MODE SELECTION AND RESOURCE ALLOCATION IN D2D COMMUNICATION UNDERLAY CELLULAR NETWORKS

By

Hesham Mohammed Hussien

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
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in
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Title of Thesis:

Mode Selection and Resource allocation in D2D Communication Underlay Cellular Networks

Key Words:
Device to Device Communication; Stochastic Geometry; Mode Selection; Resource Allocation.

Summary:

Due to the higher demand for the data rates and massive growing of data and broad band services, Device to device (D2D) communication is considered as an essential part in 5G networks. D2D communication enables the networks to have high data rates, low power consumption and low latency.
D2D communication is allowing direct communication between the transmitter and receiver without relaying the data through BS. Four modes of operation are available in D2D communication (i.e Reuse, Dedicated, Cellular and Silent mode).
In this work we present a mode selection algorithm based on the relative distances between the node to achieve minimum signal to noise ratio for both Cellular and D2D users.

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List of Abbreviations

D2D	*Device to device*
BS	*Base station*
LTE-A	*Long term evolution advanced*
M2M	*Machine to Machine*
IOT	*Internet of Things*
SISO	*Single input single output*
MIMO	*Multiple input multiple output*
SINR	*Signal to noise plus interference ratio*
SNR	*Signal to interference ratio*
C(A)	*Column space of matrix A*
R(A)	*Rank of matrix A*

Abstract

Due to the higher demands in data rate and massive growing of broadband services, Device to device communication is considered an essential part in 5G networks. Device to device communication allows the cellular networks to provide high data rates, low latency and low power consumption.

Device to device communication is allowing direct communication between the transmitter and receiver without relaying the data through the BS .Four modes of operation can be occupied in D2D communications which are reuse, dedicated, cellular and silent mode. The challenge is how to choose the proper resource block and the right mode of operation to satisfy the minimum quality of service (QoS) of the network.

In this work, we purpose a mode selection algorithm that performs resource allocation and efficiently assigns the D2D pair to one of the four modes. By using stochastic geometry analysis, we derive optimal distance thresholds which serve the D2D pair to choose the proper mode and also satisfy the rate constraints.

Also we extend our work to use this mode selection algorithm for MIMO system, and proved that we can use the SISO results to imply it to MIMO system. Then we introduce the decoding and precoding matrices in order to increase the network capacity through using the available degree of freedom given from spatial diversity.

In this work we present a mode selection algorithm based on centralized approach (i.e The BS takes the role of mode selecting and resource allocation), using the relative distances between the transmitting and receiving nodes in the network in order to achieve minimum QoS for both D2D pairs and cellular users.

Numerical results are presented to show the effectiveness of the algorithm in increasing the network capacity and the data rates for the D2D pairs rather than the existing ones.

Chapter 1 : Introduction

In the last decades, there has been a rapid growth in mobile technology and finding an efficient way to connect people from analog mobile communication (1G) until the current generation (4G). The main goals of these developments are supporting higher data rates, increase the network capacity and high spectral efficiency.

In cellular networks, the data is relayed through the BS (i.e centralized approach) whatever is the distance between the transmitter and receiver. Although this approach is convenient in terms of interference management and resource allocation, but due to the higher demand of the higher data rate, it becomes unsuitable to use the same approach due to the limitation of the resources.

Device to device (D2D) communication is considered a main component in 5G networks due to the great gains that can be achieved as higher data rates, low power consumption, low latency and higher spectral efficiency.

D2D communication is allowing direct communication between the UEs to increase the network capacity (i.e the number of users in the network) using the same resources in the network. D2D communication technology is considered as a promising added component to LTE-A system in order to enhance the system capacity and users throughput [1].

D2D communication technology gives the network four types of gains [3]:

- Proximity gain: where short range communication using a D2D link enables high bit rates, low delays and low power consumption.
- Hop gain: D2D communication allows one hop communication directly between the transmitter and receiver rather than ordinary type of the communication through the BS which is considered as 2 hop communication.
- Reuse gain: where D2D pairs use the same resource block (frequency/time) of the cellular user simultaneously.
- Pairing gain: The UE can select either cellular or D2D communication.

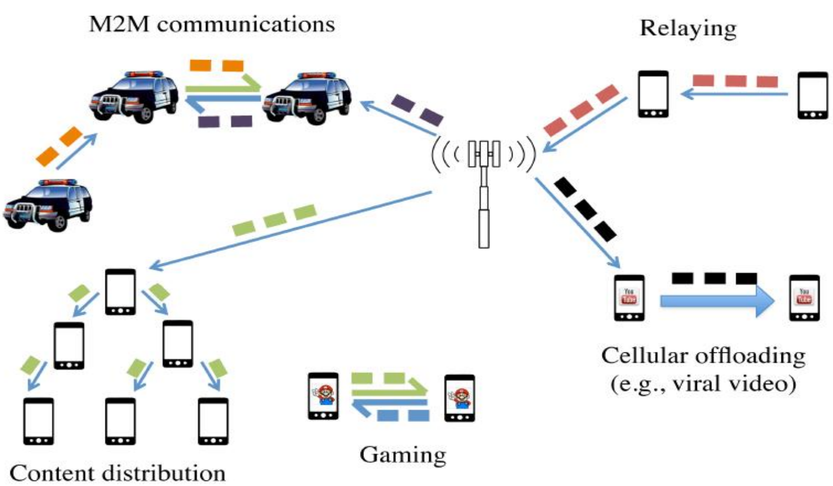

Figure 1: Different Approaches for D2D communication [1]

As shown in figure 1, D2D communication is not only used for direct communication between users, but also it is used to extend the network coverage area through relaying the data to the network edge devices which suffer from poor coverage through relaying the data through other devices. Also it is used in machine learning especially in machine to machine communication (M2M) to update the experience of other machines through M2M communication to enhance their performance. Moreover it can be used in gaming application and video transferring services which require a high data rate within short distances.

