CAREER: Securing Sensory Side-Channels in Cyber-Physical Systems

CNS-CAREER-1453647

PI: Selcuk Uluagac

Cyber-Physical Systems Security Lab (CSL)
Electrical & Computer Engineering Department
Florida International University
E-mail: suluagac@fiu.edu, Web: http://nweb.eng.fiu.edu/selcuk

Abstract

Cyber-Physical Systems (CPS) integrate devices that can interact with each other and the physical world around them. With CPS applications, engineers monitor the structural health of highways and bridges, farmers check the health of their crops, and ecologists observe wildlife in their natural habitat. Using sensory side-channels (e.g., light, temperature, infrared, acoustic), an adversary can successfully attack CPS devices and applications by (1) triggering existing malware, (2) transferring malware, (3) combining multiple side-channels to increase the impact of a threat, or (4) leaking sensitive information. The project investigates the sensory (e.g., acoustic, seismic, light, temperature) threats to CPS devices and applications and evaluates the feasibility and practicality of the attacks on real CPS equipment. The result is novel sensorl-aware security tools and techniques for the CPS devices. Specifically, the principal investigator (1) analyzes the physical characteristics of the sensor attacks to understand how the physical world impacts the cyber world of CPS devices; (2) investigates the information leakage through the sensors; and (3) develops a novel IDS particularly designed to be aware of the sensor attacks [1, 2, 3, 4].

World of CPS…

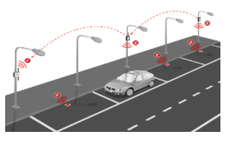
CPS: convergence of all these technologies, they are everywhere!

Sensors in different domains

Smartwatch

Smart home

Medical

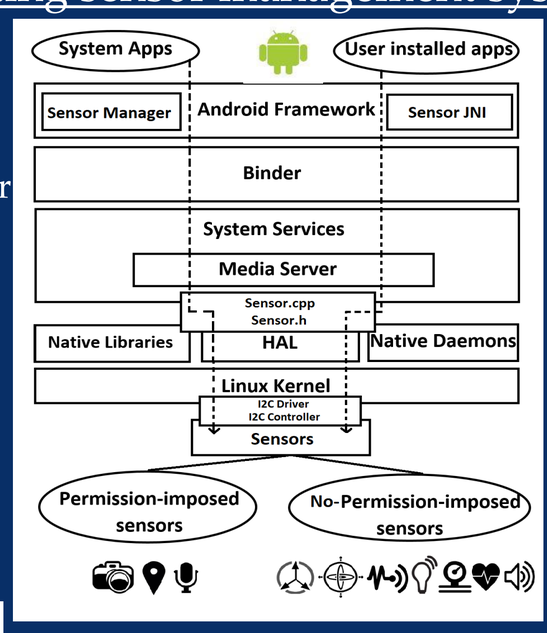


Smart city

Existing sensor management systems

Features

- Existing operating systems (e.g., iOS, Android, Windows, Blackberry) have similar sensor management frameworks.
- Permission-based access provided by the system.
- Only selective sensors are covered.
- Sensor access to different apps provided by Hardware Abstraction Layer (HAL).



Android Sensor Management System

Limitations

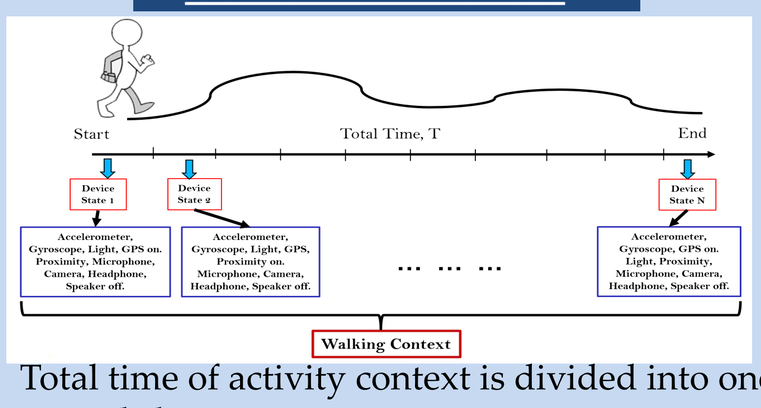
- Permission based management system.
- Only enforced in selective sensors.
- On screen sensors (e.g., accelerometer, gyroscope, light sensor) are considered secure and no permission is needed for access.
- After granting permission, users cannot control how apps use sensors.

A novel solution is needed for securing sensory-channels of CPS devices.

Our Contributions

- Design of a context-aware sensor-based threat detector to address the limitations of existing sensor management systems.
- Implementing proposed framework in both standalone smart devices (smartphone, smart watch) and connected smart environment (smart home and Office).
- Training the framework with real-life user data for different activities and device configurations.
- Testing proposed framework against different threats to both standalone and connected smart devices.
- High accuracy in sensor-based threat detection with minimum system overhead.

