SECURITY ANALYSIS OF EMERGING SMART HOME APPLICATIONS

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- Related Work
- SmartThings-Big Picture
- Security Analysis
- Proof-of-concept attacks
- Defense Mechanism

Motivation

- Huge number of connected gadgets, systems and appliances that do a wide variety of different things.
- Though it provides user with benefits, it also expose user to security risks

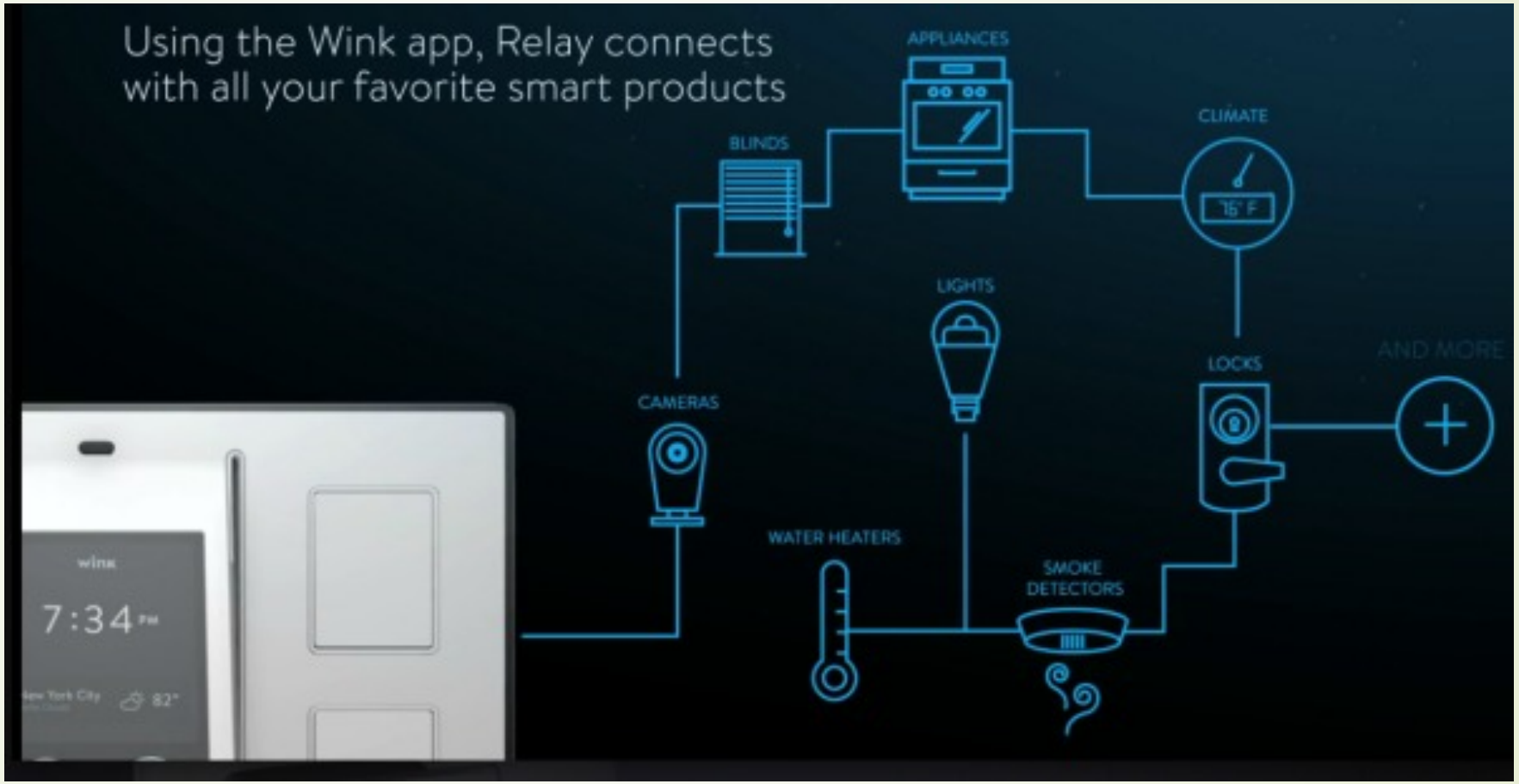
Related Work

- A framework for evaluating security risks associated with technologies used at home- Denning
- Device front
  - MyQ garage system, Wink Relay touch controller, Honeywell Tuxedo Touch Controller
  - Investigate the feasibility of causing physical harm through the explosion of CFLs through an exploited home automation system
  - Use Case : sharing smart devices with others
- Protocol Front – Zigbee and Zwave protocol
- Investigation on cause of over privilege due to insufficient API documentation and guidelines on different types of permission- Felt

IoT Paper

- First in-depth security analysis of one such “smart home” platform that allows anyone to control their home appliances from light bulbs to locks with a PC or smartphone.
- Demonstrate programming framework design flaws
- Analyze protocol operating between SmartThings backend and the client-side web IDE
- Remote attacks that weaken the home security system independent of specific protocol in use.
- Evaluation of SmartThings capability model in protecting sensitive device operations

