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Instrument: Integrated Project

Thematic Priority 2

D4.2.1 Report on the Mountain Rescue Service Concept

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Abstract

The purpose of this document is to define the concept of the prototype implementation for the Mountain Rescue service concept. It presents a reference scenario based on an analysis of typical search and rescue operations conducted by Mountain Rescue teams in the English Lake District.

This document is the conclusion of 18 months of discussions, analyses and lab/field trials. It is also heavily influenced by the requirements and guidelines defined by workpackages 1, 2 and 3.

The Mountain Rescue concept outlined in this document serves as a guide for the final implementation and demonstration that will occur in the final 12 months of the project. However, it is plausible that certain technical issues and/or implementation details may be adapted or altered during deployment trials and testing.

Keywords:

Mountain Rescue, Mobile Networks, Ad-hoc Networks, Manemo, Presence Management, Video streams, Voice communication, Directory Services

History of Change

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V0.2	Draft	15/02/08	Added Mountain Rescue scenario and walk-through	Martin Dunmore
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v1.1	Draft	09/07/08	Minor changes in response to comments from internal reviewer (Bryan McClaughlin). Re-sampled images to reduce file size.	Martin Dunmore
v1.2	Final draft	17/07/08	Minor changes in response to comments from internal reviewer (Socrates Varakliotis).	Martin Dunmore
v1.3	Final version	18/07/08	Final editing, addition of glossary	Martin Dunmore, Panagiotis Georgopoulos

Table of Contents

List of Figures

List of Tables

Executive Summary

Deliverable 4.2.1 'Report on the Mountain Rescue Service Concept' presents both functional and technical views of a possible communications solution for mobile search and rescue teams in areas of little or non-existent fixed communications infrastructure.

It includes different actors such as Group Leaders, Team HQ, Mountain Rescue Workers, Police, Hospitals and Ambulance Paramedics.

Based on the real experiences of Mountain Rescue personnel coupled with state-of-the-art ICT solutions, this document introduces the ongoing implementation of a prototype solution for Mountain Rescue services that is applicable to other mobile search and rescue missions (e.g. the aftermath of earthquakes, tsunami and major terrorist attacks). Characteristics such as harsh environments, destroyed or absent infrastructure and limited available resources are common to all of these examples and are evident in Mountain Rescue scenarios.

The Mountain Rescue service solution is based on the work completed and ongoing in other work packages. Requirements for the service solution are defined in WP1, the solution for mobile networking is being investigated in WP3 and the core user services and their integration belongs to WP3.

Activity 4.2 in WP4 seeks to implement and deploy these solutions and recommendations. At the time of writing, the majority of hardware and software solutions have been identified and/or developed. This deliverable describes these solutions. Although we are at a relatively early stage of deployment trials, this deliverable also reports on some early progress in this area. Further deliverables in activity 4.2 will report on the detailed deployment trials that will commence in the final nine months of the project.

This deliverable will be updated via the documentation of the prototype realisation at the end of the project.

1. Introduction

This deliverable describes the concept for the Mountain Rescue service scenario of the u-2010 project. The main goal of this scenario is to show the u-2010 results in a mobile search and rescue environment where the search locations are remote, possibly hostile in terrain type and have little or no fixed communications infrastructure.

The scenario described in this document is based on the Mountain Rescue service scenario described in the u-2010 deliverables D1.1.1 [1] and D1.1.2 [2]. The scenario has been further enhanced based on ongoing discussions with the CMRT (Cockermouth Mountain Rescue Team) and experiences with development and early deployment testing. The CMRT is one of 12 rescue teams in the English Lake District and covers a search area of around 600Km^2. It operates 365 days a year with rescue workers totalling 1500 hours per year on rescues. Despite this commitment, the CMRT is a registered charity and is funded solely by voluntary contributions; the rescue workers themselves are all unpaid volunteers [6].

Innovation in mobile networking and ICT systems can greatly benefit search and rescue operations in emergency and crisis situations. Being able to move entire networks (as well as single user devices) in a seamless manner in response to specific areas of need is of critical importance. The new Internet Protocol, IPv6, plus related network mobility protocols can help us achieve this. In addition, the ability for a command and control centre to monitor and manage rescue personnel and other resources in real-time can significantly increase operational efficiency. The ability to support mobile search and rescue teams in such fashion is the focus of Lancaster University's involvement in the u-2010 project. Our testbed concentrates on Mountain Rescue in the English Lake District, Cumbria, UK. The domain of Mountain Rescue services is an ideal candidate with which to test out the u-2010 paradigm. Typical Mountain Rescue missions consist of one or more mobile teams that need to communicate in areas where there is little or no communications infrastructure. However, the underlying principles of our research will apply to any mobile search and rescue operations such as in the aftermath of tsunamis, hurricanes, floods, earthquakes and major terrorist events. Initially, the users of the system we are deploying are the Cockermouth Mountain Rescue Team (CMRT). The user base will most likely be expanded to include other mountain rescue teams within the Cumbria region. In addition, a secondary deployment in Slovenia will see the Slovenian Mountain Rescue Association (SMRA) as the main users.

The rest of this document is structured as follows. The following section describes the general Mountain Rescue service scenario and defines the users and their roles. Section 3 provides an example walk-through of a typical Mountain Rescue operation and details the use cases that arise from this. The fourth section gives a technical overview of how the envisaged scenario can be realised; this involves the monitoring and management system, user services, networking technologies deployed and results of preliminary tests. Finally, section 5 draws conclusions on the scenario and its deployment.

2. The Mountain Rescue Service Scenario

Lancaster University is on the border of the English Lake District, which is extremely popular with hikers, fell runners and mountain climbers. In cooperation with the CMRT, Lancaster University is deploying IPv6 mobile routers to provide them with an on-mountain data networking solution. Lancaster University is also responsible for network connectivity of all the schools and colleges in the Lancaster and Cumbria counties via the CLEO (Cumbria and Lancashire Education Online - http://www.cleo.net.uk) initiative, which uses CANLMAN (Cumbria And North Lancashire Metropolitan Area Network – http://www.canlman.net.uk). The importance of this is that we can provide the backhaul network access that the Mountain Rescue service's mobile networks can rely on.

2.1. Scenario Description

In a typical Mountain Rescue operation, each Mountain Rescue Team (e.g. CMRT) will have several search groups which will be assigned to a base vehicle and, in turn each individual rescue worker will be assigned to a search group. This leads to an obvious hierarchical relationship as depicted in Figure 1.

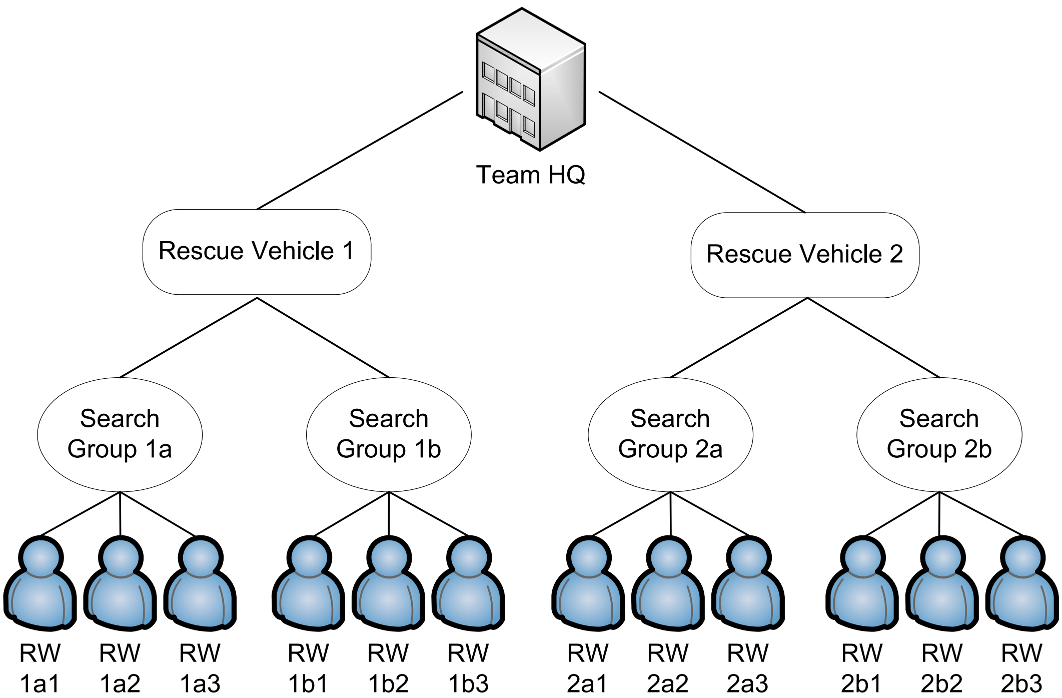

Figure 1 Rescue Network Hierarchy

However, these relationships are loose in that rescue vehicles, search groups, and individual rescue workers may sometimes change their 'points of attachment' as a search operation evolves. We determine that each search group represents one distinct local network, with its rescue workers being nodes on that network. Since each search group can change location, the search group network becomes mobile. In a similar fashion, the rescue vehicles are their own distinct mobile networks, only the Team HQ remains static. To further complicate things, any rescue worker can move in such a fashion that they can attach to a network of a different search group or even a different rescue vehicle. How all this complex cooperation can be organised using IPv6 and network mobility is discussed below.

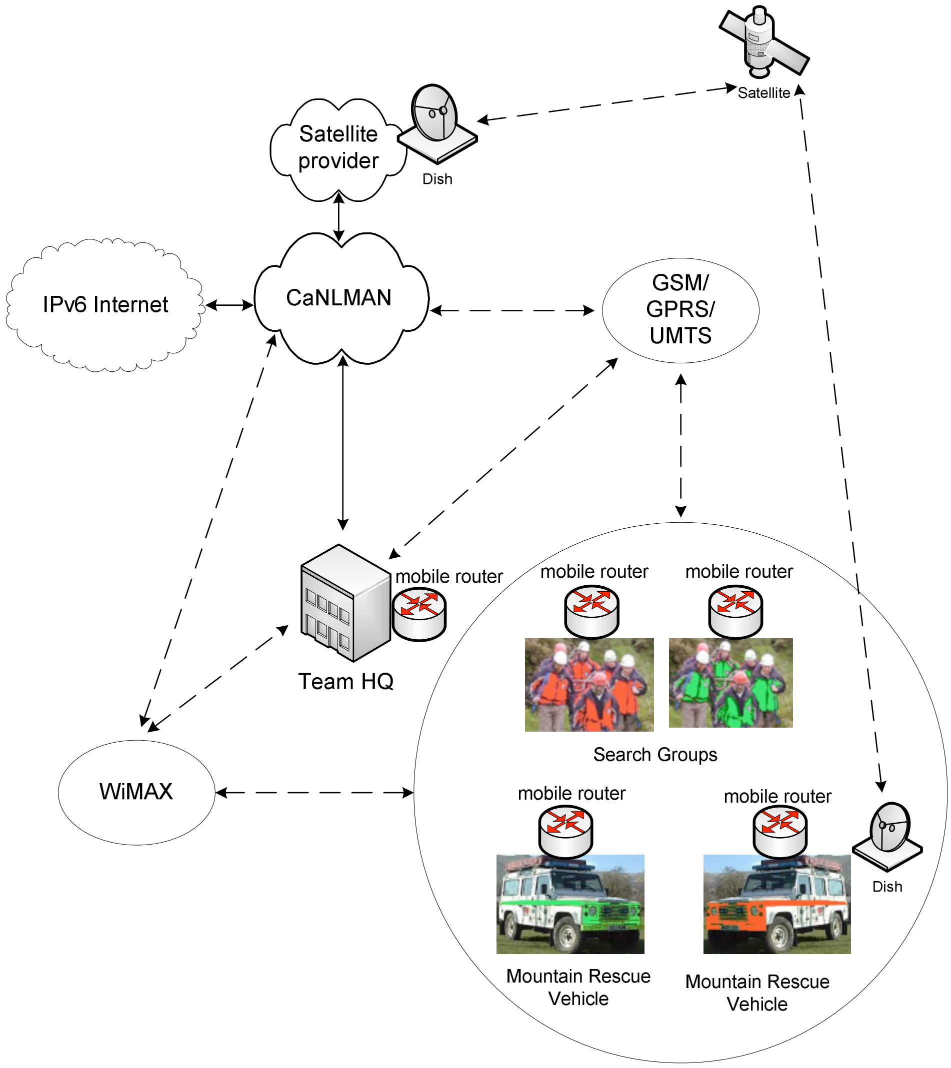

Figure 2 General Scenario Concept

Enabling efficient communication for Mountain Rescue scenario can be achieved by interconnecting the search areas with the HQ of the team. However, providing sufficient network connectivity in such remote rural locations is very challenging. The choice of network infrastructure is limited as wired connectivity is restricted to major towns. In addition, fixed public networks such as GSM, GPRS and UMTS have patchy or non-existent coverage in some areas. However, any connectivity we can provide on CANLMAN plus any public wireless networks, plus possible satellite connectivity (provided by u-2010) can all be exploited by IPv6 mobile routers. Furthermore, we can build coverage 'on-demand' by locating portable 802.11/WiFi, 802.16/WiMAX or GSM/GPRS base stations with the mobile routers. Figure 2 illustrates an example network infrastructure for the Mountain Rescue deployment for the CMRT.

Mobile routers are located with the rescue vehicles. Using high gain directional antennae, we can project a hotspot of connectivity across an area being covered by the search groups assigned to that vehicle. Network technologies such as 802.11 and/or 802.16 can be used to achieve this connectivity. The vehicle mobile routers can use GSM/GPRS/UMTS connectivity as the uplink to the Team HQ. Other options are to support point-to-point or point-to-multipoint WiMAX (or similar) links or bi-directional satellite links via appropriate antenna and transceiver assemblies on the rescue vehicles connected to the mobile routers. Small form factor mobile routers are integrated into backpacks of designated rescue workers thus providing connectivity for each search group. In general, each search group will have its own 802.11 hotspot that rescue workers can connect to. Thus, rescue workers are not only connected to others in the same search group, but also with Team HQ (located many kilometres away) via their rescue vehicle and also with rescue workers from other search groups via the wireless networks of different search groups and the search vehicles. If a rescue worker has connectivity to any of search group's wireless network then they have connectivity to the overall network. Since the mobile routers can also bridge different wireless networks, the effective coverage area can be expanded. Yet it is IPv6 and network mobility that truly facilitates this capability. Using IPv6 neighbour discovery a rescue worker's device will automatically detect the network of a different search group and attach to it without any user involvement (assuming the usual network has been lost). Any existing applications would normally be broken at this point. However, using NEMO or MANEMO, introduced in Chapter 4, the applications can go on using the old IPv6 addresses and do not even realise the device has moved.

2.2. Definition of Users and Roles

The following table defines the users that have been indentified in the Mountain Rescue Scenario

Table 1 Users and Roles

User	Role
Team HQ	The headquarters of the Mountain Rescue team. This is where all search and rescue operations are controlled, managed and monitored from. Typically, the HQ will be located many kilometres from the search areas
Controller	The controller is located in the Team HQ and is responsible for organising the overall search and rescue operation from the initial emergency call until the mission is terminated.
Police	The Police will receive the initial emergency call and are responsible for contacting the controller at the Team HQ and passing on all the details of the incident. The Police may also take part in the search and rescue operation by, for example, searching car parks for the missing person's vehicle or calling hotels and campsites to see if they have any information on the missing person.
Informant	The informant is the person who makes the emergency call requesting Mountain Rescue service. This may be the casualty himself or a third party. Depending on the situation, the information provided by the informant can range from specific to extremely vague. The informant will be in voice contact with the controller after the Police have contacted the HQ.
Group Leaders	Group Leaders are assigned to each search group and have the responsibility of making sure the search group follows the intended search patterns.
Rescue Workers	Rescue workers are the unpaid volunteers that make up the Mountain Rescue team. They are responsible for conducting the search and rescue operation according to the intended plan. Group Leaders are also Rescue Workers.

Ambulance Paramedics	Ambulance Paramedics attend to the scene when they are signalled to do so by the controller at HQ. Since it can take several hours to locate a missing person, there is little sense in the ambulance departing for an unknown destination when the emergency call is first made. Ambulance paramedics wait by the nearest roadside (identified by the controller) for the Rescue Workers to carry the casualty down the mountain.
Hospital	The hospital is responsible for the long term treatment of the casualty. The emergency room of the hospital will be placed on standby and informed of the casualty's condition as the search and rescue operation progresses.
Air Force	If the casualty is an inaccessible position, or if his injuries are life threatening, the controller will request an airlift to hospital. The air force is placed on standby when the casualty is located and then stood down or scrambled once the team doctor and group leader(s) have determined the right course of action.

