Threshold Based Best Custodian Routing Protocol for Delay Tolerant Network

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Abstract: Delay Tolerant Network (DTN) is a kind of network in which the source may not be able to establish the stable and uninterrupted path to destination due to network partitioning, dynamic topology change and frequent disconnections. In order to dealt disruption and disconnections a store, carry and forward paradigm is used in which node stores the incoming messages in its buffer, carries it while moving and forward when comes within the transmission range of other nodes. Message forwarding contributes and important role in increasing its delivery. For instance, probabilistic routing protocol forwards message to a node having high probability value to meet message destination. These protocols cannot handle a situation in which the node continually transmits messages even the probability difference is very small. In this paper, we have proposed a routing protocol known as Threshold Based best custodian Routing Protocol (TBbcRP) for delay tolerant network. We have proposed a threshold-based method to compute the quality value which is the ability of node to carry message. A self-learning mechanism has been used to remove the delivered messages from the network. Moreover, a buffer aware mechanism has been used that make sure availability of buffer space at receiver before message transmission. We have compared the performance of TBbcRP with Epidemic, PRoPHET and Delegated Forwarding. The proposed TBbcRP outperforms in terms of maximizing the delivery probability, reducing number of transmissions and message drop.

Keywords: Delay Tolerance Network , store-carry-forward, routing protocols , algorithms.

1 Introduction

With advancement in communication technologies [1-2] it is now possible to interconnect mobile nodes, stand-alone computers and provide an innovative way to join the social and business communities. Despite, other communication architectures such as LAN, WLAN, the mobile ad hoc networks have gained more popularity. In ad hoc networking routing protocols [3-6], the source and destination establishes the end-to-end path prior to the transmission of data. This prerequisite is impossible in highly disrupted wireless applications such as wildlife monitoring, deep-space communication and military networks. Such environments suffer frequent disconnections, dynamic teleology change and network partitioning due to node mobility. In addition, limited network resource, for instance, buffer space, bandwidth, energy and processing power of nodes makes routing a real challenge.

Delay Tolerance Network (DTN)[7] is a kind of network that aims to provide the communication via opportunistically connected mobile nodes. A novel method called as the store, carry and forward is used in which nodes stores the message in their buffers carries them while moving and forwards when connected to other nodes. The DTN routing protocols can be classified as

single copy and multi copy. In single copy protocols, the unique copy of the message exists in entire network [8,21]. These protocols are capable to operate under limited resource but reduce delivery ratio and raises the delivery delay. Multi copy routing protocols transmits the redundant copies of each message to all connected nodes [9-13]. Therefore, the message can reach to its destination via multiple intermediate nodes. As a result, multi copy routing protocols minimize the delivery delay and maximize the delivery [14-18].

The multi copy routing protocols are more robust, but unreliable due to consumption of high volume of network resources. The probabilistic routing protocols were proposed to reduce the resource consumption that considers node behavior such as its movement pattern, encounter history [12,14,27] before the transmission of the message. A carrier node with probabilistic protocol continues to forward message to high probable relay nodes. This issue was addressed in [19] where Vijay Erramilli et al. proposed a new message forwarding technique called as Delegated Forwarding. In this method, each node maintains a quality metric and forward the message to another node only if it has high quality metric which have been seen by the message. Later, in [20][23-24] the authors present the variations of Delegated Forwarding. The previous works has not defined a method to compute quality value of nodes.

The contribution to this paper is as follows

- We have proposed a routing protocol called as Threshold Based best custodian Routing Protocol for Delay Tolerant Network (TBbcRP).

- We have used a self-learning method to remove the previously delivered messages from the network.

- A threshold-based method has been used to assign the quality value to network nodes.

- We have compared the performance of TBbcRP with Epidemic, PRoPHET and Delegated Forwarding in terms of minimizing number of transmissions, number of drops, overhead while raising the deliver probability.

1.1 Review of DTN routing protocols

In dynamic surroundings like intentions topology change, node mobility and frequent network partitions, problem is to select a suitable relay node for a message. In addition, scarce network resources such as limited buffer space, bandwidth, and low power of nodes makes data routing even more challenging. Therefore, prototype of a good routing protocol must focus on minimizing the consumption of network resources and delivery of more messages to their destinations. In flooding based routing protocols such as Epidemic protocol [13] each node encounter results in the exchange of messages. The encountering nodes further diffuse the message copy and process continues.

