Cooperation Enforcement Schemes in Delay Tolerant Networks: A Survey and Future Perspectives

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Abstract - A Delay Tolerant Network (DTN) is an intermittently connected network, where intermediate nodes are responsible for storing, carrying and forwarding messages between source and destination nodes in the absence of a continuous end-to-end path. Non-continuous connectivity, finite storage and bandwidth make the role of relay nodes critical. Existing routing protocols in DTNs assume that these nodes always show willingness to store, carry and forward messages from other nodes. However, some nodes may exhibit a selfish behavior due to resource limitations or rogue operation, and deny their cooperation, thus leading to performance degradation of the network. This paper surveys the schemes proposed in the literature to stimulate cooperation in DTNs.

Keywords - *Delay tolerant networks; selfish behavior; incentive; cooperation.*

1. Introduction

Delay tolerant networks were first proposed for interplanetary communication. However, with its increasing popularity and promising approach to deliver data in extremely challenged environments, it has been applied to a wide variety of applications like vehicular networks, mobile social networks, pocket switched networks (PSNs), underwater networks, and military networks [1], [2].

One of the main challenges of DTN protocol design is the fact that unlike in Internet no continuous end-to-end connectivity is available. So the message delivery depends on the mobility of nodes and is operated in an opportunistic way through store-carry and forward relaying.

Apart from intermittent connectivity there may be some other causes that may make routing protocols inefficient. For instance, some of the relay nodes may not cooperate to store, carry and forward (SCF) messages destined to other nodes. Such nodes are referred to as selfish nodes. Among other reasons, this can occur if nodes want to save their limited resources such as buffer storage and bandwidth.

The presence of such selfish nodes in the network will eventually lead to performance degradation.[3] A variety of strategies have been proposed in literature to tackle with selfish node behavior. These strategies basically give nodes incentives to make them cooperativeto store and forward other nodes' messages. This paper presents a comprehensive literature review on this problem and the solutions proposed.

2. Social Attributes of DTN

Similar to the way humans behave differently with people in different relationships, nodes in DTNs also tend to show different behavior depending on their social ties with other nodes [4]. There are some common attributes of social based networks in DTNs. Among those *community, centrality and friendship* are fixed in routing environment of a network and other are outcomes of the behavior of a node. Awareness about these attributes might be helpful to improve the routing performance [5][6][7]. A node's social behavior can be utilized to improve the network overall performance [8][9]. These attributes are explained briefly in the following sub-sections.

2.1Community

In social terminology, community is a group of nodes who meet frequently. Community concept came from the theory of graph and from the social life of humans [10][11][12]. Community shows that nodes belonging to same community have more interaction as compared to other

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nodes. People from same community have higher chances of meeting each other. The same scenario can be applied on people carrying devices because when people meet each other there is possibility that their wireless devices also get connected. Hence, meeting frequency of same community nodes is higher and they can pass messages to each other in less time as compared to the nodes from other community.

Fig.1 shows the concept of community in social networks. Here rings represent communities and nodes are shown by small circles. Bubble Rap [13], Label routing[14] and SimBet[15] are some routing protocols that use community and centrality concepts for forwarding messages. Having knowledge about the structure and members of the community allows designing a better routing protocol for a DTN [16][17].

2.2 Centrality

Usually the community can be represented as a graph where vertices represent nodes and the edges represent the connectivity between nodes. Centrality of a node is the count of direct contact to other nodes. It defines the social concern of the node [18]. Some of the centrality measures are *betweennees*, *degree* and *closeness* [19][20]. Betweennees shows how many shortest paths are available through that node, degree centrality shows how many nodes are directly connected to the node, and closeness shows the inverse of its average shortest distance to all other nodes in the graph. For example, in Fig. 1 node "A" has 7 direct connected edges to other nodes which is more than other nodes, hence it has highest degree centrality. Degree of each node depends on the number of connected edges, and a node having higher centrality has large number of direct links to other nodes, which accounts for its higher possibility to forward the message to other nodes. It works like a hub in the network.

