mmWaves

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References

- Demystifying 60GHz Outdoor Picocalls, ACM Mobicom 2014
- Cutting the Cord in Virtual Reality, ACM Hotnets 2016
- http://networks.rice.edu/files/2014/10/11adPaper.pdf

60GHz waves are an emerging technology which increase throughput but introduce new challenges

- Overview
- Motivation
- Challenges:

  - 1: Wave Characteristics & Environment
  - 2: Need for Directional Antennas
  - 3: Changes at the MAC Layer
- Discussion

Goal: Improve Throughput!

- Mobile broadband usage is skyrocketing -- in 2010, global mobile data traffic was 237 Petabytes/month. In 2016, it was 7.2 exabytes per month
- This is caused by a combination of more people getting mobile devices and higher-traffic applications, such as HD/3D video and VR
- This is expected to continue blowing up for the next few years.

So, the government has allocated 57.05-64.00 GHz for 802.11ad “WiGig” which offers 7GB/s of throughput. Uses 2.16GHz channels (50x wider than 802.11n)

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

Nitsche, 802.11ad:

MCS index	Modulation type	Coding rate	Phy rate (Mbit/s)	Sensitivity power (dBm)	Tx EVM (dB)
0 (Control-PHY)	Direct-sequence spread spectrum with 32 $\pi/2$-BPSK chips per bit	1/2	27.5	−78	−6
1	$\pi/2$-BPSK (with each bit repeated twice)	1/2	385	−68	−6
2	$\pi/2$-BPSK	1/2	770	−66	−7
3	$\pi/2$-BPSK	5/8	962.5	−65	−9
4	$\pi/2$-BPSK	3/4	1155	−64	−10
5	$\pi/2$-BPSK	13/16	1251.25	−62	−12
6	$\pi/2$-QPSK	1/2	1540	−63	−11
7	$\pi/2$-QPSK	5/8	1925	−62	−12
8	$\pi/2$-QPSK	3/4	2310	−61	−13
9	$\pi/2$-QPSK	13/16	2502.5	−59	−15
10	$\pi/2$-16-QAM	1/2	3080	−55	−19
11	$\pi/2$-16-QAM	5/8	3850	−54	−20
12	$\pi/2$-16-QAM	3/4	4620	−53	−21

For comparison, 802.11ac using 16-QAM can transmit at best 650Mbit/sec

Overview

mmWaves:

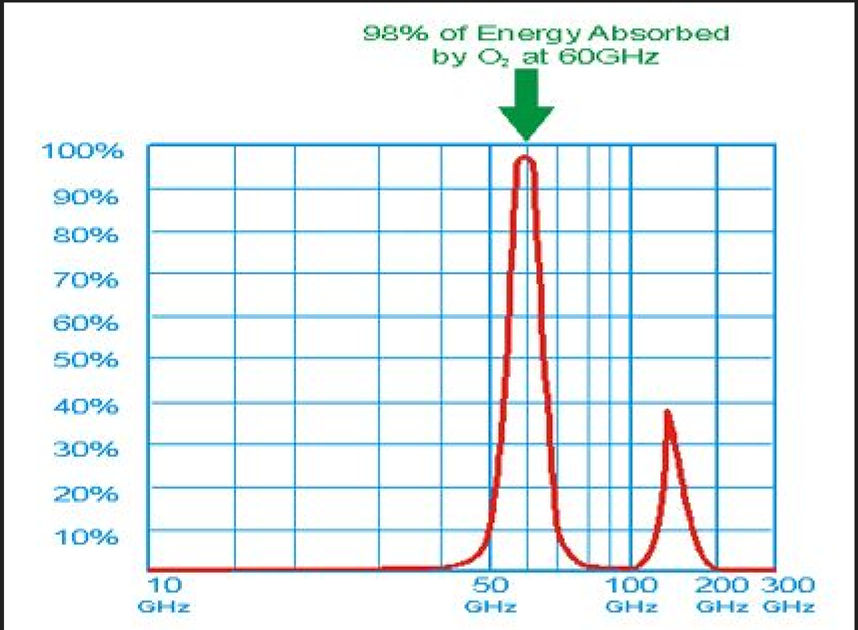
- Are RF waves in the 60GHz band (λ≈5mm) defined in the IEEE 802.11ad standard.
- Transition from omni-directional to directional usage of wireless medium
- Have different signal propagation characteristics compared to, for example, 2.4 GHz WiFi (λ≈12.5cm)

