"Efficient Routing in Disaster Area Network and Human Mobility Using Wireless Adhoc Networks"

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1. Abstract

The recent disasters, whether natural or man-made, have shown that the existing communication infrastructure was totally destroyed or stopped functioning due to over usage. Communication services must be facilitated for rescue and relief workers to collect the information about the victims and damage of property. Victims would like to send the messages to family and friends about their well-being. The information collected from the disaster scenario must be sent to the main control station connected with the outside world, for quick actions and coordination. The network of human being acting as rescue and relief workers, victims, and vehicles such as ambulances and providing relief goods, can be created on a temporary basis. The unique characteristic of disaster scenario is that the connectivity between nodes is intermittent and in the absence of cellular or any other networks, they may have to communicate using peer-to-peer mode.

Another type of network formed by a human being at the places like educational campus, research conference and social neighborhood, where it is assumed that communication infrastructure is not obtainable, but it needs on a temporary basis. Moreover, recent progresses in communication technologies have shown proliferation in network formed by human being carried mobile devices such as smart phone and digital gadgets called Pocket Switched Network (type of Delay Tolerant Network). These networks also demand peer-to-peer mode of communication, when other means of communication is not accessible in some situations and intermittent connectivity is observed.

The requirements as stated above, for the provision of temporary network infrastructure would be satisfied by wireless adhoc networks. Wireless Adhoc Networks such as Mobile Adhoc Networks (MANETs) and Delay Tolerant Networks (DTNs) can be deployed on an urgent basis without need of the infrastructure, when the existing communication infrastructure is totally paralyzed or unavailable. MANETs mostly operate in the dense network with the assumption of end-to-end connectivity between pairs of the source and the destination. Some of the situations like military, post disaster, etc., there is intermittent connectivity among the nodes all the time. DTNs are the most appropriate in the above situations as they have characteristics to function in a disconnected network by using the paradigm of store, carry and forward to route the messages. One of the most challenging tasks in these types of networks is the routing because connectivity is opportunistic. It is not possible to predict that when one node will come in contact with another node. The mobility of nodes generates the transmission opportunity and the guaranteed delivery of the message is totally depends on the selection of suitable relay nodes.

The mobility of nodes has a great impact on the performance of the routing protocols in DTN and they exhibit varying performance for a different scenario. Our work in this thesis is mainly on routing in DTN, which is divided into two parts: a post disaster situation and human mobility. The first part proposes a map based architecture and synthetic mobility model to mimic the movement pattern of different entities (objects) involved in a post disaster scenario. Also, routing schemes have been proposed to suit these architecture and mobility model by exploiting the movement pattern of the objects. In the second part, we propose routing protocols for human mobility scenarios like campus and conference by utilizing the social characteristics of a human being. The implementation of a map based architecture and routing protocol, and the simulations have been done in the ONE simulator and compared the results with the existing schemes.

2. Brief description on the state of the art of the research topic

This section presents the literature review of the work done in a disaster area network (a post disaster scenario) such as proposing of synthetic mobility models, map based network architectures and evaluation of the existing Delay Tolerant Network (DTN) [1] routing protocols and in the human mobility scenario, social based routing protocols based on the human social characteristics.

2.1 Post Disaster Scenario

Various solutions have been proposed in the literature for a post disaster area network situation to provide recovery from crisis, which is a very complex task. A quick and synchronized response must be given to the rescue and relief entities, the first responders and victims present in the post disaster scenario. Another important action is to save the lives as much as possible, meet the needs of the victims and minimize the losses due to the disaster. The collection and analysis of situational data of the disaster affected area are one of the most important necessities to minimize injury, loss of life and property damage [2]. This information is helpful to the main coordination center of the rescue and relief operation to coordinate and manage the resources. The first few hours after the incident of the disaster are very important, afterwards the possibility of finding survivors is low. Nowadays, people mostly use handheld devices such as smart phone, digital gadgets, etc. to communicate with each other by making calls or sending the text SMS through the Internet using social networking applications such as Facebook, Twitter, WhatsApp etc. But the existing communication infrastructure like GSM, telephone network may be damaged or stopped functioning due to over usage. Thus, there is a strong need for rapid deployment of communication networks that can provide considerably required connectivity and communication capabilities for rescue-workers and stayers of a disaster affected zone to restore the stability.

