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A Smartphone based Framework for Disaster Management

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Abstract**:** *A Mobile Ad Hoc Network (MANET) is defined as a collection of two or more nodes connected with each other through some kind of wireless communications and networking capability that enables them to communicate with each other without the need of any centralized server. This enables the wireless nodes to dynamically form a network to exchange information without using any existing fixed network infrastructure. It is an autonomous system in which mobile hosts connected by wireless links are free to be dynamically behaving as either the nodes or act as routers at the same time. The main advantages of MANET are robustness, flexibility and mobility. In this paper, we explore these advantages of MANET for disaster management. Whenever a disaster occurs, the major problem that hampers the relief operation is lack of communication as most of the times the communication networks in the disaster affected areas are damaged partially or fully. The MANET being a kind of on demand network, comes as a rescue for the damaged networks and can be of tremendous use in disaster management.*

Keywords: Smartphone Networks, Wireless Networks, MANET, Disaster Management, Ad Hoc Networks.

INTRODUCTION

An Adhoc network is a set of independent nodes connected together with a wireless link [1]. The nodes in the ad hoc network communicate with other nodes without any physical connection or fixed topology. The nodes can instantly form the network whenever the need for communication is established and communicate using radio waves. It is a distributed network and the nodes communicate with each other without fixed station access point (AP) or base station. [2]. Due to the absence of a centralized server, the nodes in an ad hoc network also act as routers to send and receive the data. The main advantage of adhoc networks is that due to their non-static nature, the single point of failure is avoided which makes them more robust and ideal for adverse conditions such as disaster management. Various man-made and natural disasters have highlighted the need for effective communication systems that would help in disaster management in warning and rescue operations. Whenever a disaster situation occurs, problems in the process of disaster management come up due to the lack of communication facilities. Due to the damage of communication network, it becomes impossible to send disaster warnings to nearby areas and to transmit updates about the exact situation of losses after disaster monitoring that could aid in rescue operations. During disasters, the Local Area Networks (LANs) are also affected and they cannot be used for communication either. The overall scenario in a disaster struck area is hostile and in order to operate in such environments the networks deployed should be robust and irrepressible. An emergency on demand network has to be set up that has to provide the required Quality of Service (QoS) to ensure augmented performance with limited resources. Moreover all this has to be done in a limited time span as lives are at stake. Whenever a disaster strikes, communication links are often disrupted partially or fully, but for the disaster relief teams, these links are very essential in order to effectively provide disaster recovery and for this they have to find information about critical questions such as which are the affected areas exactly, how many people have been injured or died, where the injured are exactly located and the amount of manpower and medical help needed[3]. In disaster and emergency situations, communications can save lives. In earlier times, when the communication systems were not much developed, the relief operations in disaster like emergency situations was not very effective. Even today, in under developed nations, where the communication infrastructure is weak, the emergency management is poor. The lack of funds for communication development leads to weaker infrastructures as compared to the developed nations where lot of focus is given to the development of communication facilities. The breakdown of communications infrastructure, due to the collapse

of antennas and buildings and disruption of power supply in the affected areas is the usual effect of disaster. Whether partial or complete, the failure of communication infrastructure leads to delays in rescue operations in disaster affected areas and ultimately causes loss of lives and damage to property which could have been prevented [4]. Despite the increasing trustworthiness of modern communication networks, the risks associated with communication failures are a cause of serious concern because of the growing dependence on these systems for emergency situation management. Wireless adhoc networks are therefore finding way into all sorts of emergency management situations. In this paper we have discussed about disaster management and the role of MANETs in disaster management. We have also proposed a framework to utilize the smartphone adhoc network for disaster management.

WIRELESS AD HOC NETWORKS

A wireless adhoc network also referred to as a mobile adhoc network (MANET) is a collection of two or more devices or nodes which are connected to each other through wireless communication media. The networking capability of these networks is established with or without the need of any centralized server or access point. These nodes can dynamically form a network to exchange information without using any existing fixed network infrastructure. It is an autonomous system in which mobile hosts are connected by wireless links and these nodes are free to act as nodes themselves or as routers at the same time as per the communication requirements of the network. All nodes in a wireless ad hoc network may have to act as a router and host at the same time as the network topology in an adhoc network is also dynamic and may change with nodes joining and leaving the network. These special features of Mobile Ad Hoc Network (MANET) makes this technology of great use but is accompanied by several challenges [8].

