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MANET Based Emergency Communication System for Natural Disasters

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***Abstract* – Natural disaster stricken many areas of world every year, efficiency of rescue operation is very critical to life saving of trapped victims. However, cellular communication system is usually crashed when disaster hits an area which makes coordination very difficult among rescue volunteer teams. Unfortunately many of existing emergency communication system may not be feasible. In this paper, we proposed concept of hybrid cellular-MANET architecture which use working cellular base station if they are not crashed. We also give a routing scheme for this emergency scenario which efficiently utilize available communication and energy resources of devices. The proposed emergency communication architecture is aware of mobility of devices and also support self organizing feature of MANET. This communication model can be setup in disaster hit area within few hours.**

Keywords – MANET, Disaster area, Emergency Communication

I. INTRODUCTION

Almost every year natural disaster like flood, tsunami, earthquake, landslide, hurricane etc of varying intensity hit many areas of the world. Because of these accidental events many lives trapped in disastrous area. These trapped people may have large chance to survive if they rescued within 72 hours referred as *"Golden 72 hours"* [1]. These affected victims in disastrous area need a communication system for various reasons like reunion of family, allocation of relief resources and rescue teams. However, when disaster occurs, the communication facilities, which it is fixed or mobile hampers. Rescue operation in these disastrous areas become extremely difficult because of the loss of communication system. Now days it is a tedious job to reestablish the communication system. As a result, many trapped victims died because they did not get any chance to be rescued.

In these disastrous situations, trapped lives need a communication system with the same priority as they need water, food, medical facility, protection and shelter. Emergency communication system is considered as life saving support system which provides emergency facilities to victims, support rescue teams to help victims and as a communication infrastructure in disastrous area [1][2].

A hybrid cellular mobile ad hoc network (hybrid cellular MANET) can provide a solution for emergency communication system in disaster hit areas. In this kind of network, mobile nodes (devices) connected through Wi-Fi interface to each other and they can also connect directly to the access points which are dropped in disastrous area [3][4]. This emergency network uses the features of cellular communication if any of base station is alive [3][5]. In existing emergency communication solutions, there is a need of extra equipments such as satellite phone and user should be aware of operation of these devices [3]. But in the proposed system, trapped victims use their smart phones or similar devices for communication purpose. There is no need of any new devices or new technology.

There are many major challenges to design such a hybrid cellular-MANET. Mainly this kind of system must be adaptable to the changes in topology of the network. This network must efficiently utilize the energy resource of devices and available communication system [6]. There is no requirement of modifying existing wireless infrastructure because deploying wireless infrastructure in disaster hit area is not only difficult but also a time consuming task.

Several hybrid architectures have been proposed before by integrating cellular communication system and MANET. However, they have many limitations which made them impractical when they are supposed to provide communication between nodes in disaster area and the hosts in outside world.

We have proposed a routing protocol which is aware of energy and mobility of nodes, and have self-organizing feature. This protocol works on the proposed architecture of hybrid cellular- MANET as illustrated in figure 1.

The rest of paper is organized as Section 2 presents the related existing work. In section 3, detailed design of proposed hybrid cellular-MANET emergency communication system is explained. Section 4, describe how search and rescue operations for trapped victims is done. Finally, section 5 concludes the paper.

II. RELATED WORK

A. Communication support for disaster Recovery operation

Lu et al. [7] proposed two types of communication architecture for disastrous area; one is *"Two-Tier Wi-Fi/Satellite Network"* and other is *"Multi-Tier Wi-Fi/WiMax/Satellite Network"*. In both of the approaches they use satellite link to interchange and sharing of information to headquarter which is hundreds of kilometer away from disaster hit area. But the biggest problem of using satellite link for communication is the long propagation delay of network signal. In *Two-Tier* Approach rescue teams at different location interchange information of each other with the help of satellite communication system. That means two nearby

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rescue teams, if they want to share information take much more time than manual way. To rectify these issues a Multi-tier model is proposed.

