Detection of Selfish Nodes in D2D Communication Networks

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DECLARATION

I, Kivumbi Timothy declare that the work in this proposal is original and has never been used before in any university or institution as an academic requirement.

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Introduction

1.0 Introduction

D2D communication has in the recent years been explored as a technique by which mobile users in close proximity can communicate through direct links without physical infrastructure support [7]. D2D was thought of to be a novel and attractive underlay to Long Term Evolution Advanced (LTE-A) networks designed by 3GPP (the 3rd Generation Partnership Project). This kind of communication has been looked at as one of the key technology building blocks for 5G and next generation communication. D2D is envisioned to satisfy a wide range of the 5G requirements including good data rate, low latency, high coverage and high channel capacity.

Given the fact that D2D networks do not need installation of physical infrastructure, they have come as a reliable solution for communication in a wide array of situations such as areas hit by disaster. In these situations, direct links may (temporarily) extend or substitute cellular network connections, when the operator services become unavailable to mobile users. The application of D2D in communication is a promising approach that can enable offloading the bandwidth-intensive social content delivery to users' mobile devices and allow them to share this content locally on their devices [1].

Besides the instantaneous closeness and proximity of mobile users, their social aspects of interaction also play an important role in determining the properties and reliability of D2D links. Taking human social ties into consideration, the level of interaction between users can be used to establish D2D links. Therefore any user can join the network if they have a strong social connection with people who are already in the network. By observing users' social interactions, it becomes feasible to admit users into the network. The use of sociality as another dimension for establishing a network creates a more reliable and stable structure where users can efficiently share content.

1.1 Social Communities in D2D communication

A fundamental approach to consider in the design of social-aware content dissemination frameworks is the use of social communities. Communities in networks represent groups of nodes that are more strongly interconnected with each other creating strong ties between them. By using social graphs, in which nodes are the network users and edges are the connections or interactions between the pairs of nodes, it is possible to detect and explore social communities for content dissemination. The use of social communities in D2D forwarding is such a crucial aspect. A message has a greater chance of being delivered to the destination if it gets to any member of a community that the destination belongs to.

Users who encounter one another more often will most likely form a social community. Therefore, the longer a user stays close to another user, the kind of interaction between them is prolonged and thus the social tie becomes stronger. This forms the basis of durable social communities for content dissemination in D2D networks [2].

With emerging demands for local area services in connected communities, D2D communication is viewed as a vital aspect for the next-generation networks. It therefore emerges as a promising approach for dealing with the traffic overload problem in cellular networks. Mobile users, however, need to sacrifice their limited resources such as battery, cache memory to share content with others. This forces some nodes to exhibit selfish behavior by choosing not to participate in content sharing.

1.2.1 D2D Link Properties

A D2D link between two friends can be looked at as a more stable link for content dissemination. A stronger contact tie indicates that the corresponding D2D link can deliver more data since the users have more in common. The social tie can be interpreted as the link's strength in light of sociality, as a complement to the physical connection between users in the real world. Both the physical and social aspects can affect the D2D transmissions and further influence the network in terms of content dissemination [3].

Given the open environment of D2D networks, and their distributed structure, such networks are vulnerable to significant impact from selfish nodes. Selfish users behave inactively in delivering content to other nodes in the network, but still would like other users to deliver content to them. This kind of behavior is also known as free-riding in peer to peer systems [4].

1.2.2 P2P Communication

Peer-to-peer (P2P) applications are enormously popular forms of sharing content such as files, Voice–over–IP and gaming and more [5]. Without doubt, users have growing enthusiasm to have wireless networked devices for faster content sharing. A group or community of users may want to receive multimedia files from one particular source. The use of a data connection to facilitate the transfer would be costly [6]. An ideal solution would be to employ peer-to-peer sharing among devices, in order to leverage free peer-to-peer wireless links versus expensive packet data networks for file sharing purposes. The connected devices could then share the content within themselves without the use of any intermediary hosts, servers and would therefore escape service provider billing [6]. Therefore a group of users who are interested in the same content, and they seem to be in close proximity with each other, they can easily use D2D connections to get the content in a cooperative or opportunistic fashion.

