Integration of Up-to-Date Technologies for Emergency Response

Fire Response Community in Smart Space

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Abstract—**The paper addresses the problem of organizing a resource community in a smart space. The resources making up the community aim at joint emergency response actions. A smart framework for integrating emerging technologies of smart space, Web-services and Web-based communities was developed. In this framework, Web-services represent smart space's resources and Web-based community members. A service-oriented architecture was designed to coordinate Web-service interactions. The smart framework applicability was tested via a scenario-based organization of an emergency response community aiming at fire response actions. The main research challenge is to show how facilities provided by the emerging technologies of Web-based communities and smart spaces can be used for emergency management.**

Keywords—smart space; service-oriented architecture; Web-services; Web-based community; emergency response

I. Introduction

Emerging technologies of Web-based communities, smart spaces, and Web-services, have the potential to impact emergency management dramatically. The research on the investigation of the possibilities of these technologies for emergency response was initially introduced in [1].

Web-based communities offer advantages of instant information exchange that is not possible in real-life communities. Availability of operational information [2][3] as well as potentialities to instant information exchange [4][5][6] are of great importance to success in emergency response operations. Usually, in such operations joint efforts of independent parties are required. To involve the parties in the emergency response actions and to coordinate them, operational information about the parties' facilities, availabilities, locations, etc. is needed. In this connection, organization of a community of emergency response actors as a Web-based community, whose members can share and exchange operational information, seems to be a promising idea.

Unfortunately, in real life it is occurred quite often that people would not like sharing information – "At the agency level, and even within agencies, there has been the culture that you don't share information for a variety of reasons, whether it's because of classification or "need-to-know," you just don't share information. There are also sometimes some bureaucratic or personal reasons [7]". Smart spaces provide good facilities to overcome this problem since a smart space is a sharable system by definition. Smart space is any virtual or real location equipped with passive and active artifacts. These artifacts have the processing and communication capabilities to interact with each other in a (mutually) beneficial way [8]. The smart spaces gather information from the environment and provide embedded services according to this information. This means first, that people do not have to provide any information if they do not have intentions of doing that; instead, the smart space will do this, and second, that smart spaces act in a context-aware manner.

The information sharing facilities provided by Web-based communities and smart spaces have suggested an idea to combine these facilities for organization of emergency response communities. These facilities are supplemented with smart spaces' capabilities to context aware service provision.

Any smart space is comprised of a large number of informational, computational, and acting resources. Web-services offer advantages of seamless information exchange between autonomous resources of smart spaces [9]. This fact was a reason to use Web-services as mediators between resources of the smart space and members of the emergency response community.

Research presented in this paper addresses the organization of a resource community in a smart space. The purpose of the community organization is participation of its members in emergency response actions. The main research challenge is to show how facilities provided by the emerging technologies of Web-based communities and smart spaces can be used for emergency management.

A smart framework that serves to integrate concepts of smart space, Web-services and Web-based communities is proposed to achieve the research purpose. This framework is based on the earlier developed hybrid technology supporting context aware operational decision support in pervasive environments [10]. Although some research has been done since the hybrid technology was published, this paper presents first extension of this technology with Web-based communities.

In the framework, resources of the smart space are represented by sets of Web-services. As a result of this representation, the emergency response community comprises Web-services representing units taking these actions. Service-oriented architecture is used to coordinate

Web-service interactions. The Web-services constituting this architecture implement resources' functionalities, produce model of the emergency situation, provide emergency response services, and represent participants of the emergency response actions and other people somehow involved in the emergency situation. An applicability of the proposed framework is demonstrated via a scenario-based organization of a Web-based community aiming at fire response.

The rest of the paper is structured as follows. Section II provides a comparative analysis of the present research with related ones. In Section III the scenario of fire response actions is described. The smart framework is discussed in Section IV. Results of scenario execution are given in Section V. Main research findings and approach limitations are discussed in the Conclusion.

II. RELATED RESEARCH

This Section focuses on approaches dealing with integration of different emerging technologies to multi-parties cooperation, particularly to emergency response. The main focus of the discussion is Web-based communities and smart spaces since the combination of facilities provided by these technologies is the main research challenge. Other problems that the present research concerns as e.g., ontology management, service composition, constraint satisfaction problem solving, etc. are out of consideration in this Section.

The role of social media and online communities in emergency situations is being thoroughly investigated within the research area of crisis informatics [11]. Online forums [12], Web portals [13], Tweeter [14][15], micro-blogging [16], social networks [17][18], and other forms of social media are believed to be powerful tools enabling collaboration of different parties to respond more effectively to emergencies.

There is no extensive literature on the subject of emergency management in smart spaces. One of the possible examples is DrillSim environment [19]. The purpose of this environment is to play out a crisis response activity where agents might be either computer agents or real people playing diverse roles. An activity in DrillSim occurs in a hybrid world that is composed of (a) the simulated world generated by a multi-agent simulator and (b) a real world captured by a smart space. In order to capture real actors in the virtual space, DrillSim utilizes a sensing infrastructure that monitors and extracts information from real actors that is needed by simulator (such as agent location, agent state, etc.).

