HYBRID CELLULAR-MANET BASED COMMUNICATION ARCHITECTURE FOR NATURAL DISASTERS

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Abstract: *Every year, Natural disaster hits so many areas of our planet, efficient ways of rescue operation is directly proportional to life saving of survivors. Communication system either wired or wireless usually down due to disaster. This makes communication between rescue teams and victims very tedious. Unfortunately available existing solutions are not sufficient to provide communication system in early hours of disaster hit. In this paper, concept of hybrid cellular-MANET architecture with routing algorithm has been proposed. Proposed routing scheme efficiently utilize available energy and communication resources of devices used in this architecture. Mobility of Wi-Fi enabled devices used in the system, taken in the consideration while developing the architecture. The proposed system supports self organizing feature of MANET. The proposed communication system can be established in disaster hit area in very short span of time.*

MATLAB is used as a simulation tool to simulate the proposed approach and routing algorithm. Various simulation conditions and parameters are considered while simulating the approach. As per reachability result, impact of FAPR, impact of access point density and impact of speed of node is determined on different scenarios. Packet level simulation results shows results of proposed routing algorithm by doing comparison of End-to-End delay and packet delivery ratio between classic hop-count routing and proposed routing algorithm.

Keywords: *Hybrid Cellular-MANET, Post Disaster Scenario, Emergency Communication System*

I. INTRODUCTION

Natural disasters such as earthquake, flood, landslide, tsunami etc of varying intensity hits many areas of the Earth. These disaster events kill millions of peoples each decade and leave millions more homeless. If these survivors rescued within 72 hours of disaster hit, the chance of survival increased largely. These 72 hours referred as "Golden 72 hours" (Yao-Nan Lien et.al.(2009)). These victims need communication infrastructure for many reasons like allocation of relief and rescue resources and reunion of family. However, when disaster strikes, the communication links either fixed or wireless often disrupted. For disaster relief works, these links are very much essential. Any sort of communication becomes extremely difficult due to the loss of communication network. Failure of communication system leads to preventable loss of life, because of error or delay in rescue and relief response. Re-establishment of communication infrastructure in disaster affected area is still a tedious job. As a result, thousands of people died before they got a chance of rescue.

In such emergency situations, survivor needs any sort of communication link with the same priority as need of water, food, medical facility, protection and shelter. Emergency communication system is considered as life saving support system (Lien et.al.(2009);Hung-Chin Jang et.al.(2009)). MANET can offer an efficient and effective solution for such emergency situations. A solution for emergency communication system can be provided by hybrid cellular-MANET. In such network, mobile devices connected to each other using Wi-Fi link in peer to peer fashion and forms an ad-hoc network. These devices also have communication links to the access points, dropped by rescue teams (Narayan et.al. (2012); Mahapatra et.al.(2010)). Ignorance of working cellular base station is not an efficient approach, so in proposed system working base stations are taken in consideration while establishing the communication architecture (Narayan et.al. (2012);V. Ramesh et.al.(2012)). The proposed model uses smart phones and similar devices for construction of such emergency communication network. No new technology or new devices are needed for these communication arrangements.

So many challenges are faced to design such a hybrid cellular-MANET. These systems should be adaptable to the changes in topology, efficiently utilize the energy resource and available communication system (Zheng et.al. (2014)). There is no need to modify existing wireless infrastructure system because deploying wireless network in such critical area is difficult also time consuming.

Several hybrid architectures have been proposed before by integrating cellular communication system and MANET. But many limitations are there which made them impractical to provide communication in disaster affected area.

A self-organizing routing protocol, aware of energy and mobility of devices has been proposed. 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 explains the related existing work. In section 3, describe detailed design of proposed hybrid cellular-MANET emergency communication system is explained. Section 4, shows simulation results of comparison between traditional Hop-Count and proposed routing algorithm. Section 5, concludes the paper.

