CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

Information Technologies Institute

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Presenter: Georgios Rizos

"Challenges in Medical Device Communication: A Review of Security and Privacy Concerns in Bluetooth Low Energy (BLE)"

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Presentation

by Georgios Rizos

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Aims of our review

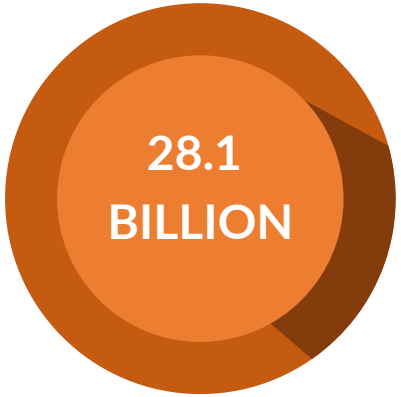
Our review aims to :

- ✓ describe possible attacks against the BLE protocol.
- ✓ assess the security aspects of medical devices, when using BLE.
- ✓ inform about recent vulnerabilities of BLE devices and cyber incidents on medical devices.
- ✓ highlight some mitigation strategies designed specifically for BLE applications.

“The need behind for our review”

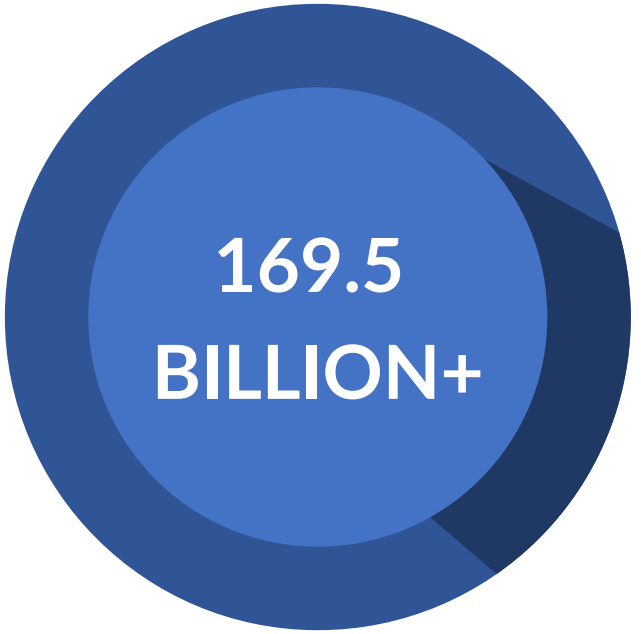
Increasing number of medical IoT devices

The global wearable medical devices market size was estimated at USD 28.15 billion in 2022 and is expected to hit over USD **169.58 billion** by 2030 with a registered Compound Annual Growth Rate (CAGR) of 25.6% from 2022 to 2030



2022

MIoT market size



2030

+603% increased

“The need behind for our review”

on-demand usage of BLE in healthcare devices

The 2020 Bluetooth Market Research report highlights that the healthcare wearable market, encompassing connected blood pressure monitors, continuous glucose monitors, pulse oximeters, and electrocardiogram monitors, witnessed a surge in demand, resulting in 12 million shipments in 2020 alone. This upward trajectory is anticipated to continue, with projected shipments reaching 52 million in 2025.

BLE protocol stack

is divided into three parts

Application Layer

it's responsible for the application logic, user interface and data handling.

It's architecture is highly depended on each particular implementation

Host

is composed of several layers

- Generic Access Profile
- Generic Attribute Profile
- Security Manager
- Attribute Protocol
- Logical Link Control and Adaptation Protocol

Controller

Host Controller Interface (HCI) includes the following layers

- Link Layer
- Physical Layer

BLE Attacks

divide into various categories

Next, we will mention basic attacks categories and describe how to implement them against the BLE protocol. Additionally we will present some BLE-specific attacks that exploit distinct BLE vulnerabilities.

ATTACK 01

General Cyber Attacks

operates passive and active eavesdropping attacks, MitM and Replay Attacks

ATTACK 02

Device Cloning Attacks

spoofs MAC address, name and GATT characteristics

ATTACK 03

Cryptographic Attacks

compromises BLE protocol's encryption, weaknesses and key exchange mechanism

ATTACK 04

Denial of Service Attack

targets the master BLE device, acting as common DoS

ATTACK 05

Distortion Attack

exploits the vulnerabilities of BLE protocol services, trying to disrupt the services

