Rendezvous Based Routing in Opportunistic Networks

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ABSTRACT

Opportunistic Networking is one of the most extreme evaluation of multi-hop wireless network. In opportunistic networks the node mobility can create contact opportunities among nodes, which enable the mobile nodes to communicate with each other even if a route connecting to them never exists. As a result, nodes can physically carry buffered data while they move around the network area until they meet the forwarding opportunity. However, opportunistic routing requires sufficient amount of mobile nodes in order to satisfy carry-store-forward paradigm. The performance of this challenged protocol decrease when the number of mobile nodes decline. This paper proposes a novel routing technique to facilitate the mobile node routing in extreme sparse network called the rendezvous based routing. This proposed protocol can bridge the gap of space and time domain in opportunistic environment. The result of this paper shows that our proposed technique can increase the efficiency index defined as delivery ratio per average latency of very sparse opportunistic network environment.

KEYWORDS

Network, Routing, MANETs, OppNets, DTNs

1 INTRODUCTION

Opportunistic Network (OppNet) is a dynamic wireless network without fixed infrastructures and does not guarantee the existence of an end-to-end path for forwarding the data packet. OppNet exploits node mobility to create the communication opportunities among mobile nodes. In order to enable end-to-end communication, the opportunistic routing protocol employs asynchronous store-carry-forward for messages exchange [1]. In this scheme, nodes can physically carry stored data while they move around the area until they can get in contact with suitable next-hop node. Within the opportunistic paradigm, a message can be delivered from a source toward a destination even though an end-to-end path never exits by exploiting the sequence of connectivity generated from node mobility [2]. Basically OppNet is consisting of these characteristics: intermittent network contacts, occasional existing end-to-end path and highly variable or extreme link performance. Currently OppNet can be applied to develop numerous applications such as wireless sensor network (WSN), underwater sensor networks (UWSN) pocket switched networks (PSN), people centric network and transportation networks [3].

Even though, this OppNet proposes to overcome the poor performance of traditional end-to-end based Mobile Ad hoc NETworks (MANETs) which suffering from disruption, sparse network density and limited device capacity [4]. Realistically, OppNet requires sufficient amount of nodes to carry the messages along to where they move and forward to other encountered nodes. As a result, traditional opportunistic routing performance suffers under extreme sparse network especially with node with limited resource [5].

This paper proposes a novel scheme called Rendezvous Based Routing, which aims to increase the performance of OppNet in extreme sparse environment. The goal of this research is to bridge the gap of time and space domain in

OppNet environment by utilizing the meeting point concept. Mobile nodes under Rendezvous protocol can communicate with each other even if they visit the same place on different time.

The remainder of the paper is organized as follows: Section II gives a brief overview of Rendezvous Based Routing model. Section III describes the simulation setup and results. The conclusions are given in Section IV

2 RENDEZVOUS ROUTING MODEL

2.1 Motivation and background

The term *Rendezvous* can be referred as a meeting point or the time appointment which can be denoted as space and time domain. This taxonomy in OppNet scheme has been widely used, for example, Ko et al. [6] proposed a rendezvous protocol to facilitate neighbor discovery or probing operation in order to save energy consumption. In this paper, we refer the term rendezvous as a meeting points among mobile nodes. Currently, there are several approaches to address the communication in sparse network environment. Take Data MULEs (Mobile Ubiquitous LAN Extensions) [7] as an example, this three-tier architecture (sensors, mobile agents and access points) proposed the use of MULEs mobile agents to randomly move around picking up data from sensors when in close range and dropping it at access points. Another approach is called Message Ferrying (MFs) [8] which is additional special mobile nodes that are injected into the network. These ferries act as a moving communication infrastructure for the network and responsible for carrying data for all nodes in the network. Similar to MFs and MULEs concepts, Thowboxes [9] have also been proposed to increase the capacity of the network. Throwboxes are battery-powered devices with storage and processing capabilities which can improve the throughput of the system if they are placed in strategic points within the network. Other node types proposed in [10] are called Robots with the aim to increase transmission opportunities. Robots are autonomous agents which may indeed be useful in some OppNet environments from a reliability or a delivery delay perspective. However, it is questionable whether this approach will increase or decrease the energy efficiency of the system as a whole.

Aforementioned researches are similar in the concept of injecting a special node as a fix infrastructure with the aim to increase the contact opportunity among mobile nodes. Although this research proposes the use of special node injected to the environment, the concept of utilizing the special node is different. In our implementation, this Rendezvous node is designed to facilitate the rendezvous point where mobile nodes can exchange data even they visit the same location at different time.

