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Threshold-based Time Tag Routing in Intermittently Connected Mobile Networks

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ABSTRACT

This paper presents a routing scheme named threshold-based time tag routing (TTTR), for intermittently connected mobile networks. Multi-copy and flooding based routing schemes are common in this type of network. While the performance of flooding based schemes on some of the parameters like delivery ratio and end-to-end delay are better than the multi-copy routing schemes, they consume lot of network resources. This paper used both the routing techniques effectively to obtain better performance. The time tag (life time) of the messages plays an important role in this protocol. When messages have more time tag value, few copies of them are allowed to be distributed in the network. If the messages are not delivered within the threshold value of time tag, the nodes are allowed to give out the messages to the nodes with no copy of this message until the message expires. The proposed routing scheme's performance is better than the existing routing protocols compared.

KEYWORDS: Intermittently connected mobile network, threshold-based time tag routing

INTRODUCTION

Intermittently connected mobile network (ICMN) is a network in which a collection of small number of mobile wireless and mobile hosts distributed sparsely. The nodes in these networks may have very less number of nodes (sometimes not even a single node) in their transmission range to communicate. This leads to frequent partitions in the network. Two nodes that need to communicate directly may not be able to do it so because of the distance between them, power constraints, environmental conditions, other propagation obstacles etc [15,16]. In order to transmit the data from a source to its destination, the traditional routing protocols may not be useful in ICMNs as these protocols assume that, connected paths exist between them [1]. In networks where frequent disconnection exists, a node is allowed to store the message, and carry it until it encounters the destination or another relay node and hence it is known as store-carry-forward approach.

A message is considered as successfully delivered when the node with the message encounters the destination and offloads the message. Even though there is no direct link from the source to destination the messages will be successfully delivered using the links temporarily created by nodes when they are on their move. So the store-carry-forward approach and the links created by the nodes for a short period of time, out of their mobility are useful in routing in intermittently connected networks. Few of the networking applications which use this type of networks include Wildlife tracking Zebranet, providing network connection to people of separated villages to communicate, sensor networks with low power devices collecting statistical information and vehicular ad hoc networks.

A routing scheme named, Threshold based Time Tag Routing in ICMNs is proposed in this paper. A message will be useful in the network for a certain period of time called time tag value, which is effectively utilized in this routing scheme. The Opportunistic Network Environment (ONE) simulator [2] is used here to perform the evaluation of this proposed work. The random waypoint mobility model is used for the simulation. The simulation results showed that the proposed protocol achieves better delivery ratio, lesser overhead, latency and buffer occupancy.

Related Works:

Intermittently Connected Mobile Network comes under the general category of Delay/Disruption Tolerant Networks (DTN) [3]. The routing protocols designed for MANETs deliver a good number of messages in well-connected networks, whereas they fail to deliver the messages to the nodes of different partitions in a network. So store-carry-forward approach is used to route messages in intermittently connected mobile networks. The source node which generates the message or the other relay node which has the copy of the message has to keep the message with itself until it sees the destination or it meets other relay node.

Many routing protocols proposed for this type of network in the literature. The protocols proposed earlier for these networks blindly flood the messages throughout the network, whereas which were developed later try to reduce the number of copies. To reduce the number of copies, various utility based protocols are proposed in the literature.

The first work for partitioned network is proposed by Vahdat and Becker [4], the Epidemic routing protocol. When a carrier node of one partition comes in contact with another partition, it quickly spreads the messages it has to this partition. Each node in the network maintains a bit vector called summary vector, which contains the list of messages it has in its buffer. When two nodes are in contact they exchange their summary vectors to get to know about the messages that are not available in their buffers. Both the nodes exchange the needed messages from the other node, which are unknown to them.

