RTTMM: Role based 3-Tier Mobility Model for Evaluation of Delay Tolerant Routing Protocols in Post Disaster Situation

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Abstract: In Internet of Things (IoT) the devices are interconnected through Internet with several redundant paths, but they are still vulnerable to the effects of large scale disasters such as earthquakes and floods. The disaster area may be disconnected from the rest of the Internet and the need arises to get information about the victims. Adhoc networks like MANETs and DTNs are most suitable to support the communication in partitioned networks, such as a network in a post disaster situation. Even an adhoc network becomes one of the essential network architecture in IoT and attracted lots of attention in the last decade. The disaster affects the several regions with different intensities called each region as disaster event which are located nearer to each other. Each disaster event is assigned a group of rescue entities with hand held IoT device, where they perform the tactical operation. The movement pattern of the rescue entities in a post disaster area is described by a mobility model which is used to evaluate the routing protocols for post disaster scenario networks. Existing mobility models for post disaster scenarios do not distribute the rescue entities in proportion to the intensity of disaster events in the case of multiple events occurring simultaneously. In this work, we propose the Role-based 3-Tier Mobility Model (RTTMM) to mimic the movement pattern of different rescue entities involved in the disaster relief operation by distributing them based on the proportion of the intensity of the disaster event. Our model generates the mobility traces of the rescue entities, which are fed as input to the DTN routing protocols. We also evaluate the performance of existing DTN routing protocols using the traces obtained from RTTMM.

1 INTRODUCTION

The Interne of Things (IoT) consists of massive deployment of heterogeneous devices which are battery operated and interconnected through wireless network interfaces. The IoT communication architectures facilitate such devices not only connected to the backbone (i.e. the Internet) using infrastructure-based wireless networks, but also to communicate with one another autonomously, without the help of any infrastructure such as temporary wireless network (Petersen, 2015). This temporary or adhoc based networks are MANETs and DTNs which will become the important network architecture in IoT (Reina, 2013). Even in IoT, devices are interconnected through the Internet all the time. But in many situations such as military and disaster, they become disconnected from the Internet backbone and communication needs to carry out using ad hoc manner.

Natural or man-made disaster may destroy the existing communication infrastructure, making it difficult for rescue entities to communicate among themselves and the outside world to perform relief operations. Mobility characteristic of the rescue entities in a post disaster situation is very different from other environments, like campus, conference and military. Relief workers, policemen, emergency vehicles and ambulances have different movement patterns in the disaster affected area. The mobility model of a disaster scenario mimics the movement pattern of rescue team members to inspect the event areas, providing medical service and relief goods, and collect the information about victims and damage due to the disaster. Existing mobility models like Random Walk (RW) and Random Way Point (RWP) cannot be used to model the movement of rescue entities. In the literature, the authors have proposed mobility models to imitate the movement pattern of the entities in a post disaster scenario. The models can be categorized into synthetic and map based models.

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The synthetic mobility model by Nelson et al. (Nelson, 2007) assumed that when an event (for example, disaster) occurs, some entities (relief workers) are attracted towards the event and others (civilians) flee away from the events. This model assumes that even though the event lasts until the relief operation ends, but rescue team members are always working around recently happened event. This model does not distribute the dedicated relief workers to the specific event areas when multiple disaster events occur simultaneously. Another synthetic mobility model by Aschenbruck et al. (Aschenbruck, 2007) is based on separation of rooms (zones). Zones are established in the disaster affected area also called incident location and movement of rescue entities is restricted only inside their respective zones. This model is suitable only for single incident location or disaster event because it needs same set of zones to be created for each disaster event.

Gupta et al. (Gupta, 2015) proposed a 4-tier map based DTN architecture to provide communication infrastructure in the post disaster scenario and the area is divided into shelter points (SPs) with Throw boxes (TBs) being placed in each SP. This model emulates only the movement pattern of relief workers inside the SP and assumes that the messages are delivered from the SP to the main coordination center through Data Mules (DMs).

The existing models do not distribute the rescue entities to the disaster event in proportion to its intensity at different events need a varying number of rescue entities. Moreover, each rescue entity performs the relief operation with a pre-defined unique role, and their movement is restricted to the specified trajectory. These demands a suitable mobility model for the post disaster scenario to realistically mimic the movement patterns of rescue entities. In this paper, we propose the Role based 3-Tier Mobility Model (RTTMM) which mimics the movement of rescue entities and the unique role assigned to them. The rescue entities are distributed to the events in proportion to their intensity values and movement of relief workers is restricted in their respective event area only. We implemented tool in C++ language to generate the movement traces of RTTMM.

