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A History of Encounters Probabilistic Routing Novel Scheme in Delay Tolerant Networking

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Abstract: A delay-tolerant network is a network designed so that temporary or intermittent communication problems and limitations have the least possible adverse impact. One major issue should be considered to enhance the performance of data delivery in such challenging networking environments: A routing strategy for the network. The routing strategy determines which message should be forwarded when nodes meet. This study proposes an enhanced routing scheme which is using the technique of History of Encounters Probabilistic Routing Novel Scheme: HEPRNS. The experimental results show that HEPRNS have better results over the history of encounters probabilistic routing novel schemes such overhead and latency in terms of increasing the number of nodes and shortest the path map based movement, which is compared with the other schemes such as Epidemic, PRoPHET, Spray and Wait, MaxProp.

Key words: Delay tolerant networking, delivery rate, overhead, latency, history of encounters probabilistic routing novel scheme

INTRODUCTION

Delay Tolerant Networking (DTN) is an end-to-end network architecture designed to provide communication in and through highly stressed networking environments. The networking environments include those with intermittent connectivity, large and variable delays and high bit error rates (Demmer and Fall, 2007). DTN is the area of networking which addresses challenges in disconnected, disrupted networks without end-to-end connection. DTN is designed to operate effectively over extreme distances such as those encountered in space communications (Zheng *et al*., 2008).

These have something in common with more and more devices incorporating computing and networking technology in less traditional networking environments. Computer networking in such environments faces new challenges and new techniques and protocols are required. And all these challenges can be characterized as follows (Haas and Pearlman, 2001):

- **intermittent connectivity:** If there is no end-to-end path between source and destination, the end-to-end communication using the TCP/IP protocols does not work. New protocols to support the communications without an end-to-end path are required
- **long or variable delay:** In addition to intermittent connectivity, long propagation delays among nodes and variable queuing delays at each node contribute to end-to-end path delays that can defeat Internet protocol and applications that rely on quick return of acknowledgements or data
- **asymmetric data rates:** The Internet supports moderate asymmetries of bi-directional data rate for users with cable TV or asymmetric DSL access. But if asymmetries are large, conversational protocols will not work
- **high error rates:** Bit errors over transmission links require correction or retransmission of the entire packet, which can result in more network traffic. For a given link-error rate, fewer retransmissions are needed for hop-by-hop than for end-to-end retransmission

Routing in DTN is active area of research and acquires the attention of researchers as being the most adequate solution for the problem of intermittently connection in Mobile Ad hoc Networks (MANET). The challenge is to find a routing algorithm that can deal with dynamic environment causing networks to split and merge, considering nodes mobility.

DTN is a message-based store, carry and forward overlay network architecture. DTN architecture is designed to provide communication in intermittently connected networks by moving messages towards destination via store-carry-and-forward networking model that supports multi-routing algorithms to acquire best path towards destination.

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In this study we enhance the performance of DTN routing protocols by accomplishing these goals.

SCHEMS

Routing schemes for DTN: We review routing protocols in DTN and presents common DTN routing schemes.

Vahdat and Becker (2000) presented a routing protocol called Epidemic. Epidemic routing protocol is a routing protocol which exhibits the shortest end-to-end delay in intermittently connected mobile networks. It floods messages into the network. The source node sends a copy of the message to every node that it meets. The nodes that receive a copy of the message also send a copy of the message to every node that they meet. Eventually, a copy of the message arrives at the destination of the message. This protocol is simple but may use significant resources. Excessive communication may drain each node's battery quickly. Moreover, since each node keeps a copy of each message, storage is not used efficiently and the capacity of the network is limited. Each node can only be expire messages after some amount of time or stop forwarding them after a certain number of hops. After a message expires, the message will not be transmitted and will be deleted from the storage of any node that holds the message. An optimization to reduce the communication cost is to transfer index messages before transferring any data message. The index messages contain of messages that a node currently holds. Thus, by examining the index messages, a node only transfers messages that are not yet contained by the other nodes. So replication of packets in ERP increases the probability of packet delivery by maximizing the number of nodes carrying packets.