2.2 Protocol description

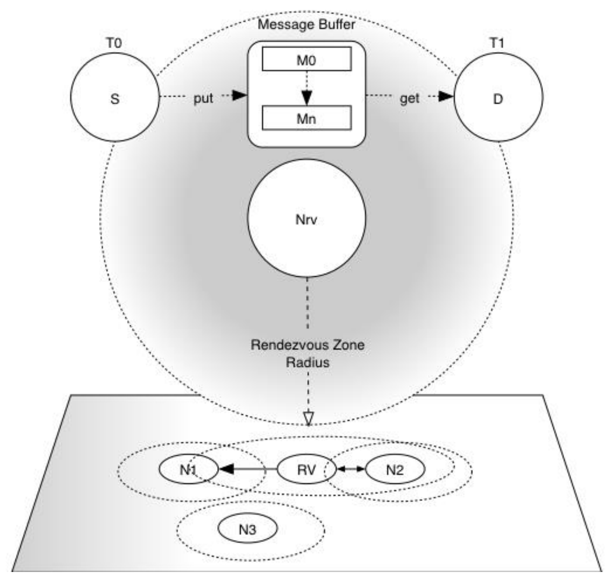

Figure 1. System model

We model this protocol as common mobile nodes in OppNet environment. Additionally, we add a new type of node called Rendezvous

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node with the aim to increase the opportunistic contacts in the network. This Rendezvous node acts as a mailbox to store the data waiting for the destination nodes to retrieve the messages destined to them. A Rendezvous node (N_{rv}) is equipped with higher radio range and buffer capacity than normal mobile node in our implementation. Fig. 1 shows the simple system model of Rendezvous protocol. Source node at time t_0 can send the messages to destination node at time t_1 by put the messages into the N_{rv} memory. This method can help bridging the space and time domain from source toward destination node. From the figure, once node N_1 is in the vicinity or N_{rv} radio range, it can receive the messages destined to itself but it cannot send the message to N_{rv}. On the other hand, node N_2 can exchange the messages with N_{rv} since its radio range can reach N_{rv} node. Node N_3 is out of the radio range of N_{rv}, thus it cannot exchange messages with N_{rv}. This mechanism can help the source and destination nodes to meet at the specific meeting point even they visit this location at different time.

A main challenge of designing this protocol is the placement of N_{rv}. Since we design this protocol to improve the network performance in very sparse node density, we cannot clearly determine the optimal N_{rv} station such as high node density area. However, we can find optimal geolocation based on some movement pattern such as habitual behavior of wildlife [11]. For example, we can put N_{rv} in certain food resources area to gather the data from the sensor that embedded with animals. In our experiment, we place the N_{rv} on the optimal location of Random Way Point (RWP) movement model. The spatial distribution in RWP mobility model is transformed from uniform to non-uniform distribution with time. It finally reaches a steady state condition where the node density is maximum at the center of operational area [12]. As a result, we perform the experiment with N_{rv} at this optimal center point of playfield.

3 EVALUATION

3.1 Simulation setup

Parameters	N_i	N_{rv}
Simulation Time	10800 Seconds	
Message Size	500 KB - 1 MB	
Node Buffer	150 MB	1 GB
Radio Range	10 Meters	100 Meters
Transmission Speed	54 Mbps	
Router	Rendezvous — Epidemic	
Moving Speed	0.5 - 1.5 m/s	
Movement Model	RWP	

Table 1. Simulation parameters.

In our experiment, we use ONE (Opportunistic Network Environment) [13] as the tool to evaluate the performance of our protocol. We compare our protocol with traditional Epidemic routing protocol [14]. The size of areas are varied in order to analyze the impact of node number starting from dense to sparse network environment. Therefore, we fix the number of node to 50 nodes then increase the area size to gain the relationship of node density. The mobility model is in fact a natural phenomenon in OppNet since the performance of network protocols mainly depends on the node movement. In general, the popular entity mobility models are Random Way Point model, Random Walk model, Reference Point Group Mobility or real mobility trace. In this paper we evaluate our protocol on the most widely used mobility model, Random Way Point. The nodes in the simulation are divided into two group: normal mobile nodes N_i and a rendezvous node N_{rv}. The placement of an N_{rv} is in the center location of simulation area. The detail simulation parameters are listed in Table. I

3.2 Metric

The following metrics are taken into consideration for the assessment of our proposed protocol.

