Seamless and Reliable Integrated Communication and Service-enabling Platform for Emergency Service Support based on Multi-Agents Middleware

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Abstract- The importance of telecommunications services for the management and control of critical situations for the security of citizens has been always recognized: in particular, in this work we describe the solution designed and developed in an Italian research project, called CI6 (Centro Integrato per Servizi di Emergenza Innovativi). In this project the focus was to develop an integrated centre able to provide the decision maker with all the possible value added information concerning the state and the possible evolution of the crisis.

From a technology research viewpoint, a 2-layered middleware merging a communication middleware (the CHIMERA platform) and an agent-based SW middleware has been integrated and implemented as CI6 service-enabling platform: this 2-layered IC platform natively supports data gathering & aggregation coming from various sources to produce value added information (say CI6 information) as CI6 service content: on-field operations data, external uncorrelated information sources (e.g. infomobility, meteo) as well as the results coming from the expert system simulations and re-planning are examples of information sources for CI6 system. This is the “Network-Centric Operations” approach to support life-critical emergency services. It will shown how this platform can enable the required seamless and reliable communication system and service distribution layer for CI6 users.

The communication middleware has been provided by the CHIMERA platform we have developed which able to connect analogical / digital local radio network and satellite system for remote communications as well as to provide fast availability of communication and broadband using legacy equipment.

I. INTRODUCTION

As documented by the evolution of the European Security Research, with its increasing amount of allocated funds, the theme of “Security” is perceived by the European population as a problem that is far away from being solved yet. The security threats are still representing a major social concern for the European Community and a significant step forward must be performed by the end-users to address with success the security missions as outlined by the Commission.

The security of citizens invests a wide range of aspects such as water safety, air and food protection, anti-terrorism, crisis management, etc. [1].

In all the above aspects rapid exchange, correlation, and processing of information can play a key role in preventing or immediately recognizing a critical event and managing the critical situation in the most effective way. Indeed, the importance of telecommunications services for the management and control of critical situations for the security of citizens has been always recognized [2]. Furthermore, the advances in sensor technologies, with the possibility to interconnect them wirelessly [3] and process the gathered information in real time have amplified the importance of the various subsystems integration issues. Accordingly, a modern platform aimed at the securing of various events that may be critical for the safety of the citizens must integrate the following technologies [4]:

- Secure tracking and monitoring
- Wireless technologies for the interconnection to the network infrastructure
- Mobile wireless access technologies
- Sensors and networks of sensors
- Distributed middleware for the correlation and processing of heterogeneous data
- Value Added Applications and Services to make effective C2 operations

Furthermore, emergency operations in case of disaster, due to either natural or human causes, require fast availability of
communication capabilities through the deployment of communications facilities, to guarantee voice and data communications within each rescue team (among all team members) and among different teams all the time and a full command and control communication system.

Many ad hoc networks architectures designed and proposed in the recent past years have two major drawbacks limiting their uses for emergency rescue teams: the former is the difficulty of using a data network for voice, which is the key communications resource during emergency operations, the latter is a low efficiency of the connectivity protocols, mostly due to IP-architecture, which is not optimized for the radio communication channel. In addition, the link to the remote center may often be either unfeasible due to lack of connectivity or unreliable for many reasons due to security and possible outages, consequence of the disaster event.

This paper shows as the combined use of ad hoc networks or other local network and radio and satellite systems represents the key solution to guarantee the required flexibility and degree of service. Indeed, these two technologies are not in competition, as they might appear, but absolutely complementary. In fact, ad hoc mobile networks are characterized by very small terminals, low consumption, limited capacity per user terminals and, most important, they can work in a very limited coverage range. On the contrary, satellite systems work with medium/large dimension, medium/high power user terminals and very wide coverage areas. Moreover, the MANET are very suitable to work also in indoor environments while the satellite systems can not work in NLOS (no line of sight) environments.

Moreover legacy equipments have to be re-used and the operator on field using a kind of terminal has to be able to communicate with other operator using another kind of terminal. The concept of interoperability without to use the infrastructures is one of the most important focus for communication in a emergency scenario and it will be explained in this paper.

Here we describe the solution designed and developed in the research project, called CI6 (Centro Integrato per Servizi di Emergenza Innovativi). In this project the focus was to develop an integrated service centre constituted with all the features previously listed, in order to provide to the decision maker all the possible information concerning the state of the crisis. This is “Network-Centric Operations” approach to support life-critical emergency services.

Interoperability system and last generation of middleware have been used to create a communication and distributed layer. Concerning the interoperability system we developed a communication platform named CHIMERA that is able to connect analogical or digital local radio network and satellite system for remote communications. CHIMERA has to also be able to provide fast availability of communication and broadband using legacy equipments.