1.2.3 Wi-Fi Direct

Devices may be set up to communicate directly with each other without the need for an Access Point or internet connection [7]. Wi-Fi Direct, also called Wi-Fi peer-to-peer comes as a new Wi-Fi standard that can be leveraged to support such kind of communication. It supports regular Wi-Fi speeds, which could be up to 250 Mbps. Wi-Fi direct can achieve connection much longer distances than Bluetooth [8]. A mobile user can also obtain the content files from other users in proximity, through short-range communications. Wi-Fi Direct is a recent protocol standardized by the Wi-Fi Alliance [9], with the aim to enable D2D communications between nodes, or peers for content sharing using direct communication links. This allows mobile devices (e.g., smartphones, tablets) to directly connect over unlicensed bands and transfer content or share applications anytime and anywhere without fixed infrastructure support [10].

Wi-Fi Direct is based on P2P architecture and created to make connections simpler and more convenient for proximate users. Wi-Fi Direct creates direct connections among proximate devices without the need for a traditional Wi-Fi infrastructure network. The Access Point like functionality is implemented dynamically on a D2D device creating a group of devices that can communicate in P2P fashion. This helps to reduce the limitations that traditional Wi-Fi architecture can bring about, by supporting P2P communications. This makes it easy to cater for mobility aspects of users [11]. One peer in the group acts as Group Owner (GO). Such a node acts as the Access Point in the network. The other devices are called clients. The roles within the group are not predefined, but are assumed upon group formation. After the GO is elected, the role of each peer remains unchanged during the whole group session. Only when the GO leaves the group, the peers become disconnected and a new group must be created [9].

With this concept, it becomes feasible to create a network topology of D2D systems in which devices are free to join or leave P2P groups without having a massive impact on the network [11]. Social relationships tend to reflect the closeness degree of users in a social setting. For D2D communication to be effective, the degree of preferences on similar contents is required for determining the best relay link in the communication [12]. This also helps to determine which user can be allowed to be part of the network. This process is known as peer discovery.

The devices need to find other nearby devices by a peer discovery procedure. After mode selection, the system needs to allocate spectrum resources to the cellular and D2D links depending on the existence of a strong ties between nodes [13].

In this work, we address the content delivery by leveraging the social ties information in D2D networks for peer discovery. The social relationship, is modeled as the probability of selecting similar contents for D2D pair formation and content sharing.

1.3 Social Network Based Systems

Social networks help create communities in which users communicate with their real-world acquaintances in form of virtual connections [4]. These networks are continually growing both in the number of communities and the overall population. Since a user's friends are usually trustworthy and share similar interests, it becomes evident that online friendships can be exploited to perform reputation estimation for content dissemination in D2D networks.

1.3.1 Social Trust and Reputation evaluation

A node’s trust level in a social network determines its willingness to be cooperative in message or content dissemination. When a node becomes non-cooperative in either service providing or sharing content. This node is regarded as a selfish node. Therefore its reputation score goes down. The network performance is greatly affected if there are more selfish nodes than cooperative nodes [14].

Thus, node reputation is needed to evaluate nodes that be exploited for content sharing. Since both the reputation and social degree of a node reflect its trust level. Mechanism such as Watchdog [15] tend to address the problem of selfish nodes is addressed in mobile ad hoc network. Each node in the network has its own watchdog component for monitoring the neighbors. This helps forwarding nodes to choose the best route which excludes non-forwarding selfish nodes. However an aging mechanism is needed to remove old or random encountered users. These nodes cannot be trusted and need to be pruned from the network.

1.3.2 Node Selfishness in D2D Networks

Much as users can mapped together as having similar interests, the users are can still be selfish. Because D2D networks are usually distributed without central management, selfish users survive easily in D2D file sharing systems. Selfish nodes are not willing to share resources within the network [3]. Node cooperation is thus an important aspect if reliable D2D performance is to be attained. It becomes important to identify the selfish nodes from the network and isolate them. The process involves determining a pre-defined reputation threshold that is used to determine users' trustworthiness. If a node's reputation value is lower than the threshold, it is regarded as a selfish node and will not be chosen as a server and eventually isolated from the system. This can greatly improve network performance in terms of message delivery ratio.

