Wireless Security

Survey by Evi Bernitsas
18-750 Wireless

Definition: Wireless Security

- "Wireless network security primarily **protects a wireless network** from unauthorized and malicious access attempts.
- … Typically, wireless network security is **delivered through wireless devices** (usually a wireless router/switch)
- … which **encrypts and secures** all wireless communication by default."

Common Security Types

Wired Equivalent Privacy (WEP)

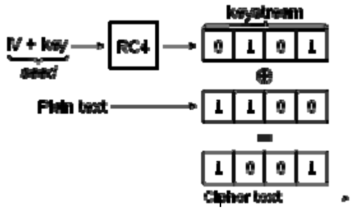
- Security **algorithm** for IEE 802.11
- Part of original 802.11 ratified in 1997 to provide **confidentiality**, which the traditional wired network did not provide
- WEP uses 40 or 104 bit keys.
- WEP has now been replaced by Wi-Fi Protected Access (WPA)

Wi-Fi Protected Access (WPA)

- Developed because of weaknesses found in WEP
- WPA also referred to as IEEE 802.11i standard (WPA2 released in 2004)
- Instead of 40 or 104 bit keys, uses Temporal Key Integrity Protocol (**TKIP**)
- TKIP **dynamically generates** new 128-bit key for each packet

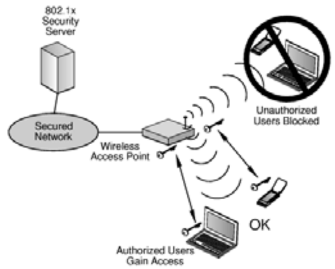
Wired Equivalent Privacy (WEP) Algorithm

- Uses RC4 stream cypher (now unsafe)
- uses 40-bit key (WEP-40) and is concatenated with a 24-bit initialization vector (IV) to form the RC4 key
- This key stream is then used to **encrypt** the plain text using XOR
- This produces the cipher text which is then sent.



Wi-Fi Protected Access (WPA/WPA2) Algorithm

- WPA uses Temporal Key Integrity Protocol (TKIP) uses a unique **key** for each packet that is **dynamically generated** (128 bits)
- WPA2 encrypts the network with a 256-bit key and uses the encryption method called **AES (Advanced Encryption Standard)**
- Includes **message integrity check** to prevent altering and resending of data packets.



A few Security Issues with WPA/WPA2

- **Weak Password**
- **WPA packet decryption:** injection attacks
- **No forward secrecy:** once an adverse person discovers the pre-shared key, they can decrypt all encrypted Wi-Fi packets transmitted in the future and even past
- **Predictable Group Temporal Key (GTK):** The random number generator is not entirely random

Wireless Security Publication #1: *Keystroke Recognition Using Wi-Fi Signals*

Kamran Ali, Alex X. Liu, Wei Wang, Muhammad Shahzad

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Wireless Security Publication #1: Keystroke Recognition Using Wi-Fi Signals

- Keystroke privacy is critical
- WiFi signals can be exploited to recognize keystrokes
- While typing a certain key, your hands and fingers move in a certain formation and direction, which generates a unique pattern in the time series of **Channel State Information** (CSI) values.
- This produces a CSI waveform
- This paper proposes a system to recognize keystrokes called **WiKey**.
- WiKey uses simply a router (sender) and a laptop (receiver) and achieves 97.5% detection rate for detecting keystroke, and 93.5% accuracy for continuously typed sentences.

Definition: Channel State Information (CSI)

In wireless communications, channel state information **(CSI)** refers to known **channel properties** of a communication link. This information describes how a **signal propagates from the transmitter to the receiver** and represents the combined effect of, for example, scattering, fading, and power decay with distance.

Typical keystroke recognition approaches

- **Acoustic emission**: different keys produce different typing sounds OR sounds from keys arrive at surrounding smartphones at different times.
- **Electromagnetic emission**: electromagnetic emanations from the circuit underneath are different for each key.
- **Computer Vision**: recognize keystrokes with a camera.

WiKey System

- WiFi signals can be exploited based on how keystrokes affect how the signal propagates (affects the Channel State Information (CSI))
- They call this the **CSI-waveform**
- Because of high data rates, WiFi cards provide enough CSI values within the duration of a keystroke to construct a high resolution CSI-waveform for each keystroke

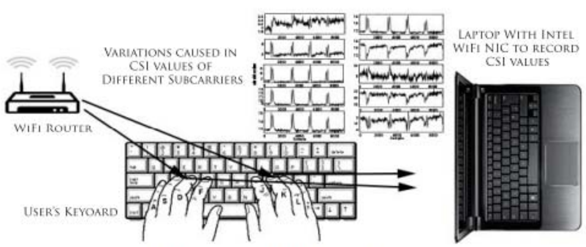


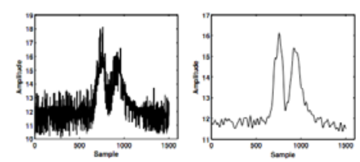
Figure 1: WiKey System

Technical Challenges

1. Finding the beginning and the end points of individual keystrokes

2. Distinguishing features for each of the 37 keys

   - Typical features such as power, mean amplitude, rate of change and signal energy cannot be used because these are almost identical between keys.
   - Discrete Wavelet Transform (DWT) is used to reduce the number of samples but still preserve the **shape**. Classification is done based on shape of the wave.



