IoT hacking

IoT basics

- Internet of things
- Extends Internet connectivity beyond standard devices to everyday objects
- Usually uses IPv6 due to the limited number of IPv4 addresses
- Operating systems: Linux or Windows (10) IoT

Top-level components

- **Device**
  - Includes hardware and software that directly interact with the world.
  - They connect to a network to communicate with each other, or to centralized applications
- **Gateway**
  - Enables services to reach cloud services.
  - Infrastructure component providing security and protocol translations
  - Also used as a service that process data on behalf of group or cluster devices.
  - Often a device e.g. smart home hub.
  - Usually from the same vendor
- **Cloud**
  - See cloud computing
- **Sensors**
  - Detects, measures or indicates any specific physical quantity
  - E.g. light, heat, motion, moisture, pressure, or similar entities
  - Converts them into any other form which is mostly, electrical pulses.

IoT communication models

Device-To-Device (D2D)

- Direct communication between devices
- Uses a medium such as Bluetooth Low Energy etc.
- Common in home automation systems e.g. light bulbs or wearables e.g. smart watch and heart monitor.
- Simpler security
- E.g. **Vehicle-to-vehicle (V2V)**
  - Uses Vehicle Ad Hoc Network (VANET)
    - Based on MANET i.e. decentralized wireless network (without routers)

Device-To-Cloud (D2C)

- IoT device directly communicating with the cloud server
- Often uses ethernet or WiFi
- Lets the user (and an application) to obtain remote access to a device
- E.g. smart card for dogs, remote monitoring
- Two credentials:
  - the network access credentials (such as the mobile device's SIM card)
  - credentials for cloud access
- E.g. Nest Learning Thermostat

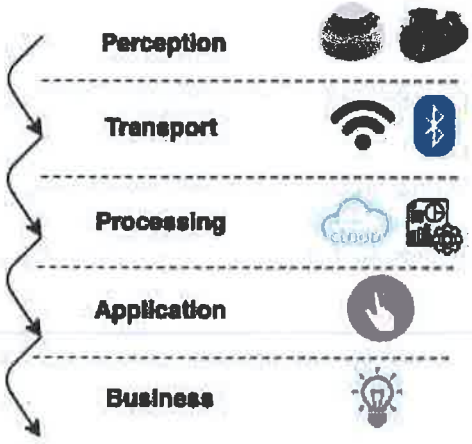
Device-To-Gateway (DTG)

- IoT devices basically connect to an intermediary device to access a cloud service
- Often includes an application software operating on a local gateway device (like a smartphone or a "hub")
- Gateway provides security, protocol translation and usually does aggregation
- E.g. Samsung SmartThing ecosystem

Back-end data-sharing

- Extends device-to-cloud model
- Access are granted to the uploaded data to third-parties
- E.g. Map My Fitness that compiles data from other applications

Five layer IoT architecture

- Each layer is utilized by layer below without knowledge of other layers
- 

- Read more: IoT Elements, Layered Architectures and Security Issues: A Comprehensive Survey

Business layer

- Includes business models
- System management
- **Key security components**: privacy protection
- **Vulnerabilities**

    - Business logic attack: exploits a programming flaw
    - Zero-day attack: exploits security hole unknown to the vendor

Application layer

- Graphic data representation
- Application specific services
- **Key security components**: authentication, key agreement
- **Vulnerabilities**
    - Cross site scripting: injecting code through e.g. JavaScript
    - Malicious code attack: can activate itself or require user attention to perform an action.
    - Dealing with Mass Data
        - Caused by massive amount of data transmission
        - Can lead to data loss and network disturbance

Processing (middleware) layer

- Data analytics: storing, processing and analysis of data
- **Key security components**: key security layer, secure cloud computing, antivirus
- **Vulnerabilities**
    - Exhaustion: Can disturb memory, battery e.g. after effect of a DoS
    - Malware

Network (transport) layer

- Data transmission: Transfer the data through network
- E.g. Wi-Fi, bluetooth
- **Key security components**: encryption, identity authentication
- **Vulnerabilities**
    - Denial of Service (DoS) Attack with redundant requests
    - Main-in-The-Middle (MiTM) Attack: to intercept and manipulate data in real-time
    - Storage Attack: Changing data stored in device or cloud
    - Exploit attack: Exploits vulnerabilities in an application, system or hardware

