Enabling High-Quality Untethered Virtual Reality

NSDI 2017

Headset’s cable not only limits player’s mobility but also creates a tripping hazard

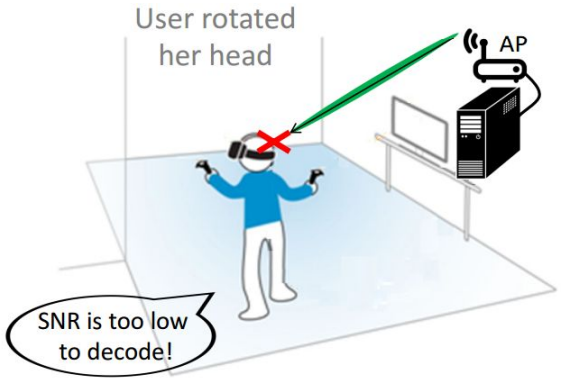
Go Wireless

- Wifi
  - Cannot support required data rates
  - Zotac has gone as far as stuffing full PC in player’s backpack

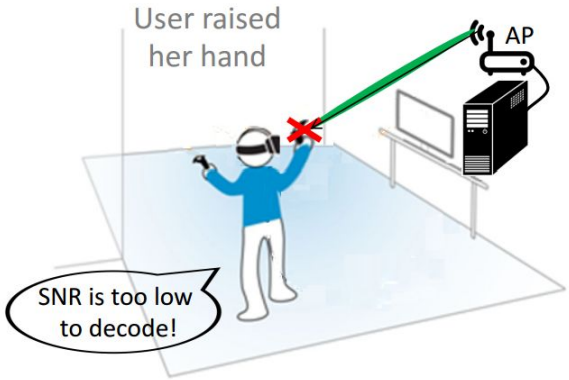
- mmWave
  - High frequency RF signals in range of 24 GHz and higher
  - 802.11ad operates in mmWave and can transmit over 2GHz bandwidth and deliver upto 6.8Gbps

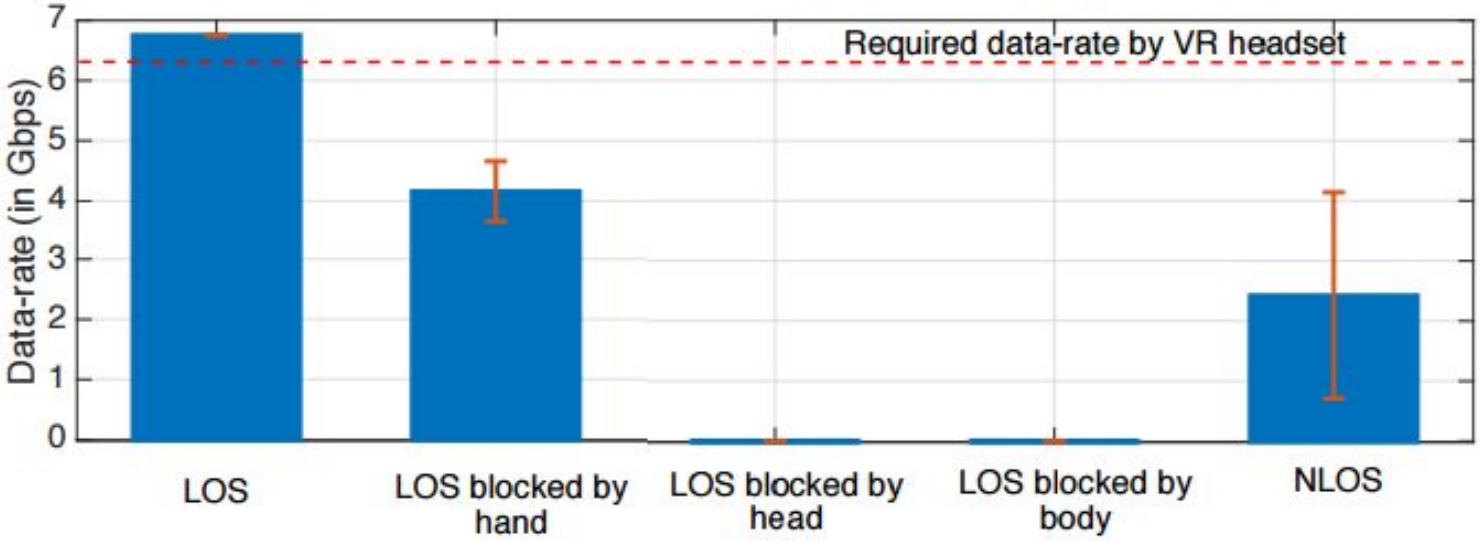
mmWave - Fundamental Challenges

- Blockage
  - mmWave links require line of sight between transmitter and receiver
  - A small obstacle like player's hand can block the signal



