BLE-Guardian: Protecting the Privacy of BLE Users

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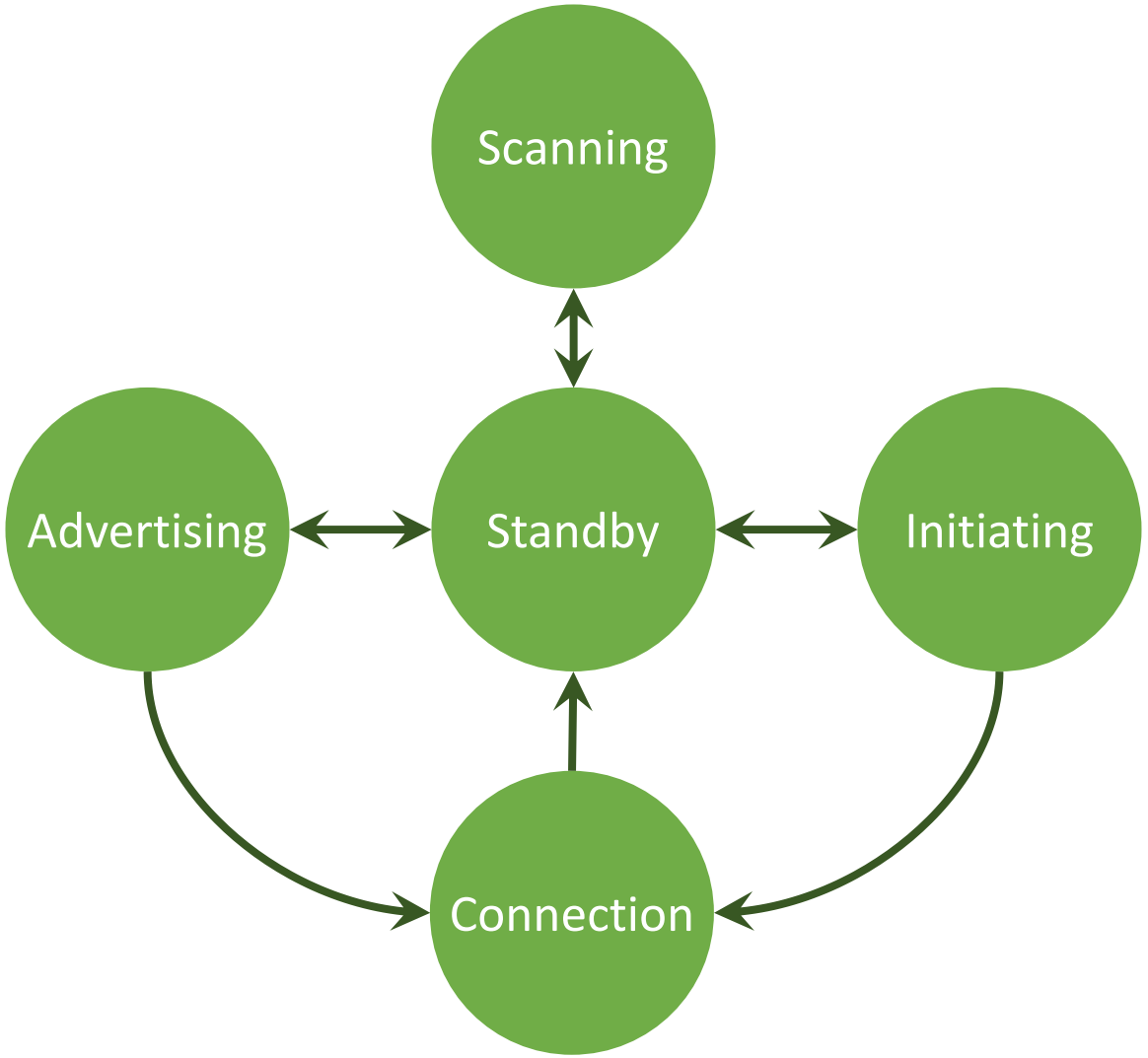
What is Bluetooth Low Energy?

- Attractive communication technology
  - Short range
  - Low energy footprint
  - Supported by most hosts
- Currently:
  - 74K unique products with BLE support
- 2013:
  - 1.2 billion BLE products shipped
- 2020:
  - 2.7 billion BLE products expected

BLE Primer

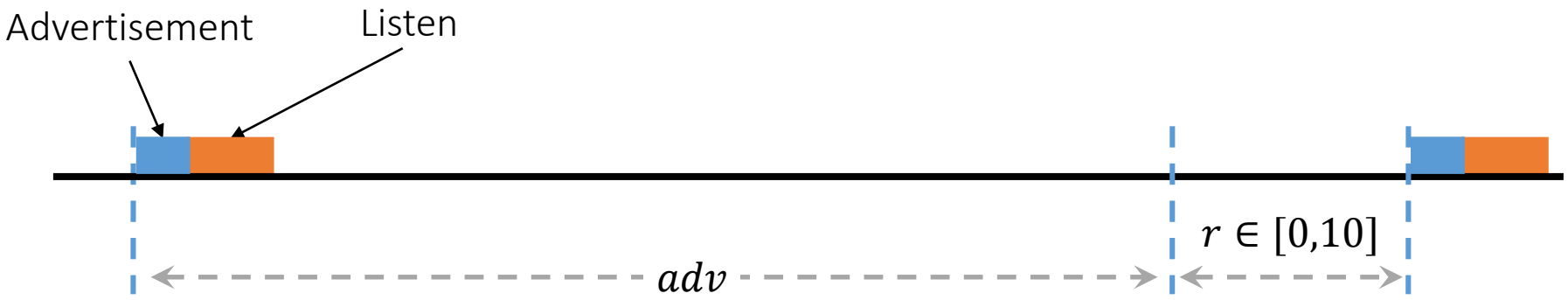


- **Standby:** Low Power Mode. Receiver and transmitter switched ‘off’
- **Advertising:** Used by low power ‘Server’. Only transmitter required.
- **Scanning:** Used by ‘Client’. Receiver listens to advertising channels.
- **Initiating:** ‘Server’ sends connection request
- **Connection:** After scanning, ‘Client’ responds to ‘Server’ advertisement

BLE Advertisements

- 3 dedicated advertising channels:
  - 2402 MHz (*37*), 2426 MHz (*38*), 2480 MHz (*39*)

Type	Description	Frequency
ADV_DIRECT_IND	Connect to a particular device only	3.75 ms, but only for 1.28 seconds
ADV_IND	General presence known + connections	20ms – 10.24s



