MES: A System for Location-Aware Smart Messaging in Emergency Situations

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Abstract. Location is considered the most significant element of context in ubiquitous computing. Location information, besides system context information, can offer rich queries for handling information especially in emergency systems. This paper introduces the Mona Emergency System that uses context information in providing emergency services such as sending warning messages to an identified location. MES context information includes actor, danger and point of interest information. This paper describes the MES methodology to obtain and distribute warning messages during emergency situations. MES is a new approach that defines message targets and content using spatial relations.

Keywords: context-aware messaging and addressing, emergency systems, spatial information, ad-hoc communication, ontology.

1 Introduction

Emergency systems submit to the procedures that support effectively dealing with tragedy within society [1]. Recently, in communication, context information is utilized as substitute to previous addressing methods such as IP addresses [2]. Modern technology can assist in decision making and saving time in disaster management [3]. Government utilizes all the accessible resources to terminate hazards. For instance, in Australia 2009 [4], Victorian government employed all available resources to stop the bushfire. However, it reported at least 166 deaths. A lot of survivors stated that, they did not have enough information about where to go and the fire movements, which caused some panicking. In addition, rescuer teams did have enough knowledge about the survivors and the levels of threat encountered by these survivors. In addition, the rescuers do not have any clue about the survivor movements and personal information such as age and health conditions. This information can assist different rescue team that work together with information that can improve the rescue mission [5].

The contribution of this paper is to introduce an approach to highlight the significance and advantages of using context information for addressing and messaging purposes during hazard times. We designed the Mona Emergency System (or MES, for short) to improve the flow and the content of the messages during risky periods. MES proposes generating alert messages for actors within affected areas

K. Zheng, M. Li, and H. Jiang (Eds.): MOBIQUITOUS 2012, LNICST 120, pp. 276–288, 2013.

using context information. The MES compares and examines context information such as name, location, type and status to assist in the messaging process. It is assumed that the MES utilizes different sensors from mobiles to gain context information. We employ the use of spatial relations via the use of structured English expressions using words such as "close", "near", "far" and "away" to help describe the message receivers. MES provides a new approach to defining the message targets using spatial relations. We design the Mona-ont ontology to describe and organize knowledge about danger situations.

The paper is structured to present an extensive overview of the Mona Emergency system as follows: the MES concept and design, the MES architecture, the message exchange process for the context information and the Mona-ont ontology. In addition, the paper describes the MES message structures as well as services and techniques that assist in supplying the actors with the right alert messages at the right time with the right context information; we illustrate the concepts of the MES via screenshots.

2 The Mona Emergency System (MES)

2.1 Concept and Design

The Mona Emergency System is used to generate alert messages during danger situations. The MES designed to improve the flow of exchanged information between the actors within the system. The system uses real-time context information that are collected and stored in the MES database. The MES employs spatial relations, qualitative and quantitative, to determine the significance of message targets and content. In the MES, controlled English expressions identify destinations and content of messages using context. Mobile phones are used to report information about the actors within the system. Danger information is passed to the MES database via any institution. Furthermore, the POI information can be entered and modified manually in the MES database. The MES transfer RCC8 or Egenhofer relations[1] into understandable English expressions to describe emergency situations. We define MES spatial relations for the following reasons:

- assist in distributing the right message at the right time,
- define and address the message target during the hazard times using available context information,
- describe the alert message content using the spatial relations between the system entities such as survivor, rescuer, safe points and danger areas,
- present sufficient knowledge about certain events to the rescue team, and
- label some dynamic spatial relations in such a way as to describe an event.

MES spatial relations structure context to indicate the situation of actors in the rescue process. The context model can be modified according to the usage environment. MES utilizes various types of context related to entities within the system. Figure 1 demonstrates the entities expressed in the MES model, which includes actor devices, services, hazards information and points of interest.

