Wireless Network Security and Privacy

无线网络安全及隐私

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About Me

Xiaoyu Ji 冀晓宇

2010: EE, BS, Zhejiang University
2015: CS, PhD, HKUST
2017-Now: Professor, ZJU

Research interest: IoT security, Embodied AI security, wireless and sensing security

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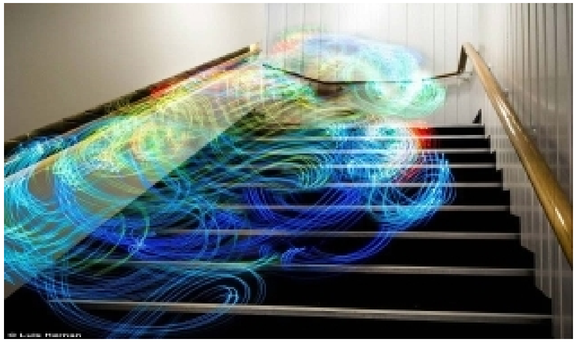
About You?

- **Basic personal information**
  - Name
  - MS/PhD/??
  - Department
  - Advisor
  - Research Area
    - Interests
    - Experience

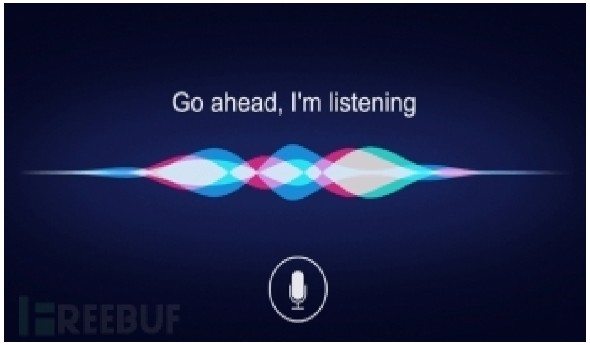
- **About this course and you**
  - Why do you take this course?
  - What you expect to learn (or any goal)?
  - What keywords run into your mind regarding wireless security?
  - What specific problems or topics are you interested in?

What is this course about?

- What is security?
- Is wireless secure, and why if not?
- What is privacy issues in wireless networks?
- How to enhance the secure of wireless networks?



• Head-worn
• Straps
• Shirts
• Wrist-worn
• Clips
• Shoe-worn / Foot pods
Apps

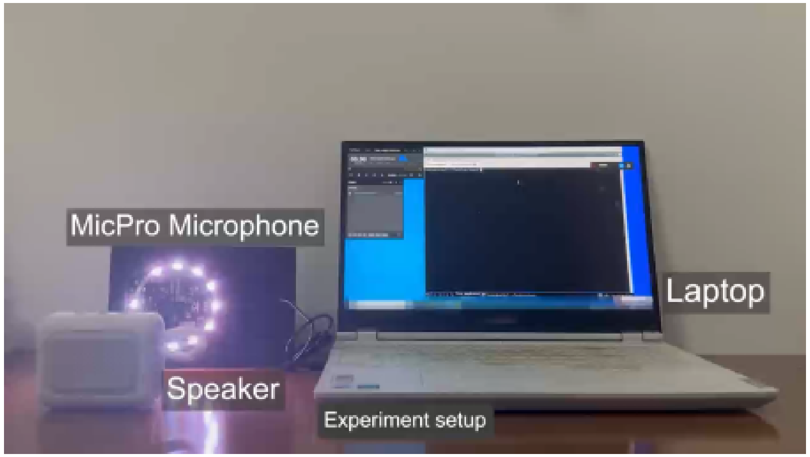


Top X research problems in USSLAB

- Sensor Neural Networks
- Sensor-oriented security and privacy problems
- Wireless signal for malware injection/ bug exploitation
- Wireless and electromagnetic signals to attack
  - GhosTouch series
  - Control manipulation
- Physical adversarial example
  - Laser to fool autonomous driving
  - Sound to fool autonomous driving
- Voiceprint/ASR/ASV security
  - Siri，小度小度，天猫精灵……
- DolphinAttack and its defenses
- Nonspeaker as speaker to attack ASR
- GhosTouch, wired GhosTouch
- Liveness detection
- ……

Sensor-oriented security and privacy

- MicPro (CCS’23) and CamPro (NDSS’24)
- Audio/Facial privacy protection on sensors