II. RELATED WORK

Lu et al. (2007) proposed two emergency communication models for disaster hit area i.e. “Two-Tier Wi-Fi/Satellite Network” and “Multi-Tier Wi-Fi/WiMax/Satellite Network”. Satellite link is used to exchange and share information. But the biggest issue with satellite link is large propagation delay of network signal. Rescue teams at different positions exchange information using satellite link. If so, then two nearby rescue teams, took more time than if they opt manual way. Multi-tier model rectified this issue. One extra layer, named as WiMAX Layer is used In Multi-Tier Architecture. WiMAX layer is put in between Wi-Fi Layer and satellite layer. WiMAX layer is used to provide inter rescue team communication. Transmission speed is up to 63Mbps for downlink and 28Mbps for uplink in WiMAX, in range of approx 11 kilometer. But still the communication between headquarter and rescue teams was done by satellite link. If this architecture is used, propagation delay is high transmission, at least one node in each rescue team have to connected with satellite, higher power consumption in satellite transmission is another big issue. High frequency is required, Signal losses like signal absorption, sun radiation effect etc are possible, jitter, end to end delay and packet loss is very high. Due to environment conditions signal attenuation and fading is also there.

2.2 MANET Based P2Pnet

Jang et al. (2009) proposed a temporary network which supports emergency communication. In this proposal, a MANET is established using Wi-Fi enabled devices

owned by rescue team members. In first phase, to support emergency information system in very early hours after disaster hit a MANET is constructed. An autonomous P2P ad hoc group communication system named as "P2Pnet" is formed in 2nd phase. In infrastructure less, server less and internet blocked environment, P2Pnet support emergency communication. In this architecture information is transmitted to headquarter using mobile base stations or satellite (VSAT).
In this proposal mobile base station is used to transmit information to outside world but mobile base station is very limitedly available. These devices are very costly. Transport system is paralyzed in disaster area, to provide mobile base station is again a difficult task. These kinds of devices are very heavy so it can't be dropped by Air. As VSAT is used for outside communication again limitation of satellite communication comes in consideration. It may be possible that portable power generators are not available for fulfilling power related requirement.

2.3 A joint network for disaster recovery and search & rescue operation

Narayan et al. (2012) proposed a portable disaster recovery wireless network architecture which provide a common solution for both disaster recovery network (DRN) and search & rescue operation (SRN). PDRN provide uninterruptable survivor-to-crewmember communication. APs are used in both situations such as fixed and mobile. Both cellular and Wi-Fi interface is available in AP. PDRN phones use access point as their base station and exchange information with command center. PDRN phone is picked by victim and his/her status is conveyed to command center than command center take necessary action for rescuing the victim. PDRN phones are used by only one user.

This model has some limitation like, it is assumed that survivor stay at the same location from where he/she conveyed is status, and in real time it's not necessary. It may be possible that two or more survivor approaches to the same PDRN device.

2.4 MANET Based Emergency Communication System

Ramesh et al. (2012) proposed a communication model, in which network is formed using smart phones. In that proposed method, the help requesting message is forwarded until it reaches a phone having cellular signal or internet. Phones are grouped in the form of patches. Bluetooth technology is used in these patches. Piconets in scatter net having non overlapping fashion are established using these patches. A node from any patch which does 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 is not found. And finally that request message delivered to emergency services.

Some drawbacks, such as Bluetooth technology limits the size of MANET. It is assumed that patches form a non overlapping network, but it is practically impossible.