Challenge 1: Wave Characteristics

60 MHz Waves:

- Cannot penetrate concrete and other building materials
- Are strongly absorbed by oxygen
- Have significantly more free space loss
- ISI

$$\text{Loss} = P_t / P_r = (4\pi d)^2 / (G_r G_t \lambda^2)$$
$$= (4\pi f d)^2 / (G_r G_t c^2)$$



Challenge 1: Wave Characteristics

60 MHz Waves:

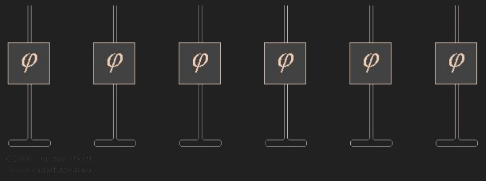
- Cannot penetrate concrete and other building materials -- but they can be reflected.
- Are strongly absorbed by oxygen, Have significantly more free space loss -- so they can be deployed more densely than wifi (more spatial reuse).
- ISI -- This is pretty bad, since the symbol period ends up being ~ns (3.6uS in 802.11ac). But it only works 1-10m anyway with directional antennas, when coupled with the above problems, so ISI is less of an issue.

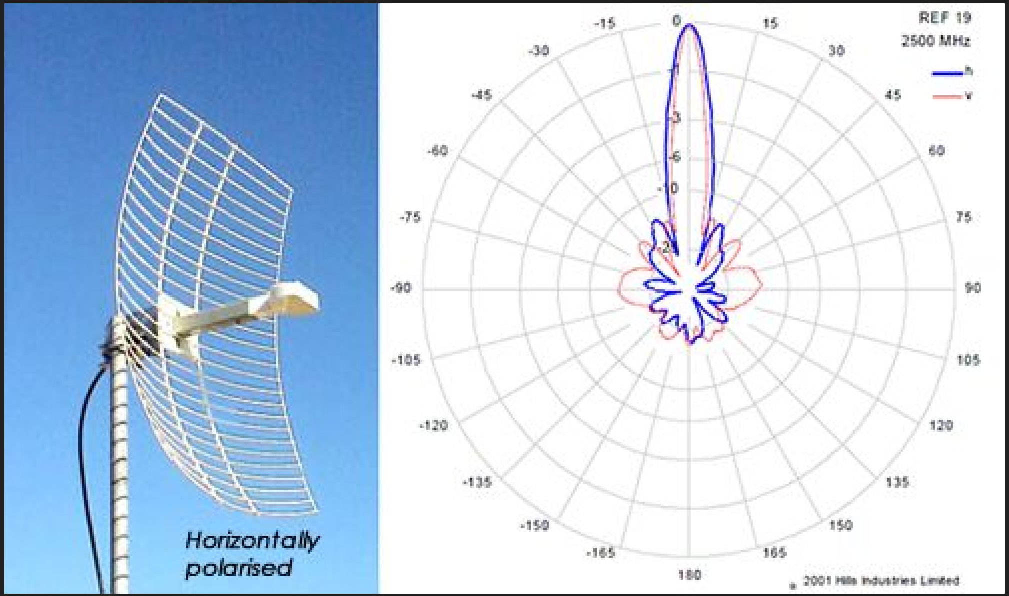
Plus, they can use much smaller antennas!

Nitsche, 802.11ad, Demystifying 60GHz Picocells

Challenge 2: Need for directional antennas

To get the desired range and throughput, directional antennas (either phased arrays or multiple directional antenna elements) must be used.





