DATA DELIVERY PREDICTABILITY IN INTERMITTENTLY CONNECTED MANETS

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Abstract

Network that functions without any infrastructure is said to be Mobile Ad Hoc networks (MANETs). Each node present in this network chooses any route and moves autonomously. At the same time rely on upon each other to send its messages to target nodes. Most of the routing protocols for MANETs tend to be designed with the presumption in which not less than one particular route is available between the source and destination. Furthermore it is assumed that, all nodes are involved in packet forwarding process. But this assumption does not hold good for all real time situations for the reason that of the high mobility and less density of the nodes present in the network and short coverage range of every node. Possibilities arise in the network so that a node could not forward the data to any of the nodes and so it necessitates packets to be stored up in the nodes buffer until it encounters an appropriate node. For deciding the apt receiver node, status of the network and contact statistics of the nodes are required in order to boost up the packet delivery ratio and to trim down the delivery delay and the total number of transmissions. We proposed E-B-M method which takes the best forwarding decision based on the past encounter history and the behavior of the nodes.

Keywords: *Intermittently connected, Mobile Ad hoc Network, Data delivery certainty, Ageing, Transitivity, Buffer Occupancy, Misbehaving nodes*

I. Introduction

Making a network that functions without any infrastructure, central administration and routers is achieved through ad hoc mode of communication. Mobile ad hoc networks comprise of set of mobile nodes independently move in any direction, organize by itself, leave or connect with the network when requires. Multi-hop radio relaying, Decentralized nature, low node density, less memory, less power, light weight mobile devices and dynamic network configuration are the features of MANETs which makes it different from other wired and wireless networks. Thus routing in MANETs happens to be one of the most challenging tasks. Most of the existing routing protocols for MANETs are developed with the assumptions that there exists at least one path between the Source node and the Destination node at all the times throughout the packet forwarding process. Even if any situation arises in the network that the nodes are misbehaving, switched off or moved out of the path, alternative paths can be selected in order to precede the communication without any hindrance. Routing protocols are developed with route repair and route maintenance mechanisms. But all such protocols are designed only with the assumption that all the nodes in the network are cooperative and at least one node present at all the time in the transmission range of the other. But these assumptions do not work well for some of the real life environments and such type of network is said to be intermittently connected Mobile Ad hoc Network (ICMAN). Routing of packets in intermittently connected network [1],[2],[3],[4] is based on *store-carry-and-forward* model. Suppose, if a node that is not connected to other nodes has a message copy to forward, it stores and carries the message in its buffer until there arises an appropriate communication opportunity. Many examples are given for such networks in real life including ecology monitoring, search and rescue operations, Vehicular ad hoc network, military networks etc.

The rest of the paper is sectioned as follows. Section II explains the work related our work. Node selection strategy along with the model calculations are explained in Section III. The results obtained and the parameters used for the simulation are discussed in Section IV. Conclusion and future work to be done to enhance further the proposed algorithm is given in Section V.

II. Related Work

The related work correspond to our paper is discussed below for detailed understanding. In intermittently connected Manets, when the possibility of forwarding the data is null, the nodes store and carry the packets until it encounters an appropriate node within its communication range to forward it. This mode of communication continues until the message reaches its destination. Based on the number of copies forwarded, Store-Carry and Forward model of routing protocols are classified into three types. They are (1) Forwarding, (2) Flooding and (3) Controlled flooding. Only a single copy of the message is forwarded through the intermediate nodes to the destination in Forwarding Scheme. Multiple copies are spread into the network in flooding scheme. Only the limited copies are spread into the network based on some criteria in Controlled flooding scheme. Regarding the utilization of the network and node resources Forwarding schemes perform well. But the delivery ratio and the delivery delay are the worst in such cases. Better Delivery ratio and delivery delay can be achieved in Flooding schemes, but the utilization of the resources are very high which is not practically possible. Hybrid of these two schemes which takes the advantages of both the categories is said to be called Controlled Flooding.