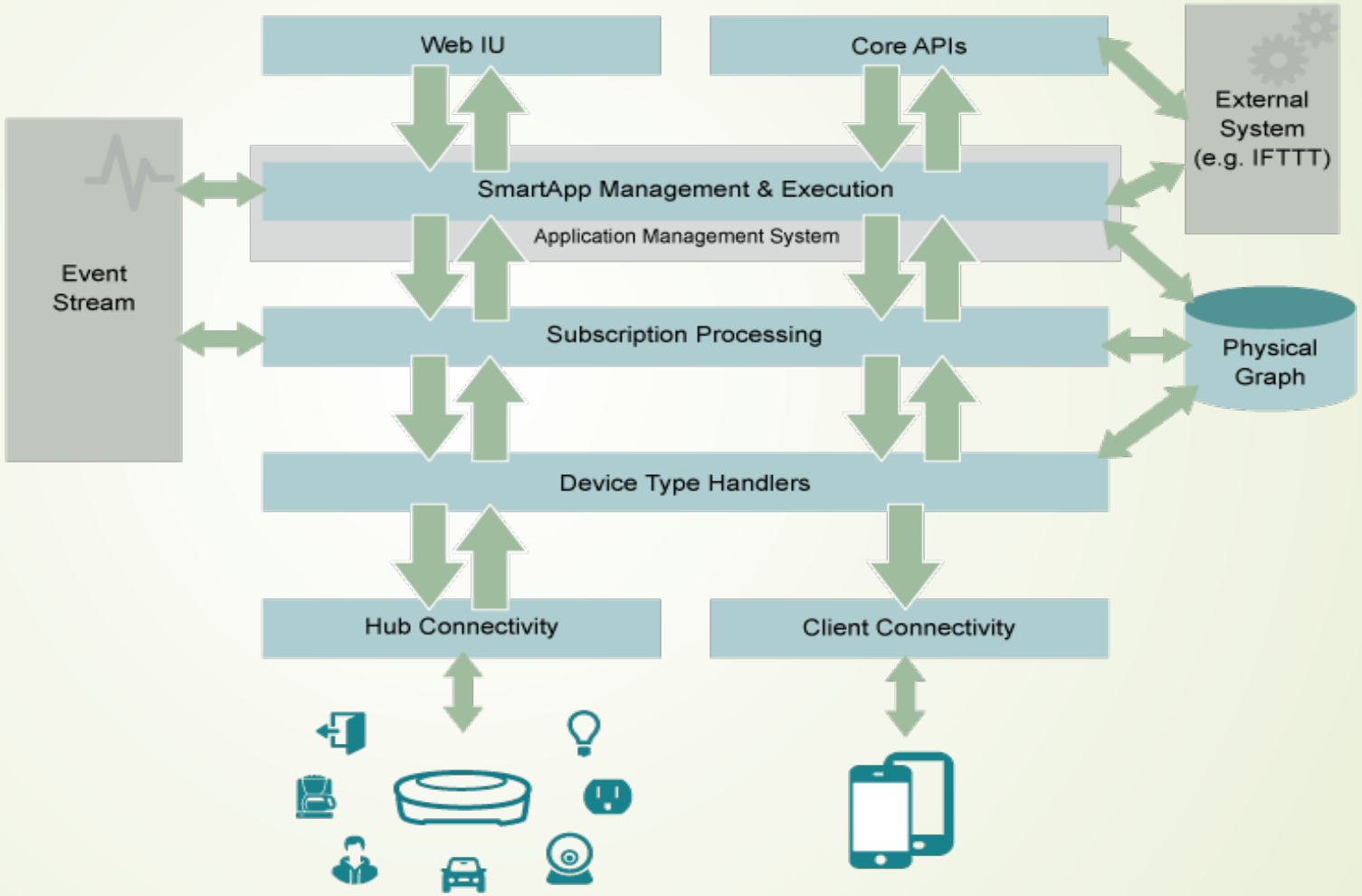
Smart Home applications



SmartThings

- SmartThings interconnects separately operating home appliances to create a fully connected SmartThings home controlled by smartphone apps.
- The main goal of SmartThings is to provide a new class of automation by connecting appliances to one another, to the Internet, and to homeowners.

Big Picture


Web IU
Core APIs
External System (e.g. IFTTT)
Event Stream
SmartApp Management & Execution
Application Management System
Subscription Processing
Physical Graph
Device Type Handlers
Hub Connectivity
Client Connectivity

SmartThings - cont.