To some extent potentialities of smart spaces in emergency have been exploited in an architecture that intends to improve the collaboration of rescue operators in emergency management via their assistance by a Process Management System [20]. This system is installed on the smart phones and PDAs of the rescue operators. It manages the execution of emergency-management processes by orchestrating the human operators with their software applications and some automatic services to access the external data sources and sensors.

In part of integration of emerging technology-driven paradigms for different purposes, ideas of an integration of paradigms of Web services, Web 2.0, pervasive, grids, cloud computing, situated computing, and crowd sourcing that are considered to be the candidates that can support collective resource utilization and multi-parties cooperation with mutual interests [21] can be pointed out. Integration of paradigms of virtual organizations and Semantic Web is offered to be used for organization of resources and services into a collaborative association to handle different kinds of emergency events [22].

The above approaches address different aspects of emergency management. All they integrate various emerging technologies to achieve their goals. The novelty of the present research lies in combination of information from the smart space and from Web-based communities for coordination of emergency response activities.

Like the approaches considering the problem of searching for efficient transportation routes within the emergency response problem (e.g., [23][24]), this research searches for such routes and uses them as the basis for joining independent units from diverse locations in a collaborative community. The community members are coordinated via Web-based interface. They are provided with the ability to exchange operational information and interact on-line using different Internet accessible devices.

III. SCENARIO

Suddenly, in some area inside a smart space the emergency event of a fire has started. Resources of the smart space as, e.g., fire sensors recognize it and send the appropriate signal to a smart space's service taking the role of the dispatcher. In the surroundings of this area available mobile fire brigades and emergency teams as well as hospitals with free capacities are found. Based on some criteria (see Section V) several of the brigades, teams, and hospitals are selected for the joint fire response actions. A plan for these actions is proposed to the selected emergency responders. The plan is a set of emergency responders with transportation routes for the mobile responders, required helping services, and schedules for the responders' activities. The plan is displayed on Internet accessible devices of the hospital administrators and the leaders of the fire brigades and emergency teams. These persons are organized in a Web-based community to exchange information about their abilities, availabilities, surrounding conditions, etc. with the purpose of the joint actions coordination.

Potential victims are evacuated from the fire place using the ridesharing technology. Potential victims here are people who have been out of danger so far or have got themselves out of the dangerous area. In the scenario it is proposed that persons who need to be evacuated set the location where they would like to be conveyed into an application installed in their mobile devices. The application finds drivers able to transport these persons. The found drivers receive an appropriate signal. In the mobile devices of the drivers and persons the ridesharing routes are displayed.

Generally speaking, the destinations for the evacuated people do not matter. In actual usage evacuee can just run the appropriate application and it will search for bypassing cars.

It is supposed that the scenario takes place in a smart space. The main requirement to fulfill the scenario is Internet accessibility for the persons involved in it. A smart framework has been developed for this scenario.

IV. Smart Framework

Smart Framework is defined here as a framework that is intended to coordinate operations of various autonomous resources of a smart space in context aware way to assist people in attaining their objectives. Sensors, databases, applications and other kinds of components of the smart space including humans and organizations are regarded as resources. The framework is planned to conceptually show how smart spaces and Web-based communities can facilitate the coordination and effectiveness of emergency response operations. Technical problems like failed Internet connections, discharged devices, power off, etc. are not addressed in the framework. As well, reliability and security problems (unregistered services, information incompleteness, unauthorized access, etc.) are out of the research scope.

The framework (Figure 1) is supported by an application ontology that represents non-instantiated domain & problem solving knowledge of the emergency management domain [25]. This ontology is formalized by means of the formalism of object-oriented constraint networks. Problems represented in such a way can be processed as constraint satisfaction problem.

The application ontology specifies knowledge that can be needed in various emergency situations. Generally, in different situations different problems can arise independently on the situation type. In particular situation only a piece of knowledge relevant to this situation is needed. In this connection, whenever an emergency event occurs, knowledge and information relevant to the current emergency situation are extracted from the application ontology and integrated into an *abstract context*. This context reduces the volume of knowledge and, correspondingly, the complexity of the problem to be solved.

The task of relevant knowledge determination is treated as ontology slicing operation. The abstract context is an ontology-based model of the current emergency situation. As the two components make up the application ontology, the context specifies domain knowledge describing the current emergency situation and problems to be solved in this particular situation.

The domain constituent of the abstract context is instantiated by resources of the smart space. An *operational context* is then produced. The operational context embeds the specifications of the problems to be solved. The input parameters of these problems, which correspond to properties of the classes of the domain constituent, are instantiated. The operational context reflects any changes in information, so it is a near real-time picture of the current emergency situation. The operational context is the base for organization of a community that unites members whose aim is taking joint actions on emergency response.

