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Probability based Power capable Spray and Wait routing protocol in Delay Tolerant Network

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Abstract —*The Delay Tolerant Network is an Emerging Disruption Tolerant Network, which usually deals with communications in extreme challenged environments. There is not any end to end path between source and destination means there may not any direct path exist between them even if they communicate with each other because of mobility of nodes and store-carry and forward scheme. Many routing protocols used in DTNs which follow Store, Carry and Forward paradigm and transfer data among disconnected network. To improve delivery ratio, Average delay and overhead ratio in DTNs, this paper used Probability based Spray & Wait Protocol. This paper calculates the probability of the next relay node and utilizes the information about quality of node and remaining power to allocate the number of copies to the next relay node in the spray phase.*

Keywords- *Delay Tolerant Network; Probability; Power; Quality of Node; Routing protocol;*

I. INTRODUCTION

Delay Tolerant Network is a **Disruption-tolerant Networking** in which a direct attached path from source to destination does **NOT** exist. There is no end-to-end path from a source to destination. The connectivity of the network is maintained by different nodes only when they come into the transmission ranges of each other. If a node has a message copy but it is not connected to another relay node, it stores the message until an appropriate communication opportunity arises.

In Existing heterogeneous wireless network, mobility of nodes, limited radio range, physical obstacles and wireless ad-hoc network helps to communicate between nodes without any existing infrastructure or path. Ad-hoc network sachem assumes end to end connectivity between any pair of nodes that exists. Protocols like TCP/IP have a limitation over long distance. Because of long distance, high delay, low bandwidth, satellite failures, disruptive connections, solar flares, cruel environment of space, communications at bottomless space and non-habitat areas results into poor performance. Delay Tolerant Network is a way out for computer structural design that proved benefit to the technical issues in heterogeneous network which may lack continuous connectivity [1].

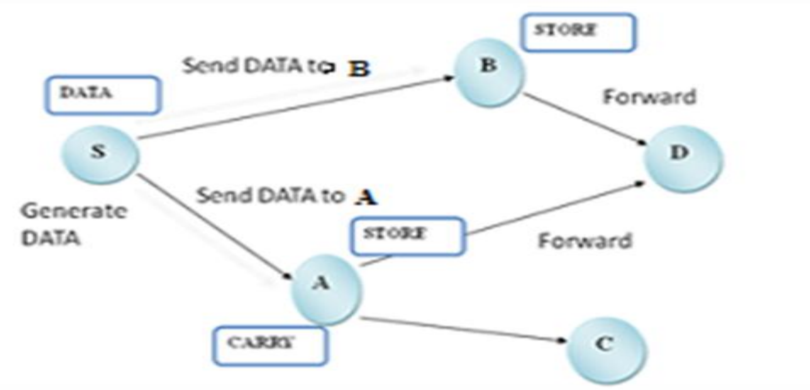

Fig 1. Delivery of Data in DTN

DTN is based on the principle of store-carry-forward (See in above Figure). This mechanism requires persistent storage and bundle protocols. Bundle is the basic unit of transmission and storage in DTN structural design. Bundle contains application data and is routed through intermediate relay nodes to last destination. The store-carry and forward operates over multiple paths and extremely long timescales. Nodes act as a message ferries that carry messages between disconnected nodes [2]. It is advantageous as use of wireless bandwidth is not required but traffic flow need buffer space at message ferry. This unique mechanism poses a security challenge. DTN is vulnerable to privacy, reliability, authenticity, wormhole attacks etc. A sophisticated attack observed is black hole attack in which malicious intermediate nodes are present in network that can provide attacked fake metrics to another node. It also advertises itself as having the shortest path to the destination node [3].

Section II goes over related works, describes several typical DTN routing protocols. Section III describes in detail the proposed work on Probability based Power capable Spray and Wait Routing Protocol. Section IV describes the performance evaluation. Section V shows the results to analyze the routing protocols and conclusion is given in section VI.

