The mobile scenario influence on DTN routing

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Abstract - Delay Tolerant Networks (DTNs) focus on scenarios where most of the time contemporaneous end-to-end paths between source and destination do not exist, and mobility should be explored for message delivery. In this paper, we classify the common scenes by the regularity of the nodes into six scenarios, then compare the performance of common DTN routing protocols at different scenarios by simulation. We discuss the influence of scenario for each protocol. And we also discuss the buffer size and transmission range's influence. Our work is helpful for new DTN routing protocol's design and analysing.

Keywords - DTN network, scenario classify, routing protocol, simulation

I. INTRODUCTION

DTN (Delay Tolerant Network) is a network model abstract from ad hoc[1], wireless sensor network (WSN)[2] and other wireless network. At this typical kind of network end-to-end path may never exist.

In these challenging environments, popular ad hoc routing protocols such as AODV[3]and DSR[4] fail to establish routes. When instantaneous end-to-end paths are difficult or impossible to establish, routing protocols must take to a "store and forward" approach, where data is incidentally moved and stored throughout the network in hopes that it will eventually reach its destination. So new routing protocols has been proved[5].

We compared by simulation of several common routing protocols' performance in different environments, we try to explain why different protocols perform different perform in different environments. Also we have analyse influence of the storage space and communication radius to the protocol performance.

II. REALTED WORK

A. Classify of DTN routing protocols

There are many ways to classify the routing protocols. One of the most immediate ways to create a taxonomy is based on whether or not the protocol creates replicas of messages. The paper [9] divide DTN routing protocols into three categories by the number of copies sent. They are: Single Copy Strategy, Limited Copies of Strategy, Unlimited Copies of Strategy.

1. Single Copy Strategy

In the routing of Single-Copy Routing Strategy, one node only send a package to another nearby. First Contact and Direct Delivery are both representative strategies.

2. Unlimited Copies Strategy

In the routing of Limited Copies of Strategy, a node will send the message to a part of nodes it encounters selectively. Spray and Wait[4], Probabilistic Routing Protocol using History of Encounters and Transitivity (ProPHET)[3] are the representative protocols.

The Spray and Wait protocol is composed of two phases: the spray phase and the wait phase. When a new message is created in the system, a number N is attached to that message indicating the maximum allowable copies of the message in the network. During the spray phase, the source of the message is responsible for "spraying", or delivery, one copy to N distinct "relays". When a relay receives the copy, it enters the wait phase, where the relay simply holds that particular message until the destination is encountered directly.

The 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 (delivery predictabilities) 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.

3. Unlimited Copies Strategy

In the routing of the Unlimited Copies of Strategy, a node will send the packet to all the nodes it encounters. Its representative strategy is Epidemic Routing[16].

In Epidemic Routing Strategy, the node will send all the data to the nodes it encounters. If the buffer is full and it will drop the earliest message.

B. How to judge a routing protocol

According the protocol evaluation criteria proposed by Spyropoulos and Others[5], five aspects should be considered to judge whether a routing protocol is good or bad:

1. Compare Flooding Algorithm, if there's less transmission
2. If there is fewer competition of lines, especially at high load.
3. Less delay than existing mechanism of a single copy of multiple copies, closer to ideal value.
4. the Influence of network size and node density to performance.
5. Whether require less prior knowledge.

In the third chapter, we discuss why we have to classify the nodes and how to do this. In the fourth chapter, we correspond the sorted nodes to the real scene and perform simulations on the simulate platform. In the fifth chapter, we give the specific result of different routing protocols at different scenarios. In sixth chapter, we explain the reason of different performance of different routing protocols in different scenarios. In the seventh chapter, we summarized the work we have done.

III. CLASSIFICATIONS OF NODES

Because the DTN network's characteristic "store and forward". The messages' transport rely on the movement. If the nodes at scenario not move, this network model will retrograde into a WSN network.

So at DTN network, different time will have a different connected path. Finding a path to transport the message from the beginning to the destination node is a NP-hard[10] problem. More specifically online algorithms without complete future knowledge and with unlimited computational power, or computationally optimal algorithms with complete future knowledge, can be arbitrarily far from optimal[10].

