Vigilia: Securing Smart Home Edge Computing

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Vulnerable Smart Home IoT Devices

CVE-2016-5053

Access via TCP port 4000

CVE-2018-3911

HTTP header injection

CVE-2012-3002

Bypassed authentication

CVE-2017-6520

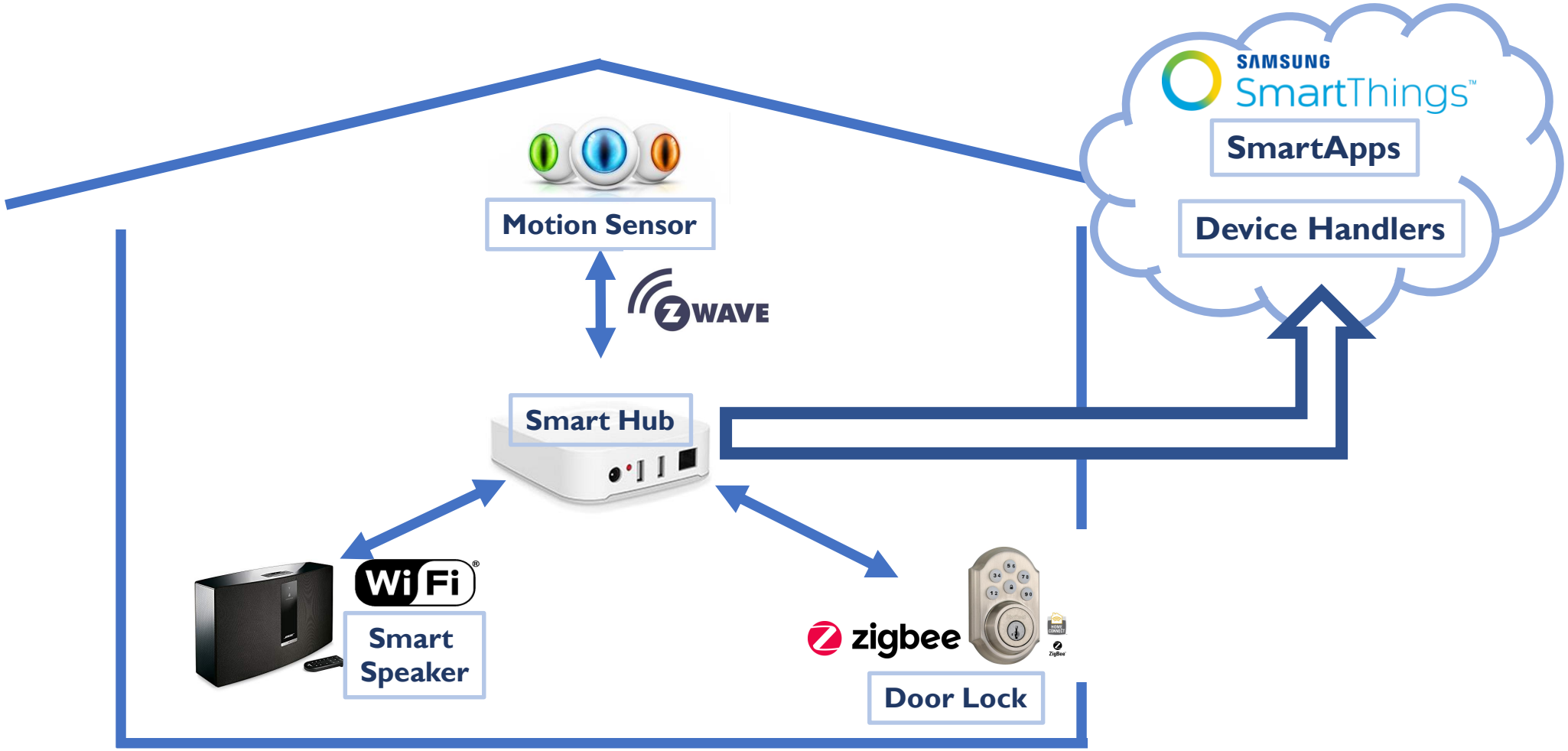
Access via UDP port 5353

CVE-2013-6949

Improper STUN/ TURN

http://support.smartthings.com/, http://www.amazon.com/2

SmartThings
Platform for Smart Home IoT Devices



https://www.samsung.com/, https://www.smartthings.com/, https://www.zigbee.org, https://www.techhive.com, https://www.wi-fi.org, https://www.kwikset.com/, https://www.h-3-digital.com

Enhanced Auto Door Lock
SmartApp Example

Marketplace **Safety & Security**

Enhanced Auto Lock Door

by Arnaud
Automatically locks a specific door after X minutes when closed and unlocks it when open after X seconds.

Kwikset SmartCode 910
ZigBee

HOME CONNECT

ZigBee

SmartThings Multipurpose Sensor
ZigBee

https://github.com/SmartThingsCommunity/SmartThingsPublic/blob/master/smartapps/lock-auto-super-enhanced/enhanced-auto-lock-door.src/enhanced-auto-lock-door.groovy, https://www.kwikset.com/, https://www.samsung.com/

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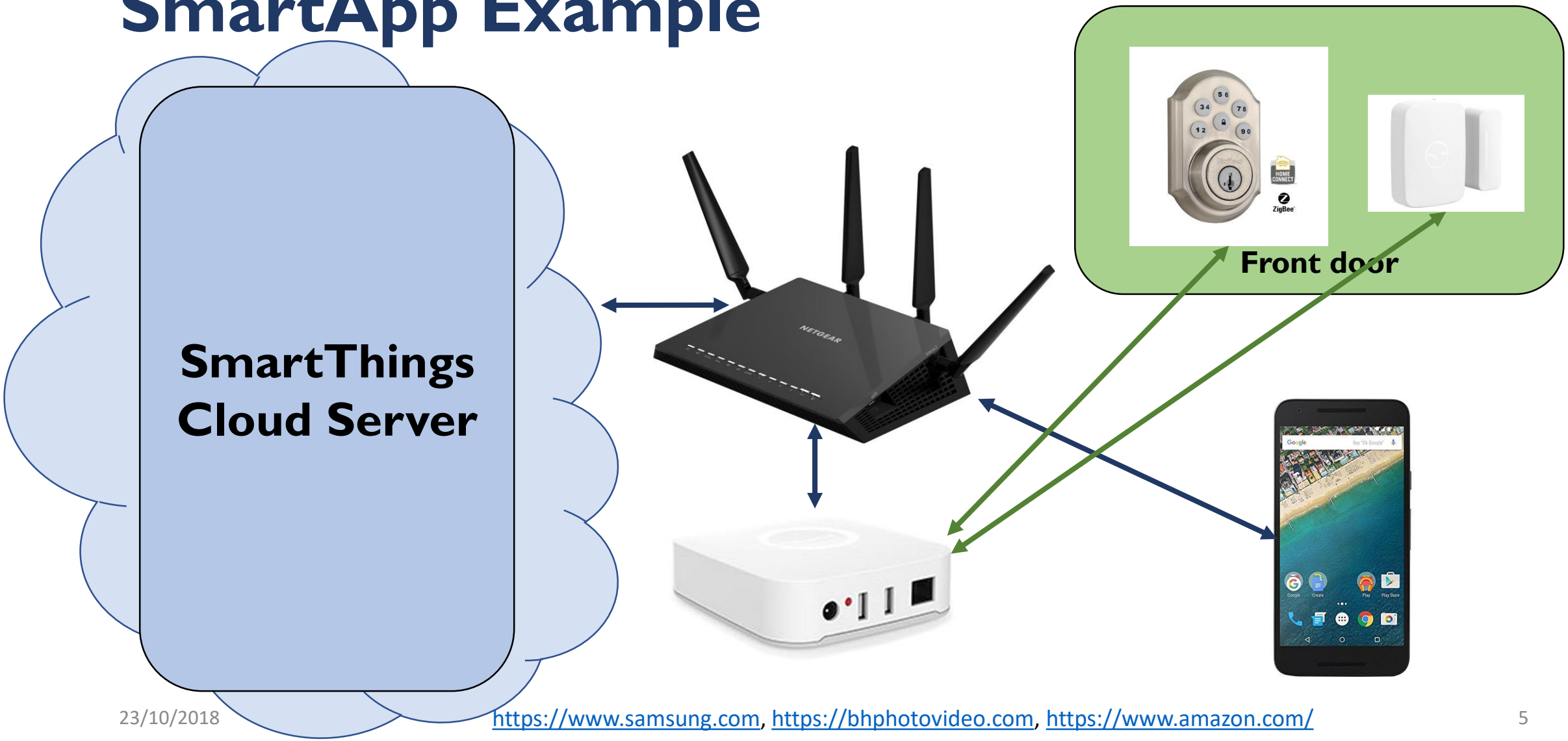

https://www.samsung.com, https://bhphotovideo.com, https://www.amazon.com/

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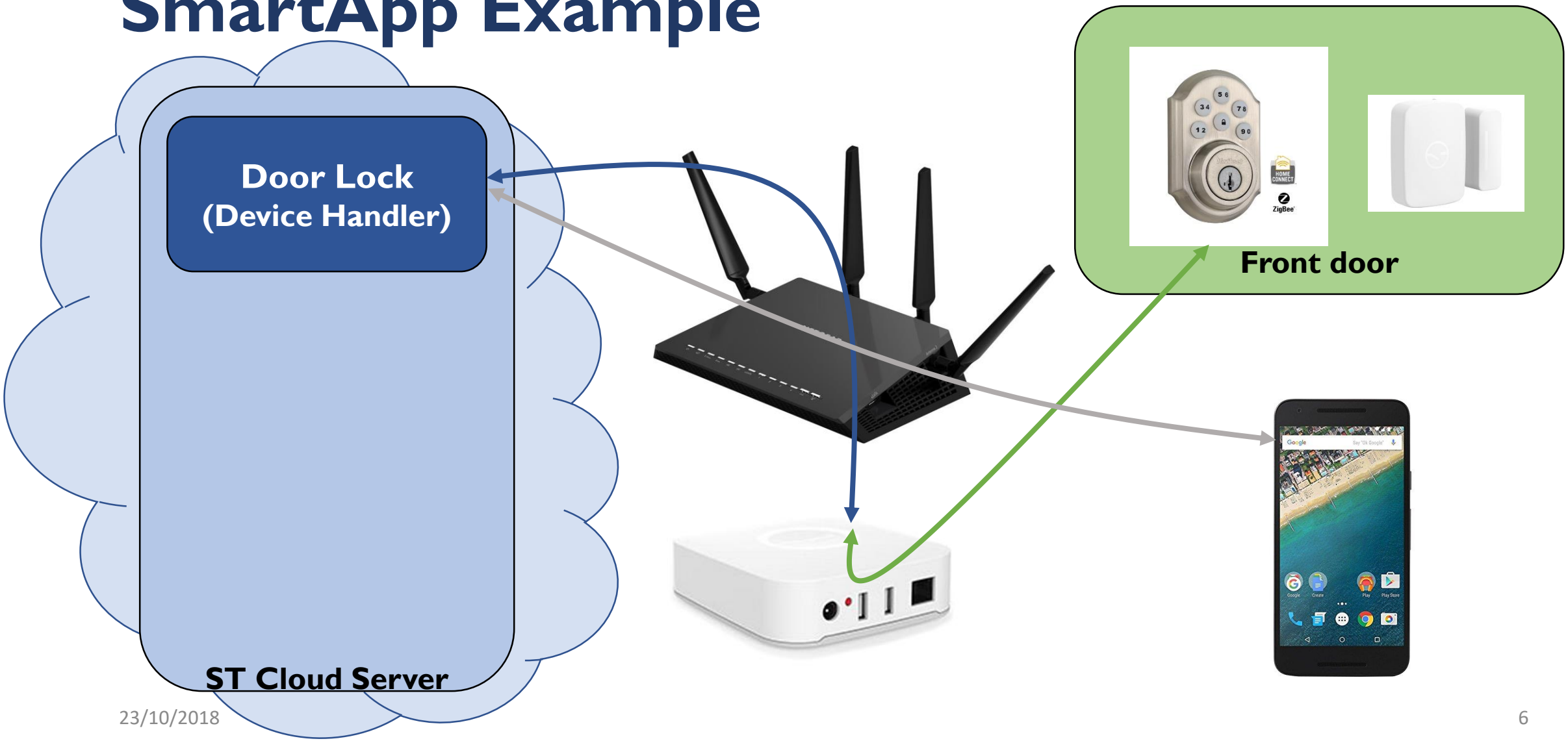

