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A Simulation Based Study of Well Known Routing Protocols for Delay Tolerant Network

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Abstract: Delay tolerant networks are class of wireless ad-hoc networks in which end-to-end direct path between source and destination does not exist all the time. Conventional routing techniques are not feasible due to intermittent connectivity; therefore DTN emphasis on store and forward routing mechanism. DTN provides connectivity and communication in areas such as to extend the reach of internet to space, interconnect planets and underwater communication, which were considered to be unapproachable, distant and unfriendly. In this paper performance of some well known routing protocols for DTN is measured using different mobility models, number of nodes, transmission ranges and buffer sizes and present a comparative analysis in term of variety of parameters such as delivery ratio, overhead and latency. Based on the observations derived from simulation study, we also proposed a location based algorithm called "Grid based routing algorithm" for delay tolerant network. The goal of proposed algorithm is to provide prior knowledge of network to nodes, control flooding and number of transmissions in network. Grid based algorithm use concept of location information of nodes. By having location information messages are only delivered to the neighbor that is nearer and in direction towards to the destination.

Key words: Routing protocols · Epidemic · PROPEHT · Spray and wait · Grid based routing.

INTRODUCTION

Wireless networks are becoming more famous day by day, with the development of cheap technologies and information is available anywhere anytime. Wireless networks have numerous applications in various fields, some of them are: industrial applications, m ilitary applications, personal area networks, inter-village communication and wireless sensor networks. Wireless networks are classified as: infrastructure-based networks and infrastructure-less networks. In Infrastructure-based networks, access points or base stations are responsible to provide communication between mobile nodes. Examples are satellite networks, Wi-Fi, cellular networks and WLAN, as shown in Figure 1.

Infrastructure-less network does not rely on access points, base stations or some central administration to provide communication, example includes Mobile Ad-hoc Network (MANET) and Vehicular Ad hoc Network (VANET) [1] as shown in Figure 2.

Due to dynamic network topology, traditional internet routing protocols like distance vector and link state are unsuitable for ad-hoc network, which results in link instability. Therefore, different routing schemes are proposed for MANETS which are as: *on-demand or reactive* (DSR [2] and AODV [3]) and *table driven or proactive* (DSDV) [4]. MANETs rely on prior end-to-end connected link between nodes to forward packets. If node mobility is extremely high and continuous link between nodes does not exist due to network partition, it becomes difficult to forward messages to intended destination.

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Fig. 1: Infrastructure-based network

Fig. 2: Mobile ad-hoc network

These limitations gave rise to another type of network termed as Delay Tolerant Network (DTN) [5, 6] that exploits high node mobility and route messages among nodes without having connected path between them. DTN has application in various types of networks such as VANETs, inter-planetary networks (IPN), underwater networks, terrestrial networks, WSN and military networks [7, 8].

The rest of this paper is organized as follows: Section 2 discusses the concepts of some well known routing protocols for DTN. Section 3 presents the simulation results and comparative analysis of these protocols under four different scenarios and performance is measured with different parameters. Section 4 provides proposed routing algorithm with discussions. Conclusion is drawn in Section 5 and finally section 6 provides some indications of future research.

Literature Review: routing techniques, with varying characteristics, are proposed by different researchers. In this section we review routing in DTN and presents common DTN routing protocols.

PROPHET Protocol: PROPHET is a Probabilistic Routing Protocol using History of Encounters and Transitivity [9, 10]. While delivering messages there might be some nodes that meets each other on regular basis and there might be some nodes that do not or quite often meet each other. PROPHET exploits this assumption and allocates probability metric value called *delivery predictability* to each node as high, medium and low according to number of contacts they made. Whenever two nodes encounter each other they exchange delivery predictability values. If two nodes do not have any contact or very rare contact, a low predictability value is assigned to them. A medium value is assigned if numbers of contacts are less frequent and delivery predictability value is high if two nodes encounter each other on regularly basis. PROPHET also has transitivity property and it states that if node X regularly meets Y and node Y regularly meets node Z, therefore Z is a suitable node for X, therefore X marks Z's delivery predictability value as high in its summary vector [11]. PROPHETv2 [12] is the improved and modified version of PROPHET which maintain original ideas and design with only modifications in delivery predictability and transitivity updates [13].

PROPHET protocol has been successfully implemented in northern Sweden to provide Internet access such as email services and web access [14].

The problem with this scheme is that as number of nodes increases overhead ratio also increases. It consumes a lot of resources to process and store historical values.

