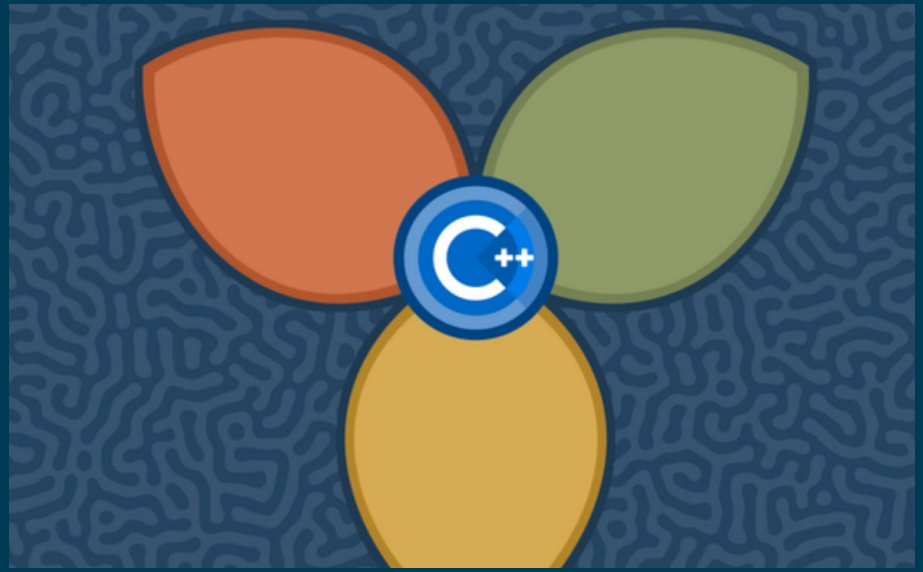
Introduction to

the Internet of Things



@Dafna_Mordechai

https://www.iot-workshop.online/

Hello!

- Dafna Mordechai, BSc. in Computer Science,
  The Hebrew University of Jerusalem (2008)
- RT Embedded Software Engineer
- Love technology, and love sharing it with others

@Dafna_Mordechai

https://www.iot-workshop.online/

IoT – The Internet of THINGS

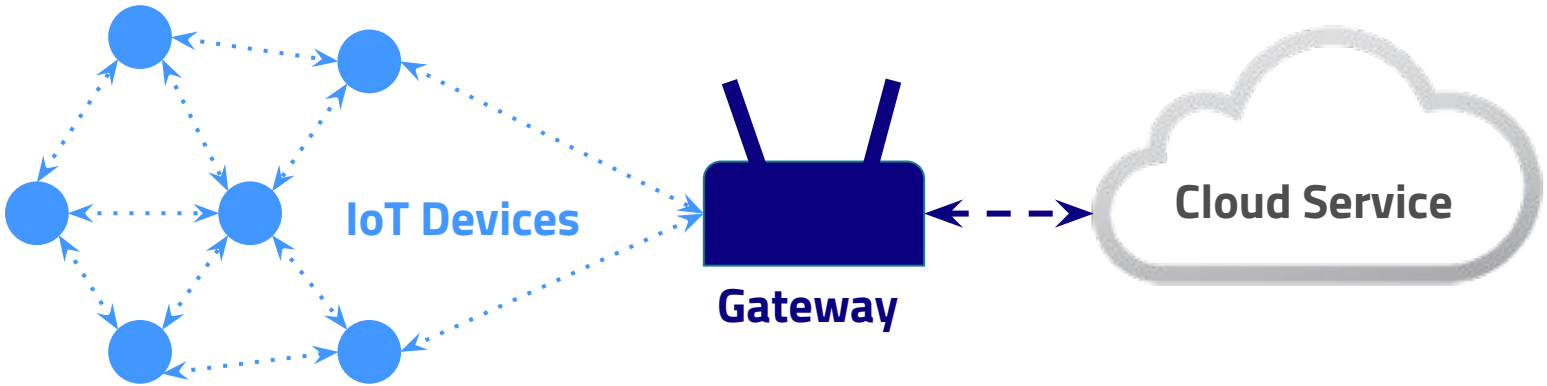
The Internet of Things refers to connecting machines and other physical objects to the internet, usually in order to gather information from sensors and to control systems from a distance.

"We project that there will be more than 55 billion IoT devices by 2025, up from about 9 billion in 2017."