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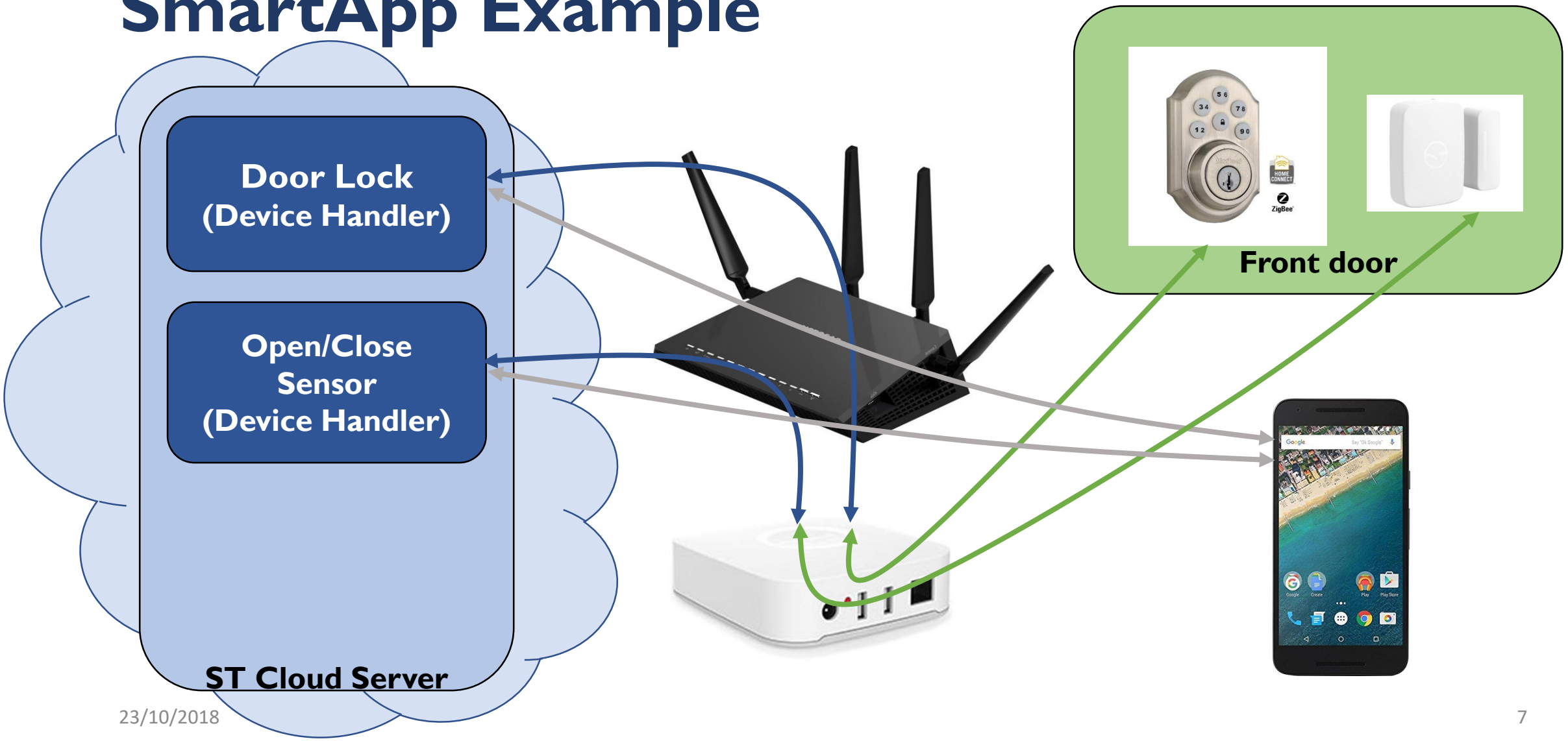
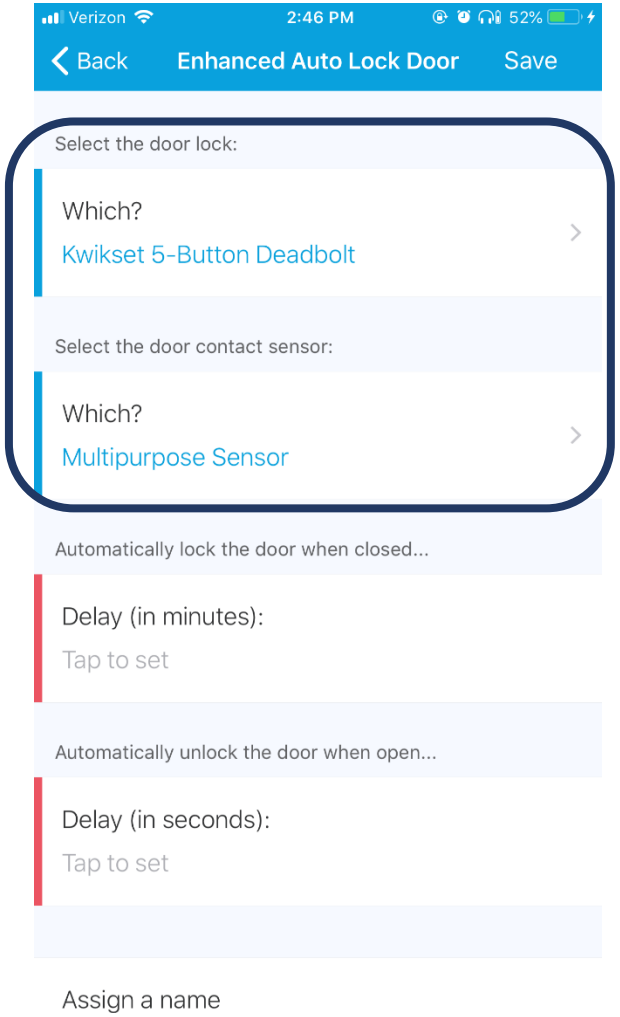
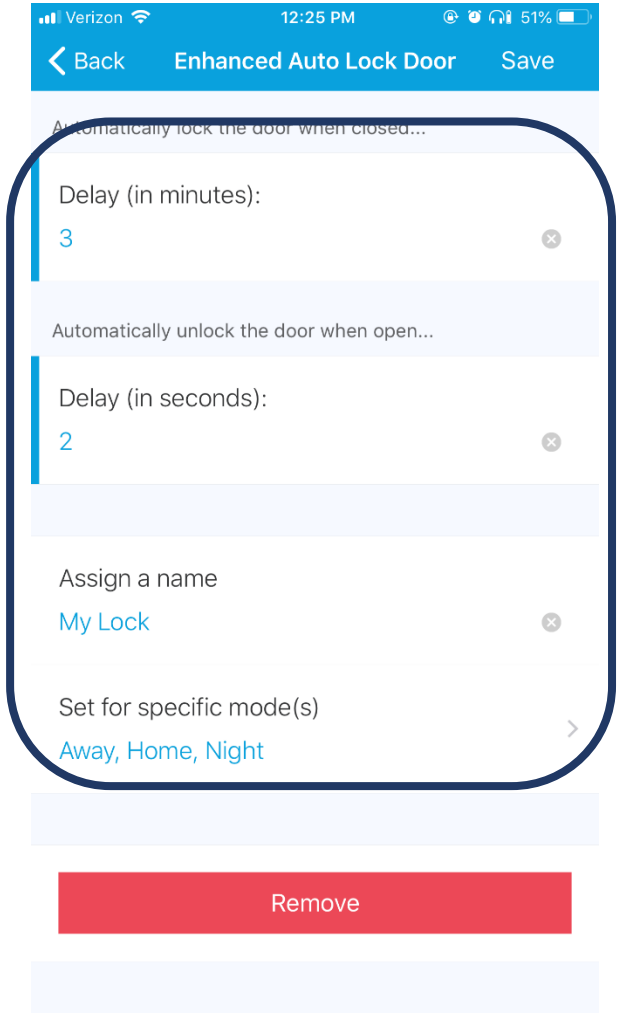


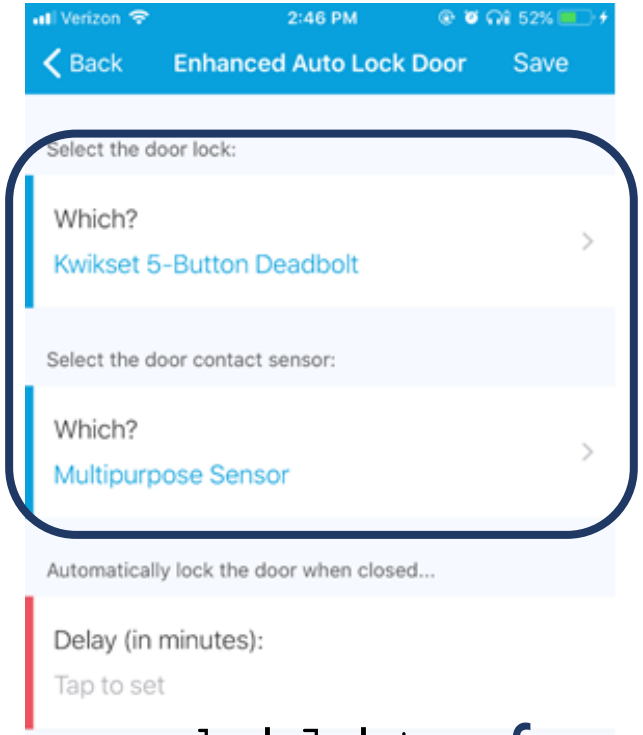
Enhanced Auto Door Lock SmartApp Example

- Install SmartApp
  - Enhanced Auto Lock Door
- Choose door lock and sensor





Enhanced Auto Door Lock SmartApp Example



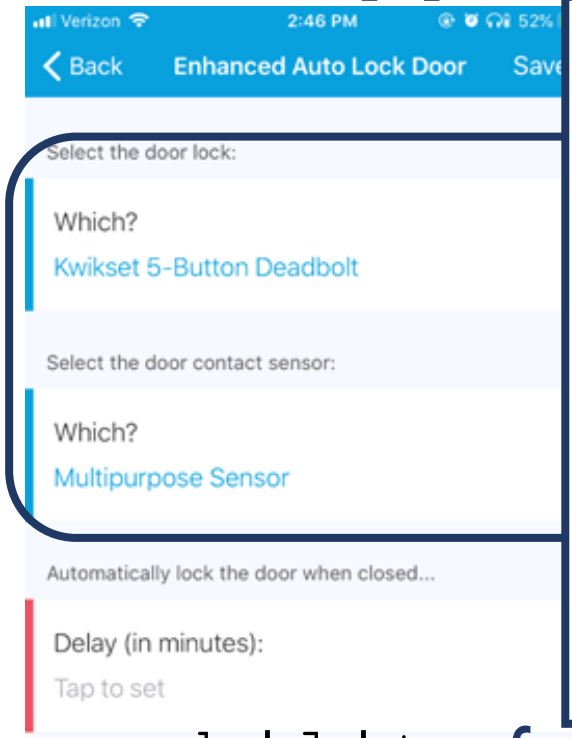

```
preferences{
    page name: "mainPage", install: true, uninstall: true
}

def mainPage() {
    dynamicPage(name: "mainPage") {
        section("Select the door lock:") {
            input "lock1", "capability.lock", required: true
        }
        section("Select the door contact sensor:") {
            input "contact", "capability.contactSensor",
required: true
        }
        section("Automatically lock the door when closed...") {
            input "minutesLater", "number", title: "Delay (in
minutes):", required: true
        }

        ...
}
```

