iSurvival: A Collaborative Mobile Network System for Disaster Management

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Abstract. When disaster strikes, optimal access to real-time information of the disaster situation during 'blind time' – the time prior to the arrival of the first responders - and during response and recovery stages is essential to improve the effectiveness of the first responders and recovery. This paper describes a disaster management system, iSurvival, which uses specialist applications on the smart phones of those affected by disaster and wireless devices of first responders, to establish Wireless Mesh Networks (WMN), to facilitate the secure exchange of information in the disaster area, when the normal GSM and 3G telephone networks are compromised or unavailable. This information is further communicated with central control centre for analysis and resource scheduling for effective mobilisation of emergency services which are involved in rescue and recovery. The research, currently under the analysis and design stage, has been awarded a 'Special Mention' from Nokia for Ideas for Development Challenge 2012.

Keywords: Disaster, wireless mesh networks, smart phones, Instantaneous Digital Infrastructures

1 Introduction

Disasters, natural and man-made, require a timely and co-ordinated response to improve the effectiveness of the first responders and emergency organisations. Disaster Management is defined as "... range of actions and processes to control disaster and emergency situations and to provide a framework to prevent and/or lessen the effect of disaster before, during and after a disaster…" [1].

When disaster strikes, the public infrastructure and utilities, including, communications networks - terrestrial networks, voice services and cellular networks - are damaged, impaired, marginally available, intentionally shutdown or non-existent as in the case of remote areas. The need for a flexible and rapidly deployable communication infrastructure is a pre-requisite for optimal provision of real-time information between the victims in the disaster area and the first responders during the response and recovery stages of disaster management. Equally important and critical to disaster management is the access to information during the 'blind time'- the time immediately after the disaster and prior to the arrival of first responders, as it offers vital insight into the disaster situation and improves the effectiveness of the first responders and mobilisation of emergency services.

There is a growing recognition that technology enhanced disaster management systems could help to reduce fatalities of human lives during disasters. A recent example includes the aftermath of the Haitian earthquake in January 2010, where a

WiFi network was the first network to come alive to establish communication with trapped people. The evolving landscape of wireless and mobile technologies, voice and data convergence, computing and modelling capability of services, the growth trend in mobile phones and their ubiquitous uptake is driving the research to harness their potential for integrated technological solutions.

This paper describes a disaster management system, iSurvival, which utilises the resilient and self-configuring capabilities of a Wireless Mesh Networks (WMN) and the capability of smart phones to establish a P2P (peer-to-peer) network using Bluetooth or WiFi in the disaster area to facilitate phone to phone communications. The iSurvival system utilises specialist software applications, the iSurvival applications, available on victims' smart phones and first responders' wireless devices, to instantiate Instantaneous Digital Infrastructures (IDIs), which facilitate routing and forwarding of secure information in the disaster area. When temporary telecommunication infrastructures are set up by first responders at a disaster site, wireless and mobile technologies from GSM, WiFi, WiMax and others are used as backhaul networks to communicate information from the disaster area to a control centre for analysis, access to services and databases to help co-ordination between emergency services involved in rescue and recovery.

Of the many non-technical challenges faced by disaster relief systems, a critical challenge is the adoption and usability of technology in the event of a disaster. The role of the community and NGOs in disaster management solutions cannot be undermined due to their well-established experience in disaster rescue, relief and rehabilitation of victims under disaster situations. This research is conducted as a pilot study in association with external partners, the Northamptonshire Emergency Services, who would be associated throughout the system development life cycle.

The structure of the rest of the paper is as follows: following introduction, Section 2 overviews research in disaster management solutions using wireless and mobile technologies. Section 3 presents a brief overview of system functionality; Section 4 offers a logical overview of the iSurvival applications. Section 5 discusses testing and evaluation of the system. Section 6 concludes the paper with future directions in research implementation.

2 Literature Review

There remains a significant research gap in the field of disaster management in terms of network architecture, protocol design, application development, network interoperability and security [2].