Epidemic routing is particularly resource hungry because it deliberately makes no attempt to eliminate replications that would be unlikely to improve the delivery probability of messages. This strategy is effective if the opportunistic encounters between nodes are purely random. But in realistic situations, encounters are rarely totally random. Data mules move in a society and accordingly tend to have greater probabilities of meeting certain mules than others. The Probabilistic Routing Protocol using History of Encounters and Transitivity (Prophet) protocol uses an algorithm that attempts to exploit the non-randomness of real-world encounters by maintaining a set of probabilities for successful delivery to known destinations in the DTN and replicating messages during opportunistic encounters only if the mule that does not have the message appears to have a better chance of delivering it. An adaptive algorithm is used to determine the delivery predictabilities at each mule. The mule M stores the delivery predictabilities P(M, D) for each known destination D. If the mule has not stored a predictability value for a destination, P (M, D) is assumed to be zero. The delivery predictabilities used by each mule are recalculated at each opportunistic encounter according to three rules.

Burgess *et al.* (2006) presented a routing protocol uses flooding technique called MaxProp. In MaxProp if a new node discovered, new messages to the node will attempt to be replicated and transferred. MaxProp determines first which messages should be transmitted and or dropped. It maintains an ordered-queue based on the message's destination and it ordered by the estimated likelihood of the future path to that destination. Path likelihoods estimated by each node in which is maintaining a vector of size n-1, where n is the number of nodes in the network, consisting of the likelihood the node has of encountering each of the other nodes in the network. Encountered nodes exchange their estimated node-meeting likelihood vectors when they meet. The vectors are kept updated by every node. Each node can compute a shortest path via a depth-first search where path weights indicate the probability that the link does not occur. Path weights are added to determine the total path cost and are computed over all possible paths to the desired destinations. The cost for any destination is determined by selecting the path with the least total weight. Then, messages are ordered by destination costs and transmitted and or dropped in that order.

Spray and Wait has phases: Spray phase and wait phase. When a new message is created in the network, a number M is attached to the message indicating to the maximum allowable copies of the message in the network. In the first phase, spray, the originate node of the message is responsible for spraying, one copy to M intermediate nodes. When the intermediate node receives the copy, it go into the second phase, wait, where the intermediate node that particular message until the destination is encountered directly (Spyropoulos *et al.*, 2005).

Social-structure in human society: A social structure in the society formed of nodes that are connected by one or more specific types of interdependency. While the links show relationships or flows between the nodes the nodes in the social network are the people and groups. The notion of social structure in the society is grouped into structurally related groups or sets of roles, with different functions, meanings or purposes (Howard, 2008).

The social structure refers to the idea that society is separated into different levels according to social characteristics such as a race, class, language, gender and religion. Social network analysis presents both a visual and mathematical analysis of human relationship. One example of social structure is the online social network which refers to social network websites. When you sign up with any of those social network websites, you will be able to meet new friends, reconnect with people you already know, build up the relationships over time, learn from their language and share what you know. Furthermore, you can find some of your hometown or other parts of the world even though there is no prior knowledge of their nations or locations.

In these social networks, when you add a highly-social person to your list, it will make the process quick to add and find friends in your hometown or other parts of the world without prior knowledge of their locations. In general, it could classify people in online social networks based on their social connectivity. This social connectivity called social-structure of each person.

The study utilizes the concept of social-structure in social network. The routing protocol uses the social-structure concept in forwarding procedures. The node will forward messages to encountered nodes only if those nodes classified as highly connected in the network, which is similar the highly-social person in your list.

History of encounters probabilistic routing novel scheme: DTN have been proposed to address data intermittent communication challenges in networks where an instantaneous end-to-end path between a source and destination may not exist and the links between nodes may be opportunistic, predictably connectable, or periodically based on connecting (Balasubramanian *et al.*, 2007). We focus on the Delay-Tolerant Mobile Ad Hoc Network to design a probabilistic routing protocol applicable to work in this intermittently connected environment to improve the end-to-end message delivery ratio in a multi-hop scenario where link availability can be low (Gong *et al.*, 2006; Spyropoulos *et al.*, 2007). It is that the algorithm designed to 1) maximize message delivery rate, 2) minimize the total resources consumed in message delivery, 3) minimize the number of hops used in routing and 4) minimize message latency (Spyropoulos *et al.*, 2008).

The routing algorithm will overcome the problem of periodically-disconnected network by applying the factor of history on encountered of each node for forwarding strategy. It employed the concept of history of encountered which is similar to the concept of social structure in social network to forward messages to encountered nodes. Messages will be transferred towards destination via store-carry-and-forward technique that is used in DTN based routing protocols. The new approach is called History of Encounters Probabilistic Routing Novel Scheme (HEPRNS).