Epidemic Protocol: Epidemic protocol [15] is flooding based protocol to solve routing issues for DTN. A node with flooding nature forwards message to every other node it meet. Epidemic protocol makes use of carrier nodes to deliver messages between source and destination. Epidemic protocol works on the assumption that sender of message do not have any prior information about location of nodes and network topology. For example a source node S, wanted to send a message to a destination node D, without having connected path between them. S flood out the messages to its two neighbors, N1 and N2, that are in direct transmission range of S. After some time *T*, N2 moves toward another host N3 and transmits the message to it. N3 is in transmission range of destination and finally sends the message to it.

This scheme guarantees the delivery of data with high probability but it suffers from high network traffic because of high numbers of transmission on network. Epidemic consumes a lot of network resources such as buffer space and bandwidth.

This scheme is suitable for the animal monitoring networks such as ZebraNet and SWIN, where nodes follow random mobility pattern and contacts cannot be predicted [16, 17].

Spray and Wait Protocol: Flooding schemes experience the drawback of high network congestion and consumes a lot of energy and bandwidth while routing messages [13]. To cope with these limitations, spray and wait routing scheme was introduced. To avoid flooding behavior in this scheme; a threshold value has been defined on number of copies per message that are exchanged among nodes.

It comprises of two phases called: Spray phase and Wait phase [18]. Spray phase says that sender node can only forward L number of copies instead of forwarding copy to every node encounter. L is the limit imposed by protocol that restricts wild flooding of messages in network. Wait phase says that each intermediate node that has copy of message must hold message with itself until it encounters destination node. Intermediate node will not pass copy of message to some another node it encounter other than destination.

From authors point of view [18, 19] this scheme provides improved performance with respect to delay, overhead and delivery ratio under high network traffic.

It is robust and scalable, retaining its performance advantage over a large range of scenarios. It suffers from the drawback that relay node waits until it encounters the destination. This may result in dropping of packet if TTL expires.

Direct Contact: In this scheme source node is responsible for routing messages to destination node without relying on intermediate nodes. Nodes keep the message with itself until it encounter destination node. This scheme does not consume a lot of resources (bandwidth and buffer space) as other protocols do [20]. The delivery ratio for this scheme is not so high because of above mentioned fact but it is one of the simples routing schemes.

RESULTS

Opportunistic Network Environment (ONE) [21] simulator has been used to analyze the performance of well known routing protocols for DTN. ONE joins together movement models, routing simulation, reporting and visualization at single platform.

In this section, performance of PROPEHT, Epidemic and spray and wait is analyzed under four different scenarios such as mobility models, transmission range, number of nodes and buffer size. Performance is measured in terms of delivery ratio, average latency and overhead ratio.

Scenario 1: Mobility Models: A mobility model decides how the nodes move in the network for the period of simulation. Table 1 shows the simulation parameters for scenario 1.

Figure 3, 4 and 5 shows the comparison of delivery ratio, overhead and latency respectively in various mobility models. It is clear from the results SPMBM performs well than other models as it tries to route data through shortest path, it has high delivery ratio while overhead and latency are low.

Scenario 2: Buffer Sizes: Routing protocol exhibits different behaviors if the buffer size of node is varied. As the node has limited buffer space there are more chances that packets will drop and affects the overall delivery ratio. Table 2 provides the parameters for scenario 2.

Figure 6, 7 and 8 shows the results of various buffer sizes. As the buffer size increases nodes have enough space to hold the packets therefore packet drop ratio will be reduced and delivery ratio will be increased. The overall overhead is minimized with the increase of buffer size because nodes do not need to perform extra computations to decide which messages to be hold in buffer. Although latency of epidemic and PROPEHT is high due to flooding base nature of protocols.

Scenario 3: Number Of Nodes: As the number of nodes increases in the network, more nodes has chance to be the part of routing. To a certain threshold it increases

