NETWORK CONNECTIVITY FOR IoT SYSTEMS

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Lecture #5

6.S062 Mobile and Sensor Computing

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NETWORKING: “GLUE” FOR THE IOT

IoT’s “technology push” from the convergence of

- Embedded computing
- Sensing & actuation
- **Wireless networks**

THE IOT CONNECTIVITY SOUP

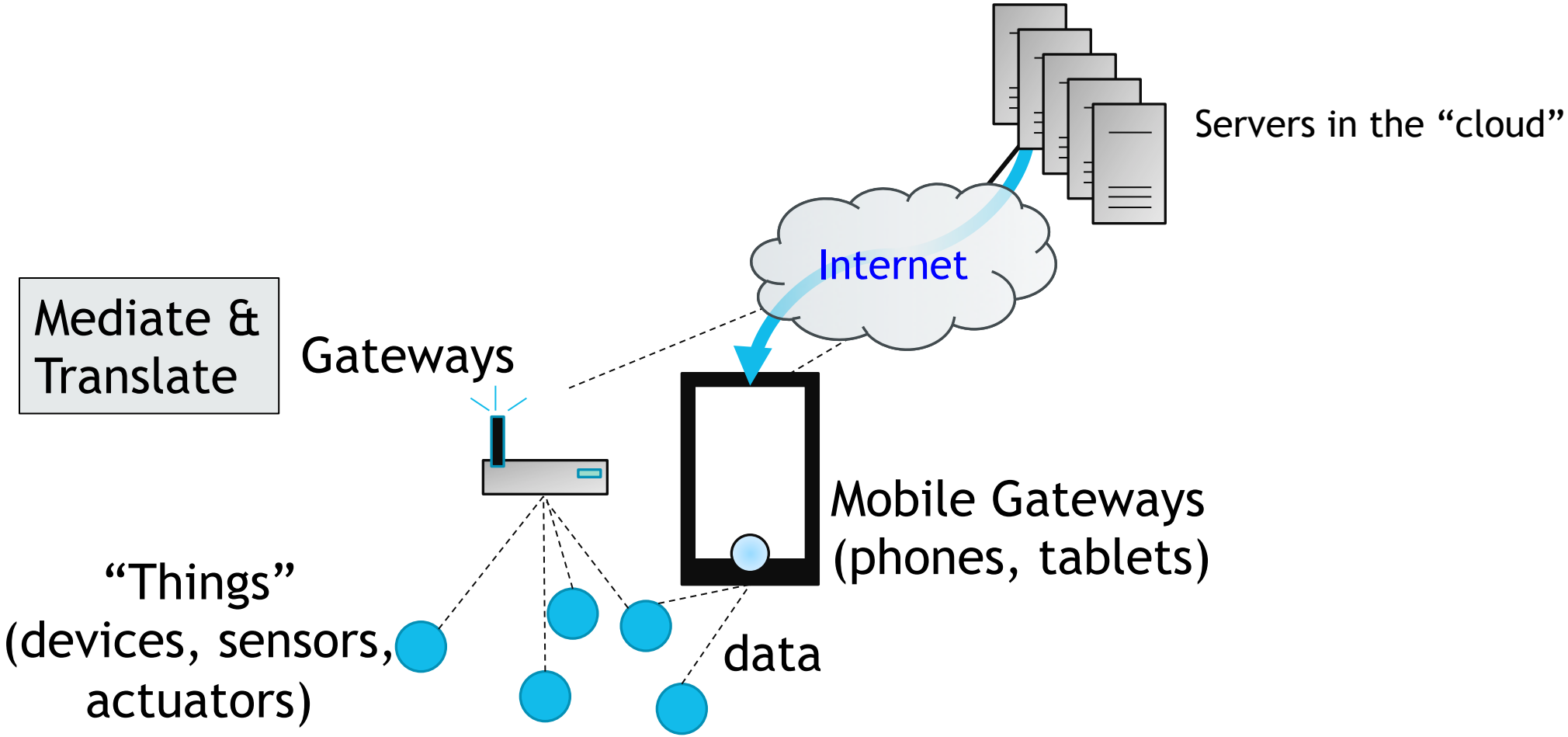
NETWORKING: “GLUE” FOR THE IOT

Many different approaches, many different proposed standards.
Much confusion

One size does not fit all: best network depends on application

What are the key organizing principles and ideas?

