Enhancing Message Dissemination in Device to Device Communication Networks through User Interest Groups

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Abstract

In today's highly connected world with growing need for content, fueled by proliferation of mobile devices, message dissemination through social groups and communities has become the norm. Social networks have moved from just connecting people to solving community problems such as access to health care information. The increasing trend to shift from wired to wireless networking provides an opportunity to explore D2D communication as a promising alternative to existing infrastructurebased networks. With D2D communication, short-range radio technologies such as Wi-Fi and Bluetooth are best suited to meet the growing content demands of users.
Most of the content dissemination frameworks focus on flooding content between nodes that are merely in close proximity with each other. This ignores the behavior and level of social interaction between mobile nodes. This research improves the performance of D2D communication networks by exploiting social interaction and behavior of mobile nodes in a community setting by designing a message dissemination algorithm which captures user interest of shared content to replicate messages in a multicast group. Evaluation results show that our algorithm achieves good network performance through message delivery probability and latency.

Key words: *Mobility, Multicasting, Device to Device, Social Networks*

Introduction

HUMANS tend to form social and community networks that represent a range of social, mobility and behavioral structures derived from the level of social interaction. Because mobile communication devices are carried by humans, it is thus feasible to leverage the social behaviors to assist D2D communication where mobile users in close proximity can exchange messages through direct links even without physical infrastructure support [1] or cellular connection [2]. This can greatly improve message dissemination in these networks. A promising area in the use of the social structures involves aggregating nodes with similar interests into content communities.
A user is expected to obtain content from nodes with similar interests, so it is probable that these nodes belong to the same community and are therefore most likely to be good relays for messages [3].

A common approach to deliver messages in D2D networks involves flooding the network with messages without a selection criteria. Much as this approach is simple and straightforward, it leads to resource wastage as some nodes may not be interested in the messages being shared.

To overcome such challenges, an alternative would be to allow direct exchange of content among by matching user interests against the type of content being transmitted. This means that users only receive content which matches their interests.

Inline with this approach, authors in [4] proposed, a socialaware content-based opportunistic routing approach (SCORP) that makes message routing decisions basing on users' daily interactions and interests. Such an algorithm relies on a match between shared content and the interests attached to it by the subscribers. The general idea is to combine content knowledge, user interests and social proximity to attain faster content reachability to interested parties. Since SCORP relies on individual nodes to forward messages [5] , it places heavy burden on the nodes. A major limitation to this approach is that it cannot perform well in dense scenario networks where the number of users is likely to increase. Also when a node that has interest is not available at the time of message creation, the node cannot get the message. This also means that when new nodes join the network, the creator of the message has to regenerate the message for the new nodes.

In this work we use Multicast delivery whereby the creator generates only one message for all the receivers. By replicating messages in the network, we can maximize the number of delivered messages, while minimizing the delivery latency. We can thus have a more robust network that can perform well even when the node density is high by developing a routing algorithm that will improve D2D communication message dissemination through user multicast and interest groups.
Because mobile communication devices may be carried by humans, it is thus feasible to leverage human social behaviors to assist D2D communication for efficient message dissemination.

Statement of the Problem

Given the dynamic nature of nodes in D2D networks, a continuous end-to-end message path to the destination cannot be guaranteed. This leads to intermittent connectivity incase a forwarding node is not found. To counter this problem, most of the content dissemination models focus on flooding content between nodes that are merely in close proximity with each other. A major limitation to such an approach for message dissemination is the lack of consideration for the level of social interaction and mobility of users. This wastes network and device resources such as battery.

A better solution would be to use replication based forwarding using multicast interest groups where nodes subscribe to messages that are of interest to them and can thus replicate them in the multicast group for others. By having more message replicas in the multicast group, we can increase message delivery probability and as such improve network robustness in dense scenarios.
Therefore this research explores the possibility of putting together a combination of mobility patterns, social behavior and content interest in a social setting to come up with a suitable message dissemination framework. We therefore model relay cooperation based on social, proximity and interest characterized cooperation in a D2D communication scenario in a dense scenario network context to improve message delivery ratio.
The rest of this document is organized as follows. In section II we present the Literature Review related to social aware content dissemination. The main aspects include D2D use cases, Interest based routing. Section III introduces the methodology used to design a user interest based content dissemination framework as well as the simulation environment and scenarios used. In this chapter we provide an overall description of the mobility patterns and movement models used to represent the real world behavior of users in social settings. Section IV presents the results of the experimental evaluation realized through simulation of our system other state-of-the-art systems to compare the performances using various metrics such as average delay. Section V concludes this document by summarizing its main points and presenting future work that could enhance the work presented in this document.