1) Message delivery ratio (ρ) is defined as the fraction of the total number of messages delivered (m_{del}) to the total number of messages created (m_{cre}) Messages are dropped once the TTL value expires. A low ρ indicates that the buffer sizes are insufficient to handle the rate of messages in comparison to average delay experienced by a message to get from the source to destination nodes [15].

$$\rho = m_{cre} / m_{del}$$

2) Message latency (L_i for message i) is defines as the time between when a message is generated to the first time the message is received by the destination.

$$L_{avg} = 1/m_{del} \sum Li$$

3) Message overhead (O) is defined as the fraction of the total of relayed messages (m_{rel}) to the total number of delivered messages. Messages are dropped once the TTL value expires.

$$O = m_{rel} / m_{del}$$

4) Efficiency index (E) is defined as delivery ratio per message latency. In order to get a comprehensive comparison among the protocols, we use this composite metric to clearly present our key performance. The goal of our implementation is to increase ρ while maintain or minimize L_{avg}. Thus, the higher efficiency index indicates better network performance in this implementation.

$$E = \rho / L_{avg}$$

3.3 Simulation Results

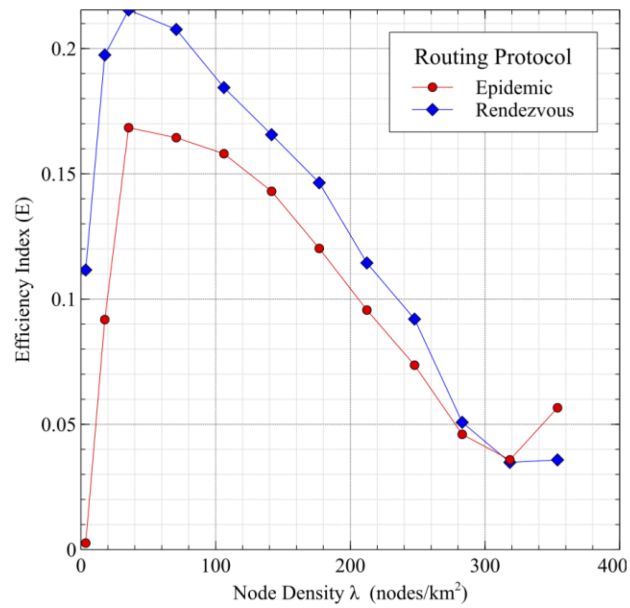

Figure 2. Efficiency index per node density

Firstly we present the result of protocol key performance as efficiency index in order to see the overview of composite matrices comparison. Consequently, we elaborate the detail of each metric result to evaluate the effect of network sparseness to each parameter. Fig. 2 shows the efficiency index of our protocol comparing to the traditional Epidemic protocol. The value of E from Rendezvous protocol by overall is higher than Epidemic counterpart except when the node density is greater than 320 node/km^2. It can be clearly see that Rendezvous perform significant higher when the node density less than 100 node/km^2 suggesting very sparse environment. In addition, Rendezvous gains more efficiency nearly 2 times over Epidemic when the sparseness is lower than 40 node/km^2. This graph shows that the Rendezvous protocol perform better delivery ratio per latency than Epidemic protocol especially in extremely sparse network which can address the problem statement of this research.

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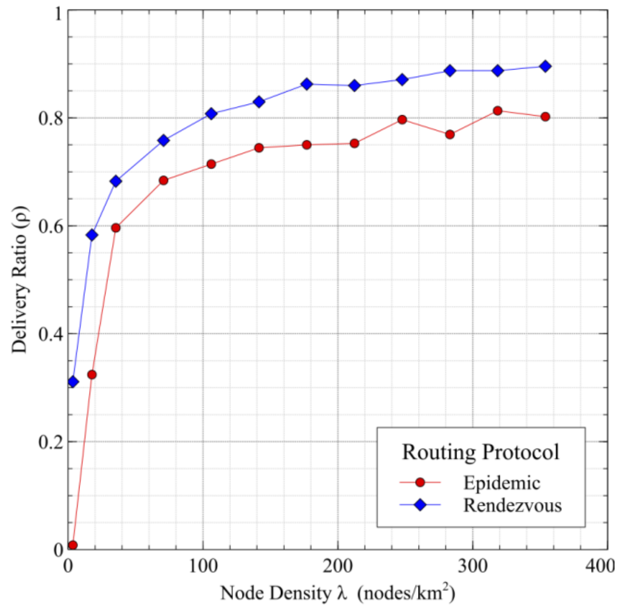

Figure 3. Delivery ratio per node density.

