Practical Experiences in Using Heterogeneous Wireless Networks for Emergency Response Services

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Abstract

Emergency services are one of the main application areas that can benefit from the adoption of wireless communication technologies. Unlike other application domains where all devices have very similar capabilities, we foresee that for emergency services the key is being able to build a heterogeneous wireless communication platform which encompasses the advantages of each of the different existing technologies. In this paper, we analyze the main requirements, describe a possible supporting architecture and report some real experiences in collaboration with our local emergency response service (112).

I. INTRODUCTION AND MOTIVATION

Wireless communications are currently being present in many applications in our daily life, as well as in many products and services. It is certainly one of the areas whose importance in the society is experimenting an unprecedented growth. On other hand, emergency response is also an area that is rapidly changing due to the continuous incorporation of new cutting edge communications technologies. So, it becomes natural to apply recent advances in wireless networking to the highly important area of emergency response and management. In particular, we are very interested in exploiting the easy deployment, increased bandwidth and huge reliability of recent technologies.

In our proposal, we consider the use of Wireless Mesh Networks (WMNs). They have emerged as a key technology for next-generation wireless networking, due to their easy deployment, ability to work with little infrastructure and survivability. WMNs are dynamically self-organized and self-configured, where nodes are automatically create an ad hoc network and maintain the mesh connectivity. We also consider the integration of WMNs with existing high-capacity wireless technologies such as WiMAX and UMTS. Our final goal is to be able to provide real-time images from the place where the emergency is taking place to the remote control center so that more informed decisions for the emergency management can be made.

In this paper, we analyze the requirements and solutions for efficient video distribution from first responders to the control center of the emergency service, in the particular case of our local emergency coordination centre (112, which is similar to 911 in USA). We also set up a demonstration prototype (Fig 1) and report some performance results to assess whether a heterogeneous wireless network can fulfill the needs of our local emergency services.

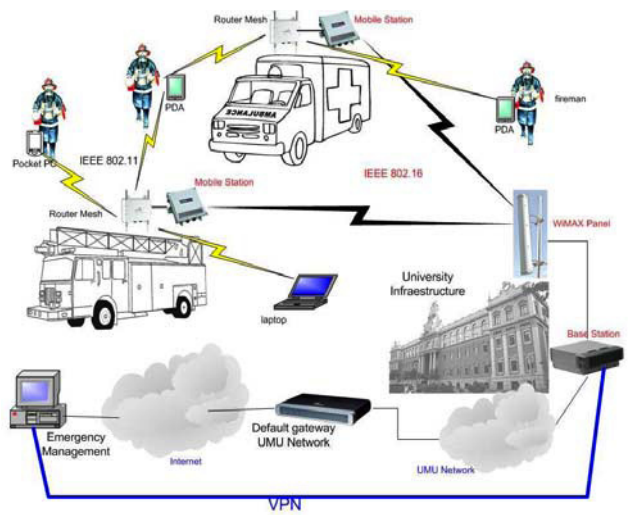

Figure 1. Logic structure of proposal architecture.

The rest of the paper is organized as follows. The first section describes some related work. Section II analyzes and describes the requirements to solve existing shortcomings in traditional emergency technologies. Section III addresses the main performance requirements which must be satisfied by the proposed communication architecture. The remaining three sections describe the proposed solution, the test-bed setup and lessons learnt and finally the experimental results from our experiments. Section VII concludes this paper.

II. RELATED WORK

In [1] several problems which appeared during the natural disaster happened in US because of Katrina Hurricane are analyzed in relation to communication, management and infrastructure supply. Main conclusions state that incompatibility of available technologies is identified as a great problem, and the lack of frequency bands, caused a low communication rate among responsible entities of emergency groups. These three deficiencies are identified as top priority issues which should be addressed in the design of communications architecture for emergency services.

