Ubiquitous Computing in Emergency: Profile-Based Situation Response

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ABSTRACT

Ubiquitous computing opens new possibilities to various aspects of human activities. The paper proposes an approach to emergency situation response that benefits of the ubiquitous computing. The approach is based on utilizing profiles to facilitate the coordination of the activities of the emergency response operation members. The major idea behind the approach is to represent the operation members together with information sources as a network of services that can be configured via negotiation of participating parties. Such elements as profile structure, information source model and negotiation protocol are described in detail.

Keywords

Profile, negotiation, service, emergency response, ubiquitous computing.

INTRODUCTION

Critical aspects of emergency situation management incorporate managing and controlling sources of information, processing real-time or near real-time streams of events, representing and integrating low-level events and higher level concepts, multi-source information fusion, information representation that maximizes human comprehension, reasoning on what is happening and what is important (Jakobson et al., 2005; Scott and Rogova, 2004; Smirnov et al., 2007).

In this paper the emergency situation management is considered to include the following type of operations: medical care, evacuation, fire fighting, and accident investigation. These operations can involve such autonomous entities like public/governmental organizations, different private organizations and volunteers (referred to as operation members). A traffic accident is considered in the paper as an example of the emergency response operation.

Organization of collaborative environments from autonomous entities is a focus of approaches to building context aware decision support systems (e.g., Kwon et al., 2005; Burstein et al., 2009), self-optimization and self-configuration in wireless networks (Cordis, 2008), organization of context-aware cooperative networks (Ambient Networks Project, 2006) and collaborative context-aware service platforms (Ejigu et al., 2008), etc.

The paper proposes an approach to creation of a decision support system aimed at situation management. The approach benefits of the features of ubiquitous computing and incorporates technologies of context management, intelligent agents, Web-services and profiling. Ubiquitous computing (ubicomp) is a post-desktop model of human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities. In the course of ordinary activities, someone "using" ubiquitous computing engages many computational devices and systems simultaneously, and may not necessarily even be aware that they are doing so (Wikipedia, 2009).

The technology of Web-services is used as a technology allowing the heterogeneous resources (operation members and information sources) to cooperate for a common purpose. This technology defines formal interface agreement (W3C, 2004), but does not address the semantics of those interfaces. To provide the Web-services

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with semantics and to make them active components capable to collaborate, an agent-based service model is used. In different approaches integration of intelligent agents and Web-services has been applied for various purposes. E.g., it was a basis for distributed service discovery and negotiation system in B2B (Lau, 2007); (Moradian, 2010) describes a way to protect secret business information from being disclosed, modified and lost. In the approach presented in this paper agents "activate" Web-services when required and make Web-service descriptions sharable via using an ontology.

In real life situations it is often necessary to take into account a continuously changing situation including people movement, traffic situation (e.g., to take into account traffic jams, closed roads, etc.) that makes the problem more complex and requires its solving in real-time. For this purpose the approach utilizes the technology of context management. The context is constantly updated to provide up-to-date information for situation management.

Application of the profiling technology significantly facilitates the emergency situation management. Dynamic profiles are considered for example in (Carillo-Ramos et al., 2007) and (Kirsch-Pinheiro et al., 2006). The authors of (Thomsen et al., 2009) propose dynamic user profiles that reflect the current situation of the user (e.g., his/her location). In the presented approach the profile is considered as an information source for forming the situation context. The operation member profiles contain such information as available transportation, current geographical coordinates, competencies and preferences of the operation members. Competencies are described by operation member capabilities, capacities, price-list in case of implementation by a private organization, and quickness. The preferences determine the constraints preferable for the operation members.

The paper is structured as follows. In the second section the motivating scenario is described. Then the proposed approach is presented. Sections 4-6 describe the major principles of the approach. Most important results are summarized in the conclusion.