Three main components

- Hubs
- SmartThings Cloud Backend
- Smartphone companion app

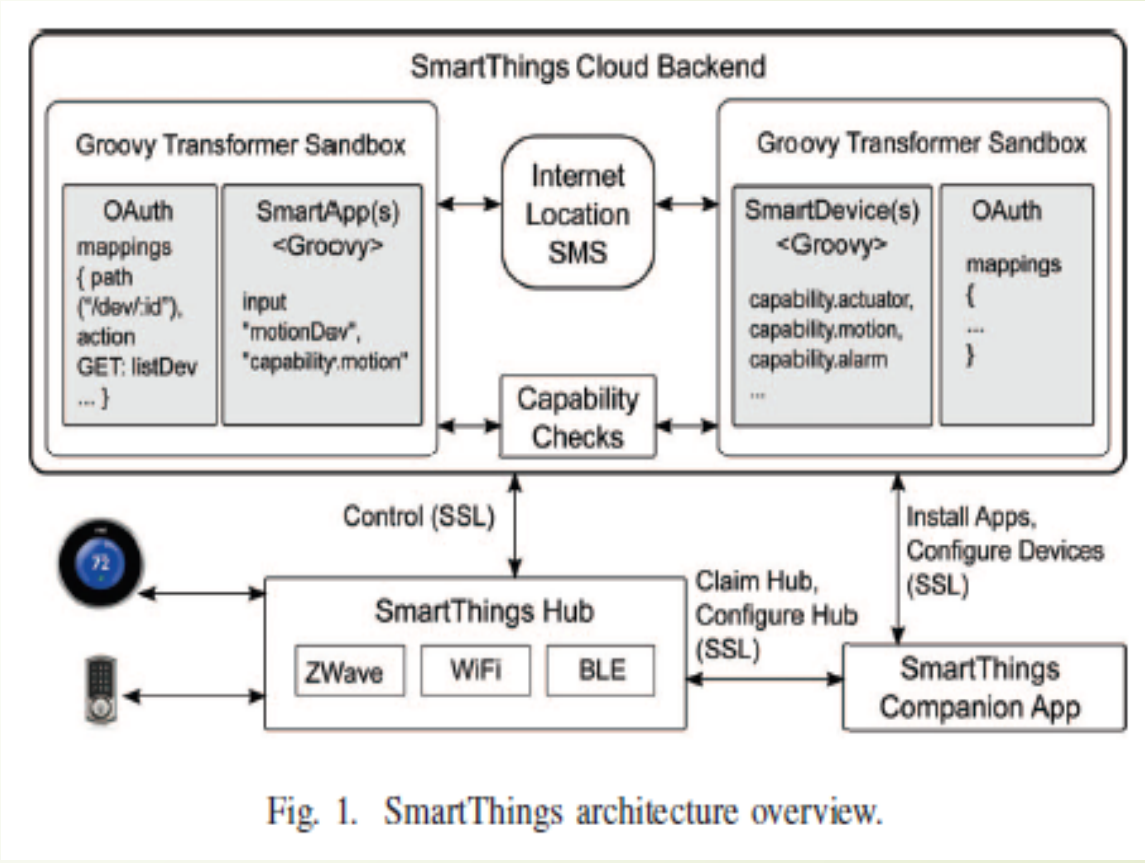
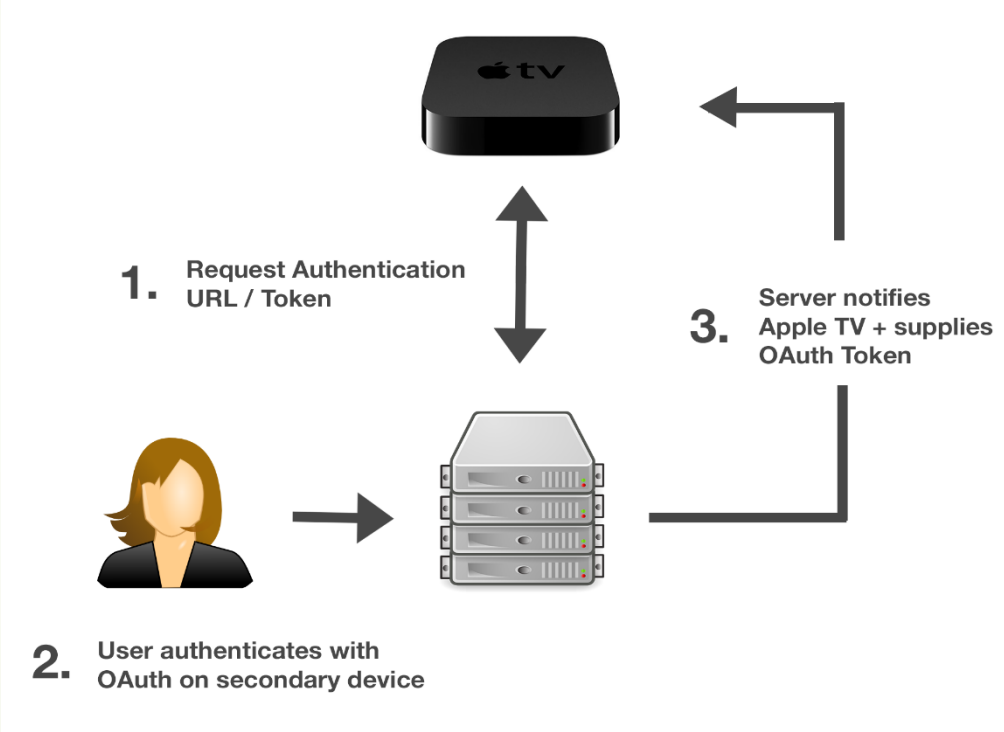


Fig. 1. SmartThings architecture overview.

SmartThings System

- SmartApps and SmartDevices
- Capabilities and Authorization
- Events and Subscriptions
- Webservice SmartApps
- Sandboxing



SmartApp Structure

```
definition(
    name: "DemoApp", namespace: "com.testing",
    author: "IoTPaper", description: "Test App",
    category: "Utility")

//query the user for capabilities
preferences {
  section("Select Devices") {
    input "lock1", "capability.lock", title:
        "Select a lock"
    input "sw1", "capability.switch", title:
        "Select a switch"
  }
}

def updated() {
  unsubscribe()
  initialize()
}

def installed() {
  subscribe sw1, "switch.on", onHandler
  subscribe sw1, "switch.off", offHandler
}

def onHandler(evt) {
  lock1.unlock()
}

def offHandler(evt) {
  lock1.lock()
}
```

Listing 1. SmartApp structure.

