Location Awareness Rescue System : Support for Mountain Rescue Teams

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Abstract—**Aiding the efficient collaboration and coordination of rescue teams is a difficult task especially in a mountainous region. Challenges emerge from quickly alerting and debriefing rescuers, to deploying them effectively, and also coordinating and monitoring them in the rural search domain. Knowing the exact location of the rescuers and vehicles involved in a mountain search and rescue mission is a key element for the successful progress of the mission and aids the mission coordinator, who usually stays at the headquarters, to take fast and informed decisions. In this paper we present the devised Location Awareness Rescue System that targets the aforementioned challenges, and provides location information and updates of the rescuers in a real time manner as they are deployed in the rescue domain overlaid onto interactive maps. The results from our tests show that our system is a proficient presence management solution that can provide precise location information by recovering from any periodic or total connectivity loss, and also improve and support mountain rescue teams leading to more effective and successful missions.**

Keywords; location awareness; mobility; rescue system; GPS

I. INTRODUCTION

Efficient support, coordination and collaboration in search and rescue missions are of critical importance as every minute matters. A key element to increase the possibility of saving lives in search and rescue operations, is the knowledge of the exact position of each rescuer and rescue vehicle throughout the mission, as it aids the mission coordinator, who usually stays at the headquarters (HQ) of the team, to keep a broader picture of the mission and take fast and informed decisions. The concept of location awareness gains even more attention in rescue missions taking place in rural and uninhabited areas, such as a mountain, where the physical characteristics of the domain make the finding of the casualty/casualties harder and the coordination of the rescue team even more difficult.

Our research team at Lancaster University has developed a Location Awareness Rescue System (LARS) that informs the mission coordinator of the exact location of the members of the team and the all-terrain vehicles involved in a real-time manner as they are deployed in the rescue domain. The basic principle behind the system is the transmission of coordinates obtained from the Global Positioning System (GPS) from a client application that resides in lightweight devices that the rescuers carry, to a server application located at the HQ of the team via the most suitable and available connectivity option. In turn, the server application receives all the GPS coordinates, processes them and plots them onto interactive maps to inform the mission coordinator of the progress of the mission. LARS's capabilities are not limited to monitoring rescuers, but also provide effective means to support rescue missions from the very early stage of alerting and debriefing rescuers for an emergency, to the medium stages of informing them of any position/health status information of the casualty if known, to the final stages of calling them back at the HQ for debriefing and analyzing the mission. Furthermore, LARS records the rescue missions and has the ability to replay and help the team analyze and study them offline, to improve future operations.

II. BACKGROUND

The valley areas around the Lake District (Cumbria, Northwest UK) combine a nice setting of mountains and lakes that attracts approximately 12 million individuals every year for hiking, fell running and mountain climbing in a picturesque environment. Our collaboration with the Cockermouth Mountain Rescue Team (CMRT) [1], one of the twelve rescue teams operating in the area, allowed us to analyze thoroughly the way the team operates and build a practical system customized to a real-life scenario that evolves as follows. In the case of an emergency incident a call is made to the HQ of the CMRT, located at Cockermouth (Cumbria, Northwest UK), and the members of the team, which are mostly volunteers, are called to report to the HQ. When enough members of the team arrive at the HQ, they are divided into independent search parties that are composed of a cluster of rescuers and all-terrain vehicles, are briefed on the incident, and dispatched to the area that it is most likely that the incident has occurred in order to locate the casualty. The mission coordinator of the team stays at the HQ and tries to remotely organize the rescuers and improve the efficiency and the accuracy of the mission.

In order to provide LARS's services for the CMRT's operations, we designed a hybrid network that interconnects the mountain rescue domain with the HQ of the team and transfers all the required data using various wireless interfaces with different propagation. Our networking model (described in more detail in [2]) envisages the independent search parties of a mission as mobile networks and provides connectivity among the devices within a mobile network (i.e. among rescuers) using short-range wireless hotspots (802.11b/g). These hotspots

This research has been funded by the U-2010 Integrated European Research Project under the 6th European Research Framework Program.

are provided in the area where rescuers roam from a mobile router (WIFI and HSDPA/GPRS enabled) that a member of each search party is carrying in a backpack and therefore follows the mobility of the group. Connectivity among these networks is provided using long-range wireless hotspots (using long-distance 802.11/802.16) that are projected from high-gain directional antennas attached to the all-terrain vehicles that are parked as close to the incident as possible. To further extend the wireless communication described, mobile routers are also able to directly interconnect with one another via an additional wireless interface configured in ad-hoc mode, and form an on mountain mesh network. Backhaul network access to the Internet for these on mountain networks is gained as the all-terrain vehicles relay data to either the nearest wireless point of presence (PoP) of the Cumbria and Lancashire Education Online network (CLEO), or via the Astra 1E satellite, using a small satellite dish mount on the roof of some of the vehicles. It is important to mention that connectivity is provided unobtrusively and seamlessly to the client applications running on the rescuers' end-devices, without them being concerned with the exact connectivity option used.