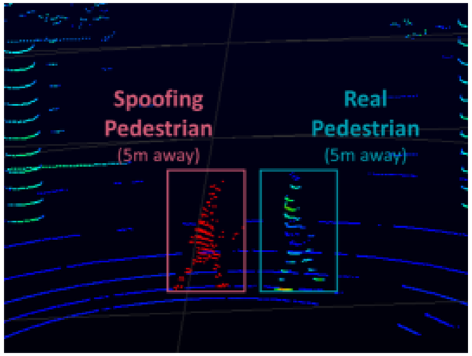


MicPro

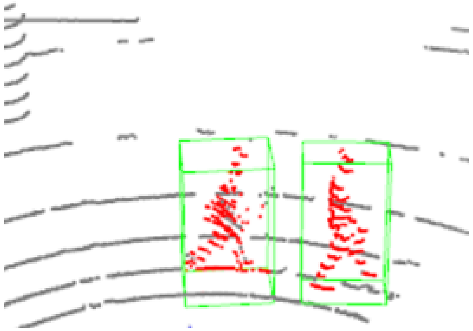
CamPro

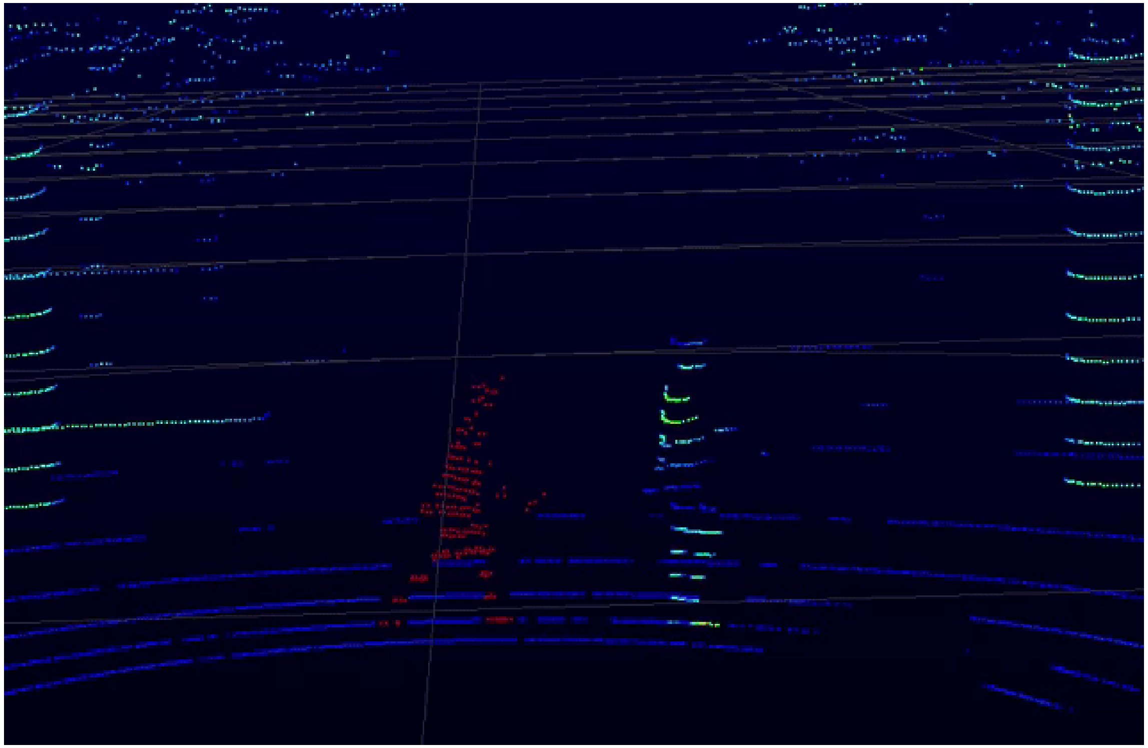
Physical adversarial example

- ADV-Lidar (IEEE SP’23)