- `capability` for security
  - SmartApp can only bind with and control certain devices, e.g., `capability.lock`

Enhanced Auto Door Lock SmartApp Example



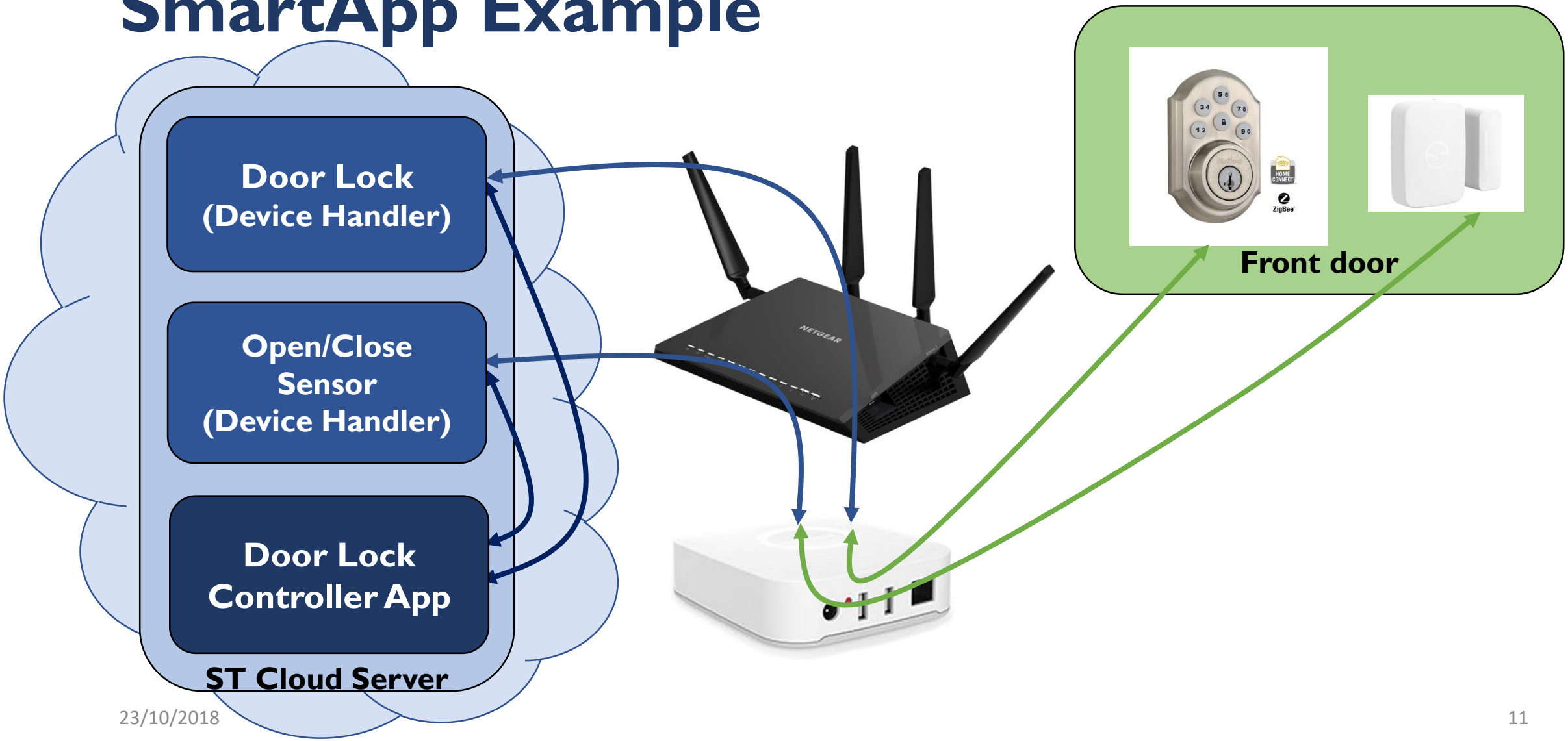

```
def lockDoor(){
    log.debug "Locking the door."
    lock1.lock()
    ...
}

def unlockDoor(){
    log.debug "Unlocking the door."
    lock1.unlock()
    ...
}

def doorHandler(evt){
    if ((contact.latestValue("contact") == "open") && (evt.value == "locked")) {
        ...
    }
    ...
}
```

- `capability` for security
  - SmartApp can only control certain device features, e.g., `lock1.lock()`

Enhanced Auto Door Lock
SmartApp Example



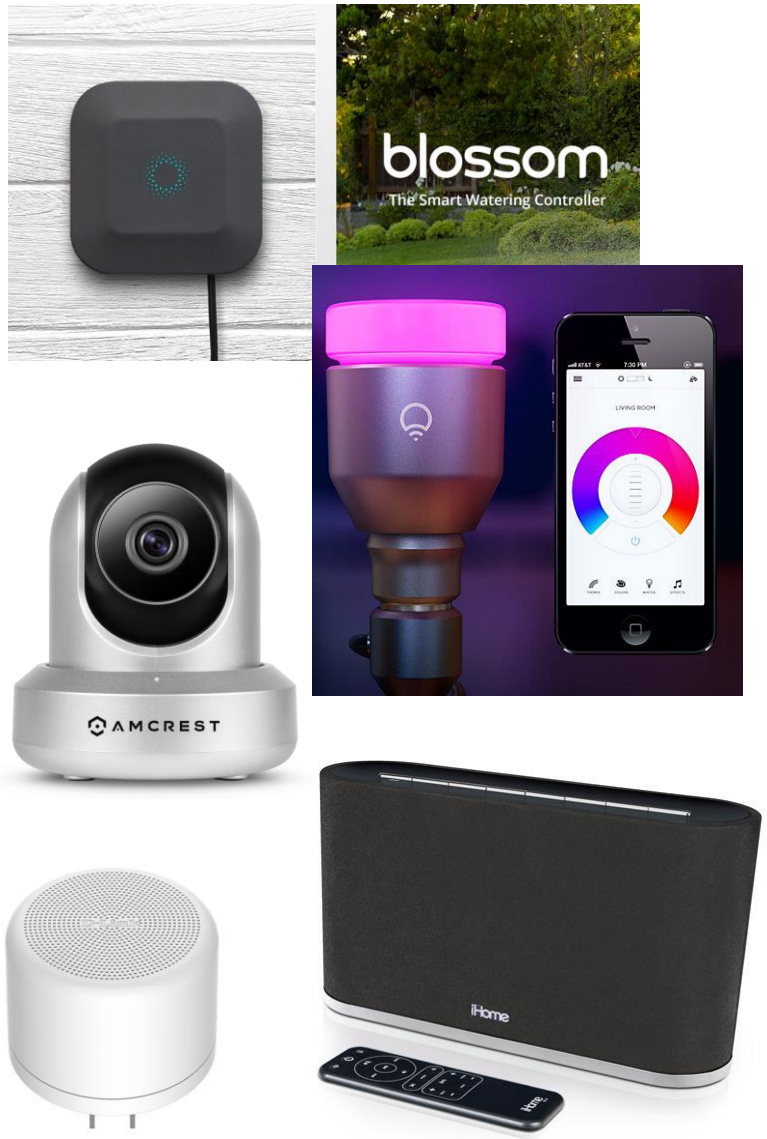
SmartThings Is Not Secure!

- Capability model breaks down
  - It is easily subverted!

- SmartThings prone to attacks
  - WiFi device attack
  - Cloud server attack
  - Bad SmartThings code attack

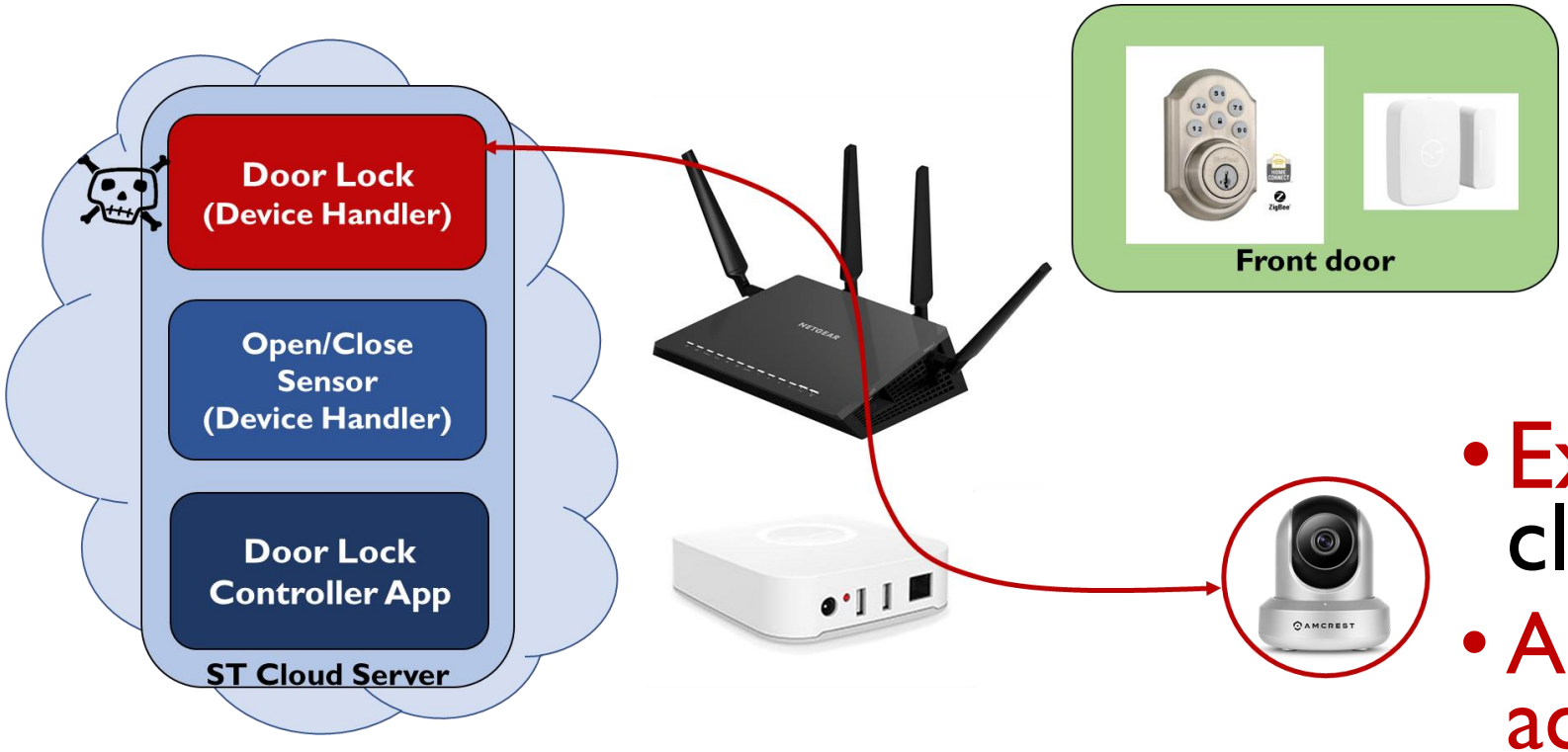
WiFi Device Attack

Device	Attack
Blossom sprinkler	Unauthenticated API access via port 80
LIFX light bulb	Unauthenticated access via port 56700
iHome speaker	Unauthenticated access via port 80
Amcrest camera	Weak authentication for video stream via port 80
D-Link siren	Brute-force-able PIN guessing via port 80



 http://www.kickstarter.com/, http://www.crutchfield.com/, https://www.amcrest.com, https://www.dlink.com/

