Applications of Ad Hoc Networks in Disaster Management Areas

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ABSTRACT

In this paper we have studied the infrastructure less wireless networks especially in emergency situations where groups of rescuers must be on site to accomplish emergency tasks. It is necessary to establish a wireless communication in real time between individuals or groups. The nature of Ad Hoc network makes it suitable to be used in the context of emergencies or when the existing infrastructure is destroyed. In emergency cases Ad Hoc networks can be used to deploy small spontaneous networks quickly. Since nodes can be moved easily, the network may change rapidly and randomly. The ability of the nodes to be mobile makes it difficult to find an optimum route for the packet transfer. Optimizing the consumption of energy in disaster areas is the main objective of this paper, and is achieved by the combination of a low-power consuming algorithm and a power-aware routing strategy. A specific set of simulation studies tells a reduction in energy consumption whereas network performance is not affected much. This is the most important issue of our work in emergency situation, individuals can communicate longer and give more chance to rescuers to find them.

Keywords  
Ad Hoc, AODV, Long Term Evaluation, Sensor Nodes, Sleep-AODV, WARPWING, WSN

1. INTRODUCTION

Ad hoc networks does not require the aid of any centralized administration or fixed infrastructure such as base stations or access points but have the potential to offer effective communication services for groups of wireless mobile users. Nodes in an ad hoc network, automatically establish routing among themselves. Each node in an ad hoc network acts as a router and forwarding packets for other nodes and also acts as a host. Ad hoc networks have different characteristics like self-creating, self-organizing, self- administrating, multi-hop routing, dynamic network topology, network scalability, autonomous, infrastructure less and also some complexities like energy constrained operations, limited physical security, bandwidth constrained variable capacity links. It can be used in situation where infrastructure is not available, not trusted, too expensive or unreliable though it has many design challenges [1]. Mobile ad hoc networks provide pervasive computer environments that support users in accomplishing their tasks, accessing information and communicating anytime, anywhere and from any device therefore these are expected to become an important part of the future 4G architecture. Due to this kind of nature of ad hoc networks, it can be used in many applications like tactical network, emergency services, commercial and civilian environment, home and enterprise networking, education, entertainment, sensor networks, context aware services and coverage extension. The main objective of this paper is to present a survey of existing solution for disaster area scenario using ad hoc network and discuss various challenges for the same.

1.1 Ad hoc Network in Disaster Areas

Ad hoc networks are mainly appropriate for those applications where the deployment of a new fixed infrastructure is purposefully, spontaneous and practically difficult or not possible. Thus, ad-hocs are considered as the most suitable for disaster scenarios due to their capability of being self-organized, self-repairing, and self-recovery networks. Communication among team members is no more possible during disaster which may be caused by natural or man-made events because the infrastructure may be totally destroyed. Ad hoc networks are built up in different ways which are based on type of disaster area scenario. Several authors have proposed solution for particular type of disaster area scenario using ad hoc networks in order to perform relief or rescue operation model shown in Figure 1.

For the disasters which happened in Germany in May 2005 during preparation of the World Youth Day and FIFA Soccer World cup 2006, suspension railway crash in Wurppertal in 1999 and fire in amusement park near Cologne in 2001 D. G. Reina [2] has discussed three different disaster scenarios using ad hoc network. Using various performance metrics applicability of ad hoc
network in disaster area is shown in it. Quisle, L. E. and Galan, L. M. [3] have analyzed emergency and rescue scenario in urban area using ad hoc network. To test the performance of existing routing protocols they calculated the density of nodes and mobility model.

To provide communication between helicopters and first responder Y. Jahir and M. Atiquzzaman [4] proposed ad hoc network architecture for avionic application in disaster area.

Because Radio Frequency (RF) link, alone, does not provide high bandwidth for video application so, they have considered Free Space Optics (FSO) as primary link and RF as secondary link for communication. FSO links alone can be used for faster communication but mixture of FSO and RF can be used as backup path. They used AODV as base protocol to implement the idea of multi path (AODV-Hybrid) and result shows that AODVH performs better than AODV in terms of packet loss, average delay and throughput.