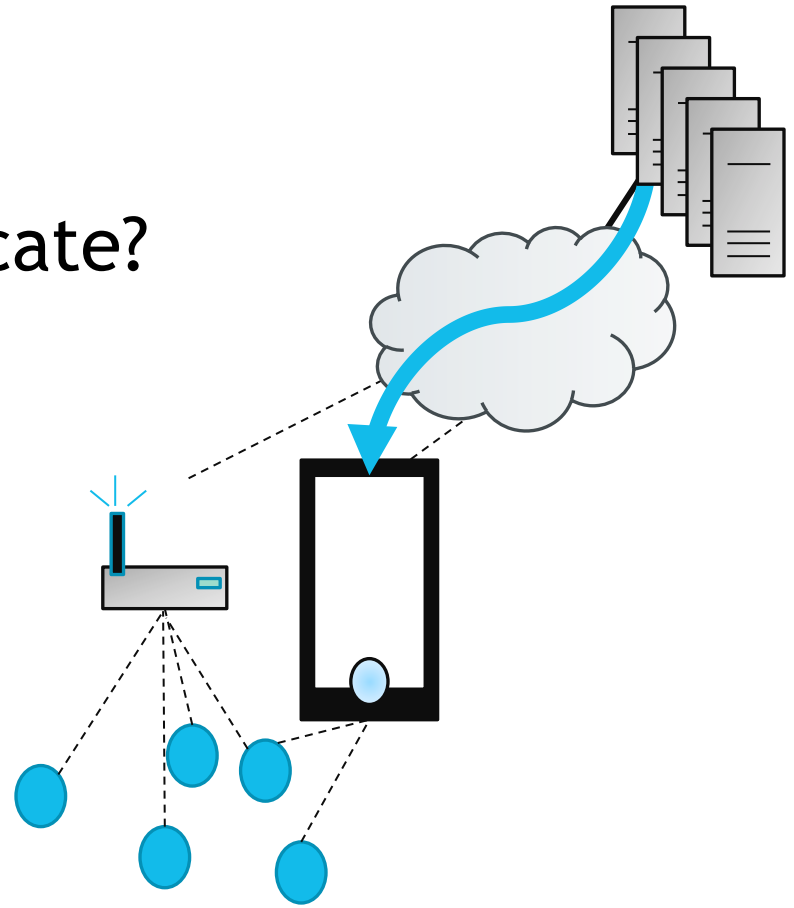
ARCHITECTURE, SIMPLIFIED



BUT, IN FACT, A RICH DESIGN SPACE

How should gateways and things communicate?

Many answers, many approaches

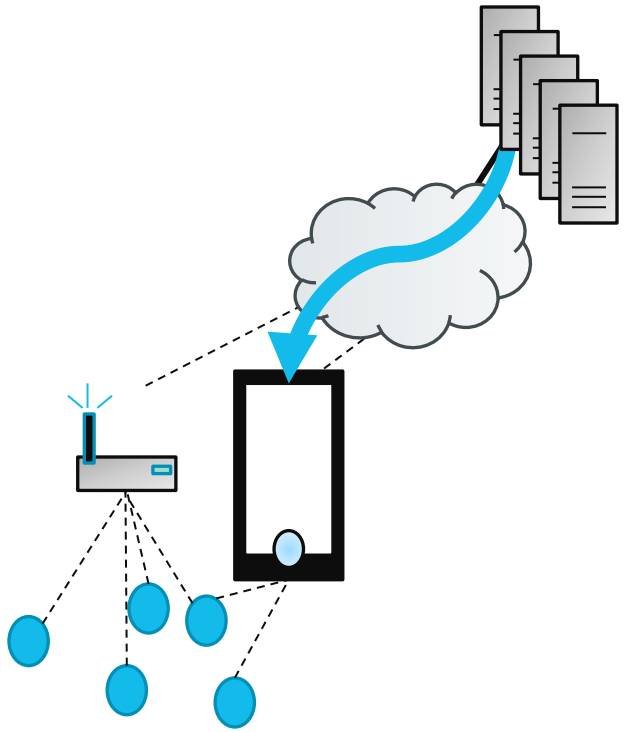


CAN’T WE JUST USE THE WIRELESS INTERNET?

Cellular and Wi-Fi

Yes, we can…

except when we can’t!



WIRELESS INTERNET FOR IOT?

Cellular (LTE/4G, 3G, 2G) and Wi-Fi are

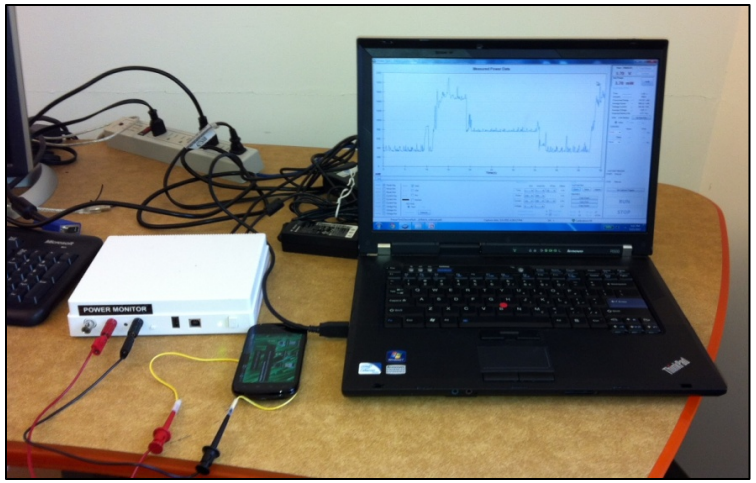
+ Widely available
+ High bandwidth (for most purposes), so can support high-rate apps

