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An Application of Ad Hoc Networks in Disaster Area for Search and Rescue Operation: A Survery and Challenges

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Abstract: Ad hoc network is infrastructure less network which posses characteristics like decentralized administration and very less efforts for setup. Due to this, it is most suitable for many applications like military, disaster area, rescue operation, collaborative computing and conference meeting where it is not possible to setup wired network or infrastructure based wireless network. During any disaster which can be natural or man-made, existing infrastructure may be destroyed so, ad hoc network can facilitate communication among team members (nodes) of rescue team during post disaster situation. There are many challenges for ad hoc network like modeling mobility, connectivity, routing protocol, broadcast method, and energy saving when it is applied to such disaster scenario. This paper presents a survey on ad hoc network for disaster area and discusses challenges and solution which are presented in literature as well some future direction.

Keywords: ad hoc networks; mobility model; routing protocol,; connectivity; broadcast; disaster scenario

I. INTRODUCTION

Ad hoc networks have the potential to offer effective communication services for groups of wireless mobile users, without requiring the aid of any centralized administration or fixed infrastructure such as base stations or access points. In an ad hoc network, nodes automatically establish routing among themselves. Each node in an ad hoc network acts not only as a host but also as a router and forwarding packets for other nodes. Ad hoc networks are having different characteristics and complexities like self-creating, self-organizing, self-administrating, multi-hop routing, dynamic network topology, energy constrained operations, limited physical security, bandwidth constrained variable capacity links, network scalability, autonomous and infrastructure less. Despite many design challenges, it can be used in situation where infrastructure is not available, not trusted, too expensive or unreliable [1]. Mobile ad hoc networks are expected to become an important part of the future 4G architecture, which aims to provide pervasive computer environments that support users in accomplishing their tasks, accessing information and communicating anytime, anywhere and from any device. 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. The remaining paper is organized as follows. Section 2 discusses on how ad hoc network is useful for disaster area and existing solution proposed in literature. Section 3 describes challenges when ad hoc network is used in disaster area situation as well future direction for the research. Finally conclusions are drawn in section 4.

II. ADHOC NETWORK IN DISASTER AREA SCENARIO

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, MANETs are considered as the most suitable candidates for disaster scenarios due to their capability for being self-organized, self-repairing, and self-recovery networks. Disaster which may be caused by natural or man-made events, infrastructure may be totally destroyed and communication among team members is no more possible. Ad hoc networks are setup in different way 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.

D. G. Reina [2] has discussed three different disaster scenarios using ad hoc network 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. It shows the applicability of ad hoc network in disaster area using various performance metrics. Quispe, L. E. and Galan, L. M. [3] have analyzed emergency and rescue scenario in urban area using ad hoc network. They also calculated the density of nodes and mobility model to test the performance of existing routing protocols. Y. Jahir and M. Atiquzzaman [4] proposed ad hoc network architecture for avionic application in disaster area which provides communication between helicopters and first responder. As Radio Frequency (RF) link only 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. Only FSO links can be used for faster communication and

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mixture of FSO and RF 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 in than AODV in terms of packet loss, average delay and throughput.

III. CHALLANGES

When ad hoc network is applied for disaster area scenario then there are some challenges that must be met by ad hoc networks. For example, there must be 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 four challenges; modeling mobility, connectivity, broadcasting and routing protocol which are as follows:

A. Modeling Mobility

Mobility model represents the realistic movement of team members in disaster area scenario during relief operation. Many authors have proposed mobility model for disaster scenario which are as follows:

N. Aschenbruck, E Gerhards-Padilla and Peter Martini [5] proposed the mobility model for disaster area based on separation of room. The model is based on an analysis of tactical issues of civil protection and which provides characteristics influencing network performance. During any disaster situation, civil protection forces including rescue teams and fire brigades are structured and their movement is strictly organized. The team members do not move randomly but there may be one group leader which commands where and how to move or in which are to work. 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. Injured patients are transferred to patient waiting area from where they are moved to casualty clearing station to provide them first aid. If patients are required to transfer 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 determined 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. In future, performance analysis can be carried out of existing power control algorithms and routing protocols for this mobility model. Group mobility is not taken into account in this model so, it can be explored as further research.

S. Pomportes, J Tomasik and V. Veque [6] have proposed composite mobility model for disaster area which is based on power-law model instead of RWP. To represent sufficient 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.