The operation of HEPRNS relies on the knowledge of the mobility of nodes to forward messages based on encountered nodes in the history of their encounters before. It determines the history of encounters probabilistic factor of any node based on how many nodes did this node encounter until the moment of meeting a new node. If node a meets node b and the history of encounters probabilistic factor of node a is greater than node b, so it means that node a encountered more nodes than node b until the encountering time. Then, node a will not forward any messages to node b but will do. HEPRNS uses the history of encountered nodes to predict its future suitability to deliver messages to next node toward destination. An index of encountered nodes called a summary vector is kept by each node. Each node maintains the summary vector that lists all encountered nodes during its mobility. The buffer size of each node controls the size of the summary vector. When two nodes meet, they update the summary vector. Then, they exchange summary vectors which in this case also contains the list of encountered nodes stored at their nodes. This information in the summary vector will be used to decide which messages to request from the other node based on the history of encounters factor used in the forwarding strategy.

The forwarding strategy depends on the history of encounters of nodes in the network. It creates a metric called history of encounters at every node in DTN. It indicates how highly encountered the node is, which the number of nodes encountered till that time is. The calculation of messages delivery depends on the history of encounters metric. When the nodes meet, the first thing to do is to update the metric, then they swap the number of encountered nodes till moment of meeting so that nodes that are often encountered more nodes have a high delivery probability. Encountered nodes exchange the number of earlier contacts without any details of those nodes. If they meet the same number of nodes in the past they exchange new messages and if one of them encountered more nodes than the other in the past, only the node with low number of earlier contacts will deliver the new messages to the node with high earlier contacts. When the message arrives at a node, there might not be a path to the destination available so the node has to buffer the message. On each encounter with another node, a decision must be made on whether or not to transfer that particular message.

The model is based on the probability of an event equals the ratio of its favorable outcomes to the total number of outcomes provided that all outcomes are equally likely. According to the classical definition, the probability P (A) of an event A is determined a priori without actual experimentation. It is given by the ratio:

$$P(A) = \frac{N_A}{N} \quad (1)$$

where, N is the number of possible outcomes and NA is the number of outcomes that are favorable to the event A. In HEPRNS, when node a, encountered 9 nodes carries messages to deliver to final destinations, meets node b, encountered 6 nodes, node a will not forward any messages to node b since:

$$P(a)\left[= \frac{N_a}{N}\right] > P(b)\left[= \frac{N_b}{N}\right] \quad (2)$$

We will forward messages from a node to another only if the probability of the encountered node is greater than the node that carried the same messages.

EVALUATION PERFORMANSE

Simulation Environment: The Opportunistic Network Environment (ONE) simulator is special simulator for the DTN (Keranen and Ott, 2007). Because the ONE simulator is accord with the characteristic of DTN on the aspects of moving model, energy model and routing strategy of nodes compared with other software. So a great many researchers is using the ONE simulator to simulate the DTN. It mainly contains five core boxes. The report box appoints the types of output table. The routing box appoints the routing strategy of messages, which is divided by groups. The movement box appoints the moving strategy of nodes which is also divided by groups. The input box appoints the interfaces of input event classes. Finally, the core box appoints some core classes and interfaces. The ONE simulator provides a powerful tool for generating mobility traces, running DTN messaging simulations with different routing protocols and visualizing simulations interactively in real-time and results after their completion.

We describe the simulation setup to evaluate the performance of HEPRNS and common DTN routing schemes. We select Epidemic, PRoPHET, Spray and Wait (SnW), MaxProp and HEPRNS which are in the ONE simulator.

We began the simulation with changing numbers of nodes of 4500×1200m. The buffer size is 100 Mbytes steps for each node. All the simulation setting and parameters are showed on Table 1.

Table 1: Simulation setting

Parameters	Value
Simulation area (W×H)	4500×1200
Number of nodes	1-200
Simulation time (h)	12
Movement Model	No. of nodes increasing
Shortest path map based movement	
Buffer size (Mbytes)	100
Range (m)	50

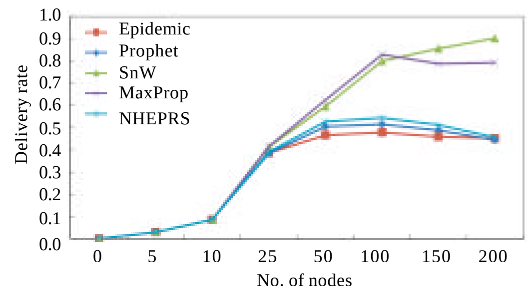

Fig. 1: Delivery rate in terms of No. of nodes increase

Evaluation of DTN routing schemes: From delivery rate, overhead and latency demonstrate how those protocols act comparing to our approach by changing the number of nodes and shortest path movement. Then we define the delivery rate, overhead and latency demonstrates in the following.