ATTACK 06

Surveillance Attack

gather information, cause of lack of proper security enforcement

ATTACK 07

Treacherous Attack

gains full system access, establishing a trusted relation between the devices

General attacks

Passive Eavesdropping

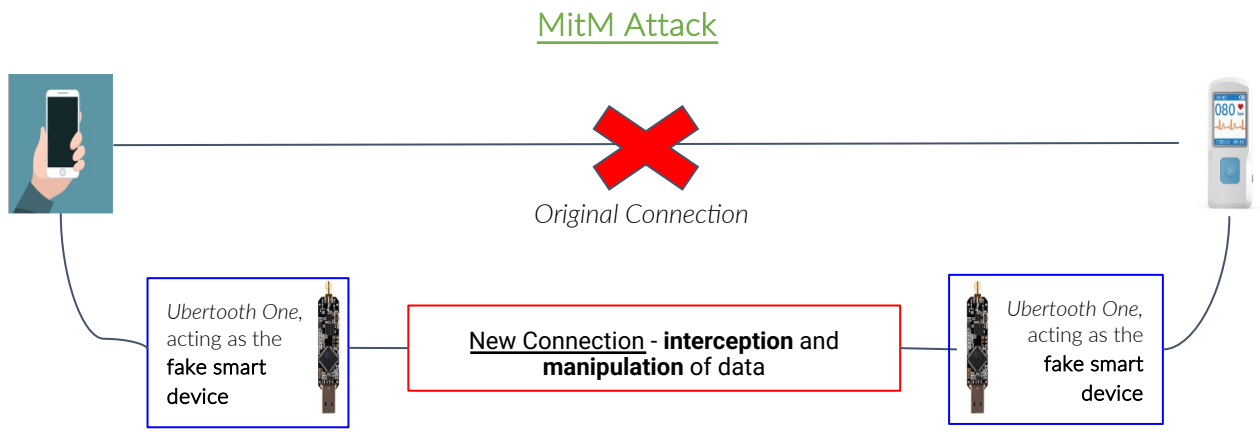
Unauthorized access and monitoring of Bluetooth communications. This form of attack involves the use of specialized software and hardware tools capable of intercepting and analyzing Bluetooth traffic (Ubertooth One).

Man in the Middle (MitM)

BLE MiTM attack necessitates the utilization of two BLE components (ex. Ubertooth One) with the capability to act in unison.

Replay attack

A form of attack for wireless communications where the attacker captures legit communication packets and then re-transmits those packets at a later time.



Denial of Service

Battery Exhaustion

One of BLE's features is its brief wake period. This attack targets this unique feature of BLE by keeping the device awake all the time.

Denial of Sleep

These attacks can reduce the lifespan of the sensing nodes by several orders
of magnitude, rendering the network unusable

Offline PIN cracking *

Can done in many ways, such as using brute force to crack the PIN, or via a dictionary attack. The security vulnerability of BLE is that the length of the Temporary Key (TK) to generate the encryption key might be too short.

Jamming

By jamming only packets sent by the peripheral to the central device, an attacker can trigger the timeout in the central device and then hijack the BLE connection.

BtleJack: a jamming attack example

This attack was published in 2018 by Damien Cauquil and implemented in the tool BtleJack [1]. Btlejack provides everything you need to sniff, jam and hijack Bluetooth Low Energy devices. It relies on one or more BBC Micro:bit devices running a dedicated firmware.

[1] D. Cauquil, "You'd better secure your BLE devices, or we'll kick your butts!", virtualabs.fr/BtleJack [retrieved: August, 2023]

Cryptographic Vulnerabilities

Device Authentication

This attack is feasible because of a cryptographic weakness of the passkey-based pairing of BLE.

Blue Mirror

During a reflection attack an intruder will collect a message in the authentication protocol, then send it without modification to the original sender.

BLUR attacks

These attacks allow to impersonate, MiTM, and establish unintended sessions with arbitrary devices, by obtaining the Cross-Transport Key Derivation (CTKD).

There are some forms of authentication attacks that crack the shared keys exchanged in the pairing process and they are as follows:

- Guessing Pairing Key : The attacker brute forces the six-digit pin key used for authentication.
- Eavesdropping Encryption Key : The Attacker uses Ubertooth One to read all the key exchange messages and decrypt it. One way to do that is by using Crackle [2].
- Stealing Link Key From the Device: There are many BLE devices in the market whose hardware is not secured enough to protect the stored encryption key

[2] "Crackle : cracks BLE Encryption (AKA Bluetooth Smart)", https://github.com/crackle [retrieved: August, 2023]

BLE Specific

Backdoor

Applying this method, gains the trust of the victim device through the pairing mechanism, while not appearing on the victims list of paired devices. In this way, the attacker can monitor the activities of the victim device.

BlueBump

The attacker gains the trust of the victim, then deletes the link key, then the attacker requests the victim to initiate another link-key, managing to remain concealed in the paired list of the victim device.

