WEB-BASED EMERGENCY RESPONSE COMMUNITY
Framework and Case Study on Fire Response Community

Alexander Smirnov, Tatiana Levashova, Nikolay Shilov and Alexey Kashevnik
St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences, 39, 14th line, St. Petersburg, 199178, Russian Federation

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Abstract: The research addresses the problem of exploitation of smart space's facilities for the organization of resources of a smart space into an emergency response community. The members of such a community and people involved in emergency are enabled to use Web-based interface for their communications and making decisions, i.e. they organise a Web-based community. The paper proposes a framework that incorporates concepts of smart space, Web-based communities, and Web-services. The framework replaces real-world resources of the smart space with their service-based representations. As a result of this replacement, the emergency response community comprises Web-services representing resources providing emergency response services. Service-oriented architecture serves to coordinate interactions of the Web-services the framework deals with. The applicability of the proposed framework is demonstrated by a simulated case study on organization of a fire response community.

1 INTRODUCTION

Recently, technologies of smart space environments, Web-services, and Web-based communities have received much attention due to facilities offered by them. The smart environments provide efficient facilities for organization of their resources in a context-aware way to assist people in their needs (Lamorte and Venezia, 2009); (Özçelebi et al., 2010). Web-services offer advantages of seamless information exchange between the resources of smart environments (Schroth, 2007) and a potential for lower integration costs and greater flexibility (Microsoft Corp., 2003); (Oracle, 2005). Web-based communities are beneficial in instant information exchange and online decision making.

The present research addresses the problem of exploitation of smart space's facilities for the organization of resources of a smart space into a community aiming at emergency response. The members of this community and people involved in emergency are enabled to use Web-based interface for their communications and making decisions. In this way they constitute a Web-based community.

The paper proposes a framework that incorporates concepts of smart space, Web-based communities, and Web-services. This framework replaces real-world resources of the smart space with their service-based representations. As a result of this replacement, the emergency response community in made up of Web-services representing resources that provide emergency response services. Various sensors, actuators, electronic devices with computational capabilities, etc. as well as humans and organisations are considered as various kinds of resources comprising the smart space.

An emergency response community is organised based on emergency response plan. The problem of planning emergency response actions is solved by computational resources of the smart space. Service-oriented architecture serves to coordinate interactions of the Web-services the framework deals with. The applicability of the proposed framework is demonstrated by a simulated case study on organization of a fire response community.

The rest of the paper is structured as follows. Section 2 presents a brief survey of related research. Section 3 introduces the framework intended for organisation of emergency response communities in smart spaces. The service-oriented architecture and interactions of Web-services constituting the framework are discussed in Section 4. Section 5 demonstrates the applicability of the framework via

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organization of a fire response community. Main concluding remarks are summarized in Section 6.

2 RELATED RESEARCH

There is no extensive literature on the subject of organization of Web-based communities in smart spaces or involvement of members of such communities in joint actions. An example of coordination of different users doing collaborative activities from diverse locations through different devices is the use of a hypermedia model to describe and support group activities in intelligent environments (Arroyo et al., 2008).

The role of social media and online communities is being thoroughly investigated within the research area of crisis informatics (Hagar, 2010). Online forums (Palen et al., 2007), Web portals (Mandel et al, 2010), Tweeter (Starbird and Palen, 2011); (Starbird and Palen, 2012), micro-blogging (Vieweg et al., 2010), social networks (Armour, 2010); (Krakovsky, 2010), and other forms of social media are believed to be powerful tools enabling collaboration of different parties to respond more effectively to emergencies.

To some extent potentialities of smart spaces in emergency have been used in an architecture that intends to improve the collaboration of rescue operators in emergency management via their assistance by a Process Management System (Catarci et al., 2010). 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.

The idea close to the integration of Web-services into an emergency response community has been studied in research addressing the investigation of effectiveness of actor-agent communities in context of incident management (Gouman et al., 2010). Although the preliminary research results are inconclusive, they allow ones to suggest that agents, at least, can efficiently support humans in achieving a common goal.

