

EMBEDDED SYSTEMS PROGRAMMING 2015-16

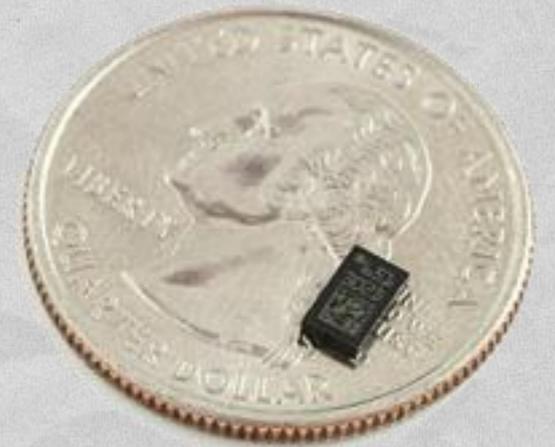
Accessing Hardware

HARDWARE LIST

- Accelerometer
- Vector magnetometer (compass)
- Gyroscope
- GPS and/or other location facilities
- (Front/rear) camera
- Microphone
- Speaker
- Battery

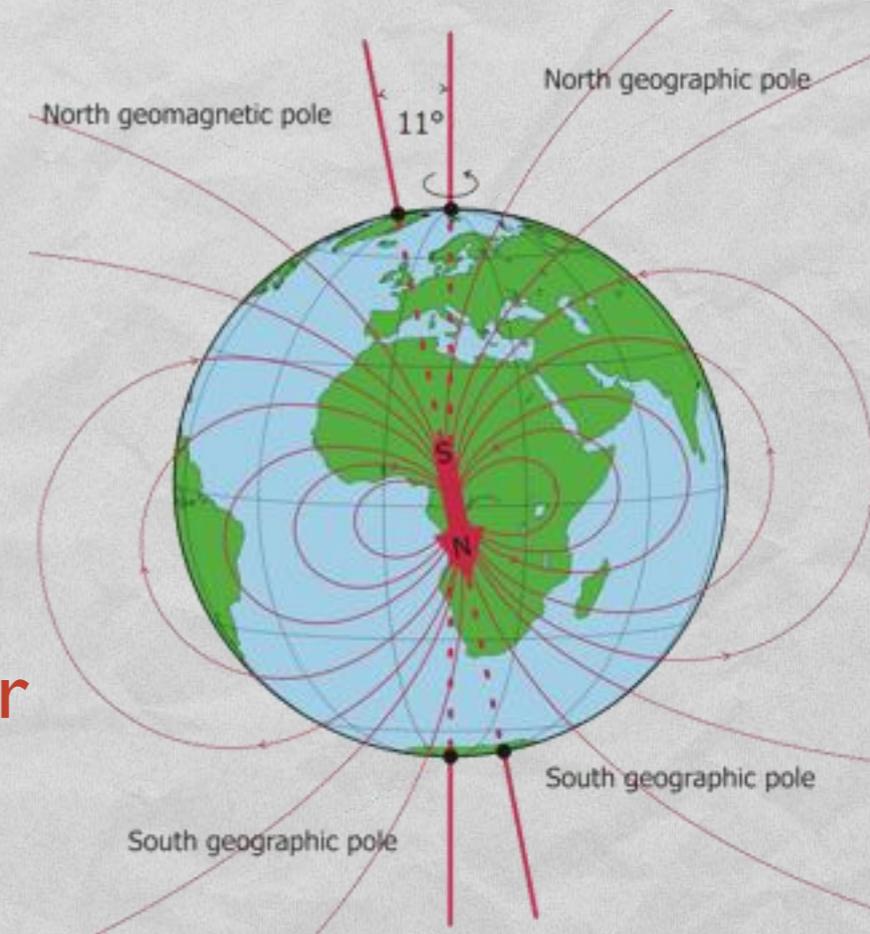
ACCELEROMETER

- Measures proper acceleration in m/s^2 along one or more axes
- Acceleration due to the force of gravity is detected
- In smartphones and similar devices
 - Solid-state, 3-axis MEMS accelerometer
 - Reads per seconds: some hundreds
 - Measurement range: from 0 to ~ 10 g's
 - Can be used to detect the orientation of the device. However, a simpler tilt sensor can be used for this purpose



