IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Volume-5, Issue-1 E-ISSN: 2347-2693

Device-to-Device Communication in Wireless Network using mmWave within Small Cells and Exploiting Spatial Reuse

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Available online at: www.ijcseonline.org

Received:26/12/2016 Revised: 04/01/2017 Accepted: 20/01/2017 Published: 31/01/2017

***Abstract*— Recently, extreme demand of mobile communication, small cells in millimeter wave bands within macro-cell network is attracting the attention in academics as well as the industries. Evolution of 4G is essential in keeping up with the exponential growth of mobile data network traffic. Up to 7GHz bandwidth has been allocated worldwide for license-free 60GHz radio frequency. Multiple giga-bites per second can be transmitted by utilizing the huge unlicensed bandwidth using mmWave communication in the 60GHz band. Numerous amount of spectrum available in micro frequencies are able to provide cost effective communication between the nodes in small cell via high capacity backhaul. Wireless backhaul is an attractive option for small cells as it provides a less expensive and easy-to-deploy over fiber. However, there are multitude of bands and features (e.g. LOS/NLOS, spatial multiplexing etc.) connected to wireless backhaul that need to be used smartly for small cells. Candidate bands include: sub-6 GHz band that is useful in non-line-of-sight (NLOS) scenarios, microwave band (6–42 GHz) that is used in point-to-point line-of-sight (LOS) scenarios, and mmWave bands (e.g. 60, 70 and 80 GHz) that are recently being commercially used in LOS scenarios. In many deployment topologies, it is more beneficial to use aggregator nodes, located at the roof tops of tall buildings near small cells. The protocol supports concurrent transmission in minimum frequency to the greater extent. Further to enhance the efficiency of network, performance analysis and different parameters will be calculated**.

Keywords- D2D, Heterogeneous cellular network, millimeter wave, MAC scheduling, spatial re-use.

I. INTRODUCTION

In this modern world mobile communication has become an emerging technology attracting man kind to adopt to these innovative technologies. This has led to rise in demand of high capacity for wireless transmission to transmit HD contemporary multimedia such as IP telephony, video and radio broadcasting, and interactive remoter learning. Device-to-device (D2D) communication that enables direct communication between neighbouring mobiles is an exciting and innovative feature of next-generation cellular networks. It will facilitate the interoperability between critical public safety networks and global commercial networks based on.

Device-to-Device (D2D) communication is a technology component included in LTE-A. The existing researches allow D2D communication as an underlay to the cellular network to increase the spectral efficiency. In D2D communication, user equipment's (UEs) sends data signals to each other over a direct link using the cellular resources instead of through the Base Station, which differs from Small Cell where users communicate with each other by the help of small low-power cellular base stations. D2D users communicate directly while remaining controlled under the Base Station. Therefore, the possible of improving spectral utilization has boosted much work in recent years, which shows that D2D communication can improve system performances by reusing cellular resources. Thus, D2D is expected to be a key feature supported by next generation cellular networks. Taking into account the massive increase in traffic demand is going to be exited in multiples of 1000, assumed by the networking professionals/experts even by some industries. In order to meet this exponential growth in the traffic demand, new frequency spectrums has been evolved for improvement in transmission link of communication devices [1]. 7-GHz spectrum of 60-GHz Millimeter wave (mmWave) frequency bandwidth has been allocated for license-free for short range high speed transmission [4].The 60-GHz band is considered to be efficient enough for real-time streaming of both compressed and uncompressed data moreover it enables high-speed multi-gigabit data communication rate and broadband applications [3]. In this paper, we carry out a survey of mmWave communications for wireless network. We first summarize the characteristics of mmWave communications. Due to the high carrier frequency, mmWave communications suffer from large propagation loss, and beamforming (BF) has been adopted as an essential technique, which indicates that mmWave communications are perfectly directional. Besides, due to weak diffraction ability, mmWave communications are sensitive to blockage by hurdles such as humans and furniture. Then we introduce two standards for mmWave communications in the 60 GHz band. There are numerous advantages of using broadband

60-GHz radio channel. Availability of large bandwidth it is playing an essential role for high-speed short-range data transfer between communicating devices with speed about 15 dB/km [5].