- Mobility
  - mmWave radios use highly directional antennas
  - Transmitter's beam needs to be aligned with receiver's beam

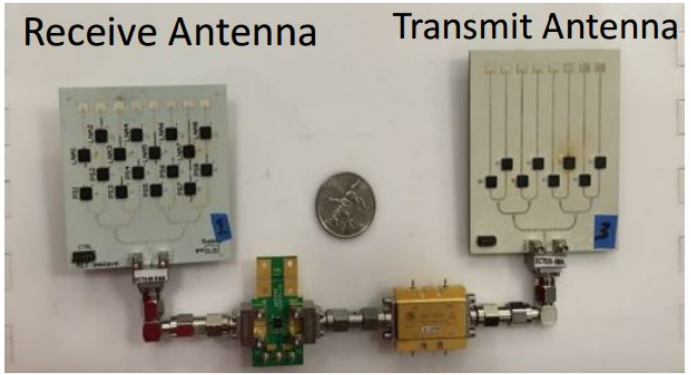


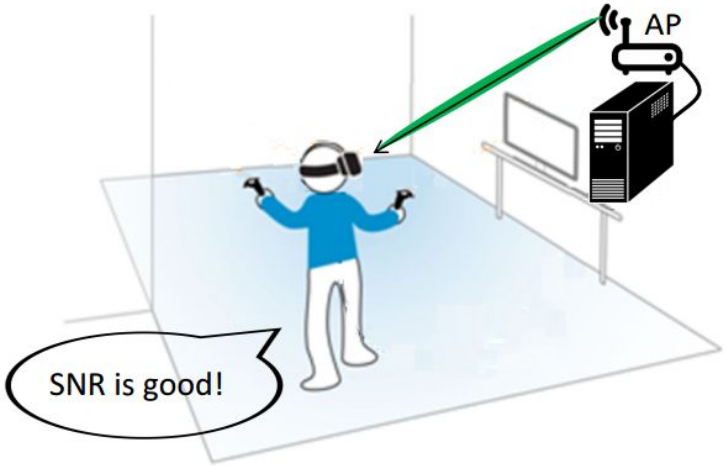


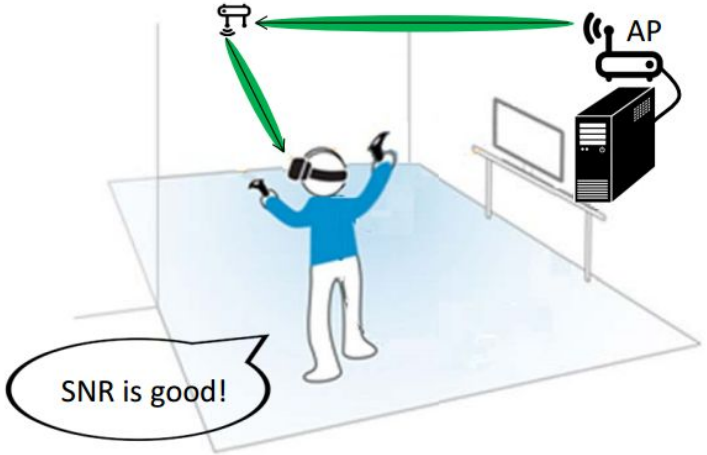
How to maintain LOS at all times?

Programmable mmWave Mirrors

- mmWave mirror works by capturing RF signal on receive antenna, amplifying it and ‘reflecting’ using transmit antenna
- Control
  - Angle of incidence
  - Angle of reflection
- Can be steered electronically in a few μs







- AP transmits VR content
- AP transmits control information to mirror over bluetooth

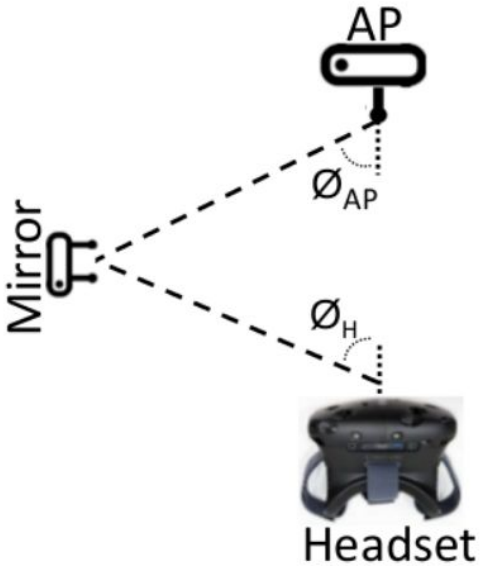
Beam Alignment and Tracking (I)

