Frontiers in Communication

Reto Achermann

Distributed Systems Seminar
Localization?

Connection?

Authenticate?

Reliable
Fast
Energy Efficient
Does not work with all devices
Many collisions with lots of devices

Power consumption

Limited spectrum

22 MHz

Channel Center Frequency (GHz)

1 2.412
2 2.417
3 2.422
4 2.427
5 2.432
6 2.437
7 2.442
8 2.447
9 2.452
10 2.457
11 2.462
12 2.467
13
14 2.484


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Primer on signal transmission: Signal Strength

Blocked and reflected by surfaces and walls
Signal to Noise Ratio

\[ SNR = 10 \log \left( \frac{P_{\text{Signal}}}{P_{\text{Noise}}} \right) \text{db} \]
Shannon-Hartley Theorem

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

\[ C = B \cdot \log_2 (1 + \frac{S}{N}) \]
THE ELECTROMAGNETIC SPECTRUM

These waves travel through the electromagnetic field. They were formerly carried by the aether, which was decommissioned in 1897 due to budget cuts.

Absorption Spectra:

Hydrogen:
Helium:
Depends:
Tampon:

Red Orange Yellow Green Blue Violet

Visible Light
Talk Outline

- Low Power WiFi
- Physical Waves
- Visible Light Communication
Passive Wi-Fi: Bringing Low Power to Wi-Fi Transmissions

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

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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
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Approach: Back Scatter

22Mhz main lobe of WiFi

Too much interference

Backscatter Approach: Shift by $\Delta f$ using square wave approximation
Results: Move Passive device between

\[ d_1 + d_2 = 45 \text{ ft} \]

Passive Wi-Fi / Plugged in device separation:
- 5 ft
- 15 ft
- 25 ft
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
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 \textbf{distance}

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Approach: Using vibratory ratio

- Abundant availability
- Works on touch
- No RF radiation

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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

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Prototype
Results: Median Throughput

VoiP Bandwidth [1]
28.8 Kbps - 87.2 Kbps

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Application: Table Top Communication

Exchange business cards, slides, ... really?

NFC Bandwidth [1]
106 to 424 kbit/s

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Application: Authentication Token

Throughput:
7.41 Kbit/s with ring
2.23 Kbit/s with watch
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Visible Light Communication, Networking and Sensing: A Survey, Potential and Challenges


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Waves generally travel in all directions

This is maybe not what we want

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

RGB Inside the Camera

- Incoming Visible light
- Visible Light passes through IR-Blocking Filter
- Color Filters control the color light reaching a sensor
- Color blind sensors convert light reaching each sensor into electricity

 Millions of light sensors
Challenges: Rolling Shutter
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
- 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
ProjecToR: Agile Reconfigurable Data Center Interconnect

Monia Ghobadi et al. SIGCOMM ’16
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ProjecToR: Results

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

Flow completion times improved by 30-95%
Cost reduction by 25-40%

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Summary

Low Power WiFi

Usability?
Distances 4m/20m?

Physical Waves

Cool idea for unlock.
Finger print?

Visible Light Communication

Communication for cars?