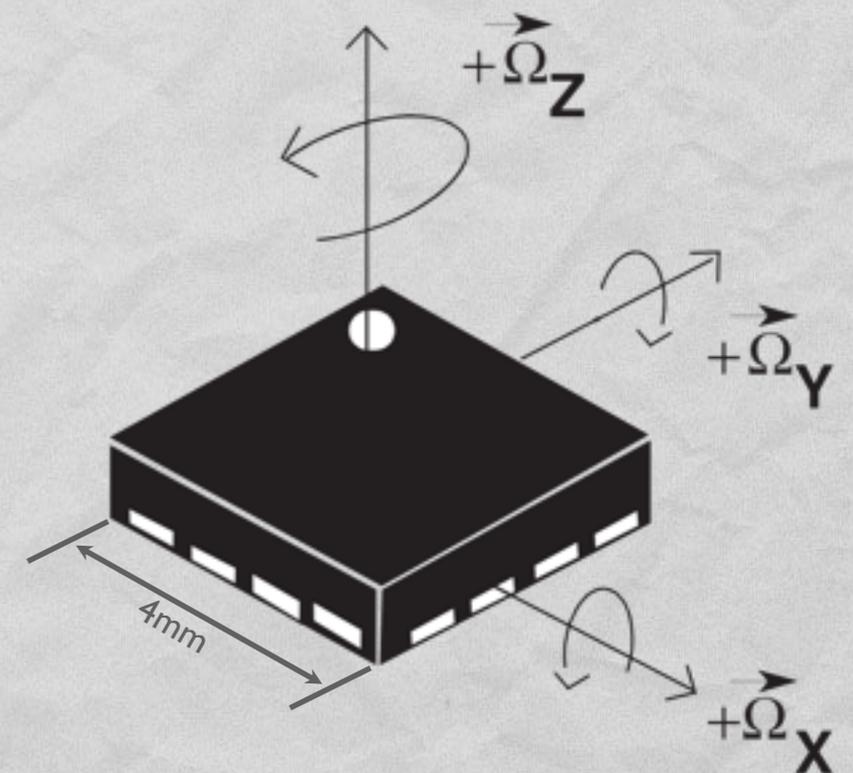
VECTOR MAGNETOMETER

- Measures the strength of the magnetic field (in T) along one or more axes
- Can be used to determine orientation with respect to the magnetic or (if position is known) geographic North
- In smartphones and similar devices
 - Solid-state, Hall-effect 3-axis magnetometer
 - Reads per second: ~ 10
 - Measurement range: from 0 to $\sim 2000 \mu\text{T}$

