Social Roles for Opportunistic Forwarding

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ABSTRACT

Opportunistic networks exploit human encounters to enable new mobile networked applications. Efficient routing for these types of networks relies on utilising encounters between nodes so that messages are moved closer to their destination. Previous work has looked at using encounter-based social network data for routing. It is unclear how fairly these schemes distribute the forwarding of messages. In this work we investigate this and look at the potential of classifying nodes using "social roles" to find nodes with equivalent connections that can be used for forwarding.

Categories and Subject Descriptors

H.3.4 [**Information Storage and Retrieval**]: Systems and Software—*Social Networking*; C.2.2 [**Computer-Communication Networks**]: Network Protocols

General Terms

Performance, Algorithms

1. INTRODUCTION

The devices used in opportunistic networks are likely to be small battery powered devices carried by individuals, alongside (or in conjunction with) the current mobile phone networks. Since these devices run on batteries, it is important that we conserve power.

Since topology changes can be very frequent due to human mobility, we can try to take advantage of this by using the opportunity to pass messages when nodes do encounter one another.

Current protocols include "BUBBLE Rap"[6] and "SimBetTS"[4], which use indicators from the structure of the network and network topology history to identify nodes that would be best suited for message forwarding.

Since energy consumption is an important factor, there may be a trade off between node lifetime and the need for nodes to forward messages in order for the network to be useful. If there is a particular subset of nodes being frequently asked to do a large share of the forwarding, then this has the potential to balkanise the network and reduce network performance.

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Thus the following PhD thesis statement is proposed:

> Current opportunistic forwarding schemes do not lead to a fair allocation of nodes messaging resources. By exploiting the social structure of opportunistic nodes in an opportunistic network we can build forwarding schemes that are both efficient and fair.

In order to address this statement there will be three research contributions: i) Demonstrating that self-reported social networks can be used for efficient message forwarding. This is covered in previous work [2]. ii) Showing that existing schemes for opportunistic routing are unfair to network users. Existing schemes use calculations of utility and ranking that may cause specific subsets of nodes to be overloaded due to being repeatedly selected by the routing mechanism to forward messages. iii) Developing a new routing scheme that uses social information for message forwarding.

The rest of this abstract covers the following: the current research on the fairness of existing schemes and development of a new routing scheme using social structure information.

2. SOCIAL ROLES FOR FORWARDING

In society, we are members of various roles. For instance, in a network of positions in a business, we can imagine assistant managers connect managers to ordinary employees. To extend this analogy: if an assistant manager is not available to pass on work instructions to the employees, the manager may select another assistant manager to do this, as all assistant managers perform the same task (passing on instructions).

Perhaps passing messages on to nodes performing a similar role in an opportunistic network would be useful if expected nodes are unavailable, or to constrain message flooding. We aim to utilise the network of connectivity between node roles to explore the possibilities of roles being useful in certain circumstances for forwarding.

In order to find these roles we analyse the "regular equivalence" of node contact networks. Regular equivalence is a social science technique for constructing "a partition of nodes into classes such that nodes of the same class are surrounded by the same classes of nodes"[3]. All nodes of a role are connected to nodes in the same roles as those connected to by all other members of their role. In the example above, managers connect to assistant managers who connect to ordinary employees.

For instance, consider three roles $(0,1,2)$, are connected in the following manner: $\{0,1\}$,$\{1,2\}$. If node a in role 0 is intending to pass a message destined for node d in role 2 to intermediate node b in role 1, but instead meets node c from role 1, it may be beneficial for a to pass the message to c, since it is probable that c and d will meet. Note that nodes b and c do not need to ever have contact.

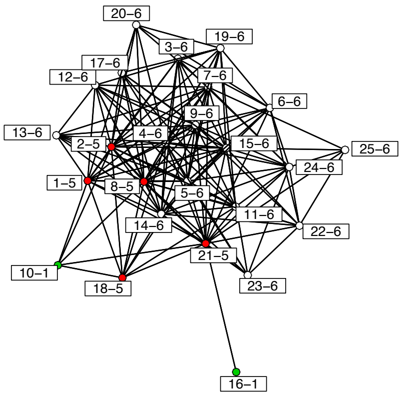

Figure 1: Role assignment for nodes in our SASSY data. Labels show node ID followed by assigned role.

By attempting to find alternative nodes that can be used for forwarding, it may be possible to prevent heavily-used nodes from running out of battery due to excessive message passing. If a particular node is being overloaded, messages could be passed to others in the same role instead. This could increase the fairness of the protocol. Furthermore, alternative nodes in the same role can provide forwarding opportunities that result in message delivery.

In order to compute the social roles, the network must be initially partitioned according to some selection criteria[3]. Examples of such criteria could include: popularity (the number of unique nodes encountered); betweenness centrality (the extent to which a node lies on shortest paths between other nodes); time since last encounter (the likelihood of nodes meeting); information flow (the direction of message passing between nodes); or battery level (categorise nodes based on battery level to avoid draining low batteries).

We have used betweenness centrality to make our initial partition, and then use the Kanellakis-Smolka algorithm[7] to compute the role assignments. We performed this role analysis on our SASSY connectivity data[2] which contains a trace of the physical proximity contact patterns amongst a group of 25 individuals for 79 days. Roles are given an arbitrary number so that they can be distinguished from one another. The role allocations are shown in Figure 1. We observe that there are three roles to which nodes can be assigned. We see that nodes in role 1 are connected to role 5; similarly role 6 also connects to role 5. Nodes in role 5 are connected to nodes of both 1 and 6.

We have developed "HopRole", a forwarding scheme in which nodes pass a message if the role of the node encountered is within x hops away from the role of the sender of the message in the role connectivity graph. This is to explore whether constraints on the role distance have an impact on the number of messages that nodes must forward.

3. EVALUATION

We have performed a preliminary experiment to demonstrate the usefulness of roles: a trace-driven simulation using our SASSY data of nodes randomly passing messages to one another according to an exponential distribution for 79 days. We compare the performance of our HopRole scheme (role range 0 and 1) against Epidemic routing. Nodes have an infinite message buffer and there are two TTL values for messages: 1 day and 10 days. Each combination of input parameters was run 100 times.

We observe that all three schemes have a similar delivery ratio (MessagesDelivered/MessagesSent). The difference in delivery ratio and cost (MediumAccesses/MessagesSent) between the Epidemic and HopRole range 1 schemes is not significant ($p = 0.89$). The Epidemic and HopRole range 0 schemes are significantly different ($p < 0.01$). However this ratio is still comparatively good, and the delivery cost for the HopRole range 0 scheme is around a quarter of the cost of Epidemic routing.

4. FUTURE WORK

We will perform further trace-driven simulations using three different datasets: our SASSY data; Reality Mining [5]; and Hope [1]. We will perform a comparison of the BubbleRap scheme, SimBetTS, Epidemic routing and our own scheme based on the role analysis described above. We will compare fairness of the schemes with respect to the maximum cost of message sending. Fairness is challenging to define in the domain of opportunistic routing. Existing fairness metrics may be inappropriate for this network scenario, and a new metric may need to be developed.

We hope to show that role based schemes distribute the message sending and do not unfairly rely on a small subset of nodes. We will investigate whether a role based scheme can be used to increase the lifetime of nodes frequently used for routing, while still offering similar performance to existing protocols.

5. CONCLUSION

This work describes how social roles have the potential for use in opportunistic forwarding routing protocols. We are currently developing a forwarding scheme that uses these roles. Current work is also being done to analyse the distribution of messages sent by nodes in trace driven simulations of existing forwarding schemes.

6. ACKNOWLEDGEMENTS

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