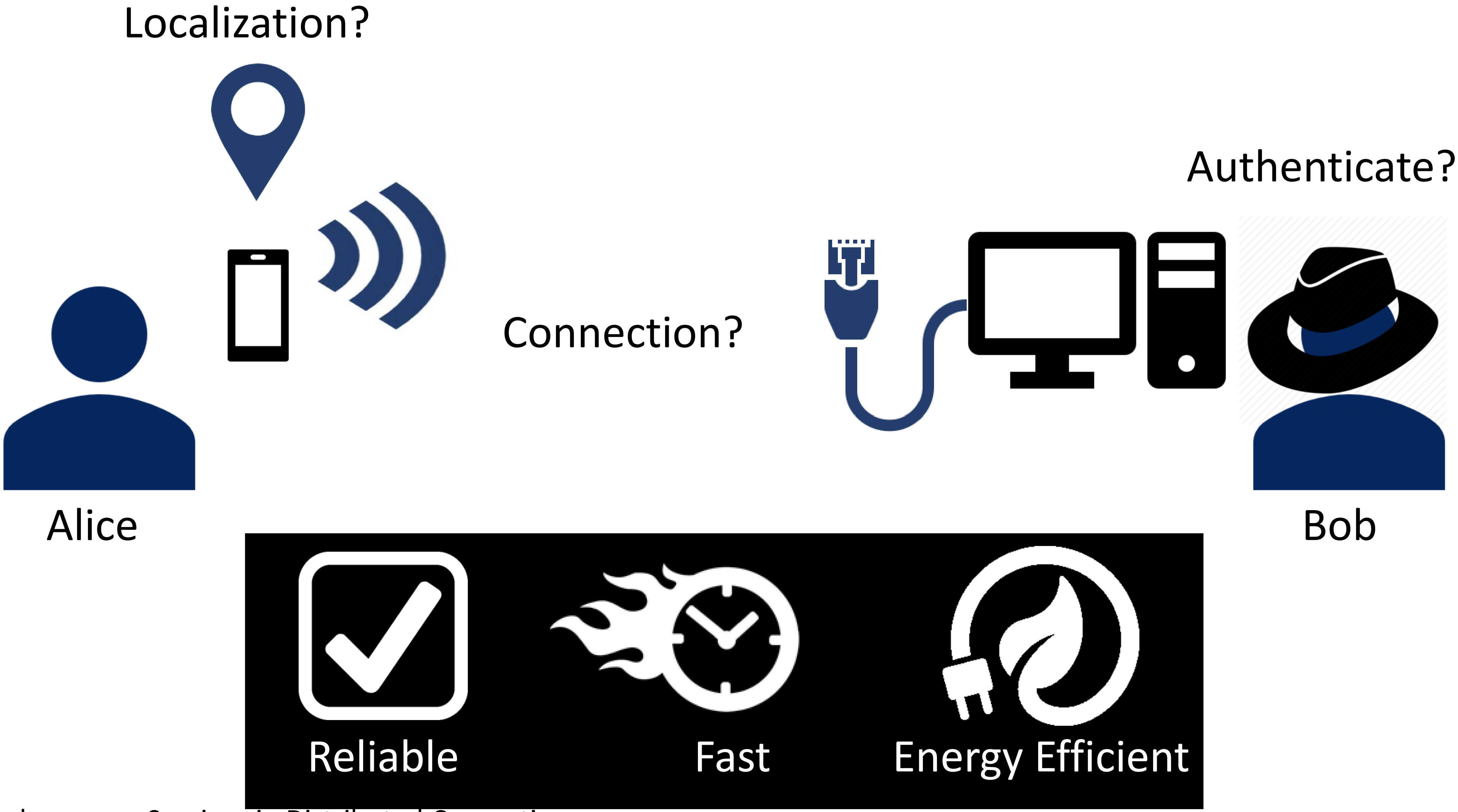
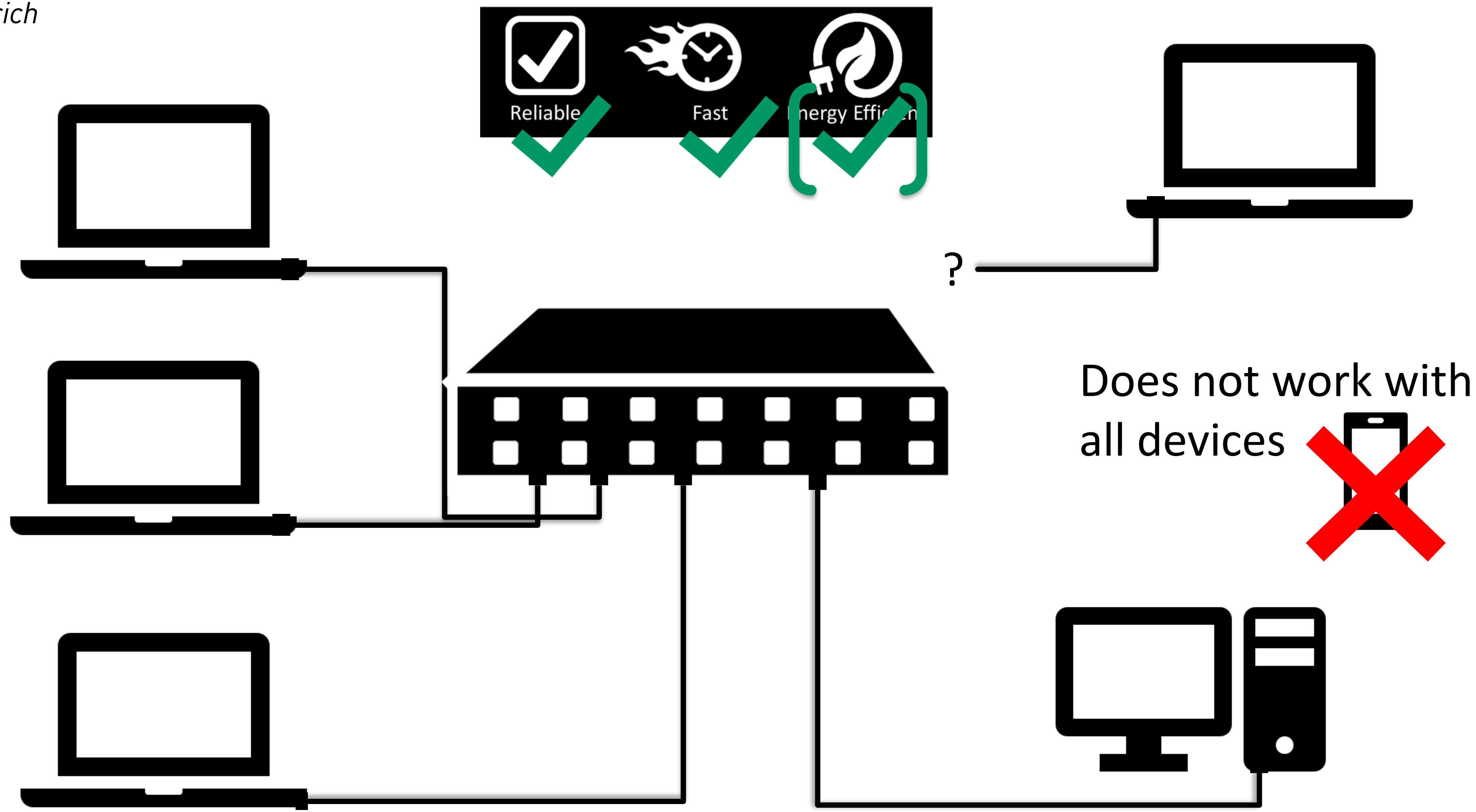
ETH zürich

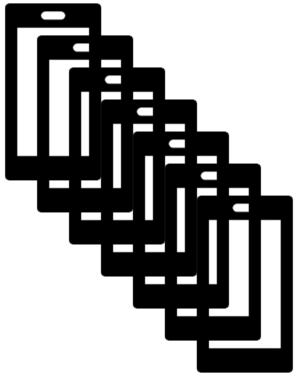
Frontiers in Communication

Reto Achermann

Distributed Systems Seminar

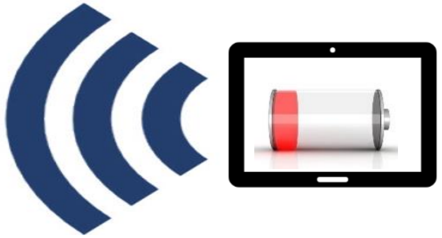

Localization?
Authenticate?
Connection?
Alice
Bob
Reliable
Fast
Energy Efficient


Reliable
Fast
?
Does not work with all devices

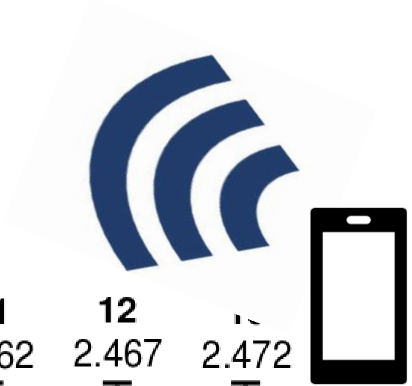


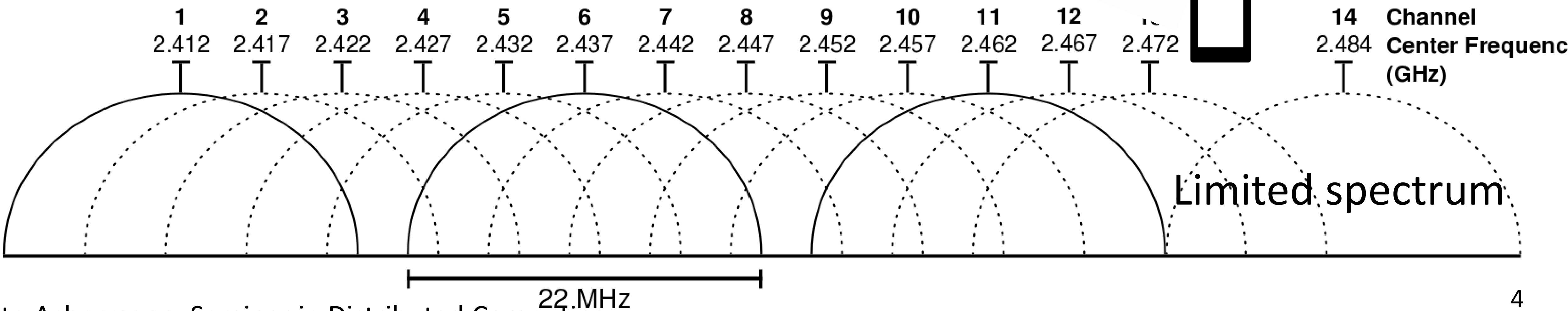
Many collisions with lots of devices

power consumption



Eve

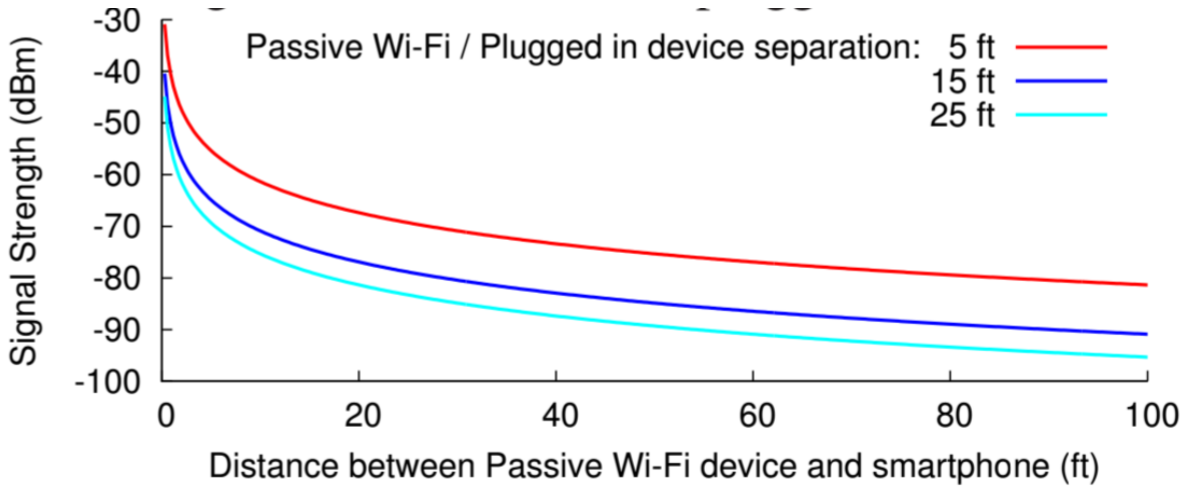




Limited spectrum

By Michael Gauthier, Wireless Networking in the Developing World https://commons.wikimedia.org/w/index.php?curid=8353678

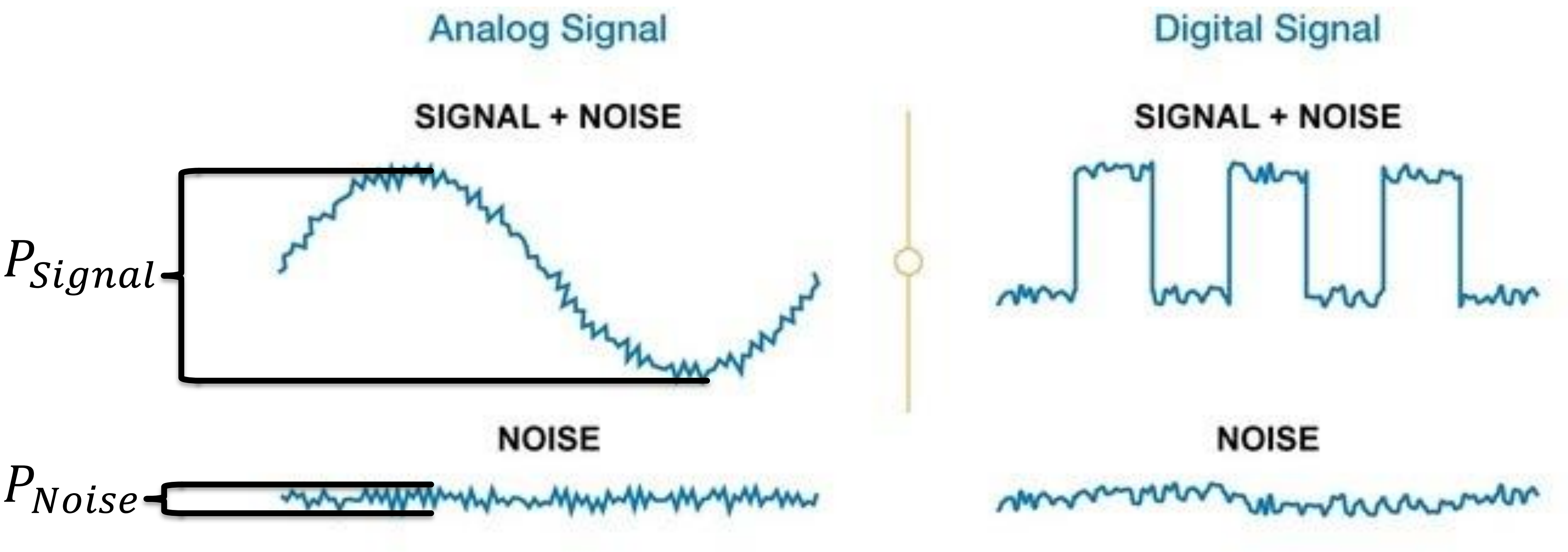
Primer on signal transmission: Signal Strength