The mobility patterns of the crew members in a post disaster scenario are totally different than other scenarios. Hence, they must be modelled and become promising to the nodes involved in post disaster to take the forwarding decisions in routing. The following subsections discuss the existing synthetic mobility models, map based network architecture and the evaluation of routing protocols proposed till date in a post disaster scenario.

2.1.1 The Existing Synthetic Mobility Models

The synthetic mobility models for a post disaster area generate the movement patterns of crew members and victims based on mathematical formulas.

Aschenbruk et al. [3] proposed a post disaster mobility model based on the separation of rooms. The disaster prone area is divided into different zones such as incident location, a casualty clearing station, ambulance parking area and technical operation command. Each zone is assigned a group of entities such as incident location is a given set of relief worker to transport the patients to next zone which is a casualty clearing station. Authors have implemented BonnMotion tool [4] to generate the movement traces for the above mobility model. Though, one of the main limits of this mobility model is that it only studies the mobility of crew members, while the mobility of victims is not taken into consideration. Even they simulated the post disaster operation for one incident location, but it needs to setup all the zones for individual incident location when a disaster occurs on more than one location in specific regions.

Nelson et al. [5] presented event and role based mobility model to describe the movement pattern of the objects in a disaster scenario. It was the first mobility model that was reactive in role based nature of environmental events. Three different entities are considered in the model: object, role and event. The physics based gravitational model is used to define the flee and approach actions for the objects. The gravitational force is given by $= (G * m\_1 * m\_2)/d\^2$. Mass m1 and m2 are replaced with mass (I - Intensity) of the event in the above equation and the resultant force of attraction and repulsion for any object is calculated by $F = I/d\^2$. Based on the event intensity and distance from the event, forces are applied to the objects and they react accordingly as per their assigned role. The one of the limitations of this model is that it does not assign the dedicated set of crew member in the event areas. The crew member remains working near recently happened event and they follow random based movement in the scenario. But in reality, they perform the tactical movement in the specific event area.

2.1.2 The Existing Map Based DTN Architecture and Mobility Model

Another type of possibility is to consider scenario based on real map and incorporate the movement of nodes in the restricted area of that map. The advantage of the map based model is that we can get more accuracy than synthetic model, but the mobility of the nodes still generated through mathematical formulas. Several authors have proposed map based mobility model and architecture for a post disaster situation as follows.

Uddin et al. [6] first proposed map based mobility for DTN, where the mobility of both rescue and relief members, and victims is taken into account. According to the types of disasters such as hurricane, tornadoes, fire, etc., the movement of the populations either precedes (e.g. hurricane) the event or follows (e.g. fire) the event. They concentrated on the fore-warned move of populations before the disaster to evacuation centers. There are a small number of coordinating centers and large number of evacuation centers. Emergency vehicles move between coordination center and evacuation center to supply relief goods. In addition, some relief workers are also assigned to the evacuation center to distribute the relief goods and the police officer patrol on whole area. All the entities are carried with DTN enabled devices, which facilitates the communication between them. The authors considered the movement of entities on real map and also damage occurred to infrastructure and transport system. The disaster has associated an intensity, which reveals the potentiality of the damage. This mobility model may not be appropriate, when several disaster events occur in some distant places in the same city.

Another effort made by Gupta et al. [7], they proposed 4-tier map based DTN architecture for post disaster relief and situation analysis. The disaster affected area is divided into different clusters called Shelter Points (SPs). Each SP is assigned a group of relief workers (tier-1) and stationary placed Throw Box (TB) known as tier-2 device. Data Mules (DMs) such as a high speed vehicle, travel back and forth between SPs. Master control station (tier-4) which is also immobile, placed at the location from where connectivity to the outside world can be reached. Each relief worker is held with DTN enabled mobile devices. The relief workers gather the information and send to its SP and later on it is transferred to the main control station. The drawback of this architecture is that relief workers follow arbitrary movement inside SP, but in reality it should be premeditated.

2.1.3 Evaluation of the Existing DTN Routing Protocols

This subsection presents the existing DTN routing protocols evaluated using the above mobility models or architectures in a post disaster scenario.

