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Analysis and Evaluation of DTN Routing Schemes in Post Disaster Scenario

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***Abstract*— Disruption tolerant Networking (DTN) is an attempt to provide communication when the end-to-end path does not exist, especially when the phenomena of network partition occur, due to the movement of mobile nodes. Numerousrouting schemes have been proposed for DTN networks so far. In this paper we explorethe performance of six types of routing schemes for DTN Network namely First Contact, Direct Delivery, Epidemic, Spray and Wait, PRoPHETv2 and MaxProp, whit several varying parameters. The performance is analyzed and evaluated in terms of Delivery Ratio, Average Latency and Delivery Cost. The simulation carried out in scenario of a post disaster, to provide network connectivitywhenthe telecommunications infrastructure failures due to physical destruction of network components during disasters strikes. All protocols were simulated by using Opportunistic Network Environment (ONE) simulator.This work is an extension to previous work for explore the performance of these six routing schemes in case of network congestion and a post disaster scenario.**

Keywords *— Disruption Tolerant Network, Routing Schemes, Opportunistic Network Environment (ONE) Simulator.*

I. INTRODUCTION

The failures of telecommunicationsinfrastructureoccur due to some of mechanisms, one of main cause which lead to these failures is physical destruction of network components which can occur when natural disaster strikes, such as earthquakes and hurricanes, or during manmade disasters such as wars. The disasters can cause communication network become unable to provide services. This communication services save lives when disasters occur. Therefore, there is a strong need to providing communications when the existing network infrastructure damaged due to disaster strikes. In such these scenarios DTN networks are particularly important in case of a post disaster, and it is can be used to provide network connectivity.A temporary networks can be provided by using wireless mobile devices such as smart phones, PDAs and laptops. All these devices are assumed to have persistent storage used to hold the bundles during the store-carry-and-forward process, these devices carried by people,each device can acts as source, destination or intermediate node using Wi-Fi interface [1].

This paper is structured as follows: in Section II we briefly discuss DTN routing schemes that are used in our scenario. In Section III we describe the simulation environment.Performance of routing schemes are analyzed and evaluated through a series of experiments in Section IV. Section V concludes the paper and point outfuture work.

II. DTNROUTING SCHEMES

Numerous routing schemes with different objectives have been proposed so far, for DTN networks, to deal with the fact that nodes are not constantly connected, to provide good delivery ratio and minimum latency with reduce the cost of transmission. These challenged network environments require suitable routing schemes to overcome a challenging problem [2]. The features of the six types of routing schemes which are simulated in our scenario are explained below.

A. First Contact Routing Scheme

This routing scheme uses one bundle transmission. The source node generate a single bundle and transmit it randomly to the first contact (FC). When the link between nodes is not exist the node will carry the bundle and wait until come in contact with the other node. This routing can reduce consume the limited resources such as storagecapacity, bandwidth, and energy, but increases the latency and delivery ratio is poor due to the only a single copy is sent and the next hop is selected as randomly [1,3].

B. Direct Delivery Routing Scheme

As the FC routing, Direct Delivery (DD) routing uses one bundle transmission. No information about network topology requiring, but the source require a direct link to transmit bundles immediately to destination. In single copy schemes if any node carrying the bundle fails, the bundle will be lost due to there is only one bundle copy available in to the network, thus delivery ratio is poor [1,3].

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Vol.33 pp.78-85

C. Epidemic Routing Scheme

Epidemic routing scheme uses replication strategy, flooding multiple copies of the same bundle in the network, whichis the simplest approach to transmitbundle to the destination.This strategy increases the possibility that one of copies will find it is way to the destination. Epidemic routing assumes that each node has unlimited storage space and bandwidth [1].

D.Spray and Wait Routing Scheme

Spray and Wait (SaW)routing schemeproposed in [4]to overcome blind flooding the network and reduce resource consumption in the Epidemic routing. It isconsists of two phases. Spray phase: In the spray phase, when a source node generates a new bundle, it is responsible for spraying or delivery L bundle copies to the first L encountered intermediate nodes. Wait phase: If the bundle is not reached to it is destination in the spray phase, theL intermediate nodes carrying a bundle copy perform direct deliver to the destination, or the bundle is dropped due to of storage overflow or time to live expiry. Spray phase is same as Epidemic but with partial flooding,and wait phase is same as DD routing [2,3,5].