In the framework, the resources of the smart space as well as people involved in the emergency in any way are represented by Web-services. Service profiles capture capabilities of the resources, organizations, and people and delivery constraints, i.e., the profiles describe the functional

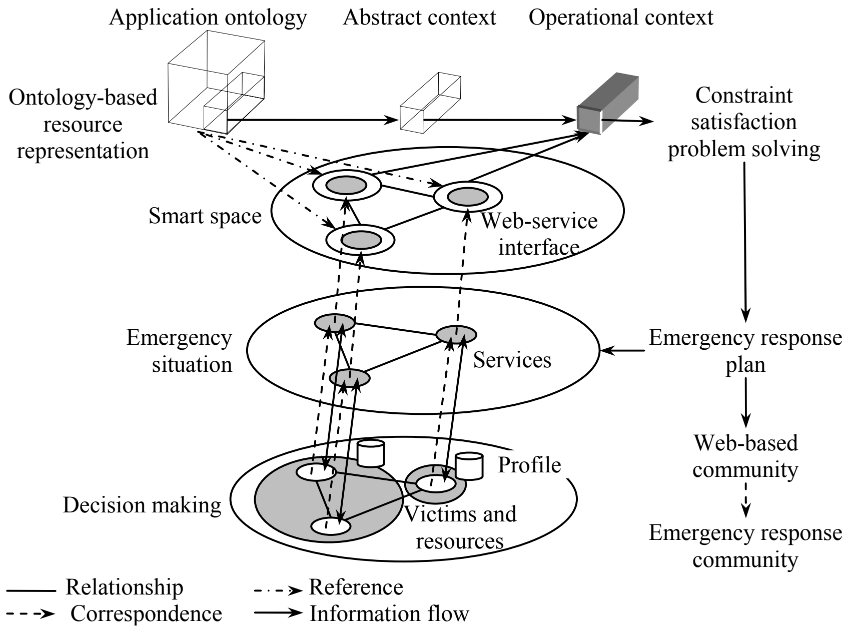

Figure 1. Generic scheme of smart framework

and non-functional service semantics [26]. The functional service semantics is described in terms of the input and output parameters of the service by means of WSDL. The WSDL service descriptions are complemented with SA-WSDL [27] annotations. The annotations enable to describe the non-functional service semantics, which is expressed with respect to service's cost model, availability, competence, and weight. The problem of compliance of service data models with the internal data model are resolved by wrappers. Due to the representation used the community purposed to emergency response actions comprises Web-services representing entities taking these actions.

The community is organized by specially developed emergency response services embedded in the smart space. Input data for the community organization are information characterizing the current emergency situation, particularly the situation type, and types of services relevant to the response actions. The types of services are represented in the abstract context. The current situation is represented by the operational context.

The emergency response services select possible community members and generate a set of feasible plans for actions. The set of plans is generated using the constraint satisfaction technology. A heuristic-based algorithm implements the plan generation [28]. Then, an efficient plan is selected from the set and submitted to the possible community members to their approval. This is the case of Web-based communications on the plan implementation. The members participating in such communications organize a Web-based community. If the plan is approved by all the members the emergency response community is considered to have been organized. Otherwise, another plan is taken up. The option of rejection is provided for due to the rapidly changing emergency situations – something may happen between the moment when a plan is selected and time when the possible community members receive this plan. The process of re-planning is an iterative process repeated till a plan suited all the members is found. The approved plan is thought to be the guide to joint actions for the members of the emergency response community.

As practice has shown, emergency response actions, besides actions on emergency control and first aid, have to foresee opportunities to evacuate potential victims from the dangerous areas. In the smart framework this purpose is achieved by applying functions that the ridesharing technology provides.

A. Service-Oriented Architecture

To coordinate interactions of the Web-services within the smart framework a service-oriented architecture is proposed. It comprises three groups of services (Figure 2).

The first group is made up of core services responsible for the registration of the Web-services in the service register and producing the real-world model of the emergency situation, i.e., creation of the abstract and operational contexts. Services belonging to this group are as follows:

- *registration service* registers the Web-services in the service register;

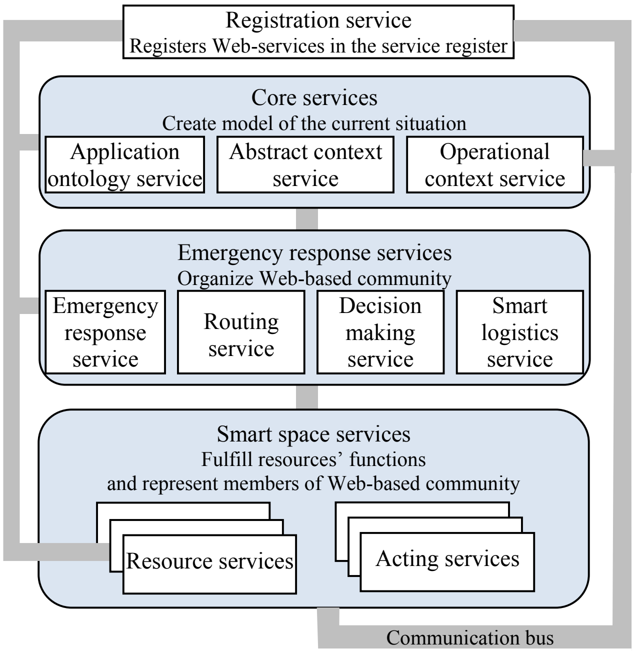

Figure 2. Service-oriented architecture

- *application ontology service* provides access to the application ontology;
- *abstract context service* creates, stores, maintains, and reuses the abstract contexts;
- *operational context service* produces operational contexts.

