A Survey on Routing Algorithms of Mobile Social Network

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***Abstract*—Mobile Social Network (MSN) is gaining popularity day by day since the emergence of smartphones, tablet and other mobile devices. Human collaboration is increasing due to rapid use of MSN. MSN uses social behavior for making better routing decision and to improve routing performance. MSN applications provide diverse services both to application developers and users. In this paper, we present a survey about different MSN routing protocols, social characteristics of routing mechanism. The motivation of different routing schemes is to ensure optimization of data sharing and message transmission. We also discuss some increasingly popular MSN applications and their demand to the users. We analyzed time complexity of routing strategies and compared the protocols based on some metrics.**

***Index Terms*—Mobile Social Network, Opportunistic routing, Community, Socially selfish, Delay Tolerant Network**

I. Introduction

In the recent years, the usage of social network has increased exponentially. As mobile devices have gained huge popularity these years, almost everybody carries mobile devices. In recent years, Facebook, Twitter are the most popular social networking applications which provide instant access for the users from anywhere using Internet. Mobile social network is combination of two notions i.e. social network and mobile network, shown in Figure 1. More specifically, Mobile Social Network(MSN) is a network with social characteristics where mobile users having similar type of interest move around and communicate with each other by their smartphones, tablets etc. MSN is one kind of Delay Tolerant Network (DTN) lacks continuous Internet connectivity owing to mobility of users. Moreover, mobility of users can cause difficulty for data sharing and data transmission [4]. Hence, routing packets in MSN is different from other wireless network and routing packets to the destination is a challenging problem.

As MSN is a combination of DTN with social behavior pattern, it has got enough attention to the researchers. Ongoing research is going on both on Web based MSN [4] and Distributed MSN. In web based MSN online applications are used for communication by the mobile users through WiFi connection. Web based MSN is designed on central server communication. On the other hand, Distributed MSN does not use the concept of central server rather mobile users share data by forming group, without the help of central server communication. For instance, in video chatting, users share video within the community.

Researchers have proposed different routing mechanisms to address routing problem in MSN. The authors of [7] have proposed social-aware routing algorithms based on community home model. In real world, people form a community who share some common interest. For instance, students who have common interest in the same course they go to same class room to form a student community. Likewise the mobile users having similar interest visit some locations frequently called *homes*. Home-aware community is the key concept of [7] where each community home is capable of storage and transmission of messages. In [5], authors have introduced Socially Selfishness for increasing routing performance in MSN. They introduced socially selfish routing which denotes that a node is willing to forward packet to another node with whom it has social bonding. The basic concept of this paper is compared to real life example, where people are actually socially selfish which means people are inclined to forward packets to other people with whom they share a social bonding. Social ties can be also categorized into two types: *stronger* and *weaker*. Nodes prefer to route packets to others sharing *stronger* tie. The researchers of [6] developed a mechanism to address the routing problem due to discontinuity of Internet connection. They proposed a *zero knowledge* MSN routing algorithm named *Homing Spread* which ensures efficient packet routing.

In this survey paper, we summarize different routing strategies of [7],[5],[6]. Our main contributions of this paper are summarized as follows:

- We explain different routing methodologies proposed in [7],[5],[6].
- We compare and contrast the routing algorithms
- We provide advantages and limitations of proposed mechanisms of the papers

The rest of the paper is organized as follows: applications of MSN are described in Section II. Routing protocols are discussed in Section III. Comparison between algorithms are given in Section IV. Discussion and Conclusion is given in Section V and VI respectively.