E.PRoPHETRouting Scheme

PRoPHETv2 is updated version of the PRoPHETrouting scheme, proposed in [6]. Using the enhancements to thea delivery predictabilitybut maintains the original ideas. The original ideasof PRoPHETrouting is that movements of mobile nodes are not purely random, but it has repeated mobility patterns, and it is can be predict using information obtained from previous meets.Every node maintains delivery predictability informationof all nodes. When two nodes meet, they exchange and update the information to calculates a probabilistic metric to forward the bundle to the highest delivery node which may meet the destination node [1, 7].

F. MaxPropRouting Scheme

MaxProp flooding routing scheme, it is based on selecting of which bundle has priority to transmitted first and or dropped from storage space. Each node has a routing table contains values of delivery likelihood for other nodes. Each node can calculate the cost for each route to forwards bundles to the destination. It forwards the bundle to any node in the network having high probability of encountering the destination node [1,8].

III. SIMULATION ENVIRONMENT

The main objective of this sectionis presented a detailed of disaster environment and mobility models used for the scenario. Additionally, simulation parameters and performance metrics are described. The simulation scenario were conducted using ONE simulator with program version of 1.5.1.

A.Disaster Environment

The simulation scenariohas been run on the map of Tripoli city converted to Well-known text format by using Geographic Information System program (OpenJUMP). The map of Tripoli is shown in figure 1 with area size about 10x 20Km.

The scenario assumethat the telecommunications infrastructure iscompletely damaged due to strikes of disaster. Six clusters are assumed in this scenario, sites of some clusters are in a realistic locations such as medical centers and hospitals, police and fire station. Whereasother clusters are in a virtual sites.The nodes in this scenario are categorizes in two different types. First type are carrier nodes, these nodes are usually vehicles that move across these clusters, such as ambulances , police cars, and civil defence vehicles, using Route Map-Based Movement. These nodes are responsible for carrying and forwarding bundles between clusters. They are not generating or receiving bundles as sources or final destinations. Second type are internal nodes or cluster nodes which are usually people move in the clusters using Shortest Path Map Based Movement instead a random walk movement .

The clusters are stationary local locations such as police and fire station, medical centers and hospitals, relief camps. The movement of people in the clusters is restrained to these locations and only move within it. Theassumed clusters in this scenario are:(1) EmergencyOperation and Evacuation Centers, (2) Tripoli Medical Center,(3) Tripoli Central Hospital, (4) Bab Ben Gasheer Police Center and Fire Station, (5) Relief Camps,(6) Disaster Area. Figure 2 shows the sites of clusters and the paths between them.Screenshot of the ONE simulator's GUI showing the clusters in this scenario can be seen in figure 3.

Fig 1: Tripoli Map.

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Proceeding of Engineering and Technology –PET
Vol.33 pp.78-85

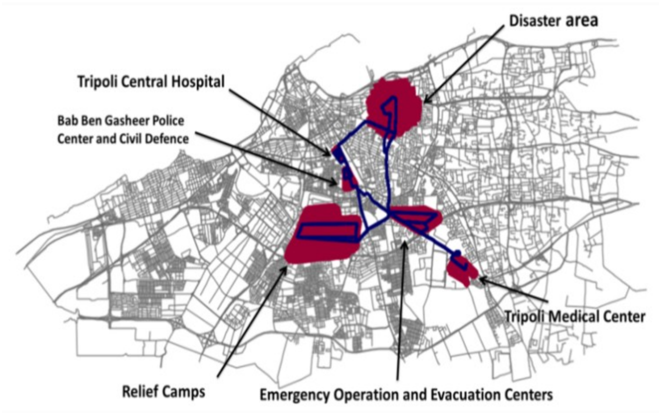

Fig 2: Clusters Locations and the Paths Among Them.

