WIRELESS AD-HOC ARCHITECTURE FOR DISASTER RELIEF

Gunaratne G. T. C[1], Jayarathne P. V. M[2], Sandamini S. S. P[3] , De Silva D. S [4]

[1]thilina9gtc@gmail.com, [2] nishmj.88@gmail.com, [3]shriviprasansa@gmail.com, [4]saman@eie.ruh.ac.lk

ABSTRACT

Disasters of different scales could cause complete or partial failure of conventional communication systems. Communication and exchange of information are the cornerstones of any disaster response for informed decision making. Hence raises the requirement for a rapidly deployable, robust to failures and easily maintainable communication network. Especially for relief operations conducted to save thousands of human lives, establishing emergency communication is vital. Establishing communication using technologies independent from the conventional systems and service providers is a challenging task as feasible technology options are very limited.

Use of portable wireless Ad-hoc networks for establishing communication in a post disaster situation in order to coordinate field activities of rescue crews can solve many problems exists in currently used systems for such a situation. In this paper, a wireless Ad-hoc network architecture is proposed to promptly insure communication means to grasp the information within the disaster area for rescue teams and disaster survivors. A prototype system is constructed to evaluate the function of the network and its performance through several disaster applications such as VoIP, broadcasting alerts and warnings, peer to peer texting and file transferring.

Keywords – **Ad-hoc, Wi-Fi, Node, Post disaster communication, Smart Device**

1. INTRODUCTION

World has become a ground for numerous disasters where mass destructions strike almost daily. Irrespective of the fact that they are natural disasters or manmade catastrophes, hundreds of thousands of people become victims. Survivors find them-selves trapped without any means of reaching for help with no water, electricity nor communications. In natural disasters like Tsunamis, floods, earthquakes, hurricanes and storms or human caused events like large scale terrorist attacks or nuclear disasters, conventional communication systems can be totally wiped out making the rescue operations extremely difficult. More panic situations occur as people have no way of knowing whether their near and dear ones are affected.

Communication and Exchange of information are cornerstones of any disaster response for informed decision making. Management of resources in such situation is very difficult. Rescue personnel spread across wide swaths of the disaster area. Situational awareness is maintained using hand-written tables and charts. Updates arrive in the form of verbal messages via radio or courier. In this environment wireless ad hoc networks can significantly enhance situational awareness by improving and automating updates, monitoring and reacting to status changes, and extending data communications across the entire disaster [1].

There are Wide area Disaster information Networks (WDN) developed using internet over the combination of wired and wireless network. In a situation where internet or wired network is completely unavailable it is necessary to move for completely wireless network technologies [2][4]. Deployment of mobile ad-hoc networks can enable communication among temporarily assembled user terminals without relying on conventional communication infrastructure [5]. Devices having wireless communication technologies such as Wi-Fi, can be used as nodes or access devices to connect with installed sink nodes in an emergency ad-hoc network. Hence there is the possibility of using the Wi-Fi feature of laptops, smart phones, tablets or any such device to establish this type of networks. Many of the researchers have focused their research towards different architectures, protocols and schemes for disaster management, among them well known architectures are WSNPDM (Wireless Sensor Network Protocol for Disaster Management) and LEACH (Low-Energy Adaptive Clustering Hierarchy) [3]. Implementation and performance analysis of disaster management network architectures will be beneficial for the whole world to manage great disasters.

In this project we have proposed a wireless communication system aiming disaster relief communication and disaster survivor detection. Access to the system is done through Wi-Fi capable smart devices such as smart phones. In the present most people carry smartphones equipped with IEEE 802.11which makes the system effectively applicable [8]. A prototype system was constructed to evaluate its function and performance through several disaster applications such as Voice over IP (VoIP), file transferring and Message broadcasting. Prototype system also includes android application which enables smart phones to connect with the network. The system meets many of the problems exist in current emergency communication systems and can be improved in various ways to use for number of applications.

