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A Semantic WEB Services Platform to support Disaster and Emergency Management

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***Key words*:** Agent Platform, Jade, Ontology, Sesame, Semantic Web, Distributed Systems, Emergency Management

Abstract: The importance of telecommunications services for the management and control of critical situations dedicated to security of citizens has always been 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). Focus of this project was to develop an integrated centre able to provide important informations concerning the state and possibile evolution of the crisis for decision makers. The knowledge base is managed by means of homogeneous schema to represent information (ontology of domain) and by means of semantic rules defined by the analysis of the domain. The communication layer has been provided by the CHIMERA platform we have developed, which is 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.

Keywords: Agent Platform; Jade; Ontology; Sesame; Semantic Web; Distributed Systems; Emergency Management.

1. INTRODUCTION

During crisis events, operators and decision makers work in difficult and complex environments that could require, in order to take decision, rapid exchange of informations as video, images, weather information, resources already engaged for emergency and resource yet available, and so on. The correlation of data 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 always been recognized [Mrozinski, 1975].

This paper presents a multi-layered platform (CI6) that supports data gathering and aggregation coming from various sources to produce value added information (say CI6 information). The goal of this project consists in developing a decision support system to coordinate and to simplify the management of critical situation. CI6's information domain is very rich; for example: mobility information, meteorology, current resources availability, cartography, textual communication with operators, information about rescue team and their equipment, stratification of different data, monitoring of emergency evolution, unicity of support system.

A hypothetical scenery could be a sea emergency, for example: a broken-down ship gives an alarm by satellite terminal interfaced by CI6. CI6 will be able to visualize alarm and its properties (typology, localization, vehicle's identification and so on..). A CI6's user can visualize the alarm and can decide to manage it. An occurring alarm can be managed both through a predefined scenery, and creating a new one. When user creates a new scenery, the CI6' s decision support system suggests the possibility that two or more alarm could be about the same critical situation. Both creation of a new scenery and the selection of an existing one allow to use all services and functionalities before described.

2. MULTI-AGENT SW MIDDLEWARE ARCHITECTURE

2. 1 Introduction

The proposed architecture is a 3-tiers one: "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 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 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 easier to change the business rules of the system with minimal impact to the rest of the system.

2.2 Middleware architecture

In CI6 project data layer is formed by all existing information sources; the business services layer implement the system's business rules; the user interfaces layer formats the information and presents it to the user (Figure 1).

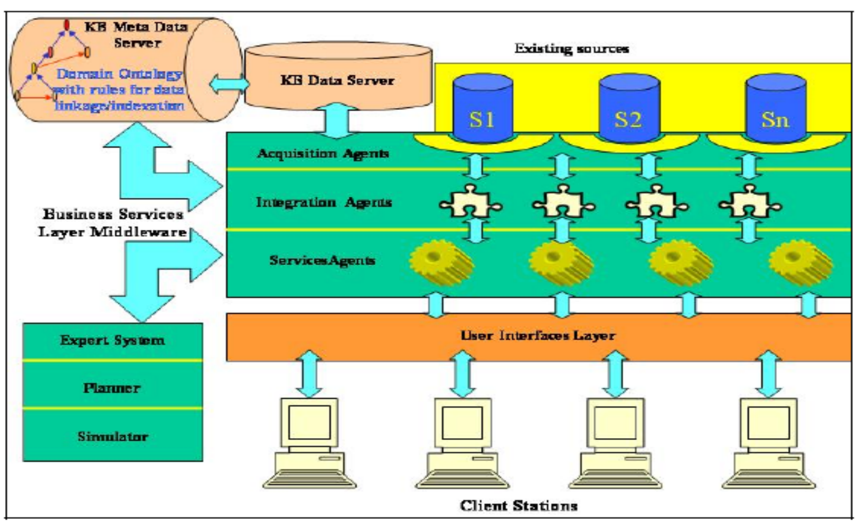

Figure 1. 3-tiers Multi-Agent SW Middleware Architecture

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 methodologies of knowledge representation and fruition.

A KB defined and implemented after this model offers more flexibility of use and an enhanced capability to find the useful information. Each domain object is represented at a first level in a taxonomy, a hierarchical structure of object's categories; the taxonomy, enriched with a set of functional relationships, constitutes the domain ontology.

The KB of the proposed architecture consists of two primary modules: **KB Data Server**: is the actual place were the data are stored; **KB Meta Data Sever:** uses the ontology for the classification of data and rules for the creation of a semantic relations among pieces of information.