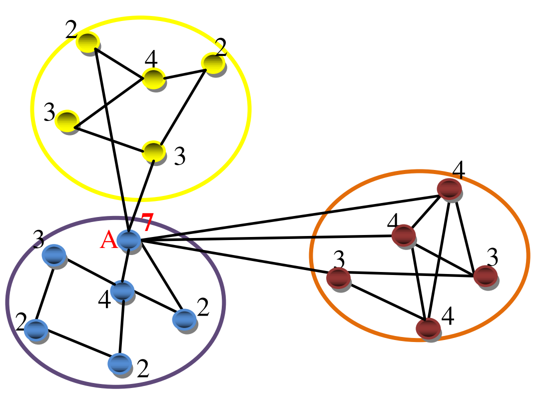


Fig. 1: Concept of community and centrality in a social based network. Here numbers shows the degree centrality of node

2.3. Friendship

As in DTNs, generally nodes do not have continuous end-to-end path all the time. But nodes that belong to the same community have higher probability of meeting. Nevertheless, nodes that are not from the same community may also meet regularly, and this forms the concept of *friendship*. For example, in a school meeting probability of two faculties is higher than the meeting probability of faculty and students. So there is a possibility to forward the message through the node that has this type of relationship for better performance.

In DTNs, friendship between two nodes may be determined by using history of encounters together with the meeting schedule. In social routing algorithms, a message is forwarded to the node that has higher global ranking until it reaches the destination community. Then, from there onwards it is forwarded on the basis of local ranking. By the creation of a friendship community, two nodes can be considered indirect friends if they have no direct contacts but if they have mutual friends. So they can contact each other through them [21].

3. Selfishness

Selfishness can be described as the non-cooperative behavior of nodes in the SCF message delivery process. It can be expressed in two ways: first nodes may refuse accepting data that is not of their interest and destined to other nodes; secondly, even if they accept such data, they may refuse to relay it to other nodes. If nodes do not see some benefit in forwarding the messages, they will not show willingness to accept this task.

The reason behind this behavior is that nodes may want to preserve their resources (e.g., buffer space, bandwidth, and energy) and hence give priority to their own messages. Selfish behavior decreases the overall performance of the network in terms of delivery ratio and delivery delay [22][23].

Due to property of selfishness, nodes will not show similar behavior to all the participating nodes of the network. Nodes exhibit two types of selfishness which are collusion and noncooperation. Existing protocols for social based routing consider that nodes are cooperative and ready to forward messages. However, due to limited resources wireless devices will exhaust soon if they utilize all their resources for other node and because of this nodes do not show willingness to use their resources for other nodes.

There are some strategies which are used to motivate the nodes for working in cooperation mode as relay nodes. Because of this cooperation they will get credits or in other words if a node helps another node then it will help him back in need.

3.1.Types of Selfishness

A selfish node may behave differently with different types of nodes in the network. Its behavior may change from node to node and community to community. A node may forward the messages of its community nodes but it may not forward the messages of the nodes from other communities. This means it is working only for those nodes who belong to its own community. The two types of selfishness which were discussed above, further classified as follows. Collusion is further classified into two types, individual selfishness& social selfishness,[23] while the non-cooperation divided into non- forwarding of messages and dropping of messages.

Node who show individual selfishness are ready to help the nodes who belong to its own community, because these might be the node who have helped him before or may be useful in

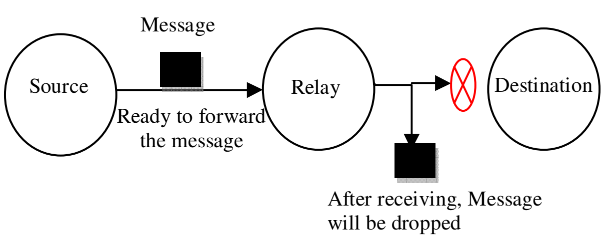


Fig: 2 dropping of message

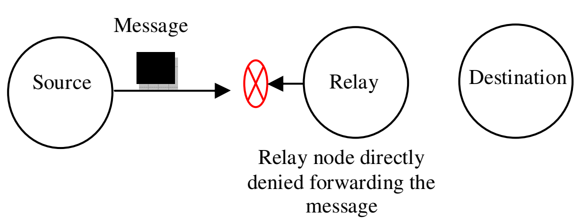


Fig: 3 Non-Forwarding of message

future. In Social selfishness, node gives preference and its services to other nodes on the basis of social ties with them.

Basically two types of activities are involved with Selfish nodes, non-forwarding of messages and dropping of messages. Non-forwarding of message means saying no to forward the message, while dropping of message implies that the node was ready to forward the message but after receiving the message, it will drop them and remove from its storage to free its buffer space.