[1] http://www.w3.org/2005/Incubator/geo/XGR-geo-ont-20071023/

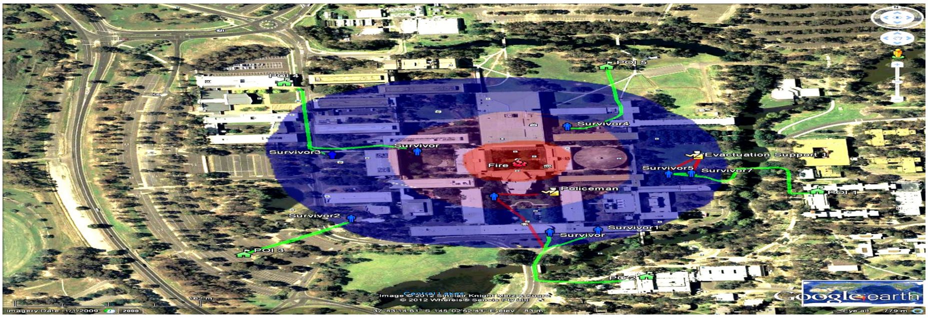

Fig. 1. The MES spatial overall view over a fire at La Trobe University

Figure 1 presents the MES distributed entities and its spatial relation during fictional fire scenario. The MES messaging services structured depends on multi-context information gathered from MES entities included such as actor, dangers and points of interest information. This offers dynamically modified messaging services to the actors' mobile devices.

The MES uses the available context information that includes the actor, danger and POIs to compare and match the context knowledge. For example, the MES computes and contrasts the location coordinate information (latitude and longitude) of actors, POIs and the danger using the Haversine formula[2]. The context information relating to actors such as rescuer and survivor are actor ID, location, status as well as some personality information such as age and health condition.

Actor ID is used to recognize the actor and the location used to place the actor. In addition, status used to distinguish the actor's danger event such as "stuck" or "safe", and health condition illustrates the health situation about the actor such as "disabled" or "fit". During an emergency situation the MES categorize survivors into two types; general survivor, representing people within the region that may encounter a dangerous situation and flag-bearer, where in the case of launching new ad-hoc network connections, an actor (called the *flag-bearer*) can coordinate communication with other people who are unregistered with the MES on a peer-to-peer basis, in order to assist them with the right services, on behalf of MES (e.g., relaying messages, i.e., effectively, we see that messaging can be "crowd-sourced"). On the other hand, rescuer stands for organizations that are expected to help according to their specialty, such as evacuation support, policeman and fireman. In addition, the MES uses danger context information to classify the danger zones depending on the danger severity using the scale: Red, Yellow and Blue. Also, the status is employed to explain the danger situation such as "occurring", "starting", and "terminated". The type is used to show the danger type such as "bushfire" and "flood". Moreover, the MES uses context information to present the point of interest (POI) as a safe point in a rescue process such as name, location, current danger zone and status. The current danger zone in used to find the POI in the affected area, and the POI status used to label the "lost" or "destroyed" POIs in dangerous situations. The MES classifies POIs into positive and negative points of interest. For example, a lake can be allocated by the MES automatically as a positive POI, where the survivor can be directed to in a Bushfire scenario.

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[2] `http://www.movable-type.co.uk/scripts/latlong.html`

2.2 MES Mona-ont Ontology

We develop the Mona-ont ontology [6] to capture, form and filter information about disaster conditions. The information is expressed by the use of context information in emergency situations such as about actors, dangers and safe points. Mona-ont ontology is utilized in emergency situations to:

- describe the targets/destinations/receivers for context-aware messaging,
- support explaining events in emergency situations,
- help defining the emergency situation concepts and its attributes,
- express and discover the spatial relations that link MES concepts,
- allow the spatial relations to be understandable by humans,
- assist in building and modelling the Mona Emergency System,
- defining appropriate message contents for actors (including directions for survivors),
- allow sharing information between concepts within MES, and
- assist simulating the scenarios.

We use the editing tool called Protege[3] to build the Mona-ont ontology. The Mona-ont ontology captures knowledge in disaster situations, to be used by possibly different organizations involve in a rescue operation. Figure 2 highlights Mona-ont relationships between MES concepts. The Mona-ont ontology contains concepts that may be involved in emergency situations. For example, region, disaster management, emergency situation, affected area, actors and points of interest. The region represents the area where danger is happening and a disaster management unit manages the region, aggregates the context information from actors and provides alert messages to the actors. Actors represent survivors and rescuers, and emergency situation represents context information about a danger (e.g., a bushfire, or a flood) such as type, range, direction and speed of the danger. Affected area refers to the hazard/danger zones. Finally, points of interest (POI) symbolize the geographical features (man-made or natural) that can assist in a rescue operation.