Martin-Campillo et al. [8] evaluated the existing routing protocols such as epidemic, Prophet, MaxProp and Time to Return (TTR) [9]. From the result of the simulation, they draw two conclusions. First, MaxProp is the best routing in all scenarios in terms of delivery probability irrespective the number of nodes and message generation rate. Another, TTR forwarding shown far below delivery probability than MaxProp but lower overhead and cost per message. Takahashi et al. [10] evaluated the different routing protocols such Directory Delivery, First Contact, Epidemic, Spray and Wait, and Prophet. To evaluate the routing protocols, the fairness issue is considered in delivering the messages between nodes in the disaster area. It is concluded that none of the above routing protocols could achieve the fairness criteria.

Saha et al. [11] evaluated five existing routing protocols named epidemic, spray and wait, spray and focus, and Prophet uses cluster mobility model [12] for disaster scenarios. The result concluded that spray and wait shown the lowest overhead ratio. Moreover, no routing protocol is superior in terms of delivery probability, but it is dependent on the other parameters. Martin-Campillo et al. [13] proposed new routing protocols by using the mobility model [3] of disaster situation. Previously, the same authors proved that TTR forwarding has shown lower cost and overhead, but it is negative by producing lower delivery probability. Also, it was shown that MaxProp outperformed in delivery probability but at the cost of overhead. Hence, they combined the advantage of both: MaxProp and TTR and presented two new routing schemes PropTTR and PropNTTR. The routing protocols have been evaluated in terms of energy efficiency, delivery probability and delivery cost by varying the number of nodes and the message sizes. The result concluded that PropTTR shown a good delivery ratio than TTR and PropNTTR performed close to MaxProp but with decreased overhead ratio and energy consumption.

Inwhee et al. [14] proposed new routing protocol, which assigns the priority to the messages. This protocol gives higher priority to those messages with high delivery probability than others with low probability. Message priority based routing achieved high delivery ratio, low overhead ratio and even low delivery delay than MaxProp routing. Gupta et al. [7] proposed new DTN routing protocol (DirMove) to suit their map based architecture. The routing protocol keeps the track of the recent direction of movement of mobile nodes by calculating the distance at two successive time instances from the destination. Along with movement direction, it also considers the past history of successful delivery and delivery latency. The authors compared DirMove routing with the existing protocols such as epidemic, spray and wait, EBR, Prophet, RAPID [15], MaxProp by varying the number of nodes. DirMove routing outperformed in delivery probability, delivery delay and number of dropped messages than MaxProp but at the cost of little increase in overhead ratio.

Very few routing protocols have been proposed till date specifically for a post disaster scenario. Even though, they perform better in a specific mobility model or network architecture. Still the current research trends are in improving the existing network architecture, proposing new one and devising the routing protocol to suit the specific architecture or mobility model.

2.2 Routing Protocols in Human Mobility Scenario

The human mobility is an embryonic field which is dedicated to extracting patterns that govern human movements. Many authors have analyzed the human mobility traces in real time and concluded that human mobility is not random, but by socializing behavior of human [16].

Since handheld devices such as mobile phone, PDA etc. is carried by human being and it has made possible for the devices take into account the human relationship characteristics such as contacts with other people, time spent with them, and the level of relationship between people. Social based forwarding decisions reflect the people's socially meaningful relationships where the relationship information comes from aspects such as human mobility, interaction, and social structures [17]. In literature, researchers proposed many such schemes by considering the social characteristics [18] such as centrality, similarity, community and friendship in human beings. Following are some of the social based routing protocols based on one or more above characteristics utilized in forwarding decisions.

Hui et al. in [19], presented the first proposal called Label routing to use the social characteristic (e.g. community) of human beings by the routing protocol in Pocket Switched Networks (PSN). Each node attaches a small label to indicate its affiliation or group to others. The routing protocol used this label to select the next relay node. A node forwards the message either directly to the destination or the next hop which is having the same label as the message destination. This routing scheme is very simple to implement because it needs the label to be assigned in prior. In label, the message forwarding is done only through members of the same community as relay nodes. For example, the sender node does not contact any member of a community of the destination, the message delivery may fail even other prominent nodes exist in the network. Mtibaa et al. [20] proposed the PageRank routing based on an algorithm in search engine, which assigns the importance to the web page within the set of pages. Similarly, PeopleRank discovers the most popular nodes in a social context and forwards the messages as these nodes more likely meet with others.

