Inside Job: Understanding and Mitigating the Threat of External Device Mis-Bonding (DMB) on Android

Muhammad Naveed[1]
Xiaoyong Zhou[2]
Soteris Demetriou[1]
XiaoFeng Wang[2]
Carl A. Gunter[1]
[1]University of Illinois at Urbana-Champaign
[2]Indiana University at Bloomington

External devices enhance smartphone’s capabilities

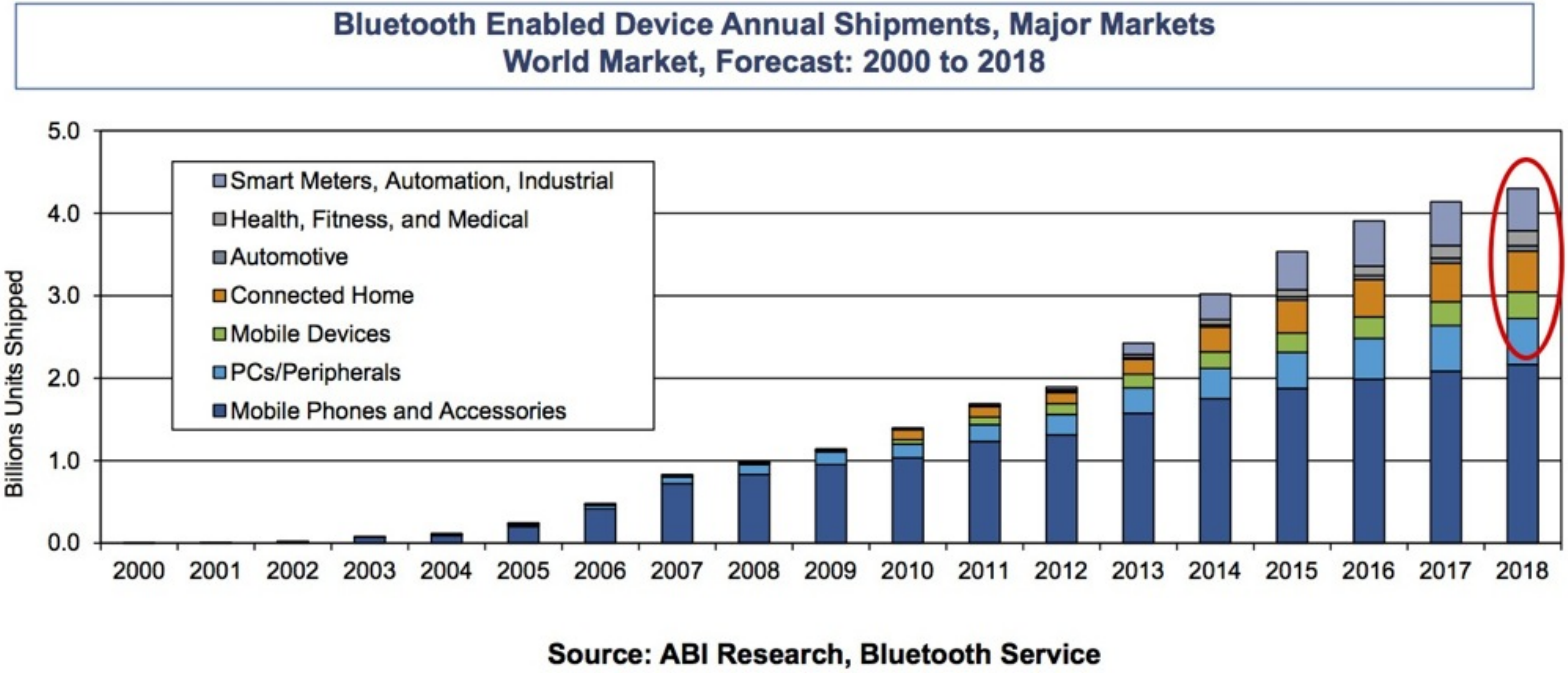
iThermometer

Temperature monitoring device for babies and elderly persons

Other devices

- FDA approved devices
- Sync information to EHR or web-account
- Wrong amount of insulin can kill

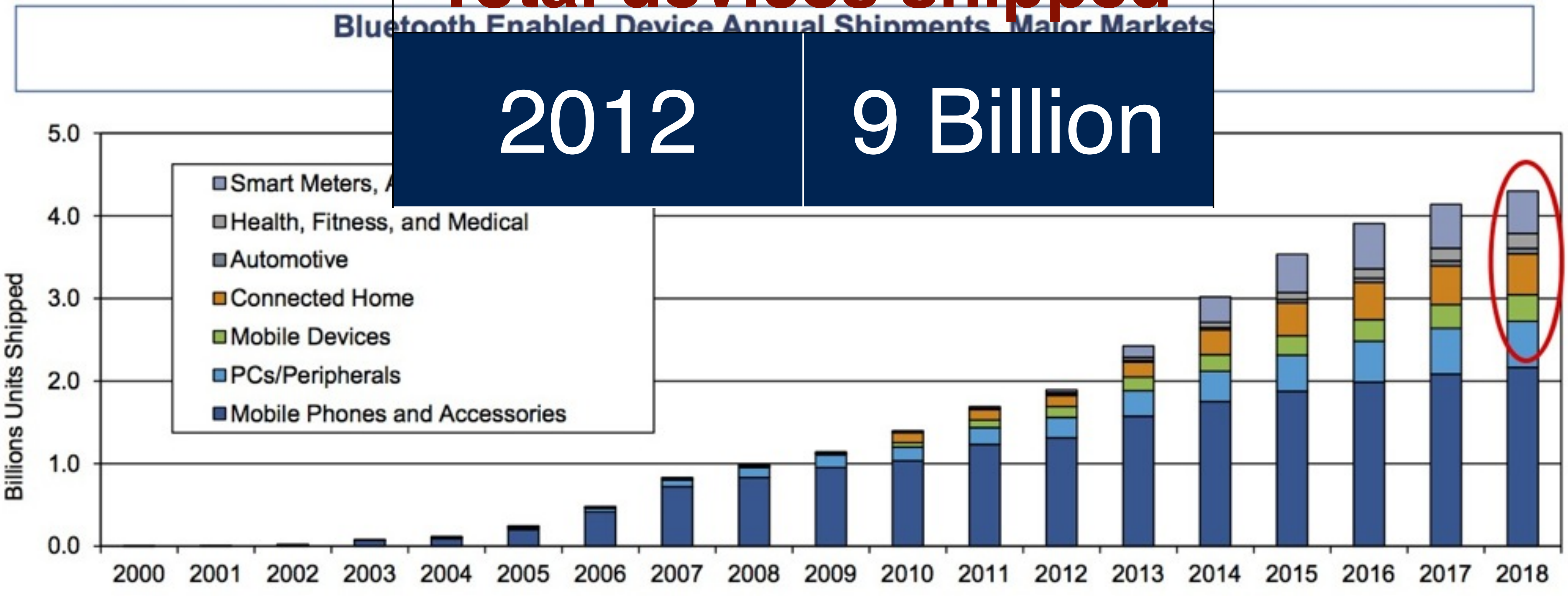
Bluetooth Devices



Source (for both numbers and figure): http://www.bluetooth.com

Bluetooth Devices

Total devices shipped	
2012	9 Billion



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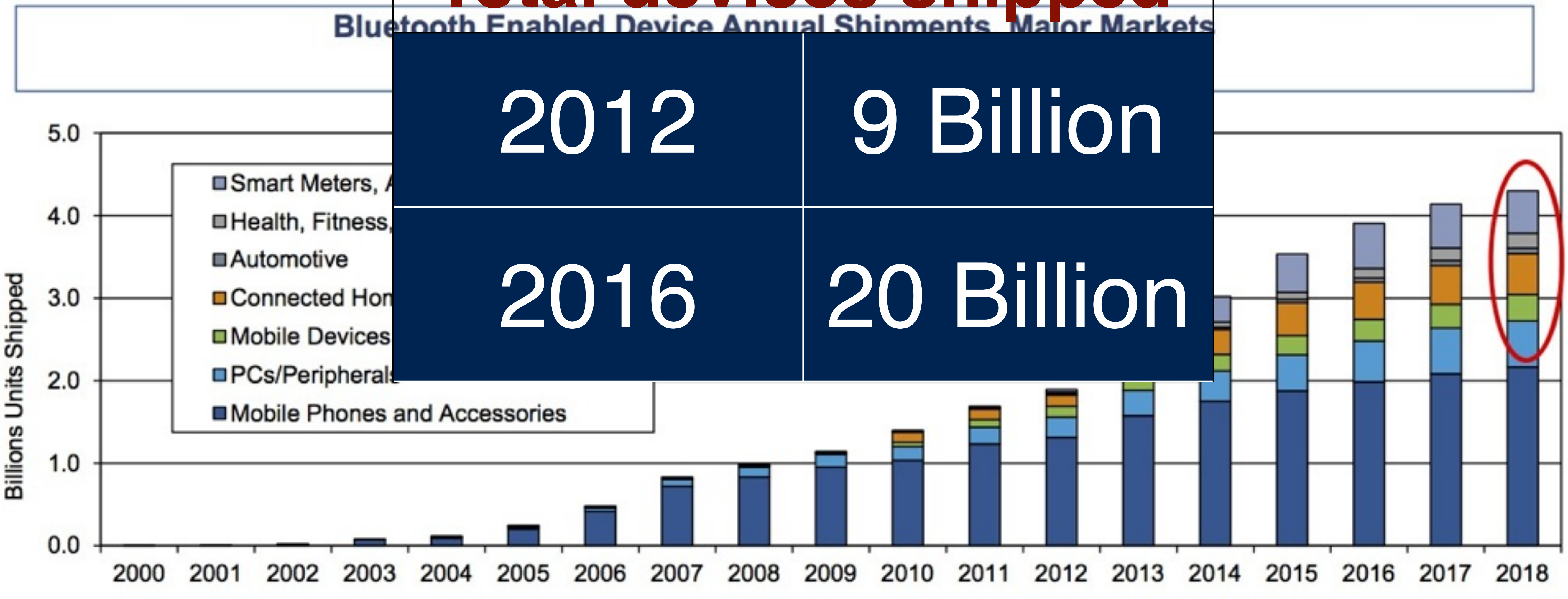
Bluetooth Devices

Total devices shipped

2012	9 Billion
2016	20 Billion



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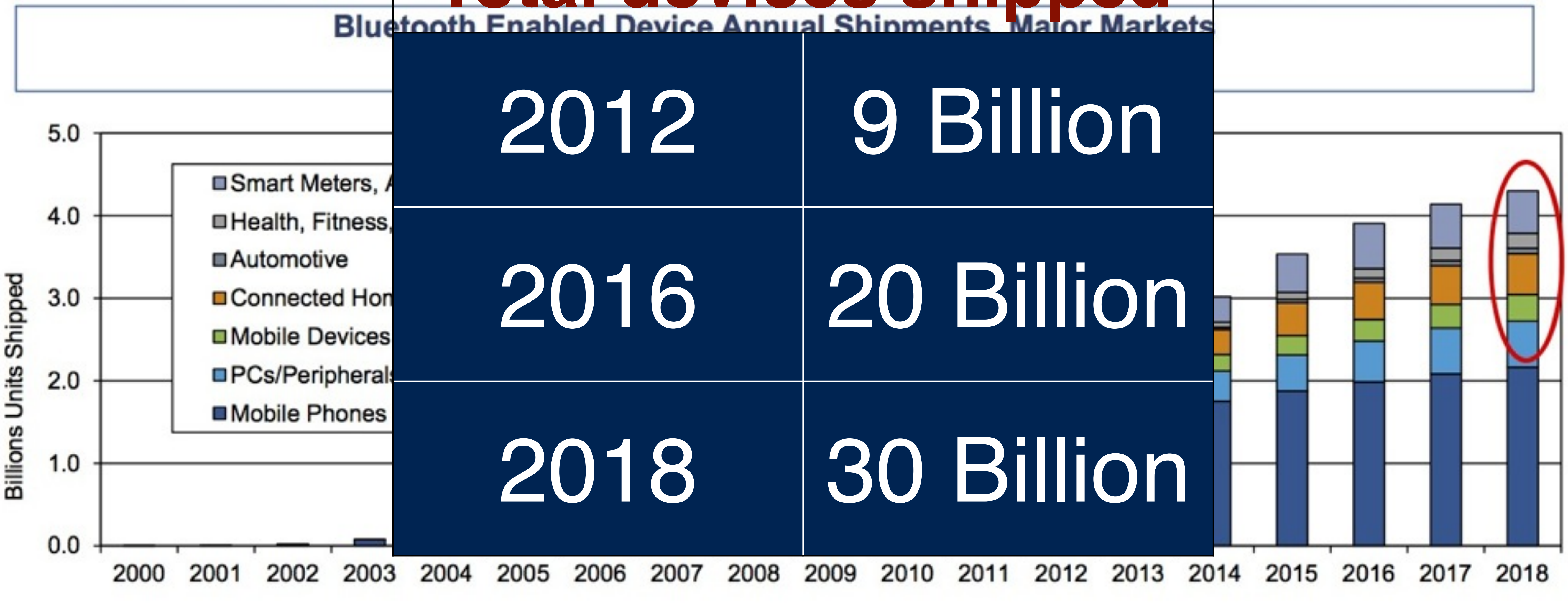
Bluetooth Devices

