Web-Based Community for Fire Response Actions

Scenario and Smart Framework

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Abstract—**The paper addresses organization of a Web-based community in a smart space, members of which aim at joint fire response actions. A smart framework for integrating concepts of smart space, Web-services and Web-based communities was developed. In the framework Web-services are proposed to represent the resources of the smart space and the members of the Web-based community. To coordinate Web-service interactions a service-oriented architecture was designed. An applicability of the smart framework was tested via a scenario-based organization of a Web-based community.**

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

I. INTRODUCTION

Recently, Web-based communities have received much attention due to offered advantages of instant information exchange that is not possible in real-life communities. Availability of operational information [1][2] as well as potentialities to instant information exchange [3][4][5] 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 exchange operational information, seems to be a promising idea.

It is well known, that emergencies are rapidly changing situations characterized by context information. Context information is vastly available in a smart space [6]. Any smart space is comprised of a large number of various sensors, devices and other kinds of resources. It embeds a lot of services that are expected to be automatically provided according to the particular situation. The resources of the smart space can share information and services independently on their physical location.

The smart space technology has suggested an idea of exploiting its information sharing facilities and context aware service provision for the purpose of organization of Web-based communities. Research presented in this paper addresses the organization of such a community, members of which aim at joint fire response actions.

To achieve the research purpose a smart framework that serves to integrate concepts of smart space, Web-services and Web-based communities is proposed. This framework is based on the earlier developed hybrid technology supporting context aware operational decision support in pervasive environments [7]. Although some research has been done since the hybrid technology was published, this paper presents first extension of this technology with Web-based communities.

Due to Web-services enable seamless information exchange between distributed components of a smart space, the idea behind the framework is to use Web-services as mediators between resources of the smart space and members of the Web-based community. This idea is implemented via representation of the smart space's resources and the community's members by sets of Web-services. As a result of this representation, the Web-based community organized for fire response actions comprises Web-services representing units taking these actions.

To coordinate Web-service interactions service-oriented architecture is used. Service-oriented architecture facilitates the interaction of service components and the integration of new ones. The Web-services constituting this architecture implement resources' functionalities, produce model of the fire situation, provide fire response services, and represent participants of the fire response actions and other people somehow involved in the fire situation.

An applicability of the proposed framework is demonstrated via a scenario-based organization of a Web-based community.

The rest of the paper is structured as follows. Section II provides a comparative analysis of the presented research with related one. 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 findings are summarized in Conclusion.

II. RELATED WORK

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 [8]. Another on-going research tries to use social networks to form groups of individuals engaged in crises management efforts. These groups are suggested collaborating in crisis situations [9].

Ideas of an integration of emerging technology-driven paradigms belong to those aimed at organization of a collaborative environment for emergency response using potentialities of emerging technologies. Perspectives on the integration of paradigms of Web services, Web 2.0, pervasive, grids, cloud computing, situated computing, and crowd sourcing are considered to be the candidates that can support collective resource utilization and multi-parties cooperation with mutual interests [10]; 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 [11].

Emergency response as search for emergency responders, their coordination, and calculation of time-efficient or cost-effective transportation routes for them taking into account road states and conditions is a goal of many studies (e.g., [12][13], and many others).

The above approaches address different aspects of emergency management. All these approaches integrate various emerging technologies to achieve their goals. But no one of them investigates both the problems of planning response actions and involvement of the participants of these actions into Web-based communities jointly.

The presented research shares the idea of the integration of emerging technology-driven paradigms. It integrates the paradigms of smart space, Web-based communities, and Web-services to organize a community of units to concur in fire response actions. Like the approaches considering the problem of searching for efficient transportation routes within the emergency response problem, the given 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 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 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 units. It offers routes to the fire location for the fire brigades; and a transportation plan with routes to the fire place for first aid and to hospitals for transportation of the injured people for the emergency teams. 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. A person who needs to be evacuated sets the location where he/she would like to be conveyed into an application installed in his / her mobile device. The application finds a driver able to transport the person. The found driver receives an appropriate signal. In the mobile devices of the driver and the person the ridesharing routes are displayed.

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. For the scenario implementation a smart framework has been developed.

IV. Smart Framework

Smart Framework is defined here as a framework that is intended to coordinate operations of various 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 are regarded as resources.

Basically, the framework has been projected to assist in management of any emergency response actions. It is supported by an application ontology that represents non-instantiated domain & problem solving knowledge of the emergency management domain [14].

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 is an ontology-based model of the current situation.

The abstract context is instantiated by resources of the smart space. An instantiated abstract context is *operational context*. The operational context is the base for organization of a community that unites members whose aim is taking joint actions on emergency response.

