Poster: Enabling On-Body Transmissions with Commodity Devices

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Summary

In this poster, we show for the first time that commodity devices can be used to generate wireless data transmissions that are confined to the human body. Specifically, we show that commodity input devices such as fingerprint sensors and touchpads can be used to transmit information to only wireless receivers that are in contact with the body.

Categories and Subject Descriptors

C.2.1. [**Network Architecture and Design**]: Wireless Communication; B.0. [**Hardware**]: General

Keywords

On-body communication; fingerprint sensor; touchpad; capacitive coupling; physical layer security

1. INTRODUCTION

We demonstrate that sensors available on commodity smartphones and laptops can generate signals usable in on-body communication systems. Wireless transmissions limited to the human body provide unique security at the physical layer of a communication system making it immune to eavesdropping or man in the middle attacks. Potential applications include establishing secret keys for secure communication with wearable devices [4] and key-less entry doors. Fig. 1 illustrates an example of a door authenticating a user in response to a secure transmission through their body from a smartphone.

A device that could be repurposed for on-body communication must satisfy the following constraints: 1) the transmitter and receiver should be in direct contact with body, 2) the transmitter should generate reliable electromagnetic (EM) signals to implement a communication system, 3) the EM signals should be within tens of megahertz as high frequencies do not propagate well through the body [1]. We analyze the EM signals produced by commodity fingerprint sensors and touchpads to show they satisfy the above constraints. We leverage these findings to build prototype communications systems that achieve data rates up to 50 bps.

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(a) Authenticating door locks (b) Secret keys for wearables

Figure 1: Example applications for on-body communication

2. COMMUNICATION SYSTEM DESIGN

We explain the design of our on-body communication system below.

2.1 Transmitter design

Capacitive fingerprint sensors and touchpads apply drive signals when sensing that couple well to the body of a user, but do not propagate well through air. To verify this, we run experiments to compare the strength of received signals on air versus through the body. Fig. 2 shows that signal strength is fairly uniform over the body at various distances but decreases rapidly over the air.

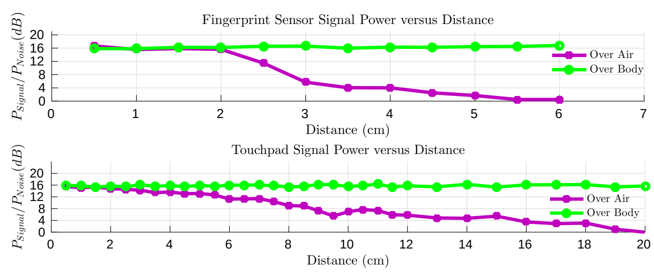


Figure 2: Comparing the strength of the EM signals

We leverage this coupling to the body to demonstrate transmissions of amplitude modulated signals through the body. Specifically, we communicate one/zero bits using software control to perform/not perform a scan operation on the Verifi P5100 USB fingerprint sensor. Additionally we power cycle an Adafruit touchpad to produce amplitude modulated signals.

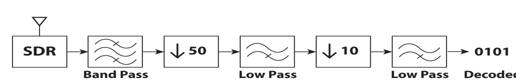
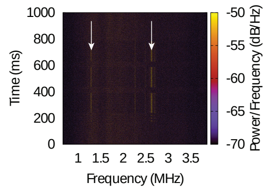


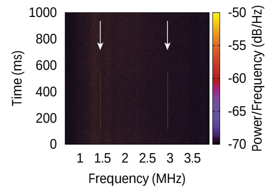
Figure 3: Block diagram of the receiver.

2.2 Receiver design

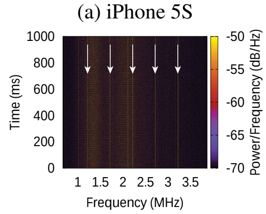
We implement our receiver using a software defined radio (SDR) coupled to the body using a wrist strap covered in conductive copper



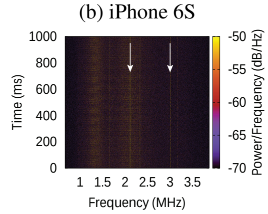
(a) iPhone 5S



(b) iPhone 6S



(c) Adafruit Touchpad



(d) Lenovo Trackpad

Figure 4: **Spectrograms of the four input devices.** The white arrows are shown in the graphs for emphasis.

tape. The received signal is filtered and downsampled to decode data as shown in Fig. 3. We note that in all experiments the receiver is battery powered to prevent unintended connections to the transmitter that would skew results.

3. EVALUATION

We evaluate the fingerprint sensors on the Apple iPhone 5s and 6s as well as the Verifi P5100 USB fingerprint sensor. Additionally we analyze signals produced by a Lenovo Thinkpad T440s trackpad and an Adafruit Capacitive touchpad.

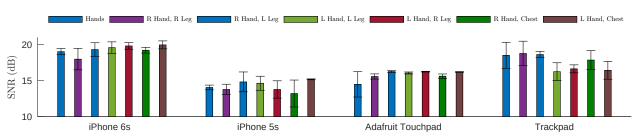


Figure 5: SNR for Different Locations on Body

3.1 Frequency response of input devices

We characterize the frequency response of each device by asking a participant to touch the fingerprint sensor or the touchpad, while we record the signal from our SDR receiver placed on their opposite wrist. Fig 4 shows the spectrogram of these signals over a period of one second.

3.2 Signal strength across the body

Next, we evaluate how these signals propagate to different locations on the body. Using the same devices above we compute the signal to noise ratio (SNR) at different points on the body as follows:

$$SNR = 10log_{10}\left(\frac{P_{ON}}{P_{OFF}}\right)$$

Here P_{ON} and P_{OFF} are defined as the average measured power when the input device is ON and OFF respectively. Fig. 5 shows negligible differences in attenuation of 2-3 dB across different locations on the body.

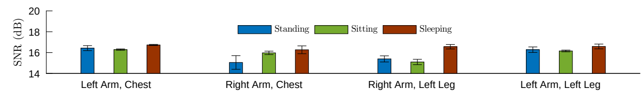
3.2.1 *Effect of Posture*

Additionally, we evaluate the effect of subjects' posture on signal propagation. Figs. 6 show the measured SNR values as a function of different posture.

3.3 Different data rates

Finally, we analyze the data rates we achieve with the Adafruit touchpad and the Verifi fingerprint sensor. Fig. 7 shows that for the touchpad, as the bit rate increases the SNR slightly decreases. This is most likely due to the time required to power on the touchpad sensor.

(a) iPhone 6S



(b) Adafruit Touchpad

Figure 6: Signal strength for different body postures.

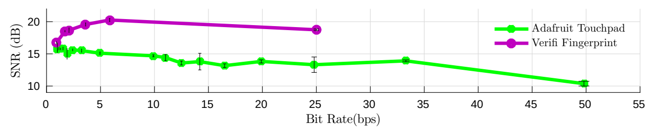


Figure 7: SNR as a function of bit rate.

4. RELATED WORK

Researchers have explored a variety of approaches to transmit information through the body [2]. Detailed models of the human body are developed in [5]. We build on this foundational work to show that commodity input devices with fingerprint sensors or touchpads produce EM signals that propagate on the human body and can be repurposed to transmit data through the body. A complete description of this work can be found in [3].

5. DISCUSSION

Our prototype is limited to external touchpads and fingerprint sensors rather than those built into commodity smartphones and laptops due to their limited APIs. However, if a company like Apple were to expose greater control of their fingerprint sensors such as the ability to perform repeated scans, we could use our technique to modulate data at a low rate. Finer grained software access could even enable higher data rates on these devices in the future.

6. REFERENCES

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