2. NETWORK ARCHITECTURE

Configuration of the proposed post disaster communication system is shown in FIGURE 1. System consists of multiple wireless access nodes, Wi-Fi capable smart devices, long distance transceiver and the data centre. A wireless node consists of two communication equipment, one is used for inter nodal communication and the other one is used as the access point for end users. Both communicate using IEEE (Institute of Electrical and Electronics Engineers) 802.11b, g, n Wi-Fi standards. A node has the ability to cover an approximate circular area of 100 m radius. These nodes are portable so that can be carried to the field easily. They can be installed in the field with or without elevation from the ground where installing them on pole with an elevation would enhance the performance. Nodes should be installed in the operation area in a distance less than 100 m so that an Ad-hoc network is organized among the nodes.

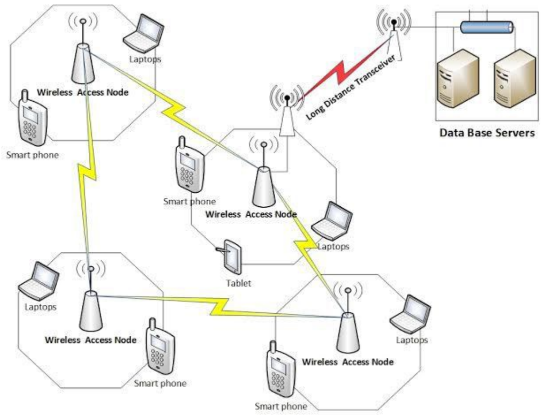

FIGURE 1: System configuration

Whole network is connected to a data centre through a long distance communication link. Network should have more than one long distance links to ensure redundancy. Nodes having a long distance transceiver unit other than the internodal communication and use access units are called super nodes. This link can be defined as a gate way to wide area network through which the disaster information can be exchanged.

Smart devices at the user end provide the functions for W-Fi communication. Application installed in these devices enable services such as peer to peer messaging, message broadcasting and VoIP. End user application is the software element of the proposed system hence by installing the application any user with a smart device such as smart phones and tablets can connect with the network. The application is mainly aimed to be installed in rescue member's smart phones where facility is provided to download it by connecting with nodes.

3. WIRELESS NODE

A network node consists of basically two parts for inter nodal communication and user access. Communication is facilitated by IEEE802.11b, g, n standard wireless LAN (Local Area Network) [6]. (2.4GHz transmission frequency, 54Mbps network bandwidth) A node covers a 100m diameter area and supportive Wi-Fi capable smart device can communicate within the coverage area of a node. Further details of wireless network node are shown in TABLE I.

TABLE I

SPECIFICATIONS OF WIRELESS NODE

Standard	IEEE 802.11b,g
Frequency	2.4 GHz
Signal Power	10 mW
Transmission Speed	54 Mbps
Maximum Distance	100 m

A. Super Node

A super node consists of a long distance transceiver unit other than the internodal and user access units. FIGURE 2 illustrates block diagram of the super node. This long distance transceiver works as the link to WAN environment which connects with a data base or a disaster information server.

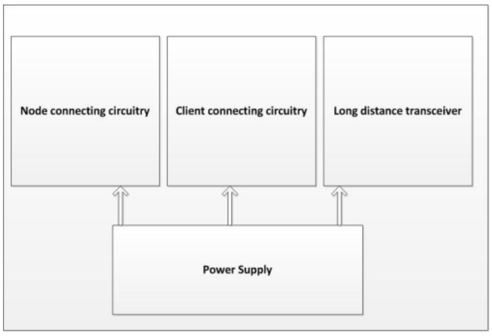

FIGURE 2: Block diagram of the super node

Long distance transceiver is a separate module which can be connected to any wireless node in the network using an Ethernet cable. Such node is then considered as a super node having the potential of linking with the data centre located far away from the field.

B. Long Distance link

Realizing of the long distance link causes problems as there is limited number of wireless technologies for long range communication which requires less amount of infrastructure. In this paper we propose two possible technologies. One is satellite communication of which equipment configuration is costly and bulky. Other one is ZigBee of which data rates are very low and requires a clear LOS (Line Of Site) for long distance communication. In this implemented network the long distance link is realized by a ZigBee link to make it low cost. This link does not carry all the traffic in the network to the outside instead it is there to send only the most critical messages and to get important data from a connected data centre or a nearby network of same type.