Web-services comprising the second group are responsible for the generation of alternative plans for actions and the selection of an efficient plan. This group contains:

- *emergency response service* integrates information provided by different resources about the number of injured people, and the location, intensity and severity of an emergency event;
- *routing service* generates a set of feasible plans for emergency response actions;
- *smart logistics service* implements the ridesharing technology;
- *decision making service* selects an efficient plan for actions and coordinates the (re)planning procedure.

The third group comprises sets of services responsible for the representation of the resources, organizations, and people and implementation of their functions. This group includes:

- *resource services* provide data stored in the resources' profiles and implement functions of the resources (smart ones as well);
- *acting services* provide data stored in the profiles of the emergency responders and victims; represent roles played by people or organizations; communicate on the plan implementation.

B. Organization of Web-based Community

We describe a Web-based community aimed at fire response actions.

The starting point for community organization is receiving by *emergency response service* of the signal that a fire event is taking place. Fire-prevention smart sensors had recognized some fire and sent this signal. Other kinds of smart information resources inform *emergency response service* of the number of injured people, and the location, intensity and severity of the fire.

Based on the information about the fire location, *emergency response service* requests the GeoInformation System (GIS) for a map of the fire area and the adjacent territory. The map contains some predetermined information as locations of the airports, buildings, roads, railway lines, water bodies, etc.

Using knowledge represented in the application ontology *abstract context service* determines what kinds of mobile teams and organizations providing response services are needed for the fire response actions and kinds of roles of the individuals involved in the fire situation. This service extracts knowledge related to the listed kinds of concepts from the application ontology and integrates it into an abstract context. In the case of fire, such kinds of teams are fire brigades and emergency teams; kinds of organizations are hospitals; kinds of roles are leader of a team, car driver, victim, etc. The referred kinds of concepts represent objects to be instantiated in the operational context.

Operational context service instantiates the abstract context and produces in that way an operational context. For the instantiation *operational context service* uses information provided by the following resources of the smart space:

- GPS-based devices installed on the vehicles of mobile emergency teams and fire brigades to fix the positions of these teams and brigades and to determine what types of vehicles they use;
- databases to find addresses and contact information of the fire departments, emergency services organizations, and hospitals;
- smart sensors to receive information which routes are available (e.g., where traffic jumps are, or some roads can be closed for traffic for some reasons);
- hospital administration systems to find out free capacities of the hospitals.

Operational context service passes the operational context to *routing service*. *Routing service* analyses types of routes (roads, airlines) that the emergency teams and fire brigades can follow depending on the vehicles they use. Based on the information about the number of injured people, the intensity and severity of the fire *routing service* calculates number of emergency teams and fire brigades needed to succeed in the response actions. The information about the number of injured people, the intensity and severity of the fire is received from *emergency response service*.

Then, *routing service* selects possible fire brigades, emergency teams, and hospitals that can be involved in the response operation and generates a set of feasible plans for actions. The actions are scheduled taking into account the availabilities of fire brigades, emergency teams, and hospitals; the types of vehicles that teams and brigades use; the routes available for these types; and the hospitals' free capacities. The problem of transportation routes planning incorporates the shortest-path problem.

Decision making service using a set of criteria selects an efficient plan from the set of feasible plans. The selected plan and the operational context are submitted to the leaders of the emergency teams, fire brigades that have been included in the plan, and to the hospitals' administrators. They have access to the operational context through any Internet-accessible devices (notebooks, PDAs, mobile phones, etc.). These persons organize a Web-based community to communicate on the plan implementation.

Persons who need to be evacuated invoke *smart logistics service* that is responsible for the evacuation. Clients of this service are supposed to be installed on the Internet-accessible devices of car drivers and other people involved in the fire situation. The persons enter the locations they would like to be conveyed. *Smart logistics service* determines the persons' locations and searches for cars going to or by the same or close destinations that the persons would like to be. It searches the cars among the vehicles passing the persons' locations. This service reads information about the destinations that the car drivers are going to from the navigators that the drivers use or from the drivers' profiles. The profiles store periodic routes of the drivers.

Based on the information about locations and destinations of the person and the found cars, *routing service* generates a set of feasible routes for person transportations. *Decision making service* determines efficient ridesharing routes. The criteria of the efficiency are minimum evacuation time and maximum evacuation capacity.

