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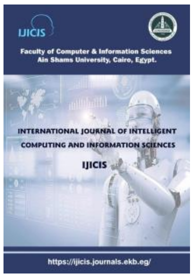

A Review of Routing Protocols for Mobile Social Networks

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Abstract*- A Mobile Social Network (MSN) consists of nodes that are related socially, in addition to their physical connection through wireless links. In terms of mobile devices, social connection reflects the frequency of encounter, so that the users of these devices are socially connected if they communicate with each other frequently. This layer of social connectivity, combined with the physical connectivity of being in the communication range of each other, can help improve the routing performance. However, it also inherits the challenges of mobile adhoc networks. These challenges include the limited energy resource, intermittent connectivity, and the limited storage. To overcome these challenges and improve routing efficiency, social metrics are exploited to carefully choose the candidate relays in MSNs. In this paper, the routing protocols proposed or candidate to be implemented in MSN are reviewed, focusing on the routing metrics used to select the candidate relays. In addition,* the authors *describe a list of performance measures that are useful in comparing current and future MSN routing protocols.*

Keywords: *Mobile Social Network (MSN), Routing, Social Profile*.

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1. INTRODUCTION

Mobile Ad Hoc Networks (MANET) comprise mobile devices that interact dynamically through an infrastructure-less wireless network. MANET is an autonomous network in which each node not only serves as an end point, but also as a packet forwarding router to other nodes.

Many routing protocols have been developed for MANETs that address their requirements and limitations. Some of these protocols are well suited to the dynamically changing topology. The big challenges are addressed in case of low resources, such as limited computing and battery power, while packet forwarding consumes a lot of such resources. The connection between nodes is usually temporary, time-dependent, and unstable as nodes move freely.

Social Networks have now become a significant addition to mobile networks. Implementing a social network on top of a MANET forms a mobile social network (MSN). There are several applications of MSNs. One of the applications could be a social network among students and staff in a school or a university. The social network could be used to access the learning management system or to take attendance and could be used to socially interact between staff and students. In all these examples, there are groups within the network who interact socially on top of their physical wireless connection. One observation that could be noticed is that individuals with similar interests are likely to meet and contact each other frequently through their mobile devices. Therefore, inside the network, there are clusters which are defined based on the social interactions among their members. Using this feature, the authors can improve the routing performance of the underlying network.

Many web-based social networks have created mobile applications to give their users instant real-time access, such as Facebook and Twitter. However, these applications are based on the internet as a physical infrastructure. In MSN, there is no infrastructure and each node function as a router [1], [2], and [3], and thus users communicate with each other when they are in the proximity.
By utilizing the social connectivity among users, the authors can search for users with similar interests, and establish and maintain communication between them. Moreover, the authors can improve the performance of routing protocols by reducing end-to-end latency and maximizing the delivery ratio.

Routing in MANET is carried in an opportunistic way as the end-to-end connections do not always exist. A connection between two nodes may not be always available or may not be possible at all. MSN routing utilizes a store-carry-forward strategy where relay nodes carry the messages to reach their destinations.

As shown in Figure.1 (A), depending on the number of message copies in the network, routing techniques can be classified into single-copy and multiple-copy routing. Single copy routing indicates that only one copy of a message exists at any time on the network. Multiple-copy routing is when messages are duplicated, and each copy allows independent routing decisions to reduce the transmission delay. However, multiple-copy routing often consumes a large amount of network resources. As shown in Figure.1 (B), routing can also be classified according to the destination to be unicast, broadcast, or multicast. In multicast routing, a selected group of network nodes is specified to receive the message from the sender.

The contribution of this paper can be summarized as follows:

1. A survey of the multicast routing protocols for Mobile social networks.

2. The survey focused on protocols which select receivers based on their characteristics, specifically the node social profile.
3. A social profile may include static information, such as age, name, and interests, as well as dynamic information, such as the frequency with which nodes are encountered.
4. The packets will be sent depending on the similarity measures made between encountering nodes.

The remainder of the paper is presented in the following sections. In Section 2, a comparative study between routing protocols is quoted. The authors present a comparison table of MSN routing protocols in Section 3. The performance matrix is discussed in Section 4. In Section 5, conclusions are drawn.