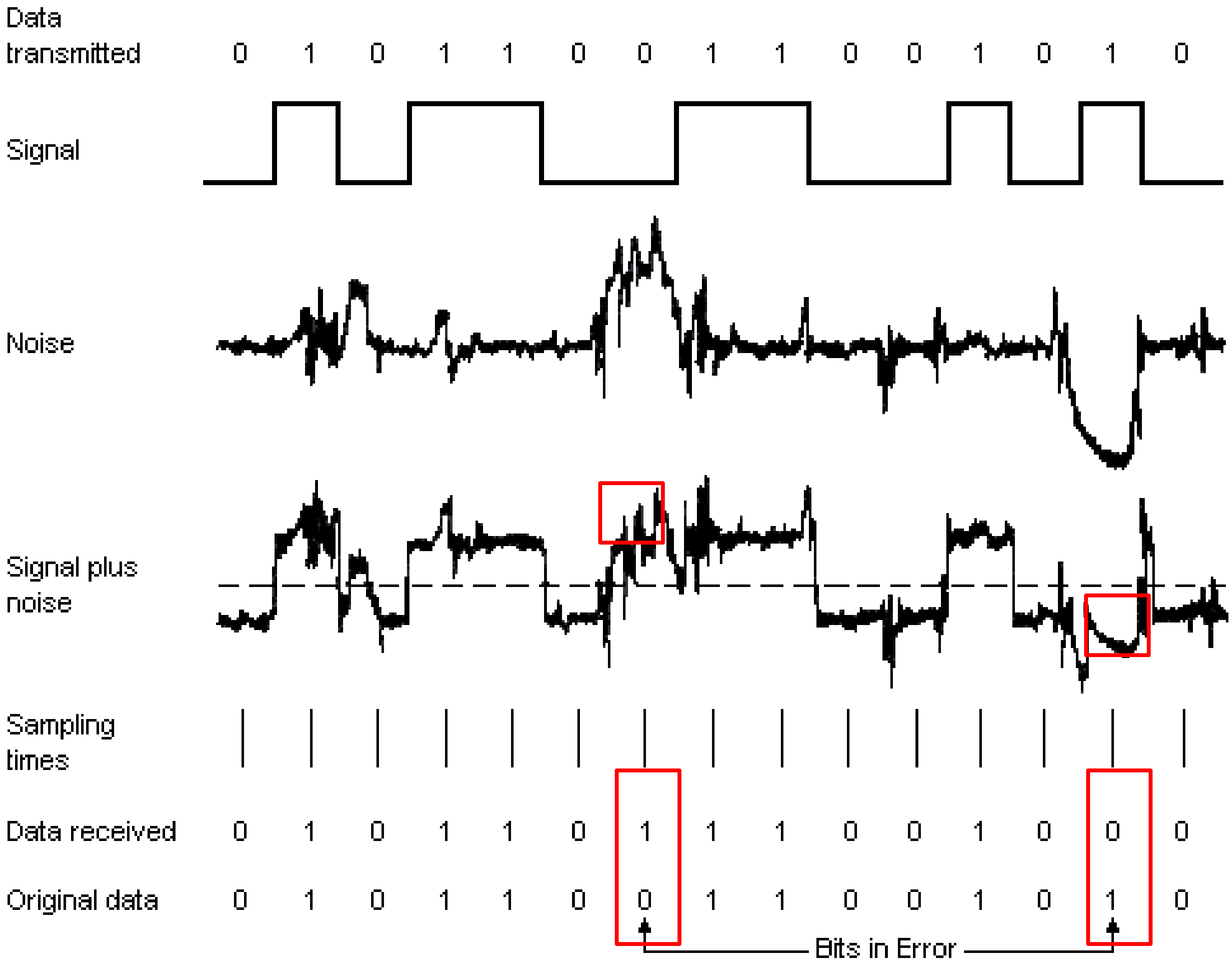


Blocked and reflected by surfaces and walls

Signal to Noise Ratio

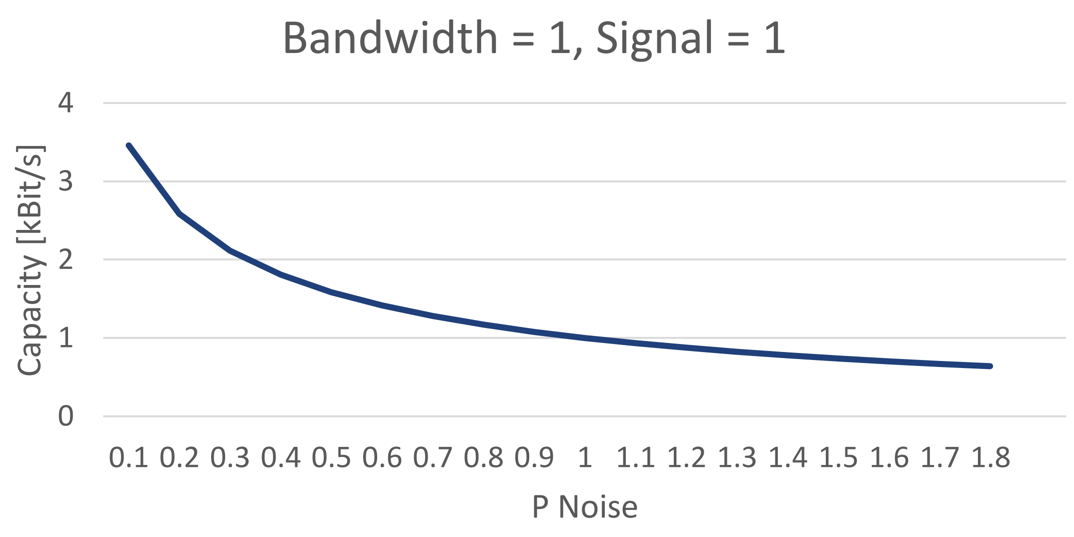
$$SNR = 10 \lg\left(\frac{P_{Signal}}{P_{Noise}}\right) db$$



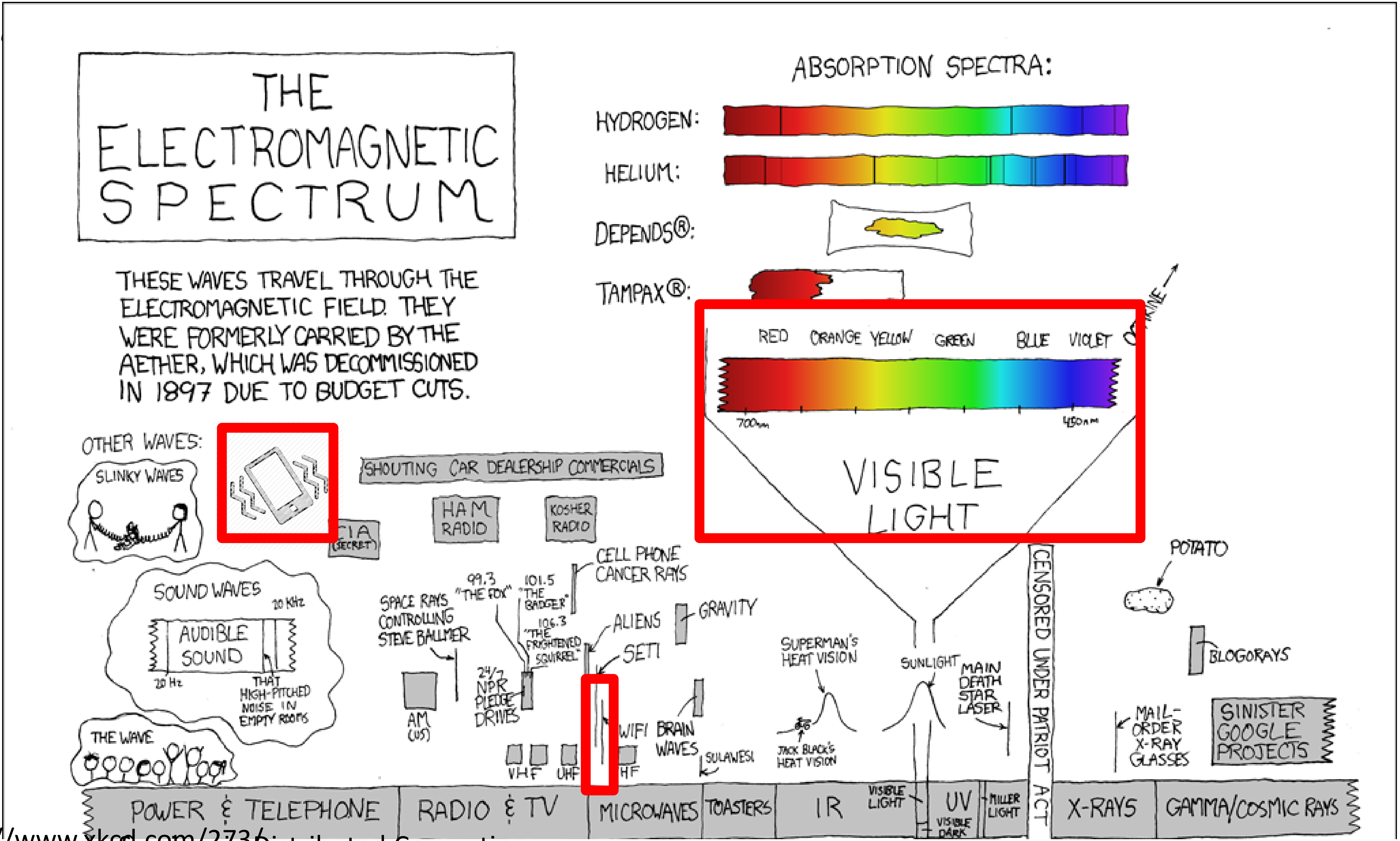

Data transmitted
0 1 0 1 1 0 0 1 1 0 0 1 0 1 0
Signal
Noise
Signal plus noise
Sampling times
Data received
0 1 0 1 1 0 1 1 1 0 0 1 0 0 0
Original data
0 1 0 1 1 0 0 1 1 0 0 1 0 1 0
Bits in Error

Shannon-Hartley Theorem

- C: Channel Capacity (kBit/s)
- B: Bandwidth of the channel (Hz)
- S: Signal Power (avg)
- N: Noise interference (avg)



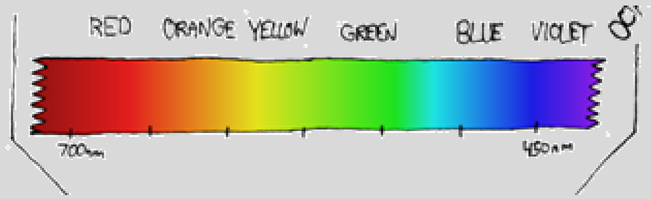
$$C = B \cdot \log_2\left(1 + \frac{S}{N}\right)$$



https://www.xkcd.com/273/

Low Power WiFi

Physical Waves



Visible Light Communication

Talk Outline

Low Power WiFi

Physical Waves

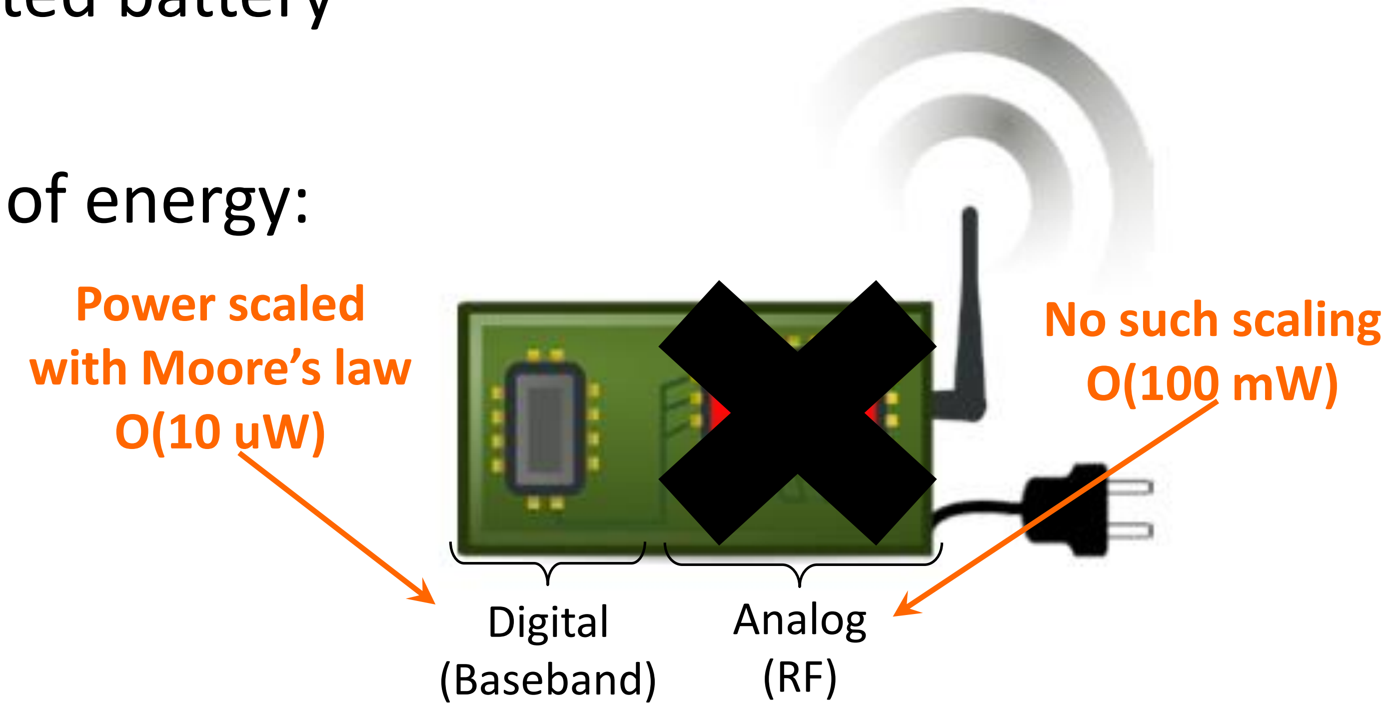
Visible Light Communication

Passive Wi-Fi: Bringing Low Power to Wi-Fi Transmissions

Bryce Kellogg, Vamsi Talla, Shyamnath Gollakota, and Joshua R. Smith. NSDI 2016.