BLE Security and Privacy

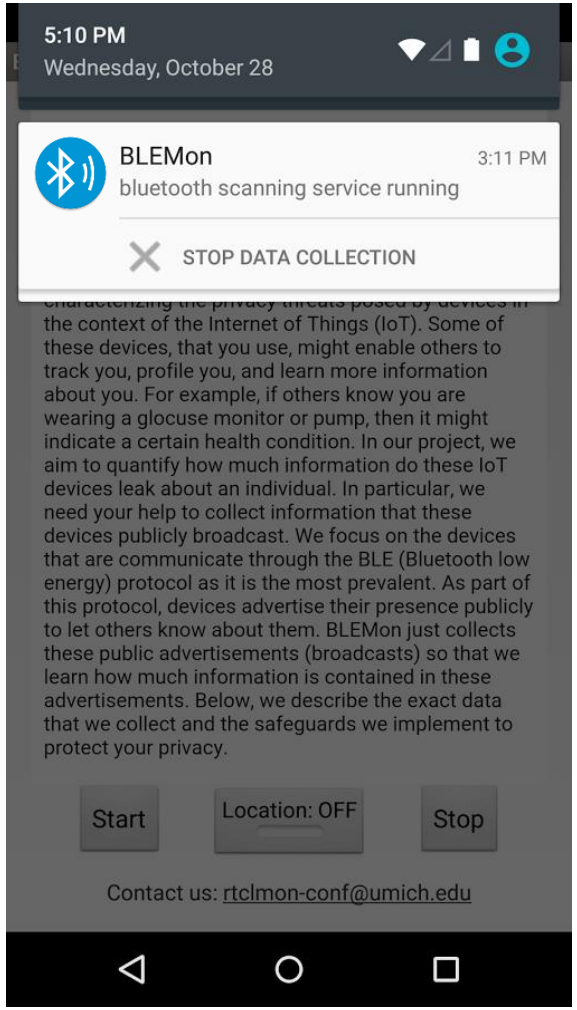
- Pairing & bonding
  - Prevent unauthorized access to device or secured services
- Address randomization
  - Prevent user tracking
- Direct Advertisements
  - Prevent user tracking and profiling

BLE Privacy & Security Effectiveness

- *Passively* scan for BLE advertisements
- Collect:

`<Timestamp, BT Address, advertisement content, RSSI>`

Site	Participants	Period
Hewlett Packard Labs	1	40 days
Ann Arbor	13	2 months
Phone LAB/ SUNY Buffalo	86	2 months



BLE Privacy & Security Effectiveness

- Indirect Advertisements
  - Detected 214 different unique **types of** devices
- Address Randomization

Name	Description
ihere	key finder
DEXCOMRX	Glucose monitor
Frances's Band ea:9d	smartband
Otbeat	heart rate monitor
JS00002074	digital pen

Revealing Names

Device	Days observed
One	37
Flex	37
Zip	37
Forerunner 920	36
Basis Peak	25

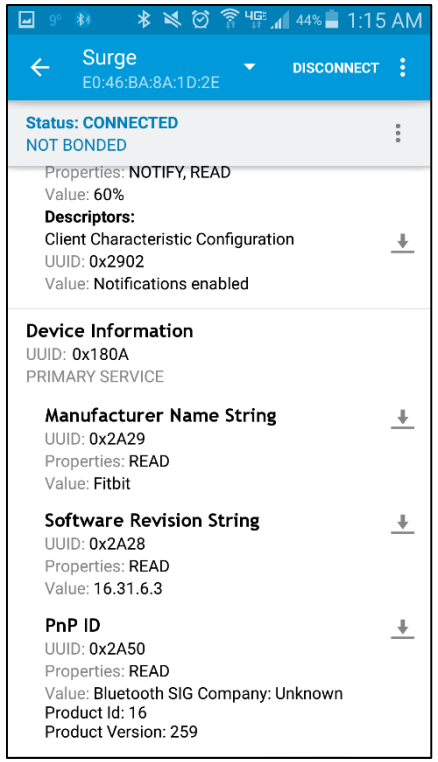
Consistent Addresses

Address
00:17:E9:CB:F3:61
00:17:E9:CB:F5:01

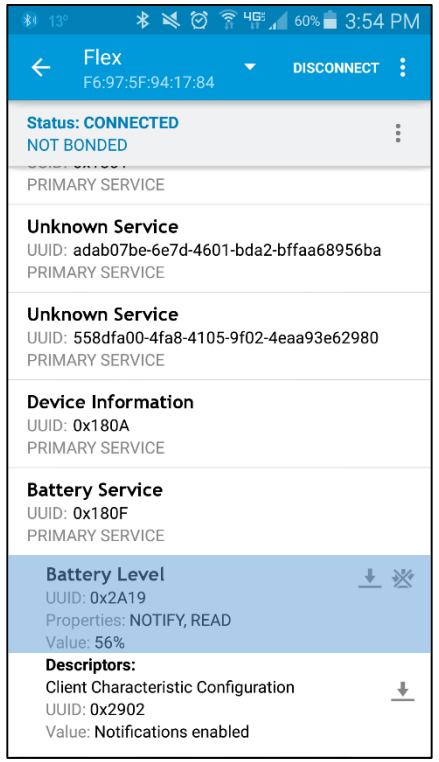
Poor Randomization

BLE Privacy & Security Effectiveness

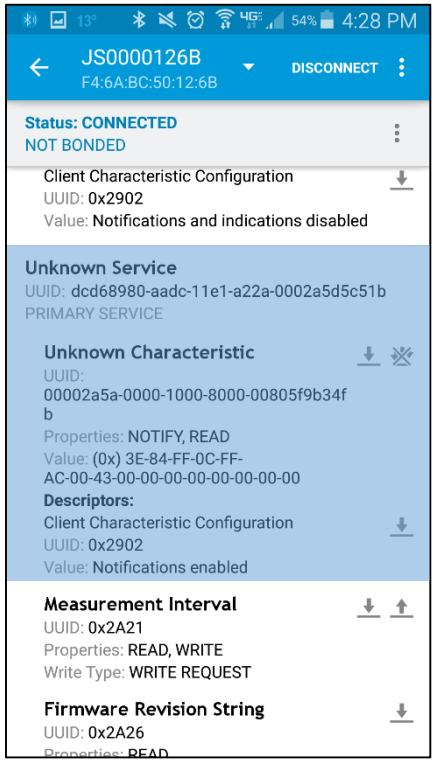
- Device Pairing



Advertise and accept connections

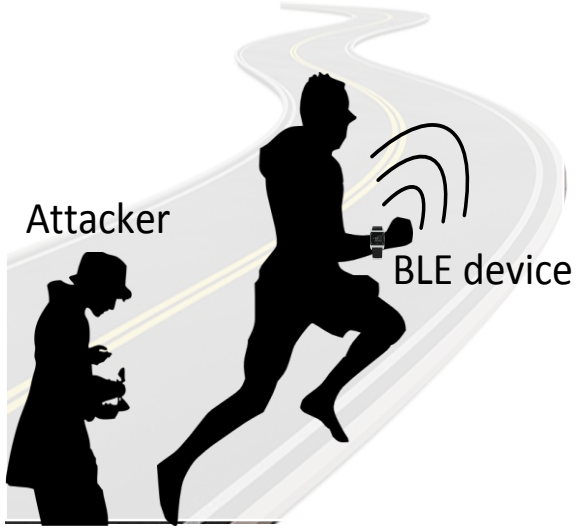


Battery level



Unique identifiers

It all starts with the advertisements…



Tracking User

Consistent addresses, poor randomization, unique device names and identifiers

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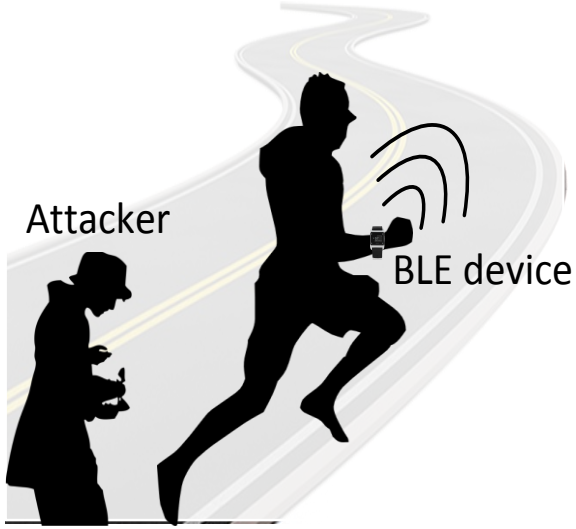