Cloud Server Attack



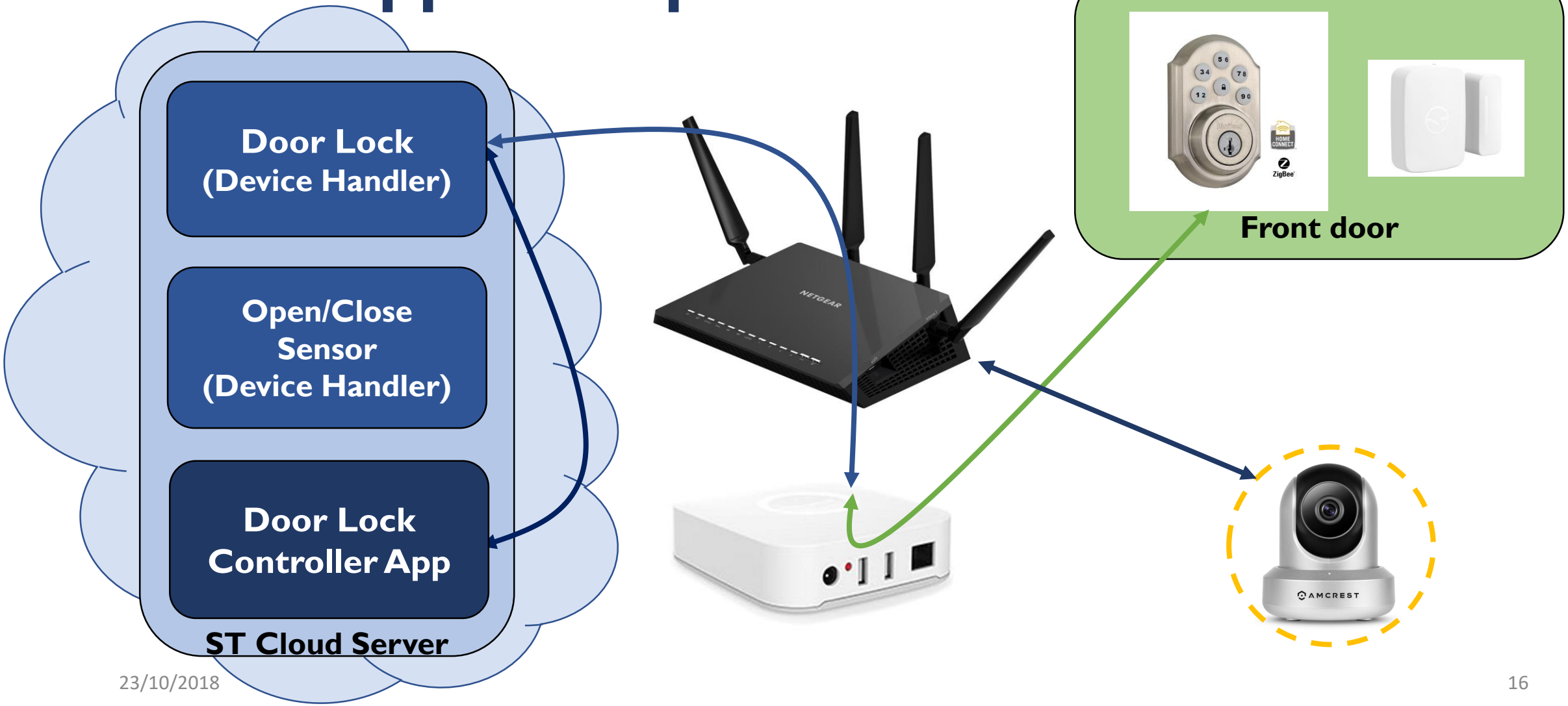
- Excessive access to cloud servers
- Arbitrary network access
- Smart hubs bypass router firewall "legally"!

Bad SmartThings Code Attack

- Device capability has security in mind, but flawed!
  - It restricts access based on capabilities
  - But, not enforced at network level

- Device handler code could be made to conspire with SmartApp
  - Spy on SSDP traffic of other devices
  - Communicate with arbitrary IP and ports
  - Send commands to arbitrary devices

Enhanced Auto Door Lock
SmartApp Example



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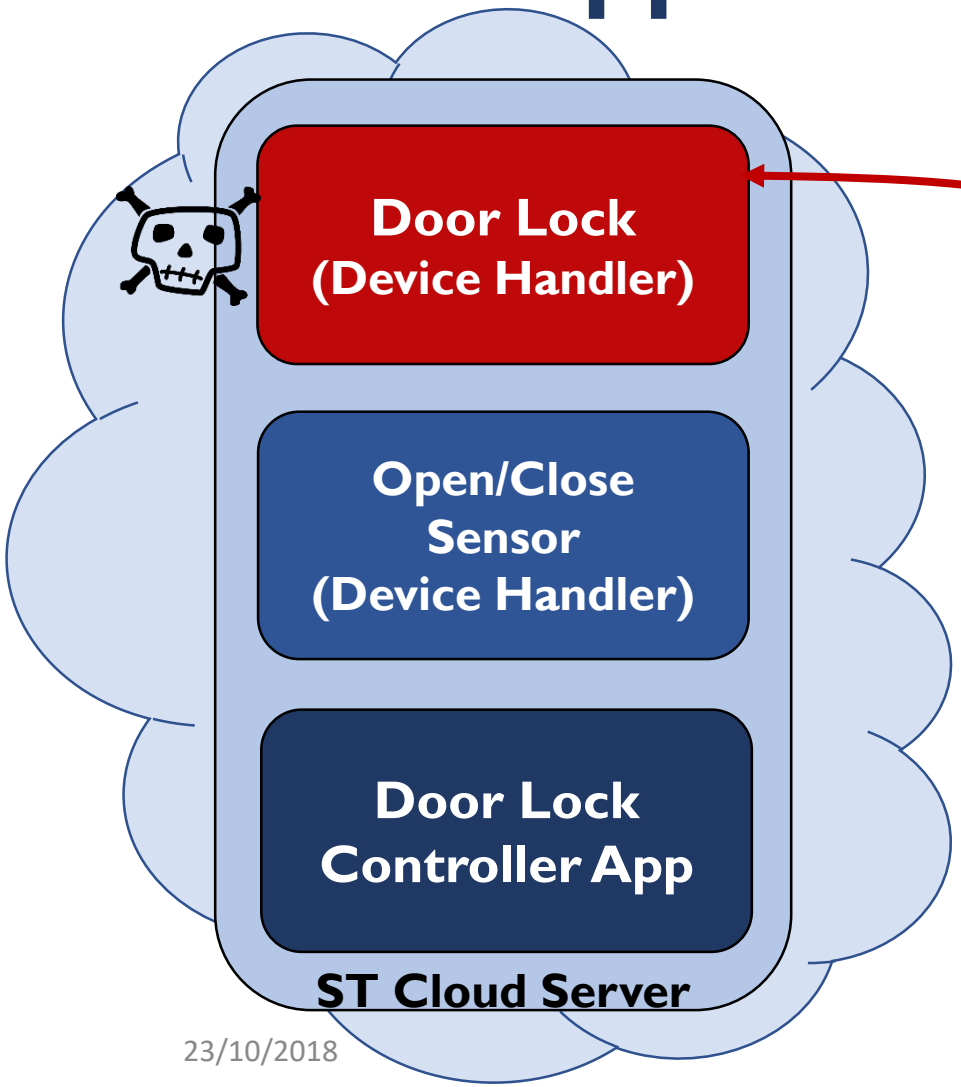
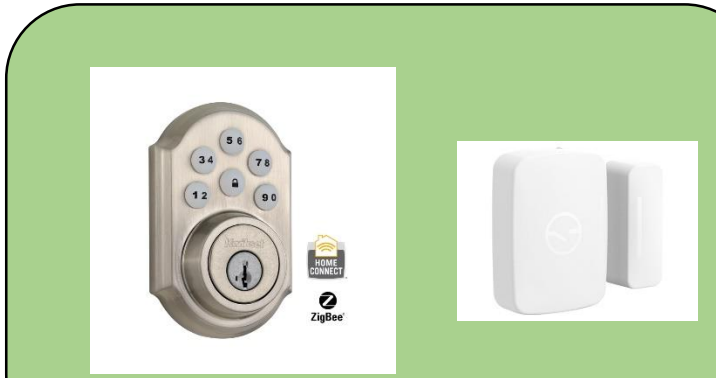




This device handler now CONTROLS the camera!

Enhanced Auto Door Lock SmartApp Example

Security Problem!

Door Lock Controller App

ST Cloud Server

https://www.featurepics.com/, https://www.youtube.com, https://www.dailymail.co.uk, https://www.collegehumor.com/

Threat Model

- Devices have vulnerabilities
- Attackers have full knowledge of the system
- Attackers have access to the home network via compromised device
  - **Not** physical access

Vigilia

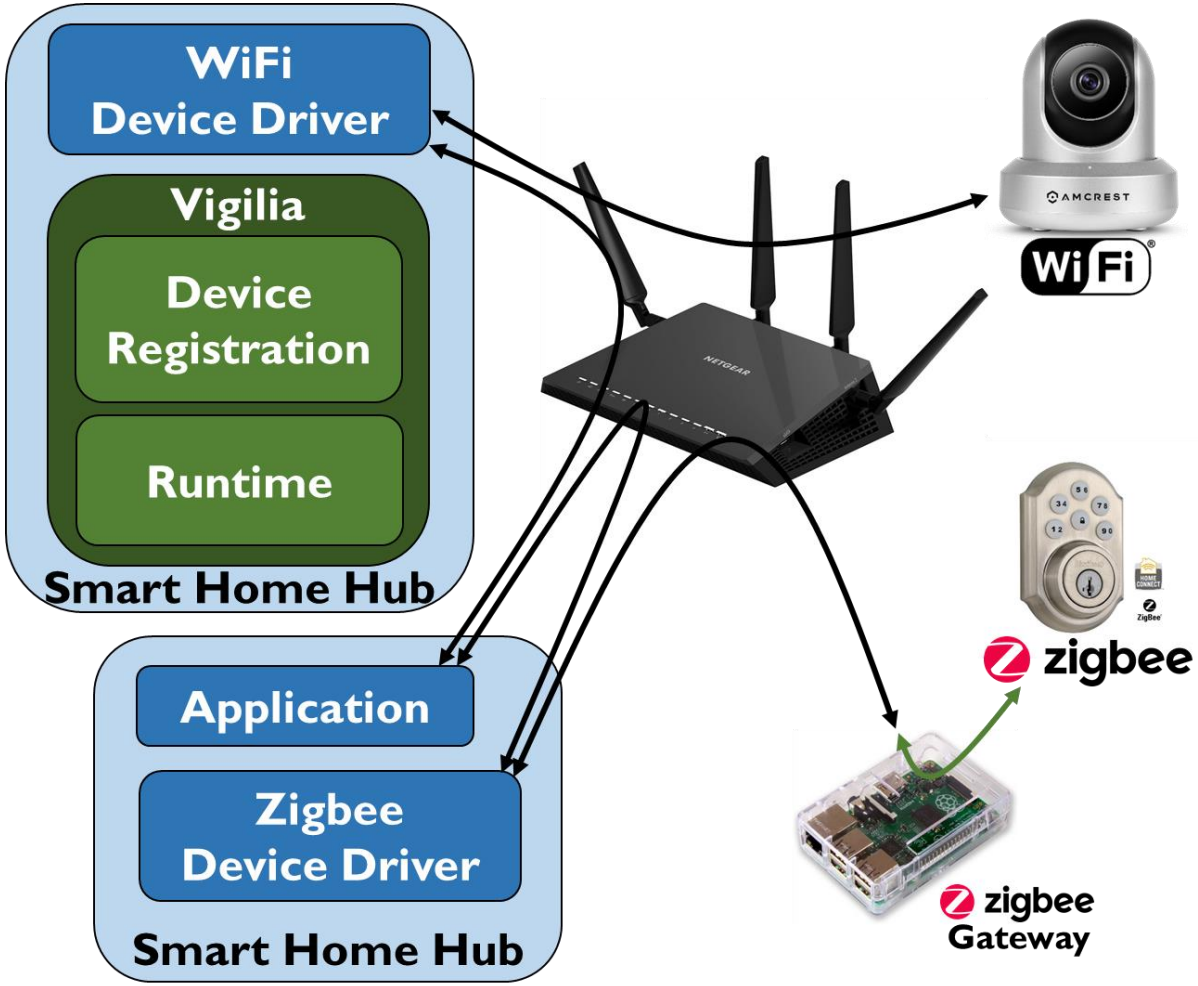
- Why not just fix SmartThings?
  - SmartThings is a closed solution
  - None of its source code is available
  - SmartApps run on SmartThings cloud