Wi-Fi transmitter consumes 500 - 700 mW

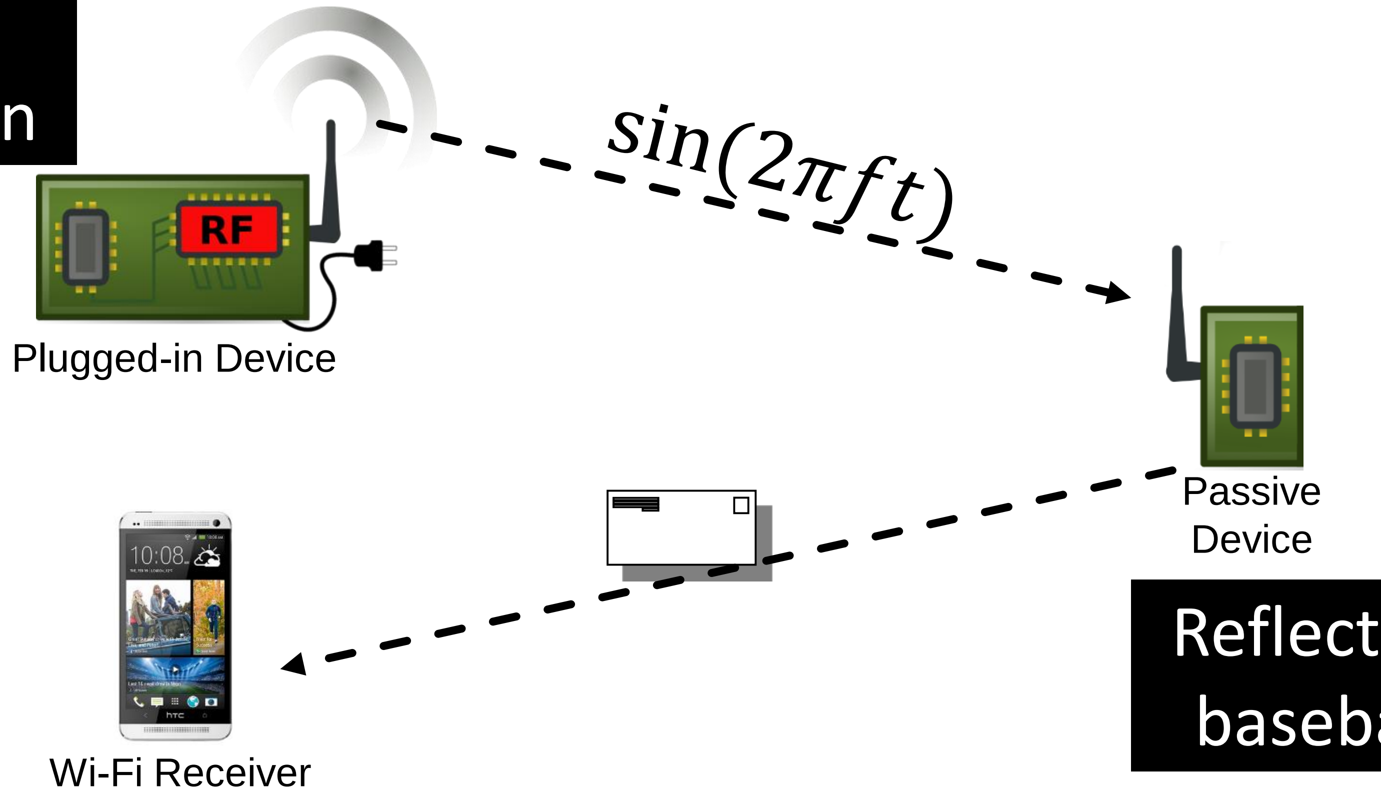
- IoT: Many small sensors with limited battery
- Wi-Fi transmitters consume a lot of energy:
  - Microphone:
    Audio: 50 uW
    Wi-Fi Chipset: **670 mW** → **65 uW**
    Camera:
    Visuals: 10mW
    Wi-Fi Chipset: **680 mW** → **14mW**



Get rid of power hungry analog RF

Passive Wi-Fi Idea: Use of Back-Scatter and reflections

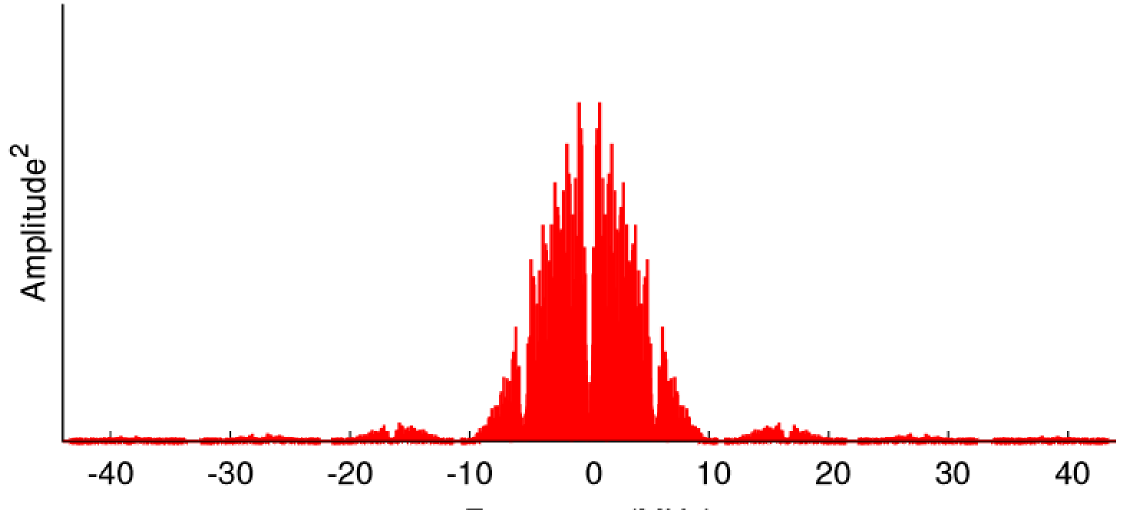
Power Hungry RF function
"Tone" generation