But, each has two big drawbacks

- **High power**: not suitable for battery-operated scenarios
- Cellular: often high cost (esp. per byte if usage-per-thing is low)
- Wi-Fi: OK in most buildings, but not for longer range

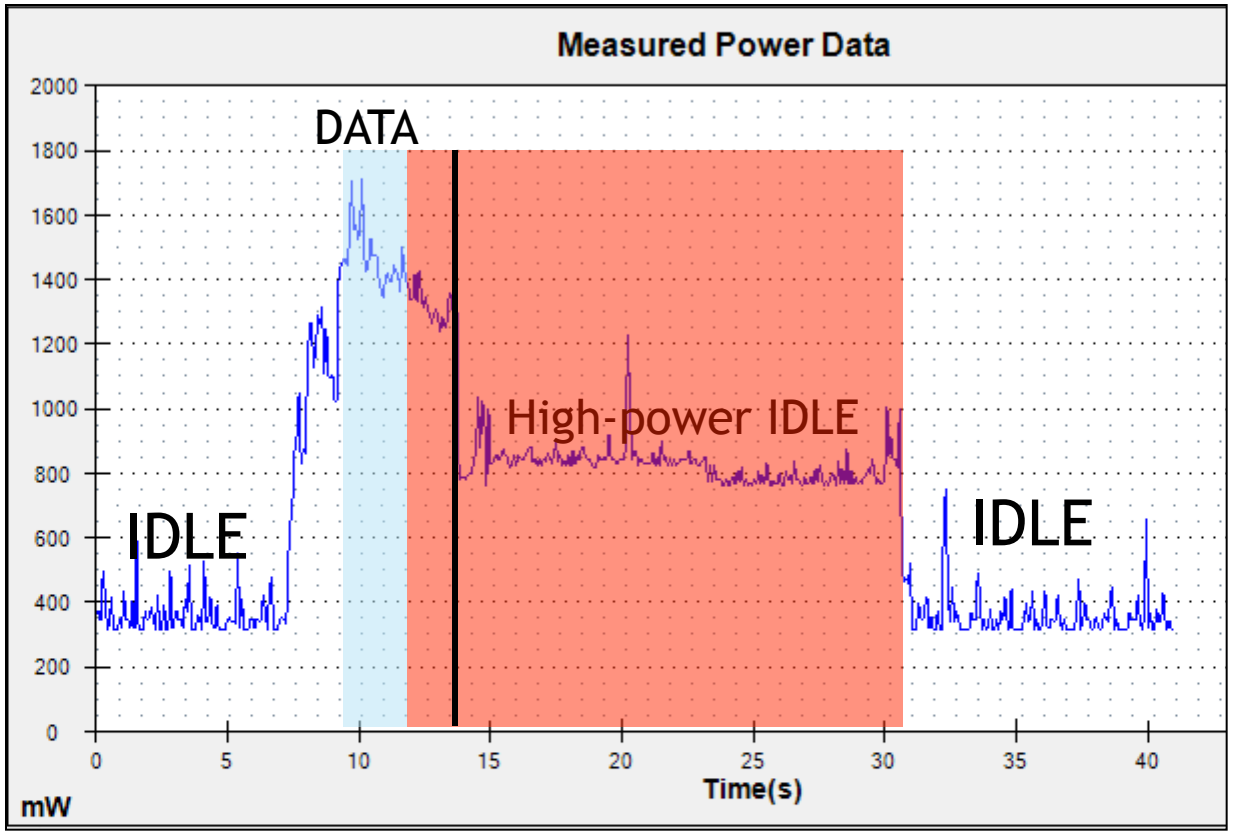
Wi-Fi: In-building powered things (speakers, washers, refrigerators, …)
Cellular: High-valued powered things (e.g., “connected car”)