Context Awareness

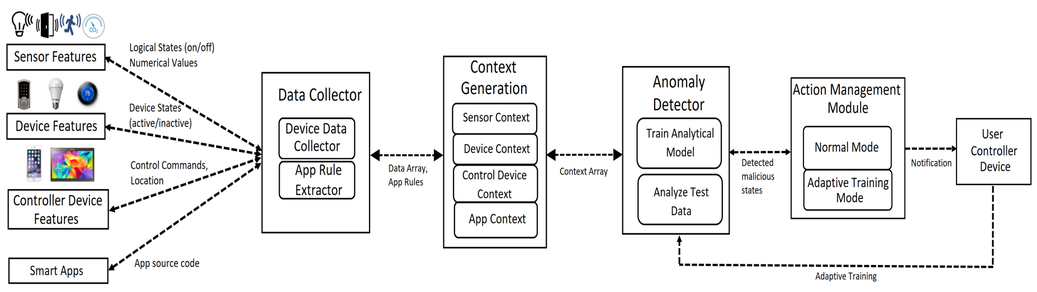


- Total time of activity context is divided into one second slots.
- Each second represents one or multiple device states.
- Each device state consists of different sensor conditions (on/off state of the sensors).

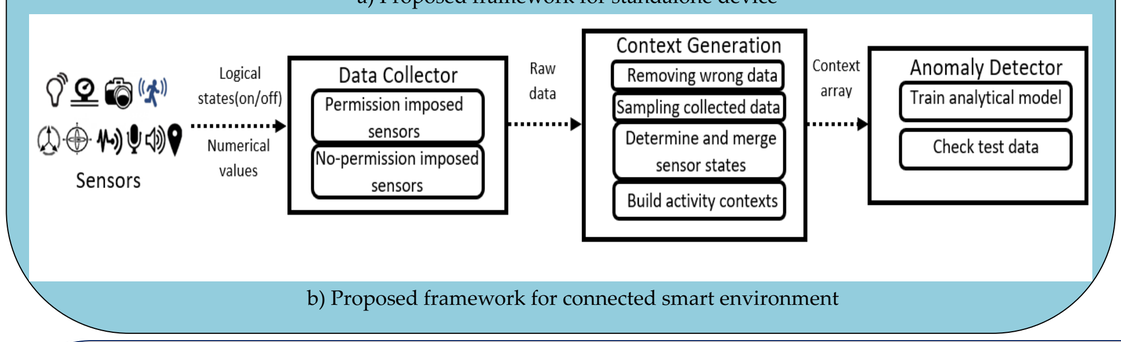
Adversary Model

Triggering Malware via Sensor	• Malicious app installed in the device triggered by a message via sensors (e.g., light sensor).
Information Leakage via Sensor	• Information saved or recorded in the device transferred via sensor.
Denial-of-Service	• Malicious app installed in the device impede the normal operation using sensors.
Transfer Malware via Sensor	• Exploiting sensory channels to transfer malware to a device.