A probabilistic metric called delivery predictability is used in Probabilistic Routing Protocol using History of Encounters and Transitivity (PROPHET) [5]. This approach estimates, the delivery predictability for every node to reach destination. When two nodes meet, they exchange summary vectors, which contains the delivery predictability information. The messages are forwarded only to the node, whose delivery predictability is above the threshold value for the destination and higher than that of the other encountered node. To predict the mobility of the nodes, the probabilistic metric is calculated using mobile carrier node's profile in Probabilistic Routing Protocol for Intermittently Connected Mobile Ad hoc Network (PROPICMAN) [6]. Based on the two-hop neighbor nodes node profiles, the sender can select the nodes as message forwarders whose probability of delivering the message is higher than its own. Semi-probabilistic routing [7] produces estimates for message forwarding using the host mobility and connectivity changes. A combination of probabilistic and deterministic decisions is used to perform routing in this scheme. This paper considers an environment with some stable zones which utilize proactive routing and other potential carriers to communicate among different stable groups. When a node sends a message to another node of the same zone, the local zone information of the message is used to deliver it synchronously. A node which changes its set of neighbors frequently can be considered for forwarding as there is a possibility to meet the destination quickly. A contention aware mobility prediction routing named Predict and Forward (PF) is proposed by Elwhishi et al [13]. This multi copy routing protocol uses the contact durations and probability distribution of future inter-contact to decide the message forwarding. The next hop to forward the message is the node with the highest delivery probability to the destination. The message is delivered to the encountered node only if it has sufficient memory space.

To reduce the overhead of flooding based schemes, Spyropoulos et al. proposed Spray and Wait [8] routing protocol. This routing consists of two phases namely Spray and Wait. The source node spreads a limited number of message replicas to the other encountered nodes. If the destination is not found in the spray phase, the nodes which have the message replicas give the message only to the destination in the Wait phase. A variation on Spray and Wait is made in Spray and Focus [11], where spray phase works as in spray phase of spray and wait, whereas in wait phase, an utility function is used to forward the message. Instead of fixing a common replication factor of messages by the source node, in Adaptive Multi-Copy routing for packet delivery in ICMANs [9], each of the intermediate relay nodes independently decide the replication factor based on the end-to-end delay target and the current network conditions. In RAPID [12], the statistics of available bandwidth and the number of message replicas is used to derive the routing metric. To decide which message is to be replicated first the marginal utility of replication is used. The inter-encounter time rate of each node pair is used to make the decision on message forwarding in Self Adaptive Routing Protocol (SARP) [10].

Threshold Based Time Tag Routing Scheme:

In this proposed scheme, the network consists of a set of mobile nodes. The contact information of other nodes in this network is not known a priori. The nodes which are in the transmission range of other nodes can forward the messages. In intermittently connected mobile networks, a message is delivered to the destination, if the source meets the destination or the source node uses the other relay nodes to take the messages and deliver to the destination. In this routing scheme, a message is delivered as a whole. Since all the nodes are mobile nodes, the storage space is limited in each node.

A node creates a message by itself, where it is called as the source or receives messages from other nodes, where it is named as relay nodes. In this routing scheme each message on creation is assigned a time tag value $Time_i$ and a message replication count. Message replication count indicates the number of replicas of the message that can be spread in the network in the initial phase as in Spray and Wait [8]. $Time_h$, a threshold for time tag is fixed for this routing scheme. On each update interval the time tag value is updated. When $Time_i$ is lesser than the threshold value $Time_h$, the following events take place.

When node N1 meets another node N_2, they first exchange the list of acknowledged messages. Then this list is updated in their acknowledged lists. If node N1 has messages for which N2 is the destination, first N1 forwards those messages to N2 and vice versa. Then N1 forwards the other messages to N2. This process is repeated by N2 also. As in Spray and Wait, in the first phase, if a node has more than one message replica, it forwards half the number of message replicas to the encountered node, if it does not have the same message. When a node has a single copy of the message, when it has time tag greater than threshold value, it gives the message only to the intended destination. Otherwise it forwards the message to nodes whichever it meets, with no copy of this message.

In this routing scheme, the time tag value gives the amount of time the message lives in the network. Here, its value is represented in terms of minutes. Whenever a new message is created, this time tag also is assigned to it. Its value gets decremented on each update interval. Once the value of time tag reaches zero, the respective message will be deleted from the node's buffer. Since the nodes have limited buffer space, and the contact schedule is not known in advance, the messages need to be stored in the node's buffer for a long period of time. When a node needs to forward a message to another node, the other node must have sufficient buffer space to accommodate the message. If buffer space is not sufficiently available, or if there is no space in the encountered node, then one or more of the messages in the encountered node need to be deleted.