Figure 2 illustrates the Mona-ont ontology spatial relationships that link the system's concepts and express events at risky situations. The Mona-ont ontology represents knowledge that is shared between actors within ME system. The qualitative spatial relations are mapped to a variety of values that help the MES in performing practical messaging functionalities. For example, the relation "near" represents a scope of values between 100 meters and 250 meters (this mapping can be changed depending on the geographical scales intended for the messaging). This mapping assists in discovering and filtering target and content of the alert messages. The MES spatial relations described as follows:

- Danger_relation: describe emergency situation within region such as "in", "within" and "out of".
- Position_relation: define concepts positions within the Mona-ont ontology such as "near", "far", "next to", "close to" and 'away'. For example, it links an actor with POIs and affected areas within the region, and also to describe the relative positions between the actors themselves.

[3] http://protege.stanford.edu/

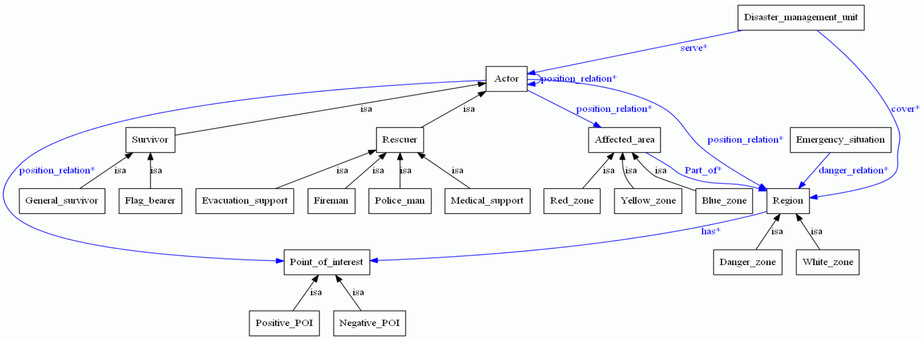

Fig. 2. Overview of the main concepts in the Mona-ont ontology

2.3 MES Architecture

Inspired by [7, 8], we employ numerous types of context-aware adjustment in the MES server side and the actor side. The MES employs a client-server architecture at the top level and multiple actors at the lower levels. The client-server architecture establishes the communication between the disaster management unit and the actor within the region while peer to peer communication occurs where the actors connect with each other via any type of ad-hoc communication. MES' overall architecture includes generally three main components, which are the actor; the disaster management unit and the database (see Figure 3).

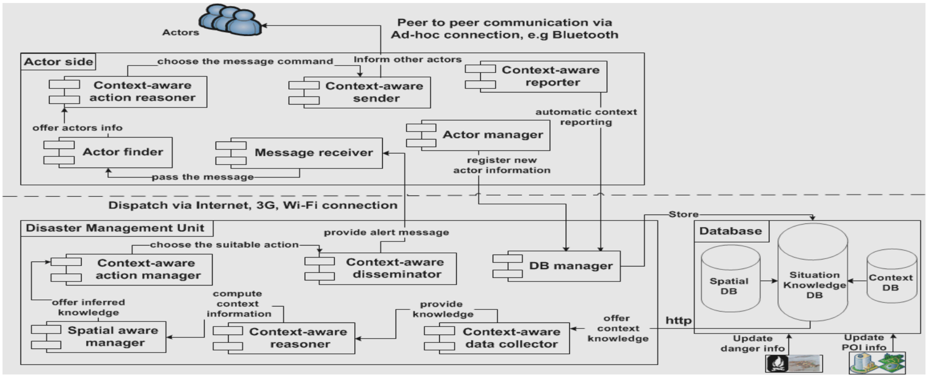

Fig. 3. MES architecture

The figure presents the MES architecture and the flow of information between the system entities and its component. The components are distributed into two levels. First, the actor side includes the survivor and the rescuer. Second, the server side includes the database and the disaster management unit. The database contains information about dangers area, actor and evacuation points. The evacuation points are particular points of interest (POI). The disaster management unit is responsible for the MES functionalities such as generating the automatic and the manual messages.

To start with, first, the database has the knowledge about the region including information about the emergency situation entities such as the danger information, actor and POI information. The database offer context knowledge to the disaster management unit via http. The data base consists of three parts:

- a spatial database includes the spatial relationships between emergency entities,
- a situation knowledge database with the spatial information and context information to be supplied to the disaster management unit, and
- a context database containing available context information about the system entities such as location, status and health condition, as noted earlier.