Our research group has specifically designed and developed a suite of networking protocols that run on the mountain rescue network and specifically on the mobile routers, and administer seamlessly all of these available connections [6]. This protocol suite, dubbed as the Unified MANEMO Architecture (UMA) [5], combines the NEMO Basic Support protocol [3] and OLSR [4] in one unified and enhanced solution that solves the research problems and routing inefficiencies of the respective areas. UMA ensures that communication between the rescue workers' devices and the HQ is constantly maintained irrespective of the routing path it takes place via.

III. SYSTEM DESCRIPTION

Fig. 1 illustrates a high level architectural diagram of the client-server model that LARS principally follows. LARS is composed of :

1) A *Client application* that runs on a small and lightweight device that each rescuer carries during a mission in the mountain rescue domain

2) A *Server application* that resides in a server machine at the HQ of the rescue team

3) The *Data transfer* that happens between the client and the server application that can be conceptually seperated to two main functionality blocks; the alerting and the monitoring. The former is realized when alerting rescuers for an emergency, monitoring their replies and also exchanging additional messages with them during a mission. The latter is realized when monitoring rescuers as they are deployed in the rescue domain with the use of an intelligent Communication Framework (CF) and the connectivity options that can interconnect and transfer data from the mountain rescue domain to the HQ of the team.

A. *Alerting*

LARS's alerting functionality is partially based on an advanced decision engine, integrated in the server application, that interacts with a rescue personnel database, and partially on the Mplify's AlarmTilt servers [7] that make the actual alert. When the mission coordinator is informed for an emergency incident he enters the details in the server application and when these are processed he is presented with the most suitable and available rescuers for the mission. Subsequently, he can very quickly and effectively alert them by using a combination, or all, of the following means; voice calls, SMS and emails.

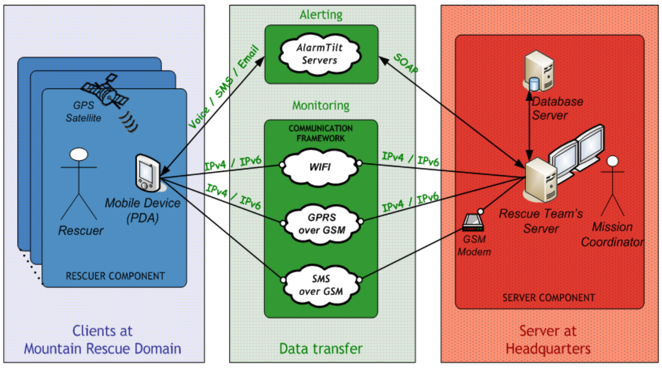

Figure 1. High-level architectural diagram of the LARS

B. *Monitoring*

LARS is a proficient presence management solution that has been designed to aid the missions of the CMRT by tracking the rescuers during each stage of a mission. The basic principle behind this location awareness functionality is the transmission of GPS coordinates from the mobile devices that the mountain rescuers carry or are placed in the rescue vehicles, to the server application that runs on the team's server at the HQ. Therefore, the application on the client end device obtains GPS coordinates and then identifies the best available connectivity option (directed by the CF) for the transmission of the coordinates to the server application.

1) *Communication Framework*

To provide the monitoring functionality of LARS we need to reliably transmit the GPS coordinates from the client applications running in the mountain rescue domain, to the server application running at the HQ, over the mountain rescue network. Therefore, we have designed a refined Communication Framework (CF) that includes three network connectivity options that are available, viable and feasible for the transmission of the GPS coordinates. The first one is to transmit the coordinates via IP over the WIFI mountain rescue network using an 802.11 (or 802.16) interface, the second one is via IP using GPRS over the GSM network and the third one is via SMS over the GSM network. The client application is able to identify the availability of each of the connectivity options and then use them according to the following priority directed by the CF; WIFI, GPRS and SMS. A full analysis of their prioritization cannot be provided here, but it can be briefly stated that the WIFI and GPRS connectivity options have higher priority as they are IP-based. However, although the SMS functionality is fairly limited in transmitting only a fixed set of characters, is considered as very valuable and increases the reliability of the transmission, as it is simple and connectionless, and can be used in occasions where the GSM signal is poor and IP data transfer cannot take place.

