Probability Optimization Research in Opportunistic Network

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Abstract. The opportunistic network has the characteristics of node mobility and sparse distribution, which can cause the problems that it is not a stable communication link between the source node and the destination node, the communication is easy to break and the delivery ratio is low. This paper makes use of the encounter interval to estimate encounter probability. Then it selects the retransmission nodes exactly base on encounter probability. This paper also defines a message value model, which calculates the value of each message in the transmission queue. Messages value determines transmission order, which will reduce meaningless transmission. The simulation results show that the proposed routing protocol can effectively improve the delivery probability, reduce the network overhead ratio.

1 Introduction

There is no stable end-to-end communication link [1] in opportunistic network, which is different from the traditional mobile ad hoc networks (MANET) [2]. Messages transmitting achieves though the encounter probability of mobile nodes, which is a "store-carry-forward" communication mode. In opportunistic network, the uncertainty of mobile nodes, energy and storage capacity limitation lead to the interruptions of the communication link and the rapidly changing network topology so that the traditional end-to-end routing protocols are not effective. Therefore, the design of efficiently suitable routing protocols for opportunistic network becomes a hot research topic.

In recent years, the research of PRoPHET [3] is a hot spot, because the encounter probability estimation is not accurate, messages delivery probability is not ideal. In addition, transmitting messages without any control leads to forwarded messages may be discarded. Such forwarding is meaningless and adds unnecessary network overhead.

Researchers put forward some optimization scheme aiming at the problems of the PRoPHET. Literature [4] proposed a routing protocol based on Historical Intervals of Contacts (HICR). HICR computes encounter time series between nodes firstly, then computes average encounter time interval between nodes and sorts average encounter time interval in ascending order at last. HICR forwards the messages to destination node when the average encounter time interval of some node is shorter than itself. HICR raises the messages delivery probability, but due to not thinking about the messages attribute value would inevitably have meaningless transmission and higher network overhead. Literature [5] proposed a routing algorithm called ED_PROPHET. ED_PROPHET makes ratio between the weighted average duration and the time of sending each other cached messages between the communication nodes as influence factor to update the probability. But the performance is affected by the cache size and bandwidth. The application scenario is limited. Literature [6] proposed a routing protocol called BPAS that evaluate forwarding probability with information of encounter for opportunistic network. BPAS uses encounter frequency， connectivity duration and disconnected duration as elements to estimate the probability of message forwarding for the purpose of message can close to destination node. BPAS has higher delivery probability. BPAS applies to the larger node density network environment judging from protocol simulation results. Because the node density is larger, the encounter frequency increases, the disconnected duration is lesser, messages delivery probability will increases .When the nodes density is small, network performance is poor.

On the basis of the above literatures research, this paper puts forward Opportunistic Network

Routing Protocol Based on Messages Value (ONPMV).The idea is to make use of the encounter time interval to estimate encounter probability and define a messages value model, which calculates the value of each message in the transmission queue. Messages value determines transmission order, which will reduce meaningless transmission so as to improve the network performance of the PRoPHET.

2 ONPMV

ONPMV Considers that the choice of the forwarding nodes and messages value properties affect the performance of network, optimizes the encounter probability estimation, defines the messages value model. Messages delivery bases on the replication strategy.

2.1 Encounter Probability Optimization

Encounter probability is the basis to choose the forwarding nodes, whether encounter probability estimate is accurate influences messages delivery probability deeply. The classic encounter probability calculation as shown in formula (1).

$$p_{(a,b)} = p_{(a,b)old} + (1 - p_{(a,b)old}) * p_{init} \tag{1}$$

Due to not considering node historical encounter information, the calculation results of the formula (1) deviate from the actual situation. This paper makes use of the encounter time interval to estimate encounter probability, within a time period, if the local node A and B encounter, the encounter probability $P_{(a,\,b)}$ as shown in formula (2).

$$p_{(a,b)} = p_{(a,b)old} + (1 - p_{(a,b)old}) * p_{init} * \theta^{\bar{t}} \tag{2}$$

$P_{(a,\,b)}$old represents last encounter probability of node A and B. P_{init} represents the initial encounter probability, when the P_{init} value is 0.75, network performance is optimal [7]. $\bar{t}$ represents the average time interval. θ is impact factor, which is used to optimize the influence of initial encounter probability to the new probability, the experience value is 0.98.

When the local node A and node B do not meet within a time period, the encounter probability attenuates according to the formula (3).

$$p_{(a,b)} = p_{(a,b)old} * r^k \tag{3}$$

The attenuation factor is r^k, r∈[0,1）.

Encounter probability has transmissibility. If the node A and node B often encounter, node B and C are often encounter, then can let the node B as forwarding node between node A and node C. The transitivity encounter probability calculation as shown in formula (4).

$$p_{(a,c)} = p_{(a,c)old} + (1 - p_{(a,c)old}) * p_{(a,b)} * p_{(b,c)} * \beta \tag{4}$$

` β is connecting factor, the empirical value is 0.25.

2.2 Messages Value Model

Messages value model is used to calculate the value of messages in the transmission queen. Opportunistic network make use of the encounter probability between nodes to complete message transmission, so the encounter probability of a node to a destination node is necessary to messages value model; The sparse distribution and random node mobility make the messages are persisted in local cache most of time. If time-to-live (TTL) of messages is small, the messages may also be discarded caused by a lack of TTL. So TTL is necessary to messages value model; Energy and cache space are limited in opportunistic network, the long messages may be discarded because of shortage of cache. So messages length is necessary.

