ANALYSING EFFECT ON NETWORK PARAMETERS USING MMWAVES IN WIRELESS COMMUNICATIONS

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***Abstract*— Millimetre waves (Mmwaves) are the new paradigm in wireless communications. The existing cellular networks rely on microwaves which have been shown to be limited in terms of bandwidth, latency, throughput and other performance parameters in the light of new requirements of 5G communications. Millimeter waves have nearly 800 MHz bandwidth, utilize spatial diversity, reduced latency etc. The use of Millimeter waves will enable densification of networks, achievement of nearly 1000x enhancement in throughputs, reduction in latency to less than 10 milliseconds, etc. The use of mmwaves requires new protocols to account for newer model of channel access (OFDM or better), beamforming and beam tracking, both contention-free and contention-based access etc. One such protocol is IEEE 802.11ad. The feasibility of millimetre waves has already been assessed. The requirement is now to translate it into reality.**

***Keywords*— 5G, millimetre waves, Protocol, PHY layer, MAC, Simulator, IEEE 802.11ad**

I. Introduction

MM Waves in wireless communication are intended to offer vastly improved realizations on the requirements of bandwidth and latency over the existing deployment of microwaves based wireless communications. The realization to shift to different frequency band came with the limits to spectrum use and latency in microwave range. Even with the use of MIMO, Carrier Aggregation and OFDM, the data requirements of future were not expected to be met. This required an entirely new Radio Access Technology. Although the utility of mmwaves was known, its limitations in terms of rapid attenuation and performance conditional on appropriate weather conditions did not allow much research to happen on their use in wireless communications. However, with the advent of beamforming based solutions, which can overcome to a significant extent the rapid attenuation associated with this frequency band, the analysis of mmwaves for wireless communications is now gaining speed. [1][2][3]

II. Mmwave protocol

So far, IEEE 802.11 ad (also known as WiGig) is the only full suite of protocol utilizing mmwaves and having some features of 5G. It is however designed for small distance and operates between 57 to 71 GHz. [9][10]. Other protocol regarding use of mmwaves in wireless communication have not yet been released.

2.1 Features of IEEE 802.11ad protocol

2.1.1. Access to the Medium: The IEEE 802.11 ad protocol relies on using beacon intervals for channel access: each beacon interval comprises Beacon Header Interval ATI, BTI and Data Transmission Interval (DTI). The PHY layer is of four different types, based on categorization of Modulation and Codiing Schemes (MCS) for different requirements:
2.1.1.1. Control PHY – with MCS0 at 27.5 Mbps. This type of PHY is utilized for Beamforming Training Phase.
2.1.1.2. Single Carrier PHY- with MCS1-12 at 385 to 4620 Mbps. This type of PHY is utilized for uplink and for power limited devices such as mobile phones.
2.1.1.3. OFDM PHY- with MCS 13-14 at 693 to 6756.75 Mbps. This type of PHY is utilized for highest data rates
2.1.1.4. Low Power (LP)-SC PHY with MCS 25-31. This involves lower power consumption than the SC PHY layer due to the use of low-density parity check (LDPC) codes instead of the Reed Solomon Codes.
2.1.1.5. SC PHY layer due to the use of low-density parity check (LDPC) codes instead of the Reed Solomon Codes.

2.1.2. Beamforming

The standard provides a directional communication scheme that utilizes beamforming antenna gain to overcome increased attenuation in the 60 GHz band . The beam forming relies on quasi-optical propagation behavior, low reflectivity and high attenuation for directional signal focus. The directionality is through “virtual” antenna sectors that discretize the antenna azimuth. These antenna sectors can be implemented with precomputed antenna weight vectors for a phased antenna array or with multiple directional antenna elements. [8]

Communication between the nodes in the protocol happens through selection of optimal pair of receive and transmit sectors to optimize signal quality and throughput. This beamforming training, is facilitated by the discretized antenna azimuth. The first sector matching, is followed up by a second beam training for further refinement of the found sectors. While in general higher antenna gain is desirable, it leads to stronger directionality and a higher number of narrow antenna sectors.

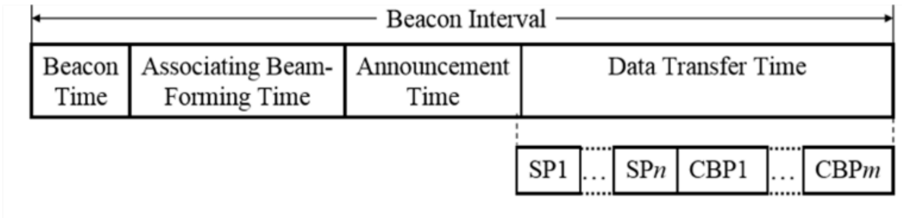

Fig 1: IEEE 802.11 ad Beacon Interval for Medium Access[10]

2.1.3. DMG Relay operation and Fast session transfer[10]

The transmission of mmwaves can be greatly affected by the presence of obstacles. This is more likely to happen as the tranmission is undertaken through beamforming mechanism. Although there is likelihood of some transmission taking place through the Non-LOS mode, it is sometimes for convenient for the transmission to be handled (ie. ongoing session transfer) by microwaves. This change in operational band is known as session transfer. As the lag involved in such transfer is quite low in the protocol, it is indicated as “Fast” session transfer.