Total devices shipped

2012	9 Billion
2016	20 Billion
2018	30 Billion



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Fundamental Problem

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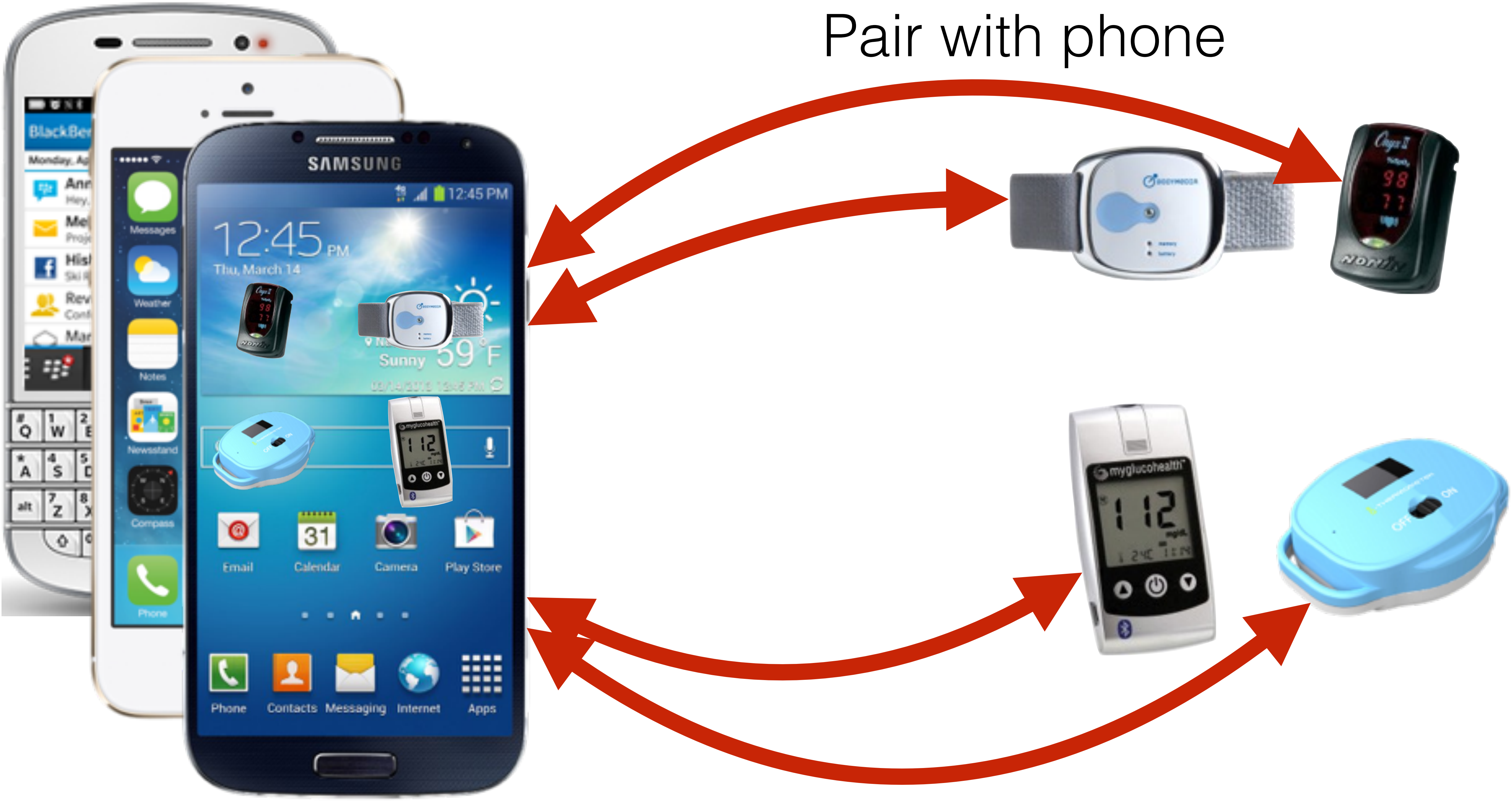

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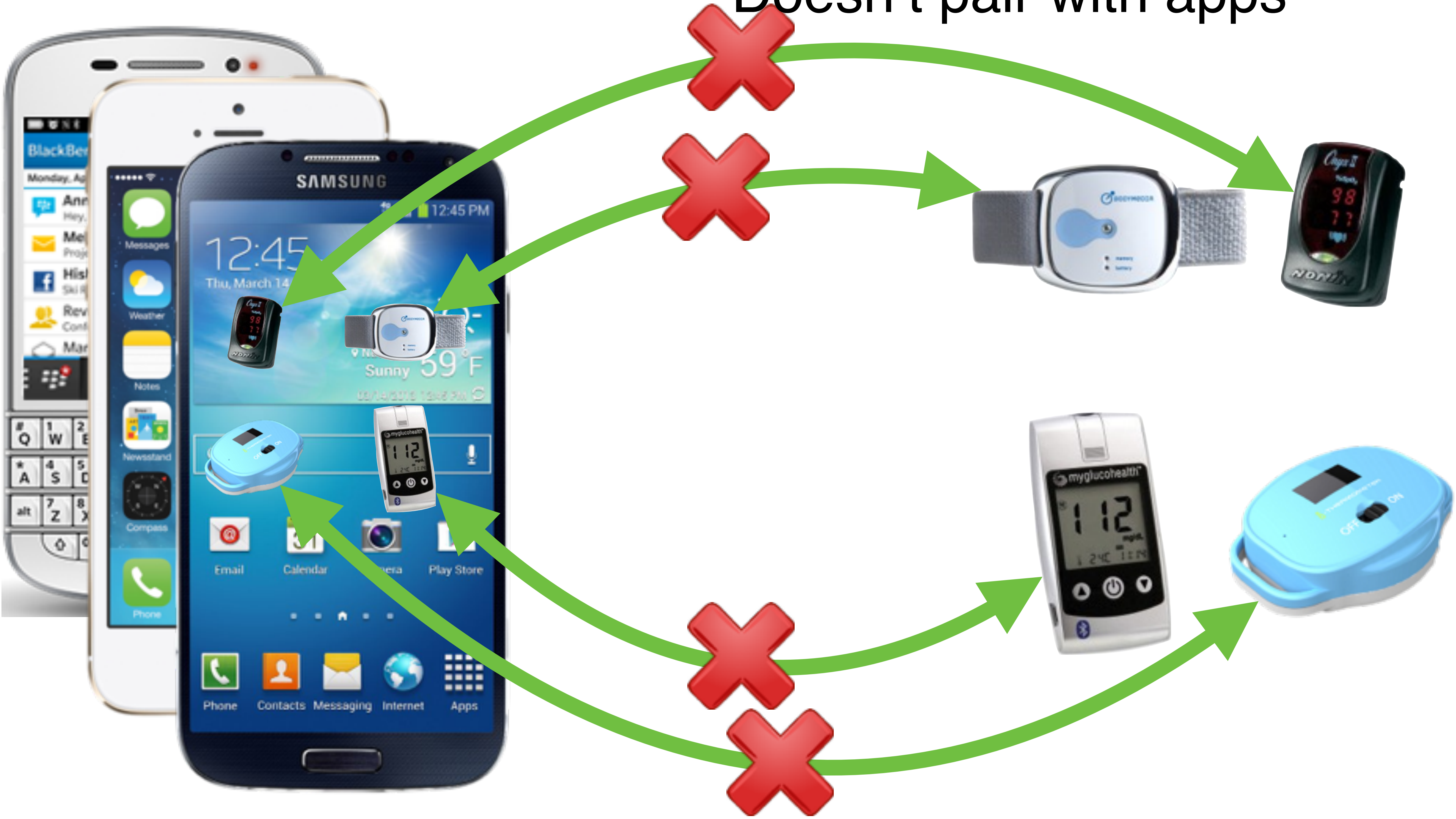
Doesn’t pair with apps



External devices and Android design

- Android is not designed to protect these external devices

- We designed the following two attacks to show the problem:

  - Data-stealing attack

  - Data-injection attack

Device Mis-bonding Attacks

Adversary Model

- A malicious app with BLUETOOTH and BLUETOOTH_ADMIN permissions is installed on the victim's phone
- Additionally, physical proximity is required for data-injection attacks

Normal Scenario

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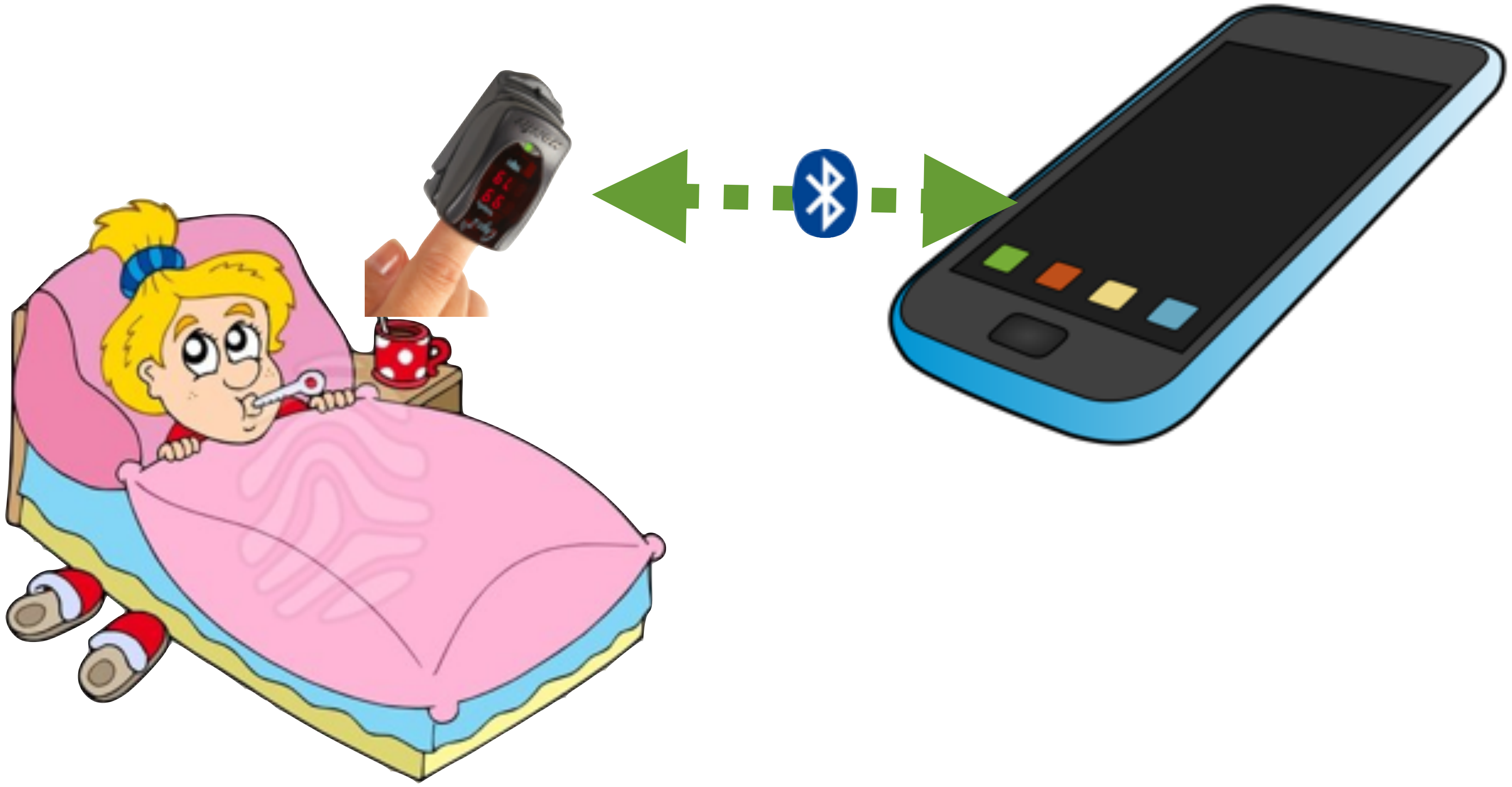