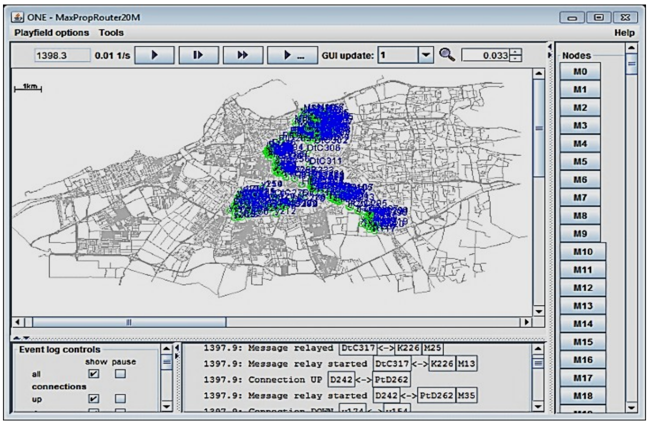

Figure 3 :Screenshot of the ONE simulator's GUI.

B. Mobility Models

Mobility model helps to simulate closely the real life scenario of mobile nodes. Therefore, appropriate mobility models are required to be included in the simulation software's to evaluate performance of DTN routing schemes across many scenarios [9]. ONE simulator can be combined multiple mobility models in one simulation. The following models will be run in our simulation

1)*Cluster Movement*:Modeling mobility for disaster area is unpractical, because the node movements in disaster areas are varies and cannot be completely predicted, based on type of disaster. The ONE simulator hasprovided different kinds of mobility models. But none of them completely matches with post disaster movements[10, 11]. It has provided cluster scenario where the route of carrier nodes is one circle route between all the clusters locations, such this circle route may increases the latency and decreases the delivery ratio. Thus, the routes should be independent routes between clusters, according to the need of cooperation among them.

In our scenario all clusters areas on the map are converted to WKT format which are done using OpenJUMP software. Each cluster represent realistic location except the disaster area which represent circle with diameter approximately of about 800m. All clusters nodes using Shortest Path Map Based Movement.In this model the nodes choose a random locations on the map. Each node choose point as destination randomly, and calculatethe shortest path to it is destination [1,12.13].

2)*Route Map Based Movement*:Movement of nodes are completely random in this type, but following predetermined paths inside the map. This type has effectively performance in simulating nodes movement, particularly, in the case of vehicles routes [1,12].

C. Simulation Parameters

The ONE simulator need parameters to running scenarios. Table 1 summarizes the parameters for the scenario. Table 2 illustrates the routing scheme parameters. Table 3 illustrates bundle event interval. Each node use IEEE 802.11b (11Mbps) .

Table 1: Simulation Parameters.

Name of Parameter		Value of Parameter			
No. of Nodes	Carrier Nodes	54	78	104	130
	Internal Nodes	96	146	220	294
	Total	150	224	324	424
Traffic Load (bundle/ interval time)		5,10-10,15-15,25- 25,35			
Simulation Time		14400s			
Network Interface		WI-FI Interface			
Transmit Range		100m			
StorageCapacity		10MB,20MB,40MB,60MB			
Bundle Sizes		500KB-1MB			
Bundle TTL		60m,120m,180m,240m			
Node Speed	Pedestrian	1m,1.5m/s			
	Vehicle	30km,50km/h			

Table2: Routing Schemes Parameters.

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

Table3: Bundles Created per Bundle Event Interval in Seconds.

Bundle EventInterval	5,10	10,15	15,25	25,35
Bundles Created	2061	1201	739	487

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Vol.33 pp.78-85

D. *Performance Metrics*

The following are the performance metrics used for the performance analysis of the routing schemes.

3)*Delivery Ratio*:The delivery ratio is the ratio of total number of bundles arrived to their destination to total number of bundlescreated by the source nodes [1].

4) *Average Latency*: latency is time taken by all bundlesfrom they are created at source to it is at reached destination successfully [1,14].