Over the communication layer, in order to guarantee the providing of different and distributed information by the network we used a middleware based on multiagents platform. Middleware is a platform that connects components or applications. It is used most often to support complex, distributed applications. It includes web servers, application servers, content management systems, and similar tools that support application development and delivery. Middleware is especially integral to modern information technology based on XML, SOAP, Web services, and service-oriented architecture. Software agents provide the technology necessary to dynamically negotiate, select, and utilize the appropriate services required in today’s highly dynamic business world. In this paper, we describe an application in which an agent java based platform like JADE, is used to define a middleware system in definition of an services architecture to support emergencies management. This provides the necessary first step of integrating agent technology with other mainstream web server, application server, DB, communication and security technologies, to produce a scalable, robust platform for intelligent applications of various kinds.

This architecture has been proposed to fire fighters, civil protection, police and others, to be tested on the field and a real operational conditions.

The paper presents in section II the 2-layered system architecture. In section III and IV communication platform and the developed multi-agents service-enabling platform are explained. Then the conclusions are reported.

II. 2-LAYERED SERVICE-ENABLING ARCHITECTURE

Due to the life-critical targets, CI6 services need a seamless and reliable platform to rely on: we propose and have implemented a 2-layered IC platform which natively supports data gathering & aggregation coming from various sources to produce value added information (say CI6 information) as service content: on-field operations data, external uncorrelated information sources (e.g. infomobility, meteo, current resources availability), results from the expert system simulations and re-planning are examples of information sources for CI6 system.

It is intuitive that such services must obey to severe requirements and constraints in terms of seamlessness, robustness and reliability. CI6 services must be fully operative wherever the users and on-field operators are located, whichever telecommunication infrastructures and terminal equipment are available, and whenever the emergency occurs.

These definitions are originated in practical considerations to overcome some constraints related to the large spread of frequency carriers and radio terminals currently adopted by the various Forces often unable to communicate directly each to the other and the heterogeneity of the various service components and external information sources currently in use by the Civil Protection and other institutional entities.
Thus our approach to system design has been the definition of a 2-layered service-enabling platform based on the vertical integration of a communication system called CHIMERA (see details in sec. III) and a SW middleware (see details sec. IV) as depicted in Fig 1.

The SW middleware relies on the communication primitives offered by CHIMERA which assures seamless connectivity among any system component. Users/operators can be located on the field (On-field Forces) and on the Service Centre (which can be either the CI6 Service Centre located at some Telespazio’s premise or an emergency Operation Centre located at any national district): they can access to CI6 services (Client-Side and Server-Side) supported by the SW middleware through custom Graphical User Interfaces (GUIs) implemented on the suited Radio Terminals and in each computing equipment. Environmental data are gathered from external information sources, usually provided by specific remote content providers.

III. COMMUNICATION MIDDLEWARE: THE CHIMERA PLATFORM

CHIMERA is the IP based platform implemented to support and achieve voice and data interoperability between the set of on-field operators, who usually use heterogeneous radio technologies (i.e. HF, VHF, UHF, TETRA, etc.) and the emergency management infrastructure located in the Control Centre.

CHIMERA platform is composed by the following subsystems:

- The IP network used as a communication backbone between the different subsystems. It comprehends the technologies involved in traffic transport, routing and administration;
- Interface subsystem between IP network and radio devices (RIS – Radio/IP Interface Subsystem);
- Operative Subsystem (OS) for the integrated communication handling, used by operators that are involved in radio communications on a routine basis;
- Control and Administration Subsystem (CAS);
- Other Users Subsystem (OUS), identifies all the other entities (i.e. offices and other structures) that usually are not involved in radio communication handling but that may occasionally participate to radio communications.

Fig. 2 depicts the described subsystems and the relation between them:

In the picture, the OUS is linked with a dash line to IP network cause it may only occasionally join the system IP network on Control & Administration or Operative Subsystem request.

The system may be deployed on a network already in use by other IP services or on a newly created network. The IP network may be logically divided into functional subnetworks dedicated to specific services thus dividing Radio Over IP services from other IP services. Otherwise the system may be deployed over a dedicated IP network.

The physically or logically dedicated IP network has to be configured in order to support all the needed simultaneous voice communication links.

Radio/IP Interface Subsystem is composed by the devices that provide interface functionalities between radio networks and IP network. These devices are named Radio Gateways. They are physically linked to radio devices and convert the voice and data radio communications to VoIP communications. Radio Gateways allow interoperability between different radio networks direct linked to the same or to different Radio Gateways. They can extend the radio communication capabilities through all the IP network. Radio Gateways permit half duplex and full duplex voice communications through connected radio devices. They make possible data transmission and remote radio control depending on radio devices capabilities.

