Distinguishing Users with Capacitive Touch Communication

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If only the phone knows who is interacting with it by itself ...

 unknowingly had a veritable shopping spree in Smurfs’ Village on her mom’s iPhone. According to the Washington Post, Madison accessed the incredibly popular game (which is a FREE download in iTunes, by the way) and merrily played as it is to be played, racking up quite a bill in the process - $1,400 to be exact.
Current identification/authentication methods

Users switch from one device to another more often
Other identification/authentication methods

- Biometric based
  - Require additional hardware or space

- Bluetooth token
  - Accidentally authenticate devices within the close proximity
Other identification/authentication methods

- NFC-based methods
  - Require NFC hardware

What could be a more intuitive way of identifying users for today’s off-the-shelf devices?
Identifying users through their touches

Capacitive touch sensing is pervasive

Associating user identifier to touches

Capacitive Touch Communication
(Hardware token + Software decoder)
Capacitive Touch Communication

Overview

- A wearable hardware token
  - Generates electrical pulses
  - Spoofs the touch screen to create touch events

- Software decoder
  - Retrieves originally transmitted bits from the touch events
  - No modification to hardware or firmware of off-the-shelf devices
Creating Artificial Touches
Capacitive touch screen background

- Sensors measure the additional capacitance of a human body
- Array of conducting electrodes behind an insulating glass layer
- Structure of a touch event registered to the operating system

<table>
<thead>
<tr>
<th>Timestamp</th>
<th>Event Type</th>
<th>Pointer ID</th>
<th>(X,Y) coordinates</th>
<th>Touch Size</th>
<th>Touch Amplitude</th>
</tr>
</thead>
</table>
Creating Artificial Touches

“Spoof” the touch screen

- Affecting the capacitance measurement by injecting signal to create artificial touch events
Creating Artificial Touches

Experimented with different signal sources

- Different waveforms
- Voltages: 1-20V peak to peak
- Frequency: 100Hz to 120KHz
Creating Artificial Touches

Experimented with different signal sources

Touch screen responses to 10 Vp-p square wave signals at frequency from 100Hz to 120KHz
Encoding bits with touch events

Input bit sequence

Transmitter
(A hardware token)

Electrical Pulses

Channel
(Touch screen hardware and firmware)

Artificial Touch Events

Receiver
(Software decoder)

Received bit sequence

On-Off Keying modulation

Threshold-based demodulation
Encoding bits with touch events

Input bit sequence

Transmitter
(A hardware token)

Channel
(Touch screen hardware and firmware)

Electrical Pulses

Artificial Touch Events

On-Off Keying modulation
Threshold-based demodulation

• Unsynchronized
• Unknown processing delay
• Highly correlated channel
• Variable delay between symbols
• Low bandwidth

• Offline calibration to select thresholds
• Simultaneously synchronize and demodulate
Offline Calibration

Determine number events for **ones** and **zeros**

- Transmit a known bit sequence.
- Synchronize Tx and Rx using a sliding window:
  - The correct bit synchronization maximizes number of events in all **1s** and minimize that of **0s**
- Count the number of events in each bit **0s** and **1s**
Offline Calibration

Determine number events for ones and zeros

- Offline calibration to select thresholds
- Simultaneously synchronize and demodulate
Minimum Distance Demodulation
Simultaneously synchronize and demodulate

- Assumption:
  - All possible messages are known

- Demodulation:
  - Try all possible starting points
  - At each starting point, compute the correlation between the event sequence and all messages
  - Select the message and starting point that give the highest correlation (decoded message)

Example

Message = 011
Possible Messages = \{001, 011, 111\}

<table>
<thead>
<tr>
<th>Starting Position</th>
<th>001</th>
<th>011</th>
<th>111</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>202</td>
<td>18</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

1e = 7
0e = 1
Evaluation with Function Generator

• Metrics:
  – Detection Rate & False Acceptance Rate

• Methodology:
  – Messages with length of 2-5 bits.
  – Repeatedly transmitted 5000 times for each message
Evaluation with Function Generator

- Bit period gets smaller as the data rate increases
Evaluation with Function Generator

- Bit period gets smaller as the data rate increases
Prototype

Building a wearable hardware token

TI-MSP430 F2722

9V

30pF

560 Ω

180 Ω

Ring Surface
Prototype

Building a wearable hardware token

- The ring generates pulses with longer rise time
- Contact point is not as good as of the AFG electrode
Prototype

Building a wearable hardware token

![Graph showing detection rate (%) for different bit rates (2 bits, 3 bits, 4 bits, 5 bits) at 4 bits/s and 5 bits/s.]
Prototype

Building a wearable hardware token

- Can be improved with better hardware design
- Trading data rate for DR and FAR by ECC
Possible applications

- Parental control applications
  - Sharing devices with your children/spouse
  - 2-3 bits to be transmitted
- Weak authentication
  - Pincode level (i.e. ~13 bit of entropy)
Possible applications

• Distinguishing different types of tokens
  – Board games on touch screens
  – Different coloring styluses
  – A few bits to be transmitted
Possible applications

- Multi-user games/collaboration
  - 1-2 bits to be transmitted
Transmitting through a finger

- The electrode in contact with a human finger

- Detecting the presence of the ring when the user swipe
Transmitting through a finger

- Ring-presence detection rate

92% detection rate and 97% false positive rate.
Conclusion

Capacitive Touch Communication

- Multi-user games
- Parental control
- Medical security
- Portable SIMCARD

Device authentication

- Vehicular security
- Home security
- Payment Credit Ring

Signet Ring
Thank you!

Demo video is available on YouTube at: http://tinyurl.com/8nc65ro