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Social Group-Based Routing in Delay Tolerant Networks using Fuzzy Logic

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Abstract: ***Delay tolerant networks (DTNs) may lack continuous network connectivity. Routing is thus challenging since it must handle network partitioning, long delays, and dynamic topology and limited power sources in such networks. Social Group-Based routing is an optimal routing, the protocol maximize data delivery while minimizing network overhead and packet delay by efficiently spreading the packet copies in the network. Social grouping concept is used for routing effectively by selecting minimum hop path from the all possible path of tree contacts. The members of its own group should be known to all and message is forwarded to member of other social group only. Messages to the nearest group is forwarded without waiting for the other group member, by selecting most suitable relay node from the same group. The fuzzification of degree of connectivity that strengthen by frequent meeting of nodes and the mobility of nodes help to fuzzify the membership of nodes in the case of overlapping communities to select the better relay node. The protocol achieves higher delivery ratio, less network overhead and less average delay compared to other routing protocols.***

Keywords: Social-based routing, Delay Tolerant Network, Fuzzy logic, social group, social characteristics

1. Introduction

Delay or disruption tolerant networks (DTNs) [1] have wide applications in environments, such as space communications, military operations, and mobile sensor networks. Intermittent connectivity in DTNs results in the lack of instantaneous end-to-end paths, large transmission delay and unstable network topology. Routing is thus challenging in such networks. DTN routing method uses a similar paradigm, the 'store and forward' fashion or the 'spray and wait' mechanism. If there is no connection available at a particular time, a DTN node can store and carry the data until it encounters other nodes or it will spray the data to the available nodes hoping for final delivery. This results in network overhead. The consideration of social characteristics [2] provides a new way of designing DTN routing protocols. In most of the DTN applications, mobile devices are used and carried by people, whose behaviours are better described by social models. This opens the possibilities of social-based DTN routing, in which the knowledge of social characteristics are used to make better forwarding decision. Based on this observation and taking the recent advances in social network analysis, several social-based DTN routing methods have been proposed to exploit various social characteristics in DTNs (such as community, centrality, friendship, similarity and social energy) to assist the relay selections. Correctly using these characteristics can improve the DTN routing performance compared to probabilistic routing and opportunistic routing.

The consideration of social characteristics [3]-[9] provides a new way of designing of DTN routing protocols. In most of the DTN applications (e.g. vehicular networks, mobile social networks, disease epidemic spread monitoring and pocket switched networks), a multitude of mobile devices are used and carried by people, whose behaviours are better described by social models. This opens new possibilities of social-based DTN routing, in which the knowledge of social characteristics are used to make better forwarding decision. Social relations and behaviours among mobile users are usually long term characteristics and less volatile than node mobility. Based on this observation and taking the recent advances in social network analysis, several social-based routing methods have been proposed recently to exploit various social characteristics in DTN (such as community and centrality) to assist the relay selections. Correctly using these social characteristics can improve the routing performance.

The relay nodes are selected in social-based routing based on social characteristics. The social metric values of nodes are calculated and nodes with highest value is selected as suitable relay node. In some cases there may be more than one suitable relay node. In optimal routing only one node is to be selected as relay node and the suitable relay node can be selected based on its membership value. Using fuzzy logic [12]-[14] the node membership can be varied among the groups since the node that belong to overlapping communication area behave as if it belongs to two groups. The membership of such nodes can be varied among the groups and can select the better relay node.

2. Related works

The previous study includes several social-based DTN routing methods that take advantage of positive social characteristics in networks. Hui et al. [3] introduces a routing method based on community labels in Pocket Switched Networks. To reduce the amount of traffic created by forwarding messages in PSNs, the proposed routing method uses a labelling strategy to select forwarding relay. Daly et al. [4] proposed a social-based routing protocol which uses betweenness centrality and similarity metrics to identify some 'bridge' nodes (with high values of these metrics) in networks. A common neighbour with the destination can be fnd out with high delivery performance. The forwarding strategy, Bubble Rap Forwarding, proposed by Hui et al. [5] also relied on two social characteristics community and centrality. They assumed that each node belongs to at least one community and its node centrality (either betweenness or degree centrality) in the community describes the popularity of the node within this community. This allows fast transfer of messages. Lunan et al. [6] proposed a group based routing protocol in which the relay node is selected based on social group information obtained from historical encounters. Social group is formed based on the information obtained from network and the community groups. Group formation require entire information about network. Bulut et al. [7] also used friendship to aid the delivery of packets in DTNs. They introduced a new metric, social pressure metric (SPM), to accurately detect the quality of friendship. If the source node fail to meet a node in the same friendship community with the destination, the delivery fails. Fan Li et al. [8] proposed a new metric social energy to quantify the ability of a node to forward packets to others, inspired by general laws in particle physics. Social energy is generated via node encounters and shared by the communities of encountering nodes. The social energy of any node decays over time. A node with high social energy is a good forwarder of messages. Tamer et al. [9] proposed Social Group Based Routing that is based on social grouping. Here, a node will forward data to member of other group only since it is useless forwarding to the same group. The relay node is selected based on several constraints. This routing protocol is efficient, that achieve high delivery ratio and with less delay. In this paper a new approach for Social Group Based Routing is proposed finding some situations in which the protocol perform low.