MOTIVATING SCENARIO

Let us consider the following scenario. A group of people is travelling by vehicle. Suddenly this vehicle is involved in a traffic accident. The vehicle is supplied with a GPS (Global Positioning System), a smart sensor, and a transmitter. Each person has a mobile device (e.g., a mobile phone) that can measure impact on their owners (e.g. with a help of G-sensor) and transfer their current location. Near the accident site there can be people with medical experience or police who can provide for the first aid and better explain the situation to the specialists. These people are also considered to have mobile devices, which would inform them about the help needed. The proposed case study scenario is described below and represented in Figure 1.

The goal of the approach is to produce efficient plans of actions for both the people at the accident site and the rescue facilities (ambulances, firefighters, etc.) based on available information from different sources and benefiting from the features of the ubiquitous computing. The efficiency is estimated via a multicriterion function taking into account time taken for the situation response and associated costs.

The information about the people in the accident (their locations, possible injuries, some specific data (e.g., diseases such as diabetes or allergy, etc.) is stored in their mobile devices. This information and the information about the existing local infrastructure (available hospitals, road network, etc.) are transferred to the system. Besides the listed information, the system acquires additional information and knowledge required for problem solving. Some of this information and knowledge is acquired from available sources such as medical databases, weather conditions' sensors and Internet-sites, weather forecasts' sources, etc. The information from the sources is extracted in a particular context (incident location, type of incident, etc.). Other information is provided by the operation members: the ambulances, hospital and evacuation facilities provider(s) supply to the system actual information about their facilities and current and possible future capacities.

Most of the information supplied to the system can be of certain probability or uncertain. The objective here is to reduce the situation response time and, as a result, to increase the probability of the patients (the people injured in the accident) survival (see the graph in Figure 1).

Taking into account the current locations, competences, capabilities and current conditions of people at the accident site the decision support system might instruct them and the operation members through their mobile devices to perform certain actions. E.g., doctors can be instructed to perform the first aid and to explain to the medical brigades that would arrive in a certain time the situation and conditions of the injured people.