In this paper we have considered three factors involving in unproductive resources. That includes (1) transmission between the nodes that lacks past history of encounters with the destination address (2) transmission between the nodes that lacks enough buffer space to hold the message (3) transmission between the nodes that lacks forwarding the packets to the next node in order to conserve its own resources (packet droppers). Transmitting the data to the nodes in these categories consume network resources but will not optimize the network performance like packet delivery ratio and delivery delay. There are many protocols which consider some utility functions. In our paper we have used history based routing as the major utility function. In history based routing protocols [5],[6], history of encounters between nodes are utilized to make the routing decision with the idea that a node already has encountered the destination many times, has the opportunity to meet the destination again. Information about the history of the contact is not sufficient to decide the forward decision process. If the buffer space is not vacant, then the packets are dropped without further being routed. So it is necessary to check the availability of buffer space in the encountered node before forwarding the message to it. Frequency of occurrence of the contact with other nodes in the network along with the information of available buffer space is discussed in the existing papers.

Controlled flooding algorithms forward only a limited number of copies and offer an efficient utilization of network resources. The algorithms used for deciding the best nodes to forward message copies are diverse in each of the existing routing protocols based on various requirements. Epidemic routing [7], [8] uses multiple copies flooding scheme. No node selection strategy is used in this protocol. During every contact between the nodes sharing of data occurs. Whichever node comes in contact carries the message copies. As a result, it yields multiple copies within short period of time. But the performance analysis of epidemic routing explains that this approach consumes high bandwidth, buffer space and energy. Therefore this approach is unsuitable for resource constrained networks. In order to overcome the disadvantages of epidemic routing, the algorithms with controlled flooding have been proposed. In Prophet routing protocol [9], nodes give messages to other nodes they meet with a certain data delivery probabilities. The calculation of the data delivery predictabilities in this protocol has three parts. Distinct equations are used for calculating data delivery probability, ageing and transitivity. If the number of computation increases in the nodes, then it will lead to increase in the resource consumption of the nodes. In [10] Ling designed a feedback adaptive routing scheme which is based on the factor that only determines the node mobility. In this algorithm higher the mobility of the nodes, higher is the messages transmitted through those nodes. But, higher the mobility does not mean that there arises the possibility of meeting the destination nodes frequently.

To cope up with long disconnections in the network, messages must be buffered in each node for long period of time. This means all the intermediate nodes require sufficient buffer space to store and carry all the messages that are to be forwarded during future communication opportunities. It means availability of the buffer space in the nodes should be proportional to demand in the network. Otherwise packet dropping occurs. So the routing protocols might need to consider the available buffer space of the encountered node when making forwarding decisions. A possible forwarding strategy, which is implemented in epidemic routing, is that when a node meets another one that is not the destination, the entire content of the buffer is forwarded with the encountered node without checking the possibility of holding the message in its buffer. This may lead to partial transmission of the data which is not useful and requires repeated transmissions of the same data. To optimize the usage of network resources, unnecessary forwarding of message to the node with limited buffer size should be avoided. In this way chances of packet drop due to buffer overflow at the next hop node can be reduced. Joint consideration of history of encounters and Checking of buffer occupancy are the existing methods used in the routing protocols to limit the total number of transmissions to preserve the unnecessary consumption of the resources. To our knowledge none of the existing routing protocols considered history based routing protocols, buffer occupancy along with the detection and mitigation of misbehaving node or selfish nodes in the network which is one of the sources of unproductive resources.

Nodes in the network are classified into co-operative nodes and non co-operative nodes. Nodes which are ready to help for others communication are co-operative nodes. In order to save its own resources some nodes in the network will not participate in forwarding process. They are called non co-operative nodes. Non-cooperative nodes otherwise called as malicious nodes reduce the packet delivery ratio and consumes the network resources. Techniques called Watchdog and path-rater are used along with the routing protocols to mitigate the misbehavior nodes from routing process. The disadvantage in watchdog technique is, it checks the transmission of message from the next node. But it will not check the reception of message by the second intermediate node. In order to overcome this disadvantage 2-hop acknowledgement technique is used. The drawback in both these techniques is the increase in the percentage of overhead with the percentage increase of misbehavior nodes.