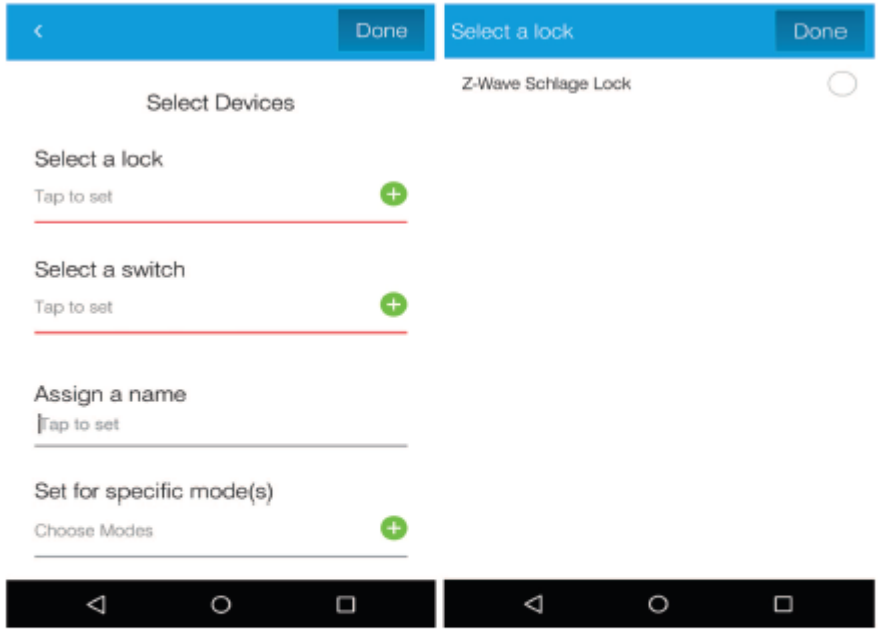


Fig. 2. Installation user interface and device enumeration: This example shows that an app asks for devices that support `capability.lock` and `capability.switch`. The screen on the right results when the user taps on the first input field of the screen on the left. SmartThings enumerates all lock devices (there is only one in the example). The user must choose one or more devices that the app can access.

Security Analysis

- Occurrence of over privilege in SmartApps
- Insufficient sensitive event data protection
- Insecurity of third party integration
- Unsafe use of groovy dynamic method invocation
- Unrestricted Communication abilities via API Access control

Occurrence of over privilege in SmartApps

Because of SmartThings Framework

- Capabilities – Coarse-grained, providing access to multiple commands and attributes for a device (55%)
  - E.g. Capability.lock (Commands: lock and unlock, attribute : lock)
- SmartApp obtain more capabilities than it request because of SmartApp-SmartDevice binding (42%)
  - E.g. SmartApp uses capability.battery

Light

Allows for the control of a light device

Preferences Reference

capability.light //consider it for Oven

Attributes

***switch:* ENUM**

A string representation of whether the light is on or off

off

The value of the switch attribute if the light is off

on

The value of the switch attribute if the light is on

Commands

off()

Turn a light off

on()

Turn a light on

Lock

Allow for the control of a lock device

Preferences Reference

capability.lock

Attributes

***lock:* ENUM**

The state of the lock device

locked

The device is locked

unknown

The state of the device is unknown

unlocked

The device is unlocked

unlocked with timeout

The device is unlocked with a timeout

Commands

lock()

Lock the device

unlock()