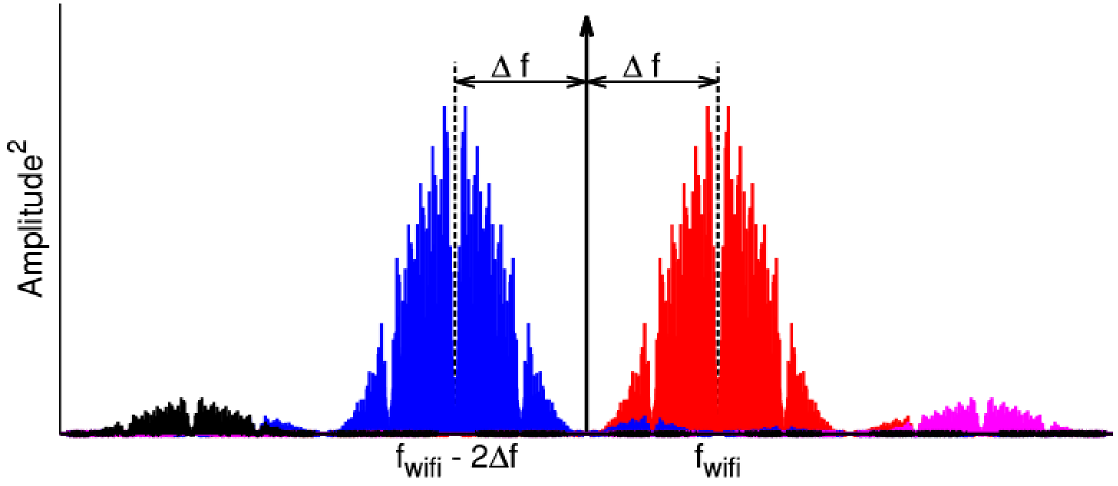


Reflection using digital baseband operations

Partially borrowed from the NSDI talk

Approach: Back Scatter



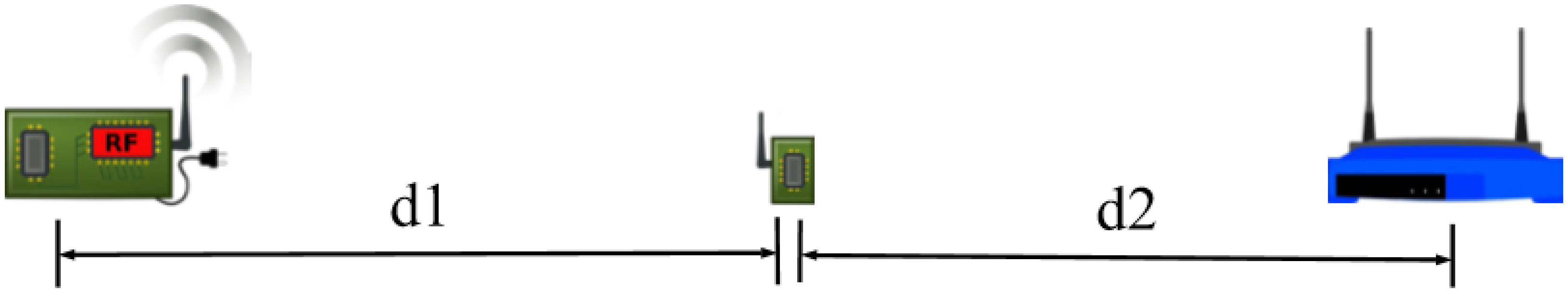


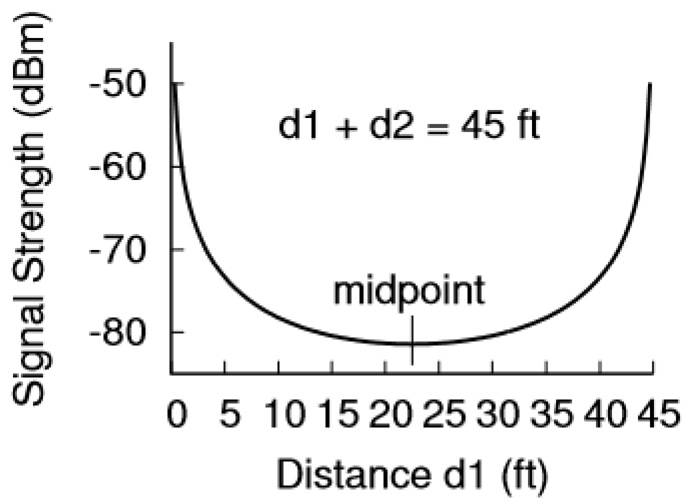
22Mhz main lobe of WiFi

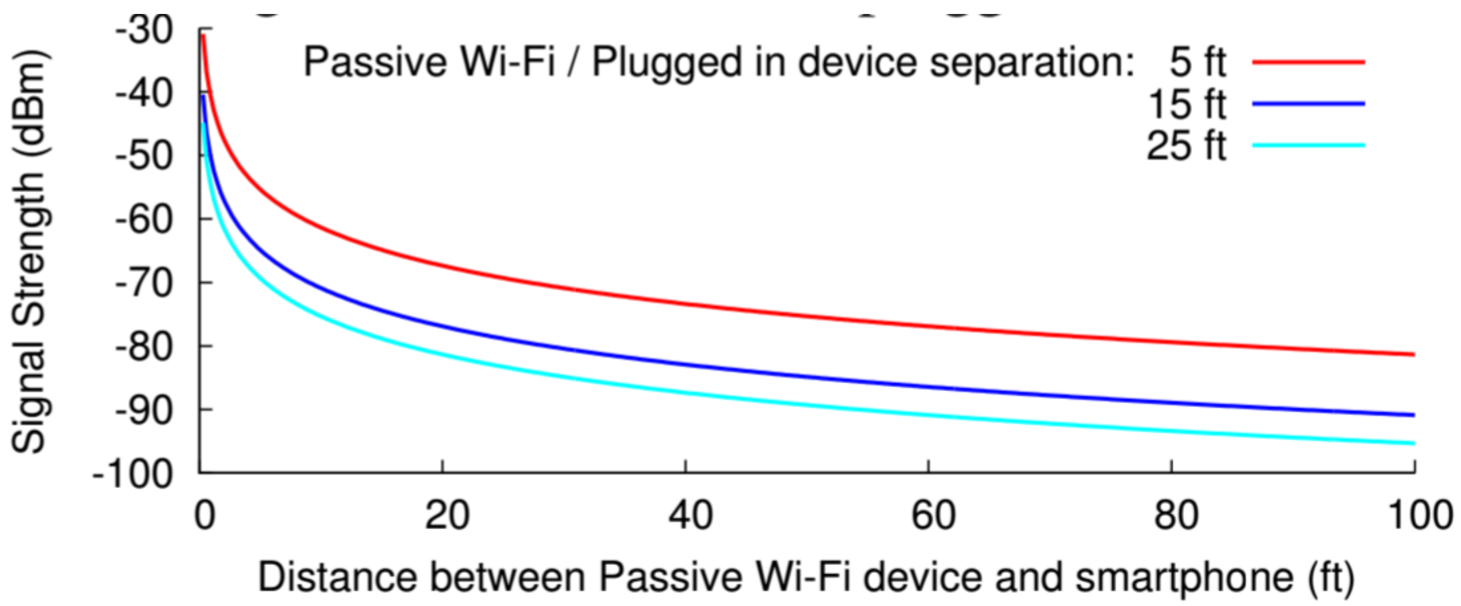
Too much interference

Backscatter Approach:
Shift by Δf using square wave approximation

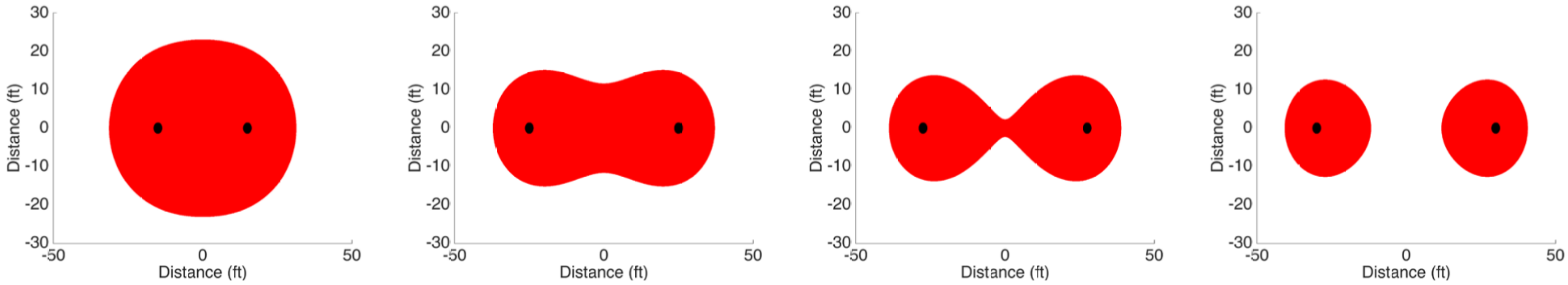
Results: Move Passive device between





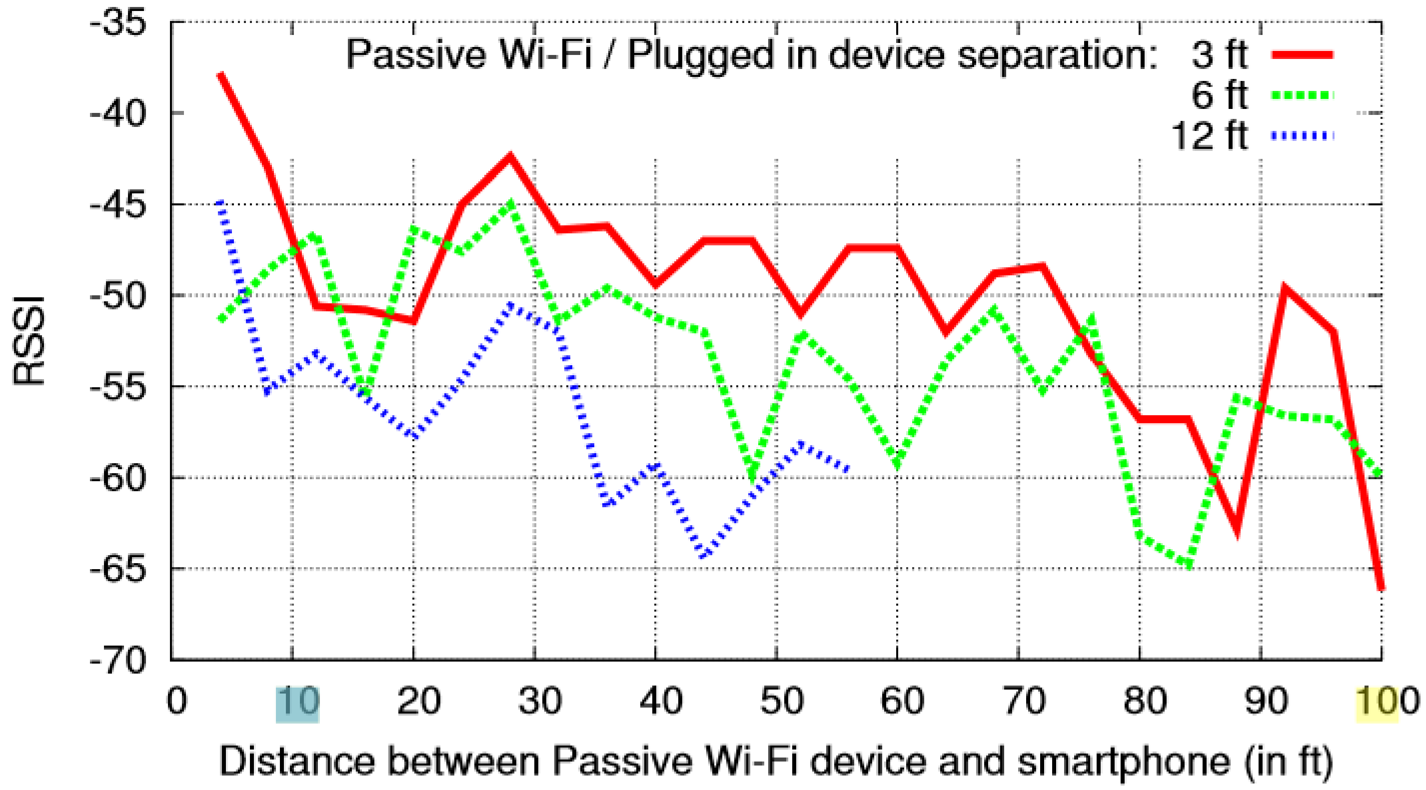


Results: Move passive device away



(a) 30 ft Separation (b) 50 ft Separation (c) 55 ft Separation (d) 60 ft Separation

Results: Move passive device away



Low Power WiFi

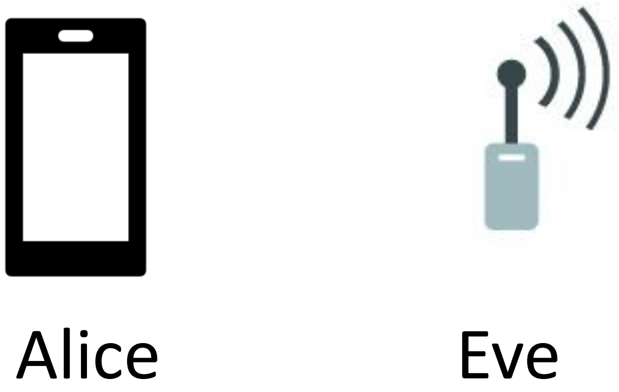
Physical Waves

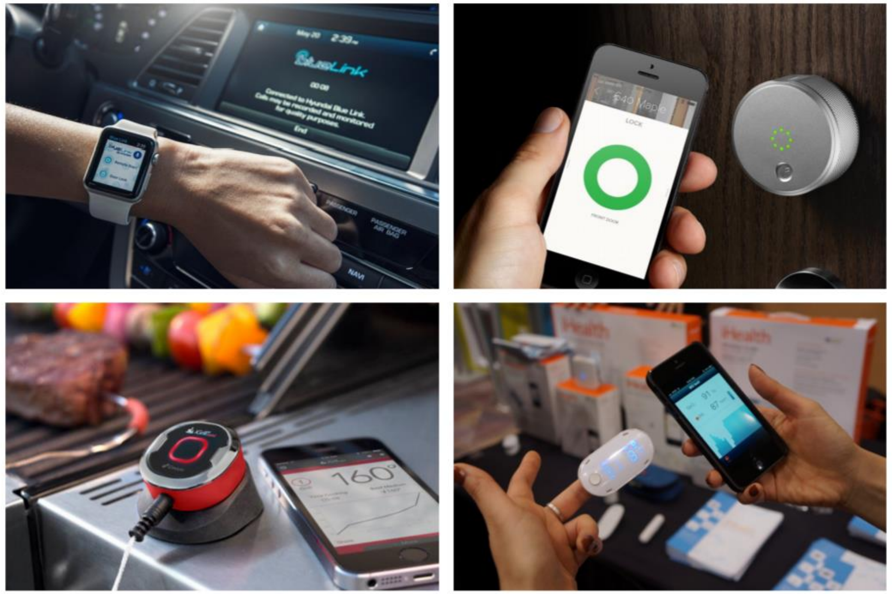
Visible Light Communication

Ripple II: Faster Communication through Physical Vibration

Nirupam Roy and Romit Roy Choudhury. NSDI 2016.

Short range communication is central to many applications





- Use WiFi, Bluetooth, NFC
- Radio based communication operate at **distance**

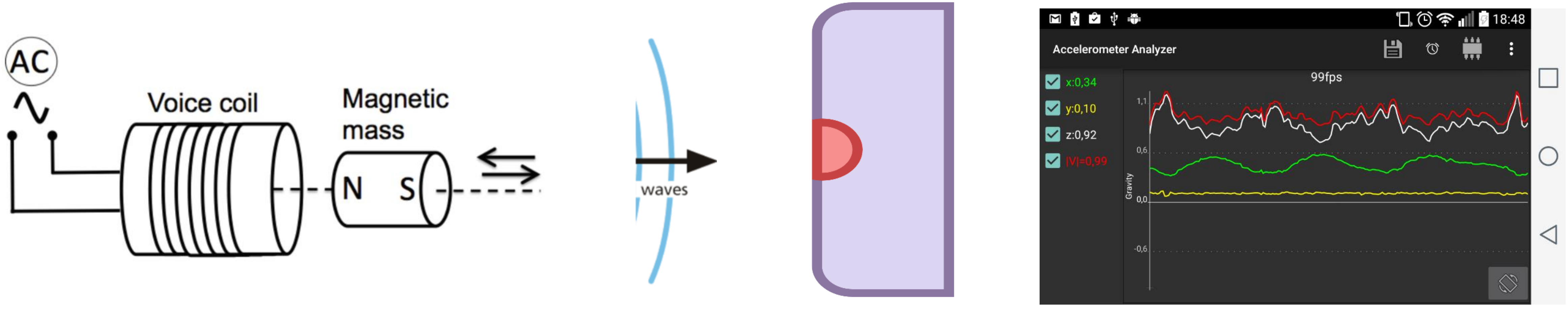
Approach: Using vibratory ratio

Abundant availability

Works on touch

No RF radiation

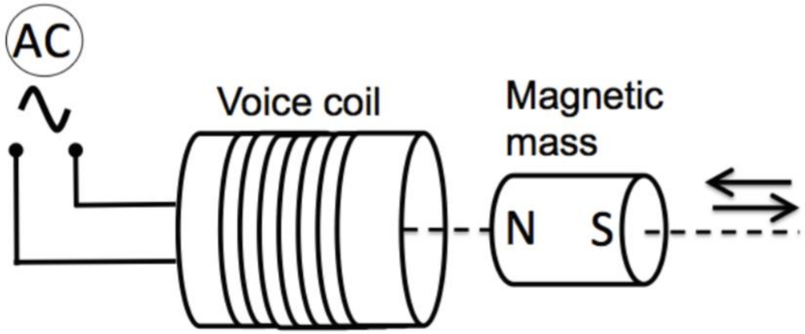
Physical Wave Setup of Ripple I

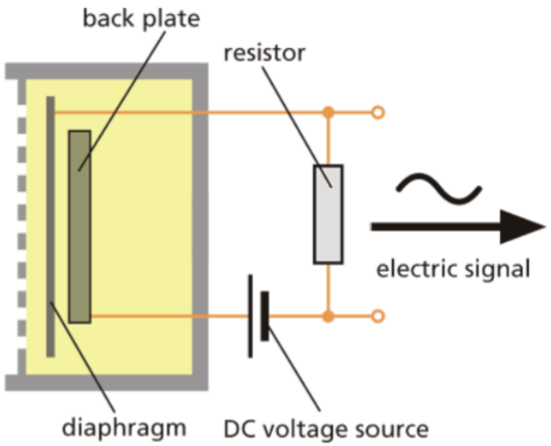


Vibration Physical Waves Sensor Data Analysis

Problem: Resolution of accelerometer is too low
Bandwidth: 200 bits/s
If we just could improve the sensitivity…