XBeePro 868 module is used in implementing ZigBee link. The module is connected to the super node through Arduino uno module using an arduino uno supportive XBee shield. XBee provides a serial link with the Arduino board where it should be converted to Ethernet so that the long distance transceiver data can be transmitted through the nodal IP network. For this serial to Ethernet conversion an Ethernet shield is used in-between the Arduino board and node connecting circuitry. This type of a configuration is only required in the network side. At the other end of the long distance link where the data base servers are, XBee module can directly communicate with a server machine through the serial port.. Long distance link network end configuration is shown in FIGURE 3 below.

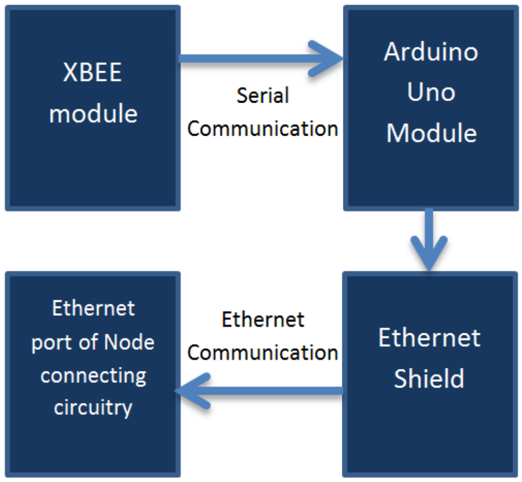

FIGURE 3: Long distance transceiver network end configuration

Specifications of the XBee module are shown in TABLE 2.

TABLE 2

SPECIFICATIONS OF ZIGBEE LINK

Module	XBee-PRO 868
Standard	IEEE 802.15.4 based
Frequency	868 MHz
Transmission Speed	24 Kbps
Maximum Distance	Clear RF LOS range up to 40 km

As the long distance link comprises a lower data rate of 24 Kpbs, from the through put that can be utilized, the amount of data can be transferred through this link to and from the data centre to the field is limited. Hence this link is effective only in transmitting broadcast text messages from the data centre and update text messages from the field.

C. Inter Nodal Link Establishment

The multiple wireless network nodes are mutually and automatically connected by auto configuration function by which the links from one wireless node to the neighbour node whose electro-magnetic field power density is the strongest among them and repeating this procedure to organize minimum spanning tree network. Thus, an adhoc network is organized in the disaster area. .When a wireless network node moves or is failed, then the network node also automatically selects the best neighbour node as the same procedure. Thus, dynamically reconstructing communication links a wireless adhoc network is maintained.

4. PROTOTYPE EVALUATION

In order to verify our proposed system, a prototype system shown in FIGURE 4 was constructed and its functions and performance were evaluated for different applications through field experiment. Four wireless network nodes were launched for testing purposes on a field area to organize into a wireless adhoc network and to be connected to database servers through long distance transceiver.

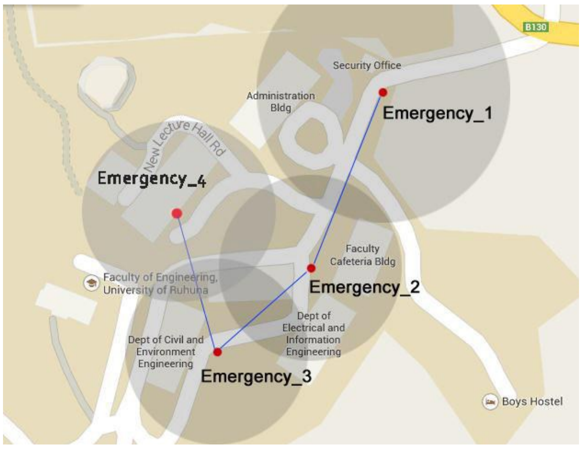

FIGURE 4: Installation of nodes for system evaluation

Wireless nodes were pole mounted in order to achieve higher efficiency with longer distance for effective communication. End devices were connected to wireless nodes through Wi-Fi and data streams were generated through the devices. Using software installed in the end user devices speeds and other performances of the nodes were measured.