Daly et al. [21] proposed Simbet routing, which uses similarity and betweenness centrality metrics together to select the relay node towards the destination. Betweenness centrality metric discovers the nodes which work as bridge node inside their locality, while similarity metric finds the common nodes with the destination which act as the forwarder. Simbet utility is computed using a weighted combination of similarity and betweenness centrality. A node forwards the message only if encountered node shows higher values of SimBet otherwise it continues to hold the message and wait for other nodes with higher value.

Hui et al. [22] proposed routing like Simbet called BubbleRap that uses two different social characteristics such as centrality and community. A node belongs to at least one of the communities and it is identified using distributed community detection algorithm [23]. The centrality are of two types: global centrality and local centrality, which measure the popularity of nodes in a whole network and within local community respectively. The message forwarding process in BubbleRap is done two stages. In the first stage, the message is relayed to the global central node towards the community of the message's destination. In the second stage, once the message is reached to one of the members of the local community, the forwarding is done using local centrality to deliver the message to the final destination. BubbleRap quickly transfers the message to the destination or inside its community. But it experiences one problem, when the destination node belongs to the community whose all members have low values of global centrality, it is difficult to find relay node from its community.

Bulut et al. [24] introduced the friendship routing based on friendship metric called Social Pressure Metric (SPM) from the histories of encounters between two nodes to construct the friendship community. The messages are forwarded to destination directly or the node containing the destination in its friendship community.

3. Objectives and Scope of work

The following are the objectives:

1. To propose network architecture and its routing protocol for DTN in a post disaster situation by exploiting the characteristics of participating nodes in order to improve the delivery probability by decreasing overhead ratio and the cost.
2. To propose a routing scheme for DTN in human mobility scenario based on the social characteristics of a human being to improve the delivery probability.

The scope the work is as follows:

1. The post disaster situation analysis is very challenging task in case of failure or total destruction of the existing network infrastructure. The network setup based on DTN helps in facilitating communication services for rescue and relief workers, and victim to exchange the messages in the absence of continuous network connectivity. Along with the suitable network architecture, an efficient routing also plays an important role in achieving many performance measures such as higher delivery probability and minimum delivery delay with lower overhead and energy consumption, which are the major concerns for a post disaster scenario.
2. The network formed of human being carried mobile devices with interfaces such as Bluetooth, Wi-Fi, etc. has made information exchange possible via peer-to-peer mode and in multi hop fashion. The social characteristics such as community, centrality etc. related to a human being do not change frequently, but over the longer period of time and can be used in the forwarding decisions by the routing protocols in DTNs. The proposed routing schemes improve the delivery ratio in the network of human being at the places such as education campus, social neighborhood and conference.

4. Original Contribution by the Thesis

The contributions of our work in the support of the above said discussions are as follows. The work in thesis is divided into two threads: one is routing in DTN for disaster area network (1-2) and another is routing in DTN for human mobility scenario (3-4).

1. We propose a map based DTN architecture for a city like region, which mimics the movement patterns of rescue and relief entities, and victims on real map of disaster affected region. The rescue and relief workers follow the strategic movement in the specific event area. The routing protocol to suit this architecture is also proposed, where a node takes the forwarding decisions by utilizing the knowledge such as dissimilarity coefficient, encounter information, speed and time to return.
2. We also propose Role based 3-Tier Mobility Model (RTTMM) which distributes the rescue and relief entities to the disaster events into the proportion of intensity of a disaster event. Moreover, two routing protocols proposed for this mobility model by exploiting the movement characteristics of the nodes involved in a post disaster scenario. EMDBR utilizes encounter and movement direction information in selecting the relay node. The existing work reveals that MaxProp has outperformed in terms of delivery probability irrespective of mobility model in a disaster scenario. So, we propose MEMDBR that uses the features of both MaxProp and EMDBR together to take the forwarding decisions.

3. In the second part of this thesis, we propose social based single copy routing protocol, which select the suitable relay node from community members based on social metrics such as similarity and friendship utility together. Each node identifies the community members using Inter Contact Times (ICTs) with other nodes based on the power law characteristics.
4. We observed that community similarity is very low in the early stage of simulation in the existing community based routing such as BubbleRap so, we propose a node scheduling approach to enhance the delivery probability.
5. Based on the observation in social community that people meet to very few persons more frequently and spend more time with community members only. We propose Contact Duration (CD) and Contact Frequency (CF) based forwarding approach, once the message is reached inside its local community, unlike local centrality of BubbleRap.