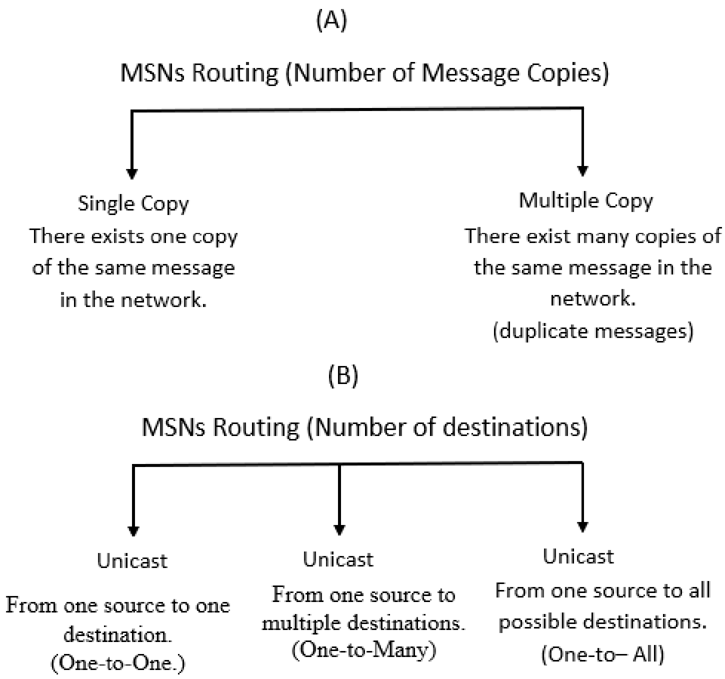

Figure.1. Types of MSNs Routing.

2. REVIEW OF MOBILE ADHOC ROUTING PROTOCOLS

Many classifications have been proposed in the literature for MANET routing protocols [24]. In this work, the authors will adopt a classification based on the layer of the available routing metrics. Most of the previous routing protocols use metrics that are available at the network or link layer to transmit the packets. Recently, some protocols were developed to utilize metrics that are available at the application layer, such as the user social profile.

1. Routing based on network or link layer metrics

The routing protocols are classified into blind and criteria-based routing. In blind routing, all nodes are candidates to be relays, regardless of their characteristics. The criterion in blind routing is just the space proximity, so that wireless communication can occur. In blind routing, and given unlimited resources, the delivery ratio improves. However, the unlimited resource assumption is not practical, and these protocols consume the resources of the mobile nodes and the network. Epidemic routing [13] is one of the implementations of this class.

In criteria-based routing, metrics are used to select the candidate relays, in addition to the space proximity of course. These metrics may include one or more of the different resources available at the mobile nodes, such as delay, throughput, power, memory, and many others. Taking these metrics into consideration helps reduce the resource consumption as in blind routing. However, the challenges become in measuring and verifying the metrics' values. The criteria-based routing can be further classified based on the metrics used. In the following, the authors review some of the metrics used in criteria-based routing.

In [11], energy-aware Centrality-based Forwarding (ECF) is used to calculate the importance of the node in the network. The value of a node's relationship to other network nodes is defined by the basic concept of centrality. In [23], Community-based routing (CBR) is used to create network communities and determine the most valuable node in each community. As mobile nodes have limited battery and power, the authors in [20] store the contact history between nodes to create a contact graph and then extract communities from this graph. To limit the number of copies of network messages produced, each community's central node is preferred to carry the messages.

In [17], the authors study the types of communities, and create a community graph to detect the relationship between nodes. Nodes in the same community have close relationships.

In [15], The authors propose a method to make nodes aware of the data transmission probabilities to destinations. This method is used in conjunction with central nodes and social communities.

In [16], the authors discuss the concept of creating homes from the network nodes. Each home has a set of optimal relays, which have a minimum expected delivery ratio to the destinations.

In [22], The authors use machine learning to create a global predictive model that predict routing decisions for each message.

In [4], A prediction delivery value is measured for the nodes to be chosen as the relay candidates. The probability matrix is calculated to measure the transitivity between nodes.

2. Routing based on Application layer metrics

Application layer was not traditionally used in routing since it is not implemented in routers. However, in MANETs, mobile devices work as routers, in addition to being the end users. Therefore, there have been a recent trend in research to modify routing protocols developed specifically for MANETs to use application layer metrics. The authors focus on the protocols that exploit the social features of the network users to enhance the routing protocol.

In [14], the content-based opportunistic routing protocol (SCORP) studied the network nodes' social habits and generated a node's interest history. The selection of relay nodes tagged with shared interests was identified. Messages are sent to relay nodes which have common interests

with the message's destination. The protocol ignored the location of nodes or the frequency of contact meetings.
A protocol was proposed in [9] to calculate a common relationship value that defines the direct and indirect relationships between encountered nodes.
In [8], the similarity measurement between nodes guide the transmission of messages determined by the number of mutual friends. They assumed that each node in the network has a direct relationship with a given percentage of the nodes in the network. If a node has an indirect connection with another node, but the two nodes linked with intermediary nodes, thus improve the chance of message transmission.
In [10], the authors suggested that merging the online social network, which represents the application's online connection, with the offline social network, which represents the users' behaviour and interests, would improve message delivery.
In [5], the similarity between users is calculated through location histories and interest factors. GPS-enabled mobile devices access the location data. Where there are common interests, or where geographical locations are very close to each other, a connection between nodes is formed. If there are no clear paths between nodes, friends will be used to relay messages.

The concept of creating features to describe the network nodes is introduced in [6], the authors proposed a Social Profile Multicast (SPM) method for choosing the social features of user profiles. Social characteristics are used to pick relays for multicast routing. Distance value and common languages are two social properties that are used according to reports from the Infocom06 trace [21].
The number of contacts between the two nodes was determined by the distance value; if the distance was low, the similarity was high. The same language between two nodes exposed their close relationship.