3. Proposed work

In this section a new routing method is introduced which is the enhanced version of the method, proposed by Tamer et al. [9]. In [9] Social Group Based Routing is described that route the packet in DTN based on social group using the metric degree of connectivity. It is an optimal routing method in DTN with minimum network overhead and less packet cost. But there are two drawbacks for this method.

In Social Group-Based Routing, a node should know the nodes that belong to its group (having strong connection) and those that are not. The node will send the packet only to another node which is not a member of the same group since it is useless to carry multiple copies within the same group. If there is a relay node that belong to the group of source node, with a single hop to destination; that node is not selected for relay since that node belong to the same group (even it is the best relay node). So a relay node should be chosen irrespective of group in optimal routing that maximizes packet delivery with minimum network overhead and delay is needed. Also while sending the message the nodes that belong to two communities are not considered. For sending the message, since the node belong to two groups, every time it is not selected as relay since it is the same group member. This increases the message forwarding time and reduce the message delivery ratio. So the fuzzifcation of node membership is needed in optimal routing that maximizes packet delivery with minimum network overhead and delay is needed.

3.1 Optimal Routing in DTN

Optimal route for a message is that maximizes certain utility or minimize defined cost. In this protocol, it minimize delay, minimize number of hops, and maximize number of delivered messages. Minimizing the hop count will achieve the highest packet delivery ratio with minimum network overhead. To find the optimal route for a message, first all possible path for that message is found and from that, an optimal path for message is selected.

3.1.1 Finding all possible paths for message

All possible paths for a message m is find by tracing the tree of node contacts. A valid path is the one that has timely ordered contacts from source to destination and does not violate the message lifetime (TTL) constraint. The set of constraints that are to be followed to select the set of paths are:

(a) Flow Conservation: Every node $n \in N$, except for the source and destination, included in the selected path of a message m should be associated with two contacts:– A contact in which the node receives the message from the previous node on the route and a contact in which the node sends the message to the next node on the route.

$$\sum_{c1 \epsilon C} x_{c1}^{n} - \sum_{c2 \epsilon C} x_{c2}^{n} = 0 \quad \forall n \epsilon N, if\ n = R_{c1} = S_{c2} \qquad (1)$$

where C is the set of all contacts, c represent contact between nodes, S_c is the sender node of contact c and R_c is the receiver node of contact c.

(b) Source and Destination: The source node is associated with only one contact in which message m is sent by that node. The destination node is associated with only one contact in which message m is received by that node.

$$\sum_{c \epsilon C} x_c = 1 \qquad (2)$$

(c) Contacts order: Contacts along the message route should have increasing order of their starting times. If there are two contacts c1 and c2 that are candidates to be in message m route in the order c1-c2, then it should verify that $t_{c1} < t_{c2}$, where t_c represents starting time of contact and T represents total time.

$$t_{c1} x_{c1} + (T - t_{c2}) x_{c2} < T \qquad (3)$$

(d) Message Lifetime: The starting time of the any contact on the message route should be less than the message lifetime (L_m).

$$t_c x_c < L_{m,} \forall\ c \in C \qquad (4)$$

3.1.2 Finding the optimal path for message

Set of paths, Pm, for each message m are the inputs and one path (the optimal route) for each message m is the output. The objective is to minimize the total number of hops (contacts) for all the routes and to select optimal route there are some constraints. They are:

(a) Buffer constraint: The total amount of message bytes transferred during each contact should not exceed the receiver buffer capacity.

(b) Contact duration: The sum of all message transfer times during a contact should be less than the duration of that contact..

(c) Paths per Message: For each message, there should be only one path selected.

3.1 Protocol Design

This protocol is based on social grouping among the network nodes to maximize data delivery ratio while minimizing network overhead by efficiently spreading the packet copies in the network. The two nodes belong to same social group if they contact each other frequently compared with other nodes. For example, in an institution the people of same class meet frequently than the other people. So they will be in contact with the same group members and are capable to send message to same group. The routing protocol reduce network overhead by spreading small number of packet copies. This also reduces the packet cost and group based approach ensures data delivery. The previous social based routing protocol uses inclusive social metrics, which forward the packet to nodes with strong social connections. The network wide information from source to destination is needed to predict the path and this is the disadvantage of these previous [3]-[8] approaches.