Related Work

Research work reviewed in literature reveals content dissemination techniques do exist but most of them focus on flooding the network with messages [7]. This greatly affects network resources. A few other schemes like PRoPHET algorithm try to adapt the concept of probabilities by considering the likelihood of a node meeting another node to act as a relay, sometimes an encountered node is not interested in the shared message. This lowers the chances of the messages being transmitted and hence affects network resource allocation.

Authors in [6] introduced the concept of communities through Bubblerap algorithm with the assumption that every node in the network belongs to a given community. By using this concept, the algorithm can identify influential nodes in the network to be used as relays for messages. Routing protocols such a SocialCast [8] and SCORP [4] rely on user interest to deliver messages. In community or social networks, the links that connect pairs of nodes can be derived from the interests shared by the nodes. Nodes belonging to same community are likely to have similar interests and therefore have strong social ties between themselves. These ties can be used to determine the level of social trust among people in a community.

People tend to interact with others and form relationship networks. Tie strength plays a vital role in our ability to access resources and in the way we associate with other people around us. Tie strength also affects the nature and frequency of interactions between pair of users. The stronger the relationship or interaction levels, the stronger the tie strength. The existence of strong social ties indicates social trust between two connected users can imply their willingness to deliver messages across D2D communication when these devices are within proximity of each other [9]. Nodes with weak or no social tie with other nodes are likely to be poor relays and will drop messages of other nodes.

It is worth noting that some authors have considered socialaware such as the use of SCORP algorithm for content and message dissemination by using shared interests. Such an algorithm shows good performance in rather less dense network scenarios. Also because the algorithm only focusses on data retransmissions to only interested nodes,in an event that interested nodes were not present to receive the messages.
We therefore recognized the need to exploit the multiple characteristics and user behavior in social settings to increase network capacity in dense scenario networks using multicast groups to improve the overall performance in networks with highly mobile nodes.

Methodology

We base our work on SCORP algorithm [4] which takes into account the social proximity between nodes and the content knowledge that nodes have to make forwarding decisions.
Every single node should be able to get a copy of a specific message item which interests them. Precisely for SCORP, every Messagej in the buffer of the CurrentNode is replicated to Nodei if:

- Nodei has interest message that is being transmitted
- The social weight of Nodei towards a node having that interest is greater than the weight that the CurrentNode has towards any node with the same interest.

This leads to fewer message replicas created to only those nodes that have interest in the content being shared hence improving network resource usage.

Algorithm Design

We use SCORP algorithm to fetch the user interests and the message content type.
Besides taking into account the interest that users have in the content, we also need to define the message replication range. This defines a geographical area in which the message remains relevant and accessible to

users that have interest in it. Within the message zone, we are therefore expected to create replicas only to nodes that indeed have interest in the content carried by the message to be forwarded.

The following are the technologies, tools and techniques that we used for algorithm implementation;

- Java and its libraries were used to create the Algorithm scripts, the graphical interfaces of the application on which the algorithm was deployed for evaluation.

Data:
Get Node interests using SCORP algorithm (Node.getInterests) in the message content (Message.getContentType) that is being transmitted.
Get Message type using SCORP algorithm (Message.getContentType)
Message Transmission range Meassage TTL Node location, Node Interests,
Result: Message forwarding in a multicast group based on user location and Interests
initialization;

```
while Node is still in message zone do
    Create message with defined TTL and Tagged
    message type;
    if Node with interest in the message is in message
    zone then
        Replicate message to encountered node if it is in
        range and has interest in the message;
    else
        Delete message if node is out of message zone;
    end
end
```

Algorithm 1: Our Algorithm

- The java programming language was further used in the creation and design of the routing logic, and behaviour of the nodes.
- The ONE Opportunistic Network Environment simulator [10] was used for generating mobility traces, running messaging applications and visualizing both simulations interactively in real-time and results after their completion.
- Java programming language was used to create Routing modules and message creation Routing modules that define how the messages are handled in the simulation.
- We used Eclipse to compile the source code in Windows environment with Java 6 JDK.

Mobility traces and datasets
In order to obtain information about mobile users behavior in social settings, we analyzed user mobility traces. In our experiments we used different mobility models based on human mobility traces from [11]. They consist of different mobility patterns depicting how humans move about a city carrying mobile devices. In the real world, people often walk in groups and do various activities together, resulting into social interactions. Mobility patterns that represent the movement patterns of users were used to infer user mobility in community settings to represent how users move along roads and to other points of interest such as shops.

User Interest and message Modeling
In our model, node groups were assigned different and random interests. Each group has a set of defined interests that may or not overlap with the interests of other groups. The interests were inform of simple keywords like 'music', 'sport' etc.