1.4 Background

Humans tend to form social and community networks that represent a range of social and mobility and behavioral structures. Because mobile communication devices may be carried by humans, it is thus feasible to leverage the social behaviors to assist D2D communication in order to improve message dissemination in these networks.

A promising area in the use of the social community information involves identifying selfish nodes through social trust between node pairs. A user is expected to obtain information and content from cooperative nodes and these are nodes that belong to the same community and are therefore most likely to have similar interests [16].

A lot of work in literature has focused on then use of contact and mobility patterns in order to select centrally located users that are important for the network in terms of having higher influence. Such applications rely on algorithms that make use of metrics such as centrality and page-rank to determine the influence of a node [18]. The general idea is to transform these highly central nodes into the position of data forwarders to all other nodes on the network.

While most of the previous studies in literature have assumed that these nodes are cooperative and are willing to participate in D2D communication, it is worth noting that in certain scenarios like news sharing in subscription-based services, advertisement systems, product recommendations, these potential helpers need more convincing reasons to undertake D2D communication [17]. Due to this reason therefore, there is need to;

- Model and characterize the content sharing pattern of each user basing on the individual social activities and mobility patterns.
- To determine the spreading impact, which can be obtained from user behavior and movement histories, the mobility impact among users can be analyzed based on mobility traces to determine selfish nodes.

1.5 Statement of the Problem

One of the most basic problems in D2D networks is how to deliver efficiently content between mobile nodes. Given the dynamic nature of nodes in these networks, content dissemination becomes challenging. Presence of selfish nodes forcefully degrades the performance of a network. Most of the content dissemination frameworks focus on flooding content between nodes that are merely in close proximity other, without putting into context the cooperative behavior of nodes and the social propagation of content.

Our study is to investigate how social propagation and mobility patterns can be jointly utilized to improve content replication in D2D networks. Specifically, our approach involves determining social-physical graph model, which characterizes users' community-wise social relationships to determine selfish nodes in D2D communication links.

By designing a social and mobility framework which captures the popularity of shared content based on social interactions between users, selfish nodes can be identified, pruned and thus avoided in communication.

1.6 Objectives

1.6.1 General Objective

To design a mechanism that will use human social characteristics and mobility patterns to determine selfish nodes to improve the network performance in terms of message delivery.

1.6.2 Specific Objectives

1. To establish a social and mobility pattern data set for modelling social interactions between users in a D2D scenario.
2. Design a social and mobility model which captures the popularity of shared content based on social interactions between users to determine selfish nodes in the network.
3. Validate and evaluate the proposed model.

1.7 Significance of the study

- We examine the probability and capacity of relay assisted D2D networks over reputation score.
- We model relay cooperation based on social and mobility characterized cooperation probability in a community network context.
- We improve message delivery ratio by leveraging social and mobility patterns of user.

Literature Review

2.0 Introduction

Social network theory can be used to model interactions between users who share the same interests into communities. People with similar interests tend to aggregate themselves and communicate with each other more frequently. By exploiting these social network dynamics, nodes with common interests and high contact frequencies can be classified and analyzed to reveal interesting social aspects such as social ties from their interactions.

To better understand the interactions between people, social network graphs are determined. This is done by aggregating the contacts generated by mobile nodes to a graph, in which an edge represents two nodes socially connect with each other. Social network graphs come in as an important representation of networks.

2.1 Use cases of D2D communication

A number of approaches can be used to share content among mobile devices or nodes. To be precise, any forwarding or data dissemination scheme proposed for opportunistic networks, can be employed for D2D networks [18]. In D2D communication systems therefore, two devices can disseminate content either directly or via relays, without control from the base station [19].