This paper presents an approach where Device to Device communication is done by a new defined protocol using a frequency band. After devices being connected, through scheduling algorithm scheme efficient path is selected for data transfer. Further according to the performance analysis better understanding study is made for concurrent transmission within the nodes via communication link.

II. RELATED WORK

Recently many related work has been published on scheduling for small cells in the mmWave band. C. Sum et al [6] [7], proposed a system where, the protocols based on IEEE 802.15.3c, if the specific threshold is low in multi-user-interface (MUI) multiple links are scheduled to communicate in the same slot. As the system used a single time slot to transfer packets, packets with larger size where a problematic to be transferred. Cai et al. [8], proposed a system, to formulate the conditions that concurrent transmissions exceeds TDMA and to support concurrent communication the concept of Exclusive Region is introduced. Qiao et al [9], proposed, Multi-Hop-concurrent Transmission (MHCT), to enhance the throughput and to address the link blockage.

Some other work based on central coordinator to coordinate the transmission in WPANs[10], Gong et al [14], proposed a protocol CSMA/CA is used to derive virtual carrier sensing and to distribute the Network Allocation Vector information on the basis of Piconet Coordinator (PNC). But its disadvantage was that it does not focused on special reuse. [11] Proposed frame based directional MAC protocol for scheduling overhead over multiple concurrent transmission in a row. FDMAC derives full special reuse by Greedy Coloring algorithm with low complexity and high through performance [10]. Related work on wireless backhaul networks, the advantage of 60GHz band for short range high speed transmission is diagnosed through analysis and comparison with E-band technology [12].

[13] Explained the challenges to design the backhaul and radio access network jointly in a cloud based mobile network, in which design ideas for the physical layer, the MAC layer and the network layer. In the earlier works no ideas where invented for direct transmission between the devices to enhance performance of network.

Many focused on small cell in the mmWave bands range such as 28GHz, 38 GHz and 73 GHz for communicating in the range of 200m and above. In the 60GHz band there are distributed MAC protocol [8]. [5] A 60GHz piconet architecture for existing LTE network was established to increase network capacity by investigating characterizing range, attenuation due to reflection, sensitivity to movement and blockage, and interference in typical urban environment. In this paper, firstly transmission scheduling of access network as well as backhaul network is done then D2D transmission is performance is improved. D2D high-speed transmission and spatial reuse in 60GHz small cell.

III. EXISTING SYSTEM

In the existing system, multiple small cells are deployed, in each small cell there are numerous wireless nodes, provided access services by an AP (Access Point). Services to the APs is within boundary of the cell. These APs are connected to Internet via direct high speed wired connection. Protocol for connecting devices in named as D2DMAC. The D2DMAC protocol is a Frame based protocol. System has two phases, the scheduling phase and the transmission phase. Scheduling phase includes scheduling of frames to be transmitted and in the transmission phase, frames ready for transmission are being transmitted via direct path or ordinary path as scheduled in the scheduling phase and finally on the basic of working of system, performance analysis is done by using various performance measuring parameters. By using higher frequency bands, such as the millimeter wave (mmWave) bands between 30 and 300 GHz, and bringing the network closer to users by a dense deployment of small cells, HCNs can significantly boost the overall network capacity due to less interference and higher data rates.