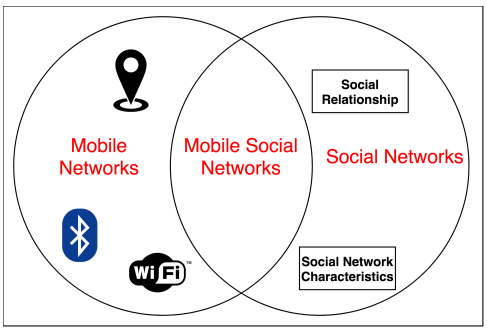

Fig. 1. Relation between Mobile Networks and Social Networks

II. Applications of MSN

A. Online Social Networking Service:

Online social networking applications are gaining popularity because people are eager to know each other and to make new friends. Virtual social network is attracting a lot of people. MSN provides freedom to the users to move anywhere which results in user satisfaction.

B. Location Tracking Service

Location based service i.e. Global Positioning System(GPS) is very important applications of MSN. People can get specific information about a location using their mobile device. Location information can be shared with other people into the network. Finding location for instance bank, university, restaurant has become easy using MSN [4].

C. Health Care Service

MSN is being used for providing proper health care service for physical and mental illness. In recent time, several health care applications are gaining attention to the health conscious people. These applications provide treatment information and guidance to the patients.

III. Routing Methodologies

1) Community Aware Opportunistic Routing: Community Aware Opportunistic Routing (**CAOR**) algorithm proposed in [7] ensures efficient routing while minimizing the computational cost. The routing scheme in [7] is based on home centric community model depicted in Figure 2. Basic idea of this algorithm is to deal with community homes rather than nodes because the number of homes are far less than number of nodes which results in lower computational cost. Authors are referring the routing technique as opportunistic routing because routing decision is made based on opportunistic rule. And this mechanism allows sender to deliver messages by optimal relay set. CAOR has two phases: *Initialization Phase* and *Routing Phase*.

Initialization Phase: Instead of handling large number of nodes *Initialization phase* simplifies the network based on community homes. In this phase *optimal betweenness set* has been determined. According to [7], if a home l sends a message to another home l', then it takes a relay set for delivering the message and if the relay set gives smaller delay for sending message than other relay sets then it is called optimal betweenness set. Based on the concept of *optimal betweenness set*, the whole network including all homes has been converted into a simplified network.

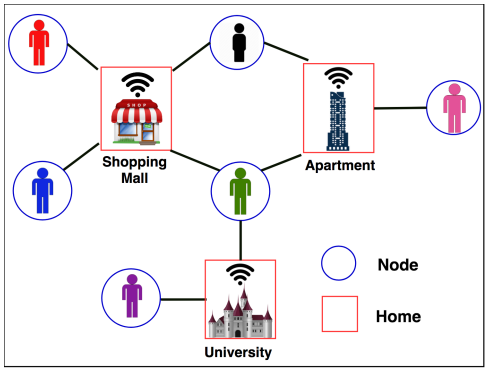

Fig. 2. Home centric Community

Routing Phase: Routing phase follows opportunistic routing to deliver messages and compute minimum expected delivery delay using Reverse Dijkstra algorithm. A node v gets the directed weighted graph from home and extends the graph by adding the destination node. The opportunistic routing ensures to achieve the optimal delay for delivering the message. Moreover, They extend the algorithm by computing residual probability (The probability that a node v visits its home l for k times) when the home nodes have no ability to store messages and the extended algorithm uses these nodes to act as the message relays. The algorithm uses 0.9 residual probability which can achieve almost optimal performance.