By having users in the same geographic location D2D communication can be employed to offload and share content. For example, it will be useful in any kind of community event such as sports or people working on together in a conference setting. Because the devices are in close proximity with each other, the network will have high data rates and low end-to-end delay [20].

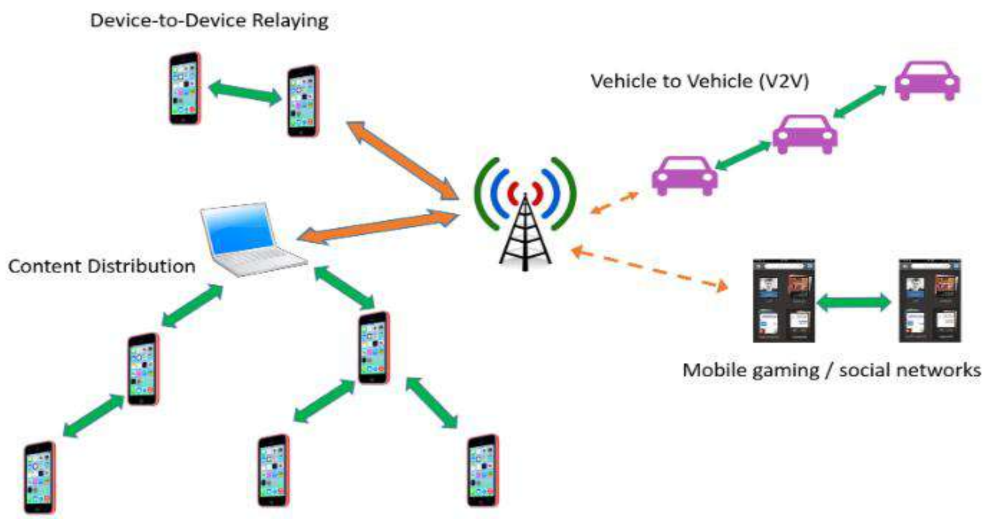

Figure 1: D2D Application

As a result, D2D networks can be used to support a large number of use cases like cellular offloading from base stations, multicasting of content to various recipients, video dissemination, and M2M communication such as smart phone to TV. Other application areas can be in the form of public safety services, location-aware services, social networking, smart grids, D2D for e-health message dissemination, D2D for smart city [19]. All these can be implemented as P2P community networks. For example, in case of a natural disaster, like an earthquake or landslide, traditional cellular networks can get destroyed. In such a situation, it would be feasible to setup a wireless network between terminals for rescue operations, using D2D communication.

2.2 Community detection

Community detection algorithms have been widely used to understand the structure of networks. In a social context, interactions in the real world can be represented and organized using communities. To further study the underlying aspects of these interaction, graph theory can be introduced. A graph can be constructed from these interactions to show how nodes encounter each other regularly for long periods of time [21].

2.2.1 Social network graph

A social network graph is a global mapping of users and how they interact with each other. Such a graph is an abstract graph where vertices represent people and edges describe social ties between them [22].

Social interactions and networks are often modeled as graphs in which a node denotes a person, and an edge indicates the kind of relationship that exists between people.

A range of social ties, derived from social metrics may be used to describe the different social relationships among people such as co-workers, friends and family. From a well-constructed social graph, a variety of social metrics such as communality, centrality, and similarity can be easily determined and evaluated to support social-based approaches to content and message dissemination in many systems such as D2D networks.

A lot of research has been done on community detection in routing protocols for D2D communication through Community-Based Routing: It is believed that nodes have more opportunities to contact in the community, which is beneficial to forwarding messages for other members of their community [23]. Identifying a Community in such cases is the basis of forwarding data. Nodes are grouped into communities by a community detection algorithm. By applying a community based forwarding strategy, data can be forwarded among nodes. Furthermore, extracting communities can also reveal some structural or behavioral properties of the nodes such as selfishness.

2.2.2 Community-based Routing

Community-based routing improves the forwarding efficiency depending on the higher meeting probabilities in the same community. It has been shown that forwarding messages through socially connected nodes or nodes from the same community can achieve better delivery performance in a small conference environment than random forwarding [21].