CELLULAR POWER CONSUMPTION

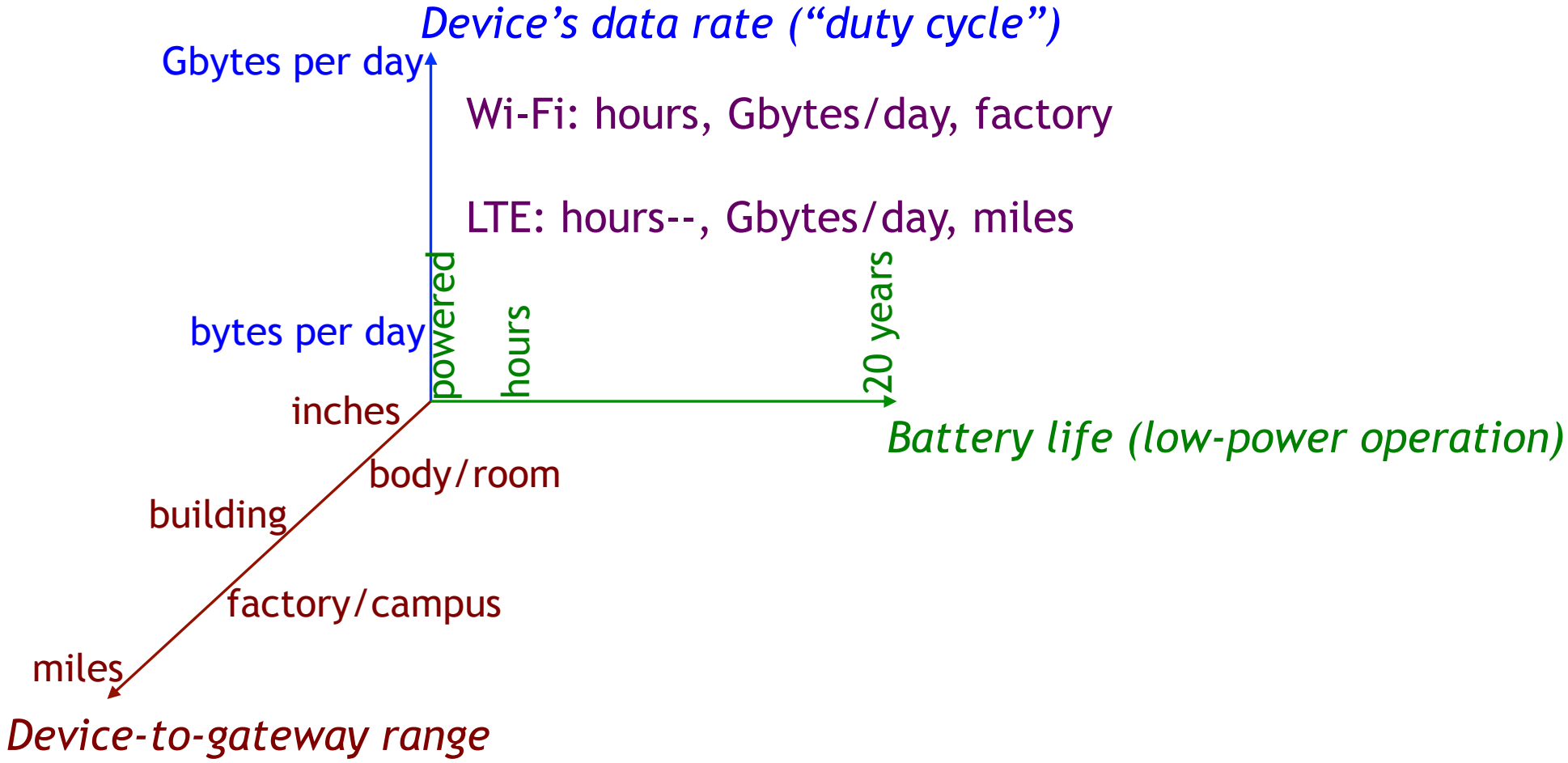


Power monitor apparatus

Deng & Balakrishnan, "Traffic-Aware Techniques to Reduce 3G/LTE Energy Consumption," CoNext 2012.



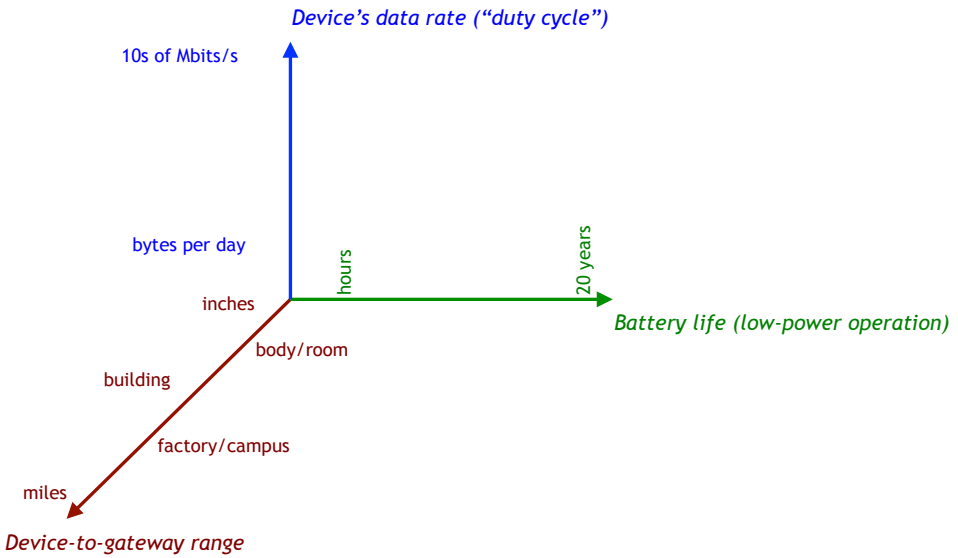
IOT NETWORK DESIGN SPACE



WHY SO MANY IOT NETWORKS?