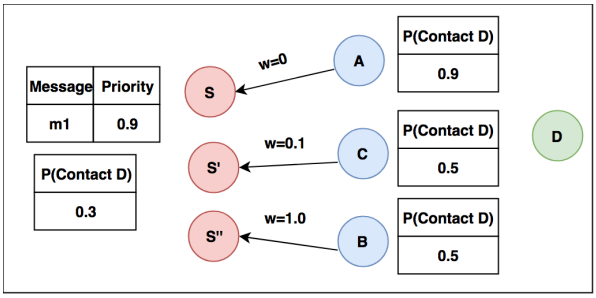

Fig. 3. Packet forwarding based on user willingness

2) Social Selfishness Aware Routing: Social Selfishness Aware Routing (**SSAR**) algorithm in [5] provides better routing performance as well as maintain social selfishness. Each node is associated with a buffer where it stores packet according to its priority. Incoming packets with higher priority is stored and in case of buffer overflow packets with lower priority are dropped. Packet forwarding depends on contact opportunity and willingness to forward. The authors designed a scheme for the reduction of packet dropping rate as well as maintaining social selfishness. For ensuring higher packet delivery rate and lower packet drop rate SSAR developed the forwarding process based on Multiple Knapsack Problem with Assignment Restrictions (**MKPAR**). This algorithm takes greedy approach to forward packets which is dependent on a node's contact opportunity and its willingness to forward the packet.

In this algorithm the selfish gain of a packet is the product of it's priority p and it's delivery probability ΔP, so selfish gain= p . ΔP. From the equation it is clear that the higher the priority, the larger the selfish gain is. Similarly, the higher the delivery probability is, the larger the value of selfish gain will be. **SSAR** mechanism ensures that in a candidate packet set C, the packets with higher selfish gain are forwarded efficiently. Packet forwarding according to selfish gain is depicted in

TABLE I
COMPARISONS OF MSN ROUTING PROTOCOLS [8, 1]

Routing Protocol	Community	Centrality	Similarity	Social Selfishness
CAOR [7]	✓	✓		
SSAR [5]				✓
HS [6]	✓			
SimBet [2]		✓	✓	
Bubble Rap [3]	✓	✓		

Figure 3.

3) Zero Knowledge Routing: Homing spread (**HS**) in [6] is a *zero knowledge* routing algorithm consisting of three phases:*homing, spreading, fetching*. In the *homing* phase, source sends copies to homes. Homes send copies to other homes and mobile nodes in *spreading* phase. In *fetching* phase the destination fetches message from the message holder. **HS** provides optimality for decreasing expected delivery delay to destination. The algorithm sets higher priority for the community homes to spread messages quickly into the network. **HS** also computes expected delivery delay using Markov Chain Model.

The authors of [6] have determined all possible states in a *state transition graph* and also *state transition function*. The authors denote the state transition function as *probability density function* which takes the state transition from s to s', where s, $s' \in S$ and S is the state space. In the final step, the end state is added into the graph to complete the state transition graph.

4) SimBet: SimBet [2] is well-known algorithm based on social routing. This protocol uses betweenness similarity and centrality to find some bridge nodes in the network. In this algorithm, a node estimates the neighborhood nodes (Pre-estimated betweenness centrality metric and social similarity) and instead of sending information to the whole network, it sends the information to its neighbor nodes.

5) Bubble Rap: BubbleRap [3] is packet routing methodology based on community and centrality characteristics. In this algorithm two assumptions are considered by authors,

- Each node has a global centrality in the whole network

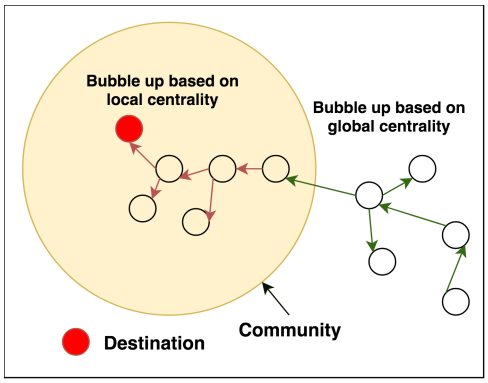

Fig. 4. Illustration of Bubble Rap Algorithm

- Each node belongs to at least a community

BubbleRap algorithm has two phases [8]: bubble-up phase based on the global centrality and bubble-up phase based on local centrality. When a node s gets a message with the information of destination d, it bubbles the message based on the global centrality and this process continues until the message reaches to a node which is in the same community with destination d. Then the algorithm steps into the second phase (bubble-up phase based on local centrality) and bubbles up the message based on local centrality till the message reaches the destination. Comparison of the algorithms are shown in Table I.