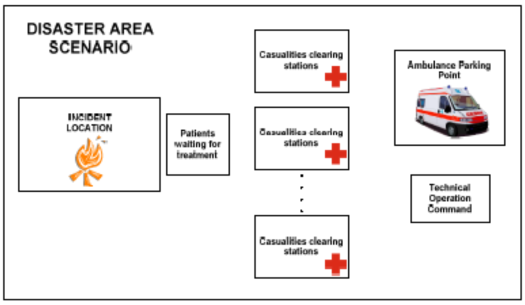

Figure 1. Disaster Area Scenario based on Separation of Rooms

D. Costantini, M. Munch, A Leonardi, V. Rocha, P. S. Mogre and R. Steinmetz [9] have proposed role based urban disaster mobility model 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. It is based on information collected through extensive interview with first responders which depends on two entities called agents and events. Agents will have different roles and therefore different mobility behavior. An event which can be fire or collapsed building, which affects the behavior of agents. They have proposed their own simulator to produce realistic and reasonable simulations. The result shows the benefits for search and rescue operations; in particular it increases the number of discovered victims and related information and offers a faster discovery.

B. Connectivity

Cooperation in disaster scenario is of significant importance in order to support disaster managers identifying and coordinating required tactical movements and response [10]. This can be only achieved if there will be connectivity among the team members of rescue team. So, connectivity is considered as one of quality of service parameters which should be guaranteed in order to achieve the sufficient level of cooperation. Connectivity can be achieved by increasing the transmission power but it depends on the devices as well technology being used. Connectivity 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. In literature, many authors D. G. Reina *et al* [10] improved connectivity in disaster area by placing auxiliary nodes in deployed scenario. Authors have proposed grid architecture to place auxiliary nodes (5 and 10) which is shown in Fig. 2 at specific distance which works only as a forwarder. The disaster mobility model is based on separation of room [5] and scenario is generated using BonnMotion [11]. Connectivity is measured as rechability

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metric which is ratio of number of nodes that receive broadcast packet to the total number of nodes in scenario. Broadcast packet is chosen because it is used to disseminate emergency data in ad hoc network. There are two types of communication between team members: one is inter-communication which is between two members of different area and other is intra-communication which is between two members of same area. There are total 126 positions of nodes at a distance of 50m and out of them 5 or 10 are placed at particular position to increase the connectivity. They used Genetic Algorithm (GA) to find the optimal place of auxiliary nodes and NS-2 is used to find the fitness (rechability). Result shows that by placing 5 and 10 auxiliary nodes connectivity is improved by 23% and 37% respectively for inter-communication. Inter-communication connectivity is increased by 8% and 11% with 5 and 10 auxiliary nodes respectively.

It is observed that placement of most of the auxiliary nodes is either inside particular area or on the border. So, one can reduce the size of grid architecture by placing auxiliary nodes only inside the area and border. Instead of GA, Particle Swarm Optimization (PSO) or Cuckoo Search (CS) can be applied to find the optimal position of auxiliary nodes in reduced grid architecture as a further research.

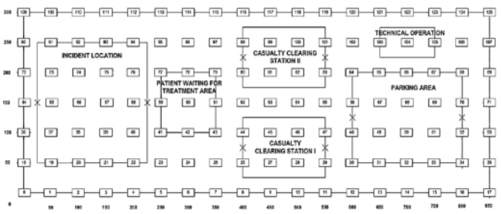

Figure 2. Grid Architecture

C. Broadcast

Broadcast is the important for disseminating emergency message among rescue team members to exchange tactical information efficiently. Routing protocol uses broadcast approach for route discovery and transmit error message for invalid route. Due to limited communication range and battery life of nodes in ad hoc network, it is required to optimize energy consumption while designing broadcast method. The broadcast methods used earlier for ad hoc networks are categorized in statistical or geometric and network topology based [12]. The former category depends on some threshold value based only on local information, while in latter category uses network topology information to decide broadcast schedule. Some authors have presented the concept of adaptive broadcasting methods which are more efficient than aforementioned.

