IoTReplay: Troubleshooting COTS IoT Devices with Record and Replay

Author: Kaiming Fang & Guanhua Yan

University of Minnesota
Driven to Discover®

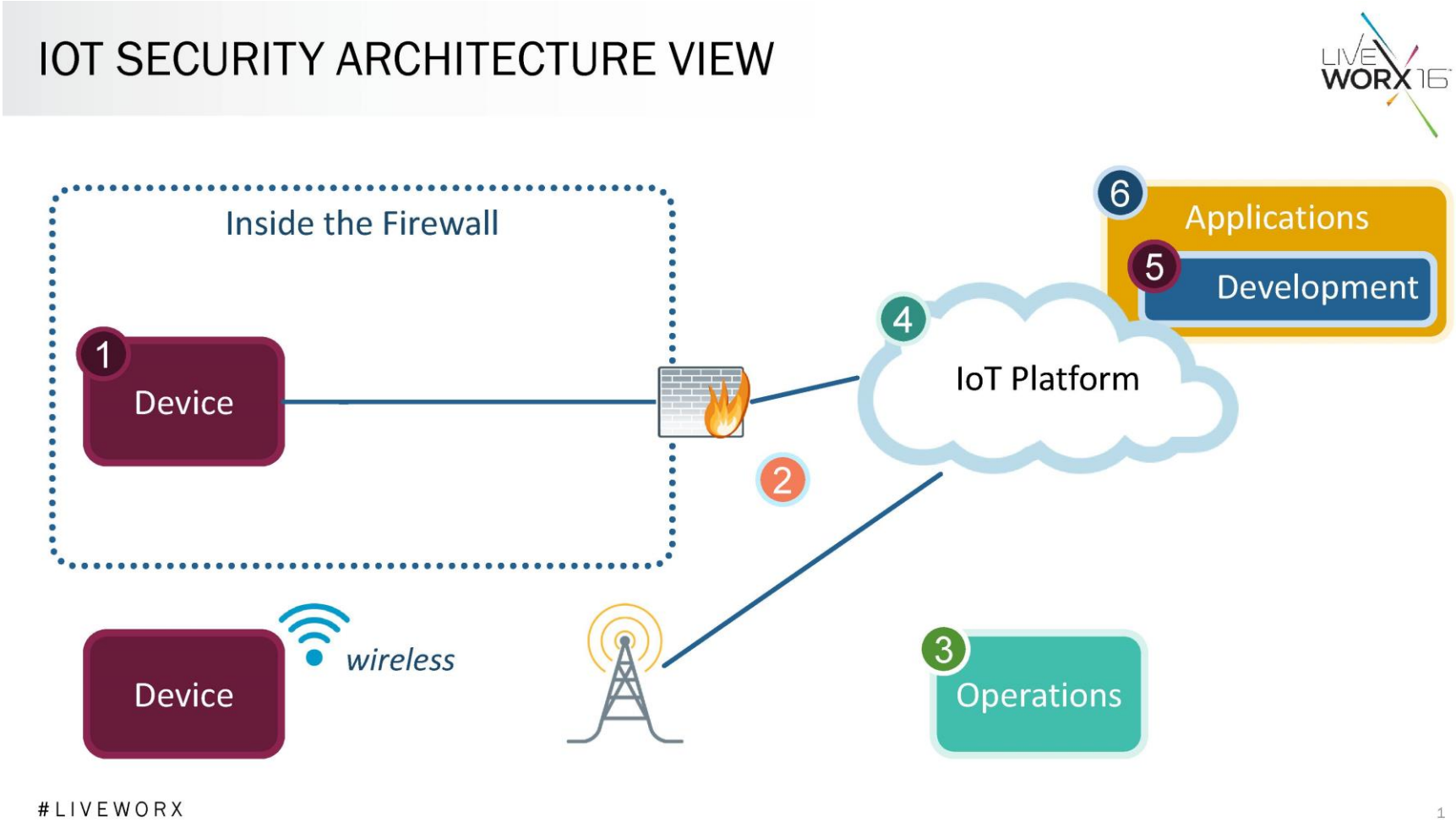
What are the IoT devices?

IoT devices are Internet of Things devices.

Examples:

- Remote Home Control
- Collect Environmental Data
- Automated, Farm-watering Systems

Typical Operation Model of IoT Devices



Key Contributions of This Paper

1. Identify key challenges in record & replay for IoT devices.

2. Identify types of events to be recorded & replayed.

3. Design a system to record & replay IoT devices.

Problems with Testing IoT Devices

IoT Devices are convenient but difficult to be tested.

Reasons:

Problems with Testing IoT Devices

IoT Devices are convenient but difficult to be tested.