There are some proposals for emergency situations based in WMNS. In [2] proposed a Hybrid wireless mesh network with particular application for emergency and crisis scenarios, where performance measurements are obtained during a real mesh testbed. In [3] authors present the GeoBIPS architecture (which using underlying wireless mesh networking technology) an overview of the different hardware and software components. The improvements carried out in this work have been the channel selection algorithm and the On The Go Coverage Indicator.

Based on the architectures proposed in the literature [2-5], and considering the general and our specific requirements based on the experience provided by the 112 emergency service of Region of Murcia, we concluded that a solution based on three layers is suitable to provide a wireless infrastructure connected to the wired backbone network linked with the control center. In addition the architecture is designed on the basis of different existing technologies, deployed for giving a wireless network with a maximum coverage and relying on specific emergency services.

III. PERFORMANCE REQUIREMENTS

As first priority, a public safety communication system must be able to provide reliable voice, image and video data to allow an acceptable rendering quality. The proposal presented in this paper comprises communication areas provided with a great bandwidth, a wider coverage and with an extended flexibility to adapt to deployment and topological changes.

The delay of messages transmissions from the source to the target devices has to be minimal, in order to deal with real time demands. In this kind of scenarios, this delay cannot be higher than 150 ms and not only for voice over IP but also for video streaming.

The communication bandwidth related to paths without broken links, has to be enough to offer video-streaming services. The recommended bandwidth is around 512 Kbps for combined audio/video streaming, taking into account that this value is only for one connection. Regarding the bandwidth required for video only transmissions, it depends on some factors such as image quality or frame rate. Our experience shows that the minimum video traffic rate is 384 Kbps for one video channel and 128 Kbps for two audio channels, when the image size is 320x240 pixels.

With the lens that video and sounds emission are not negatively affected, the latency obtained during this process, defined as the time difference between the moment in which a link fails and the moment in which an alternative router starts being used [6], has to be minimized for this kind of applications, since the quality of service could be suffer a negative impact.

Communication systems for dealing with emergency management must be reliable and robust, in order to operate under adverse situations and hostile environments. Robustness is just one of the main features of wireless mesh networks [7]. The communication platform must also be self-healing in order to react quickly to topology changes, since critical emergencies (like fires) require fast adaptive networks.

IV. PROPOSED ARCHITECTURE

The proposed architecture is based on a wireless mesh network at the road edge, and technologies are involved are WiMAX (802.16), and Wi-Fi (802.11a/b/g), to create the real mesh. It also considers 3G technologies for first response and establishment of the initial communication between terminals at the emergency place and the control center. The real tests carried out with the system demonstrate the advantages of this mesh network.

The scenario considered is composed by three important parts. First, the WiMAX deployment performs gateway functions for the nodes of the mesh network; Second, WiMAX clients are located at emergency vehicles and are directly connected to base station, which is placed in a strategic place to give a major coverage. These WiMAX clients are connected through the wired interface to mesh routers, which also brings wireless coverage to mobile devices used by emergency staff. The third and last element is the emergency center, where applications used for emergency management are hosted.

In the diagram of Fig. 1, there are two wireless technologies which operate at once. On one hand WiMAX is used to communicate each vehicle (trucks, cars, motorcycles) with the base station and the wired network. The WiMAX deployment is connected with the control center, using VPN, which provides a secure communication environment. On the other hand, a wireless router into vehicles is used to create a mesh, with multiple radio interfaces to exploit the available bandwidth. Since they use multiple radio interfaces, the simultaneous channels maximize the WMN capacity [8].

The logical structure presented in this document also includes 3G/2G cellular technologies, due to the rapid response they offer and their great expansion. Thus, the first response to an emergency situation could be notified from a mobile device, establishing an initial video connection with the emergency services center. As a response to this first action, the necessary resources are sent to the emergency scene (emergency vehicles with a WiMAX client). The incident area network is then established to offer Wi-Fi coverage to mobile devices, with a personal area network (mobile phones, laptops, PDAs, etc…). In this moment it is already possible to broadcast video in streaming and establish a common data connection between end devices and the service center. This way, the incident scope is accurately determined, and subsequent actions can be performed depending on the emergency.