The rescue entities with the devices of a post disaster network may remain disconnected for a significant amount of time. Such a network cannot be supported by traditional wired networks like TCP/IP or Ad hoc wireless network such as MANETs which require a continuous network connection. The above requirement of a disconnected network can be accomplished by opportunistic networks, such as DTNs to support the communication among the rescue entities. The performance of such a network mainly depends on the mobility of the rescue entities (devices of the network). A mobility model is therefore required to carry out the performance evaluation of the network. The movement traces of the mobility model used in a disaster scenario have also a great impact on the performance of routing protocols in DTNs. The performance of routing protocols has been found to vary depending on the mobility model that is used.

Many authors have evaluated the performance of DTN routing protocols such, as Prophet (Lindgre, 2003), Epidemic (Vahdat, 2000), MaxProp (Burgess, 2006) and SprayAndWait (Spyropoulos, 2007) using mobility models (Aschenbruck, 2007; Nelson, 2007) of the post disaster scenario. To compare the effectiveness of RTTMM, the performance evaluations can be carried out using the realistic mobility model proposed in this paper. The main problem in analyzing the performance of a routing protocol for post disaster scenario is the absence of a realistic mobility model which distributes the rescue entities in proportion to the intensity of the disaster event.

The mobility traces generated by RTTMM are fed as input to the DTN routing protocols. The performance parameters of routing protocols like delivery probability and delivery delay are most important in the post disaster operation as they deal with information about human lives and give a picture of the damage. The device carried out by rescue team members is battery operated and with limited storage so, energy consumption and buffer storage are to be considered. Therefore, we also evaluate the routing protocols for overhead ratio and cost per message which show the energy conservation in the network. The existing routing protocols are also evaluated by varying number of devices, buffer size and message size using ONE simulator (Keranen, 2009).

The rest of the paper is organized as follows: Section 2 presents related works on the mobility modelling in a disaster situation, different network architectures and existing routing protocols. Sections 3 and 4 explain RTTMM and its analysis, respectively. The performance and simulation parameters are discussed in Section 5. The simulation results and discussions are presented in Section 6. Finally the conclusions are drawn in Section 7.

2 RELATED WORKS

To model the mobility and select the most appropriate wireless adhoc network architecture for the post disaster situation is a challenging task and is currently an active area of research. This Section describes the existing mobility models and multi hop wireless adhoc network, such DTNs, for the post disaster scenario. These are followed by the existing DTN routing protocols, evaluated for the disaster mobility scenario.

2.1 Existing Disaster Mobility Models

The mobility models proposed so far can be divided into synthetic and map based mobility models as described below.

2.1.1 Synthetic Mobility Models

A number of authors have proposed synthetic mobility models to impersonate the movement pattern of objects in a disaster situation to provide communication in the disaster situation. Aschenbruck et al. (Aschenbruck, 2007) presented a synthetic mobility model called separation of room which divides the disaster areas into different zones: incident zone, casualty clearing and patient waiting area, transport zone and technical operational command. The BonnMotion tool developed by Aschenbruck et al. (Aschenbruck, 2010) allows generation of the mobility traces for this mobility model. This model is mainly used to provide medical treatment in the post disaster scenario. It however has the disadvantage of requiring the set of zones to be established for each event area.

Another synthetic mobility model presented by Nelson et al. (Nelson, 2007) assigns a unique role to each object. They propose low level gravity based mobility model in which events apply forces to the objects (civilians, relief workers, policemen etc.). Consequently, civilians flee away from the event and the relief workers approach the event. The drawback of this model is that relief workers are always attracted to the recent event and they do not follow the tactical movement inside the event area.

2.1.2 Map based Mobility Models

Uddin et al. (Uddin, 2009) presented the first map based mobility using DTNs in post disaster situation. They simulated the mobility for both rescue entities and victims, including the different centres (fire station, neighbourhood, house, medical camp, relief camp and police station) that are established after the disaster. Movement patterns are also defined for rescue members and victims by extending the map based movement model in the ONE simulator on a built-in map of Helkensi city. This mobility model included the impact of disaster on the transportation network and modelled the population and relief vehicles only.

Gupta et al. (Gupta, 2015) proposed 4-tier map based DTN architecture to provide communication infrastructure with respect to the flood disaster which occurred in the Uttrakhand State of India in 2014. The disaster area also called activity area is divided into shelter points (SPs) which are the particular areas assigned to the group of relief workers to investigate the scene. Each SP is allocated static TB, which collects the information within its SP for further transmission to Main Control Station (MCS). Data Mules (e.g., ambulances, boats, helicopters) collect the data from SP and deliver to the MCS which is connected to the outer world. The authors in their work have assumed that inter SP communication is managed by DMs, but they have not emulated the movement pattern of them to deliver the messages to the final destination (MCS).