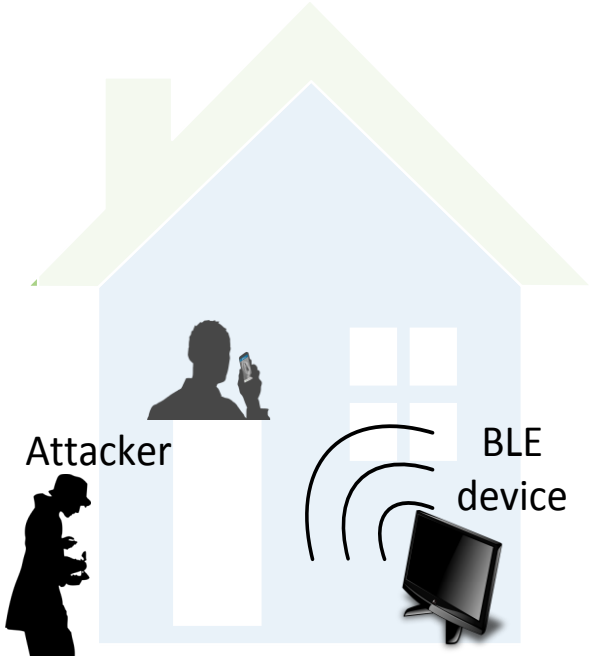

Tracking User

Profiling User

Health situation, user's lifestyle, behavior, preferences, and personal interests

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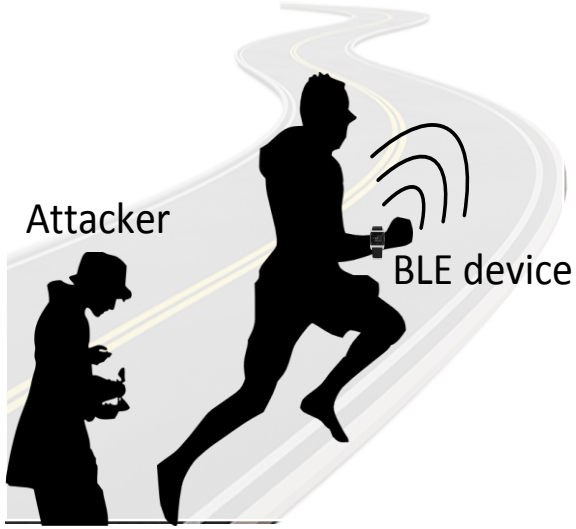
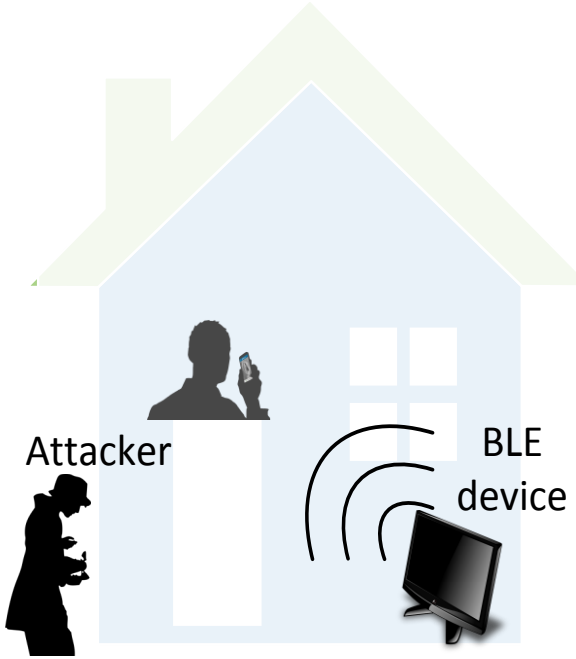
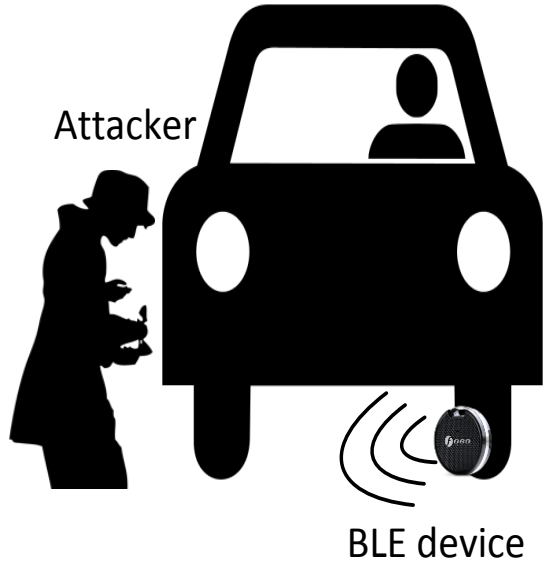