The EncoCent approach is implemented in [7], where nodes have value-weighted features. The social similarity value between a node and its destination is calculated using social and historical knowledge, and the betweenness centrality utility of a node is calculated using network node social connections. They suggest that each node has a set of common information, each of which has a weight given to it.
In [12], The authors proposed two protocols that differ in how they choose relays: social-aware forwarding and social-obvious forwarding. The first choose relays depending on their rank, which was determined by the degree and betweeness centrality, while the second choose relays at random.
In [19], the authors proposed a social similarity-based multicast algorithm (Multi-Sosim). Social features are used to separate the nodes in the communities based on the similarity between nodes.
In [18], the authors improved their work in [19] and proposed two multicast algorithms; Multi-CSDO, which involves only destination nodes in community detection, separated the destinations based on social similarities. The network nodes were then grouped into Multi-CSDR communities. Finally, they assigned the destinations and relays communities to each other. As a result, the nodes carry destinations that are socially similar.

In [27], the survey summarizes previous outstanding research to clear up any lingering doubts about MANETs' actual deployment. Table [1] summarizes the comparison of MSN routing protocols. There have been several previous works that compare routing protocols in MANETs and its different variants [24]. However, this paper focuses on MSN routing protocols.

Table 1: Comparative Study of MSN routing protocols

Routing criteria		Reference number	Similarity measurements	Possible extension
Related preferences and geographical proximity		[5]	Common location and interests, or mutual friends.	Needs a high number of participants nodes.
Static Social Profile		[6]	Common language and low distance between nodes	The selected similarity features can be increased.
		[7]	Importance prioritization based on the given social feature weight	The Importance of features can be measured based on user's preferences.
		[14]	Interests historically assigned to the nodes	Enhance the similarity features to cover the dynamic user's attitude.
The Social Relationship		[8]	Number of common friendships that extracted from direct and indirect nodes	
		[9]	Number of direct and indirect nodes	
Online and Offline Social Profile		[10]	Merge the online connection and offline behaviour of network nodes	Enhance the message delivery and add more dynamic features that describe the nodes.
Community-social profile-based perspective		[19]	Extracted social features to create social communities and split the messages to these communities.	Enhance the similarity features to cover the dynamic user's attitude.
		[18]	Create social communities for nodes and communities for destinations then compare communities to assign the destinations to communities.	
		[12]	Pick the relays based on two concepts; the ranked nodes and the second choose relay randomly.	Enhance the similarity measurements (centrality matrix)
		[26]	They create static social profile to the users and exploit the relation to perfectly select the relays	Enhance the social profile to contain dynamic features

Table [1] highlights the characteristics of routing protocols based on an analysis of relevant literature. For each routing protocol, its routing criteria and similarity measurements are presented.

Each MSN protocol enhancement is driven by improving the similarity measure to select the appropriate relays. In MSN, the ideal route is not discovered as it is based on nodes which occasionally contact each other. The most discussed MSN routing challenges are:

1. Selecting the minimum number of relay candidates who will carry the messages to their destination.
2. Minimizing the number of transmitted messages because, practically, mobile phones have limited resources. Most of the mentioned protocols assumed that the mobile phones have unlimited resources.
3. Delivering the messages to all the required destination(s).

3. PERFORMANCE MEASURES

Routing protocols are evaluated using several performance measures. The authors surveyed the mostly used performance measures in MSN as follows:

1. Relay count: The number of intermediate nodes that a message goes through between the source and destination nodes.
2. Delivery ratio: It is determined using two parameters: the total number of delivered messages divided by the total number of messages created.
3. Overhead ratio: The proportion of redundant messages to overall messages in the network.
4. Hop count average: The average number of relay nodes with successfully transmitted messages.
5. Dropped packets ratio: The number of dropped packets in the network divided by the total number of messages created.

A successful protocol should achieve a high delivery ratio and low overhead ratio. In fact, because mobile phones have limited resources, the lowest hop count and overhead ratio would save mobile resources [25].

It is important to note that the performance metrics' values cannot be ideal, so any proposed algorithm should be compared to other protocols to prove its outcomes.

4. CONCLUSION

Smartphones have enabled a wide range of applications that run on adhoc networks. One of the most widespread applications is social networks that become the staple application among all ages in all the world. Running a social network on top of a mobile adhoc network creates a mobile social network (MSN). To enhance message routing in MSN, routing protocols are developed to use the social interactions between the network users to improve the routing performance. If properly used, knowing the social interactions can increase the delivery ratio, and decrease both the dropped packets and the power consumption. In this paper, a review of the routing protocols developed for, or are candidates to work in MSN are introduced. The objective is to help select or design the better routing strategy using the newly added social feature. It was found that the utilization of the social interactions achieved better performance of the routing protocols running in MSN. To further extend this work, dynamic social profiles with the location and contact history could be utilized to better enhance the routing performance.

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