Wireless Networking CS4222/5422

Tutorial 4

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Q1

What is the typical battery capacity of common devices that you use in your daily life such as wearables (Apple Watch/Fitbit), earphones, laptops, and mobile phones?

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Device	Battery Capacity
Apple Airpods Pro 2	49.7 mAh
Apple Watch Ultra	542 mAh
Fitbit Sense	266 mAh
Apple MacBook Pro M2	58.2 Wh (Watt hour)
Galaxy S23	3900 mAh
Apple iPhone 14 Pro Max	4323 mAh
Oura Fitness Ring	15 – 22 mAh

Apple MacBook Pro M2

Battery and Power[1]

- Up to 20 hours Apple TV app movie playback
- Up to 17 hours wireless web
- 58.2-watt-hour lithium-polymer battery

Samsung Galaxy S23

BATTERY		
	Type	Li-Ion 3900 mAh non-removable
	Charging	25W wired, PD3.0, 50% in 30 min (advertised)
		15W wireless (Qi/PMA)

https://www.gsmarena.com/
https://support.apple.com/kb/SP870?locale=en_GB

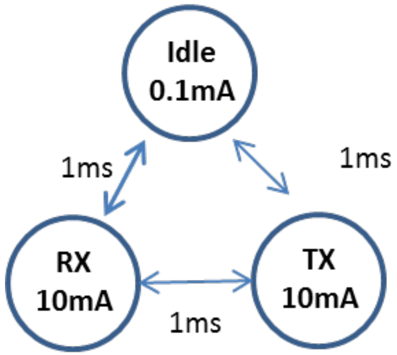
Q2

A. In the figure representing state transition diagram, which chipset is more suitable for used in Internet of Things applications? Explain your reasoning.

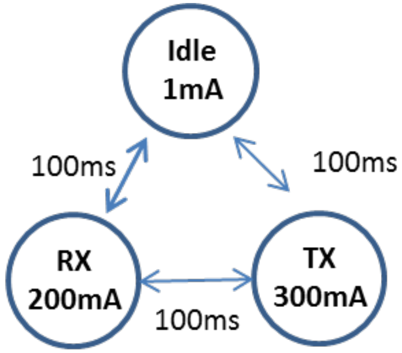
B. For the chipset chosen in the question above, assume that the devices are designed to operate at a very low duty-cycle (<0.01%) and you are allowed to reduce the current drawn from only one of the states (idle, receive (RX) or transmit (TX). Which state would you reduce the current from?

A) In the state transition diagram, which chipset is more suitable for IoT applications?

- **Chipset 1** is more suitable for used in low power wireless sensor network.
- Compared to chipset 2, it has *lower state switching* time and consumes *less power* in all three states

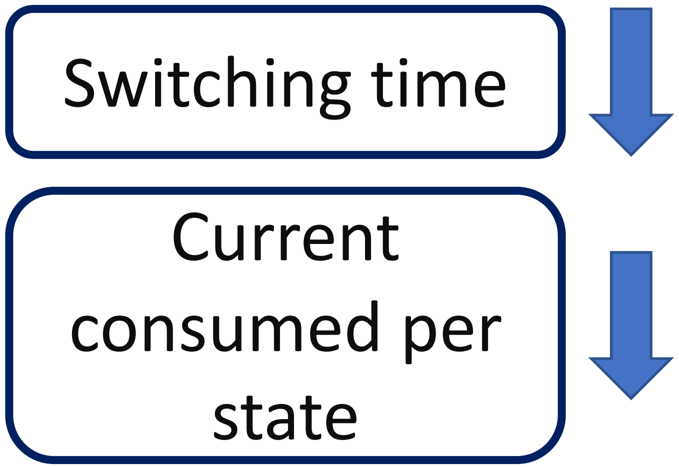


Chipset 1



Chipset 2

Required Properties

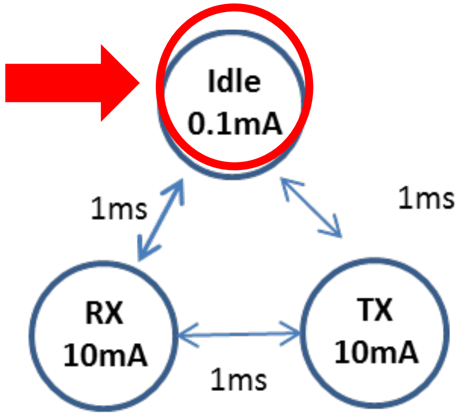


B) Assume that the devices are designed to operate at a very low duty-cycle (<0.01%) Which state would you reduce the current from?

