A Reliable Wireless Mesh Infrastructure Deployment at Crisis Site

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Abstract

Emergency communication infrastructure should allow fast and reliable information dissemination to assist community and ease mitigation activities. Failure in communication networks and information exchange in past has impeded the responders’ efforts resulting in huge loss of lives and economical impacts. Reliability, quick reconfiguration and interoperability are specific requirements of a robust communication infrastructure at disaster sites. We have deployed a wireless mesh Test bed at several drills on campus and in the city to identify the vulnerabilities of the existing communication infrastructure and enhance the network capacity and performance. We present the real measurements obtained over the deployment of the wireless mesh test bed at disaster site followed by an analytical discussion of the important observations concerning the factors that impact performance or cause network congestion.

1. Introduction

When a crisis occurs, first responders are immediately sent to the site. While the most pressing needs of the people impacted by disaster are being addressed, there is an effort in establishing a communication infrastructure at the site to provide connectivity locally and to the outside world. This enables first responders to communicate with command and control center. Considering all the advances in the communication technology in recent years, it is very beneficial to deploy the new technology at disaster site for a more reliable and faster service. However there are a large set of technical and sociological challenges before a wide deployment of new technology can become a reality.

The infrastructure should consistently detect and dynamically adapt to the changing network circumstances including different devices using various technologies joining and leaving the network. The scale and frequency of the recent disasters such as World Trade Center, Asian Tsunami and Hurricane Katrina confirm the strong need for a reliable communication infrastructure that support distributed command and control systems. Such networks enable different first responders exchange information and ensure the best information exchange at all stages of an emergency including mitigation, preparation, response, and recovery. Disaster response and recovery are more time sensitive and have a more specific need for quick deployment and easy reconfiguration of the communication infrastructure while mitigation and preparation usually allow a longer planning time. The future communication infrastructure should be quickly configurable and deployable and allow reliable information sharing to increase community preparation and ease mitigation activities.

In this work, we present technical and sociological challenges along with network performance evaluation based on the measurements carried out over the network. The main objective of this infrastructure is to provide first responders with a local network to communicate with each other and eventually to Internet.

2. Technical and Sociological Challenges of Real Deployment

Recently Wireless Mesh Networks (WMNs) have become very popular research area for the use of unlicensed spectrum and low cost of IEEE 802.11b/a/g-based off-the-shelf devices [5] [6]. In [7] real measurement results are presented to study the feasibility of mesh network for all-wireless offices. Another work by [8] presents measurements over an outdoor wireless mesh network. Interdependencies among different components of a system, within and among specific infrastructure areas such as power or transportation and on social behavioral affect community [11].

At a disaster site there may exist partial network coverage or none. In either scenario a mesh network can be deployed. This local network can get connected to the outside world by using any available technology at the site. Local connectivity is more urgent as failure to hear others’ communication at disaster site has caused loss of lives in the past. Cross-Tier diversity effect is inevitable in a heterogeneous environment. Ideally different devices
operating over different physical layers should not interfere. Real measurements over the network show that the network performance and application response time in a heterogeneous environment are not merely affected by one source. All different end users share the same network resources and cause interference and impact performance of one another [3]. This effect can be moderated by forcing adequate distance between interfering devices and changing the topology by selectively turning nodes on/off. In a chaotic environment where all different systems share the same network resources, recovery mechanisms from congested network is not trivial. While network congestion, resource allocation and meeting minimum quality of service are resolved in the established and mature standard such as 802.11, they continue to be highly challenging problems where all different devices and technologies interfere in a non-traditional model. Mesh boxes with multiple interface cards provision interoperability in a heterogeneous environment as different devices are able to uniformly connect to the network through the appropriate interface cards. Network performance can be optimized by tuning the relevant parameters based on real measurements. Traffic management and resource allocation is achieved by changing network topology (turning nodes on or off) and selectively allowing particular types of traffic. Social artifacts and tradition play a crucial role in deployment of new technology in addition to the technical requirements in the evolutionary design of future communication infrastructure. The cost to upgrade the existing infrastructure should be low. The new technology should be designed in a modular fashion so that it is easily upgradeable with the technology evolution without the need to replace the entire system. This leads to an economic deployment solution which is affordable for different public and private agencies. Furthermore, it is important to consider the amount of knowledge and training required for community to operate with new technology.

3. Performance Evaluation and Results

A local wireless mesh infrastructure was established at the drill site as part of the NSF-funded RESCUE project (Responding to Crises and Unexpected Events) [3] to provide local connectivity. This was based on a scenario involving a terrorist attack and gas spill at the Calit2 (California Institute for Telecommunications and Information Technology) building on the UCSD campus coordinated by part of San Diego Metropolitan Medical Strike Team (MMST).

The gateway was connected to Internet through a wired backhaul link. Patients were equipped with iTags, wireless handheld devices communicating their medical status, treatment record, and vital information to medical personnel at the site [2]. The wireless access nodes have multiple interface cards to communicate with different devices using different technologies in a heterogeneous environment. When a node or a link fails the connectivity is maintained through alternate routes. This characteristic improves reliability, as unavailability or failure of sub-components of the system does not affect the overall performance of the system and the service will be continuously available [10]. This architecture is scalable as additional wireless access nodes can join the network without causing a service interruption by connecting to the closest node with best signal strength to expand the coverage.

Our test bed consists of 5 wireless access points, about 25 iTags and several laptop clients. We have captured network and application data during this drill to evaluate network performance [9]. All network data is sent over Transport Control Protocol (TCP) for FTP which retransmits packets if they are actually lost or experience a long delay (retransmission timeout occurs or 3 duplicate ACKs received). Therefore the network experiences a longer application response time. The difference between network and application data shows the amount of protocol overhead.

One source of (potential) bottleneck in the network is the large number of small packets traveling over the network. Nodes 1 and 2 have a bilateral communication with server while the rest of mesh nodes in the network mainly receive data from server. This is more of control information sent by server over a uni-directional communication. Therefore nodes 1 and 2 have quite a large number of application turns indicating the number of times the direction of communication changes between source and destination which cause delay. The application performance can be enhanced by sending fewer larger packets. In this drill protocol chattiness and retransmission can cause bottleneck in the network.

Figure 1 shows the number of retransmission each node experiences. We see that node 2 has a large number of retransmission which is due to existence of error-prone links in this case (network congestion is not the cause in this scenario) and as a result the network throughput varies drastically from other nodes. There is a large number of small control packets exchanged between server and node 2 (about 42% of
total packets) as RSRB messages (Remote Source Route Bridging) [4].

Figure 2 shows the total amount of application and network data exchanged between server and mesh nodes. Application throughput is approximately the same between server and all mesh nodes. However network throughput, including all application data and network protocol overhead, is similar for all mesh nodes except node 2. The network behaved differently between server and node 2 because of an error-prone link which was verified by the signal strength measured during the drill.

![Graph of Retransmission from server to Mesh nodes](image1)

Figure 1. Number of retransmissions from server to the nodes

![Graph of Application and Network data from server to the nodes](image2)

Figure 2. Application and Network data from server to the nodes

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5. References