Smart logistics service sends appropriate signals to the drivers included in the ridesharing routes and displays on the drivers' devices the routes each driver is selected for. The points where the driver is expected to pick up the passenger(s) is indicated in the routes. The ways the passengers have to walk to these points are routed for them as well. Besides the routes, the passengers are informed of the model, color, and license plate number of the car intended for their transportation.

The view of the routes displayed on the devices of the individuals involved in the fire situation depends on the roles of these individuals.

C. Communications on Plan Implementation

The used model of decision making oversteps the limits of the three-phase model [29] towards communications of emergency responders on the implementation of the decision proposed by *decision making service*. The emergency responders communicate online using Internet-accessible devices and Web-based interface. Procedures of making decisions on plan implementation by professional emergency responders (emergency teams, fire brigades, hospitals) and by car drivers and evacuees are different.

The procedure of making decisions by the professional emergency responders is as follows (Figure 3). If the plan is approved by all the responders, this plan is supposed to be the plan for actions. Otherwise, either this plan is adjusted (so that the potential participant who refused to act

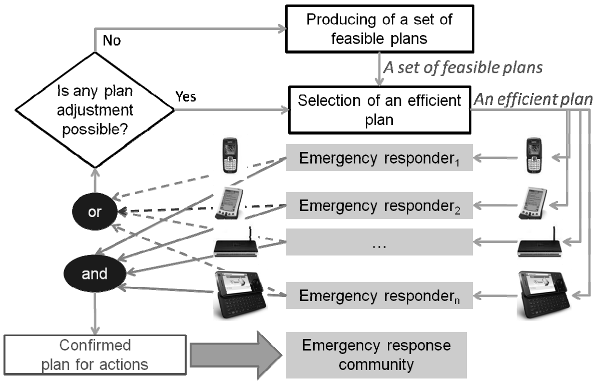

Figure 3. Decision making by professional emergency responders

according to the plan does not appear in the adjusted plan) or another set of plans is produced.

The plan adjustment is a redistribution of the actions among emergency responders that are contained in the set of feasible plans. If such a distribution does not lead to a considerable loss of time (particularly, the estimated time of the transportation of the injured people to hospitals does not exceed “The Golden Hour” [30]) then the adjusted plan is submitted to the renewed set of emergency responders for approval. If a distribution is not possible or leads to loss of response time a new set of plans is produced, from which a new efficient plan is selected and submitted to approval.

As soon as representatives of all the emergency teams, fire brigades, and hospitals have approved the plan they are in, *decision making service* sends them an appropriate signal that the joint actions can be started.

Figure 4 shows service interactions when all the emergency responders agree to participate in the joint actions according to the plan selected by *decision making service* (in the figure the emergency responders are represented by vehicles that they use – ambulance, fire truck, and rescue helicopter). We could see that *decision making service* sends simultaneous messages to all the emergency responders with the plan for each responder, waits their replays on plan acceptance (Ready), and sends them simultaneous messages to take the response actions (Start).

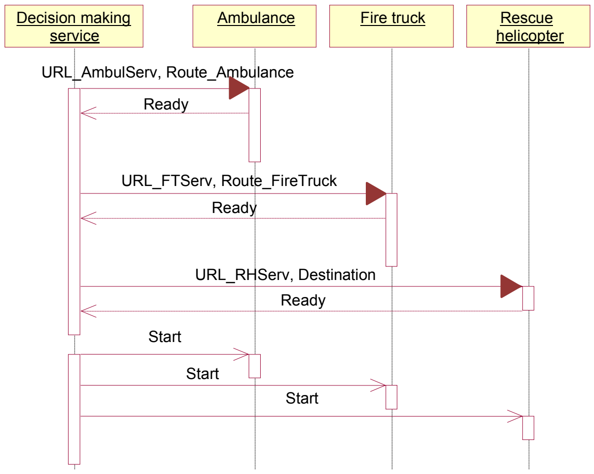

Figure 4. Emergency responders accept emergency response plan

Figure 5 demonstrates service interactions in case when all the ambulances selected for the response actions are not ready to participate in them and *routing service* does not manage to adjust the selected plan. Two ambulances (Ambulance 1 and Ambulance 2) replay “Not ready” to the messages of *decision making service*. This replay is accompanied with the messages to *decision masking service* and *operational service* with the reasons of their refusals. Examples of such reasons are the road has been destroyed, the ambulance has blocked, etc.