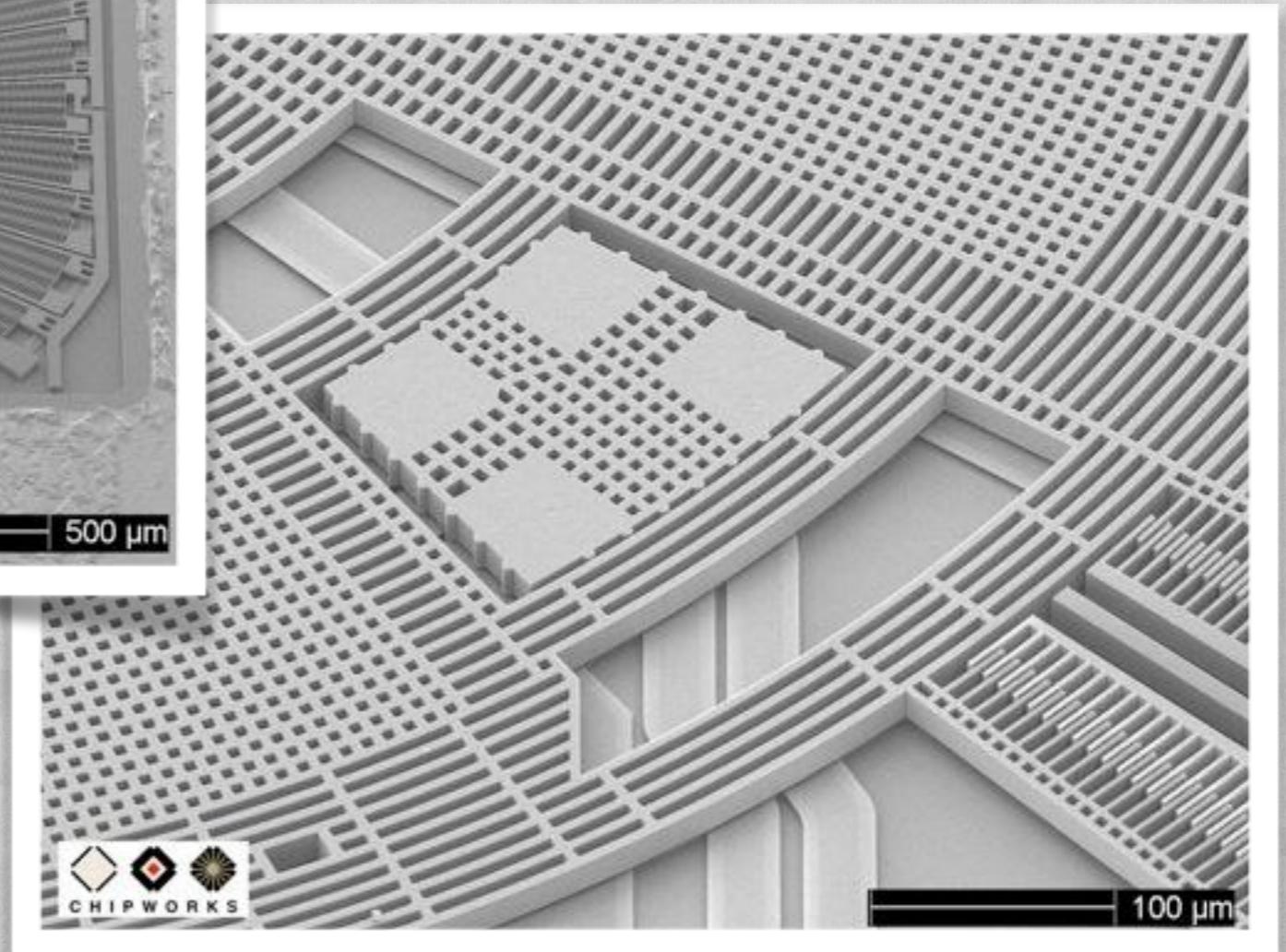
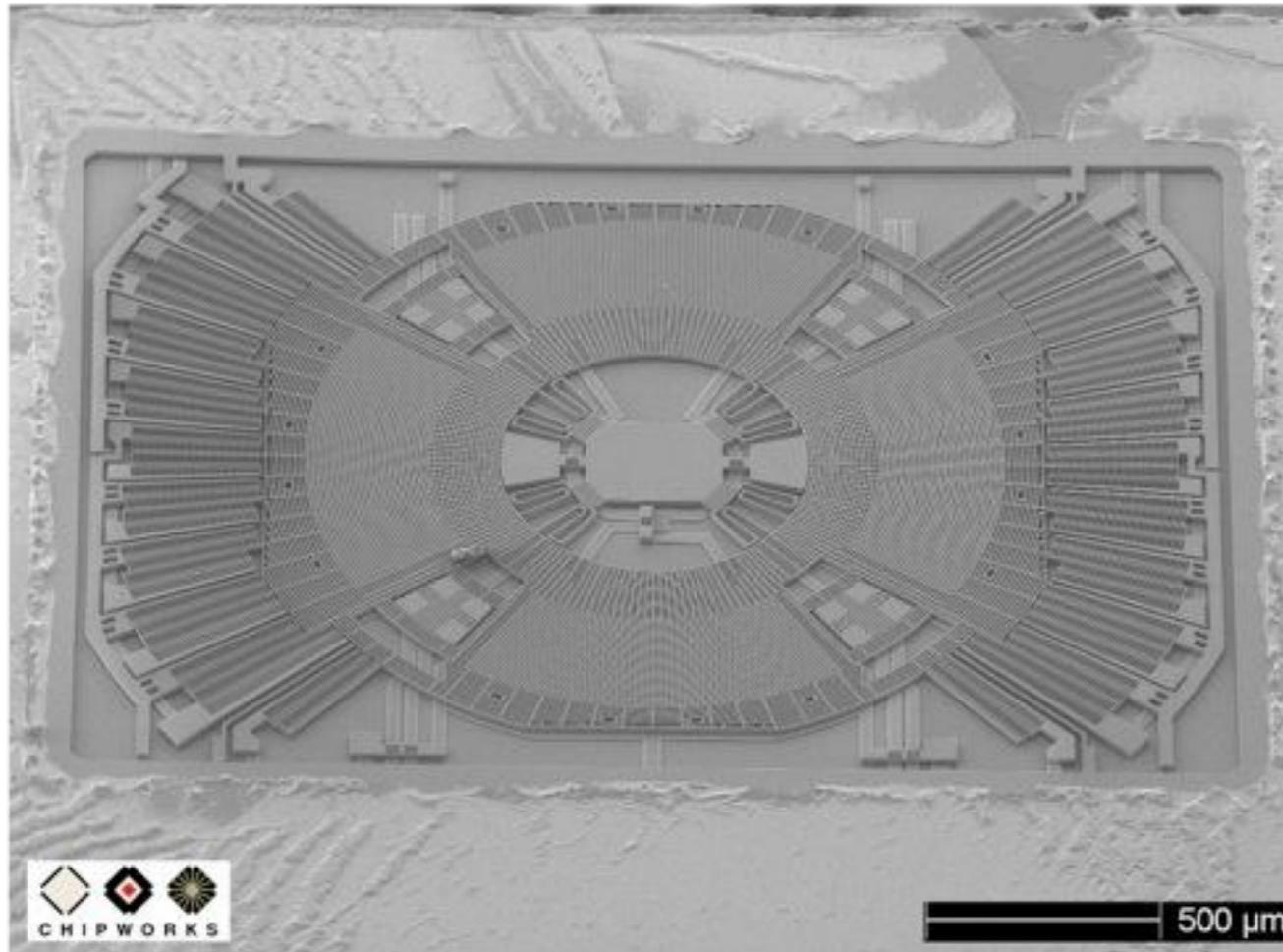


GYROSCOPE (1/2)

- Measures **angular velocity** (in rad/s) along one, two or three axes
- Can be used to determine orientation without the need of a compass
- In smartphones and similar devices
 - Vibrating-structure, 3-axis MEMS gyroscope
 - Reads per second: ~ 100
 - Measurement range: from 0 to ~ 35 rad/s

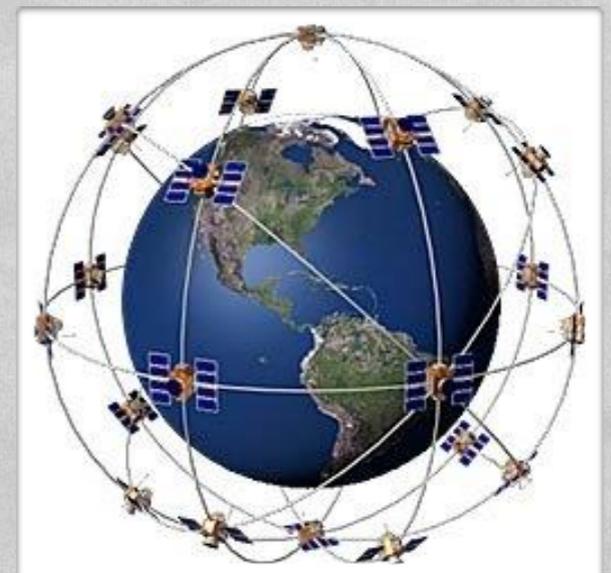


GYROSCOPE (2/2)