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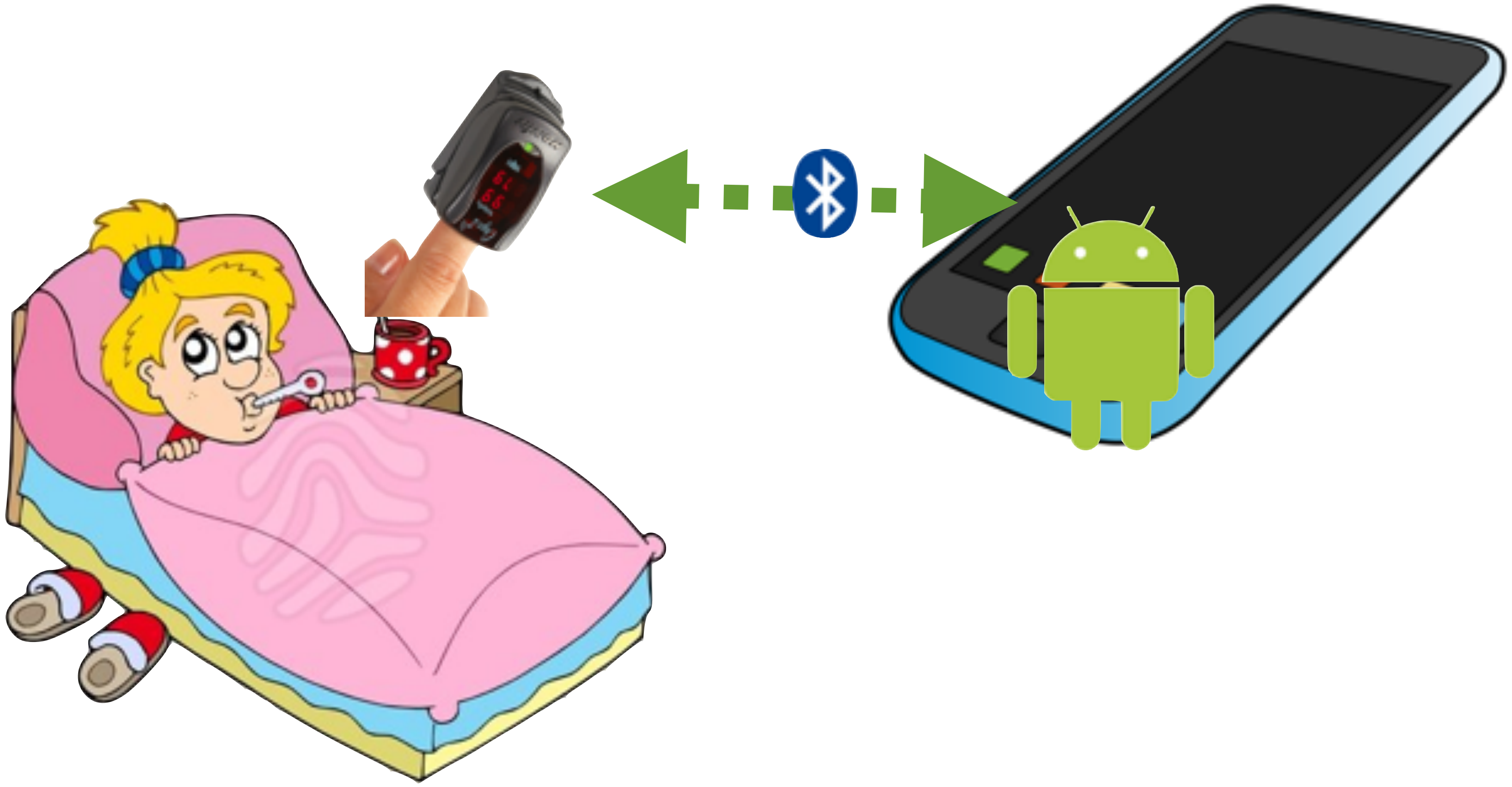

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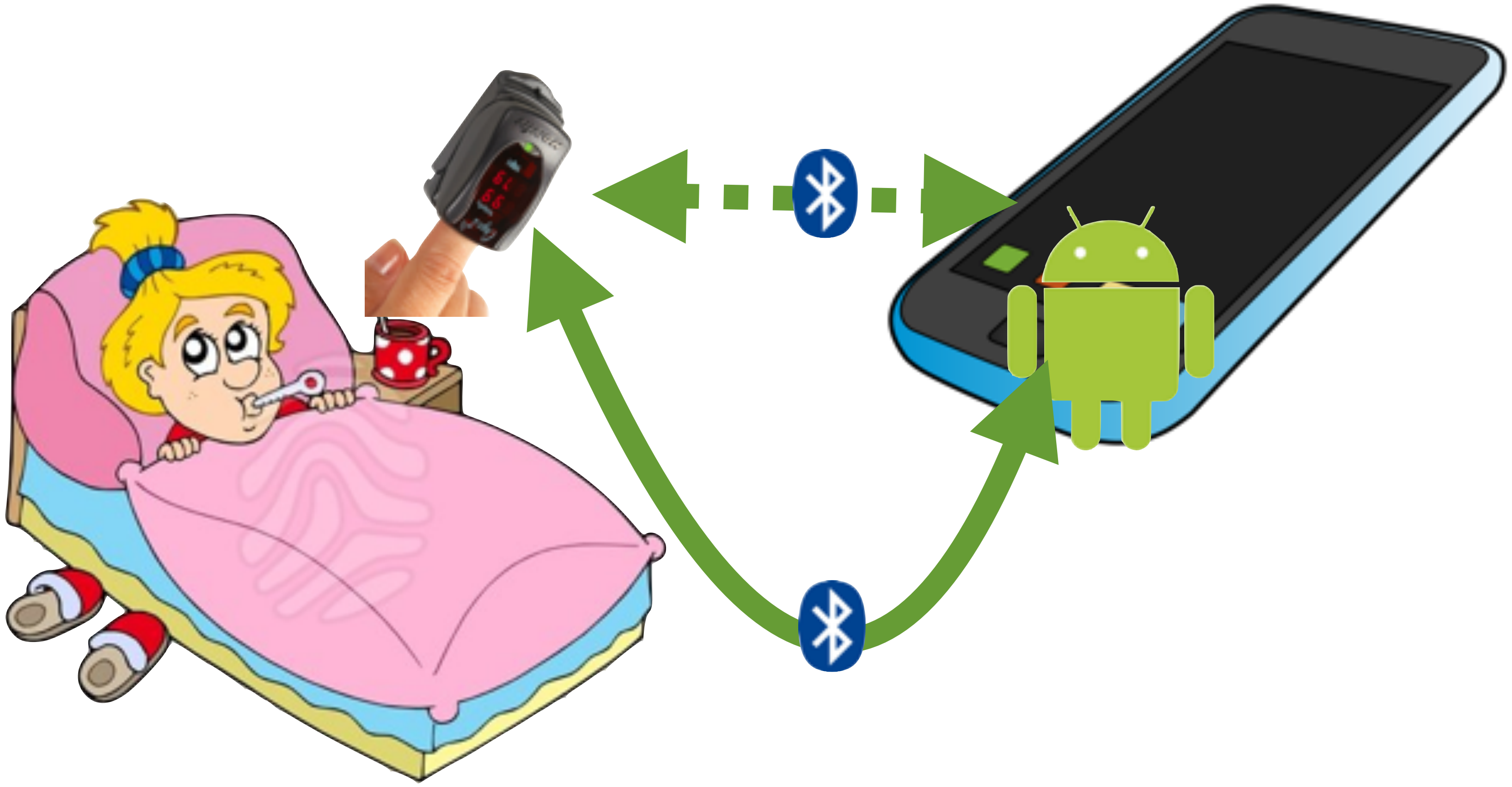

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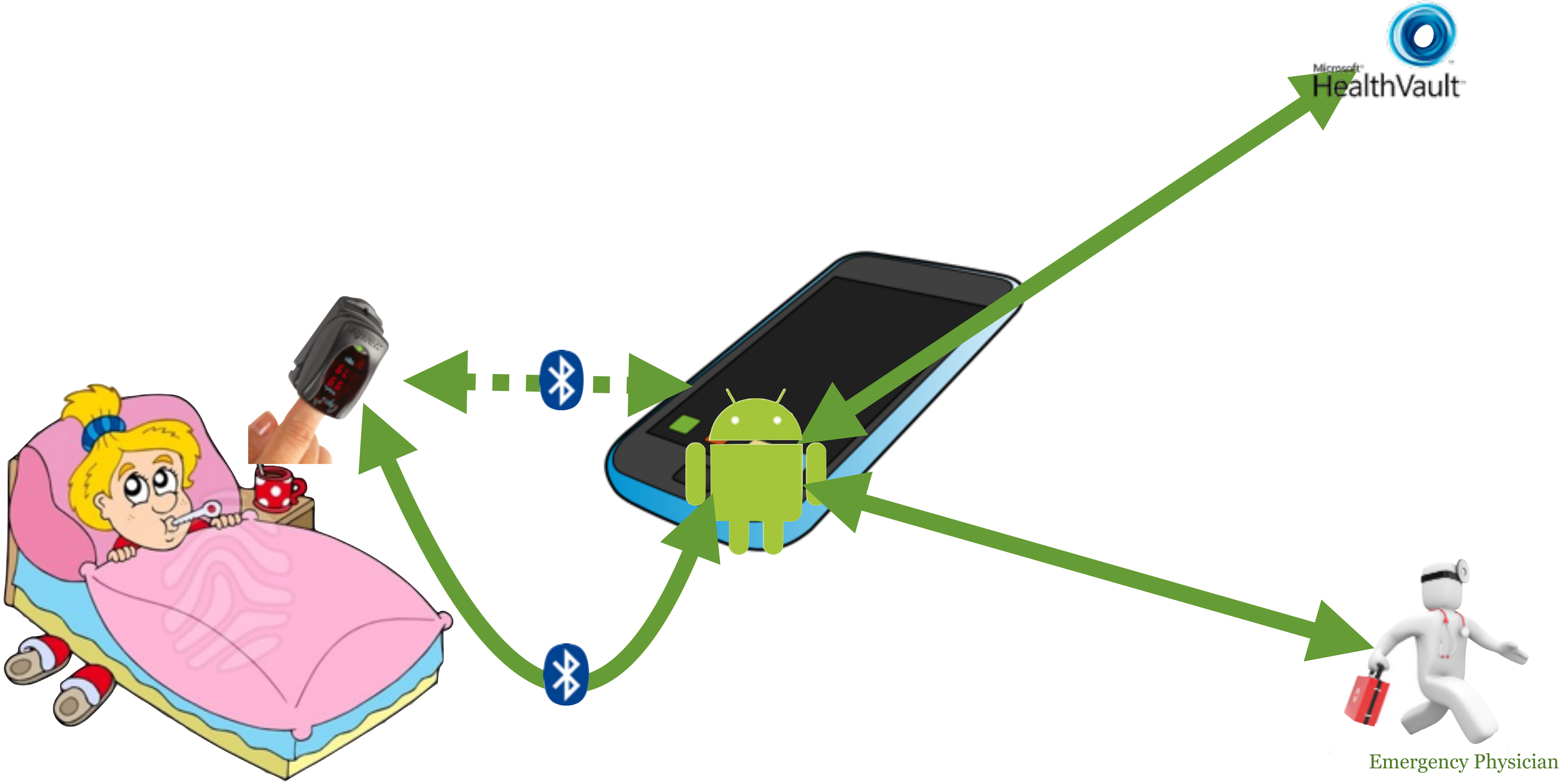
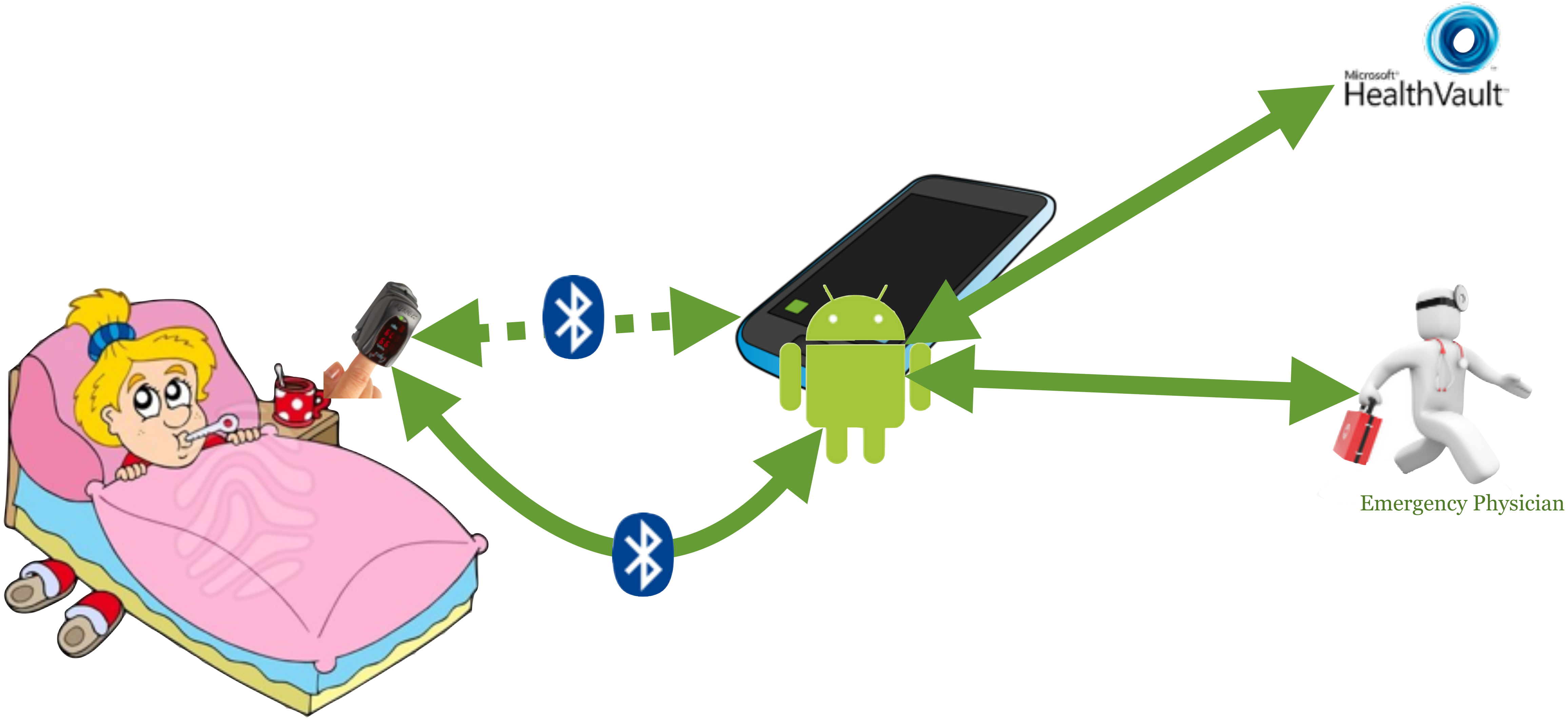