To analysing the ability that a routing protocol using the historical knowledge. We divide the nodes into three categories by the mobility of nodes:
1. The position that node next time will be can be calculated by the historical knowledge. This always happened at Interplanetary Internet (IPN)[11][17][19].
2. The position that node next time will be can be predicted at a region by the historical knowledge. This always happened at city bus system.
3. The position that node next time is totally random. It has no relationship with the historical knowledge. This kind of scenario always not happened at society. But some movement model epitomize it well such as Random Way Point model, Random direction model.

The first scenario has their special routing protocol such as CCSDS File Delivery Protocol[12]. Because these routing protocols are design for the special scenario, it do not have the general adaptability. So we will not discuss these scenarios in our work. We will only discuss the scenario 1 and scenario 2.

Also, whether there is basement node can also effect the performance of DTN network. If the routing protocol could find the basement node and passing the message to the basement. We guess it will increase the number of nodes that this message will meet and then increase the possibility that the message meet the destination node. To test whether is right, we also have two scenarios classify by whether there is basement or not.

With a Cartesian Product of two classifications above, we can get four different kinds of nodes here:
1. Nodes with fixed ones and distributed in a specific scope with particular probability.
2. Nodes with no fixed ones but distributed in a specific scope with particular probability.
3. Nodes with fixed ones and random distributed in a movement area at any time.
4. Node with no fixed ones but random distributed in a movement area at any time.

IV. SIMULATE SCENE AND IMPLEMENT

Based on the different four situations we have mentioned before, we have found four real scenarios:
1. Numbers of buses running at San Francisco, basement is able to transport the message with the bus.
2. Numbers of buses running at San Francisco, basement cannot transport the message with the bus.
3. Numbers of nodes walk as random way point model, these also exist some basement that will not move.
4. Numbers of nodes walk as random way point model and there is no basement.

All of these four scenario using same basic parameters: The map is 4500m*3400m big, the nodes' transmit range is 10m and the bandwidth is 250kBps. Each node will create a message every 25 seconds to every 35 seconds. And the message is between 500KB to 1MB large. The difference of these scenario is the mobility of nodes.

The motion model of four scenarios are defined below:
1. Sixty buses in three groups, each group has their own stops in order, bus run as uniform motion in a straight line between two stops. After arrived the stop, the bus will stop for some time (the time is distributed in 0 to 3mins random). When the bus leave the stop, bus will random choose a speed between MAX and min (20m/s and 10m/s). The bus stops can also create and transport the message.
2. The buses are running in the same way as scenario 1. The only difference is the bus stop can not create or transport the message.
3. The nodes are separate at the square, each node random choose a speed between MAX and MIN (20m/s and 10m/s). After reach the destination, the node will pause for a while, this time is also random choose between MAX pause time and MIN pause time (20s and 10s). After arrive the destination, the node will random chose a new position. There exist some nodes that will not move. We call them basement, the basement can also storage and transport the message.
4. The node are running in the same way as scenario 3. But there is no basement nodes.

During the simulation, each node will random choose another node and send the message. After the simulation is done, we compare the average time delay and delivery ratio at different routing protocols. All the simulation was done under ONE[8], and we using MATLAB to create our figure.

V. SIMULATE RESULTS AND ANALYSING
A. Bus movement model with basement

Delivery ratio

![Graph Image]

**Fig. 1 delivery ratio at Bus movement model with basement scenario**

Fig. 1 shows the delivery ratio of five routing protocols (First Contact, Direct Delivery, Spray and Wait, PROPHET, Epidemic) in order. The X axis represents the buffer, Y axis represents the transport range, and Z axis represents the delivery ratio.

From the figure we can see that the buffer increasing will increase the delivery ratio, this fit for every routing protocol, the difference is only the effect level. The effect to Epidemic is much bigger than the protocol Spray and Wait and PROPHET. This is because the Epidemic is using unlimited copies of strategy, so the usage of buffer is much larger than the protocol which is using limited copies.

Also from the figure we can know increasing the transmit range has no help to Epidemic routing protocol. But for other routing protocols, increasing the range may help the nodes find the destination node or the node that have much possibility to send the message the destination.

Average delay

![Graph Image]

**Fig. 2 average time delay at Bus movement model with basement scenario**

Fig. 2 shows the average time delay of five routing protocols (First Contact, Direct Delivery, Spray and Wait, PROPHET, Epidemic) in order. The X axis represents the buffer, Y axis represents the transport range, and Z axis represents the average time delay.