The business services layer is defined as an intelligent middleware based on a MAS. In Multi-Agent Systems (MASs) the agents are considered to be autonomous entities, capable of modifying the way in which they achieve their objectives. Main characteristics of a MAS can be summarized as it follows: (1) each agent has incomplete information or capabilities for solving the problem (thus, has a limited viewpoint); (2) there is no system global control; (3) data/knowledge are distributed; and (4) computation is asynchronous. Such features makes a system fault tolerant (e.g.: a system is still able to work when a part of it is out of action), increased in flexibility and in adaptability. As a MAS, we used the JADE (Java Agent Development framework) environment [Di Napoli, 1998].

Implemented Jade agents categories comprehend "acquisition agents", "negotiators" or "service agent", that allow a user to access to suitable services during a management of emergencies [Di Napoli, 1998], [Bellifemmine, 2004], [Minei, 1997].

Starting from emergencies management domain, on the basis of the identified user needs an analysis activity has been focused on: 1) Identify and analyse the existing resources identifying existing data, associated services and available interfaces. 2) Identify new services and additional resources which will be useful to implement the cooperative approach. 3) Identify the service flow and the fruition of the established body of knowledge with an user oriented approach.

In our approach the service-oriented middleware platform is based on a 3-tiers architecture, composed by: 1) Acquisition Layer 2)Integration Layer 3)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 the system with the available resources. The service-oriented architectural approach ensures the maximum amount of interoperability, as the information and services integration are platform independent. This approach proves very effective in the case that an additional resource should be integrated, so a real modularity is guaranteed to the system.
- The integration layer has the objective to organize the information associated with the resources. Its task is accomplished through an explicit representation schema, making use of a domain specific ontology and semantic integration rules. The ontology is the reference schema for the development of a knowledge base
- 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. Different data profiles are internally defined. The adaptability to the data is necessary because different types of data are defined; 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 could operate. The components are: **The Observation Module –** acquires the data from the user observing his behaviour (if the system is in adaptivity mode), from the user himself or acquiring them from context in which the user operates.

The Presentation Module – selects contents and modalities to display the information driven by the data acquired from the Observation Module. **The User Modelling Engine** – selects the user profile following the observation of the user and of the operative context. The engine can have additional components like inferential rules in case the acquired data is not perfectly adapted to the stored situation profile.

3. SEMANTIC ASPECTS: SESAME AND JADE INTEGRATION

The proposed architecture is based on the integration of JADE (for agent developed) and SESAME (for the management of relation among elements of domain). The middleware has the advantage to use both a software agents architecture and structured domain by means of RDF and RDF Schema (semantic net).

The domain of CI6 is composed by a set of resources, each associated to a set of properties. Two of these are strictly required, for they identify the resource and the related services. Other properties link the resource with other resources of the system. The two strictly required properties are: **HasService**: points to the description of a functionality belonged to resource and available to users; **HasSource**: points to the physical location of resource (for example: database, tool S\W, Web Services, etc.).

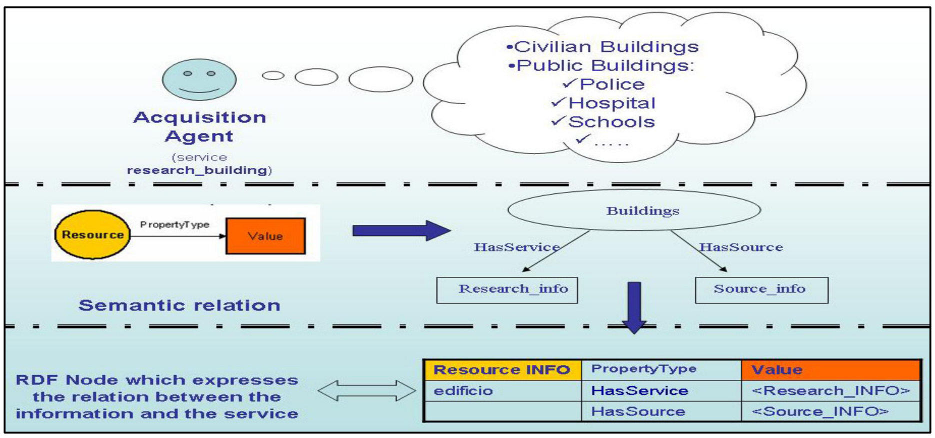

Figure 2. Schema of "collaboration" between Jade agent and a semantic net.