Operative Subsystem includes the Dispatch Consoles dedicated to the handling of operative communications. These Console allow the simultaneous use of multiple voice and data communications link, in full or half duplex mode, through a single communication software. Communication links may be established with all the recipients described before (i.e. radio networks, other console, standard VoIP/ISDN/PSTN/Other users, etc.). These Consoles can be used by the operators for:
• Voice and data communication with radio networks (through the IP network and Radio Gateways services);
• Voice and data communication with operators using other Consoles;
• Voice and data communication with operators in the Control & Administration Subsystem;
• Voice communication with personnel in the Other Users Subsystem or with users using non IP networks like PSTN, ISDN or other.

Control & Administration Subsystem includes the operative stations devoted to Remote Administration and Control of Radio Gateway network. The remote control software allows the setup of interoperability links between different radio communication networks and the management of some configuration parameters.

Other Users Subsystem is composed by all the users that do not usually operate with radio communications but that may occasionally use voice communication with radio devices. The users in this Subsystem can use standard VoIP phones or software or dedicated software clients for their voice and radio communications.

Due to the integration between IP networks and radio communications, CHIMERA platform offers several practical advantages as Radio Communication networks may be used by each user residing on the IP network. This can be done by a simple personal computer equipped with the suited software or by IP phones and handheld devices such as PDA. Moreover Radio devices may be remotely managed using the same IP network. Interoperability between different radio networks and between radio networks and other networks like telephone or satellite networks can be accomplished. The adoption of standard technologies allow interoperability with different manufacturers’ devices or networks. This reduces integration effort and maintenance cost.

Thanks to the convergence of data, voice and other applications over the IP media, CHIMERA allows the use of a unique transport media, reducing the costs for deployment, use and maintenance of the network. IP protocol is transported by almost all telecom providers allowing the worldwide deployment of IP communication links.

Over the communication system we developed a middleware based on software multi-agents able to allow easy and distributed communications among the sources involved in the crisis events. This sources can refer to localisation, weather conditions obtained through the access to a meteo Web-Server, environment conditions rely on the measures of typical parameters obtained through wireless sensors networks.

IV. MULTI-AGENT SW MIDDLEWARE ARCHITECTURE

The proposed architecture is 3-tiers: “3-tiers” is a client-server architecture where the user interface, functional process logic, data storage and data access are developed and maintained as independent modules. This is a layered architecture, in which layers close to the user are built upon lower layers that are closer to the machine. In GUI- and data-intensive applications like CI6 system, the separation (and distribution on different computing nodes) of the data management layer from the presentation and application logic layers provides concrete advantages allowing the replacement of one tier without affecting the others. Moreover, it makes it easier to implement load balancing. The most volatile parts of the system (in case of changes in requirements) will be the user interface and the system's business rules. By separating user services from other services, the system's user interface can be changed without impacting the rest of the application. Similarly, by separating business services from other services, it's far easier to change the business rules of the system with minimal impact to the rest of the system.

For a 3-tiers architecture we need to define: first, data layer, which in CI6 project is formed by all existing information sources; second, business services, which implement the system’s business rules; third, user interfaces, which format the information and present it to the user (see Fig. 3).

![Fig. 3.3-tiers Multi-Agent SW Middleware Architecture](attachment:fig3.png)

The data layer is composed by the available sources. The proposed architecture foresees the definition of a Knowledge Base (KB) that contains the whole knowledge related to the domain. The suggested approach to define the KB is based upon an ontological model and takes into account the most recent representation and fruition methodologies of knowledge. A KB defined and implemented after this model offers more flexibility of use and an enhanced capability to find the information useful to the accomplishment of the task requested. This result is possible thanks to a precise representation of the object that belongs to the domain through the definition of an appropriate taxonomy, a hierarchical structure of object’s categories. Once defined the taxonomy, the second step is the definition of functional relationships...
between objects. The taxonomy and the set of functional relationships represent the domain ontology.

With respect to the proposed architecture, KB consists of two fundamental modules:
- KB Data Server is the actual place were the data are stored;
- KB Meta Data Server keeper of the ontology for the classification of data and rules for the creation of a semantic relations among pieces of information.

In our architectural approach we have defined the business services layer as an intelligent middleware based on Software Agents. In particular we have defined the agents in JADE framework.