- Vigilia is an **open-source** implementation of SmartThings
  - Improved security aspect of SmartThings
  - Managed communication through cross-layer techniques

Vigilia Handles Excessive Access

SmartThings has

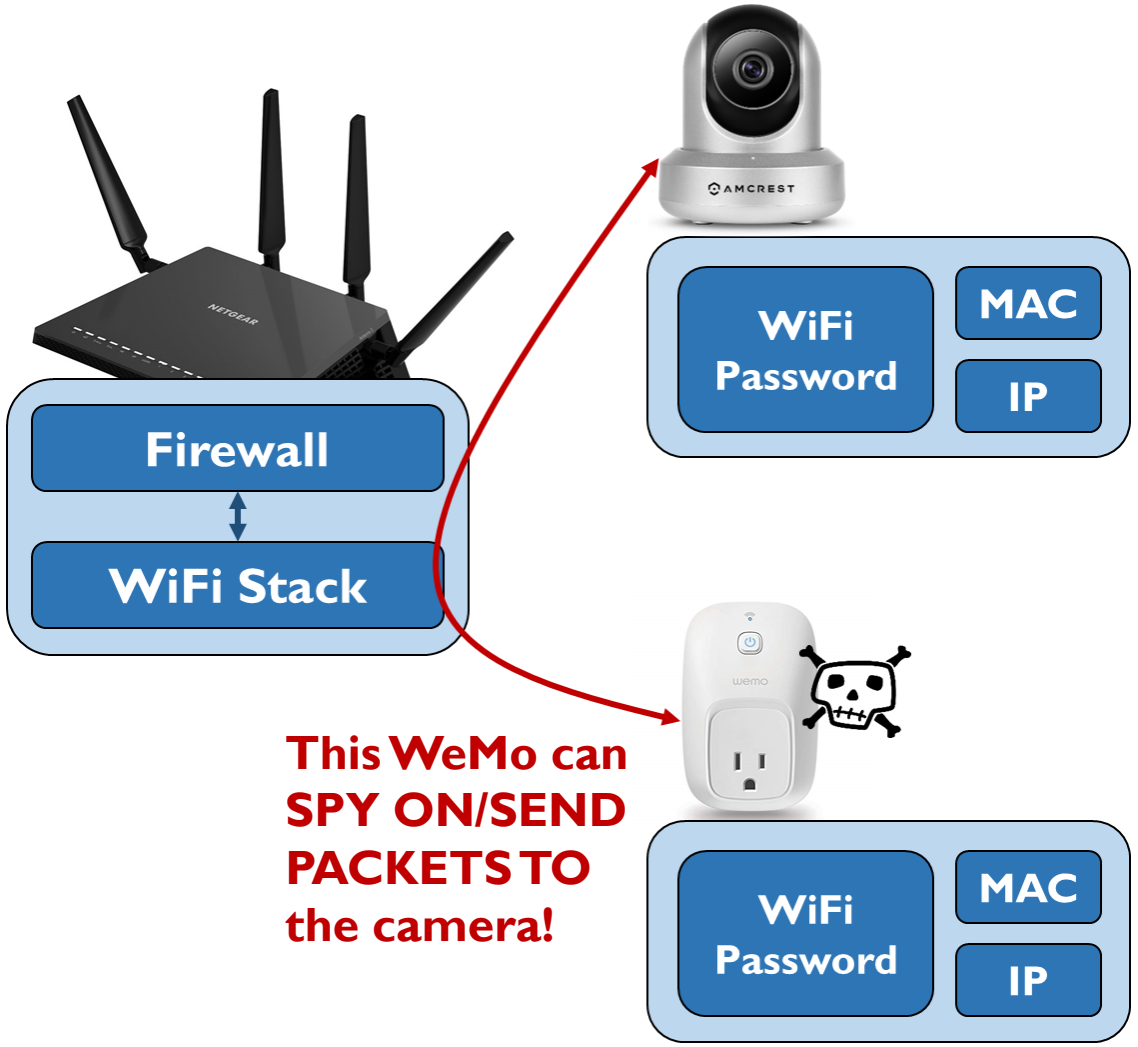
- **Configuration**
  - Install/register device
  - Binding with device handler
- **Capabilities**
  - Which specific device handler?
  - Which specific feature?
  - Binding with app
- **Restrict** communication at **network level!**



Typical Home Network

Problems

- Devices have no unique secrets
  - Can spy on packets sent to other devices
  - Can masquerade as other devices or even router
  - Can lie about MAC or IP
- Devices send packets directly to other devices
  - without going through the firewall



Vigilia Network

- Assigns
  - a **unique** WiFi **password**
  - to each WiFi device

Unique WiFi Password

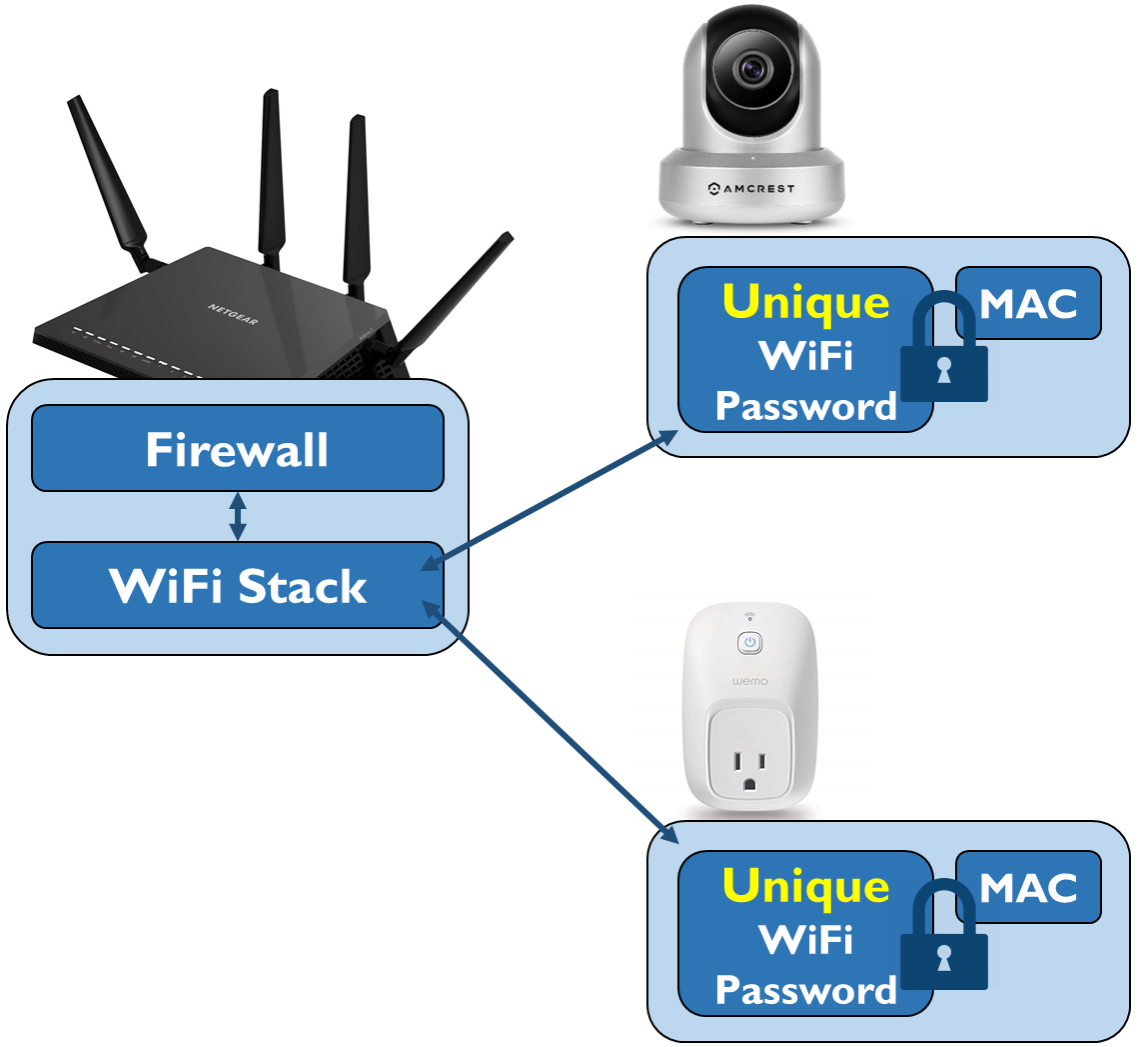
Result

- Devices **can't spy** on traffic between devices!

Unique WiFi Password

Vigilia Network

- Vigilia uses hostapd
  - to **lock MAC** address
  - to **specific** WiFi password

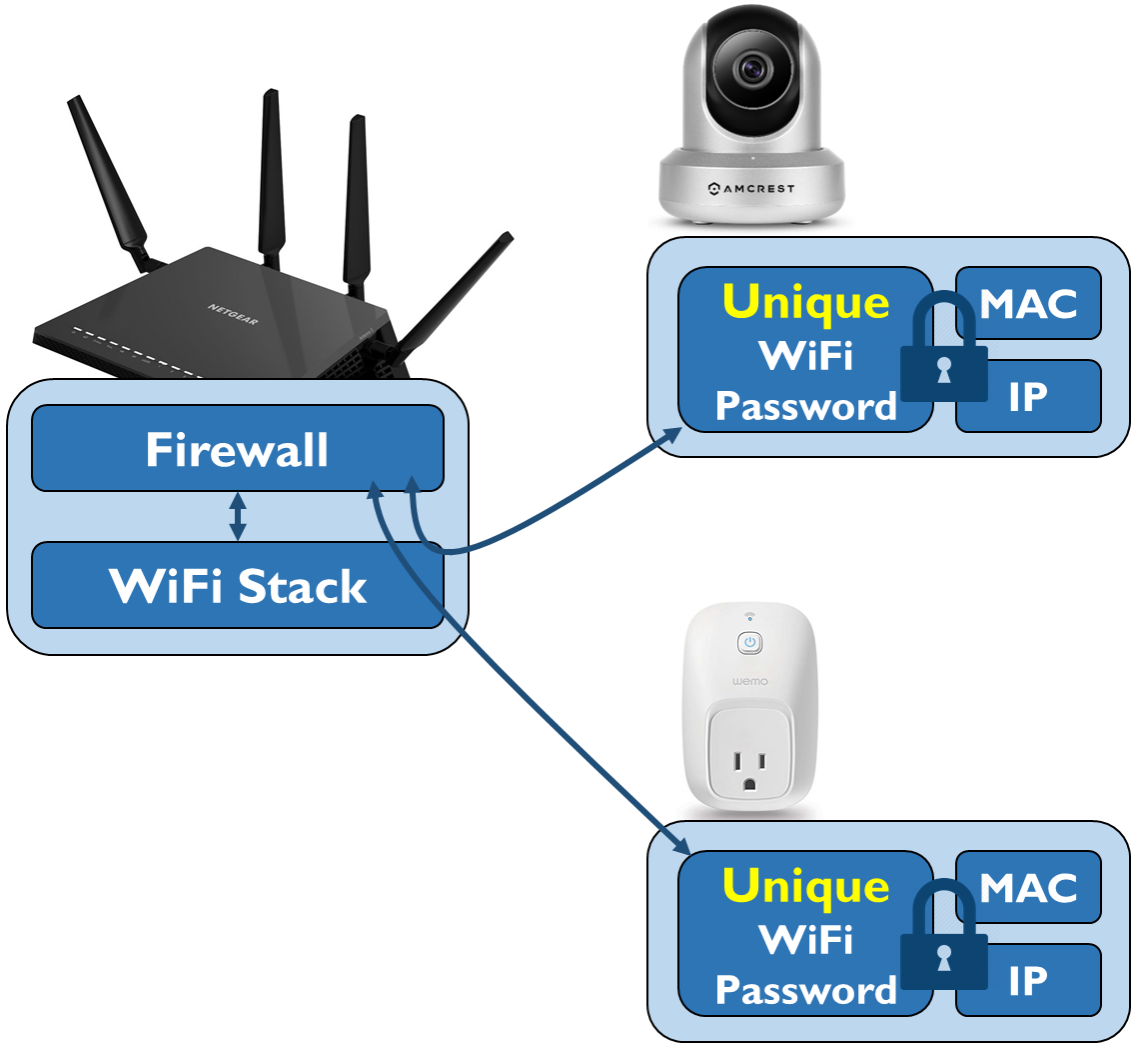


Result

- Devices **can't lie** about **MAC** addresses!

