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Evaluating the Impact of Network Conditions on Routing Performance in Delay Tolerant Networks

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Abstract

The impact of network conditions on routing performance in DTN network has been investigated by means of the simulation experiment. The results show that appropriate number of duplicate messages is a simple and effective policy for store-carry-forward routing design. It performs well in most of the network conditions. It performs well in most of the network conditions in terms of delay, packet delivery ratio and overhead.

Keywords*: DTN; routing; store-carry-forward; flooding; multicopy*

1. Introduction

Store and forward is a communications strategy in which message is sent to an intermediate station where it is kept and sent at a later time to the final destination or to another intermediate station. The intermediate nodes acts as a route to relay message. In general, this strategy is used in networks with intermittent connectivity, especially in delay tolerant networks (DTN). Node in the network stores data locally, and upon contact with other nodes, forwards the data [1].

The typical DTN protocols can be classified into single-copy protocol and mulit-copy protocols. Only single-copy of each message exists in single-copy protocol, such as Direct Delivery and First Contact [3]. In multi-copy protocol, multiple copy of each message exists in the network, such as Epidemic [4, 5], Spray and Wait [6] and MaxProp [7],.

In Direct Delivery, the node carries messages until it meets their final destination. In direct delivery router data packet can be transmitted in one hop [8].This strategy does not relay message. It uses exactly one-hop message transmission when source node is directly met with destination node. In First Contact routing the nodes forward messages to the first node they encounter, which results in a "random walk" search for the destination node and only a single copy of every message in the network. To prevent two nodes who stay in contact for a long time exchanging the same messages back and forth, the receiving node accepts a message only if the message has not passed through it before[10].

Epidemic routing, also known as Flooding, in contrast, forwards all non-duplicated messages, including its own, to every node it encounters – eventually delivering its messages to the appropriate destinations[8]. Epidemic router is assumed that each node has infinity memory. In this case, all the nodes can store the entire messages during contact with other nodes. When the contact is available

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node can exchange all the messages existing in its buffer. [16].

Most practical algorithms seek a compromise between these extremes. These approaches rely on limiting replications within the network, more intelligently coding the messages, using heuristics to gain insight into the topology and dynamics of the network or using a combination of these methods. Two examples of classical approach that have been deployed in the field are MaxProp and Spray and Wait [6].

Spray and wait router has spray phase and wait phase. In spray phase source node forward the packet to a limited number of L different node. If destination is found then the message or packet transfer is successfully transmitted. If not than wait phase is started [7].When the destination is encounter the message will be directly transmitted[16].

MaxProp is flooding-based in nature, in that if a contact is discovered, all messages not held by the contact will attempt to be replicated and transferred based as summary vector for exchange. MaxProp tries to determine the priorities of message transfer and which messages should be dropped first. MaxProp maintains an ordered queue based on the destination of each message, ordered by the estimated likelihood of a future transitive path to that destination[1][17].

Performance analysis of different routing protocols is the major step before selecting and designing the routing protocol.

In this paper, performance analysis is carried out in single-copy and multi-copy protocols under different network conditions, such as memory space, traffic, time-to-live, mobile speed *etc.*. The performance analysis is compared in terms of delay, packet delivery ratio and overhead.

The remainder of this paper is organized as follows. Section 2 presents the simulation methodology. Simulation results are presented in Section 3. Conclusion is in Section 4.

2. Simulation Methodology

The performance of proposed protocol is compared with several related works. The simulations were performed in ONE 1.41 simulator. The ONE is a simulation environment that is capable of generating node movement using different movement models, routing messages between nodes with various DTN routing algorithms and sender and receiver types and visualizing both mobility and message passing in real time in its graphical user interface.[1].

2.1. Performance Metrics

(1) Delivery Probability is the ratio of data packets being successfully received by the destination nodes versus data packets being sent by the source nodes.

(2) Latency represents the average delay of message from creation to delivery.