Unlock the device

Example of over privilege

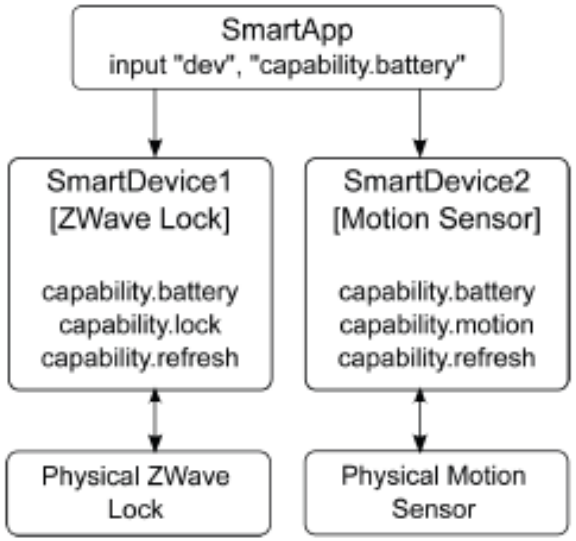


Fig. 3. SmartApps vs. SmartDevices vs. Physical Devices: When a user installs this SmartApp, SmartThings will show the lock and the motion sensor since both the corresponding device handlers (SmartDevice1 and SmartDevice2) expose the requested capability.

Insufficient sensitive event data protection

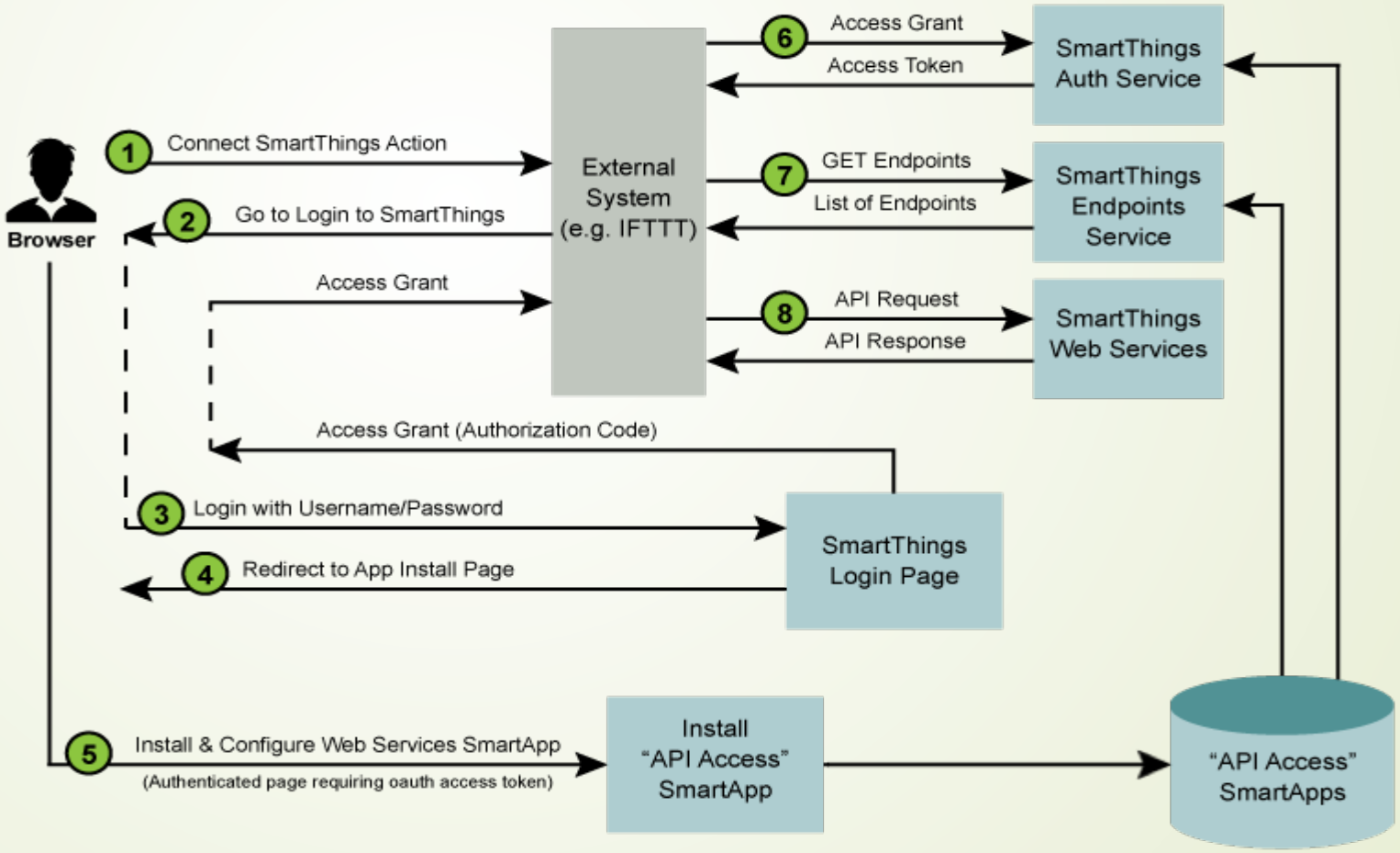
Because of insecure event sub-system design