Business Insider, IoT report, 2018

https://www.businessinsider.com/internet-of-things-report

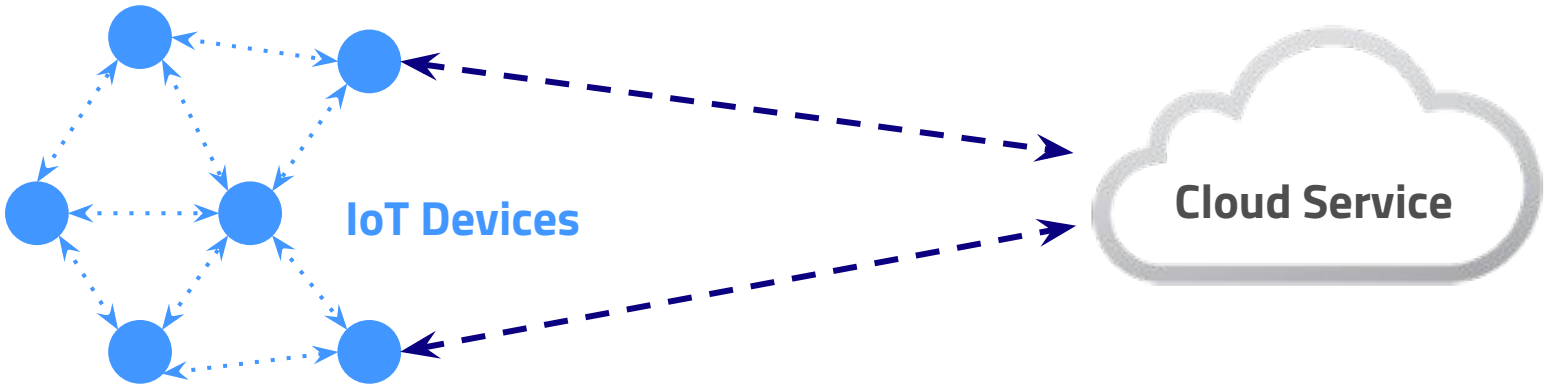
IoT – The Internet of THINGS



- Sensors / Actuators
- Wireless Communication

- Monitoring
- Analytics
- Control

IoT - The Internet of THINGS



Low-power, wide-area network (LPWAN),
e.g NB-IoT

Different THINGS have different NEEDS

Agriculture

Medical

Industrial

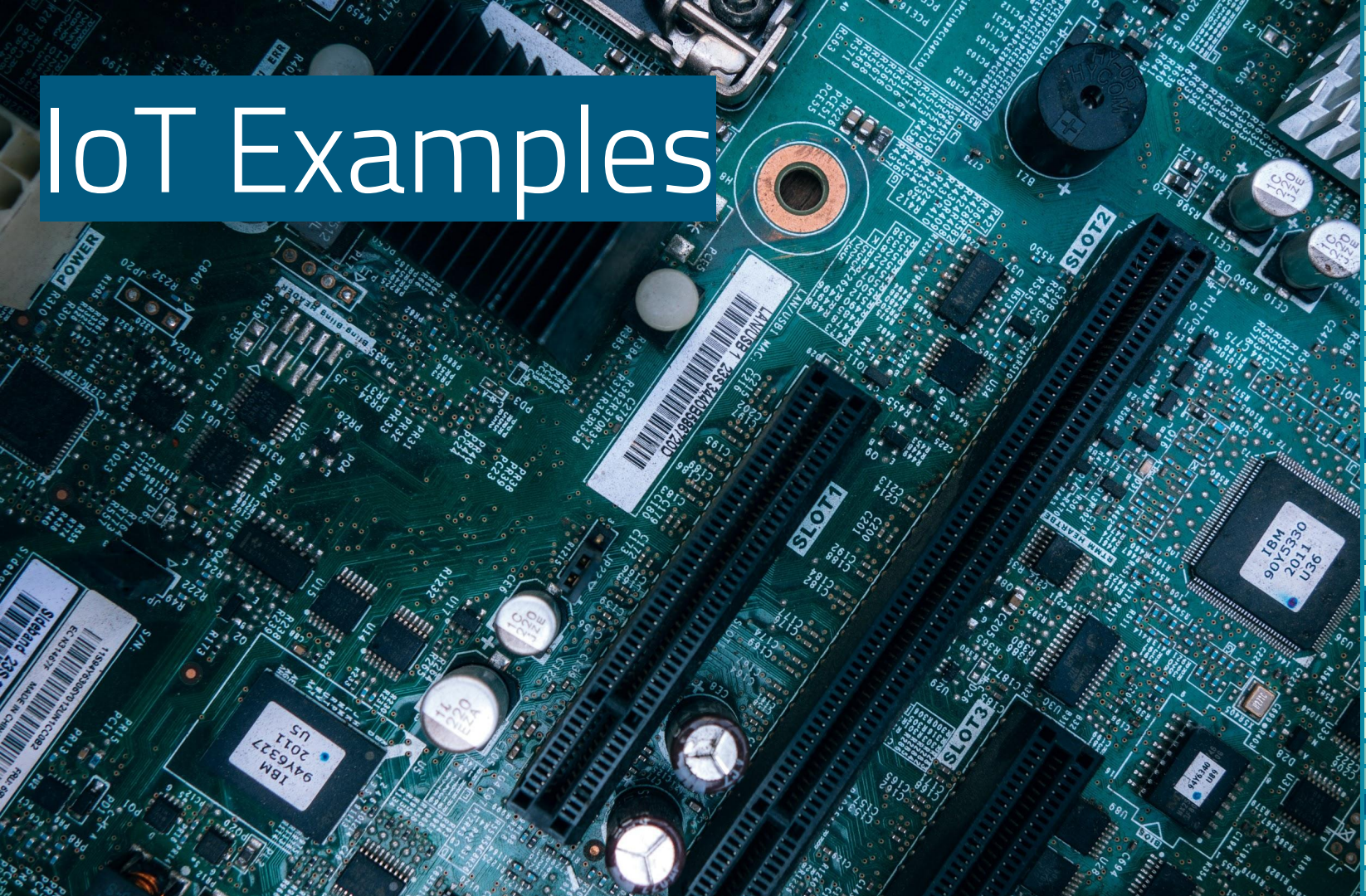
- Resources - Computing Power / Memory / Storage / Wireless Communication
- Peripherals - Sensors / Actuators
- Power Consumption
- Cost

Just how “SMART” devices get?

Just how “SMART” devices get?

(Intelligence) Algorithms
(Behaviour) Actuators
(Communication) BLE
(Memory) RAM / FLASH
(Perception) Sensors

IoT Examples



Personalization

Monitor, Analyze, Improve.

Wearable Fitness Tracker

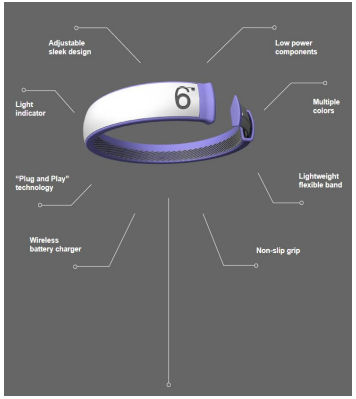
POLAR®

Vital Signs Monitor

EarlySense

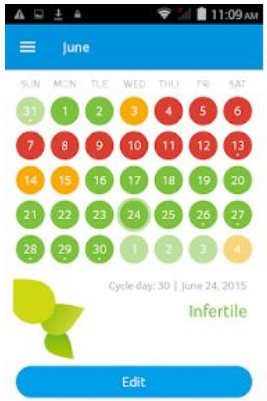
- Heart Rate
- Respiratory Rate
- Sleep Cycles
- Stress Levels.