(3) Overhead Ratio is defined as:

$$overhead\ ratio = \frac{number\ of\ relayed\ messages - number\ of\ delivered\ messages}{number\ of\ delivered\ messages}$$

2.2. Simulation Configuration

Table 1 summarizes the simulation configuration of this paper.

Table 1. Simulation Configuration

Parameters	*Values*
Simulation time	21600s
Buffer size	5M-35M
Wait time	0-120
Maximum peed	20m/s
Message TTL	18000s
Transmit speed	2 Mbps, 10Mbps
Event generators	30s,35s,40s,45s,50s,55s,60s
Message sizes	500KB – 1.5MB
Number of Nodes	480

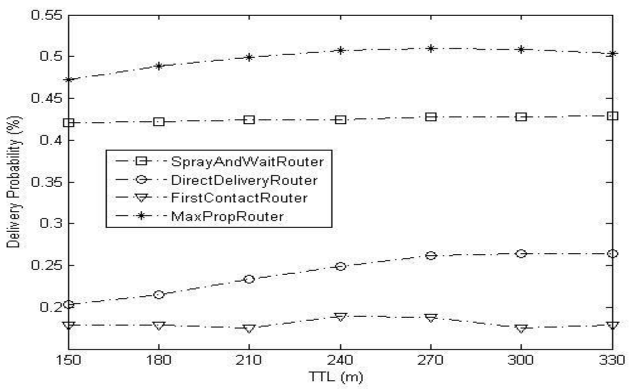
3. Simulation Results

This section shows the simulation results under different network conditions.

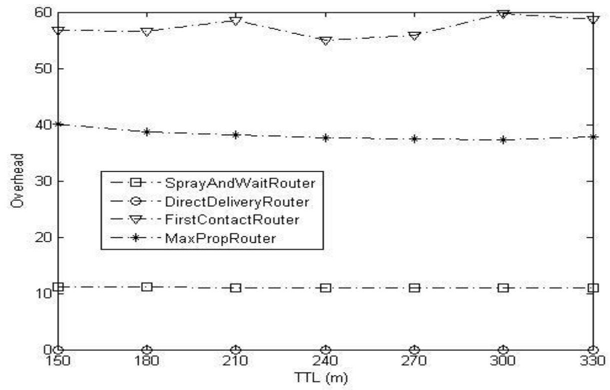
3.1. Varying TTL

TTL (Time-To-Live) is used to limit the lifetime of message in network. TTL is usually implemented as a timestamp attached in the message. Once the prescribed timespan has elapsed, message is discarded. TTL can be used to improve performance of caching.

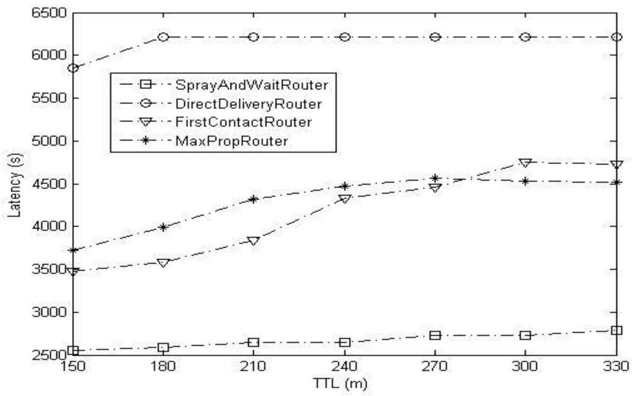
In opportunistic networks, a node stores the messages in its local memory, and searches a suitable opportunity to forward messages. In this way, packets are not discarded during network disconnections but are locally stored. The intermediate nodes act as routers and forwards messages to neighbors crossing multihop. When no forwarding opportunity exists, or no other nodes in the transmission range, or neighboring nodes are considered not useful to reach the destination, intermediate nodes store the messages and exploit any contact opportunity with other nodes. In all these scenarios, the challenge is efficient data storage and distribution.



