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Performance Evaluation of Disruption Tolerant Network Routing Protocols in Urban Area Scenario

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Abstract— **In this paper it has been have investigated the performance of six different stochastic routing protocols for Disruption Tolerant Network namely, First Contact, Direct Delivery, Epidemic, Spray and Wait, PRoPHETv2 and MaxProp routing protocols, against varying various parameters, buffer size, message time to live (TTL), traffic load, number of nodes, under the same network parameters which be done using Opportunistic Network Environment (ONE) simulator with program version of 1.5.1. Each routing protocol evaluated based on its performance using three performance metrics which include: Delivery Probability, Average Delivery Delay and Overhead Ratio. The simulation carried out in scenario of urban area, to provide the needed communication in case of failures of telecommunications infrastructure due to network congestion which occur due to a heavy use. The simulation scenario have been run on the a realistic map of Tripoli city. From the results obtained from the simulation it is analyzed that the MaxProp achieves the highest delivery probability and the lowest average delivery delay in all varying parameters. Changing parameters values have slight impact on the performance of MaxProp. MaxProp provides overhead ratio much lower than Epidemic and PRoPHETv2 but slight higher than Spray and Wait.**

Keywords— PRoPHETv2 , MaxProp, Time To Live, protocol DTN's and Network

I. INTRODUCTION

Disruption Tolerant Networks (DTN's) are wireless mobile networks. These networks are defined as a class of challenged networks. Where the connection between source and destination at any time is probably low or unlikely to exist, especially when the destination is not in the same region of the source. The nodes maintained the connectivity of mobile network, only when they are come into the transmission ranges of each other. Therefore, each node in these networks uses store-carry-and-forward mechanism to route the messages. This mechanism is repeated from one node to another until the message reaches it is destination or dropped after amount of time to live value. Whenever two nodes encounter, the amount of data they can transmit is limited. Nodes do not know the duration of each opportunity. The nodes are assumed to have persistent storages used to hold the contents of messages indefinitely during the store-carry-and-forward process. This strategy help DTN networks to overcome the problems associated with intermittent connectivity and partitions in the network [1,2].

DTN networks are used to provide network connectivity in challenged environments such as undeveloped areas without Internet connections, deep space communications field, military fields, sensor networks and the monitoring of nature. DTN networks are particularly important in case of network congestion, which occur during the continuously communications over the telephone networks or any infrastructure nodes in densely populated cities and highly congested regions, during big sports events like World Cup or Olympics Games, or after disasters where the people need to communicate with each other calling family and friends [3].

The network congestion can cause communication network become unable to provide services. In such this scenario DTN networks can be used to provide the needed communication. Since most of people carry some handheld *devices* so, in this scenario it assumes that the nodes are wireless *devices carried* by *people*. The smart phones, laptops and tablets devices can provide a temporary networks by connecting the devices to construction of these networks and changed from the infrastructure mode to *infrastructure-less* mode. Where each node in the network carries it is own router with it and acting as mobile routers, and all nodes cooperate in carrying traffic and sending

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messages to their neighbour. Every device can acts as intermediate node using Bluetooth or Wi-Fi connection.[4].

The rest of paper is organized as follows: Section 2 reviews routing in DTN and presents routing protocols in DTN. In section 3 the simulated environment is described. Section 4 describes the simulation results to analyze the routing protocols. Section 5 concludes the paper and provides guidelines for future work..

II. ROUTING PROTOCOL IN DTN

Routing is one of the main components in the DTN architecture, routing in DTN is challenging due to of high delays and intermittent connectivity. The traditional routing protocols fail to work correctly or may even stop working completely in DTN environments due to the rapid topology changes. Therefore, DTN network needs appropriate protocols to deal with its properties. During the past few years there are several routing protocols have been proposed and enhanced for DTN network. There are several of classification schemes have been proposed DTN routing protocols according to several categories: Flooding or Forwarding, Blind or Guide, Single copy or Multiple copy and Deterministic or Stochastic. All existing DTN routing protocols fall into two categories: deterministic and stochastic routing protocols.[4].

A. *First Contact Protocol*

First contact (FC) strategy, is simplest strategy to send the message from source node to destination node in DTN networks and does not require network information to forward message. In this routing protocol only one copy of each message exists in the network. If there is no connection available the node will store the message and carry it until encounter with the other node. The message is forwarded randomly to the first contact, the source node and the intermediate nodes will deliver the message to the first node when it is come into the transmission range. It doesn't determine the *next hop* on the path to the intended *destination,* and then delete the message from the persistent storage. However, the node will not drop the transferred message directly, the First Contact protocol employ First In First Out (FIFO) queuing

B. *Direct Delivery Protocol*

Direct delivery (DD) is also single copy scheme DTN routing protocols, in the Direct Delivery the source node generates only one copy of each message exists in the network. The source node does not forward the message to the intermediate nodes when they are come into the transmission ranges, the source node keeping the message in persistent storage if there is no connection available between the *source and destination* and carry it until it becomes directly contact to the destination node and delivered only to the destination node. As the First Contact routing protocol the Direct Delivery employ First In First Out message queuing .