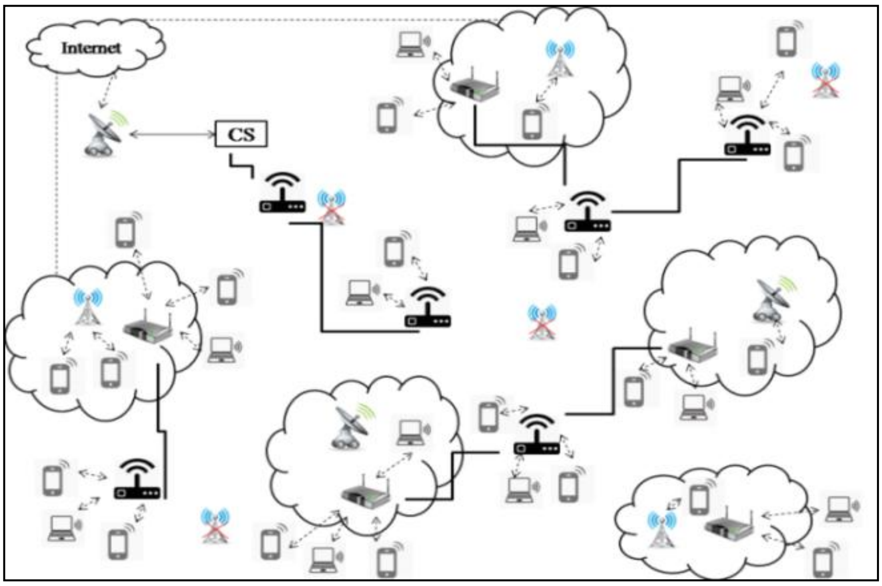
III. PROPOSED HYBRID CELLULAR-MANET FOR COMMUNICATION IN POST DISASTER

The objective of proposed model is to establish communication between survivors and rescue professionals & their team. Onsite control station is established to provide accurate information system for mobility, organization and coordination of rescue volunteers (Narayan et al. (2012)) . This architecture provides emergency communication supporting network and an information system.

3.1 System Architecture

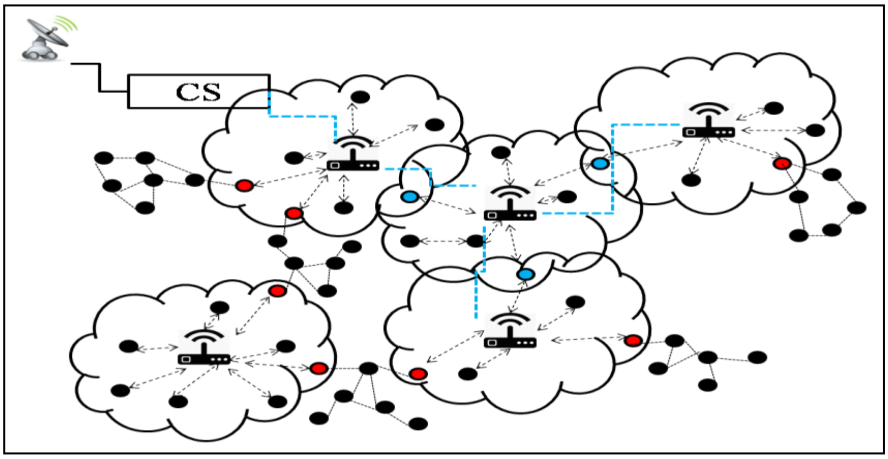
As described in figure 1, the proposed model contains an on-site control station disaster hit area. Established control station act as headquarter for all type of rescue operations (Guowei et.al (2010)). Control station also works as information center which process information of disaster situations in different location of disaster affected areas. Once the information is processed by control station, decision regarding mobility, organization and coordination of rescue teams are taken. Rescue and relief resources are prevented from misplacement just because of the information provided by control station (Lien et.al.(2009);Hung-Chin Jang et.al.(2009)). Cellular and internet facility is provided using vehicular mobile base station to the control station. It is a critical component of the architecture, which is operated only by professionals.

Access points are another important component of this architecture used to setup a wireless communication infrastructure in disaster affected area (Narayan et al. (2012)). These deployed APs cover almost complete disaster area. If these APs are dropped by air, then it is wrapped in a cabinet and as it touches the ground that cabinet breaks and APs start working. Portable power generators or solar panel fitted with AP are main power source. APs have both cellular and Wi-Fi interface to construct MANET in disaster area (Narayan et al. (2012)). An infrastructure based wireless communication network is established by these APs. APs start working and registers to the on-site control station. AP establish communication link with control station using multi-hopping. APs having cellular coverage act as gateway, it directly forward data coming from mobile nodes to the control station. Minimum hop distance concept is used while AP transmits data of mobile nodes towards control station.