Physical Wave Setup of Ripple II





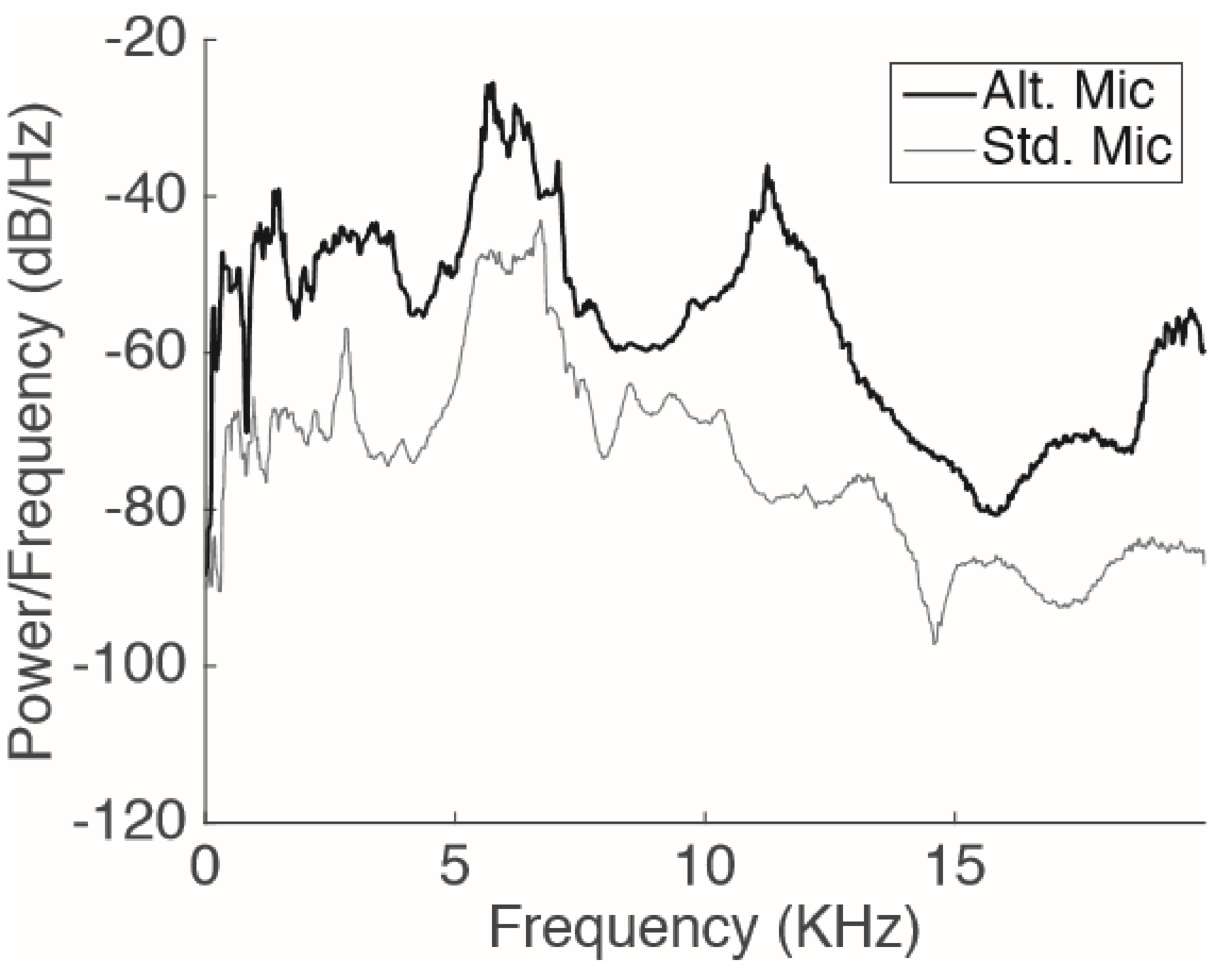
Vibration

Physical Waves

Microphone

Problem: Microphone also picks up sound waves

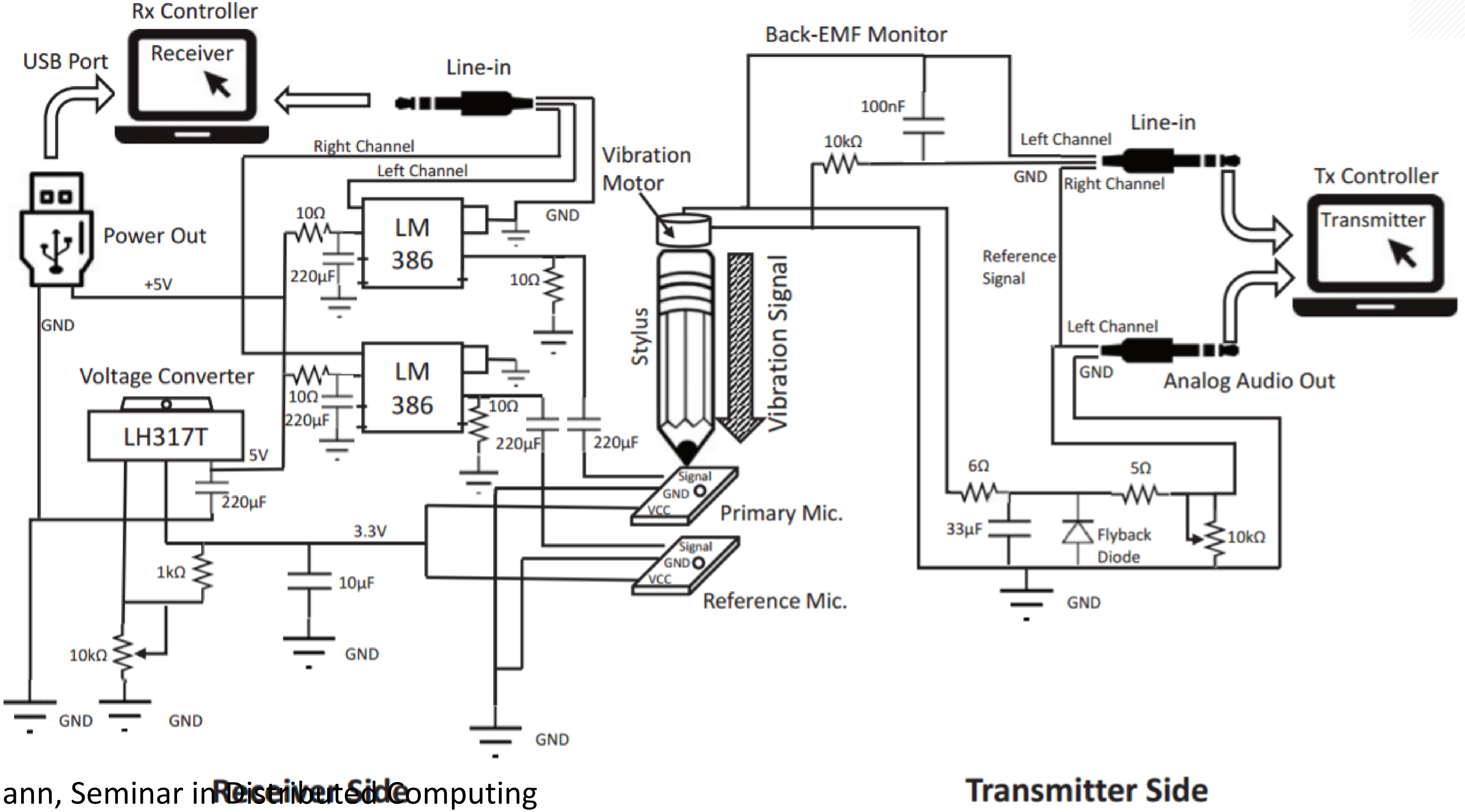
Idea: Cover the sound hole



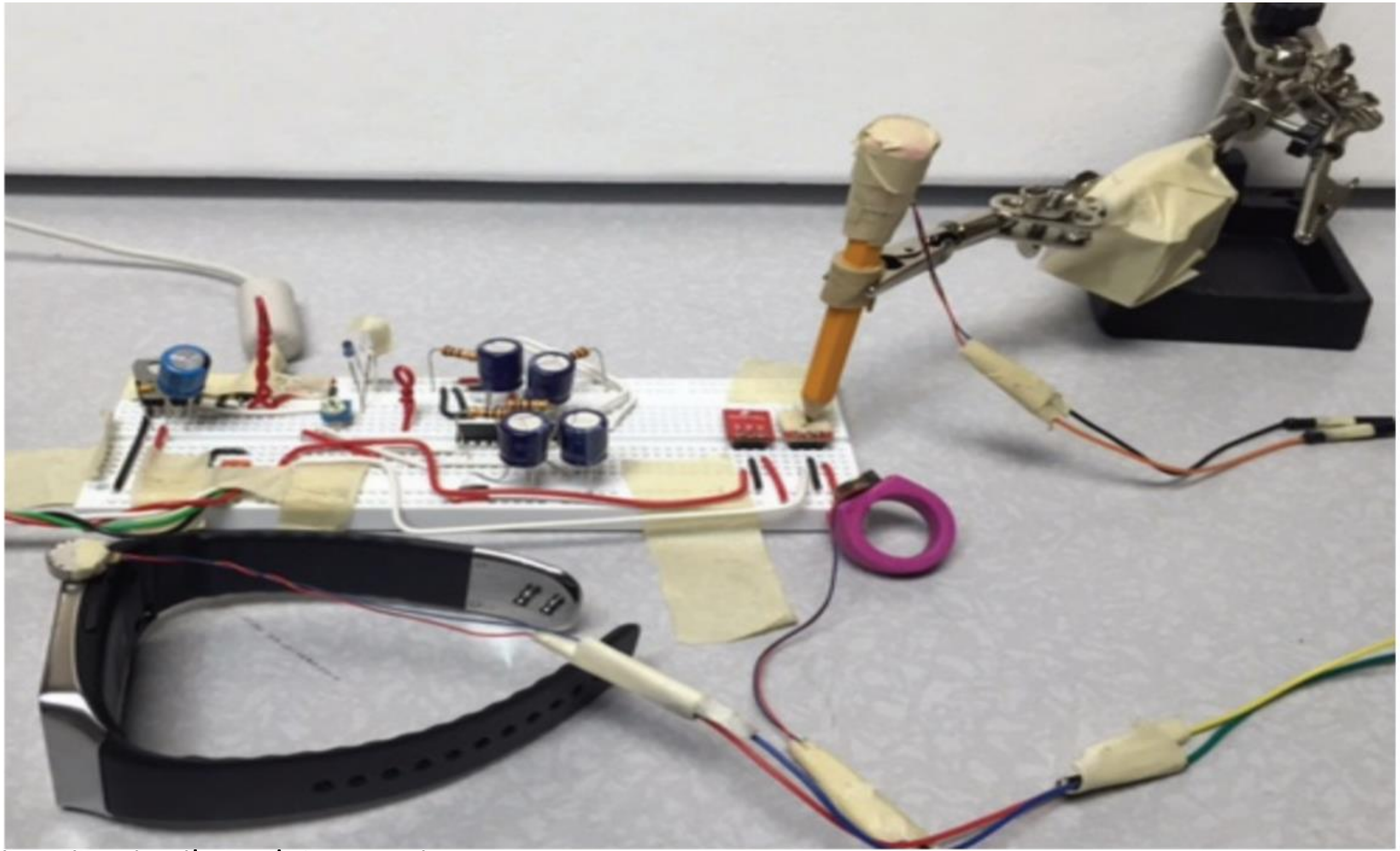
Average gain of 18.2dB

+ ambient sound cancelling
(not trivial, e.g. phase mismatch)

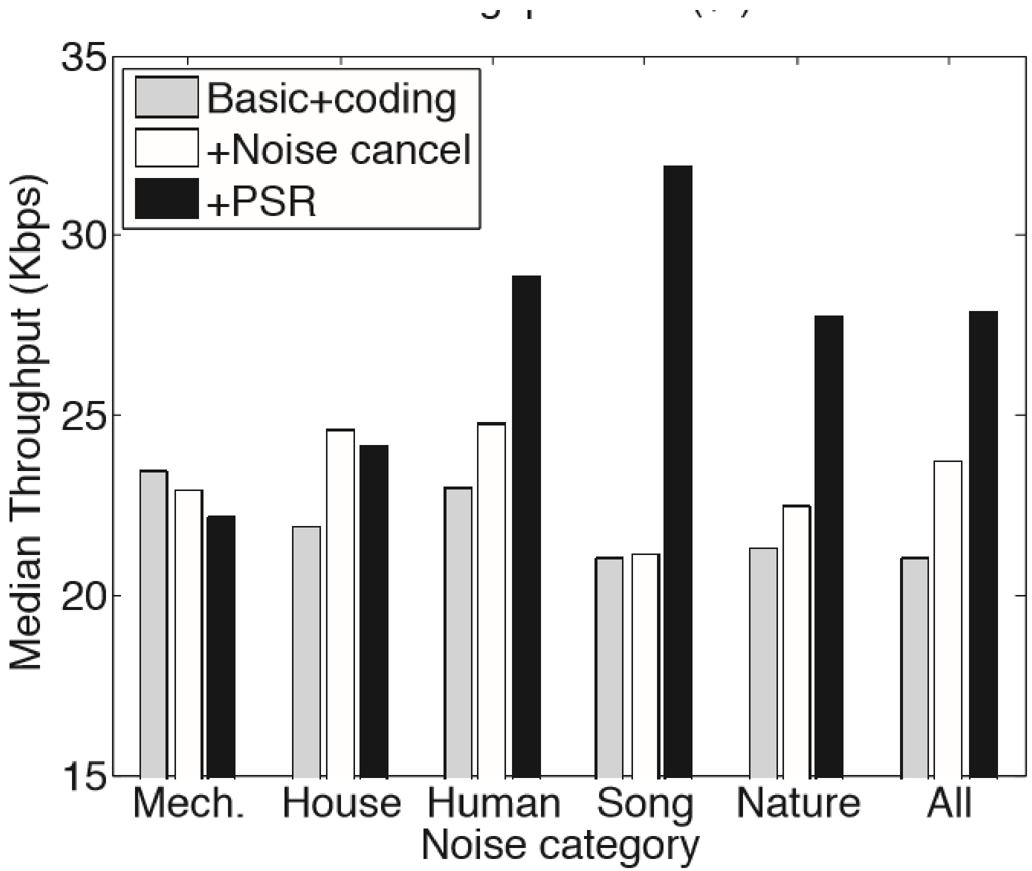
Prototype


Rx Controller
Receiver
USB Port
Line-in
Right Channel
Left Channel
Power Out
+5V
GND
10Ω
220µF
LM 386
GND
10Ω
LM 386
10Ω
220µF
10Ω
220µF
220µF
Voltage Converter
LH317T
5V
220µF
3.3V
1kΩ
10µF
10kΩ
GND
GND
GND
GND
Vibration Motor
Stylus
Vibration Signal
Signal
GND
VCC
Primary Mic.
Signal
GND
VCC
Reference Mic.
Back-EMF Monitor
100nF
10kΩ
Left Channel
Line-in
GND
Right Channel
Tx Controller
Transmitter
Reference Signal
Left Channel
GND
Analog Audio Out
6Ω
5Ω
33µF
Flyback Diode
10kΩ
GND
Receiver Side
Transmitter Side

Prototype



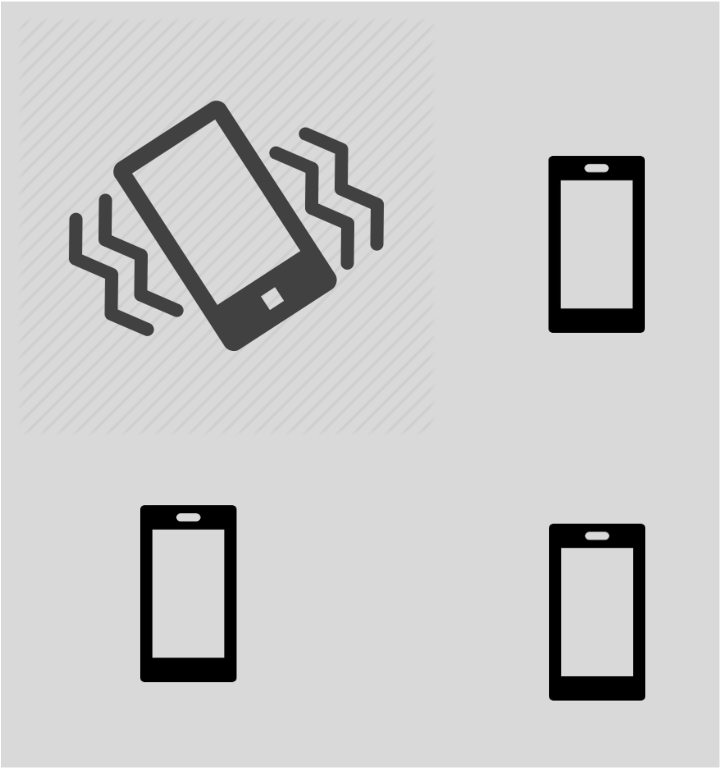
Results: Median Throughput

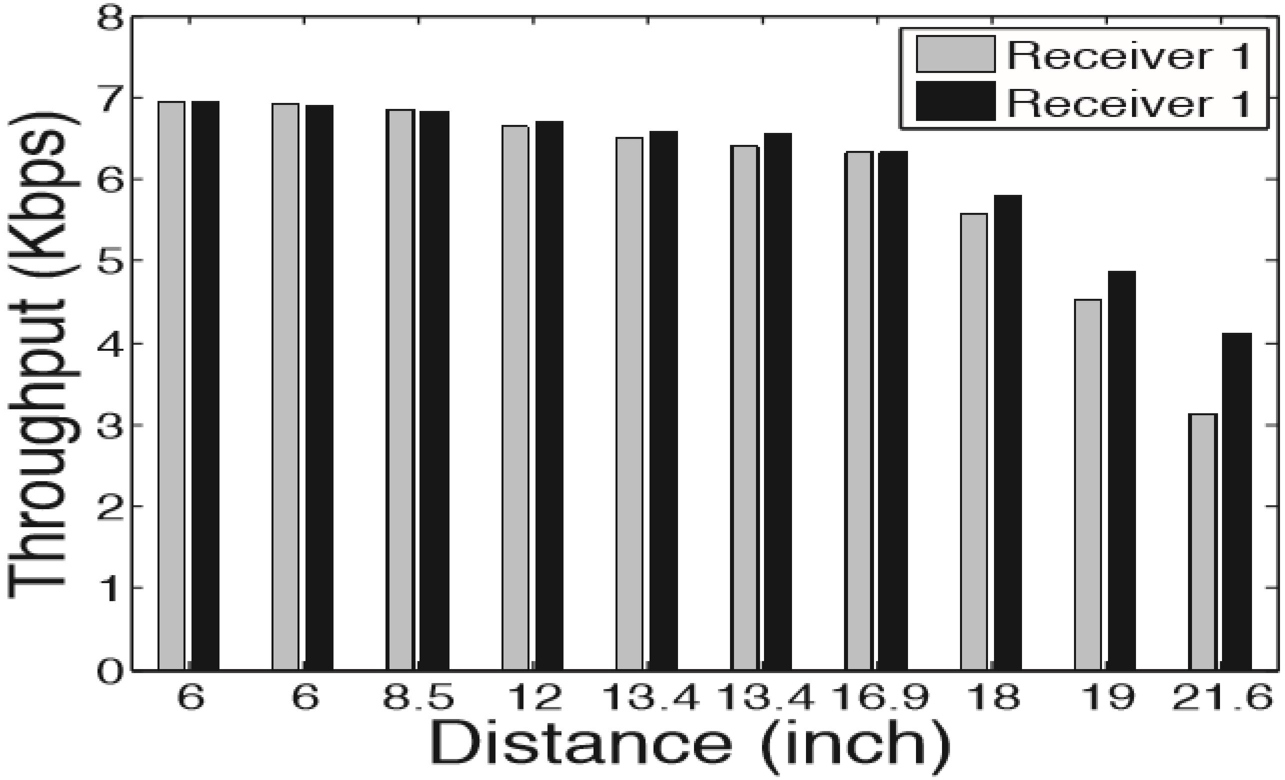


VoiP Bandwidth [1]
28.8 Kbps - 87.2 Kbps

[1] http://www.cisco.com/c/en/us/support/docs/voice/voice-quality/7934-bwidth-consume.html