2.2 DTNs for Disaster Scenario

DTNs are most appropriate in a disaster situation due to their inherent characteristic to operate in the absence of end-to-end path and continuous network connectivity. In recent years, researchers have presented many solutions for disaster scenario using DTNs in the form of system to help in disaster recovery and mobility models as discussed in Section 2.1.

Martin-Campillo et al. (Martin-Campillo, 2010) developed a system to collect victim information using electronic triage and mobile devices in disaster situation. Legendre et al. (Legendre, 2011) summarized the work done in wireless network which is able to uphold the communication during a disaster when the existing communication infrastructure is damaged. They also proposed Twimight which is an Android based application, sends tweets using Tweeter severs in normal mode while it uses opportunistic contacts in disaster mode between mobile devices in the absence of network connectivity.

Fujihara et al. (Fujihara, 2012) presented real-time disaster evacuation guidance system which helps the evacuee himself to gather the information about road blockage and danger areas due to fire and share that information opportunistically with other mobile devices. Fajardo et al. (Fajardo, 2014) presented a content based data prioritization method that gathers the images of the disaster area and images with critical content is sent faster than non-critical content in order to handle critical events immediately.

2.3 Existing DTN Routing Protocols in Disaster Scenario

Many DTN routing protocols have been proposed in the literature which can be categorized into flooding based, forwarding based and social based routing protocols. The forwarding and flooding based routing protocols have been evaluated by the authors for the existing mobility models in a post disaster scenario. The social based routing protocols find their applicability in the human mobility only so, they are not suitable in a post disaster mobility. Martin-Campillo et al. (Martin-Campillo, 2013) evaluated the performance of Epidemic, Prophet, MaxProp and Time-To-Return (TTR) in disaster scenario using model by Aschenbruck et al. (Aschenbruck, 2007). It is concluded that MaxProp gives best performance in delivery probability and TTR in overhead ratio and cost per message. Saha et al. (Saha, 2011) evaluated Prophet, Epidemic, Spray and Wait, MaxProp and Spray and Focus routing protocols using a cluster based mobility model.

Inwhee et al. (Inwhee, 2010) proposed message priority based forwarding protocol which handles messages according to priority. Martin-Campillo et al. (Martin-Campillo, 2012) proposed new energy efficient routing and evaluated using synthetic mobility model by Aschenbruck et al. (Aschenbruck, 2007) for post disaster situation. Nelson et al. (Nelson, 2009) evaluated the performance of existing routing protocols (Epidemic, MaxProp, Spray and Wait, Spray and Focus and Prophet) using event driven role based mobility model and proposed Encounter Based Routing (EBR) protocol. Recently, Bhattacharjee et al. (Bhattacharjee, 2015) evaluated existing routing protocols such as MaxProp, Prophet, Spray and Wait (SnW), Epidemic routing using four different mobility models: custom map based mobility, post disaster mobility model, Random waypoint model and Cluster movement model for disaster scenario. The majority of above works used existing routing protocols such as Epidemic, Prophet, MaxProp, EBR and SnW to evaluate the mobility model for disaster situation. So, we use the same routing protocols in order to evaluate RTTMM model.

3 RTTMM: ROLE BASED 3-TIER MOBILITY MODEL

This Section discusses the proposed synthetic mobility model which emulates the movement pattern of different rescue entities working in the post disaster scenario. Sections 3.1 and 3.2 explain the different entities involved in the disaster scenario, disaster events, and the role assigned to a rescue entity with its movement pattern.

3.1 Rescue Entities and Events

The following Sections describe the different rescue entities involved in the post disaster relief operation and the disaster events.

3.1.1 Rescue Entities

There are five different kinds of rescue entities involved in the model: relief worker, policeman, ambulance, emergency vehicle, hospital and relief camp. These entities are categorized into specific tiers. Mobile devices held by a policeman and relief worker are treated as tier-1 devices. Ambulance and emergency vehicle mounted with devices called DMs are termed as tier-2 devices. Hospital and relief camp placed at fixed location usually at distant place to avoid the recurrence of the disaster event called TBs have connectivity with the outside world are termed as tier-3 devices. Also, each event area is allotted one fixed TB and placed in the center.