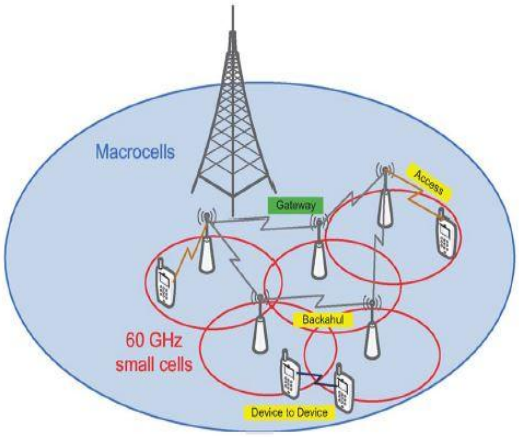

Fig. 1. Dense deployment of small cells in the 60 GHz band underlying the macrocell network [1]

System Overview

A. System Model

Considering a scenario where, multiple small cell are deployed. In each small cell there are several wireless node and an access point, which provide access services within the cell network.

These APs are connected to the Internet via high speed wired connection, which are known as Gateways. These APs communicate with the Gateway to send/receive dada to/from Internet.

A bootstrapping program is embedded with the system, using which the central controller get the up-to-date information of network topology and the location of APs and WNs in the network.

B. D2DMAC Operation overview

D2DMAC is a frame based protocol. There are two phases in the frame, a Scheduling phase and a Transmission phase. In scheduling phase each of the WNs reports there traffic demand to APs.

In transmission phase, first a transmission path is selected optimally between the direct path and the ordinary path for each flow. Then the simultaneous transmission is done with minimum number of time slots.

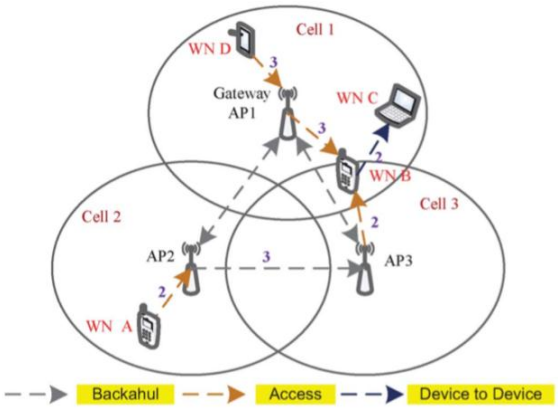

Fig.2. An example of D2DMAC with three cells.[1]

➔ **Steps for Transmission Scheduling.**

- **Initialization:**

Input:

- The set of selected paths of all flows;
- Obtain the set of hops;
- Obtain the weight of each hop;

Working:

- Obtaining the set of first unscheduled hops
- Obtaining the hop with the largest weight
- Calculating SINR of the link
- Finally selecting an appropriate path

C. *Problem Overview*

In the above scenario, maximum transmission efficiency should be achieved in such a way that the traffic demand should be accommodated with a minimum number of time slots. To accomplish this, direct path is preferred to ordinary path.

In fig. 2, there are three small cells. In cell 1, nodes C and D are connected to AP1, in cell 2 node A is connected to AP2,, in cell 3, node B is connected to AP3. There are four flows in the network, A→ B, B→ C, Gateway → B and D→ gateway. The traffic demand of A→ B, B→ C, Gateway → B and D→ gateway are 5,6,7 and 8 respectively. This demand is numerically equal to the number of packets to be transmitted.

D. Performance Analysis and overview

Performance analysis is done theoretically by presenting the condition for the concurrent transmission.

Considering a deployment of small cell in the 60 GHz band [15], where 9 APs are uniformly distributed in a square area of 50m X 50m and gateway is placed at the center point. There are 30WNs uniformly distributed in this area. In this scenario, two traffic modes are considered, the Poisson Process and Interrupted Poisson Process (IPP).

1) **Poisson:**
From each flow the packets arrives with arrival rate λ following the Poisson Process.
2) **IPP:**
From each flow the packets arrives following the Poisson Process.

Finally the system performance is evaluated by following four metrics.