5. Methodology of Research, Result and Discussions

This section discusses the proposed routing protocols in DTNs for a post disaster scenario and human mobility scenario in Sec. 5.1 and Sec. 5.2 respectively. The performance of the routing protocols is accessed using following one or more parameters:

1. *Delivery probability*: It is defined as the ratio of number of messages delivered successfully to the total number of message generated.
2. *Delivery latency or delay*: It is the time elapsed between the creations of the messages at source and delivered successfully to the destination.
3. *Average overhead ratio*: It is the ratio of the difference of the total number of messages relayed minus delivered successfully to that of the number of messages delivered successfully.
4. *Average hop count*: It defines the number of nodes through which successfully delivered messages travelled from the source to the destination.
5. *Routing efficiency*: It is defined as the ratio of delivery probability to that of an average overhead ratio.
6. *Cost per message*: It is defined as total number of message transmissions divided by the total number of successfully delivered messages.

5.1 Routing in a Post disaster scenario

We propose two different network architectures, and suitable routing protocols for them in post disaster scenario as follows:

5.1.1 Proposed Map Based Architecture and Routing Protocol in DTN

First, we propose the map based architecture for a post disaster situation on real map of the city using DTN as network architecture. We divide the disaster struck zone into different event areas and each is allotted group of rescue and relief workers to collect the information along with their assigned task. Each event area is allotted stationary Drop Box, which is an information repository for that event area. The relief and rescue workers, policemen and victims follow the different movement pattern in their respective event area. The relief workers return to Drop Box with a different time period. Also, several household are created, the victims are evacuated there and move around. Some of the civilians work as volunteers and move across the household to help the victims. Policeman patrol the event area to avoid the robbery, etc. We have implemented the above network architecture in ONE simulator [25] by extending the built-in map based mobility model to generate the movement traces, which are fed as input to the routing protocol.

To suit the above network architecture, we also propose routing protocol, which takes the forwarding decisions based on time to return, dissimilarity coefficient, encounter ratio and speed of the nodes. The nodes which show lesser time to return to the Drop Box is more preferable. The dissimilarity coefficient measures the dissimilarity of encountered uncommon nodes and it gives the new exploration made by the nodes in terms of spreading the messages. The nodes exhibit encounters with other nodes and fixed locations. The speed of the nodes is dissimilar so, nodes with higher speed deliver messages quickly before they expired. The weighted combination of the above parameters is considered by experimental analysis to decide the final forwarding metric. We simulated only one event area and it is assumed that inter event area communication takes place through Data Mules. The result of the proposed routing protocol is compared with the existing schemes such as Epidemic [1], Prophet [27] and MaxProp [28] by varying buffer sizes, message sizes, time-to-live and number of nodes. The performance parameters like routing efficiency, average delivery delay, average overhead ratio and message drop count have been considered to analyze the routing protocols. The results demonstrated that the proposed routing protocol outperformed in all the performance parameters other than an average delivery delay, which is comparable with the others.

5.1.2 Proposed Synthetic Mobility Model and Routing Protocols

The role based 3-tier synthetic mobility model is proposed, which mimics the movement pattern of rescue and relief entities, ambulances, emergency vehicles and policeman. It is assumed that multiple events occur at very nearby location and dedicated group of crew members assigned to each event into the proportion of the intensity of the disaster event, unlike the existing synthetic mobility model [5]. Some of the relief workers move arbitrarily inside the event area and others return from time to time to the center of the event area. Our model has shown high network connectivity, average node degree and maximum node degree during the entire period of simulation than the existing one [5].

We have exploited the movement characteristics of the objects such as movement direction and encounter information, moving in a post disaster situation in above mobility model and propose two different routing protocols. First routing protocol (EMDBR) makes the forwarding decision based on the movement direction and encounter information. We found that it outperformed in overhead ratio, but achieved moderate delivery probability than MaxProp. Hence we propose, second routing protocol (MEMDBR) by combing the advantages of both: MaxProp and EMDBR. We have varied the parameters such as the number of nodes, buffer sizes and message sizes to evaluate the performance of proposed routing protocols against the existing schemes like Epidemic, Prophet, MaxProp, Spray and Wait [29], and EBR [30]. MEMDBR outperformed in almost all performance parameters than MaxProp on variable buffer sizes, number of nodes and the message sizes.