(A. Delivery Probability)



(B. Overhead Ratio)



(C. Latency)

Figure 1. Varying TTL (A. Delivery Probability, B. Overhead Ratio, C. Latency)

The TTL affects the memory cache by specifying the TTL value, which sets the length of time that messages are held in local memory. If a message in the memory cache has not been delivered during the defined period, that message is phased out of the cache. Due to its characteristics such as long communication delay, high dynamic topology, sparse distribution of nodes and frequent link break, TTL may be a key factor that affects the protocol performance[14].

If system memory is not limited, setting the TTL entry to unlimited disables the message discarding and allows cached message to remain in the cache. Setting the TTL entry to large value is useful if memory is enough, as shown in Figure 1. Delivery probability will increase if they are kept in the memory with long TTL. Because the latency represents the average message delay from creation to delivery, the latency is increasing with the increasing in delivery probability.

Long TTL can improve the protocol performance to some extent in theory. We consider such a random mobility model and study the effect of node mobility on network. The longer the node exists, the more area will be searched. Due to the longer TTL, the fraction of the area that has ever been searched increases and approaches one as TTL goes to infinity. Therefore, node mobility itself can be exploited to search more area before TTL expiration of message.

That is, the rate at which the searched area increases over longer TTL than short TTL. By virtue of longer TTL, nodes may improve the probability to encounter the potential destination node when searching larger area.

3.2. Varying Memory Size

The results shows that memory constraints can severely affect the performance of DTN routing schemes. Performance improves in all the cases when the memory size is increasing, as shown in Figure 2. With very large memory size, the stress of memory requirement is relative not heavy. The performance change of all the protocols is not obvious when the queue size of a node is above some threshold. This is because that there is not much requirement on memory space in itself and the computational cost of choosing relay node[14].

If TTL is not unlimited, increasing the memory size will not always improve the performance. Message may be discarded due to expiration of TTL even if memory is still enough to cache message.

Suppose that there are M nodes in the network, that messages are N bytes long, and that they can be delivered in their entirety during the contact times between nodes. Direct delivery uses only N bytes of bandwidth and minimum buffer space. Since Direct delivery only stores its own messages and transfers the messages only once.

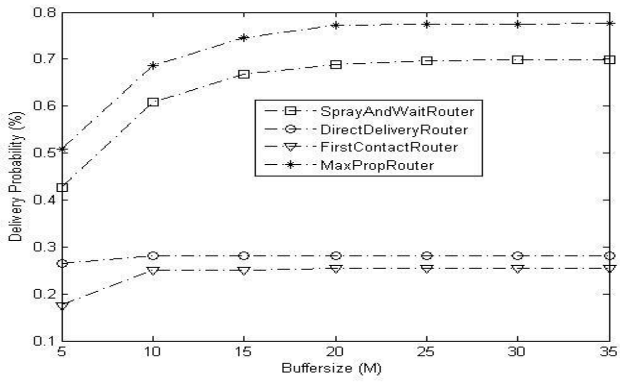
However, since delivery only occurred when the source node meets the destination node, the messages may never be delivered and stored in the memory to experience long latencies.

Epidemic routing, on the other hand, forwards all its messages to intermediaries conceivably. Epidemic uses N(M-1) bytes of bandwidth to transfer data in addition to the auxiliary information exchanged when the nodes encounters to determine which messages are non-duplicated and ready for exchange. In addition to bandwidth, large buffers may be required to store in-transit packets to achieve minimum latency.