- After a SmartApp is approved to access a SmartDevice, it monitors any data published by SmartDevice (e.g. Lock codes)
- SmartApp which acquired 128-bit identifier(unique to SmartDevice) can monitor all the events.

  subscribe(deviceObj, attrstring, handler)
- Events generated from devices can be spoofed. As the framework,
  - does not have control over raising events
  - verify the integrity or the origin of an event by triggered SmartApps

Insecurity of third party integration

- OAuth bearer token – attached to request while invoking the WebService SmartApp HTTP endpoints



Unsafe use of groovy dynamic method invocation

- String representation of a command is received over HTTP

  def str = “foo”

- The string is executed directly by dynamic method invocation (method can be invoked using name as a string)

  foo()

Unrestricted Communication abilities via API Access control

- No restrictions on outbound Internet communication of SmartApps

  -leaks sensitive information

Empirical security analysis

TABLE II
BREAKDOWN OF OUR SMARTAPP AND SMARTDEVICE DATASET

Total # of SmartDevices	**132**
# of device handlers raising events using `createEvent` and `sendEvent`. Such events can be snooped on by SmartApps.	111
Total # of SmartApps	**499**
# of apps using potentially unsafe Groovy dynamic method invocation.	26
# of OAuth-enabled apps, whose security depends on correct implementation of the OAuth protocol.	27
# of apps using unrestricted SMS APIs.	131
# of apps using unrestricted Internet APIs.	36

TABLE III
COMMANDS/ATTRIBUTES OF 64 SMARTTHINGS CAPABILITIES

	Documented	**Completed**
Commands	66	93
Attributes	60	85

TABLE IV
OVERPRIVILEGE ANALYSIS SUMMARY

Reason for Overprivilege	**# of Apps**
Coarse-grained capability	276 (55%)
Coarse SmartApp-SmartDevice binding	213 (43%)

PROOF-OF-CONCEPT ATTACKS

A. Backdoor pin Code Injection Attack

- Over privilege using SmartApp-SmartDevice coarse-binding
- Stealing an OAuth token using the hard-coded secret in the existing binary
- Getting a victim to click on a link pointing to the SmartThings Web site
- Command injection to an existing Webservice SmartApp

Stealing the OAuth Token

GET https://graph.api.smartthings.com/oauth/authorize?

response_type=code&

client_id=YOUR-SMARTAPP-CLIENT-ID&

scope=app&

redirect_uri=YOUR-SERVER-URI

parameter	**value**
response_type	Use code to obtain the authorization code.
client_id	The OAuth client ID of the SmartApp.
scope	This should always be “app” for this authorization flow.
redirect_uri	The URI of your server that will receive the authorization code.

Command Injection Attacks

- WebService SmartApp associated with the third-party Android app uses Groovy dynamic method invocation
- Format of the command string needed to activate the SmartApp endpoint

```
1  mappings {
2    path("/devices") { action: [ GET: "listDevices"]
       }
3    path("/devices/:id") { action: [ GET:
       "getDevice", PUT: "updateDevice"] }
4    // --additional mappings truncated--
5  }
6
7  def updateDevice() {
8    def data = request.JSON
9      def command = data.command
10     def arguments = data.arguments
11
12     log.debug "updateDevice, params: ${params},
         request: ${data}"
13     if (!command) {
14       render status: 400, data: '{"msg": "command
           is required"}'
15     } else {
16       def device = allDevices.find { it.id ==
           params.id }
17       if (device) {
18         if (arguments) {
19           device."$command"(*arguments)
20         } else {
21           device."$command"()
22         }
23         render status: 204, data: "{}"
24       } else {
25         render status: 404, data: '{"msg": "Device
             not found"}'
26       }
27     }
28 }
```

Listing 2. Portion of the Logitech Harmony WebService SmartApp available in source form. The mappings section lists all endpoints. Lines 19 and 21 make unsafe use of Groovy dynamic method invocation, making the app vulnerable to command injection attacks. Line 23 returns a HTTP 204 if the command is executed. Our proof-of-concept exploits a similar WebService SmartApp.