3.1.2 Disaster Events

Disaster events may be an earthquake, fire damage, landslide, flood, hurricane, etc. An event has an associated intensity value which defines the level of impact of the disaster. We identify the damage radius for each event that is determined based on the intensity of the event so that relief workers always restrict their movement inside the damage radius. Our RTTMM supports multiple events to occur simultaneously or sequentially. When an event happens, the relief workers, ambulances and emergency vehicles are assigned to the event in proportion to the intensity of the event. For example, if two events occur simultaneously with intensity values of i_1 and i_2, the relief workers are distributed to the events as given in Equation (1). Where, n_t is the total number of relief workers in the disaster scenario.

$$n_1 = \frac{i_1}{i_1 + i_2} * i_t \text{ and } n_2 = n_t - n_1 \quad (1)$$

n_1 and n_2 are the number of relief workers distributed to the events 1 and 2, respectively, based on the values of their intensity. Similarly, ambulances and emergency vehicles are also assigned to the events in proportion to their intensity values.

3.2 Role and Movement Pattern of Rescue Entity

Each rescue entity is assigned a unique role and it acts accordingly. For example, the relief workers move within the damage radius of the event area. Each relief worker randomly selects the distance to travel within the damage radius from the center and returns to the same point. The same movement pattern is repeatedly followed again and again. Ambulances move between the hospital and the event area and transfer victims from the event area to hospital. Similarly, emergency vehicles also move between an event area and the relief camp to provide relief goods for the victims to be distributed by the relief workers. The policeman performs patrolling by randomly selecting event locations, hospital and relief camp.

4 ANALYSIS OF THE RTTMM

The mobility model RTTMM discussed in the previous Section needs to be analyzed to know the characteristics of the network and the behavior of the devices which can be used by network designers to select the appropriate Ad Hoc network and propose a suitable routing protocol. We compare our mobility model with Event Driven Role-based Mobility Model (EDRMM) because it exhibits similar characteristics with RTTMM but not strategic movement of relief workers. Both the models have been analyzed using different parameters which are described in Sec. 4.1.

4.1 Parameters for Analysis

The following three parameters are considered to analyze the mobility models which show that whether the network of the post disaster remains connected or not and the device will have more opportunity to forward the messages.

1. *Average Device Degree:* It is defined by the average number of neighbors per device and it is used to differentiate the connectivity of the network.
2. *Maximum Device Degree:* The maximum device degree is the maximum number of neighbors of a device.
3. *Clustering Coefficient:* It represents a measure of the degree to which devices in a graph tend to cluster together.

4.2 Results for Analysis of RTTMM

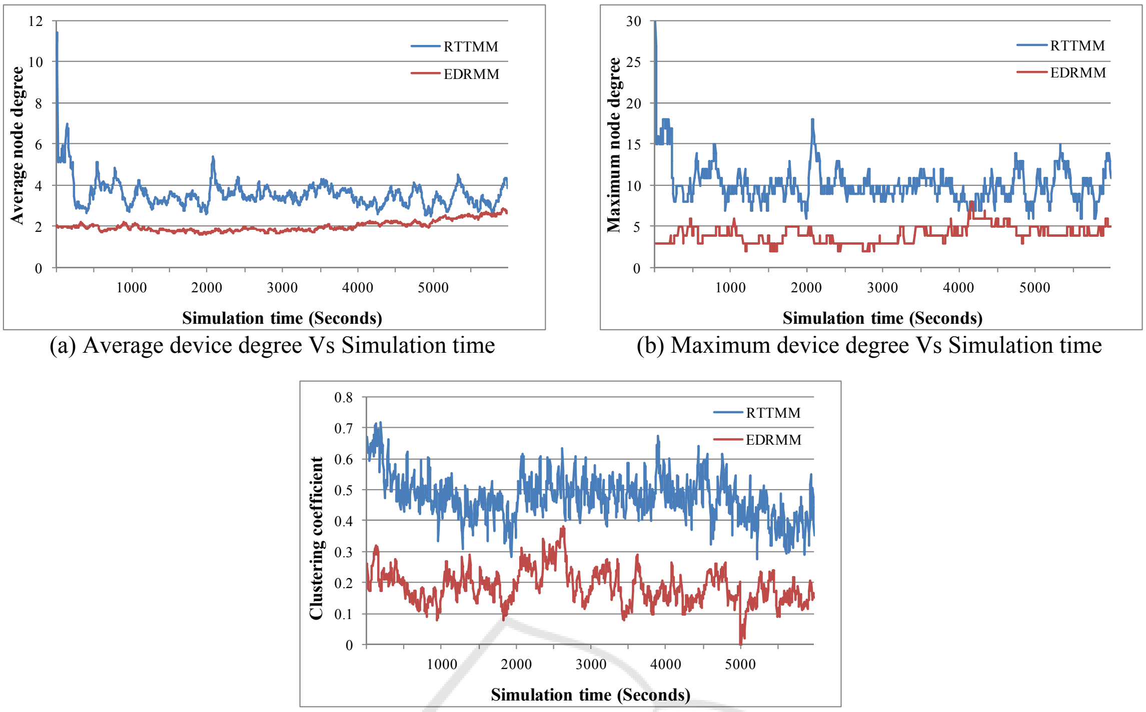
In order to assess the mobility model discussed in Sec. 3, the following scenario is considered. The simulation is carried out for 6000 seconds with a square grid size of 3000 m^2. There are total 52 mobile devices involved in a disaster scenario: 38 relief workers, 2 fixed TB in the center of the event area, 4 ambulances, 4 emergency vehicles, 2 policemen, 1 hospital and 1 relief camp. The transmission range of each device is set to 50 meters. Two events occur simultaneously with intensity values of 4000 and 2000. The speed of the relief workers, ambulance and emergency vehicle and policeman is set to 3 m/s, 12 m/s, and 7 m/s respectively. The same configuration parameters are set for EDRMM and it also includes some specific settings, which are taken as per (Nelson, 2007). Average results for 10 different simulations with different random seeds are collected.