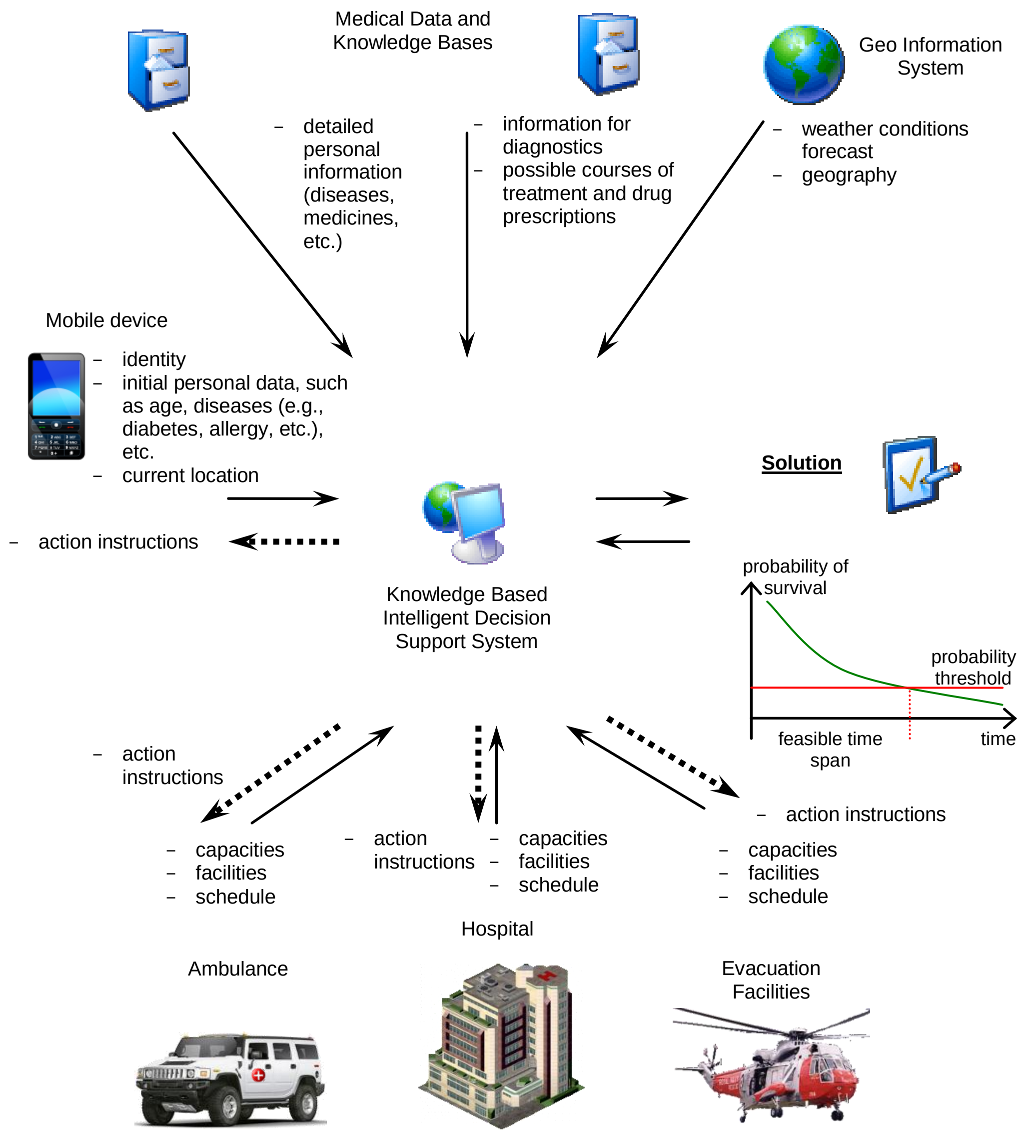

Figure 1. Case study scenario

APPROACH

Figure 2 represents the generic scheme of the approach aimed at emergency situation management. The main idea behind the approach is to represent the operation members and information sources by sets of services provided by them. This allows replacing the configuration of the emergency situation response facilities with that of the distributed services. To resolve the problem of semantic interoperability between the services they are represented by Web-services using a common dictionary supported by an application ontology of the emergency situation management domain (Smirnov et al., 2009). This ontology consists of 7 taxonomy levels, more than 600 classes, 160 attributes, 40 hierarchical constraints, 50 associative constraints and 30 functional constraints.

At the first stage of the research the main ideas the approach is based on were formulated:

1. A common shared application ontology (AO) serves for terminology unification. Each service has a fragment of this ontology corresponding to its capabilities / responsibilities. This fragment is synchronized automatically when necessary (not during the response operation).
2. Each operation member is represented by a *profile* describing its capabilities.
3. Web-service standards are used for interactions. External sources (e.g., medical databases, transport availability sources, weather forecasts' sources) should also support these standards and the terminology defined by the AO. This is achieved by developing wrapping services for each particular source.