Despite the fact that in Epidemic protocol, each message may have more than one path to reach destination, Epidemic protocol consumes high volume of network resources. The control on creation of message copies can reduce the resource requirement. In this background, qouta based routing protocols were emerged where each node was given the opportunity to transmit the n number of message copies for example Spray and Wait[10], Spray and Focus[11], Spray and Wait binary QoN Spray and Wait[26].

The Spray and Wait algorithm consist of a Spray phase, where node spread n message copies to its neighbors called as relays. If the destination is not found in the Spray phase then each node Wait until contacted to message destination. In Spray and Wait protocol, message transmission was limited only to the neighboring nodes. This problem was solved in binary Spray and Wait protocol in which a source node on encountering forwards the $n/2$ message copies to the connected

node while keeps $n/2$. In addition, the receiver node was also privileged to distribute $n/2$ message copies. This hierarchical forwarding improves the performance of Spray and Wait and increases message delivery. The spraying protocols work well when the node movement is Independent and Identically Distributed (IID) which is not possible for real world scenarios where each node exhibits its own movement pattern.

These challenges motivate the researchers and various utility functions were introduced in spraying algorithms. For example, Spray and Focus [11] protocol starts by distributing the $n/2$ message copies like Spray and Wait binary, however when the node left only one copy of message then it shifts to the Focus phase where the nodes forwards the message to neighbors by observing its suitability to meet the destination. The suitability is determined by the time since two nodes last saw each other. Quality of node Spray and Wait [26] improves the performance of Binary Spray and Wait algorithm by introducing QoN (Quality of node). The QoN is represented by an integer number which describes encountering frequency of one node to encounter with other node in a given time interval. The primary objective of Quota based routing protocols was to control the transmission of message copies.

Despite the fact that spraying algorithms has exploited the encountering history of nodes, other factor such as mobility patterns or positional coordinates can improve the routing procedure. For example In [28], the author designs a mobility based spraying strategy Most Social First, Most Mobile First (MMF), Last Seen First (LSF). The Shen Ling et [22] observe the node mobility and introduce a influence factor which is determined by the mobility of the nodes.

In [12] Lindgren et al. introduces PRoPHET protocol which reduces the number of message transmissions by introducing a new metric called as delivery predictability and transitive connectivity. The nodes are capable receive a message only if they constitute a high value of predictability and transitivity. As expected, PRoPHET protocol compared to Epidemic protocol minimizes the number of transmissions.

The variation of PRoPHET such as PROCS [29] introduces a new message forwarding method which observes movement pattern of nodes and their time sequence In [19] Vijay Erramilli et al. propose a new message forwarding technique called as Delegated Forwarding. In Delegated Forwarding, each node maintains a quality metric and forwards the message to another node only if it has high quality metric which have been seen by the message. The protocol works well to and controls the transmission of the message on the relay nodes. However, it does not provide any solution to control the transmission of the source messages. In [20] author modified the algorithm by updating source message with the probability value of high quality node. In this way, the replication was also controlled from the source messages. In [23] the author defines the Delegated Forwarding by designing cost-based drop and transmission methods. According to this, the message that is close to their destinations are assigned the high priorities by defining a replication count number called as the Delegated number. Yunsheng Wang et.al [30] proposed for single copy multicast, multi copy multicast and Delegated Forwarding multicast algorithms.

1.2   The proposed threshold based best custodian routing protocol

In proposed TBbcRP, each network node maintains the time information about encountering to other nodes in a vector called as Previous Encounter Vector (PEV). The PEV consists of node id *nid* and Encounter Time (ET). We have used ET to assign the quality value which describes the future encountering likelihood among same nodes. The high quality value indicates that node is more likely to delver message. The quality information is stored in the Quality Vector. The Quality Vector consists of node id and Quality Value (QV).

Principal-1. When nodes contact, they assigns quality values by using upstream and down-

stream time threshold:

$$TD = CurrentTime - ET(ni). \tag{1}$$

When the node encounters first time, they initializes the default quality in the Quality Vector and Current Time in the ET of PEV. If nodes have encountered previously, then the Time Difference (TD) is computed by subtracting the Current Time from the ET by using Equation 1 and Threshold Streams module is invoked. The Threshold Stream module updates the quality value for a node by mapping the TD in the pre-defined collection of threshold queue. Table 1 shows the meaning of variables used in TBbcRP.