Reasons:

1. Complex Working Environment

Problems with Troubleshooting IoT Devices

A network of IoT Devices are complex and difficult to troubleshoot.

Reasons:

1. Complex Working Environment
2. Difficult to Reproduce Users' Actions

Problems with Troubleshooting IoT Devices

A network of IoT Devices are complex and difficult to troubleshoot.

Reasons:

1. Complex Working Environment
2. Difficult to Reproduce Users' Actions
3. Lack of Sufficient Documentations

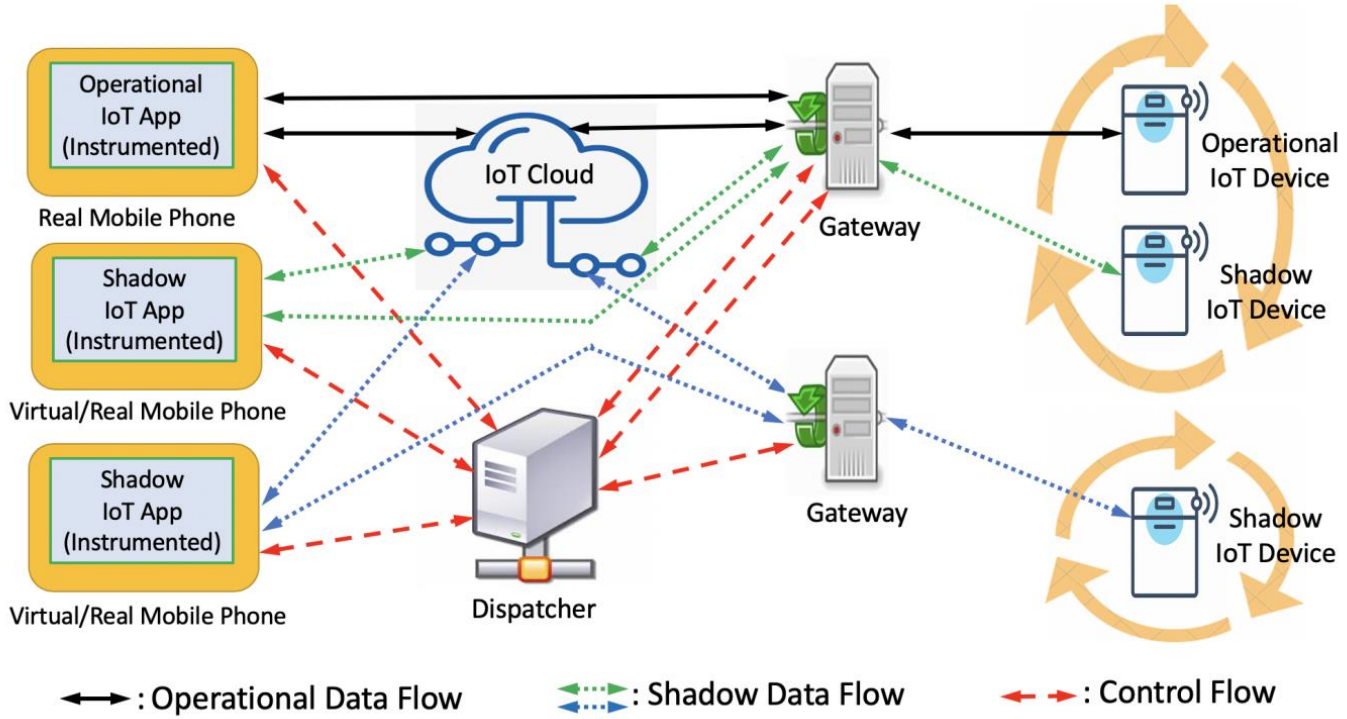
Proposed Approach

Record & Replay

1. Record the sequence of actions (along other useful information) that is executed.
2. Replay the same sequence of actions to diagnose (or debug) the system.

