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Device-to-Device Communications Enabled Energy Efficient Multicast scheduling in mmWave Small Cells: A survey

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ABSTRACT

The widespread use of smart devices and mobile applications is leading to a massive growth of wireless data traffic. Supporting the upcoming demands of data volume, communication rate, and system capacity requires reconsideration of the existing network architecture. Traditionally, users communicate through the base station via uplink/downlink paths. By allowing Device-to-Device (D2D) communication, that is, direct transmission between the users, we can enhance both efficiency and scalability of future networks. In this paper, we reviewed some of the challenges brought by the integration of D2D communication in future cellular systems, and validate the potential of this technology by means of proper scheduling algorithms to improve throughput of future wireless communication system. In this review, recently developed scheduling algorithms are discussed over the traditional methods of computer communication. A best recent method, Energy Efficient Multicast Scheduling (EMS) is discussed for mmWave small dense cells.

Keywords* :— *Device-to-Device (D2D), Scheduling, Energy Efficient Multicast Scheduling (EMS).

I. INTRODUCTION

It is estimated that there will be 10,000 times data traffic in comparison with the present day scenario, before 2030. There is a growing belief among network operators and researchers that communications will be composed of emerging technologies in addition to technologies currently in use [1]. Using technologies such as Wi-Fi and LTE-A in coherence with emerging technologies which fulfils the requirements set by 5G will help in driving future communication systems beyond 2020. The evolutions of each of the cellular system generations were driven by key factors. The first generation of cellular communication used analogue transmission channels and was mainly concerned with providing voice services. The second generation implemented the digital technology which helped in obtaining better voice quality and services such as text messaging were introduced[2, 3]. The requirement for fast data services and more voice capacity was the driving factor behind the third generation of cellular systems. 4G systems such as LTE were developed in order to provide topmost data rates for multimedia applications and improving the capacity. The fifth generation of cellular systems is expected to provide the data rates of the order of gigabits along with zero latency [4].

High data rates reaching the values of gigabits per second are expected in both the uplink and downlink but that does not necessarily indicate the need for the installation of high capacity networks in all places. Densely populated urban areas are the places of prime importance where the need for new networks capable of supporting high capacity is the most prevalent. Even though the maximum data rate for 5G systems is expected to be of the order of

10 Gbps, the data rates at the cell boundaries should reach 100 Mbps [5, 6]. This generally ensures mobile internet to be a viable replacement for fixed-line broadband. It is also expected that communications between humans will not be the only use case for the next generation of mobile communication. Machine- to-machine communications (M2M) which can also be attributed as the 'Internet of Things' (IoT) will be one major use case, as huge advancement in machine to machine communications are expected [7, 8]. This basically indicates that in addition to machines being supervised by humans they will also be communicating among each other. Thus stable links and lower delays in transmission (latencies) are desired as machines can process information much faster than human beings [9].

5G cellular systems are embracing millimeter wave (mmWave) communication in the 10-300 GHz band where abundant bandwidth is available to achieve Gbps data rates. One of the main challenges for mmWave systems is the high propagation loss at these frequency bands. Although it can be partially compensated by directional antennas [1], [2], the effective communication range of a mmWave base station (mmBS) remains around

100 meters at best. Thus, base station deployment density in 5G will be significantly higher than in 4G [3], [4]. This leads to high infrastructure cost for the operators. Besides the cost of site lease, backhaul link provisioning is in fact the main contributor to this cost because the mmWave access network may require multi-Gbps backhaul links to the core network. Currently, such a high data rate can only be accommodated by fiber-optic links which have high installation cost and are inflexible with respect to relocation [10].

To date, much of the research on mmWave communication has been dedicated to issues faced by the mobile users (UEs) in the access networks. How to maximize performance such as throughput and energy efficiency in mmWave backhaul and access networks has received less attention. Here, one of the important issue need to be addressed: that is scheduling of the transmission over the links [11-16]. A naive scheduling which lets the Evolved NodeB (eNB) serve all the mmBSs in a round robin fashion is neither practical nor efficient. If mmBSs' links to the eNB are weak compared to their links to other nearby mmBSs (which in turn have high-capacity links to the eNB), a schedule allowing multi -hop routing is much more favorable since it alleviates the bottleneck at the eNB. At the same time, the limited interference at mmWaves makes it efficient to maximize spatial reuse and operate as many links simultaneously as possible. The goal of the paper is to design a scheduler that exploits these characteristics to optimize mmWave backhaul efficiency [5]. A blockage robust and efficient directional MAC protocol, termed BRDMAC, which is frame based is used as the core of BRDMAC is a heuristic blockage robust scheduling algorithm, which includes a relay selection algorithm and a scheduling algorithm. These two algorithms are shown to be near-optimal and have low computation complexity [6, 7].