(a) Original time series (b) Filtered time series

Figure 2: Original and filtered CSI time series

Steps to filtering CSI-Waveform

1. Channel State Information: All Information about the channel state

2. Noise Removal: Low Pass Filtering

1. Frequencies due to hand movements are between 3Hz and 80Hz

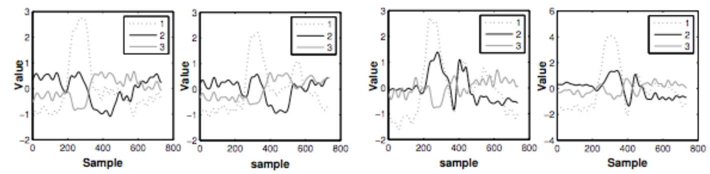
3. Noise Removal: PCA Based Filtering

1. maximizes variance of data
2. minimizes mean squared distance

4. Keystroke Extraction

5. Feature Extraction

Keystroke Waveforms



(a) Keystroke waveforms for key **i** (b) Keystroke waveforms for key **o**

Conclusion:
Keystroke Recognition Using Wi-Fi Signals

- WiKey achieves 97.5% detection rate for detecting keystroke, and 93.5% accuracy for continuously typed sentences.
- This only works in a controlled environment.
- Future testing will be conducted in harsher wireless environments.

Wireless Security Publication #2: *Acoustic Eavesdropping through Wireless Vibrometry*

Teng Wei, Shu Wang, Anfu Zhou and Xinyu Zhang

University of Wisconsin - Madison, Institute of Computing Technology, Chinese Academy of Sciences

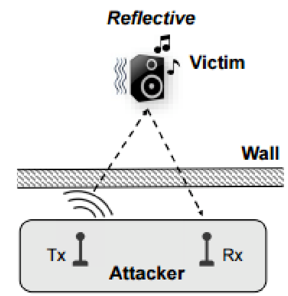
Wireless Security Publication #2:

Acoustic Eavesdropping through Wireless Vibrometry

- **Acoustic eavesdropping** is used to decode a lot of subtle acoustic sounds like keystrokes and printers, but is **only useful** if the microphone is in close **proximity**.
- Loudspeakers refer to anything from large entertainment systems to your PC or smartphone loudspeakers
- Loudspeakers cause **acoustic vibration**
- This paper is based on decoding noises emitted by loudspeakers from a **distance**
- The vulnerability lies in the translation between acoustic vibration and radio signal fluctuation.
- Contaminated radio waves can be captured by a receiver and decoded to find the original sound coming from the loudspeakers

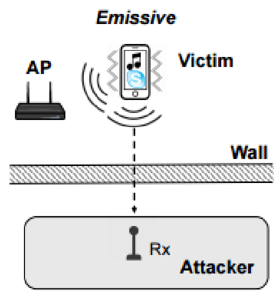
Reflective Vibrometry

- Adversary: pair of radio transmitter and receiver
- Transmitter continuously sends radio signals as receiver decodes the sound vibration from the signals disturbed by the loudspeaker vibration



Emissive Vibrometry

- Adversary: radio receiver
- Target loudspeaker is located near a WiFi radio on the same platform (smartphone)
- Loudspeaker's motion causes tiny variation in the WiFi radio's outgoing signals, which is then heard and recovered by the receiver



Basic Audio-radio Transformation (ART) Algorithm

- Audio vibrations modulate the radio signal magnitude/phase
- Harnesses the received signal strength (RSS) and phase information to "demodulate" acoustic signals from the target loudspeaker.
  - Isolates irrelevant radio signal components
  - extrapolates the audio signals
  - projects them onto the time-domain (which is audible to humans)

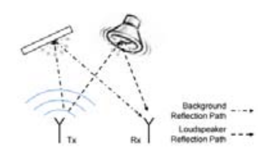


Figure 2: Illustration of loudspeaker modulation and multipath effects of reflective radio vibrometry.

Demodulating Transformed Audio

- Get one audio sample from every m radio samples
- For each radio sample, we segment it into S segments containing m samples.
- FFT - time-frequency domain translation to get this closer to human hearing
- Bandpass filter to keep only frequencies between 20 Hz and 1500 Hz (range of human voice)

Algorithm 1 Decoding the audio that is modulated by ART

INPUT: received radio samples $y[t]$
OUTPUT: recovered audio samples $d^*[s]$
/*Get one audio sample from every m radio samples*/
foreach segment s in set $[0{:}S)$
    $y_s \leftarrow y[sm+1,(s+1)m]$ /*Segment radio signals*/
    $z(v) \leftarrow \sum_{u=1}^{m} y_s(u) e^{\frac{-i2\pi vu}{m}}$ /*FFT analysis*/
    $g(s) \leftarrow \left|\frac{z(\lfloor \frac{f_c}{f_b} \times m \rfloor)}{m}\right|^2$ /*Pick RSS of CW's freq.*/
endforeach
$d^* \leftarrow filter_{bandpass}(g)$ /*Filter out the DC component*/

Conclusion:
Experimental Validation of Accuracy vs. Microphone

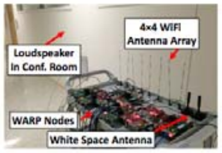


Figure 15: ART hardware platform. Testing ART outside a conference room.