All the nodes and devices are responsible to organize themselves dynamically for the communication between each other and to provide the required network functionality in the absence of fixed infrastructure. Thus, in such kind of networks, the maintenance, routing and management are performed by all the nodes.

MOBILE AD HOC NETWORKS (MANET)

A Mobile Ad hoc Network (MANET) is an independent network of mobile devices that are connected over various wireless links. It works on a limited bandwidth. The network topologies are dynamic and may vary from time to time. Each node on a MANET may act as a router for transferring data among the connected devices. This network has the capability to operate by itself or it may be connected to a fixed network through an access point. The application of MANET can ranged from small, static networks that are limited by bandwidth and power, to large-scale, mobile, highly dynamic networks[10].

Since a MANET does not require a fixed infrastructure, it is a highly suitable network in circumstances where fixed infrastructure is not available or is damaged due to a disaster and setting up of new infrastructure is not possible as it will be costly and time consuming.

The nodes on a MANET work as routers also and separate installation of routers is not required. This leads to quickly installation of the network with minimum user intervention. There is no central access point for the network and the topology is not fixed. Therefore, all the devices are free to move and can join and leave the network as per the requirement. MANETs can be connected to the Internet as different types of devices can be used in this network that can be made compatible with existing cellular network infrastructures to extend the coverage and interconnectivity.

ROUTING PROTOCOLS FOR MANETS

Routing in MANETs consists of Route discovery and route maintenance.

Route discovery is the process of Initial discovery of valid route from source to destination. For this, the Source node can send a query for a destination node. Only destination node responds to query and if the destination is located in source's transmission range, destination responds and the link is established. No periodic routing updates are needed in MANET.

Route Maintenance process of maintaining the route once established. Nodes can determine broken links through ACK/NACK included with most protocols. If a link is broken, the node that detects the broken link

either reports this information back to the sending node or the node can try to fix the broken link by sending out its own route request to the destination. If no ACK/NACK is present in the link-layer protocol, nodes can listen to channel to determine if next hop transmits packet or not. If the node does not hear forwarding of packet, it assumes that the link is lost. Explicit routing acknowledgements can also be used to determine the state of the links.

The routing protocols in MANET are classified as Proactive Routing Protocols and Reactive Routing Protocols.

Proactive Routing Protocols

A proactive approach to MANET routing seeks to maintain a constantly updated topology understanding. The whole network should, at all times, be known to all nodes. This results in a constant overhead of routing traffic, but no initial delay in communication.Proactive routing are those protocols that require the nodes to continuously evaluate and update the routes. Each node maintains consistent, up-to-date routing information in the form of a table with the next-hop to reach every node in the network. Changes in link state are transmitted throughout the network to update each node's routing table.

Proactive routing protocol: OLSR (*Optimized Link State routing)*

The *Optimized Link State routing*(OLSR) is a table-driven proactive routing protocol. It uses the link-state routing scheme in an optimized manner to distribute topology information. In a traditional link-state algorithm, link-state routing information is flooded throughout the network. OLSR also uses this approach, but since the protocol runs in wireless multi-hop scenarios the message flooding in OLSR is optimized to preserve bandwidth. The optimization is based on a technique called *MultiPoint Relaying (MPR)*.

Being a table-driven protocol, OLSR operation mainly consists of updating and maintaining information in a variety of tables. The data in these tables is based on received control traffic, and control traffic is generated based on information retrieved from these tables. The route calculation itself is also driven by the tables [14].

Reactive Routing Protocols

Reactive protocols seek to set up routes on-demand. If a node wants to initiate communication with a node to which it has no route, the routing protocol will try to establish such a route.Reactive Routing Protocols are those routing protocols where the nodes evaluate and update routes only when they are needed. When a node has a packet to send, it checks to see if it has a valid route to the destination. If there is no valid route known, node must send out a route-request message to obtain a valid route (controlled flooding of the network). Data is sent to the destination using the valid route. This type of routing is efficient if the routes are not used often. Routes are created only when needed. This requires "route discovery" and "route maintenance". This is also called "source-initiated on-demand routing" and the goal is to minimize the amount of overhead compared with proactive routing at the expense of latency in finding a route when it is needed.