Because engineers love inventing technologies!

But really because you can pick many interesting regions from this design space



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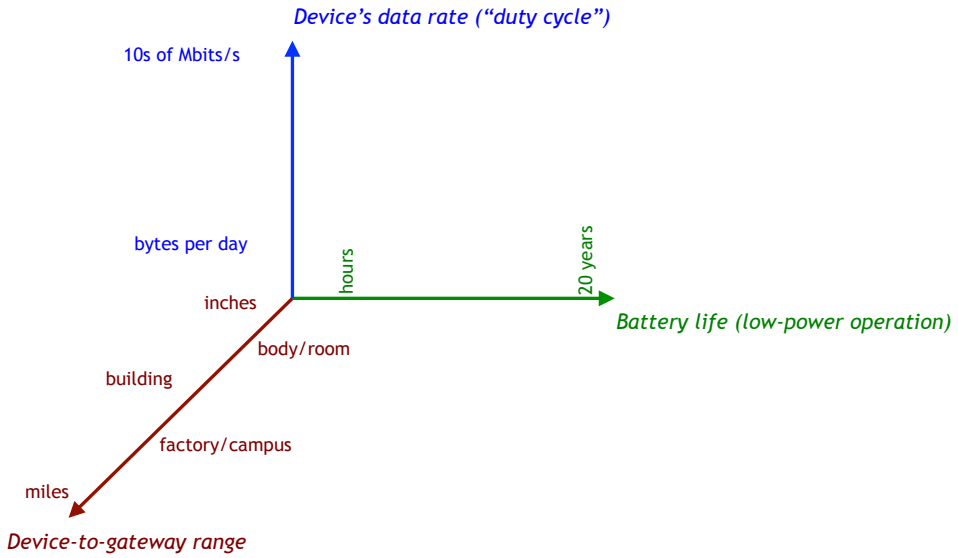
- And technology evolves fast