Table 1: Meaning of variables used in TBbcRP

Symbol	Description
n_i , n_j	node i and node j
PEV,ET	Previous Encounter Vector, Encounter Time
QV	Quality Value
TD	Time Difference
QP	Quality Points
Vd	Vector Deliver
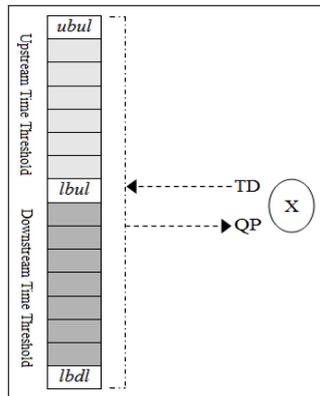
Figure 1: Structure of Threshold Queue

Figure 1 show the structure of threshold queue which is divided into Upstream Time Thresholds and Downstream Time Thresholds. The Upstream Time Thresholds further defines its Lower Bound of Upstream Limit (lbul) and Upper Bound of Upstream Limit (ubul). The Upstream Thresholds are used to decrement quality value while Downstream Thresholds are used to increase quality values. The nodes encountering after large interval of time shows high TD value and relevant Quality Points (QP) are subtracted from quality value of node. When the time difference is above the ubul then quality value of node is initialized to zero. The Downstream Threshold starts after lbul and defines its Lower Bound of Downstream Limit (lbdl). The Downstream Threshold is used to increment the quality value of nodes. For instance, nodes encountering after small interval of time are expected to encounter again. The TD is mapped and relevant Quality Points (QP) are incremented in the quality value. When time difference is lower than the lbdl then maximum Quality Points (QP) are assigned to the Quality Value (QV).

Figure 2 shows the algorithmic flow of threshold based method in which node X and node Y have established connectivity. The node X and Y has maintained Previous Encounter Vector
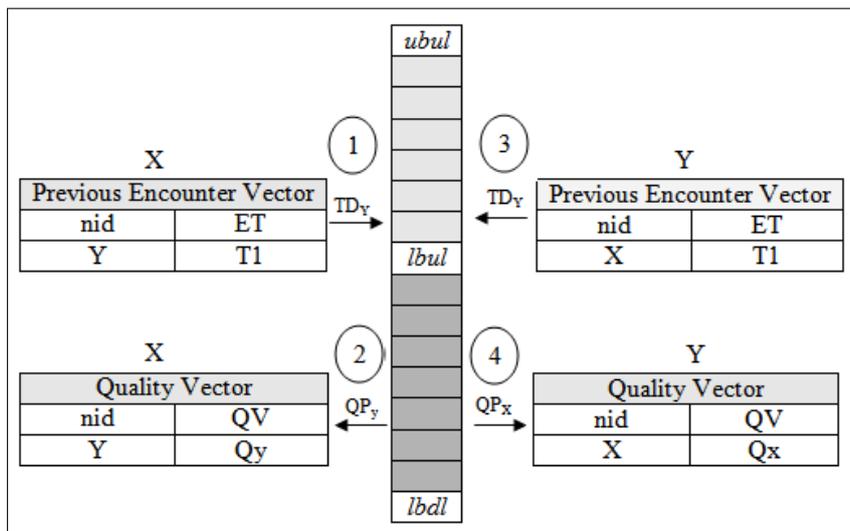
Figure 2: Threshold Based best custodian Routing Protocol Example

(PEV) and Quality Vector. In step one, X map TD_Y which represents time elapsed since X has seen Y. In step two, the relevant quality values QV_Y will be given to X. The same steps are followed by node Y.

1.3   Self learning method to remove delivered messages

Since, DTN is a highly disrupted environment where it is not possible to keep the track of the transmitted messages via central administration. Hence, most of the time the message even after finding their destinations cannot convey their delivery status to the other nodes, and message replication continues even it is delivered. When the network resources scarce then replications of delivered messages produce high overhead on the buffer space, bandwidth and energy. Despite the influence of other factors, these messages also produce the congestion that a node overcomes by dropping its stored messages. Hence, a solution is required to remove the delivered message from network. Inspired by immunity based routing protocol, we have defined a de-centralized mechanism to remove the previously delivered messages.

Principal-2. The algorithm states that when a node deliverers a message to the current connection as a final recipient then it stores the message id in Vector Delivered (Vd) and remove it from the buffer.