Reactive routing protocol:AODV (*Ad-Hoc On-Demand Distance Vector* routing protocol)

The *Ad-Hoc On-Demand Distance Vector* routing protocol is a reactive routing protocols, and in this protocol the topology information is only transmitted by nodes on-demand. When a node wishes to transmit traffic to a host to which it has no route, it will generate a *route request* (RREQ) message that will be flooded in a limited way to other nodes. This causes control traffic overhead to be dynamic and it will result in an initial delay when initiating such communication. A route is considered found when the RREQ message reaches either the destination itself, or an intermediate node with a valid route entry for the destination. For as long as a route exists between two endpoints, AODV remains passive. When the route becomes invalid or lost, AODV will again issue a request [14].

DISASTER MANAGEMENT

A disaster is an unforeseen event or an accident caused by human intervention or due to natural calamities that causes loss of lives and infrastructure in the affected areas. Although it occurs rarely but it cannot be avoided whenever it's bound to occur leading to catastrophic loss of property, money and lives resulting in tremendous damages to human civilization, ecosystem and the overall environment. Disaster management is the process of

monitoring, controlling, planning and responding to the disaster situation and includes both pre and post disaster activities. It refers to the management of both the risk and the consequences of disaster. [5]

Disaster monitoring and management is one of the most challenging and important application of wireless ad hoc networks. It is so because whenever a disaster occurs, it destroys the communication networks and one of the initial steps in disaster management is to set up communication with the affected areas. As establishing infrastructure based networks are neither feasible nor suitable in these environments, wireless adhoc networks seem to be an effective means to establish communication. The disaster being an unforeseen event, strikes suddenly and does not give time to the authorities for advance planning to anticipate and manage the situation to minimize its effect.

Phases of Disaster

The emergency managers prepare for and respond to a disaster in four phases: 1) mitigation; 2) preparedness; 3) response; and 4) recovery.The model helps frame issues related to disaster preparedness as well as recovery after a disaster. Each phase has particular needs, requires distinct tools, strategies, and resources and faces different challenges.

MITIGATION *Pre-Disaster Mitigation Efforts*	**PREPAREDNESS** *Education, Outreach and Training* *Emergency Management Planning*
RESPONSE *Immediate Response to Stakeholders*	**RECOVERY** *Post-Disaster Recovery Plan*

Phases of Disaster

1) Mitigation

Mitigation involves steps to reduce vulnerability to disaster impacts such as injuries and loss of life and property. This might involve changes in local building codes to fortify buildings; revised zoning and land use management; strengthening of public infrastructure; and other efforts to make the community more resilient to a catastrophic event.

2) Preparedness

Preparedness focuses on understanding how a disaster might impact the community and how education, outreach and training can build capacity to respond to and recover from a disaster. This may include pre-disaster strategic planning and other logistical readiness activities. The disaster preparedness activities guide how to better prepare people and the business community for a disaster.

3) Response

Response addresses immediate threats presented by the disaster, including saving lives, meeting humanitarian needs (food, shelter, clothing, public health and safety), clean-up, damage assessment, and the start of resource distribution. As the response period progresses, focus shifts from dealing with immediate emergency issues to conducting repairs, restoring utilities, establishing operations for public services (including permitting), and finishing the clean-up process.Initial period of disaster management assesses and deals with

the most pressing emergency issues. This period is often marked by some level of chaos, which can last a month or more, depending on the nature of the disaster and the extent of damage.

4) Recovery

Recovery is the fourth phase of disaster and is the restoration of all aspects of the disaster's impact on a community and the return of the local economy to some sense of normalcy. By this time, the impacted region has achieved a degree of physical, environmental, economic and social stability.

THE ROLE OF ICT in Disaster Management

At the mitigation stage, people have to be taught about disasters and how should they react in case a disaster strikes. Media such as television and radio is generally used to spread awareness. Social networks can play an important role in this activity.