- Laser to fool autonomous driving



Point cloud

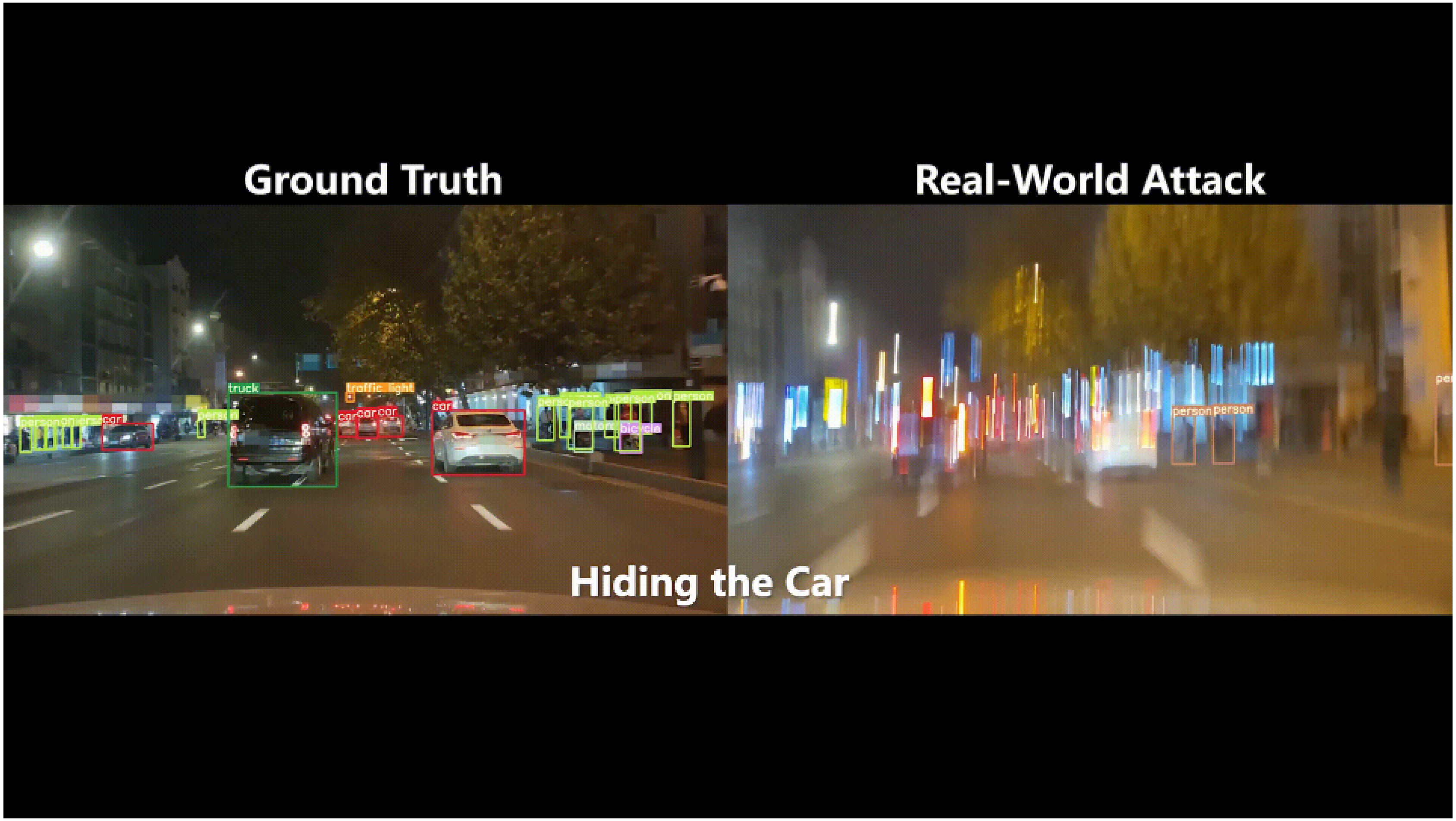




A spoofing ”pedestrain” point cloud (left) and a benign pedestrian point cloud (right) are both detected by SECOND.