In Multi-Tier Architecture, they use one more WiMAX Layer is used. WiMAX layer is in between Wi-Fi Layer and satellite layer. In this model, inter rescue team communication is done using WiMAX station. Benefit of using WiMAX is that it provides high speed transmission up to 63Mbps for downlink and 28Mbps for uplink, with a range of 11 kilometer. Transmission between headquarter and rescue teams done by satellite communication.

There are some problems with this model like, propagation delay is high in satellite transmission, at least one node in each rescue team should be connected to satellite link, power consumption is much higher in satellite communication which is a major drawback because power resource is very crucial in disastrous area. In this model, there is a need of high frequency, many kind of signal losses such as signal absorption, effect of sun radiation etc are there while we use satellite transmission, end to end delay of packet, jitter and packet loss is very high and signal attenuation and fading is also there due to environment conditions.

B. MANET Based P2Pnet

Jang et al. [1] proposed a temporary network which supports emergency communication and networking, one of the most urgent tasks for rescue mission in disaster affected areas. In their proposal, a MANET is constructed using Wi-Fi enabled notebooks owned by rescue volunteers. The implementation of this model completes in two phase, first a simple MANET is formed to support emergency information system in very early hours after disaster hit an area. In second phase, an autonomies P2P ad hoc group communication system called *"P2Pnet"* is constructed using local wireless intranet based P2P and MANET technology after few more hours of disaster happened. P2Pnet support temporary emergency communication under infrastructure less, server less and internet blocked environment. Firstly Wi-Fi supportable notebooks carried by rescue professionals construct a multi-hop wireless intranet and then using P2Pnet technology a higher level mission specific network is formed to support urgent transmissions need such as push to talk, mobile social networking, VoIP, instant messaging etc. In this proposed model information is transmitted to headquarter which is hundreds of kilometer away from disaster hit area using mobile base stations or satellite (VSAT).

There are some issues with this proposal like, they use mobile base station to transmit information to outside world but availability of mobile base station is very limited, only very few are available. Cost of these mobile base stations is very high. In disaster affected area roads and transport system is almost blocked so providing these mobile base stations in that area is also a very difficult task. These mobile base stations are very heavy and if they dropped by air, they are crashed when collide with earth surface. And if VSAT is used for outside communication once again all those issues and limitation with satellite communication comes in mind. In this approach, it is assumed that rescue volunteer have Wi-Fi enabled notebooks or devices, and portable power generators are available in disastrous area for fulfilling power resources need of those devices, but it is not necessary that portable power generators are available in disaster affected areas.

C. Scheme for disaster recovery using Hybrid Network Model

Chen et al. [8] proposed a hybrid network model in which a group of adjacent cells served by cellular base station is considered. However, due to disaster some of base station crashed so their cells are treated as dead cells as there is no cellular coverage. This is also possible that due to deterioration of connectivity some mobile nodes within the cell do not able to receive signal. To recover from these issues a hybrid model is proposed which combine cellular network and ad hoc network. Nodes are directly connected to cellular network if they are in working base station range and if there is no cellular signal then nodes are working in ad hoc network fashion and communicate with their neighbor. A node which is operating in cellular environment works as a gateway, able to transmit packets coming from neighbors operating in ad hoc mode. A node working in ad hoc network tries to setup a route to operational base station using multi-hopping. If node have route to at least one base station, it make an entry and forward data to that base station. If there is traffic congestion in that base station, node mark that base station as "*busy*" for certain interval and again search for operation base station.

The limitations and issues with this approach are, there is no awareness regarding available communication system and power resources of nodes. A lots of transmission is going through a node either it is transmitting or not. There is a possibility of network portioning. There may be possible that due to disaster there is no base station is in operational state, if so then this model completely fails.