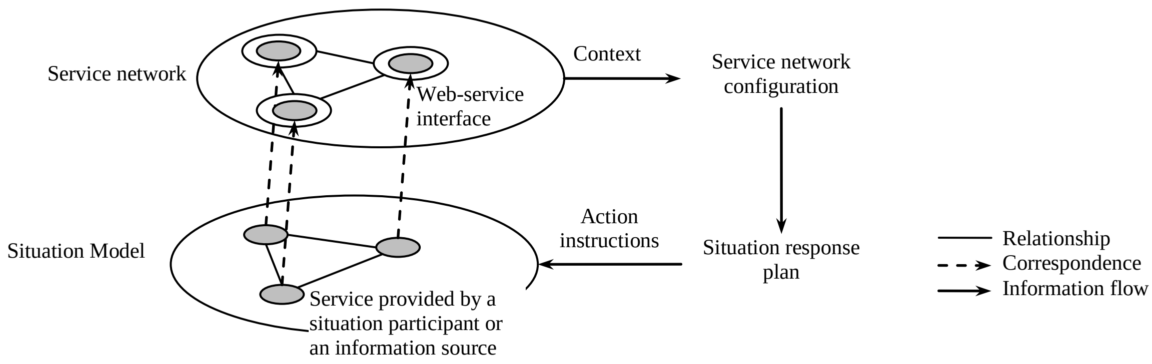

Figure 2. Generic scheme of the approach

4. Each service is assigned an intelligent agent, representing it (together they will be called "*agent-based service*"). The agent collects information required for situational understanding by the service and *negotiates* with other agents to create ad-hoc action plans. The agent has predefined rules to be followed during the negotiation processes. These rules depend on the role of the appropriate member.

Below, the main elements of the approach, namely the profile structure and negotiation protocol are described in detail.

OPERATION MEMBER PROFILE

The structure of the operation member profile is given in Figure 3. Competencies and preferences of the operation member are important for determining, which member is capable of carrying out a specified task and, hence, can be chosen as a team member. Member competence is determined by capabilities, capacities, price-list and quickness. The operation member profile represents the following types of information about the member: *General Information*, *Operation Member Information*, *Instruction History*, *Operation Member Preferences*.

The *General Information* part describes general information about an operation member organisation. It contains a name of organisation, its identifier in the system, date of its foundation, and URL of the organization's Web page.

Operation Member Information is a set of tuples describing information about an operation member. Each tuple possesses the following properties:

- Member Name, Interests – the name of an operation member and his/her interests;
- Location – current geographical location of a member, it can be taken into account for estimating a rapidity and quality of acting instruction performance in a particular situation; this property is used by GIS for generating the map of the region representing the situation, road network, operation members, and hospitals.

