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Evolved Multimedia Broadcasting and Multicasting Services in LTE-A using Device to Device Communication

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ABSTRACT

With the rapid growth in data services including multimedia downloading, video conferencing, live streaming and mobile TV in the last few years, there has been increased demand of LTE broadcasting. However, there are many challenges in this area and one of the biggest problems occurs when several users subscribe to the same multimedia service. Then it becomes inefficient to transmit the same content multiple times to subscribers via unicast. This problem is aggravated when the number of users coming in between the multicast session is huge. In order to overcome this, dynamic scenario is proposed that incorporates Device-to-Device (D2D) communication along with Multimedia Broadcasting and Multicasting Services of LTE. This is achieved by integrating multicasting and D2D communication between the users. The performance of static as well as dynamic scenario is compared on various metrics. In addition to this, performance of various device discovery protocols supporting this model has been analyzed and compared with static scenario. As the demand for newer multi-media rich data applications is rising, there is an urgent need for using some novel techniques. In this regard, D2D communication can be used that allows direct communication between proximate devices without using the direct link through the base station or evolved NodeB (eNB). One of its main benefits is that offloads the traffic from the network and leads to improvement in energy efficiency. However, the major challenge in using D2D communication involves discovering the proximate users in order to set up direct links between them. The critical prerequisite in establishing D2D communication involves efficient device discovery so that D2D links could be established quickly and transmission over these links can be carried out smoothly. Among the various device discovery protocols, direct device discovery protocols is one of the categories in which discovery process is not controlled by the network. Further, these protocols are scalable and can be implemented in out-of The coverage scenarios . In this work, network performance of various direct device discovery protocols for establishing D2D links under both static and dynamic scenario is being studied.

I. INTRODUCTION

Device-to-device (D2D) communications has been recognized as one of the promising technologies for handling the explosive growth of cellular data demand. In this chapter, we introduce the concept of D2D communication, as well as its usage prospects and design issues. Finally, we describe the structure of this thesis and detail its main contributions. 1.1 D2D communications in future cellular networks The mobile communications sector has experienced an explosive growth during the last decades, both in the number of mobile subscribers and in the data traffic demands. The dramatic increase in data traffic is mainly due to the proliferation ofsmart devices and the massive usage of mobile applications. As reported in [1], only in 2016 the global monthly data traffic grew around 70 percent, and is today morethan thirty times the amount of voice traffic. Going forwards, according to Cisco's latest report [2], the global mobile data traffic will increase sevenfold between 2016 and 2021 (see Fig 1.1), with an average traffic generated by a single smartphone close to 6.8 GB per month, a fourfold increase compared to 2016 [2]. Richer web content, increasing social networking applications, audio and, above all, video streaming1 are factors that will continue raising the amount of data traffic in cellular networks. In addition, the spread of wireless devices accessing mobile networks for new applications beyond personal communications (e.g., machine-type communication [3] and wearable devices [4] for home security, automotive, healthcare, etc.) are also contributing to the globalmobile traffic growth. The need to support this traffic explosion is certainly the main challenge of the next generation cellular systems, referred to as the fifth Generation (5G). In fact, The mobile video traffic represents the largest contributor to the global mobile traffic growth (currently it accounts for more than half of all data and it is foreseen to reach around 80 percent in 2021), fueled by high-definition video streaming and the increasing use of embedded videos in social media and webpages [1]