The idea beyond the present research of treating emergency response as the problem of planning emergency response actions in an efficient manner is shared by many studies, e.g., (Ng and Chiu, 2006); (Ling, 2009) and many others.

The approaches above address different aspects of organisation of communities of actors (including emergency response communities) sharing a common goal. They integrate various emerging technologies to achieve their goals. But no one of them investigates jointly both the problems of planning response actions and involvement of the participants of these actions into Web-based communities.

3 FRAMEWORK

The proposed framework is intended to coordinate operations of various resources of a smart space in context aware way to assist people in attaining their objectives. The framework distinguishes two kinds of resources in the smart space: information and acting. The information resources are various kinds of sensors and electronic devices that provide data & information and perform computations. Particularly, some information resources are responsible for problem solving. The acting resources are people and /or organisations that can be involved in the response actions, i.e., emergency responders.

3.1 Emergency Response Community

As known from e-Government practice, participation of different stakeholders in e-Government's activities can result in broader (integrated) solutions (Rainford, 2006); (Chourabi and Mellouli, 2011). So, the framework assumes partnerships of different stakeholders in emergency response actions. It integrates emergency services the smart space provides and voluntary sector as the partnerships (Figure 1). It is considered that the smart space provides emergency response services on first aid, emergency control, and people evacuation. The services on first aid and emergency control are services rendered by professional emergency responders, whereas the evacuation services are provided by the voluntary sector. This sector is represented by car drivers – they are the volunteers ready to evacuate the potential victims.

Access to the emergency response services is achieved through wire or wireless Internet-accessible devices. Communications between the participants of emergency response actions are supported by Web-based interface. In this way these participants organize a Web-based community.

The professional emergency responders and the volunteers make up the emergency response community. They use Web-based interface to make decisions on action plans, to exchange information during the response actions, and to communicate with victims.

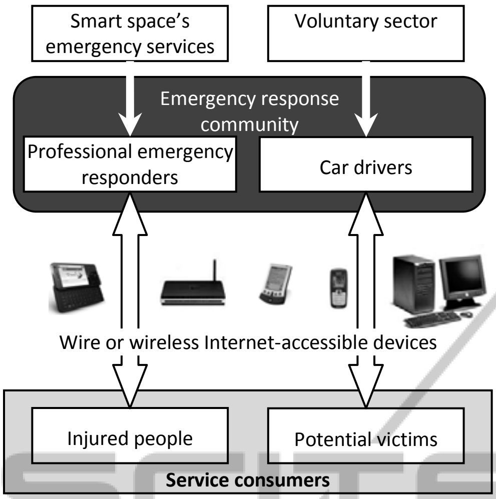

Figure 1: Emergency response community in smart space.

3.2 Generic Scheme of Framework

The idea behind the framework is to represent the resources of the smart space, emergency responders, and people in any way involved in the emergency by sets of Web-services. Each of the listed objects is characterized by its profile. A profile, besides typical information characterising an object (object's name**,** address, etc.), holds a set of context sensitive properties, e.g., the object's location, its availability, role, etc. The Web-services provide data stored in the profiles and implement the resources' functionalities. As a result of the representation used, the emergency response community comprises Web-services representing emergency responders taking the response actions.

The framework guides the emergency response as follows (Figure 2). Whenever an emergency event occurs, resources of the smart space recognize the type of event and determine other event characteristics (the location, intensity and severity of the event, etc.). Based on the type of emergency and knowledge represented in an application ontology of the emergency management domain, special developed services create an *abstract context*. This context is an ontology-based model of the emergency situation of the given type at the abstract (non-instantiated) level. It represents knowledge relevant to the emergency situation, i.e., kinds of services required in the given emergency situation and other knowledge related to these services.