II. RELATED WORK

2.1 Epidemic

The Epidemic routing [4] was proposed to provide packet delivery in disconnected ad hoc networks. Because there is not give any guaranteed existing route for communicating pairs, the effort to find a route is not carried out any more. Instead, waiting for opportunities to meet the destination and buffering the packet is the essential strategy for the epidemic routing. Moreover, in order to increase the probability of a packet to meet its destination, letting other intermediate nodes carry a copy of this packet is a second measure carried out by epidemic routing. This packet copy dissemination is achieved during the movement of the node carriers by exchanging the summary vectors between two relay nodes.

For the summary vector, all nodes will keep records of the received packets within itself in the form of a table. Generally, this table is indexed with the packet ID which is unique in the network. Then, the binary value corresponding to each packet ID entry in the table represents whether the packet with this ID has been received by this node: 0 for not received and 1 for received. Therefore, the summary vector is used to receive new packets and avoid receiving the same packet for a node when it meets a new neighbor.

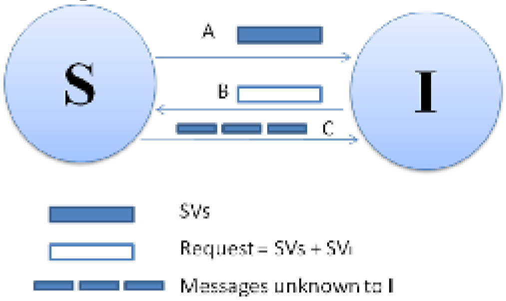

Fig.2 Exchange of Summary vector in Epidemic Routing

When a new neighbor comes into range or contact, the node with smaller ID will start the summary vector exchange. The node having received the summary vector from its new neighbor node will compare this summary vector with its own one to determine which packets for the new neighbor node are needed and which packets for itself are needed. Then it will send the packets that its neighbor needs to its neighbor node and request the packets it needs from its neighbor node. Fig. 2 shows this summary vector exchange scheme. By performing this routine, the packet and its copies can be disseminated to all the nodes in network.

2.2 Spray and Wait

Simple Spray and Wait (SaW) [5] is an improvement of Epidemic routing which has controlled flooding. It controls the blind forwarding strategy of Epidemic routing protocol by associating a number of message copies L to the generated message at source node. L shows the maximum allowable copies of a message in the network.

SaW has two phases: (1) Spray phase and (2) Wait phase. The source node initially has L number of copies of a message. In the spray phase the source node forwards L copies to L distinct nodes. If all these L nodes are not the destination node then they enter into the wait phase till the direct transmission to the destination node.

Binary Spray and Wait (BSW) [5] improves SaW. In Binary Spray and Wait, the source of a message initially starts with L copies. When it encounters first node with no copies then it hands over half copies to that node and keeps half of them. Now this process is repeated for both source and relay that has $L > 1$ message copies, and when the node either is left with only one copy, it switches to wait phase and wait till the direct transmission to the destination.

However Saw and binary Spray and Wait forward constant L number of copies i.e. blindly forward message copies to relay node without calculating performance factor of the node.

2.3 PRoPHET

The Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoPHET) establishes a summary vector that indicates what messages a node is carrying. It also establishes a probabilistic metric called delivery predictability, $P(a, b) \in [0,1]$, at every node a for each known destination b. This indicates how likely it is that this node will be able to deliver a message to that destination. The calculation of the delivery predictabilities has three parts. First, whenever a node is encountered to any intermediate node, then the metric is updated as in Eq.1, where Pini is an initialization constant

$$P(a,b) = P(a,b)_{old} + (1 - P(a,b)_{old}) \times P_{ini} \quad (1)$$

Second, if a pair of nodes do not encounter each other after a period of time, they are less likely to be good forwarders of the messages to each other, thus the delivery predictability value must age. Eq.2 shows the aging equation, where $\gamma \in [0.1]$ is the aging constant, and k is the number of time units that have elapsed since the last time the metric was aged.