Vigilia Network

- Vigilia **isolation + hairpin**
  - **force** all communications to go through **firewall**
  - firewall **locks IP to MAC**



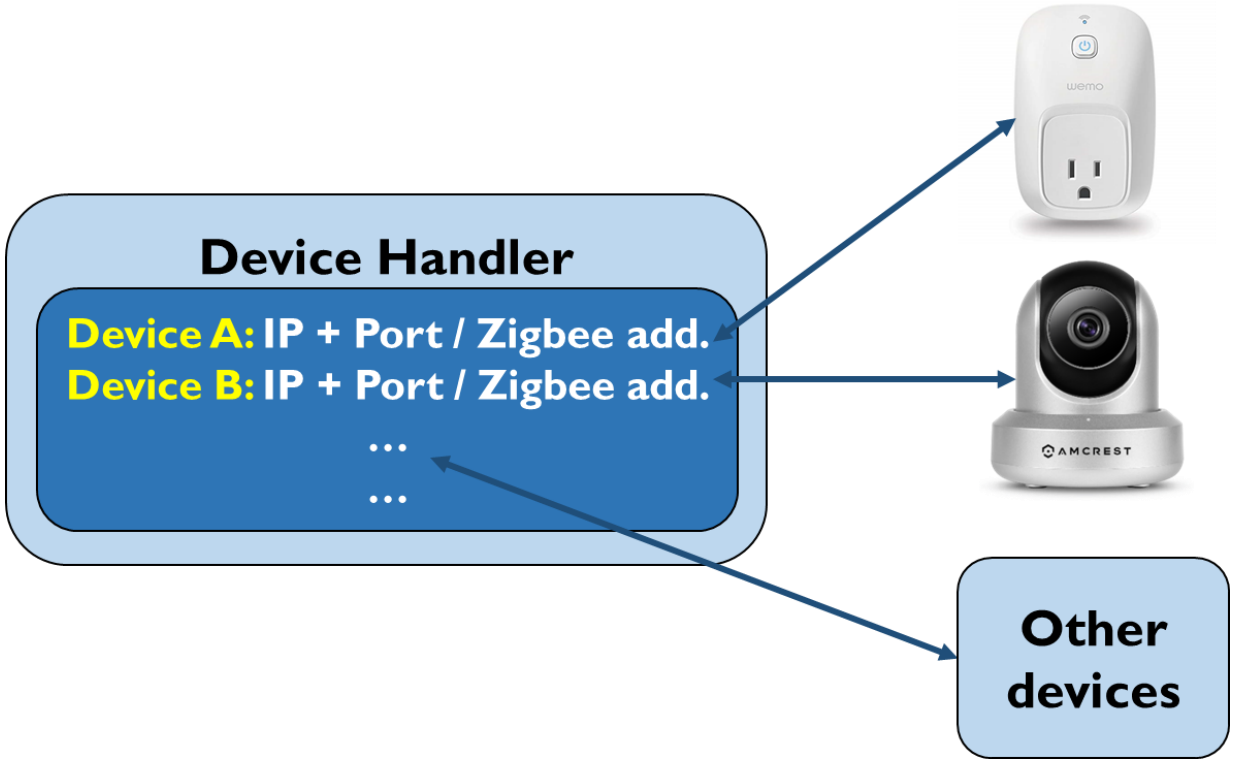
Result

- Devices **can't communicate** unless firewall **allows**
- Devices **can't lie** about **IP** addresses

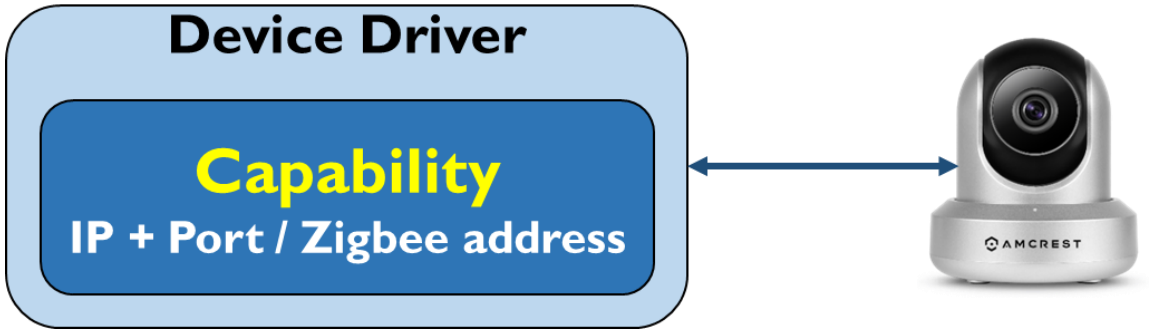
SmartThings Device Model

Problem

- Device handlers have excessive network access
  - TCP/IP handlers can specify and connect to any IP + port
  - Zigbee handlers can specify and connect to any Zigbee device address
  - All handlers can see SSDP traffic



Vigilia Device Model



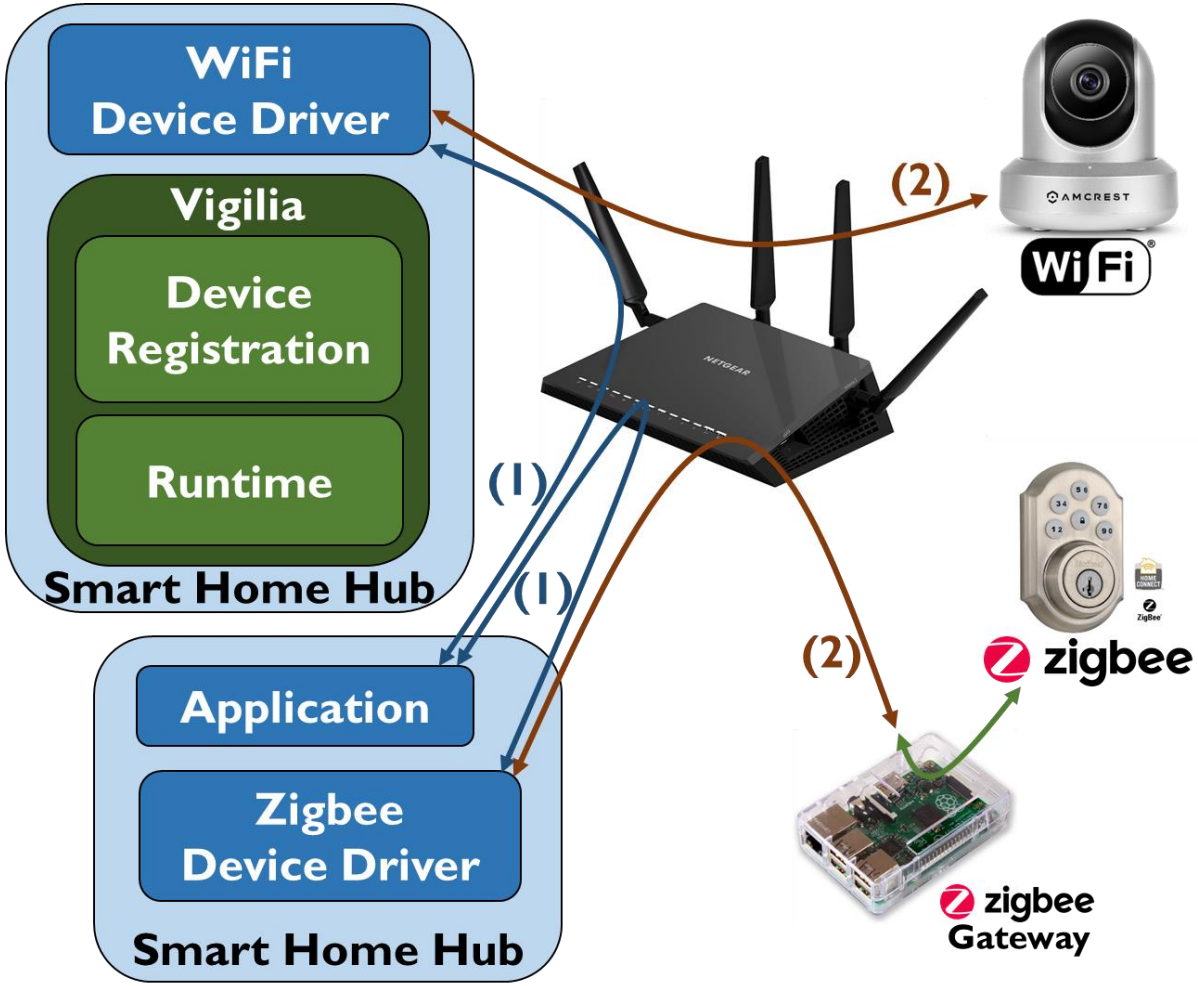
- Vigilia tracks local devices' IP addresses
- Vigilia gives drivers access to devices via capability
- Capabilities only allow communication with specific devices
  - Drivers only specify which devices
  - Runtime assigns driver IP + port / Zigbee address
  - Runtime can confidently enforce firewall rules without breaking

Vigilia Configuration

- Configuration contains two types of binding

  (1) App to device handler/driver

  (2) Device handler/driver to device



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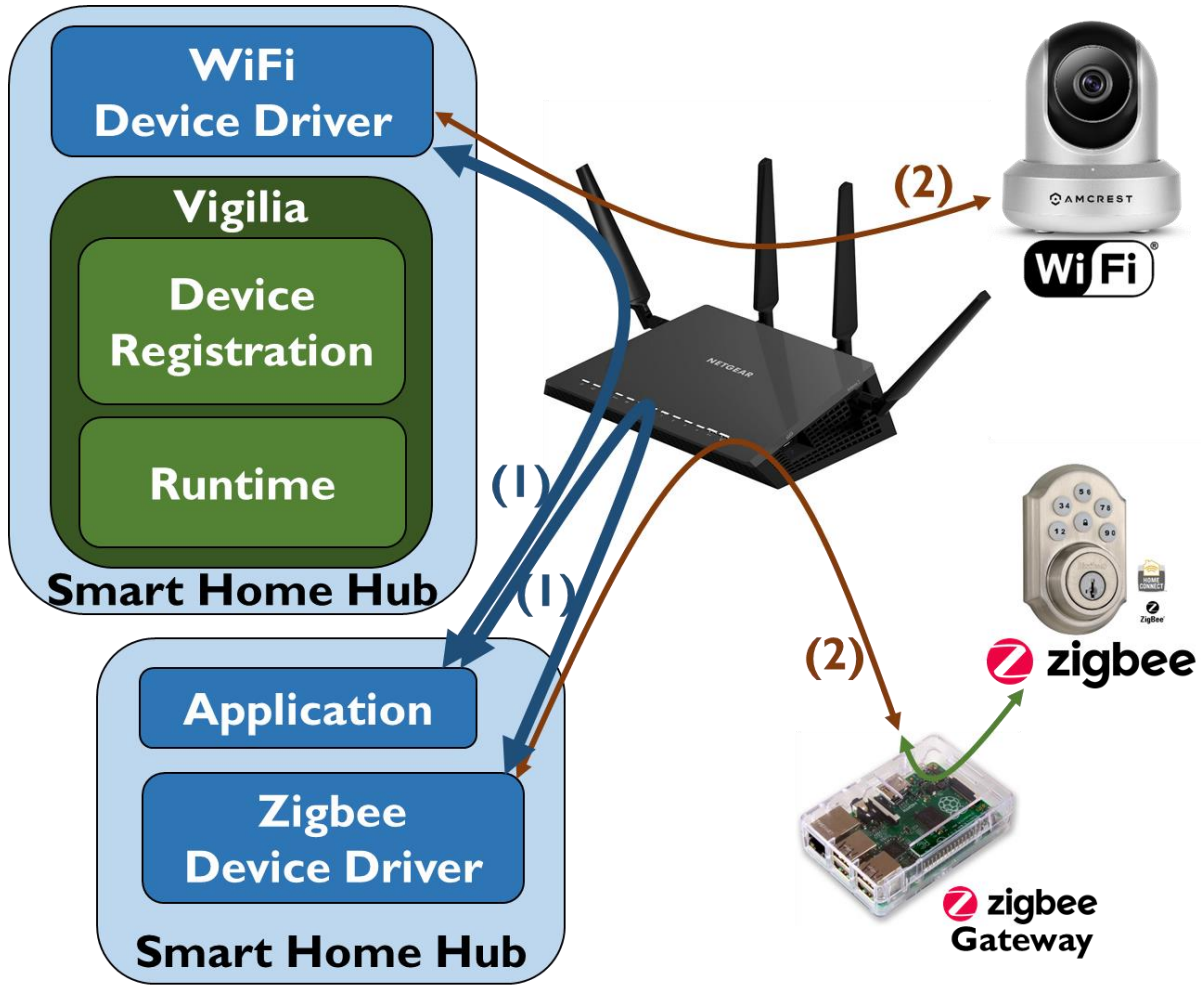