Application: Table Top Communication





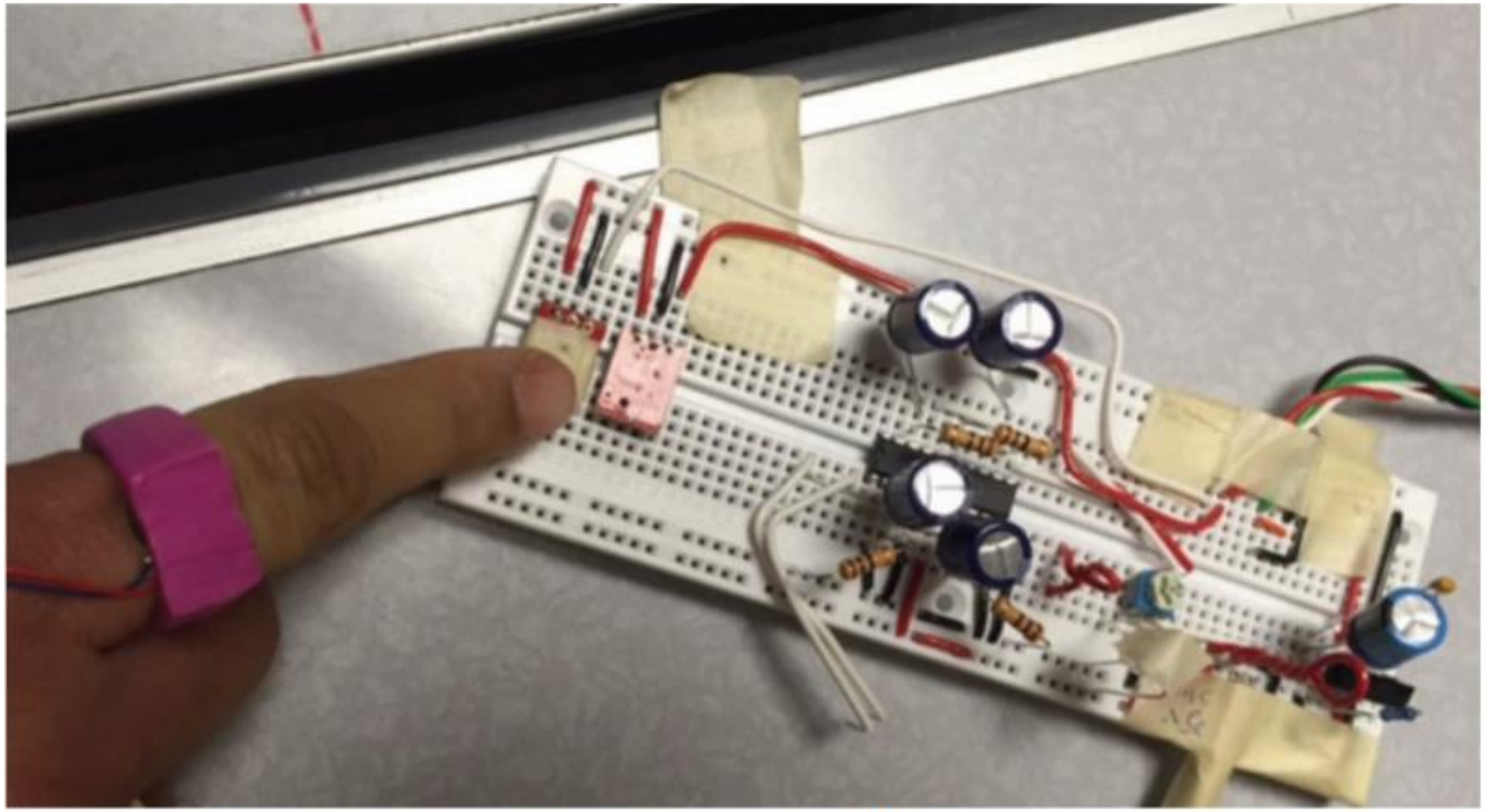
Exchange business cards, slides, … really?

NFC Bandwidth [1]

106 to 424 kbit/s

[1] ISO/IEC 18000-3

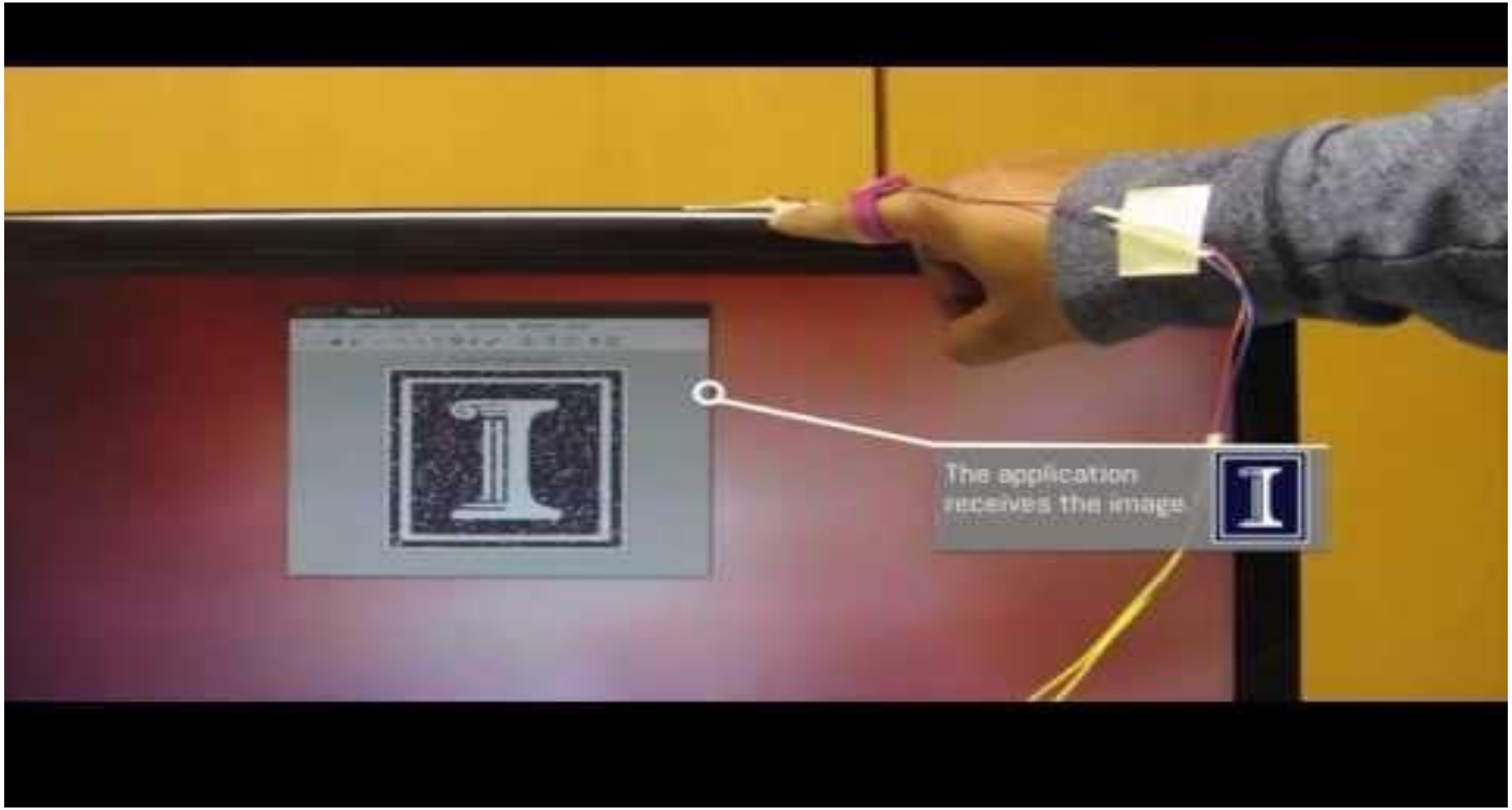
Application: Authentication Token



Throughput:

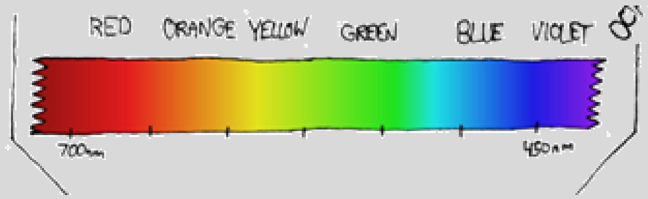
7.41 Kbit/s with ring
2.23 Kbit/s with watch

Video



Low Power WiFi

Physical Waves

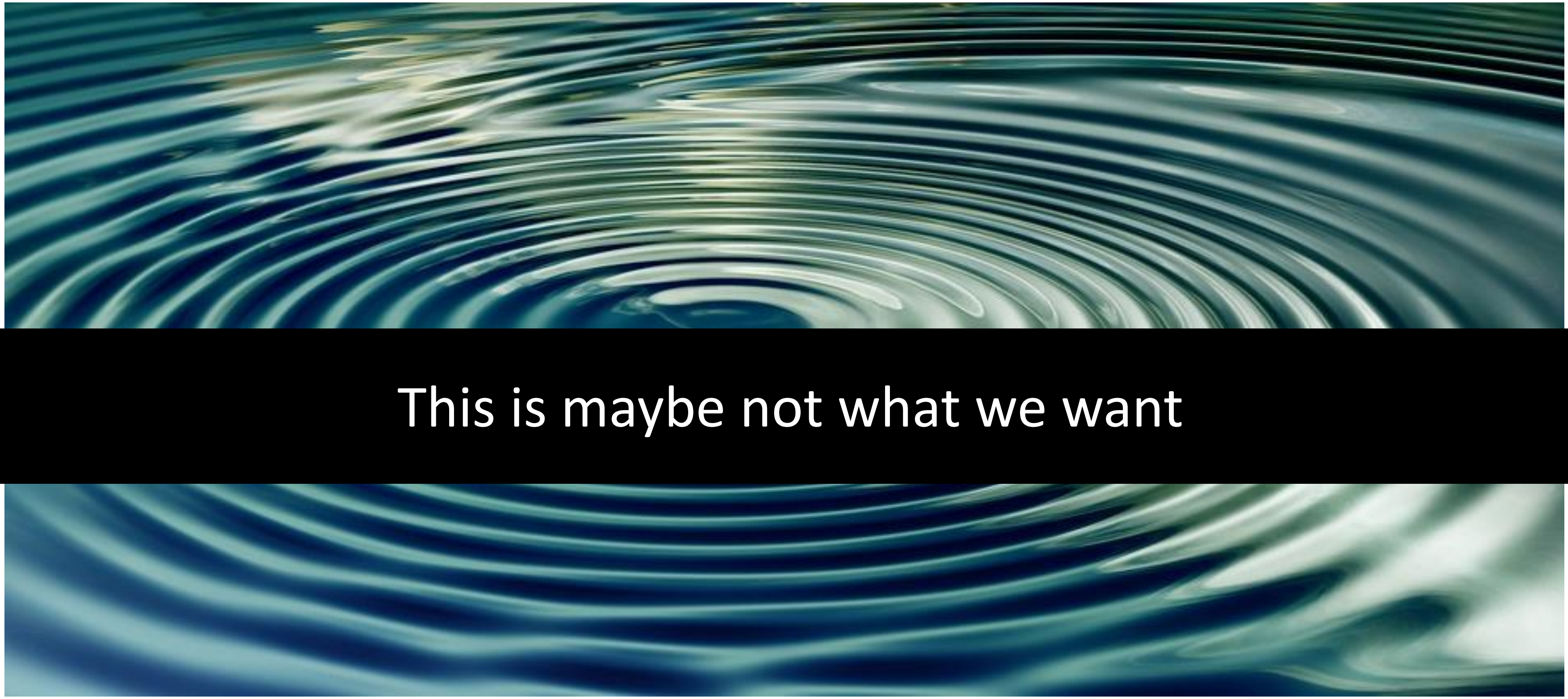


Visible Light Communication

Visible Light Communication, Networking and Sensing: A Survey, Potential and Challenges

Parth H. Pathak, Xiaotao Feng, Pengfei Hu, Prasant Mohapatra. IEEE Communications Surveys & Tutorials. 2015.

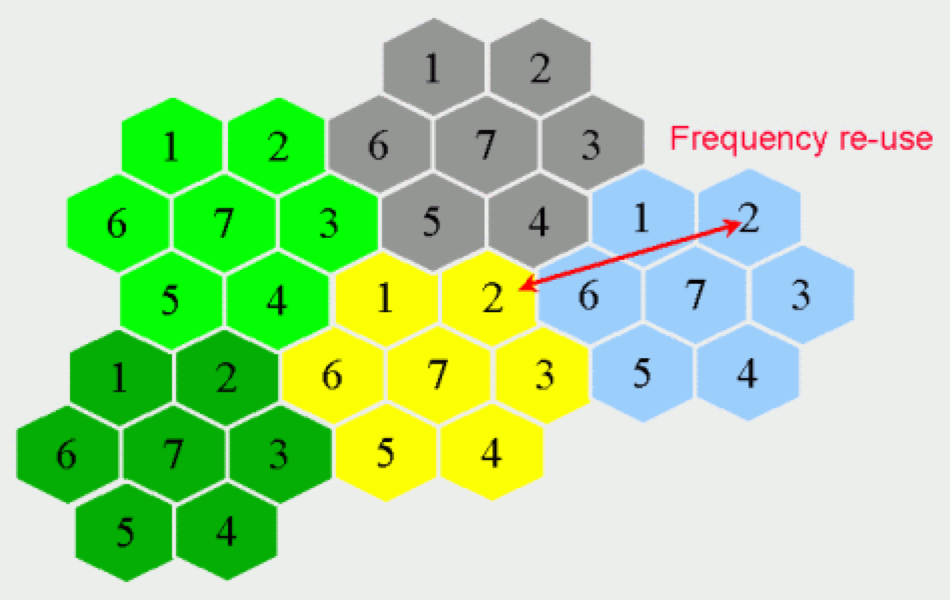
Waves generally travel in all directions