The TBbcRP , each network node maintains a vector called Vector Delivered (Vd). When a node forwards the message copy to a connection as final recipients it inserts the message id in Vd and removes the message from the list of its carried messages. This module is invoked after the threshold computation and before the transmission of messages.
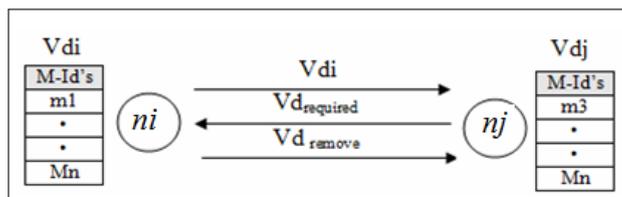
Figure 3: Exchange of previously delivered messages

Figure 3 show the technical flow of removing delivered messages. Accordingly, on encounter-

ing, ni forward Vdi [16-17] to nj. Vdi hold ids of delivered messages known by ni. nj subtracts Vdi from Vdj to get Vd$_{required}$ that holds list of delivered messages not known by nj and send it to ni by using Eq. (2).

$$Vd_{required} = (Vdi - Vdj) \tag{2}$$

ni computes Vd_{remove} by intersecting Vd$_{required}$ from Vdi and send it to nj by using Eq. (3).

$$Vd_{remove} = (Vd_{required} \cap Vdi) \tag{3}$$

Finally, nj removes the Vd_{remove} messages from buffer and update Vdj by using Eq. (4).

$$Vdj = Vd_{remove} \cup Vdj \tag{4}$$

1.4   Control on message replication by buffer space

The DTN message consists of message header and payload header. The payload header contains the actual contents of message. The message header is collection of control information such as message identification, hop count, and time to live. The DTN node utilizes control information to forward and drop messages. In TBbcRP, we have included a new data field in message header called as Recent Quality (RQ). The RQ is an integer value initialized with zero for the messages generated by the source.

Principal-3 When a transmitter forward the message copy it updates the RQ of message with the of quality value of receiver, while the receiver will update the RQ of message to its own.

The principal 3 is about the implementation of Delegated Forwarding in message header. We have used the same concept in DF++[24]. Briefly, after transmitting message copy, the sender node updates the RQ of message header to quality value of node which receives message. Similarly, receiving node update the message RQ to its own quality value. The idea is that the receiver or transmitter will not replicate the message until the encountered node has higher quality value than the RQ.

Principal-4. The transmitter will forward the message only if the QV of receiver to meet with the message destination is greater then the RQ and available buffer space at receiver is capable to store the message.

The high quality nodes are likely to encounter the message destination. However, if we forward a message to a congested high quality node then this forwarding decision may degrade the network performance. Since, the congested node will drop its previously stored messages to accommodate the new one. In our previous work, DF++ [24] and CFBARP [25] an adaptive mechanism has been defined to dealt with buffer space. Hence, the node forward the message only if the quality value of receiver is high as well as available buffer is able to accommodate the incoming message. After transmission, the transmitter will subtract the message size from available buffer.

2   Simulation and Results

This section provides the performance analysis of existing and proposed routing protocols in terms of minimizing the message transmissions, message drop and raising the delivery probability by ONE simulator [31]. ONE is event driven simulator written in java and has been designed to evaluate the DTN applications. The reality of simulation has bee increased by using a city based environment which consist on pedestrian, cars and Trains. The pedestrians were divided into two groups with 40 members at each group. The pedestrian are moving with shortest path map based movement model at the speed between 0.5km/h and 1.5 km/h. Each pedestrian has been

carrying mobiles with 2MB of buffer size. The transmission range of mobile nodes is 10 meters. The 40 cars are moving via map route movement at the speed between 10km/h-50km/h. Finally, six trains are moving via map route movement at the speed between 7km/h and10km/h. The random size message generated from the sample of 100K-300K and the inter message creation interval is 25s-35s. The bandwidth if equally distributed at 2MBPS.
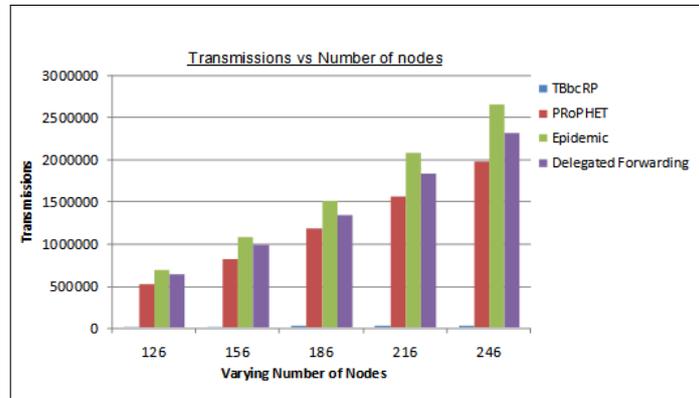
Figure 4: Transmissions by varying number of nodes