The rest of this paper is organized as follows. In section II, we discussed Device-to-Device (D2D) communication for future wireless networks. In section III, different energy efficient multicast scheduling in mmwave small cells are discussed in detail. Finally, Section IV concludes this paper.

II. D2D Communications in Future Cellular Networks

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 proposed to enable cellular user equipment (UE) to communicate at an extreme high frequency (30GHz – 300GHz), so that it may utilize more bandwidth and thus improve the system throughput [14]. Hyper- dense small cells deployment is under test to meet the "1000x mobile data traffic challenge" by Qualcomm and other institutes [15]. Massive MIMO is proposed 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 [16]. LTE-unlicensed is developed to allow cellular UE sharing unlicensed frequency bands with Wi-Fi [17]. 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.

A. D2D Communications

D2D technology in cellular networks brings several benefits to both mobile users and network operators. First, users can experience high data rates, low latency, and reduced energy consumption because of the direct short-range communication and its potentially favorable propagation conditions. Second, the cellular- coverage range can be extended and the per- area capacity improved without additional infrastructure cost. A simplified example of D2D communications is shown in Figure 1. Note that the figure shows two kinds of UEs: Cellular UEs (CUEs) and D2D UEs (DUEs). The difference between the two UEs is that DUEs transmit and receive data without eNB relaying, CUEs always communicate via the base station [7-10]. In certain situations, it may be necessary for the UEs to send their information via eNB. For instance, if the distance between two UEs is very large, direct D2D communication cannot take place. Thus, CUEs and DUEs are expected to coexist, at least at present.

In fact, cell-edge users, that usually experience poor performance in uplink and downlink transmissions, can communicate directly to nearby terminals or to the base station by means of mobile users acting as relays. In the latter case, both a D2D link between the cell-edge user and the relay user, and a traditional connection between the relay and the cellular infrastructure are established. Third, by allowing spectrum reuse between traditional cellular communications and direct D2D communications, spectrum efficiency can be enhanced, allowing for a larger number of concurrent transmissions [4,5]. Significant improvement in the spectral efficiency is also foreseen to be achieved by integrating D2D communication with in-band full-duplex operations. Full-duplex communications enable simultaneous transmission and reception on the same time/frequency resource, at the expense of self-interference at the transmitter [16]. Given the short distance between D2D users, the required transmission power is in general low, which reduces the self interference level [7]. Finally, because D2D communication offers the opportunity for local management of short- distance transmissions, it allows for data offloading from the base station, which alleviates network congestion and traffic management effort at the central nodes [8, 9]. Given all these promising advantages, the integration of D2D communication in future cellular networks has become an attractive research area.

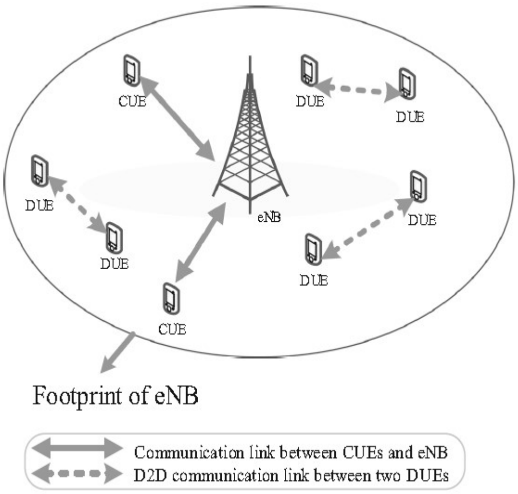

Figure 1 : Mm Wave 5G cellular network architecture with D2D communications enabled.

B. Millimeter Waves

The increase in bandwidth is an approach by which the throughput of the system can be improved. However, the spectrum below 6 GHz is occupied by existing technologies, therefore, making it unsuitable for future cellular communications. The use of higher frequencies has been proposed by researchers and academia. The propagation at these higher frequencies was thought to suffer from losses due to attenuation caused by the atmosphere and rain, especially around 60 GHz frequencies. The advancement of semiconductor technology has helped in overcoming the propagation loss related problems [1].

The millimeter wave band is situated between 30 GHz and 300 GHz frequency band of the EM spectrum. The large unlicensed bandwidth present in the millimeter wave frequency has attracted the attention of the industry and academicians.