Let's introduce an example. The resource "Map Server" offers functionalities such as: selection of maps, zoom on maps, size of distance, geo-references information, etc. A physical address is associated to the resource. A form of "collaboration" between JADE agent and semantic net managed by SESAME is introduced in (Figure 2): 1) A jade agent has knowledge (ontology) about the particular area of domain it has to interact with. 2) The semantic relations associated to each node belong to (area subset of) the net of relations that describes the CI6 domain. 3) The structure of RDF node that belongs to semantic net managed by SESAME.

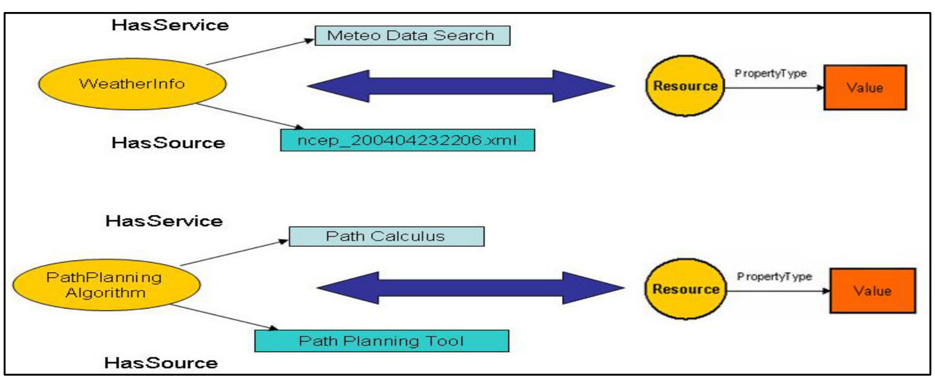

Figure 3. Example of resources "Weather" and "Path Planning Algorithm"

In (Figure 3) we can see the resources: “weather information” and “path planning algorithm”.

To explain the phases of interaction between JADE agent and semantic net, we use a simple example: the request, by a JADE agent, of a specific service.

CI6's architecture involves five entities (Figure 4): a Service agent; a DF agent; an acquisition agent; Sesame; one or plus database.

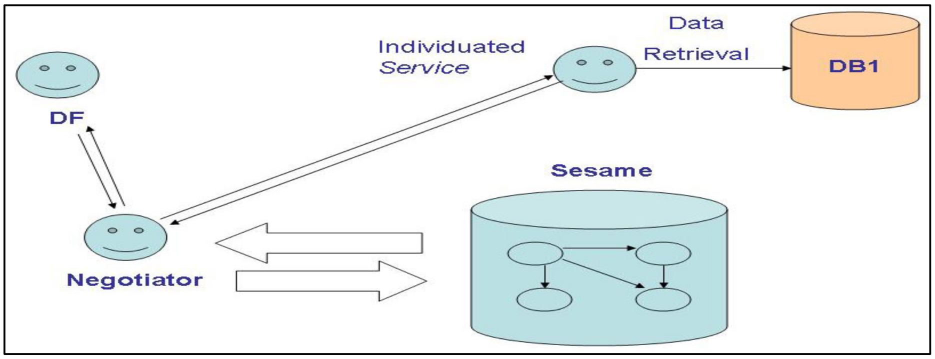

Figure 4. Entities involved in interaction between Jade agent and semantic net

The process of querying the semantic net by agents pass through the following steps (Figure 4): ***Interrogation***: Service agent forwards the request to SESAME to know the necessary information. ***Result***: by the interrogation, the service agent knows the value of relations “HasService” and “HasSource” (and of other eventual relations). ***Found Acquisition agent*** *can access to service*: Service Agent forwards to DF Agent the request to know the address of the application agent that can access to service; ***Access to information***: the Service Agent requests the service to Acquisition Agent and forwards it the source's address. The Acquisition Agent accesses to database and sends the information to service agent.

As an example of application of CI6's architecture, we briefly describe the service we called ***stratification service.*** Information about cartography, street map, weather, building maps, paths calculated by the integrated *path planning service*, are dynamically integrated on request. It’s possible to extract information according to the desiderated level of stratification.

In this way the user (the Emergency Room operator) can have an integrated view of the Emergency scenery, in order to choose the best solutions to face the emergency.