5) *Delivery cost*: It isreflects the cost the routing scheme should pay, in terms of copies of one bundle relayed to deliver this bundle, and it is defined as the ratio of difference among the total number of copies of all spread bundles and the total number of delivered bundles to the total number of delivered bundles.[1,15].

IV. SIMULATION RESULTS

We have used ONE simulator to analyze and evaluate the performance of different routing schemes with varying parameters, storagecapacity, bundle time to live (TTL), traffic load and number of nodes.All results are plotted in figures by usingGnuplotprogram.

A. *Effect of Varying Storage Capacity*

1)*Effect of Varying Storage Capacityon Delivery Ratio*: As shown in figure4the delivery ratio of Epidemic and PRoPHETv2 are directly proportional with thestoragecapacity.The performance of DD, FC and SaW schemesare not impacted.This is because theyare limited copiesschemes (single copy and n copies)so, they are require much less storagecapacity. Delivery ratio of MaxProp increased when the storage increased to20MB and then stabilize when the storage is greater than the relayed bundles, it obtains better results.

2) *Effect of Varying Storage Capacityon Delivery Cost*: As shown in figure 5 Epidemic begin with largest value of the cost,thiscostgoes down rapidly as the storagecapacityis increases, this occurs because more copies can be stored.PRoPHETv2 performs well thanEpidemic.In DD routing the delivery cost is zero for any changing storagecapacity,becausethe source node deliver the bundle only to the destination node.SaW routing gets better results than flooding schemes,because it issprays limit number of copies bundle.FC also has low delivery cost. MaxPropha s low costafter limitedcopies schemes.

3)*Effect of Varying Storage Capacityon Average Latency*: In figure 6 it can be seen that the MaxProp obtains better results, the average latency and delivery ratio of MaxProp are effected when storage capacity increased until reach 20MB. PROPHETv2 has the lower average latency if compared with Epidemic, the average latency for both routing schemes decrease as the storage capacity increases.

FC routing scheme obtains the worst performs. It is can noticeable that the DDrouting schemegets latency lower than FC, Epidemic and PROPHETv2, This phenomenon

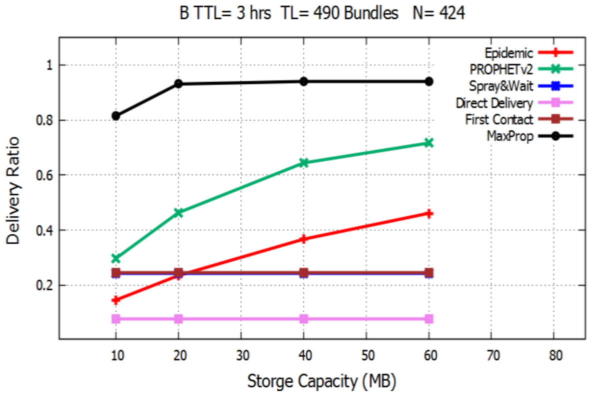

Fig4: Effect of Varying StorageCapacityon Delivery Ratio.

can be explained that the source node cannot leave it is cluster so, all source nodes delivered bundles to the destination nodes in same cluster. It can be seen that changing storage capacity has no effect on performance of DD , FC and SaWrouting schemes.

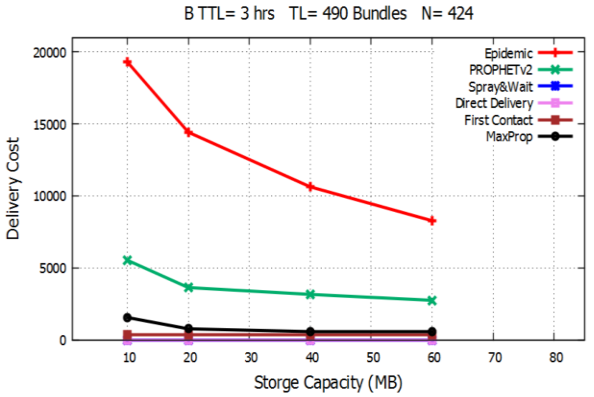

Fig5 :Effect of Varying StorageCapacityon Delivery Cost.