A number of metrics can be used to represent the social ties that exist between nodes or people. Most of the communities are constructed basing on how similar nodes are. A community metric like similarity can be used to construct the neighboring graph which considers the encounter frequency, encounter length, and separation period in the encounter history. Then, based on the neighboring graph and the associated similarity of other nodes, a community can be formed and studied.

By leveraging this concept of communities we can be able to determine which nodes are likely to be the best relays for messages. A lot of work in literature has exploited this by grouping people that are more likely to influence each other into the same communities, with the hypothesis that people will participate more efficiently in these communities in their future encounters.

2.3 Impact of Human Behavior on Social Opportunistic Forwarding

Taking advantage of both the social popularity and context similarity of nodes can be a good way to improve network performance. Nodes with higher social popularity will meet more nodes and will have high chances of bringing messages closer to the destination. It is also possible to explore and exploit the possibility using human behavior and social characteristics to create an opportunistic forwarding system that can offer better message delivery. Thus it becomes natural to identify the most influential Nodes as well as the most selfish nodes that should be avoided to improve the performance of the network [24].

2.4 Social-Aware D2D Communication

Social trust is an important social phenomenon among socially connected people. The behavior of humans can be used to understand the kind of social trust among people. Therefore, a node is willing to expend its limited resources such as device battery and share data with other nodes with which it has social connections. Hence the existence of social trust and cooperation between the corresponding users can force them to disseminate data toward each other [25]. To maximize the receiving nodes' total utility with the selected messages, it is crucial to ensure that each node has a reputation score that can be used to determine the selfishness level of each node.

2.5 Opportunistic forwarding in D2D

- **PRoPHET:** The use of a probabilistic approach was first introduced in the PROPHET algorithm. PRoPHET (Probabilistic Routing Protocol using History of Encounters and Transitivity) uses the history of last encounters to deliver messages. The algorithm studies pairwise contacts between nodes to make routing decisions. It estimates probabilistic metric called delivery predictability [26]. This routing protocol based on the probability of node's contact with another node. The message will only be sent to a node that has a higher probability of delivering it to the destination.
- **BubbleRap:** The BubbleRap algorithm is based on the assumption that every node in the network belongs to given community and therefore leverages community structure to forward messages. By working out the node centrality within a particular community,

BubbleRap can efficiently make forwarding decisions. The forwarding paths can be selected based on the correlated interaction between nodes or humans in a community. The algorithm uses the centrality metric to identify the most influential nodes within communities. Messages are replicated based on global centrality until they reach the community of the destination host (i.e., a node belonging to the same community) [27].

- **GROUPS-NET** considers the meetings between groups as a factor for content sharing. By considering the mobility of users and how they meet in group settings, GROUPS-NET can find most stable nodes for content dissemination. This algorithm puts into consideration social aspects of users and it was found to outperform Bubble Rap in terms of cost-effective content delivery in large-scale scenarios [28].

2.6 Cooperation Issues in D2D Networks

In a D2D scenario, network constraints (such as limited storage capacity, limited network bandwidth, and limited energy) coupled with selfishness of nodes can bring a great effect on the network performance.

Nodes may not be able to always cooperate due to resource limitations or even due to non-cooperative behavior [29]. There has been much work done on routing in D2D communication. However, less effort has been put into the study of non-cooperative behavior of nodes.

Therefore, the willingness of nodes to relay messages for other nodes plays a significant role in the routing process. It is important that all nodes in the network or community reflect cooperative behavior [30]. This ensures that the overall performance of the network is not compromised.

It is therefore imperative that selfish nodes are detected and encouraged to cooperate. This would improve the network performance (in terms of message delivery and associated delay) by not involving them in the routing process.