There are some challenges when ad hoc network is applied for disaster area scenario which must be met. For example, connectivity among the team members of rescue team, prediction of movement of team members, fast delivery of emergency messages, efficient utilization of battery power of nodes and security from outside attacker. Here we are considering some challenge; modelling mobility, connectivity, routing protocol as follows:

2. CHALLENGES


2.1 Modelling Mobility

During relief operation in disaster area scenario the mobility model represents the realistic movement of team members. Some of the models proposed by authors are as follows:

The mobility model for disaster area based on separation of room is proposed in [5], the model is based on an analysis of tactical issues of civil protection providing characteristics that influence network performance. During any disaster situation, movement of civil protection forces including rescue teams and fire brigades is strictly organized and structured. The team members do not move randomly but there may be one group leader which commands where and how to move. According to this, whole disaster scenario is divided in to five groups; incident location, patient waiting area, casualty clearing station, ambulance parking area and technical operational command as shown in Fig. 1. Incident location is that where actual incident is happened. Patients are transferred to casualty clearing station to provide them first aid after they have been kept in patient waiting area. If there is a requirement to transfer the patients to hospital then it is done by ambulances which are parked in specific area. Whole operation is commanded by team members who are in technical operation command area. They determine the mobility of each area using Random Way Point (RWP) model. Some of nodes may join/leave the network at any time. Each area is having entry and exit point through which node can enter or leave the specific area. Authors have compared their mobility model with RWP model and show realistic traffic modeling. Composite mobility model for disaster area which is based on power-law model instead of RWP has been proposed by S. Pomportes, J Tomasik and V. Veque [6]. To suffice the level of realism, it accommodates the essential features of disaster scenario like obstacle avoidance, group mobility, leader displacement more accurately than RWP. It uses Reference Point Group Mobility (RPGM) [7] model for group mobility, Levy–Walk model [8] for nodes mobility inside area and Voronoi diagram to avoid obstacles. They evaluated various aspects of their model like Levy–Walk does not concentrate the nodes in center of the simulation area as compared to RWP, the distribution of node degree for RPGM, RWP and Levy–Walk model and impact of obstacles on their mobility model.

A role based urban disaster mobility model has been proposed by D. Costantini, M. Munch, A. Leonardi, V. Rocha, P. S. Mogre and R. Steinmetz [9] for search and rescue operation. This mobility model is designed to represent the outdoor mobility in an urban post-disaster scenario. Instead of dividing the disaster area into sub-area, there will be an initial random movement of either first responder or victims. The information collected through extensive interview with first responders decides this, which depends on two entities called agents and events. Agents will have different roles and therefore different mobility behavior. The behavior of agents is affected by an event which can be fire or collapsed building. To produce realistic and reasonable simulations they have proposed their own simulator. It increases the number of discovered victims and related information and offers a faster discovery, which is the result that shows the benefits for search and rescue operations.

2.2 Connectivity

Cooperation in disaster scenario is of significant importance in order to support disaster managers to identify and coordinate for required tactical movements and response [10]. Connectivity among the team members of rescue team is a must to achieve this. So, one of quality of service parameters is based on the connectivity which should be guaranteed in order to
achieve the sufficient level of cooperation. By increasing the transmission power connectivity can be achieved but it depends on the devices as well technology being used. This issue can be considered as topological problem where objective is to find best topology to optimize parameters like end-to-end delay, bandwidth, throughput and minimizing energy consumption. Connectivity in disaster area has been improved by many authors like D. G. Reina et al [10] by placing auxiliary nodes in deployed scenario. Grid architecture to place auxiliary nodes (5 and 10) at specific distance which works only as a forwarder is also proposed by authors as shown in Fig 2. The disaster mobility model is based on separation of room [5] and scenario is generated using Bonn Motion [11]. A ratio of number of nodes that receive broadcast packet to the total number of nodes in scenario is the measuring criteria for reach ability metric shown in Figure 2.

**Fig 2: Grid Architecture**

Inter-communication and intra-communication these are the two types of communication between team members. Inter-communication is between two members of different area and intra-communication is between two members of same area [12]. There are total 126 positions of nodes at a distance of 50m and to increase the connectivity out of them 5 or 10 are placed at particular position. To find the optimal place of auxiliary nodes they use Genetic Algorithm (GA) and to find the fitness (reach ability) NS-2 is used.