D. A joint network for disaster recovery and search & rescue operation

Narayan et al. [3] proposed a portable disaster recovery wireless network architecture which provides solution for both disaster recovery network (DRN) and search & rescue operation (SRN). PDRN enables survivor-to-crewmember communication without any service interruption. Architecture of this proposed model consist one or more Access points (APs), Gateway nodes, DRN phones and on-site command center. APs in this model can use as either fixed access points or as mobile access points. AP has two kind of communication interface, one for cellular communication network and other for Wi-Fi enabled devices. PDRN phones are dropped in disaster hit area and when these special devices touch earth surface it start functioning, it start beeping. These PDRN phones use access point as their base station and transmit information to command center using network established by APs. When a trapped victim pick the beeping PDRN phone is automatically connects to the command center then victim convey his or her status to the command center and ask for rescue himself. PDRN phones continue beeping and flashing LED up to when their battery drained. PDRN phones are used by only one user, as the victim completes his conversation that phone change its state to unavailable. This concept is helpful in search and rescue operation of trapped victim.

This model have some limitation like, they have assumed that survivor who just asked for rescue help to command center stay at the same location from where he picked the

PDRN phone, while in real kind of situation it is not necessary. There may be a possibility that more than one PDRN phones fallen on one location. It is an issue, if two or more survivor approaches to the same PDRN device.

E. MANET Based Emergency Communication System

Ramesh et al. [5] proposed a communication architecture in which an ad hoc network is established using smart phones. In that proposal it is possible to pass help requesting message between phones until they are received by a phone which has internet access or cellular facility so that it could be forwarded to emergency services. In this proposal smart phones are grouped in to patches. These patches are formed using Bluetooth technology. Patches more or less resemble piconets in scatternet in a non overlapping fashion. According to this architecture, a node from any patch which does have any such node who have internet or cellular connection, send a help requesting message. This message forwarded from one patch to another until the patch with a node having either cellular connection or internet facility, receive it. Then finally that request message delivered to emergency services.

This proposed architecture also has some drawbacks such as Bluetooth technology is used to form MANET, which limits the size of MANET, we can use Wi-Fi interface also. In this approach, it is assumed that patches are forming a non overlapping networking, but practically it in not possible to have non overlapping groups with mobile nodes.

III. PROPOSED HYBRID CELLULAR-MANET FOR EMERGENCY COMMUNICATION IN POST DISASTER SCENARIO

The proposed model is able to fulfill the objective of providing emergency communication infrastructure to establish communication between trapped victims and rescue volunteers. A control station is used to provide an accurate information system for mobility, organization and coordination of rescue teams [3]. This proposed architecture provides a communication support for this emergency scenario and an information system.

A. System Architecture

As shown in figure 1, in the proposed architecture, there is an on-site control station which is established within few hours after disaster hit an area. This control station works as headquarter for all rescue operations in disaster affected area [8]. This also works as an information center about disaster situations in different affected areas. Control Station gives instructions to rescue teams for their operation. Mobility, organization and coordination of rescue volunteers decided on behalf of information processed by control station. Because of this control station, rescue and relief resources are prevented from misplacement [1][2]. This on-site control station is connected to a vehicular base station by which it gets the internet facility and cellular coverage. This is a very important component of this architecture, operated by only professionals of rescue and emergency services.

The second major component of this architecture is Access points which are dropped either by air or by rescue teams to setup a wireless infrastructure in disastrous area [3]. These APs are dropped in such a fashion that they cover almost complete disaster affected area. If these APs are dropped by air, they are covered in some kind of cabinet and as they touch the earth surface that cabinet breaks and APs start working. To deal with power resources of these APs, solar panel is fitted with these APs so that, if portable power generators are not available in disaster area then also APs can work. These APs are available with two type of communication interface i.e. Cellular interface for accessing facility of cellular communication system and other is Wi-Fi interface to establish MANET [3]. These APs set up a fixed kind of wireless communication infrastructure in post disaster scenario. As these APs are dropped in that area, it starts working and registers to the on-site control station. APs are fixed in such a way that they also cover area of control station. AP establish communication link with control station either directly or via other AP. APs which have cellular coverage works as gateway access point, they can directly forward data coming from mobile nodes to the control station or to the outside world. AP transmits data of mobile nodes towards control station or outside world using the concept of minimum hop distance.