Challenge 2: Need for directional antennas

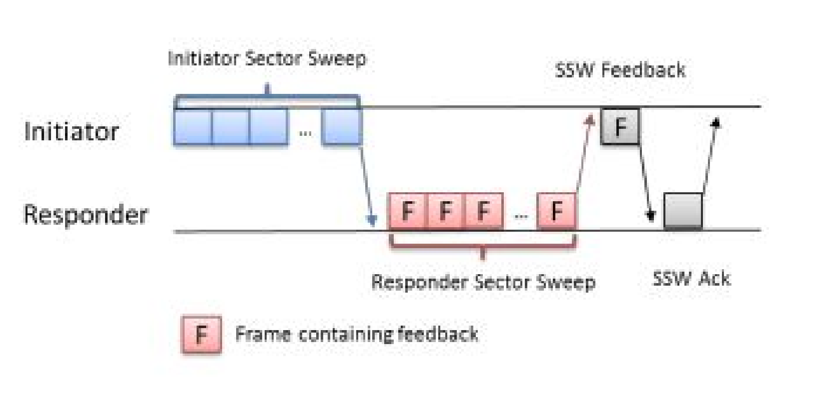
But then we need to resolve...

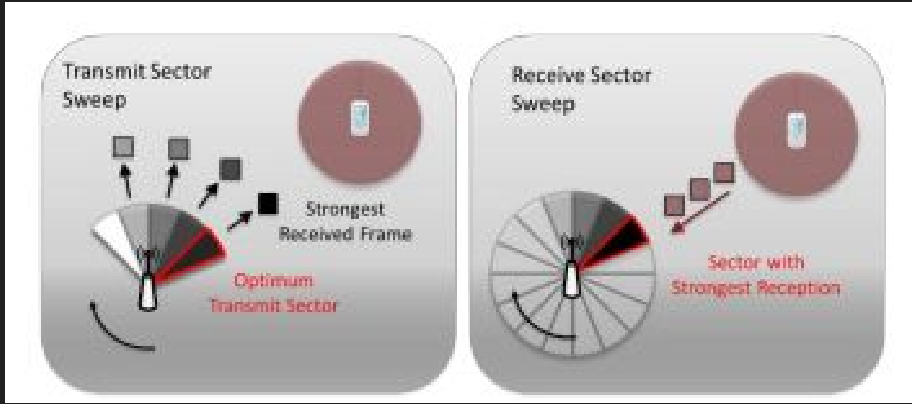
- How do we associate with an access point?
- How do we deal with deafness?

In addition, the transmitter and receiver need to agree on optimal sectors (setup!) and poorly trained beams can damage an entire system

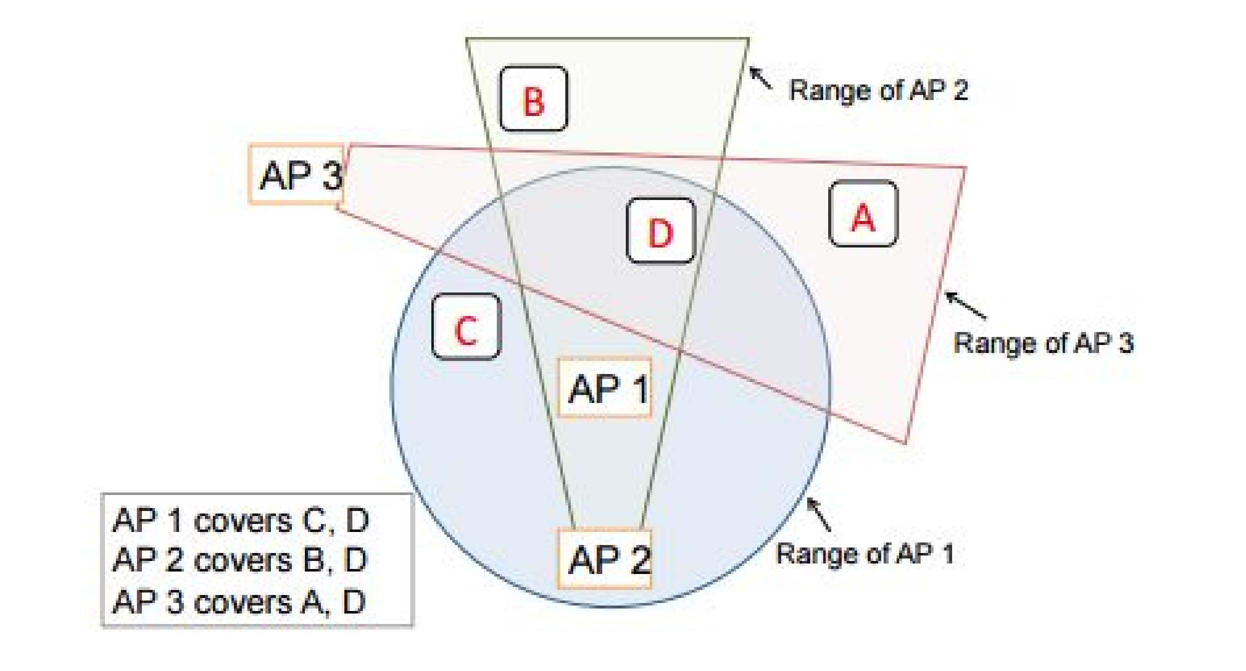
How do we associate with an access point?