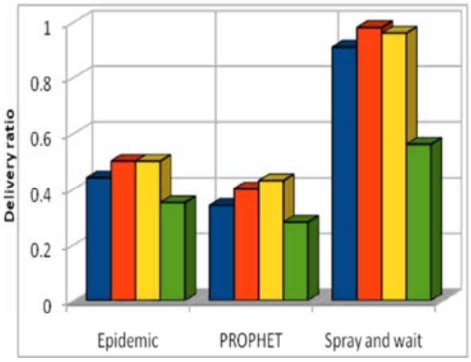

Fig. 3: Delivery ratio for mobility models

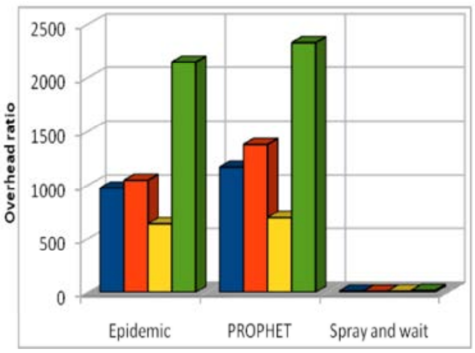

Fig. 4: Overhead ratio for mobility models

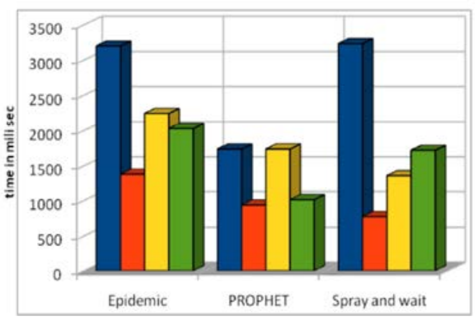

Fig. 5: Average latency for mobility models

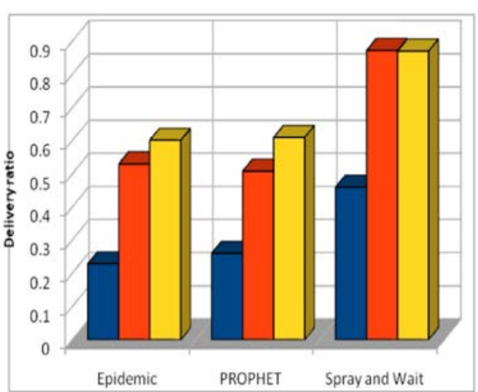

Fig. 6: Delivery ratio for buffer sizes

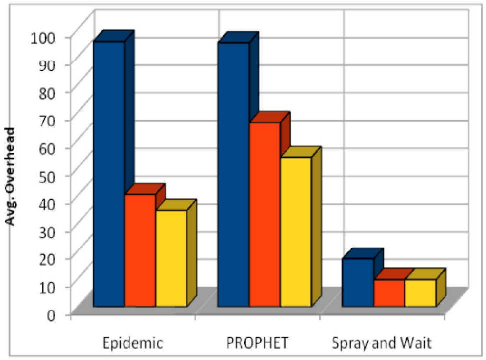

Fig. 7: Overhead ratio for buffer sizes

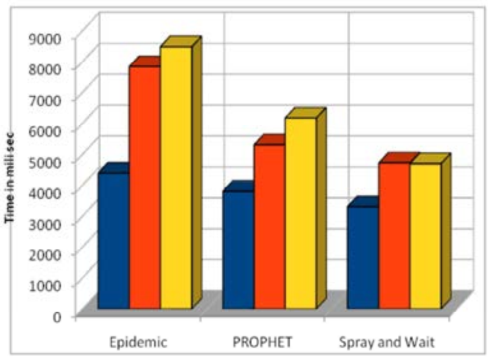

Fig. 8: Average Latency for buffer sizes

Table 1: Scenario-1 parameters

Parameters	Values
Simulation area (width x height)	4500 X 3400 m
Time	43K sec
Buffer size	50 M
Transmission range	100 m
Number of nodes	200
Mobility models	Map Route Movement (MRM),
Random Way Point (RWP),	Map Based Movement (MBM), Shortest Path Map Based Movement (SPMBM)

Table 2: Scenario 2 parameters

Parameters	Values
Simulation area (Width x Height)	4500 x 3400 m
Time	43K sec
Buffer size	5M, 50 M, 100M
Transmission range	100 m
Number of nodes	125
Mobility Model	SPMBM

thedelivery ratio. If the number of nodes increases the thresh hold it may create congestion on network. Table 3 provides simulation parameter for scenario 3.