3. Example Scenario Walk-through

There are many permutations to how a particular Mountain Rescue emergency is played out. In this chapter, we present a walkthrough of one possible emergency scenario that involves all of the deployment components in WP4. For information on how emergencies are generally handled and which criteria can affect the details of a particular emergency scenario, please refer to D1.1.1 [1].

The scenario consists of six phases

1. Pre-activities
2. Emergency call
3. En-route to location
4. Arrival at location
5. Search
6. Rescue and Recovery

Each of these phases contains one or more ‘snapshots’ which describe the important actions and events that take place between the users. Each snapshot is in the form of a table with columns representing different users and each row representing actions and events in chronological order.

3.1. Phase 1: Pre-Activities

In general day-to-day operation, there is little activity for the Mountain Rescue team aside from their scheduled training routines. Since all members are volunteers, they also have their main employment duties to concentrate on. As a result, rescue workers can be in arbitrary locations and at various levels of preparedness at any given point in time. It is therefore extremely useful for the Mountain Rescue team to be able to monitor this information so that they can react more efficiently when an emergency call is made.

3.1.1. Snapshot 1 – Monitoring Rescue Worker Availability

The Presence Management system allows controllers located at the team’s headquarters (HQ) to determine which rescue workers are available and which can respond quickly should there be an emergency call.

Table 2 Snapshot 1 - Monitoring Rescue Worker Availability

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
1	The Team HQ receives periodic location updates from PM devices on rescue workers								Presence Management devices located on rescue workers periodically transmit their location to HQ.
2	The controller at HQ is able to monitor the locations and availability of the rescue workers. This information is stored in a live database using directory services.								

3.2. Phase 2: Emergency Call

When Mountain Rescue assistance is required, a member of the public will make an emergency call (999 in the UK, 112 in Europe). The person making the call is known as the 'informant' and is often a concerned friend or relative of someone who is missing. In some cases, the casualty (the person who is missing or in distress) is able to make the emergency call himself. The informant may or may not be able to provide accurate location information for the casualty. Whatever the accuracy of the information is, by consulting the knowledge databases at the Mountain Rescue HQ the controller can view details of the location/area in question including terrain difficulty, nearby roads and reception quality for fixed radio based communications such as GSM, GPRS and UMTS.

With information obtained from the knowledge databases, the monitoring and management system is able to provide the controller in the HQ with suggestions for search group organisation, search locations and search patterns. Thus, the controller can draft a search and rescue plan before the first rescue workers being to arrive at the HQ.

3.2.1. Snapshot 2 - Alerting

In this snapshot, the informant places the emergency call, which is routed to the local (Cumbria) Police. The police notify the controller at the Mountain Rescue HQ and the rescue workers are alerted. The controller is in voice contact with the informant.

Table 3 Snapshot 2 - Alerting

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
3			The informant makes an emergency 999 or 112 call requesting Mountain Rescue assistance - a man has failed to return home from his walk.[1]						
4		The 999 or 112 call is routed to the Police who notify the Team HQ of the details							
5	The controller enters all the details of the emergency into the monitoring and management system and triggers the alert. The alert is sent to all available personnel (determined from the database								

[1] The informant may also be the casualty. However, in this walk-through we assume the informant is a separate individual (e.g. a concerned relative of the casualty).

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
	via directory services).								
6				All available team personnel are notified of the emergency and send a response back to HQ.					
7	The controller assembles responses and prepares a search and rescue plan aided by the monitoring and management system.								

3.2.2. Snapshot 3 – En-route to HQ

Once the available rescue workers have been alerted and begin heading to the HQ, the controller can draft the search and rescue plan based on which rescue workers are responding and the details of the emergency.

Table 4 Snapshot 3 - En-route to HQ

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
8	The controller monitors the progress of the rescue workers who are en-route to the HQ and drafts search groups accordingly.								Presence Management devices located on rescue workers periodically transmit their location to HQ.
9	Controller briefs personnel on the			Group Leaders are	Rescue				

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
	nature of the emergency and the planned search and rescue operation.			assigned to each search group	workers are assigned to their groups				

3.3. Phase 3: En-route to Search Location

Once all (or enough) rescue workers reach the HQ, everyone is briefed on the emergency and the draft search and rescue plan is discussed. The team is divided into search groups, group leaders are assigned and rescue vehicles take the search groups to their planned search locations.

3.3.1. Snapshot 4 – En-route to Search Location

In this snapshot, as the rescue teams are en-route to the search domain, the controller at HQ receives new information from the informant that means the original search and rescue plan needs to be changed. The controller redirects one of the search groups that are en-route via voice and instant messaging.

Table 5 Snapshot 4 - En-route to Location

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
8	The controller monitors the progress of the rescue vehicles en-route to their locations								Presence Management devices located inside rescue vehicles periodically transmit

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
									their location to HQ.
9	The controller is in contact with the informant and receives new information that now suggests the casualty could be located in one of two possible mountain locations								
10				The controller establishes voice contact with one vehicle and redirects it to a second location. The redirect command is also sent as an instant message to the rescue vehicle and to all those inside the vehicle.					.

3.4. Phase 4: Arrival at Location

When the rescue vehicles arrive at their pre-determined search locations, the rescue workers begin their search patterns according to the search and rescue plan. The rescue workers stay in contact with each other via temporary wireless networks that are established from the rescue vehicles and between the rescue workers.

3.4.1. Snapshot 5 – Establish Network Infrastructure

Uplinks to the Internet are established from the rescue vehicles. These uplinks will be one or more of wireless point-to-point links with available PoPs, bi-directional satellite connection or GPRS/UMTS.

Temporary, directed wireless hotspots are established from the rescue vehicles to cover the initial search patterns of each search group. This connectivity is extended by the backpack routers carried by the rescuers.

Table 6 Snapshot 5 - Establish Network Infrastructure

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
11				Rescue vehicles arrive at their locations and establish their uplinks to the Internet. Wireless point-to-point links are established with any nearby CLEO PoPs. The Astra2Connect satellite link is established. Any GPRS/UMTS connectivity is established if available.					
12				Temporary hotspots are beamed into the intended search locations using optimised antennae.					
13				All personnel switch on their backpack routers. The MANEMO routers automatically connect to each other and learn the routes available via the established uplinks. The MANEMO routers help to extend the overall range of the temporary hotspots by connecting to each other as the rescuer workers conduct the					

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
				search.					
14	Controller sees any uplinks that are established by the rescue vehicles since the management and monitoring system is notified during establishment.								

3.5. Phase 5: Search

As the search groups are conducting their search and rescue operations, the controller at HQ can see all of their movements and status via the Presence Management system, which is interfaced with the Monitoring and Management system. Thus, the team can avoid searching areas twice and areas that have been missed are easily identified by the controller. The rescue workers are in voice contact with each other and have instant messaging capability. The controller at HQ also has voice contact and instant messaging capability to all or any of the rescue workers.

Sometimes, new information can be obtained which affects the search and rescue plan. This needs to be communicated to the rescue workers so that they can be given new orders.

3.5.1. Snapshot 6 – Search Operations

The rescue workers are kept in contact by a combination of their backpack mobile routers, the hotspots provided by the rescue vehicles and ad-hoc mobility networking protocols that automatically manage the network configurations. Steerable, directed antennae at the rescue vehicles are able to track the movements of the search groups to provide the best connectivity possible. Mobile routers in backpacks allow for the extension of the network footprints as the rescue workers move further away from the rescue vehicles.

Table 7 Snapshot 6 - Search Operations

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
15				Rescuers begin their search patterns according to the rescue plan. Steerable antennae at the rescue vehicles track the movements of the search groups.					
16				After some time, the search groups are out of range of the vehicle hotspot. Before this happens, a warning is sent to a group so that a backpack router can be stationed to act as a relay. Backpack routers also pickup any available GPRS/UMTS connectivity to act as gateways for the group.					
17	The controller monitors the search patterns of the search groups. Routes that rescuers have taken are highlighted and any unsearched areas are apparent.								PM devices send continuous location updates to HQ.
18	Using directory services, the details of any rescuer can be displayed on screen.								
19	The controller can select to call an individual, a group or general broadcast by selecting the users on-screen.								
20					One rescue worker takes a wrong turn in poor				

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
					visibility and moves away from the main search area.				
21	Controller sees the rescue worker moving away and establishes voice contact to advise him to turn back.								
22	If voice contact is unsuccessful, an instant message is sent to the rescue worker and other rescue workers from the same search group.								
23				The group leader sees the message and establishes local voice contact with the rescue worker to advise him to turn back.					
24					Rescue worker hears the group leader and turns back.				

3.5.2. Snapshot 7 - Search Reorganisation due to New Information

During the search and rescue operation, the controller is able to inform the rescue workers of any new information that could affect the search and rescue plan.

In this snapshot, new information is obtained and the search and rescue plan is changed so that one search group must relocate to another area. The Monitoring and Management system automatically suggests the optimum way to do the relocation and what search patterns should be conducted at the new search location. This information is passed to the appropriate search group.

Table 8 Snapshot 7 - Search Reorganisation due to New Information

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
25		Police find the vehicle belonging to the casualty; it is parked in a different mountain location to the ones being searched! The controller at the team HQ is notified.							
26	The controller uses the monitoring and management system to determine which search group should be redirected. Based on the amount of area already searched correlated with statistical information on previous incidents and current locations of the search groups, one search group is identified to proceed to a new location.								
27	The controller establishes voice contact with the group leader and sends instant messages to all group members. The group is ordered to			The group receives the new orders and immediately heads back to the rescue vehicle.					

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
	proceed to the new location.			Rescue workers of the search group switch off their backpack routers to conserve battery life.					
28	The controller monitors the progress of the search group en-route to the new location.								PM devices send continuous location updates to HQ.
29	The controller uses the monitoring and management system to devise a search plan for the new location.								
30				When the rescue vehicle arrives at the new location, the Internet uplinks are established.					
31				Temporary hotspots are beamed into the intended search locations using optimised antennae.					
32				All personnel switch on their backpack routers. The MANEMO routers automatically connect to each other and learn the routes available via the established uplinks					
33				Rescuers begin their search patterns according to the rescue plan.					

3.6. Phase 6: Rescue and Recovery

Eventually the casualty will be found by a rescue worker. When this happens, all nearby rescue workers converge on the location and a request for an ambulance is issued. The rescue workers must stabilise the casualty as best as possible and pass relevant medical information to paramedics and or the hospital emergency room. The group leader and doctor must decide if the casualty is to be carried down the mountain to the ambulance or should be airlifted to hospital.

When the casualty is secure in the ambulance (or airlifted to hospital) the entire team returns to the HQ for debriefing.

3.6.1. Snapshot 8 – Casualty Found

When the casualty is found, the appropriate rescue worker alerts the entire team via an instant message, which includes the casualty's location. As the nearby rescue workers converge on the location, the controller at HQ requests an ambulance places an Air-Force helicopters on standby.

Table 9 Snapshot 8 - Casualty Found

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
34					Rescue worker finds the casualty. Rescue worker broadcasts a general instant message alert, which includes the location of the casualty, to HQ and all search personnel.				
35	Controller sees the alert and					Ambulance		Helicopter	

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
	immediately contacts the ambulance station. The monitoring and management system automatically suggests the optimum route and final destination for the ambulance. The controller contacts the Air-Force to put a helicopter on stand-by.					despatched to location.		and crew placed on stand-by	
36					All members of the search group converge on the casualty's location with haste. The other search groups make their way back to their rescue vehicles.				

3.6.2. Snapshot 9 – Rescue Operation

When the medical personnel reach the casualty, they provide first aid and place biomed sensors on the casualty. This sensor information is transmitted over the temporary wireless networks to ambulance paramedics in the arriving ambulance and to the hospital emergency room. In this snapshot, it is decided that a helicopter is not necessary so the controller informs the Air Force that they can stand down.

Table 10 Snapshot 9 - Rescue Operation

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
37					The search group's doctor administers first aid to the casualty. Biomedical sensors are placed on the casualty. Helmet mounted video cameras capture video and still images of the casualty.				
38						Data from the biomedical sensors and video images are transmitted to the ambulance and hospital emergency room.			
39					The group doctor determines that the casualty's injuries are not life threatening and that the situation is not time-critical.				
40				The group leader					

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
				determines that the route back down to the waiting ambulance is relatively straightforward for stretcher carry.					
41	The controller is informed of the situation and calls the Air Force to stand down the helicopter.							Helicopter and crew stand down.	
42				The search group stabilise the casualty and secure him in a stretcher for the carry down.					
43	Controller monitors the progress down the mountain.			The casualty is carried down to the waiting ambulance.		Paramedics and hospital monitor data from the biomedical sensors.			

3.6.3. Snapshot 10 – Casualty Recovery

The controller at HQ can monitor the progress of the stretcher carry and can call for additional assistance from other search groups if it is required. Once the casualty is secure in the ambulance, the group leader signals a mission terminate message to the entire team. Once back at the HQ, the team uses the monitoring and management system logs to replay the mission and analyse their performance to see if lessons can be learned for future operations.

Table 11 Snapshot 10 - Casualty Recovered

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
44				Search group reaches the ambulance and the casualty is transferred to the waiting paramedics					
45						More sophisticated biomedical sensors may be placed on the casualty inside the ambulance. The sensor data is transmitted to the hospital emergency room.			
46						The ambulance departs for the hospital.	Emergency room monitors the casualty's condition.		
47				The group leader sends an instant message to all personnel that the mission is terminated.					
48				All personnel head back to HQ for debriefing.					
49	At the debriefing, the management and monitoring system has recorded all messages and events and has a replay functionality. This allows the team to evaluate their performance								

Step	Team HQ	Police	Informant	Group Leaders	Rescue Workers	Ambulance Paramedics	Hospital	Air Force	PM devices
	during the mission.								

3.7. Use Cases

The following table outlines the use cases that are applicable to each snapshot of the walk-through. A use case exists when a specific application or service is used by one or more users. The user cases defined for the Mountain Rescue scenario are:

- Alerting
- Presence Management
- Voice Communications
- Instant Messaging
- Directory Services
- Monitoring and Management
- Video Streaming
- Biomedical Sensors

All of these applications and services rely on particular technologies and backend implementations, which are described in more detail in chapter 4.

Table 12 Use Cases for Each Snapshot

	Use Cases							
	Alerting	Presence Management	Voice Communication	Instant Messaging	Directory Services	Monitoring + Management	Video Streaming	Biomedical Sensors
Phase 1: Pre-activities								
Snapshot 1: Monitoring availability		✓			✓	✓		
Phase 2: Emergency Call								
Snapshot 2: Alerting	✓		✓		✓	✓		
Snapshot 3: En-route to HQ		✓	✓			✓		
Phase 3: En-route to Location								
Snapshot 4: En-route to Location		✓	✓	✓				
Phase 4: Arrival at Location								
Snapshot 5: Establish Network Infrastructure		✓	✓	✓	✓	✓		
Phase 5: Search								
Snapshot 6: Search operations		✓	✓	✓	✓	✓		
Snapshot 7: Search reorganisation		✓	✓	✓	✓	✓		
Phase 6: Rescue and Recovery								

Snapshot 8: Casualty found		✓	✓	✓	✓	✓		
Snapshot 9: Rescue operation		✓	✓	✓	✓	✓	✓	✓
Snapshot 10: Casualty recovery			✓	✓		✓		✓

4. Technical Concepts

To complement our network mobility solution for Mountain Rescue, we have developed (and are still developing) a system that allows the coordinator of the Mountain Rescue Team to monitor and manage search operations in real-time. The system is present at the Team HQ, and at the rescue vehicles, and utilises several knowledge databases in addition to providing real-time location updates of rescue personnel and vehicles. The knowledge databases consist of: Rescue Personnel, Geographical Information System, Previous Incidents, Communications and Search Theory.

4.1. Monitoring and Management of Operations

The Monitoring and Management system for the Mountain Rescue team is an integration of several different hardware and software components. In essence, it consists of an application backend, located in the HQ and rescue vehicles, that consults knowledge databases, monitors locations of personnel and vehicles, provides automated search and rescue planning and is integrated with the alerting software. The main components are described in the following sections.

4.1.1. Knowledge Databases

The rescue personnel database contains detailed information on the Mountain Rescue personnel. This information includes any specialist skills (e.g. medical, dog handling, climbing), their contact details and work patterns (rescue workers are volunteers), current location and availability. When an emergency call is received at the Team HQ, the system automatically searches the database and displays which Team members are available and the set of skills that are covered.

The Geographical Information System (GIS) contains all the geographical data relevant to the Mountain Rescue Team's jurisdiction. This includes detailed terrain maps, roads, land features, car parks, hotels, campsites etc. It also has a dynamic element so that events such as rockfalls, landslides, severe weather, livestock movements, road blockages and traffic conditions can be overlaid onto the static geographical information. The system can query this database to gain geographical information for any area with the region. It is used primarily for displaying locations of personnel and vehicles during a search operation.