Figure 1 shows the metrics as a function of time for RTTMM and EDRMM. As shown in Figures 2(a) and 2(b), the average device degree and maximum device degree are always higher in RTTMM due to planned movement of rescue team members. At the start of the simulation before the disaster event occurs, all rescue team members gathered at one place (for ex. Relief workers and emergency vehicles at relief camp) which shows higher values of the average and the maximum device degree in the same Figure. These metrics are important because they show the information about number of neighbors a device has at any point of time which can offer the high network connectivity.

Figure 1(c) depicts the average clustering coefficient of all the devices which shows that the network remains more clustered in RTTMM than EDRMM due to the strategic and confined movement of rescue team members. These analyses prove that RTTMM is more suitable for use in post disaster situation.

5 EXPERIMENTAL SET UP AND PERFORMANCE METRICS

In this section, we describe the configuration parameters for RTTMM and the performance metrics for the evaluation of the routing protocols.



(a) Average device degree Vs Simulation time

(b) Maximum device degree Vs Simulation time

(c) Clustering coefficient Vs Simulation time

Figure 1: Analysis of mobility models: RTTMM and EDRMM.

5.1 Configuration Parameters

The configuration parameters of RTTMM, which generates the mobility traces of rescue entities for input to the routing protocol, and the configuration parameters of ONE are described below. Table 1 shows the parameters of RTTMM and ONE that are common to all the experiments, unless explicitly specified. We have taken 10 message copies for the SnW and EBR routing protocols; settings for the other routing protocols are as per default implementation available in the ONE simulator.

5.2 Performance Metrics

The following performance metrics have been considered to assess and compare the performance of the existing routing protocols with RTTMM using DTNs.

1. *Delivery Probability or Delivery Ratio*: It is calculated as the ratio of the number of messages successfully delivered to the destination to that of the total number of messages generated in the network.
2. *Average Delivery Delay or Latency*: Delivery delay is the time elapsed between the creations of the message at the source and delivered successfully to the destination. Average delivery delay is average of delivery delay of all the delivered messages.
3. *Average Overhead Ratio*: It is the ratio of the difference between the total number of messages relayed minus delivered successfully to that of the number of messages delivered successfully. This is also a measure of the additional number of transmissions required for each message to be delivered from source to the destination.
4. *Cost per Message*: It is defined as the total number of message transmissions divided by the total number of successfully delivered messages.

6 EVALUATION OF DTN ROUTING PROTOCOLS

In this Section, we analyze the performance of five RTTMM as the mobility model. The main objective of evaluating these routing protocols is to verify their effectiveness and applicability in the post disaster scenario. The Section 4 has shown that RTTMM offers more network connectivity than existing model EDRMM so, we have chosen the movement traces of

Table 1: Configuration parameters of RTTMM and ONE simulator.

Parameter	Value
Simulation area	3000 m^2
Simulation time	6000 seconds
Transmission range	50 meters
Transmission speed	2 Mbps
No. of devices	100, one hospital and one relief camp
Message generation interval	One message/second from relief workers; One message every 30-35 seconds from hospital and relief camp
Message size	25k
Buffer size of relief workers	5 MB
Buffer size of DMs and TBs	100MB
Speed of relief workers	3 m/s
Speed of ambulance/emergency vehicle	12 m/s
Speed of policeman	7 m/s
No. of events	2
Damage radius	20% of intensity value
Event intensity	$I_1 = 4000$, $I_2 = 2000$

RTTMM as input to the routing protocols. To demonstrate the effectiveness of the routing protocols, we varied the number of devices, buffer sizes and message sizes. The average of 10 simulation runs is considered on different input files generated using RTTMM for a 95% confidence interval.