Increasing the transmit range will all of these protocols decrease the delay. It was because increasing range will increasing the number of nodes that could connect with this node. And it also increasing the time that two nodes could meet. Both these two reasons could help the node sending the message to the destination node or the node that have much possibility to send the message the destination.

But as we can see, larger buffer lead to higher delay. This is because with larger buffer, more message will be stored. This will increase the number of messages that be transmitted.
B. Bus movement model without basement

Delivery ratio

![Fig. 3 delivery ratio at Bus movement model with basement scenario](image)

Fig. 3 delivery ratio at Bus movement model with basement scenario

This figure is similar to Fig. 1, but compared with definite data it is a little less than Fig. 1. This is because there is no basement in this scenario. Message could not "stay" at one place and wait for the destination node.

Average delay

![Fig. 4 Average delay at Bus movement model with basement scenario](image)

Fig. 4 Average delay at Bus movement model with basement scenario

This figure is similar to Fig. 3, but also because there is no basement for "stay". The definite delay time increased.

C. Random way point model with basement

Delivery ratio

![Fig. 5 delivery ratio at Random way point model with basement scenario](image)

Fig. 5 delivery ratio at Random way point model with basement scenario

This figure is similar to Fig. 1 because of the same reason. But the movement model is more irregular. These routing protocols perform less delivery ratio than Fig. 1.

Average delay

![Fig. 6 Average delay at Random way point model with basement scenario](image)

Fig. 6 Average delay at Random way point model with basement scenario

Because of the same reason, Fig. 6 shows a higher average delay than Fig. 2.

D. Random way point model without basement
Delivery ratio

Fig. 7 delivery ratio at Random way point model without basement scenario

Because there is no basement and the irregular, Fig. 7 show the worst delivery ratio of all these four scenarios.

Average delay

Fig. 8 Average delay at Random way point model without basement scenario

The same reason as Fig. 7, Fig. 8 show the highest average delay of all.

VI THE IMPACT ANALYSING UNDER DIFFERENT SCENARIO

A. Epidemic routing protocol

Epidemic routing is a Unlimited Copies Strategy. This protocol has the similar performance at different scenario, it has a liminal buffer and liminal range. After surpassing this liminal value, increasing the buffer or range will not increase the delivery ratio. Increasing the range will decrease the delay, but when the delay time decrease obviously, the delivery ratio will decrease obviously.

Cause of these due to the messages have no clear destination to transport. The more copies it send, the more delivery ratio it will be. But with the increasing of sending copies, the delay will increase too.

B. Spary and Wait protocol

Spary and Wait has a good performance at the whole simulation, especially at the low buffer and low range, it has better performance than other protocols. This protocol also have a liminal buffer and liminal range, after surpassing this liminal value, increasing the buffer or range also will not increase the delivery ratio. The average time delay only depends on the range, and the buffer size will not effect the delay.

Cause of these due to the copies of the message is limited, the usage of buffer is also limited. So the liminal buffer is much more less than epidemic routing. But increasing the ratio range will help the nodes find the node that have larger possibility delivery the destination.

C. Direct delivery protocol

Because the Direct delivery routing protocol will only transport the message when the node meet the destination node, so the buffer size just effect the number of messages that could be stored at the node. The more message the node could store, the higher delivery ratio. And there is no routing in this protocol, so the average time delay is just depend on the transport range.

D. First contact protocol

First contact routing protocol will send the message to the node that first meet, this protocol also has a liminal buffer and liminal range. But compare with the Epidemic routing protocol which also chose the node with no prior knowledge, it's liminal buffer is much more less.

Large contact range will help the node meet more nodes.

E. PROPHET protocol

PROPHET routing protocol is a protocol like spary and wait, they are both the routing protocol using the priori knowledge. But compare with spary and wait, it has a much less delivery ratio. It may because at the scenario we set is too random, protocol cannot calculate the right connections by history.

VII CONCLUSIONS

We assot the real world nodes by the way they move and whether there exist the basement. And find the scenario fit
it, then analysing the different routing protocols' performance by compare the average delay and delivery ratio.

We also discuss the elements' effect: the buffer size and transmit range. So both internal cause and external cause has been discussed. The result we had can be used for choosing the routing protocol and the design of hardware and new routing protocol.

But the moving model is not same as the real moving. At the real world, the nodes will not move randomly. Also we do not mention the time that the node running the routing protocol, different Complexity cause different time at the real routing, this will effect the performance a lot when the nodes facing big pressure.

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