The protocol also incorporates a relay mode. This involves relay stations (RDS-Relay DMG STA) assisting source and destination stations (REDS- Relay End Point DMG stations). The protocol allows the functionality of having a direct link between the REDS and relay link through the RDS. Normally the REDS operate through direct link; however if this link is disrupted then the relay link is activated. It can also lead to the recovery of the direct link. Under the link switching mode, the RDS can operate either in full duplex or half duplex mode. In half duplex mode, the RDS receive frames from REDS in one SP and utilize the following SP to forward it to the destination REDS.

In another mode of operation of relays under the protocol, the source REDS is always aware of the direct link and the delay link, on the basis of propagation relays, at any given instance of time and utilizes this knowledge to enhance signal quality at destination REDS.

III. NETWORK SIMULATORS

This simulation was undertaken through ns3. Open source simulators have been very popular amongst researchers as they are useful for analysis of the PHY and MAC network layers and for evaluation of network performance. The most widely used network simulator is the ns–3 network simulator which is designed as a set of libraries based on a wide range of protocols in C++ and python. The ns-3, however, does not provide limited GUI functionalities and these need to be developed. One such attempt has been made and a mm wave module for WifiGig has been developed for integrating with ns-3 [10]. The code is publicly available over the web at GitHub and amenable to customization for development and evaluation of new protocols.

The throughput of adhoc wireless networks in mmwave domain can be empirically investigated through ns3

The investigation can be undertaken in mmwave spectrum with the aid of implementation of IEEE 802.11 ad in ns3. The IEEE 802.11 standards support the peer-to-peer mode independent basic service set (IBSS), which is an ad hoc network with all its stations within each other's transmission range. In an IBSS, it is important that all stations are synchronized to a common clock. Synchronization is needed for frequency hopping and power saving. The synchronization mechanism specified in the IEEE 802.11 standards has a severe scalability problem. The probability that stations may get out of synchronization is pretty high in large IBSS. A new synchronization algorithm has been proposed for large-scale ad hoc networks.

The advantage of ns3 is the use of run time parameters through the command line which can be used to examine results for a wide combination of parametersThe simulation framework involved the Evolved Packet Core set up, remote host connected through a packet gateway for generating the traffic and backhaul through X2 interfaces. The existing mmwave module in ns3 employs the traditional contention-based access only, but with the added features of beamforming and MIMO.

Various requirements (& use cases) for high speed wireless network setup in a localized space can exist. Some of these are:

a) Requirements of Internet of Things (IOT)
b) Improving latency (Latencies up to 50 milli seconds are easily achievable)
c) Data transfer to high speed users
d) Adapting to network densification (there will be an explosion in number of devices that would be connected to the 5G networks.)

IV. SIMULATION

The simulation has the objective of ascertaining the dependence of mmwave transmission on distance and also to explore some of the advanced functionalities of IEEE 802.11ad (Fast Session transfer, Relay mode of operation) and the limitations on achieving these functionalities.

The number of nodes was kept at 4 in a diamond shaped grid pattern. The relay stations were at opposite sides of the diamond and the Access Point and the Receiver at other ends.

Access Point
Station 1 (REDS) Station 2 (REDS)
Relay DMG station

Figure 2: Grid positions for simulation

The other simulation parameters are the following:

Table 1: Simulation parameters

SN	Simulation parameter	Simulation value
1	Antenna	Directional 60GHz antenna with 12 sectors, Tx 10dBm==10 W, Tx gain, Rx gain=+10 Energy detection threshold=-79+3 dBm
2	Socket type and transmission rate	TCP Bulk Sender, 100 Mbps data rate
3	Channel Model	Friis Propagation Loss Model
4	Channel Condition	With Blockage
5	MAC	Both Contention based and Contention free
6	MCS	OFDM 6756.75 Mbps
7	Mobility Models	Constant position model

The node setup in the simulation was considered as the following in three scenarios, numbered Grid 1, Grid 2 and Grid 3 based on the positions of the nodes:

Table 2: x,y,z coordinates of nodes involved in the simulation

Type of node	Grid 1	Grid 2	Grid 3
Access Point	0,1,0	0,1.5,0	0,2.5,0
Station 1	0,-1,0	0,-1.5,0	0,-2.5,0
Station 2	-1,0,0	-1.5,0,0	-2.5,0,0
Relay End Point DMG Station	+1,0,0	+1.5,0,0	+2.5,0,0

V. RESULTS

The performance of the network was analysed by observing simulator output in the form of text files. Based on the observed results of temporal variation of throughput, the following plots were prepared and analysis undertaken:

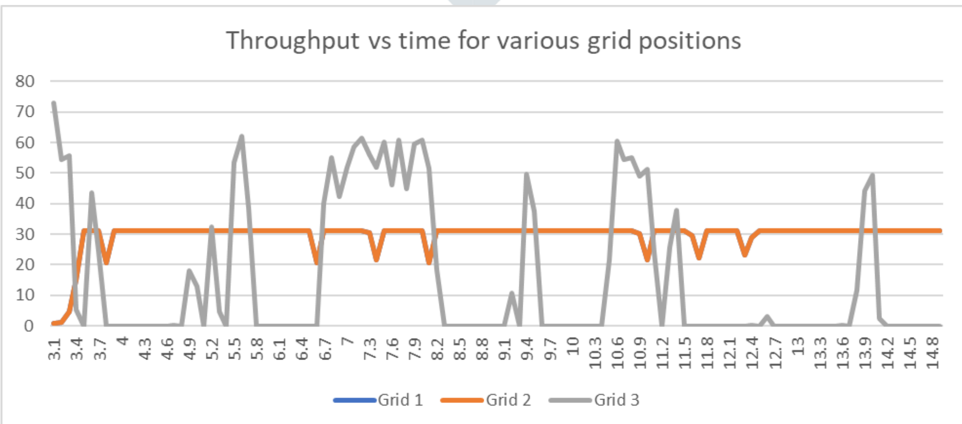

Fig 3: Througput (in Mbps, y axis) vs simulation time (in seconds, x axis) for various Grid positions.

The performance of the network can be seen to be unaffected at distances < 5m. Above this distance the link becomes erratic and the quality of service cannot be assured.

Another critical parameter in the IEEE 802.11 ad protocol is the service period ie. the period during which contention free access is guaranteed. This will have an impact on the overall network performance as it has to be matched to the data rate and presence of other stations in the network. The effect of reducing service period time from 800 milliseconds to 400 milliseconds in grid III position can be seen from the following figure.

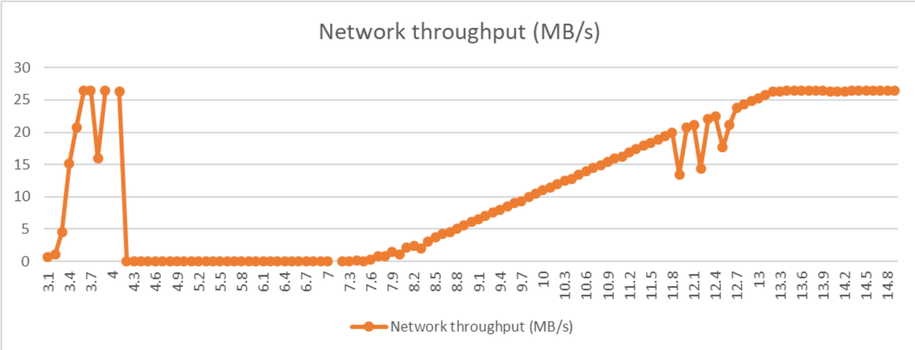

Fig. 4: Variation of network throughput (Y Axis in Mbps) vs simulation time (X axis in seconds) due to link switching at reduced Service Period of 400 milliseconds.

In the above figure the effect of link switching is clearly visible from 4 seconds onward when the transmission is switched from direct link to relay link. The situation is restored at 7 seconds. In between, the relay link is unable to adapt to the data rate and shows nil reception. After 7 seconds, after the direct link is restored there is a linear rise in the network throughput which plateaus to a constant depending upon the network conditions.

Thus the choice of SP is critical for deployment of relay mode of operation in IEEE 802.11 ad networks. Higher SP would be required for better link establishment in relay modes.

VI. CONCLUSION AND FUTURE WORK

The performance of the grid network was observed to be severely degraded beyond 5m distance between the stations on the grid. For closer grid distances the average throughput recorded was 29.3818 Mbps degraded due to increase in number of users (network densification). This is possible as the large amount of bandwidth available could satisfy all the bandwidth requirements of the users. However, the effect of network densification at several orders of magnitude higher was not tested as the simulator takes inordinately long time and produces inordinately large data for the validation.

Further research will be undertaken in the realm of improvement of MAC parameters for performance improvement.

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