Second, the disaster management unit is responsible for the MES' main functionalities such defining the messages and the target of the messages. Also, capturing and filtering the context information about hazards situation. This information is used for the automatic and the manual messaging, presented on the relevant user interface forms. The disaster management unit components work as follows:

- *Database manager* (DB) responsible for registering the new actor information with the DB and keep updating the actor context automatically in a certain time,
- *Context-aware data collector* which collects the context information from the DB about the entities during danger time and passes the knowledge to the context-aware reasoner such as "there is survivor called Mr. Ahmed", and its current danger zone and POI information,
- *Context-aware reasoner* compares the collected context information that is ready for action such as computing that Mr. Ahmed's location falls within the red zone range,
- *Spatial aware manager* offers inferred knowledge and converts the quantitative information to qualitative aspects such as Mr. Ahmed is in the red zone "near" the hospital,
- *Context-aware action manager* constructs instructions or guidance information (in messages sent to actors) depending on context and decides the suitable action to be preformed such generating the automatic messaging to be sent to Mr. Ahmed in case of a lost POI, and
- *Context-aware disseminator* is responsible for sending the information to actors according to the context, providing the right alert to the actor at the right time using client server architecture via the obtainable connection method such as internet, 3G and Wi-Fi.

Finally, the actor side represents the survivor and the rescuer within the MES covered region. The actor side components are as follows:

- *Actor manager* is responsible for registering the new actor information and reporting the context information automatically,
- *Context-aware reporter* keeps reporting the actor context information to the disaster management unit automatically,
- *Message receiver* is in charge of the displaying the alert message,
- *Actor finder* searches for other actors within the available range using any communication tool such as Bluetooth in order to establish ad-hoc connection (peer to peer architecture),

- *Context-aware action reasoner* is responsible for choosing the message command by defining the right actor to forward the message to, and
- *Context-aware sender* is in charge of sending the message to the other actor within the available range.

This section describes the flow of information between the system's main components. Actors are required to register his/her information using an actor ID such as name, together with age and health conditions, with the disaster management unit which stores the information in its database. Once the danger occurs, the disaster management unit calls the information from the DB to be computed and processed. The MES disaster management unit identifies the danger zones, and the positive POI to assist in the rescue operation. The MES compares and matches location information and filters/selects the target actors depending on the available context in order to identify the message targets and contents. Once a message is received, the survivor can spread and share the message using peer to peer communication tools such as Bluetooth.

2.4 Message Exchange Process

This section gives an overview about the message content that been an exchange between the MES entities. The MES uses several type of contexts information in order to be widely aware of definite transformation in the region during the risk time (see Figure 4). Context information exchanged between the disaster management unit and the actor stored into the database. The context information depends on the actor category, the time and the event. For example, actors record location information more often according to their movement and the danger expanding, as oppose to when the actors are far from danger.

