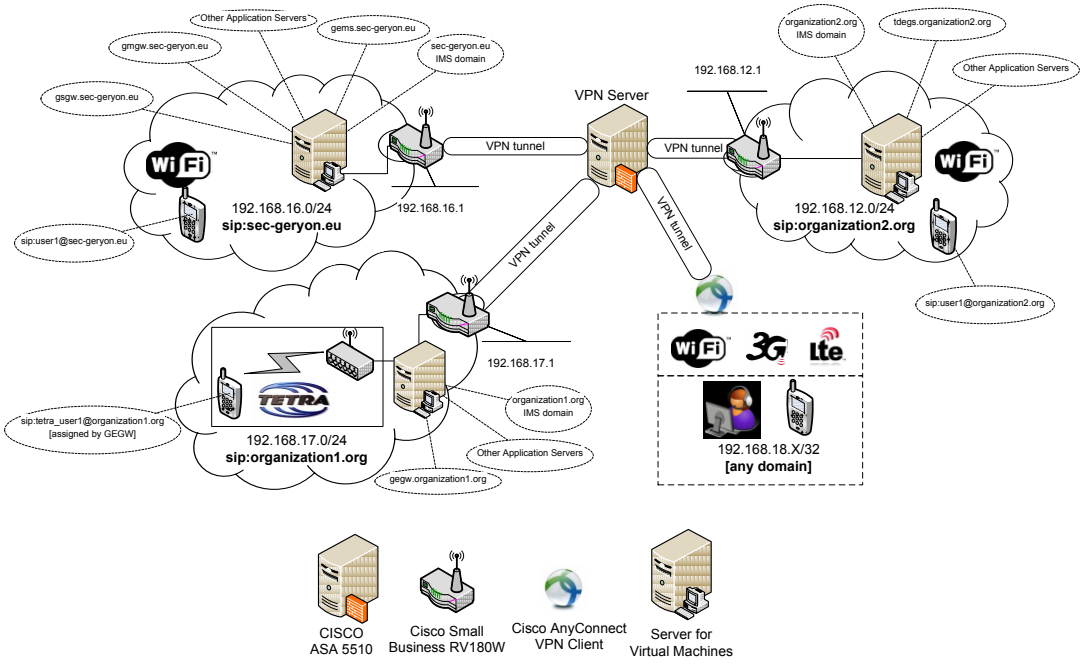

Fig.4 GERYON small scale fully operational prototype.

The described GERYON prototype follows a European deployment, since sec-geryon.eu domain is deployed at UPV/EHU labs, Spain, the organization1.org domain is deployed at ITELAZPI's commercial TETRA network, Spain, and the organization2.org domain is deployed at NCSRD labs, Greece and uses COSMOTE's live LTE network as access. Based on the previously described testbed, Figure 5 depicts a high-level illustration of the possible path that the IMS signaling messages may follow and how the VPN connections are used.

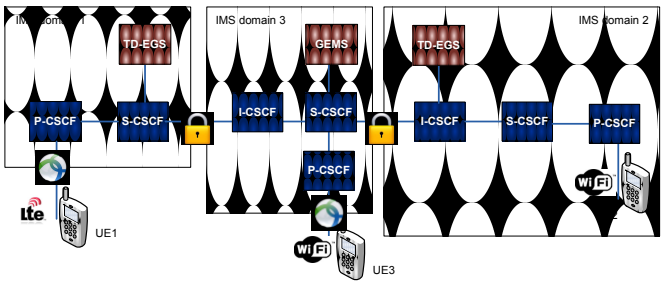

Fig.5 GERYON IMS signaling path

Following this description, two main GERYON emergency services are presented, as they have been tested at the prototype platform, namely the Multi-organization location services and the Full-duplex dynamic group call between different technologies.

A. Multi-organisation location services

According to GERYON specification, a common approach is adopted by the different organizations to provide with internal presence information to the GERYON Presence Server. This way, authorized GERYON users are able to retrieve this information in order to make some kind of fleet control involving heterogeneous professional organizations. Figure 6 depicts this process.