Result shows that connectivity is improved by 23% and 37% respectively for inter-communication by placing 5 and 10 auxiliary nodes. Inter- communication connectivity is increased by 8% and 11% with 5 and 10 auxiliary nodes respectively.

It is observed that most of the auxiliary nodes are either placed inside a particular area or on the border. So, reduction of the size of grid architecture can be done by placing auxiliary nodes only inside the area and border.

### 2.3 Routing Protocols

An important role in performance of ad hoc network is played by routing protocols. They are responsible for deciding how information is going to flow in network. A routing table which keeps the information about routes to destination is maintained by the nodes in an ad hoc network. Based on the management of routing table, they are categorized in proactive, reactive and hybrid routing protocol. The proactive routing protocols maintain routes to all destinations, even though route is not currently active. The reactive routing protocols maintain only active route means the inactive or those routes whose life time is over, are removed from routing table. Hybrid protocols are combinations of both reactive and proactive protocol. Routing protocol’s performance is also measured and based on mobility of nodes in any scenario like disaster, military or human mobility.

The performance of reactive routing protocols for disaster mobility model was evaluated by D. G. Reina et al [2]. They have considered three reactive routing protocols: Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Ah hoc On Demand Multi path Distance Vector (AOMDV). Three different realistic disaster scenarios with different number of nodes and area size with 50 Constant Bit Rate (CBR) connections were taken by these authors. Result shows that AODV provides best result for all routing metrics: throughput, average end to end delay, normalized routing load and packet delivery fraction. DSR and AOMDV could be suitable for those cases where mobility is low but in rescue operations mobility is very high as injured patients are taken to the hospital as soon as possible.

Author [16] have proposed the design of ad hoc network for disaster scenario and tested the performance of routing protocols like AODV, DSR and Destination- Sequenced Distance Vector (DSDV). The disaster scenario is divided into four equal sized sub regions. The nodes inside the regions represent members of rescue team with personal communication devices with very low speed of 1 m/s. And other set of node (5) which are vehicles of rescue operation, moving at a speed of 20 m/s. For locating positions of each other and to inform one another the location of the disaster these nodes communicate with each other.

Evaluated the performance of ad hoc network in emergency and rescue operation for urban area using AODV, DSDV and Cluster Based Routing Protocol (CBRP). Result shows that performance of CBRP is better than AODV and DSDV in terms of sending packet rate, average delay and jitter and packet loss rate [14].

### 3. PROPOSED SOLUTION

In any emergency, the need for communication increases significantly. Thus, this paper presents a model to help enhancing and repairing the destruction in the network and communication channels, using Ad Hoc Wireless Networks. Main objective behind this model is to help the recovery and minimize time needed to reach the totally destroyed areas, since using an end-to-end will cause congestion and high load on the same paths available. Moreover this increases power consumption and increase delay time [13].

To overcome the challenges as mentioned in our paper we are proposing the following solutions:

- In order to maintain connectivity at the time of necessity of emergencies, we are using the LTE.
• For creating the path between the nodes, the routing protocol that we selected is AODV routing protocol.
• Last but not the least, in order to model and analyse the mobility of the nodes we are using Warpwing technology.

3.1 Long Term Evaluation
The LTE provides connectivity between the User Devices (UD) and the IP networks. It provides high rate at very low latency and these connections can be used by almost any application that uses IP communication. LTE is basically divided into two parts: the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core. The E-UTRAN contains the base stations called the evolved NodeBs (eNBs) that implements the radio protocol stack and it is responsible for radio transmission. During disasters, it is absolutely crucial that the important communications are always established. LTE can be used to support Multimedia Priority Services (MPS). MPS specified by 3GPP is a subscription-based service that can be used during network congestion to deliver and complete high priority tasks.

3.2 Adhoc On-Demand Distance Vector
The reactive on demand routing protocols establish the route to a particular destination only if it is needed. Adhoc on-demand Distance Vector (AODV) is one of the commonly used reactive on demand routing protocols in mobile ad hoc network (MANET). AODV is a reactive enhancement of the DSDV protocol.