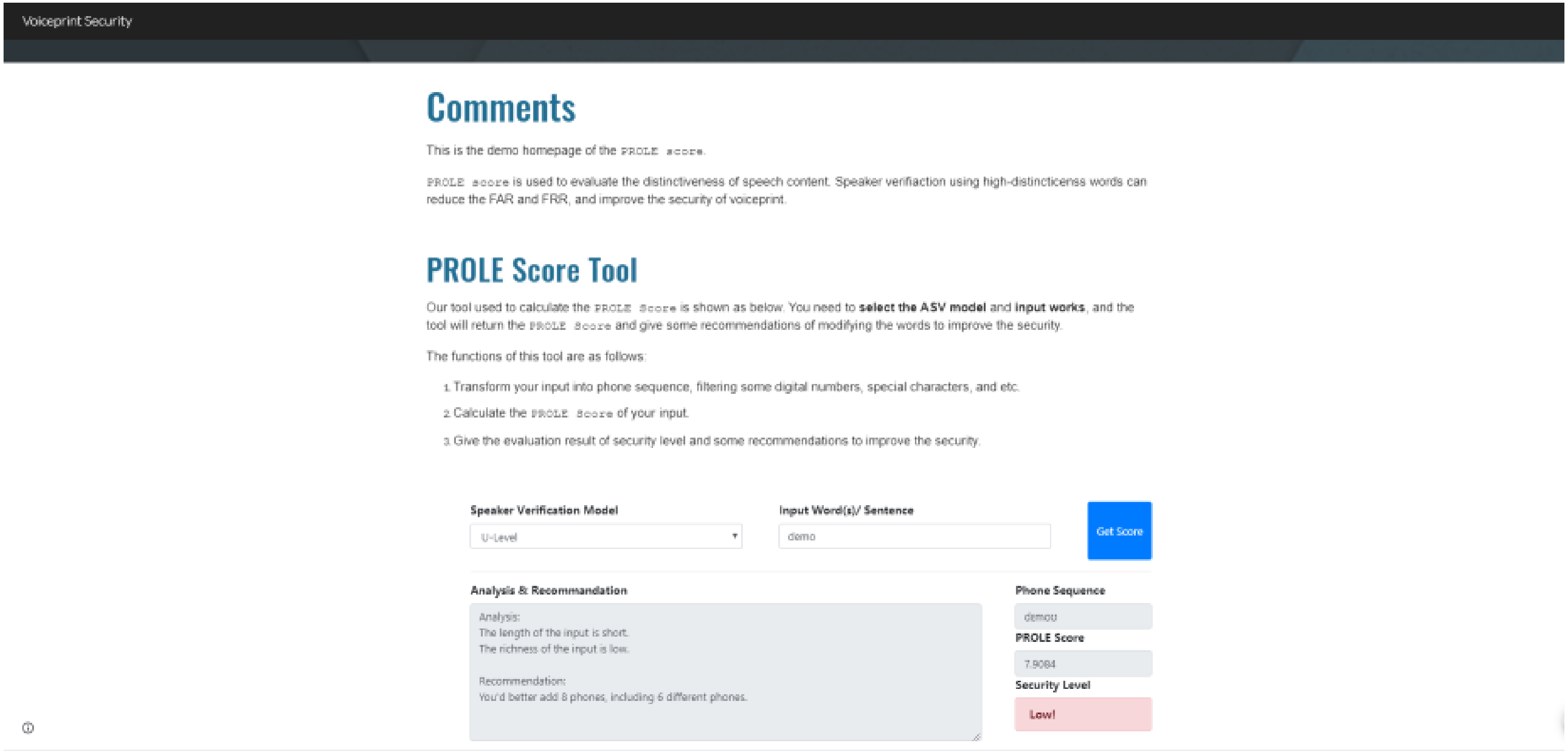
Physical adversarial example

- Poltergeist (IEEE SP’21)
- Play sound to fool autonomous driving



Voiceprint security

- PROLE Score (USENIX Security’22)
- How to measure voiceprint security
  - www.usslab.org/prolescore



Comments

This is the demo homepage of the PROLE score.

PROLE score is used to evaluate the distinctiveness of speech content. Speaker verifiaction using high-distincticenss words can reduce the FAR and FRR, and improve the security of voiceprint.

PROLE Score Tool

Our tool used to calculate the PROLE Score is shown as below. You need to **select the ASV model** and **input works**, and the tool will return the PROLE Score and give some recommendations of modifying the words to improve the security.

The functions of this tool are as follows:

1. Transform your input into phone sequence, filtering some digital numbers, special characters, and etc.
2. Calculate the PROLE Score of your input.
3. Give the evaluation result of security level and some recommendations to improve the security.

Speaker Verification Model: U-Level

Input Word(s)/ Sentence: demo

Analysis & Recommandation

Analysis:
The length of the input is short.
The richness of the input is low.

Recommendation:
You'd better add 8 phones, including 6 different phones.