Data-stealing Attack



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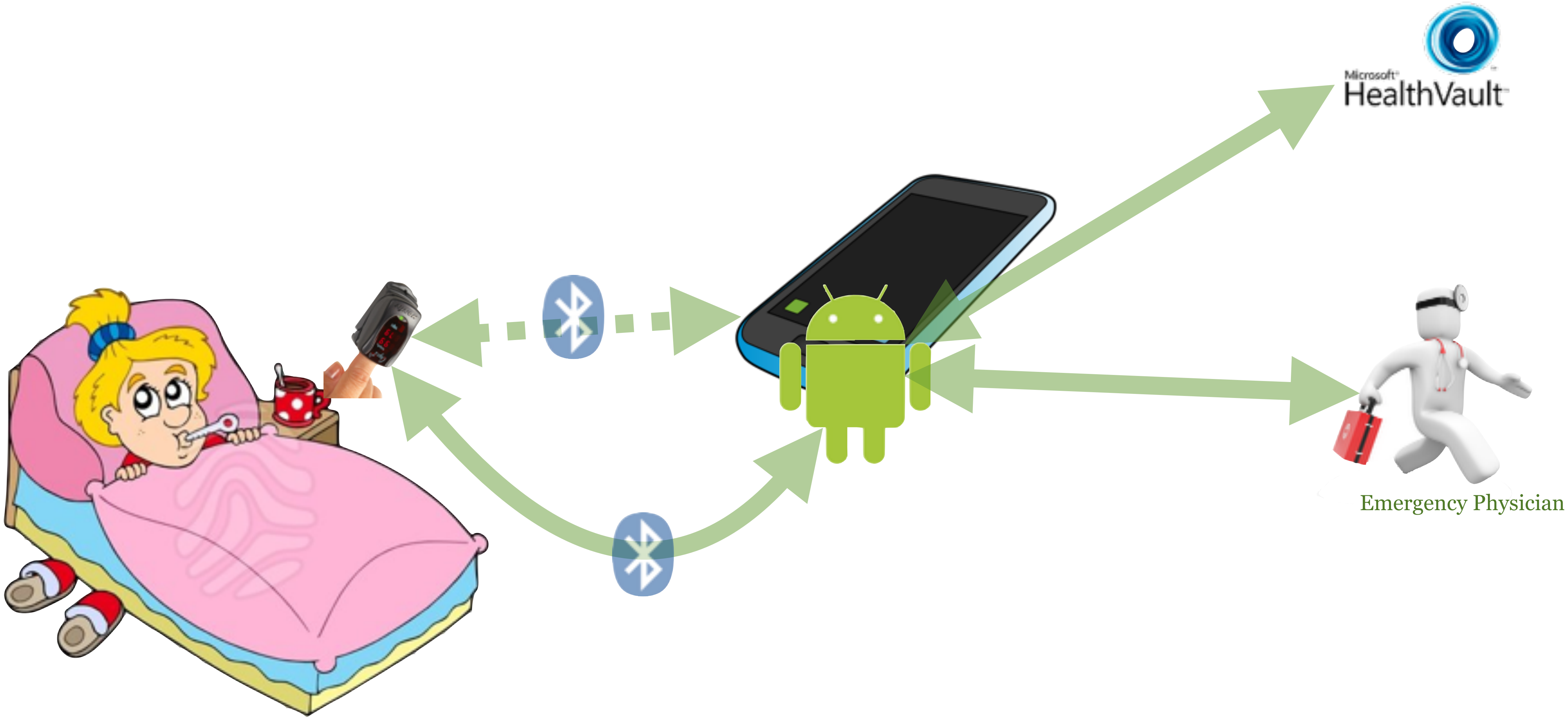

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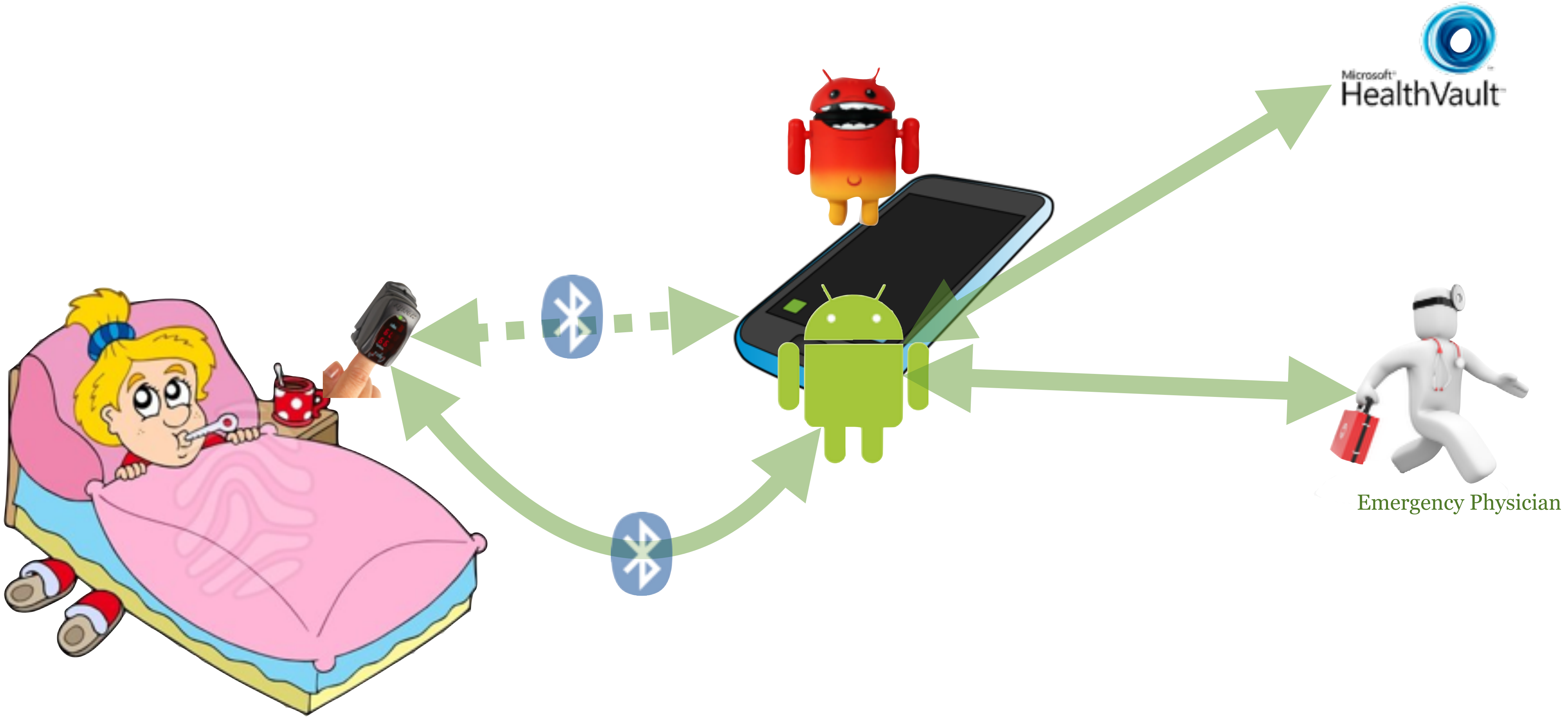

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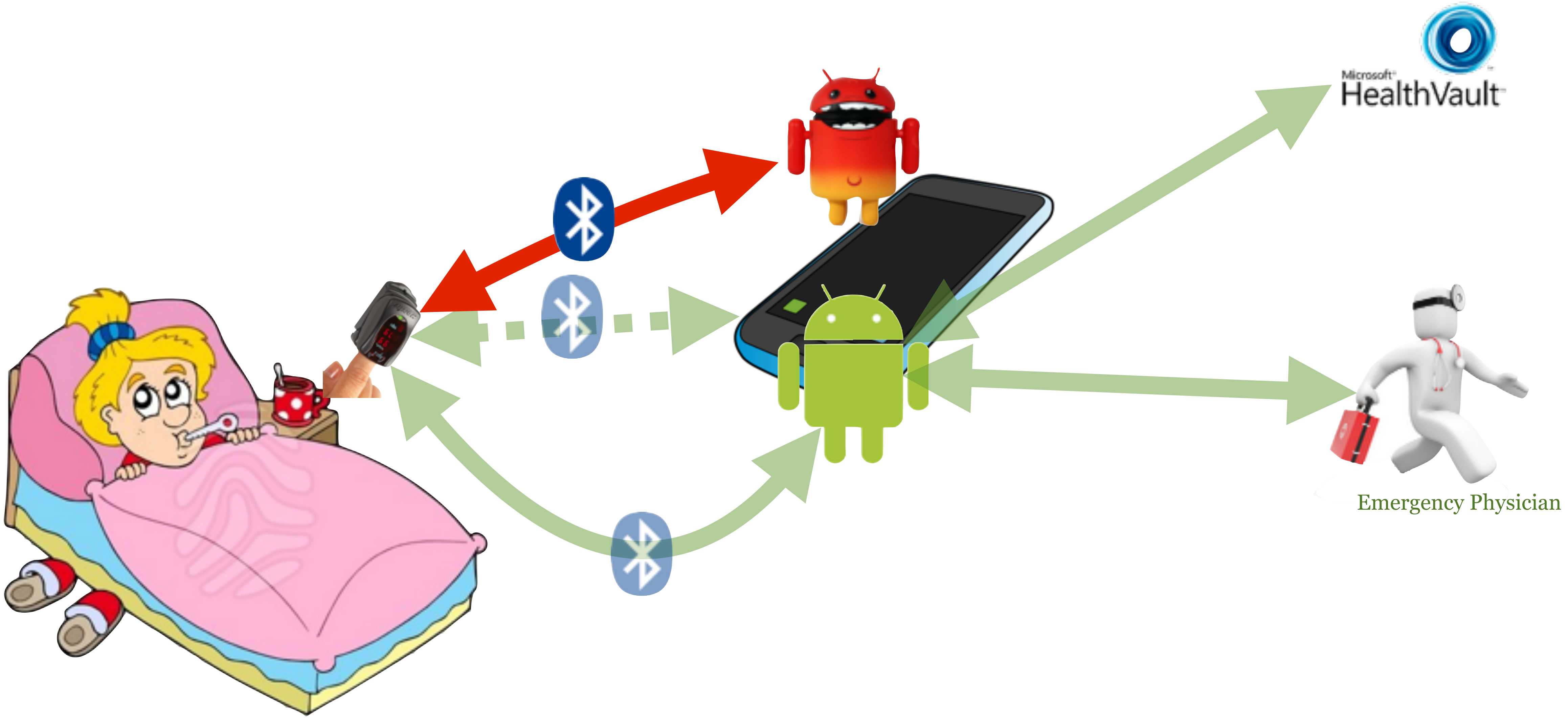