1.1. Problem Definition

D2D Communication has four different modes of operation can be listed as follows:

- Silent mode: when there are no available resources to support the D2D communication, the devices neither transmit nor receive.
- Reuse mode: D2D pairs (i.e transmitters and receivers) communicate directly using the same resource blocks used by the cellular users and transmit on the same resources simultaneously.
- Dedicated mode: The cellular network gives a portion of its resource blocks to the D2D links to support direct communication between the pairs.
- Cellular mode: the data between the D2D pair is relayed through the BS without any signaling.

The reuse mode is better mode in terms of network capacity, however it suffers from the interference that comes from the cellular users and the D2D pairs allocating the same resource block. On the other hand, the dedicated and cellular modes do not suffer from this interference, but they are the worst in terms of spectral efficiency.

Note that: the cellular mode pairs can be considered as same as the cellular users, however the cellular mode pairs are in the same communication region (i.e the D2D pair can communicate directly without the BS). Only we use this mode in order to minimize the transmission power between the transmitter and the receiver when the distance between them is too large.

The challenge is how to select the proper mode of operation for the D2D pair, which can be differed from an algorithm to another based on what we need to increase the total rate of the network or the D2D pair or minimize the transmission power in the network.

1.2. Thesis objective

In this work, we study the problem of mode selection and resource allocation, and try to make an algorithm in order to improve the following aspects:

- Increase the network capacity (i.e the D2D pairs allocated in the reuse mode).
- Guarantee minimum signal to noise ratio for both D2D and Cellular users.

Stochastic geometry analysis is used in order to derive the distance thresholds that used in the algorithm in order to selecting the proper mode of operation for the D2D pair.

1.3. Organization of the thesis

The Thesis consists of seven chapters including the Introduction chapter. The remaining chapter can be listed as follows:

Chapter 2 describes the background that can be helpful to understand the concept of D2D communication, the different types of D2D communication, the different scenarios of D2D communication, the concept of cognitive radio and the MIMO systems. Then we will describe the previous works that investigate the problem of the mode selection from different points of view and how can they solve this problem.

Chapter 3 describes the system model we used in our problem including the network layout, the user distribution, the channel model, spectrum portioning and resource allocation and illustrates the rate equations for the different modes.

Chapter 4 describes the mathematical formulation for the distance thresholds used in the algorithm and illustrates briefly the proposed algorithm and how it determine the proper mode of operation for the D2D pair and selects the available resource block.

Chapter 5 describes the mathematical formulation for the MIMO model and how we use the results we have in SISO case and apply it in MIMO system. Also we illustrate how to design the decoding and precoding matrix in order to maximize the network capacity.

Chapter 6 show the numerical results of the proposed algorithm for both MIMO and SISO cases and show the effectiveness in order to achieve data rates higher than the minimum rates.

Chapter 7 illustrates the conclusion of our thesis and the future work that can be added in order to extend this work.

Chapter 2 : Background and Literature review

2.1. Background

In this section, we introduce and illustrate some definitions and concepts in order to understand D2D communication and it is also needed to derive the mode selection algorithm.

2.1.1. Cognitive radio

It is considered one of the techniques used in increasing the network capacity, through increasing the number of users using the same operating band of the networks. The main principal of the cognitive radio is to make the users operate in the time slots which the frequency channels are vacant which is called dynamic spectrum access as shown in figure 4.

The users in cognitive radio networks are classified into primary users and secondary users. The primary users may be considered as the cellular users of the network so they must be allocated with a given channel from the BS, while the secondary users may be considered some other local applications which required the use of licensed band channel. The secondary user transmitter sense the spectrum in order to find a spectrum hole, then the secondary user receiver adapt itself in order to receive the data on the same spectrum hole.

Although the cognitive radio approach increases the network capacity, but it is based on the spectrum sensing which is not easy issue to find a spectrum hole and synchronize the hole with the receiver.

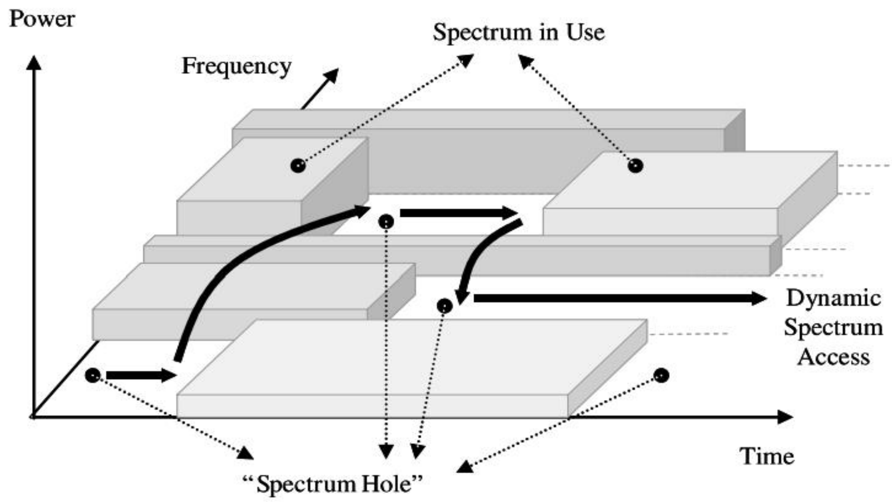

Figure 2: Dynamic spectrum access[10]