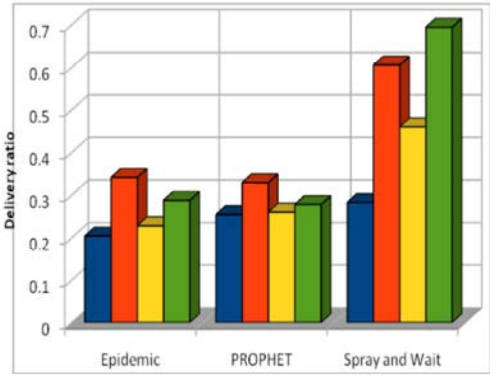

Fig. 9: Delivery ratio for no: of nodes

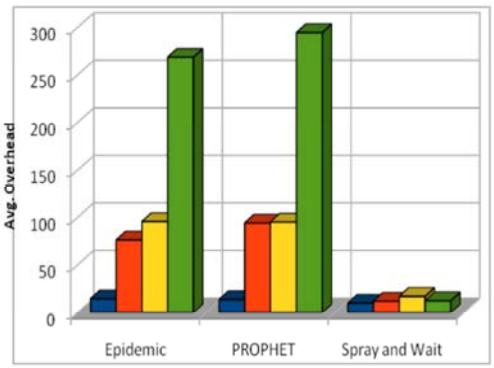

Fig. 10: Overhead for no: of nodes

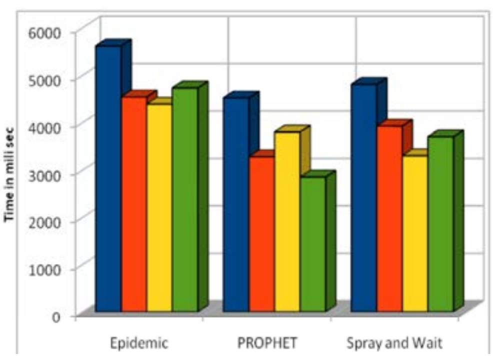

Fig. 11: Average Latency for no: of nodes

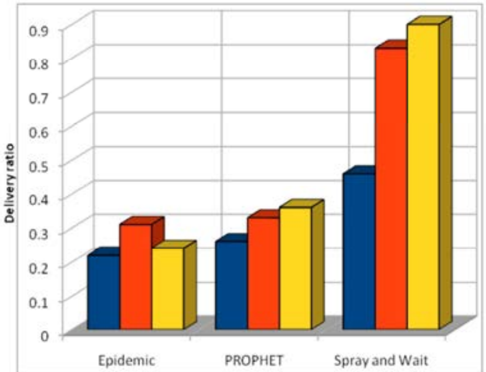

Fig. 12: Delivery ratio transmission ranges

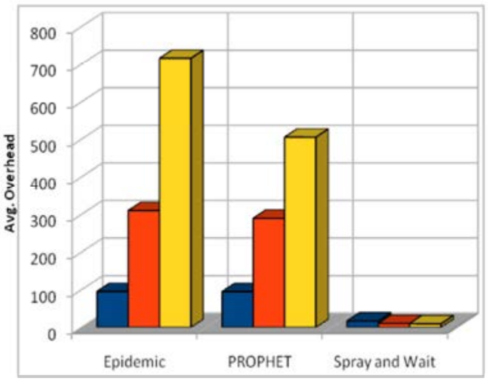

Fig. 13: Overhead for transmission ranges

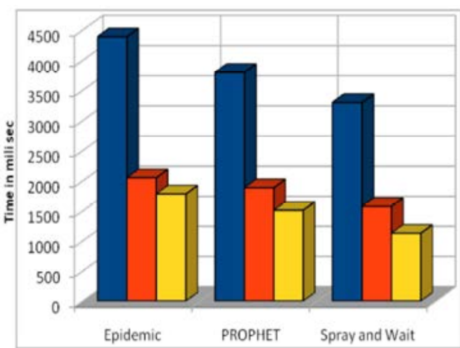

Fig. 14: Average Latency for transmission ranges

Table 3: Scenario 3 parameters

Parameters	Values
Simulation area (width x height)	4500 x 3400 m
Time	43K sec
Number of nodes	50, 100, 125, 200
Mobility Models	SPMBM
Transmission rang	100 m
Buffer size	5 M

Table 4: Scenario 4 parameters

Parameters	Values
Simulation area (Width x Height)	4500 x 3400 m
Time	43K sec
Transmission range	10m, 50m, 100 m
Buffer size	5 M
Mobility Models	SPMBM
Number of nodes	125

Figures 9, 10 and 11 show the result of various numbers of nodes participating in routing process. Although delivery ratio increases with the increase of nodes because more nodes participate in delivering message but on the other hand overhead and latency also increases. The overhead of PROPHET is high because it has to keep track of past encounters and compute delivery predictabilities values of nodes. To a certain threshold value latency is reduced but with the introduction of more nodes it also creates congestion on network due to which latency rate also increases.