2) Unified Message Format

An important feature of the CF is that it defines a Unified Message Format (UMF) that is used for the transmission of the GPS coordinates from the clients to the server regardless of the connectivity option used. This simplifies the procedures for the transmission, reception and processing of the packets both on the client and the server side. UMF is composed of nine text fields of fixed size, separated by a character delimiter. These fields include values for the connectivity option used for the packet being sent, the node ID of the device that sent the packet, a security code unique for each device and a sequence number for the packet being sent from that client. In addition, UMF includes a timestamp for the date and time that the packet was created and transmitted, a pair of GPS coordinates presenting the current location of the rescuers and finally a field for possible extensions.

IV. CLIENT APPLICATION

The client side of the LARS is composed of lightweight and small end devices, such as tablet PCs or PDAs, that are carried by the rescuers or are placed in the all-terrain vehicles involved in a mission. The main aim of the client application concerns the location awareness and tracking functionality of LARS, which is accomplished by obtaining GPS coordinates, identifying the best suited connectivity option according to the CF and using that option for the transmission of the GPS coordinates to the server application. Consequently, the client devices should be GPS, WIFI, GPRS and GSM enabled to be able to facilitate the Mountain Rescue Team's requirements and utilize the connectivity options. For the purpose of our research, HP IPAQ 6915 and 915c PDA devices are used, running Windows Mobile 5.0 and 6.0 respectively. As Fig. 2 illustrates the client application presents real-time information to the rescuer (such as his location on a map, GPS information and others) without requiring any input from him. Our decision for the unobtrusive design and execution of the client application is based on the idea that we do not want to distract the attention of the rescuer who has more important tasks to do during a mission.

The client application is able to work seamlessly in two basic modes; online mode and offline mode to confront periodic or total connectivity loss if required. The online mode includes the transmission of the coordinates when at least one connectivity option is available and usable. On the contrary, when no connectivity option is available the application works in offline mode and stores packets for later transmission. These packets, that will be transferred when connectivity is regained, are flagged as offline since they include the location that a rescuer has been in a past. This flag is used by the server application to distinguish the way online and offline packets are presented to the mission coordinator. The transition from online to offline mode and vice versa, is done automatically without any intervention from the rescuer.

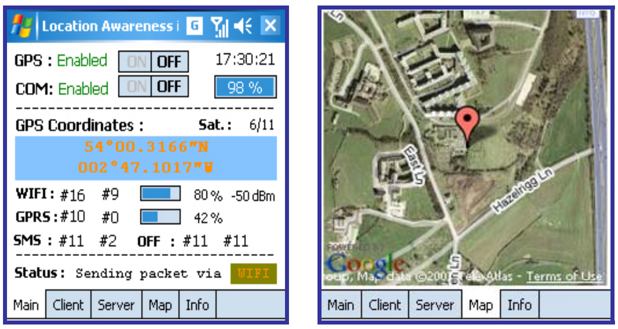

Figure 2. Screenshots of the Client Application

V. SERVER APPLICATION

The high-level aim of the server application running at the HQ is to efficiently alert rescuers to an emergency, monitor their replies and then track them as they are deployed in the rescue field in real time. This tracking is done by listening to incoming packets that are sent from the clients regardless of the connectivity option used for their transmission (WIFI, GPRS, SMS). Then, the server application processes the payload of each arriving packet and plots the received GPS coordinates of the rescuers onto two different and complimentary map implementations (Google Maps and Ordinance Survey Maps) to assist the coordinator to track the progress of the mission. The thorough processing that the server application imposes on the incoming packets enables other features to be supported, such as authentication and identification of the clients, splitting merged TCP packets and re-ordering of the received packets since all of them follow the UMF.

The server application presents two main GUI forms to the mission coordinator, namely the Control Form and the Map Form (Fig. 3), each runs full-screen on its own monitor. The Control Form has three different tab-pages; the Alert tab, that is used for alerting and sending additional messages to the rescuers, the Map tab that holds a Google Maps implementation using JavaScript for satellite images, and a Log tab presenting analytical log information. The Map Form has a separate map implementation using very detailed Ordinance Survey Maps that need to be always visible and thus runs on a separate monitor to the Control Form. When the initial alerting phase through the Control From has finished, the coordinator focuses his interest on the Ordinance Survey maps of the Map Form (Fig. 3), and monitors the progress of the mission as real-time information is retrieved and overlaid concisely on the Ordinance Survey maps. Both map implementations allow interaction such as scrolling and zooming in and out, in addition to exposing the identity of the rescuer when a marker