In the first phase of disaster and at the place of the incident, there are nodes everywhere, some of them are isolated, and so the network is not loaded. The purpose of sleep- AODV protocol is to minimize the routing messages (overhead) caused by the large number of nodes, because a routing path with many entrances involve a large number of control packets, which consume more energy in the transmission and reception mechanism [15].

In the second phase when the topology can change drastically, mobility of node causes unstable nodes, we called every node as an unstable node whose links are broken after t second. Unstable nodes generate broken links, and at the same time the generation of control packets also affects, energy is consumed unnecessarily. Our sleep-AODV protocol checks the unstable nodes. They don’t need to have active paths, isolated nodes and nodes that are in areas where there is no communication. In the third phase there is stability of the network, because every node takes its proper place. AODV minimizes the number of packets involved in route discovery by establishing routes on-demand.

3.3 WARPWING
WARPWING stands for the Wireless Autonomous Robot Platform with Initial Navigation and Guidance. Users adapt parts of WARPWING to their varied custom applications, as are we. WARPWING is used to read the location the network of nodes, where they are placed at and which node is connected to which node, i.e. which node can transmit data to which node. WARPWING works well on any topological location while knowing the location of every node and the working condition of every node. So, it will tell which node is to be used for the transmission of data in the network. It defines the most optimum path on which the nodes to be used for transmission so that energy is used only by those nodes and energy is conserved, while the data is received quickly.

It reads live location of every node and checks which node is working better than other, which node will require less energy than other node. In this technology the location and stats of each node is fed into its software so that it can design the optimal path from each node to each other node.

4. RESULTS
Each point in the following graphs has been obtained by averaging out the result of five different simulations. Confidence intervals of 95 % have been added to the bar graphs.

4.1 Traffic Impact on the Network in Disaster
In figure 3 Sleep-AODV protocol loses a quantity of data packets from a low load (5.15) compared with AODV protocol. But these performances are predictable high network load more at low load because the packets sent with its stable paths in AODV against by increasing traffic causes interference and congestion, which causes more loss packets over node mobility and worm sending invalid paths, that explains this loss compared Sleep-AODV with increasing number of communication sessions.

Fig 3: Consumed Energy vs Traffic
Figure 4 shows us an idea of undelivered packets because the sources did not find their destinations. Note that all nodes using the AODV protocol is available and the number of undelivered packets is zero some of the number of connections. As against the AODV protocol Sleep the number of undelivered packets is increasing with increasing number of connections, because the nodes are inaccessible in the time to sleep. But despite this loss Sleep-AODV protocol is better than AODV in the network at high load as we have already shown in Figure 5.

In figure 6 for the two protocols we see that they have a long time packet transfer and they are influenced by the increase in traffic because of increased traffic leads to the occurrence of more collisions and more congestion. Consequently, data packets spend more time in queues communication interfaces due to frequent retransmissions. This explains the increase in the period of the two protocols by increasing the number of communication sessions. In all cases, the period of Sleep-AODV is the worst that can be trivially explained by the fact that the data packets spend more time in queues source nodes pending establishment paths because that are inaccessible knots (old).

The figures 7 reflects the evolution of the traffic overhead in terms of network load, we see that the control traffic increases dramatically with the number of connections. We also observe that the difference of control traffic generated by the protocols is very low when the number of connections is 5, but the difference increases dramatically when the network load increases (25, 35 connections). The overhead traffic generated by AODV represents 20% of that generated by Sleep-AODV heavy load, this is justified by the use of a larger number of control packets for the calculation and maintenance of roads because there inaccessible nodes in the case of sleep-AODV protocol because the state still sleeping.

5. CONCLUSION
We have presented the paper for post disaster operation using ad hoc network to provide the relief operation. We also discussed the challenges like modelling mobility, connectivity and routing protocol for ad hoc network to perform efficiently in disaster scenario, which we fought by using, mainly, three technologies which are WARPWING, LTE, AODV Routing protocol.

We have demonstrated by various scenarios that the proposed solution is efficient and provides a significant
performance on the level of packet reception and energy consumed. This also enables the Ad hoc nodes to repair any distortion or interruption in the communication channels in the disaster areas. In which should help in the recovery and rescuing in such areas.

6. REFERENCES