WMNs are increasingly being incorporated in disaster management solutions with a mesh architecture providing easy configuration, resilience, quickly deployment and interoperability in a heterogeneous environment with minimum interdependencies. Raheleh and Ramesh [3], present the results from a campus trial of deploying a wireless mesh network to provide first responders with an infrastructure for local communication, with the network connected to the outside world through a wired backhaul. With disaster solutions incorporating wireless MANETs (Mobile Ad-hoc Networks) and WMNs, the potential issues in forwarding information through instant

communications system include node mobility, efficient address allocation mechanisms and non-usability of wired routing protocols. While multicast streams are the most popular traffic pattern in many applications of MANET, A.K. Vatsa et. al. [4] have proposed multicast-based routing mechanism using efficient address allocation over a mesh-based and tree-based multicast through the random casting method of node selection. Another solution uses Cluster-Mesh based Multicast Routing (CMMR) methodology [5] that combines network clustering and mesh-based multicast routing **to** provide scalability and robustness to multicast routing by grouping nodes into link-layer clusters and forms a backbone using cluster-heads. Roc, et. al. [6], present a set of design patterns to support communication and coordination in mobile ad-hoc scenarios. With the SafeMesh, Asad, *et al.* [7], propose a routing protocol that implements modifications to AODV (AD-hoc on demand Distance Vector routing protocol) and achieves significant performance improvement in terms of the packet delivery ratio, routing overhead and latency over other contemporary routing protocols.

With the increasing trend of smart phone usage, a number of mobile application-based solutions are available using smart phones for disaster management. MyDisasterDroid [8], is a disaster management system, implemented in an Android-based mobile platform that uses genetic algorithms to facilitate the logistics for the rescue and relief operations during a disaster. Although the use of smart mobile devices and applications in disaster scenarios can improve collaboration dynamically, nevertheless, it poses interesting challenges, such as user's mental attention, small screen size, unavailability of reliable network, reduced power, and battery consumption [9]. The iSurvival system will address these challenges that would take into account technology adaptability, ease of usage and effective GUI techniques.

The paper describes characteristics of an optimum, scalable routing solution that would build on existing research to cater to heterogeneous wireless technologies and permit fast adaptation of the flow of information through a dynamically changing topology of connected wireless mesh networks in the disaster area. The research provides an integrated technological solution that not only builds and develops on existing research using smart phones, WMN and web technologies, but also offers a unique solution to capturing communication during blind time.

3 iSurvival System

The iSurvival system (Fig. 1) is a disaster management system that uses special applications on the smart phones of end-users in the disaster area, the victims, to create wireless mesh networks. The system design is currently being researched with regard to implementation platforms, issues on smart phone density, security and data protection with external partners. Furthermore the research is currently exploring how the iSurvival system integrates with the existing national emergency services framework.

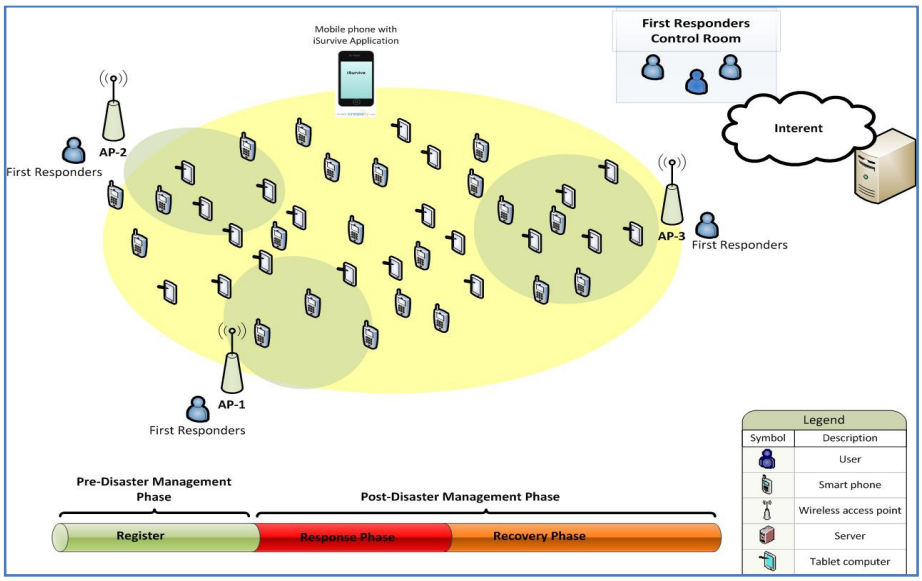

Fig. 1. iSurvival System

The system is designed around three main communicating entities within and outside the disaster area that include end-users in the disaster area, the *victims*, onsite specialist team, the *first responders,* and offsite specialist team, the *control centre,* using specialist applications, iSurvival, for the smart phones of victims, the wireless devices of first responders and the web based system at the control centre.

