Energy Efficient Multicast Scheduling in Device-to-Device Communications Enabled mmWave Small Cells

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Abstract : The last decade brought major changes in cellular networks, as explosive growth in data traffic and users capacity demands requires more and more network capacity and backhaul capability. Future wireless technologies have been developing to tackle these challenges. One of the current emerging technologies is the device-to-device (D2D) communications technology. This enables connection within cellular systems between two user equipments (UEs) to communicate with each other directly by reusing cellular radio resources. In this case, D2D is able to offload data traffic from central base stations (BSs) and significantly improve the spectrum efficiency of a cellular system, and hence this is the key technology for the future generation mobile communication systems. With a super greatly increased traffic rate from huge bandwidth of mmWave communications, for higher energy efficiency this should be mitigated. This paper, propose an energy-efficient multicast scheduling scheme, referred to as EMS algorithm, which utilizes both D2D network and concurrent transmissions to achieve more energy efficiency. In this algorithm, a D2D path planning algorithm establishes multi-hop paths between D2D and a concurrent EMS allocates the network links on the D2D paths into different pairs. Then, the transmission power of links is managed by the power control method. Simulation of EMS with various system parameters describes the best performance of algorithm in terms of energy as compared with the state-of-the art methods.

Index Terms - Device-to-Device (D2D), mmWave communications, Energy-Efficient Multicast scheduling (EMS) scheme

I. Introduction

Recent years we have seen an explosive growth in data demand which requires an evolution of current cellular network. As a result, a wide range of new wireless technologies have been developed for such challenge. Millimeter wave mobile communication is used to enable cellular user equipment (UE) to communicate at an extreme high frequency (30GHz – 300GHz), so it may utilize more bandwidth and thus improve the system throughput [1]. Hyper-dense small cells deployment is under test to meet the “1000x mobile data traffic challenge” by Qualcomm and other institutes [2]. Massive MIMO is used as an evolution from conventional point-to-point MIMO in order to help concentrate energy into ever smaller regions of space to manifestly improve the throughput and radiated energy efficiency [3]. LTE-unlicensed is developed to allow cellular UE sharing unlicensed frequency bands with Wi-Fi [4]. Finally, device-to-device (D2D) communication is proposed to offload local data traffic from cellular base stations (BSs) and improve cellular spectrum efficiency by enabling two UEs in proximity to communicate with each other directly reusing cellular radio resources.

There are some new challenges for D2D communications in next generation cellular networks. In [3, 4] introduces a game-theory approach for the research of business value of D2D communications. We note that there may have four major emerging challenges for D2D in the next generation network [5]. mmWave is proposed for the next generation networks for very high data rate networks, as it enables cellular UEs operating at high frequency. It is quite suitable for D2D communications as it targets at short-range communications. It has unique propagation model and thus require new researches in how to combine D2D with mmWave network [6]. Current researches focus on D2D coexisting with macro cells, which the system model is relatively simple [7-10]. The mutual interference situations for both D2D and CC UEs will be much more complicated if taking hyper dense small cells into consideration. In addition, mode selection between CC small cell communications or D2D communications becomes a new problem to the system.

Day today applications like TV streaming, advertisement information broadcasting, and broadcasting services can be supported by the multicast group service, where BS provides multiple users with the same data [11, 12]. Simultaneously, there will be many user devices present near to each other in the user-required region. In this case, device - to - device (D2D) communications in physical proximity can be exploited to conserve energy and improve the efficiency of energy [13, 14]. Comparisons are done with D2D communications reuse of cellular frequency band, by this interference between D2D communications is minimized in the mmWave band and the cellular communication systems. In the multicast group services, BS needs to give service to each user one by one serially as in the traditional methods and since the transmission links are managed and hence, it is to achieve better network performance [15]. With D2D communications enabled, mobile users with the multicast traffic are able to forward the multicast traffic to other mobile users using best D2D channels, and there will be more non-neighbor links, and concurrent data transmissions can be enabled to achieve best performance. Thus, we assume the same capability for the BS and mobile stations in this paper.