Intelligent broadcasting methods also have been proposed [13], which based on machine learning approach. Each node maintains classifier and trains it on data which are collected from the network environment. There are three classes of their protocols which are pure machine learning, inter-protocol learning and intra-protocol learning. New probabilistic approach for broadcasting [14] which overcome the limitation of existing scheme like they are not suitable for real life scenario such probability of rebroadcast operation and threshold rebroadcasting permission which is caused by collecting local neighborhood's connectivity by broadcasting HELLO packets. They used number of neighbors and transmission range to determine the probability of forwarding. Result shows that packet collision and overhead is reduced compare to blind flooding, smart probabilistic broadcasting and fixed probability flooding.. A new dynamic counter based broadcasting method is proposed [15] which use dynamic threshold value to increase successful delivery rate of packets and throughput of network. Result shows that their method outperforms counter based and flooding scheme, in terms of reducing overhead by 28% for low speed (1 m/s) nodes and 58% for high speed (20 ms/s) nodes.

D. G. Reina *et al* [16] proposed technique to optimize broadcasting in disaster area scenario using GA. Many broadcasting techniques are proposed in literature but there are not any adaptive broadcasting schemes for disaster response scenario so far. They proposed probability based broadcasting techniques which uses local topological features of nodes like similarity and dissimilarity coefficient to know the condition of their neighborhood. If both nodes share numerous neighbors that means both are similar and if they share low number of neighbors then it is dissimilar. Also they used other parameters that are to be adjusted such as Random Assessment Delay (RAD), the minimum forward probability and probability function exponent. GA is used to find the optimum value for each of these three parameters and fitness is calculated based on product of rechability and save rebroadcast.

D. Routing Protocols

Routing protocols play important role in performance of ad hoc network. They are responsible for deciding how information is going to flow in network. Nodes in ad hoc network maintains routing table which keep the information about routes to destination. 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 thought route is not currently active. The reactive routing protocols maintain only active route means inactive or whose life time is over, route is removed from routing table. Hybrid protocols are combinations of both reactive and proactive. Routing protocol's performance is also measured based on mobility of nodes in any scenario like disaster, military or human mobility.

D. G. Reina *et al* [2] evaluated the performance of reactive routing protocols for disaster mobility model [5]. They have considered three reactive routing protocols: Adhoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Ah hoc On Demand Multi path Distance Vector (AOMDV). Authors have taken three different realistic disaster scenarios with different number of nodes and area size with 50 Constant Bit Rate (CBR) connections. Result shows that AODV provides best result for all routing metrics: throughput, average end to end delay, normalized routing load, 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.

S. Kumar, R. K. Rathy and D. Pandey [17] 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 and nodes inside region represents members of rescue team with personal communication devices with very low speed of 1 m/s. Another set of node (five) which are vehicles of rescue operation, moving at a speed of 20 m/s. These nodes communicate with each other for locating positions of each other and to inform one another the location of the disaster.
In their study they have taken both the directional movement and random movement of vehicular nodes as follows:

Directional Movement: The 5 nodes are placed on the diagonal with the node on the centre is fixed. The other four nodes are moving on the diagonal with 20m/s towards the centre node and again go back towards the corner. These four nodes are communicating with the centre node and also with the nodes in the adjacent regions.
Random Movement: In this scenario the vehicle nodes are moving randomly with 20m/s.

Result shows that overall disaster recovery operation monitored from centre of terrain with four fast moving vehicle nodes moving along the diagonal and communicating with the nodes in sub region's rescue team members provide better results as compared to random motion of all the five fast moving nodes. The packet-loss is very low for the DSR protocol compared to AODV and DSDV. The simulation results reveal that DSR should be considered for a scenario where paths are limited to few hops and there is a requirement of less number of control overheads.

It is concluded that none of the existing routing protocol is suitable for disaster scenario which can satisfy all its requirements to carry out rescue operation very efficiently.

Quispe, L. E. and Galan, L. M [18] 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.

IV. CONCLUSION

In this paper, we have discussed application of ad hoc network in disaster scenario. Due to characteristic of ad hoc network, decentralization and infrastructure-less, it can be setup spontaneously if existing infrastructure and communication system is destroyed after any disaster happens. We have presented the survey of post disaster operation using ad hoc network to provide the relief operation. We also discussed the challenges like modeling mobility, connectivity, broadcast and routing protocol for ad hoc network to perform efficiently in disaster scenario. Some future directions are also suggested which can be the part of further research.

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