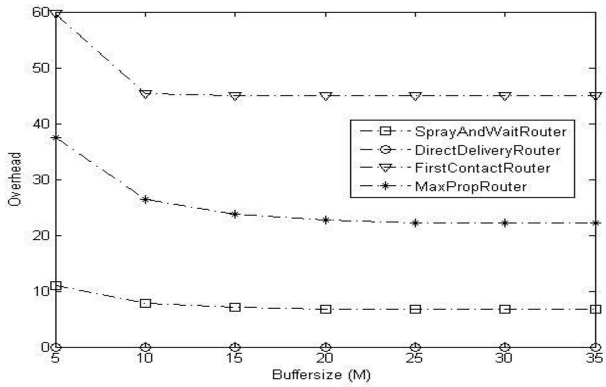
In Spray and Wait, the source node copies its message to the first r intermediaries it encounters. These intermediaries then use direct delivery to forward the message to the intended destination. Using this approach the r redundant copies reduce the expected latency of the network while using only rN bytes of bandwidth. Obviously, if r = 0 this method is equivalent to direct delivery. When r gets larger, it behaves as epidemic routing.

Single-copy schemes are not so good in packet delivery but have lower overhead. Direct Delivery forwards messages directly between the source node and the destination node. It relies on the mobility of the nodes. Because the Direct delivery routing protocol will only transfer the message when the node meet the destination node.

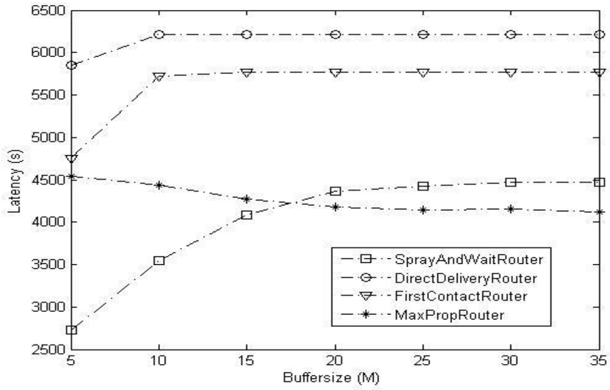
The buffer size effects the number of messages that could be stored and carried of the node. If the nodes can carry more messages, higher delivery ratio may be improved to some extend. First contact routing protocol will send the message to the node that first meet, this protocol also has a liminal buffer.



(A. Delivery Probability)



(B. Overhead Ratio)



(C. Latency)

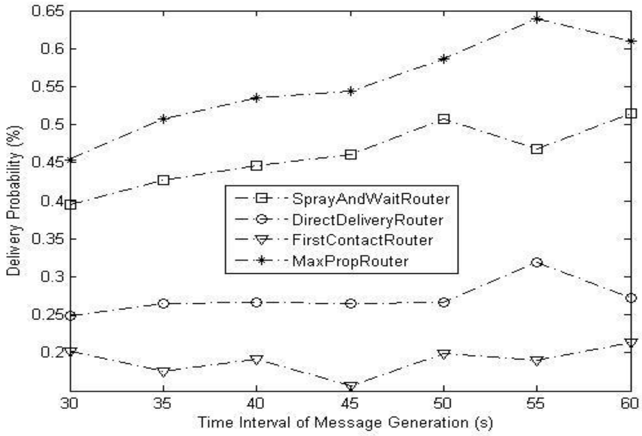
Figure. 2. Varying memory size (A. Delivery Probability, B. Overhead Ratio, C. Latency)

Multi-copy protocol adopts a store-carry-forward strategy. That is, a node buffers and carries a message when it receives the message. Then it moves and passes the packet on to new nodes that it encounters. Multi-copy protocols, such as MaxProp protocol and Spary and Wait protocol performs good in delivery rate than single-copy protocol, especially at the high buffer. Same as the single-copy protocols, the memory size will not obviously affect the delivery rate, delay and overhead when the memory size is beyond the threshold. Because the impact of memory on protocols is not the key factor when the memory is large enough. [10].