C. *Epidemic Protocol*

Epidemic routing (ER) algorithm was originally designed for synchronizing replicated databases by Demers et al. in [5]. This algorithm was modified by Vahdat and Becker to forwarding data in a DTN and introduced as a flooding-based forwarding routing algorithm in [6]. Epidemic routing protocol does not require network information while forwarding message, because it is blind flooding based routing protocol. In this routing protocol when any node generated message or received a copy of message it forwards a copy of it to all nodes when they come in to the transmission ranges of each other. Thus, the destination node is guaranteed to have received the message.

D. *PRoPHET Protocol*

Probabilistic Routing Protocol using History of *Encounters* and *Transitivity* (*PRoPHET*) is proposed in [7]. The fundamental assumption in the PRoPHET routing protocol is that mobility of nodes is not completely random as it is mostly assumed to be, but it has a number of deterministic properties such as repeating behaviour, and it is can be predict using knowledge obtained from previous encounters with other nodes. This routing protocol assumes that the mobile nodes tend to pass through some locations more than others, which means that passing through previously visited locations is highly probable. The PRoPHET routing protocol first estimates a probabilistic metric called delivery predictability. Each node has a list of the delivery predictability (DP) of every other nodes and calculates a probabilistic metric for each known destination before transmitting a message. The PRoPHET routing uses probability to make a decision if one mobile node that is frequently encountered having higher delivery predictability than other nodes to forward message to the destination node. [4, 8].

E. *MaxProp Protocol*

MaxProp routing protocol proposed in [9] by Burgess et al. from University of Massachusetts, Amherst. MaxProp is flooding routing protocol designed for vehicle-based disruption tolerant networks. MaxProp routing is based on prioritizing both the schedule of messages forwarded to other nodes and the schedule of messages to be deleted from the persistent storage. These priorities are based on the path likelihoods to nodes according to historical data and also on several complementary mechanisms including lists of previous encounters of intermediates nodes, acknowledgments and a head-start for new messages. MaxProp protocol addresses scenarios in which either the transfer duration or persistent storages available in the nodes are limited resource in the network. The main part of MaxProp protocol is a ranked list of messages, stored in persistent storage of the node based on a cost assigned to each destination. The cost is an estimate of delivery likelihood. MaxProp assigns a higher priority to new messages and also attempts avoid reception of duplicate messages. This routing protocol uses acknowledgments sent to all nodes to delete the remaining copies of a message in the network when the message reaches it is final destination. MaxProp routing Drop Least Encountered (DLE) algorithm proposed dropping messages with the lowest likelihood of delivery [1,9, 10].

III. SIMULATION ENVIRONMENT

In this section first, it describes the urban environment used for simulation. Second it summarizes two mobility models used in simulation. Third it provides details about the specific parameters used for simulation. Fourth it defines the performance metrics that are considered in this work.

All simulations have been performed using ONE simulator, which specifically designed for evaluating DTN routing and application protocols.

A. Urban Environment

The map data defines the space and paths of vehicles and trams with stations and stops, in which the mobile nodes can move inside the simulation area. In our simulation novel realistic map is used as urban environment instead to the ones typically used in ONE simulator (Helsinki). it uses realistic map of Tripoli city exported from Open Street Map [10], which has been converted to Well-known text format (WKT) by using OpenJUMP software, which is the only format acceptable by the ONE simulator. Figure 1. shows Tripoli map in WKT format with area size approximately of about 20000 x 10000 m².

The scenario implemented on a realistic map of Tripoli city assume that telecommunications infrastructure failures occur due to network congestion. The scenario assume there are sixteen groups, eleven for buses and three for trams they use only the roads that are defined in the map

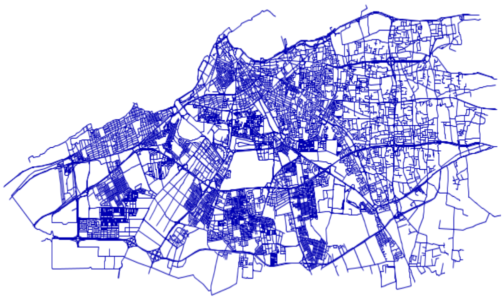


Fig 1: Tripoli Map in WKT Format

using Route Map Based Movement mobility model, and the other two groups one for cars and one for pedestrians and those groups move randomly around the map using Shortest Path Map Based Movement. The paths of the buses and trams in Tripoli city are gathered from websites of General Company for Rapid Transfer, and Railroad Project and Execution Management Board. All the paths are converted to WKT format and defined in WKT files. Figure 2 shows the several paths on Tripoli map in WKT format for buses and trams.

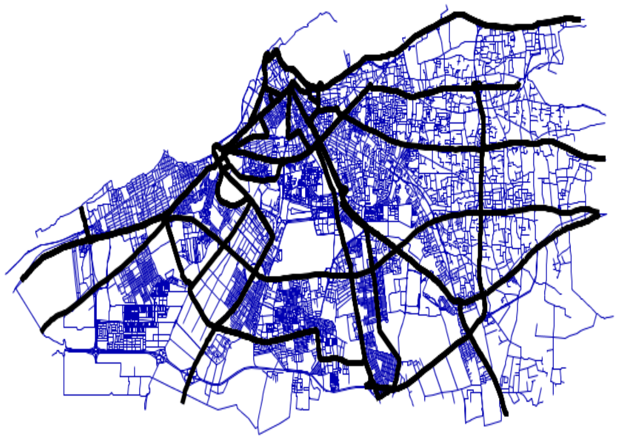


Fig 2: Multiple Paths for Public Transport in WKT Format

B. Mobility Models

Mobility models are used to simulate and evaluate the performance of DTN protocols where the performances of DTN routing protocols are very dependent on the underlying mobility of nodes and it is characteristics. However, it is difficult to assessment performance of DTN routing protocols in real world environment [11]. The following mobility models are used in our simulation.