If a message is no longer needed in the network, feedback mechanisms provide a way to delete it. Immediately after the reception of a message, the destination sends an acknowledgement to the nodes in the network. If a node with the copy of a message receives the acknowledgement for the same message will delete the message from its buffer. A message in the node's buffer gets deleted if it reaches the destination and the destination sends acknowledgement to the source and the other nodes or if its time tag expires or deleted using the expunge list to make room for new message.

The routing protocol works in the following way:

When node N1 encounters node N2

```
N1 and N2 exchange the acknowledge lists
N1 and N2 update their acknowledge lists
If N1 has message msg for N2(destination)
 Forward message msg to N2
          Delete message msg from N1
          N2 sends acknowledgement
          end if
If N2 has message msg for N1(destination)
          Forward message msg to N1
          Delete message msg from N2
          N1 sends acknowledgement
          end if
for each message msg in N1
   if (Time_msg > Time_h)
      if freeSpace(N2)
           N1 forwards half number of message copies of msg to N2
      else
          Delete messages from N2 to make room for new message msg
          N1 forwards half number of message copies of msg to N2
      end if
    else
     N1 forwards the message to all encountered nodes
   end if
end for
```

Simulation:

To evaluate the performance of the proposed protocol, the ONE (Opportunistic Network Environment) is used in this work [2]. The proposed TTTR is compared with the existing Epidemic, Prophet and Spray and Wait routing protocols. The protocols are evaluated using the metrics like delivery ratio, overhead, latency and buffer occupancy.

Delivery ratio is calculated by taking the ratio between the number of messages delivered and the number of messages created.

$$Deli.Ratio = \frac{no.\ of\ messages\ delivered}{no.\ of\ messages\ created} \quad (1)$$

Latency is the time elapsed between the message creation and message delivery.

$$Latency = message\ creation\ time - message\ delivery\ time \quad (2)$$

Overhead is calculated by taking the ratio between the number of messages relayed and the number of messages delivered.

$$Overhead = \frac{no.of\ messages\ relayed - no.of\ messages\ delivered}{no.of\ messages\ delivered} \quad (3)$$

The buffer occupancy indicates the amount of buffer space consumed by the messages.

$$Buff.Occupancy = \frac{(bSize - freeBuffer)*100}{freeBuffer} \quad (4)$$

A. Simulation Setup:

The nodes in the network move in 1500 m x1500 m area with the transmission range of 30 m. The transmit speed of all the nodes is 2 Mbps. The moving speed varies from 0.5 m/s to 1.5 m/s and the nodes wait at some places for a time period of 0 to 120 s. On each 25 seconds a message with 500kB is generated in thenetwork.100 nodes of homogeneous type is used in the network. The buffer size is varied between 5 MB and 45 MB. The simulation time is 43200 s. The random waypoint mobility model is used in the simulation. The time tag value of each message is 60 minutes and the time tag threshold is 10 minutes. Initially six message copies are allowed to spread in the network for first 50 minutes. The destination nodes after receiving the messages send back the acknowledgements to the source and the other nodes. If the nodes which receive the acknowledgements have message copies of delivered messages, they will immediately delete those messages from their buffers. This is one of the ways in which the buffer space is made to be consumed less in this proposed work. If the messages do not reach the destination within first 50 minutes, then the nodes with the undelivered messages will be allowed to forward the messages to other nodes without these messages that come in their transmission range for the remaining 10 minutes. Many messages that are not delivered in the first 50 minutes will get an opportunity of getting delivered in the next 10 minutes as many nodes will have these messages. Once the time tag of a message expires, the nodes with the message copies of that message will delete them. So buffer space will not get wasted.