The framework relies upon the Web-service technology. In this framework the resources of the smart space as well as the organizations and people involved in an emergency situation in any way are represented by Web-services. Each of them is characterized by a profile describing its capabilities. Due to this representation a community purposed to emergency response actions comprises Web-services representing entities taking these actions. Figure 1 represents the generic scheme of the smart framework.

The community is organized by specially developed Web-services embedded in the smart space. Input data for the community organization are information characterizing the current 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 Web-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. Then, an efficient plan is selected from the set

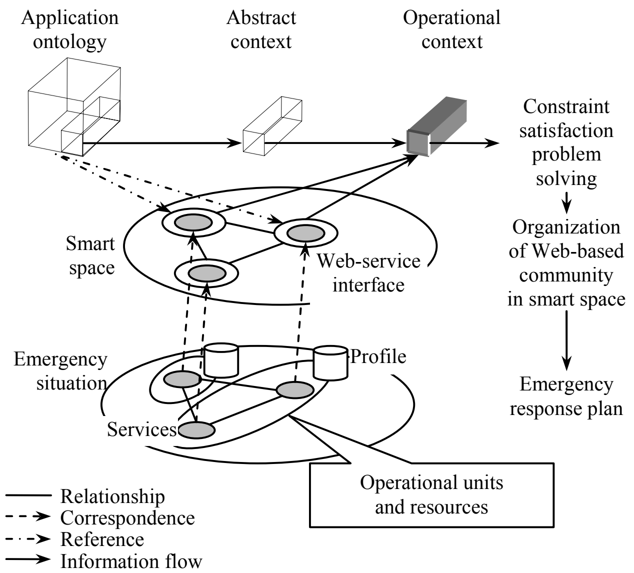

Figure 1. Generic scheme of the framework

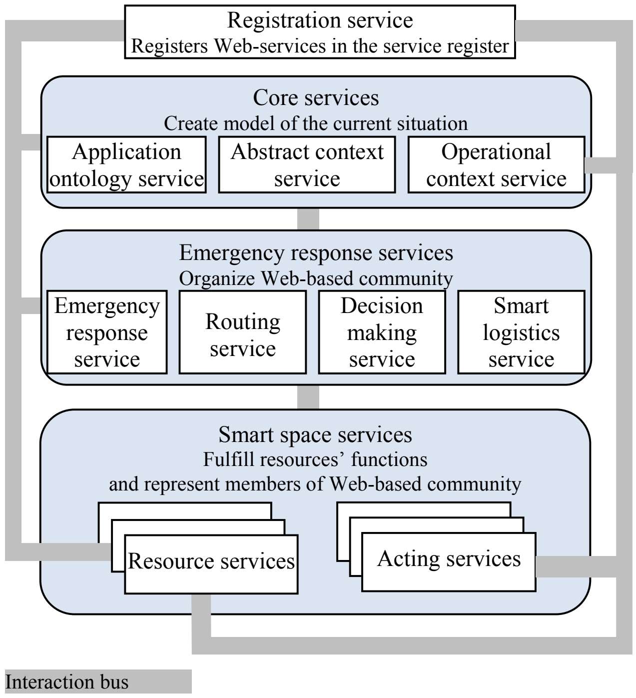

Figure 2. Service-oriented architecture

and submitted to the possible community members to their approval. If the plan is approved by all the members the community is considered 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 replanning 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 of the community members.

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 applying the ridesharing technology.

A. Service-Oriented Architecture

Web-services comprising service-oriented architecture (Figure 2) of the smart framework 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 operational contexts;
- *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 concerts the actions among the participants of the response operation;
- *resource services* represent properties and implement functions of the resources (smart ones as well);
- *acting services* represent properties of organizations or people and roles played by them in an emergency situation.

To make the Web-services "active" components agent-based service model is used [15].

B. Organization of Web-based Community for Fire Response Actions

In the context of this paper a fire event is considered as an emergency. Therefore below, organization of a Web-based community aimed at fire response actions is described.

The starting point for community organization is receiving by *emergency response service* of the signal that a fire event takes 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

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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 fire departments, emergency services organizations, and 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. Thus, the abstract context is represented by the map above and knowledge about objects to be instantiated.

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., somewhere traffic jumps can be, 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, waterways, etc.) 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 browsers (a browser supported by a notebook, PDA, mobile phone, etc.). These persons either approve the plan pressing "submit" button or decline it pressing "reject" button. In the latter case *decision making service* has to adjust the selected plan (so that the potential participant who refused to act according to the plan does not appear in the adjusted plan) and submit it 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.

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 mobile 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.