The service agent associated to the stratification service (the stratification agent) queries the Sesame repository according to the illustrated schema: ***Interrogation of semantic net***: Stratification Agent forwards to SESAME the request about the information that user (operator) intends to integrate. In fact relevant information vary according to the different Emergency scenarios. ***Result of query***: for example, the Stratification Agent knows, among other information, the URL of the Web Service to obtain the cartography and the Acquisition Agent’s name associated to the cartography resource. **Found Acquisition Agent can access to service**: Stratification Agent forwards to DF Agent the request to know the address of, for example, the Acquisition Agent for Cartography (the Cartography Service Agent), the Acquisition Agent for Weather (the Weather Service Agent), and so on. **Access to information**: the Stratification Agent requests cartography information to the Cartography Service Agent, the weather information to the Weather Service Agent and so on. When all acquisition agents respond to the Stratification Agent, it collects information and shows them to the user (the emergency operator).

For example, in the case of the occurrence of an emergency in via Gianturco, Naples, by means of the stratification service the operator can invoke a path planning algorithm to calculate the best evacuation plan in function of the integrated information about traffic conditions, weather conditions and GPS signals of emergency operators (Figure 5).

The important thing to notice here is that the best response about evacuation plan is possible only on the basis of an integrated information, such as the information given by the stratification service. In fact, analysing only a partial information, only non-optimal evacuation plans could be calculated.

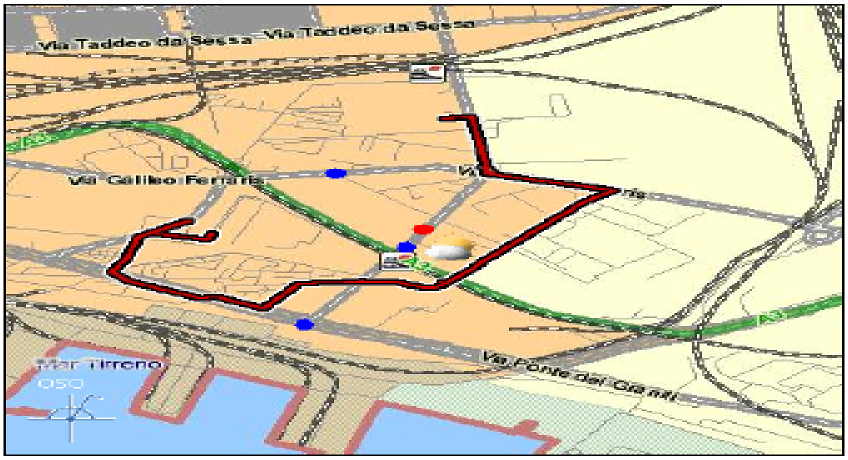

Figure 5. Example of Stratification Service

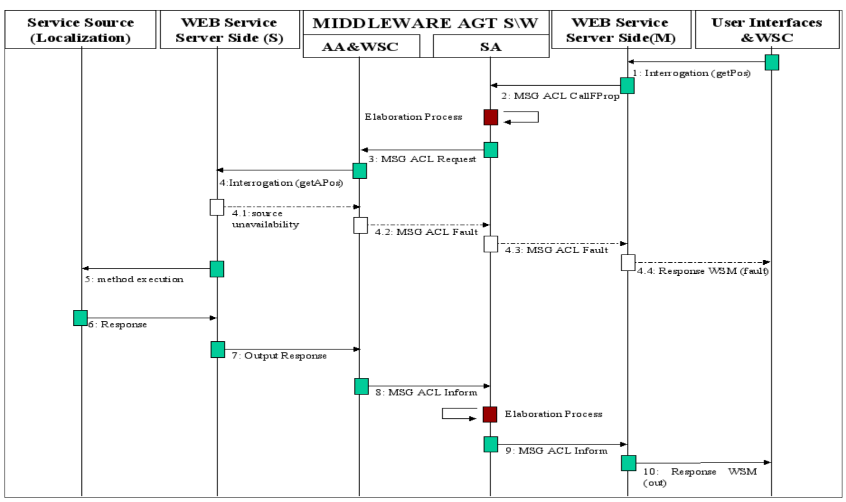

Figure 6. Flow of interaction of module of CI6

In Figure 6 is showed the flow of interaction of module of CI6 to obtain localization service.

4. COMMUNICATION MIDDLEWARE: THE CHIMERA PLATFORM

CHIMERA [Luglio, 2007] is an IP based platform implemented to support and achieve voice and data interoperability among the different operative teams on-field, who usually use heterogeneous radio technologies (i.e. HF, VHF, UHF, TETRA, etc.) and the emergency management infrastructure located in the Control Centre. Figure 7 shows the CHIMERA concept that is based on tree main levels: Terrestrial segment; Satellite segment; IP Gateway.