Scenario Settings

Our work involved simulating a working day interaction of people in the city involving between 40 to 280 nodes divided into groups of people and vehicles. Each node has a Bluetooth interface. For our simulations, we assumed communication between mobile users in a city using mobile devices such as smart phones that are always turned on throughout the day. We also assumed up to 50MB of free RAM for buffering messages in these phones given that the Time To Leave (TTL) was set to 300s. We assumed a working day to be 8 hours long, and a day is characterized by movements from home, to office and other meeting spots such as bars and restaurants.

Evaluation Parameters

For a comprehensive comparison of the routing algorithms, we used performance parameters to evaluate and compare the algorithms using the ONE simulator to determine the Delivery Probability, Message Replications and latency.

Our Improved Algorithm Design

Our improved routing algorithm extends the SCORP algorithm, by introducing multicasting based on information of nodes location.

We introduce a concept message space or anchor zone to represent the location where mobile users can receive and replicate messages. This is based on the operation of the Floating Content communication service [13].

A node creates a message M and specifies a message zone by defining its center P and two radii, a and r, as shown in Figure 1. The radius, a represents the availability range within which the information item is kept alive and accessible to any node that joins the multicast group. No copies of the message can exist outside of a; r denotes the replication range within which nodes can replicate the item to others when they encounter.

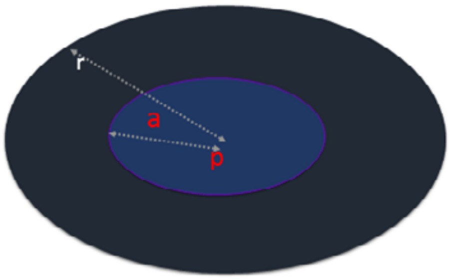


Figure 1. Defining a message zone for created messages

When two nodes *N1* and *N2* meet in the message zone of a message *M*, assume *N1* has *M* while *N2* does not, then *N1* will replicate *M* to *N2*. The replication mechanism is completely based on the location of nodes, thus in the simplest situation, all the nodes in the message zone should have a copy of the message.

We assume that the message space, has an influence range or propagation range inside which users can obtain and replicate messages.

Every message created comes with a TTL for which it stays in the network before it finally expires. Whenever a node possessing this content comes within the transmission range of some other node not having that content, the content is replicated. When a node possessing the content moves out of the geographical limits of that message, the node deletes the content and as such the message can be obtained again if the node joins the message space again.

Since users who are socially connected are likely to be geographically close to each other and share the same information and interests, our algorithm is a good improvement to SCORP algorithm [4] which only relies on message interests.
We therefore combine geographical location of users together with their interests for message replication as shown in figure 2.

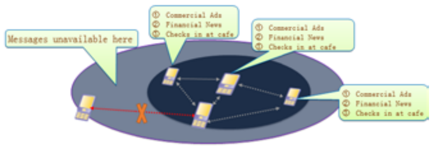


Figure 2. The network model assumes a group of proximate and cooperative mobile devices

Performance Evaluation

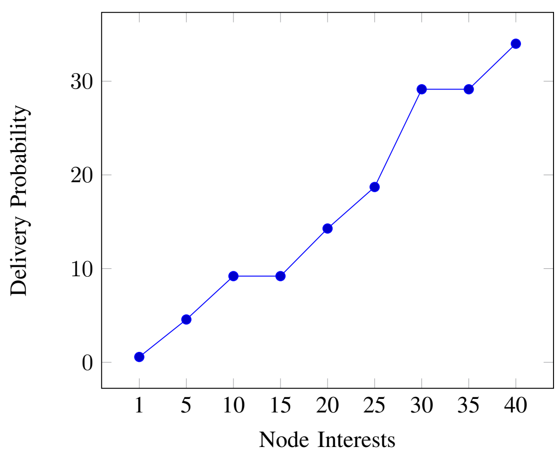
A. Interest-Based Message Dissemination We begin by presenting results from the evaluation of SCORP algorithm that uses interest-based message dissemination.
We analyse its performance by varying the number of interests. Simulation results show that to have better performance, we need to have a reasonable number of interests defined.

- Delivery probability: Message delivery increases with increase in interest per node. The simulation results show that delivery probability increases with an increasing number of interests per group. This is because as the number of interests increases, the network has more carriers of messages to the destination hence a higher delivery probability. The more interests a node has, the better it is to deliver content to others since they potentially share interests as shown in figure 3.
- Latency: As more interests are realized in the network, more forwarders become available for transmitting the messages hence the better the reachability. This brings about the lower values of the latency with increase in the number of interests as shown in figure 6.