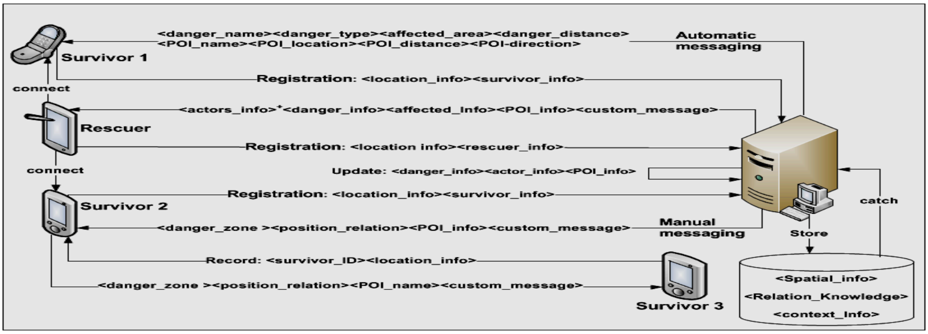

Fig. 4. Message exchange among the system's client-server components

Figure 4 describes the variety of context that has been exchanged between the MES disaster management unit and the MES actor. First, the context information at the registration level from the actor to the MES disaster management unit; the survivor registers using location information and survivor personal information such as ID, name, age and health condition. Furthermore, the rescuer registers using location information and personal information such as ID, name and institution. This context information is stored into the MES database via the MES disaster management unit. Second, relevant guidance context information is sent from the disaster management unit to the MES actor. There are two modes for messaging the survivors at this stage. In the automatic mode, the MES disaster management unit will send the danger information including danger name, danger type, affected area, danger distance and POI information such as POI name, location and distance. On the other hand, in the manual mode, the MES disaster management unit will send danger zone or the affected area, position relation, POI name and a custom message, such as "Mr. Alaa in a yellow zone near the lake please stay there". In addition, the rescuer will receive context information about the danger information and the survivors' information. Third, the guidance context information can be exchanged between survivors using peer to peer communication. A registered survivor is allowed to forward the alert message it received to other unregistered survivors, according to their context information. The unregistered survivors record their IDs and location information and that to the registered survivor in order to receive the alert messages (which include the automatically sent messages received from the MES in the automatic mode and custom messages sent manually). Finally, the disaster management unit updates the actor; danger and POI context information depending on the events during danger times.

3 MES Message Context Model Structure (EBNF), MES Services and Proof of Concept

3.1 Automatic Messaging

This mode provides an automatic alert messaging service to the survivors during hazardous situations, without involving human decisions. The MES automatic message content structure is designed as the following: first, the system decides on the survivor(s) that will take delivery of the message according to his/her (their) location(s). Then, the system informs the survivor about the existing danger type and zone, the distance from the danger (e.g., fire), the information about the related POIs that include the name of the POI and locations which clarify the areas (e.g., suburbs) that have the POI as well as the actual distance to the available safe POI and the direction. The structure of the automatically sent message is as follows (in EBNF):

<message>::=<actor1>+<danger_type><affected_area><danger_distance>
<POI_name><POI_location> <POI_distance>

<actor1>::= <survivor_ID>.
<danger_type>::= "fire" | "flood" | "earthquake" | "nuclear_danger".
<affected_area>::= "red_zone" | "yellow_zone" | "blue_zone".
<danger_distance> ::= REAL_NUMBER.
<POI_name>::="lake"|"hospital"|"evacuation_center"|"school"|"playground".
<POI_location>::= "Bundoora" | "Reservoir"| "Kingsbury".
<POI_distance>::= REAL_NUMBER

The message target is defined according to several contexts during danger times. For instance, survivor 'aaa' is within a fire inside a red_zone, 945 meters from the centre of the fire as well as the name of the available safe POI name such as "Latrobe Hospital" and its location (which is in the suburb "Bundoora" and the actual distance to that POI which is 294 meters). Moreover, the MES messages survivor 'Alaa' about the danger type, current danger zone and the distance as well as the POI information. For example, 'Alaa' is in fire inside yellow_zone with 1050 meters from the danger centre next to CP3 building and its location (which is Bundoora and the actual distance to that POI which is 198 meters); see Figure 5.

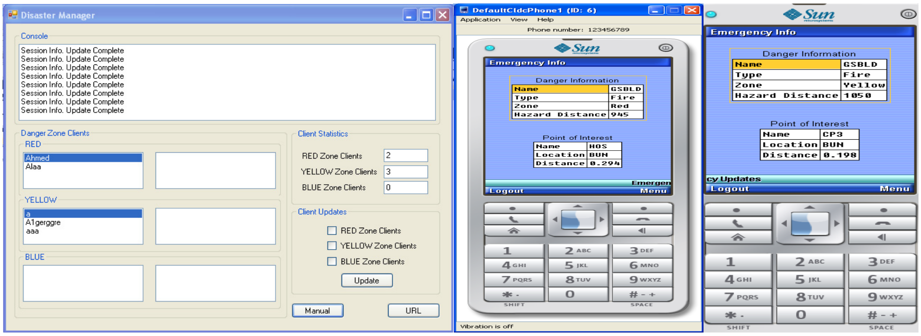

Fig. 5. Disaster manager for automatic messaging

Figure 5 shows the disaster management automatic messaging form which offers additional services such as providing a list containing the survivor IDs in the danger zone that they are located in. Additionally, it shows a summary of the number of the survivors positioned in the different zones. Moreover, the form updates the actor context information automatically according to the danger zone using the update options (e.g., messages containing location updates from actors, sent periodically). The automatic form offers visualization for the data via web services by the use of the URL command which will be activated in the future work to provide online services.