Perception layer

- Physical objects that gather environment data
- Sensors, actuators e.g. heat sensor
- **Key security components**: encryption and key agreement, sensor data protection
- **Vulnerabilities**
    - Eavesdropping: real time attack to intercept privacy communications.
    - Node Capture: capturing a key node such as gateway to reveal information.
    - Fake Node and Malicious: adding node to input fake data to stop transmitting real information

- Replay (play back) attack: eavesdrops a communication and reusing it to authenticate.
- Timing Attack: Extract secrets by observing respond time

IoT connectivity

Wireless IoT connectivity

Approx. range up to	Connectivity	Speed
10 cm	NFC	424 kbit/s
1 m	RFID	300 tags per second
10 m	Li-Fi	100 gbit/s
60 m	Bluetooth low energi (BLE)	1 or 2 mbit/s
100 m	WiFi	1300 mbit/s
1 km	Wi-Fi HaLow	78 mbit/s
2 km	5G	20 gbit/s
30 km	LTE-Advanced	300 mbit/s
70 km	Celullar	- (depends on 4g etc.)
1000 km	LPWAN	200 kbit/s
World-wide	VSAT	16 mbit/s

Short-range wireless communication

- **Bluetooth Low Energy (BLE)**
  - Newer versions of bluetooth (after 4.0)
  - Optimized for battery usage.
- **Wi-Fi**
  - Wireless network protocol using radio waves.
  - Wi-Fi 6 specification standard (2020) is the latest standard (x6 faster).
- **Radio-Frequency Identification (RFID)**
  - Data storage tag that can be attached to an item for tracking
  - Passive tag has range up to 1m while active tags can go up to 100m.
  - Used in e.g. passports, credit cards.
- **Li-Fi (Light-Fidelity)**
  - Similar to Wi-Fi, but using visible light for communication
- **Near-Field Communication (NFC)**
  - Based on a radio frequency (RF)
  - Used e.g. in phones, payment cards
  - Must either either physically touch or be in a few centimeters of each other.

Medium-Range Wireless Communication

- **LTE-Advanced**: Formally submitted as a candidate 4G, often being described as 3.9G.
- **Wi-Fi HaLow**: low power, long-range, also known as "WiFi for Internet of Things"
- **5G**: Introduced in 2019, highest with minimum of 10 Gbps

Long Range Wireless Communication

- **Low-Power Wild-Area Network (LPWAN)**
  - Long range communication (up to 10 km) at a low bit rate
- **(VSAT) Very Small Aperture Terminal**
  - World-wide satellite communication technology uses small dish antennas
- **Cellular** using e.g. radio towers to spread e.g. 4G, 5G..

Wired IoT connectivity

- **Ethernet** (cat 6 up to 10 Gbps speed)
- **Power-Line Communication (PLC)** : using electrical wiring to carry power and data, around 200 Mbit/s.

IoT security

IoT threats

- **Lack of security**
  - Speed at which IoT is advancing makes it harder to keep up with evolving security requirements.
  - Being short on processing power and memory leads to lack of security solutions and encryption protocols.
- **Vulnerable interfaces**
  - For both device interfaces and other interfaces (e.g. cloud) it interacts with
  - E.g. lack of authentication/authorization, lacking or weak encryption, and a lack of input and output filtering.
- **Physical security risk**
  - Cannot secure them as traditional devices by e.g. the storage of routers in secure cabinets
- **Lack of vendor support**
  - The support of a certain device may get discontinued
- **Difficult to update firmware and OS**
  - Some require manual intervention to be upgraded, some cannot be upgraded at all
  - Being compliant makes harder to do changes to e.g. medical devices.
- **Interoperability issues**
  - Interoperability: "the ability to make systems and organizations work together" | Wikipedia
  - Each solution provides its own IoT infrastructure, devices, APIs, and data formats
  - Caused by competitive nature of IoT e.g. vendor lock-in

OWASP Top 10 IoT (2018)