The rest of this paper is organized as follows: The section II describes related work about Device-to-Device communication for future wireless networks and different energy efficient multicast scheduling in mmWave small cells in detail. Finally, Section II describes the proposed EMS algorithm for energy efficiency. Results are discussed in section III and section IV concludes this paper.

II. RELATED BACKGROUND

In this section, we focus on the D2D communication and developing new technologies for D2D communications in order to optimize the energy efficiency.

A. D2D Communications

Device-to-device communication that enables direct communication between nearby mobiles is an exciting and innovative feature of next-generation cellular networks. The benefits of D2D communication are: Increased network efficiency, Less power consumption and long battery life, Efficient traffic load management, Connection can be established even during absence of network, Network extension without adding complex hardware like base stations, Applications of D2D communication, Public safety and security services, Machine to machine peer to peer communication, Vehicle to vehicle communication and autonomous driving applications, Cellular offloading (to WLAN network for faster data transfer), Gaming and local social networking, Content distribution, local advertisement and location-aware services and Local area emergency broadcast and warning messages. Figure 1 shows the Device-to-device communication network architecture.

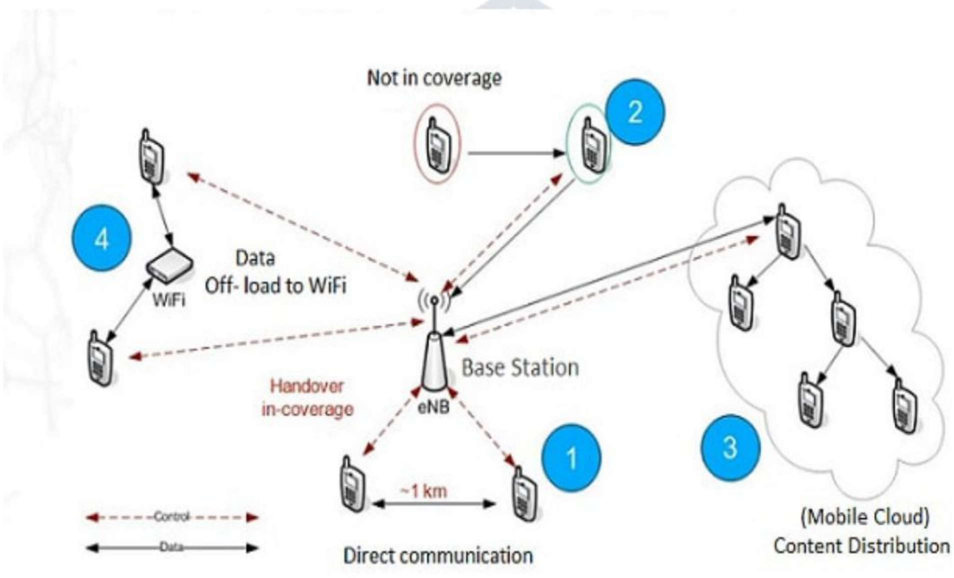

Figure 1: Device-to-device communication network architecture.

Device-to-device communication network architecture describes four different scenarios as follows:

Scenario 1: If two devices are in proximity they can start communication like sharing data. This helps to improve data rate, reduce power consumption of devices and total load reduction of base stations. The control will be handled by base station.

Scenario 2: During the absence of an active mobile network connection or insufficient signal reception, D2D enabled devices can establish an alternative communication interface with its surrounding devices which are connected mobile base stations. It will help the node with no coverage to maintain a connection to the mobile network.

Scenario 3: Multiple devices can connect to a device which has an active connection to base station and further extend this network with adding connection to more devices. All devices in this small mobile cloud will receive same data in the form of advertising or messages from the source.

Scenario 4: In this case, multiple devices are offloaded to Wi-Fi data connection for communication. Control signals to devices (UE) will be handled by the base station. Wi-Fi offloading offers much higher data rate, less power consumption and avoid traffic overload of base stations.

Other Scenarios: D2D communication is used in vehicle to vehicle communication and peer to peer communication applications in the same way. All these cases, one node will connect to main base station (transmitting station) and other devices form a small network to communicate each other [1-8].