The iSurvival system addresses the preparedness, response and recovery stages of disaster management system (Fig.1). As part of the *preparedness phase* of pre-disaster management, the end-users download the application from the project website, www.isurvival.co.uk, to smart phones and register their profile to a web-based system, managed at the control centre. The communication during response and recovery phases is 'user-centric' as it relies on victims to initiate the communication process using the iSurvival application on the functioning smart phones that helps to establish wireless mesh networks, called the Instantaneous Digital Infrastructures (IDIs), in the disaster area. The IDIs, created transparently, allow co-operation and the exchange of information using smart phones between victims and are analogous to 'wireless intercoms' in the absence of cellular infrastructures in the disaster area. The iSurvival application helps to save the communication in victims' smart phones and creates a distributed knowledge base. This distributed knowledge base created during *blind time* is accessible to first responders when they connect to IDIs in the disaster area, using the iSurvival application on their wireless devices. The IDIs facilitate bidirectional communication between victims and first responders using instructions, messages, images and video.

The recovery phase relies on forwarding distributed knowledge base and real-time information to the *control centre*, using ubiquitous wireless, voice and mobile network infrastructures for analysis, data-aggregation, resource scheduling, and access to services and databases to help co-ordination between the emergency

services involved in rescue and recovery. *The control centre* provides additional services for data validation, monitoring and logging as well as tracking the victim's data from the information received from a disaster area and the profile available through the initial registration on the web-based system. The issues of security - the confidentiality, integrity and availability - are essential, as effective disaster response depends on rapid access to *reliable* and *accurate* data, from the disaster situation. For example, in the context of a terrorist attack, without adequate encryption and source authentication primitives an adversary may snoop and/or insert false crisis information. The iSurvival system utilises user data, registered with the web-based system during the preparedness phase to verify and authenticate identity of victim in the disaster area.

4 iSurvival Implementation Technologies

The three entities in the iSurvival system are the victims, the first responders and the control centre. These get connected through the WMN using the following specialist iSurvival applications:

4.1 iSurvival Mobile

The Mobile App software design has two separate tasks/threads. The background thread seeks to establish and maintain itself as part of a mesh network and to establish a link with one or more first responders. The implementation of this part of the software has to take into account that the mesh network may change topology and its role as a leaf or branch node may change over the time of the disaster period. As shown in Fig. 2, the foreground task seeks information from the victim regarding the disaster and the victim's situation within the disaster. Initially, upon a mesh network having been established, victims will be able to exchange information about their circumstances. When the mesh network connects to a first responder, the victims' data will be uploaded to the first responder for further uploading to the data centre. Victims will also able to communicate outside their network through the first responder. A high level overview describing the iSurvival mobile App process in pseudo code follows:

```
if (user_response == disaster){
Gather and store user data
do {
  if (FR WiFi network present){
    Connect to FR then Upload user data
    Enter Interactive mode
  }
  else if (WiFi MESH present){
    Connect to WiFi MESH
    Exchange cooperative data (I have survived)
```

```
 } while (FR not present)
  Connect to FR then Upload user data
  Enter Interactive mode
}
else if ( Bluetooth MESH present) {
   Connect to Bluetooth MESH
   Exchange cooperative data(I have survived)
   while (FR not present) {
        Connect to FR then Upload user data
        Enter Interactive mode
     }
}
} while (not connected)}
```