Next we evaluate the protocols in the detail based on each metrics. In Fig. 3, the delivery ratio of each protocols are compared. Both protocols show similar trend of decreasing in the deliverable when the node density decline which is common phenomena of OppNet routing environment. However, Rendezvous protocol gains about 20% higher delivery ratio in average. This graph shows that our protocol can successfully delivery more messages to the destination than Epidemic protocol even in the very low node density (less than 10%). With this Rendezvous concept, the objective of this research of increasing delivery performance in sparse network of OppNet is met.

The detail of overhead ratio is elaborated in Fig. 4. It can be clearly seen that the gap of Epidemic and Rendezvous protocol is decreasing with lower node density. Rendezvous protocol perform significantly better on the high density node with nearly 100% at the node density of 310 nodes/km^2.

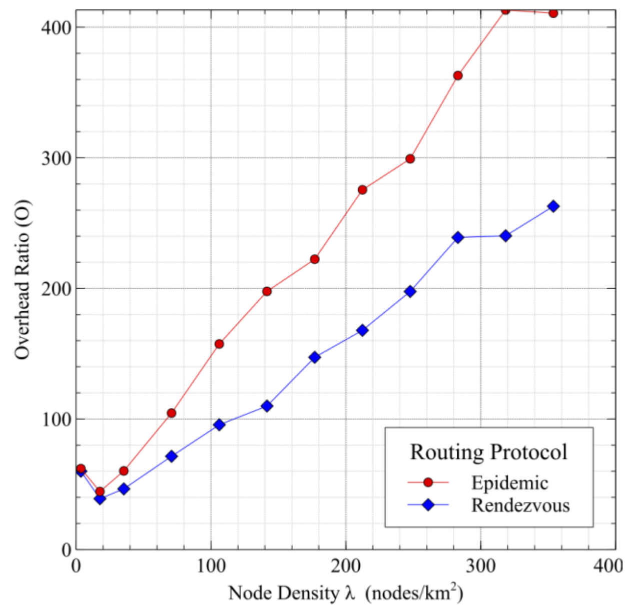

Figure 4. Overhead ratio per node density

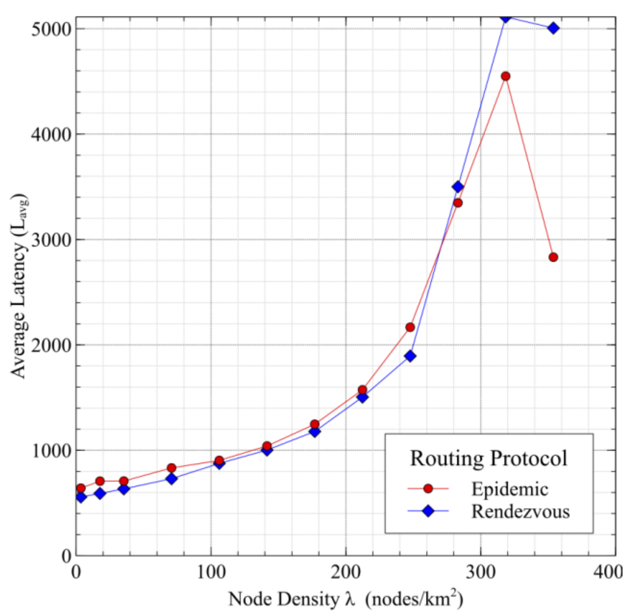

Figure 5. Average latency per node density

4 CONCLUSION

OppNet concept can be deployed in several extreme network scenario such as tactical network or wildlife monitoring which consist of stochastic node movement in very sparse environment. In this paper, we proposed the use of Rendezvous based concept in order to maintain the messages in one place as long as the messages can be delivered. By injected a special node, N_{rv}, into the network, the gap between time and space domain of mobile nodes are bridge. Messages can be transferred from source node to destination node even if they are not in the same location at the same time with the help of rendezvous node. The results clearly show that the delivery ratio of Rendezvous based protocol significantly improve over Epidemic protocol especially in the sparse environment. The overall of average latency of Rendezvous is also improved over the traditional Epidemic protocol. Both metrics can be concluded with efficiency index which presenting the key performance of our protocol. The Rendezvous based routing protocol gains notably higher efficiency index than traditional Epidemic protocol. In addition, the overhead ratio of Rendezvous protocol is significantly lower than Epidemic. This implies that the energy utilization of OppNet mobile nodes can be improved. In the future, we can extend this concept of Rendezvous to create smarter nodes that can determine the optimal placement in stochastic environment. The other interesting research that can be extended from this paper is the energy consumption analytical since this concept plays a vital role in limited energy of mobile node in OppNet.

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