The abstract context is instantiated by resources of the smart space. The resources continuously fill up the abstract context with real-world information characterising the emergency situation. In this way an *operational context* is produced, which is a model of the emergency situation representing fully-instantiated real-world objects relevant to it. Particularly, the operational context contains

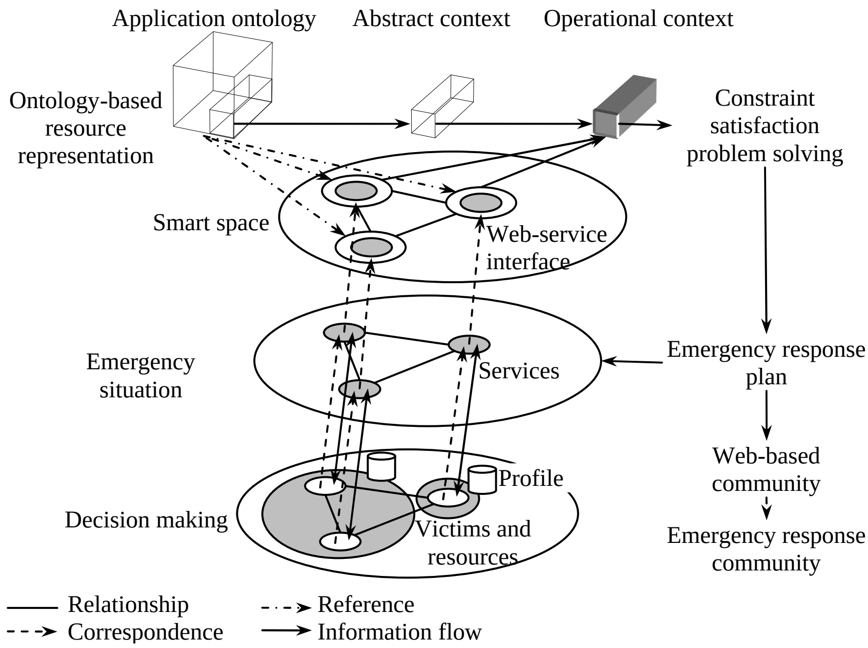

Figure 2: Generic scheme of the framework.

information about the locations of potential emergency responders along with some other their characteristics (their availabilities, capacities, etc.).

The operational context serves as the basis for producing a plan of response actions. An emergency response plan is a set of emergency responders with transportation routes for the mobile responders, required helping services, and schedules for the responders' activities. The problem of plan producing is solved as a constraint satisfaction problem, the result of which is a set of feasible action plans.

From the set of feasible plans an efficient plan is selected. For this, some efficiency criteria are applied. For professional emergency responders the following efficiency criteria are provided for: minimal time of arriving of professional emergency responders at the emergency location, minimal time and cost of transportation of injured people to hospitals, and minimal number of mobile teams involved in the response actions. For car drivers efficiency criteria are minimum evacuation time and maximum evacuation capacity.

The efficient plan is displayed on the Internet-accessible devices of emergency responders that are in this plan for making decisions if they are ready to act according to the plan or not. The procedure of making decisions is provided for two reasons. Firstly, emergency situations are rapidly changing ones – something may happen between the moment when a plan is selected and time when the possible community members receive this plan. Secondly, resources of the smart space may be disabled in emergency and because of this operational information may be not available; therefore the operational context may not meet the real state of the situation.

The approved plan is thought to be the guide for the response actions. The emergency responders scheduled in this plan organise the emergency response community.

3.3 Decision Making

Decisions on action plans are made online using Internet-accessible devices and Web-based interface. But procedures of making decisions by professional emergency responders and volunteers are different.

For the professional emergency responders an emergency response plan is a set of professional emergency responders (emergency teams, fire brigades, rescue parties, hospitals, etc.), a set of services these responders have to provide in the emergency situation (fire extinguishing, transportation, first aid, etc.), a set of transportation routes to go to the emergency location and to transport injured people to hospitals, and schedules for the responders' activities.