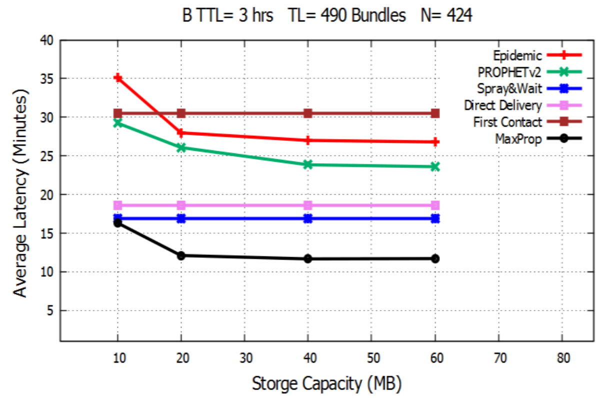

Fig6: Effect of Varying StorageCapacity on Average Latency.

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Proceeding of Engineering and Technology –PET
Vol.33 pp.78-85Proceeding of Engineering and Technology –PET
Vol.33 pp.78-85

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B. Effect of Varying BundleTTL

1) *Effect of Varying Bundle TTL on Delivery Ratio*: In figure 7 it can be noticeable that the PROPHETv2 performs well than Epidemic in term of delivery ratio,for both routing schemes the delivery ratiogoes down rapidly as the bundle TTL increases, this is due to overload the storagecapacity. Again MaxPropperforms quite well, it producebest result. Changing bundle TTL has no effect on performance of MaxProp and limited copies schemes.Limited copies schemeshave poor delivery ratio.

2) *Effect of Varying Bundle TTLon Delivery Cost:*In figure 8 it can be seen that the Epidemic scheme has the largest value of delivery cost, PROPHETv2 performs much better than Epidemic in term of delivery cost, but higher than other routing schemes.For both schemesthe deliverycost increase as bundle TTL increases. MaxPropgets delivery cost much better than the other flooding algorithms but higher than Saw routing. The lower delivery cost provided by DD, SaW and FC schemes respectively.

3) *Effect of Varying Bundle TTLon Average Latency*: Figure 9 illustrates average latency over time to live among existing routing schemes. Increasing value of bundle TTL gives effect to increase the average latency of PROPHETv2, FC and Epidemic routing schemes. This is due to increasing lifetime of the bundleincrease the waiting time of the bundle in storage,but with higher latency. FCrouting has the biggest value of average latency. In DDrouting and SaWschemesrouting the average latency settle when reached to 2 hours value. MaxPropschemegets the lowest value of average latency and the it is value constant during changingbundle TTL.

C. Effect of Varying Traffic Load

1) *Effect of Varying Traffic Load on the Delivery Ratio*: Figure 10 demonstrates that delivery ratio for MaxProp, PROPHETv2 and Epidemic decreases when traffic load increase, this is due to injecting more bundles into the network, which causes storages to overflow anddiscarding many of stored bundles. MaxPropdecrease rapidly than PROPHETv2 and Epidemic, but it obtainsbetter delivery ratiothan the other schemes. Compared with MaxProp, the second best routing scheme, PROPHETv2.DDachieves worst performance in delivery ratio. SaW, FC and DDschemes are limited copies, they have almost constant delivery ratioin any value of traffic load.

2) *Effect of Varying Traffic Load on the Delivery Cost*: Figure 11 illustrates that the Epidemic begin with largest value of the delivery cost and it is goes down rapidly. PROPHETv2 begins with value much less than the Epidemic scheme.A storage overflow occurswhen injecting more bundles into the network, which lead to an increase in discarding bundles. MaxProp in the considered scenario is low as compared to the cost of the Epidemic and PRoPHETv2 schemes. Limited copies schemes have lowest delivery cost.