There may be a possibility that some of cellular base stations are alive, completely ignoring of these working base stations is not an effective approach. If a base station is still working after hitting by a natural disaster, we can use that Base station to provide cellular support to our proposed architecture [8][9][5]. Using these base stations we can get internet facility or cellular communication which is a necessary requirement in disastrous area. We may also have some vehicular base stations present in disaster hit area which can be placed in area to provide cellular support in emergency communication.

Mobile devices such as mobile phones and notebooks carried by trapped victims and rescue volunteers can be directly connected with the APs installed by rescue team [1], if they are in coverage area of APs. These mobile nodes directly forward their messages to control station through APs. As a mobile node comes in the coverage range of AP, it automatically gets registered with AP [3]. Each mobile nodes and APs have some unique physical address by which they can be distinguished. Mobile nodes also form MANET in between each other. Some of mobile nodes forward data of their neighbor nodes which are not present in AP coverage area, known as gateway node. Relay node helps to forward data coming from neighbor AP towards control station using its AP.

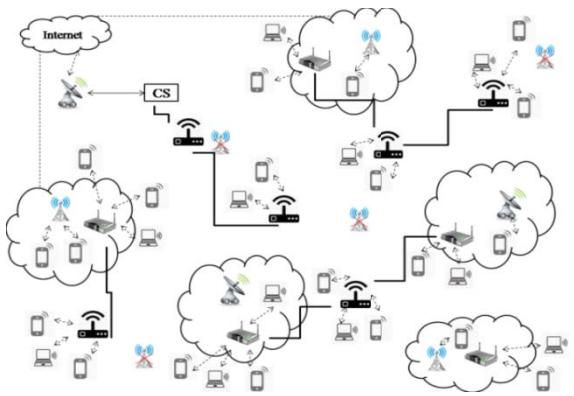
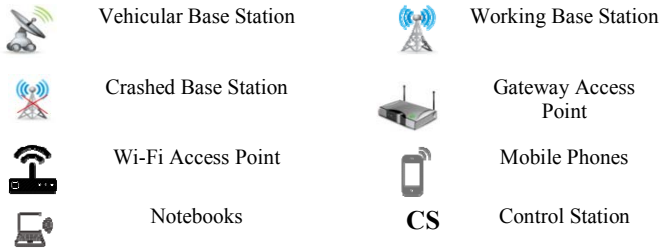


Fig. 1 Proposed Hybrid cellular-MANET Architecture



System Architecture with no cellular coverage

Figure 2 shows the communication model if there is no cellular communication network present in post disaster area. In this scenario, APs establish a wireless communication infrastructure with on-site control station. Mobile nodes connect each other with wireless link such as Wi-Fi Technology and form a mobile ad hoc network.

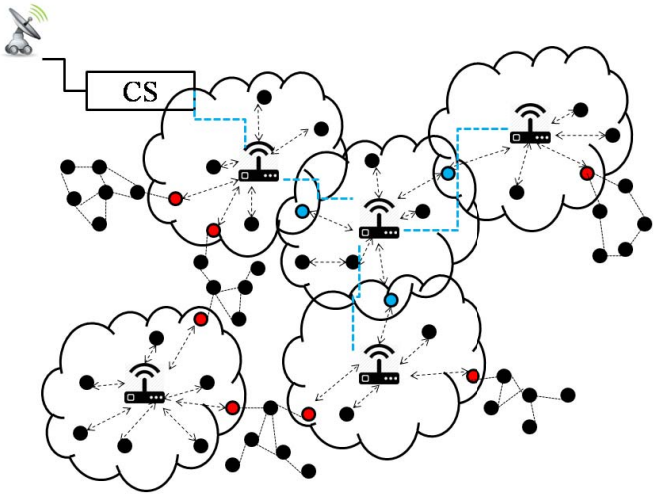


Fig. 2 System Model with no Cellular Coverage

Gateway Node
Relay Node
Terminal Node

B. *Routing in proposed System Architecture*

There are three types of routing procedures in MANET, which are, table driven (Proactive) routing protocol, On-demand (Reactive) routing protocol and Hybrid routing protocol [12]. We used reactive routing concept in our proposed protocol. Routing of messages sent by mobile nodes present disaster towards control station, also have two cases i.e. routing with cellular coverage and routing in non-cellular coverage.

