Challenges of wireless

Shared, exposed medium

Interference

• from other users
• from same user! (multipath)
• from external environment

Signal attenuation (path loss)

Dynamic & unknown physical medium

Security
3D Beamforming for Wireless Data Centers
Weile Zhang (UCSB & Xian Jiaotong U.), Xia Zhou (UCSB), Lei Yang (Intel Labs), Zengbin Zhang (UCSB), Ben Y. Zhao and Haitao Zheng (UCSB)

Bootstrapping Energy Debugging on Smartphones: A First Look at Energy Bugs in Mobile Devices
Abhinav Pathak and Y. Charlie Hu (Purdue University) and Ming Zhang (Microsoft Research)

Rateless Spinal Codes
Jonathan Perry, Hari Balakrishnan, and Devavrat Shah (MIT)

Picasso: Programmable Signal Shaping to Exploit Fragmented Spectrum
Steven Hong, Jeff Mehlman, and Sachin Katti (Stanford University)

The Case for Antenna Cancellation for Scalable Full Duplex Wireless Communications
Mohammad A. Khojastepour, Karthikeyan Sundaresan, and Sampath Rangarajan (NEC Labs America), Xinyu Zhang (Univ. Of Michigan), and Sanaz Barghi (Univ of California, Irvine)

Precise Indoor Localization using PHY Layer Information
Souvik Sen (Duke University), Bozidar Radunovic (Microsoft Research), Romit Roy Choudhury (Duke University), and Tom Minka (Microsoft Research)
3D Beamforming

[Zhang et al.]

(a) Rack-based DC

(b) Container-based DC

(c) 2D Beamforming

(d) 3D Beamforming
maps using both horn antenna and antenna arrays. The transmi
IEEE 802.11ad standard [2].

If the transmit power is greater than -71 dBm, the noise level defined by the
Figure 2: a typical horn antenna with 10
for concurrent links. For example, consider a link using
intended direction [20, 27]. These factors, together with
dio design artifacts lead to signal leaked outside of the
Figure 1(d), each sender points its beam towards a
ceiling reflections to connect racks wirelessly. As shown
forming (or containers) and the ceiling.

transmit power. A single link can interfere

11m

27 racks in a typical deployment with 160 racks in a

10 dBm

Key properties of 3D Beamforming.

(a) Link data rate (Gbps)

(b) Interference region, horn antenna

(c) Interference region, antenna array

3.3D BEAMFORMING

To address the above limitations, we propose
Radio interference constrains the number of concur-

3D beamforming requires three hardware components:
• Beamforming Radios
• Electromagnetic Absorbers
• Ceiling Reflectors

Alternatively, increasing spacing between racks leads to

rent links, and thus also network throughput. Separat-

3.1 Feasibility

Here we assume that there are no obstacles between top of rack
We define a rack as interfered with if its perceived interfere

• 3D beamforming

To form a link, two endpoints point their antennas at
between the sender and receiver, and

indoor 60 GHz LOS links [22], the resulting indirect

horizontal plane, eliminating the antenna blockage problem

Extended Link Connectivity.

3D beamforming bypasses obstacles in the hori-

tion model, 3D beamforming improves link capacity for our needs.
They Can Hear Your Heartbeats

[Gollakota, Hassanieh, Ransford, Katabi, Fu, SIGCOMM’11]

Key contributions

- Secure an insecure device without modification
- Small full-duplex radio
Announcements

Homework due 11:59 p.m. tonight

Happy Thanksgiving!