- 0.01% duty cycle. Therefore, for each second,
  - ➔Active for 0.0001 s, Idle for 0.9999s

Current Consumed (TX/RX)
= 10mA X 0.0001
= 10^{-6} A

Current Consumed (Idle)
= 1mA X 0.9999
~ 10^{-4} A



Chipset 1

Idle state component is ~100x larger!

Q3

Given Wireless Communication Technologies (Bluetooth, ZigBee, WiFi, LoRa, LoRea, Judo)

1. Calculate the energy (in Joule) require to transmit 1 bit for different technologies listed
2. For low power IoT devices, should you always select the network technology with the lower transmission energy per bit? Explain your answer
3. In addition to energy needed to transmit/receive a bit, what other criteria(s) should you take into account when selecting a network technology for use in a low power Internet of Things?
4. What kind of applications would choose each Technology?

Specification	Bluetooth	ZigBee	WiFi	LoRa	LoRea (Backscatter)	Judo (Backscatter)
VDD(V)	1.8	3.0	3.3	3.3	2	0.12
Transmit (mA)	60	30	220	28	0.035	0.7
Receive (mA)	50	25	210	13.8	N.A	N.A
Bitrate (Mb/s)	1.2	0.25	54	0.027	0.003	0.1

A) Energy Consumption to Transmit 1 bit

- Power (W) $= Voltage(V) \times Current\ (A)$
- Energy (J) $= Power(W) \times Time\ (s)$
- For one bit to transmit, $Time\ (s) = \dfrac{1}{Bitrate\ (bps)}$

Therefore, Energy required to transmit one bit = $Power(W) \times Time\ (s) = Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)}$

Energy Requirement for:

- **Bluetooth** $= Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)} = \dfrac{1.8 \times 60\times10^{-3}}{1.2\times10^{6}} =$ 0.09μJ
- **ZigBee** $= Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)} = \dfrac{3 \times 30\times10^{-3}}{0.25\times10^{6}} =$ 0.36μJ
- **WiFi** $= Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)} = \dfrac{3.3 \times 220\times10^{-3}}{54\times10^{6}} =$ 0.013 μJ
- **LoRa** $= Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)} = \dfrac{3.3 \times 28\times10^{-3}}{0.027\times10^{6}} =$ **3.42 μJ**
- **LoRea** $= Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)} = \dfrac{2 \times 0.035\times10^{-3}}{0.003\times10^{6}} =$ 0.023 μJ
- **Judo** $= Voltage(V) \times Current\ (A) \times \dfrac{1}{Bitrate\ (bps)} = \dfrac{0.12 \times 0.7\ \times10^{-3}}{0.1\times10^{6}} =$ **0.84 nJ**

B) Always choose low Tx Energy tech for low power IoT devices?

- **No**, depends on the application type. For example,
  - if there are lots of data to transfer, go for lowest energy per bit (WiFi)
  - if Idle period dominates and data to be transferred is low, choose ZigBee, BLE or Backscatter
  - If operation on small batteries or energy harvesting chose Backscatter
  - If high communication range is required chose LoRa

C) Beside Tx/Rx Energy, what other criteria(s) are crucial in low power IoT?

- We can consider the following criterion:
  - Ability to turn active/idle/off quickly (shortest time)
  - Form factor (size of antenna)
  - Maximum current draw (high current draw might make small batteries infeasible)
  - Ability to form network

D) Example application for Bluetooth

Sufficiently high data-rate (≈ 2Mbps)

Short range (<10m)

Low battery constraints

Most smart devices we use:
Earphones
Wireless Mouse/Keyboard
Speakers
Smart Watch

*Credit: Google Images

E) Example application for LoRa

Low data-rate (< 30kbps)