Tracking User



Profiling User



Harming User

Fingerprinting of and unauthorized access for sensitive systems and devices

Research Questions

Can we effectively fend off the threats to BLE-equipped devices

(1) in a device-agnostic manner,

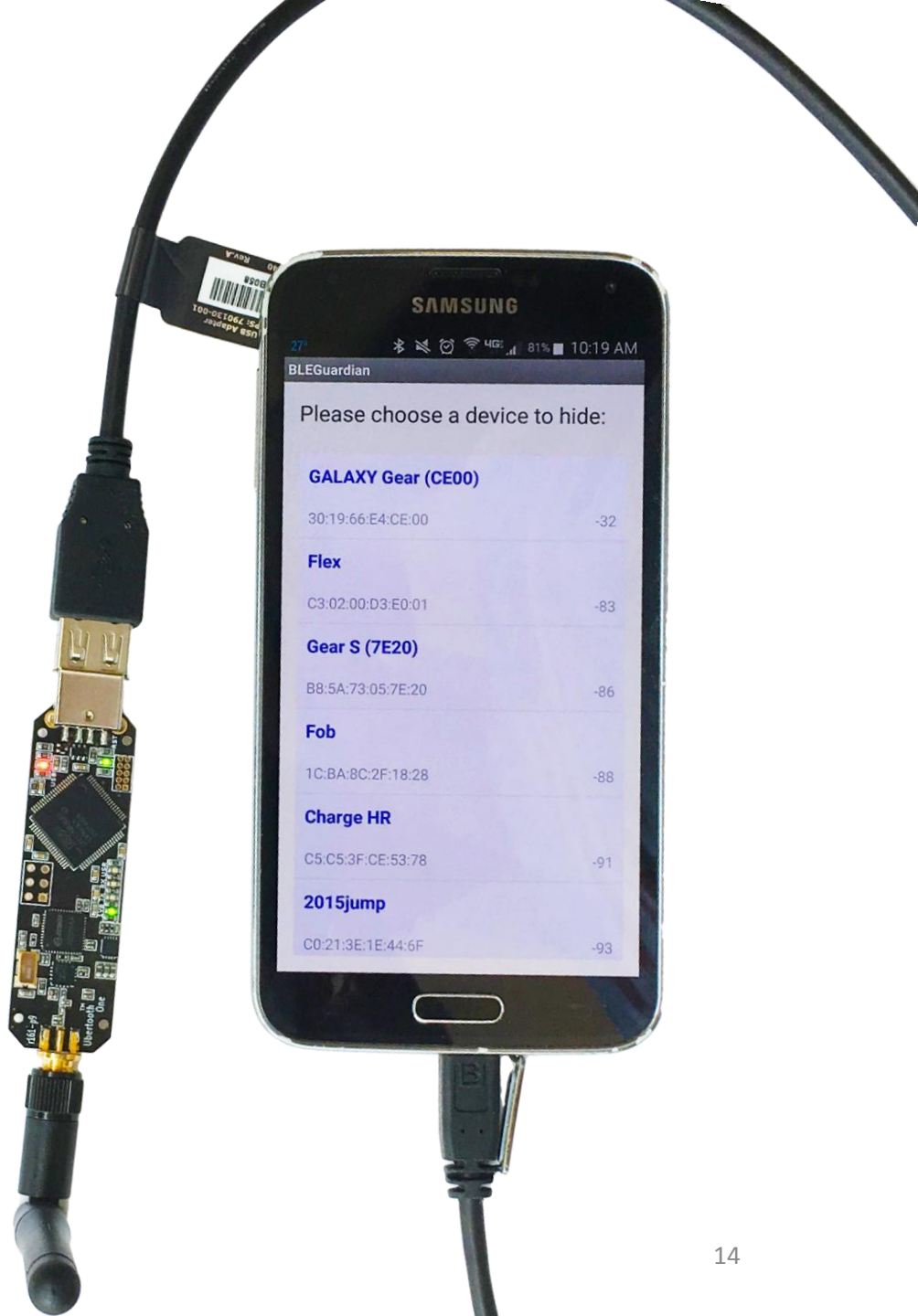
(2) using COTS (Commercial-Off-The-Shelf) hardware only, and

(3) with as little user intervention as possible?

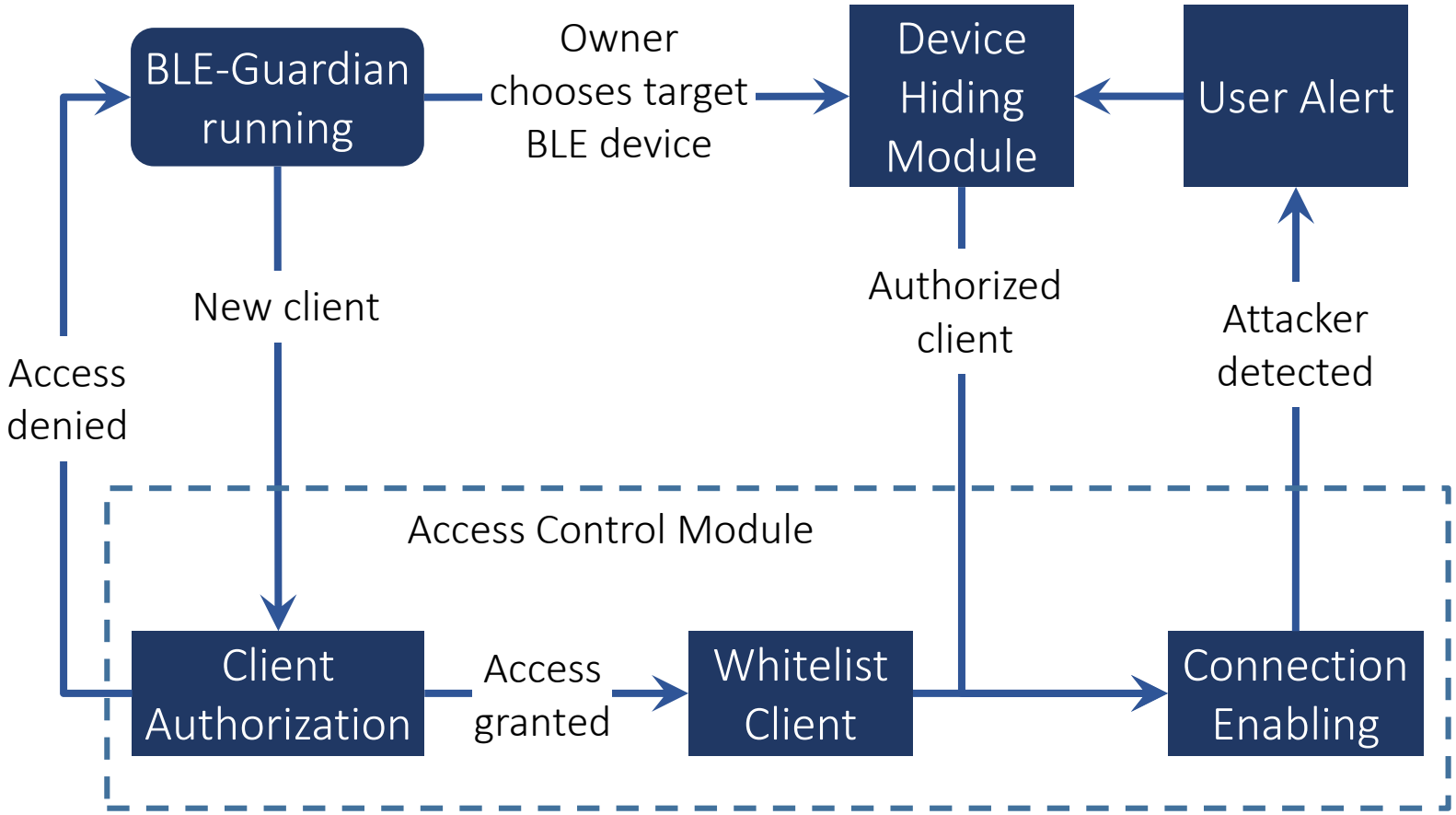
BLE-Guardian

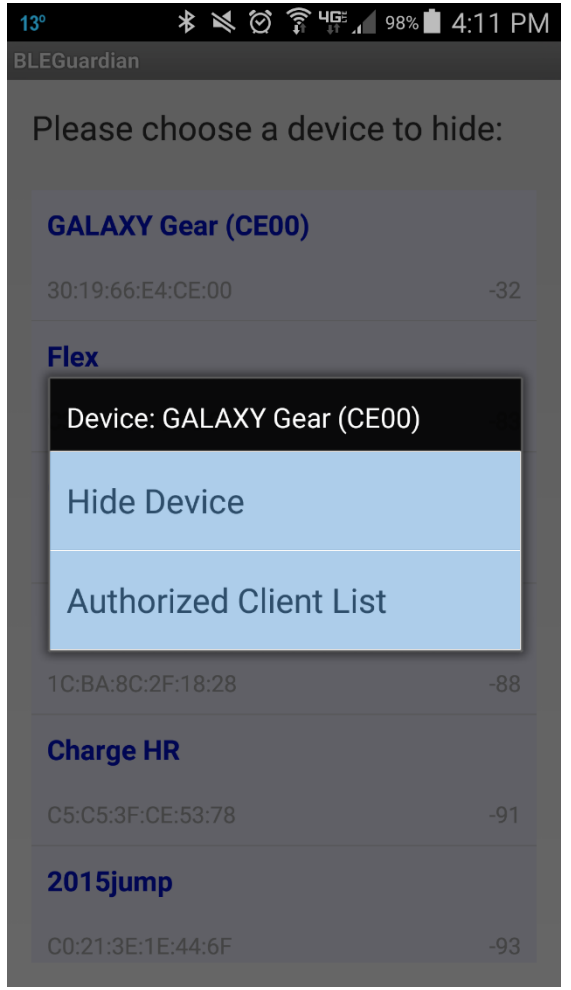
BLE-Guardian

- Ubertooth One
  - Programmable BT radio
  - Open source firmware
  - Rx/Tx on each BT channel
- User-level app
  - Control BLE-Guardian
  - Update firmware seamlessly