Framework Overview

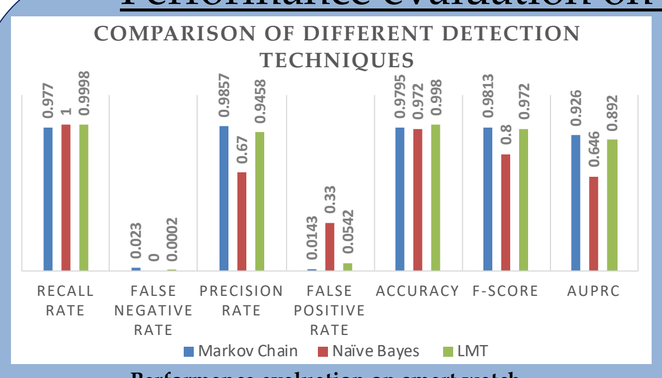


a) Proposed framework for standalone device

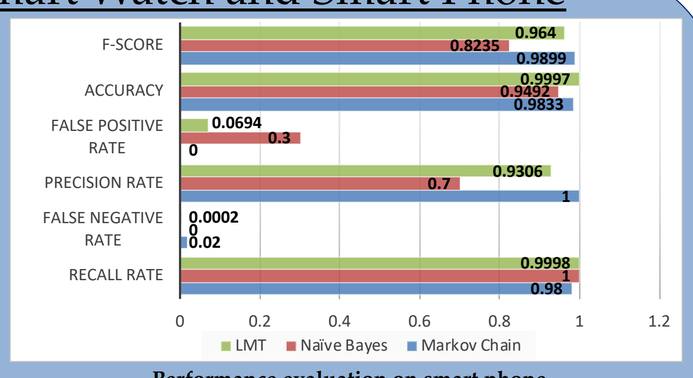


b) Proposed framework for connected smart environment

Performance evaluation on Smart Watch and Smart Phone



Performance evaluation on smart watch



Performance evaluation on smart phone

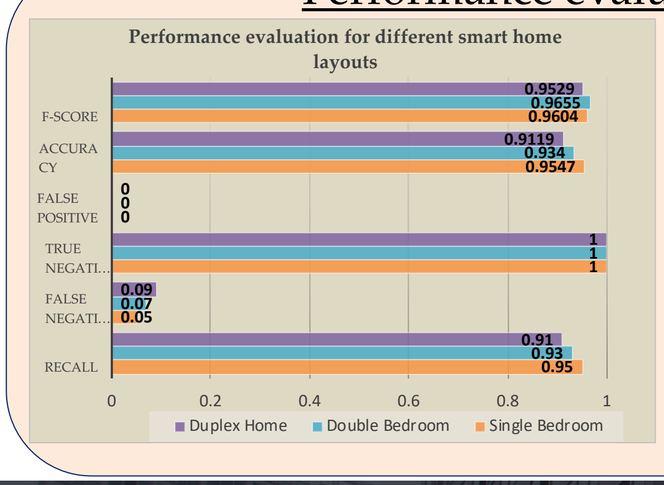
Data Collected from
- 42 users
- 7 different activities!
- LG Watch Sport

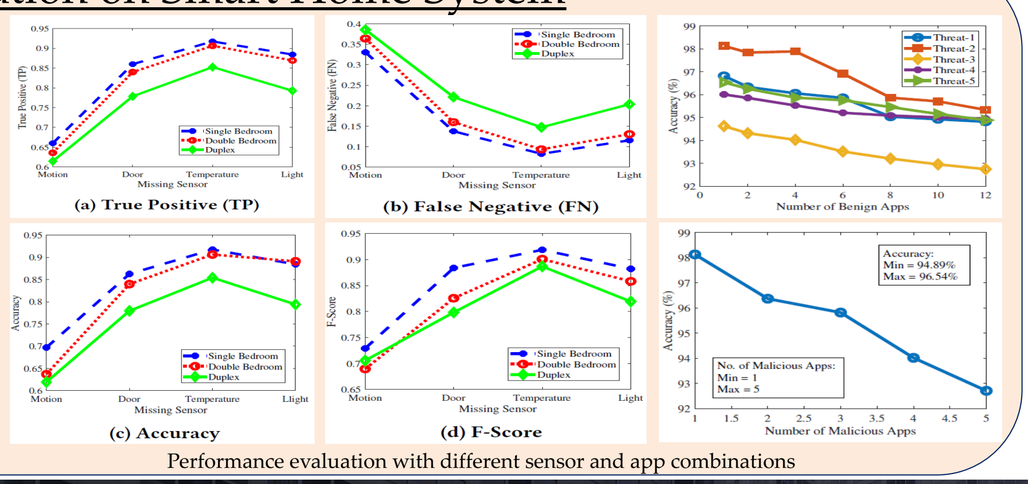
Task Category	Task Name
Generic Activities	1. Sleeping
	2. Driving as driver
	3. Driving as passenger
User-related Activities	1. Walking with smart watch in hand
	2. Playing games
	3. Browsing
	4. Making phone calls

Data Collected from
- 50 users
- 9 different activities!
- Samsung Galaxy S5 Due

Task Category	Task Name
Generic Activities	1. Sleeping
	2. Driving as driver
	3. Driving as passenger
User-related Activities	1. Walking with phone in hand
	2. Walking with phone in pocket/bag
	3. Playing games
	4. Browsing
	5. Making phone calls
	6. Making video calls

Performance evaluation on Smart Home System





Performance evaluation with different sensor and app combinations

Future Work

1. Test proposed framework on different CPS devices.
2. Evaluate performance of the framework against different active malware.
3. Comprehensive evaluation of the framework including frequency-accuracy trade-off, battery-accuracy trade-off, and battery-frequency trade-off.

References

[1] A. Selcuk Uluagac, Venkatachalam S., and Raheem A. Beyah,"Sensory Channel Threats to Cyber Physical Systems: A Wake-up Call," In Proceedings of the IEEE Conference on Communications and Network Security (CNS), October 2014, San Francisco, USA.

[2] "Amit Kumar Skder, Hidayet Aksu, and A. Selcuk Uluagac6thsense: A context-aware sensor-based attack detector for smart devices," in 26th USENIX Security Symposium (USENIX Security 17) Vancouver, BC: USENIX Association, 2017.

[3] Amit Kumar Sikder, Leonardo Babun, Hidayet Aksu, and A. Selcuk Uluagac, " AEGIS: A Context-aware Security Framework for Smart Home Systems ", Acccepted to 2019 Annual Computer Security Applications Conference (ACSAC 2019), San Juan, Puerto Rico.

The 4th NSF Secure and Trustworthy Cyberspace Principal Investigator Meeting (2019 SaTC PI Meeting)
October 28-29, 2019 | Alexandria, Virginia