Performance Evaluation with multicasting

We further introduced multicast groups based on user geographical location. From our results, it is worth noting that nodes with common interests tend to encounter each other at a high rate, we therefore use this observation together

Figure 3. Effect of node Interests on Delivery Probability



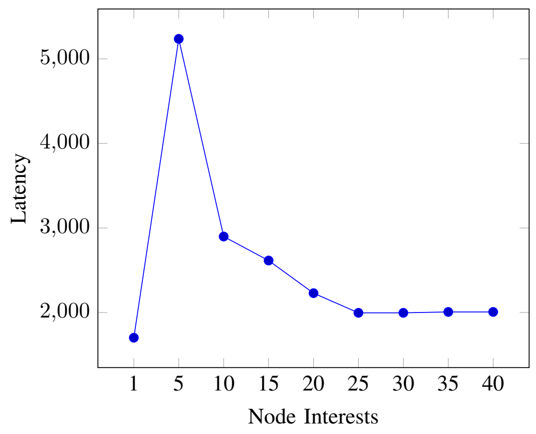


Figure 4. Effect of node Interests on Latency

with multicasting to improve message dissemination in dense node scenarios. Thus, a node can belong to a community of other nodes with similar interests and this can improve nodes chances of sharing messages. Message replications With our routing algorithm, multiple copies of a message can be present in the network at any given time. For a message to be delivered successfully, at least one of the copies has to reach the destination before it expires. Our algorithm makes use of the information about the topology and transmission range of the message for better reachability. In multicasting networks, messages are replicated throughout the network for all the node encounters. Increasing the number of nodes allows for increased number of message copies to be generated. SCORP being a single copy model uses only the message interests of nodes to make message forwarding. Because of this, fewer messages are forwarded leading to fewer message replications as shown in 5.

Latency The delivery latency for our algorithm tends to be lower as compared to SCORP algorithm as shown in figure 6. The values tend to remain significantly low even when the node density increases.

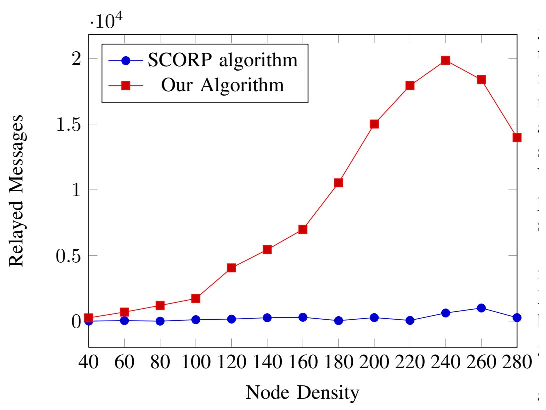


Figure 5. Relayed messages against node density

SCORP however shows significantly high values of latency. This is because some nodes can be far from the message creator. With multicasting however, message delivery is restricted to a predefined transmission range hence lower values of latency. Our improved algorithm uses many branches in the multicast group to forward the copies, so it has the shorter latency. SCORP considers long routing paths that are attached to node interests. This generates longer routes as compared to our algorithm that considers a defined range of transmission in form of multicast message groups. This ensures that there is at least one copy of message maintained in the network.

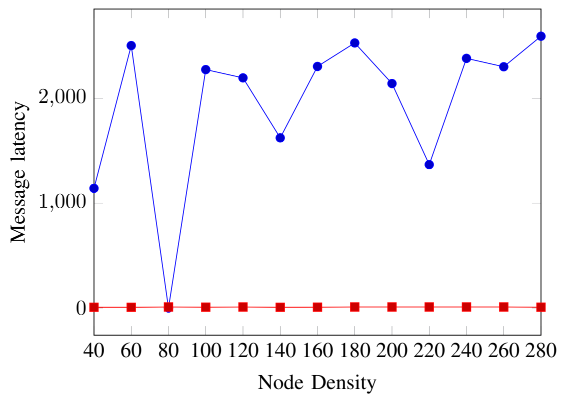


Figure 6. Latency against node density

Conclusion

In this work, we focused on evaluating an algorithm that makes use of content interest to deliver messages. We further improved the algorithm by introducing the multicasting model, whereby messages created by the nodes have a defined range for which they remain available to other nodes the multicast group. With this approach, a mobile node that has a message to share can be able to provide the message to another mobile node when they pass within radio range of one another by using opportunistic communication. We evaluated our model and simulation results show good performance in dense urban scenarios applications ie even when the node density increases.

We defined delivery probability and latency as the primary performance indicators and we created a number of simulation scenarios by varying the node density in the network.

We studied two such cases involving a purely interest based routing algorithm which we improved by adding an aspect of location awareness to ensure best service message delivery by using a concept of masticating node groups based on geographical location.

An important conclusion is that while other routing mechanisms suffer from traffic congestion when users increase, simulation results show that our model can be implemented for the applications that operate in areas having high user density.

Our model can therefore be applied in a number of dense or urban scenarios that rely on node mobility and location awareness for message dissemination. The advantage of this is that this kind of model can perform well in areas that have high number of users such as a city centres, urban areas and disaster situations.

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