	Vehicular Base Station		Working Base Station
	Crashed Base Station		Gateway Access Point
	Wi-Fi Access Point		Mobile Phones
	Notebooks	**CS**	Control Station

Figure1: Proposed Hybrid cellular-MANET Architecture



Gateway Node
Relay Node
Terminal Node

Figure 2: System Model with no Cellular Coverage

Ignorance of working cellular base station is not efficient thing. If suppose, after a disaster hit, base station is still working then use this in proposal model (Guowei et.al (2010); Ramesh et al. (2012); E. Onwuka et.al (2011)) Critical requirement of cellular signal or internet in disaster area can be fulfill by these base station. Some of vehicular base station (if available) can be deployed in disaster affected area to provide cellular support.
Mobile devices have direct connection with deployed Aps (Lien et.al.(2009)), if present in coverage of APs. Messages coming from these nodes can be directly forward to onsite control station. Nodes present in service range of AP, gets registered automatically (Narayan et al. (2012)). Mobile devices and APs uniquely distinguished by physical address. MANET is also established in between mobile devices. Nodes, doesn't having any coverage signal use multi-hopping to send its data. Relay nodes forward data of neighbour AP to control station. System Architecture with no cellular coverage is shown in figure 2.

3.2 Routing in proposed System Architecture

Table driven (Proactive) routing protocol, On-demand (Reactive) routing protocol and Hybrid routing protocol (Abolhassan M et.al.(2004)) routings are possible in

MANET. Reactive routing technique is used in proposed routing protocol. Routing with cellular coverage and routing in non-cellular environment are two cases for routing in proposed model.

Control station maintain list of unique physical addresses of registered APs and mobile nodes. After registration, AP starts broadcasting beacon signal message in its coverage range (Abduljalil et.al. (2006)). Mobile node receives beacon signal and reply with registration message containing physical address of mobile node encapsulate with sequence number. AP periodically broadcast this beacon signal to maintain the topology and availability of nodes. Sequence number is used to avoid loops and to differentiate old and new messages (Zheng et.al. (2014)). RSSI (received signal strength indication) concept is used when node gets beacon signal from two or more AP.

Nodes do not having any sort of communication signal form MANET and gets connected to AP via relay node. Beacon signal is forwarded by relay node in this MANET, and then those nodes reply with physical address attached with sequence number. If node receives more than one beacon then it uses minimum hop count to get registered with AP. State of mobile nodes such as dead (if it moves somewhere else or mobile node is down) and *alive* (if mobile node is present in AP's coverage area) is also maintained by AP.

3.3 Route discovery and message transmission

Source nodes first broadcast a route request message to all its neighbours and then these nodes forward the request towards nearest AP. if node have direct link to the AP, it unicast route reply message to the requesting node (Abduljalil et.al. (2006); Zheng et.al. (2014)). If node gets two or more reply then path with minimum hop count is selected (Fujiwara et.al (2004)).After route setup, data packets sent towards control station. If source node is in coverage of AP, then data directly transferred to control Station. Time-to-live (TTL) is maintained by each broadcasted control message (Zheng et.al. (2014)), after TTL expiration, control messages is ignored by nodes. Figure 3 illustrated the process of route discovery and message transmission. Algorithm 1 describes the functioning of route discovery and message transmission