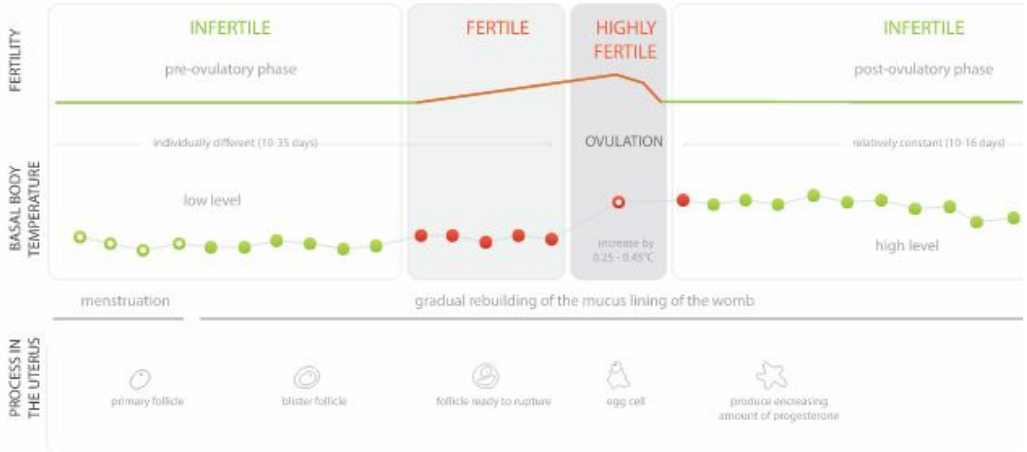
Wearable Smart Devices Controller



Fertility Monitor

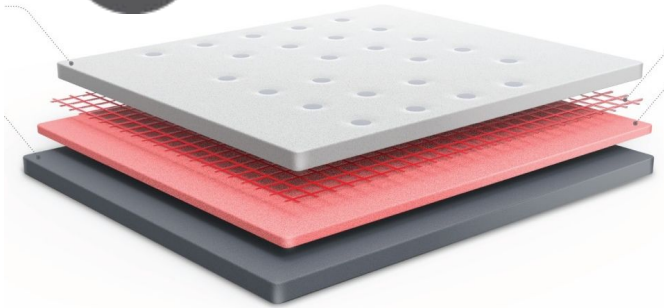
daysy®

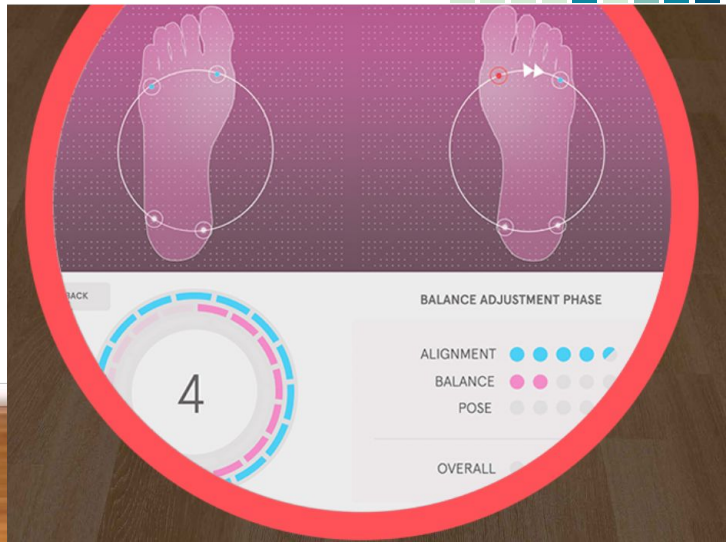




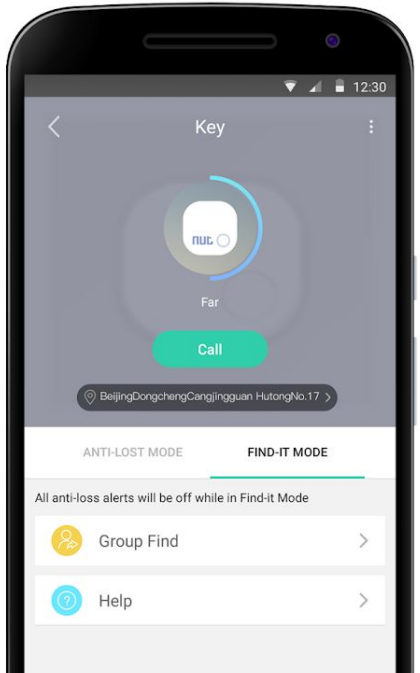
Fitness and Lifestyle

SmartMat





GPS Tracker

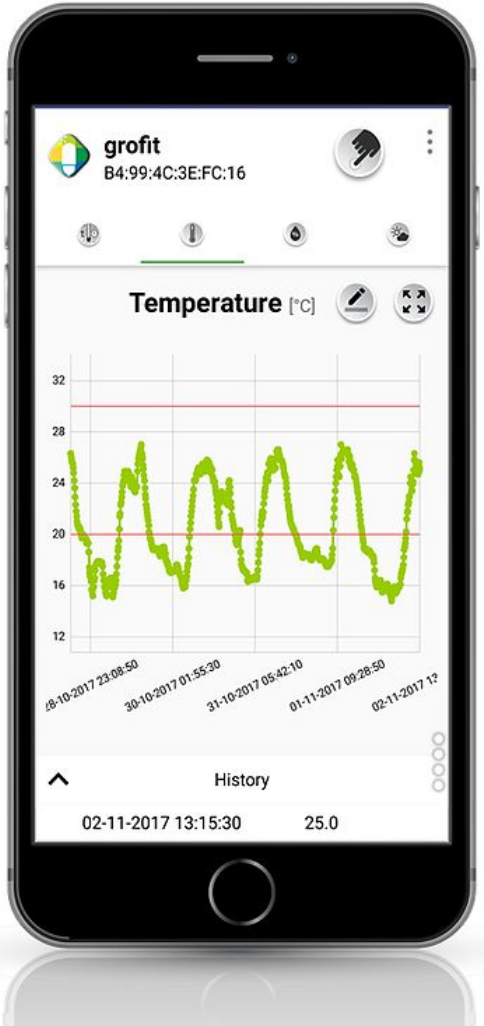

12:30
Key
Far
Call
BeijingDongchengCangjingguan HutongNo.17
ANTI-LOST MODE
FIND-IT MODE
All anti-loss alerts will be off while in Find-it Mode
Group Find
Help

Industrial

Monitor, Analyze, Improve.

Agriculture

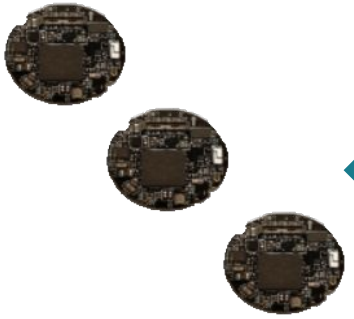
grofit
Grow More Profit



Local sensor station
IoT devices that measuring environmental conditions

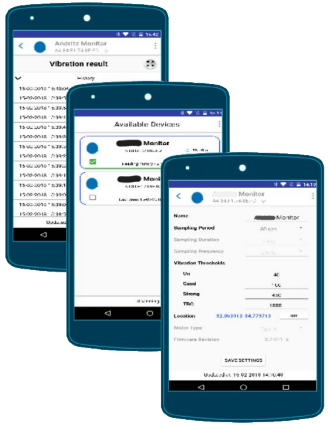
IIoT - Machine Monitoring System

Sensor Unit (2€ size)



BLE

Android/iOS Gateway



4G/Wi-Fi

Cloud DB

- Vibration frequency
- Edge computing
- Data serialization
- Mobile SDK communication

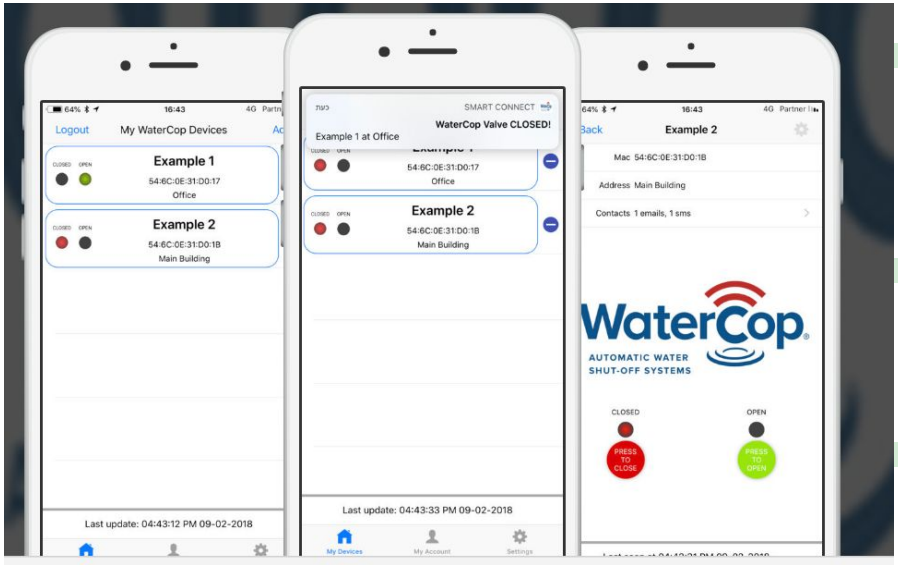
- Mobile SDK
- Communication with 2E units and DB
- Gateway android/iOS app
- Data display app