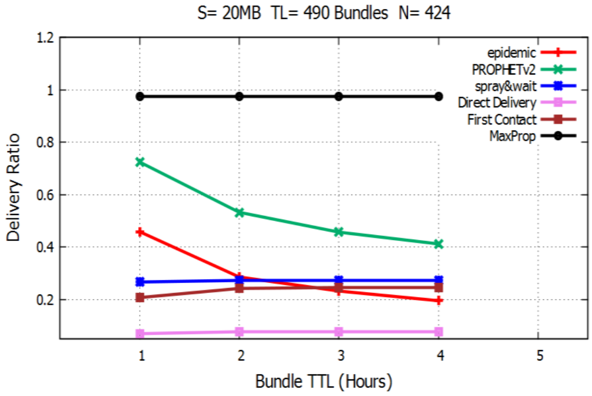

Fig 7: Effect of Varying Bundle TTL on Delivery Ratio.

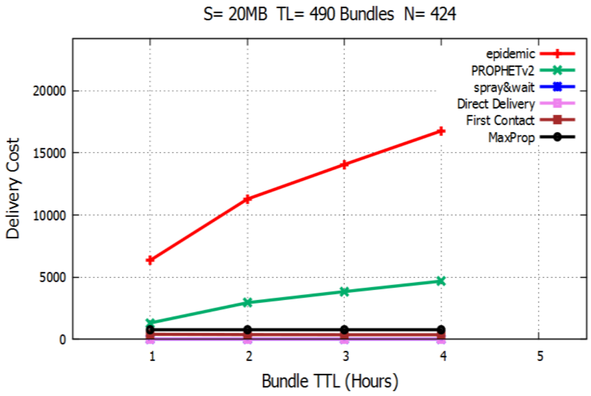

Fig8 :Effect of Varying BundleTTL on Delivery Cost.

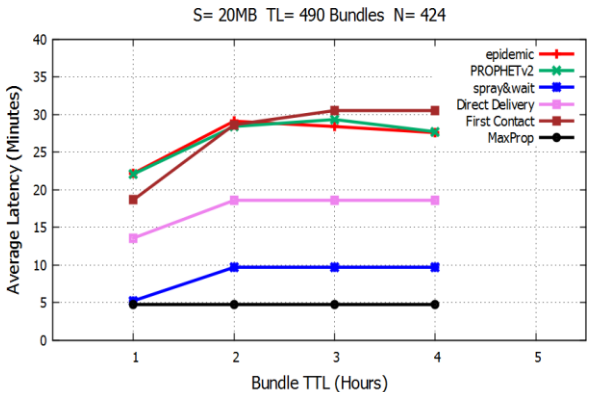

Fig 9: Effect of Varying BundleTTL on Average Latency.

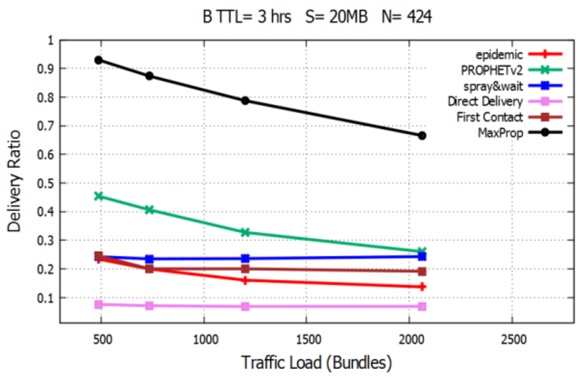

Fig10 :Effect of Varying Traffic Load on Delivery Ratio.

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3) *Effect of Varying Traffic Load on the Average Latency*: As clear in figure 12 the FCroutingperforms very badly,when injecting more copiesit is latency increase. Epidemic is the second routing gives the highlatency. PROPHETv2 begins with value higher than Epidemic, but as traffic load increase it is latency decrease less than the Epidemic.DD schemegetslatency lower than FCrouting, Epidemic and PROPHETv2, this is because any source node cannot leave it is cluster so, all source nodes delivered bundles to the destination nodes in same cluster and probability encounter between them is high. SaW keeps the latency low. MaxProp presents best latency but as traffic load increase the latency increasesslightlythan SaW routing.