Details of all previous call-out incidents are stored on the Previous Incidents database. This includes the locations of the casualties, their injuries, the nature of the accident, the weather conditions, time of year etc. All this helps the system use statistical techniques to extrapolate likely locations for missing casualties when their locations cannot be ascertained from the emergency call. The most likely problem areas where the casualty might be located can be displayed in the control room and relayed to the devices of the rescue workers.

The Communications database holds 'maps' of coverage areas for several wireless networking technologies such as GSM/GPRS, Tetra and 802.11 as projected from vehicles in certain locations. The purpose of this is so that the Mountain Rescue Team know in advance where there are black holes in connectivity so they can adapt accordingly. For example, cross-referencing with the GIS also allows controllers at HQ to analyse terrain and reception data and then inform rescue vehicles of the optimum locations to park in order to provide temporary connectivity to the search groups on the mountainside.

We also have a Search Theory database embedded in the system in the form of a Search Theory Automatisation software component. This can suggest search patterns for the search groups to take based on the information obtained from the emergency call and the cross-referencing of the other databases. It also includes statistical information from previous operations and can advise the monitoring interface to identify locations with higher probabilities of finding the casualty.

4.1.2. Presence Management (Location Management and Tracking)

The main feature of the system is the real-time tracking and monitoring of rescue personnel, search dogs and vehicles. Using the mobile networks and wireless infrastructure provided, GPS devices in the vehicles or worn by rescue workers/search dogs continuously update the server part of the system with their locations. The locations of Team members and vehicles are overlaid onto 2D or 3D maps of the search area and displayed on terminals inside the Team HQ and inside the rescue vehicles (see Figure 3).

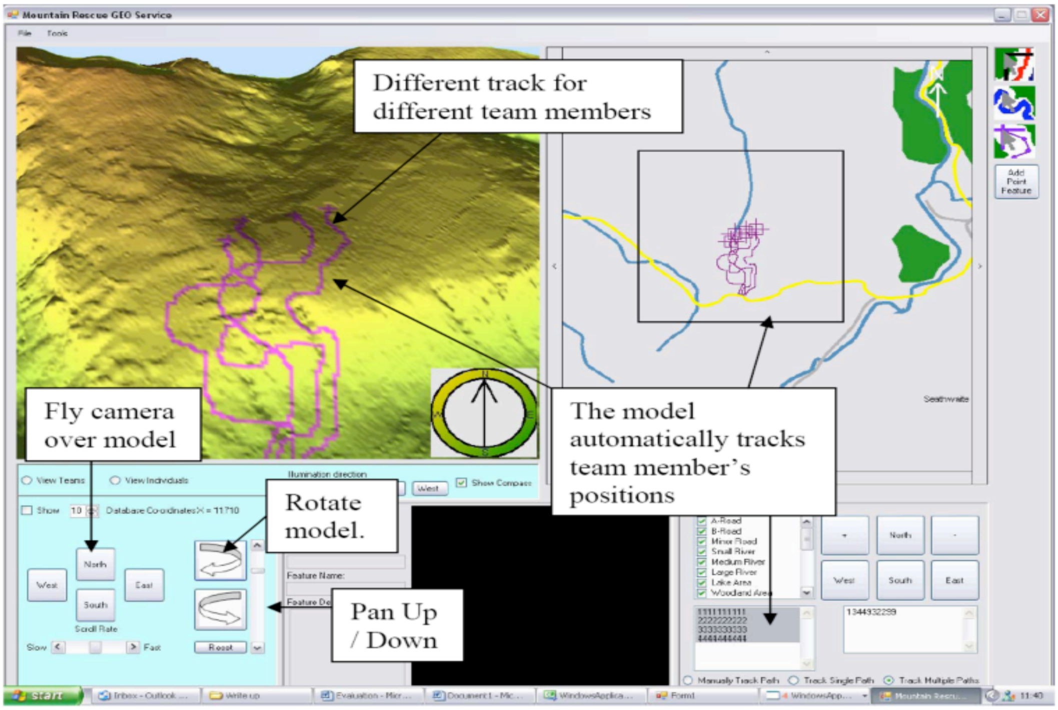

Figure 3 Screenshot of Presence Management 2D/3D modes

Users of the system can add/remove details from the display such as contours, roads, land features, rescue workers, search groups etc. The routes taken by rescue workers can be displayed as ‘snail trails’. All movements are logged so that missions can be played back later to evaluate efficiency.

The core functionality of the Monitoring Interface is supported by another system called the Location Awareness System (LAS). The scope of this system is to inform the mission coordinator of the exact location of the members of the team in a real-time manner. The basic principle behind the system is the transmission of GPS coordinates from small and lightweight devices that the mountain rescue workers will carry, to the server application that runs on the team’s server at the HQ. Generally, the mountain rescue missions take place in areas that are not inhabited and there is a total lack of fixed network infrastructure that could facilitate the needs of the team. For this reason, we include many connectivity components that could be used for the transmission of the GPS coordinates from the clients’ applications to the server.

A connectivity framework has been defined that includes the available and viable connectivity options that could be used for such a mission in a mountain rescue domain. These options have been also prioritized based on certain criteria so that the client application will choose the most suitable from the available ones for the transmission of the GPS coordinates.

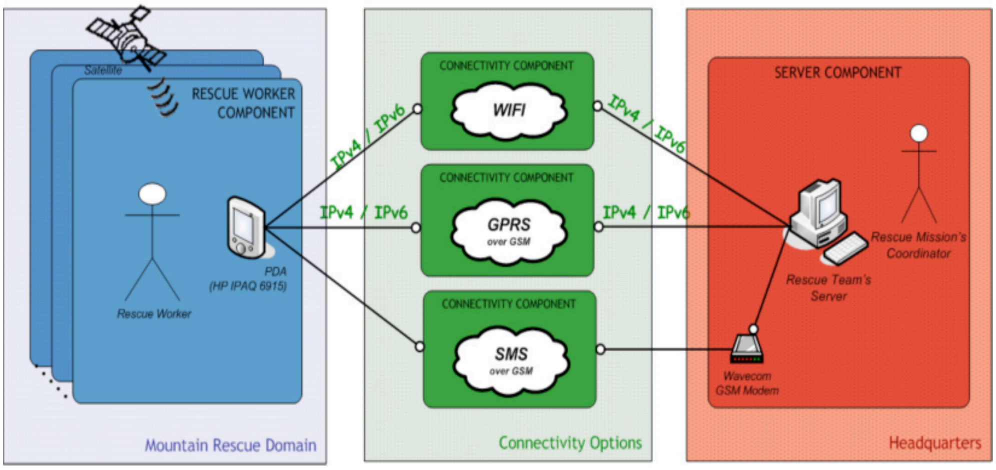

Figure 4 Presence Management System Overview

The central part of Figure 4 depicts the three significant communication options that seem viable for this domain in order to provide the transmission of the GPS coordinates. The first one is to transmit the coordinates via IPv4 or IPv6 over an 802.11 and/or 802.16 network, the second one is via IPv4 or IPv6 using GPRS over the GSM network and the third one is to transmit them via SMS over the GSM network. The client application is able to identify the availability of each of the connectivity options and use them according to the following priority: WiFi, GPRS and SMS. This priority has been built by comparing and contrasting the connectivity options based on the following criteria: availability, cost to purchase/set up, cost to run, extensibility for the provided service, ability to follow evolution and practicality. A full analysis of their prioritisation is provided in D3.2.1 [4], but it can be briefly stated that the WiFi connectivity option gets the highest priority since it is provided from the equipment that the rescue team carries (mobile routers or antennas on the all terrain vehicles) that follow the mobility of the team. Moreover, it has the ability to follow the evolution of network protocols, for example using Mobile IPv6 and NEMO.

An important feature of the connectivity framework is that it defines a Unified Message Format (UMF) that is used for the transmission of the GPS coordinates regardless of the connectivity option used. The UMF includes fields separated by a character delimiter to describe the connectivity option used for the packet being sent, the node ID of the device that sent the packet, a security code that acts as a placeholder for a shared key infrastructure and a sequence number for the packet being sent from that client. The UMF also includes a timestamp for the date and time that the packet was created and transmitted, a pair of GPRS coordinates and finally a field for possible extensions. The UMF includes data that can enable significant mechanisms to take place. For example, the server application can do a simple authentication mechanism for the client that sent a packet, based on the values of the node ID and the security code fields. Moreover, the server application can reorder out-of-sequence received packets based on the node ID and the sequence number of each packet. In addition, an identification mechanism can take place as the node ID field of each packet maps to a certain device, which in turn and with the aid of our database infrastructure maps to a certain person.

The client side of the LAS is composed of lightweight and small end devices that are carried from the rescue workers during the mission. For the purpose of our research, we are currently using Hewlett Packard IPAQ 6915 PDA devices running Windows Mobile 5.0 that in principle can support the requirements of our devised system. Each of the client devices run an application that is implemented in Visual C# using the .NET Compact Framework, libraries from the OPENNETCF SDK and calls to native DLL files of Windows Mobile 5.0. The client application is able to work seamlessly in two basic modes; the online mode and the offline mode. The online mode includes the transmission of the coordinates when at least one connectivity option is available and usable. When no connectivity option is available, the application works in offline mode and stores packets for later transmission. The transition from one mode to another is done automatically without any intervention from the rescue worker, but this does not restrict the two modes running simultaneously. The client application supports on-the-fly modification of the interval that is used for the transmission of the GPS coordinates. Thus, when a search party is in a vehicle and while they are moving towards a location, most frequent updates are needed as opposed to when rescue workers search a region on foot. The application includes a powerful log functionality with data being recorded that enables the later replay of the missions and analysis of operation efficiency. The recorded data also gives us the ability to build coverage maps and improve the coverage of the connectivity options if and when this is possible. This information can be used by the search theory component to increase the efficiency of future missions.

4.1.2.1 Location Awareness using LBS

To complement the LAS using GPS, we have also conducted an empirical study of LBS accuracy in densely and sparsely populated areas of the UK [5]. We used real-world data of three network providers to compare locations reported by their LBS (Location Based Service) with locations gained from GPS

In many of their rescue missions, the mountain rescue team are in telephone contact with the casualty via their mobile phone. In these situations, it is obvious that a positioning technology that could accurately locate the victim and supply that vital information to the search and rescue coordinator would be invaluable. Our requirements were therefore based on the need to determine the ‘‘real” accuracy of LBS technologies not only at one instance in time, but periodically, to determine how much emphasis we can place on the results supplied to us by the network operators.

The overall objective of the study was to provide a comprehensive view of accuracy in cellular positioning technology currently deployed by the three most popular operators in the UK: O2, Orange and Vodafone. In particular, its objectives are to evaluate:

- the accuracy as claimed by operators compared to “real” accuracy, as actually achieved in both densely and sparsely populated areas the impact of base station location on claimed and real accuracy
- the ability to infer the respective positioning technology based on any or all of the data aggregated during this study

From our study, we observed that none of the operators’ accuracy claims were sufficient to serve modern applications, unless a rough indication as to the whereabouts of a mobile phone is satisfactory. For example, in the case of the mountain rescue domain, this level of result means that it could at most serve as supplemental aid, rather than a primary tool. To be more specific, we found that in Manchester (large city) the overall accuracy across all providers is approximately 266m. In Ambleside (rural town in the Lake District), we discovered an eightfold decrease in accuracy in idle-mode positioning and a 60% decrease in the case of Vodafone’s dedicated-mode positioning.

4.1.3. Search Theory Automatisation (STA)

There is considerable existing work on applying search theory techniques to a search and rescue (SAR) domain such as Mountain Rescue. However, this is mostly theoretical and usually based on 2-dimensional search areas (e.g. forests, deserts). In u-2010 we are investigating and developing appropriate search heuristics and algorithms when applied to 3-dimensional terrain (i.e. altitude is a factor), and combined with statistical techniques (applied to a previous incidents knowledge database), would suggest realistic and practical search patterns for groups of rescue workers for a given incident. The number of rescuers and their relevant skills/experience is an additional input to the software.

Certain criteria is relatively simple to implement, such as epicentre-mapping - requiring only a starting point and the ability to calculate speed and distance from this point - whereas others, such as Bayesian theory necessitates careful research, planning and implementation to ensure correctness of calculation and results.

Traditionally Bayesian theory was used to search for lost sea vessels which, as far as the searchers are concerned, exist on only one plane, with water depth and environmental conditions as functions which make the likelihood of finding the subject more complicated. A truly 3D terrain will allow gradients, altitude, and the ease of getting from one point to another to be used as these functions, ideally providing more uniform data and more accurate, traceable values to be used in the equations and, hopefully, produce more efficient search patterns with the results.

The STA software component takes into account previous incidents and make use of both previous statistical data about the area in question, and specially designed heuristics, taking into account the terrain, status of the lost subject, weather interference, and other similar factors.

This use of probability can be extrapolated and expanded to very complex levels, and prove invaluable in the algorithms used in the software, as search-and-rescue is heavily based on both initial information (the area to be searched, the last known position of the lost person), as well as additional observed information. For instance, the probability of a lost individual being in a certain area will decrease a great deal once that area has been searched once without success. Other factors, too, such as the finding of discarded personal items, have a great part to play in the probability adjustments, increasing the probability of finding the subject in areas near to where the evidence is found.

Generally, for a given area, a basic probability can be assigned for the subject being located in a sub-area (for instance, a 1 in 10 chance of finding the object in area A1, a 2 in 10 chance of finding the object in area B2, etc). Search theory extends this by taking into account the likelihood of actually finding the lost object, if it is in the searched area. The probability of successfully finding the object can be modified by numerous factors, such as (in maritime searches) the depth and clarity of the water, the roughness of the sea, etc., and in land-based SAR, factors such as the amount of ground foliage, the weather, the ease of actually getting to the area to search, etc.

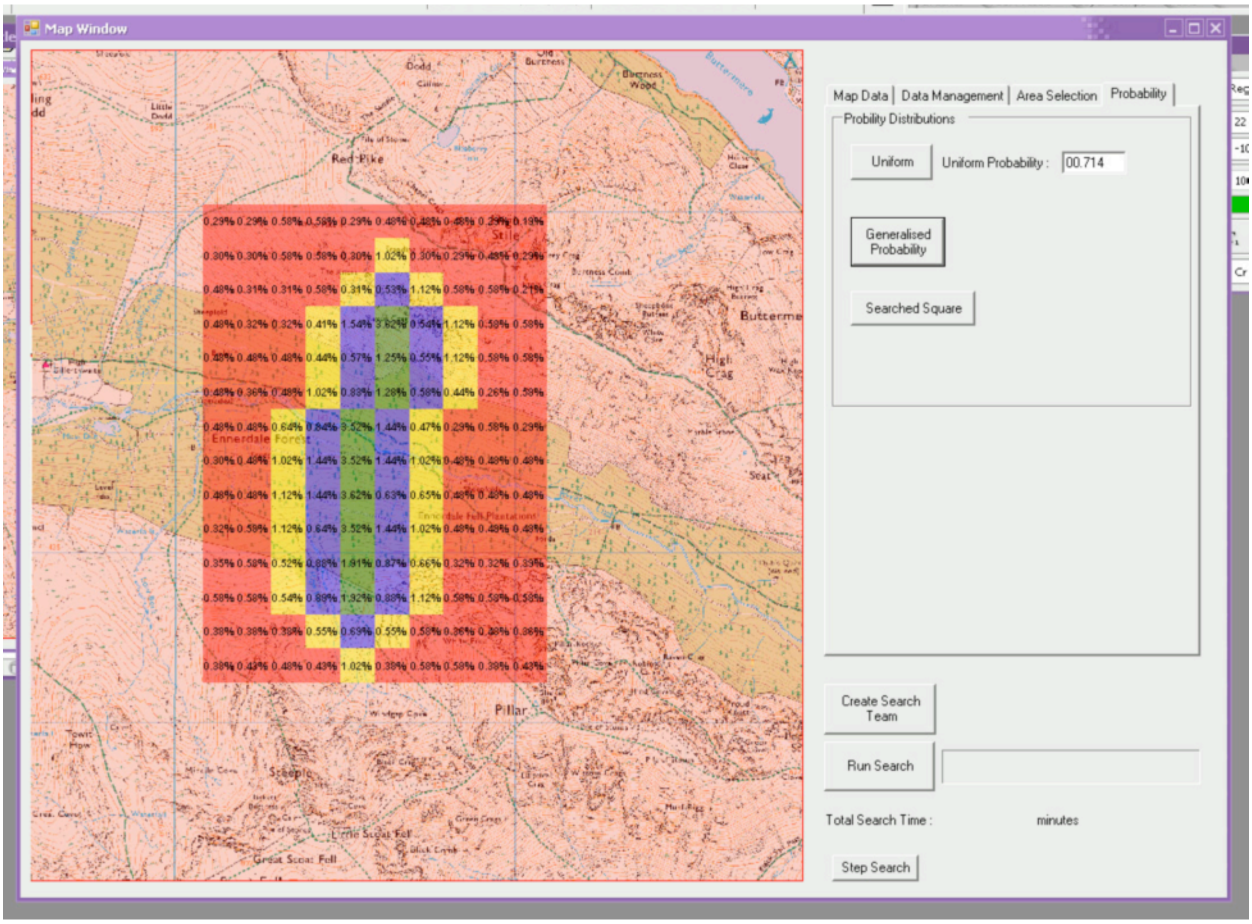

Figure 5 Probability distribution

Further to this, and particularly pertinent to this project, once an area has been searched, a sample of "a posteriori" data (that is, data based on empirical evidence) is recorded. Based on this data, the searched area's probability must logically be decreased (if the subject is not found in the area, then clearly the probability of finding them in the area is vastly reduced), and the remainder of the areas must now have a slightly higher probability of containment.