- Data uploading
- FFT analytics
- Raw Data Report
- API for 3rd party systems

ATOMATION

Electricity/GAS/Water Metering

DynaQuip®
DYNAMIC FLUID
CONTROL SYSTEMS

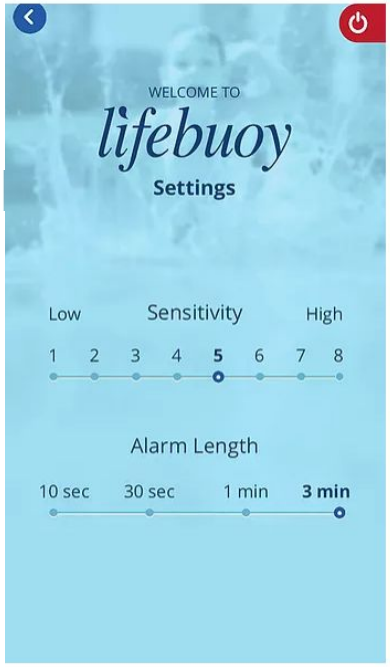


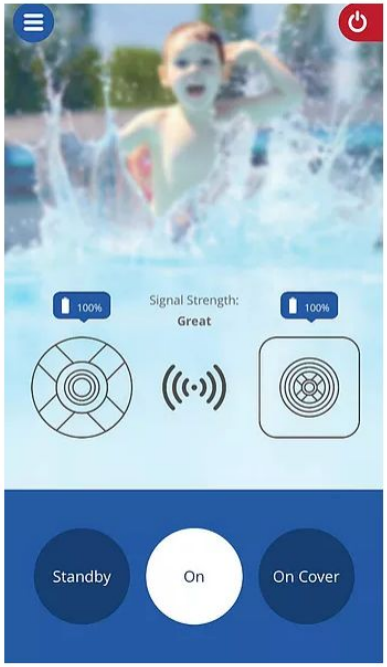
Smart Homes

lifebuoy™
make your pool safer

Pool Unit

Home Unit





Infrastructure

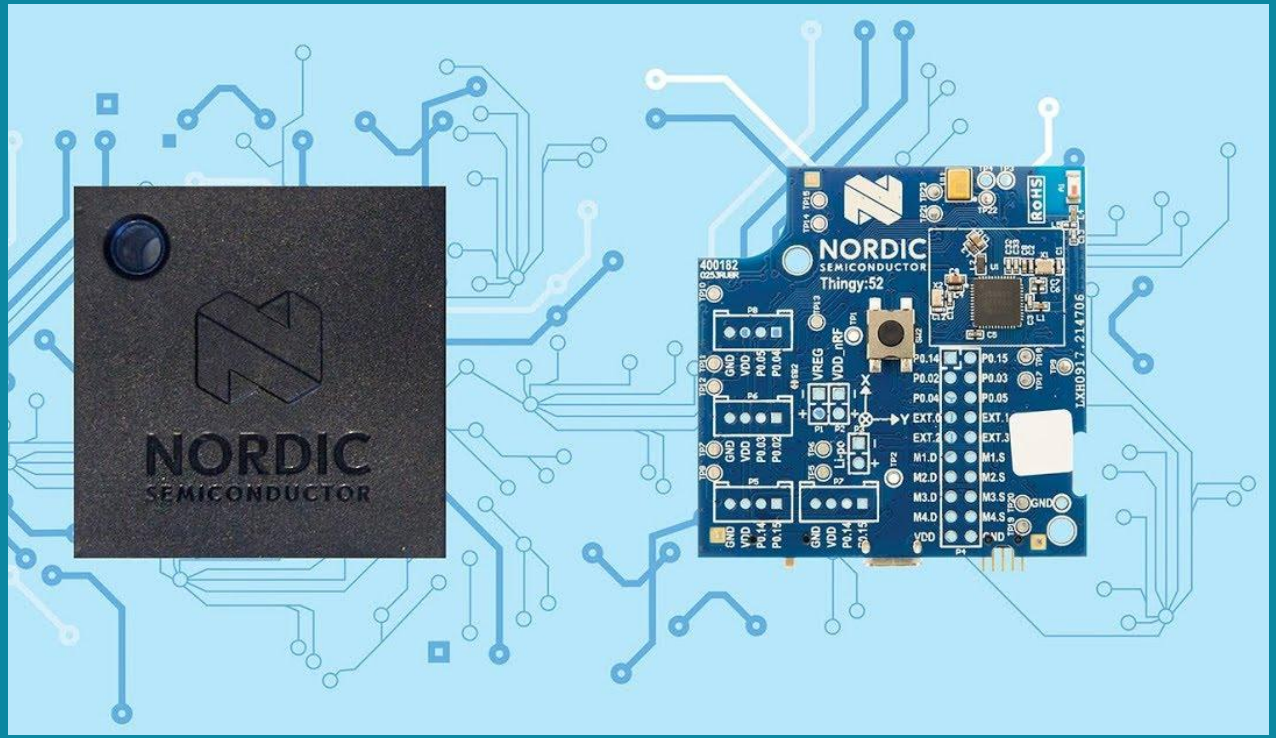
Asset Tracking

Product as a Service

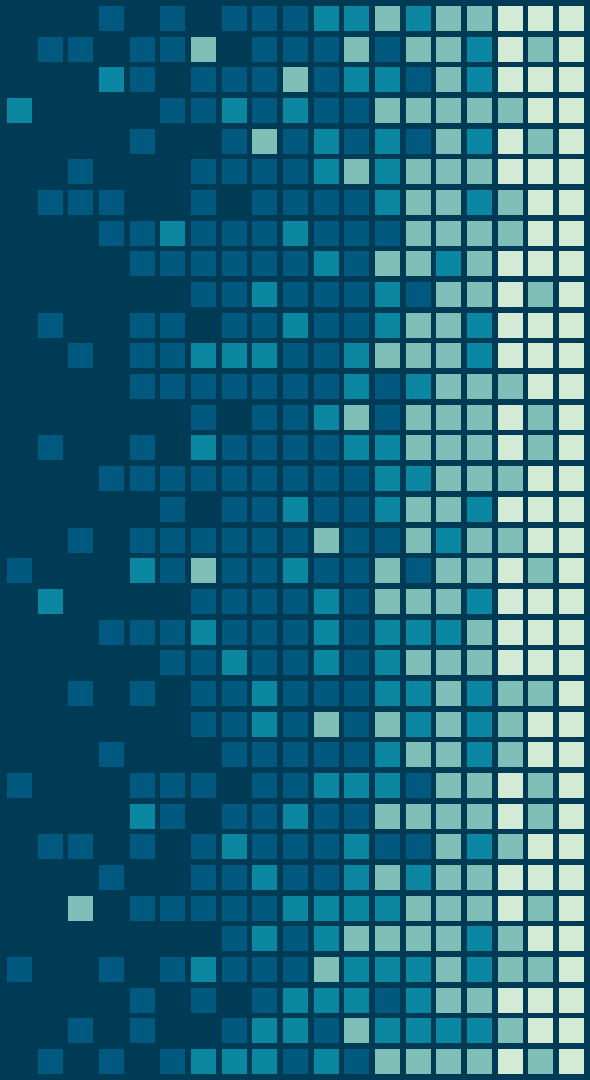
Smart Cities

Automotive Industry and Autonomous Cars

Demo



Bluetooth Low Energy



Bluetooth in a Nutshell:

- Bluetooth is **a wireless technology** standard for exchanging data over short distances.
- Bluetooth operates at frequencies between **2.4 to 2.485 GHz**
- Bluetooth is a **packet-based protocol** with a **master/slave architecture**.

In version 4 of Bluetooth, "Bluetooth Smart" was introduced (a.k.a Bluetooth Low Energy / BLE)

Bluetooth Low Energy

- Wireless communications:
  - Range
  - Data Rate
  - Network Topology
  - Power Consumption
- BLE Stack
- Advertising and Connection
- Data Module (Services/Characteristics)
- Development Tools

Wireless Protocol Comparison

	BLE	Wi-Fi
Frequency Band	2.4GHz	2.4GHz / 5GHz
Network Topology	Scatternet	Star
Range	<100m	<300m
Peak Current Consumption	<15mA	60mA RX, 200mA TX
Data Rate	1Mbps	11Mbps, 54Mbps, 150Mbps+
Peak Current Consumption	<15mA	60mA RX, 200mA TX
Standby Current	< 2uA	< 100uA

BLE Stack = App + Host + Controller

GAP Roles: Broadcaster, Observer, Central (M), Peripheral (S)