Phone Sequence: demou

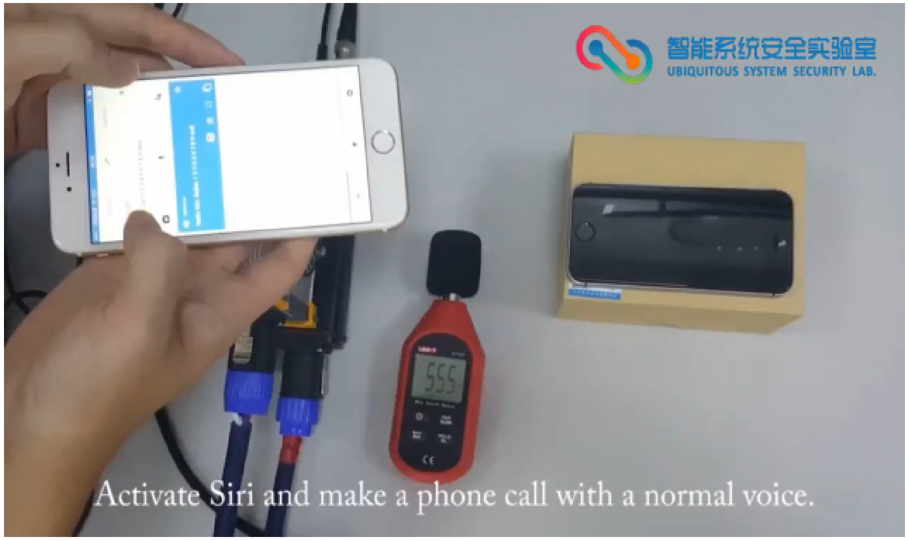
PROLE Score: 7.9084

Security Level: Low!

DolphinAttack

- **ACM CCS’17 Best paper**
- **能力效果：**通过超声波注入无声的语音指令，可对手机语音助手进行各类指令操控，如打电话、访问恶意网页
- **作用对象：**具有语音助手的手机、平板、电脑、汽车等
- **作用距离：**20米（实验室原型机，距离可提升）

实际攻击演示（近距离概念展示）


智能系统安全实验室
UBIQUITOUS SYSTEM SECURITY LAB.
Activate Siri and make a phone call with a normal voice.

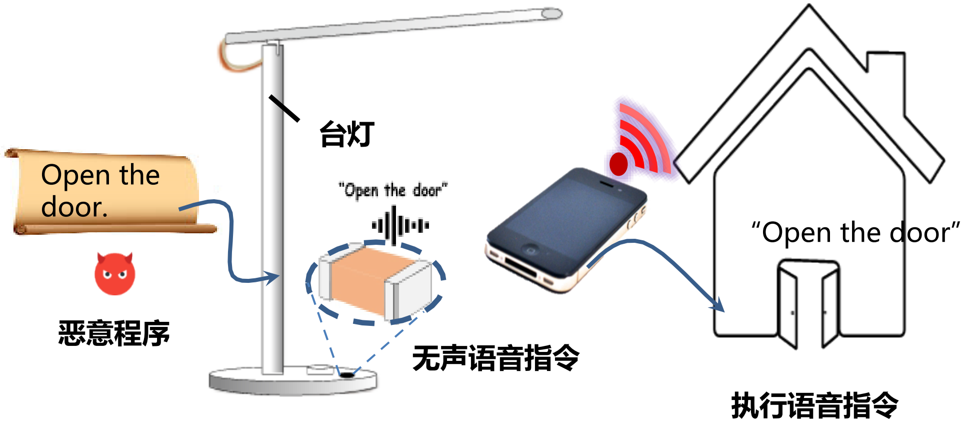
通过超声波发生装置，产生无声语音指令，可以使苹果手机的Siri语音助手执行“拨打电话”的语音指令

实际攻击演示（自制设备，20m攻击距离）

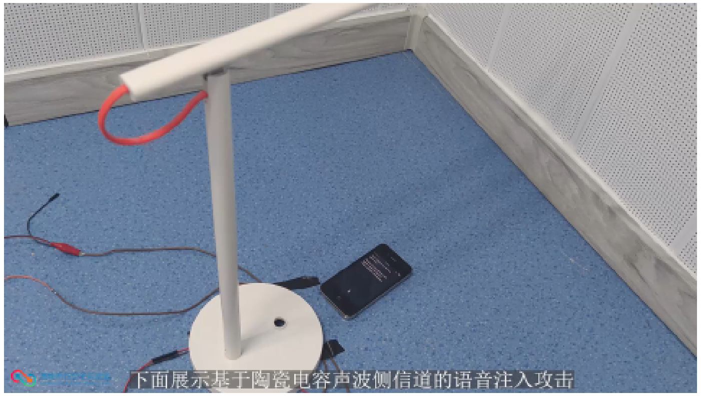
通过超声波攻击装置，在20m外发出无声语音指令，可以唤醒苹果手机的Siri语音助手并执行语音指令