The procedure of making decisions by 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 according to the plan does not appear in the adjusted plan) or another set of plans is produced.

The plan adjustment is in 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") 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.

For the car drivers the emergency response plan is a plan for evacuation of potential victims from the dangerous area. Such a plan for a driver is a ridesharing route and transportation schedule.

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 4). 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.

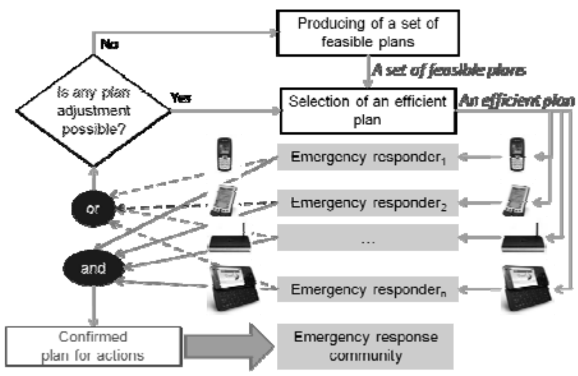

Figure 3: Decision making by professional emergency responders.

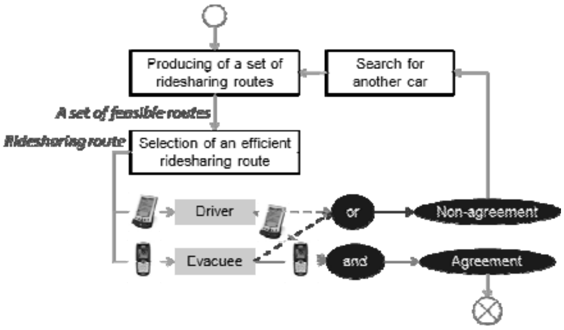

Figure 4: Decision making by car drivers and evacuees.

4 SERVICE-ORIENTED ARCHITECTURE

To coordinate the interactions of Web-services, the framework deals with, service-oriented architecture has been designed.

4.1 Architecture Components

The architecture comprises three groups of services (Figure 5). 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. the 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;
- *application ontology service* provides access to the application ontology;
- *abstract context service* creates, stores, maintains, and reuses the abstract contexts;
- *operational context service* produces the operational contexts.

Web-services comprising the second group are responsible for the organization of an emergency response community. This group contains:

- *emergency response service* integrates information provided by the city's resources;
- *routing service* generates a set of feasible plans for emergency response actions;
- *smart logistics service* implements functions of the ridesharing technology;
- *decision making service* selects an efficient plan from the set of feasible plans and coordinates the (re)planning procedure.

The third group comprises sets of services responsible for the representation of the smart space's resources, implementation of their functions, and representation of emergency responders and people in any way involved in the emergency. This group includes:

- *resource services* provide data stored in the

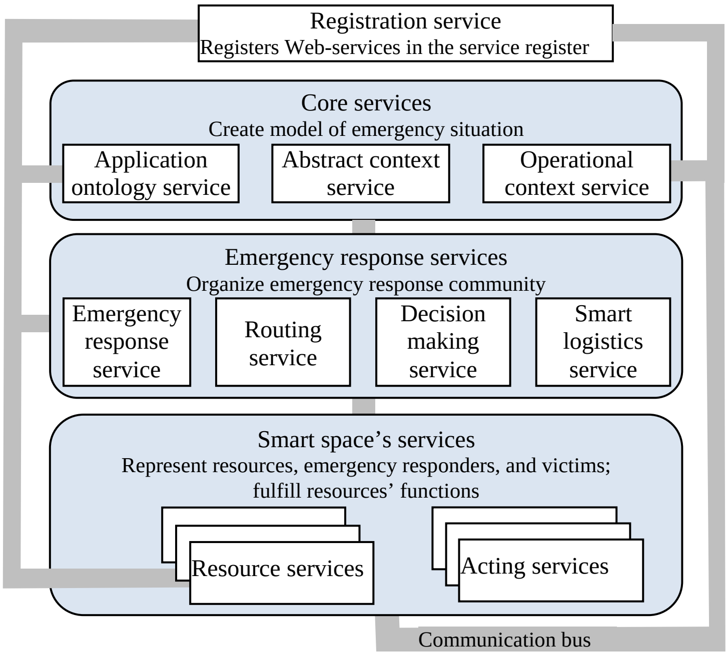

Figure 5: Service-oriented architecture.