Ultimately, the STA software allows probability maps to be generated according to different methods (e.g. Figure 5), the development of search routes for these maps, and the creation of search teams using available resources (Figure 6). Thus, we are able to plan a search of an area to be as efficient as possible and yield the highest chance of finding the lost subject as rapidly as is feasible.

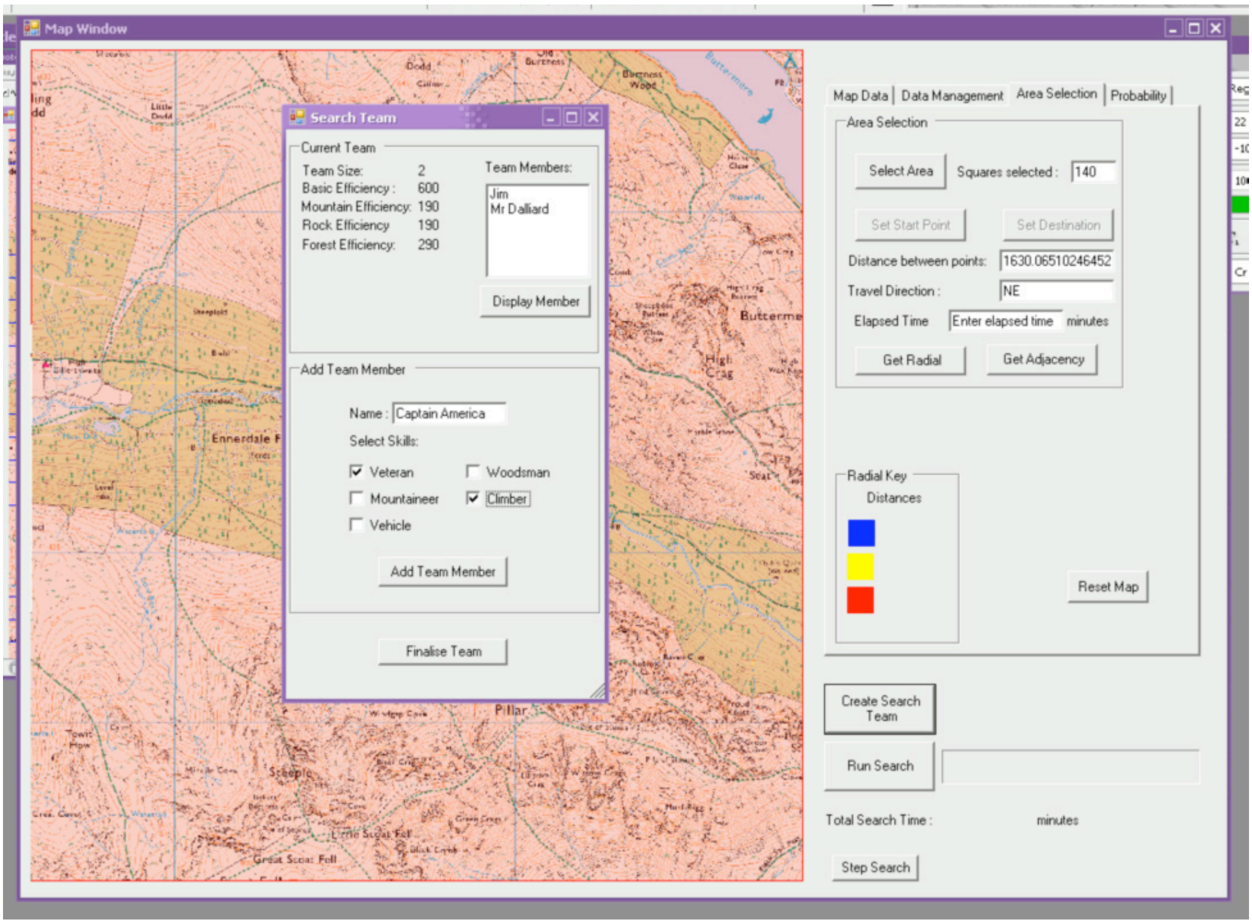

Figure 6 Assigning a Search Team

As this scenario is focused on Mountain Rescue, it is necessary to carefully and clearly select and define properties applicable to search teams. These may be diverse and impact the search team logistics in many ways. For instance, they may be properties that could affect the sweep width and coverage, such as helicopters, search dogs, or particular abilities that would make searching in particular areas more feasible or necessary (for instance, team members may have rock-climbing skills, which would make them particularly suited for searching in steep, rocky terrain). Another example of a factor impacting search efforts would be the inclusion of team members with medical skills. In this case, if it were suspected that the subject may have suffered an accident, it would be desirable that teams with medical expertise would search the more dangerous and highly-probable areas as a matter of urgency.

Certain priorities and general operational strategies are used by rescue teams when seeking a lost subject, and a number of these are implemented in the system. For instance, when a subject's last position and intended destination are known, one of the first steps will be to search along this path and areas near it, as well as any accident black spots along the route (accident black spots are gathered from the previous incidents knowledge database).

Of course, the Mountain Rescue team may wish to disregard suggestions from the STA software and instead manually determine the most effective method of searching an area rapidly. This is enabled by providing a user-adjustable confidence setting within the application.

4.2. Alerting

The HQ of the Mountain Rescue Team serves as the control room for an emergency scenario in addition to being a rendezvous point for rescue workers responding to an emergency call.

Currently, the HQ is notified by the Police when there is an emergency call and the relevant information is then sent over a paging system to all rescue volunteers. Once a suitable number of volunteers arrive at the HQ, they are briefed and then despatched to the appropriate search locations.

Rescue volunteers will have a portable device that automatically sends periodic location updates to a server (located in the HQ). The server has a backend application that displays the locations of rescue workers on a 2D/3D map.

The portable devices that the rescue workers have should be 'activated' automatically as soon as an emergency call occurs and only be 'de-activated' once the search and rescue mission has been completed.

Using an alert system, the client application is activated automatically when both the following conditions are true:

1. An emergency notification is received
2. The rescue worker is able to respond to the emergency

The AlarmTilt system from M-PLIFY is being used as the alert system for the Mountain Rescue scenario. Using a modified version of the AlarmTilt SOAP API we are implementing a system that alerts rescue workers to emergency calls and replaces (or is complimentary to) the current paging system. Messages can be sent via email, SMS, voicemail or a bespoke client-server messaging system.

4.2.1. Integration Example

A general overview of an example follows:

1. An emergency call is made to the Police who then contact the Mountain Rescue HQ and inform the controller of the details of the emergency.
2. The controller enters the details of the emergency into the alert component of the Monitoring and Management system and 'activates' the alarm. The details of the emergency are written to the operations database, located in the HQ. The operations database records all relevant information that happens in the course of a search and rescue operation. This information is used to generate logs and statistics for later analysis by the Mountain Rescue Team.
3. The Monitoring and Management system checks the Mountain Rescue Team's personnel database (located at the HQ) and sends alerts (via the AlarmTilt server) to all personnel registered as being available for this date and time. The precise nature of these alerts per rescue worker can be configured accordingly in the database.
4. Each rescue worker receives the alert on his/her device and accepts or declines to respond to the emergency call. A reply of 'accept' will automatically trigger the LAS client to start sending location updates to the HQ server.
5. The Monitoring and Management system component collates all the replies by polling the AlarmTilt server and enters the details into the operations database accordingly.

Once all the replies have been collated and entered into the operations database, the alert component has done its job. The continuing monitoring and management of the search and rescue operation is conducted by a combination of the LAS, the databases and the rest of the Monitoring and Management system. Any events during the course of the search and rescue operation are handled in a similar fashion.

4.3. Voice Service

The motivation behind the voice service is to provide an alternative means of voice communication than 2-way radio or mobile phones for keeping members of a Mountain Rescue team in contact. Members of such a team would require to be kept in constant voice communication with each other and possibly, with other Mountain Rescue teams in the area. Using more traditional means of communication, such as mobile phones or radios, can be ineffective for two reasons:

1. Coverage – In mountainous areas, GSM signals are unreliable, even if a call is established, a cut-out in signal will mean the call is dropped and the user has to dial again. 2-way radios tend to have much better coverage although even this is less than 100%
2. Cost – The expense of reserving a frequency for 2-way radios is considerable for a charity-based Mountain Rescue team. Mobile phones tariffs are much cheaper, although still unrealistic for the Mountain Rescue team to fund the bills for each rescue worker.

Using a VoIP service over the ad-hoc wireless infrastructure created by the rescue workers and vehicles, these cost issues become less significant as there is no costs for usage other than the initial cost of buying the hardware. However, a CoTS VoIP system is not applicable in this scenario since they depend on constant connectivity to the backend infrastructure (e.g. VoIP servers and SIP gateways), making them unreliable. Reliability is an essential part of Mountain Rescue communications and only a system that is dependable can be used under mountain rescue conditions. Therefore, cut-outs in network connectivity *must not* result in dropped VoIP calls (both one-to-one and group). In simple terms, the voice communication must be transmitted on a best effort basis and with no teardown of call state if there are network problems. Due to the terrain, wireless signals can fluctuate rapidly in the short term, yet can show quasi stability in the long term.

Thus, we are developing a bespoke VoIP system purely for Mountain Rescue personnel. Of course, the addition of SIP gateways and TETRA gateways could potentially allow for true global voice operation and TETRA interoperability, but this is somewhat out of scope for this deployment scenario and is being covered in depth in activity A4.3.1 for the Fire Services Solution.

Figure 7 Simple Large Button GUI for Voice

Since a Mountain Rescue team will be going out in all weather conditions and at all times of the year, they need to be well prepared for anything that they might face while out on a rescue. Due to the harsh conditions faced by the teams large amounts of protective clothing, including gloves, will usually be worn. On average, a mountain rescue team would get called out about 40 times per year [6] so the equipment used needs to be durable with infrequent use. Furthermore, the wearing of gloves necessitates large easily accessible buttons to operate the voice service. Moreover, the GUI needs to be simple, intuitive and uncomplicated so not to detract from the normal search and rescue operations that have to be performed (Figure 7).

4.3.1. Network Concepts used in Mobile VoIP

The User Datagram Protocol (UDP) is usually the main choice for sending multimedia data over networks. UDP and TCP are the two main transport protocols used in IP networks. The main differences are UDP is a connectionless protocol that does not guarantee data delivery or the order of data delivery whereas TCP guarantees that the data will arrive and arrive in order. UDP is commonly used for sending multimedia over networks as it does not matter whether some packets are lost during transmission. The delay caused by having to resend packets would not be acceptable in a VoIP system and therefore accepting lost packets is the only alternative. TCP is rarely used in streaming media as any retransmissions interrupt the play out of the media at the destination. This problem is exacerbated in wireless networks when congestion and packet loss are more likely to trigger TCP retransmission and congestion avoidance algorithms.

Multicasting is a way of transmitting to multiple hosts simultaneously whilst using the least amount of bandwidth possible. Multicasting is ideal for transmitting multimedia data such as VoIP as it only runs over UDP and it does not matter whether occasional data packets are lost.

Before developing any kind of VoIP system it is important to look at issues that will affect the operation of any system developed. Due to the nature of VoIP many different factors can affect its successful operation. Some of the major issues are discussed below.

4.3.1.1 Reliability / Packet Loss

Network reliability is a major issue when it comes to the successful operation of a VoIP system. The data needs to be transmitted in real-time otherwise there is no point transmitting the data at all, as by the time it reaches the destination it will be redundant. Any errors that occur on the network level are going to have an impact on the perceived way that the VoIP system is functioning.

Network errors typically occur in burst due to some form of interference, such as RF Interference with WiFi. Therefore, a large number of consecutive data packets are likely to be destroyed or corrupted at the same time. In a real time transmission system, such as is used in VoIP, this could lead to a service outage for as long as the network interference is present. Unfortunately, there is nothing that can be done about these types of errors, apart from retransmitting the data, which is undesirable with streaming media.

4.3.1.2 Bandwidth use / Data rate adaptation

Bandwidth usage concerns depend entirely upon the network being used and what amount of bandwidth is available as a whole. When there is very little bandwidth available on a network it is best to use as little as possible to ensure data doesn't get dropped due to network congestion. If a large amount of bandwidth is available it is acceptable to send more data as long as it doesn't adversely affect the network. If possible a compromise that uses a little bandwidth as possible while maintaining the quality desired should be used to ensure any other users of the network are not adversely affected if the amount of bandwidth available changes. A system that would adapt to the amount of bandwidth available would be the best solution.

4.3.1.3 System Delays

Delays when processing real time data, such as audio, are best avoided. Any delay incurred would affect the operation of the overall system and may hinder the ability to actually use the system. The shorter the delay on processing the data means that the round trip time of the data will be reduced, thus increasing the systems performance. In the case of VoIP most delays will be incurred when compressing the audio data for transmission and therefore a trade-off needs to be made between the audio compression technique (to minimise bandwidth usage and maximise quality), and the amount of time spent compressing the data. In actual terms the time taken should always be faster than real time otherwise breaks in the audio will be observed and the application may not work as intended.

4.3.1.4 Service Quality

Agrawal et al [7] provide an overview of what they consider to be the two most important issues when it comes to service quality with mobile VOIP. These are "The ability to schedule voice and non-real time data on a wireless access medium; and protocols to provide resource reservations in situations where one or more terminal can be mobile".

4.3.2. Audio Codecs

Compression of audio data is required to be able to conserve bandwidth on the network being used. NCH Swift Sound [8] provides a comparison of several audio CODECS that are available for use along with the data rates that they typically provide. Even though a good selection of information is available from them, a broader study of what is available is needed.

To do this many options were investigated. The most relevant findings along with background information on the types of CODEC available will now be described.

4.3.2.1 Lossless Audio CODECs

There are two main different ways of compressing data. The first of these uses a technique called lossless compression. In lossless compression, the data being compressed is not damaged by the compression process and the decompressed data is exactly the same as the original source data. Not many audio CODECS use this technique, as the compressed data size is not that much smaller than the uncompressed audio size. Recently this technique has been used more prominently as some of the new High Definition (HD) audio formats use lossless compression to maintain audio quality.

4.3.2.2 Lossy Audio CODECs

The other option is lossy compression. With this, the basic principle is that some data can be lost as long as someone using the data cannot perceive the difference. This is best described by François Fluckiger:

“With media such as sound, images, or video, it is not necessary to display more information than the human ear or eye can detect. Compression techniques may discard data without any perceived difference by humans, even though, after decompression, the original signal is not strictly reconstituted.” [9].

Many audio CODECS use this form of compression as data can be significantly compressed for storage or transmission.

4.3.2.3 Available CODECs

There is a huge range audio CODECs available that could possibly be used. Out of the range looked at the most promising are going to be detailed and one will eventually be picked to be integrated with the application during the design stages.

Speex [10] is open source CODEC that offers a wide range of features. It offers many features not available in most CODECs. Speex is based on the concept of lossy compression. It is capable of producing telephone quality audio at bit rates as low as 4kbps. Many different bit rates are available to use including ones which use variable bit rates to further reduce the data rate whenever possible. Some features of Speex are shown below. It is based on the CELP (Code Excited Linear Prediction) algorithm for compressing audio data.

- Narrowband (8 kHz), wideband (16 kHz), and ultra-wideband (32 kHz) compression in the same bitstream
- Intensity stereo encoding
- Packet loss concealment
- Variable bit rate operation (VBR)
- Voice Activity Detection (VAD)
- Discontinuous Transmission (DTX)
- Fixed-point port
- Acoustic echo canceller
- Noise suppression

GSM is an established CODEC that has been being used for many years. It is most notably known for use in mobile cellular communications technology. It is based on the concept of lossy compression. After research into this CODEC no open source version could be found which would mean any implementation would be limited to the Microsoft GSM6.10 version. This would mean customisation on it would be limited and a version of Windows that supports it would have to be used. GSM generally achieves a bit rate of around 14kbps for 8 KHz audio and 19kbps for 11 KHz audio in ideal conditions. GSM works by taking blocks of sampled data every 20ms and then compressing them. When running efficiently GSM can produce data rates around 5 times smaller than the data would have otherwise been using raw PCM data capture. GSM is based on the RPE-LTP (Residual Pulse Excited-Long Term Prediction) algorithm rather than CELP like Speex.