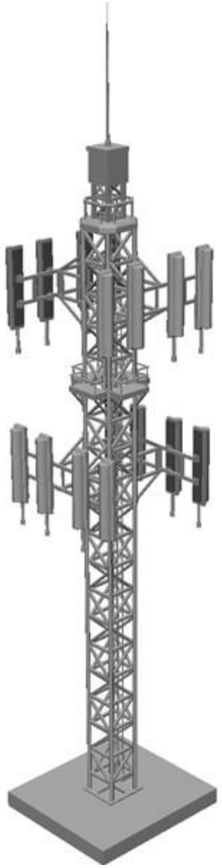
This is maybe not what we want

https://pixabay.com/en/wave-background-pattern-water-1443249/

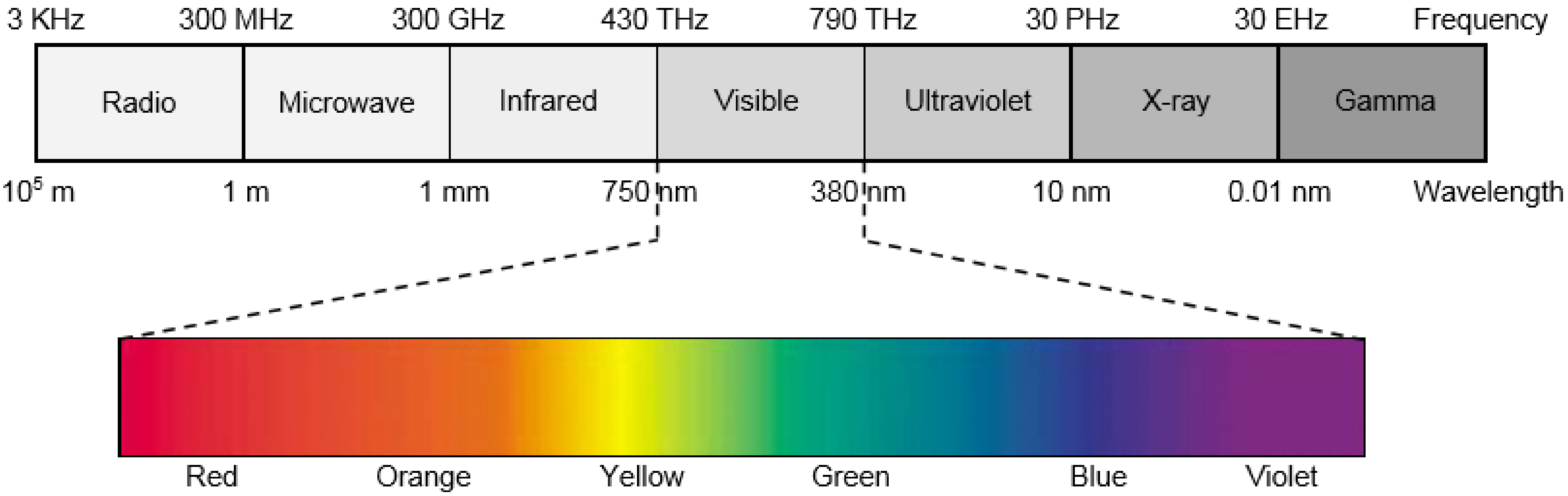
Cell towers



If only we knew how to color a 2d mesh…



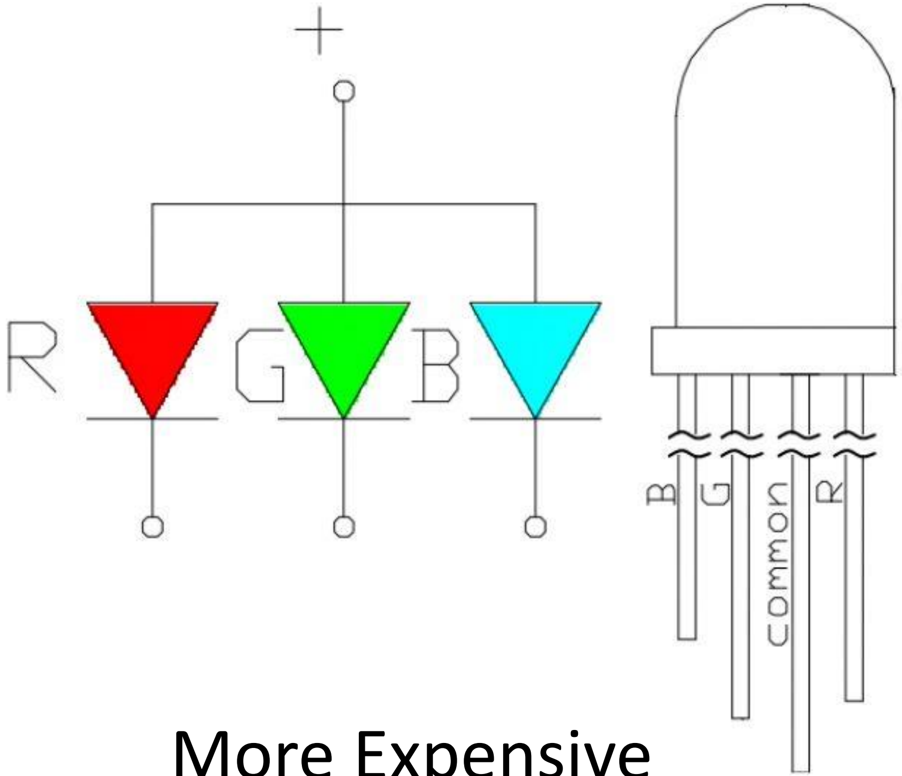
Use the visible light



The right combination results in WHITE

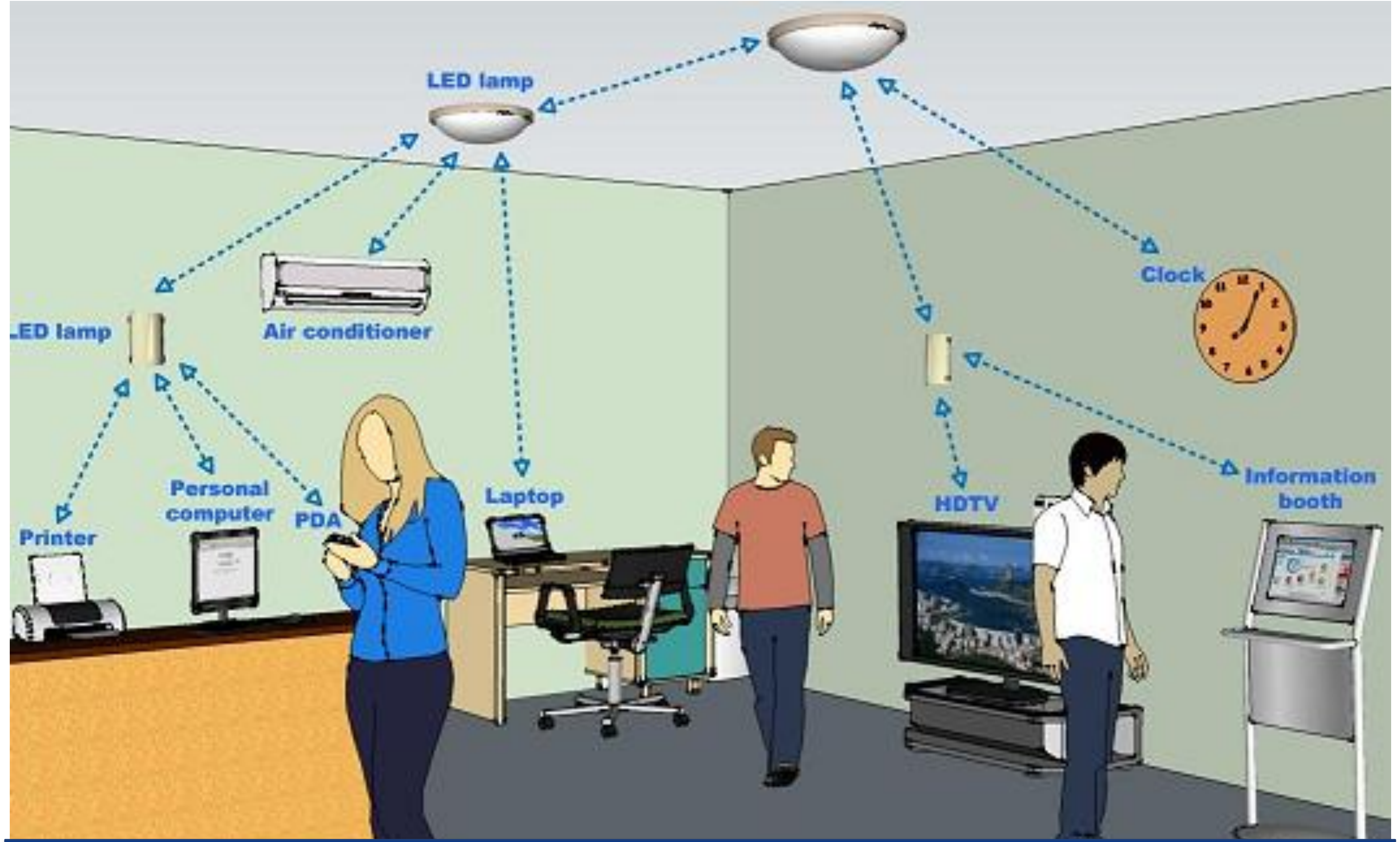
Sending device: White LED

Cheaper
Limits speed



More Expensive
Allows color shift keying

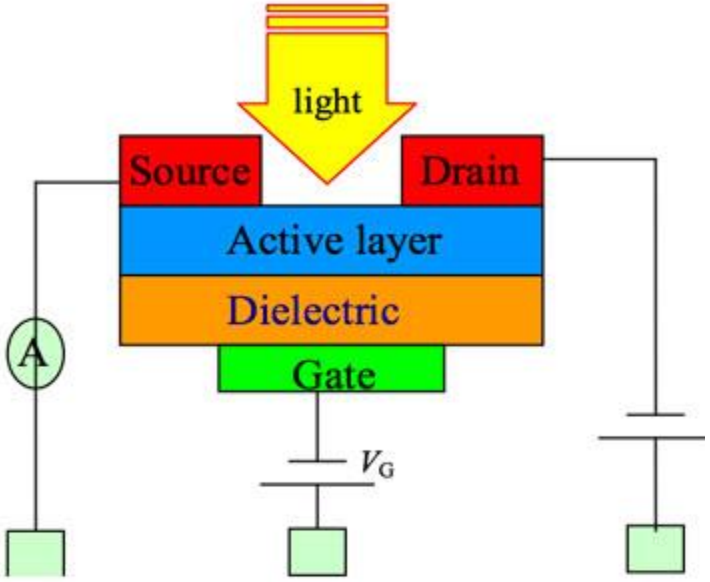
Light Communication: Contained within a Room