6.1 Effect of Varying Number of Devices

Simulations were carried out to evaluate the scalability of the routing protocols by increasing the device density. The number of devices varied from 50 to 250 in increments of 50. Experiments were carried out considering that 80% of the devices are relief workers, 3% are policemen and 17% are vehicles. Figure 2(a) shows that delivery probability is increasing with number of devices for EBR and MaxProp while it is decreasing for Epidemic, Prophet and SnW. MaxProp shows the highest delivery probability due to its wise strategy for the selection of relay devices as compared to others. EBR has next highest performance in terms of delivery probability which takes the advantage of encounter information of DMs with statically placed TBs. The forwarding strategy of Epidemic, Prophet and SnW do not work in this scenario and messages are dropped by the devices without delivering to the actual destination.

The average delivery delay of all routing protocols decreases as the number of devices increases except Epidemic as shown in Figure 2(b). EBR has lowest delivery delay amongst all routing protocols. Figure 2(c) depicts the average overhead ratio, which increases with the number of devices for all routing protocols excluding EBR. EBR has a low overhead ratio than others and which does not fluctuate while increasing the number of devices. The cost per message is increasing with the number of devices for MaxProp, Epidemic and Prophet routing protocols while it remains stable for EBR and SnW as shown in Figure 2(d). These results show that MaxProp outperforms in terms of delivery probability, but at the cost of the other three parameters. EBR has lower delivery probability than MaxProp with minimum delivery delay, overhead and cost per message.

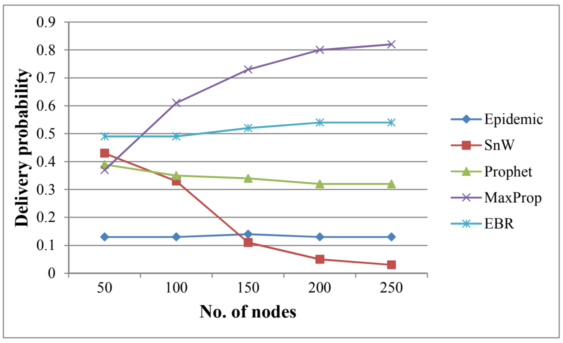
The performance of routing protocols depends on the availability of buffer space, particularly when they use multi copy message approach. We have chosen message size of 50k in these sets of experiments and buffer size is varied from 1MB to 8MB in increments of one. The buffer size is only varied for the mobile devices carried by relief workers. Figure 3(a) shows that delivery probability increases as buffer size increases for all the routing protocols. EBR shows the highest delivery probability up to buffer size of 3MB and becomes stable at 4MB. MaxProp outperforms at a buffer size of 4MB onwards as its performance is mainly depends on the available buffer space.

6.2 Effect of Varying Buffer Size

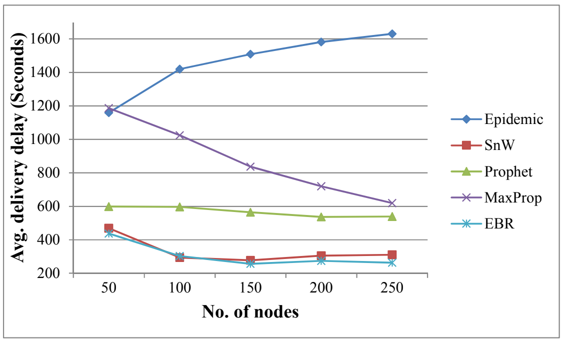
The average delivery delay is decreasing with an increase in the buffer size except Prophet as shown in Figure 3(b). EBR and SnW have the lowest average delivery delay with marginal increase with the buffer size. Figure 3(c) demonstrates that an average overhead ratio is higher for Epidemic and Prophet and decreasing with an increase of buffer size for all routing protocols. It remains lowest and stable for EBR and SnW schemes. The cost per message does not vary much for all the routing schemes and it remains mostly steady for EBR as depicted in Figure 3(d).