There are several paramount challenges in D2D communications. Peer discovery and link establishment are the first two challenges for setting up D2D communications [5-9]. For autonomous D2D communication, it requires D2D UEs to broadcast message, search potential peers and set up the links all by themselves [16].

B. Energy Efficient Multicast Scheduling in Device-to-Device Communications.

The problem of multiuser resource allocation and scheduling has been thoroughly investigated for D2D communication in mmWave cells [6]. However, they were mainly concerned on the efficient scheduling. The directional MAC methods for WPANs or WLANs in the mmWave band [1-3]. Since the standards of IEEE 802.15.3c adopt TDMA scheduling, derived the ER conditions that concurrent transmissions always outperform TDMA for both antenna models, and proposed the REX scheduling scheme (REX) brings significant spatial reuse gain. Some other two protocols based on IEEE 802.15.3c, which exploit concurrent transmissions to better performance when the multi-user interference is below a specified threshold. Furthermore, a multi-hop concurrent transmission method is proposed to address the link outage problem in cellular systems and combat huge path loss [4, 5]. For bursty traffic data, TDMA based protocols may allocate not enough medium time for some other flows, while overmuch medium time for others [11]. Some other best centralized scheduling methods are also proposed for WPANs or WLANs in the mmWave band [6, 7]. Gong et al. [8] proposed a directional CSMA/CA protocol, which exploits virtual carrier sensing to address the deafness problem. Singh et al. [9-12] proposed a multi-hop relay directional MAC protocol (MRDMAC), which exploits relaying to overcome blockage. The frame based directional MAC method (FDMAC) is proposed in [13], where the greedy coloring algorithm exploits concurrent transmissions for high energy efficiency. In the scenario of an IEEE 802.11ad WLAN, Chen et al. [14] proposed a directional cooperative

In multicast D2D communication, Naribole and Knightly [13] proposed scalable directional multicast (SDM) to train the access point with per-beam per-client RSSI measurements via partially traversing a codebook tree. Based on the learning information, a scalable beam multicast algorithm is developed to achieve the optimized multicast group data transmission time. Park et al. [17] proposed an incremental multicast grouping method, which generates adaptive beam widths depending on the locations of multicast devices to maximize the sum data rate of devices. However, D2D communications are not considered in this method. An energy efficient scheduling scheme for popular content downloading (PCDS) is designed in [19], where mobile users far from the AP obtain the popular content from nearby mobile users via D2D communication. At the same time, concurrent transmissions are also enabled to improve the performance. In terms of energy efficient MAC protocols for wireless networks in the mmWave band, Niu et al. [18] proposed an energy efficient scheduling scheme for the mmWave backhauling network, which exploits concurrent transmissions to achieve best energy efficiency.

III. Energy efficient multicast scheduling scheme

In this section, we used the energy efficient multicast scheduling scheme, EMS, for the defined problem [1]. Both D2D communications and concurrent transmissions are considered in EMS to improve the energy efficiency. First, we applied a D2D path planning algorithm to establish the multi-hop D2D transmission links. Then a concurrent scheduling method is applied to schedule the links on the D2D paths concurrently into each pairing with the interference controlled. At last, a power control method adjusts the transmission power to realize energy consumption reduction.

A. D2D Path Planning Algorithm

The D2D path planning algorithm establishes multiple D2D transmission paths from the BS, and by finding the nearest user to the last user on one of the allocated D2D transmission paths, this path is extended by including this new user. If one unallocated user is nearest to the BS, one new path from the BS to this user will be established. The number of hops on each path cannot exceed a predetermined value [2-8]. We denote the BS by A, and the set of selected D2D paths by P. The maximum hop number for each path $p \in P$ is denoted by H_m. For each path $p \in P$, the last node on p is denoted by L_p. The set of last nodes of paths in P is denoted by P_L. In this algorithm, P_L represents the set of nodes with the multicast traffic and the ability to serve other users by D2D communications. Since the AP A is the source with the multicast traffic, A is included in P_L.

B. Concurrent Multi-Hop Scheduling

Obtaining the D2D transmission paths by above algorithm, this method exploited to improve energy efficiency. Thus the concurrent multi-hop scheduling method is used to schedule the links on the D2D transmission paths into the transmission period. The algorithm controls the interference via the contention graph, and the maximum independent set (MIS) is utilized to achieve higher efficiency.

