Lightweight Display-to-device Communication Using Electromagnetic Radiation and FM Radio

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Display-to-device Communication: Demand

• Using devices to retrieve information from displays is helpful
Display-to-device Communication: Solution

• Current Method
  • Visible light channel, e.g. QR Code

• Limitations
  • Cumbersome Process
    • Take out phone, open camera, aim at the target, adjust the brightness, keep for a while, connect to the Internet…
  • Dependency on Cameras
    • Many devices do not have cameras, e.g. wrist band, smart watches, etc.
Message: “This is a figure about Lenna”
Message: “Coupon from McDonalds”
Message: “The Movie is Added to Play List”
Idea 1: EMR from Display Interface

- Display interface has ElectroMagnetic Radiation (EMR) leakage

Displaying Strip Lines

EMR Spectrum

26.5MHz 79.5MHz 106MHz 132.5MHz 185.5MHz
Idea 1: EMR from Display Interface

- Display interface has ElectroMagnetic Radiation (EMR) leakage
- EMR from VGA display interface is highly correlated with the display contents
Idea 2: Receiving EMR with FM Radio

- Modulate the EMR signal to transmit information
  - Through dedicated display content
- Use FM radio to receive
  - FM radio is widely integrated in wireless chip

**Displaying Strip Lines**

- EMR Spectrum
- 26.5MHz 79.5MHz 106MHz 132.5MHz 185.5MHz
- Wireless Chip
Design: Modulating Frequency of Display EMR

Display Content

Raster Scan Order

Signals in VGA Cable

Display Panel

\[ f_{c + \Delta} \quad f_{c - \Delta} \]

EMR

\[ \text{Information} \]

\[ \text{FM Output} \]
Be Invisible

• Fact: display protocols contain invisible periods – the Blanking Intervals after each line and each frame
• Solution: modulating EMR signals only in the Blanking Intervals
Windowing Interference

Whole EMR:

Frequency Modulated Potions:

EMR Spectrum:

FM Rx Filter Range
Frequency Over Shift Keying

FM Rx Filter Range

Bit 0

Bit 1
Put Together

Digital Baseband Samples
44.1k Samples/s

Frequency Modulation

Digital RF Samples

Fill to Frame Buffer

Frames Buffer

Cable

RF Signals

EMR

Mobile Devices
Results

Throughput (kbps) vs. Distance (cm):
- Phone
- Watch

Throughput (kbps) vs. Angle (degree):
Results

• One Action Information

The Fetch Action

![CDF](image)

QR Code (57*57)
Limitation & Conclusion

• Limitation of current work
  • Communication Distance
    • Limited by interference of harmonics
  • Based on VGA Protocol
    • Cannot be directly extended to DVI, HDMI, DisplayPort, etc.
  • Antenna Size

• Conclusion
  • EMR signals from displays have the potential to convey information
    • FM radio is a feasible way for common mobile devices to receive
  • Modulating signals in the Blanking Period to hide communication
Q&A
Thank You !