B. Door Lock Pin Code Snooping Attack

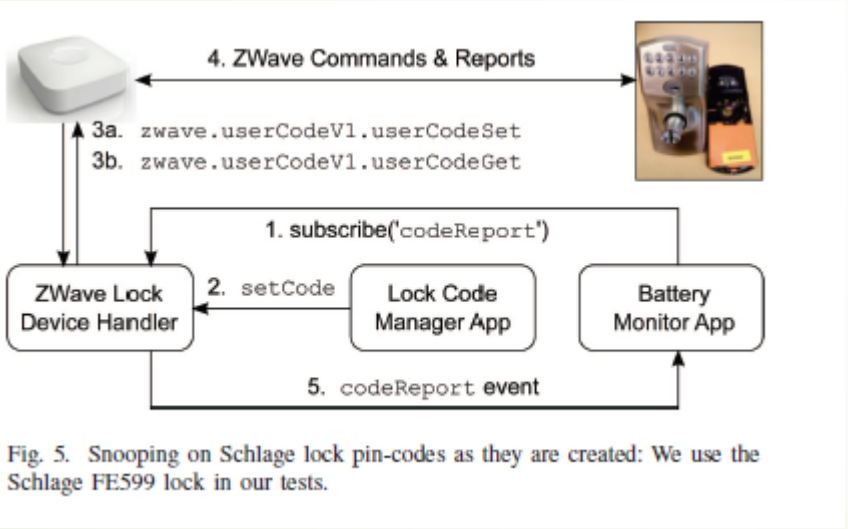


Fig. 5. Snooping on Schlage lock pin-codes as they are created: We use the Schlage FE599 lock in our tests.

1 zw device:02,

2 command:9881,

3 payload:00 63 03 04 01 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A

4 parsed to

5 [['name':'codeReport', 'value':4,

6 'data':['code':'8877'],

7 'descriptionText':'ZWave Schlage Lock code 4 set',

8 'displayed':**true**,

9 'isStateChange':**true**,

10 'linkText':'ZWave Schlage Lock']]

C. Disabling Vacation Mode Attack

- Depends on the “mode” property of the location object
- SmartThings does not have security controls around the SendLocationEvent API
- Even spoofing by the attack SmartApp
- Attack launched from any SmartApp without requiring the specific capabilities

D. Fake Alarm Attack

- Attack launched from any SmartApp without requiring the specific capabilities
- Attack SmartApp is installed in the system
- Even spoofing by the attack SmartApp
- Controlling the device

Survey Study of SmartThings Users

Table VI

TABLE VI
SURVEY RESPONSES OF 22 SMARTTHINGS USERS

Interest in installing battery monitor SmartApp:		
Interested or very interested	17	77%
Neutral	4	18%
Not interested at all	1	5%
Set of devices that participants would like the battery monitor app to monitor:		
Selected motion Sensor	21	95%
Selected Schlage door lock	20	91%
Selected presence Sensor	19	86%
Selected FortrezZ alarm	14	64%
Participants' understanding of security risks—# of participants who think the battery monitor app can perform the following:		
Cause FortrezZ alarm to beep occasionally	12	55%
Send battery levels to remote server	11	50%
Send motion and presence sensor data to remote server	8	36%
Disable FortrezZ alarm	5	23%
Send spam email from hub	5	23%
Download illegal material using hub	3	14%
Send door access codes to remote server	3	**14%**
Participants' reported feelings if the battery monitor app sent out door lock pin codes to a remote server:		
Upset or very upset	22	100%

Defense Mechanism

THANK YOU