WiMAX has been chosen since this technology represents an optimal solution for IP-based broadband wireless communications. Its capacities in terms of coverage, offered data rates and terminal mobility, makes WiMAX be easily applied on disaster scenarios. Furthermore, WiMAX fulfill QoS constraints in the field of emergency management scenarios [9]. On other hand, WMNs can be easily implemented through IEEE 802.11a/j-like radio interfaces, offering broadband capacity in emergency scenarios. An extra factor which determines the success of WMN technologies is interoperability, which is another major problem, identified in emergency response operations.

IEEE 802.16 and 802.11 must be considered both oriented to reach a full coverage of the disaster area, moreover to offer to users different connection alternatives. In that sense, in [10] authors proposed two interconnecting techniques between a Wi-Fi and a WiMAX network having into account the need to support the same QoS level between two networks.

In the real tests carried out we have worked closely with the emergency management services of Region de Murcia, conducting several tests for checking the correct operation of the video streaming transmissions. The purpose of this collaboration is to provide the necessary communication infrastructure, by means of WiMAX, to interconnect mesh network with the service central. The platform was found useful to manage incidences by means of live audio/video of a great quality, suitable to the first-person-lived incidents from the place of the disaster or emergency, managing to carry out the gesture of the available resources in a more efficient way.

V. TESTBED SETUP AND LESSONS LEARNT

As described above, the scenario is composed by elements of two different technologies, WiMAX devices and several mesh routers. In order to achieve our experiments we deploy our scenario using Alvarion BreezeAccess 4900 as the WiMAX devices and Gateworks Avila GW2348-4 as the mesh routers. The WiMAX client and mesh routers get the power supply by means of PoE described in the IEEE 802.3af standard.

The main problems we have faced related to mesh device are the followings: Firstly, the configuration of the Ad-hoc mode in the wireless interfaces, not only in the mesh routers but also in the mobile devices (laptops), since they were not very often easy to associated automatically. Secondly, it was the developing and installation of the routing algorithms into the Mesh routers. Due to the necessities of low energy consumption, they have different processor architecture (ARM). So the way to insert the algorithm in these devices is using cross-compiling technique. Finally, other obstacles were caused by the lack of information of some protocols and the configuration requirements for the kernel on these devices.

Regarding the WiMAX technology, the devices used in our testbed are not compliant with the mobile standard making difficult to get good marks in our scenario.

VI. EXPERIMENTAL RESULTS

This section shows some performance results obtained in the wireless mesh network and in the WiMAX link. Three performance tests have been carried out to verify the usefulness of the infrastructure over a real environment and also to check the efficiency of the routing protocol OLSR [11] integrated in wireless mesh routers. In order to get our experimental results we have used a CBR generator so as to get the maximum bandwidth according to our scenarios requirements. These scenarios are detailed in the following paragraph.

The first performance test was carried out using only the WiMAX technology. The target of this test was to obtain the maximum bandwidth recreating the situation explained above in the proposed architecture section, i.e., a real time audio and video broadcasting which shows the location of an incident. The second test with WiMAX and routers mesh is about to connect the client WiMAX with the router mesh in such a way that the first one is used as a gateway for the router mesh. The last experiment introduced one hop extra to the previous test using a new mesh router. Therefore, the communication from a laptop to the WiMAX client is transmitted along two mesh routers instead of using only one.