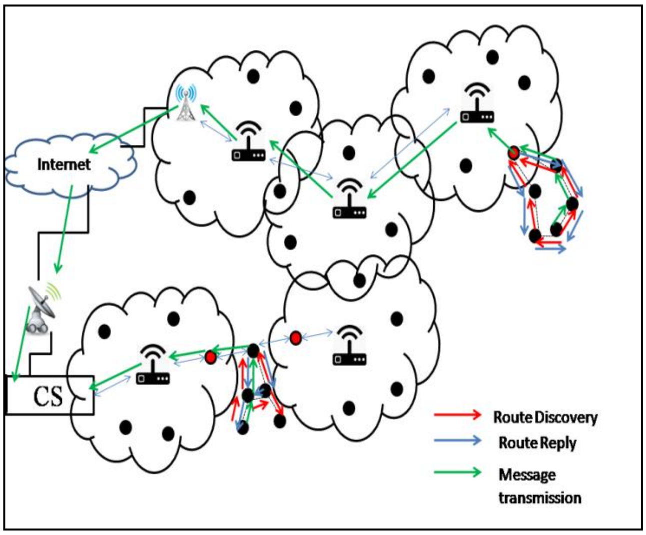


Figure 3: Route discovery and message transmission

3.4 Algorithm 1: Function for Route discovery and message transmission

Requirements: Access points and on-site Control station.

Step 1: Setup an on-site control station.

Step 2: Deploy Access points.

Step 3: Deployed access points start working and register itself with CS.

Step 4: APs establish path to CS, on the basis of **min hop count**.

Step 5: AP broadcast **beacon signal message** in its coverage area.

Step 6: Mobile node present in that area **receive** beacon signal and **reply** register message.

Step 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.

Step 8 : Gateway nodes **broadcast beacon signal** to MANET.

Step 9 : MANET Mobile nodes send register message to AP via Gateway nodes.

Step 10 : AP **receive register message** and make and entry in its table.

Step 11: AP periodically **broadcast Beacon signal** to check availability of mobile node in that region.

Step 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

Step 13 : AP forward messages, coming from mobile nodes towards CS

3.5 Route Maintenance

Mobility of nodes maintain by this phase. When node attached to new MANET then it broadcast a join control message to its neighbours. This join message forwarded towards AP until it is found. In response to received join, AP unicast acknowledgement to the requesting node. This is how node gets register with new AP. AP update its table and make a new entry for the attached node and also this update is also informed to control station. Absence of node in particular MANET is found out using periodic beacon. The state of moved node is set to dead and this change is conveyed to control station. Control station updates its table entries accordingly. Control station send data to requesting node only after its location is updated. Route maintenance is elaborated in figure 4 and respective algorithm is described as Algorithm 2.

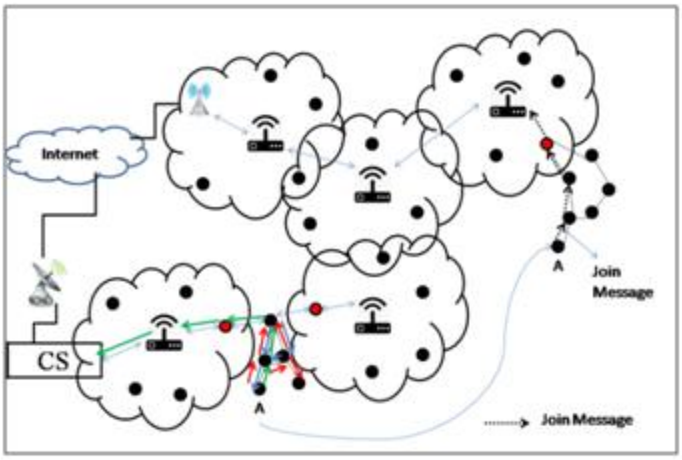


Figure 4 Route maintenance

3.6 Algorithm 2: Function of Route Maintenance

Step 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

Step 2: AP share this update to CS

IV. SIMULATION RESULTS

Packet Level simulation is performed on the MATLAB simulator to evaluate the performance of proposed routing algorithm. The access points are equipped with both 802.11b Wi-Fi interface for ad-hoc communication and cellular communication interface to get cellular link (if possible). These access points are deployed in normalized fashion within a 1square kilometre area. The average data rate r_i for the data generated at nodes i are uniformly drawn from [0,1Mbps].