When two nodes meet, successful completion of the forwarding process theoretically conforms to the inequality (5), (6).

$$p_{(a,d)} < p_{(b,d)} \tag{5}$$

$$\frac{size * n_0}{bw} \le T_e - T_l \tag{6}$$

The meaning of Inequality (5) is that node A transmits messages to node B at the condition that the encounter probability to destination of B is bigger that node A. The meaning of inequality (6) is that the transmission must be completed within the connection duration. The *size* represents the average messages length, n0 represents the total number of messages, b_w represents network bandwidth, T_e represents time that nodes come into the radio frequency range of each other, T_l represents time that nodes leave radio frequency range of each other. The parameters of Inequality (6) also must satisfy the inequality (7), (8).

$$n_0 \le \frac{2*CacheSize}{size} \tag{7}$$

$$T_e - T_l < ttl \tag{8}$$

The meaning of Inequality (7) is that the forwarded messages number less than the maximum number of messages that the two connected nodes carry. The *CacheSize* represents average size of the cache space. The meaning of Inequality (8) is that the TTL must be greater than the connection duration. Otherwise, the messages will be discarded in the forwarding nodes, *ttl* represents TTL. Due to forwarding messages should conform to inequality (5),(6),(7),(8), therefore, this article will make encounter probability, TTL and the average message size as a measure of messages value. This article defines messages value v as shown in formula (9).

$$v = \kappa * p + \lambda * ttl / TTL + \mu * CacheSize / size \tag{9}$$

P represents encounter probability, κ、λ、μ are weighted factors, experience value are 0.75, 0.15, 0.1.

3 Simulation results and analysis

3.1 Simulation Environment

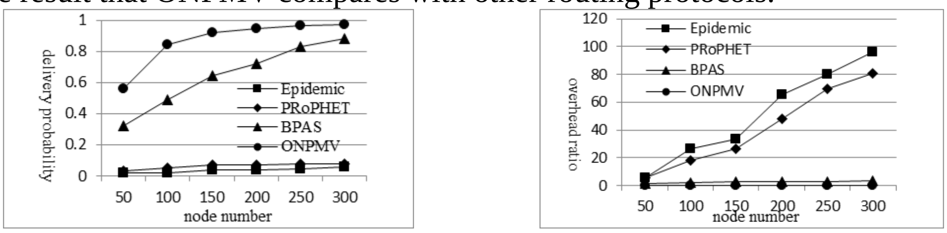
In order to verify the performance of ONPMV, this paper use The ONE (The Opportunistic Network Environment) as Network simulation platform based on Java. Messages delivery probability, the network overhead are the performance index. Detailed simulation parameter settings as shown in table 1.

Table 1 Simulation parameter settings

parameters	Simulation Time(s)	Network Area(m^2)	Transmission Range(m)	Move Speed(m/s)	Message Size(KB)	Cache Size(Mb)	TTL(minute)
value	43200	14000×10000	10	2.7-13.9	500-1024	5	300

3.2 Simulation Performance

Fig.1 is the result that ONPMV compares with other routing protocols.



(a) (b)

Fig.1 ONPMV compares with other routing protocols

3.2.1 Delivery Probability

In independent identically distributed mobile model Random Way Point (RWP) [8], this article makes simulation tests using ONPMV, PRoPHET, Epidemic [9] and BPAS to detection the performance in terms of messages delivery probability. Delivery probability is the number of messages delivered to the destination node over the total number of messages. The simulation results are shown in Fig.1 (a).

With the increase of the number of nodes, the encounter probability between nodes increases, the message delivery probability of the four kinds of routing protocol increases. In the RWP mobile model, the performance of Epidemic and PRoPHET is very not ideal, Messages delivery probability is less than 10%. Because the Epidemic always blindly forwards messages; Although PRoPHET chooses the forwarding nodes through encounter probability, but do not consider the history information of nodes encounter, which leads to encounter probability is not accurate, so the messages delivery probability is low. BPAS optimizes the encounter probability estimates between nodes to improve messages delivery probability, but BPAS do not consider the messages transmission order, which causes that smaller value messages are forwarded. Small value messages may be discarded in the intermediate nodes, which caused by TTL and cache space shortage. The possibility of the destination nodes receive the messages also fall. ONPMV makes use of the encounter time interval to estimate encounter probability. Then it selects the retransmission nodes exactly base on encounter probability, avoids forwarding a lot of low value messages and increases the messages delivery probability.

3. 2. 2 Network Overhead Ratio

Fig 1 (b) shows the performance of the four kinds of routing protocols in network overhead ratio. The overhead ratio is the number of messages copied in the network over the number of messages delivered to the destination.

As we can see from the Fig 1 (b), the overhead ratio of ONPMV and BPAS is far lower than the Epidemic protocol and PRoPHET, because the Epidemic protocol and the PRoPHET base on the flooding strategy, overhead ratio is very high; ONPMV and BPAS control message forwarding numbers through encounter probability effectively, which avoids unnecessary overhead. In addition, ONPMV chooses transmission messages according to the messages value, reduces the unnecessary forward, therefore, overhead ratio of ONPMV is the smallest.

4 Summary

This paper deeply discusses the PRoPHET and the other related advanced protocols, proposes One Opportunistic Network Routing Protocol Based on Messages Value (ONPMV). ONPMV makes use of the encounter time interval to estimate encounter probability and choose the forwarding nodes according to encounter probability, puts forward the calculation model of messages value. Messages value decides which message to transmit, which avoids forwarding low value messages in order to reduce the waste of network resources. Simulation experiments show that compared with the Epidemic protocol, PRoPHET, BPAS, ONPMV has higher message delivery probability, lower network overhead.

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