C. Small Cells and Ultra-Dense Networks

A technique by which operators can resolve the requirement for high data rates is by decreasing the size of the cell. The reduction in the area covered by a cell leads to an increase in spectral efficiency that is achieved due to better frequency reuse. Additionally, the transmission power is saved due to lower power required for propagation purposes [1]. The use of small cells for indoor coverage will also help in alleviating some of the load on the macro cells. The localized use of small cells can also be extended to scenarios such as stadiums, stations, airports, city centers and other densely populated urban areas. Such a move by the operators will help in resolving some of the capacity and coverage related needs that are encountered by current cellular technologies. The advancement of technologies which has led to the miniaturization of hardware and the added reduction in cost will enable the utilization of small cells [2].

The dense deployments of small cells form an ultra-dense network. Many researchers identify the (Ultra-Dense Networks) UDNs as suitable means for increasing the capacity of the network and providing end users with high data rates. This is accomplished due to the fact that the distances between the sites are small and interference during communications minor. The distance between access nodes varies from around 50 meters in outdoor scenarios to about a few meters indoors [15]. This basically points to the fact that ultra-dense networks are typically envisioned to provide the coverage in localized environments. In addition, UDNs should be combined accurately with cellular systems to provide coverage on a wider scale [16].

III. Literature Survey

"Device-to-Device Communications Enabled

Energy Efficient Multicast Scheduling in mmWave Small Cells" paper by Yong Niu, Yu Liu and Yong Li proposed EMS for energy efficient multicast scheduling in mm Wave small cells, which exploits both D2D communications and concurrent transmissions to reduce energy consumption. EMS establishes multi-hop D2D transmission paths by the D2D path planning algorithm.

"Millimeter-wave communications for 5G—

Part 2:Applications [Guest editorial]," by M. Elkashlan, T. Q. Duong, and H.-H. Chen in IEEE Commun. Mag. gives an overview of propagation to coverage, presenting a holistic view of research challenges and opportunities in the emerging area of mm Wave radio systems and 5G mobile broadband. The use of this technology is expected to surge in the next few years and to transform the Internet industry in the next 10 years.

"Hierarchical Codebook Design for Beam forming Training in Millimeter-Wave Communication" by Zhenyu Xiao, Tong He, Pengfei Xia, and Xiang-Gen Xia proposed two basic criteria for the hierarchical codebook design, and devise an efficient hierarchical codebook by jointly exploiting sub-array and deactivation (turning-off) antenna processing techniques, where closed -form expressions are provided to generate the codebook.

"Enabling Multi-Hop Concurrent Transmissions in 60 GHz Wireless Personal Area Networks" paper by Jian Qiao, Lin X. Cai, Xuemin (Sherman) Shen, and Jon W. Mark proposed a multi-hop concurrent transmission scheme for mm Wave WPANs.

III Energy Efficient Multicast Scheduling in mmWave Small Cells

Scheduling has been conceived as an effective technique to efficiently use the available spectrum and improve network throughput in macrocell scenarios with a large number of UEs per macrocell BS. In more detail, proportional fair (PF) scheduler is used as an appealing scheduling technique that offers a good trade- off between maximizing throughput and improving fairness among UEs with diverse channel conditions. However, the gains of PF may be limited in dense small cell networks, partly because the number of UEs per small cell BS is considerably reduced in comparison to macrocell ones, and partly because UEs may not experience very different channel conditions on different subcarriers due to the dominance of LOS propagation as UEs may be really close to their serving BS [1, 2]. These changes give rise to the question of whether the PF scheduling is as efficient for dense small cell networks as it is for macrocell scenarios, or if it can be substituted by schedulers of lower complexity. This paper analyses different scheduler types under different densification levels, and analyses some fundamental tradeoffs of network densification. The smaller the cell size, the closer the UE is to its serving BS – reducing the path loss, but the stronger the LOS – reducing the multi-user diversity. Furthermore, decreasing the cell size will not only diminish the multi-user diversity, but also will increase the interference due to the dominance of LOS. As a result, it is necessary to take a systematic view towards the tradeoffs of network densification.