4. Strategies for Prevention of Selfishness

As the number of selfish nodes in network increases, the performance of routing protocol decreases. In the current era number of devices in the network is increasing exponent, and the amount of data to transfer is also growing at a rapid rate. So, the increase in number of selfish node adversely affects the performance of the network. There are some strategies to make the node cooperate in routing the messages.

4.1. Barter Based Strategy

Barter based strategy [24] works on the fact that if a node has forwarded data of another node, then it will get back help from the same node for which it offered a service previously. It is a peer to peer incentive mechanism to motivate nodes to not to be selfish [25]. In a peer to peer transaction, a node connects to other nodes and they both can transfer the data simultaneously to each other whereas, barter based strategy restricts them to transfer the data to other nodes until the previous transaction is completed [26]. Usually the nodes classify messages into two categories, messages in which the node is interested and the one it is not interested. When node meets each other, they grant the permission to check the list of their messages. After that, they inform each other about the list of messages they are interested in. For the sake of loyalty, the transaction should be in such a way that one message at a time alternatively from each side, so that if a node stops forwarding the message then other node will not suffer a huge loss (i.e. losing only one message).

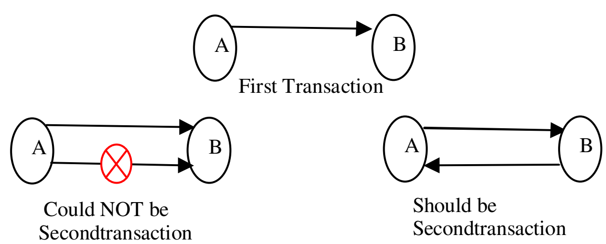


Fig: 4 Transactions in Barter Based Strategy

In this strategy, same size messages should be exchanged between nodes and a node can't transfer the next message with the same node till it does not complete the previous transaction. So, the bandwidth is reserved for long time and the duration of message buffering is more than the time taken to transfer the message. It keeps the buffer full and channel bandwidth idle for long time thereby degrading the routing performance.

4.2. Credit Based Strategy

Credit based strategy is an enhancement of barter based strategy. To remove the problem of inefficient bandwidth utilization in barter based strategy, credit based strategy was proposed. Incentive schemes do not consider social selfishness. So they can't deal with it directly. By applying incentive mechanism a node will have to make its resources available for other nodes even though there is no social tie. The source node sends some credits along with the message, which will be given to a number of relay nodes in return of forwarding the message. A source node which has higher credit gets more chance to forward its messages through relay nodes as compared to other nodes. A relay node get credits for forwarding the messages which it has received from the source node or from another relay node, so that available credit can be used later to deliver its own packets. This strategy laid emphasis on finding whether the relay nodes get credit from the source node or from the destination node since there is no third party in DTN. Two models were suggested in order to give credit to relay nodes [27].

1) Packet Purse Model 2) Packet Trade Model[28][29].

In packet purse model, the generator of the message, i.e. the source node loads some credit points with the message which has to be given to relay nodes. The loaded credit points should be sufficient to reach up to the destination and if it doesn't loaded sufficient amount, then the message will be discarded in the middle of its route. These credits are to be loaded only once, i.e. at the start. While this message forwarded from one relay node to another one or more credit points will be taken from this message by these nodes. The source doesn't know how much it has to pay for delivery of the message, since there is no predefined route for the message transfer. As relay node can take more than one point for forwarding the packet, there should be some restrictions placed on the intake of credit points. In this model, it should be compulsory that the relay node must forward the messages of source node after getting the credits for the message, but in reality it may not happen. So, the packet purse model is more reliable for source generator, because its payment will not be wasted and messages will be delivered.

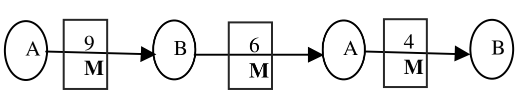


Fig: 5 Showing Packet Purse Model

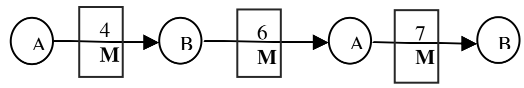


Fig: 6 Showing Packet Trade Model

Packet trade model is different from the packet purse model, because in this model whole amount is not paid by the source message generator. This model is based on the buy and resale method to gain the profit. Relay nodes takes the message from source upon receiving some credit points and forward it by taking more credit points from other nodes, hence increasing its own credit also. So at each time when the message is forwarded, the credit points get increased for its forwarding and the full payment for the delivery is paid by the destination node. In practical for each message, a node should take credit points only once, but in reality it may take credit points more than once by forwarding it to different nodes. So this scenario should be avoided for better efficiency and performance.