profiles of information resources and implement functions of these resources;

- *acting services* provide data stored in the profiles of acting resources (emergency responders) and other people involved in emergency.

4.2 Service Interactions

Service interactions in Web-based community are demonstrated by two scenarios. These scenarios introduce the service interactions in making decisions on the plan for actions intended for professional emergency responders.

Figure 6 shows Web-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). It is seen 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 7 demonstrates Web-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.

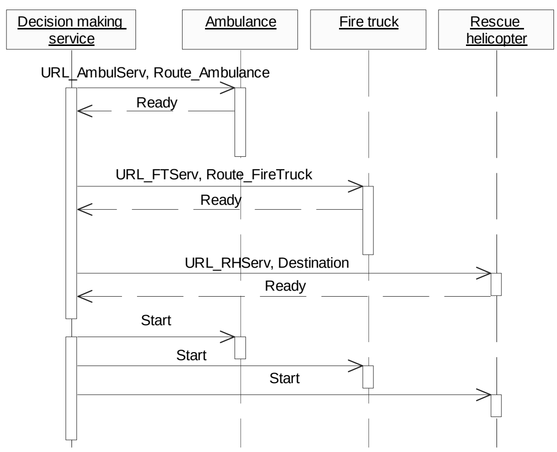

Figure 6: Emergency responders accept emergency response plan.

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*.

5 CASE STUDY: FIRE RESPONSE COMMUNITY

An applicability of the proposed framework is demonstrated via the organization of an emergency response community aimed at response to a fire event happened in a smart space. The event was simulated using an internal platform that supports a GIS-based simulation. The platform is capable to generate random failures and locations of emergency responders, and random route availabilities; it allows ones to input contextual information on types of emergency events, number of victims, etc.

According to the framework resource services recognize the fire event, fix the fire location, classify the fire severity, and registers number of victims to be transported to hospitals. In the test case 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. This information is sent to *emergency response service*. This service concludes that to extinguish the fire 1 fire brigade is required.

Based on the type of emergency (fire) *abstract context service* creates an abstract context. This context represents the following kinds of response services required in the fire situation: fire service, emergency service, and transportation service. These services are provided by the following kinds of emergency responders: fire brigades, emergency teams, hospitals, and car drivers. Besides the listed knowledge, the abstract context represents various kinds of vehicles that may be used by the emergency responders, and kinds of roles of the individuals involved in the fire situation (e.g., leader of a team, driver, victim, passenger, etc.).