2) Shortest Path Map Based Movement: Shortest Path Map Based Movement is mobility model uses a map described environment, it is a more realistic model, it manages and restricts the movement of nodes in the simulation map scenario. This model initially spreads the mobile nodes randomly in the map locations, then the mobile nodes choose their destination randomly inside the map and uses Dijkstra's algorithm to calculate the shortest path to their destination. After nodes have reached destination, they have to wait for a while and select a new destination [12].

3) *Route Map Based Movement:* In this model, nodes move randomly but always move following predetermined routes defined by the map of simulation scenario. This mobility shows effectively performance in simulating nodes movement, especially, in the case of buses and trams routes. In this model, routes within the map contain many points termed as stops on the routes. Nodes wait on each stop for a while before continuing to the next stop. Each map-based movement models obtain their configuration **data using files formatted with a subset of the WKT. These** files can be edited and generated from real world map data using any appropriate Geographic Information System (GIS) program such as OpenJUMP [12]. Moreover, in this model when using GIS software to identify the routes on the map by their longitude and latitude coordinates if this coordinates is identified unidirectional from start route to the end route and if there is another path between the ends of the selected route and it is the shortest path, then this coordinates should be identified bidirectional, in other words, the identified route should be include the coordinates of round-trip for example: LINESTRING (1,2,3,4,5,4,3,2,1) otherwise, the vehicle or tram will come

out on path when it is reached the end of the route looking for shortest path to the start of the route and the route will be circle route. This mistake existing in the default scenario provided with the ONE simulator where some trams come out on path. This mistake has negative impact on performance of some protocols such as PRoPHET and MaxProp which they are dependent on knowledge obtained from previous encounters between the nodes.

C. Parameter Setting

The simulation implemented in scenario using different mobility models. Parameters are required for creating the DTN network scenario in the ONE simulation environment. All the nodes in the scenario using IEEE 802.11b (11Mbps). The parameters for the scenario are set as mentioned in Table 1. and Table 2 show the Protocol Parameters. Table 3 shows message event interval and messages created in particular interval.

Table 1: Simulation Parameters

<table>
<tr><th colspan="2">Name of Parameter</th><th colspan="4">Value of Parameter</th></tr>
<tr><td rowspan="5">No. of Nodes</td><td>Tram</td><td>6</td><td>9</td><td>18</td><td>36</td></tr>
<tr><td>Pedestrian</td><td>25</td><td>43</td><td>72</td><td>116</td></tr>
<tr><td>Car</td><td>25</td><td>43</td><td>72</td><td>116</td></tr>
<tr><td>Bus</td><td>44</td><td>55</td><td>88</td><td>132</td></tr>
<tr><td>Total</td><td>100</td><td>150</td><td>250</td><td>400</td></tr>
<tr><td colspan="2">Traffic Load (message/ interval time.)</td><td colspan="4">10,15-15,25-25,35-35,45</td></tr>
<tr><td colspan="2">Simulation Time</td><td colspan="4">14400s</td></tr>
<tr><td colspan="2">Transmit Range</td><td colspan="4">100m</td></tr>
<tr><td colspan="2">Buffer Size</td><td colspan="4">10M,20M,40M,60M</td></tr>
<tr><td colspan="2">Message Sizes</td><td colspan="4">500KB-1MB</td></tr>
<tr><td colspan="2">Message TTL</td><td colspan="4">60m,120m,180m,240m</td></tr>
<tr><td rowspan="3">Node Speed</td><td>Tram</td><td colspan="4">10km,30km/h</td></tr>
<tr><td>Pedestrian</td><td colspan="4">1m,1.5m/s</td></tr>
<tr><td>Vehicle</td><td colspan="4">30km,50km/h</td></tr>
</table>

Table 2: Protocols Parameters

Protocol	Parameter	Value
PROPHETv2	seconds in a time unit	60s
Spray &Wait	No of message copies	6
	binary mode	True

Table 3: Messages Created per Message Event Interval in Seconds

Message Event Interval	5,10	10,15	15,25	25,35	35,45
Messages Created	2061	1201	739	487	365

D. Performance Metrics

The objective of the routing protocols is to achieve higher delivery performance, lower delivery delay and lower resource consumption. Evaluate the performance of the routing protocols for DTNs require certain performance measurements. The typical performance metrics are Delivery Probability, Average Delivery Delay and Overhead Ratio. These metrics are considered in this work [12]. The results of the metrics considered are obtained by ONE simulator. The following are descriptions of performance metric considered in this work.