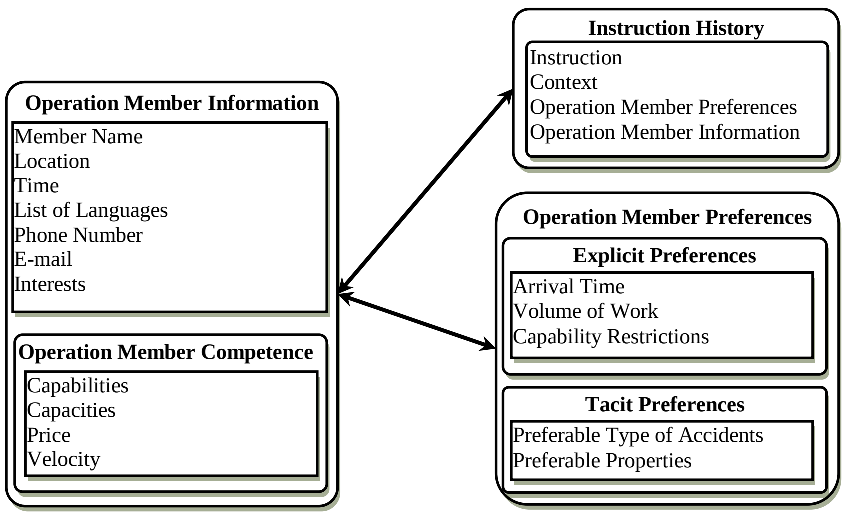

Figure 3. Operation member competence profile

- Time – time zone of an operation member;
- List of Languages – represent languages for contacting an operation member;
- Rights – determine knowledge area, that a member is authorized to access;
- Group – a member can be part of a group, based on its capabilities;
- Phone Number, E-mail – contact information;
- *Operation Member Competencies* includes the following properties:
  - Capabilities – determine types of operations that operation member can implement, the capabilities are described by a list of corresponding classes (describing possible activities) from AO;
  - Capacities – determine capacity of an operation member (in case of evacuation this attribute determines how many people this operation member can evacuate);
  - Prices – determine prices of member's activities in case of implementation by a private organization;
  - Velocity – determine velocity of operation member's activities.
- *Instruction History* is also a set of tuples. Each tuple possesses the following properties:
  - Instruction – an acting instruction sent to a member;
  - Context – a situation context used to analyze performance of a member (other members can see solutions generated in particular situations) and to identify detectable member preferences;
  - Operation Member Preferences – member preferences at the moment of an acting instruction sending. They contain a snapshot of all the properties of the category "Operation Member Preferences";
  - Operation Member Information – specific information about a member at the moment of an acting instruction sending. It contains a snapshot of all the properties of the category "Operation Member Information".

The *Operation Member Preferences* part consists of Explicit Preferences and Tacit Preferences. Explicit Preferences describe member preferences that are manually introduced by a member. These preferences are used for choosing a member for a particular situation, and contain the member preference for arrival time, volume of work, and capability constraints. The latter stores several capabilities and logical restrictions from a list of all the capabilities for the domain. *Tacit Preferences* describe automatically detectable member preferences.

A fragment of the operation member profile is shown in Figure 4. The URL describes the location of the complete profile, from which it can be downloaded.

NEGOTIATION PROTOCOL

In order to choose a protocol for negotiation between agents representing services provided by the emergency response operation members, the main specifics have been formulated as follows:

1. *Contribution*: the agents have to cooperate with each other to make the best contribution into the overall system's benefit – not into the agents' benefits;
2. *Task performance*: the main goal is to complete the task performance – not to get profit out of it;
3. *Mediating*: the agents operate in a decentralized community, however in all the negotiation processes there is an agent managing the negotiation process and making a final decision;
4. *Trust*: since the agents participate in the same situation they have to completely trust each other;
5. *Common terms*: the agents are supposed to use common terms for communication (based on the dictionary of the common AO);

The protocols analyzed in order to choose one most suitable include voting, bargaining, auctions, general equilibrium market mechanisms, coalition games, and constraint networks (Weiss, 2000). Based on the analysis of these protocols and the above requirements to them, the contract net protocol (CNP) was chosen as a basis for the negotiation model in the approach. As it can be seen from Table 1 this protocol meets most of the requirements.