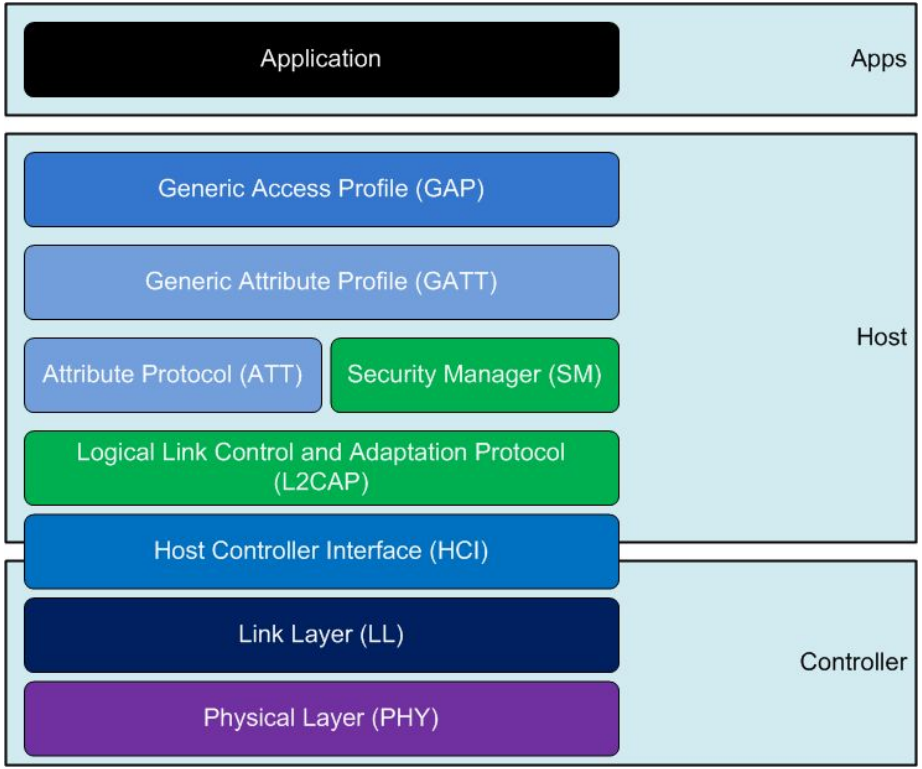
GATT: Data Layer - Client / Server / Client + Server

Security Manager (SM): Link Encryption

L2CAP: fragmentation / defragmentation for long packets (27-4 = 23)

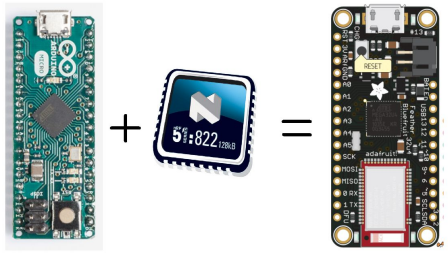
Link Layer (LL): Hard RT, HW+SW

Physical Layer (PHY): Modulation / Multiplexing

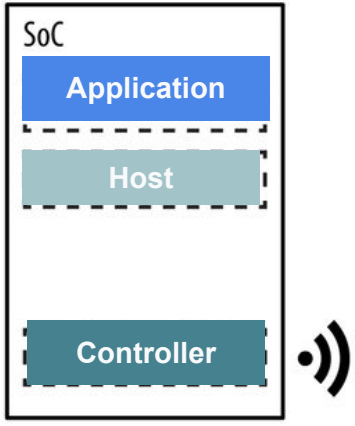


BLE Stack

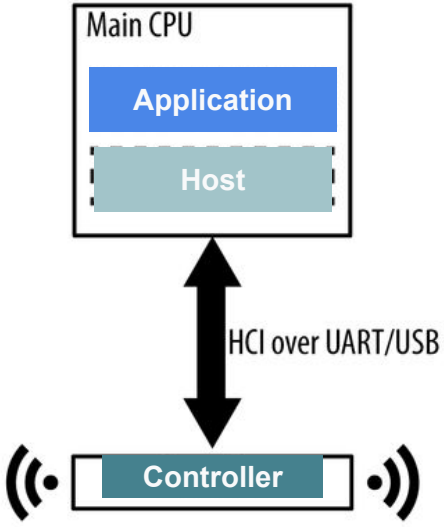
Android 4.3 (API level 18)
MAC OS
Linux BlueZ



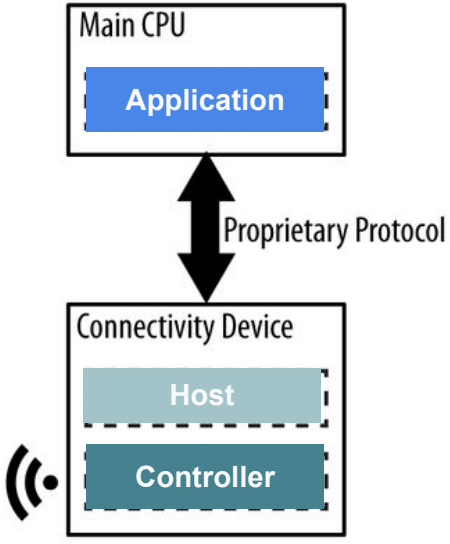
System on Chip



Dual IC over HCI



Dual IC (Connectivity Device)

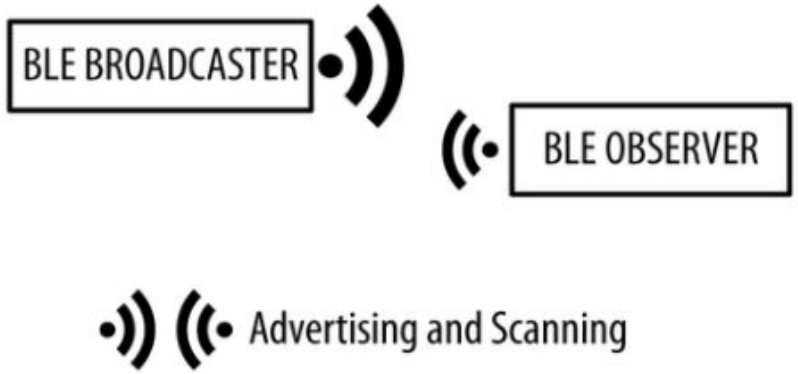


GAP Roles – Broadcasting

Connectionless communication:

Broadcaster : Transmitter Only

Observer : Receiver Only

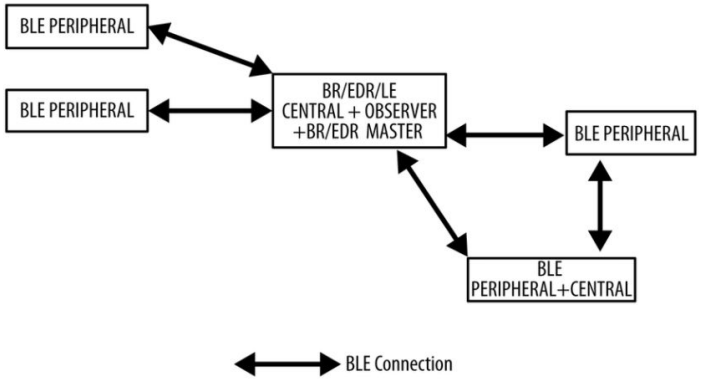


GAP Roles – Connections

Connection-oriented communication:

Central (Master) : Tx + Rx,
Initialize and manage the connection
Peripheral (Slave) : Tx + Rx
Advertises

Multirole (M + S): Central + Peripheral



BLE - Data Model

Client

A device that initiates commands / requests, and accepts responses.

Server

A device that receives commands / requests, and returns responses.

Characteristic

A data value transferred between client and server.