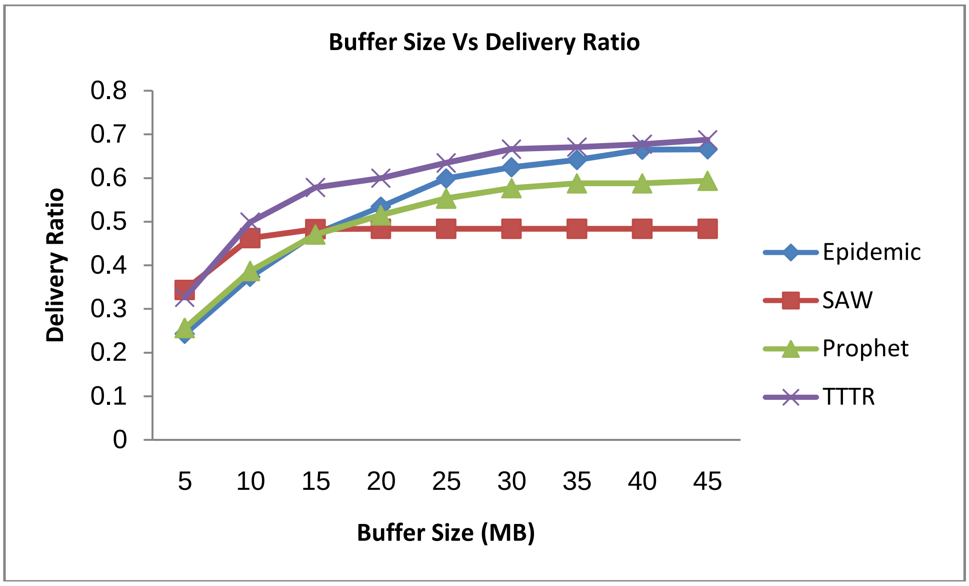

Fig. 1: Buffer Size Vs Delivery Ratio

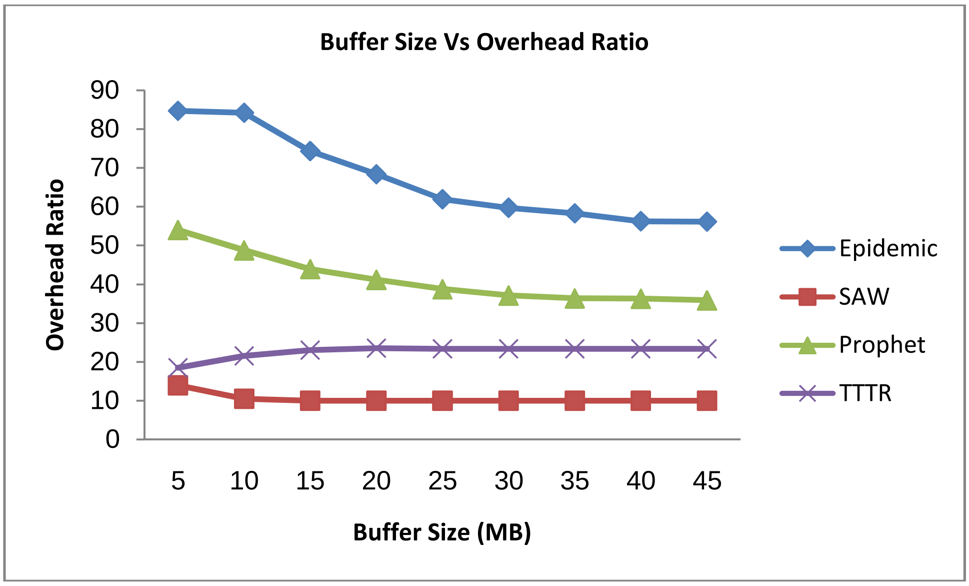

Fig. 2: Buffer Size Vs Overhead Ratio

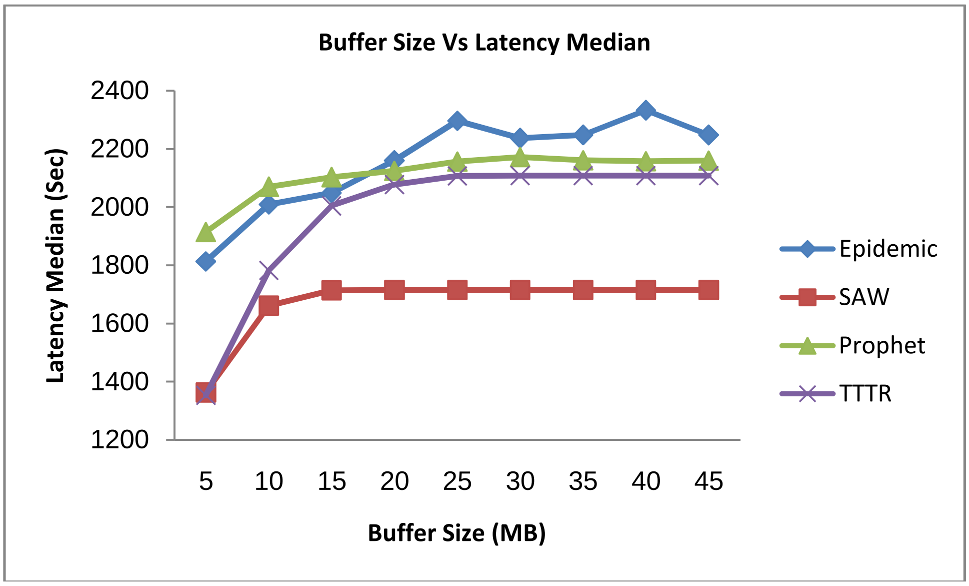

Fig. 3: Buffer Size Vs Latency Median

From the graphs it is seen that, the delivery ratio is better than the other routing protocols compared in the simulation. Since the messages that are not delivered before the threshold value of time tag are given additional preference to get delivered, most of the messages are getting delivered. The overhead and the latency for the proposed routing protocol TTTR are less for the other protocols and comparable with that of Spray and Wait. The overhead is less because many of the messages relayed, reach the destination before the expiry of the messages. The buffer occupancy is also less when compared with the other protocols and comparable with that of Spray and Wait, since we use the acknowledgement of the messages to delete the delivered ones immediately after the message delivery. So the overhead and the buffer occupancy are less in the proposed work.

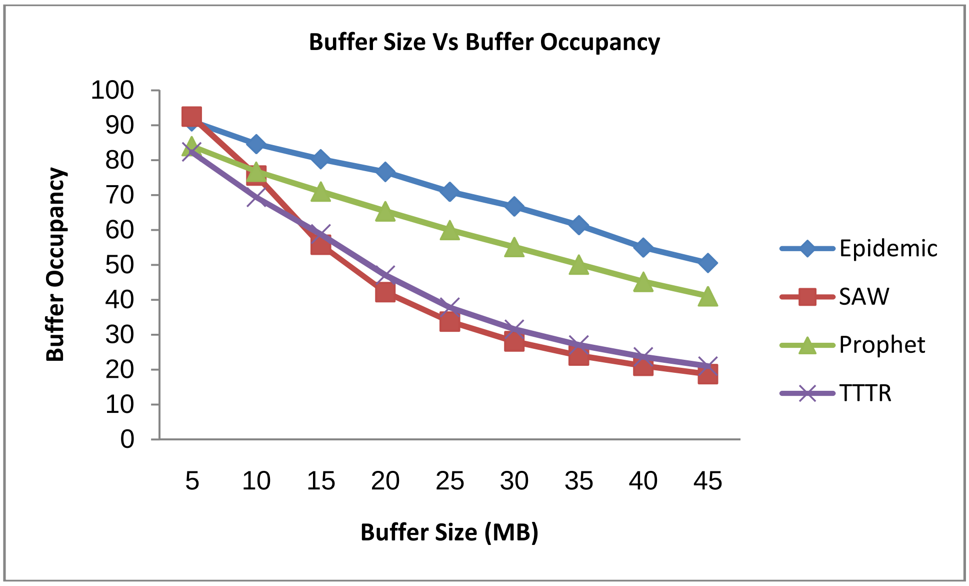

Fig. 4: Buffer Size Vs Buffer Occupancy

Conclusion:

Providing reliable communication from source to destination in the absence of end-to-end path is a great challenge in intermittently connected mobile networks. Many single copy, multiple copy and flooding based routing protocols are used in this type of networks to route the messages. Even though the flooding-based routing schemes achieve good delivery ratio they consume lot of network resources. The other single and multi-copy routing schemes use less network resources, but they are less efficient in successfully delivering the messages. The proposed routing scheme TTTR uses both the multi-copy and flooding-based routing schemes to efficiently deliver the messages to destinations while consuming lesser network resources than flooding and most of the other multi copy routing schemes. The simulation results showed that this protocol gives good delivery ratio compared to the existing schemes. The latency, buffer occupancy and the overhead are lesser than the two other existing protocols taken for comparison and comparable to that of spray and wait. This work can be further extended to heterogeneous networks.

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