4) *Delivery Probability:* The most important performance metric is the delivery probability and it is defined as the ratio of the number of messages actually delivered to the destination nodes divided by the number of messages generated by the source nodes, duplicated copies of the same message are not counted. Delivery probability for any protocol equal 1 or less [9, 11, 12].

5) *Average Delivery Delay :* Average delivery delay is another metric to evaluate the performance of routing protocol. Average delivery delay is defined as the average of time taken by all messages from they are generated at source to they are successfully delivered to their destination. The metric is simply the sum of all delivered messages delays to the number of delivered messages. DTN networks has high delivery delay much longer than that of the traditional networks due to the intermittent connectivity. [11,12].

6) *Overhead Ratio :* The overhead ratio reflects how many redundant messages are relayed to deliver one message. Overhead in transmission of the messages results in additional energy consumption. It simply reflects transmission cost in a network. It is defined as the ratio of difference between the total number of relayed messages and the total numbers of delivered messages to the total number of delivered messages. [12].

IV. SIMULATION RESULTS

The simulation of scenario has been carried out in ONE simulator on the realistic map of Tripoli city with various of, buffer size, message TTL, traffic load (number of messages generated) and number of nodes with keeping all other parameters unchanged to study the impact of these varying different parameters on the performance of the routing protocols, using three performance metrics that are chosen to analyze the performance of the deferent routing algorithms. There are six different routing protocols namely First Contact, Direct Delivery, Epidemic, PRoPHETv2, Spray and Wait and MaxProp were chosen to simulate in the scenario. Simulation results are plotted as graphs by using Gnuplot software, Gnuplot is software for plotting and visualizing data, and analyzing it using graphical methods.

E. Impact of Varying the Buffer Size

This subsection presents the impact of varying buffer size on delivery probability, average delivery delay and overhead ratio of stochastic routing protocols.

1) Impact of Varying Buffer Size on Delivery Probability: As clear in figure 3 the MaxProp achieves the highest delivery probability. Spray and Wait also gives high value for delivery probability and the performance of both protocols not affected by the varying buffer size. Epidemic and PRoPHETv2 are affected by the varying buffer size, as the buffer size increase the delivery probability of Epidemic and PRoPHETv2 increase. Direct Delivery and First contact achieve worst performance in delivery probability.

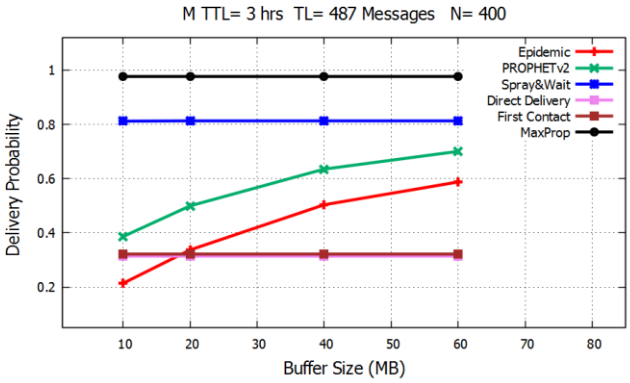
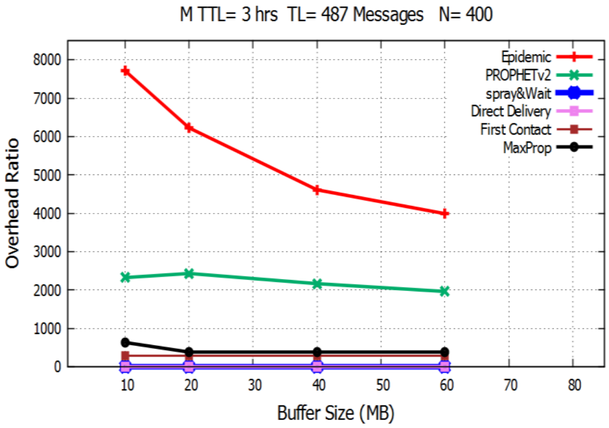


Fig 3: Impact of Varying Buffer Size on Delivery Probability

2) .Impact of Varying Buffer Size on Overhead Ratio:From the figure 4, it can be stated that as buffer size of node increases overhead ratio decreases for Epidemic, but gives the highest value of overhead ratio and costs the resource very high in this scenario. Overhead ratio of PRoPHETv2 decreases slightly as the buffer size of node increases, but it is much lower than Epidemic. Increases buffer size provide space for messages. and messages will not be dropped due to buffer overflow. MaxProp gives overhead ratio lower than Epidemic and PRoPHETv2, but a little bit higher than First Contact, MaxProp costs the resource very little. In Direct Delivery the source node is only delivered message to destination so overhead ratio will be zero for any buffer size. Spray and wait has excellent performance than Epidemic, PRoPHETv2 and MaxProp.

3) Impact of Varying Buffer Size on Average Delivery Delay : Figure 5 shows that the Direct Delivery has the highest delay time and First Contact gives the second higher routing protocol delay and the third higher routing protocol delay is Spray and Wait. Direct Delivery and First Contact are single copy schemes while Spray and Wait routing protocol is partial flooding protocol generates limited copies of messages. The average delivery delay value of PRoPHETv2 rapidly decreased as the buffer size increase, but this value is still higher than the value of Epidemic routing protocol. MaxProp achieves the lowest value of average delivery delay among all other routing protocols. It can be seen that varying buffer size has effect on performance of PRoPHETv2, while the other routing protocols do not show effect by increasing the buffer size.