GPS

- Triangulates position by accurately timing the signals of **GPS satellites** precisely located into space
- A minimum of three satellites are necessary; receivers use four or more to increase accuracy
- Non-military devices (including smartphones) have access to degraded-precision signals
 - Accuracy: $\sim 10\text{m}$
 - Number of reads per second: $1 \div 2$



OTHER POSITIONING SYSTEMS

- **Based on the Cellular network**
Requires a database of cell tower IDs
- **Based on Wi-Fi**
Requires a database of Wi-Fi networks
- **Less accurate (but less power-hungry) than GPS**

CAVEAT

- Sensors in embedded devices have
 - **poor resolution**, sometimes 8 bits or less,
 - **limited linearity**
- Not suitable for “serious business”
- **Power consumption** is high for the standards of battery-powered devices



CAMERA

- Takes pictures and videos
- In smartphones and similar devices
 - CMOS sensors
 - Fixed-focus, EdOF and autofocus
 - Multiple cameras
 - Resolution for images: from 0.3 Mpix to 41 Mpix
 - Resolution for video: from 240p to 1080p



MICROPHONE

- Captures sounds
- In smartphones and similar devices
 - Optimized to enhance voice (< 8 KHz) and suppress non-voice “noise”
 - Voice processors and multiple microphones may be present to better suppress noise
 - Stereo recording is often unavailable even when multiple mikes are available



Picture from iFixit.com



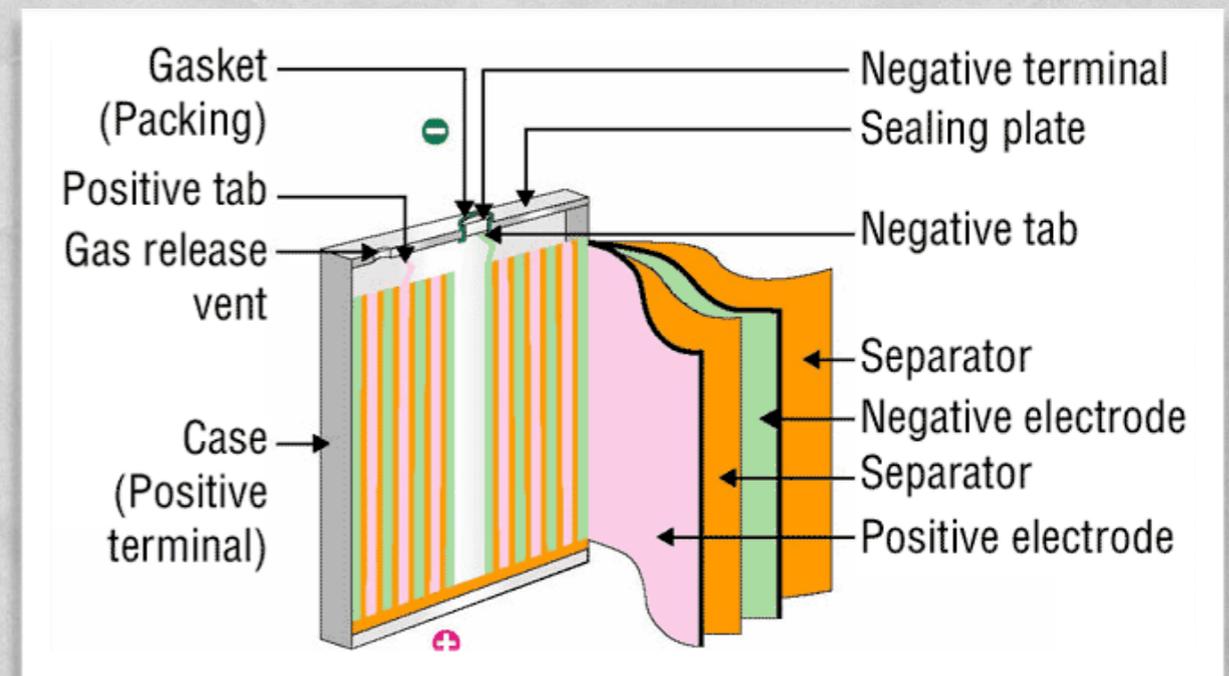
SPEAKER

- Reproduces sounds
- In smartphones and similar devices
 - Optimized to be as loud as possible regardless of the minute dimensions
 - Sometimes performance is enhanced by a tiny sound box
 - Sometimes the same speakers is used for both audio reproduction and telephony functions
 - Stereo speakers are seldom available
 - Note: an audio jack for headsets is always present



BATTERY (1/2)

- Rechargeable
- Many chemistries. Lithium-ion and Lithium-ion polymer batteries are the most common for their power density and because they can be easily made in any shape and size
- Typical voltage: 3.7 V (nominal)
- Typical capacity (smartphone): 1000÷3000 mA·h
- Occupy a sheer fraction of the volume inside the device



Picture from Digimax.rs

BATTERY (2/2)

- Deteriorates (loses capacity) if
 - it runs too hot,
 - it runs too cold,
 - it is overcharged,
 - it is not charged often enough...
- Self-discharges when not used
- Voltage varies nonlinearly during charge and discharge. The curve depends on the battery chemistry, temperature, age...