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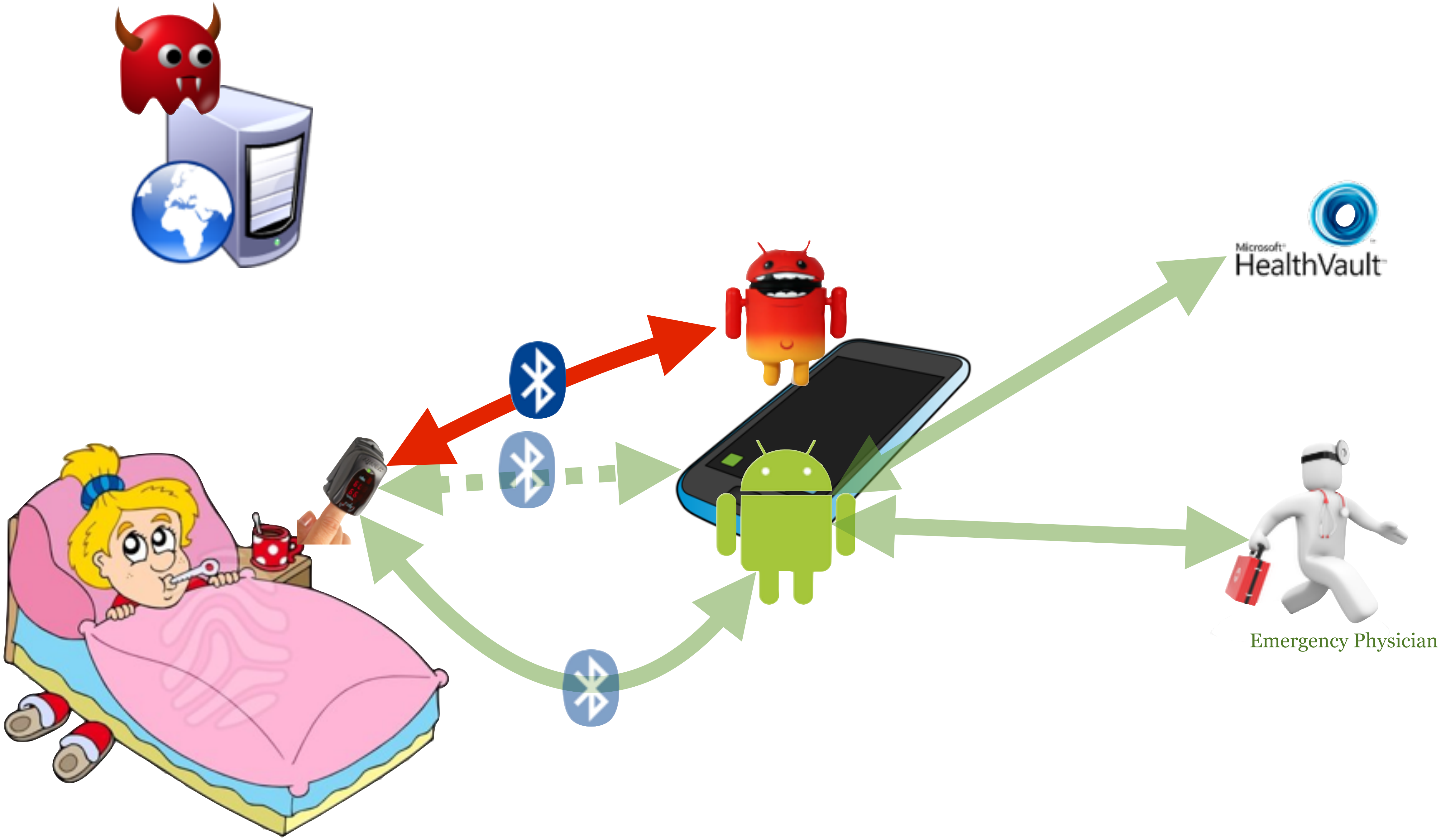

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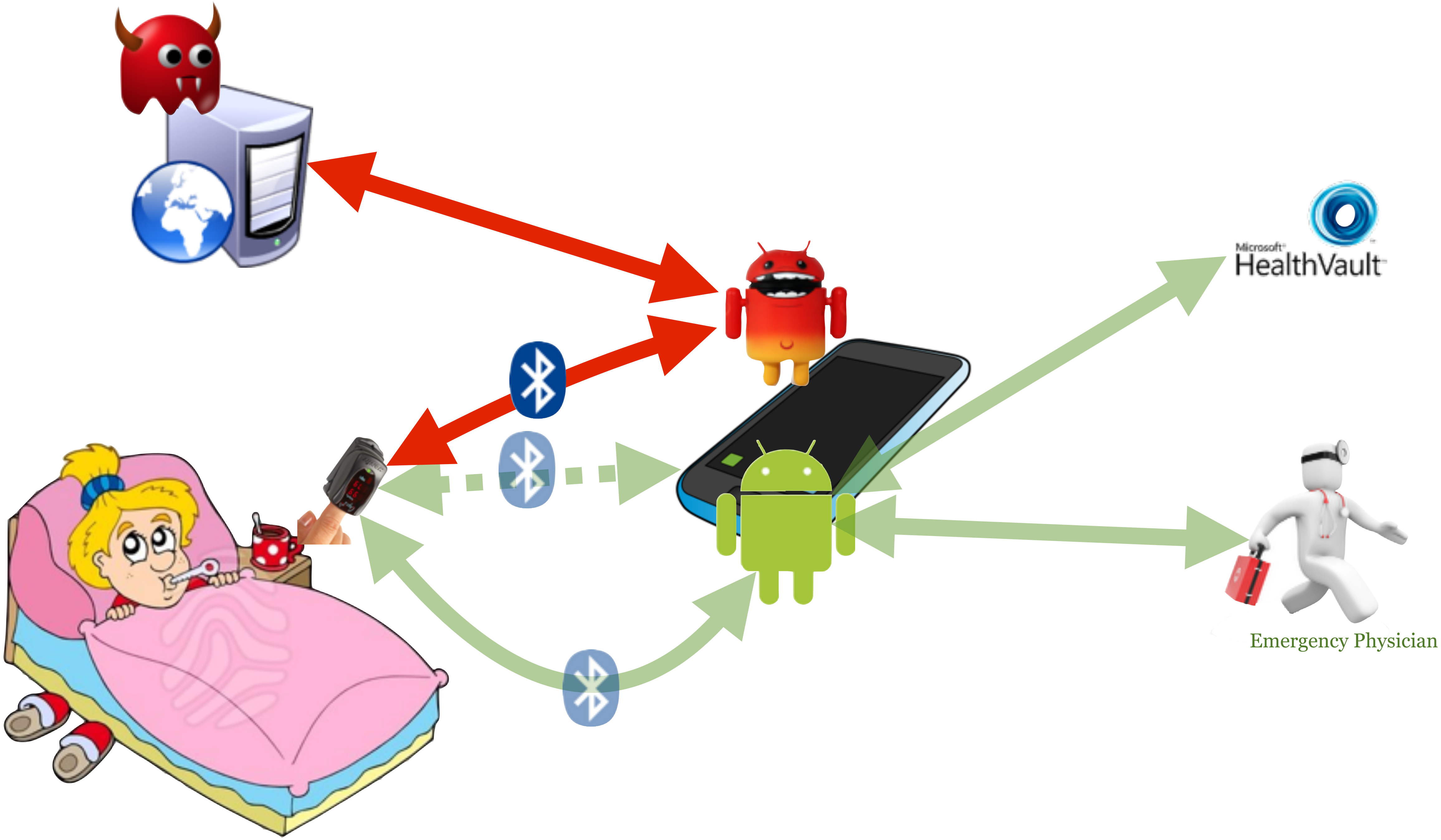

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- When to steal data?
    - Device is not always connected
    - Naive strategy: Periodic device discovery
        - Increased power usage
        - Not stealthy
- Observation: Execution of device's official app is a strong indication of the device being ON and in connection range.
    - getRunningAppProcesses() or linux command ps can find if the official app is running in O(n)
    - getRunningTasks() can find if the official app is running in O(1), with additional GET_TASKS permission

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    - **disruption**: simply disrupt the official app connect, reliable but less stealthy
    - **pre-connection**: right before the official app connects, reliable and stealthy
    - **post-connection**: right after the official apps disconnects, reliable and stealthy

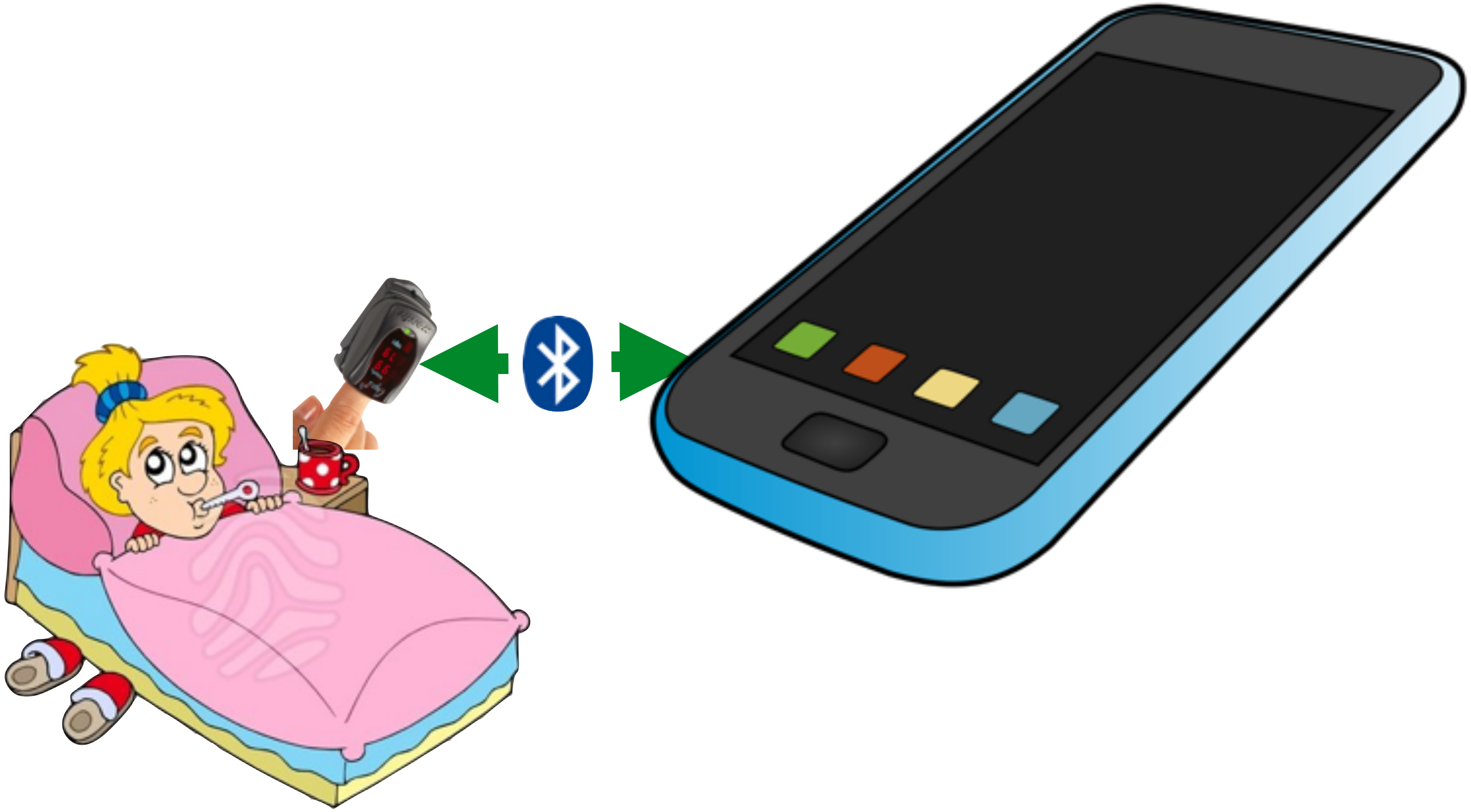
Success Rate

Target Device	Pre-connection	Post-connection
Bodymedia Link Armband	99/100	100/100
iThermometer	42/100	100/100
Nonin Pulseoximeter	99/100	92/100
MyGlucoHealth Glucometer	100/100	0/100* *device turns off automatically after sending data to the phone