Descriptor

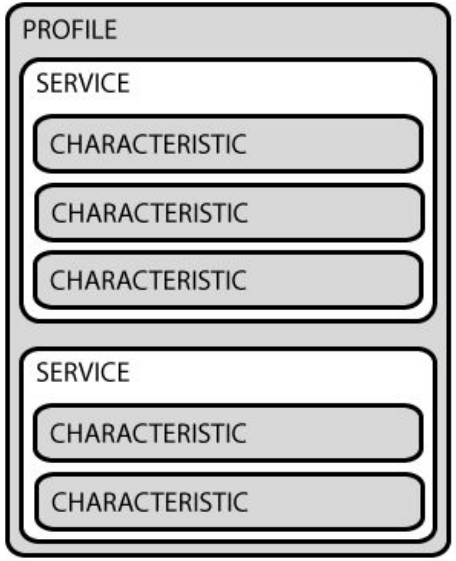
A descriptor provides additional information about a characteristic (e.g. units, range)

Service

A collection of related characteristics, which operate together to perform a particular function.

Profile

A collection of predefined Services.



BLE - Example

Profile **Services** **Characteristics**

Battery Level: 90%

Heart Rate Measurement: 80BPM

Heart Rate Max: 200 BPM

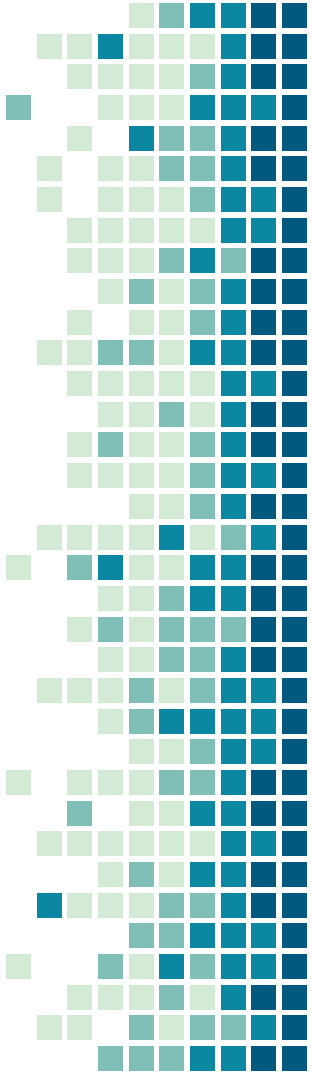
GATT Operations

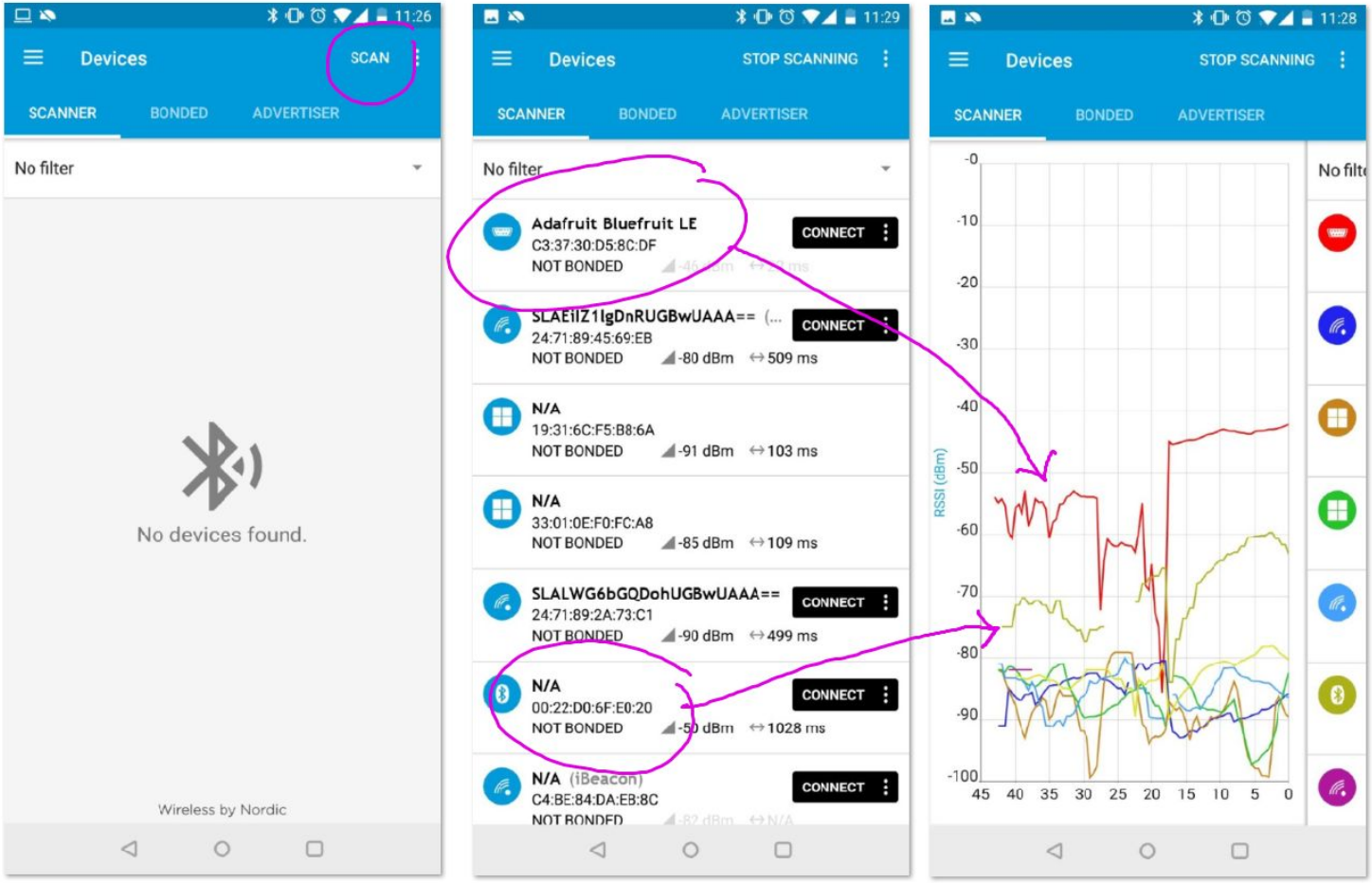
Read Characteristic

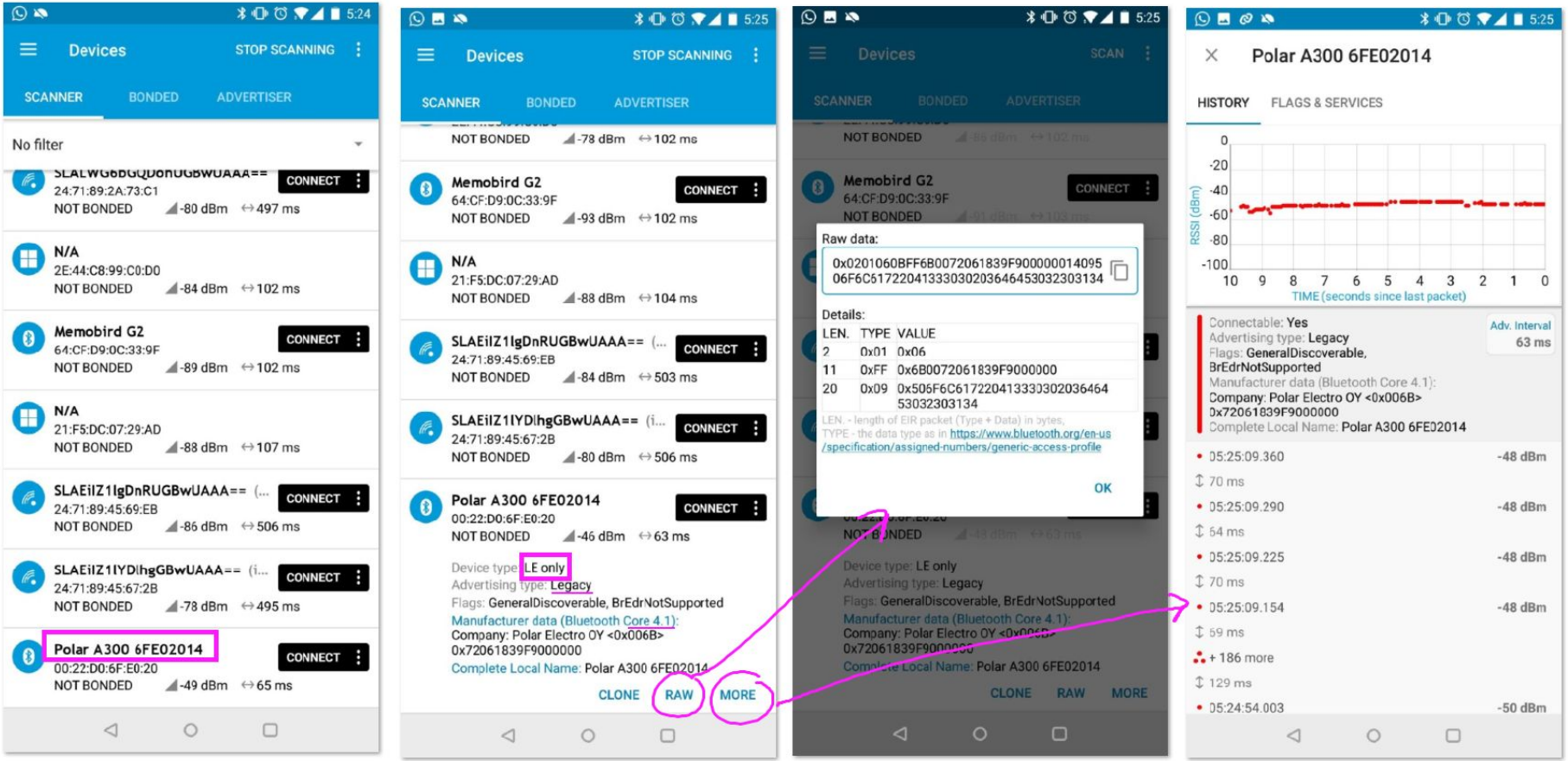
Write Characteristic

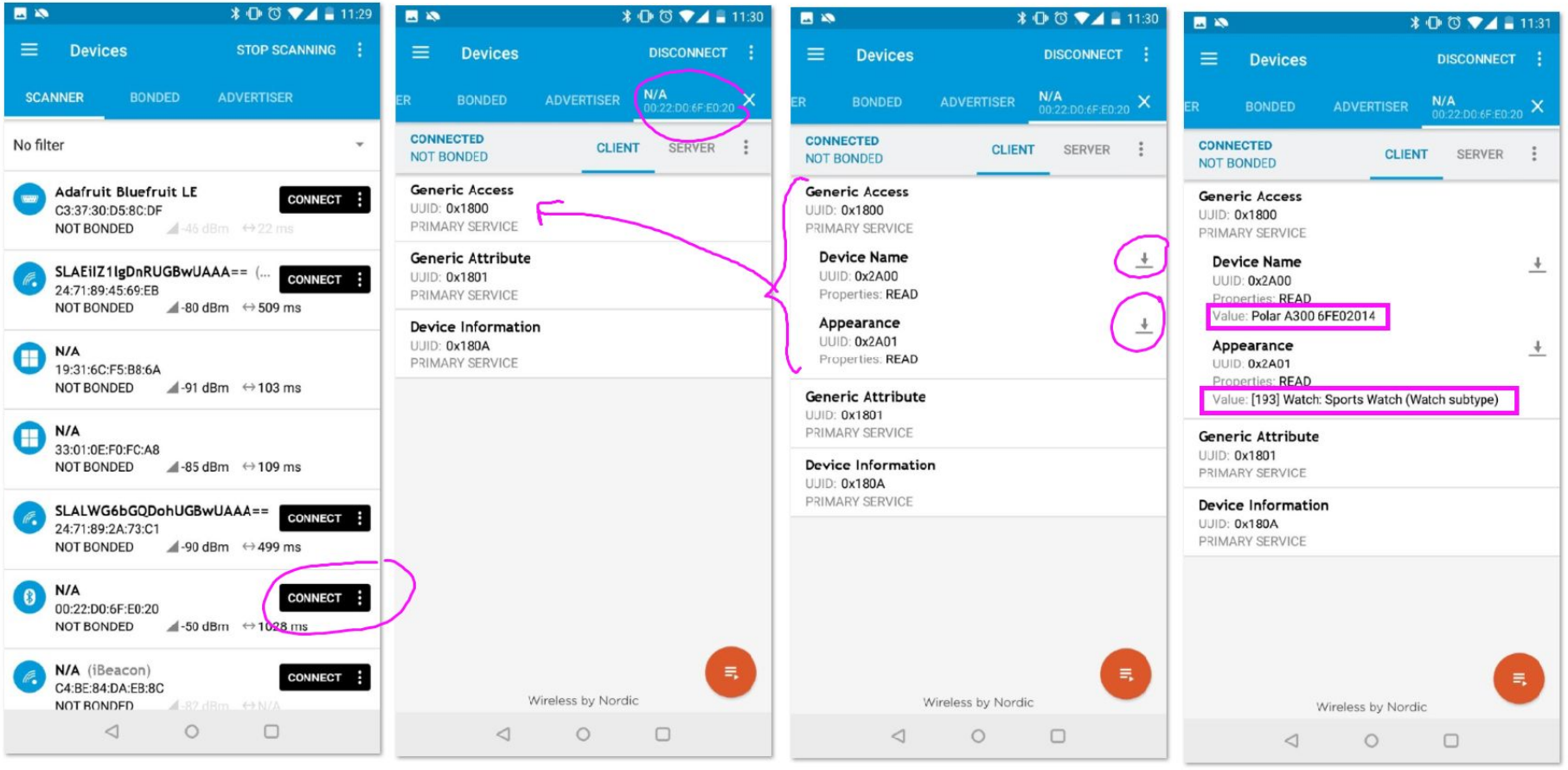
Notify

Indicate (similar to “Notify”, with client confirmation)




11:26
Devices
SCAN
SCANNER
BONDED
ADVERTISER
No filter
No devices found.
Wireless by Nordic
11:29
Devices
STOP SCANNING
SCANNER
BONDED
ADVERTISER
No filter
Adafruit Bluefruit LE
C3:37:30:D5:8C:DF
NOT BONDED
CONNECT
SLAEiIZ1IgDnRUGBwUAAA== (...
24:71:89:45:69:EB
NOT BONDED
-80 dBm
509 ms
CONNECT
N/A
19:31:6C:F5:B8:6A
NOT BONDED
-91 dBm
103 ms
N/A
33:01:0E:F0:FC:A8
NOT BONDED
-85 dBm
109 ms
SLALWG6bGQDohUGBwUAAA==
24:71:89:2A:73:C1
NOT BONDED
-90 dBm
499 ms
CONNECT
N/A
00:22:D0:6F:E0:20
NOT BONDED
1028 ms
CONNECT
N/A (iBeacon)
C4:BE:84:DA:EB:8C
CONNECT
11:28
Devices
STOP SCANNING
SCANNER
BONDED
ADVERTISER
RSSI (dBm)
-0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
45 40 35 30 25 20 15 10 5 0