Scenario 4: Transmission ranges: Increased in transmission range also increases number of contacts among nodes, as more nodes comes in coverage area. Table 4 shows the simulation parameters for scenario 4.

Figures 12, 13 and 14 show the result of varies transmission ranges. As transmission range increases more nodes come in contact with each other and facilitating the message delivery therefore delivery ratio will be high and latency will be reduced. The overhead of epidemic and PROPHET increases due to flooding based nature and computational overhead respectively.

Simulation results shows spray and wait outperforms PROPHET and epidemic in mentioned scenarios. But the one of the drawback of all these protocols is that none of the node has knowledge about network. This lack of ability makes them unsuitable for surveillance, tactical and emergency applications, where it is required to have knowledge about network, positions of neighbor and destination nodes to be known in order to deliver messages in timely and accurately manner. By keeping this in mind grid based routing algorithm is proposed in section 4.

Proposed Location Based Algorithm: The proposed location based algorithm is called "Grid based routing algorithm" (GBR). In GBR, physical area is partitioned into two dimensional logical squares of rows and columns, called grid. It is assumed that each node has complete knowledge of network that includes information of current location, location information of neighbor nodes in grid and location information of destination nodes. One of the fundamental assumptions in grid based routing is that each node is equipped with GPS receiver. Nowadays GPS-related applications are attracting more attention and popularity such applications includes tour guide systems, telematic systems and navigation system [22].

Routing protocols discussed in section 2 suffers from the problem of congestion, inefficient use of resources such as bandwidth and long delays due to no knowledge about the network. In order to overcome these problems and give location aware facility to routing process, "Grid based routing algorithm" is proposed. With the availability of GPS based systems it's now become possible to predict the location of node. In grid based algorithm, to assist routing process GPS receiver is used to predict current position of source node, position of next hop neighbor and position of destination.

In GBR, two-level hierarchical routing is performed i-e intra-grid and inter-grid. In intra-grid routing, information is shared only between the nodes that are the part of grid, while in inter-grid routing, information is shared between the grid leader nodes of two different grids. Within every grid, a grid leader node is elected that plays vital role in routing messages. The election of leader node is dynamic process, it depends on the number of contacts a node have with the grid in direction towards destination. Therefore a separate table has to be maintained that records number of contacts a node made with other neighbor nodes. The major responsibilities of leader node are: to collect data packets from local grid and sends them to neighboring grid leader node, exchanging hello messages with neighbor leader and maintain list of nodes that can be reach directly or indirectly.

The Grid Based Routing Algorithm Is Given as Follows:

Step 1: Grid leader election. The node in a grid that has higher number of contact with other gird nodes towards destination is elected as grid leader.

GRID_LEADER (N, X, Y)

{ If Number of contacts [N] > Number of contacts [A] THEN $G_{x,y}$ = Nx,y}

Where

$G_{x,y}$ is the grid leader node in current grid.

Step 2: Compute the grid distance between current grid (G_{cur}) and destination grid (G_{dest}), called it d_{curr}.

Step 3: Compute grid distance between neighbor grid (G_{neib}) and destination grid (G_{dest}), called $_{neib}$.

Step 4: Compare d_{neib} and d_{curr}, if d_{neib} is less than d_{curr} then assign value of d_{neib} to d_{curr} and assign G_{neib} to G_{next}.

Step 5: Repeat step3 and step 4 until the next suitable grid that has direction towards destination and smaller distance than other grids is selected.

Step 6: Return the coordinates of next grid $G_{next.}$

CONCLUSION

The major objective of delay tolerant networks is to provide connectivity is those regions that are not accessible. Conventional routing protocols are not suitable for DTN as they rely on to always have connected path between two nodes before data transmission begins. Therefore, to efficiently route messages between nodes is become one of the key research areas. In this paper, well known routing protocols for DTN are simulated under four different scenarios. Simulation results shows that spray and wait routing protocol outperforms epidemic and PROPHET due to its simple designs, robustness and scalability. But all of above mentioned protocols are not suitable for surveillance and emergency applications due to lack of network knowledge. Therefore grid based routing algorithm is proposed, that make use of location information of nodes to route messages. This work could be enhanced by implementing and simulating grid based routing algorithm. The performance of grid based routing algorithm will be analyzed in different mobility models and also work is in progress to develop a scenario model that is more applicable for emergency and surveillance based applications. Security issues also need to be addressed in order to be aware of malicious nodes in network. Therefore security issues related to malicious nodes will also be incorporated with grid based routing algorithm.

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