FIGURE 5 shows a pole mounted super node. In this image the long distance transceiver unit is separately patched to the wireless node which is the smaller unit on the top.

FIGURE 5: Pole mounted super node of the prototype system

Initially the Received Signal Strength Indicator (RSSI) [dB] was evaluated by changing the distance between two neighbor wireless network nodes. FIGURE 6 shows the results of the performance.

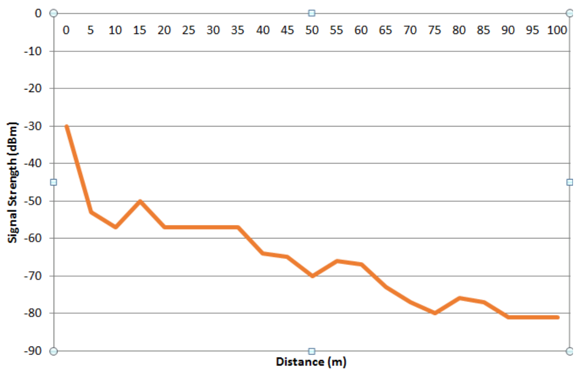

FIGURE 6: Variation of signal strength of a wireless node with distance

By generating User Datagram Protocol (UDP) data in two devices connected to two neighboring nodes frame loss rate was measured. UDP is used for real time communication applications such as VoIP [9]. FIGURE 7 shows the variation of frame loss rates with the distance for the data generated.

Considerably larger variation is shown in the results due to obstacles in the testing area that was used.

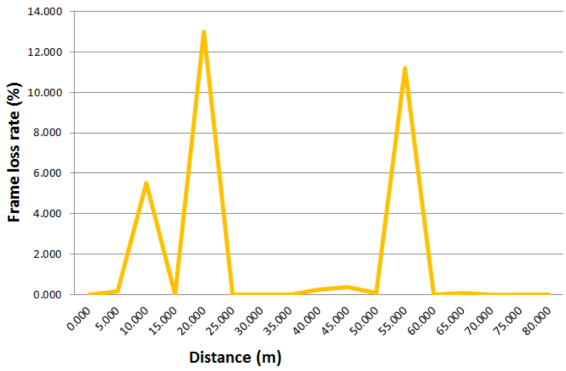

FIGURE 7: Variation of frame loss rate with distance for UDP data

For the same case jitter variation with distance was recorded and the results are shown in FIGURE 8. In voice over IP (VoIP), jitter is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes [7]. FIGURE 9 shows the variation of throughput against the distance for UDP data. When analysing these graphs, effect of obstacles to the communication performance of the network can be observed.

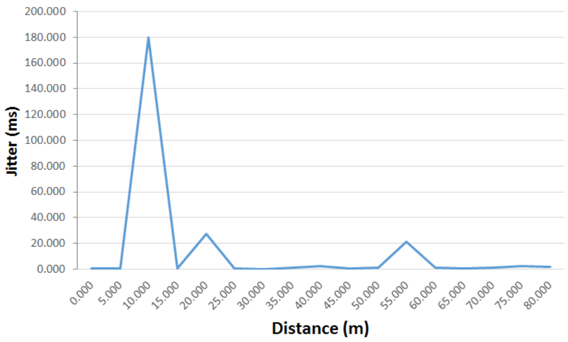

FIGURE 8: Variation of jitter with distance for UDP data

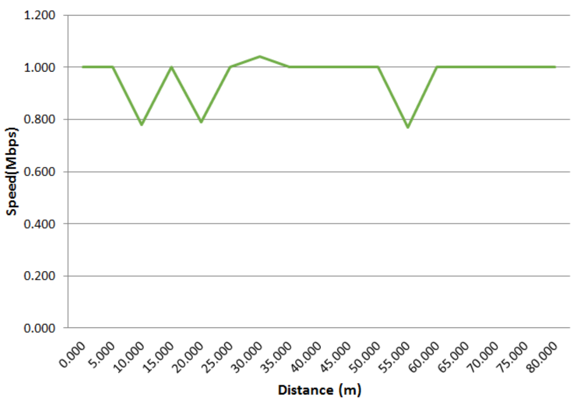

FIGURE 9: Variation of throughput with distance for UDP data

In the test area at distances of 10 m, 20 m and 55 m was rich with obstacles where a sudden drop of performance was observed. In wireless transmission due to different scenarios such as reflection, diffraction and scattering which occurs with the appearance of obstacles in the transmission path performance degradations happens.