When an AP is dropped in disaster affected area, it start working and firstly register itself with control station. Control station maintain table for registered APs and mobile nodes present in disastrous area. In these tables, unique physical addresses of deployed APs and working mobile nodes is listed. After registration of deployed AP with control station, that AP broadcast *beacon signal message* in its coverage area [10]. Mobile nodes present in that area receive that beacon message and replied with *registration message* having physical address of mobile node attached with sequence number. AP periodically sends beacon signal message after certain interval of time in its coverage area [10], to get to know that register mobile nodes are still available in its region or moved somewhere else. These beacon messages and registration messages are transmitted with sequence number for differentiating between old messages and new messages [11]. These sequence number also helps to avoid loops in registration phase [13]. If mobile node gets beacon signal from more than one AP, it gets connected on the basis of received signal strength methodology. The table of registered mobile nodes is also shared with control station.

Nodes which are not in range of any AP establish MANET between them and connect to AP using relay node (nodes which are already present in Wi-Fi coverage of AP). Relay node forward the broadcasted beacon signal to the connected MANET, then nodes forming MANET replied with their physical address attached with sequence number. Entries of these addresses made in table, maintained by AP. This table also shared with control station. This is how every mobile node present in disaster affected area gets registered with AP and control station also knows about mobile nodes present in that area. If any mobile node from MANET gets two beacon signals, then it gets registered with that AP which has minimum hop count. AP also maintain state of mobile node i.e. *dead*, if it moves somewhere else or mobile node is down and other one is *alive*, if mobile node is present in AP's coverage area.

Route discovery and message transmission

The process of route discovery in based on the concept of reactive routing. The source mobile nodes first broadcast a *route request message* to all its neighbors and then neighbor nodes forward this request towards nearest AP. As soon as a node have direct link to the AP, unicast a route reply message to the node from which a request is coming [10][11]. If requested node gets more than one reply then it select the path with minimum hop count value [14]. After route establishment, node sends this data packet to AP and then AP forward these data packets to control station. If source node present in coverage range of AP, then it directly forward data towards control station with the help of its AP. Each broadcasted control message has some fixed *time-to-live (TTL)* [11], after expiration of TTL the control messages is ignored by mobile modes. The process of route discovery and message transmission is illustrated in figure 3. The functioning of route discovery and message transmission is shown in Algorithm 1.