Motivated by the above literature survey, this paper explores history of encounter that considers nodal contact statistics, network status and buffer occupancy along with the behavior of the nodes. Goal of the E-B-M method is to choose the best node selection criteria in order to increase average delivery ratio, reduce the average delivery delay and the total number of transmissions with constrained network and node resources.

III. Node Selection Strategy

(Node Selection Method which considers Encounter-Buffer-Misbehaving Node)

The main objective of this paper is three fold. First, the proposed node selection strategy should adapt to changes in the network status. Second, the strategy should be suitable for low computation, less memory, less battery devices. Finally, it should not generate false detections and isolations of misbehaving nodes. The following sections explain the node selection strategy based on the utility functions. Resources get consumed during the communication process in the network as well as during computation process carried out in the nodes. In the proposed node selection method frequency of encounters, buffer occupancy and misbehaving nodes are considered for selecting the packet forwarding strategy.

(1) History Of Encounters (E)

Based on the idea, a node has visited a location several times before, will have better chance to visit the same location again in future. For predicting the data delivery between the source and the destination nodes, the parameters to be considered are Data delivery certainty, Ageing and Transitivity

(A) Data Delivery certainty and Ageing:

When two nodes are in the communication range of each other, they exchange the contact records which is already calculated and updated in its memory. Contact record includes data delivery certainty information to predict the possibility of reaching the destination. After that, the information is used to decide either message has to be forwarded to the encountered node or not. Node forwarding strategy based on the calculation of data delivery certainty and ageing uses Equation (1) which considers both number of past encounter and time interval between successive encounters.

$$DP(A, B) = N * DP(A, B)_{old} * e^{-\Delta t} \quad (1)$$

Where

DP (A, B) - Delivery Predictability between the node A and B

N – Number of encounters

$DP(A, B)_{old}$ - Delivery Predictability between the nodes A and B which is already calculated and stored in the contact record.

e - Mathematical constant (Euler's constant). Its value is approximately 2.718.

$\Delta t = (t2 - t1)$ – time interval between the successive encounters of the nodes A and B

Model calculation based on the above equation is given below. The calculation is made for three encounters with four different time intervals 0.5, 1, 2, and 3 time units. When the first time two nodes meet each other, the values of N, $DP(A, B)_{old}$ and Δt are set to 1. From the Data Delivery certainty values calculated below, it is clear that when the number of encounters increases, the Data delivery certainty values increases. Also it is understood that the data delivery certainty decreases with increase in the time interval between successive intervals.

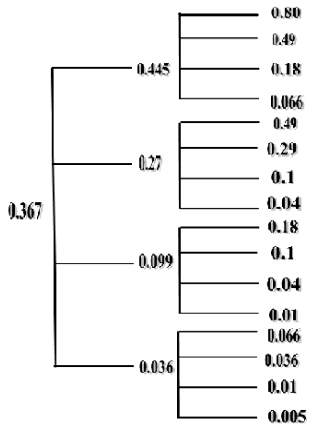

Figure 1: Model Calculation for the Data Delivery Certainty

Calculation of both data delivery certainty and ageing are done using a common equation. Therefore the energy consumed for computing the equation in a node decreases when the complexity of the equations decreases.

(B) Transitive Property

The data delivery certainty should satisfy transitive property. Even though node A and node B do not have communication range overlapping each other, transmission of data between A and B is possible if and only if an intermediate node exists in the network which meets both node A and B frequently. Using the contact record maintained in the nodes, transitive property can be achieved.