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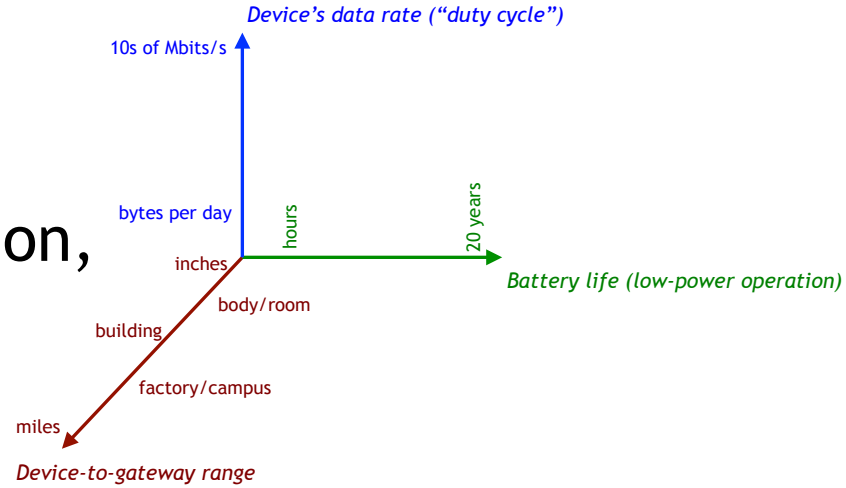
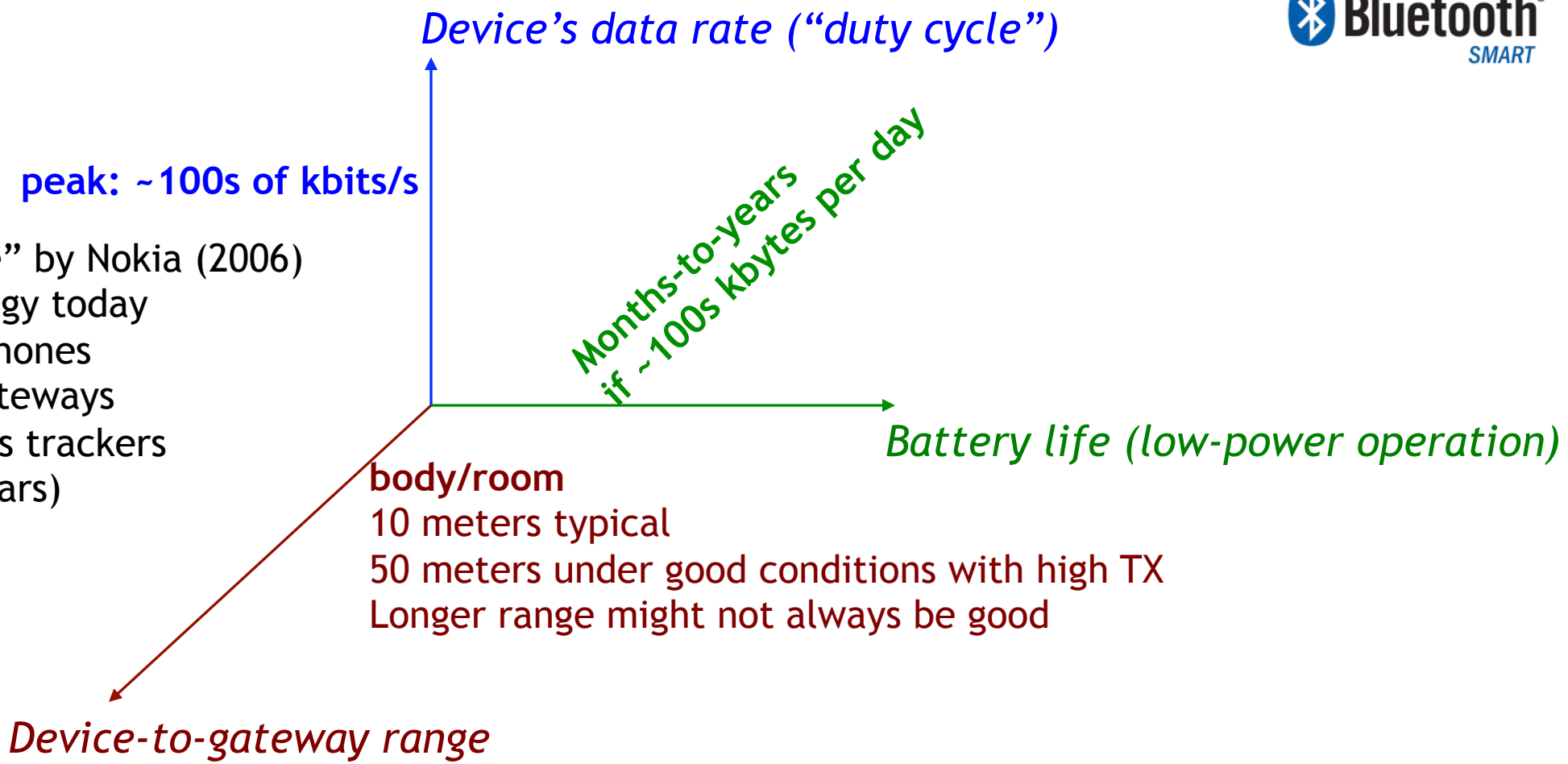
- Note, axes aren't independent
- And technology evolves fast
- And bundling into popular devices speeds-up adoption, changing the economics
  - Cf. Wi-Fi → laptops (without external cards)
  - Bluetooth classic → cell phones → wireless headsets
  - Bluetooth Low Energy (BLE) → iPhone then Android smartphones → "body/room" with months-to-years at low duty cycles



BODY/ROOM-AREA EXAMPLE: BLE



Started as "Wibree" by Nokia (2006)
Dominant technology today
Because of smartphones
Smartphones as gateways
  Wearables, fitness trackers
  Vehicles (bikes, cars)

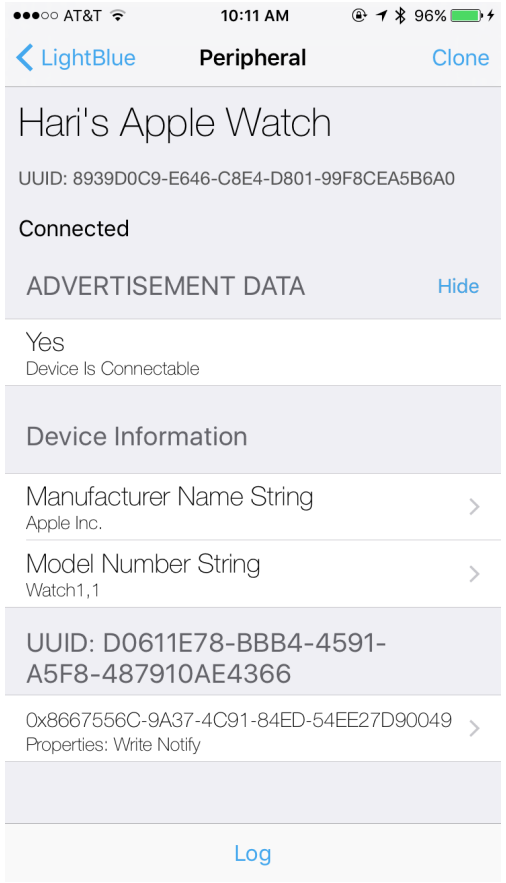
HOW DOES BLE WORK?