To evaluate the benefits of proposed routing schemes, the size of network is vary with 100, 110, 120, 140 and 150 nodes. We measure the end-to-end delay and packet delivery ratio (PDR) of proposed routing algorithm, and compare with the classic hop-count (HC) based distance vector routing algorithm. Both algorithms use multi-path routing. The difference is that, in traditional hop-count distance vector routing there is no quality measure for link, but in proposed routing scheme, the communication link is decided on the basis of received signal strength indication (RSSI) technique. The results are plotted in figure 5, 6. It is seen that, as expected, the proposed routing outperforms the classic hop-count routing in both delays and packet delivery ratio. Moreover, the network size is increases, the delay and the packet loss rate of the hop-count routing increases at the faster rate than the proposed routing scheme. Hop-count routing scheme may end up with using paths with small numbers of hops but a large number of packet losses and retransmission. While in proposed routing scheme, as the network grows larger, the path become longer and the benefits of proposed scheme is compounded.

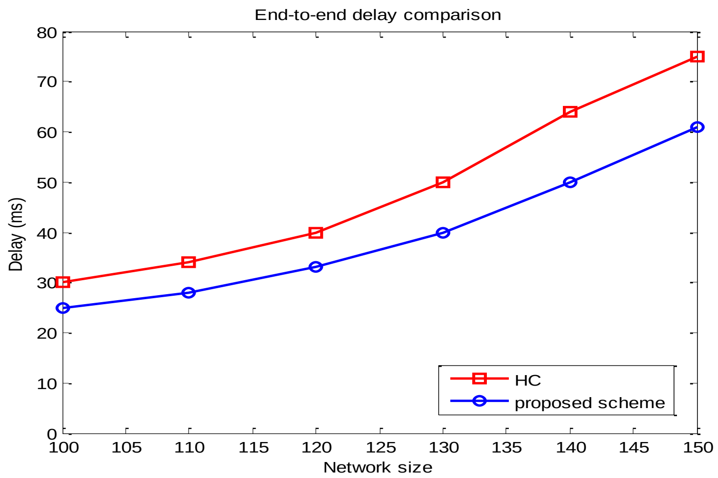


Figure 5: End-to-End Delay Comparison between Classic Hop-Count Routing and Proposed Routing Scheme

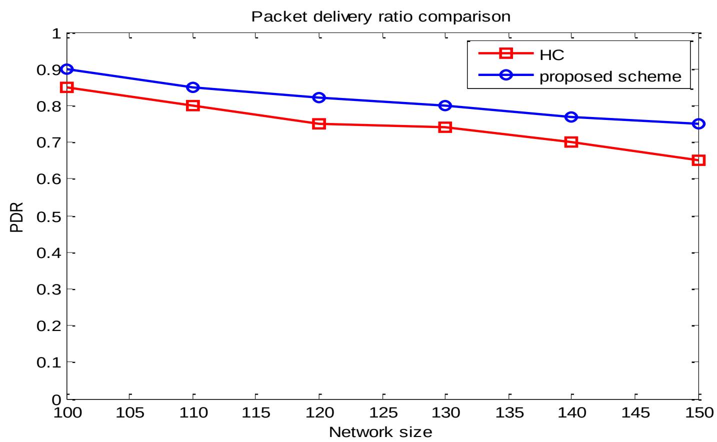


Figure 6: Packet Delivery Ratio (PDR) Comparison between Classic Hop-Count Routing and Proposed Routing Scheme

V. CONCLUSION

Hybrid cellular-MANET emergency communication architecture has been proposed in this paper. It can be deployed in disaster hit area. Both trapped survivors and rescue teams can use this architecture. In this proposed system, when all sort of communication networks are crashed, an emergency communication infrastructure is established. A mobility aware, self organized, reactive routing algorithm is also proposed for message transmission. This proposed architecture provides solution for both the problems i.e. disaster recovery network and search & rescue operation of trapped victims. Existing solutions are critically analyzed in this paper.

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