Fie 4 : Impact of Varying Buffer Size on Overhead Ratio.

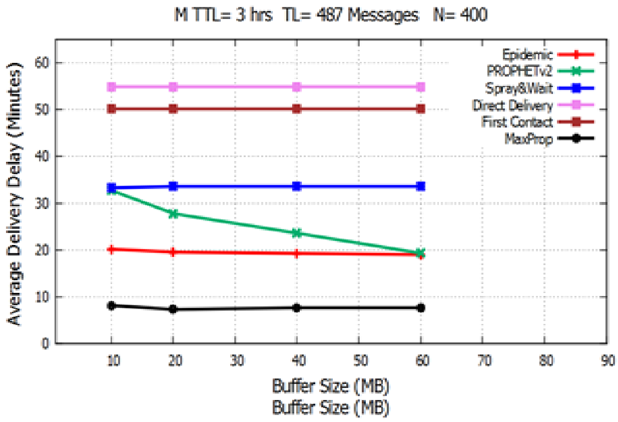


Fig 5: Impact of Varying Buffer Size on Average Delivery Delay.

F. Impact of Varying Message TTL

This subsection presents the impact of varying message TTL on delivery probability, average delivery delay and overhead ratio of stochastic routing protocols.

1) *Impact of Varying Message TTL on Delivery Probability:* Figure 6 shows that the delivery probability of

MaxProp achieves the best result of the delivery probability among the other routing schemes. It is clear that the increasing message TTL has no impact on performance of MaxProp. Spray and Wait is the second routing protocol gives the higher delivery probability, and it is delivery probability increased when the message TTL increased to two hours value, then it is almost stabilized at other values. In PRoPHETv2 and Epidemic when the message TTL increasing it overloads the buffer space available which lead to an increase in dropping messages, as soon as the message TTL increase the delivery probability of both protocols decrease. First Contact and Direct Delivery given worst delivery probability among the flooding schemes and their values are almost the same. As the message TTL increase the delivery probability of both protocols increase.

2) *Impact of Varying Message TTL on Overhead Ratio:* As shown in figure 7 the Epidemic start with lower value of the overhead ratio when the message TTL value is 1 hour as the message TTL increase the overhead ratio of Epidemic increase, Epidemic gives the highest overhead ratio. PRoPHETv2 has much lower overhead ratio than Epidemic. However, it is performance is better than Epidemic. The overhead ratio in the PRoPHETv2 and Epidemic are affected by increasing the message TTL, so the overhead ratio increases rapidly. This due to increase in dropping messages. MaxProp achieves the best result as compared to the overhead ratio of the PRoPHETv2 and Epidemic, it has much lower overhead ratio than blind

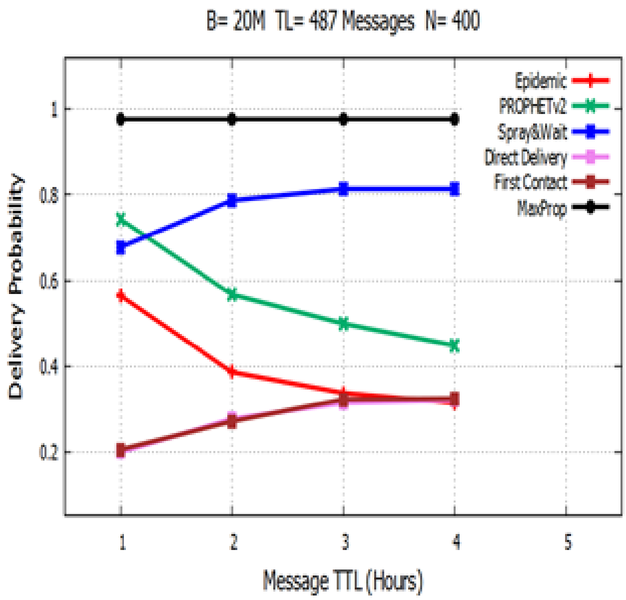


Fig 6: Impact of Varying Message TTL on Delivery Probability.

flooding and guided routing schemes but higher than Spray and Wait, First Contact and Direct Delivery. In Direct Delivery the overhead ratio will be zero for any message TTL. Spray and Wait has almost a constant overhead ratio, which is higher than Direct Delivery but lower than other routing protocols. First Contact provides almost a constant overhead ratio, it is performance not better than Spray and Wait.

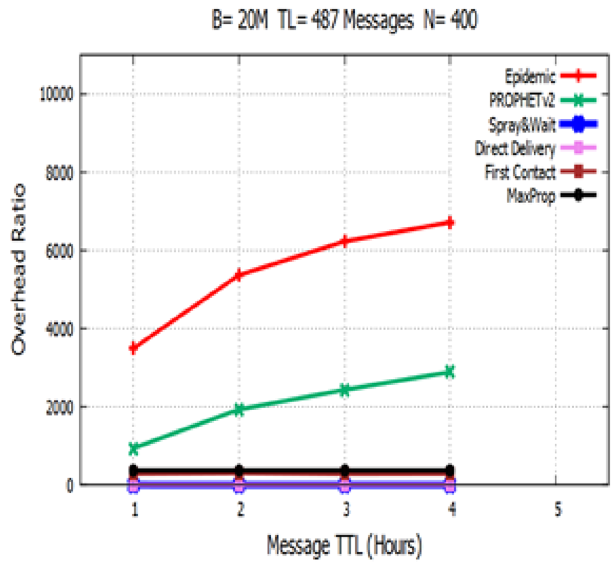


Fig 7 : Impact of Varying Message TTL on Overhead Ratio.