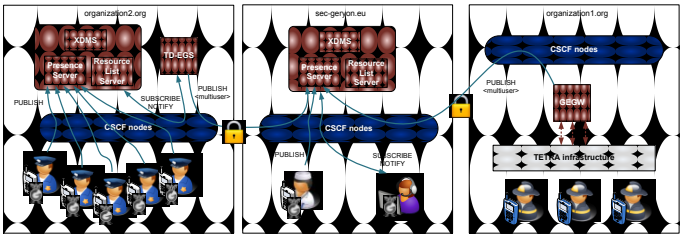

Fig.6 GERYON multi-organization scenario

As it can be observed, individual sec-geryon.eu users upload their presence information directly to the GERYON Presence Server. Then, the GEGW is in charge of retrieving the required information from the TETRA infrastructure, making the aggregation into a single document, and uploading it to the GERYON Presence Server.

In organization2.org, all the native IMS endpoints upload their presence information to a local Presence Server. By configuration, the local XDMS stores which local users belong to different GERYON-related groups. Thus, the TD-EGS subscribes to these groups through the local RLS, which makes the aggregation of individual users into groups. Finally, the TD-EGS is able to perform some identity and location operations and to publish the consolidated information to the GERYON Presence Server.

Figure 7 illustrates how the GERYON Control Room displays the accessed presence information related to different IMS domains.

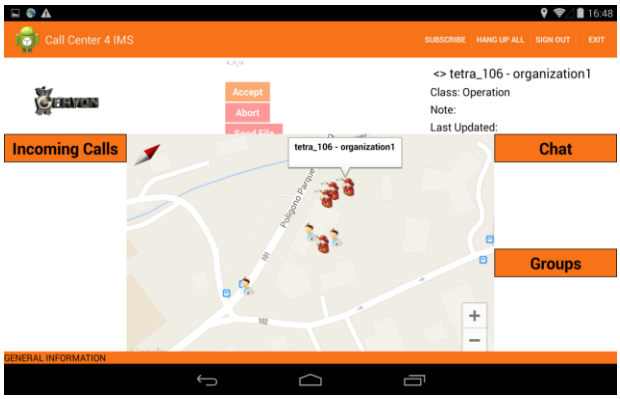

Fig.7 GERYON Control Room Location representation

B. *Full-duplex dynamic group call between IMS/non-IMS*

GERYON prototype platform has achieved interoperability between different access and emergency network technologies, i.e. TETRA and mobile terminal devices, not only for one way communication, but for full-duplex group calls as well, with participants that can be dynamically set up by the control room administrator.

More specifically, a GERYON user, the PSAP user in this case, trigger the establishment of the multiparty audio call by sending a SIP INVITE with the list of selected participants within a resource-list XML inside. Then, the call establishment arrives at GEMS, which reads the list that contains all the participants.

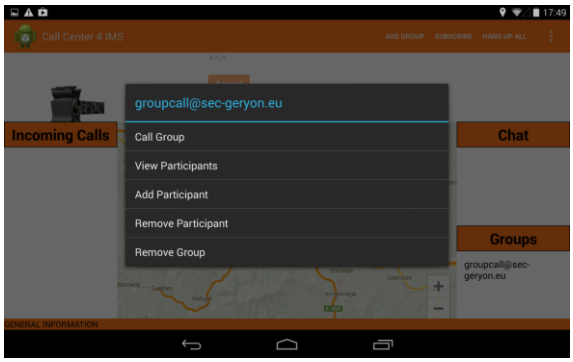

Fig.8 Addition of a user for dynamic group call.

For each participant (including the originating one), GEMS launches a B2BUA procedure to associate each participant with the GERYON Group Call Server. The GERYON Group Call Server performs the media mixing, and thus only one RTP flow is establishes with each participant.

In order to validate the specific feature of creating and triggering a dynamic group call from the GUI of the GERYON Control Room, Figure 8 present some representatives screenshots regarding this process.

VI. CONCLUSIONS

This paper presents a novel architecture that addresses the problem of interoperability between different emergency organizations, taking also into account the current diversity of technologies between traditional and future network infrastructures for Public Safety.

Base on IMS as a key enabler, the paper illustrates the proposed network architecture and the functional elements defined to support the solution. Finally, the paper overviews the experimental testbed deployed for the experimentation of the solution, and depicts the reference interfaces developed to manage the interoperability services over the designed solution.

ACKNOWLEDGMENT

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