D. Effect of Varying Number of Nodes

1)*Effect of Varying Number of Nodes on Delivery Ratio*: Figure 13 indicates that the MaxProp produces highest delivery ratio. Compared with MaxProp, the second best result gets by PROPHETv2 scheme. the delivery ratioof MaxProp and PRoPHETv2 are directly proportional with the number of nodes, whereas the delivery ratioof SaW routing is inversely proportional. FC and Epidemic routing have the same almost constant delivery ratio. DD scheme gets worst performance. Increasing number of nodes provides network connectivity and leads to increase the total network storage capacity and more bundles to be delivered. This increases both the delivery ratioand cost.

2)*Effect of Varying Number of Nodeson Delivery Cost*: As clear in figure 14 the highest transmission cost for delivering bundle is achieved by Epidemic routing. Epidemic begin with largest value of the cost. thecost goes up rapidly as the number of nodes increases. PRoPHETv2 gives much lower delivery cost ratio than Epidemic. MaxProp achieves low transmission cost and has less power consumption as compare to the Epidemic and PRoPHETv2. SaW has low delivery cost due to the limit number of spreads copies bundle. FC and DD routing have the best transmission cost due to only a single copy is sent.

3)*Effect of Varying Number of Nodes on Average Latency*: Increasing the node density provides network connectivity anddecrease the phenomena of network partition and provides faster paths to destinations nodes which decreases the average latency. Figure 15 illustrates that the average latency of all routing schemes are inversely proportional with the number of nodes.MaxProprouting obtains the lowest latency, whereas FC routing performs very badly. SaW scheme keeps the latencylower than the other schemes, while the Epidemic and PROPHETv2 have the same average latency.

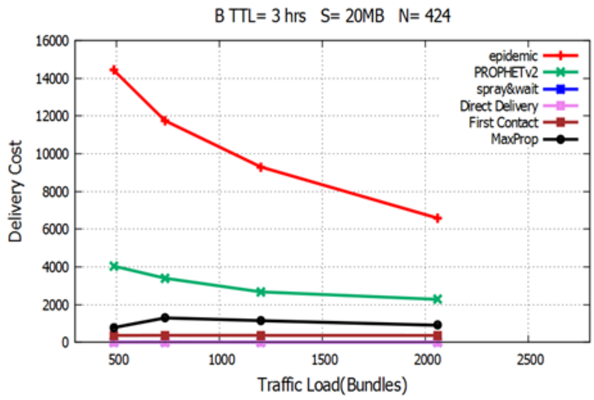

Fig11 :Effect of Varying Traffic Load on Delivery Cost.

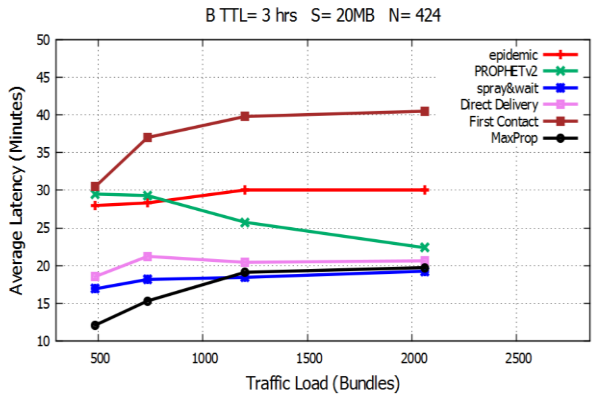

Fig12 :Effect of Varying Traffic Load on Average Latency.

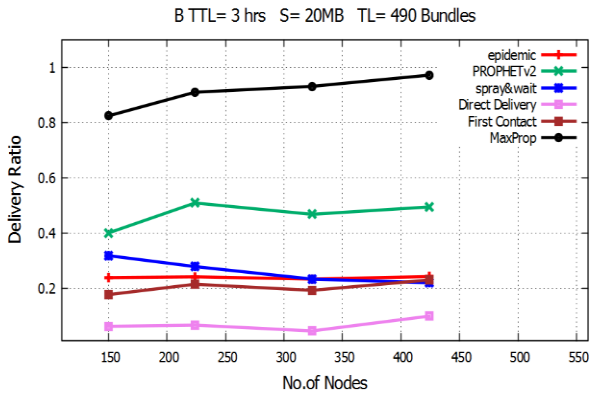

Fig 13: Effect of Varying Number of Nodes on Delivery Ratio.