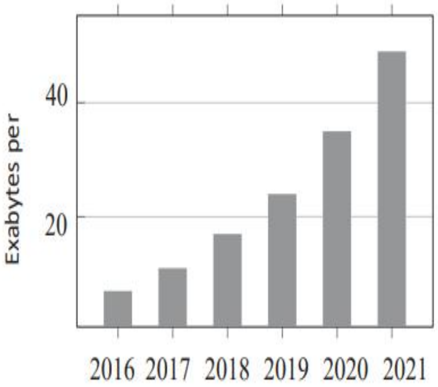


Fig 1.1.1: Global mobile data traffic,

from 2016 to 2021 The overall mobile data traffic is expected to grow to 49 exabytes (1018 bytes) per month by 2021, nearly a sevenfold increase over 2016. This figure is a modification of Figure 1.1.1 in [2]. 5G networks are meant to provide, among other targets, 1000 times larger mobile data volume per area, 10 to 100 times higher user data rate, and to serve 10 to 100 times more connected devices than current cellular systems [5]. Designing wireless networks which are able to fulfil these ambitious specifications, while taking into account constraints in terms of cost, energy, and radio spectrum, is a challenging goal for both industry and academia. As suggested by the European flagship 5G project METIS, future systems should meet the new communication requirements by means of the evolution of existing technologies, complemented by new radio concepts [6]. Existing approaches that operators can leverage in order to increase the system capacity can be grouped into three main categories: i) increase of the radio spectrum (e.g., by moving to higher frequencies); ii) improvement of the link efficiency by means of advanced communication technologies (e.g., by using multi-antenna transmissions (MIMO)); and iii) densification of the network by deploying more base stations and reducing the cell size [5].

The deployment of smaller cells as part of heterogeneous networks is a common solution to enhance the capacity in highly populated areas like, for example, businessdistricts, universities, and malls. This because small-sized cells manage higherqualitylinks and allow for increased spatial reuse [10]. However, extreme densification might also increase the network deployment and operational cost. Thus, besides cell shrinking.

II. EXISTING METHODOLOGY:

In this chapter, we present an overview of the system model used in our studies.In particular, we highlight and justify the main modelling approaches and design choices common to the remaining chapters of the thesis. Network modelling and assumptions In our studies, we consider a cellular network consisting of aset of base stations (BSs). Each BS is placed in the center of the cell and serves the mobile users located within the cell area. We assume a set of L transmitter-receiver pairs, each constituting a logical link that we label with an integer 1, 2, . . . , L. A logical link can be a pair of cellular users exchanging data through the serving BS via uplink and downlink transmissions, or a D2D transmitter-receiver pair communicating through a direct transmission. We refer to the users forming the pair l as transmitter l (Tx l) and receiver l (Rx l), respectively (see Figure 3.1.1).

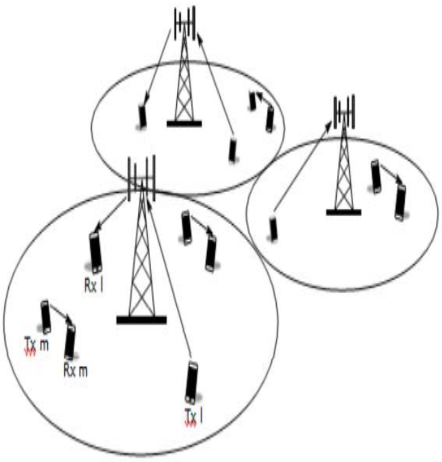


Fig 2.1.1: D2D-enabled multi-cell network model; pair l is communicating in cellularmode while pair m is in D2D mode. Black arrows indicate the communication direction.

Taking LTE as a reference system, we consider orthogonal frequency division multiplexing (OFDM) [25]. The available system bandwidth is divided into a set of F resource blocks (RBs), each of size W Hz and time duration T s. Each RB represents 23 User 1 User 2 User 3 Frequency the smallest radio resource that can be assigned to the users. In LTE, this basic unit consists of 12 consecutive subcarriers with a spacing of 15 kHz, thusoccupying a total of 180 kHz, for a time slot duration of 0.5 ms [35]. The RBs are the radio resource units that the cellular users are allocated in a scheduling period,and that the D2D pairs can request for their communications (see Figure 3.1.2).