(2) Buffer Occupancy (B)

Each node should calculate its available buffer every time after receiving the data using the Equation (2).

$$BO_{new} = BO_{old} - Msg_{size} \quad (2)$$

Where

BO_{new} – Current Buffer Occupancy

BO_{old} – Previous Buffer Occupancy

Msg_{size} – Message Size

Node which carries data with message size Msg_{size}, encounters any intermediate nodes, it checks for the following condition to be satisfied before transmission.

$$BO \geq Msg_{size} \rightarrow \text{forward message}$$

$$BO < Msg_{size} \rightarrow \text{Stay idle}$$

(3) Detecting And Isolating The Misbehaving Nodes (M)

In intermittently connected mobile ad hoc network, since store-carry and forward scheme of routing is followed it is not advised to receive the acknowledgement from the destination node. Instead, acknowledgement is received by the previous nodes from the next node throughout the routing process. Here, the acknowledgement packets take only one-hop transmission between two successive nodes. Every time when the packets are forwarded to the next node, it is necessary to acknowledge the sender by the receiver that the packets are received successfully. The knowledge of the number of acknowledgement packets received by the nodes is used to detect and isolate the misbehavior or selfish nodes from future routing process in the network with the aim to avoid the needless consumption of constrained network resources. If the packets are received successfully, acknowledgement packet is received by the sender from the receiving node. Whenever the acknowledgement packet is received by the nodes, packet delivery confirmation counter is updated by 1. If the node is dropping the packet or it is not receiving the acknowledgement from the other nodes, then packet delivery confirmation counter will not be updated. This counter is refreshed for a regular period of time t_{rfresh}. When the node wants to forward the data, it first checks whether the node has delivered any packets before or it drops the packet without forwarding from the entry in this counter. If the number of packets it received from other nodes for forwarding is equal to the number of acknowledgement packets it received for forwarding others data, it is concluded that the node is not dropping the data. If the number of packets received to forward to the other nodes $N_{pr}(F)$ is higher than the number of acknowledgements it received for forwarding others data $N_{ar}(F)$, the node is said to be selfish node. The threshold for packet delivery confirmation factor varies with respect to the number of nodes present in the network. If the number of ack packet received is high, it is not selfish node. Selfish nodes have very less or even zero acknowledgements received.

$$N_{ar}(F) \geq n_{th} (N_{pr}(F)) \rightarrow \text{ Good Node}$$

$$N_{ar}(F) < n_{th} (N_{pr}(F)) \rightarrow \text{ Misbehaving Node}$$

IV. Results And Discussion

The performance of the proposed routing algorithm is compared with two different existing algorithms and the output is analyzed under different conditions. Existing protocols for intermittently connected Mobile ad hoc Network such as Epidemic Routing and Prophet routing are compared with the proposed E-B-M method of node selection criteria. The performance of the algorithms is compared based on the metrics such as data delivery ratio, average delivery delay and the total number of transmissions.

Deliver Ratio: It is defined as the total number of messages sent from the sources to the total number of messages delivered successfully by the destination node.

Delivery Delay: It is defined as the total time required for delivering a message from Source node to Destination node.

Total number of transmissions: It is defined as the total number of messages transmitted from different sources to different destinations

Evaluation Scenarios:

Since the network is an intermittently connected mobile ad hoc network, we have considered 50 nodes moving in a 600 x600 meter network. Random waypoint mobility model is considered for the mobility of the nodes. Each source node in the network selects a random destination node. After selecting the destination, it starts generating the messages to the destination nodes during the time of simulation. After receiving each message, the nodes should send acknowledgement packet to the previous node which is in just one hop distance from it. Since the nodes are intermittently connected, Acknowledgement from the destination node to the sender node is not recommended in our approach. In order to find out the misbehavior character of each node, one hop acknowledgement is used. The network is assumed to be resource constrained, So that the network as well as nodes is considered to have limited resources. The buffer space and the battery level in each node are limited. Network Bandwidth is assumed to be limited. Therefore there arises an opportunity that the forwarding of the messages can be affected due to limited bandwidth, limited buffer space and limited battery level. Each node is provided with the transmission range of 30 meters which enables moderate network connectivity with respect to the network size considered. Our proposed algorithm is used to choose the best next hop node and forward the messages to it. The performance of the protocols is evaluated with respect to the various buffer capacities and various percentage of misbehaving nodes.