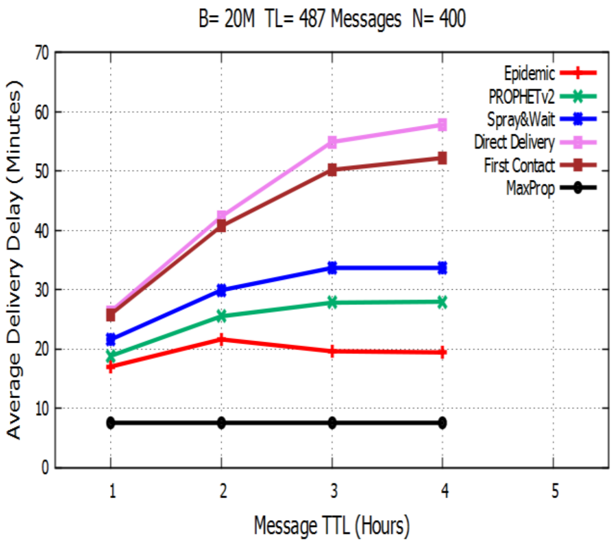


Fig 8: Impact of Varying Message TTL on Average Delivery Delay

3) Impact of Varying Message TTL on Average Delivery Delay: Figure 8 illustrates that the Direct Delivery provides the highest average delivery delay among the protocols, and the First Contact is the second routing protocol gives the higher average delivery delay. Spray and Wait is the third routing protocol gives the higher average delivery delay. PRoPHETv2 achieves average delivery delay lower than Spray and Wait routing but higher than Epidemic while the MaxProp achieves the lowest value of average delivery delay among all the other routing protocols and the value is a constant during all values of message TTL. It is clear as the message TTL increase the average delivery delay for all protocols increase except the MaxProp. This is due to increasing message TTL which allow the messages that were supposed to be dropped are *wait longer in buffers until reach their destinations, but with higher delay value.*

C. Impact of Varying Traffic Load

This subsection presents the effect of varying traffic load on delivery probability, average delivery delay and overhead ratio of stochastic routing protocols.

1) Impact of Varying Traffic Load on the Delivery Probability: From the simulation results plotted in figure 9, it can be seen that the MaxProp achieves the highest delivery probability. Spray and wait is the second protocol provides the higher delivery probability. MaxProp and Spray and wait work efficiently in high and low traffic load than other protocols, they have settle delivery probability in all values of traffic load. PRPHETv2 achieves routing performance better than the Epidemic. Delivery probability of Direct Delivery routing increases slightly as the traffic load increases while delivery probability of First Contact routing decrease.

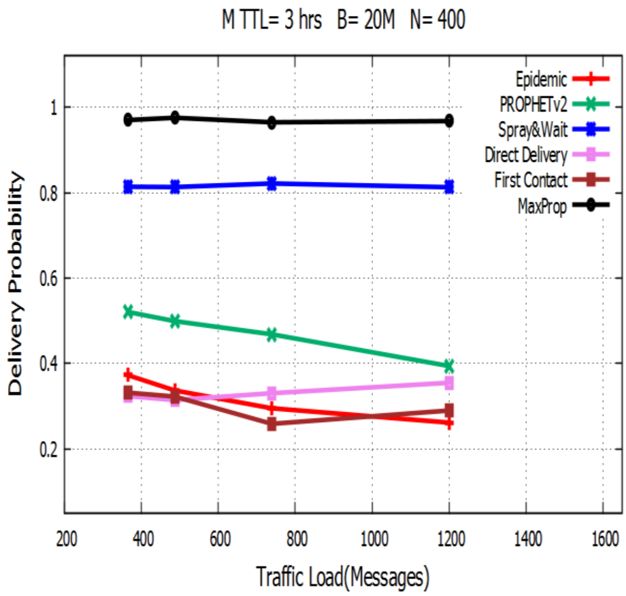


Fig 9 : Impact of Varying Traffic Load on Delivery Probability

2) *Impact of Varying Traffic Load on the Overhead Ratio:* As clear in figure 10 the Epidemic starts with highest value of overhead ratio among the other protocols.

PRoPHETv2 starts with value much lower than the Epidemic. The transmission cost of Epidemic and PROPHETv2 decrease when the traffic load increase, as soon as injecting more messages into the network the protocols are relay messages copies lower than their typical number, additionally dropping many of stored messages due to buffer overflow this leads to decrease the overhead ratio and delivery probability as shown in figure 9 and figure 10. MaxProp achieves low transmission cost much lower than the other flooding algorithms. Spray and Wait also keep overhead ratio low. First Contact routing keeps the overhead ratio a little bit higher than Spray and Wait. Direct Delivery always has zero overhead ratio.