Two parts:

1. Advertisements (aka “beaconing”) for device discovery
2. Connection phase to exchange data

Peripheral: device with data
Central: gateway

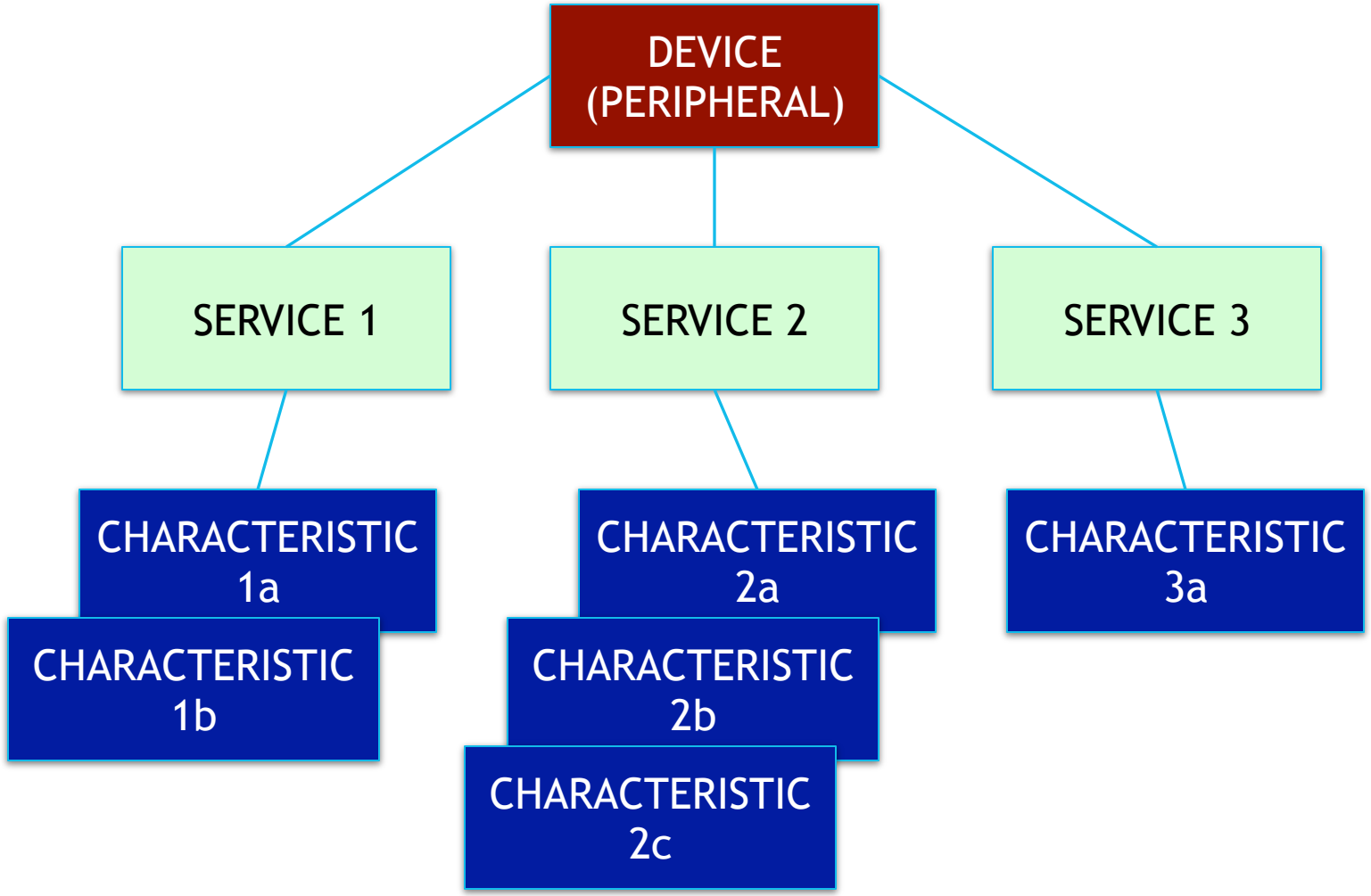
BLE ADVERTISEMENTS ARE PERIODIC



Typical period: 100 ms (“iBeacon”)
Less frequent is fine
Triggered advertisements are often a good idea

Trade-off between energy consumed and discovery latency

ON CONNECTION



READABLE
READ/WRITE
NOTIFICATIONS

Usually support OTA (over-the-air upgrades)