The nodes with strong connections are placed in one group. To measure how strong the connection between two nodes, degree of connectivity denoted by Γ_{ab} is used. This is strengthened by frequent meetings of node a and b and values are elapsed by time. When two nodes meet, they update their degree of connectivity and is given as:

$$\Gamma_{ab} = (\Gamma_{a,b})_{old} \ \gamma^k + (1 - (\Gamma_{a,b})_{old} \ \gamma^k) \alpha \qquad (5)$$

Where Γ_{ab} is the degree of connectivity between nodes a and b , $(\Gamma_{a,b})_{old}$ is the degree of connectivity before equation, α is the updating factor, γ is the ageing constant and *k* is the number of time units that have elapsed since the last time nodes a and b have met.

3.2 Protocol Description

The protocol SGBR using fuzzy logic is described in two steps. In SGBR using fuzzy logic, for the nodes that are closer to each other(near group nodes) the source node will not wait for a node from other group as relay node. So initially if the destination is reachable in single hop is checked and if so then most suitable relay node is selected from same source group based on distance and degree of connectivity. Otherwise it will check whether any node belong to overlapping community or not, if any node in that group belongs to other group then its membership is fuzzified and route the packet to destination using normal SGBR. In all the other cases the normal SGBR is used.

3.3.1 If destination is reachable in single hop

If the destination is reachable at single hop from the sender, that is the source and destination group are near to each other, then that node is not considered in SGBR. It will wait for a suitable relay node from other group to send the message. Here delay is more in sending the message. So inorder to reduce the delay, the node with 'highest degree of connectivity' is selected from the same group of source node is selected. So the time for collecting network information is not required and the delivery of message will be faster with less network overhead.

3.3.2 Fuzzification of membership

In the case of overlapping community where a node behave as it belongs to two groups or communities, the membership of node has to be fuzzifed for better forwarding. Fuzzy logic idea is similar to the human being's feeling and inference process. Unlike classical control strategy, which is a point-to-point control, fuzzy logic control is a range-to-point or range-to-range control. The output of a fuzzy controller is derived from fuzzification of both inputs and outputs using the associated membership functions. A crisp input will be converted to the different members of the associated membership functions based on its value. Here the 'degree of connectivity' and 'mobilityt of nodes' are considered for the fuzzification.

Fuzzification is the first step to apply a fuzzy inference system. Most variables existing in the real world are crisp or classical variables. One needs to convert those crisp variables (both input and output) to fuzzy variables, and then apply fuzzy inference to process those data to obtain the desired output. Finally, in most cases, those fuzzy outputs need to be converted back to crisp variables to complete the desired control objectives. Inorder to derive the membership functions (μ) for input and output variables for fuzzication 'degree of connectivity' and 'mobility of nodes' are considered. For SGBR using fuzzy logic, certain rules are considered based them. Fuzzy mapping rules work in a similar way to human intuition or insight, and each fuzzy mapping rule only approximates a limited number of elements of the function, so the entire function should be approximated by a set of fuzzy mapping rules. On these rules min-max method [14] is applied.

The conclusion or control output derived from the combination of input, output membership functions and fuzzy rules is still a vague or fuzzy element, and this process in called fuzzy inference. To make that conclusion or fuzzy output available to real applications, a defuzzification process is needed. The defuzzification process is meant to convert the fuzzy output back to the crisp or classical output to the control objective. The fuzzy algorithm is described in Algorithm 1.

Algorithm 1: Fuzzy logic algorithm

1. Define variables for Γ_{ab} and mobility
2. Construct membership function μ for Γ_{ab} and mobility
3. Construct the knowledge base rules for group membership
   a. If Γ_{ab} =HIGH and mobility=HIGH, then INCLUDE
   b. If Γ_{ab} =HIGH and mobility=LOW, then INCLUDE
   c. If Γ_{ab} =LOW and mobility=HIGH, then NOTINCLUDE
   d. If Γ_{ab} =LOW and mobility=LOW, then NOTINCLUDE
4. For the node that belong to overlapping community, convert Γ_{ab} and mobility in to fuzzy set using membership function μ
5. Evaluate the rules using min-max method on the μ values,
   $\Gamma_{ab} \circ \text{mobility} = \{[x,y];\ \max\{\min\{\ \mu_{\Gamma ab}(x,y),\ \mu_{mobility}(x,y)\}\}\}$
6. Take decision on the value obtained based on the rule created to include in group or not
7. Route using SGBR method

4. Results and Analysis

For evaluating the SGBR and the fuzzy logic method, The project is implemented using NS2. Nodes are mobile. The nodes are divided in to groups based on the degree of connectivity values using the equation specified. If there single hop to the destination or the destination is nearer to the source group, node with high degree of connectivity is selected from the same group. Also when nodes belong to overlapping community, its membership is fuzzified using the degree of connectivity and distance between nodes.