Picture from Switched.com

MORE SENSORS

- **Proximity sensor**
Typically, a photoelectric, infrared sensor
Usually, it does not return a measure and simply tells whether something is near the device or not
- **Barometer**
Piezoresistive MEMS sensor
Also used for a quicker fix of the altitude
- **Thermometer**
Typically, a band-gap sensor
- **Hygrometer**
Capacitive sensor
- **Fingerprint scanner**
Electro-optical or capacitive sensor

MORE HARDWARE

- NFC



- Bluetooth (Smart)



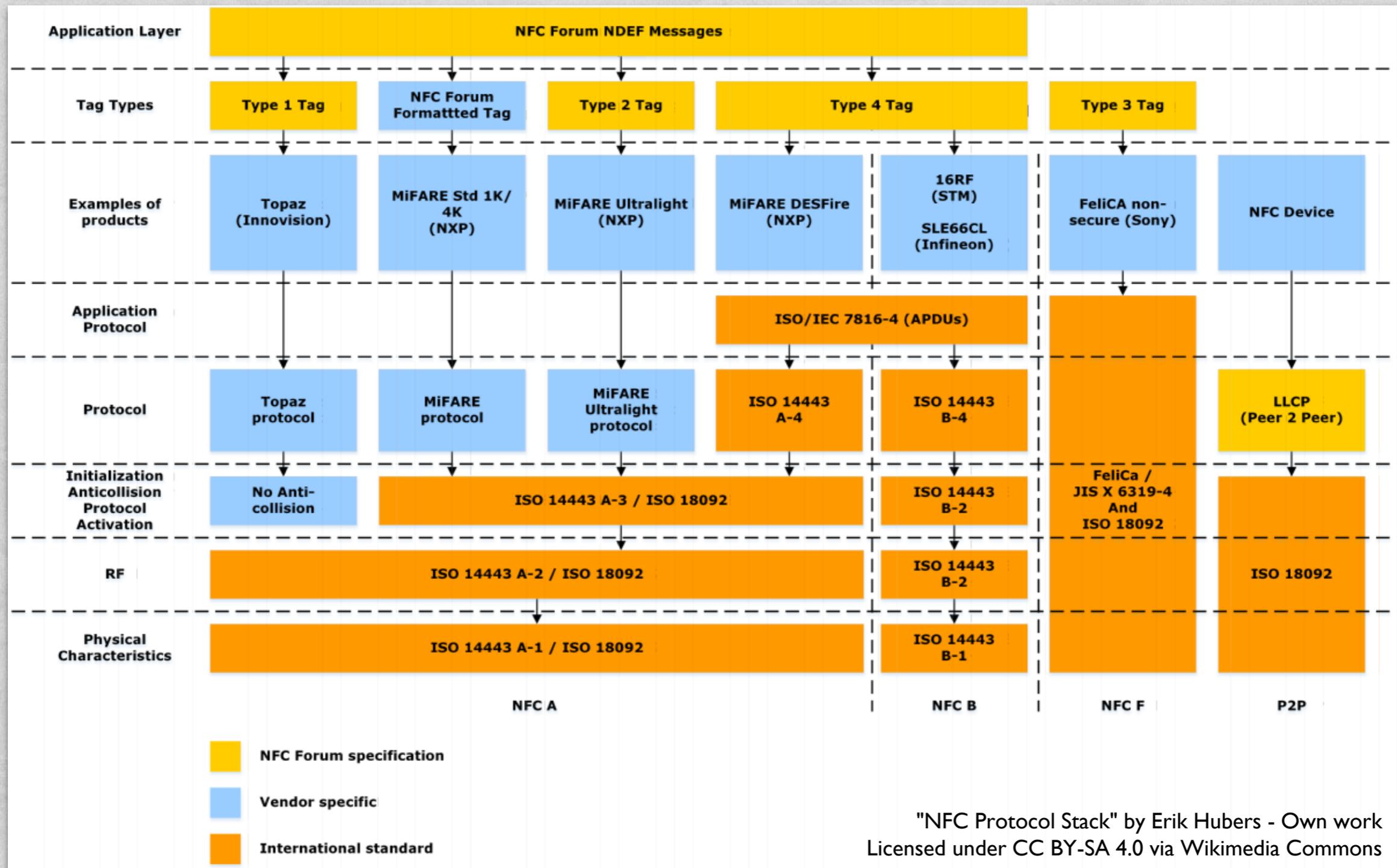
NFC (1/2)

- Proximity wireless communication
- Evolution of RFID technologies of the 1980s
- 3 modes:
NFC initiator, NFC target, NFC peer to peer
- Targets can be passive and powered by the initiator using electromagnetic induction

NFC (2/2)

- All devices can contain data, even targets (order 1K bytes)
- Protocol stack: lower levels are ISO standards, higher levels — including data encoding — are vendor specific and not interoperable
- Security is not part of the standards