Another possibility is using an MP3 encoder and decoder. It is a lossy CODEC. MP3 is commonly used for music but can also be used for streaming speech. It functions by removing from the sampled audio certain frequencies that are generally outside the range of human hearing. MP3 commonly achieves very good compression quality, generally in the range of 64kbps or 128kbps depending upon the sampling rate used. It also has a variable bit rate feature which would be useful in a harsh, unpredictable wireless environment.

The CODEC chosen was the Microsoft GSM6.10 CODEC. This was originally the first choice before the Speex CODEC was discovered during research. We also integrated the Speex CODEC but tests showed that the IPAQ processor, a Texas Instruments OMAP1510 168 MHz using ARM4 architecture, did not have sufficient performance with all the other operations being carried out to support the real time encoding of audio data on this device. The GSM6.10 CODEC is a well know CODEC that has been in use in many different applications including cellular phones.

4.3.3. Bespoke Features

There are several bespoke features within the VoIP application that specifically target the Mountain Rescue domain. One of these is the push to talk system that works in a similar way to that of a conventional handheld two way radio system. Only one user can ever speak at any one time. This is achieved through the use of a token passing system that is integrated as part of the inter-device communication system. The token passing system works by sending communication messages about a single token which is required by the application to allow transmission of audio data. The token is passed from one device to another when it is not in use; or if an authoritative group leader token request is received. The token is a flag that is used to represent whether the application has transmission control. Only one token should ever exist in a group. There are several safeguards to ensure this does not happen.

4.3.3.1 Push to Talk

The push to talk system works by sending messages via the message control system. When the application is initiated all the setup information is retrieved from an XML file including information on whether that specific PDA is a group leader. If the PDA is specified as a group leader its leader flag is set and that instance of the application is setup with a token. It would not usually be the case for more than one group leader to be in a group as more than one token would be created. This would not matter though as multiple tokens would not exist in the system for long.

If a device wishes to transmit/talk they will automatically start to transmit audio over the network if they are in possession of the token. If not, the device will set its request flag which will trigger the control system to request the token through the use of the TOKREQ message. A token request message is then built consisting of the eight letter code and the user’s ID (which was also read from the XML file on application start up), which is then sent to all other clients. A timeout counter is also activated at this point and a response is awaited. If no response is received within 35ms another request is sent and the timeout counter is incremented. There is a special case of the token request, GLTOKREQ, which is treated in the same way as the token request on the sending end. This request is only ever sent by a PDA specified as group leader.

Once a device receives a message for the control system that message is filtered out from the rest of the traffic and placed into a variable for processing by the control system. If a token request is received the device checks to see whether it has the token, if it does not no action is taken and no messages are sent out and the request is ignored. If the device possesses the token the action is dependant on what type of token request that has been just received. For a standard request the device checks whether the token is in use by checking a transmit flag. If the flag is set a TOKNOTAV message is sent which has the effect of resetting the remote devices timeout counter. Due to this the remote device will keep on requesting the token forever until the token is available or they no longer require the token. When the token is available or a special group leader token request is received the token is released to the device requesting it immediately. For this to happen a TOKEN message is constructed with the users ID, taken from the request message received, appended to the end of it. Also at this point a flag is set to indicate the token as being in transit so the token cannot be used and no other requests for the token are serviced. This is then sent to all clients and the client who has the matching ID will pick up on the message and allocate themselves the token. A TOKGOT message is created and sent to all clients partially as a response that the token has been received and partially to inform all other clients who has control of the token. Upon receipt of this message all clients will clear their token flag if they have one and move their token in transit flag to clear if it was set. A typical token request is shown in Figure 8.

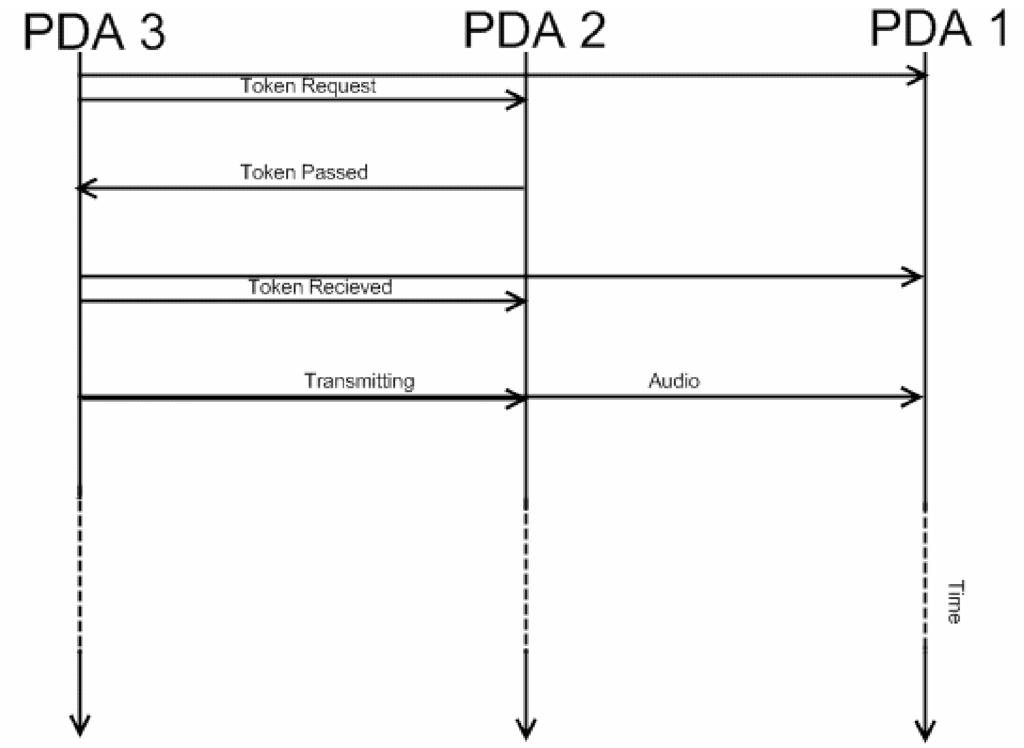

Figure 8 Typical Token Request

In Figure 8 PDA 3 requests a token from whoever has the token in the group. In this case that happens to be PDA 2. PDA responds by passing the token over to PDA 3. Now PDA 3 has the token it sends a token received message out and then begins to transmit audio.

In certain situations that could occur because of either using a wireless network or because the system uses UDP sockets not all messages may get through therefore preventative measures need to be taken to ensure that the application continues working as it should. For this very reason most messages are sent out multiple times with a typical delay of 35ms between each send. This ensures that the data is very likely to reach its destination as network errors usually occur in bursts and messages are less likely to be destroyed if they are split up in time. Furthermore time is also needed to await a response. The amount of times that each type of message is sent varies depending upon the type of message. A token request message will continuously be sent out while its timeout counter is less than 50. This gives the device with the token 1.75 seconds to respond with either the token, or a token not available message. If no response is received it is assumed the token is either lost or the device with the token is no longer active on the network. In this case a new token is created and a token received message is sent to all devices. This has the effect of destroying any other tokens that may exist in the instance that the non-responsive device has rejoined the network thus leaving only one token. In total the token received message is broadcast for a duration of 0.8 seconds from the start of a device transmitting. If another token was to enter the group after this point it would be destroyed as soon as any device began transmitting again, leaving only one token. The token message is the only message to ever be transmitted once, due to it being able to give transmission control. If this message was ever destroyed a similar situation to the disconnected device would be enacted and the token would be recreated on the requesting device.

Network problems may not be the only reason for a message not being delivered, it is not only possible but likely that a device could go out of range of the network or have its connectivity cut by the terrain. In these cases the application does its best to respond to the situation. A typical scenario where a device loses connection with the network is shown in Figure 9.

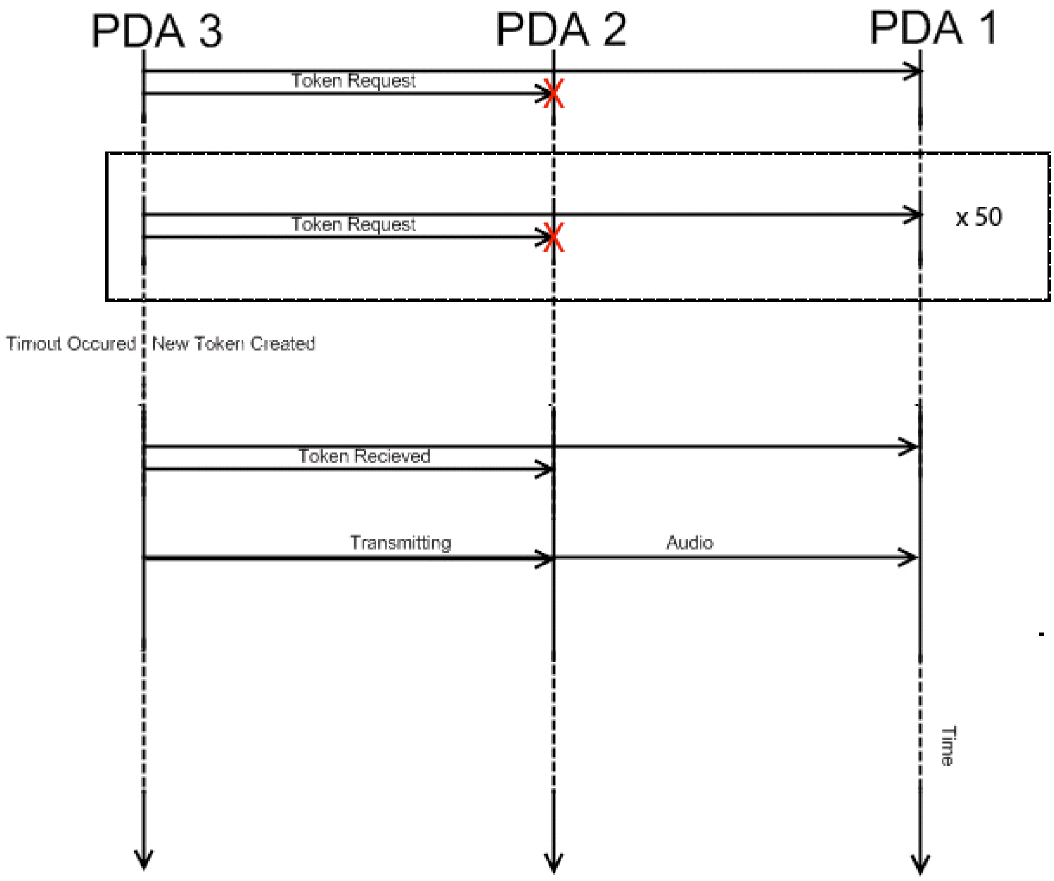

Figure 9 Missing Token - Token Request

Shown in the case above is the scenario where the token is either lost in transit or the device with the token leaves the network. In this case assume PDA 2 has the token but has become disconnected from the network. No messages would be received by PDA 2 so it can never respond, either with a token not available message, or with the actual token. PDA 3 will send a total of fifty requests over 1.75 seconds at which point if no response is received it will create a new token as it is not known when, or if ever, PDA 2 will return with the token. If PDA 2 now returns at this point with a token two tokens will exist in the system. Now a series of token received messages will be sent out from PDA 3 to all the other clients. This will have the effect of destroying the original token brought back in by PDA 2 and thus leaving only one token in the group. Now PDA 3 is free to transmit its audio stream until it is stopped or control is taken away by the group leader.

4.3.3.2 User Blackout

The user blackout feature is designed so that conversation can be limited to a certain device, or devices, in the group. The buttons on the GUI have the name of all other devices in the group and either ON or OFF labelled next to them. In a larger group, this would allow transmission to desired groups of people, such as medics, that could all be attached to the same button, whilst excluding all other personnel that do not need to hear the transmission. With smaller groups, this can be used for one-to-one or n-way transmissions.

The blackout system is relatively simple and just uses flags to block transmission to a device if the button is toggled to the off position.

4.4. IPv6, Network Mobility and MANEMO

The Internet Protocol version 6 (IPv6) [11] is the new generation of the basic protocol of the Internet. The new addressing format in IPv6 is large enough to allow even the most seemingly insignificant electronic devices to have a globally reachable presence on the Internet. This will spearhead the new drive towards ubiquitous computing and leverages new networking models such as Personal Area Networks (PANs) and sensor networks. IPv6 also includes a feature called ‘Neighbour Discovery’ which means that hosts can automatically detect an IPv6 network and configure their host addresses accordingly [13], [14]. Not only does this remove a large burden for network administrators, it is extremely beneficial for mobile hosts that can move from network to network. This is exploited by the mobile flavour of IPv6, Mobile IPv6 [12], which allows any host to roam and attach to different networks whilst hiding mobility from users and applications thus providing seamless user experience. A more in-depth description of IPv6 is out of scope for this document. However, the reader is referred to [11] and [15], the latter containing a thorough deployment guide in addition to describing the main features of the protocol.

4.4.1. Network Mobility (NEMO)

While the idea of network mobility may seem a novel idea or even an extravagance to some, for first responders in crisis situations and especially mobile search and rescue teams, it makes perfect sense. Network mobility provides the capability for distinct local networks to move and attach to different points of other networks while retaining mobile transparency to the users and applications inside the local network. Thus, teams of rescuers and emergency responders will be able to keep their usual network identities and configurations while they are moving around and attaching to different provider networks as they become available. This allows the rescue and emergency workers to concentrate on their tasks in hand rather than have to re-configure user devices to use whichever provider network is available at that precise time and location. To fulfil these requirements, the NEMO Working Group of the IETF developed the NEMO Basic Support Protocol [16]. Every mobile network contains a Mobile Router (MR), which is responsible for connecting to new networks but also hiding the mobility from nodes inside its own network. Every mobile network also has a Home Agent (HA) located on its home network, which is used as a relay whenever the mobile network is away from home.

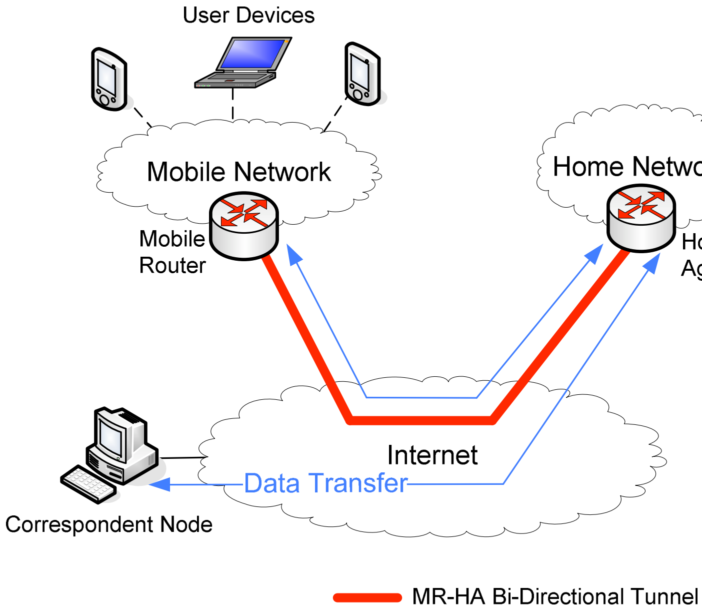

Figure 10 NEMO Basic Support

The design of the NEMO Basic Support Protocol is heavily based on the Mobile IPv6 standard. The protocol relies specifically on a bi-directional tunnel that is instantiated between a mobile network's MR and its HA located in its home network. It is via this so-called MR-HA bi-directional tunnel that all traffic destined for the mobile network must travel whenever the mobile network is away from its home network. Referring to Figure 10, the Mobile Network is away from home and a bi-directional tunnel is been established between its MR and its HA. Any packets being exchanged between the user devices on the mobile network and nodes elsewhere on the Internet, will be relayed (or 'tunnelled') via the HA. An example path taken by packets to/from a correspondent node is shown.

At first glance, the Mountain Rescue network model appears to be a swarm of mobile nodes that move randomly and therefore the best networking model to apply might seem to be a Mobile Ad-Hoc Network (MANET) model. However, as previously mentioned our Mountain Rescue Team has a distinct command and control hierarchy that needs to be reflected in the network model. While not as strict a hierarchy as a military organisation, nevertheless consultation with members of the actual team revealed that the hierarchy is important. Therefore, mobility patterns tend to verge towards distinct clusters of individuals that move randomly in relation to other clusters but in relatively similar directions in relation to individuals in the same cluster. Thus, a network mobility model is more appropriate as the routing model reflects the natural hierarchy as opposed to the flat routing architecture in MANET protocols.