The proposed Social Group-Based Routing using Fuzzy logic is compared with the existing Social Group-Based Routing for better routing. Packet delivery ratio, overhead and Average delay are the parameters. Once the modification is done it is found that the network delay and overhead involved in packet transmission is reduced slightly. In the case of nearest group, no much network wide information is required since the routing will take place by considering the nearest relay node in same group. But in the case of SGBR it will wait for node from other group without considering the suitable node from same group. The average delay comparison is shown in Figure 1.

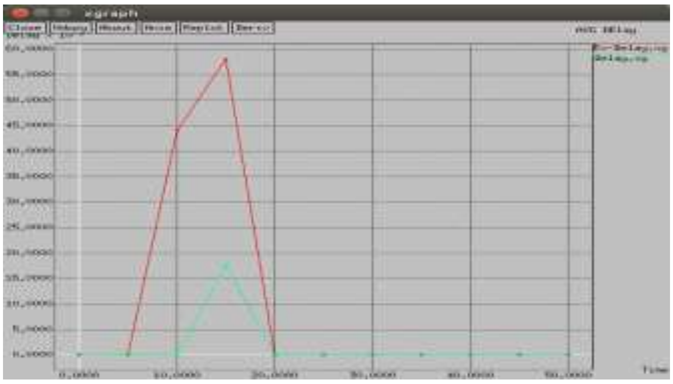

Figure 1: Average delay comparison

The average packet delivery ratio is increased slightly and packet drop is less when compared to the SGBR. Since the fuzzification of nodes that belong to the overlapping community is considered, that nodes are always selected and so the packets can reach the destination before packet life time, other wise it has to wait to get a link with the other group node. The packet delivery ratio is shown in figure 2. The network overhead is less compared to the SGBR and is shown in figure 3.

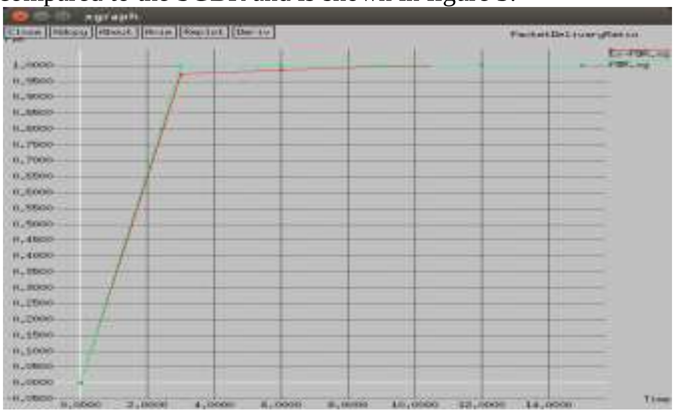

Figure 2: Packet delivery ratio comparison

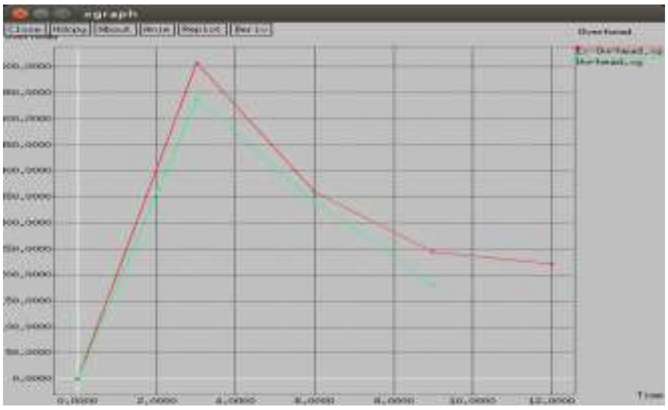

Figure 3: Network overhead comparison

5. Conclusion and Future works

The experimental results conclude that the proposed method produce better results compared to the existing SGBR. Here the time need to route to the nearest group is very less compared to the SGBR since it will not wait for a node from other group, and hence delay is less and the network wide information needed is very less. Using fuzzy logic in SGBR is much better way of selecting the relay node rather than plain routing, by fuzzification of the membership when a node belong to two groups and it perform well with the dynamic environment. Social Group-Based Routing using fuzzy logic is an optimal routing that maximizes packet delivery and minimizes delay and less routing overhead with zero or less packet ooding in network. Combining multiple metrics and routing using fuzzy logic may provide opportunities to improve the overall performance of routing and hence can reduce delay and better forwarding of packets. The drawback of this method is that this could do the fuzzification between two groups only. Multiple social metric and better fuzzy approach can be used to get better membership and forwarding.

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