Characterizing WiFi Throughput with Millimeter Waves

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Objective

Prior work [2] has investigated the feasibility of using airborne WiFi networks for providing communication infrastructure in disaster scenarios. We wish to study the feasibility of using millimeter waves to facilitate high speed downloads on mobile phones in moving cars, which will complement existing cellular infrastructure, especially as carriers approach saturation with 4G.

Research Questions

We are interested in investigating the following about the 60GHz link

- **RQ1**: How much does the throughput degrade as distance between the Access Point(AP) and the client increases?
- **RQ2**: How much does directionality affect the signal strength and hence the throughput?
- **RQ3**: What happens when there are obstacles in between?

Experimental Setup

- 802.11ad [5] uses millimeter waves and operates in the unlicensed 60GHz frequency range.
- Troughput between 1-7 Gbits/second.
- We use two 802.11ad enabled Netgear R9000 routers.
- One router is connected to the backhaul network(AP) and the other acts as a wireless access point(client).
- DD-WRT firmware[1] was installed on both routers for ease of configuration and for establishing a commandline interface to the routers.
- A wireless, 60GHz link was set up between the two routers [6].
- Run iperf3 [3] on the routers to measure throughput.
- Router connected to the backhaul network is the server and the Wireless AP is the client.

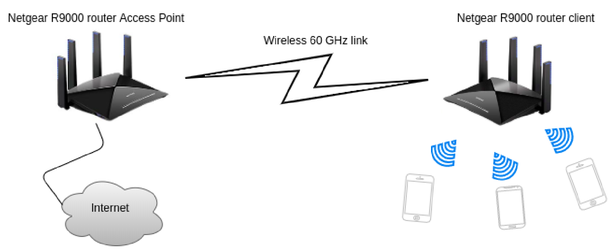

Fig. 1: 60GHz Link Setup

Effect of Distance and Orientation on Throughput

- Figure 2 and figure 3 show the variation in throughput as the client is moved to various distances from the AP.
- Throughput drops drastically when the client and AP face away from each other.
- After a distance of 8 ft, the routers were unable to connect when placed at the same height.
- This is due to a combination of the directional nature of millimeter waves and the antennae on the router facing a fixed direction.
- Figure 4 shows the variation of bitrate with the orientation of the AP.

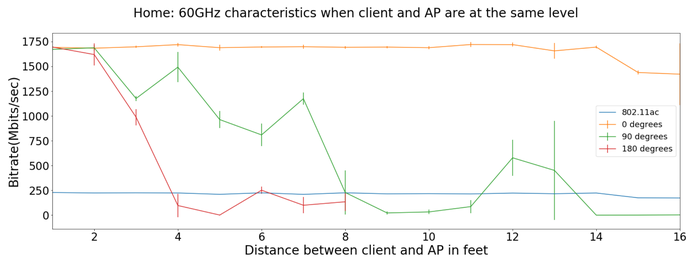

Fig. 2: Performance when client and AP are at the same level

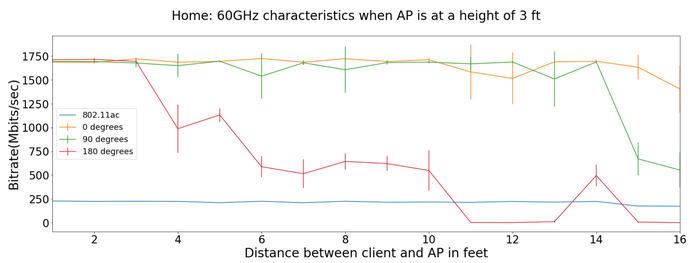

Fig. 3: Performance when AP is at a height of 3 ft

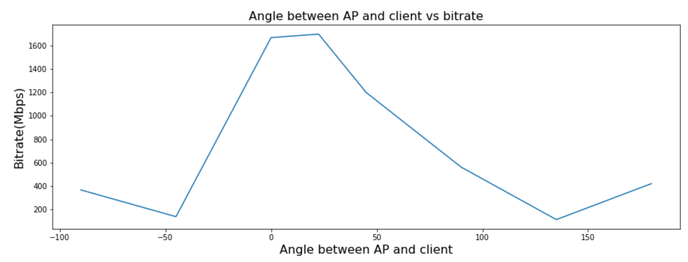

Fig. 4: Variation in Performance when AP is rotated

Effect of Obstacles

- A large box is placed in the line of sight between the routers.
- The AP was placed at a height of 3 ft and the distance between the client and the AP was set to 16 ft.
- Figure 5 shows the variation in bitrate as the obstacle moves between the client and the AP.
- Due to their small wavelength, millimeter waves are unable to penetrate obstacles like humans, metal and furniture.

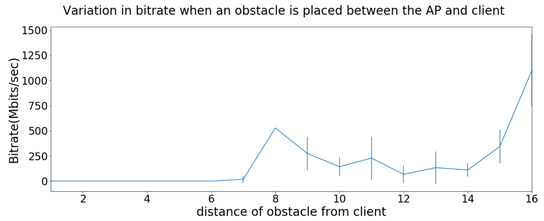

Fig. 5: Bitrate variation with placement of obstacle

Conclusion

We find that millimeter waves are very dependent on the orientation of the antennas and show intermittent connectivity in the presence of obstacles.
Millimeter waves are becoming an increasingly investigated due to their promises of high throughput. However with the current hardware, such as unidirectional antennas, millimeter technology may remian limited to home WiFi. To fully realize the potential of millimeter waves, we would need solutions that maintain beams in the correct direction even as clients move and change position. Current research on beamforming and beam searching [4] is a step in this direction.

References

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[2] Gu, Y., Zhou, M., Fu, S., and Wan, Y. Airborne wifi networks through directional antennae: An experimental study. In *2015 IEEE Wireless Communications and Networking Conference (WCNC)* (2015), IEEE, pp. 1314–1319.

[3] iperf. iperf3, 2019.

[4] Jo, O., Chang, S., Kweon, C., Oh, J., and Cheun, K. 60ghz wireless communication for future wi-fi. *ICT Express 1*, 1 (2015), 30 – 33.

[5] Nitsche, T., Cordeiro, C., Flores, A. B., Knightly, E. W., Perahia, E., and Widmer, J. C. Ieee 802.11ad: directional 60 ghz communication for multi-gigabit-per-second wi-fi [invited paper]. *IEEE Communications Magazine 52*, 12 (December 2014), 132–141.

[6] Sethuraman, M. A Tale of Two Routers, 2019.