Referring back to Figures 1 and 2, our network mobility solution defines each search group as a mobile network. In addition, each rescue vehicle is also a distinct mobile network. The home network of both rescue vehicles is the Team HQ, where a Home Agent is located. Similarly, the home network of a search group is the rescue vehicle to which it belongs. The mobile routers located at the rescue vehicles also act as a HA for the search groups that belong to it. Each search group has a mobile router (in the backpacks of designated rescue workers) which connects to other networks as the search groups move. In their usual 'home' topology all traffic proceeds as with normal routing. However, if search group 1b (Figure 1) moves away from rescue vehicle 1 and automatically picks up (using IPv6 neighbour discovery) rescue vehicle 2, the NEMO Basic Support Protocol is activated. A bi-directional tunnel is established between the MR of search group 1b and the HA located at rescue vehicle 1. Traffic is now tunnelled to/from search group 1b via the HA at rescue vehicle 1. In this way, all the user devices attached to search group 1b do not have to change their IPv6 addresses and existing application sessions are not broken due to the movement.

NEMO also supports nested network mobility. After search group 1b has moved, search group 2b could move out of range of all other networks except that of search group 1 and attach at that point. Thus, search group 2b is now connected to the overall network via search group 1b. We now have nested mobile networks as search group 2b is away from home, connected to search group 1b, which is also away from home. This introduces 2 levels of tunnelling. In general, n levels of mobility introduces n tunnels and associated tunnel overhead and latency. Further details of applying NEMO to Mountain Rescue services can be found in our previous papers [17], [18].

Thus, whilst the bi-directional tunnel approach in NEMO BS provides a good short term solution for supporting mobile networks, it does impose a sub-optimal routing model (known as triangular, pinball or dog-leg routing). In order to overcome the problems generated by triangular routing, a technique termed Route Optimisation (RO) was developed in Mobile IPv6, which allowed the mobile node to update the correspondent node with its new address after moving. However, in the case of NEMO, there are more complex issues to consider. To mirror the Mobile IPv6 RO would mean updating all correspondent nodes for every local host attached to the mobile network; an unacceptable level of overhead. Route Optimisation in NEMO is an on-going topic which has not been definitively solved as of yet. One RO technique for NEMO is to use a 'Reverse Routing Header' (RRH) which is an IPv6 routing header extension for NEMO BS that tries to 'record' the optimum path across mobile networks [19]. In tests across our test bed, we found this to be a slight improvement over NEMO BS.

4.4.2. MANEMO

Converse to the Network Mobility approach, the concept of Mobile Ad-Hoc Networking (MANET) is to design protocols to support IP communication between hosts in free moving, wireless ad-hoc networks that form arbitrary topologies that can change rapidly and unpredictably. MANET routing protocols are designed to optimise local packet delivery between hosts in the MANET and to/from the MANET gateways. However, once a node disconnects from a MANET and connects to a normal (global) access network the node will revert to the status of a normal IP device. In this situation, the node will configure a new IP address topologically correct for its new location and therefore any existing communication sessions will be dropped. MANET protocols cannot adapt to changes in global Internet connectivity in a way that is transparent and non-obtrusive to applications. Therefore, MANET protocols are of little use in the Mountain Rescue scenario, where access to temporary local networks and normal global networks can oscillate in unpredictable ways in response to the movement of the rescue workers.

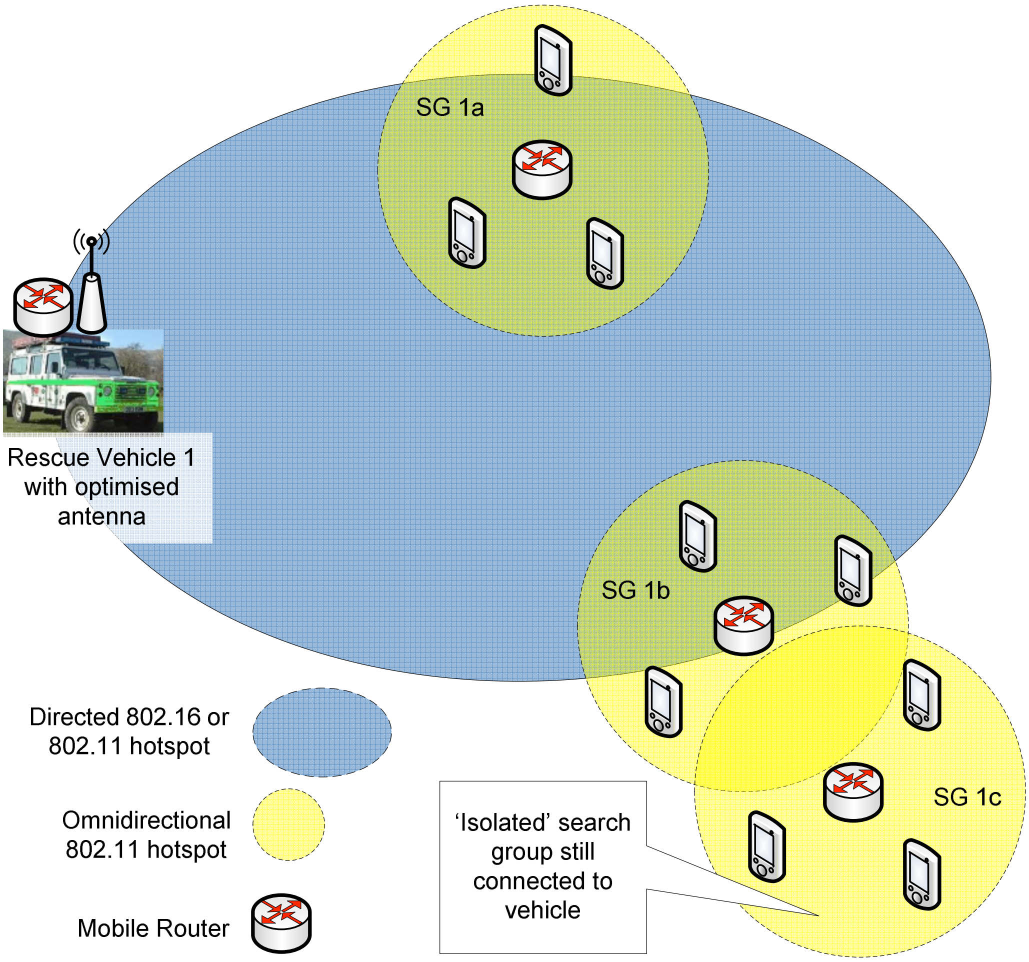

Figure 11 Using MANEMO to Extend Coverage

Considering their properties, it is possible to see how the two distinct approaches of MANET and NEMO can be combined to produce an integrated solution that possesses all of the positive features provided by both MANET and NEMO. In other words, we would like to have the scalable global connectivity properties of NEMO combined with optimised local packet delivery. This idea is born from the observation that when the NEMO Mobile Networks converge in the same location to form a nested NEMO structure, this structure itself (locally) is actually a mobile ad-hoc network of NEMO mobile networks. Therefore, local delivery can be best performed between NEMOs in the Nested NEMO structure using a MANET routing protocol (extended to support network prefixes). Thus, when a mobile network roams as a single entity, normal NEMO BS is employed but when it joins with other mobile networks to form a nested NEMO, a MANET routing protocol is used for optimised packet delivery within the nested NEMO network. In this way, a mobile router can gain access to any global connectivity and still participate in local ad-hoc routing, making it possible for a wireless-enabled rescue team to extend their search area coverage as needed (see Figure 11).

This possible solution space, combining the properties of MANET and NEMO protocols has been named MANEMO. Integrating the concepts of MANET and NEMO can provide mutual benefits for both of their respective problem domains. By using MANET concepts, the communication model of a Nested NEMO network can be optimised in a manner that best suits the characteristics of scenarios that form Nested NEMOs, we refer to these as "NEMO-Centric MANEMO (NCM)" scenarios. Conversely, the globally reachable properties provided by the NEMO concept can be used to bring additional functionality to

MANET solutions; we refer to these as "MANET-Centric MANEMO (MCM)" scenarios. We have implemented a modified version of the OLSR routing protocol [20] and have also implemented NINA [21] (see [3] for why this is relevant to u-2010) to achieve both flavours of MANEMO with respect to the requirements of the Mountain Rescue domain.

4.5. Network Deployment

This section describes the issues that needed to be considered with network deployment for the Mountain Rescue scenario and the choices that have been made.

In essence, the problem of network deployment falls into two categories:

1. The temporary wireless ad-hoc infrastructure to be deployed in search locations
2. The infrastructure needed to connect the temporary wireless infrastructure to the wider Internet

4.5.1. Geographic Region to be Covered

The first consideration is the geographic area that needs to be covered. The following figure illustrates the general search area that the CMRT covers. It is a considerably large land area that consists of several lakes, valleys and mountain ranges yet, with the exception of the town of Cockermouth itself (where the HQ of the CMRT is located), has little population and general infrastructure.

The Lake District, as with most mountain regions, is a sparsely populated area. Consequently, there is little incentive for telecommunications providers to install high-speed wireless technologies such as GPRS, UMTS or WiMAX for general public use. As a result, these technologies are not available for the Mountain Rescue teams to use; even basic GSM connectivity is intermittent and coverage tends to be limited to the towns. In remote valleys, there is often no GSM signal, although signals can usually be achieved on the mountainside, especially when there is line of sight to a town containing a GSM base station.

In short, we cannot utilise a single wireless technology that gives complete coverage in the CMRT search region. However, it is both impractical and cost prohibitive for such coverage to be deployed as part of the u-2010 project. Even if this were not the case, much of the land is protected by the UK National Trust and erecting communications towers in areas of outstanding natural beauty would not be welcome.

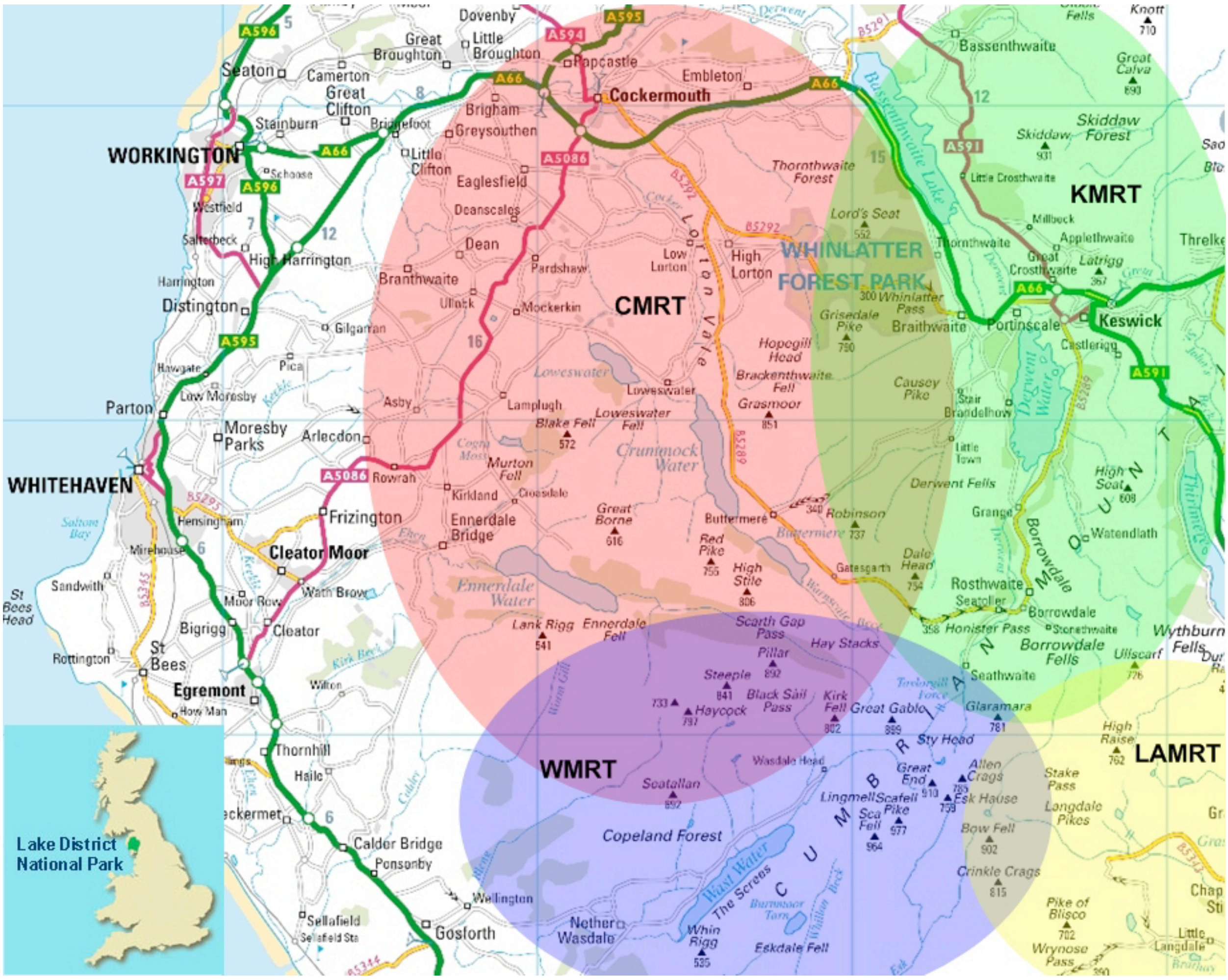

Figure 12 CMRT Search Region

4.5.2. The Search for PoPs

An analysis of the CMRT's previous incidents database reveals that the vast majority of emergency callouts occur in the mountains surrounding the Lakes of Ennerdale, Crummock Water and Buttermere. Since we cannot provide blanket coverage to the entire CMRT search area, it makes sense to provide PoPs to the Internet close to these locations.

4.5.2.1 The CLEO network

Lancaster University is responsible for network connectivity of all the schools and colleges in the Lancaster and Cumbria counties via the CLEO (Cumbria and Lancashire Education Online - http://www.cleo.net.uk) initiative, which uses CANLMAN (Cumbria And North Lancashire Metropolitan Area Network – http://www.canlman.net.uk). Fortunately, we have a connection into CLEO at Cockermouth (see Figure 13).

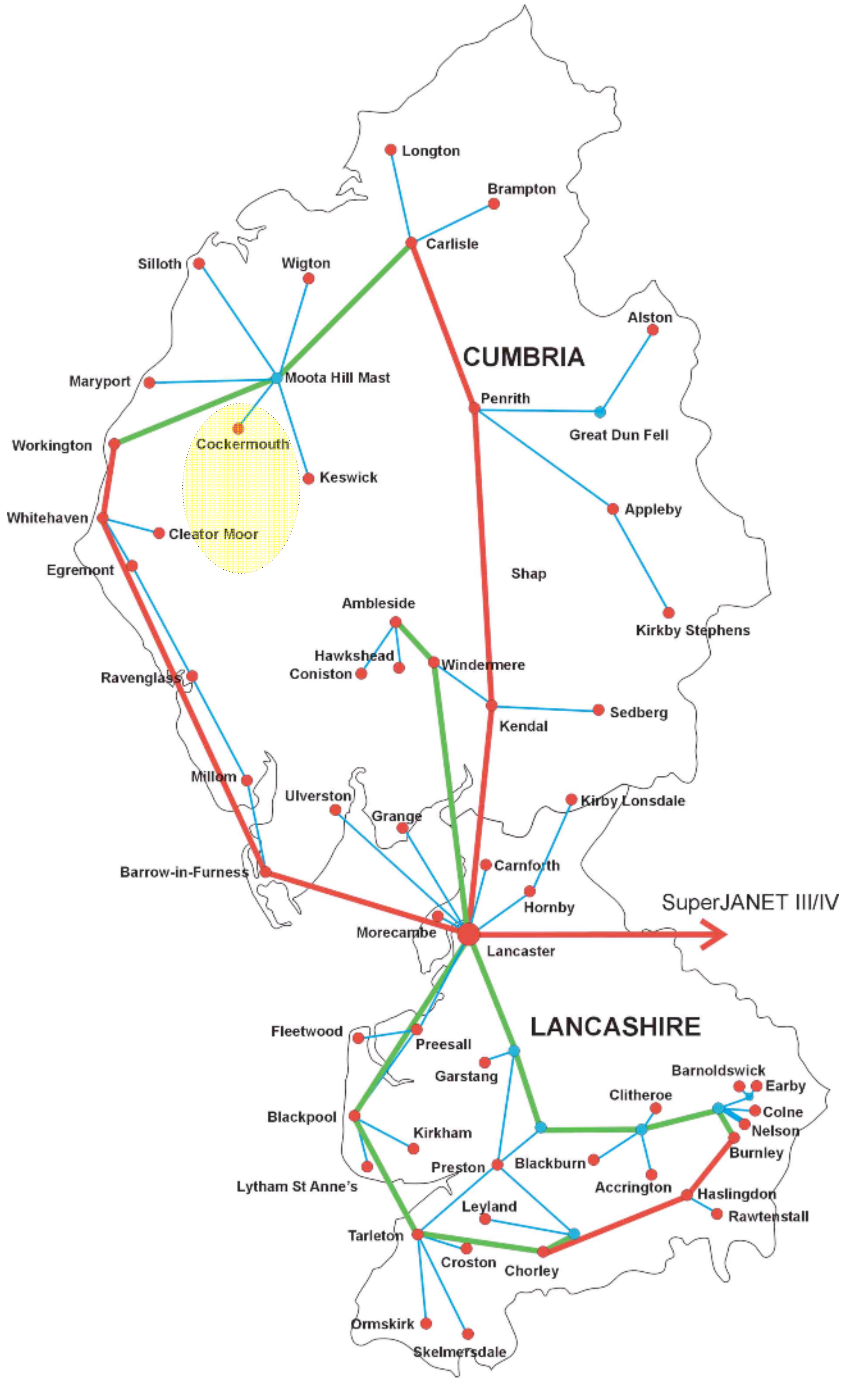

Figure 13 The CLEO Network and Cockermouth

From this connection, we have schools within the area connected to CLEO. Unfortunately, only one of these schools is remotely near to the areas of Ennerdale Crummock and Buttermere. Lorton School is several km north of Crummock Water and could serve as a PoP with appropriate permission to install a wireless mast. Permission was sought from the CLEO board and has been granted. Permission was also granted to connect the Mountain Rescue HQ into the CLEO network at Cockermouth.