Quasi-Omnidirectional: Sweep across all sectors and find the strongest pair, then refine.





How to deal with deafness?



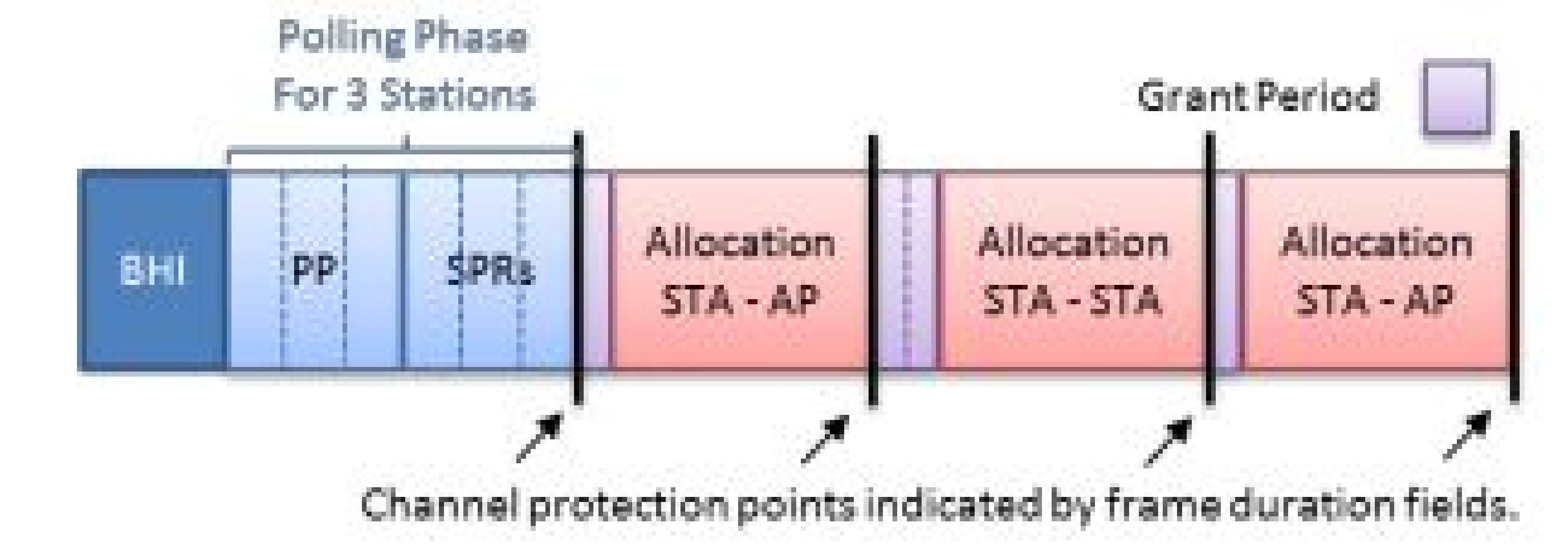
Challenge 3: Changes at the MAC Layer

- 802.11ad defines a “beacon interval” during which an access point or coordinating station quasi-omnidirectionally announces the existence of a wireless network and sends management data including the schedule and the medium access parameters
- Personal Basic Service Set (PBSS) allows nodes to communicate with each other in an ad hoc-like manner, but also has a PBSS Control point (PCP) which allows the access point to announce the network and organize nodes.
- Ad hoc with centralized controller -- possible problems?