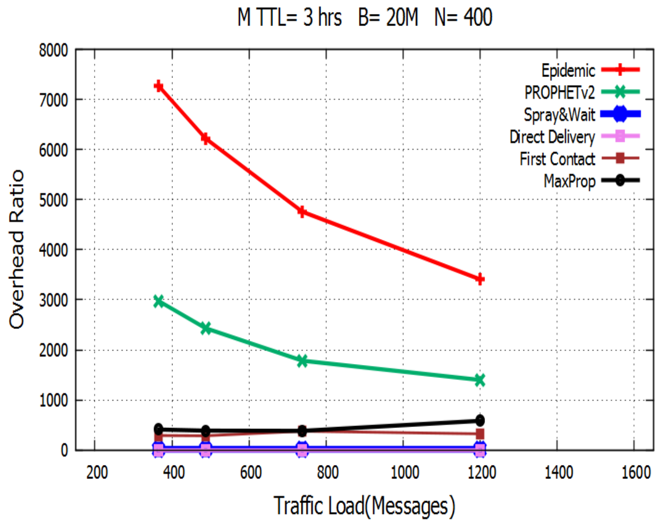


Fig 10 : Impact of Varying Traffic Load on Overhead Ratio

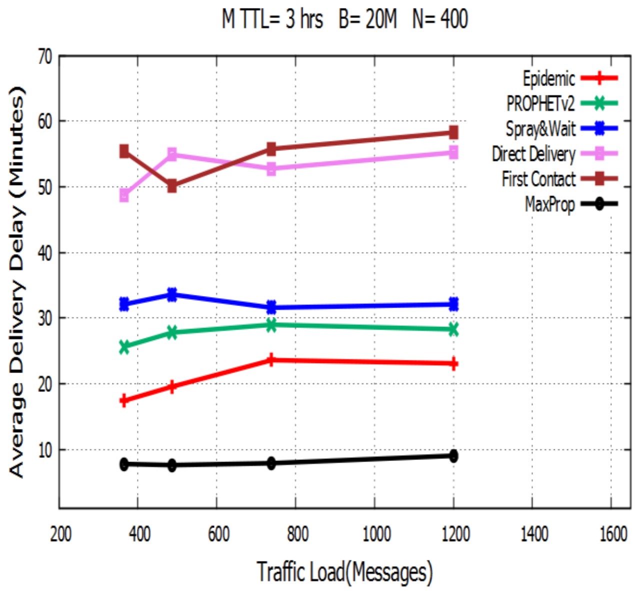


Fig 11 : Impact of Varying Traffic Load on Average Delivery Delay

3) *Impact of Varying Traffic Load on the Average Delivery Delay:* Figure 11 indicates that the First Contact provides the highest average delivery delay among all the protocols, and the Direct Delivery is the second routing protocol gives the higher average delivery delay. Spray and Wait is the third routing protocol gives the highest average delivery delay. PRoPHETv2 achieves average delivery delay slightly lower than Spray and Wait but higher than Epidemic while the MaxProp achieves the lowest value of average delivery delay among all the other routing protocols and it is value is a constant during all values of traffic load, this is

due to of it is efficient buffer management mechanisms. It can be stated that as the traffic load increase the average delivery delay for all protocols slightly.

D. Impact of Varying Number of Nodes

This subsection presents the effect of varying number of nodes on delivery probability, average delivery delay and overhead ratio of stochastic routing protocols.

1) Impact of Varying Number of Nodes on Delivery Probability: As clear in figure 12 the MaxProp and Spray and Wait achieves the highest delivery probability, it can be observed from the figure as the number of nodes increases the delivery probability of MaxProp routing is very slight increases while the delivery probability of Spray and Wait is very slight decrease. PRoPHETv2 has higher delivery probability than Epidemic and single copy routing protocols. The single copy routing protocols provide the worst delivery probability.