3.2 Manual Messaging

The manual message service offers custom message. The manual form requests the use of human interaction to define the message target and content via spatial relations. The spatial relation offer dynamic role to define messages for particular or group of survivor using structured English expressions. For example, the message target can be as the following; first, the system decides on the survivor(s) that going to receive the message according to his/her (their) location(s) and his spatial relation to danger zone. In addition, the target can be defined also using the survivor location and his POI spatial relation. The target of the manual message in EBNF is structure depend on the target as follows (in EBNF). For example, the administrator or the rescuer wants to send custom message the survivor according to the danger zone.

<message>:: = <Actor>$^{+}$<Danger_relation> <Affected_area><custom_message>

<actor>:: = <survivor _ID >

<Danger_relation> :: = “inside” | ”outside”

<affected_area> :: = “red_zone” | “yellow_zone” |“blue_zone”.

Note: <survivor_ID> ∈ <survivor>.

Second example is the administrator wants to message the survivor according to the danger zone and the POI relation. For example,

<message>::=<actor>$^{+}$[<Danger_relation><affected_area>]<POI_name><POI_position> <custom_message>

<actor>:: = <survivor _ID >

<Danger_relation> :: = “inside” | ”outside”.

<affected_area>:: = “red_zone” | “yellow_zone” |“blue_zone”.

<POI_name>::=“lake”|“hospital”|“evacuation_center”|“school”|“playground”.

<Position_relation>:: = “near” | ” close to” | “far” | ”away” | “ next_to”.

<custom_message>:: = STRING (e.g., “stay there”).

The manual form helps filtering and capturing the information about the survivors depending on several contexts. For example, Alaa and Ahmed are survivors in the blue_zone, and we want to send a custom message containing the warning "fire coming”. The manual form offers a choice to address a custom message to these survivors who are at same position relationships, such as “near the lake”. The system then takes care of resolving the words "near" and the names "Alaa" and "Ahmed" to specific distance measures and specific mobile devices (see Figure 6).

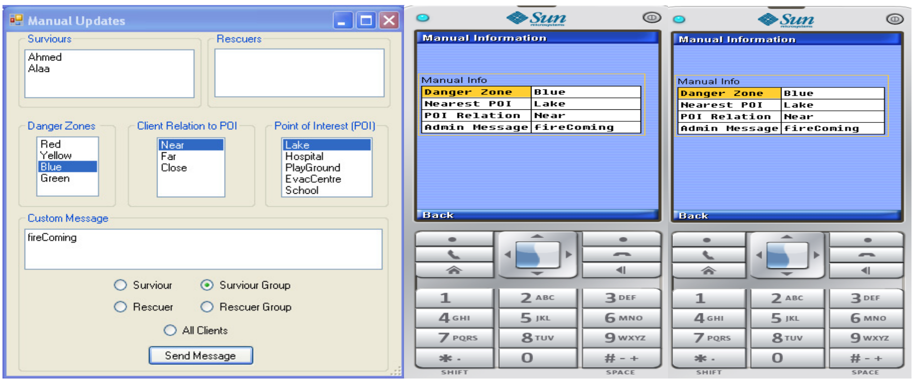

Fig. 6. Manual message to a group of survivors using particular spatial relationships

Figure 7 describes another service using the manual form such as sending a custom message only to one survivor such as Alaa who is located in yellow_zone at this stage and close to the lake, with message contents to say “stay there”. The figure shows that only one survivor receives the custom message while the others keep receiving the automatically sent messages from the server.