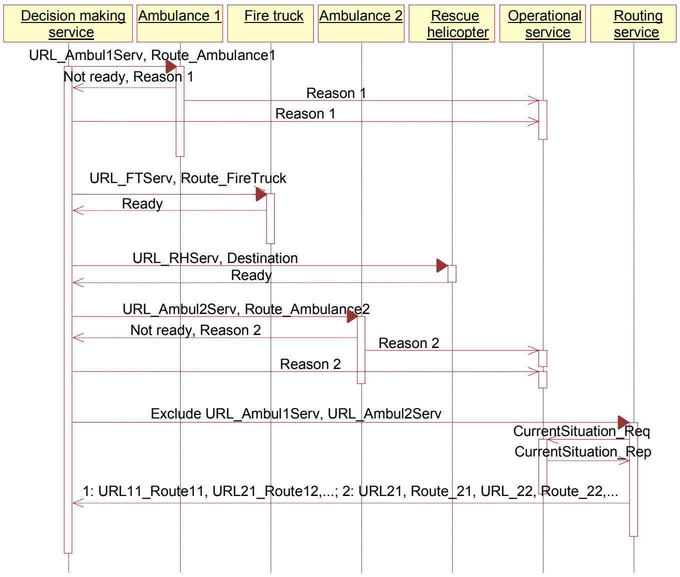

Figure 5. Plan regeneration

Decision making service duplicates the messages with the reasons for *operational service*. The duplication is a guarantee that *operational service* will receive information that it was unaware of up to this moment. As well *decision making service* sends the message on excluding the two ambulances from the list of available emergency responders to *routing service*.

Operational service corrects the operational context according to the information contained in the reasons. *Routing service* requests *operation service* of the operational context that represents the up-to-date information of the emergency situation, generates a new set of plans, and sends it to *decision making service*.

Decision making on an evacuation plan is in making agreement between the driver and the evacuee to go according to the scheduled ridesharing route (Figure 6). In case, when there is no agreement between a driver and an evacuee, another car for evacuation of this passenger is sought for. At that, the confirmed routes are not revised.

The emergency responders that are in the approved plan intended for professional emergency responders and the drivers participating in the evacuation organise the emergency response community.

V. SCENARIO USE CASE

The scenario (Section III) execution is demonstrated via organizing an emergency response community aimed at joint actions to response on a fire event happened in an urban area. The fire event was simulated using an internal platform that supports a GIS-based simulation. The platform is able to generate random failures and locations of professional emergency responders, random route availabilities, random flows of cars; it allows ones to input contextual information on types of emergency events, number of victims, etc.

In the scenario it is simulated that the fire has happened in a building, its level of severity is low, 9 injured people have to be transported to hospitals.

The application ontology used to create model of the fire situation had been created by experts via integration of parts of existing ontologies accessible through the Internet. To support the integration and necessary ontology modifications an ontology management tool – WebDESO [31] – was used. The application ontology has 7 taxonomy levels, contains more than 600 classes, 160 class attributes, and 120 relationships.

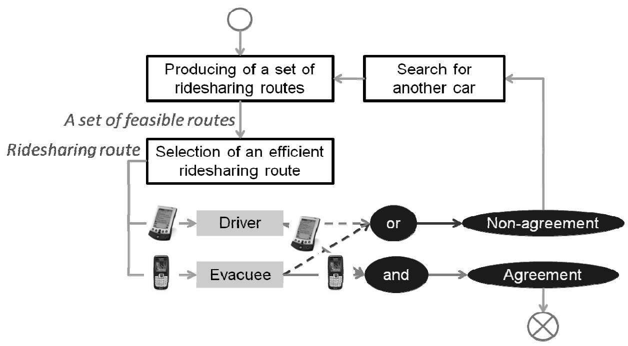

Figure 6. Decision making by car drivers and evacuees

Figure 7 presents the abstract context created to model the fire situation. This context has 4 taxonomy levels, contains 17 bottom-level classes to be instantiated, 38 class attributes, and around 30 relationships of different types. Problem solving knowledge is hidden in the class “emergency response”. This class specifies the following problems:

- select feasible hospitals, emergency teams, fire brigades, and car drivers;
- determine feasible transportation routes for ambulances, and fire engines depending on the transportation network and traffic situation;
- calculate the shortest routes for transportation of the emergency teams by ambulances, fire brigades by fire engines, and evacuees by cars;
- produce a set of feasible response plans for emergency teams, fire brigades, and hospitals;
- produce a set of feasible ridesharing routes.

In the simulated scenario 7 available fire brigades, 8 emergency teams, 5 hospitals having free capacities for 4, 4, 2, 3, and 3 patients are found in the territory adjacent to the fire place; 6 fire trucks and 1 fire helicopter are allocated to the fire brigades, 7 ambulances and 1 rescue helicopter are allocated to the emergency teams; 1 fire brigade is calculated to be required to extinguish the fire. The plan for actions designed for the emergency teams supposes that one vehicle can house one injured person.

A set of feasible plans for actions was generated for the criteria of minimal time and cost of transportation of all the victims to hospitals, and minimal number of mobile teams involved in the response actions. The set of feasible plans comprised 4 plans.