4.3 Reputation Based Strategy

Reputation of a node is considered as the grading of node's selfishness, In other words the extent to which a node is cooperative is shown by its reputation. Reputation of a node is assigned to it by observing its behavior in the network by the other nodes [29] and it relies on node to node feedback. Node A will give positive feedback to node B only if node B forwards the messages of node A and if it does not forwards the message then node B will get a negative feedback. This feedback is treated as the reputation of node B. A node with higher reputation is assumed to be less selfish on the other hand low reputation emphasizes that, this node is non-cooperative. In credit based strategy node gets benefits based on credit only and there is no harm if a node does not have any credits whereas the reputation based strategy restricts the forwarding of the message which was received from low reputation node i.e. if reputation of a node is low then no other node will take an interest to forward its messages. Existing routing protocols of DTN relies on the delivery probability and rate of flooding. These strategies do not perform malicious node checking. So the network can easily be attacked and performance deteriorated. But this proposed strategy protects the network from such attacks.

There is a possibility of cheating in this strategy, when two nodes agree to increase each other's reputation by transmitting messages between them. To prevent this, an approach was presented in [29] .It will decrease the reputation of all the nodes simultaneously and the reputation of a node will be increased only if it will act as relay node. There will be no change in reputation of source node when it forwards its own messages. In this, reputation

is calculated on the basis of credit, i.e. after forwarding the message, the receiving node will send a token back to the sender, so that the sender will increase the reputation value of the receiving node.
There are chances that the message is not delivered successfully not only because of the selfish behavior of the node but may be because the TTL value of the message may get expired.

Table1: comparison of the different prevention strategies

Strategy	Used at	Selfish Detention	Performance with selfish node in network	Delivery cost
Barter	Peer To Peer	No	Low	High
Credit	Source to destination	No	Low	Not More than barter
Reputation	Node to Node	Yes	High	Low

4.4. Routing with Aware about selfishness "SSAR"

Selfishness is a major issue in DTN. In the incentive scheme, if a node is willing to cooperate with another node then it will get help from that node in return. In reputation strategy, if a node will not help other nodes it will get punished. But in *Social Selfishness Aware Routing [30],* only the resources which are available will be utilized for the routing process, so that preserving the resources will not be a reason for a node to be selfish.

In SSAR scheme selfishness of the node can be ignored and will not affect the performance of the network. A node becomes selfish because it wants to preserve its resources like buffer and bandwidth. If the sender node forward messages more than the capacity of recipient node's buffer, then these messages will be dropped. Hence the message dropping rate will be increased and delivery ratio will be reduced.

In SSAR, a node which wants to send the message to the node must first check the willingness of the receiving node before forwarding the message.

If it is ready to forward the message then they exchange some details of the message like destination Id, TTL and the priority of the message. After receiving these details from the sender node, the receiving node creates a priority list based on its own interest by calculating some probabilities and then forwards this list back to the sender.

After verifying this list, sender decides which messages should be transferred to the target node for delivery.

For this scheme, nodes first need to calculate some probabilities like meeting probability, delivery probability buffer overflow probability. Here meeting probability is the probability that TTL value of message will expire before intermediate nodes meets its destination node. If a message has less meeting probability than its delivery probability then forwarding of that message will increase the network traffic. Buffer overflow is that, a node's buffer got filled and a new message of higher priority came, then the low priority messages will be dropped in order to accommodate those newly arrived high priority messages. Probability of this dropping is referred as buffer overflow probability. So, after obtaining all these probabilities as well as the details of available free buffer, only those messages are forwarded which have higher delivery probabilities.

5. Comparison of Strategies

This section present comparison of the different prevention strategies which are used to reduce the impact of selfishness on the network performance.

In [4], et al. *J. Miao, O. Hasan, S Ben Mokhtar,LBrunie*and *K. Yim* has given the comparisons under the Individual and social selfishness of delivery ratio and delivery latency (simulation based study) in Barter, MobiCent [31] and Ironman which are based on Barter, Credit based and reputation based strategy respectively.