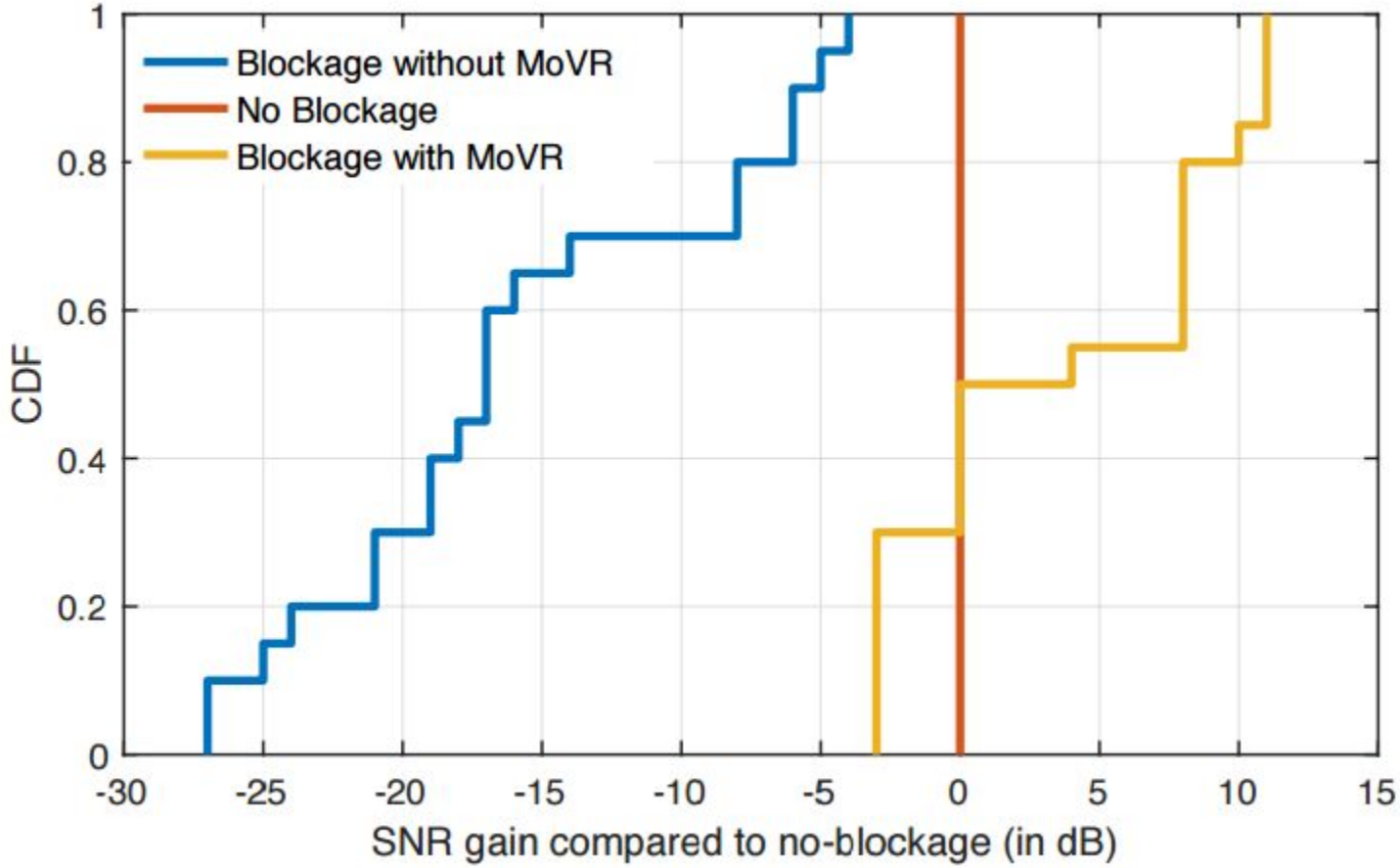
1. Beam alignment between AP and mirror
   - Set mirror's transmit and receive beams in same direction, α
   - Set AP's transmit and receive beams in same direction, β
   - Try all combinations of α and β, pick the one that maximizes SNR

2. Beam alignment and tracking between AP and headset
   - VR systems already track location and orientation of headset using laser trackers and IMU
   - Co-locate AP with one of VR laser trackers and exploit VR tracking system

Beam Alignment and Tracking (II)

3. Beam alignment and tracking between mirror and headset
    - We can get angle between AP and mirror as explained earlier
    - To estimate angle between mirror and headset
        - AP transmits to mirror
        - Mirror tries every beam angle to find the angle that gives highest SNR at headset




Blockage without MoVR
No Blockage
Blockage with MoVR
CDF
1
0.8
0.6
0.4
0.2
0
-30
-25
-20
-15
-10
-5
0
5
10
15
SNR gain compared to no-blockage (in dB)