The study of Multi-Agent Systems (MASs) focuses on systems in which many intelligent agents interact with each other. The agents are considered to be autonomous entities, capable of modifying the way in which they achieve their objectives. Their interactions can be either cooperative or selfish. That is, the agents can share a common goal (e.g., an ant colony), or they can pursue their own interests (as in the free market economy). In few words the main characteristics of a MAS can be summarized as it follows: (1) each agent has incomplete information or capabilities for solving the problem and, thus, has a limited viewpoint; (2) there is no system global control; (3) data/knowledge are distributed; and (4) computation is asynchronous. Such features are well suited to make complex space systems fault tolerant (e.g., a system is still able to work when a part of it is out of action), increase the flexibility and the adaptability of a space system (e.g., the system can autonomously assume different configurations as the reference working scenario changes). MAS researchers has developed communications languages, interaction protocols, and agent architectures that facilitate the development of multi-agent systems. One of the most currently used platforms is JADE (Java Agent Development framework) environment [5]. JADE’s kernel architecture, enables the deployment of platform-level services (such as communication, replication, persistence, and security) at runtime and the use of JADE in mobile networks. JADE is used in several possible application areas, such as:

- Mobile applications, which could use personal agents to support users on the move (personal agents facilitate search and discovery of information through interaction with peers (people or service providers);
- Internet applications to enable end users to deal with available resources’ complexity and to allow seamless access to remote resources and services;
- Corporate applications to simplify collaboration and cooperation between systems and people to achieve better results; and
- Machine-to-machine applications, such as automatic control or traffic management systems.

In our approach JADE had been used in order to define an integrated services architecture to support emergencies management. In particular thanks to JADE we have defined a intelligent middleware layer to integrate distributed heterogenous resources defining agents like wrappers. Moreover others agents defining like negotiators, allow a user to access to opportune services during an emergencies management [6], [7], [8].

Starting from emergencies management domain, on the basis of the identified user needs an analysis activity has been focused on:
- Identify and analyse the existing resources identifying existing data, associated services and available interfaces;
- Identify new services and additional resources which will be useful to implement the cooperative approach;
- Identify the service flow and the fruition of the established body of knowledge with an user oriented approach.

The scenario analysis has covered specific aspects related to data analysis, as well as more infrastructural and technological aspects.

Several technical issues have been addressed, for instance the interface between the data and the informations integration. For a clear understanding we have used the word “resources” instead of “data”, so giving evidence to the fact that we intend to have a service-oriented approach, assuming that the data need to be complemented by services in order to gain value and become effective for the users community. In our approach the concept of a service-oriented middleware platform is based on a 3-tiers architecture:
- Acquisition layer
- Integration Layer
- Service Manager

Each layer has been defined through a multi-agent system based on JADE paradigm. In particular:

- The acquisition layer has the task to interface with the available resources. The service-oriented architectural approach will ensure the maximum interoperability, as the information and services integration will be platform independent. This acquisition layer will guarantee the interface standardisation for heterogeneous information sources, establishing a common communication protocol with respect to the integration layer. This approach will prove very effective in case that an additional resource should be integrated, so a real modularity will be guaranteed to the system.

- The integration layer has a direct interface to the acquisition layer with the objective to organize the information associated with the resources. The information organization is accomplished through an explicit representation schema, making use of a domain specific ontology and semantic integration rules. The ontology will be the reference schema for the development of a knowledge base, which will be managed by a software agents’ community on the basis of the semantic integration rules making the information available to the stakeholders community.
The service manager is based on a s/w agents’ technology and guarantee the access to all the services of the system. The services are defined at this level and the s/w agents’ community negotiate at this level the resource availability on the basis of users requests.

Another important layer of the proposed architecture is the User Interfaces. To make the CI6 working in optimal condition, the interface shall contain some important features:

- Adaptability to data/user
- Adaptivity to different scenarios

The adaptability and adaptivity are interface properties that offer a different typology of interaction (functions and modality of access) to different data types. Those types of interfaces have different data profiles internally defined.

The adaptability to the data is necessary in the interface because different types of data are defined; beyond data adaptivity, also a user adaptivity based on different user typology can be proposed.

The suitability of the CI6 user interfaces is necessary due to the different scenarios in which the potential users is foreseen could operate.

V. CONCLUSIONS

The proposed communication and service-enabling platform has been implemented for CI6 system. At the time of writing, alfa tests have been successfully carried on and CI6 services are going to be tried on-the-field (beta-test) in collaboration with primary italian institutions in charge of managing emergencies at national level.

It is worth to notice that, up to now, CI6 system is just a prototype and needs to be further engineered and integrated with OSS (Operation Support System) functional modules to be commercial effective. This is the foreseen development step.

The authors wish to acknowledge the Italian Ministry of the Productive Activities for CI6 project funding.

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