NFC PROTOCOL STACK



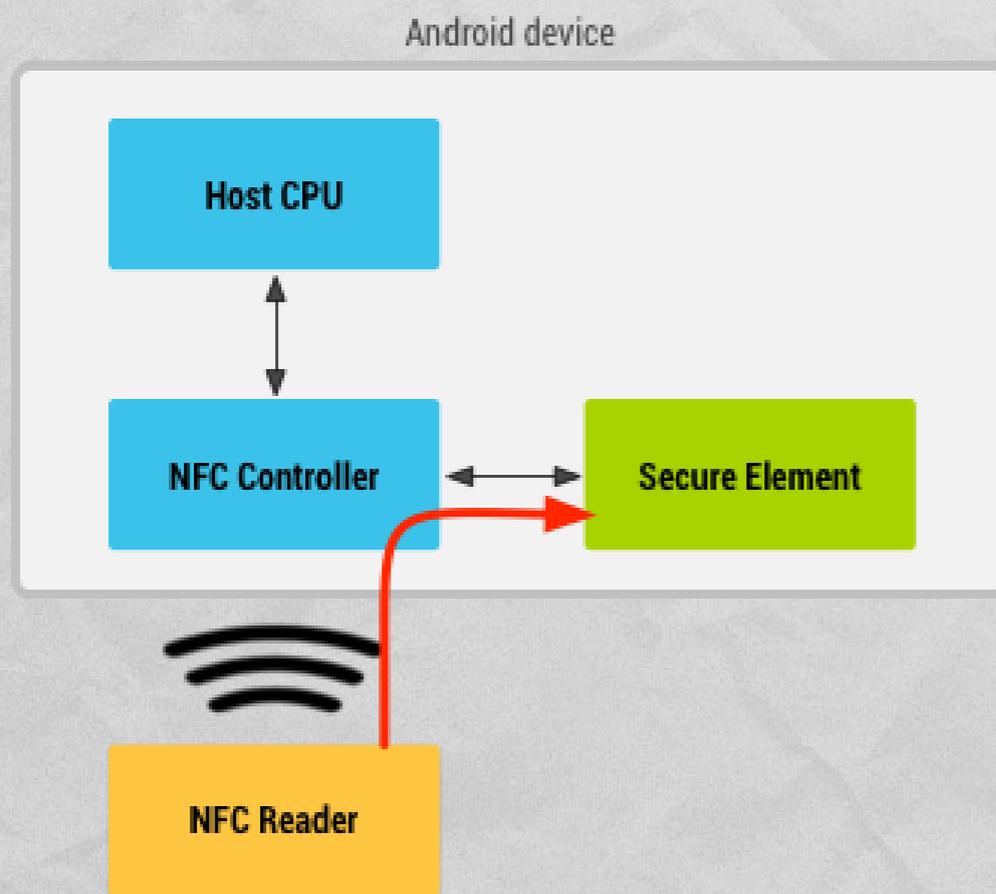
"NFC Protocol Stack" by Erik Hubers - Own work
Licensed under CC BY-SA 4.0 via Wikimedia Commons

NFC: ANDROID

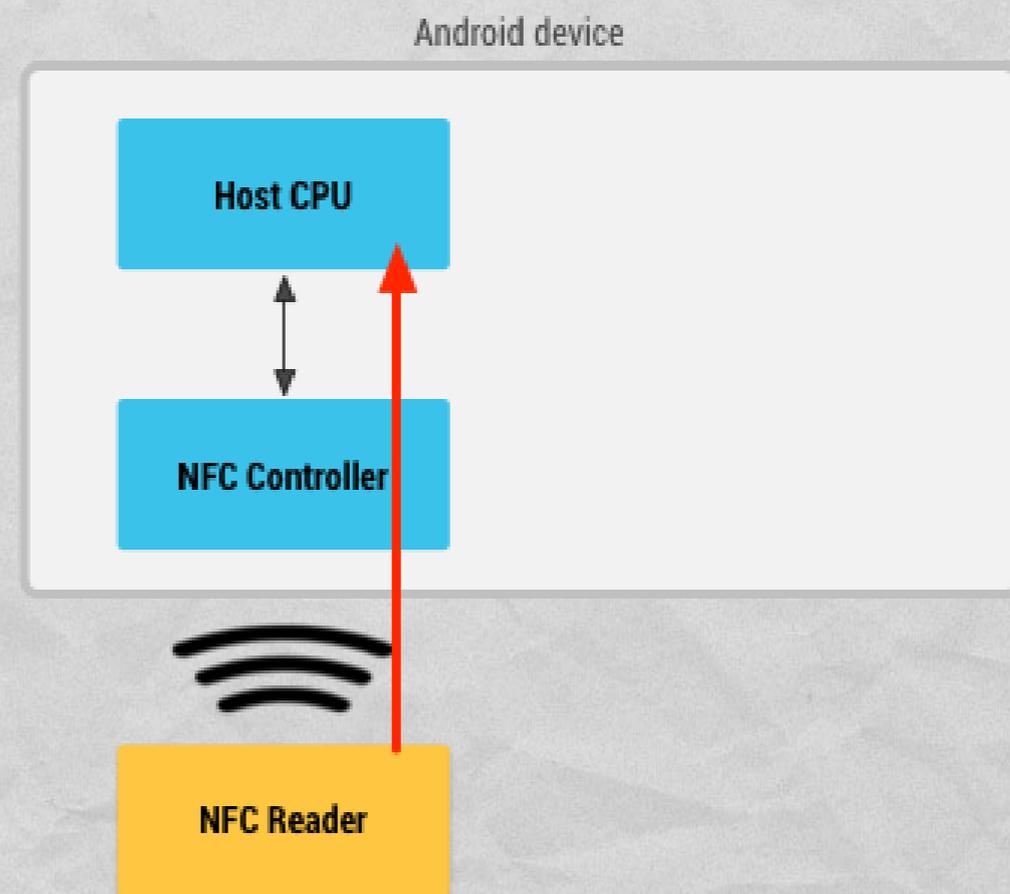
- NFC supported since Android 2.3 (2010), packages `android.nfc` and `android.nfc.tech` (2.3.3)
- Android 4.4 (2013): added NFC reader mode and host-based card emulation (`android.nfc.cardemulation` package)
- APIs based on the NDEF standard
- Google Wallet payment service