IV. ALGORITHMS IN COMPARISON

A. Time Complexity Analysis

For the computation of minimum expected delivery delay, *CAOR* [7] uses reverse Dijkstra algorithm. Minimum expected delay is ensured because of opportunistic routing rule. The algorithm works on number of community homes rather than nodes, so the computational complexity is $O(|L|^2)$. *SSAR* [5] is based on *MKPAR* which is a greedy algorithm. According to this algorithm the packets are ranked in the decreasing order of the *selfish gain*. Due to nested *For loop* in the algorithm, time complexity is $O(|C|^2)$. For determining *state transition graph* and all possible states in the graph, the *HS* [6] algorithm takes $O(|S|^2)$ execution time.

TABLE II
TIME COMPLEXITY COMPARISON

Routing Protocol	Time Complexity	Notation
CAOR [7]	$O(\|L\|^2)$	L is number of Homes
SSAR [5]	$O(\|C\|^2)$	C is candidate packet set
HS [6]	$O(\|S\|^2)$	S is state space

B. Advantages and Challenges

The main advantage of *CAOR* [7] is it has significantly reduced computational cost by by using community homes instead of nodes. Because $O(|L|^2) << O(|V|^2)$, where L is number of community home and V is number of nodes. Both routing performance is increased and social selfishness is maintained by *SSAR* [5]. As social perspective and user willingness is emphasized. packet routing strategy provides better performance. *HS* algorithm [6] ensures spreading of higher priority messages by the community homes in a quicker

way. The advantage of using *zero knowledge* routing algorithm is that it does not require any advance knowledge of contact information of nodes.

The aforementioned routing protocols provide considerably satisfactory performance because of combining multiple social metrics such as community and centrality. However, combining too many metrics may lead to poor performance under certain situation. For instance, in a dispersed DTN multiple metrics can degrade the performance [8]. Incorrect combination of metrics can also cause increase in complexity. Large set of nodes may cause computational overhead. Ensuring privacy should be another important factor for protecting user data and provide authentication. Performance of routing protocol depends on different mobility pattern, social behavior, node diversity. Therefore, a perfect routing solution addressing all these issues is very tough.

V. Discussion

The authors of [7] conducted their experiment in Dartmouth College campus. This experiment involved 507 access points and more than 500 nodes. They computed average delivery delay for different number of nodes. Source and destination nodes are selected randomly and 10000 messages are generated from these nodes. Messages are assigned time-to-live (TTL) value, a message is dropped if this time value is expired. They computed successful message delivery ratio for different number of weeks and average delay for large number of nodes. In both cases simulation result shows CAOR achieves better performance compared to SimBet and Bubble rap.

Effects of TTL has been studied in [5], the value of TTL has been varied from 0 to 125 days to observe the packet delivery ratio and cost. The results show that more packet can be delivered with increasing TTL. The routing mechanism of SSAR avoids forwarding packet to a receiver whose buffer space is already full whereas routing strategy of SimBet can not achieve this which results in packet drop owing to buffer overflow. SSAR can make a smart use of social selfishness because it considers contact opportunity, user willingness and buffer space limitation. Briefly, SSAR outperforms other algorithms in terms of social ties.

In [6], experimental testing has been conducted with varying number of homes. From the simulation result it is clear that when the number of homes increase then average message delivery delay is reduced noticeably. while evaluating delivery ratio, *Homing Spread* algorithm can deliver packets in a faster way.

VI. Conclusion

MSN creates a strong link between mobile technology and social network. MSN applications are used widely used and people are getting more attracted to the MSN applications. MSN has contribution in different sector of life such as health sector, online networking which helps people to grow larger community, social gaming etc. In this paper, we discussed about several routing methodologies, features and objective of the routing algorithms. we also gave a comparison of the algorithms based on social metrics.

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