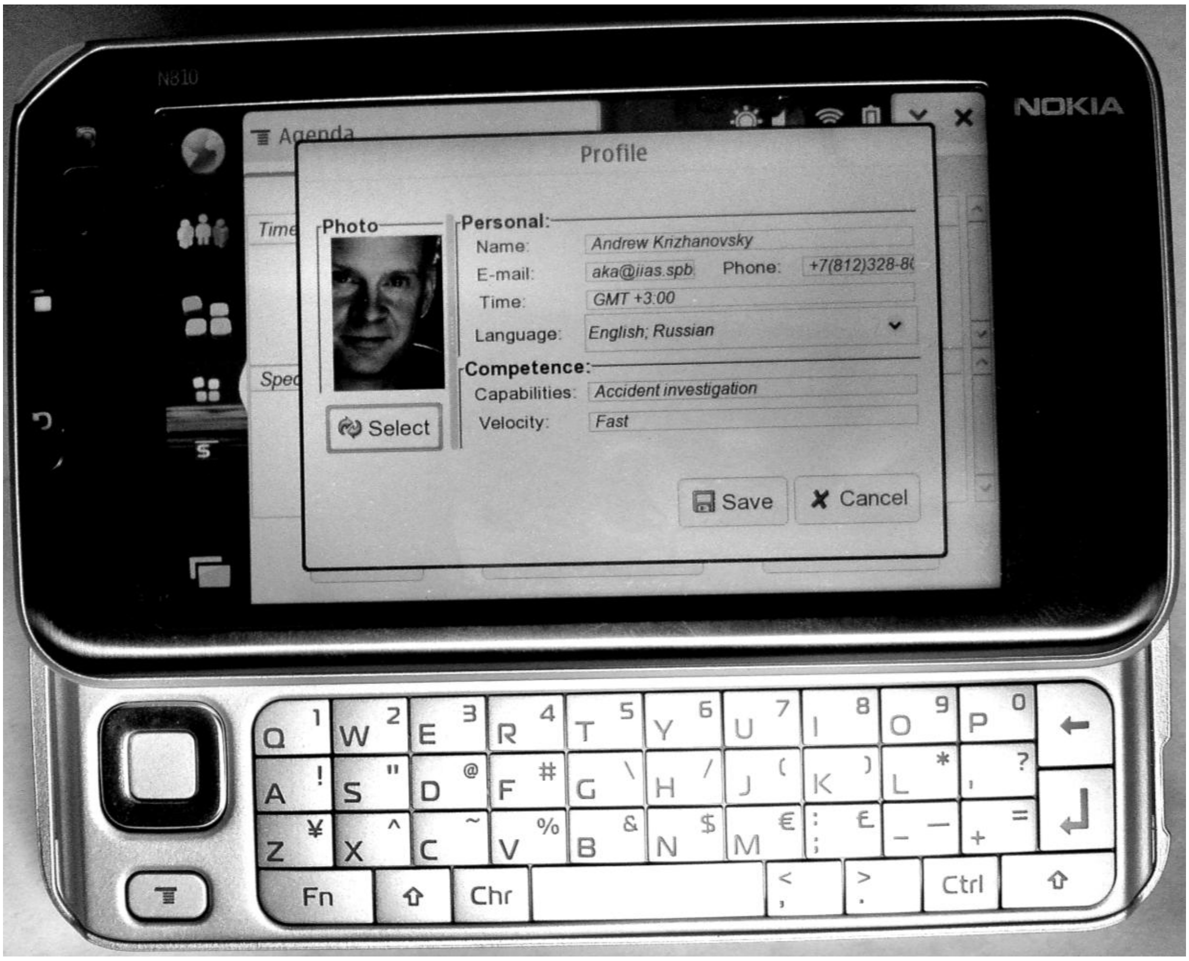

Figure 4. Example of the operation member profile

Protocols / Criteria	Voting	Bargaining	Auctions	General Equilibrium Market Mechanisms	Coalition Games	Contract Nets
Contribution	☑	☑	☐	☐	☐ / ☑	☑
Task performance	☐ / ☑	☑	☐	☐	☐	☐ / ☑
Mediating	☐	☐	☑	☐	☐	☑
Trust	☑	☑	☑	☑	☐	☑
Common terms	☑	☑	☑	☑	☑	☑

Table 1. Comparison of negotiation protocols

CNP is one of basic coordination strategies between agents in multi-agent systems. It was originally introduced by Randall Davis and Reid G. Smith (Davis and Smith, 1983). The main features of this protocol are (i) *managers* (*initiators* in FIPA) divide tasks, (ii) *contractors* (*participants* in FIPA) bid, (iii) manager makes contract for lowest bid, (iv) there is no negotiation of bids. The UML sequence diagram of FIPA-based contract net protocol is presented in Figure 5. Since CNP is a basic protocol any particular multi-agent system requires some modifications for CNP to be implemented (Payne et al., 2002). Table 2 describes the modifications made for original CNP.