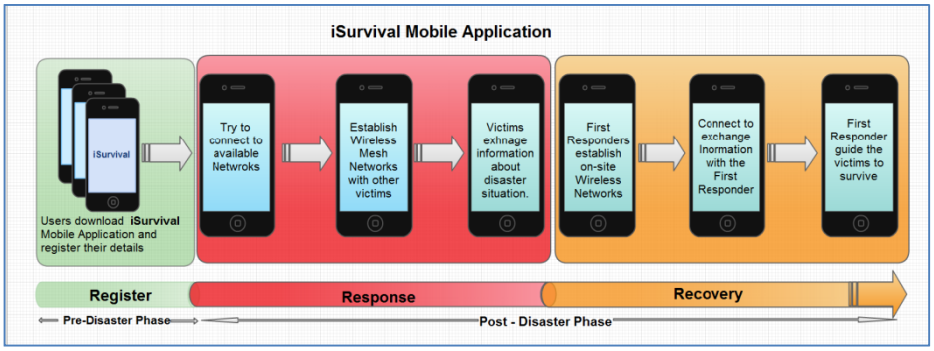

Fig. 2. iSurvival Application in different stages

4.2 iSurvival First Responder (FR)

The software for the First Responder initially attempts to link to both the Control Centre and any mesh networks created by the victims' devices. When a member of a mesh network detects a FR it will connect to it. All other nodes, on the same mesh, which are in range of the FR, will also connect directly to the FR, as shown in Fig. 1. Only devices outside the range of the FR will remain part of, potentially, a simplified mesh network or networks. When a victim connects it will upload the data to the FR and, if connected, this will be further uploaded to the control centre, as shown in Fig.2. A further complication is that both single devices and networks can connect to the FR and the FR needs to extract data from all members of a mesh network. The FR will also be capable of routing between two or more attached networks. A high level overview describing the iSurvival First Responder process in pseudo code follows:

```
initialise FR WiFi Network // Setting SSID to
"iSurvivalFR"
```

```
do {
          wait_for_connection
          if (connection == LEAF_NODE){
          Download user data from leaf node
          attempt to Upload user data to Control Centre
          }
          else (connection == BRANCH_NODE){
           for each LEAF on BRANCH {
            Download user data from leaf node
           attempt to Upload user data to Control Centre
            }
          }
} while (true)
```

4.3 iSurvival Control Centre

The Control Centre software performs two tasks. The first task is to obtain information from users who have downloaded the App prior to any disaster and this is done through a registration process. The user will also be instructed on how to use the App in a disaster scenario. The second task is to communicate with first responders reacting to a disaster and to exchange information from the FRs, where individual victims' data is uploaded to the control centre and relevant stored data, from the registration process, is downloaded to the FRs. The Control Centre software will also be able to facilitate sharing of information between FRs connected to different mesh networks. The Control Centre software will also provide an overview of disaster collated from the FRs and victims for bodies engaged in disaster relief. A high level overview describing the iSurvival Control Centre process in pseudo code follows:

```
User registration
    do{
          if (FR connects) {
             for each user (connected to the FR) tag as
                disaster victim
              return registered data on victim to FR
             do {
                if victim status changed update record
              } while (!end of disaster)}
      } while (!end of disaster)
```

5 Testing and Evaluation

The intention is to develop iSurvival applications for both mobile and web server platforms. The proposed methodology uses agile system development to include the partner's input in drafting system requirements and specifications. The partners have been consulted to review system design and validation, field testing and the final

evaluation of the complete system. Northamptonshire Emergency services have confirmed their assistance in testing of the system including facilitating the incorporation of the iSurvival system into broader emergency response exercises and explore the opportunities to further increase distribution.

6 Conclusion and Future Work

This paper discussed the iSurvival system that offers an efficient and cost-effective solution which benefits from using no special hardware, utilises the potential of ubiquitous mobile and wireless technologies, the growth trend of smart phone usage and end-user familiarity with the mobile phone technology. The perceived impact and uptake of the iSurvival system is anticipated to be global as it relies on a globally available, open standard and interoperating mobile and wireless technologies and smart phones and does not depend on any specialist radio equipment, which could have limitation due to radio spectrum usage. The added value offered by the system is the access to information during 'blind time' of disaster, normally untapped in available solutions. Future work may include producing an open framework for first responders to allow integration into the iSurvival system.

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