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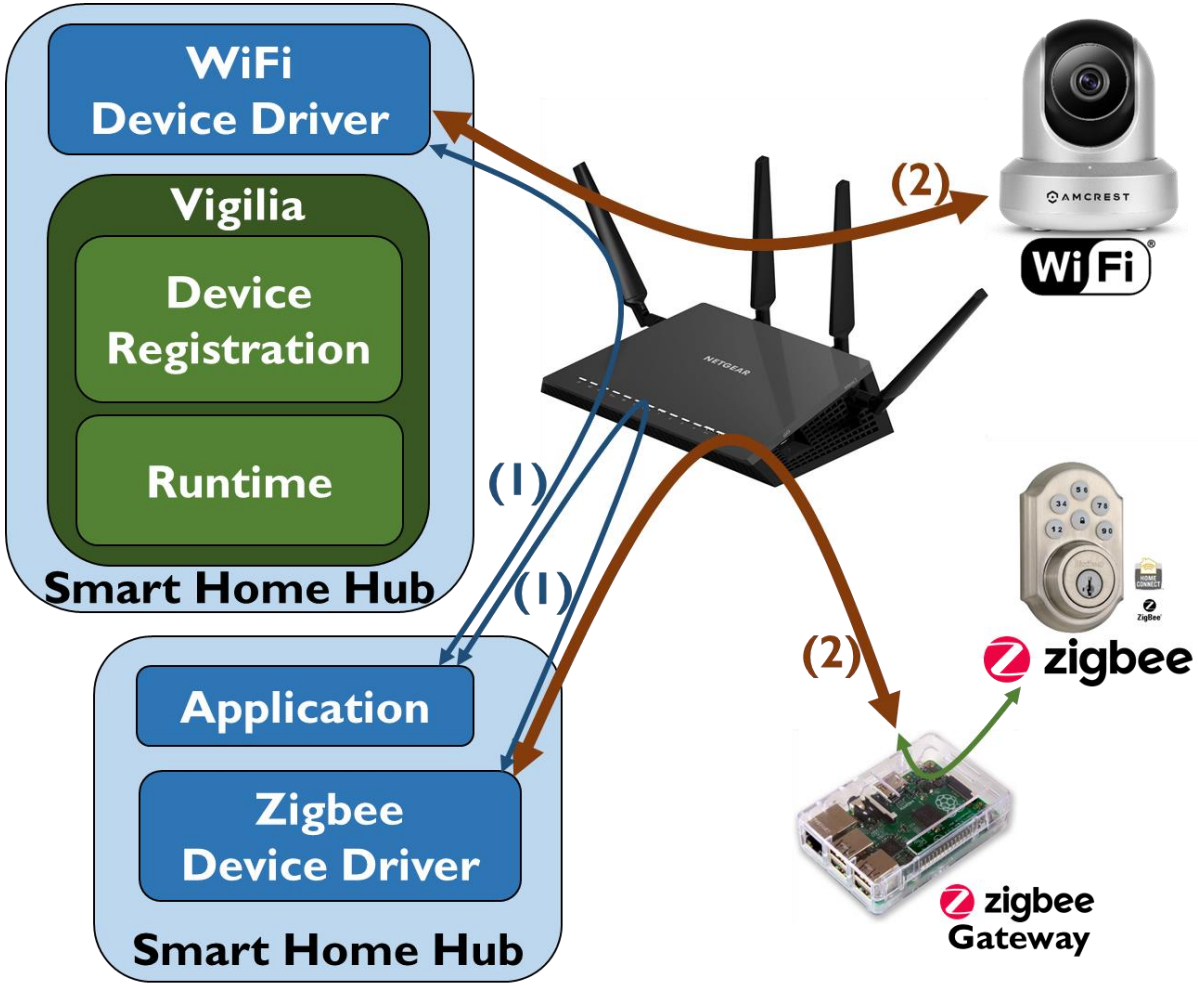
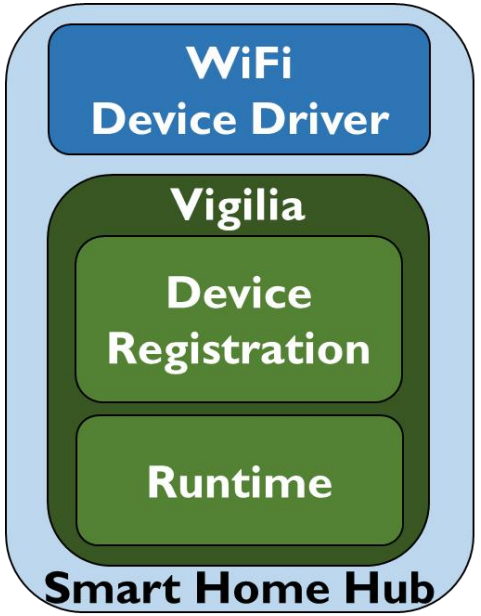
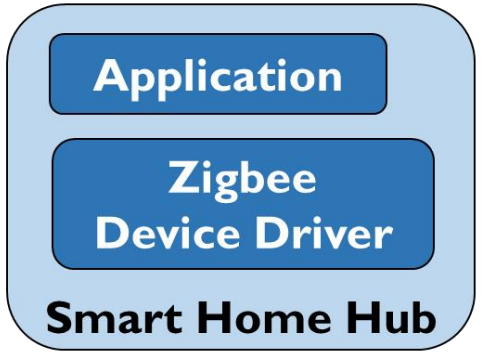


Securing App to Device Driver Binding

- **Isolate** components in **sandbox**
  - Lock to files + IP + port
- **Filter request**
  - At destination for capability access
- **Use firewall rules**
  - **Allow** specified communications
  - **Block** everything else





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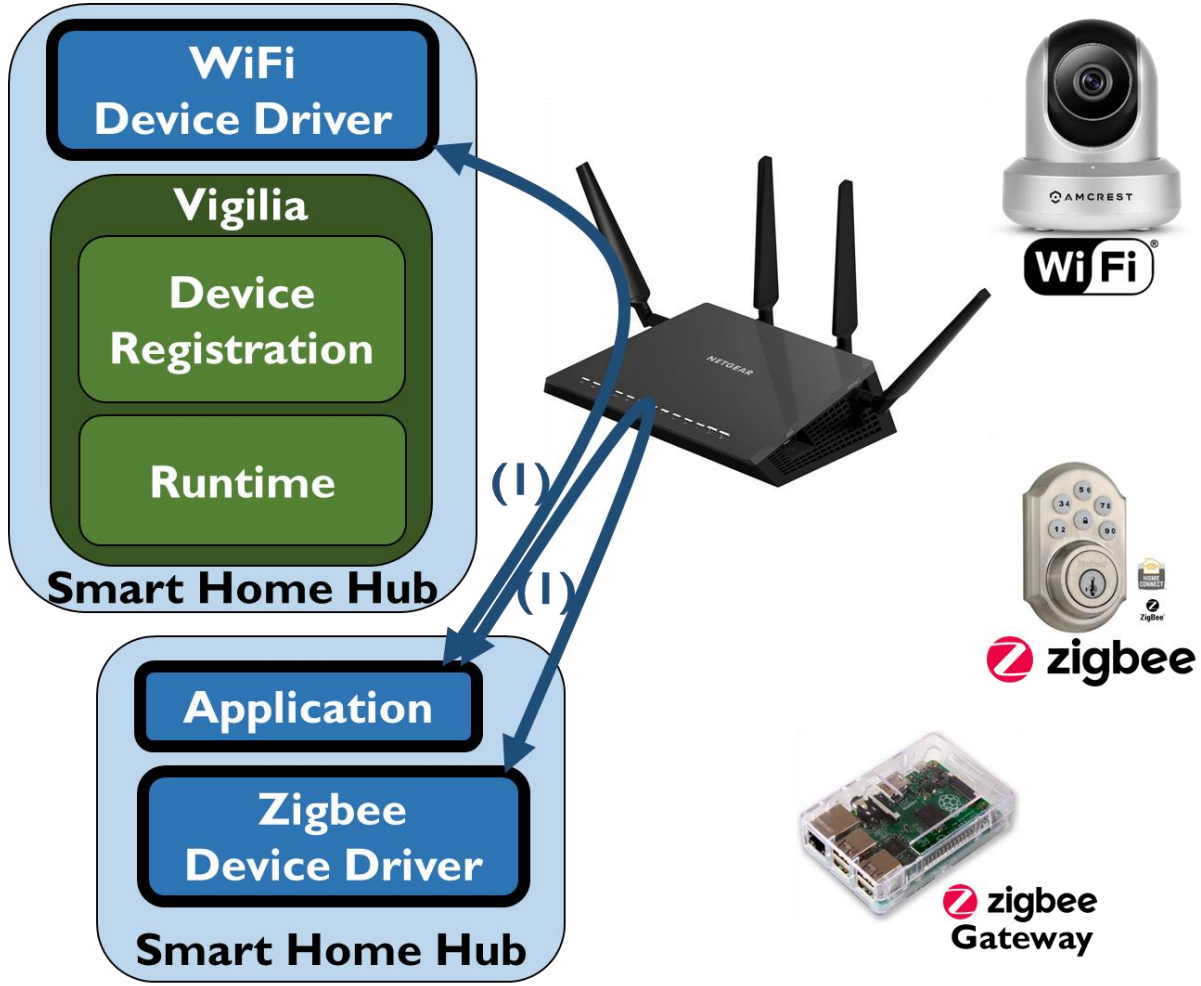

Securing TCP/IP Devices

- Device driver **capability**
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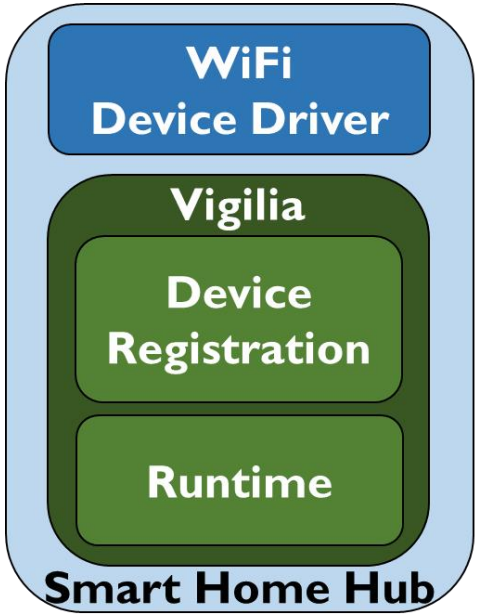