System Design

Operational (Real) World + Shadow (Testing) World



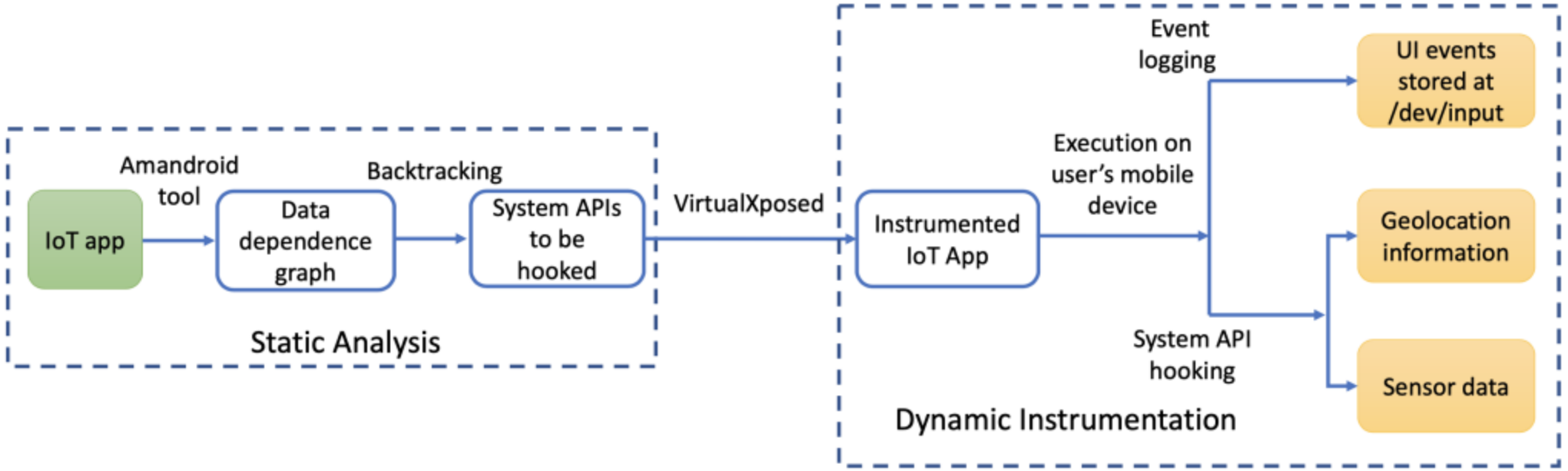
Positive Points

1. Selective Recording of Sequences of Actions
2. Usage of Edge Computing
3. Small Degradation on Performances

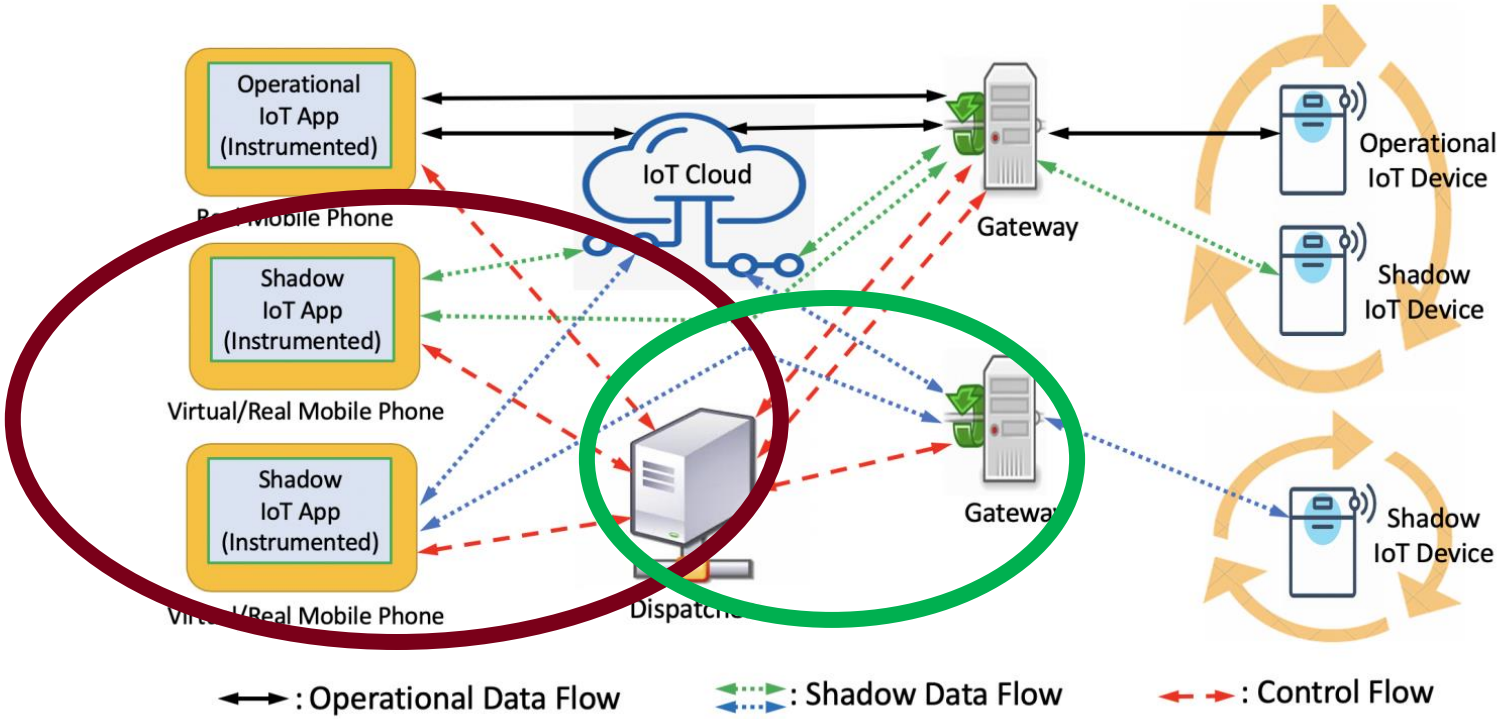
Selective Recording of Sequences of Actions