2.7 Identification of Selfish nodes

Strategies to categorize the node behavior would be to consider three groups of nodes are termed as cooperators, exploiters, and isolators [30]. Cooperators help in delivering messages. Exploiters use other nodes as free riders. An exploiter replicates messages created by itself to other nodes irrespective of their strategies. However, when it receives a message from any other node, the exploiter does not further replicate those messages. Isolators neither take help, nor provide so to the other nodes in replicating their messages. In other words, isolators directly deliver their messages to their corresponding destinations if and when an opportunity becomes available.

There is some work in the area of node misbehavior which concentrates on detecting and excluding misbehaving nodes. In [15] a system called watchdog is proposed. The system monitors the neighboring nodes to check if they actually relay the data the way they should do.

It is a collaborative contact-based method based on the diffusion of local selfish nodes consciousness when a contact occurs, so that information about selfish nodes is rapidly propagated in Mobile Ad-hoc Networks (MANETS) [15].

2.8 Social Aspects in D2D communication

By applying social metrics it becomes feasible to determine the social ties that exist within these interactions between people. A number of social metrics have been proposed and explored in graph theory. Some of the metrics highlighted include [31];

- **Centrality**: This seeks to identify the popular nodes in the network. It shows the number of edges linked to a node. Therefore a node that happens to have a high degree can be viewed as a popular one with a large number of links to others.
- **PageRank**: This metric determines the importance of node by putting into consideration the centrality of adjacent neighbors in the network.
- **Similarity**: This metric measures the degree to which nodes in a network are related.
- **Selfishness**: Selfish nodes are those that are not interested in cooperating with others. This metric therefore measures the willingness of a node to participate in communication with other nodes. A node will not forward packets received from those with whom it has no social connection or a member of its community, and it will only give priority and preference to messages received from nodes with stronger connection or similarity.

2.9 Social tie based cooperation in community networks

In community or social networks, the links that connect pairs of nodes belonging to different communities are defined as ties. Social ties play a significant role in the structures and the dynamics of community networks. 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 [32].

Methodology

3.0 Mobility traces and datasets

Mobility traces can be analyzed and modelled to reveal a lot of information, which represents the movement scenarios and meetings of people or nodes and their locations at a particular time. Mobility traces have been widely used in D2D protocol evaluation and to implement message dissemination. A number of Reality mobility traces are available for download and these traces contain vast encounter information between nodes, which can be used to reproduce both mobility and mobile social networks for simulation. These traces contain useful information mobile information such as contact frequency, contact duration.

3.1 Mobility Modeling

Mobility will be used to extract patterns for our work. We use the data from the Reality Mining, real word traces (Infocom2006) and crowdad to model mobility patterns of humans. The simulation-based approach is aimed at exploiting mobility traces depict the behavior and interaction of nodes within mobile social networks. Reality Mining trace, the most recognized human social and mobility trace, will be used to drive the simulation. The dataset will be used to determine the content generated by users, the content downloaded, and which users are sharing this kind of content.

We will then model the mobility patterns and social characteristics from contact traces to design a content dissemination framework.

We will use the ONE simulator for D2D, and map users in the social propagation traces to the users in mobility traces, i.e., the social behaviors and mobility behaviors from the traces. Using these traces, we are able to infer user mobility in community settings areas.

By varying the inter-contact duration time, messages sent during group or community interactions, we will be able to characterize the mobility and the structure of this trace to determine the reputation score of each node in the network to determine the level of selfishness.

3.2 Simulation Settings

To validate our framework, we use trace-driven simulations using the ONE (Opportunistic Network Environment) simulator [33] to determine the message delivery effectiveness. ONE simulator is a java based network simulator developed to evaluate a number of network protocols in Opportunistic networks such as those in D2D communication.

The simulation tool provides a powerful framework for generating mobility traces, running messaging simulations with different routing protocols, and visualization both simulation interactively in real-time and generating reports after their completion [26].

3.3 Evaluation criteria

In order to evaluate our model we define some metrics for evaluating their performance.

1. **Delivery Ratio:** This gives the fraction of the messages delivered to the total messages created.

2. **Latency Average**: the average message delay between when message is generated and when it is received.

3. **Hop Count Average:** The average number of hop count between the source and destination node of message.

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