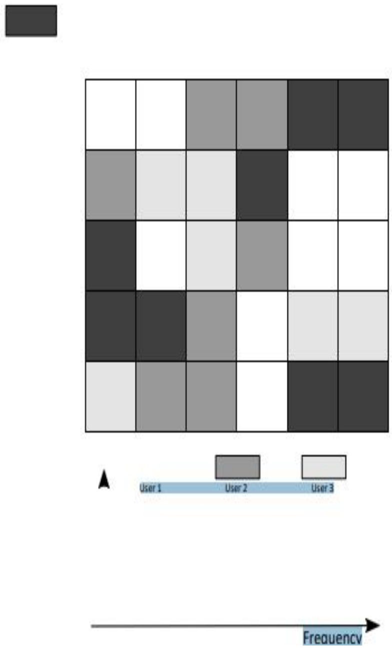


Fig 3.1.2: Example of downlink resource allocation for an LTE-like system

We assume a full-buffer traffic model, where transmitters always have data packets to send to their intended receivers. We denote by P f the power level used by Tx l when sending data to Rx m on RB f . Note that the BS can act both as transmitter and receiver, depending on whether it is involved in downlink (DL) or uplink (UL) transmissions, respectively. We consider maximum power constraints in the form

$$0 \leq P\ f \leq P,$$

where P max is the maximum allowable transmission power for Tx l.

III. PROPOSED METHODOLOGY:

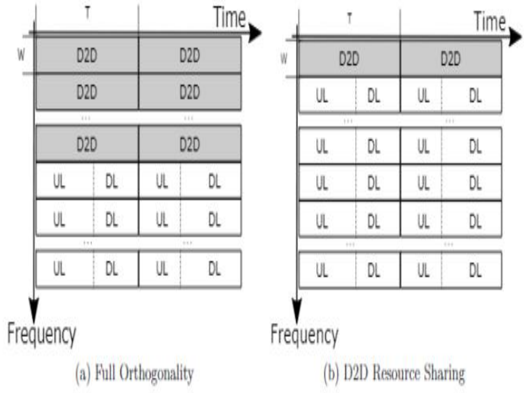
3.1 Motivation and contributions

The exponential growth of wireless data traffic is causing the energy consumption of cellular systems to escalate. As a consequence, the research community is directing significant efforts towards energy-efficient solutions for future networks. D2D technology is part of these solutions, having the potential of enhancing the energy efficiency of both mobile devices and cellular networks. In particular, D2Dpairs can use low transmission power because of their short communication distance, and the energy consumption at the BS can be reduced by offloading some of the traffic to the D2D links. Several energy-efficient designs have been proposed in the literature to benefit from the advantages of D2D communications. However, to the best of our knowledge, there are no works addressing the joint D2D mode selection and resource allocation problem for energy-optimal operations in dynamic TDD networks. Dynamic TDD systems are expected to be prominent in future networks, mainly because of their ability to handle traffic level fluctuations between uplink (UL) and downlink (DL). Moreover, they can exploit the channel reciprocity to reduce signaling and radio frequency front-end complexity, compared to Frequency Division Duplex systems. Performance improvement that can be obtained by integrating. D2D communications in cellular systems with dynamic TDD have only recently gained attention in the literature. Frameworks for D2D enhanced TDD networks are proposed in. However, they do not account for mode selection, focusing mainly on the adaptive UL/DL slot allocation for the D2D pairs to balance the traffic load, coordinate the interference, improve coverage probability and sum-rate. The authors of [108] have extended the resource allocation problem introduced in to include mode selection. Yet, the mode selection decision is based on the instantaneous SINR, and not jointly with the power and transmission time allocation, as proposed instead in this work.

3.2 System model and problem statement

We consider a single-cell network with a set of user pairs that wish to communicate, either via the base station (BS) in Cellular mode or directly in D2D mode.Each user pair constitutes a logical link that we label by an integer taking value from 1, 2, . . . L . The BS is indexed as 0 and we refer to the users in pair l as transmitter l (Tx l) and receiver l (Rx l). The mode selection policy divides the set of all user pairs into two subsets: is the subset of pairs assigned to D2D mode, and is the subset of pairs assigned to cellular mode. The system bandwidth isdivided into F of orthogonal channels of size W Hz, and time is divided into framesof fixed length of T seconds. The BS assigns to equal logical link a time-frequency physical resource, consisting of one time frame and one frequency channel. The transmission power of each pair, together with the transmission duration and the communication mode, are updated at the beginning of each time frame on the basis of the estimated large-scale fading. We assume that the largescale fading remains constant within the frame duration T 1 , and changes slowly among consecutive frames. The advantage of assigning the communication mode based on the large-scale fading, rather than on the fast-fading measurement, is to reduce the number of unnecessary communication mode switches due to temporary changes of the channel condition. In fact, if the channel gains do not change fast, it is likely that the user pairs would prefer the same communication mode for a longer time period. This is beneficial for the link configuration procedure and signalling overhead. On the other hand, to exploit or compensate for the small-scale fading and frequency diversity of the channels, we assume that a proper frequency channel assignment is applied after the communication mode selection, to further improve communication performance. This additional frequency channel allocation problem is not considered in this work.