Stealthiness

Technique	Avg. Power Consumption	Sampling Rate
getRunningAppProcessess()	8mW	2 samples/s
getRunningTasks()	3mW	2 samples/s
connect()	17mW	0.18 samples/s
startDiscovery()	15mW	0.054 samples/s
Facebook	18mW	
Gmail	1mW	

Data-injection Attack



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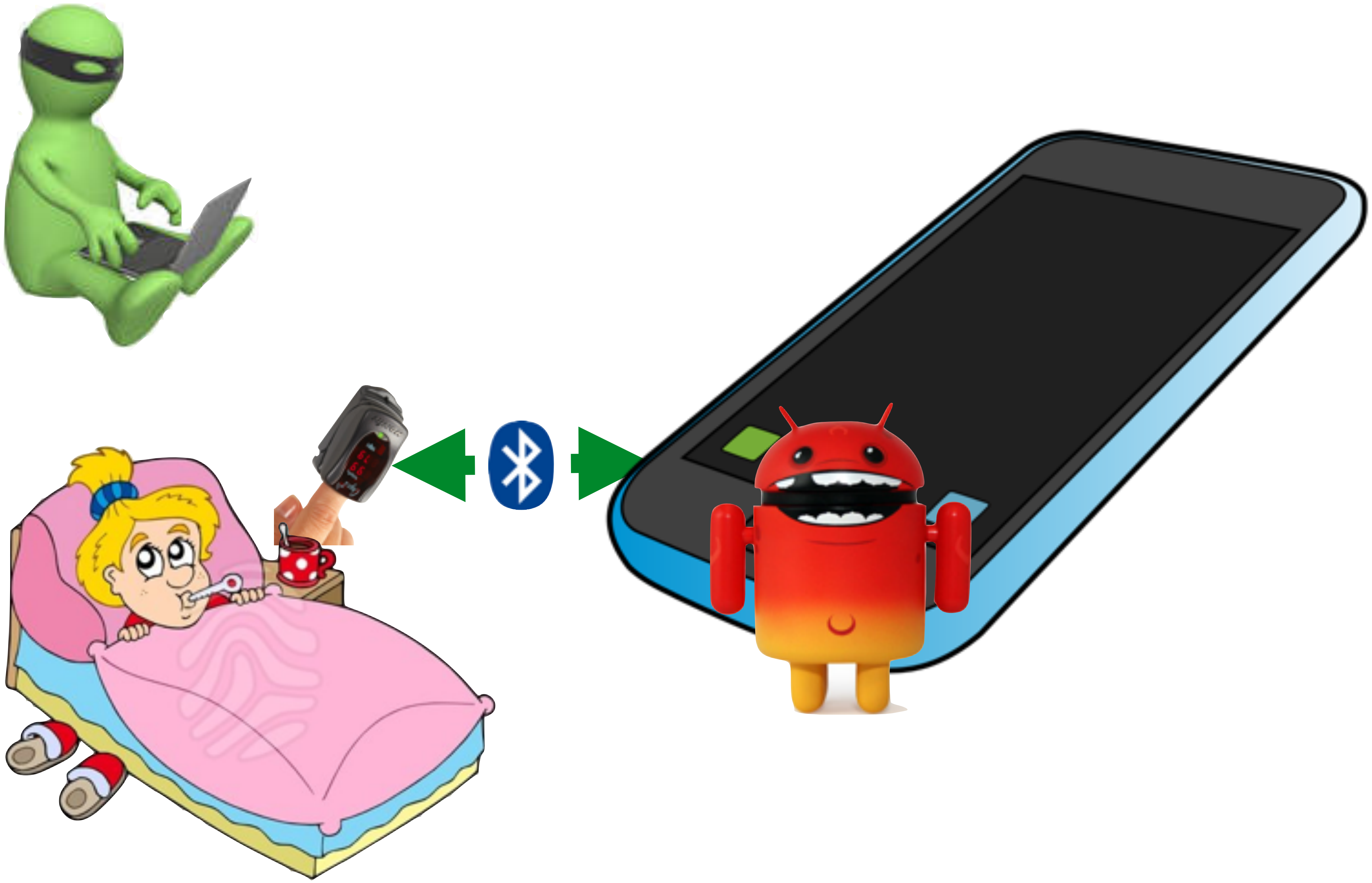

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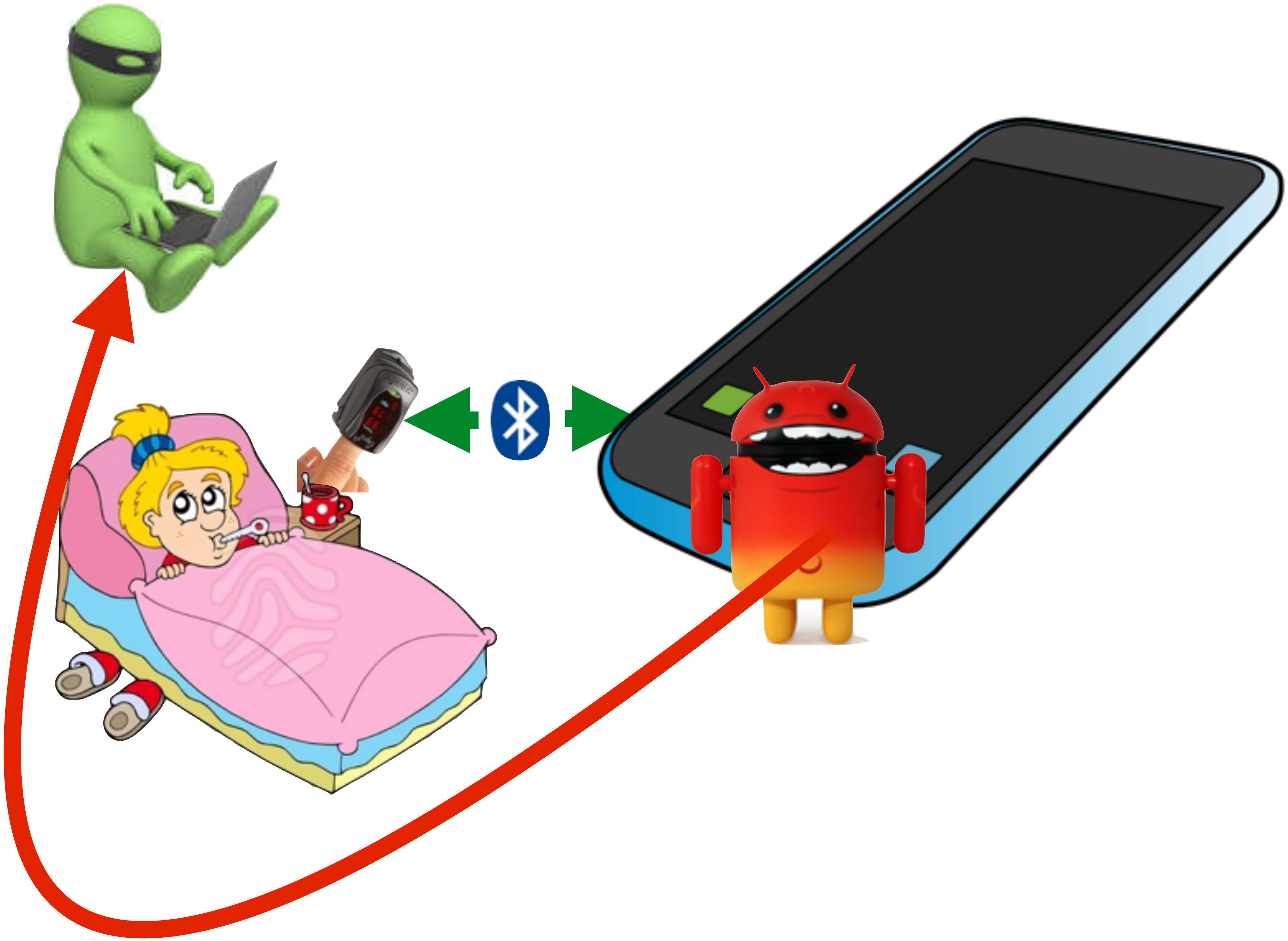

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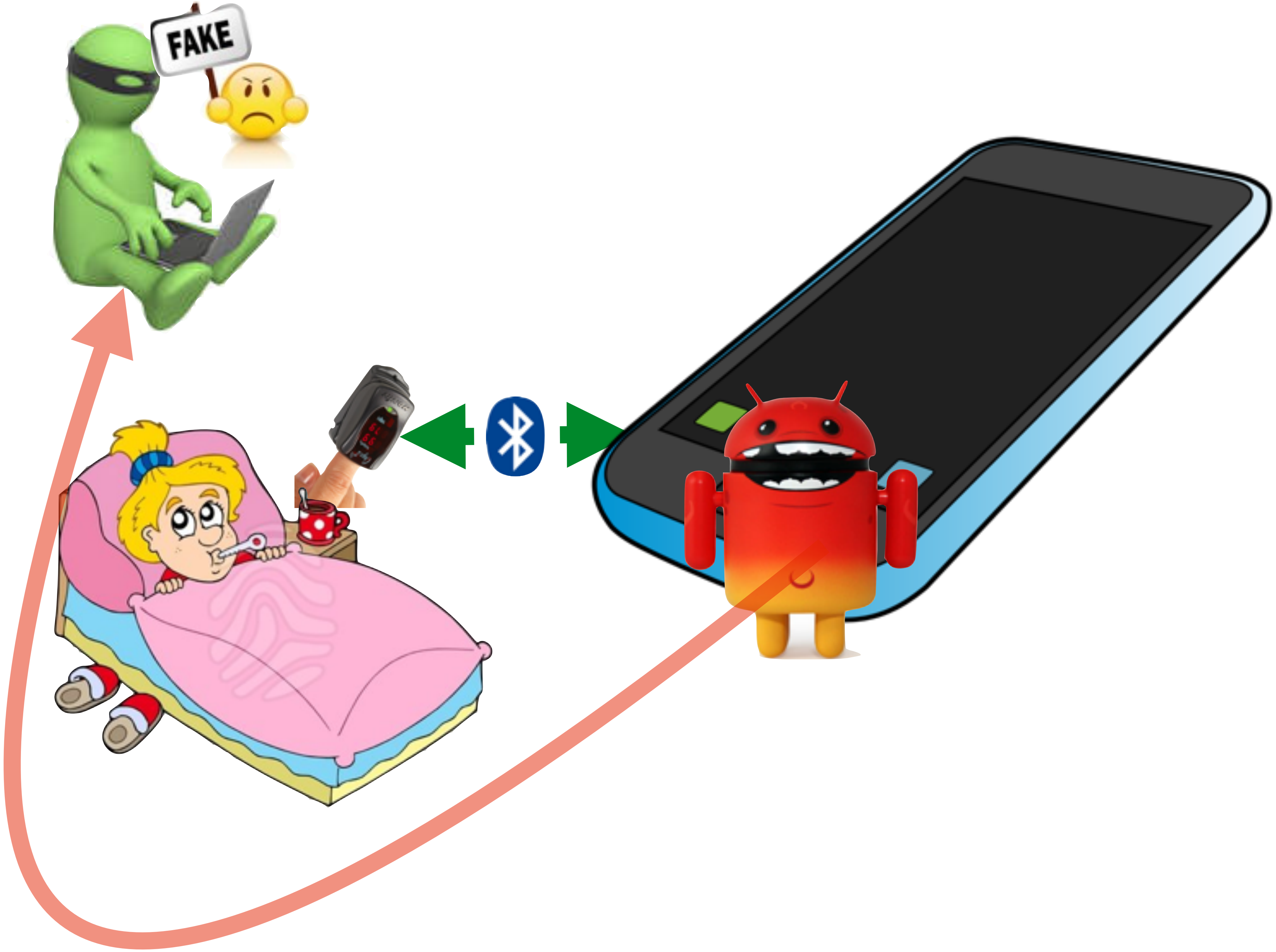