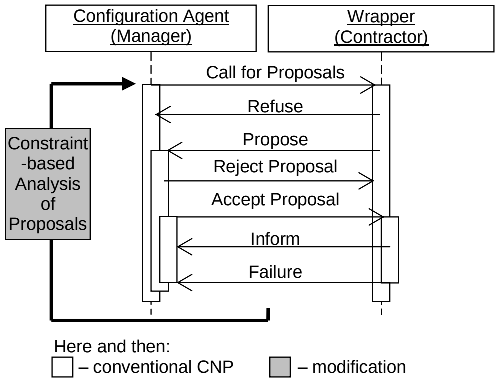

Figure 5. Example of the constraint-based iterative negotiation

Feature \ Protocols	Conventional CNP	Modified CNP
Iterative negotiation	-	the negotiation process can be repeated several times until acceptable solution is achieved
Conformation	-	concurrent conformation between manager and contractors
Available messages	fixed set of 8 messages (Figure 5)	flexible set: new specific messages and corresponding to FIPA *Request* and *Confirm* communicative acts, and message *Clone* not corresponding to any FIPA communicative act are included
Participants roles	manager and contractors	manager and two types of contractors: (i) "classic" contractors negotiating proposals, and (ii) auxiliary service providers not negotiating but performing operations required for decision support system functioning (e.g., AO modification, user interfacing, etc.)
Role changing	-	agents can change their roles during a scenario

Table 2. Changes in features of the conventional CNP

To compare the results of the conventional CNP and constraint-based CNP the following example is considered. Configuration agent (traffic accident response manager, CA) needs to involve three operation members (accident investigators that are supposed to work together) represented by the contractor wrapper agents (W1, W2, and W3), with the time and cost of help being minimal. These criteria (time and costs) have been chosen as demonstration criteria. The set of criteria can be extended with other parameters. It is also preferable for the Configuration agent to choose smaller costs if the time is the same:

```
CA: time → min, costs → min
```

The Wrappers can make different offers such that the costs inversely depend on the time of help. This dependency is described by a table function given below (the cost is measured in abstract units):

```
W1: 3.0 min/15
W2: 1.5 min/20; 2.5 min/10; 4.5 min/5
W3: 5.0 min/25; 6.0 min/15; 7.0 min/10
```

The resulting time and costs are calculated as follows:

$$time = max(time_{W1}, time_{W2}, time_{W3})$$
$$costs = sum(costs_{W1}, costs_{W2}, costs_{W3})$$

The comparison of two scenarios is presented in Table 3. The left column describes negotiation performed in accordance with the conventional CNP (Figure 6). The right column describes negotiation performed in accordance with the modified CNP; it contains concurrent conformation and iterative negotiation (Figure 7). The messages (Msg 1, Msg 2, etc.) are indicated in both the table and the figures. Msg 1 in the figure is an auxiliary message that is used to start the negotiation process. The sequence of the replies arriving from wrapper agents (e.g. wrapper 2 answers faster than wrapper 1) is more or less random and should not be paid attention.

Conventional CNP	Modified CNP
The configuration agent sends calls for proposals to all the wrappers concurrently. Besides description of the task to be performed each call contains additional constraints. In this case these constraints will contain the following: Msg2, Msg 3, Msg4: `time → min`	At the first iteration the Configuration agent sends calls for proposals to all the Wrappers concurrently as in the first scenario: Msg2, Msg 3, Msg4: `time → min`
The offers from wrappers will contain the following: Msg6: `W1: 3.0 min/15` Msg5: `W2: 1.5 min/20` Msg7: `W3: 5.0 min/25` At this stage the work of the conventional CNP ends.	Offers from the Wrappers are the same: Msg5: `W1: 3.0 min/15` Msg7: `W2: 1.5 min/20` Msg6: `W3: 5.0 min/25` From this stage the second iteration of the modified CNP starts.
	After this the Configurator analyses the results and sends new calls to the Wrappers 1 and 2: Msg8, Msg9: `time ≤ 5.0 AND costs → min`
	The Wrappers reply as follows: Msg10: `W1: 3.0 min/15` Msg11: `W2: 4.5 min/5`

The result will be 5.0 min and 60 cost units:
`W1: 3.0 min/15`
`W2: 1.5 min/20`
`W3: 5.0 min/25`
	The result is 5.0 min and 45 cost units:
	`W1: 3.0 min/15`
	`W2: 4.5 min/5`
	`W3: 5.0 min/25`

Table 3. Comparison of the conventional and modified CNP

CONCLUSION

The paper proposes an approach to emergency situation response that benefits of the features of ubiquitous computing. It is based on utilizing profiles of operation members in the emergency situation for coordination of their activities. The major idea of the approach is to represent the operation members together with information sources as a network of services that can be configured via negotiation of participating parties.