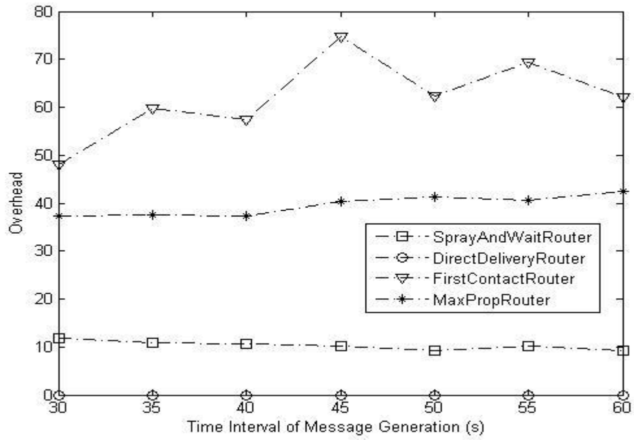
3.3. Varying Time Interval of Message Generation

Figure 3 shows performance with varying interval of message generation. Delivery rate improves in most cases with increasing interval of message generation (decreasing offered load). With very low packet rates, the stress of relay a message is relative light. With very high packet rates, the requirement in memory is high. This requires that protocols can handle the stress of data delivery of nodes before the memory is full.

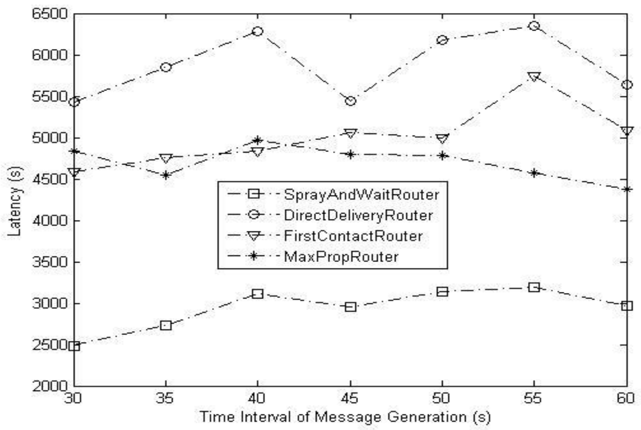
That is, the interval of message generation affects the memory cache. If messages in the memory cache have not been delivered before the memory is full, the new generated message will cause the dropping of old message in multi-copy protocols. This will degrade the delivery rate in multi-copy protocols. There is not obvious tradeoff between interval of message generation and delay, overhead.



(A. Delivery Probability)



(B. Overhead Ratio)



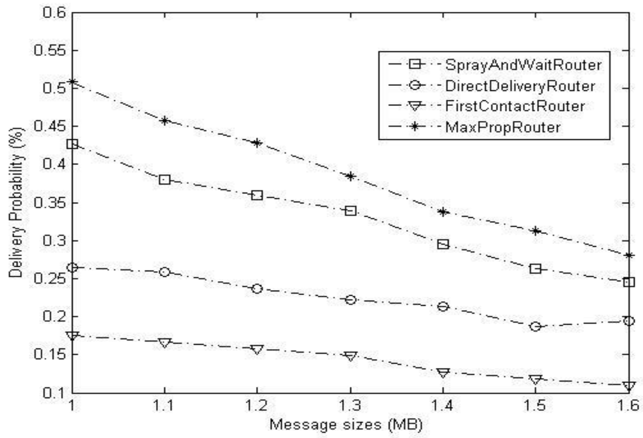
(C. Latency)

Figure. 3. Varying Time Interval of Message Generation (A. Delivery Probability, B. Overhead Ratio, C. Latency)

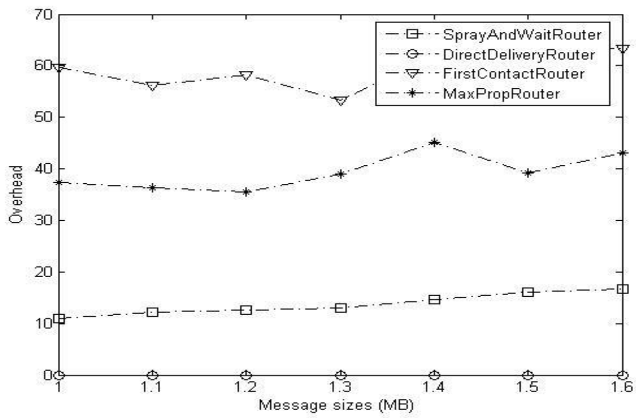
3.4. Varying Message Size

The source to destination path is not always be connected at a time instant in delay tolerant networks. The link is comprised of mobile hosts that can communicate with each other using wireless links whenever they met. This link is time-sensitive in that it is only valid for the duration when the nodes are in range of one another [1].