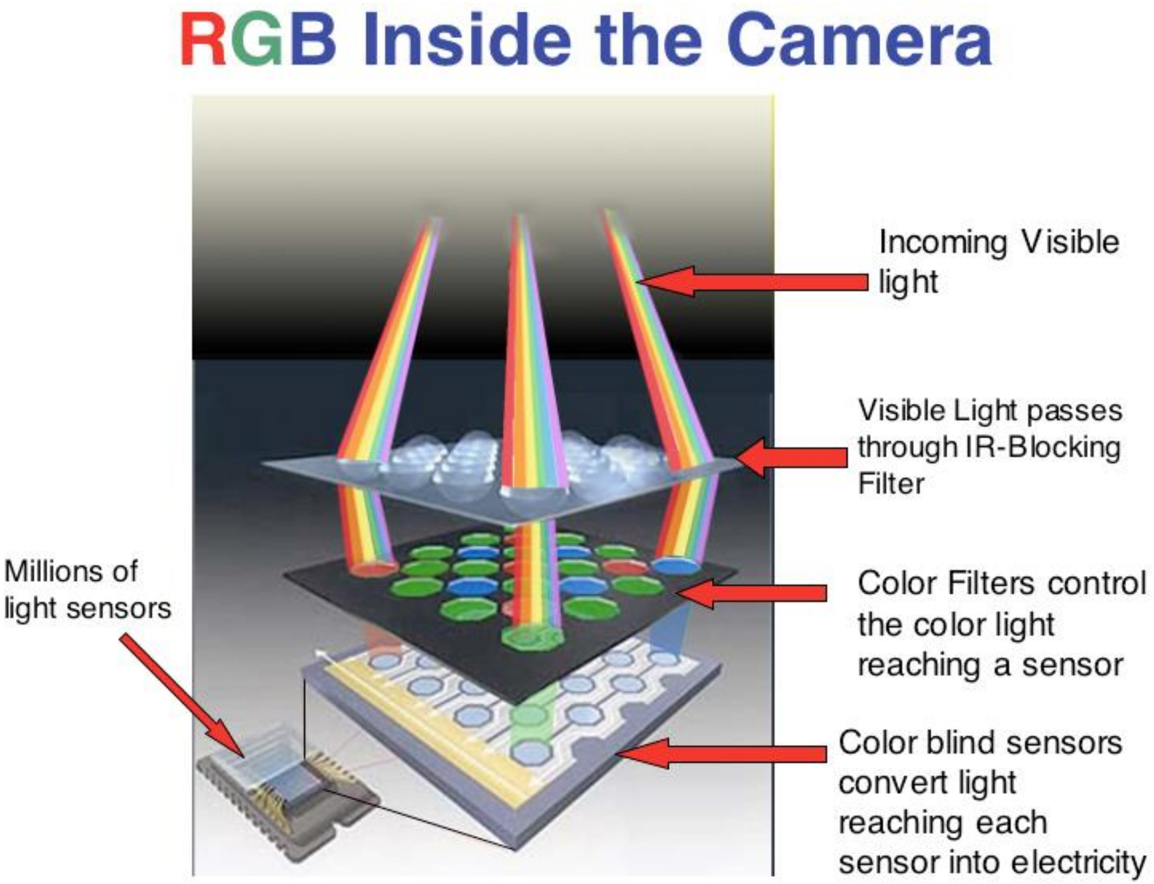


The good & bad: Light is blocked by walls, objects

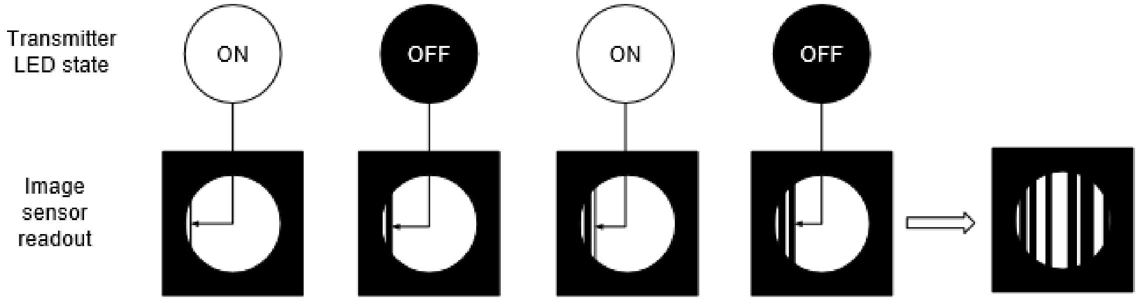
Receiving device: White LED

Photodetector





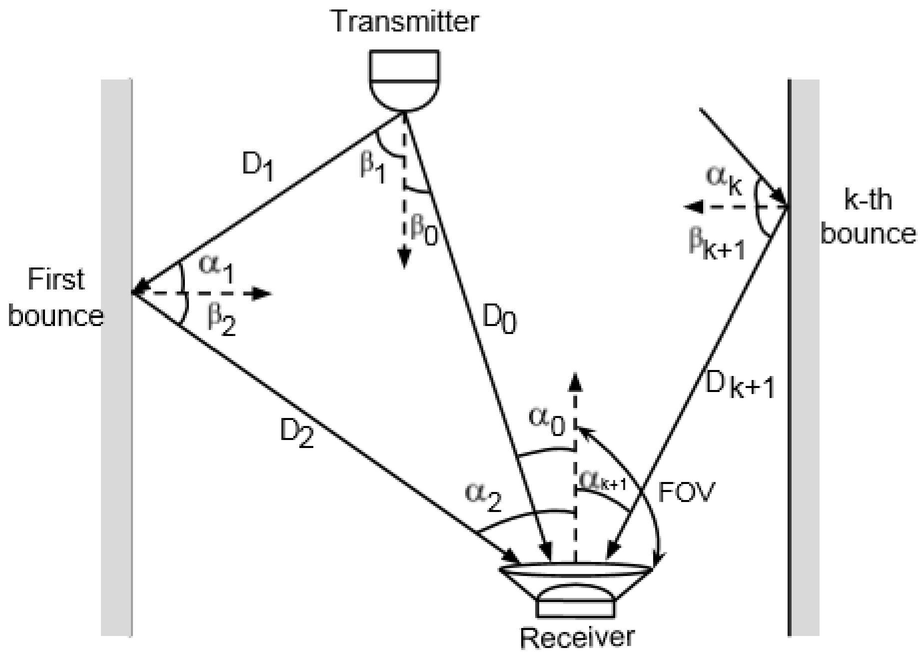
Challenges: Rolling Shutter



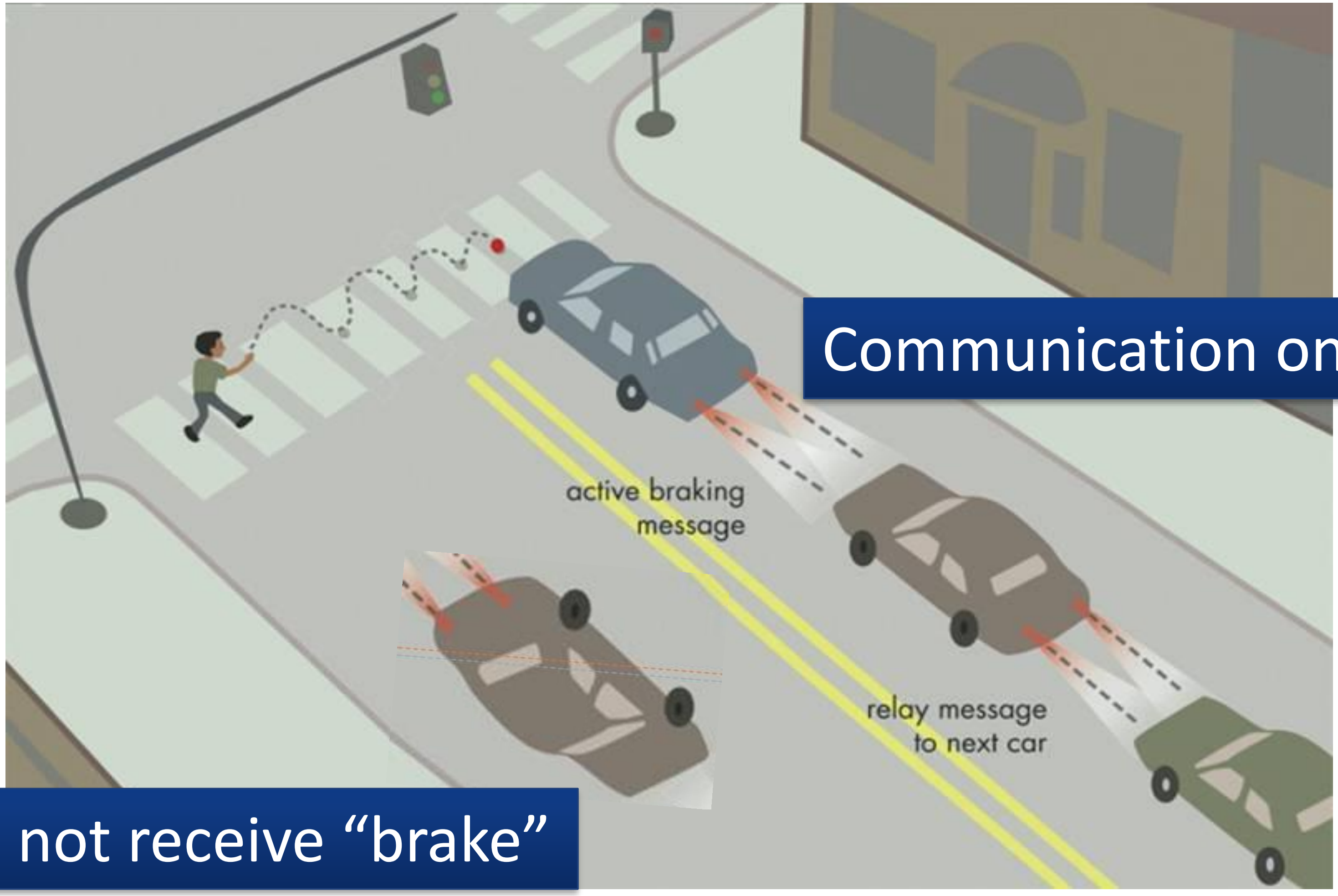
dogcamsport.co.uk

Challenges

- Non flickering: >200 Hz to avoid any harmful effects
- Interference: sunlight / other LEDs
- Angle of arrival
- Reflection



Car to Car communication



Communication only in line of sight

Other cars do not receive “brake”

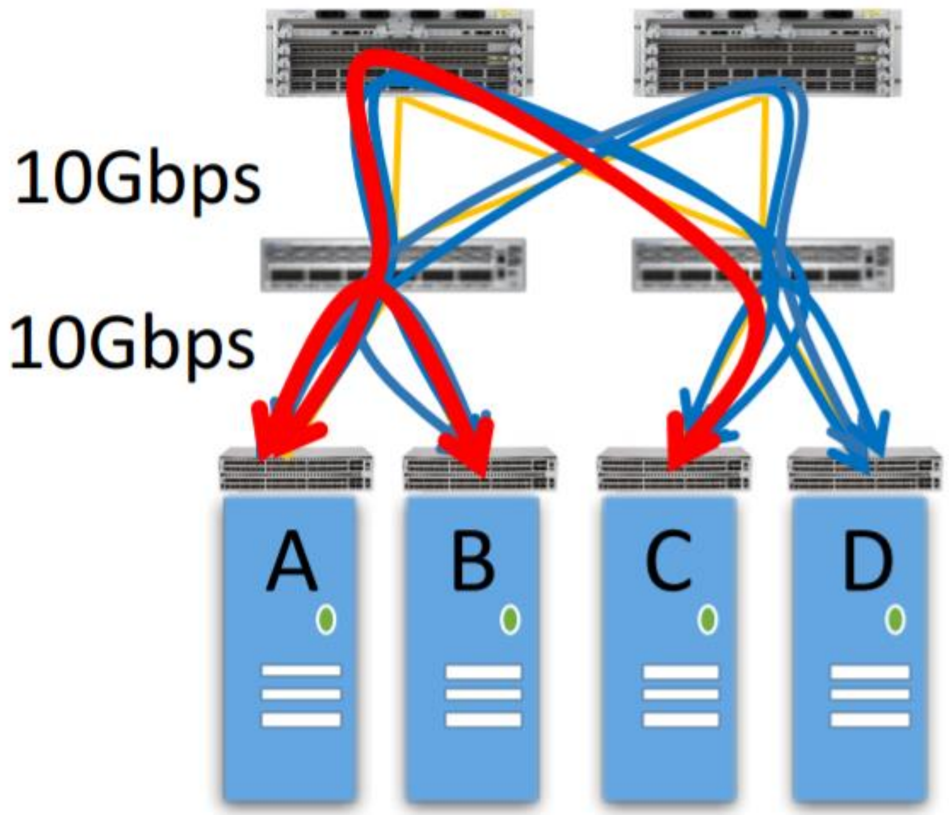
Location Service

- Works indoor
- 40cm accuracy
- Wi-Fi based: 3-6m

Configurable Data Center Interconnects using Lasers

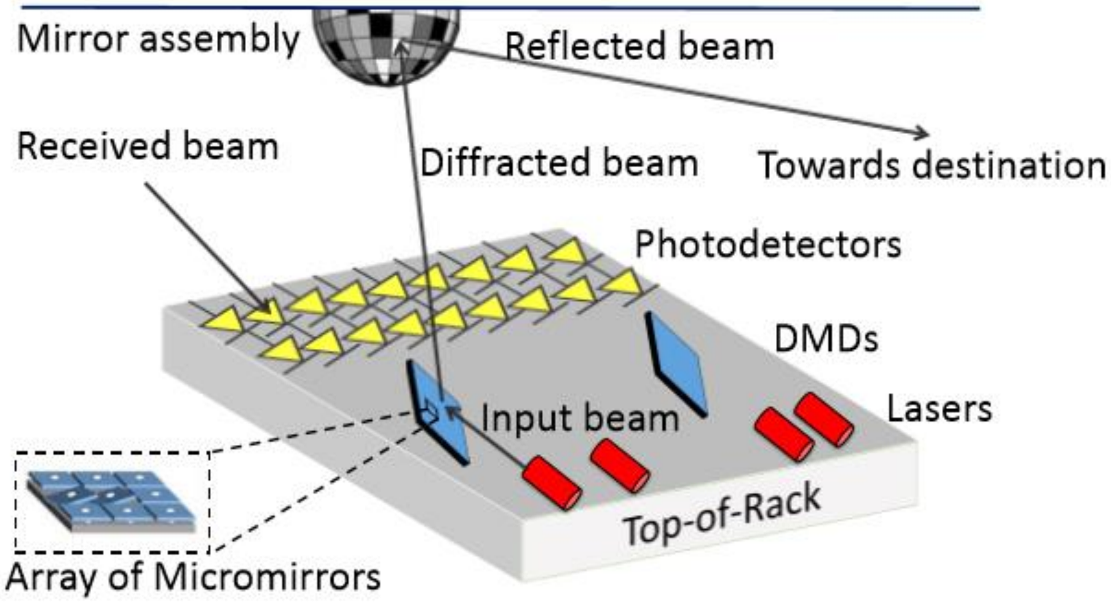
ProjecToR: Agile Reconfigurable Data Center Interconnect

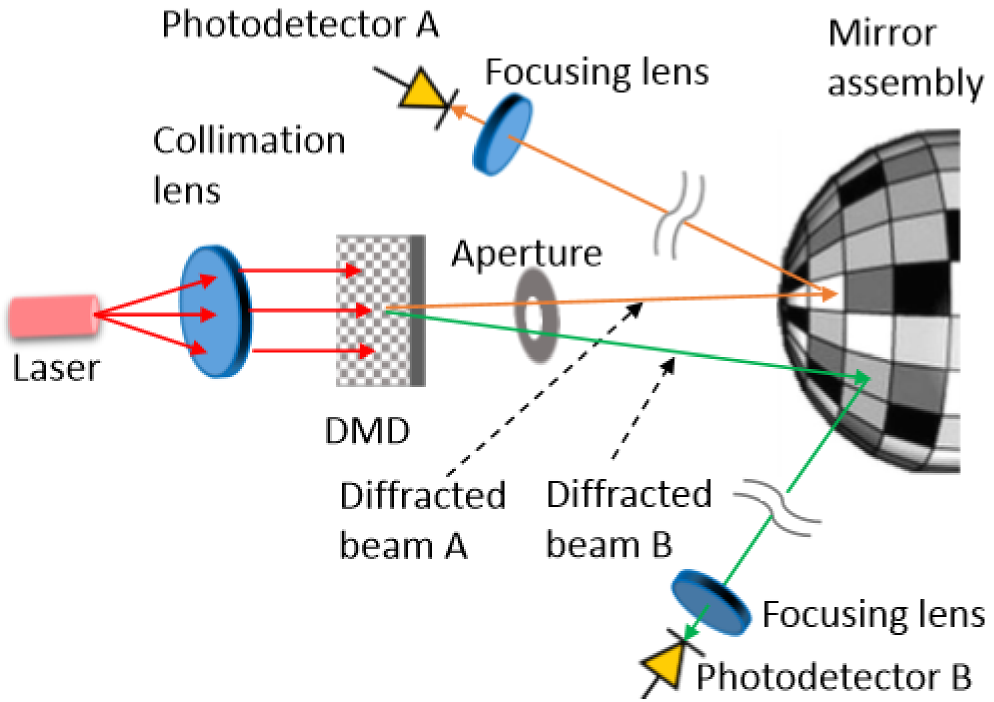
- Static capacity between ToR pairs
- Problem: Skew traffic
  Over-provisioned for most pairs
  Under-provisioned for a few others
- Idea:
  Use free-space optics for seamless reconfiguration of the interconnect



Monia Ghobadi etal. SIGCOMM ’16

ProjecToR: Agile Reconfigurable Data Center Interconnect

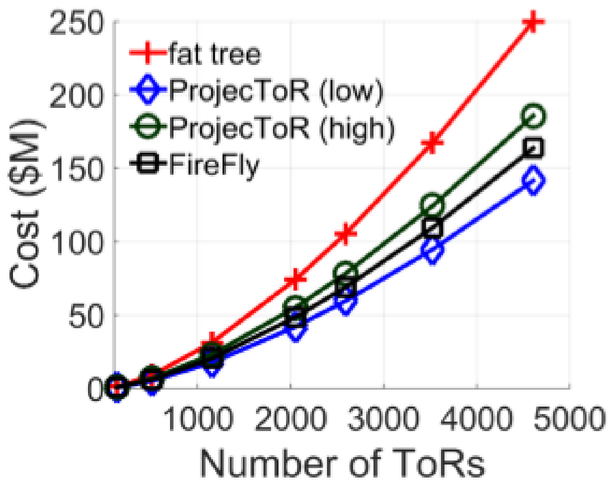


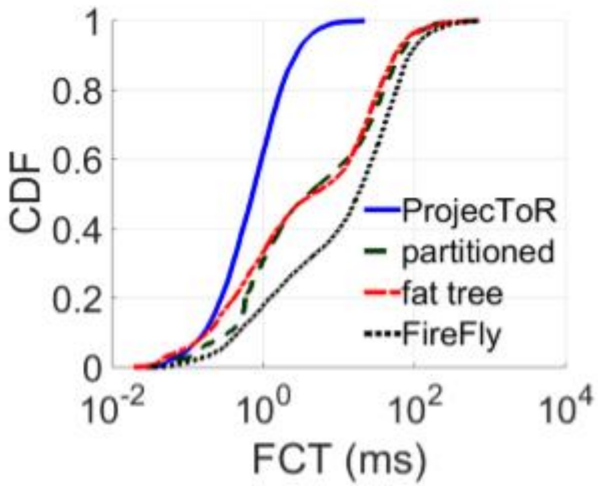


Monia Ghobadi etal. SIGCOMM ’16

ProjecToR: Results

Component	Cost ($)
ProjecToR Tx+Rx components	80(low) 180(high)
DMD	100
Mirror Assembly+Lens	50
SR transceiver	80
Optical cable/meter	0.3
ToR port	90
Galvo mirror	200





Flow completion times improved by 30-95%

Cost reduction by 25-40%

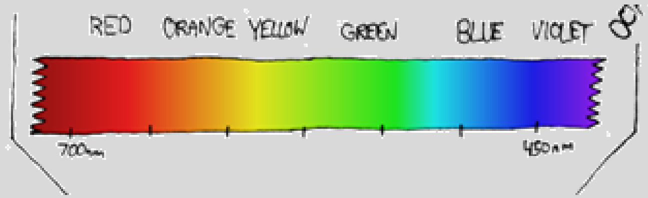
Summary

Low Power WiFi

Usability?
Distances 4m/20m?

Physical Waves

Cool idea for unlock.
Finger print?



Visible Light Communication

Communication for cars ?