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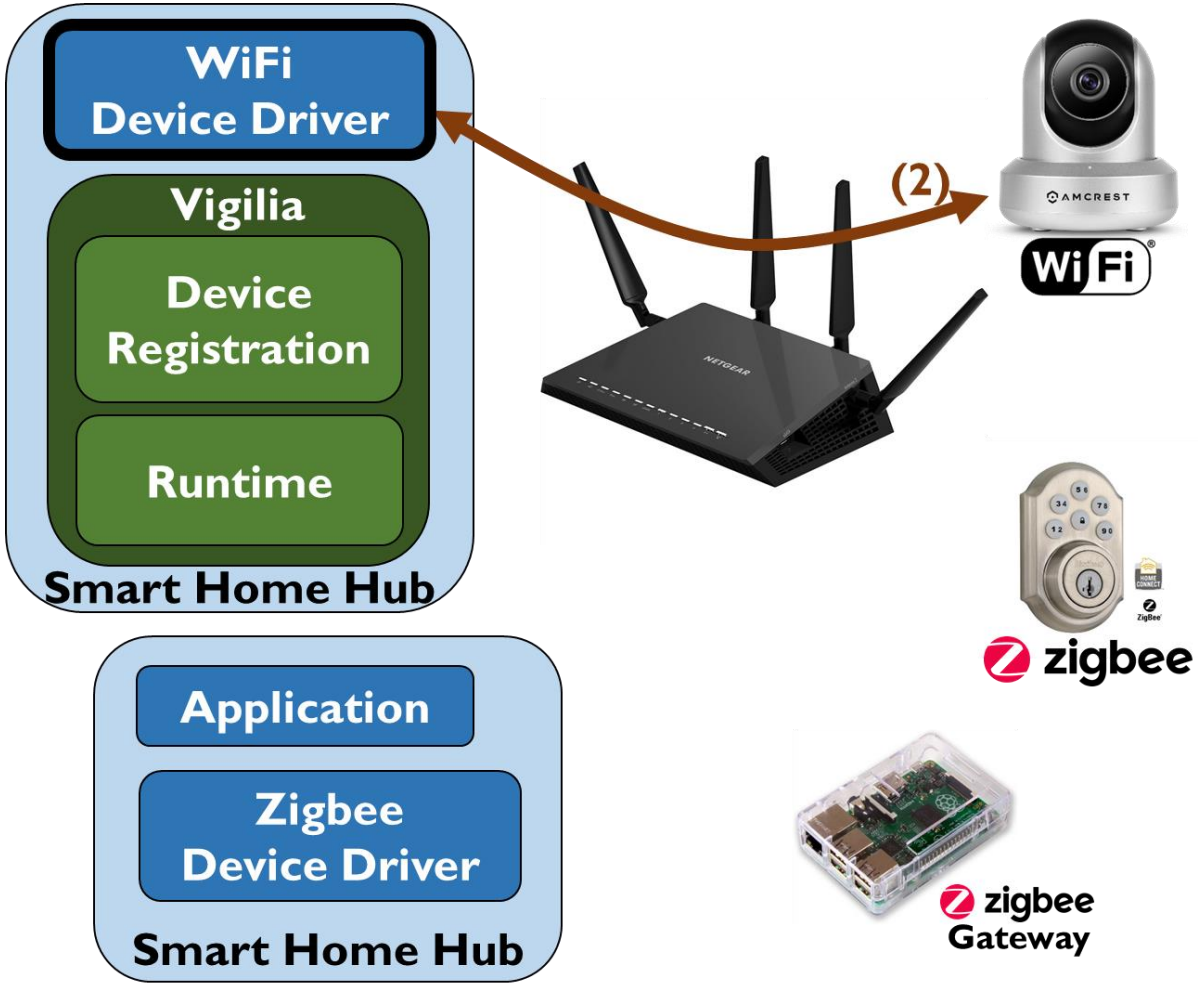
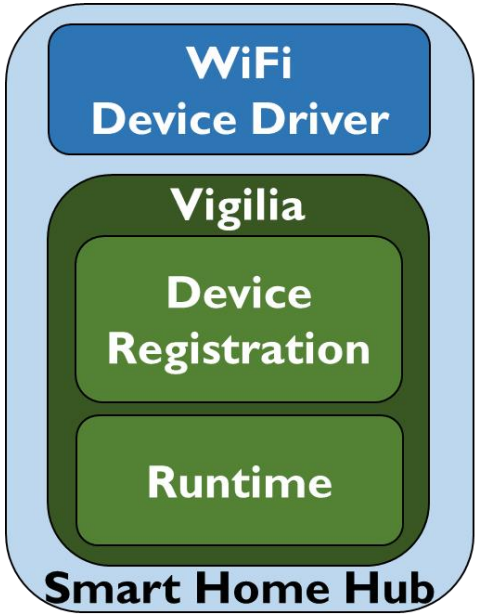
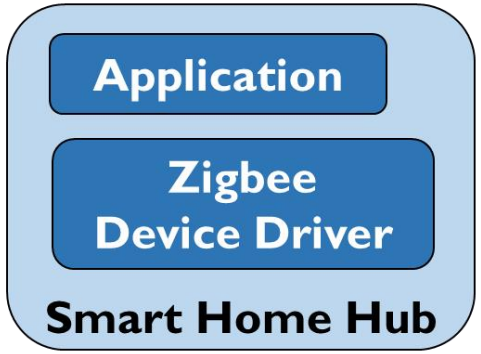


Securing Zigbee Devices

- Device driver **capability**
  - **Zigbee packet filter** on Zigbee gateway
  - Multiple Zigbee drivers can talk to gateway
  - Only **the right one** can send packets to device





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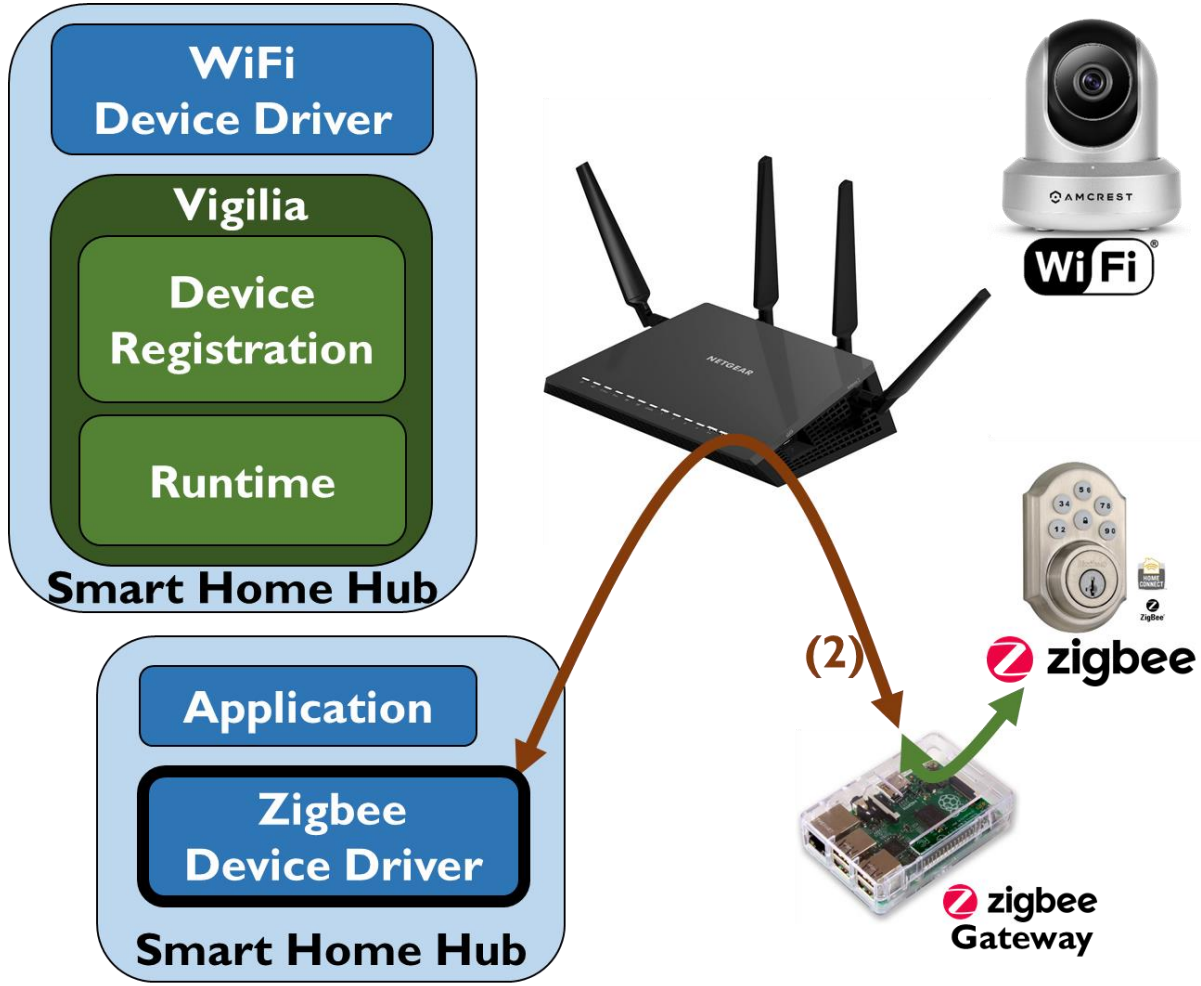

Vigilia Guarantees

- All communications from **non-malicious apps** will be **allowed**

- All communications **not explicitly configured** are **blocked**

Experience

Vigilia App	Devices	
	Input	Output
Irrigation	Soil moisture sensor (Zigbee) Weather report website https://openweathermap.org/	Sprinkler
Lights	Cameras	Light bulbs
Music	GPS (smartphone)	Speakers
Home security	Motion, water-leak, multipurpose sensors (Zigbee) Camera	Siren/Alarm Door lock

Attacks

Attack	Application	Details
Sprinkler	Sprinkler	Run API via port 80 (HTTP)
Light bulb	Lights	Turn on/off via port 56700
Speaker	Music	Play music via port 80 (HTTP)
Camera	Home Security	View camera via port 80 (HTTP)
Siren/Alarm	Home Security	Brute-force PIN & access via port 80 (HTTP)
Deauthentication	All	Jam WiFi access & let device join a malicious WLAN router

Attacks

Attack	Normal*	IoTSec	Vigilia
Sprinkler	✓	✓	X
Light bulb	✓	✓	X
Speaker	✓	X	X
Camera	✓	✓	X
Siren/Alarm	✓	X	X
Deauth. + Sprinkler	N/A	N/A	X
Deauth. + Light bulb	N/A	N/A	X
Deauth. + Speaker	N/A	✓	X
Deauth. + Camera	N/A	N/A	X
Deauth. + Siren/Alarm	N/A	✓	X

✓ = attack success

X = attack thwarted

***Normal** = standard router, including **Norton Core** and **Bitdefender Box 2**

Public IP Experiment

- 16 smart home devices
  - Exposed to the Internet – public IP
  - Duration of 10 days
- Total of **38,296** access attempts
  - TCP (e.g., TCP SYN/ACK)
  - UDP
  - ICMP

Public IP Experiment – Cameras

- Four Amcrest cameras – 14 hours of exposure

- With Vigilia – only 551 attempts
- With password only – **31,230** attempts
- No protection
  - All 4 disabled in 15 minutes!
  - 172 – 362 packets per camera
  - XML-RPC attack via HTTP (port 80)

Conclusions

- Smart home IoT devices have vulnerabilities
- Cannot manage security for individual (simplistic) devices
- Manage the communications!

- Download: **http://plrg.eecs.uci.edu/vigilia/**

Please find more details in the paper!

Thank you! ☺

zigbee

Z-WAVE

Wi Fi