Nonspeaker attack ASR

- **ACM CCS’21**
- **能力效果：**通过程序控制台灯等普通家用设备的电容发出超声波，可向智能设备的语音助手下达恶意命令，或实现隐蔽通信传输
- **作用对象：**普通家用设备、智能语音助手
- **作用距离：**10cm



基于电容发声的语音注入攻击

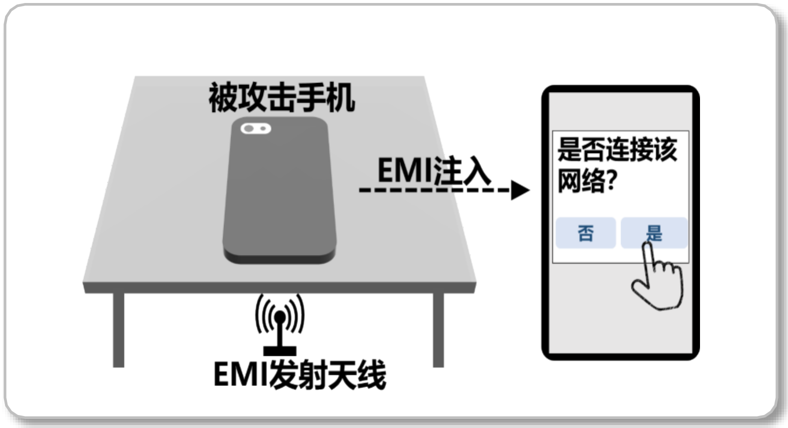


电容发声攻击演示

GhosTouch

- **USENIX Security’22**
- **能力效果：**通过电磁波操控目标手机，在无人接触屏幕的情况下实现对手机触摸屏的点击、滑动操作，可以接听电话、连接恶意蓝牙、接收恶意文件等。
- **作用对象：**有电容式触摸屏的手机、平板、电脑等
- **作用距离：**可跨桌面（攻击装置在桌下，被攻击手机在桌上）

攻击场景（连接恶意网络）



攻击装置藏在桌下，通过电磁波向桌上的手机屏幕注入虚假触摸点

实际攻击演示（接听电话）

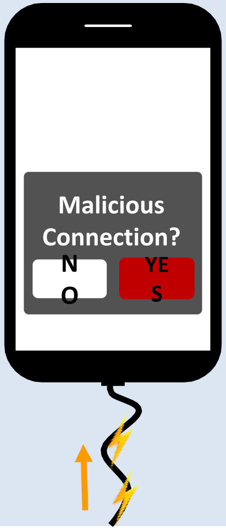
左：攻击装置　中：被攻击手机　右：拨打电话手机
通过电磁波产生虚假触摸点，实现电话接听。
透明亚克力板模拟桌子

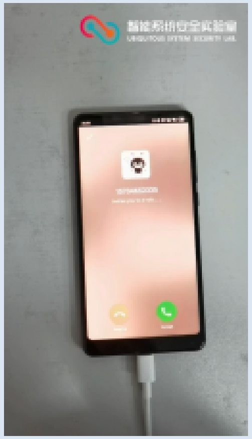
Wired GhosTouch

- **IEEE S&P’22**
- **能力效果：**通过充电线操控目标手机，可在无人接触屏幕时操控手机、有人触摸时篡改触点或使触摸无响应
- **作用对象：**有电容式触摸屏的手机、平板、电脑等
- **作用距离：**取决于充电线长度