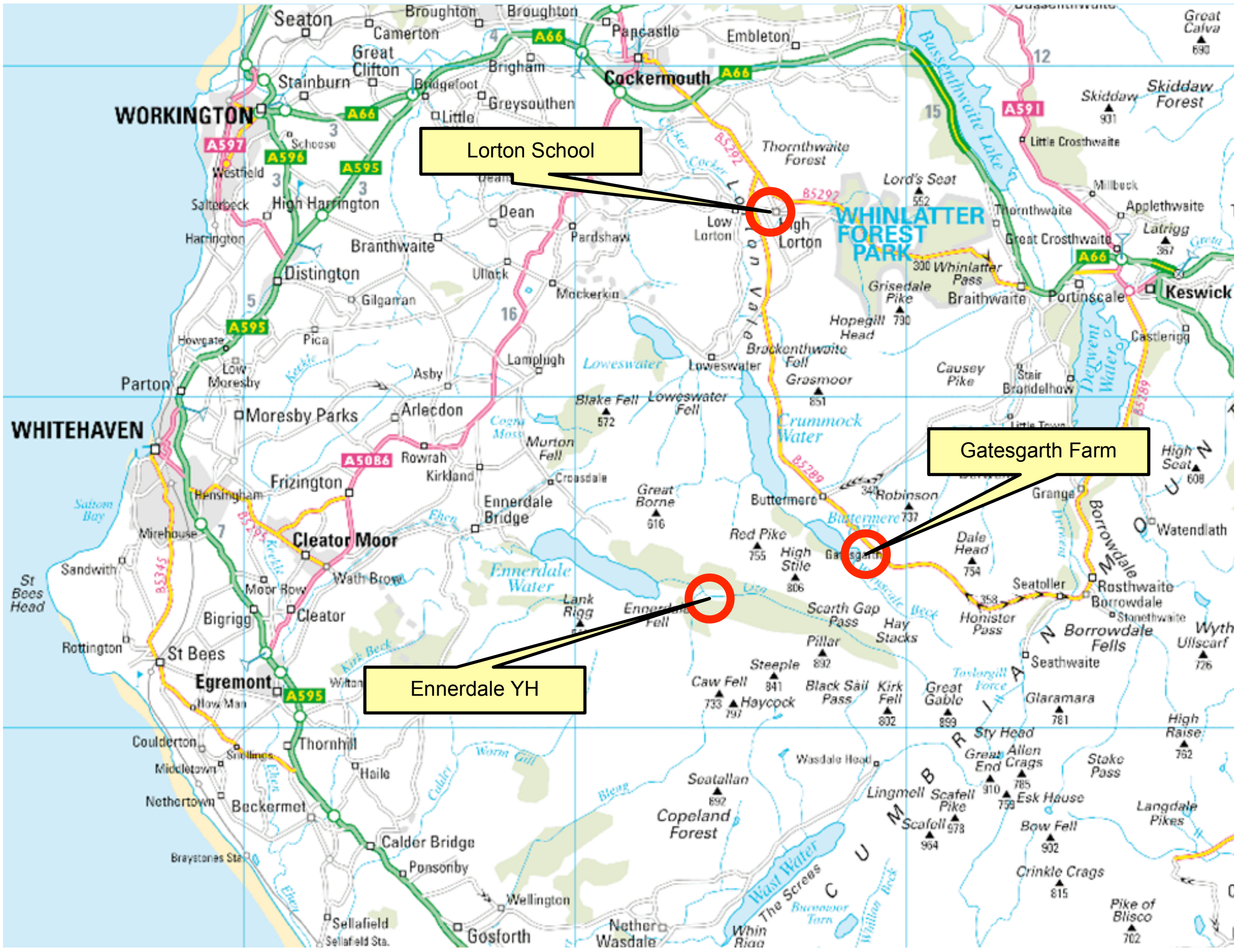

Figure 14 CLEO PoP Locations

However, to more fully cover the main CMRT search area it was apparent that we needed more PoPs that a rescue vehicle could connect to. Two more PoP locations were identified: Gatesgarth Farm near Buttermere and Ennerdale Youth Hostel at Ennerdale. See Figure 14 for an overview. It is not clear at present how we will connect these PoPs to CLEO. DSL is an option we are following at present as both locations have suitable phone lines and Lancaster University has authority to access Local Loop exchanges in the telephone network. The main problem would seem to be the distance from the buildings to the nearest exchange point, the largest being nearly 12km. It is not clear yet what kind of DSL service we can implement over such a large distance.

The main idea of these PoPs is to provide line-of-sight access to typical locations where rescue vehicles park when conducting search and rescue missions in the area. The connection between the rescue vehicles and a CLEO PoP will therefore be point-to-point wireless links. We are currently using Aries Gemini 2.4Ghz wireless Ethernet bridges.

Therefore, we have identified locations we can cover based on two factors: 1) areas that frequently have emergency callouts and 2) areas where we can have line-of-sight to a CLEO PoP.

4.5.3. Network Deployment Overview

Figure 15 provides an overview of the network deployment model and how it relates to the general Mountain Rescue scenario.

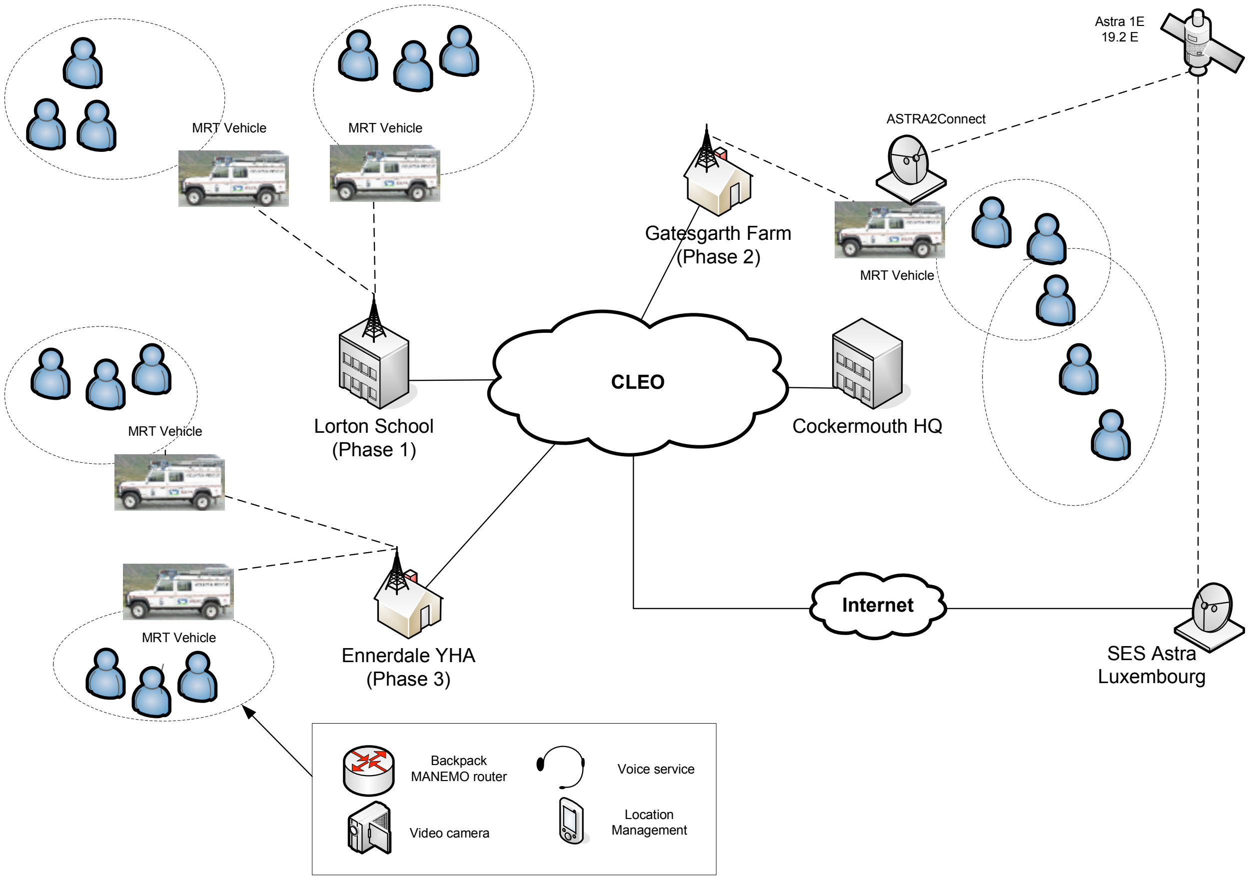

Figure 15 Network Deployment Overview

The Mountain Rescue HQ at Cockermouth is connected to the CLEO network, which is in turn connected to the global Internet via SuperJANET. The three CLEO PoPs are Lorton School, Gatesgarth Farm and Ennerdale Youth Hostel which are intended to be connected to CLEO in three consecutive phases (Lorton School is connected at the time of writing). From these PoPs the rescue vehicles can connect using 2.4Ghz wireless bridges. We have not discounted the possibility that some locations will not have line-of-sight to a PoP. In this situation, a temporary relay mast that can be rapidly deployed by a single person can be used to link the rescue vehicle and CLEO PoP. A rescue vehicle may also have a satellite dish and modem assembly to connect to the Internet via the Astra2Connect commercial home service enhanced with IPv6-inIpv4 tunnelling for the needs of u-2010. If this is used, the Astra 1E satellite will relay traffic to SES Astra at Luxembourg and then back through the global Internet to SuperJANET and CLEO.

The rescue vehicles project their wireless hotspots in the search locations of their search groups. Each rescue worker has a voice headset, Presence/Location Management device implemented on a PDA and some will also have a backpack mobile router. Some rescue workers may also have helmet-mounted video cameras and biomedical sensors for when the casualty is found.

4.6. Findings from Preliminary Tests

In this section, we discuss some of the findings and lessons we have learnt from running the system on our mobile test bed at Lancaster University and from preliminary field tests in the English Lake District.

4.6.1. Presence Management / Management and Monitoring

In our system tests we have found that to avoid location update storms to the server part of the system (when rescue workers turn on devices at roughly the same time), we configure location updates to be slightly randomised within a given time period +/- 20%. Thus, if we configure a location update period of 30 seconds, the actual period will be pseudo-random between 27 and 36 seconds. In addition, location updates are set according to the entity being located. A rescue worker will move more slowly than a vehicle or a search dog. In general, the faster the movement, the more frequent the location updates need to be. Our experience with the monitoring and management system indicates that this will be a very promising tool for Mountain Rescue services. Many simulated operations (from GPS logs of actual missions) have revealed where resources could have been deployed more efficiently and search time reduced. We are still improving the system and hope to test it on real missions in late 2008 (subject to team approval).

4.6.2. Voice Service

Due to the nature of the application and it being audio based the only true way to test the system would be to actually use it and note down any faults noticed. This is one of the only methods available as it would be difficult to programmatically test the user's experience of the audio sent over the system. There are however, ways to test the performances of the system by measuring network traffic. Both of these approaches were taken and are detailed below.

It was decided that both of these approaches were to be done at the same time, over two testing sessions. We used outdoor parkland WiFi coverage connected to CLEO to simulate a Mountain Rescue location.

The testing began by setting up two devices for use and including a laptop in the group that would just 'listen' to the transmissions so data could be recorded and analysed. This was done with the aid of Wireshark [27], a packet capture tool. After a short instruction in how to use the application, the two users began the first test.

The first test consisted of the users walking away from the wireless access point until the wireless signal was lost and then turning around and following the same route back. The results were recorded and graphed shown in Figure 16.

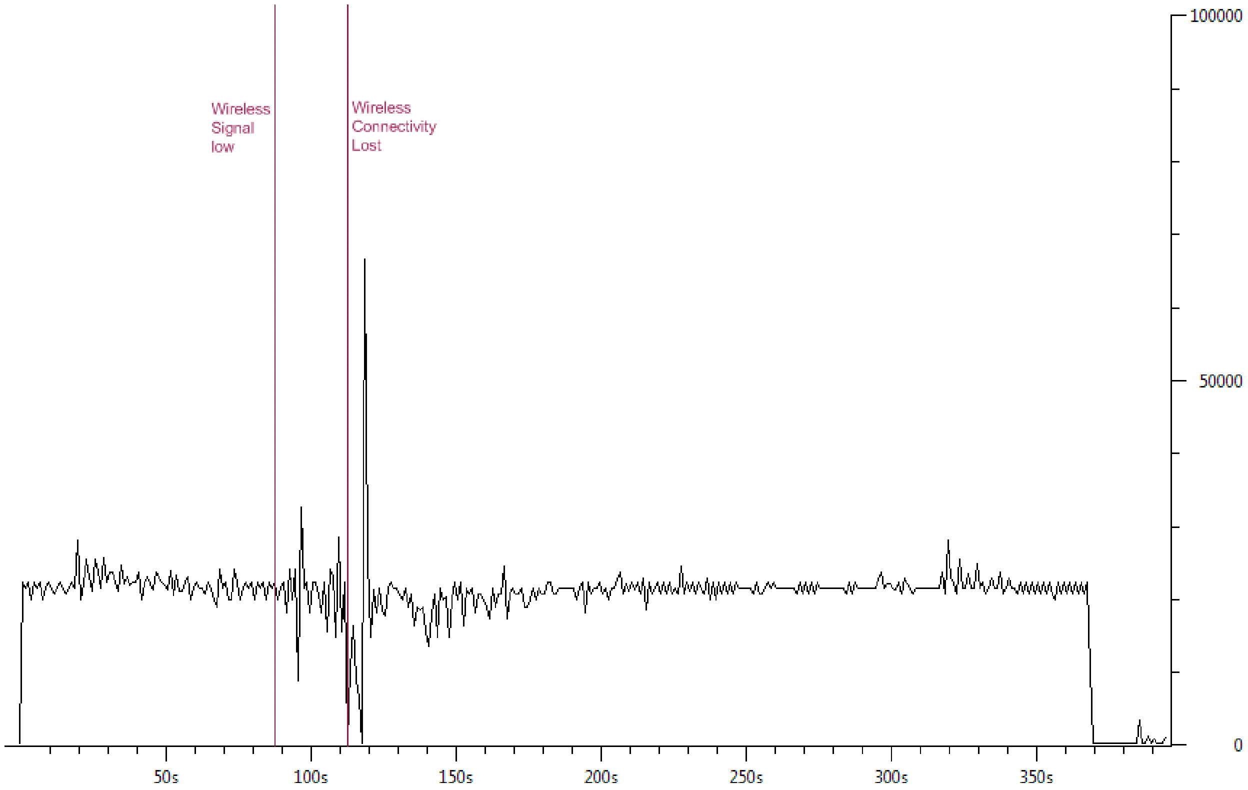

Figure 16 Data Rate (bps) / Time (seconds) Results Graph 1

The graph clearly shows that the application maintained a consistent data transmission rate throughout most of the test. The points where the wireless signal was notably low and when the signal was lost altogether are marked. Interpretation of the data shows that from the time the wireless signal became notably low to the time connectivity was lost the data rate fluctuated a lot more than when the signal was strong. It is also shown that once the device reconnects after losing connectivity there is a large spike where the data rate goes to approximately 60kbps for a very short time. This seems to be attributed to the device buffering data to send while there is no network connection. When the connection is restored, it releases this data as fast as possible onto the network. Minor fluctuations are also seen on the return trip but these stabilise out when the wireless signal becomes stronger.

The user responses from this test are consistent with the finding from the data recorded. When the signal was relatively low, small breaks in audio were present. Also, after the device reconnected to the network after losing connectivity, a small delay was noticed. This is due to a lot of data being received at once, which was being queued by the device for playback. This meant a small delay was experienced before newly received data was played back. A short discussion was also carried out with the users about how they felt the test went. A positive response was received with the delay experienced as the only notable flaw. There was a positive reaction to the ability of a device that loses connectivity to rejoin immediately after its connection is restored without having to reconfigure the device.