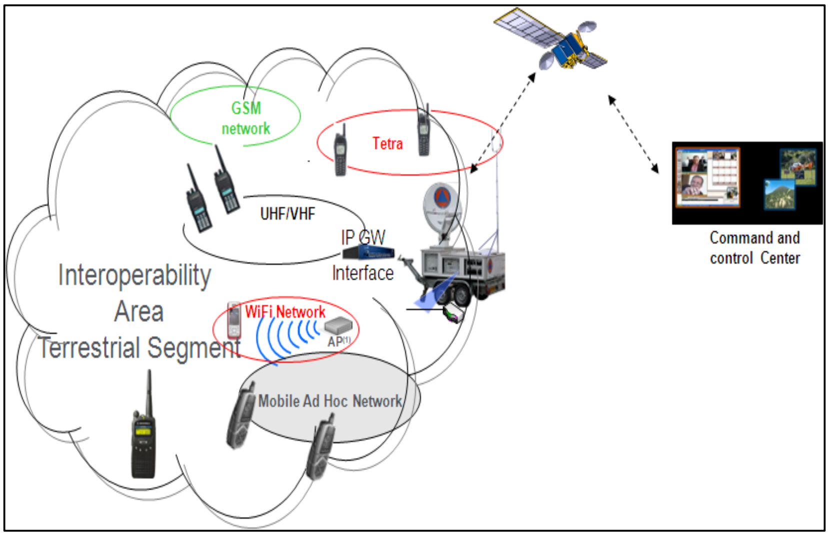

Figure 7 CHIMERA communication system

Terrestrial networks as WiMax, WiFi, Sensor Networks, MANET, TETRA and/or analog radio can be used. Moreover, this approach allows an easy way to set up interface with satellite systems. In particular, two types of satellite communications can be interfaced. A narrowband mobile terminals (GSM-like) to allow voice and low bit rate data communications from team members to any other location located even very far away, and a broadband terminals (ensuring IP interface) very small and light, easy to transport and to install when an even small size van is available and located nearby the rescue team.

The IP gateway is used to interface the terrestrial radio network and the satellite system. In particular, the Gateway is in charge to adapt the voice signal to IP protocol and is interfaced with the heterogeneous system. It is able to convert over IP format the data and voice coming from the terrestrial network. In this way, through the satellite system, it is possible to connect the network to another remote network, to a remote LAN or to interconnect users belonging to different networks ensuring the interoperability among different teams operating on the field. The IP Gateways are physically linked to radio devices and convert the voice and data radio communications to VoIP communications according to the standard protocol (H323 and SIP). 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. The IP Gateways also allows interoperability between different radio networks direct linked to the same or to different Gateways. They can extend the radio communication capabilities through all the IP network. Through the Gateways half duplex and full duplex voice communications are available. They make possible data transmission and remote radio control depending on radio devices capabilities. Due to the integration between IP networks and radio devices, CHIMERA enables the communication among the Decision Support System, Decision Maker and teams on field using IP phones, handheld devices, PDA or also radio terminals.

5. CONCLUSIONS

The domain of emergency management is a complex area because it requires dynamism and flexibility in taking decisions. The decision makers need a support system to have current and complete information to support their decision and to know the available resources for managing the emergency.

These requirements are satisfied by our middleware based on software agent which, using a semantic layer, is able to give complete, flexible and significant answers to user's request.

In fact, although CI6 is still a prototype, it satisfied the tests.

We can mention test with port authorities of Palermo and civil security of Naples among more important tests.

In first case, we simulated a sea emergency as that described in introduction while, in the second case, we simulated the management of evacuation of a city area because of flood.

The result of simulation was positive in both cases; in fact although emergencies share common aspects in their being faced, the emergencies problem, 'cause of its being complex, intrinsically involves the presence of features specifically related to each situation. For example, one of the feature of a sea emergency is the difficulty of communication, that increases increasing the distance from the coast, and that arises problems both for the signal of alarm and for communication during emergency management. In this case, the use of a satellite terminal reveals as a good choice for this type of emergency.

In the second case, it has revealed important to have a 'path planning' service as a strategic tool for the decision support system.

The CI6's architecture responds in a satisfying manner to the requirements arisen by the problem of facing emergencies; in fact the possibility to have a semantic layer (semantic net) and a layer able to elaborate simple data to produce complex information (middleware based on agent), has revealed as an appropriate instrument to manage the complexity and the variety of the analysed domain. Moreover, being modular and extensible, the CI6's architecture offers the capability to integrate other services and functionality.

Future work may be prosecuted towards the automation of the emergency type identification and, as a consequence, in the automatization of the decision about the degree of integration required for facing emergencies.

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