C. Power Control Algorithm

With links on the paths scheduled into each pairing by, a power control algorithm is proposed to adjust the transmission power of links for lower energy consumption, which is also used in [8]. To ensure the throughput achieved by our scheme not less than the serial unicast scheme, we require the number of time slots occupied by our scheme not larger than that by the serial unicast scheme, Ts. On the other hand, the better channel conditions provided by D2D links can also help to achieve lower energy consumption.

IV. Results and discussions

In this section, EMS algorithm is evaluated and its performance is compared against other schemes under various systems with different parameters. Besides, the threshold impact on the throughput of EMS is investigated.

A. Simulation Setup

In an mmWave small cell, we assumed the BS is located at the center of a square area of 10m × 17m, where several users are uniformly distributed. In the simulation, we adopt the reference antenna model with side lobe in IEEE 802.15.3c, which has a main lobe of the Gaussian form and side lobes with constant level. Along with this some other parameters are considered as maximum transmission power of 30dB, bandwidth of 2160MHz path loss exponent of 2, maximum number of hops 6 and multicast group size of 15 users.

B. Simulation Results

As per the above simulated parameters are used while simulation and here some of the results are shown and compared with previous scheduling schemes.

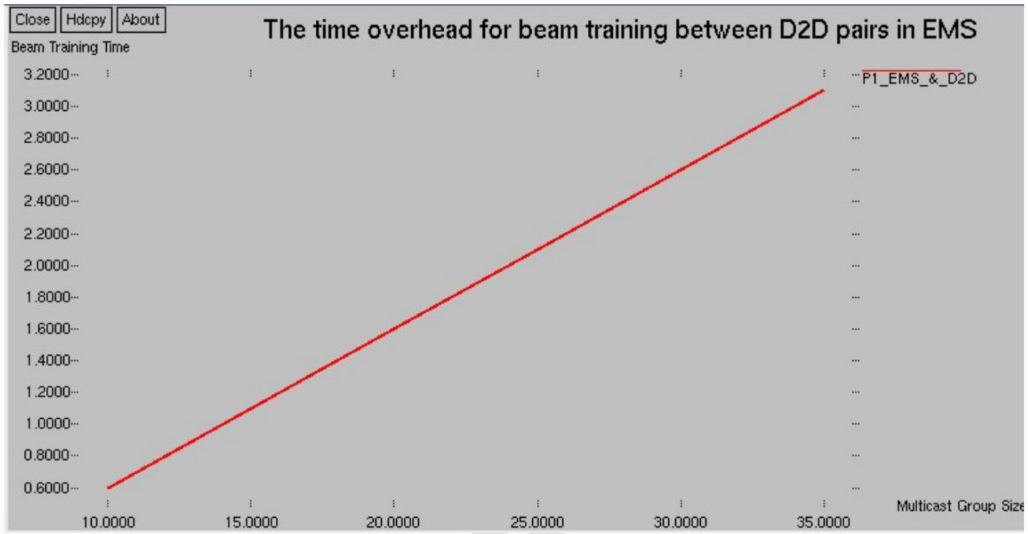

Figure 1: The time overhead for beam training between D2D pairs in EMS and the D2D scheme under different multicast group sizes.