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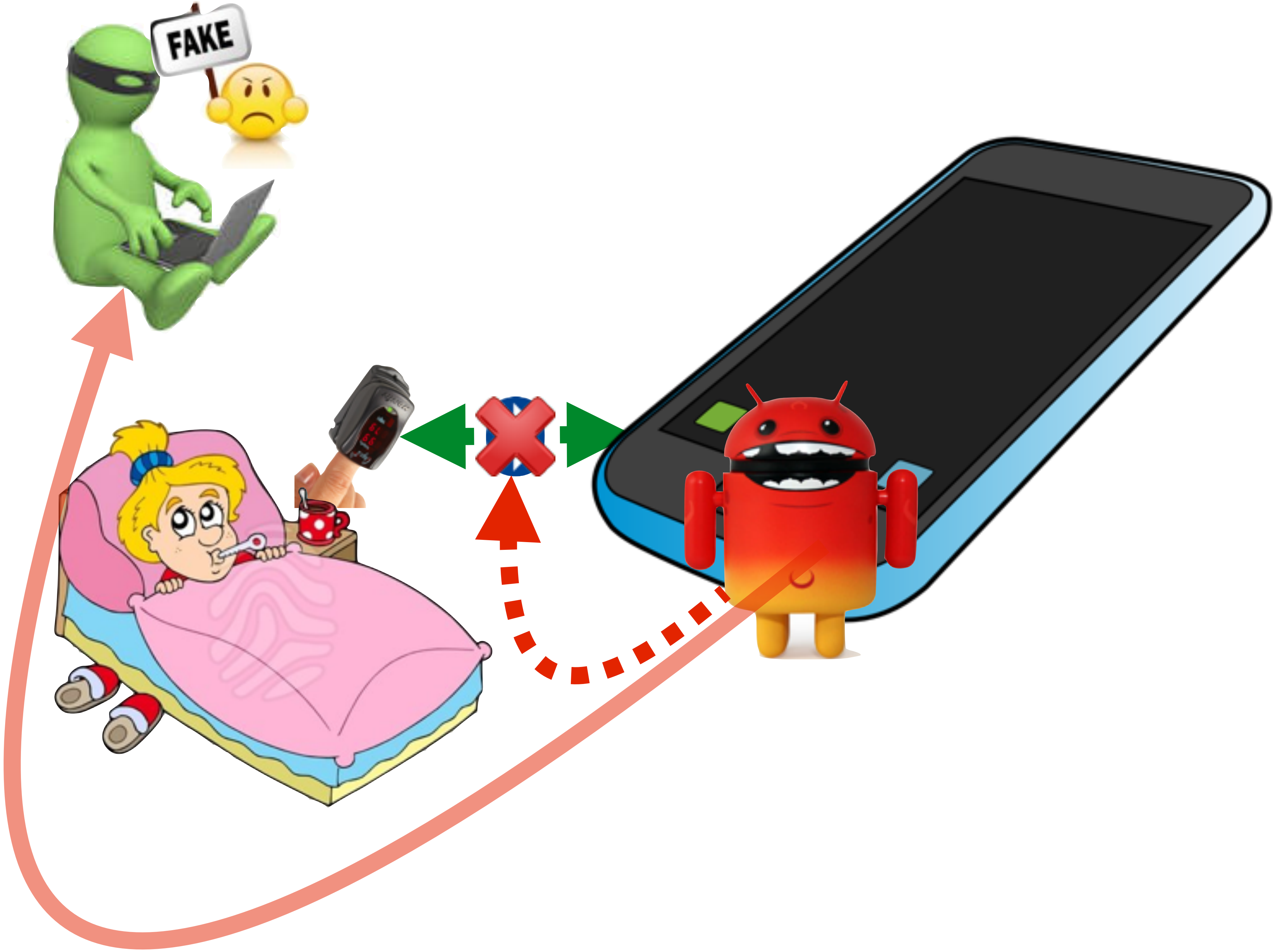

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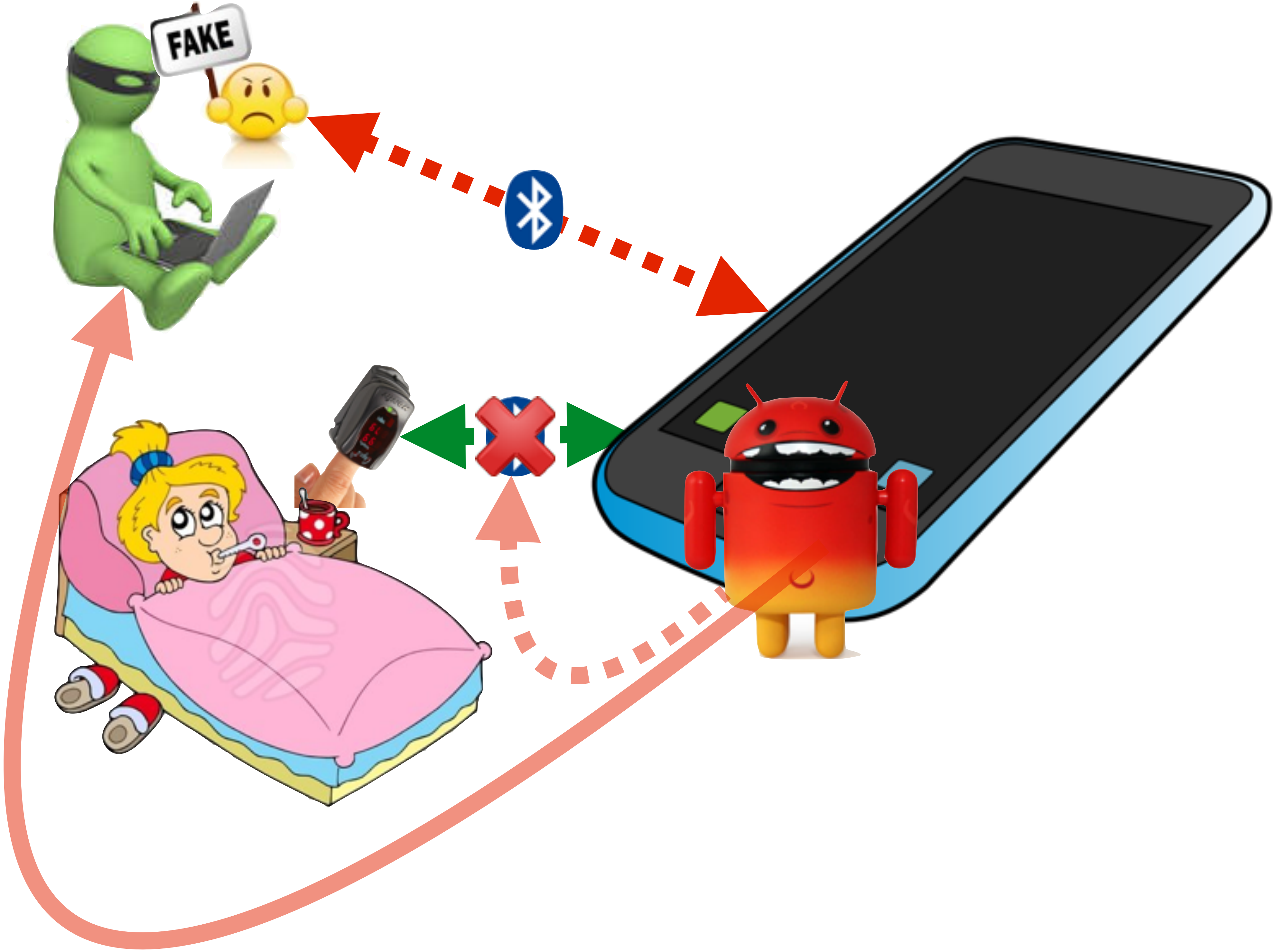

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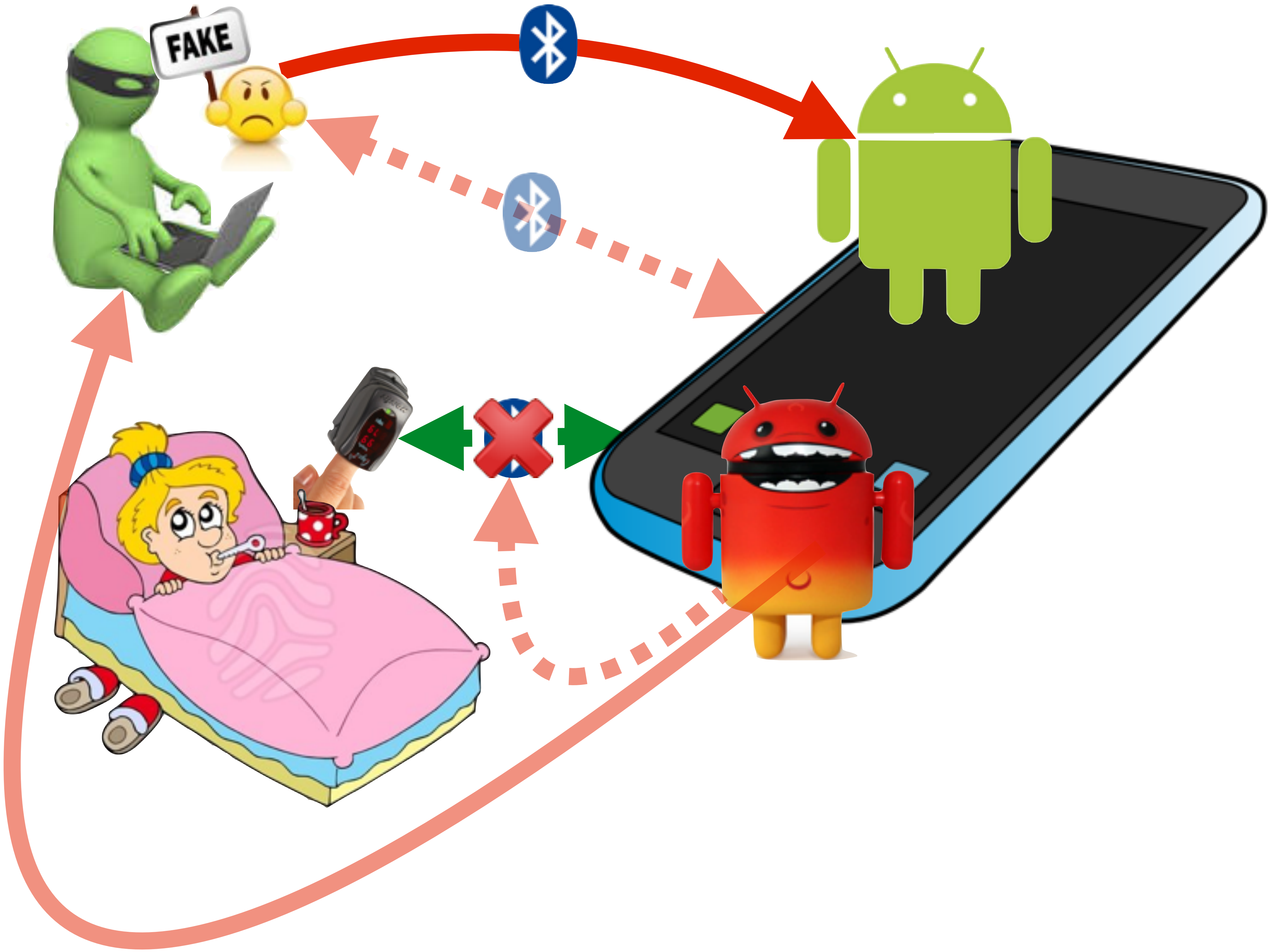

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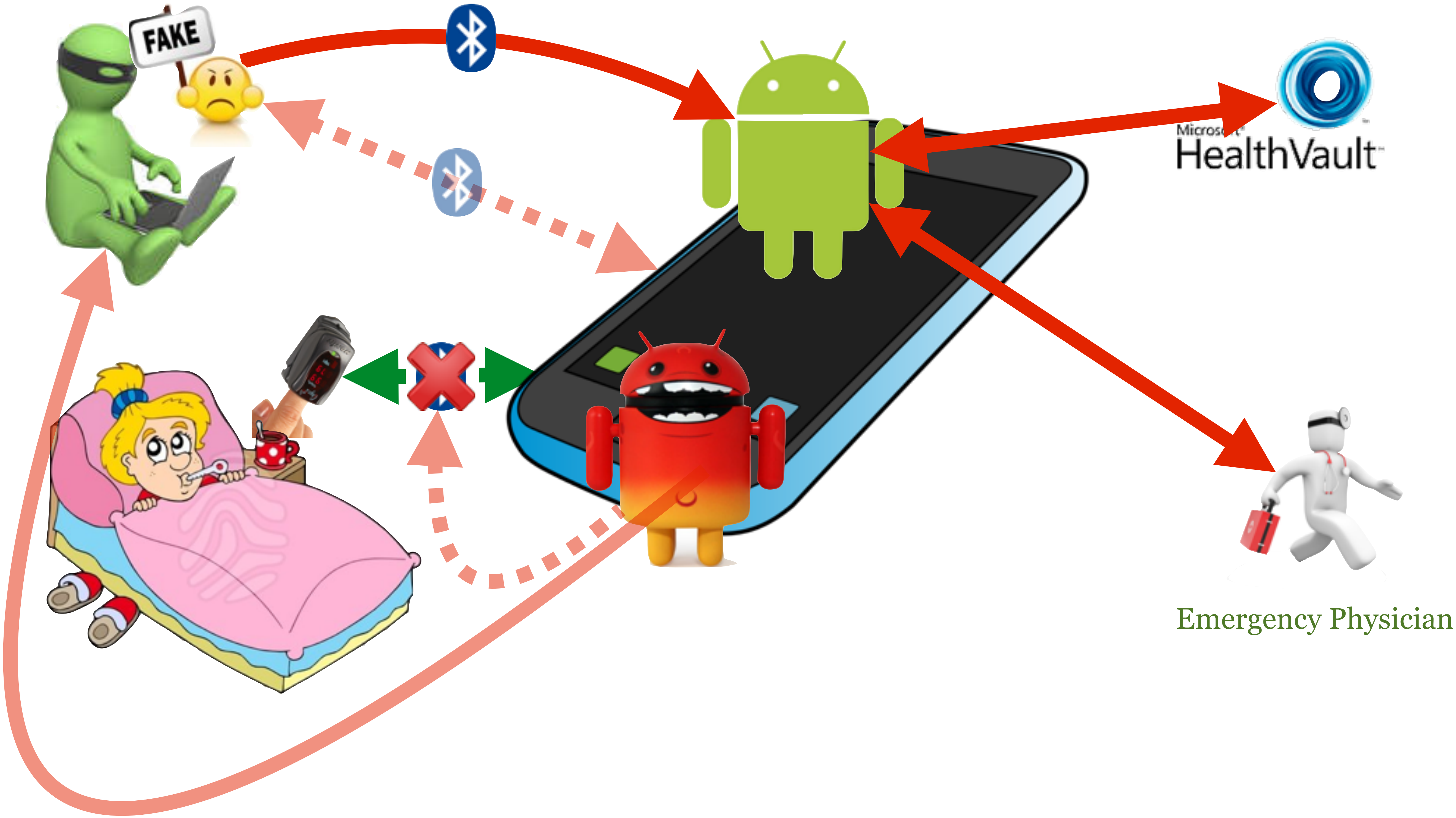