The effect of Buffer Size

To study the effect of the buffer space in the nodes, we have set the values to 50, 100, 150 and 200 KB. By varying the Buffer space of each node, the proposed algorithm is compared with the two existing protocols in terms of Delivery Delay, Delivery Ratio and number of transmissions. The proposed algorithm outperforms the existing two protocols. Generally, when the buffer size of the node increases the performance of the network also increases. But forwarding the messages to the nodes without considering the delivery certainty, ageing and transitivity increases the number of transmissions in the network in turn congestion and packet dropping occurs. Unnecessary transmissions drain the energy of the nodes.

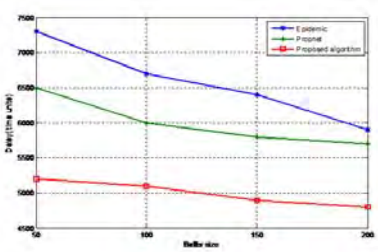

Figure 2: Buffer Size vs Delay

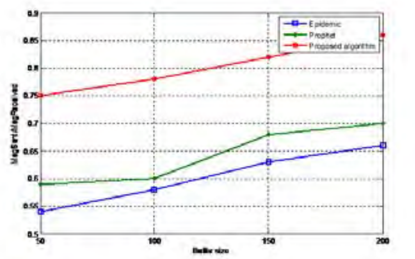

Figure 3: Buffer Size vs Delivery Ratio

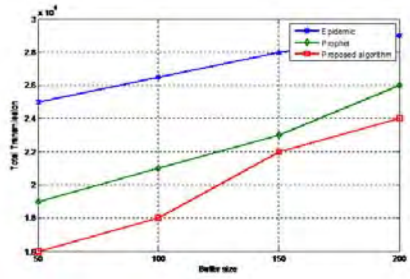

Figure 4: Buffer Size vs Total Transmissions

The Effect of Misbehaving Nodes

By varying the percentage of misbehaving nodes in the network, the proposed algorithm is compared with the two existing protocols in terms of Delivery Ratio, Delivery Delay. Increase in the percentage of misbehaving nodes in the network decreases the delivery ratio. Epidemic and Prophet routing protocols does not consider the presence of misbehaving nodes. Therefore the performance of those routing protocols gets affected. Our proposed algorithm avoids the misbehaving nodes for forwarding the data. Thus our proposed algorithm outperforms and gets unaffected by misbehaving nodes.

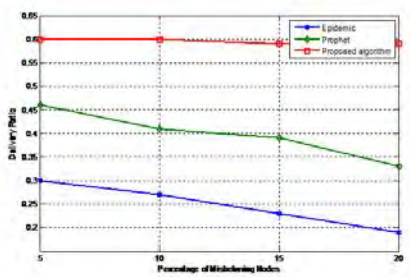

Figure 5: Percentage of Misbehaving Nodes vs Delivery Ratio

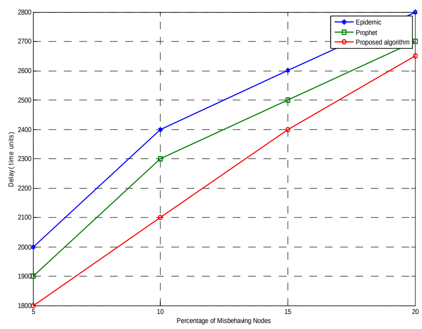

Figure 6: Percentage of Misbehaving Nodes vs Delay

V. Conclusion And Future Work

In our proposed algorithm, for node selection strategy we have considered the parameters such as delivery certainty, ageing and transitivity for choosing the best next node for forwarding the message. Our algorithm reduces the total number of transmissions in the network with good delivery ratio and delivery delay. It reduces the consumption of the network resources and the node resources due to unnecessary forwarding of the messages to other nodes. As a future work, we are planning to further enhance the performance of intermittently connected Mobile Ad Hoc Networks by considering cross layer optimization techniques.

VI. References

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