3.3 Communication in cellular mode We consider the dynamic TDD scheme, where the uplink (UL) and downlink (DL) transmissions for a user pair occur on the same frequency channel but alternate in time. The portioning of resources assigned to the UL and the DL can be reconfigured at each time frame, but it is assumed to be the same for all communications within the same cell. This intra- cell UL/DL synchronization is usually applied in practice 45 because it reduces the complexity of the inter-cell interference management in the more general multi-cell network. Moreover, to prevent intra-cell interference between concurrent transmissions in cellular mode, the BS follows the channel allocation policy of legacyLTE systems and assigns a separate channel to each cellular user (see Figure 5.3.1). To ensure that there are enough resources if all users are assigned to cellular mode, we assume F = L



(a) Full Orthogonality (b) D2D Resource Sharing

5.4 Communication in D2D mode

Each D2D pair can use the full frame durationfor its single-hop transmission, as shown in Figure 4.1. Let tl T denote the active time of pair l in D2D mode. A large body of work considers underlay in-band D2D communication, where D2D transmitters opportunistically access the radio resources occupied by cellular users. A disadvantage of underlay D2D communication in TDD systems is that the receiver of the D2D link perceives a rapid change of the interference power in one time frame when the cellular pair switches between UL and DL transmission. It is difficult to compensate for this effect without resorting to complex interference management algorithms that require detailed cross-gain knowledge and have high signaling load. Therefore, in this work we focus on overlay in-band D2D communication, where D2D and cellular communications are assigned different frequency channels so that they do not cause interference to each other (see Figure 4.1). Nevertheless, resource reuse among D2D communications has been investigated in our studies.

IV. RESULTS:

Simulation results of the proposed dynamic scenario are being compared with static scenario on various performance parameters that include system utility, throughput and end-to-end delay. Queuing theory provides the mathematical analysis of system utility which is defined as the rate at which each base station can serve the user. In other words, it is the ratio of arrival rate to the service rate. System utility (ρ) is thus given as,

$$\rho = \lambda/\mu \quad (1)$$

where, λ = Arrival rate i.e. the rate at which user calls arrive at the base station μ = Service rate i.e. the rate at which the base station can provide services to the user. In this work, following assumptions regarding network properties for the given scenario are considered:

i. It is assumed that the service rate of each base station in the network is 5(i.e., μ =5).

ii. ii. All the Base stations in the network are capable of multicasting. An input signal entered in a base station node can branch out into multiple outgoing signals.

iii. iii. The traffic pattern is dynamic, i.e., all the multicast session requests are not known before