Figure 16: Testing ART performance. Loudspeaker is inside a soundproof room.

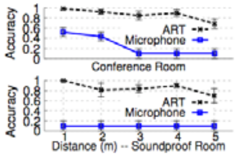


Figure 17: Through-wall recognition accuracy of ART compared with a microphone.

Wireless Security Publication #3:
SafeSlinger: Easy-to-Use and Secure Public-Key Exchange

Michael Farb - CyLab / CMU
Yue-Hsun Lin - CyLab / CMU
Tiffany Hyun-Jin Kim - CyLab / CMU
Jonathan McCune - Google Inc.
Adrian Perrig- ETH Zürich, CyLab / CMU

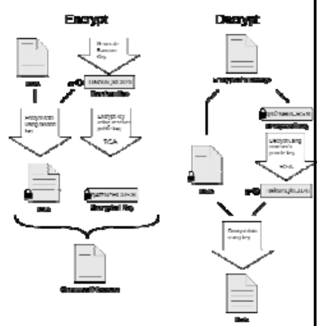
Wireless Security Publication #3:

SafeSlinger: Easy-to-Use and Secure Public-Key Exchange

- Security on the internet is entirely a **leap of faith for users** without more advanced knowledge
- **SafeSlinger** is a system currently on **Android and iOS apps**
- It allows users to **exchange public keys** between each other to support **secure messaging** and file exchange
- Also provides an **API** for importing **applications**' public keys into the user's contact information
- SafeSlinger proposes "**secure introductions**" to help ensure that messages sent between two people with the same public key are safe from attackers
- https://www.youtube.com/watch?v=IFXL8fUqNKY

Comparable Security Protocols

- SSL/TLS (Secure Socket Layer / Transport Layer Security)
  - Uses generated unique keys and TLS handshake protocol, and uses a message authentication code (MAC) to prevent altered data.
  - **Drawbacks**: Many known attacks including timing attacks on padding and RC4 (keystream) attacks. Security):
- PGP (Pretty Good Privacy)
  - Encrypts data using **random key**, encrypts key using **public key** from receiver.
  - Receiver decrypts **random key** using **private key** and uses that to decrypt the data.
  - **Drawbacks**:
    - **Key maintenance** is difficult administratively
    - Organizations cannot secure **large files** this way
    - No **email receipt** confirmation
    - Cannot scan incoming PGP email with **anti-virus**



PGP

Goals of SafeSlinger

- **Scalable:** can be done in groups
- **Easy to use:** usability of interface
- **Portability:** support heterogeneous platforms to enable interactions among smartphones of different manufacturers and OS (operating systems)
- **Authenticity:** each user should be able to obtain correct contact information from other users
- **Secrecy:** contact information is only available to other group members after the completion of a physical exchange to authenticate

Multi-Value Commitments

- Cryptographic commitment protocol is used to lock an entity to the value V without letting them know what V is
- Ex. **C = H(V,R)**
- C is the commitment value, H is the cryptographic hash function that is **one-way, collision free** and has **pseudo-random** output if R is a random and unpredictable one-time use input
- V cannot be inferred from C
- Multi-Value: **C = H(H(V1) || H(V2))**
- (|| = concatenated with)

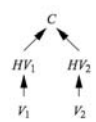
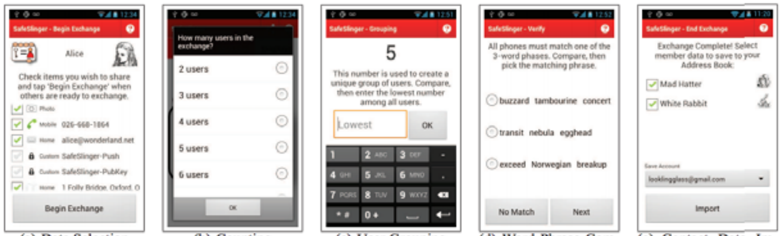


Figure 1: Multi-value commitment structure for authenticating and disclosing either V_1 or V_2.

Possible Attacks on SafeSlinger

- **Malicious Bystander:** someone who overhears the non-digital agreement and can attack the protocol by controlling the local wireless communication performing **Man-in-the-Middle attack**
- **Malicious Group Member:** A member who impersonates someone else by injecting incorrect information for another user.
- **Information Leakage after protocol abort:** Adversary may be able to cause a protocol abort and trigger leakage.

Secure Information Exchange Sequence



(a) Data Selection (b) Counting (c) User Grouping (d) Word Phrase Comparison (e) Contact Data Import

Figure 5: Secure contact information exchange sequence.

Works Cited

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