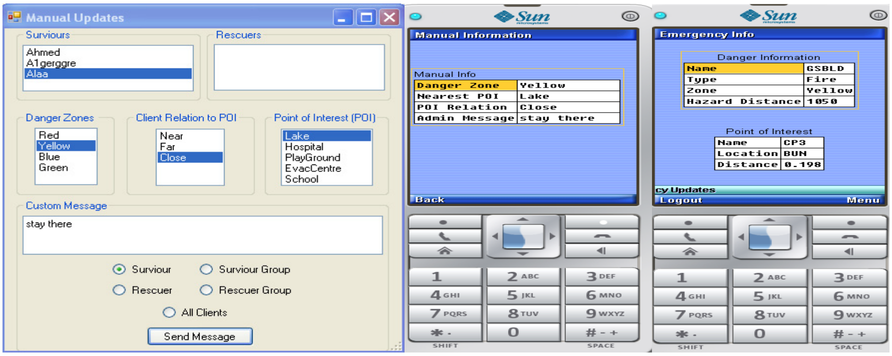

Fig. 7. Some survivors receive the automatied message

3.3 Peer to Peer Communication

The MES supports peer-to-peer emergency services by the use of ad-hoc communication. In the sense, an alert message can be forwarded from one actor to another depending on context using any peer-to-peer communication method such as Bluetooth. The message is forwarded from a registered survivor to unregistered survivor(s) according to location context information. The MES' peer-to-peer message content structure is designed the same as the automatic messaging mode plus a custom message as follows (in EBNF):

<message>::=<actor1>+<danger_type><affected_area><danger_distance> <POI_name><POI_location> <POI_distance><custom_message>

<actor1>::= <survivor_ID>.

<danger_type>::= "fire" | "flood" | "earthquake" | "nuclear_danger".

<affected_area>::= "red_zone" | "yellow_zone" | "blue_zone".

<danger_distance> ::= "945" | "775" | "534".

<POI_name>::="lake"|"hospital"|"evacuation_center"|"school"|"playground".

<POI_location>::= "Bundoora" | "Reservoir"| "Kingsbury".

<POI_distance>::= "0.25" | "0.775" | "0.999".

<custom_message>:: = STRING (e.g., "stay there").

The survivor decides on the survivor(s) that will take delivery of the message according to his/her (their) location(s). Then, the registered survivor informs the unregistered survivor(s) about the existing danger information, including danger name, danger type, affected area, danger distance and POI information such as POI name, location, distance and a custom message.

Figure 8 shows the message flow starting from the disaster management unit and ending at unregistered survivor. For example, S represents the disaster management unit and C1 and C2 registered survivors, where C3 and C4 are unregistered survivors. S can send the alert message to C1 and C2 via SMS or Internet. In addition, C1 (as a

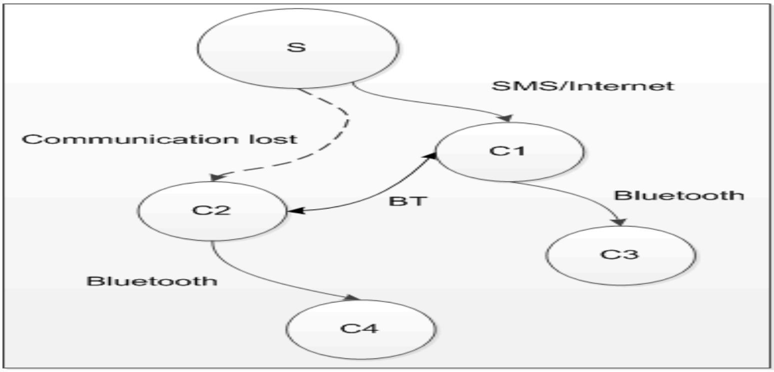

Fig. 8. Disaster automatic messaging via a peer-to-peer model

flag-bearer) can send the alert message to C3 via Bluetooth. Now, also, if C2 loses the communication with S, it will be able to receive the alert message from C1 via Bluetooth, and then C2 can send the alert message to the closest survivor C4. This service assists in spreading the alert messages around people in the danger area. It uses ad-hoc communication techniques in the case of unregistered survivors or lost communications with the disaster management unit (i.e., the main server).

4 Conclusion and Future Work

Context-awareness captures and represents the user's physical and social environments. In emergency situation there is an essential need to employ all obtainable information that may help in avoiding tragedy. The MES provides several techniques in order to send relevant emergency messages. First, the MES provides an automatic messaging service that will be generated depending on different contexts, from the disaster management unit to the actors. Second, manual messaging from the disaster management unit to the system actors can provide control and custom context-aware messaging for rescuers. Finally the system uses ad-hoc communication such as Bluetooth to send relevant messages to even those unknown to, or unregistered with the system, and so, creating greater robustness for messaging (even when some survivors are not directly reachable) – effectively crowdsourcing alert message delivery to actors (whom we call flag-bearers).

In the future, one of the main features that will be implemented within the system is sending geographical information using a map that will show the direction to the nearest safe POI as well as the danger locations, and this will be continually updated. Besides, we aim to provide online services to rescuers to access the MES via the mobile Internet, and to further evaluate the performance of our system.

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