Device Cloning

- Target device MAC address is sufficient for cloning

- Target device name and UUID can make clone indistinguishable from original device

- This information can be obtained using BluetoothAdapter.getBondedDevices()

- SpoofTooph temporarily overwrites the MAC address of bluetooth dongle

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- Clone cannot connect without this key
- Observation: We cannot get the link key, but can simply replace one
- Android’s pairing and un-pairing methods are not directly available to programmers

Connection Race

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- Observation: How Bluetooth socket works?
  - Devices are in slave mode and smartphone initiate connection
  - Paging: Devices switches between page sleep and page scan mode
  - Device accept connection only in page scan mode
  - To save power these devices have large page sleep period and small page scan period
  - Adversary can set arbitrary page sleep and page scan period in allowed range

Adversary always wins!

Distance of cloned device	1 feet	20 feet (with wall in between)
Number of observations	100	100
No. of times original device responded	0	0
No. of times cloned device responded	100	100

- Using default page sleep and page scan time period (much more than minimum)
- Clone’s radio had 2.5mW radio while original device had 100mW radio

Pervasiveness of Device-Misbonding attacks

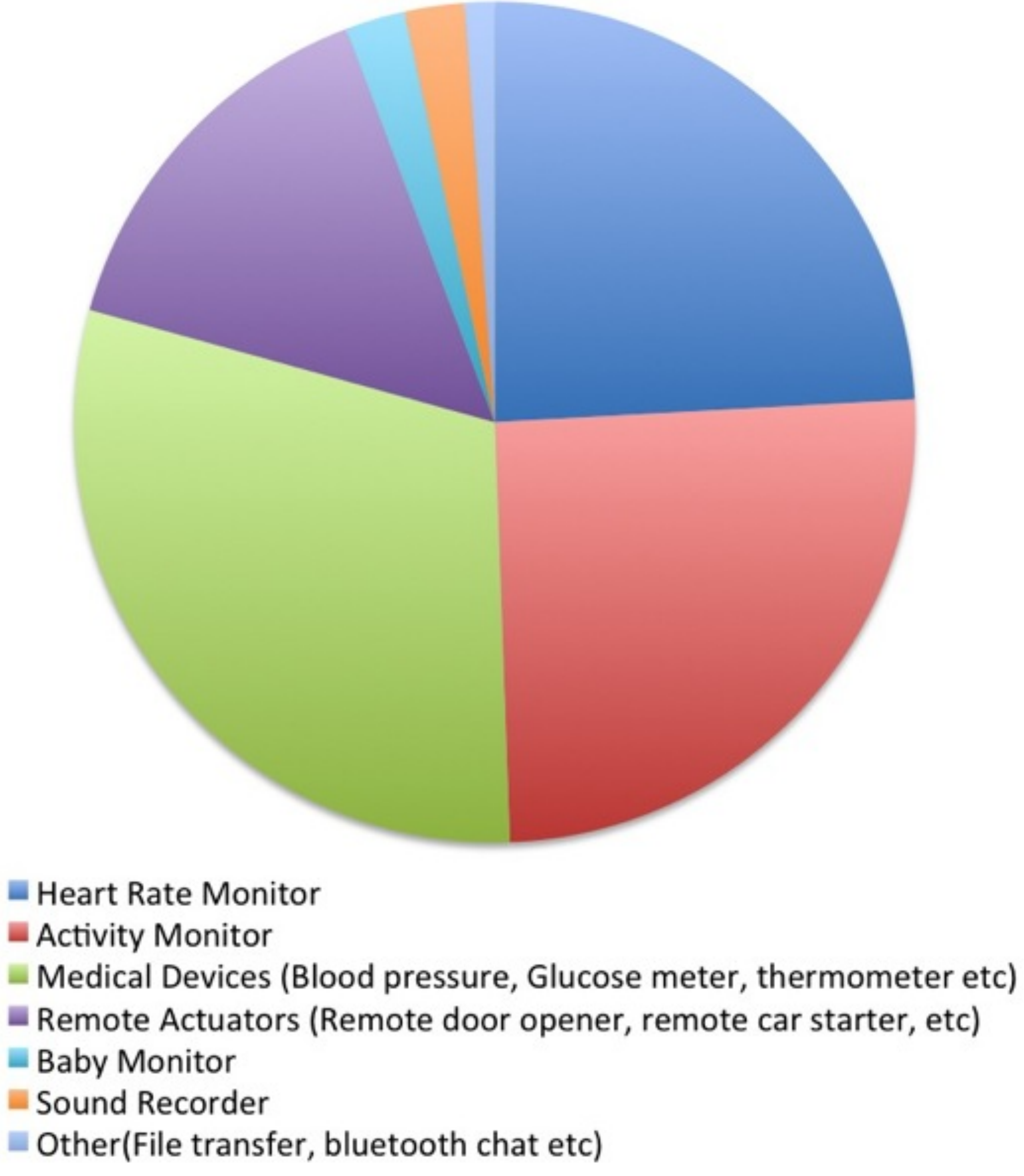
Measurement

- The problem discussed before are caused by lack of bonding between external device and app
- Device and app manufacturers can fix this issue using appropriate authentication mechanism
- We conducted a measurement study to see if any device already have such security mechanism

Methodology

- App collection: Manually searched for bluetooth apps using following search queries:
    - “Bluetooth Door Lock”
    - “Bluetooth Health”
    - “Bluetooth Medical Devices”
    - “Bluetooth Meter”
    - Out of 90 apps, 68 apps involved some private information
- Decompiled the 68 apps and studied the source code

Classification of apps



Methodology

- Searched for authentication-related programming structures
- Authentication is always based on some secret. It can come from:
    - external inputs e.g. UI,
    - web communication,
    - internal memory or
    - generated by some cryptographic operations

Manual Analysis

- Manual analysis of 20 apps. The other 48 apps were filtered out by locations of their suspicious APIs.

Authentication Methods	Libraries/ Functions used	Total	Apps with app-device authentication
Crypto	javax.crypto, bouncycastle	9	0
Internal storage	openFileInput()	15	0
Web communication	HttpClient	50	0
UI for app-device authentication	Manual	0	0

Defense
Dabinder

Source code

https://github.com/DabinderAndroid/extDroid.git

Solution

- Theoretically, device manufactures can provide protecting
    - Upgrading both app and hardware, some apps come from third parties
    - Billions of existing devices
    - Case-by-case fix can be ugly
- Better alternative is to provide an Android OS-level solution

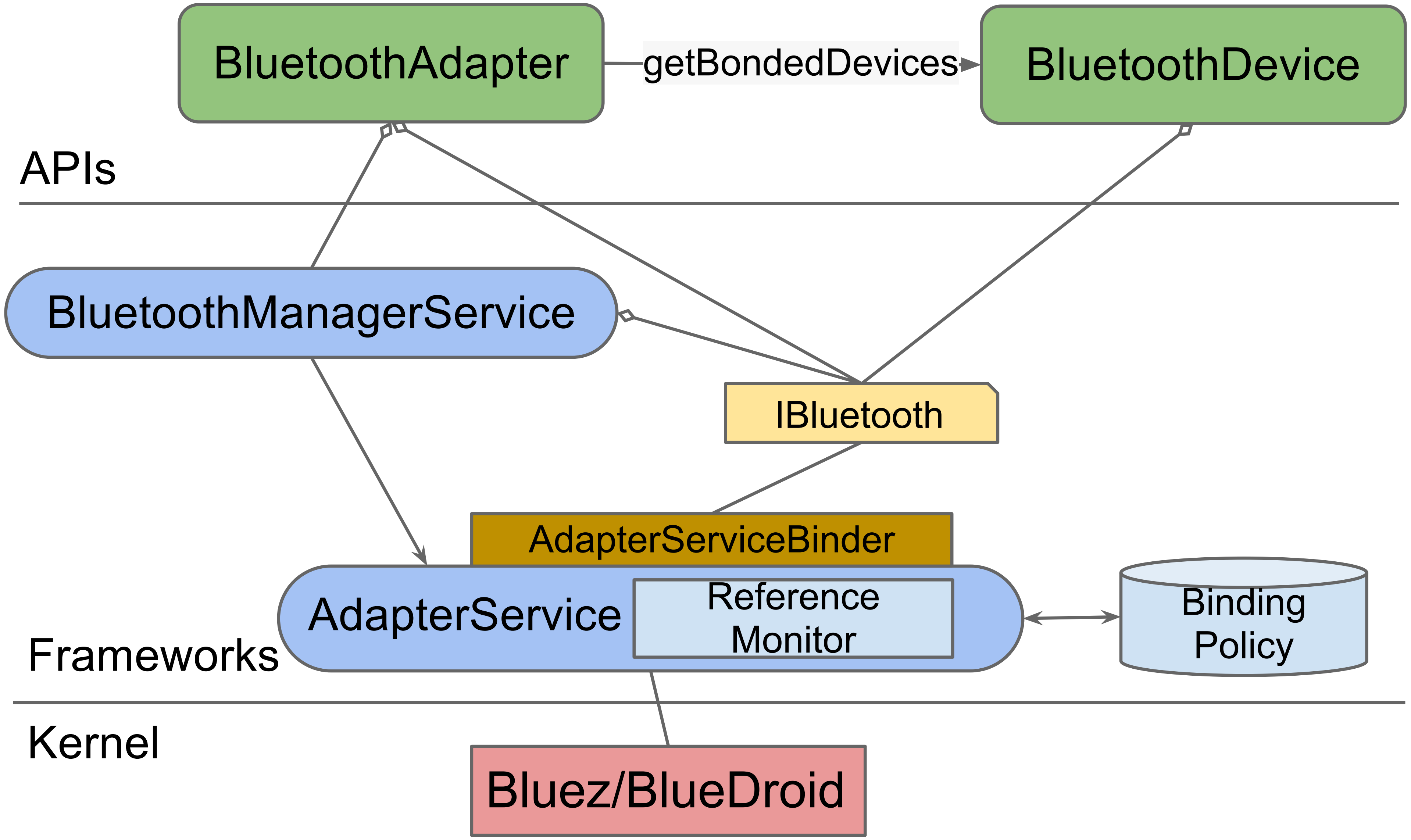
Dabinder Design

- Pairing Control
  - Maps external device MAC address to app
- Connection Control
  - Before socket established device-app mapping is checked
- Unpairing Control
  - Unpairing needs user interaction

Performance

Functions	Original	Dabinder	Delays
BluetoothSocket	mean 0.0317 SD 0.0059 ms	mean 0.0353 SD 0.0153 ms	0.0036 ms
connectSocket	mean 63.1670 SD 14.7098 ms	mean 86.5152 SD14.2201 ms	23.3482 ms
removeBond	mean 0.5319 SD0.1863 ms	mean 0.5493 SD 0.1822 ms	0.017ms

Dabinder Architecture



Conclusion

- Device Mis-Bonding (DMB) threat is serious
- Confidentially threat: Can lead to theft of private information
- Integrity threat: Can also compromise the integrity of sensitive data
- OS-level solution provides reasonable protection to bind app to the device

Thank you!

Please watch video demos at:

http://goo.gl/XXSGGU

(link is case-sensitive)

Defense: https://github.com/DabinderAndroid/extDroid.git