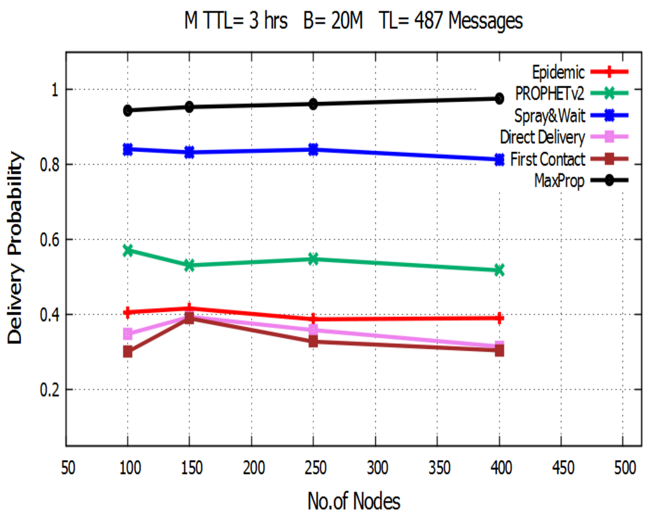


Fig 12: Impact of Varying Number of Nodes on Delivery Probability

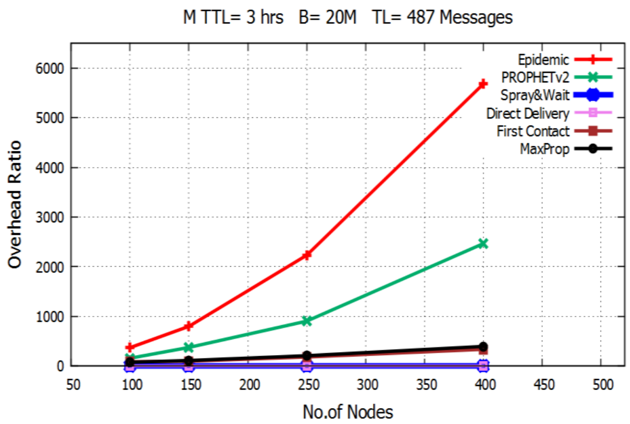


Fig 13: Impact of Varying Number of Nodes on Overhead Ratio

2) Impact of Varying Number of Nodes on Overhead Ratio: Figure 13 indicates that the Epidemic achieves worst performance for network overhead it has the highest value of overhead ratio, Epidemic consumes the limited resources such as buffer and energy with increasing the number of nodes due to the large number of copies. PRoPHETv2 has much lower overhead ratio than Epidemic due to the protocol sends messages to reliable nodes. Overhead ratio in Epidemic and PRoPHETv2 as they are flooding based routing protocols as number of nodes increases message copies in network increases this lead to rapidly increase in it is overhead ratio.

MaxProp has much lower overhead ratio than the other flooding schemes, and there is very slight increase in it is overhead ratio as the number of nodes increase. MaxProp costs the resource very little and has less power consumption as compare to the Epidemic and PRoPHETv2. Spray and Wait keeps the overhead ratio low. Single copy routing protocols Direct Delivery and First Contact are also keep the overhead ratio low.

3) Impact of Varying Number of Nodes on Average Delivery Delay: In figure 14 it can be observed that the average delivery delay for all routing protocols deceases as the number of nodes increases. This is because of increasing the number of nodes in the network which effects on the path availability and improves network connectivity, this leads to reducing the partition of the network and providing faster routes to final destination. MaxProp achieves the lowest value of average delivery delay among all the other routing protocols. Direct Delivery achieves worst performance in average delivery delay. Spray and Wait gives the average delivery delay higher than the Epidemic and PRoPHETv2. Epidemic routing has a better performance than PRoPHETv2.

V. CONCLUSIONS

In this paper it has been evaluated the performance of six different stochastic routing protocols for Disruption Tolerant Network in Urban Area, by varying various parameters like buffer size, message TTL, traffic load, number of nodes, by using the virtual real map for Tripoli city. From the simulation results plotted it is obvious that the routing algorithm which outperformed all the other routing algorithms is MaxProp routing. MaxProp routing protocol achieves the highest and the best delivery probability and the lowest average delivery delay in all varying parameters. Changing parameters values have slight impact on the performance of MaxProp.
MaxProp provides overhead ratio much lower than Epidemic and PRoPHETv2 but slight higher than Spray and Wait. Spray and Wait is the second best protocol achieving the higher delivery probability reaching up to 82%, and providing very low cost resources but has high average delivery delay. PRoPHETv2 is the third routing protocol gives high delivery probability but it is much

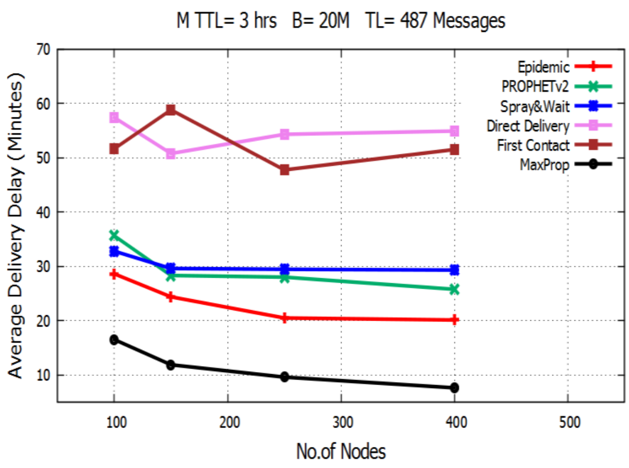


Fig 14: Impact of Varying Number of Nodes on Average Delivery Delay

lower than MaxProp and Spray and Wait routing and it is overhead ratio much higher than MaxProp. PRoPHETv2 gives high average delivery delay. Epidemic routing protocol achieves the highest overhead ratio among the other protocols and gives average delivery delay almost the same as PRoPHETv2. Epidemic has delivery probability lower the than PRoPHETv2. Epidemic and PRoPHETv2 routing are basic flooding schemes they require infinite persistent storage to achieve optimal delivery probability, but this will increase the transmission cost in a network. Performance of Epidemic and PRoPHETv2 routing are effected by varying parameters. Direct Delivery and First Contact achieve lowest overhead ratio, but provide worst delivery probability and high average delivery delay. The performance of these protocols is not clear under different environments. One protocol may be successful in one environment, but does not appropriate in another environment. So in future this work will extend to evaluate the performance of these six stochastic routing protocols in post disaster scenario by using the same realistic map.

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