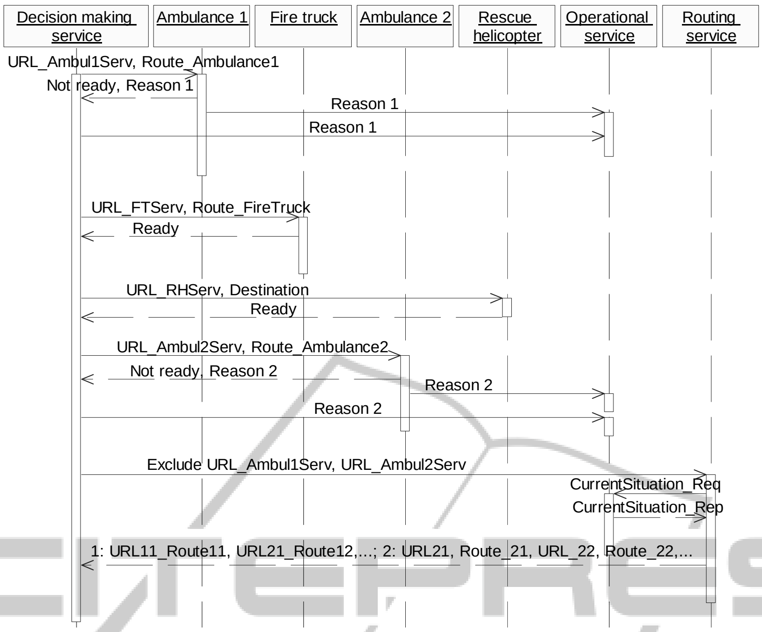

Figure 7: Plan regeneration.

Operational context service instantiates the kinds of concepts represented in the abstract context and produces in that way an operational context. For the instantiation *operational context service* uses the information provided by the resource services and acting services:

- the location and severity of the fire event;
- the number of victims;
- the current locations, availabilities, and capacities of the mobile emergency responders, i.e., fire brigades, emergency teams, and car drivers;
- the types of vehicles the mobile emergency responders use;
- the addresses, contact information, availabilities, and free capacities of the hospitals;
- the destinations of cars passing by the fire place and the cars' properties (free capacities, availabilities of baby car seats, etc.);
- the current locations of the uninjured people to be evacuated from the fire area;
- the transportation network, the route availabilities, and the traffic situation.

Operational context service passes the operational context to *routing service*. *Routing service* analyses types of routes (roads, waterways, etc.) that the emergency teams and fire brigades can follow depending on the vehicles they use. Then, *routing service* selects feasible fire brigades, emergency teams, and hospitals that can be involved in the response operation. They are selected depending on 1) their availabilities; 2) the types of vehicles they use and 3) the routes available for these types; and 4) the hospitals' free capacities.

In the simulated area 7 available fire brigades, 8 emergency teams, 5 hospitals having free capacities for 4, 4, 2, 3, and 3 patients correspondingly are found; 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.

For the found emergency responders *routing service* generates a set of feasible plans for actions. A plan for actions produced for the emergency teams supposes that one vehicle can house one injured person.

Routing service passes the operational context and the set of plans to *decision making service*. The latter selects an efficient plan (Figure 8). At that, minimal time of victim transportations is used as the efficiency criterion. 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.

As it is seen from the figure, the set of emergency responders 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 are planned to go from the fire location to hospitals twice. The estimated time of the

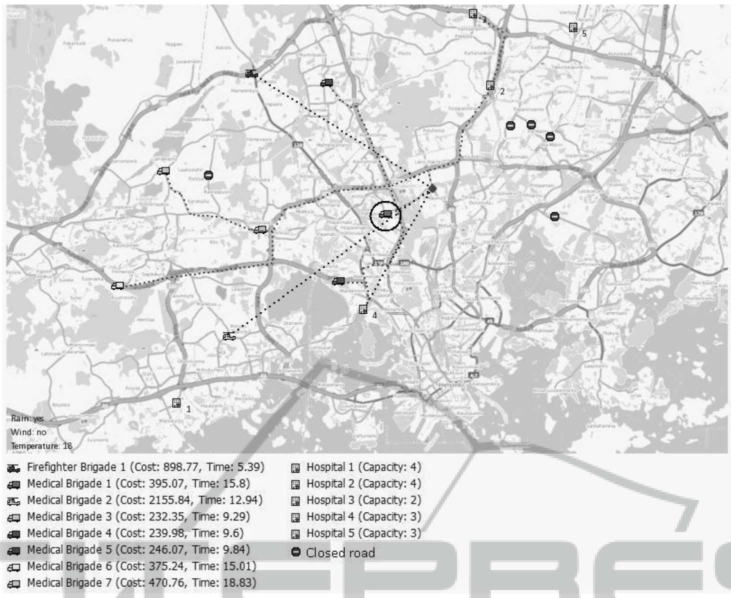

Figure 8: Plan for actions for fire brigades and emergency teams.

operation of transportations of all the victims to hospitals is 1 h. 25 min.