6.3 Effect of Varying Message Size

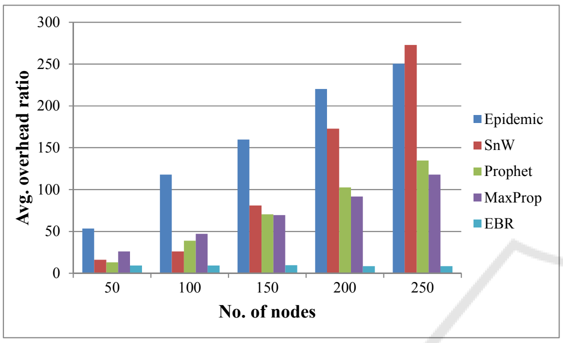
When relief workers are gathering information about the disaster area, they may need to send text as well



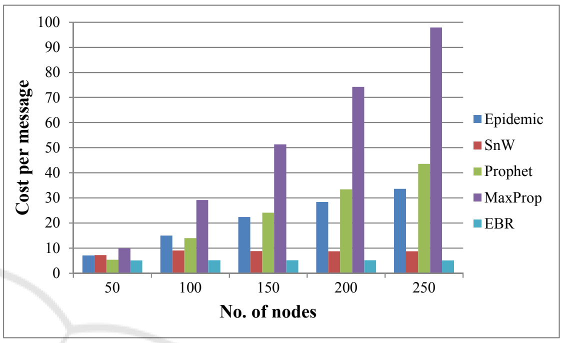
(a) Delivery probability Vs No. of devices



(b) Avg. delivery delay Vs No. of devices



(c) Avg. overhead ratio Vs No. of devices



(d) Cost per message Vs No. of devices

Figure 2: Effect of varying number of devices.

data in the form of pictures and video clips to the centres and vice versa. Here we check the performance of routing protocols on varying sizes of messages from 16k to 1MB in increment of power of 2. Average delivery probability is decreasing as message size increases as shown in Figure 4(a). MaxProp shows maximum delivery probability with message size below 64k as it starts dropping the message when it is of bigger size due to insufficient buffer space as discussed in Section 6.2. EBR performs better than all the routing protocols with big message sizes.

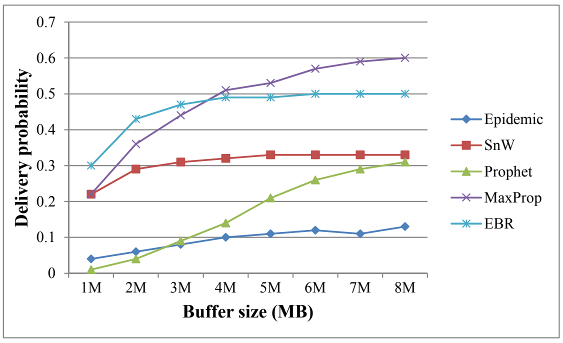
Figure 4(b) depicts that an average delivery delay is decreasing with increase in message size except Prophet and the reason is that there is decreasing of delivery probability. EBR and SnW have the lowest average delivery delay than other schemes. The average overhead ratio is increasing for all the protocols, but remains the lowest for EBR and SnW as shown in Figure 4(c). The cost per message does not fluctuate more in case of all the routing schemes and it stays mostly steady for EBR and SnW as depicted in Figure 4(d).

7 CONCLUSIONS AND FUTURE PLAN

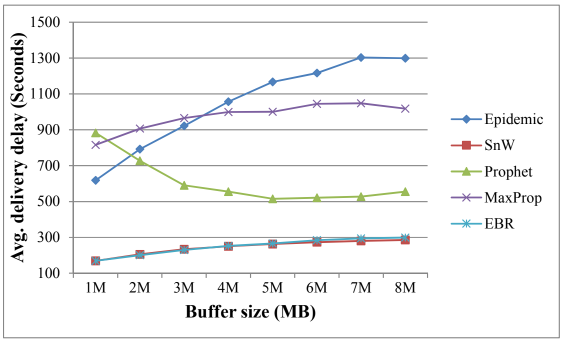
In this paper, we proposed the role based 3-tier synthetic mobility model, called RTTMM, to mimic the movement pattern of the rescue team members in a post disaster situation. RTTMM solves the limitations of existing mobility models which do not have the flexibility to assign different behavior and movement pattern for different team members. RTTMM has been compared against EDRMM and found to be more effective and applicable in a post disaster scenario.

We also evaluated the performance of five existing DTN routing protocols using the movement traces of RTTMM. The simulation results show that MaxProp outperforms in terms of delivery probability for varying number of devices and buffer sizes, but decreasing with message size. The demerit of this protocol is that it shows higher delivery delay, overhead ratio and cost per message. EBR has shown the next best performance in terms of delivery probability with the lowest average delivery delay. It also has steady overhead ratio and cost per message.