$$P(a,b) = P(a,b)_{old} \times \gamma k \qquad (2)$$

Third, the delivery predictability also has a transitive property that is based on the observation that if node A frequently encounters node B, and node B frequently encounters node C, then node C is probably a good node to forward messages destined for node A. Eq.3 shows how this transitivity affects the delivery predictability, where β is a scaling constant that decides how much the impact the transitivity should have on the delivery predictability.

$$P(a,c) = P(a,c)_{old} + (1-P(a,c)_{old}) \times P(a,b) \times P(b,c) \times \beta \qquad (3)$$

III. PROBABILITY BASED POWER CAPABLE SPRAY AND WAIT

In this section, a new routing based on the delivery probability and Quality of Node is proposed to improve performance. The proposed routing called PBPC is the improved routing based on Spray and Wait routing. It includes spray phase and wait phase. PBPC need update Delivery Probability of nodes which can be used to decide whom we have to forward message copies assignation, Quality of Node and Power decide for policy of message transmission.

The PBPC can be divided in two phase: Spray phase and Wait phase. There are three parts of the Spray phase as following:

3.1 Determine Probability of Next Node

We will find the next node with high probability of data delivery using data delivery probability which has been used in the PRoPHET routing protocol in first part of Spray phase.

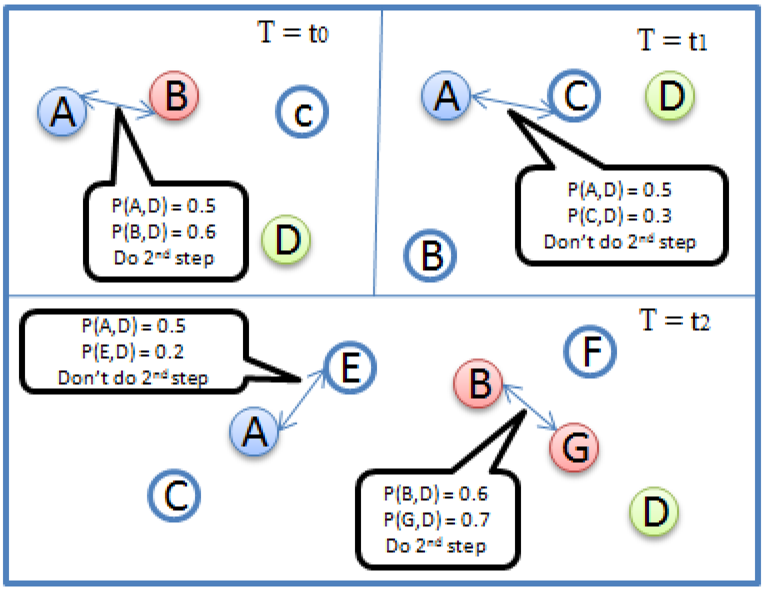

Fig. 3 Calculate Probability

3.2 Find Forward Message Copies

Quality of Node indicates the activity of a node, means that, number one node meets other different nodes within a given interval. In the same interval of time, the more nodes that one node meets, the greater the Quality of Node. Energy consumption for each node transmits and receives data with fixed transmission and reception power, respectively. So the power consumption is independent of the transmission distance between adjacent nodes. Accordingly, we adopt the following energy model in [6-7] to calculate the power consumption.

P = e * (Kr + Kt) --------------------- (1)

Where P denotes the total energy consumption of one node for receiving message and transmitting message, and e is a factor indicating the energy consumption per message at the receiver circuit.