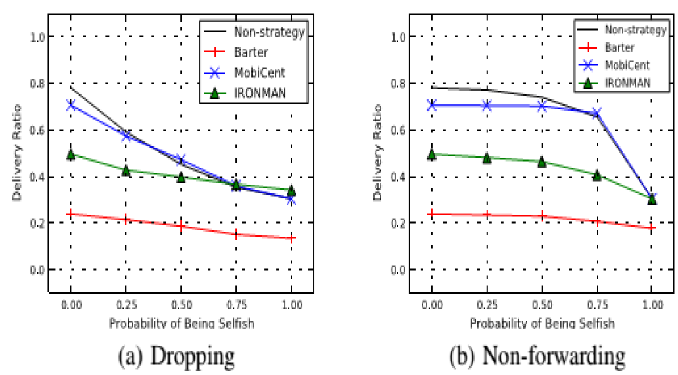
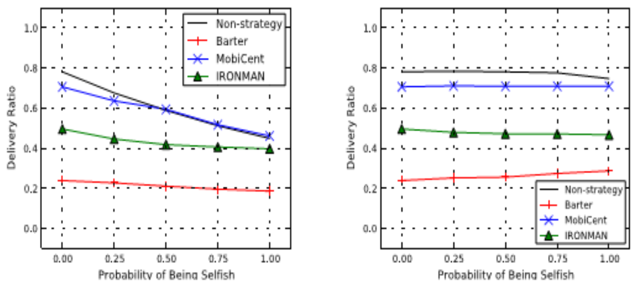


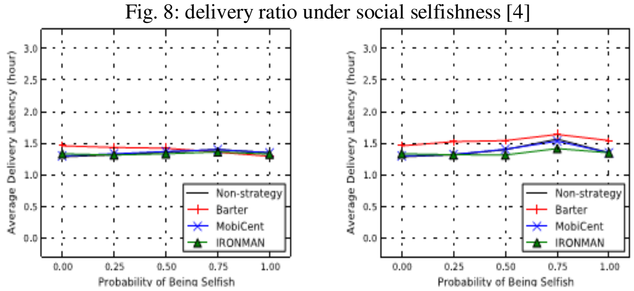
Fig 7: delivery ratio under individual selfishness [4]

Fig.7 and Fig. 8 simulation results is taken from [4], that are showing the delivery ratio performance considering the impact of individual and social selfishness on the routing respectively [4].



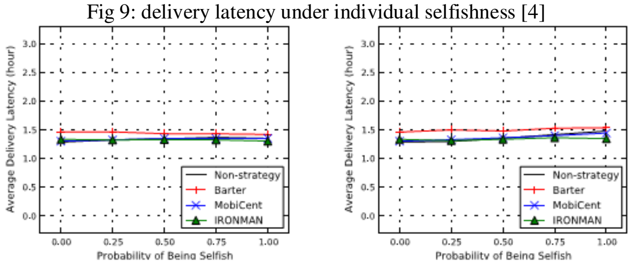
(a) Dropping (b) Non-forwarding

Fig. 8: delivery ratio under social selfishness [4]



(a) Dropping (b) Non-forwarding

Fig 9: delivery latency under individual selfishness [4]



(a) Dropping (b) Non-forwarding

Fig 10: delivery latency under social selfishness [4]

Fig. 9 and Fig. 10 simulation results is taken from [4], that are showing the delivery latency considering the impact of individual and social selfishness on the routing respectively [4].

SSAR is different from above mentioned strategies and is based on a number of probabilities. It gives better results than PROPHET [32], the basic routing protocol of DTN which works on the basis of probability. SSAR has higher packet delivery ratio and outperforms PROPHET by 35%-40%. This is because SSAR considers different factors such as node's willingness, buffer constraints etc .It will not contact low-willing nodes for routing a message, and hence the messages will not dropped by these nodes. SSAR will not forward a packet to the node whose buffer is not capable to store the incoming messages.

6. Conclusion

In DTNs, as no complete end to end path between source and destination nodes exists, the routing performance is considerably less and is largely dependent on the cooperation of intermediate relay nodes. But the selfish behavior of relay nodes may severely hamper the performance of the routing protocols. Existing protocols such as spray and wait, epidemic etc. does not consider the selfishness of the node. A review of different strategies namely: Barter Based, Credit Based and Reputation based, which may be used to prevent the impact of selfish nodes has been presented in this paper.

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