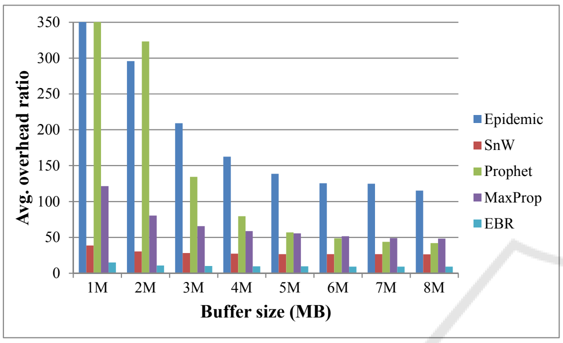
There is not any protocol which performs the best for all the metrics. It is concluded that DTNs facilitate



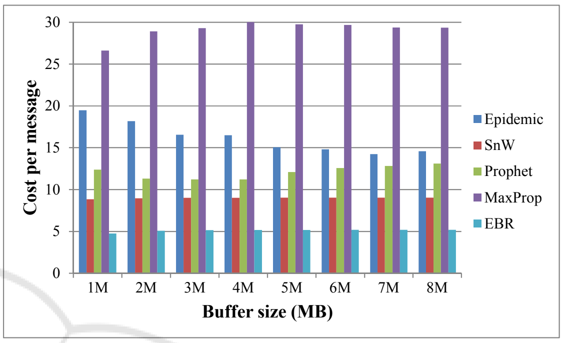
(a) Delivery probability Vs Buffer size



(b) Avg. delivery delay Vs Buffer size

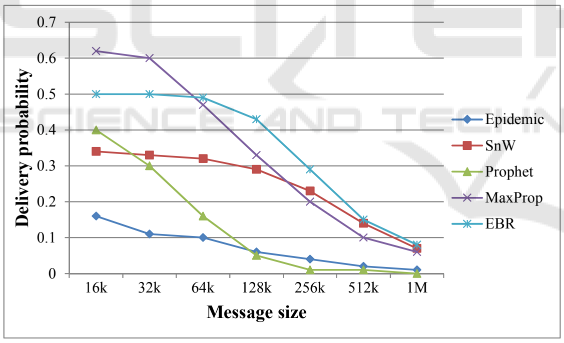


(c) Avg. overhead ratio Vs Buffer size

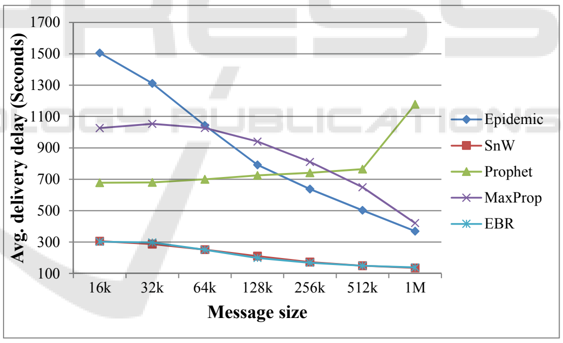


(d) Cost per message Vs Buffer size

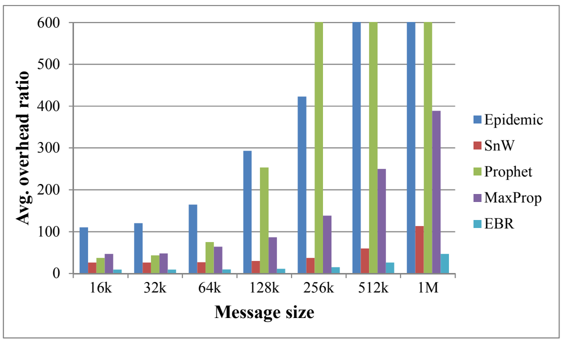
Figure 3: Effect of varying buffer size.



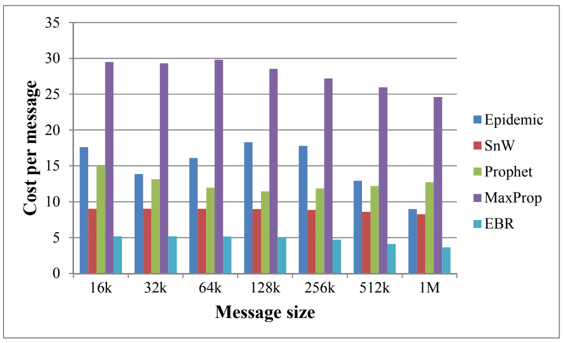
(a) Delivery probability Vs Message size



(b) Avg. delivery delay Vs Message size



(c) Avg. overhead ratio Vs Message size



(d) Cost per message Vs Message size

Figure 4: Effect of varying message size.

communication infrastructure in a post disaster scenario when network partition is observed in IoT.

The future work is to exploit the movement characteristics such as planned and scheduled movement of rescue entities from RTTMM and utilize them in the forwarding decisions by the routing protocols in DTNs.

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