There has been some related works on directional MAC protocols for WPANs or WLANs in the mmWave band. Since the standards of ECMA 387 and IEEE 802.15.3c adopt TDMA, some works are based on TDMA. Cai et al. [1] derived the ER conditions that concurrent transmissions always outperform TDMA for both omni-antenna and directional-antenna models, and proposed the REX scheduling scheme (REX) to achieve significant spatial reuse gain. There are also two protocols based on IEEE 802.15.3c, which exploit concurrent transmissions to improve performance when the multi-user interference is below a specific threshold. In the scenario of an indoor WPAN, Qiao et al. [2] proposed a concurrent transmission scheduling algorithm to maximize the number of flows with the quality of service requirement of each flow satisfied. Furthermore, a multi-hop concurrent transmission scheme is proposed to address the link outage problem and combat huge path loss. For bursty data traffic, TDMA based protocols may allocate not enough medium time for some flows, while overmuch medium time for others [2]. Some centralized scheduling protocols are also proposed for WPANs or WLANs in the mmWave band [3]. Gong et al. [4] proposed a directional CSMA/CA protocol, which exploits virtual carrier sensing to address the deafness problem. Singh et al. [5] proposed a multi-hop relay directional MAC protocol (MRDMAC), which exploits relaying to overcome blockage. The frame based directional MAC protocol (FDMAC) is proposed in [6], where the greedy coloring algorithm exploits concurrent transmissions for high efficiency. In the scenario of an IEEE 802.11ad WLAN, Chen et al. [7] proposed a directional cooperative MAC protocol, D-CoopMAC, to coordinate the uplink channel access. Niu et al. [8] proposed a blockage robust and efficient directional MAC protocol (BRDMAC) to overcome the blockage problem by two-hop relaying. In the scenario of heterogeneous cellular networks, Niu et al. [6] proposed a joint transmission scheduling scheme for the radio access and backhaul of small cells in 60 GHz band (D2DMAC), where a path selection criterion is designed to enable device-to-device transmissions for performance improvement.

In terms of multicast communication, Naribole and Knightly [9] design, implement, and experimentally evaluate 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 training information, a scalable beam grouping algorithm is designed to achieve the minimum multicast group data transmission time. Park et al. [10] proposed an incremental multicast grouping scheme, which generates adaptive beam widths depending on the locations of multicast devices to maximize the sum rate of devices. However, D2D communications are not considered in this scheme. An efficient scheduling scheme for popular content downloading (PCDS) is developed in [11], where users far from the AP obtain the popular content from nearby users via D2D communications. At the same time, concurrent transmissions are also enabled to improve performance. In terms of energy efficient MAC protocols for wireless networks in the mmWave band, Niu et al. [12] proposed an energy efficient scheduling scheme for the mmWave backhauling network, which exploits concurrent transmissions to achieve higher energy efficiency. However, D2D communications are not considered in that scheme.

The performance of RR and PF schedulers are compared under the Rician channel model. Since all RR schedulers had similar performance with a ~ 2% variance, RR and PF schedulers in terms of cell throughput with respect to the number of served UEs for different ISDs. As can be seen, when using RR, the number of served UEs per BS does not impact the cell throughput, since RR does not take into account the UE channel quality and therefore does not take advantage of multiuser diversity [13]. In contrast, PF is able to benefit from multi-user diversity, and the cell throughput increases with the number of served UEs. However, it is important to note that PF can only exploit multi-user diversity.

Finally, reviewing of all different scheduling methods, for an energy efficient and practical multicast scheduling scheme, called EMS, is proposed [1]. EMS consists of D2D path planning algorithm, concurrent scheduling algorithm, and power control algorithm. The D2D path planning algorithm establishes the multi-hop D2D transmission paths. The concurrent scheduling algorithm concurrently schedules the links on the D2D paths into different pairings, while the power control algorithm adjusts the transmission power of links for lower energy consumption with the achieved network throughput ensured [14].

A. Energy Efficient Multicast Scheduling Scheme

Energy efficient multicast scheduling scheme, EMS, for includes both D2D communications and concurrent transmissions are enabled in EMS to improve the energy efficiency. First step includes a D2D path planning algorithm to establish the multi-hop D2D transmission paths [1]. Then a concurrent scheduling algorithm is proposed to schedule the links on the D2D paths concurrently into each pairing with the interference controlled. Finally, a power control algorithm adjusts the transmission power to realize energy consumption reduction [15-17].

- D2D Path Planning Algorithm: The advantage of D2D communications relies on the better channel conditions between devices in physical proximity. D2D communications between users nearby are preferred due to less propagation loss for saving energy. 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.
- Concurrent Multi-Hop Scheduling: After obtaining the D2D transmission paths by D2D Path Planning Algorithm, the advantage of concurrent transmissions should be further exploited to improve energy efficiency. Thus the concurrent multi-hop scheduling algorithm is proposed 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 high efficiency.

IV. CONCLUSION

D2D communication in LTE-A networks has recently attracted significant research interest from both industry and academia. This has resulted in considerable research effort been made in this area. In this paper, we have presented a detailed overview of the cutting edge research work that is still ongoing in D2D communications. Discussed detailed on energy efficient multicast scheduling algorithms for D2D wireless communication networks, as these constitute the most fundamental issues. We have also extensively reviewed the recent developed energy efficient multicast scheduling algorithms such as, EMS and MIS for D2D communications. In view of these research works that have been thoroughly covered in this survey, we finally provide a detailed discussion on various open research issues in this area.

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