Event Receiver	Event Type	Shadow mode	IoTReplay Action
IoT App	UI operations	Online/Offline	Record & Replay
	Geolocation information	Online/Offline	Record & Replay
	Sensor data	Online/Offline	Record & Replay
	Network packets from IoT device	Online/Offline	None
	Network packets from IoT cloud	Online/Offline	None
	Exotic network packets	Online/Offline	None
	Timer events	Online	None
	Timer events	Offline	Start time alignment
IoT Device	UI operations	Online/Offline	Human Replay
	Sensor data	Online/Offline	Physical Replay
	Network packets from IoT app	Online/Offline	None
	Network packets from IoT cloud	Online/Offline	None
	Exotic network packets	Online/Offline	Record & Replay
IoT Cloud	Any	Online/Offline	None

Selective Recording of Sequences of Actions

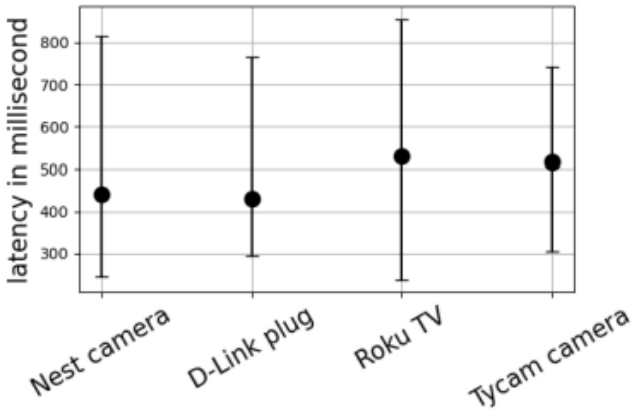


Usage of Edge Computing

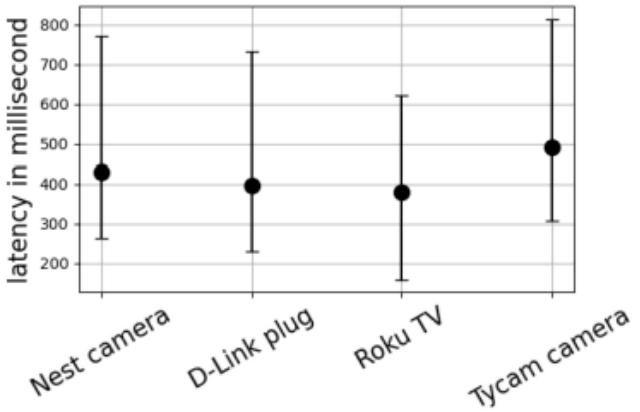


Small Degradation on Performances

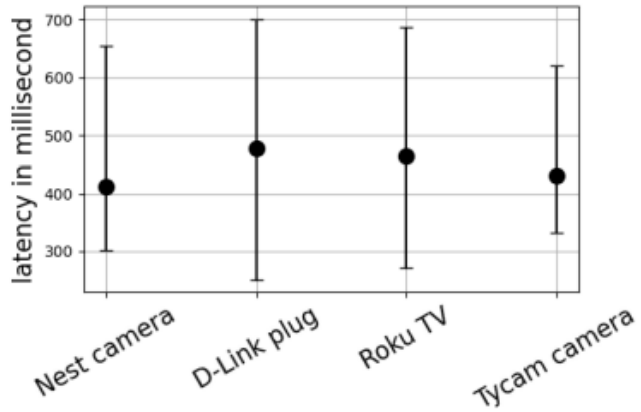
IoT App	Average frame latency (w/o VirtualXposed)	Average frame latency (with VirtualXposed)	Overhead
Google Nest camera	11.43 ms	11.62 ms	1.66%
D-Link smart plug	10.67 ms	10.83 ms	1.50%
Roku TV	10.25 ms	10.31 ms	0.59%
Tycam LTE camera	12.58 ms	13.21 ms	5.01%



(1) UI operations



(2) Geolocation & Sensor



(3) Exotic messages

Negative Points

- Only presents errors, after they have occurred.
  - The damage is already done.
  - Therefore, not desirable for less accessible applications.