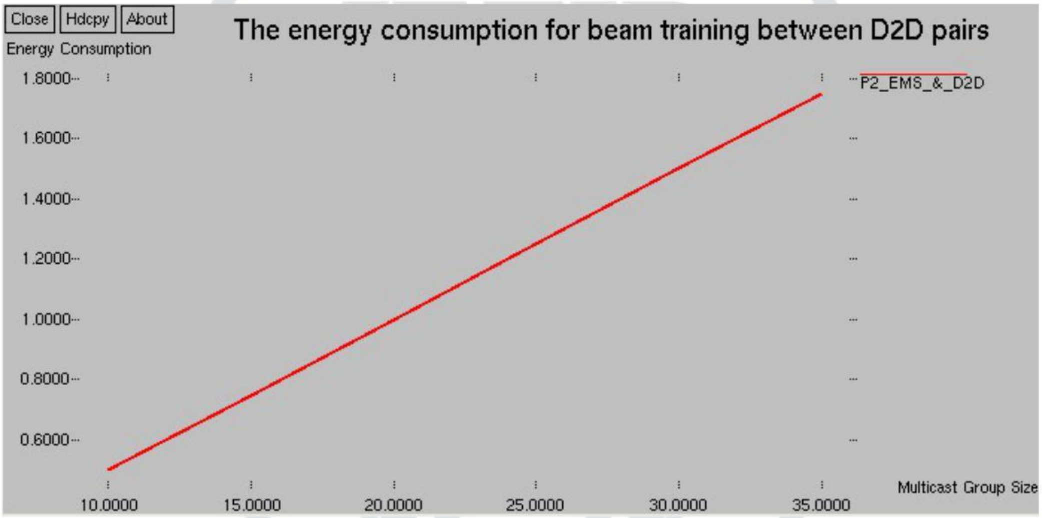

Figure 2: The energy consumption for beam training between D2D pairs in EMS and the D2D scheme under different multicast group sizes.

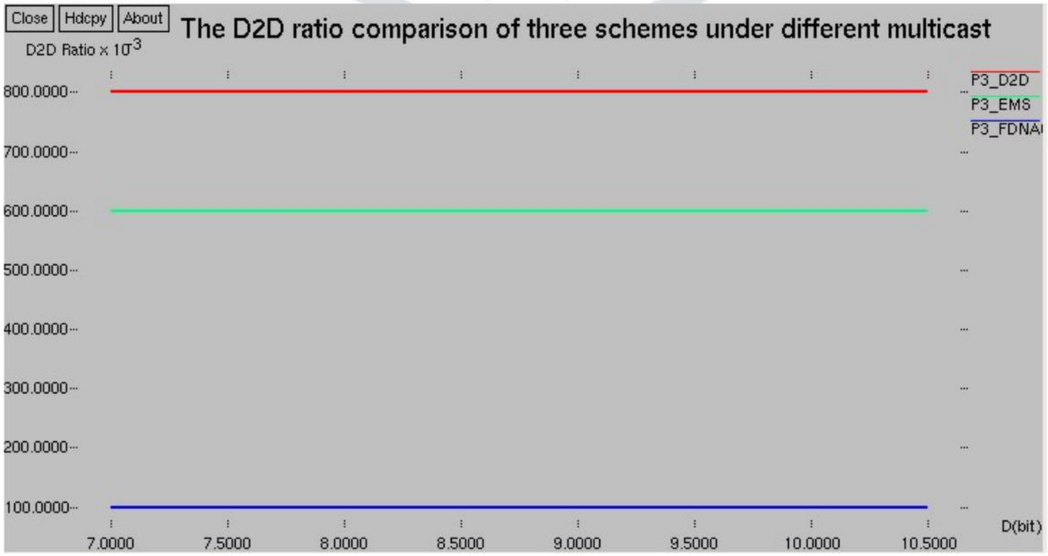

Figure 3: The D2D ratio comparison of three schemes under different multicast data sizes.