CARD EMULATION



With a Secure Element (<4.4)



Host-Based Card Emulation (4.4+)

NFC, ANDROID: SUMMARY

As of Android 5.0, three simultaneous modes of operations are supported:

- Reader/writer mode,
- P2P mode,
- Card emulation mode

Note: NFC controller is off when screen is locked

NFC: IOS

- Support introduced with iOS 8.1 and iPhone 6
- No APIs for the developer
- **Apple Pay** payment service, PassKit framework

Buy with  Pay

BOOTSTRAPPING

NFC can be used to bootstrap more capable wireless connections

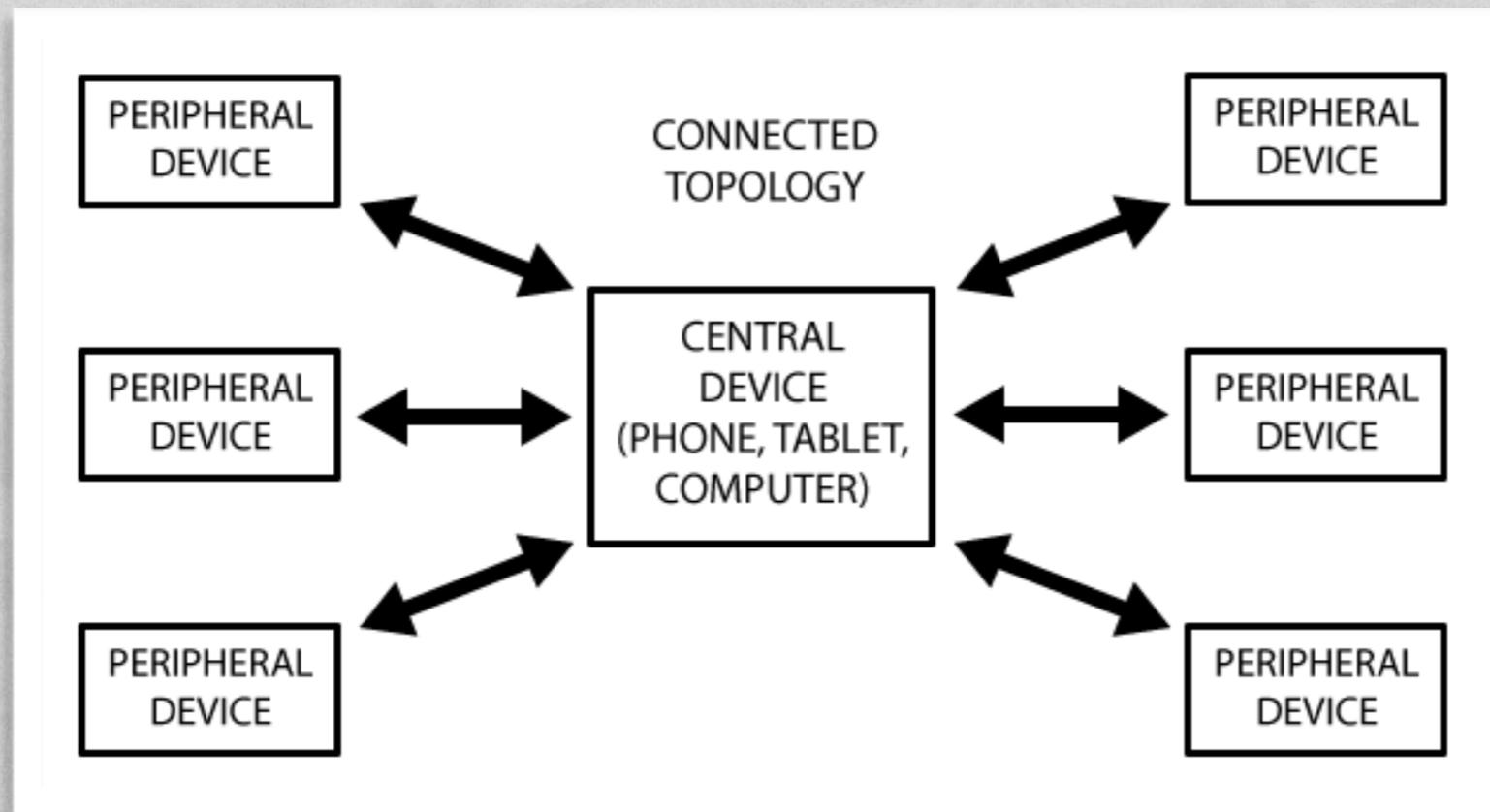
- **Android Beam (>4.1): uses NFC to bootstrap a Bluetooth connection for file transfer**
- **Samsung S-Beam: uses NFC to bootstrap a Wi-Fi Direct connection for file transfer**
- **Nokia, Samsung, BlackBerry, Sony: use NFC technology to pair Bluetooth headsets, media players, and speakers with one tap**