Figure 4 represents the results of exiting PRoPHET, Epidemic and Delegated Forwarding as compared to proposed TBbcRP routing protocol in terms of number of message transmissions. The flooding based Epidemic protocol has been showing high number of transmissions. The Delegated Forwarding has controlled the message diffusion as compared to Epidemic protocol but still forwards high quantity of messages compare to PRoPHET and TBbcRP protocols. The message transmissions are getting higher with increasing number of nodes. The reason is that, at high number of nodes, message exchange gets higher. It is possible to sustain such traffic under the infinite buffer space. However, in the current environment the buffer is limited resource thus a better quality node when receive a message by having no space mechanically triggers the drop event. Further, due to the multi copy of each message the same high quantity node may reputedly receive the dropped messages, thus cause high transmissions, message drop and waste of node energy. The proposed TBbcRP routing protocol has reduced the message transmissions.
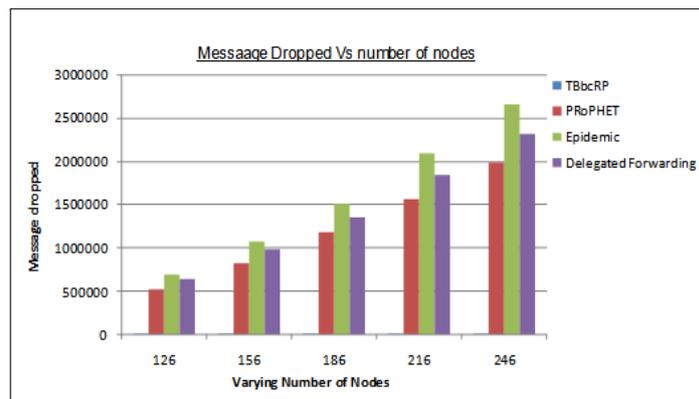
Figure 5: Message dropped by varying number of nodes

The Figure 5 depicts the results message drop by increasing the number of nodes. We can see that increasing the number of nodes has raised the message dropped. This is because the buffer space is finite, and nodes cannot accommodate all incoming messages. For instance, at increasing

number of nodes such as 186, 216, and 246, even the protocols like PRoPHET and Delegated Forwarding has dropped large number of messages. The reason is that when the encounter rate among nodes is high then multiple nodes became highly probable to receive the message. The proposed TBbcRP has shown the constant stance for all network traffic.
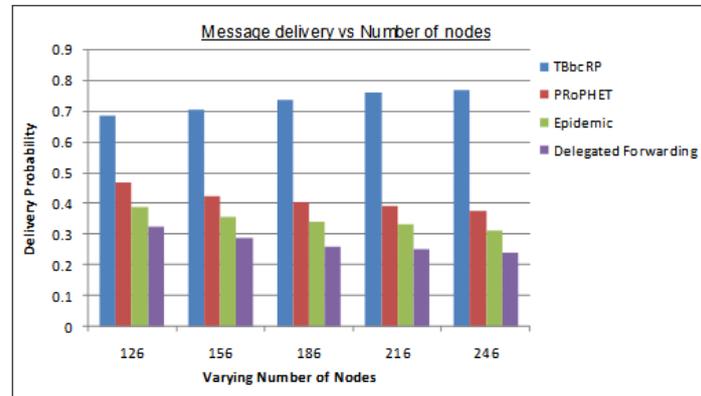
Figure 6: Delivery by varying number of nodes

The Figure 6 plot the results of existing and proposed routing protocols in terms of message delivery probability by increasing number of nodes. It can be observed that at less number of nodes such as 126, 156 the protocols such as PRoPHET, Epidemic and Delegated Forwarding has delivered more messages. Nevertheless, as the number of nodes gets higher like 186,216 and 246 less number of message find their destinations. The reason is that messages were dropped before reaching destination.

3   Conclusion

In this paper we have proposed a routing protocol called as Threshold Based best custodian Routing Protocol (TBbcRP) for delay tolerant network. A threshold based method has been proposed to compute the quality value of nodes, which is the ability of nodes to carry message. Moreover, a self learning method has been used to remove previously delivered messages from network. The proposed protocol out performs well as compared to existing strategies in terms of maximizing the delivery probability, reducing number of transmissions and message drop.

Acknowledgments

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