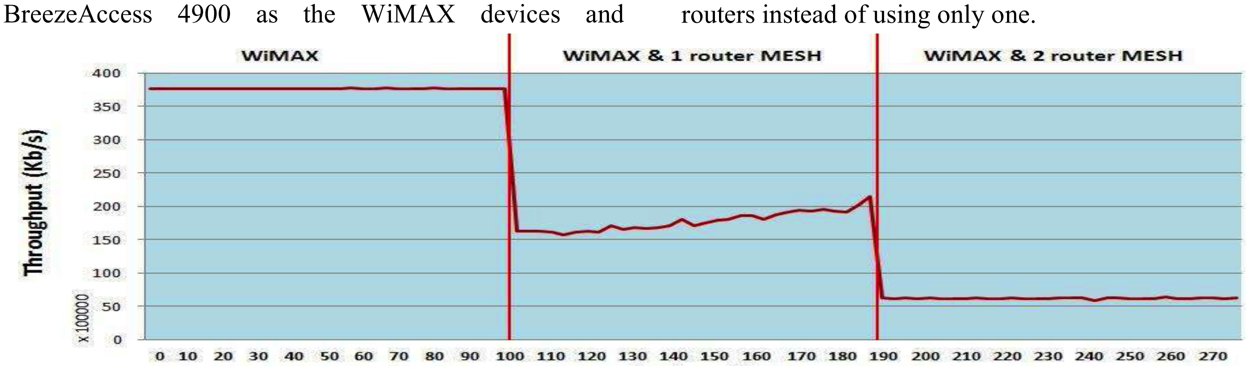

Figure 2. Average Throughput (Kbits per second)

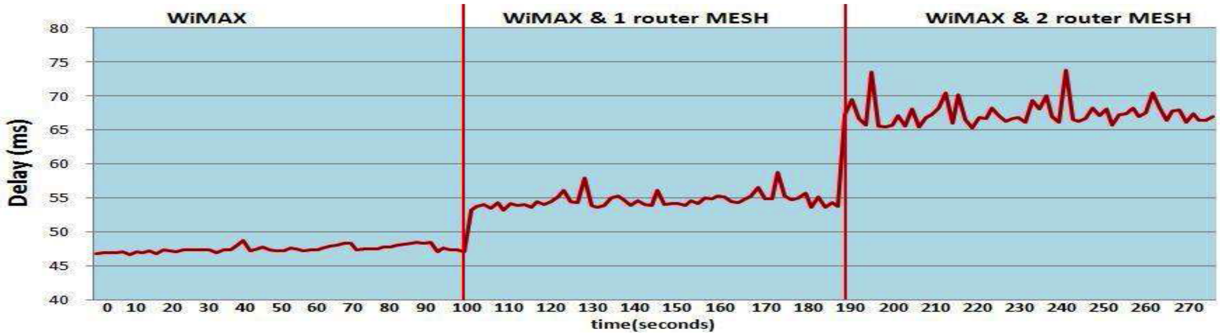

Figure 3. Average Delay (msecs)

Fig. 2 shows the maximum average throughput of each test (in Kbits per second), that can be reached without impairment of the streaming video. For the first test, we obtained a throughput of 37 Mbps with a few fluctuations in WiMAX. For the second one, we have got 17 Mbps and 6 Mbps in third one. All of them allow a quality of video higher than the demanded.

The average delay of the messages is shown at Fig. 3. It shows the performance of using different channels on 802.11 networks, as well as the achievement of requirements, since this value should not be higher to 150 ms, being 75 ms approximately in a worst scenario. In addition to the results showed in the aforementioned graphs, we have also obtained a 9% of average packet lost ratio at worst case, which is greater than the requirements of the application.

VII. CONCLUSIONS AND FUTURE WORK

The application of telecommunication technologies in areas like first response and emergency services is essential to be able to provide faster responses under critical situations or natural disasters. The networking infrastructure presented in the paper efficiently covers the requirements of applications located in this frame, and the carried out field trials study the performance of the system.

According to collected results, the efficiency of both the mesh routers and the WiMAX deployment is suitable for this type of multimedia services. This scenario comprises a simple test bed, but it effectively offer support to services demanded by the staff of emergency services.

The analysis in this paper is found very useful to identify the major problems and benefits of both WiMAX and WMNs in the development of an emergency management platform. The paper presents a real solution tested in cooperation with emergency services of Region de Murcia. A great effort is currently being carried out to unify those platforms and projects orientated to emergency services, and solve several technical problems involving wireless technologies. The aim of this research line is develop an integral infrastructure capable of hosting many emergency services, especially oriented to manage disaster conditions.

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