Devices
STOP SCANNING
SCANNER
BONDED
ADVERTISER
No filter
CONNECT
24:71:89:2A:73:C1
NOT BONDED -80 dBm ↔497 ms
N/A
2E:44:C8:99:C0:D0
NOT BONDED -84 dBm ↔102 ms
Memobird G2
64:CF:D9:0C:33:9F
NOT BONDED -89 dBm ↔102 ms
N/A
21:F5:DC:07:29:AD
NOT BONDED -88 dBm ↔107 ms
24:71:89:45:69:EB
NOT BONDED -86 dBm ↔506 ms
24:71:89:45:67:2B
NOT BONDED -78 dBm ↔495 ms
Polar A300 6FE02014
00:22:D0:6F:E0:20
NOT BONDED -49 dBm ↔65 ms
NOT BONDED -78 dBm ↔102 ms
Memobird G2
64:CF:D9:0C:33:9F
NOT BONDED -93 dBm ↔102 ms
N/A
21:F5:DC:07:29:AD
NOT BONDED -88 dBm ↔104 ms
24:71:89:45:69:EB
NOT BONDED -84 dBm ↔503 ms
24:71:89:45:67:2B
NOT BONDED -80 dBm ↔506 ms
Polar A300 6FE02014
00:22:D0:6F:E0:20
NOT BONDED -46 dBm ↔63 ms
Device type: LE only
Advertising type: Legacy
Flags: GeneralDiscoverable, BrEdrNotSupported
Manufacturer data (Bluetooth Core 4.1):
Company: Polar Electro OY <0x006B>
0x72061839F9000000
Complete Local Name: Polar A300 6FE02014
CLONE
RAW
MORE
SCAN
Raw data:
0x0201060BFF6B0072061839F900000014095
06F6C617220413330302036464530323031 34
Details:
LEN. TYPE VALUE
2 0x01 0x06
11 0xFF 0x6B0072061839F9000000
20 0x09 0x506F6C6172204133303203646 4
53032303134
LEN. - length of EIR packet (Type + Data) in bytes,
TYPE - the data type as in https://www.bluetooth.org/en-us
/specification/assigned-numbers/generic-access-profile
OK
Polar A300 6FE02014
HISTORY
FLAGS & SERVICES
RSSI (dBm)
TIME (seconds since last packet)
Connectable: Yes
Advertising type: Legacy
Flags: GeneralDiscoverable,
BrEdrNotSupported
Manufacturer data (Bluetooth Core 4.1):
Company: Polar Electro OY <0x006B>
0x72061839F9000000
Complete Local Name: Polar A300 6FE02014
Adv. Interval
63 ms
05:25:09.360 -48 dBm
70 ms
05:25:09.290 -48 dBm
54 ms
05:25:09.225 -48 dBm
70 ms
05:25:09.154 -48 dBm
59 ms
+ 186 more
129 ms
05:24:54.003 -50 dBm


11:29
Devices
STOP SCANNING
SCANNER
BONDED
ADVERTISER
No filter
Adafruit Bluefruit LE
C3:37:30:D5:8C:DF
NOT BONDED
CONNECT
SLAEiIZ1IgDnRUGBwUAAA== (...
24:71:89:45:69:EB
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103 ms
N/A
33:01:0E:F0:FC:A8
NOT BONDED
-85 dBm
109 ms
SLALWG6bGQDohUGBwUAAA==
24:71:89:2A:73:C1
NOT BONDED
-90 dBm
499 ms
N/A
00:22:D0:6F:E0:20
NOT BONDED
-50 dBm
1028 ms
N/A (iBeacon)
C4:BE:84:DA:EB:8C
11:30
Devices
DISCONNECT
BONDED
ADVERTISER
N/A
00:22:D0:6F:E0:20
CONNECTED
NOT BONDED
CLIENT
SERVER
Generic Access
UUID: 0x1800
PRIMARY SERVICE
Generic Attribute
UUID: 0x1801
PRIMARY SERVICE
Device Information
UUID: 0x180A
PRIMARY SERVICE
Wireless by Nordic
11:30
Devices
DISCONNECT
BONDED
ADVERTISER
N/A
00:22:D0:6F:E0:20
CONNECTED
NOT BONDED
CLIENT
SERVER
Generic Access
UUID: 0x1800
PRIMARY SERVICE
Device Name
UUID: 0x2A00
Properties: READ
Appearance
UUID: 0x2A01
Properties: READ
Generic Attribute
UUID: 0x1801
PRIMARY SERVICE
Device Information
UUID: 0x180A
PRIMARY SERVICE
Wireless by Nordic
11:31
Devices
DISCONNECT
BONDED
ADVERTISER
N/A
00:22:D0:6F:E0:20
CONNECTED
NOT BONDED
CLIENT
SERVER
Generic Access
UUID: 0x1800
PRIMARY SERVICE
Device Name
UUID: 0x2A00
Properties: READ
Value: Polar A300 6FE02014
Appearance
UUID: 0x2A01
Properties: READ
Value: [193] Watch: Sports Watch (Watch subtype)
Generic Attribute
UUID: 0x1801
PRIMARY SERVICE
Device Information
UUID: 0x180A
PRIMARY SERVICE
Wireless by Nordic

Your Turn!

Monitor, Analyze, Improve.

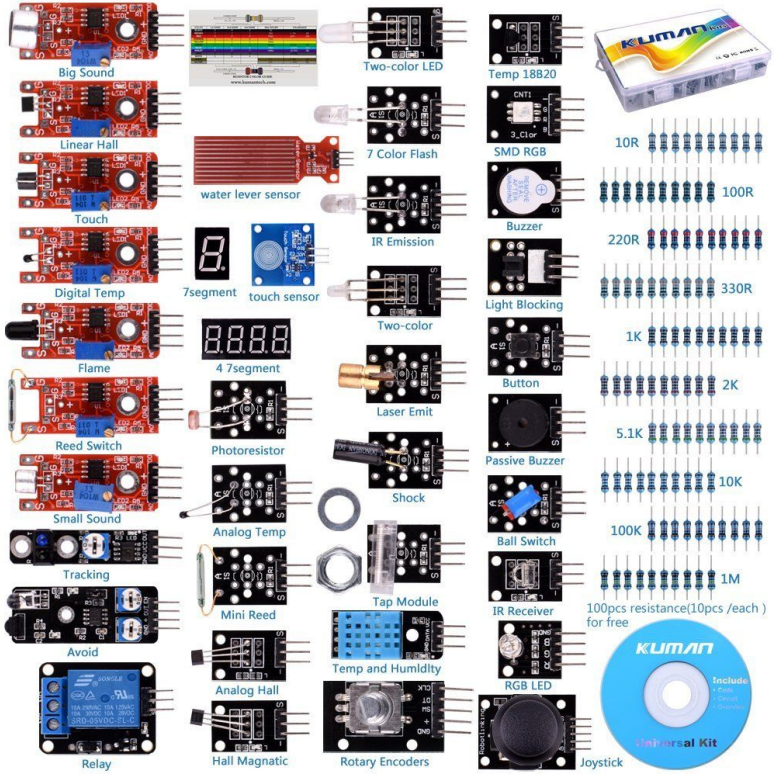
BLE Development Kits

Development kit for nRF52832

SimpleLink™ CC26x2R LaunchPad™ Development Kit

- **Many IoT boards out there…**

IoT Kit for Makers



IoT Cloud Service for Makers

3 Preparation Assignments + 3 Theoretical Presentations

6 Hands-On Exercises

https://www.iot-workshop.online

Thank You!

Any questions?

@Dafna_Mordechai

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