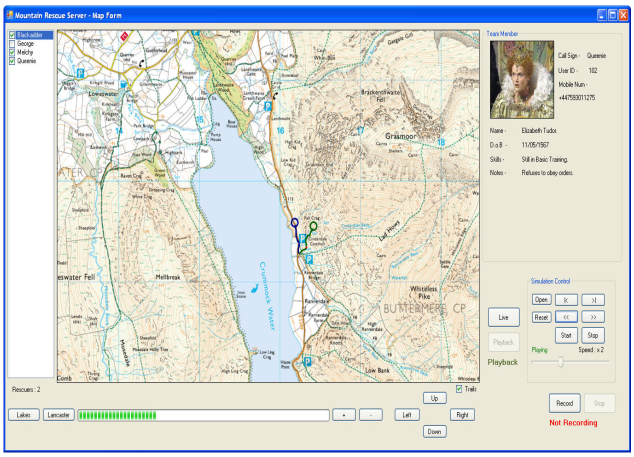

Figure 3. Screenshot of the Server Application ; Map Form

is clicked. The Ordinance Survey maps implementation can additionally draw in real time the path that each rescuer takes, and also records the whole mission for later replay and offline analysis and study. Offline analysis of missions is a very useful feature of the server application and can benefit greatly a rescue team, as it points out were the team spent unnecessary time finding or approaching a casualty. Such a study aids the team in optimizing its search patterns and ways to approach certain regions, and eventually save critical time for locating the casualty.

VI. EVALUATION

It was our strong intention to use and evaluate LARS on the actual region that it is designed to be used in. Therefore, our research team performed some testing in the Lake District and more specifically in areas around Buttermere (Cumbria, UK) where the CMRT actually operates. During our 90 minute test on this region (limited by the batteries of our equipment), two researchers of our group were alerted for an alleged emergency using the server application, and were acting as rescuers roaming individually around the region, each of them carrying a PDA running the client application. The complete server setup was replicated at Lancaster University which is approximately 85 miles (135km) away from the region that the "rescuers" were roaming in. For this test we followed our mountain rescue networking model in a more basic form. A laptop running Linux was acting as a mobile router projecting short-range wireless connectivity in the area that the rescuers were roaming in. This laptop was getting backhaul connectivity to the Internet and in turn to the server application, via a satellite connection to ASTRA 1E using a 75cm satellite dish, and via an additional long distance wireless link to CLEO's PoP at Cockermouth over a relay at Low Fell, approximately 3.7 miles (6km) away from the searched region.

During this test, it was found that both the alerting and monitoring functionalities of LARS worked effectively. The roaming researchers were successfully alerted regarding the mission and were depicted in real-time on the mapping implementation on the server application. The whole test was recorded using the associated functionality on the server application, and thus we were able to verify after the test, the high accuracy of the recorded walking trails and the precision of the transmitted GPS coordinates. Table I presents results from the packets being transmitted either in the form of IP packets over the WIFI access point to the backhaul network, or SMS messages over the GSM network. It can be observed that only 7 out of 128 packets were lost when the client applications were using the WIFI connectivity option in either online or offline mode, which translates to only a 5.4% packet loss. This is a very remarkable percentage for a wireless network taking into consideration the physical characteristics of the environment and the mobility of the persons holding the client devices. A careful examination of the clients' logs indicated that the CF handled occasions of low signal strength very successfully, and triggered TCP retransmissions, which eventually minimized the observed packet loss. Regarding the transmitted SMS messages, 11 out of 234 were not received at the server application (approximately 4.7%), a percentage that can be attributed to the sporadic coverage of the GSM provider.

TABLE I. RESULTS FROM THE ON MOUNTAIN TEST

CON. OPTION	**CLIENTS (PACKETS SENT)**		**SERVER (PACKETS RECEIVED)**	
	Online	***Offline***	***Online***	***Offline***
WIFI	121	7	114	7
SMS	207	27	198	25

Extensive log analysis showed that the client application was correctly identifying the availability of each connectivity option and managed to use it accordingly to maximize the reliability of the transmission. It is important to highlight how much the client application utilized the SMS functionality (apparently in occasions when it could not setup an IP connection over WIFI), emphasizing how much this simple and connectionless transmission option increased the robustness of the system when IP connectivity failed. Furthermore, it should be noted that the client application experienced at periods total connectivity loss and had to temporarily store 9.4% of the overall number of packets (34 out of 362) using the offline functionality of the client, which were eventually transmitted when connectivity was regained. It is important to note that if LARS did not have the offline functionality all these packets would have been lost. However, with the intelligent use of the CF in conjunction with the offline functionality the client application effectively managed to firstly, identify total connectivity loss and store the GPS packets and secondly, transmit the packets when connectivity was regained. This refined functionality of LARS maximized the reliability of the transmission, leading to an overall packet/messages loss of less than 5% despite the unpredictable mobility of the 'rescuers' and the rough morphology of the mountainous domain.

VII. CONCLUSION

In this paper we have introduced the LARS to facilitate the concept of location awareness in a mountain rescue domain, and also support various stages of search and rescue missions. Our results show that the developed system can alert and track rescuers in a real-time manner and recover from periodic or total connectivity loss, bringing great benefits to search and rescue teams.

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