In the preparedness phase, the smartphones have to be equipped with the features to form adhoc networks in case of a disaster striking. This can be implemented by assigning certain points of contact in a given area where the smartphones with adhoc capability are allocated to people so that in case of a disaster, adhoc network can be formed.

ICT has the most important role in the response phase and the proposed framework is designed to work at this phase only.

MANET BASED DISASTER MANAGEMENT

One of the major effects of catastrophic disasters is the failure of conventional communication systems. The communication towers are generally collapsed completely or partially after the disaster strikes. This further makes the rescue operations difficult as the authorities are not getting proper updates of the actual loss and the help required [6]. In order to deploy the disaster relief operations to save human lives, communication networks are extremely important. Communication and exchange of Information are extremely vital for disaster response in order to gather information and make important decisions. Therefore, one of the first things required to start the rescue operations after the disaster strikes is a rapidly deployable, robust to failures, easily maintainable and service provider independent communication system. The available technology options for this purpose are limited and one of the most helpful technologies for the purpose is of wireless adhoc networks [11]. Use of wireless Ad-hoc networks to set up a communication network by utilizing only the existing infrastructure in a post disaster situation can help in coordinating the activities for disaster management. The wireless adhoc network can be set up by using the existing laptops and smartphones also which may have not been destroyed by the disaster. These devices can communicate among themselves by forming a Mobile AdHoc Network (MANET). To communicate with the control system that is situated far away, only one of the devices in the MANET has to be connected to a long distance transceiver. Such kind of a network can be used for disaster management by enabling the disaster struck people to share the updates of the situation with the disaster monitoring team and as per the situation, the rescue operations can be planned and executed [15].

Smartphone based adhoc network

Smart Phone Ad Hoc Networks (SPANs) have evolved from the underlying concept, architecture and technology behind a wireless ad hoc network. A smart phone is a mobile device and it can be embedded with ad hoc networking technology. Then a smart phone can create ad hoc networks among themselves and with other devices like tablets and laptops. Smart phone ad hoc networks utilize the existing hardware for communication such as the Bluetooth and Wi-Fi which is commercially available in smartphones to create peer-to-peer networks without relying on cellular carrier networks, wireless access points, or traditional network infrastructure. SPANs use the mechanism behind Wi-Fi ad-hoc mode, which allows phones to talk directly among each other, through a transparent neighbour and route discovery mechanism.Smart Phone Ad Hoc Networks support multi-hop routing (ad hoc routing) and relays and there is no concept of a group leader, so peers can join and leave at will without destroying the network.

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Features of a Smart Phone Ad Hoc Network

A Smart Phone Ad Hoc Network is capable of enabling peer-to-peer communications without relying on cellular carrier networks, wireless access points, or traditional network infrastructure.

- It can provide Internet access through gateway devices, such as mobile hotspots in the mesh.
- It can operate with both stationary and portable infrastructures such as routers, mesh extenders, or other non-phone hardware.
- It uses the devices that people carry personally and use every day.
- A Smart Phone Ad Hoc Network primarily uses Bluetooth and Wi-Fi since the cellular spectrum is not available at times.

A Smart Phone Ad Hoc Network is an on demand network that can be set up and shut down as per user requirement and the nodes are free to join and leave at will.Routing protocols are implemented at the Network Layer or the Link Layer.

Some of the Important Applications of Smart Phone Ad Hoc Networks are:

- These networks can be an important source of communication in developing nations where network infrastructure doesn't exist in certain regions.
- These networks can be an important source of communication during natural disasters or terrorist incidents where existing network infrastructure is overloaded, destroyed, or compromised.
- These networks can be an important source of communication in temporary Large-scale events where huge scale communication is needed for short period of time