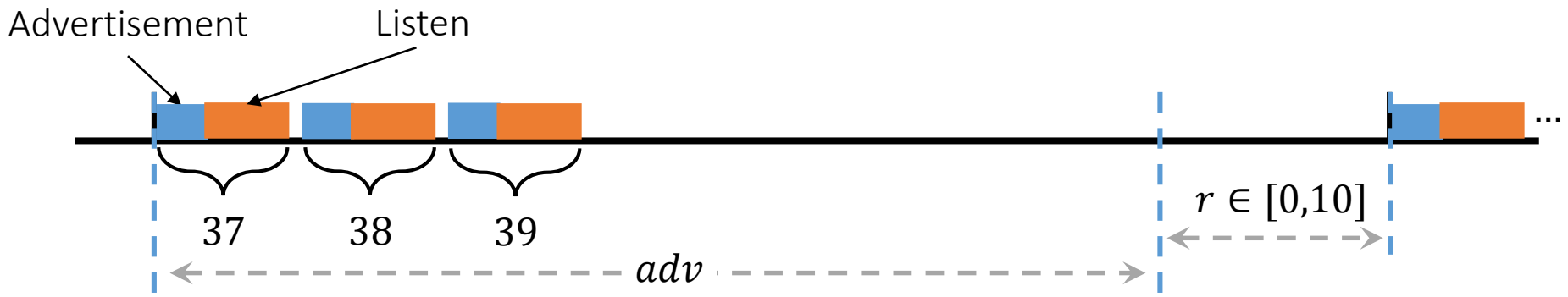
High-level Description



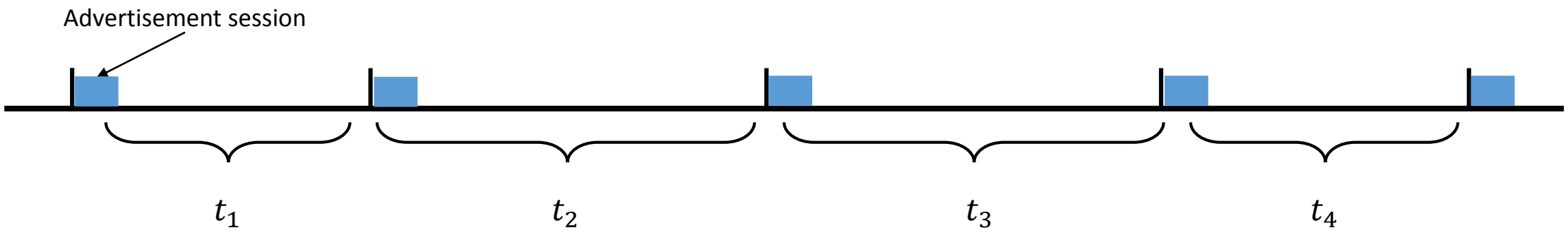


Device Hiding

- Jam BLE device advertisements to hide its existence
- Need to learn device advertising Sequence
  - Otherwise jamming will be ineffective or inefficient