V. SCENARIO USE CASE

The scenario (Section III) execution is demonstrated via organizing a Web-based community aimed at joint actions to response on a fire event happened in an urban area. It is simulated that from the scene of fire 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 [16] – was used. The application ontology has 7 taxonomy levels, contains more than 600 classes, 160 class attributes, and 120 relationships. The abstract context created to represent the situation at the abstract level has 3 taxonomy levels, contains 17 bottom-level classes, 38 class attributes, and around 30 relationships of different types.

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 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.

An efficient plan (Figure 3) was selected based on the key indicator of minimal time of victim transportations. In Figure 3 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 4 shows part of the plan displayed on the smart phone of a member of an emergency team going by ambulance.

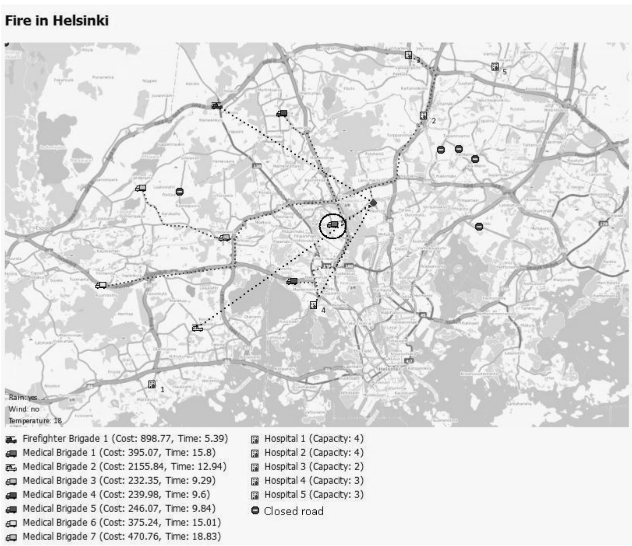

Figure 3. Plan for actions for fire brigades, emergency teams, and hospitals

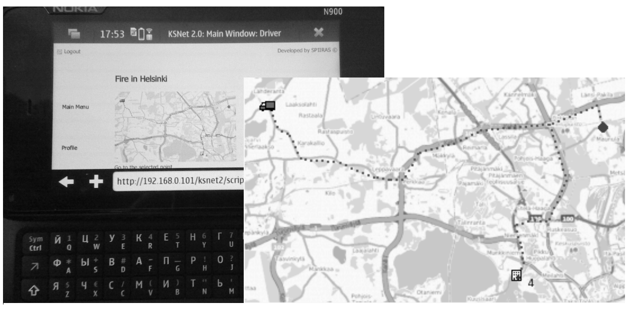

Figure 4. Plan for actions for an emergency team

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 5 and Figure 6. The encircled car in the figures shows the location where the driver is offered to pick up the passenger.

The Smart-M3 platform [17] has been used for the 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.

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.

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

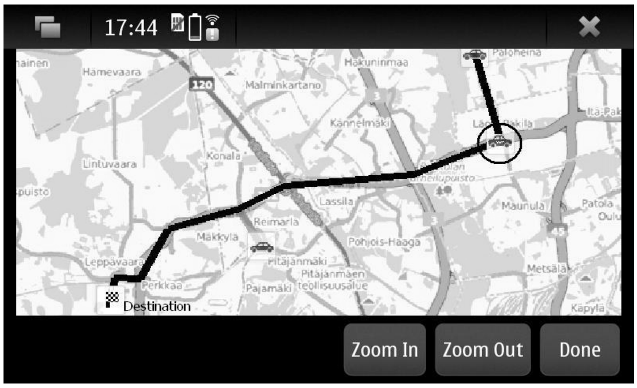

Figure 5. Ridesharing route: driver's view

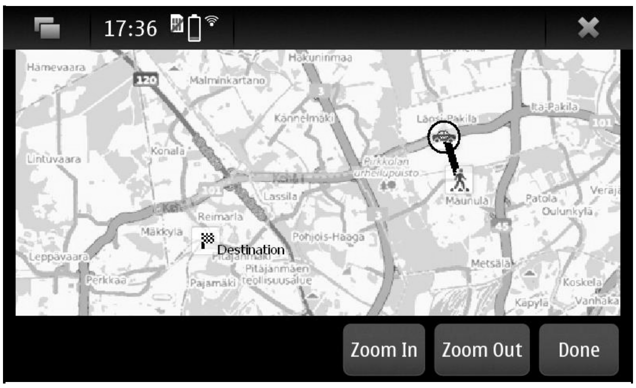

Figure 6. Ridesharing route: passenger's view

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.

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.

The applicability of the smart framework is tested by 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.

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.

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