MAC Spoofing

The attacker spoofs the MAC address as well as GATT services, with specialized software tools like Gattacker, the attacker effectively replicates the GATT services of the original peripheral device, thereby assuming the role of a counterfeit peripheral entity.

BLE Spoofing Attack, an in practise example of MAC spoofing

These attacks enable an attacker to impersonate a BLE device and to provide spoofed data to another previously-paired device, as described analytically in [3]. Additionally there are other tools to spoof your MAC address

- bdaddr [4], which is most suitable for CSR and Broadcom chip based bluetooth adapters
- gadgets as FlipperZero [5], for which there already exist firmware to change the MAC address.

[3] J. Wu et al., "BLESA: Spoofing Attacks against Reconnections in Bluetooth Low Energy", 14th USENIX Workshop on Offensive Technologies 2020 BLESA [retrieved: August, 2023]
[4] bdaddr - Utility for changing the Bluetooth device address, bdaddr [retrieved: August, 2023]
[5] Flipper Zero is a portable multi-tool for pen-testers and geeks in a toy-like body. FlliperZero [retrieved: August, 2023]

“Security and privacy for implantable medical devices, who introduced several successful attacks on an **Implantable Cardiac Defibrillator (ICD)**, compromising the confidentiality, integrity, and availability of the device.”

D. HALPERINET et al.

“Hacking medical devices for fun and insulin: Breaking the human SCADA system”, describes a possible **insulin pump** attack scenario.”

J. RADCLIFFE

“Fit and vulnerable: Attacks and defenses for a health monitoring device, by reverse engineering the communication protocol, storage details and operation codes, they identified several vulnerabilities in **Fitbit.**”

M.RAHMAN et al.

Results of cyber attacks in Healthcare

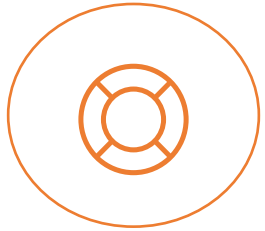
Randy Horton in his research "*What We Can Learn From Bluetooth Medical Device Recalls*", uncovered instances where Bluetooth was the reason for **device recall** in *healthcare*. These recalls highlight important lessons for developing Bluetooth-enabled medical devices. The research mentions :

- Active **implantable** devices, with connectivity issues.
- **Bluetooth-enabled** medical devices, with possible signal interferences.
- Continuous **Glucose Monitor System**, with bugs brought on by OS updates.
- Radiologic Imaging System, with improper **firmware** in the Bluetooth interface.

Mitigation Techniques

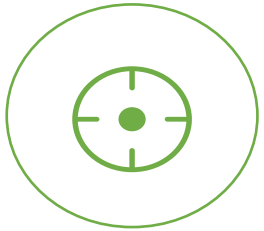
S. Shrestha

"A Systematic Literature Review of Bluetooth Security Threats and Mitigation Measures", present various **sets of rules** for users to help them perform actions safely, thereby minimizing the susceptibility to potential attacks.



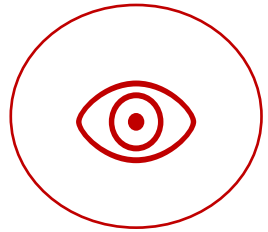
A. Ray

"Bluetooth Low Energy Devices Security Testing Framework", present a **framework**, which encompasses various software components designed to **carry out attacks**, in order to assess the security of BLE networks.



M. Yaseen

"A Novel **Framework** for Detecting MiTM Attacks in **eHealthcare BLE** Systems", introduces an innovative framework, known as MARC, which is specifically tailored to identify MiTM attacks in HealthCare BLE systems.



S. Shrestha

"Automated Security Assessment Framework for **Wearable BLE-enabled** Health Monitoring Devices", present an automated security assessment 4-stage framework designed specifically for Wearable BLE-enabled Health Monitoring Devices.

Conclusion

1. In our review we presented many ***cyber attacks***, both general type of attacks but also some BLE specific attack, due to BLE vulnerabilities.

2. We showed that, these types of ***vulnerabilities*** can raise a lot of concerns in many IoT fields and specifically in healthcare.

3. Software increasingly embedded into medical devices, provides a larger ***surface of attacks*** to malicious attacks.

4. It is critical to take the necessary measures and ***mitigate the damage*** in healthcare IoT applications, because the results of cyber attacks could be detrimental.

Future Work

PERFORMANCE

enhance the performance of BLE, like the improvement and design of the physical layer in BLE v5.x.

AVOID INTERFERENCE

research on the coexistence of BLE with other wireless technologies, as well as adaptive frequency hopping techniques to avoid interference.

BLOCKCHAIN

researchers may start looking into employing distributed type Blockchain technology to safeguard linked IoT devices.

Thank You!

Ευχαριστούμε :)

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