Nitsche, 802.11ad:

Challenge 3: Changes at the MAC Layer

- Polling-based, centralized scheduling



Discussion

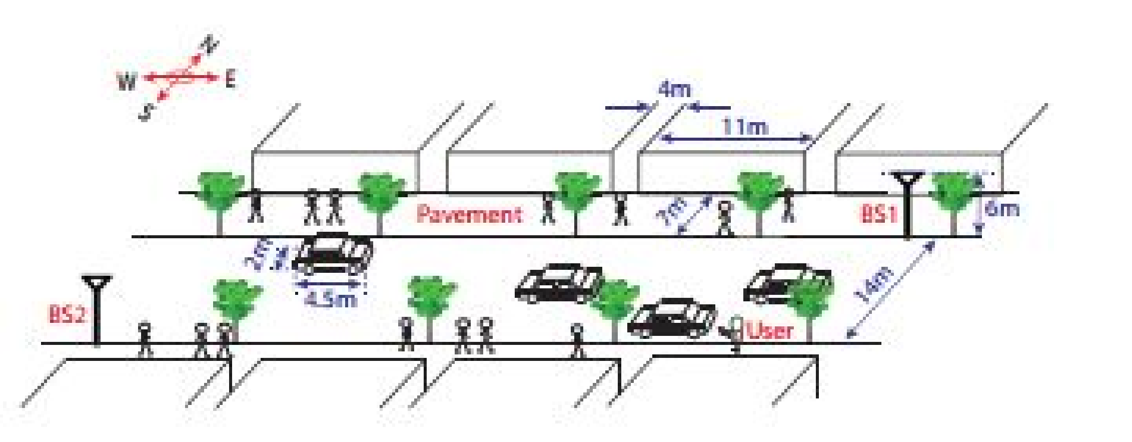
A couple technologies this enables:

- Picocells -- very small (10s-100s meter) cells for cheaper incremental deployments -- since 60GHz requires smaller antennas and interferes less
- Wireless VR

mmWaves could allow simpler cellular incrementation

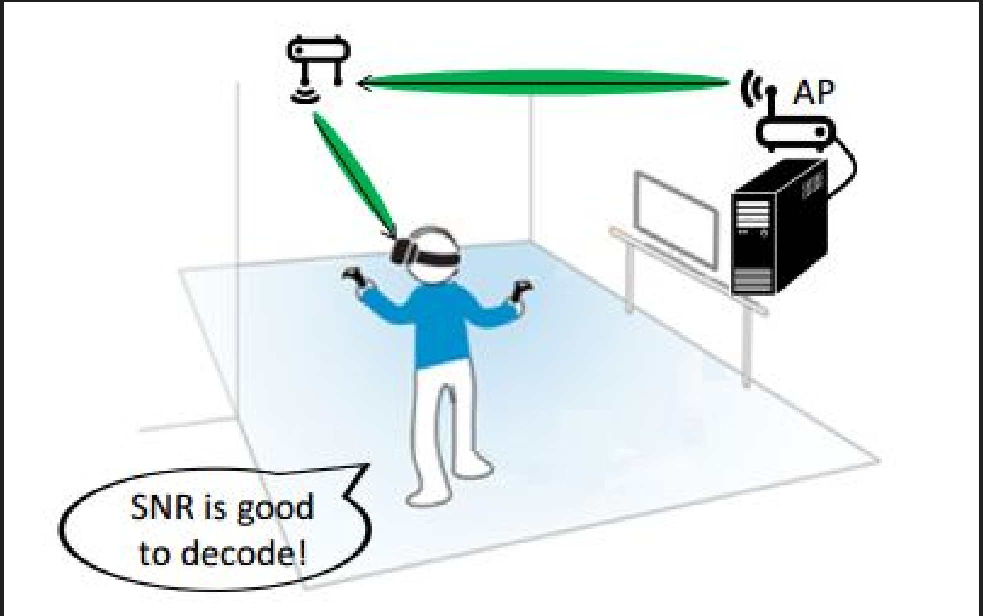
As populations gradually increase, gradual cellular infrastructure increase.

- Can cover 130m at 386Mbps
- Robust to movement of pedestrians
- Small interference footprint, directionality, ability to reflect.



mmWaves could enable wireless VR

MoVR: Can use reflectors to allow access point to communicate with VR headsets



Questions?

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