5.2 Routing in DTN for Human Mobility Scenario

We propose the social based routing in the network formed of human being carried mobile devices, in DTN.

5.2.1 Community Detection Based on Inter Contact Time and Social Characteristics Based Single Copy Routing

The existing scheme constructs the community based on aggregate contact duration and contact frequency, but it is not a good measure to detect. Hence we utilized the power law nature of Inter Contact Times (ICTs) [31] between node pairs to detect the community structure and propose the routing protocol. Each node maintains the community member list and it changes dynamically over a period of time. Also we use social characteristics such as similarity and friendship together in a selection of relay node. When two nodes encounter each other, then node first checks that whether the message destination belongs in the community list of peer node and higher value of a social metric then the forwarding is done otherwise it continues to hold the message. The routing protocol is implemented in ONE simulator and compared with the existing schemes like Prophet, Simbet and BubbleRap by varying the buffer sizes and time-to-lives. We have taken the real trace datasets [26] from two different environments: campus and conference, to evaluate the performance of the routing protocols.

The results demonstrated that the proposed routing protocol performed the best in terms of delivery probability and average delivery delay with comparable overhead ratio in the datasets of both environments.

5.2.2 Node Scheduling Approach

We analyzed the community similarity in BubbleRap routing (uses distributed community detection algorithm to detect the community structure [23]) and detected that it is very low in the early phase of the simulation. Because nodes use aggregated contact duration to add the members in the community list and they cannot be added until aggregated value of contact duration becomes higher than the threshold. We propose a node scheduling approach based on two centralities: degree and betweenness. The degree centrality is measure of number of direct links incident upon a given node and it will be the central node in the network. The betweenness centrality determines the number of shortest path passing through a node, which can work as bridge node for the others. The weighted combination of degree (0.3) and betweenness (0.7) centrality is taken into consideration by empirical analysis. The nodes are scheduled in decreasing order of centralities in order to select the relay node. We compared this strategy against BubbleRap by varying time-to-lives and used the same datasets [26] as discussed earlier. The simulations have shown the higher delivery probability, lower delivery delay with little increase in overhead ratio than BubbleRap.

5.2.3 Contact Duration and Contact Frequency Based Forwarding Approach in the Local Community

Another observation, we made inside the local community for BubbleRap routing. People meet to very few people in their community more frequently and spend more time in meeting. Based on this, we propose the contact duration and contact frequency based forwarding approach in the local community to select the relay node, once the message is reached in its community. Each node accumulates the total number of contact frequency and duration with other nodes. We modified the BubbleRap routing with this forwarding approach and compared with it by varying time-to-lives. The results have demonstrated that the modified BubbleRap outperformed in terms of delivery probability with the comparable delivery delay and little bit increase in the number of forwarding than original BubbleRap.

6. Achievements with Respect to Objectives

The objectives were to propose the efficient routing protocols in DTN for a post disaster and human mobility scenario to improve the delivery probability, by decreasing an average overhead ratio than the existing schemes.

The results demonstrated that the routing protocols proposed for the map based architecture and synthetic mobility model achieved the higher delivery probability at reduced overhead ratio and the cost than the existing schemes. Also, routing protocols presented for human mobility scenario outperformed than the existing social based methods.

7. Conclusions

In this work, we have proposed a map based network architecture and synthetic mobility model in a post disaster scenario to imitate the movement patterns of the crew members. They collect the information related to disaster and also work as message carriers along with their usual task of rescue and relief. The routing protocols have been proposed to suit the above map based network architecture and synthetic mobility model by exploiting the characteristics of the crew members. The results have proved that our routing protocols performed the best in terms of delivery probability, by maintaining the other performance parameters.

Further, we have proposed social based routing protocols by optimizing the existing schemes. Community detection was done using Inter Contact Times between the node pairs by exploiting power law nature instead of aggregate contact duration. Moreover, we have recommended the two different approaches to deliver the message to the community members and inside the community. The results have shown that the social based routing in human mobility, such as campus and conference datasets outperformed than the existing scheme.

8. List of Publications

[1] Gondaliya, N. and Kathiriya, D. (2016). Map Based DTN Architecture and an Efficient Routing Protocol in Delay Tolerant Network for Post Disaster Situation. *International Journal of Computer Science and Information Technology*, vol. 14, no. 8. (Indexing: Thomson Reuter ESCI). ISSN: 1947-5500.

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