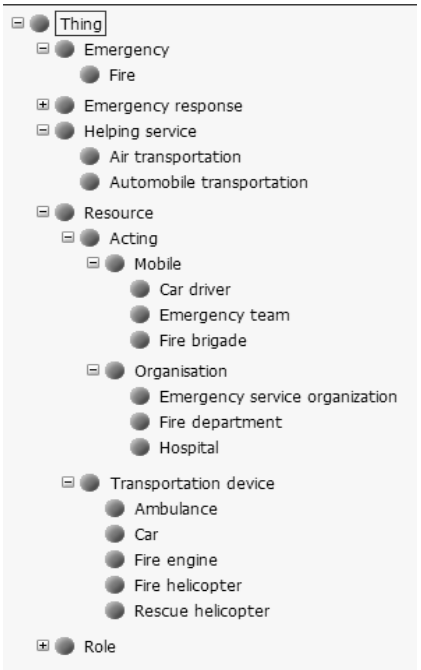

Figure 7. Fire situation: abstract context (a piece)

An efficient plan (Figure 8) was selected based on the key indicator of minimal time of victim transportations. In Figure 8 the big dot denotes the fire location; dotted lines depict routes to be used for transportations of the emergency teams and fire brigades selected for the response actions. The plan is approved by all the action participants. As it is seen from the figure, Web-based community comprises 1 fire brigade going by 1 fire helicopter, 7 emergency teams allocated to 1 rescue helicopter and 6 ambulances, and 3 hospitals having free capacities for 4, 2, and 3 patients. 1 ambulance (encircled in the figure) and the rescue helicopter go from the fire location to hospitals twice. The estimated time of the operation of transportations of all the victims to hospitals is 1 h. 25 min. Figure 9 shows part of the plan displayed on the smart phone of a member of an emergency team going by ambulance.

Results of evacuation of safe people using the ridesharing technology are as follows: 26 persons desire to be evacuated from the scene of fire; 22 persons have been driven directly to the destinations by 16 cars whereas for 4 persons no cars have been found. Examples of ways routed for a driver and a passenger are given in Figure 10 and Figure 11. The encircled car in the figures shows the location where the driver is offered to pick up the passenger. The persons that cannot be evacuated by passing cars are informed that they can be evacuated by taxi. If they agree, *smart logistics service* makes orders for taxi.

The Web-based community organised comprises 1) the professional emergency responders scheduled in the fire response plan (Figure 8) in the persons of the leaders of the emergency teams and fire brigades as well as the administrators of the hospitals, 2) the cars' drivers participated in the confirmation of the ridesharing routes, and 3) the evacuees. The emergency teams, fire brigades, hospitals, and car drivers constitute the emergency response community.

The Smart-M3 platform [32] has been used for the

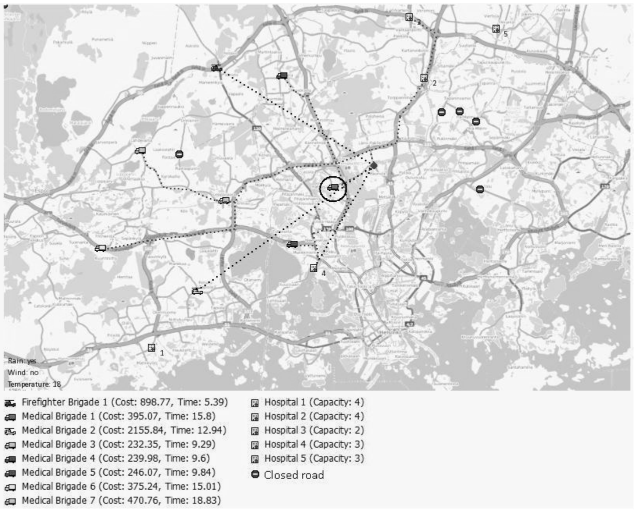

Figure 8. Plan for actions for fire brigades, emergency teams, and hospitals

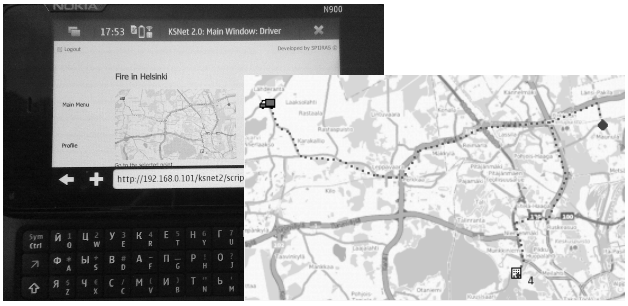

Figure 9. Plan for actions for an emergency team

scenario implementation. Tablet PC Nokia N810 (Maemo4 OS) and smart phone N900 (Maemo5 OS) play role of user devices. Personal PCs based on Pentium IV processors and running under Ubuntu 10.04 and Windows XP are used for hosting other services.

In the experiments with different datasets the execution time from the moment the emergency event was registered to the moment of producing the operational context took around 0.0007 s. The time taken to generate the sets of action plans for different datasets is shown in Table 1 and Figure 12. The approximating equation is quadratic for the total amount of objects involved in the response actions. The experimentation showed that the system already takes a reasonable time for result generation. Presented results are based on the usage of a research prototype running on a desktop PC. In a production environment the system is aimed to be run on dedicated servers and it is expected to be responsive enough to handle a large amount of objects. The future development of Smart-M3 up to the production level with a higher capacity could also contribute to the system performance.