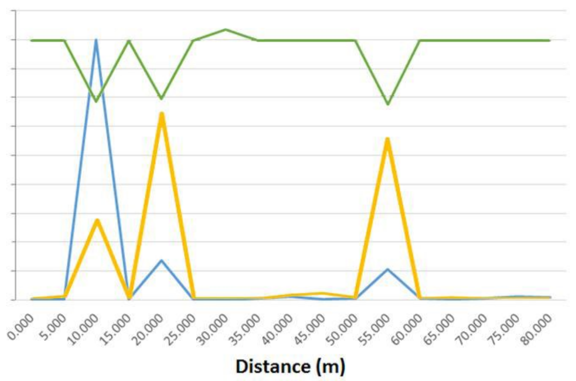

FIGURE 10: Variations of jitter, frame loss rate and throughput at same distances for UDP data.

FIGURE 10 shows the variations of jitter, throughput and frame loss rates at same distances and the vertical axis is not in to scale as the graph is intended to identify the relationship between the sudden fluctuations in each variation. In FIGURE 10 it is obvious that sudden drop in throughput and sudden rises in frame loss rate and jitter are occurred at same distances which were areas with obstacles.

Next the evaluation is done for generated Transmission Control Protocol (TCP) data. TCP is used for reliable data transmissions for applications such as file transferring. FIGURE 10 shows the variation of throughput for TCP data generated in the end user devices. The results show systems achieves higher speed for TCP data.

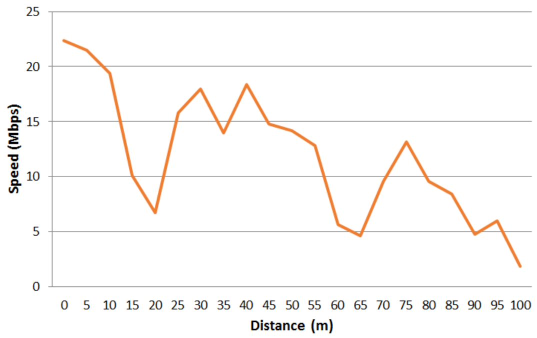

FIGURE 11: Variation of throughput with distance for TCP data.

5. CONCLUSIONS

In this paper, a wireless Ad-hoc network was proposed to promptly insure communication means to grasp the information within a disaster area for relief operations and survivor detection on the occurrence of disaster. By combining multiple wireless nodes, an adhoc network is organized in the disaster area or interrupted communication area as urgent communication means. The network is mainly aimed for the communication between rescue members who are working in relief operations in the disaster affected area. System provides different facilities other than voice communication such as broadcasting alert messages, file transferring, peer to peer texting etc. Such system could be much useful as anyone with a smart device having Wi-Fi capabilities could connect with the network. It should be considered that this type of a system may cost much lesser than the conventional systems hence can be effectively used in developing countries.

A Prototype system was constructed to evaluate its function and performance for different disaster applications. This system was evaluated in a test area which has a similar environment as in a post disaster area. The system is completely IP based where data transmission is done either as UDP or TCP. Hence the evaluation is done for both data types. According to the results it was highlighted that the system performance is low in obstacle rich areas hence the application is more suitable for post disaster areas with less obstacles. Also it is visible that TCP achieves much higher throughput than UDP, hence to achieve expected performances in real time applications such as VoIP and video transmission internodal data rates should be considerably high. Since the IEEE 802.11 b, g, n standards has a coverage area with a radius of 100 m there are limitations in spreading the network to wider areas. For this, Wi-Fi standards with longer transmission distances can be applied. For the prototype system we have successfully tested voice, broadcasting messages, peer to peer messaging and file transferring. The system is applicable for post disaster situations and with some advancement it can be successfully used as a low cost, easily deployable and effective system. Through this evaluation of the system, the usefulness of our suggested wireless adhoc network system could be verified.

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