SMARTPHONE BASED AD HOC NETWORK FRAMEWORK FOR DISASTER MANAGEMENT

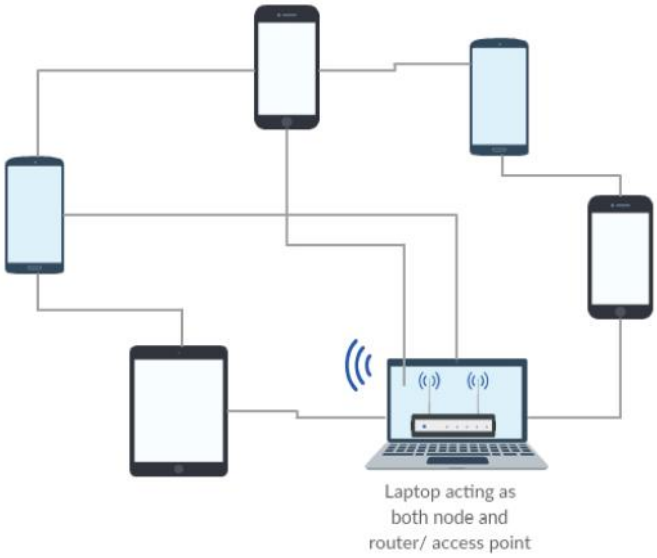

Figure 1: Smartphone Ad Hoc Network for Disaster Management

The proposed framework helps in disaster management in 3 stages.

STAGE 1:DISASTER ASSESSMENT

This is the initial phase in the disaster response. The disaster situation is assessed to find the level of losses so that action can be taken accordingly. The first priority for any emergency handling is to save the lives of people. Therefore, the disaster management team first locates the area where people are struck so that help can reach them at the earliest. This assessment is done by the emergency team visiting the disaster struck areas and also from the sky through helicopters and other aerial devices.

STAGE 2: LOCATING MOBILE DEVICES

Once the assessment is done and regions are located where people are struck, the next stage is to locate mobile devices in the region. These can be smartphones, tablets, laptops, etc. The effect of disaster on communication networks makes communicating impossible as the communication towers are usually damaged partially or fully.

STAGE 3:BUILDING COMMUNICATION

After the mobile devices are located, the communication has to be started between them. We have proposed the use of adhoc networks in this scenario. Since an adhoc network works without a fixed infrastructure, the loss of network infrastructure due to the disaster would not have an impact on the adhoc network.

We have suggested the use of a network of smartphones as they are the most common mobile device in today's world. Once the communication is established, it would allow faster relief work as the emergency workers will be able to contact each other and disseminate information about the relief work in different areas.

CONCLUSION

Disaster is a condition that is unavoidable most of the times. Disaster management deals with handling the disaster in the best possible manner and it involves disaster monitoring and disaster relief. Ensuring strong communication during disaster relief is very important for rescue operations, as it helps in locating the affected areas and people and therefore allows the relief team to reach out to them and provide help. Tragedies caused by man-made and natural disasters have highlighted serious flaws in the communication systems especially in under developed countries and the need for more effective disaster monitoring and response systems has been felt. Wireless networks are currently undergoing extensive research to create better wireless systems for emergency situations. A lot of progress has been made in wireless technology for disaster relief and the ongoing research in this area is very promising.

One of the most useful developments in the field of communication technology is wireless adhoc networks. These networks being able to function without the fixed infrastructure are very useful in situations when the communication infrastructure is damaged due to a disaster. Mobile Ad hoc Network (MANET) can be used in emergency situations for rescue operations for disaster relief where communication infrastructure is either nonexistent or damaged and an infrastructure less on demand communication network is required. This kind of a network can be set up by using small handheld devices such as smartphones or tablets and information sharing can be done from one rescue team member to another. Most of the times, disasters strike without any prior warning and establishment of infrastructure for communication is therefore not possible especially in remote areas where there are no preexisting communication systems. In this situation also, MANET is the best the solution for communication for disaster management.

Using smartphones to create an adhoc network can be a very effective component in handling the communication problems in emergency situations. In the worldwide scenario today, smartphones are the most commonly used devices for communication. In case of an emergency situation like a disaster, the communication network is destroyed but most of the small devices like the smartphones are saved. The problem is that the destruction of mobile towers makes these devices useless as communication is not possible without the availability of cellular networks. In such a scenario if the smartphone adhoc network is formed, it can act as a major communication system. But the major limitation in this regard is that most smartphones are not having adequate resources required to be a part of the wireless adhoc network. A major step in this direction would be to develop certain applications that would make it easier to set up smartphone adhoc networks.

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