VI. CONCLUSION

The problem of integration of the emerging technology-driven paradigms of smart spaces, Web-services, and Web-based communities for the fire response purposes was investigated. Most probably, judging from the literature, this is the first investigation on the integration of the mentioned technologies for emergency management aims.

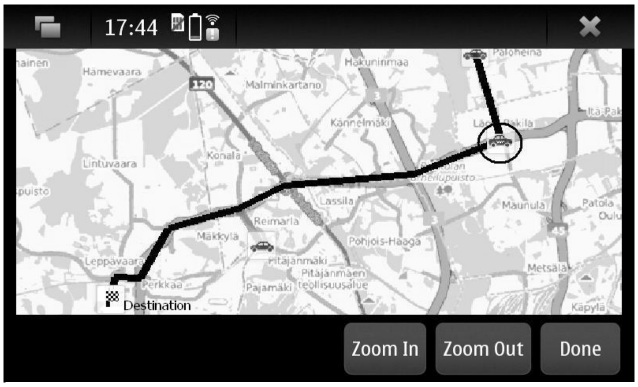

Figure 10. Ridesharing route: driver's view

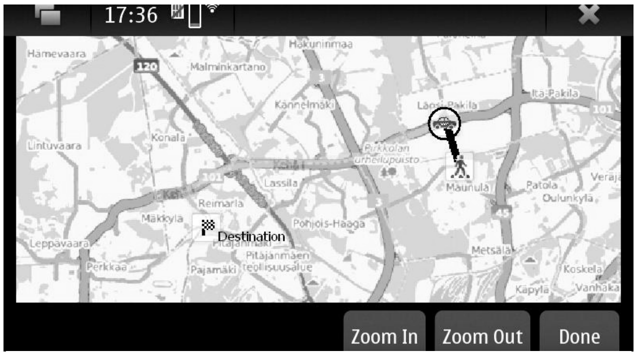

Figure 11. Ridesharing route: passenger's view

A smart framework that serves to integrate concepts of smart space, Web-services and Web-based communities has been proposed. This framework is developed to operate with Web-services representing the physical resources of a smart space and parties and individuals involved in a fire situation. The parties and individuals that are fire responders form a Web-based community. It is shown that they can communicate online independently on the devices they use, to exchange the operational information or make decisions on their readiness to participate in the joint response actions. In this direction, the present research exceeds the bounds of the three-phase Simon's model [29] towards actor communications on the decision implementation.

Due to the smart framework is built around the application ontology of the emergency management domain, this framework can be applied to organization of emergency management communities for response to different types of emergencies.

An original feature of the way the fire response actions are planned is in the involvement of ridesharing technology. Previously, the authors of this paper considered professional emergency responders to act on emergency response. In this paper, the community of professionals is extended with volunteers. Ridesharing serves as an example of the technology based on which volunteers can be involved in the emergency response actions.

To coordinate Web-service interactions within the smart framework the service-oriented architecture has been designed. The architecture contains a set of Web-services that is supposed to be sufficient to organize any fire response communities independently on types of operational units to be involved in response actions.

So far, the applicability of the smart framework was tested for response to traffic accidents and different kinds of fire events (fire in a building, a port, a city area). This paper presents the scenario of planning fire response actions in an urban area. The scenario execution has shown that the paradigm of smart space provides efficient facilities to successful emergency response. Moreover, it can be concluded that ridesharing technology can be used for evacuation of potential victims from dangerous areas.

TABLE I. EXPERIMENT RESULTS

Number of emergency responders	Number of victims	Total number of objects	Time of plan generations, s.
10	10	20	4.85
10	20	30	9.12
20	20	40	17.51
30	30	60	37.93
40	40	80	66.13
50	50	100	101.29

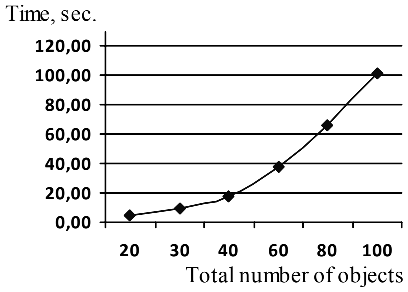

Figure 12. Dependence between number of objects involved in emergency and times of response plan generations

Some limitations of the developed framework are worth mentioning. The framework does not take into account cases when it is not found enough available acting resources or when some resources become disabled at time of the response actions. As well, the framework does not address the problem of lack of passing cars for evacuation of people from the fire area and the problem of searching for a route with changes if there are not any cars nearby the fire area going directly to the person destination. The listed limitations will be subjects for future research. Some more future research will address the problem of dynamic adaptability to following emergency events or to events concurrently happening in near-by locations.

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