BLUETOOTH SMART (1/3)

- Also known as “Bluetooth Low Energy”, or BLE
- Introduced with Bluetooth Specification 4.0
- Physical layer is completely different from “Classic Bluetooth”, and not compatible/interoperable

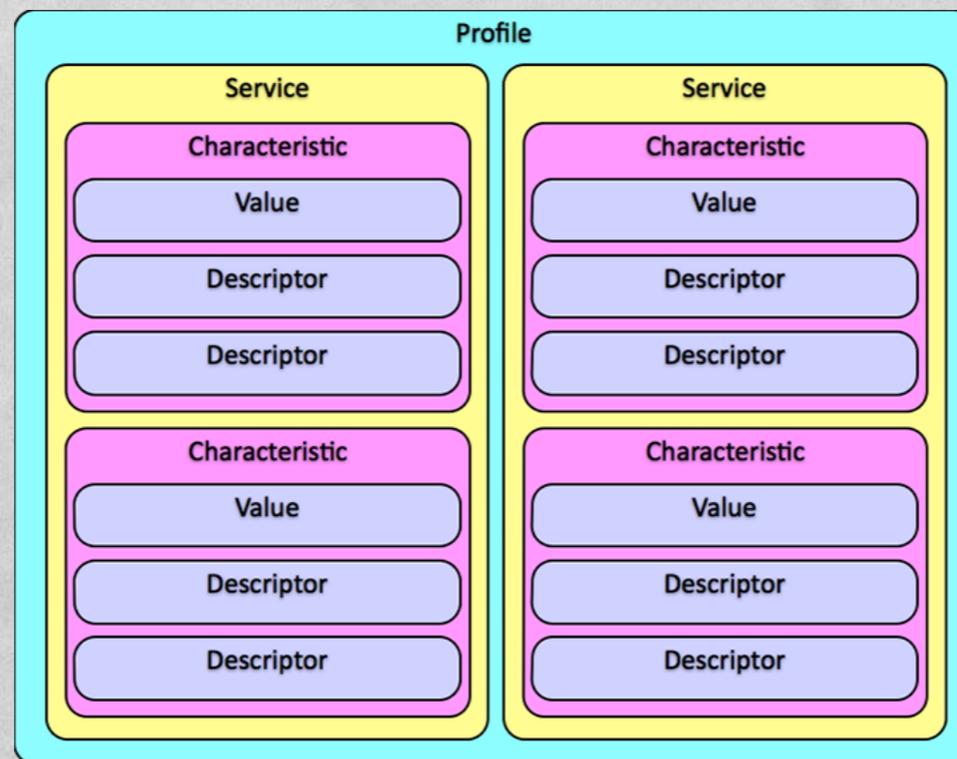
BLUETOOTH SMART (2/3)

- 2 device roles: **Bluetooth central** and **Bluetooth peripheral**



BLUETOOTH SMART (3/3)

- All current BLE application profiles are based on the Generic Attribute Profile (**GATT**)
- The central device is the GATT client, and each peripheral is a server, providing a certain number of **characteristics** organized into **services**



- A peripheral can provide multiple services

BLUETOOTH SMART: ANDROID

- BT Classic supported since Android 2.0 (2009),
BT Smart supported since Android 4.3 (2013)
- Unified `android.bluetooth` package
- Android 4.3: central only
- Android 5.0: central and peripheral;
new `android.bluetooth.le` package

BT SMART VS. NFC (1/3)

	BT SMART	NFC
Frequency	2.4 GHz	13.56 MHz
Range	50 m	0.1 m
Data rate	1 Mbit/s	From 0.1 Mbit/s to 0.4 Mbit/s
Security	128-bit AES	None

BT SMART VS. NFC (2/3)

	BT SMART	NFC
Power consumption	0.01 to 0.5 W	0 W for target, 0.5 W for initiator
Network topology	WPAN "Piconet" (up to 8 devices)	Point to point (2 devices)
Start-up time	High (discovery, pairing)	Low
Set-up time	< 0.006 s	< 0.1 s

BT SMART VS. NFC (3/3)

	BT SMART	NFC
Cost of device	order \$5	order \$0.1
Defined by	Bluetooth SIG	ISO/IEC and various SIGs
Applications	Watches, sports and fitness, healthcare, ...	Tickets, access control, payments, ...

LAST MODIFIED: APRIL 1, 2016

COPYRIGHT HOLDER: CARLO FANTOZZI (FANTOZZI@DEI.UNIPD.IT)
LICENSE: CREATIVE COMMONS ATTRIBUTION SHARE-Alike 3.0