1) Average transmission Delay: The average transmission delay of received packet.
2) Network Throughput: The total number of successful transmission until the end of simulation.
3) Average Flow Delay: The average transmission delay of flow which is transmitted either by ordinary path or direct path.
4) Flow Throughput: The number of successful transmission achieved by each flow until the end of simulation.

The earlier system [1] was capable of transmitting information from source node to destination node by a protocol named D2DMAC, where the focus was on transmitting information between the nodes with maximum frequency using the frequency band of 60GHz.

Further in 2016, [2] the same concept as of system in 2015 [1] was used to focus on downloading required content in directional mmWave small cell. An efficient scheduling system was developed for popular content downloading an

mmWave small cells called popular content downloading scheduling (PCDS).
Frequency band 60GHz enables high speed data transfer between devices, supporting real-time streaming of data (either compressed or un-compressed).

System Overview

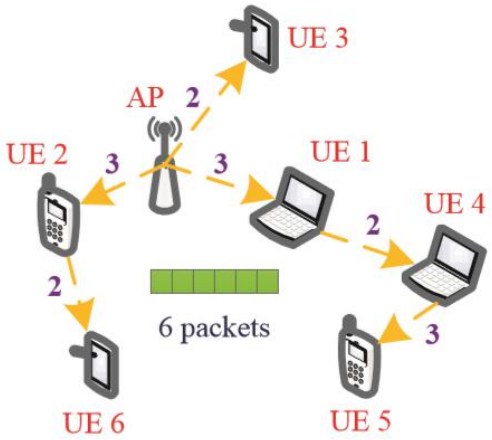

Fig.3: Network topology for small cell with six UEs [2]
As per the network topology mentioned in the Figure 3 consisting of 6 UEs and an AP with a content downloading traffic by d, d=6 i.e., 6 packets to be distributed to all UEs..
For popular content downloading Scheduling scheme, two algorithms are design, The Transmission Path Selection Algorithm and The Concurrent Transmission Scheduling Algorithm.

➔ **Steps for Transmission Path Selection:**

Input:

- The set of all UEs in a small cell;
- Channel Transmission Rate;

Working: As per the required capacity of the UEs, path is selected depending on the size of data to be transferred and number of hops required for the transmission.

➔ **Steps for Concurrent Transmission Scheduling:**

Input:

- Set of path selected transmission paths;
- Set of hops;
- Number of hopes for each path ;
- Weight for each path

Working:
Transmission of packet (data) is done through the selected path by obtaining the hop of maximum weight.
Finally performance evaluation is done on the basis of following three performance metrics.

1) *Average transmission Delay*: It is measured in units of time slot, the average traffic downloading delay from the APs to UEs.
2) *Network Throughput:* the number of successfully transmitted packet to all UEs until the end of the simulation.
3) *D2D Ratio:* The fraction of packets transmitted by device-to-device links over the total number of successfully transmitted packet.

IV. PROBLEM STATEMENT

Communication link of the network, connecting nodes (devices) have fixed channel size to transmit packets from one node to another. When a node "A" needs to transfer a packet of size 5 to node "B" and the transmission link has capacity to transfer only 3 packets in one time slot, then in that case two time slots has to be scheduled to transfer packet of size 5. Therefore, we will work to design such a communication protocol and scalable transmission link to transmit a packet of possible max size in a single time slot.

V. PROPOSED SYSTEM

Proposed system presents an approach where, a new frequency based protocol for Device to Device communication using a frequency band for transmitting the data from source node to destination node at higher frequency rate, to increase the performance and efficiency of network. Further according to the performance analysis better understanding study is made for concurrent transmission within the nodes via communication link

VI. CONCLUSION

A survey of the earlier related work has been done successfully. Which involves various emerging technologies for Device to Device communication. The initial studies showed that D2D communication has advantages such as increased spectral efficiency and reduced communication delay. However, this communication mode introduces complications in terms of interference control overload and protocols that are still open research problems. The feasibility of D2D communications in LTE-A is being studied by academia, industry, and the standardization bodies.

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