- **注入攻击**

用户无操作下注入鬼手触点

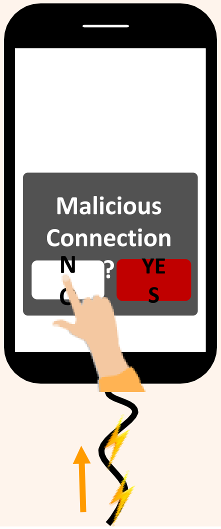




接电话

- 篡改攻击

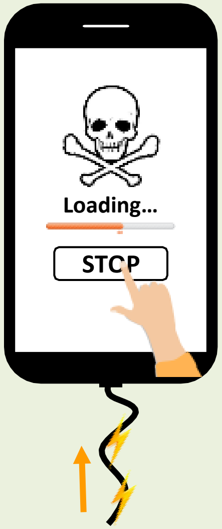
注入鬼手触点，篡改用户触点

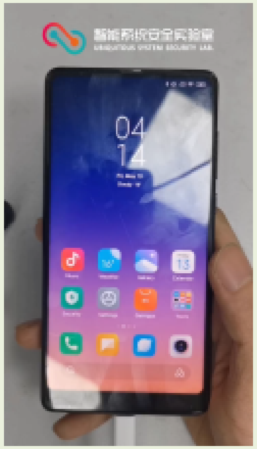


“Decline” →“Accept”

- **拒绝服务攻击**

触摸屏无法接受用户触摸操作





无法操作

Other: Signal into control

- How to manipulate to attack the control of an UAV
- What is the rationale behind

Course Goal

- **Understand the basic principles of wireless network security and privacy**
  - Wireless network basics
  - Security & privacy, especially related to wireless networks
- **Read and discuss interesting literature in the areas of wireless network security, such as:**
  - Wireless signal as an attack
  - Embodied AI attack and defenses
  - AI related security, e.g., adversarial ML
  - Software and protocol security
  - Other new trends, e.g., 5/6G security
- **Understand and get a sense on how to do research**
  - How to determine what is important
  - How to organize a research paper
  - How to ***sell*** your idea
  - How to present your work?

Administrative

Course information:

- Syllabus: publish after each course
- Reading references: TBD in next course
- **Course web**: http://www.usslab.org/courses/wnsp.html

How to reach me:

- **Email:** xji@zju.edu.cn
- **Office:** Teaching Building #2, Rm 325
- **TA:** Yu Wang (王禹)￼

Recommended reference book:

- 《物联网安全》，徐文渊、冀晓宇等
- Computer Networking: A Top-Down Approach
- “Cryptography and Network Security” by William Stallings
- William Stallings[美]著. 刘玉珍,王丽娜,傅建明等译，《密码编码学与网络安全—原理与实践》(第六版)，电子工业出版社，2004