This test was carried out again but without the laptop in the group and a third PDA being used. The only difference to this test was that all users stayed within range and moved around within the WiFi signal area. The test went according to plan and the application functioned as expected with only slight audio loss while users were in areas with a low signal. This test was repeated at a later point with the same results.

Next, a longevity test was carried out using one device and a laptop running Wireshark. The device was setup to transmit to the laptop over an extended period of time, with the results being recorded. The results were positive as the laptop recorded a consistent data rate over the duration. The results are shown in Figure 17.

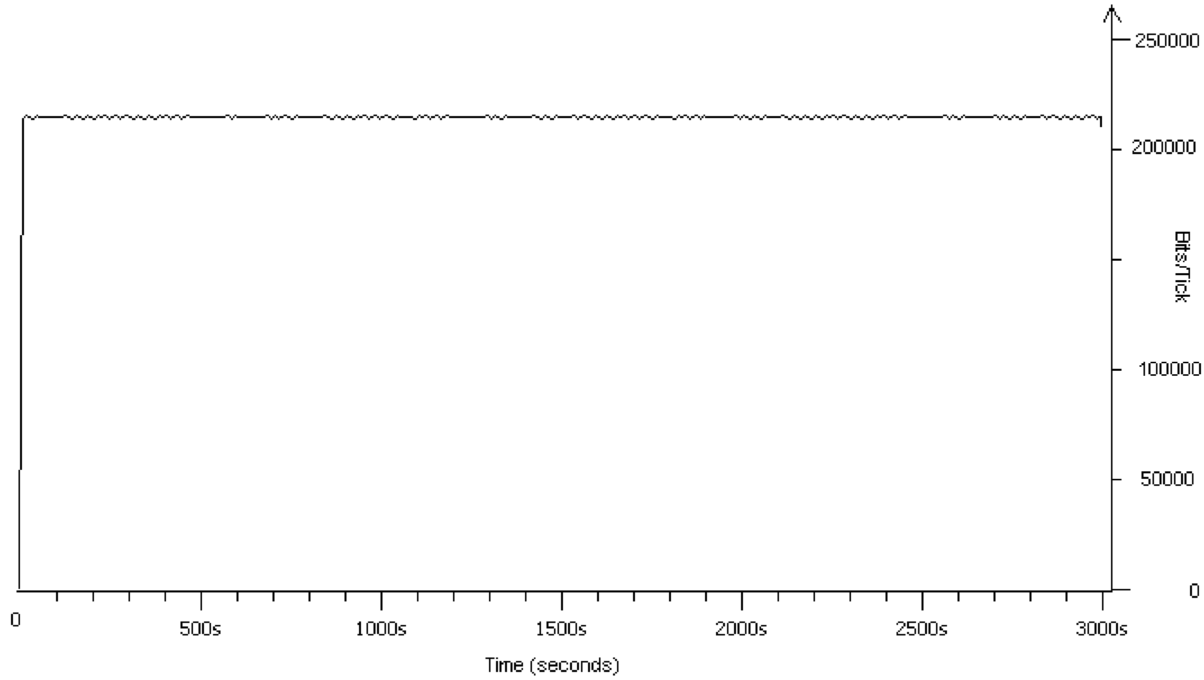

Figure 17 Data Rate / Time Results Graph 2

If this graph is inspected closely (Figure 18), it can be seen that data packets are transmitted at regular intervals, in the range of twenty one or twenty two per second. This proves that the application is functioning as intended and that stable data rates can be achieved consistently.

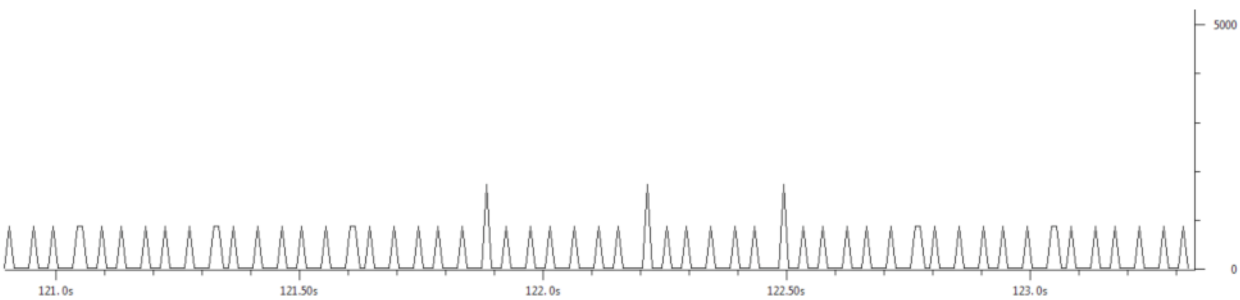

Figure 18 Data Rate / Time Results Graph 2 (Close view)

4.6.3. Mobile Ad-hoc Networks

For the mobile routers we are using five Cisco 3200 Mobile Access Routers (MARs), each running a pre-release IOS version that supports both the NEMO Basic Support Protocol and proprietary NEMO extensions such as RRH. We also use standard PCs and laptops running Linux and NEPL (NEMO

Platform for Linux) to act as mobile routers. The current mobile router devices that we use (Cisco 3200) are fine for deploying in the rescue vehicles. However, we have found them too bulky and heavy to be easily carried by individual rescue workers in their backpacks. Additionally, since the 3200 is intended to be powered via the vehicle's battery, we found it extremely difficult to replicate this using a battery light and small enough to be carried. We are thus developing prototype devices running embedded Linux that will serve as personal mobile routers.

We have shown how the NEMO BS Protocol can be used to produce a working solution to our Mountain Rescue scenario. However, NEMO BS capability is not efficient enough when mobile routers are away from home to support real-time or time-sensitive applications such as VoIP or video streaming. However, for 'elastic' applications such as the location updates for our monitoring system, it is sufficient. We also considered the NEMO Route Optimisation technique RRH's ability to improve the overall performance. We found that the RRH technique could provide some performance improvements yet it is still inadequate to support the real-time applications that we want. We have mentioned how Mobile IPv6 RO is not suitable for NEMO. However, even if we could have a NEMO RO technique similar to that of Mobile IPv6, it would still be someway short of supporting real-time applications such as VoIP due to handover latencies in the order of seconds, as demonstrated in the 6NET project. Thus, we need better RO techniques to be able to support VoIP and real-time streaming. This is why we are pursuing with idea of using MANET protocols together with NEMO to provide route optimisation for mobile networks that are close together physically although not topologically. For more details on this, please see [22].

4.6.4. Network Deployment

We have recently (May 2008) taken delivery of and deployed an Astra2Conenct satellite dish (75cm) and modem. The intention of this is to provide another option for a rescue vehicle to uplink to the global Internet. Initial tests have proven successful although there is an issue with dish alignment. The signal in the NW of England is very sensitive and a slight movement of the dish will lose signal synchronisation with the satellite. This may be problematic for the Lake District, which often has considerable winds.

From several tests with different speed test websites [23], [24], [25] we obtained an average of 995 Kbps download and 240 Kbps upload. The upload speed seems particularly promising, as it should allow for low bit rate video streams and VoIP to be transmitted from the on-location wireless infrastructure to the HQ. Another matter however, is the end-to-end delay. In other tests, we found that RTT times, from a wireless laptop connected to the Astra2Connect modem to a server located on the University network, averaged between 400 and 600ms. If we assume the average one-way delay is RTT/2, this will give us 200-300ms, which is within acceptable tolerance for voice communication. The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) G.114 recommendation [26] specifies that for high quality voice, there should be no more than 150ms of one-way, end-to-end delay. One-way delays between 150ms and 400ms can be tolerated by users with decreasing probability. One-way delays greater than 400ms are generally deemed unacceptable for interactive voice.

Using the Aries Gemini equipment, we have successfully established point-to-point links over several km between CLEO PoPs and locations where rescue vehicles would typically be (e.g. Figure 19). Using 15dBi gain directional antennae, we have seen throughputs of around 4Mbps over 6km.

Figure 19 Link Testing Between Low Fell and Hause Point Car Park (~5km)

We have also tested the ability to relay connectivity between rescue workers and the rescue vehicle hotspots. In some preliminary tests, we have observed we can achieve distances of 600m in the horizontal plane using 6dBi omnidirectional antennae connected to a simple Linux laptop acting as a wireless access point bridge. We have observed distances of 200m in the vertical plane. Data rates are around 2Mbps on average. We expect to achieve greater distances by deploying higher gain sector antennae that have a beam width more appropriate for search group coverage.

In Figure 20 the ‘rescue worker’ Panos (one of the u-2010 team at Lancaster University) is around 600m horizontal and 200m vertical distance from the access point bridge, which is connected to the rescue vehicle hotspot in the foreground. The PDA with Panos is achieving around 2Mbps throughput with the laptop in the foreground.

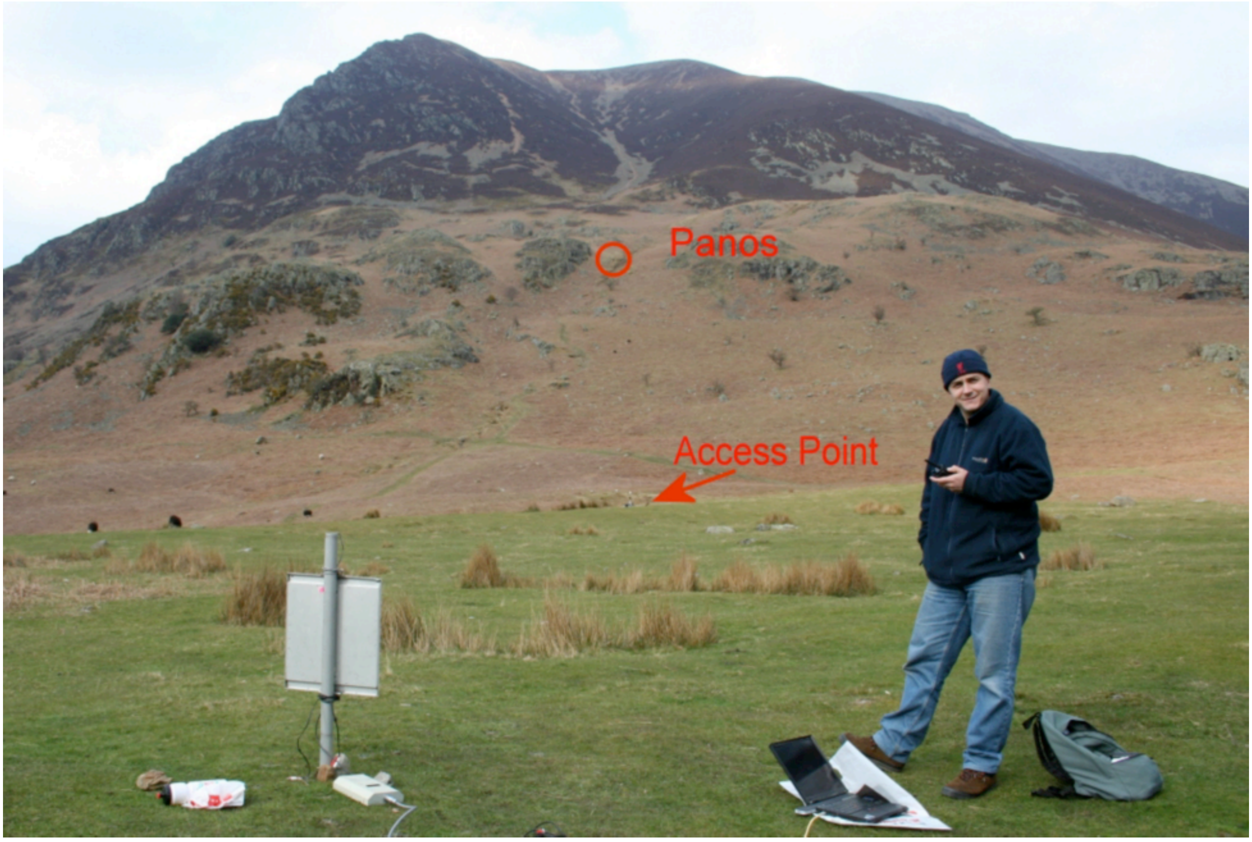

Figure 20 Wifi Range Testing at Grasmoor (Hause Point Car Park)

These distances and data rates seem very promising and should be improved upon with more streamlined hardware and antennae. However, one point worth mentioning is that connectivity is easily broken by walking behind rock outcrops and similar terrain features. Thus, the adaptability of both the network protocols and the user applications is an extremely important feature that we are focusing on.

5. Conclusions

What is clear from the preceding sections is that defining a solution for what is a complex set of requirements is no easy task. The walk-through provided in section 3 is fairly extensive, yet at each step there are several alternatives that could arise. Trying to capture every permutation is near impossible, thus we have concentrated on the majority case (with an eye on the plausible minority) rather than the unlikely minority case.

It should also be fairly clear that the proposed technical solutions hold much promise for mobile search and rescue teams. The monitoring and management system is proving to be extremely useful in analysing previous search and rescue operations in addition to organising (mock) present ones. The robustness of the system is, of course, not paramount in a prototype proof of concept implementation but we hope that further testing and refinement will eliminate most problems (such as maps freezing for several seconds due to memory consumption). The implementation of MANEMO code on backpack and vehicles routers is still ongoing with planned completion for early August 2008. Thus, the true extent to just how seamless and robust the mobile ad-hoc infrastructure can be, is yet to be determined. As stated, preliminary network tests are encouraging and should be improved upon. However, most tests have been conducted in isolation from other components thus far. For example, presence management, alerting, knowledge databases and the monitoring and management backend have yet to be tested in conjunction with the rescue workers on mountain locations connected to the wireless infrastructure. The wireless connectivity tests have so far been conducted in isolation.

It is the deployment and testing over the coming months that will truly test the suitability of u-2010 solutions for mobile search and rescue scenarios. In the build up to the final Mountain Rescue scenario demonstrator, we believe that a number of technical glitches will be ironed out. We are now moving into the final project phase where individual components will be tested in combination across the mobile ad-hoc networks and backhaul links to approximate a full solution under real search and rescue conditions. The findings from the extensive deployment and testing over the coming months will be reported in D4.2.2 and again in a final version, D4.2.3.

The final Mountain Rescue scenario demonstrator will also be applied to the needs of the Slovenian Mountain Rescue Association and demonstrated in Slovenia in April/May 2009.

Glossary

2D	2-Dimensional
3D	3-Dimensional
CANLMAN	Cumbria And North Lancashire Metropolitan Area Network
CELP	Code Excited Linear Prediction
GIS	Geographical Information System
CLEO	Cumbria and Lancashire Education Online
CMRT	Cockermouth Mountain Rescue Team
CoTS	Commercial off-the-Shelf
CODEC	Coder Decoder
DLL	Dynamic Link Library
DTX	Discontinuous Transmission
GPRS	General Packet Radio System
GPS	Global Positioning System
GSM	Groupe Spécial Mobile (Global System for Mobile Communications)
GUI	Graphical User Interface
HA	Home Agent
HD	High Definition
HQ	Headquarters
ICT	Information Communication Technology
ID	Identifier
IETF	Internet Engineering Task Force
IOS	Internetwork Operating System
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ITU	International Telecommunications Union
ITU-T	ITU Telecommunication Standardisation Sector
LAS	Location Awareness System
MANEMO	MANET for NEMO (alternative: MANET and NEMO)
MANET	Mobile Ad-hoc Network
MCM	MANET-Centric MANEMO
MIPv6	Mobile IPv6
MP3	MPEG-1 Audio Layer 3

MR	Mobile Router
NCM	NEMO-Centric MANEMO
NEMO	Network Mobility
NEMO BS	Network Mobility Basic Support
NEPL	NEMO Platform for Linux
NINA	Network in Node Advertisement
PAN	Personal Area Network
PC	Personal Computer
PCM	Pulse Code Modulation
PDA	Personal Digital Assistant
PoP	Point of Presence
RF	Radio Frequency
RO	Route Optimisation
RPE-LTP	Residual Pulse Excited - Long Term Prediction
RRH	Reverse Routing Header
RTT	Round Trip Time
SAR	Search and Rescue
SDK	Software Development Kit
SIP	Session Initiation Protocol
SMRA	Slovenian Mountain Rescue Association
SMS	Short Message Service
STA	Search Theory Automatisation
TCP	Transmission Control Protocol
TETRA	Terrestrial Trunked Radio
UDP	User Datagram Protocol
UK	United Kingdom
UMF	Unified Message Format
UMTS	Universal Mobile Telecommunications System
VAR	Voice Activity Detection
VBR	Variable Bit Rate
VoIP	Voice over IP
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
XML	Extensible Markup Language

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