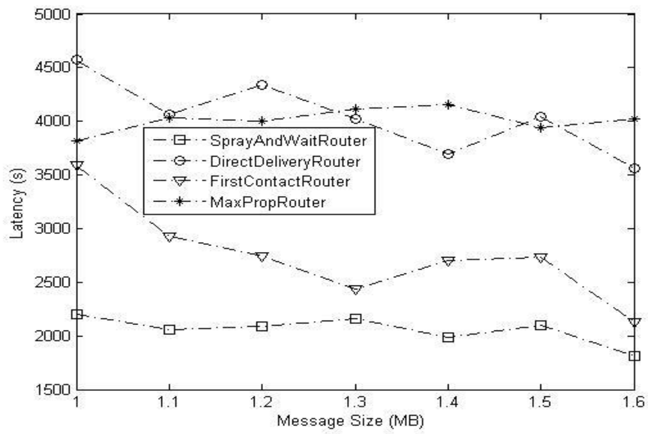
Increasing the message size and keeping it to a maximal level may lead to a longer data communication links among nodes and, hence, a lower delivery rate that due to the short duration of connection.



(A. Delivery Probability)



(B. Overhead Ratio)



(C. Latency)

Figure. 4. Varying message size (A. Delivery Probability, B. Overhead Ratio C. Latency)

Thus, the efficiency of the message transfer on a link is also a factor of the size of the message being transmitted as shown in Figure 4. Larger packets require a longer transmission time and suffer a higher probability of errors. On the contrary, a moderate message size can improve the delivery rate of protocols.
As the message size increased, the delivery rate decreased in all the protocols. As the message size increased, the overhead increased in Spray-and-Wait. The alteration of single-copy protocols are not obviously in terms of delay and overhead when the message size is changing.

3.5. Summary of Protocols Performance

Table 2 summary the results of DTN protocols under various load conditions, memory size, message size and TTL of message.

From these results we conclude that appropriate number of duplicate messages is a simple and effective policy. It performs well in most of the network conditions. It may increase the probability of delivering a packet and reduces the delay with moderate overhead at high network load

Table 2. Summary Of Protocols Performance

	Single-copy Protocol						*Multi-copy Protocol*					
	Direct Delivery			*First Contact*			*MaxProp*			*Spray and Wait*		
	Delivery rate	Over head	Latency	Delivery rate	Over head	Latency	Delivery rate	Over head	Latency	Delivery rate	Overhead	Latency
memory size	L	L	H	L	H	H	H	M	L	H	L	L
TTL	M	L	H	L	H	M	H	H	M	H	M	L
generation rate	M	L	H	L	H	M	H	M	M	H	M	L
message size	M	L	H	L	H	M	H	H	H	H	L	L

5. Conclusion

Due to its characteristics such as long communication delay, high dynamic topology, sparse distribution of nodes and frequent link break, routing are the key research issues of delay tolerant networks.

Performance analysis of different routing protocols is the major step before selecting and designing the routing protocol. The impact of network condition on single-copy and multi-copy DTN routing protocol has been investigated by means of the simulation experiment under different network conditions.

The performance analysis is compared in terms of delay, packet delivery ratio and overhead. Since the source to destination path may not be connected at any given time instant in delay tolerant networks, a store-carry-forward model should be used to design the routing protocols.

Single-copy and multi-copy routing protocols represent a natural trade-off in DTN networks. Multi-copy protocols performs better than single-copy protocols. For multi-copy protocols, appropriate number of duplicate messages is a simple and effective policy for routing design. It performs well in most of the network conditions.

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