Moving in the network, the node will encounter more number of nodes. We will add a number of new nodes from time to time in the real network. Some nodes have been in the network for a long time, whose Quality of Node are larger. However, new nodes Quality are smaller. Therefore, we divide time into a series of fragments at the same length of time. We calculate Quality of Node on each fragment and consider the influence of the Quality of Node in former fragment on the Quality of Node in the current fragment. We divide time fragments into n.

$$\sum_{i=1}^{n} ti = T \qquad t1=t2=t3=\ldots\ldots= tn \text{ ----------------------- } (2)$$

With reference to Jacobson formula [8], the Q (Quality) can be updated by Equation (3).

$$Q = \alpha * Qold + (1 - \alpha)\ Avgk \text{ ------------------------------------ } (3)$$

α is a smoothing factor, which determines the influence of the Quality of Node in former fragment on the Quality of Node in the current fragment. Qold refers to the Quality of Node at the end time of former fragment and has to be updated regularly. In our algorithm we update the Quality of Node once per Hour.

$$Avgk = \frac{k2 - k1}{\Delta t} T \text{ -- } (4)$$

In Equation (4), Avgk is the number of other nodes that one node experiences in the network during the period of time from the end time of former fragment to the current time. Nodes must first update Avgk and Q at each connection.

Two nodes encounter, if the receiver node has high data delivery probability than they will update the Quality of Nodes at first and exchange vector table. Source node has more than 1 copy, than algorithm will be run on source node to calculate the number of copies spray to the receiver node using Quality of Nodes information. And the spray phase continues until there is only one message copy left on source node. Assuming that a node A (source or relay) has N1 > 1 packet copies.

$$\mathbf{N2} = \frac{Q2}{Q1 + Q2} * \frac{E2}{E1 + E2} * \frac{N1}{2}$$

Thus, N2 will give the number of message copies for forward to the receiver node.

3.3 Forwarding Policy

After successfully calculation of Forward number copies, we can successfully forward N2 copies of message to the receiver node.

According the assumption about the Random Waypoint mobility, all nodes move independently. When a node has only one copy left, it switches to direct transmission, means that it will forward this message only to its destination.

IV. PERFORMANCE EVALUATION

We simulated and configured the disaster scenario using the opportunistic Network Environment Simulation (The ONE [9]) to determine the effect on the performance of the disaster scenario. The ONE was developed by Helsinki University and provides a map of the Helsinki area. This city covers an area of 4500 m x 3400 m, and there are 126 mobile nodes, which move along the city roads or tramways, including pedestrians, cars, Taxis and trams. Other simulation parameters shown as Table I.

In the simulation, we measured three factors, i.e., the delivery probability, the overhead ratio, and the average latency.

TABLE I. SIMULATION PARAMETERS

Parameters	**Simulation Values**			
	Cars	**Taxis**	**Trams**	**Pedestrians**
GroupID	**C**	**T**	**W**	**P**
Interface	**btInterface (Bluetooth)**	**btInterface (Bluetooth)**	**btInterface (Bluetooth)**	**btInterface (Bluetooth)**
Nodes	**40**	**6**	**40**	**40**
Speed(m/s)	**2.7,13.9**	**5.6,16.7**	**7,10**	**0.5,1.5**
Movement Model	**ShortestPath MapBased Movement**	**ShortestPath MapBased Movement**	**ShortestPath MapBased Movement**	**ShortestPath MapBased Movement**
Wait Time(s)	**0,200**	**10,30**	**0,200**	**0,200**