Long range (> 500m)

https://www.semtech.com/lora

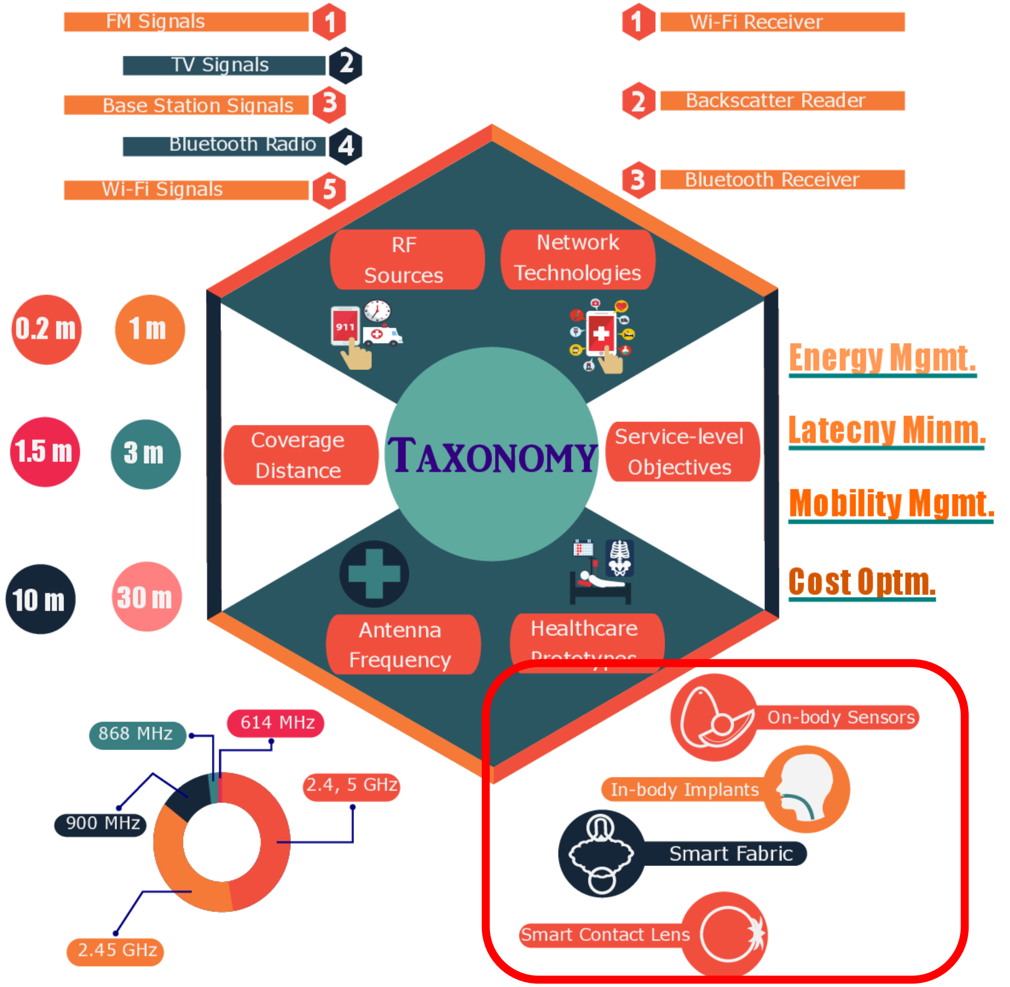
F) Example application for Backscatter

Minimal Power Draw (Few µW)

Frequent Transmission

Compact Form Factor (Sticker, Card etc.)

Harvest Ambient Energy



https://www.semanticscholar.org/paper/Applications-of-Backscatter-Communications-for-Jameel-Duan/

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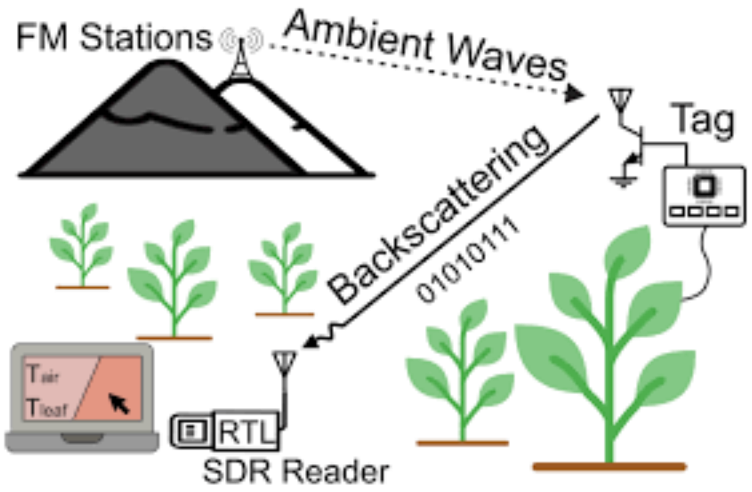

*Credit: Google Images

Thank you

Feel free to contact me at kanav.sabharwal@u.nus.edu for any clarifications