- OWASP Internet of Things Top Ten was introduced in 2004 and updated in 2018

1. **Weak, guessable, or hardcoded passwords**
   - Use of easily brute forced, publicly available, or unchangeable credentials
   - Including backdoors in firmware or client software that grants unauthorized access to deployed systems
2. **Insecure network services**
   - Unneeded or insecure network services running on the device itself
   - Bigger threat for those that are expose to the internet
   - Allows compromise confidentiality, integrity/authenticity, or availability of information or allow unauthorized remote control...
3. **Insecure ecosystem interfaces**
   - Includes web, backend API, cloud, or mobile interfaces outside of the device
   - Allows compromise of the device or its related components.
   - E.g. lack of authentication/authorization, lacking or weak encryption, a lack of input and output filtering.
4. **Lack of secure update mechanism**

    - Lack of firmware validation on device
    - Lack of secure delivery (un-encrypted in transit)
    - Lack of anti-rollback mechanisms
    - Lack of notifications of security changes due to updates.
5. **Use of insecure or outdated components**
    - Use of deprecated or insecure software components/libraries
    - Insecure customization of operating system platforms
    - Use of third-party software or hardware components from a compromised supply chain
6. **Insufficient privacy protection**
    - Use of users personal information insecurely, improperly, or without permission.
7. **Insecure data transfer and storage**
    - Lack of encryption or access control of sensitive data
    - Can be anywhere within the ecosystem e.g. at rest, in transit, or during processing.
8. **Lack of device management**
    - Lack of security support on devices deployed in production
    - Capabilities include e.g. asset management, update management, secure decommissioning, systems monitoring, and response.
9. **Insecure default settings**
    - Can be shipped with insecure settings or without ability to make restrictions.
10. **Lack of physical hardening**
    - Easily accessible physically

IoT attacks

- **Access control**
    - E.g. remote access control or gaining access to administration panels
- **BlueBorn Attack**
    - Amalgamation of techniques and attacks against known, already existing Bluetooth vulnerabilities
- **Jamming Attack**
    - Also known as **signal jamming attack**
    - Jamming the signal to prevent the communication of devices
- **Man-in-the-middle attack**
    - E.g. by sniffing through Foren6
        - Passive sniffer
        - Reconstruct a visual and textual representation of network information to support real-world Internet of Thingl
- **HVAC attack**
    - Takes place when one hacks IoT devices in order to shut down air conditioning services.
- Backdoor (not just IoT related)
- Exploit kits
- Replay attack
- Ransomware attack
- Privilege escalation

- Side channel attack
- Web application attacks, web server attacks
- Cloud computing attacks
- Mobile application threats
- DoS / DDoS
- Forged malicious devices
- Resetting to an insecure state
- Removal of storage media
- Firmware attack
- Network service attacks
- Unencrypted local data storage
- Confidentiality and integrity issues
- Malicious updates
- Insecure APIs
- Eavesdropping
- Sybil attack

Rolling code attack

- Also known as **hopping code** attack.
- Used in keyless entry systems such as garage door openers and keyless car entry systems.
- Attacker capture signal from transmitter device, simultaneously blocking the receiver to receive the signal
- Attacker uses the signal to gain unauthorized access
- E.g. stealing car with captured signal
- Tools include HackRF One hardware tool.

Firmware extraction

- Allows looking for data in filesystem or reverse engineering it for vulnerabilities.
- Flow example:
    1. `binwalk` is a common tool for it found on Kali Linux.
    2. `firmwalker` to list vulnerabilities by scanning all files.

Device memory containing credentials

- Can be used for reading/manipulating data
- Allows pushing firmware updates
- Enables usage of devices to other devices in the network

Hacking Methodology

Information gathering

- IP address
- Running protocols
- Open ports
- Type of device
- Vendor
- Shodan is a helpful search engine for IoT

Vulnerability scanning

- Scanning the network and devices to find vulnerabilities
- Search for weak password
- Software and firmware vulnerabilities
- Tools
  - `nmap`
  - `hping`
  - Firmalyzer
    - Security assessments with risk analysis in IoT networks
    - Proprietary platform

Attack

- Exploiting vulnerabilities
- E.g. running rolling code attack

Gain access

- Gain unauthorized access
- Privilege escalation
- Install backdoor

Maintain attack

- Logging out
- Clearing logs
- Covering tracks

Countermeasures

- Firmware update
- Block unnecessary ports
- Disable telnet as it's insecure protocol
- Use encrypted communication (SSL/TLS)
- Use strong password
- Encrypt drives
- Periodic assessment of devices
- Secure password recovery

- Two-Factor Authentication
- Disable UPnP