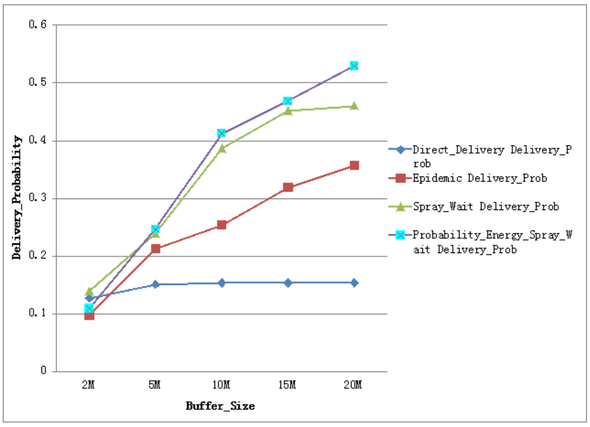

Fig 4. Delivery Probability

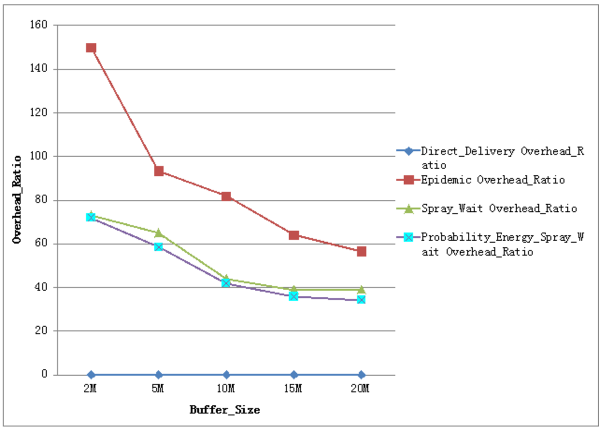

Fig 5. Overhead Ratio

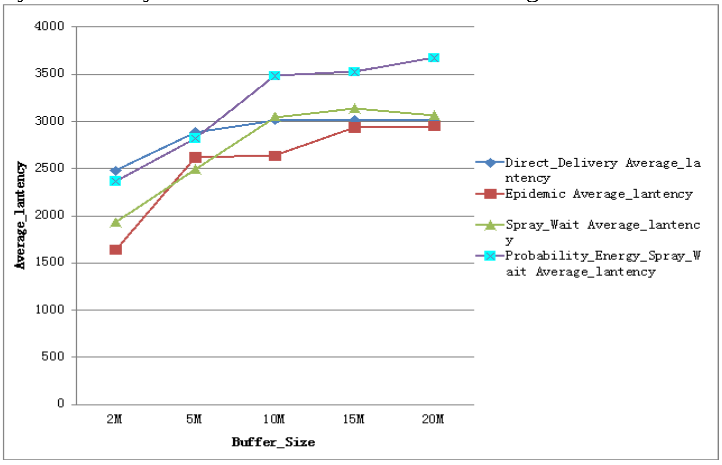

Fig 6. Average Latency

In order to verify the performance of the proposed PBPC routing protocol, a comparison was done for the delivery ratio, message overhead ratio and average latency of the direct delivery, epidemic and spray and wait that were previously proposed with the proposed PBPC routing protocol. Fig. 4 shows the message delivery ratio according to buffer size and Fig. 5 shows the overhead ratio according to buffer size.

The delivery ratio indicates the volume of packets that complete the message delivery from a source node to a destination node. A protocol with a high delivery ratio is a better routing protocol. In order to get a high delivery ratio, it will try to transfer more packets to the network and there will be a higher probability for a high message overhead to occur. However, by suppressing the increase in overhead according to the increase of the delivery ratio, this routing protocol will transfer messages only for the optimized cases of data delivery to the destination nodes and will be considered a routing protocol with better performance than a routing protocol with a similar delivery ratio. In the proposed method, it had a high message delivery ratio because the messages were duplicated based on the probability and the messages were transferred through many nodes that had a higher probability of data delivery so that it could reduce the overhead by reducing the number of unnecessary messages.

Fig. 6 shows the average latency according to the buffer size. The average delay in which a message is transferred from a source node to destination node can be compared. In DTN, the routing protocol is tolerant of the delivery latency time but too high a delay can limit the number of useable applications. Because a plural number of nodes with a high probability of having a better data delivery ratio should transfer the messages, the delay time can be reduced in the proposed method.

V. CONCLUSION

Using this routing scheme we conclude that they will increase the delivery ratio and reduce the overhead ratio. Using this scheme, a helpfulness function quality of node and remaining energy information are presented to assign the number of copies between each connected pair and avoid the blindness in the spray strategy of Spray and Wait. In order to prevent any unnecessary spray in an existing spray and wait routing protocol, proposed PBPC routing protocol was utilized. It will reduce network overhead and increase delivery ratio.

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