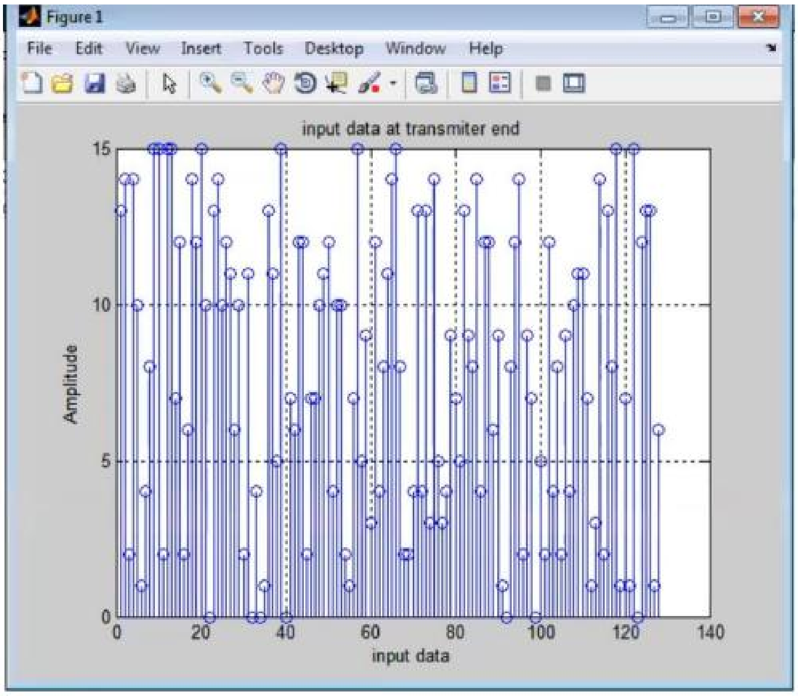


Fig 4.1: Input data at transmiter end

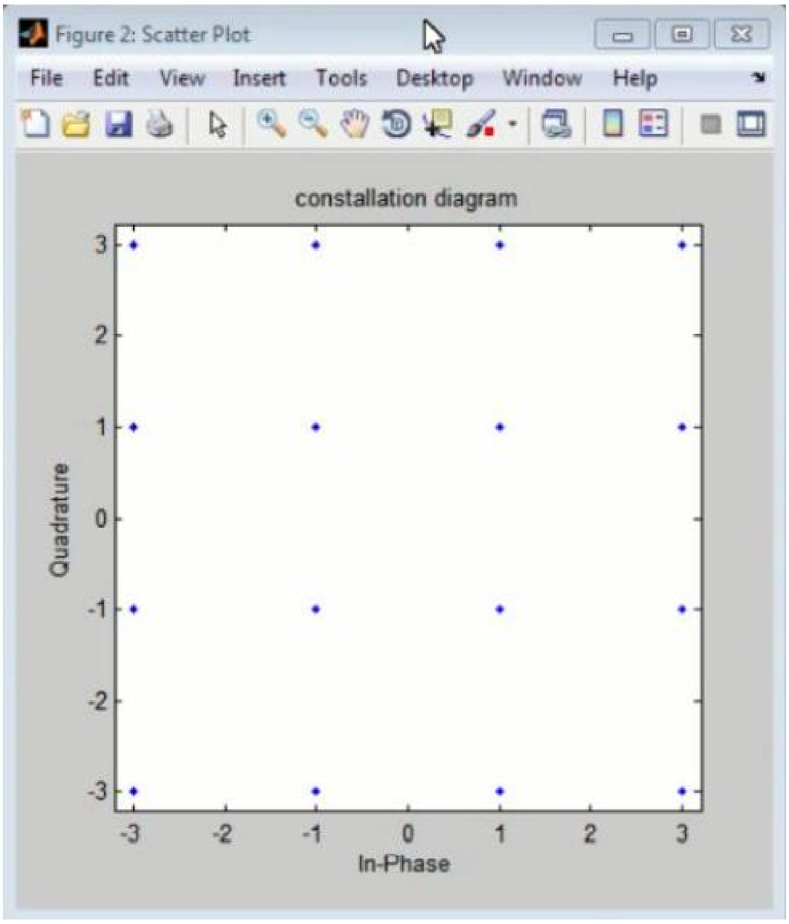


Fig 4.2: Constallation diagram

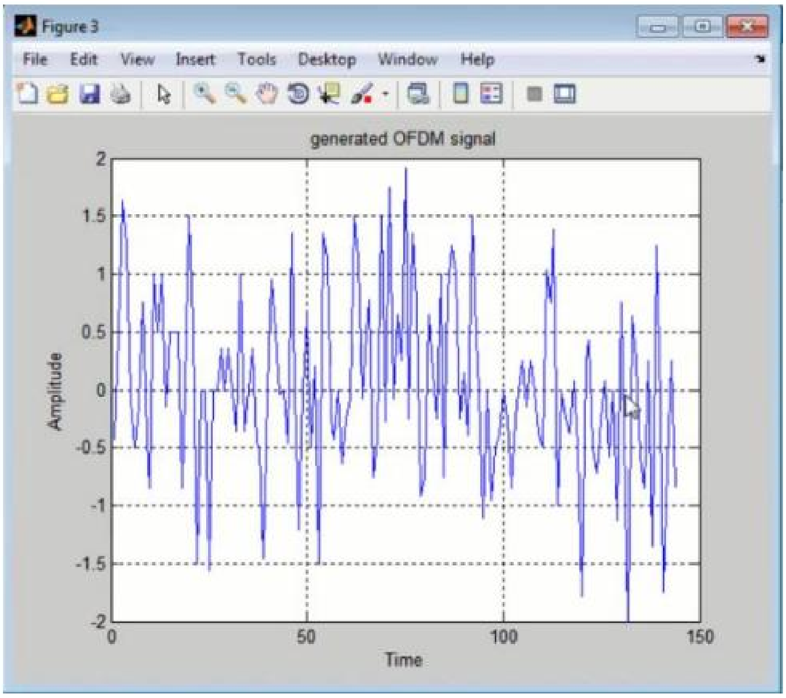


Fig 4.3: Generated OFDM signal

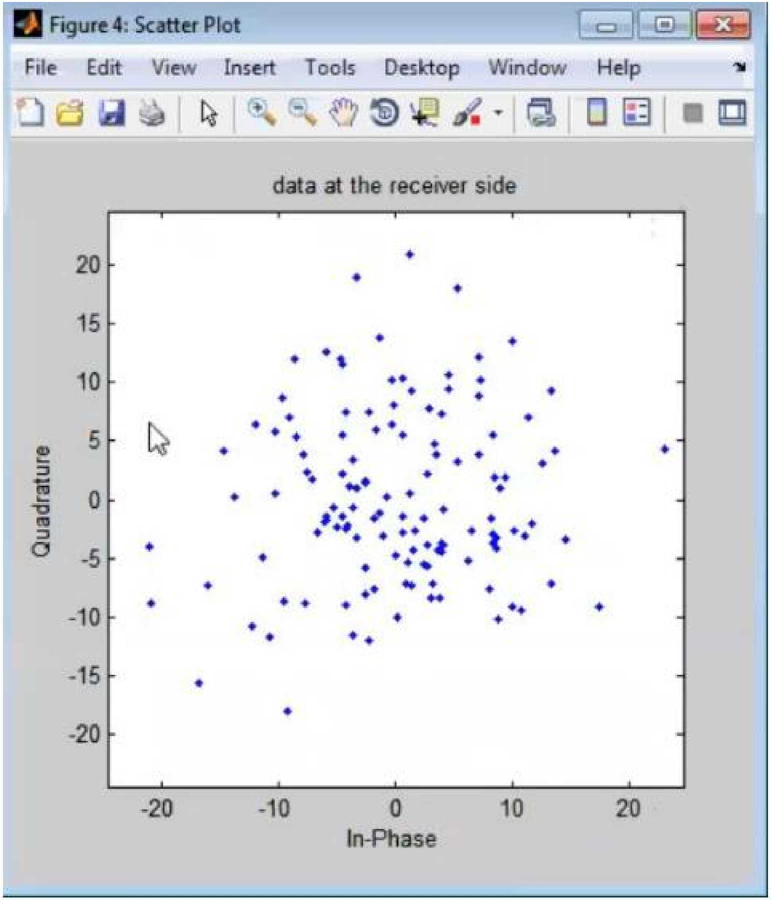


Fig 4.4: Data at the receiver side

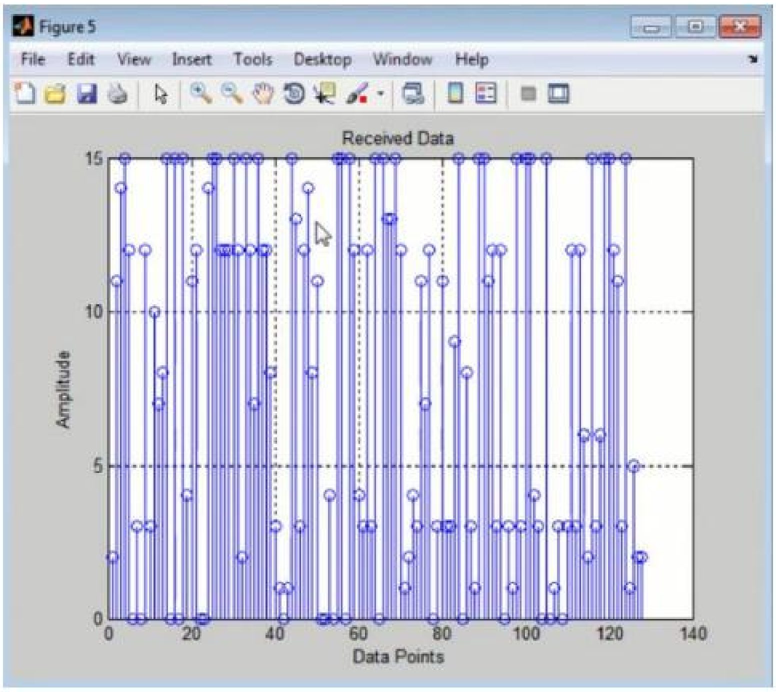


Fig 4.5: Received Data

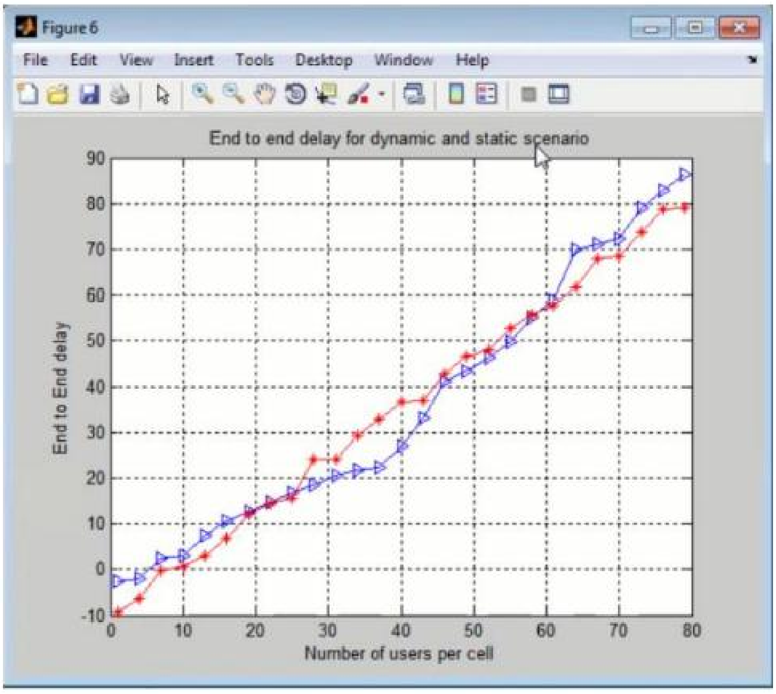


Fig 4.6: End to end delay for dynamic and static scenario

V. CONCLUSION:

In the present work, static as well as dynamic scenario is compared and analyzed. In static scenario, user statically subscribes the multicast channel, and the requests which are arriving at a fixed time interval are being served by using multicasting mode of data transmission. In order to overcome the problem faced in the static scenario, dynamic scenario that incorporates Device-to-Device (D2D) communication along with Multimedia Broadcasting and Multicasting Services of in LTE is studied and analyzed. According to the proposed dynamic scenario, after the establishment of LTE's multicast session, further users who demanded the same multimedia content would be served by device instead of the BS, thus saving the system resources and reducing the server load. The performance results of the proposed dynamic scenario were compared with that of static scenario on various performance metrics that included system utility, throughput and end-to-end delay.

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