The profiles describe both static and dynamic aspects of the operation members such as their competences or location and store the history of the acting instructions sending to them and their responses. The proposed structure of the profiles makes it possible to perform revealing of tacit preferences and competences. The algorithm of ontology-based clasterization for revealing the tacit preferences was presented in (Smirnov et al., 2005). The contract net protocol is chosen as the basis for the negotiation between the operation members.

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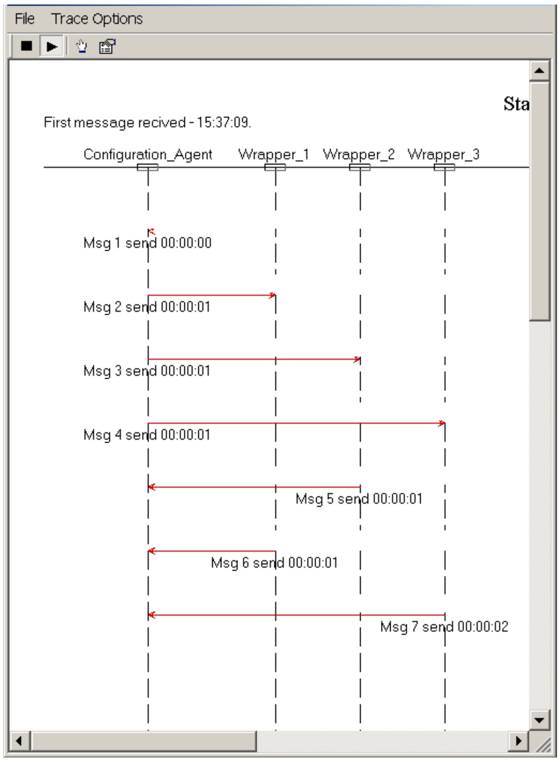

Figure 6. Experimentation: scenario 1

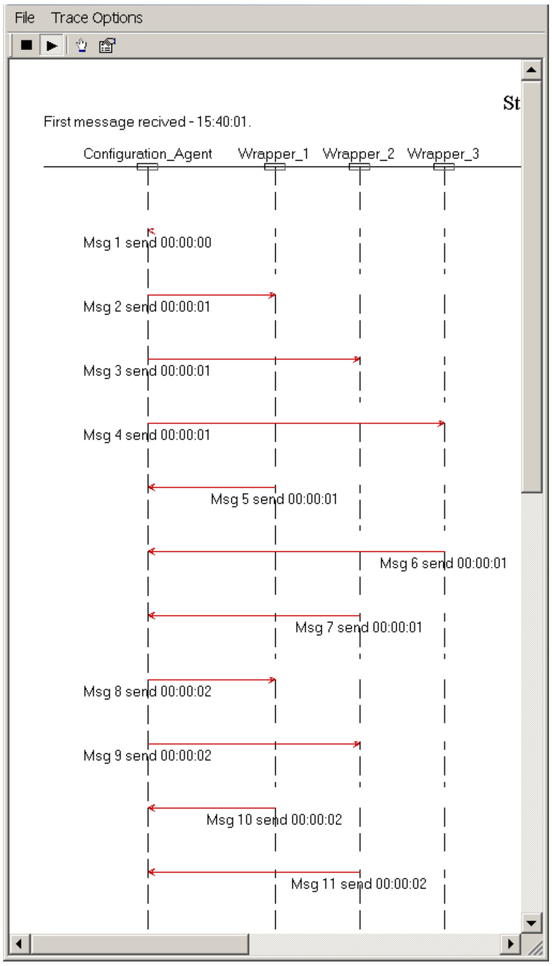

Figure 7. Experimentation: scenario 2

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