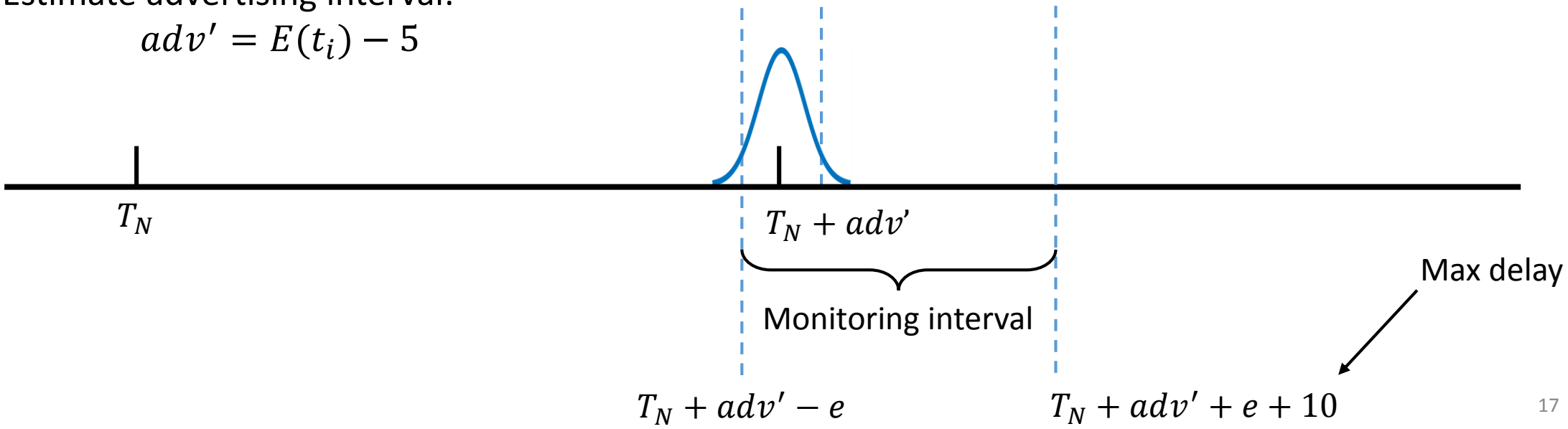


Device Hiding

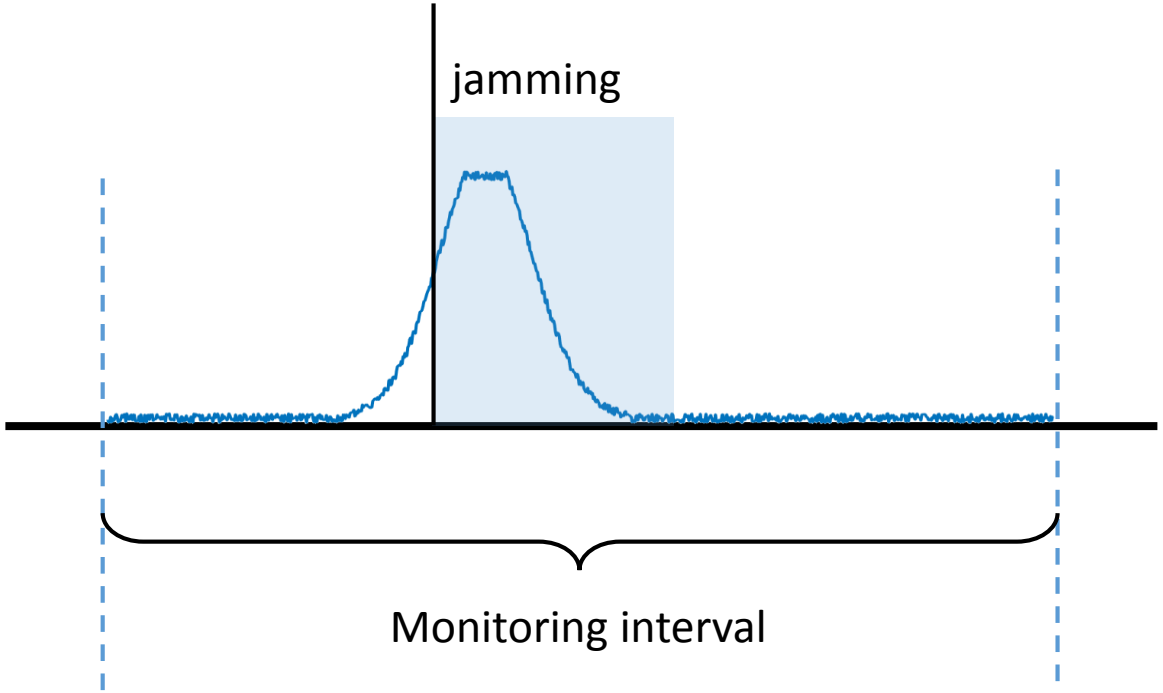


Estimate advertising interval:

$$adv' = E(t_i) - 5$$



Device Hiding



- Detect RSSI (received signal strength indication) increase
- Apply jamming and follow advertising sequence

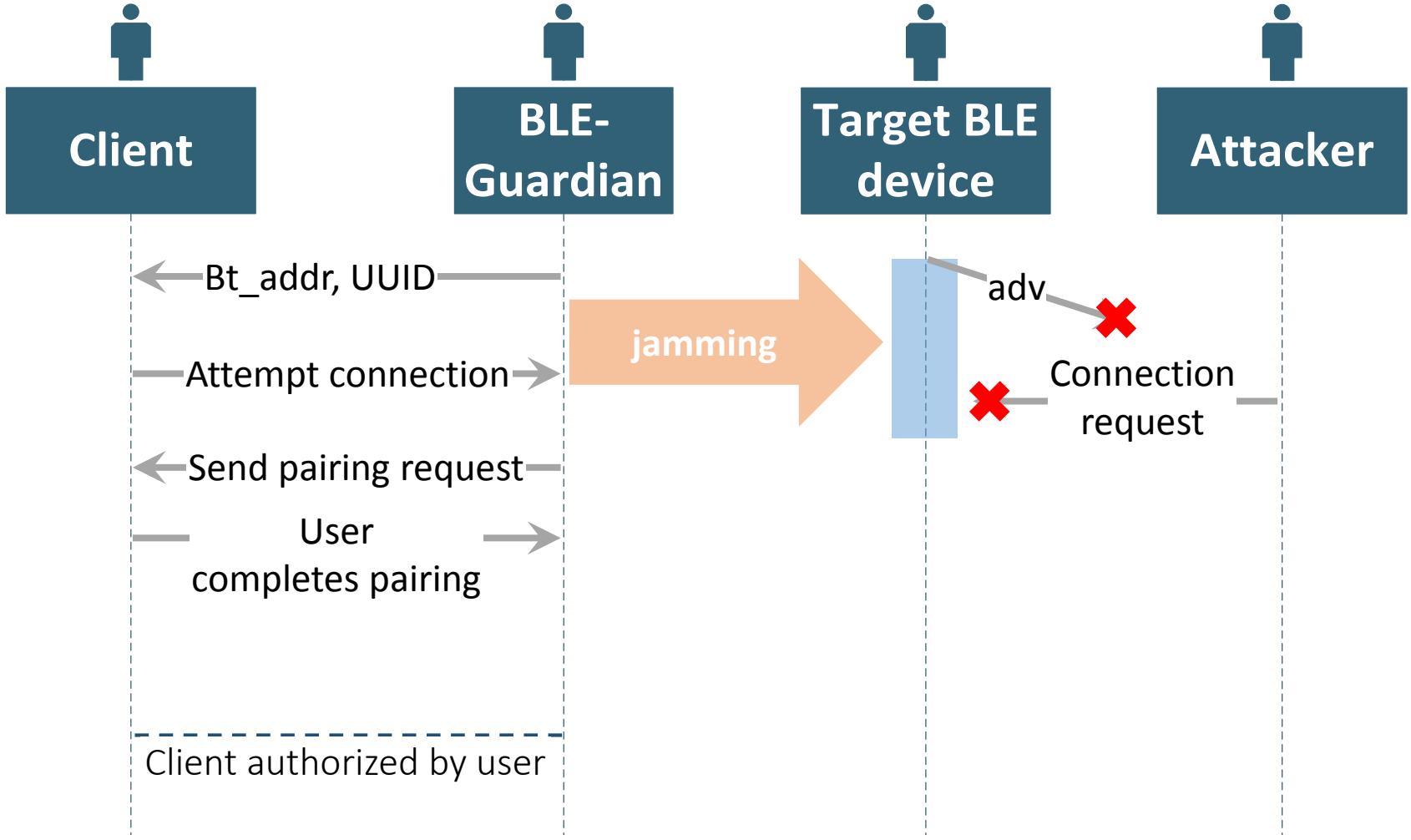
At this point, the target BLE device is hidden.

How to enable access to it?

Access Control

Authorization:

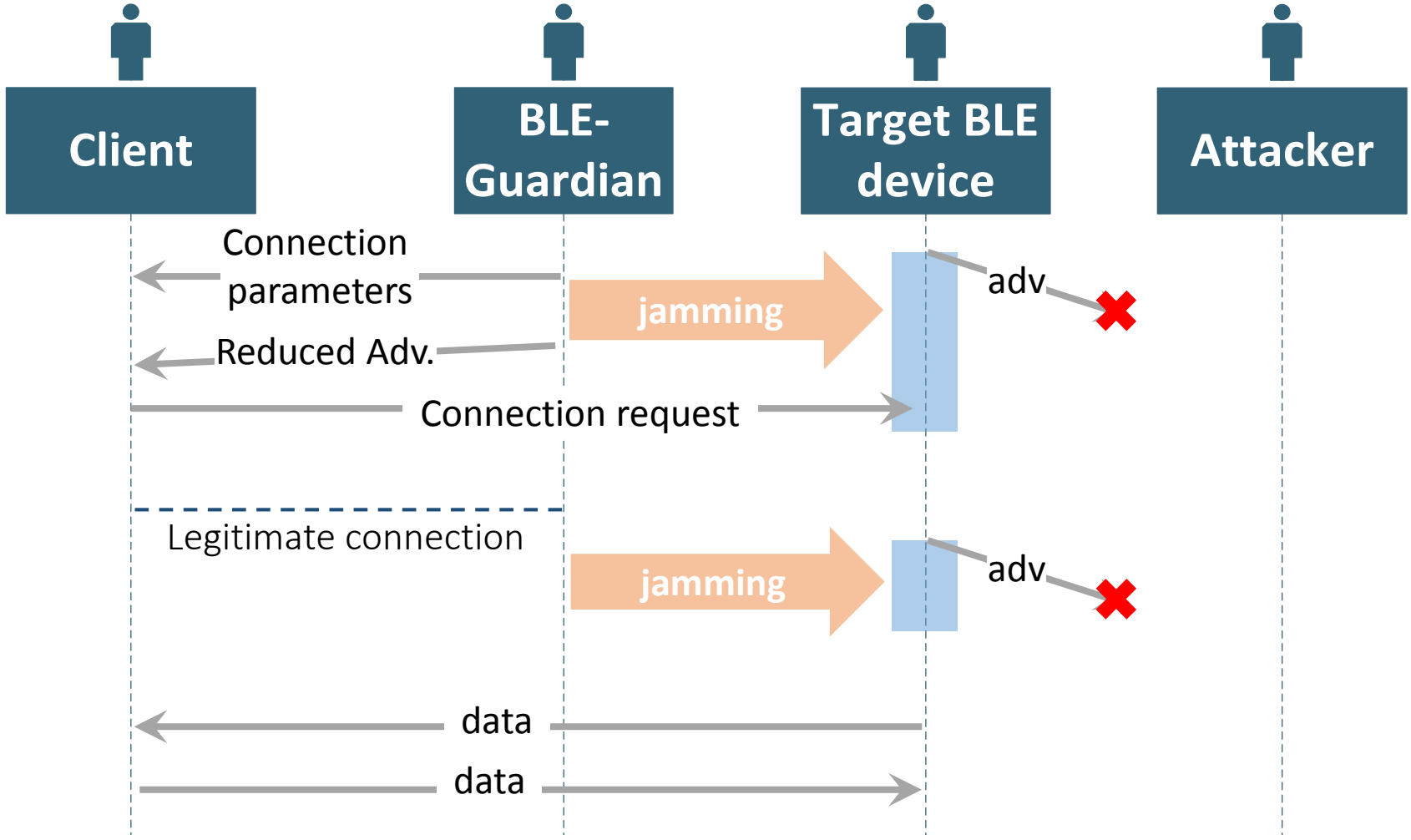
Bluetooth classic as an OOB channel.



Access Control

Connection Enabling:

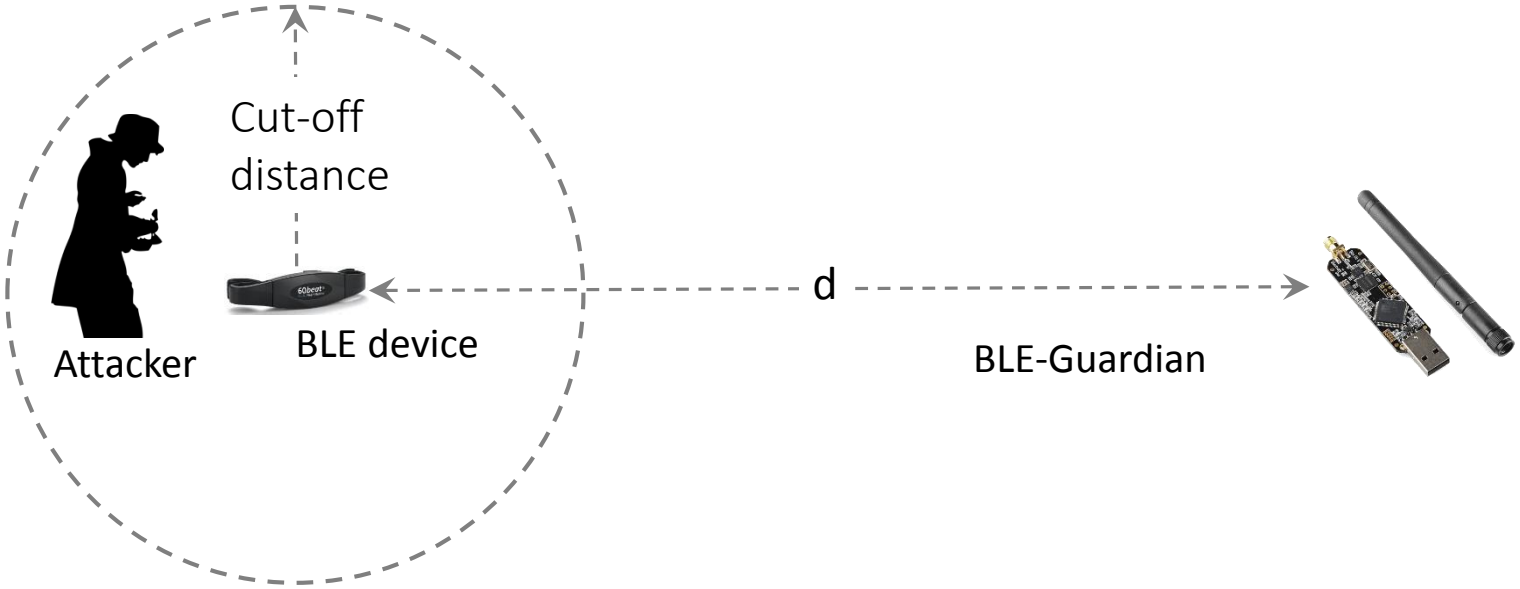
Connection parameters to distinguish legitimate connection request.



Evaluation

Evaluation

Cut-off Distance



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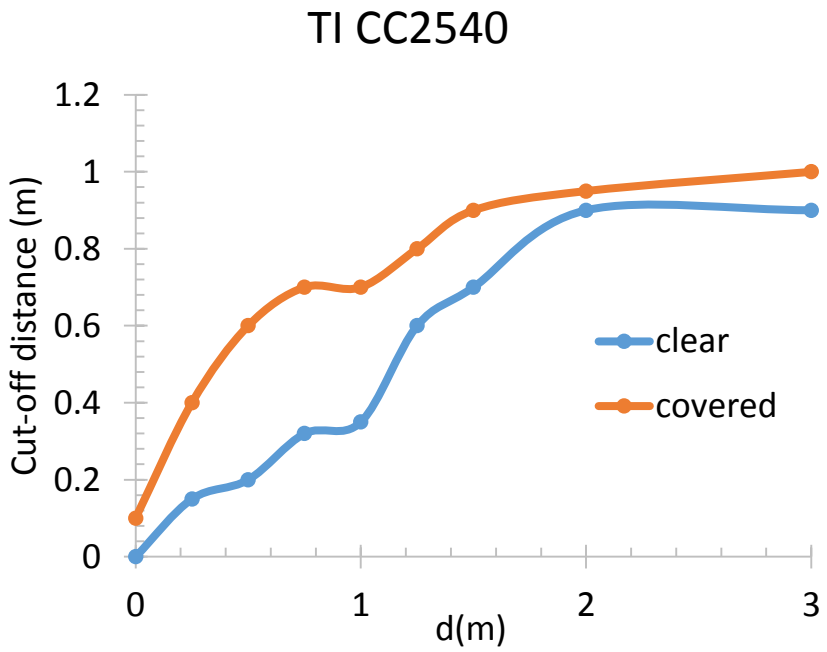
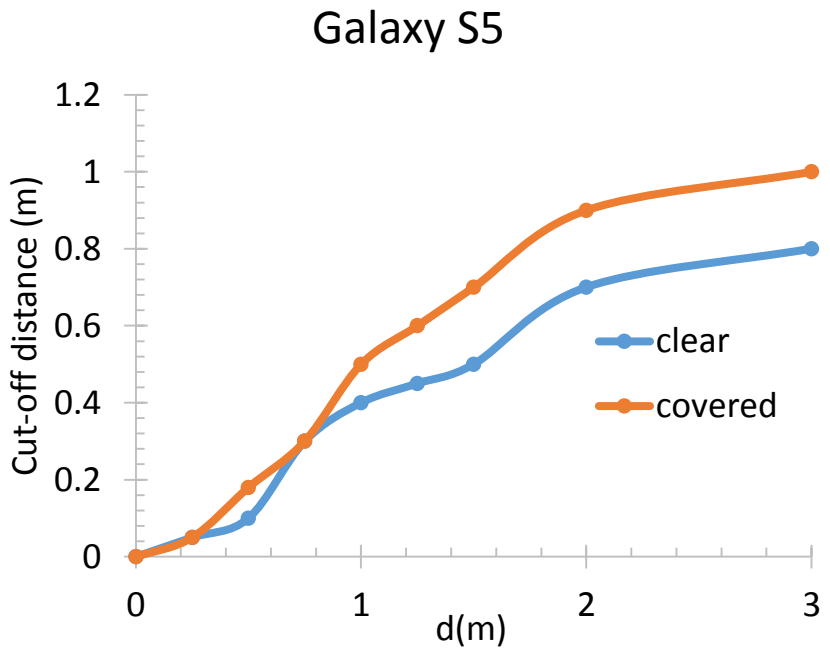
Cut-off Distance