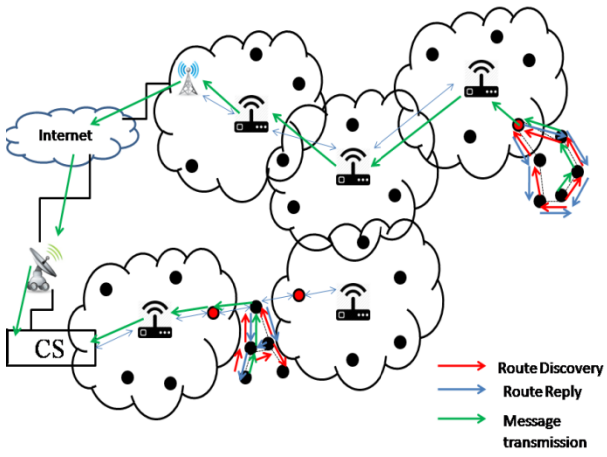


Fig. 3 Route discovery and message transmission

Algorithm 1 Function for Route discovery and message transmission

Require: Access points and on-site Control station.
1: Setup an on-site control station
2: Deploy Access points
3: Deployed access points start working and register itself with CS
4: APs establish path to CS, on the basis of **min hop count**.
5: AP broadcast **beacon signal message** in its coverage area
6: Mobile node present in that area **receive** beacon signal and **reply** register message
7: **if** Mobile nodes present in wireless area receives beacon from more than one AP
Node registers itself with AP, having more Received Signal Strength (RSS)
end if
8: Gateway nodes **broadcast beacon signal** to MANET
9: MANET Mobile nodes send register message to AP via Gateway nodes.
10: AP **receive register message** and make and entry in its table
11: AP periodically **broadcast Beacon signal** to check availability of mobile node in that region
12: Mobile node wants to transmit rescue message to CS
if mobile node present in AP coverage
directly forward message to registered AP
else mobile node forward rescue message towards AP via gateway node using intermediate node
end if
13: AP forward messages, coming from mobile nodes towards CS

Route Maintenance

This phase maintains information about registered mobile node as they are still present at their location or moved somewhere else. If a node moves at some other location and attached with a MANET then it broadcast a *join* message to its new neighbors using concept of source initiated route request technique. This join message forwarded until an AP found. After that AP unicast an acknowledgement in response of join request and then node gets register with new AP. AP update its table and make a new entry for that node and also inform control station about this update. Control station also updates its entries regarding that node. When a node leaves its location, the information regarding its absence will be known only when AP broadcast its next beacon. The AP updates moved node state as a *dead* node and also inform control station about this change. Control station changes entries of that moved or down node accordingly. Control station can forward data towards requesting mobile node after getting its updated location. The process of route maintenance is illustrated in figure 4. The functioning of route maintenance is shown in Algorithm 2.

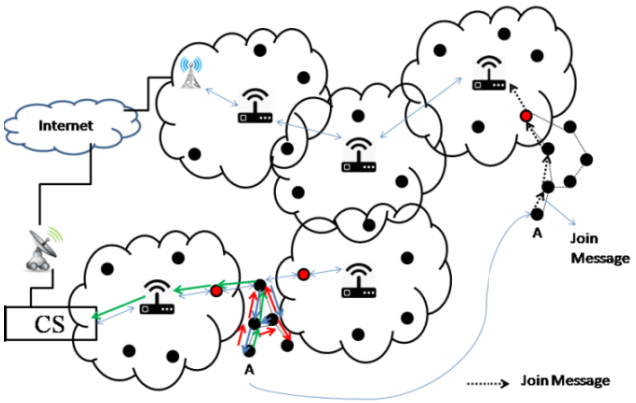


Fig. 4 Route maintenance

Algorithm 2 Function of Route Maintenance

1: **if** Mobile node **moved** from its registered AP
AP Broadcast next periodic **Beacon**
AP Update its table about node absence
AP updates CS about this change
if node attached to MANET
broadcast join message to neighbors, forwarded to nearest AP.
end if
AP **unicast** confirmation message to requesting node.
end if
2: AP share this update to CS

IV. SEARCH AND RESCUE OPERATION

When rescue teams are deploying APs in disaster hit area, they give some relevant name to the location where they have deployed the AP. If APs are dropped by air, at the time of registration with control station AP share their location coordinate with control station [3]. So control station maintains a table in which address of APs with their location is maintained. When a survivor send help message to control station with the help of his mobile phone using its AP, after referring table control station get to know that this help requesting mobile node is present in the area of that AP from which this message is originally transmitted toward control station. Then after professionals of emergency services in control station ordered rescue teams to go that location with necessary rescue and relief resources and rescue trapped survivors from that location.

V. CONCLUSION

In this paper, we proposed hybrid cellular-MANET emergency communication architecture for disaster affected area which can be used by both trapped survivors and rescue teams. In this proposed model, an emergency communication infrastructure is provided, where all other means of communication networks are not working. We also proposed a mobility aware, self organized reactive kind of routing scenario for message transmission in that area. This proposed model gives a solution for both the problems i.e. disaster recovery network and search & rescue operation of trapped victims. In this paper, we have also critically analyzed existing solution for disaster like situation.

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