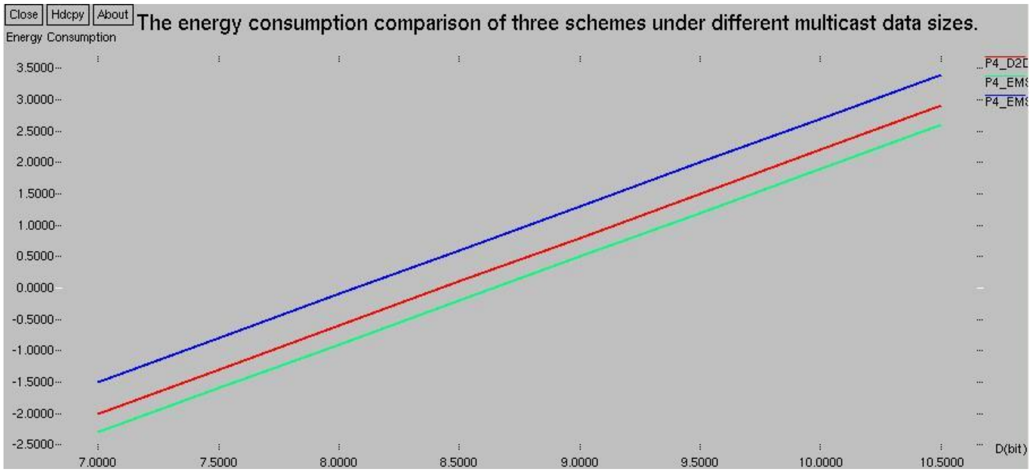

Figure 4: The energy consumption comparison of three schemes under different multicast data sizes.

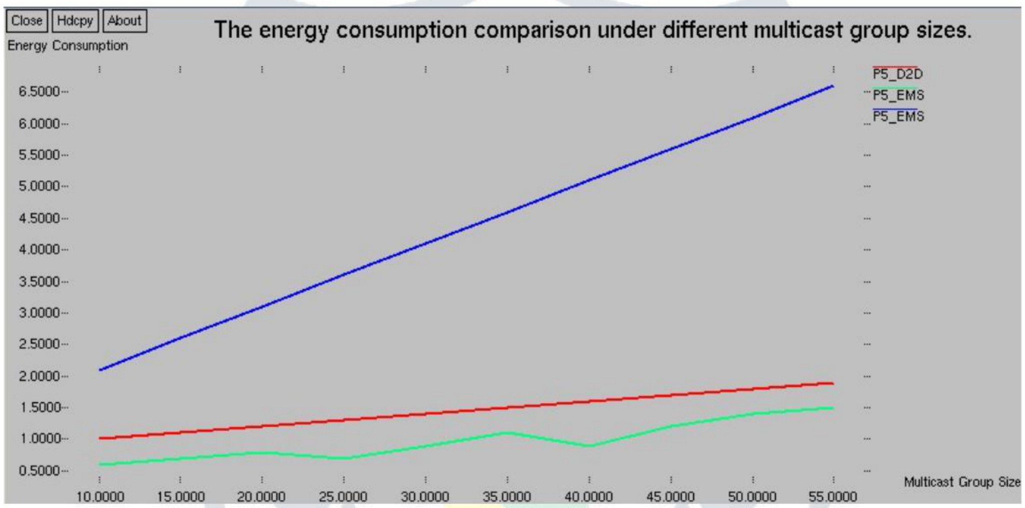

Figure 5: The energy consumption comparison under different multicast group sizes.

Figure 1 and 2 shows time overhead for beam training between D2D pairs in EMS and the D2D scheme under different multicast group sizes. With the increase of multicast group size, the time overhead increases due to more D2D pairs on the D2D paths and energy consumption for beam training between D2D pairs in EMS and the D2D scheme under different multicast group sizes respectively.

The energy consumption of three schemes under different multicast data sizes is shown in Fig. 3 and to show the gap between different methods more clearly, and these results drawn with logarithmic coordinates. The D2D ratio comparison of three methods under different multicast data sizes is shown in Fig. 4. From the results, we can observe that the D2D scheme achieves the greatest D2D ratio among the other methods. The energy consumption comparison of all three methods under different multicast group sizes is shown in Fig. 5. With the higher multicast group size, the energy consumption of all three methods increases due to more number of mobile users should be served. However, the energy consumption of EMS and the D2D methods increases with the multicast group size step by step, which demonstrates the advantages of D2D communications and concurrent transmissions in this paper.

V. CONCLUSION AND FUTURE WORK

In this paper, we discussed the role of scheduling schemes in D2D communication enabled mmWave highly dense small cells. The performance of EMS algorithm is evaluated and as compared to other schemes of scheduling for highly dense small cells. As it is one of the paramount challenges in D2D communications, it is worth further researches in following areas. The circumstances would be much more complex if D2D communications taking place in heterogeneous networks, especially coexisting with hyper-dense small cell communications. To remove those assumptions, we should consider more practical interference cancellation schemes in the future.

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