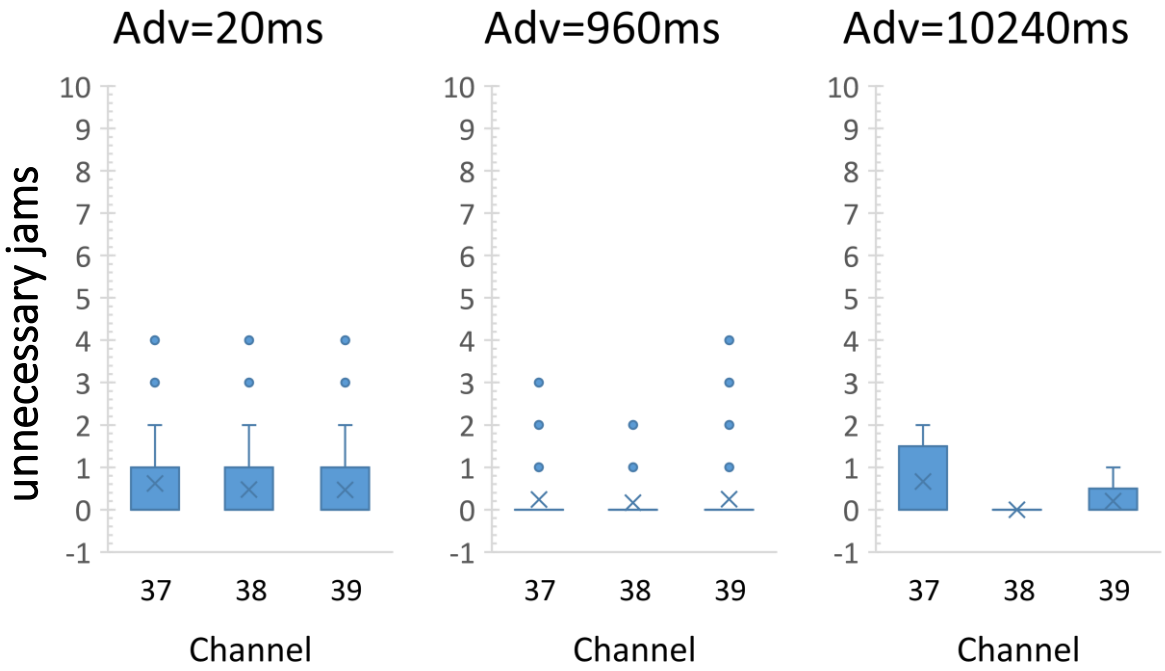


Adversary has to be within 1 m of BLE device to read its advertisements

Evaluation

Impact on Advertising Channels

1. Protect single device at advertising intervals:
   - 20ms, 960ms, and 10.24 sec
2. Two devices advertising at 20 ms
3. 15 other devices
   - With varying advertising frequencies

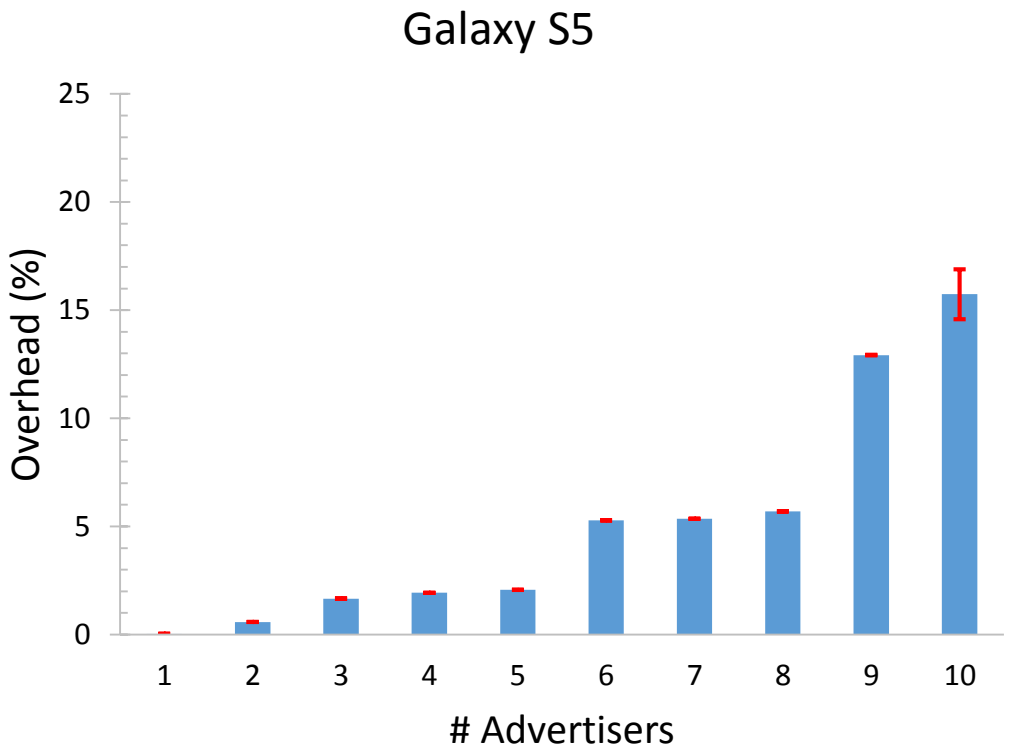


The number of unnecessary jamming instance is minimal

Evaluation

Energy Overhead

1. BLE-device and authorized clients
   - No overhead
2. Smartphone as a gateway
   - Idle power: 1370mW
   - Overhead: less than 16%



Conclusion

- BLE-Guardian
  - Privacy protection for BLE device users
  - Device agnostic and relies on COTS hardware
  - Low overhead on advertisement channels

- Future work
  - Explore other M2M protocols such Zigbee
  - Implement without needing external hardware (need firmware access)

Thank You

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