Decision making service submits the plan to the emergency responders that are in it for making decisions on this plan. The plan is displayed on the Internet-accessible devices of these responders. The view of the plan depends on the roles the emergency responders fulfill in the current emergency situation. Figure 9 shows part of the plan displayed on the Tablet PC of the leader of an emergency team.

In the test case all the emergency responders represented in Figure 8 are supposed to agree on the plan and therefore have become the members of the emergency response community.

Concurrently with the planning of the response actions activities on evacuation of people from the fire area are undertaken. Persons who need to be evacuated from the fire area invoke *smart logistics service*. This service scans cars passing the person locations. Based on the information about the person

Figure 9: Plan for actions for an emergency team.

locations and destinations, and the locations and destinations of the found cars, *routing service* produces a set of feasible ridesharing routes for the person transportations. *Decision making service* selects efficient routes.

The selected efficient routes are displayed on Internet-accessible devices of the drivers and the evacuees to confirm their intentions to go according to the proposed to them ridesharing routes. Besides the routes, the passengers are informed of the model, color, and license plate number of the car intended for their transportation.

As the drivers and the passengers confirm the evacuation plans, *smart logistics service* sends appropriate signals to the drivers included in the agreed plans. Examples of ways routed for a driver and a passenger and displayed on their smart phones are given in Figure 10 and Figure 11. For the passenger the walking path to the locations where the drivers are offered to pick his/ her up is displayed. The encircled car in the figures shows the location where the driver is offered to pick up the passenger.

In the simulated example 26 persons are supposed to have to be evacuated from the fire area. The results obtained for this are as follows: 22 persons have been driven directly to the destinations by 16 cars whereas for 4 persons no cars have been found. These 4 persons are informed through their mobile devices that they can be evacuated by taxis. If they agree, *smart logistics service* makes orders for taxi.

The Web-based community organised in the test case 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.

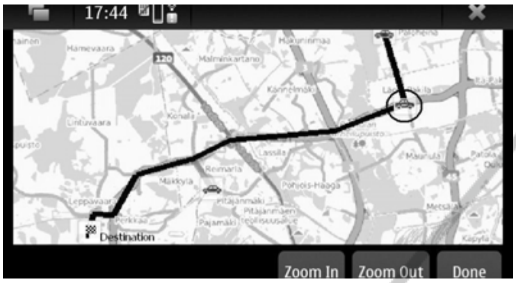

Figure 10: Ridesharing route: driver's view.

The Smart-M3 platform (Honkola et al, 2010) was used in the scenario execution. Tablet PC Nokia N810 (Maemo4 OS), smart phone N900 (Maemo5 OS), and different mobile phones served as the user devices. Personal PCs based on Pentium IV processors and running under Ubuntu 10.04 and Windows XP were 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. 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.

Table 1: Execution 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 11: Ridesharing route: passenger's view.

6 CONCLUSIONS

The problem of integration of services provided by a smart space with the purpose of organisation of emergency response communities was investigated. A framework that serves to integrate concepts of smart space, Web-services and Web-based communities has been proposed. The framework supports seamless information exchange between the resources of the smart space, allows the members of an emergency response community to make online decisions on plans for their actions and to communicate during these actions for coordination of their activities, enables Web-based communications between the emergency responders and emergency victims, supports access the emergency services that the smart space provides using any wire and wireless Internet-accessible devices.

An original feature of the way the response actions are planned is in involvement of ridesharing technology in planning evacuation activities.

Some limitations of the developed framework are worth mentioning. The framework does not take into account cases when it is not found enough available professional emergency responders 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 as well as real-life testing and implementation will be subjects for future research and activities.

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