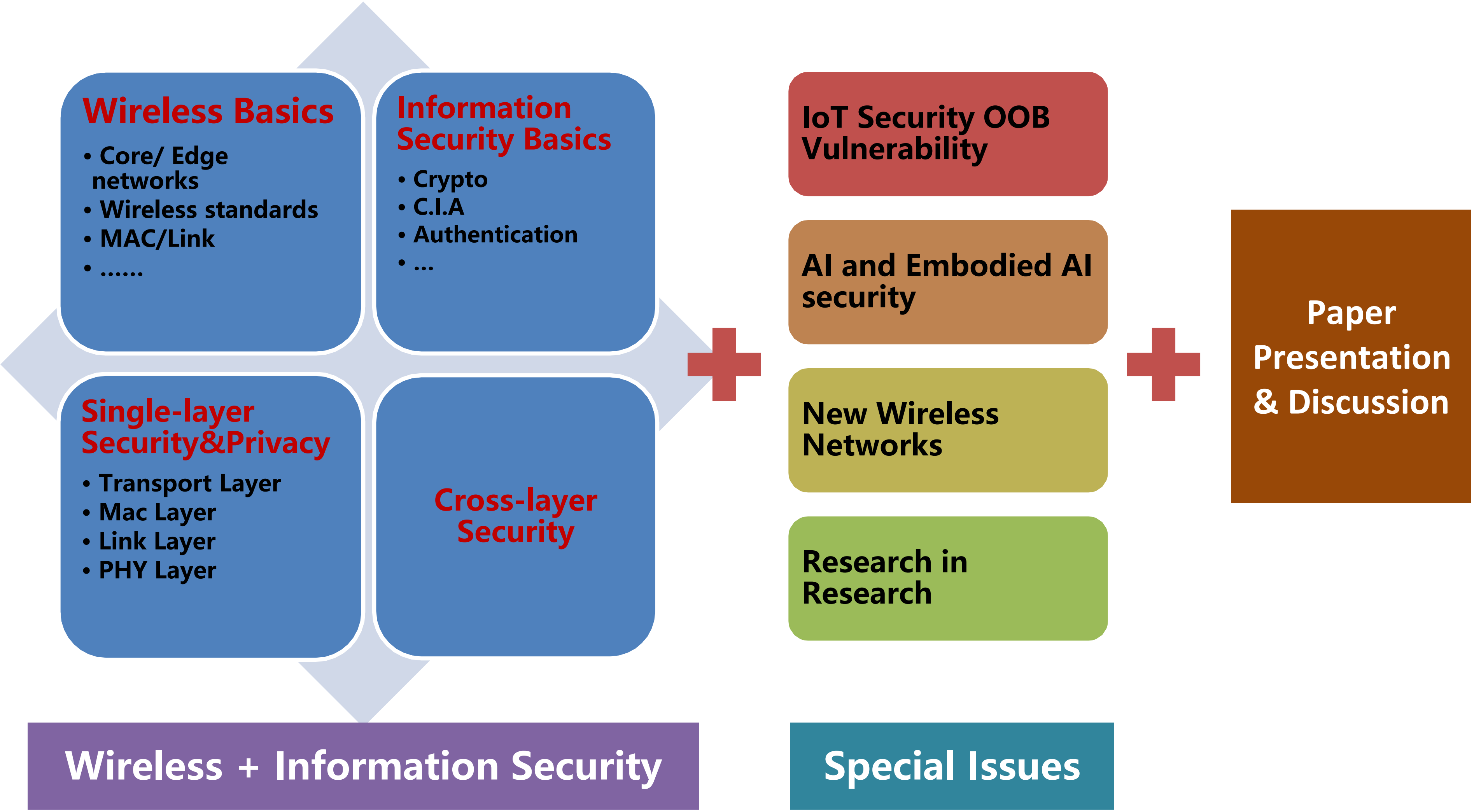
Pre-requisites

- Computer networks
- Basic programming skill, e.g., Python/C/C++
- Basic knowledge of wireless
- Strong motivation
- Curiosity

Tentative Topics

- **Wireless networks [1 course]**
  - Wireless concepts
  - Wireless standards, e.g., IEEE WiFi/802.11
  - Mobile networks: smartphones
  - Narrow-band IoT (NB-IoT), 5G
- **Information Security basics [1 course]**
  - Concept of cryptograph
  - Classical and modern cryptograph mechanisms
  - IoT authentication, hash, etc.
- **Wireless Security & Privacy [3 course]**
  - Single layer security & privacy
  - Cross-layer security & privacy
  - Location based security & privacy
- **Special Issues [2 course]**
  - **IoT Security OOB Vulnerability**
  - **AI and Embodied AI Security**
  - **Security and privacy in new wireless networks**
  - **Research in research (*)**

Course Organization



Wireless Basics

- Core/ Edge networks
- Wireless standards
- MAC/Link
- ……

Information Security Basics

- Crypto
- C.I.A
- Authentication
- …

Single-layer Security&Privacy

- Transport Layer
- Mac Layer
- Link Layer
- PHY Layer

Cross-layer Security

Wireless + Information Security

+

IoT Security OOB Vulnerability

AI and Embodied AI security

New Wireless Networks

Research in Research

Special Issues

+

Paper Presentation & Discussion

Course Organization

- **Group task**
  - 2 people as a group
  - Present 1 paper: from top-tier security conferences
  - Finish 1 project: e.g., reproduction of the presented paper, or from other sources such as GitHub
  - Presentation and project demo at the last course

Course Organization - Presentation

- Paper source: ACM CCS/Usenix Security/ IEEE S&P, NDSS, and I will recommend a list of recent papers

- Will run like a seminar
  - My introduction about the topic
  - Your presentation of papers of that topic
  - Discussion from all students

- Auditors are expected to read papers and participate

- Papers are divided into several sessions, and each session has a topic, including about 4-5 papers

Course Organization - Project

- Implement a “interesting” project based online resource, e.g., from
  - The paper you have chosen
  - Or from GitHub, etc.

- Topics:
  - Wireless security
  - Embodied AI
  - LLM security
  - Adversarial machine learning
  - Voiceprint security
  - …

- Implement and then **improve**!

Grading

- No exam!

- Grading based on:
  - 30% class discussions and participation
  - 30% presentations
  - 40% project

- Your Best Strategy
  - Come to every lecture
  - Read and summarize papers that will be presented
  - Participate in the discussion during class!
  - Enjoy the fun!