Delivered messages: Number of messages successfully delivered during simulation:

$$\text{Delivered messages} = \frac{\text{Delivered messages}}{\text{Started messages}} \times 100\,\% \quad (3)$$

$$\text{Overhead} = \frac{\text{Relayed messages - Delivered messages}}{\text{Delivered messages}} \times 100\% \quad (4)$$

Latency: Average time between messages creation and delivery.

In Fig. 1, the HEPRNS increases delivery rate with increasing number of nodes. It is because HEPRNS forward message to highly connected nodes that meet nodes that guaranteed the message delivery rate. But the MaxProp delivers more messages than other schemes when number of nodes increases. The delivery rate performance of HEPRNS is moderate. In Fig. 2, the SnW has a low overhead. The overhead performance of HEPRNS is moderate. In Fig. 3, HEPRNS outperform other in terms of latency of nodes increases than other schemes. This is the superiority of HEPRNS.

In Fig. 4, MaxProp delivers more messages than other schemes when shortest path map based on movement. In

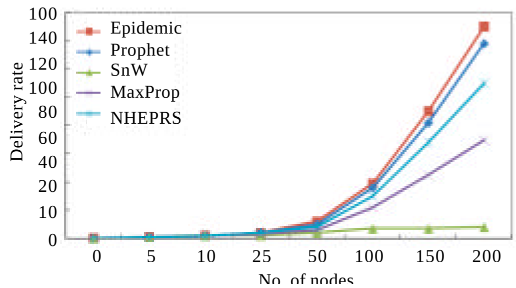

Fig. 2: Overhead in terms No. of nodes increase

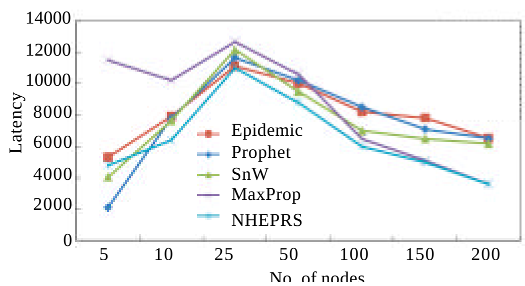

Fig. 3: Latency in terms of No. of nodes increase

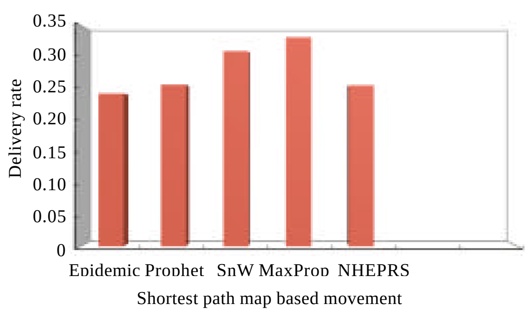

Fig. 4: Delivery rate in terms of shortest path movement

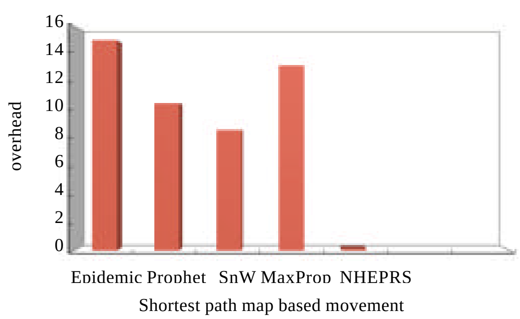

Fig. 5: Overhead in terms of shortest path movement

Fig. 5, HEPRNS has the lowest overhead in the shortest path movement. This is the superiority of

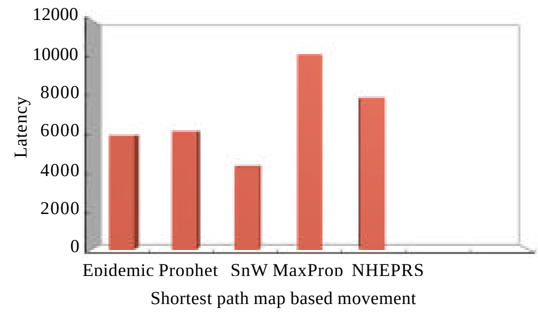

Fig. 6: Latency in terms of shortest path movement

HEPRNS. In Fig. 6, the SnW's delay is the lowest in the shortest path movement. In general, the performance of HEPRNS is acceptable and outperforms the Epidemic, PRoPHET, SnW and MaxProp schemes in terms of the pervious behavior.

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