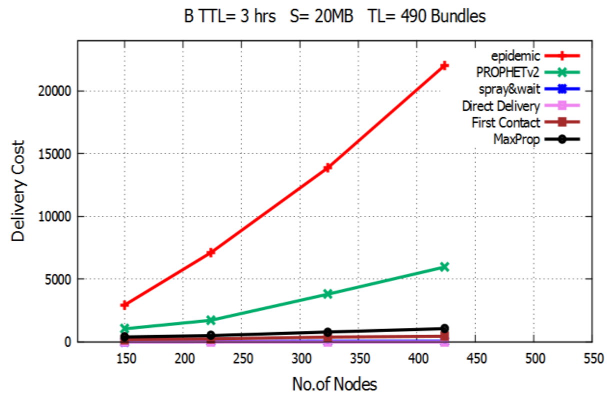

Fig14: Effect of Varying Number of Nodes on Delivery Cost.

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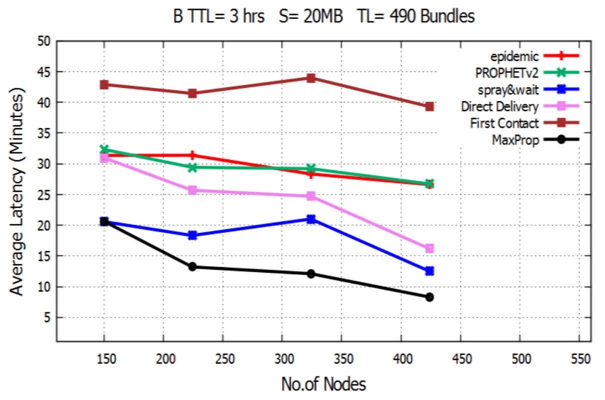

Fig 15: Effect of Varying Number of Nodes on Average Latency.

V. CONCLUSION AND FUTURE WORK

In this paper we try to analysis and evaluate the performance of different routing schemes for DTN Network in post disaster scenario. Different parameters were examined for evaluation of these routing schemes. The analysis clearly shows that the MaxProp routing scheme gives best results in terms of delivery ratio and delivery cost with low average latency. Compared with MaxProp, the second best result presented by PROPHETv2 scheme in term of delivery ratio, but gives high average latency and delivery cost. Changing parameters have effect on performance of PROPHETv2. In term of delivery ratio MaxProp and PROPHETv2 schemes are achieved the best results, this is due to the both schemes are probabilistic based approach using knowledge of previous encounters for optimal delivery which provided in post disaster scenario by the carrier nodes. Epidemic gets the highest delivery cost, and has average latency almost the same as PROPHETv2, and it is delivery ratio is lower than PROPHETv2. FC scheme produce lowest cost resources, but gets worst delivery ratio. DD scheme is absolutely not appropriate for post disaster scenario, because all the nodes of each cluster are treated as internal nodes, and they cannot leave the cluster, whereas this routing based on the source node is deliver the bundle only to the destination node. So, if the destination node in other cluster the bundle will never reach to it. For this reason all the bundles which delivered they were exchanged between nodes in the same cluster, and there is no bundles exchanged or delivered between clusters. That is why the average latency of DD scheme is lower than the flooding schemes, Epidemic and PROPHETv2 routing due to the high connectivity of each cluster. SaW routing gives low delivery cost than the other flooding schemes due to the limited number of copies bundle during the spray phase. This means it is costs the resources very little, but obtains poor delivery ratio this due to direct deliver to the destination in wait phase such as DD scheme.

In future this work can be extending to comparison and performance evaluation of different deterministic and stochastic DTN routing protocols .

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