ON CONNECTION: MAC PROTOCOL

Central orchestrates data communication
Key idea: time-schedule to reduce energy consumption

On connect: exchange parameters

- Frequency hopping sequence
- Connection interval, i.e., periodicity of data exchange (T milliseconds)

Every T milliseconds, Central and Peripheral exchange up to 4 packets, alternating turns

Then Peripheral can go back to sleep until next interval

BATTERY LIFETIME CALCULATION

Consider an IoT system with coin-cell battery-powered nodes
Battery: 250 mAh (milliamp-hours) capacity; 3 Volts
Recall that power = voltage * current and energy = power * time
So this battery has 0.75 amp-hour-volts = 0.75*3600 Joules = 2.7 kJ of energy

Example of BLE current draw:
Standby: 1 microAmp (typically in the 1-10 microAmp range)
Receive (RX): 3.3 mA
Transmit (TX): 4 mA

Suppose device transmits every second: how long does the battery last?

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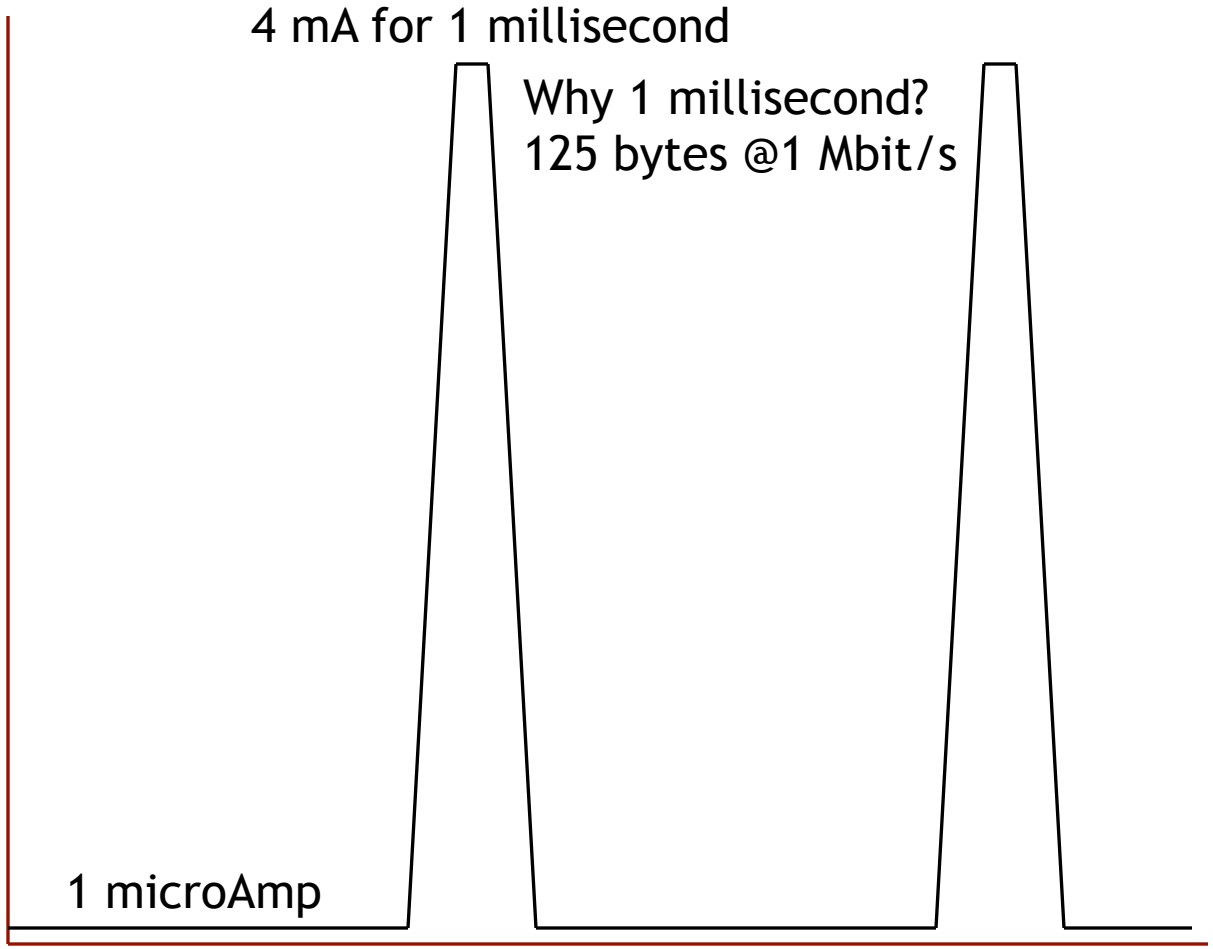
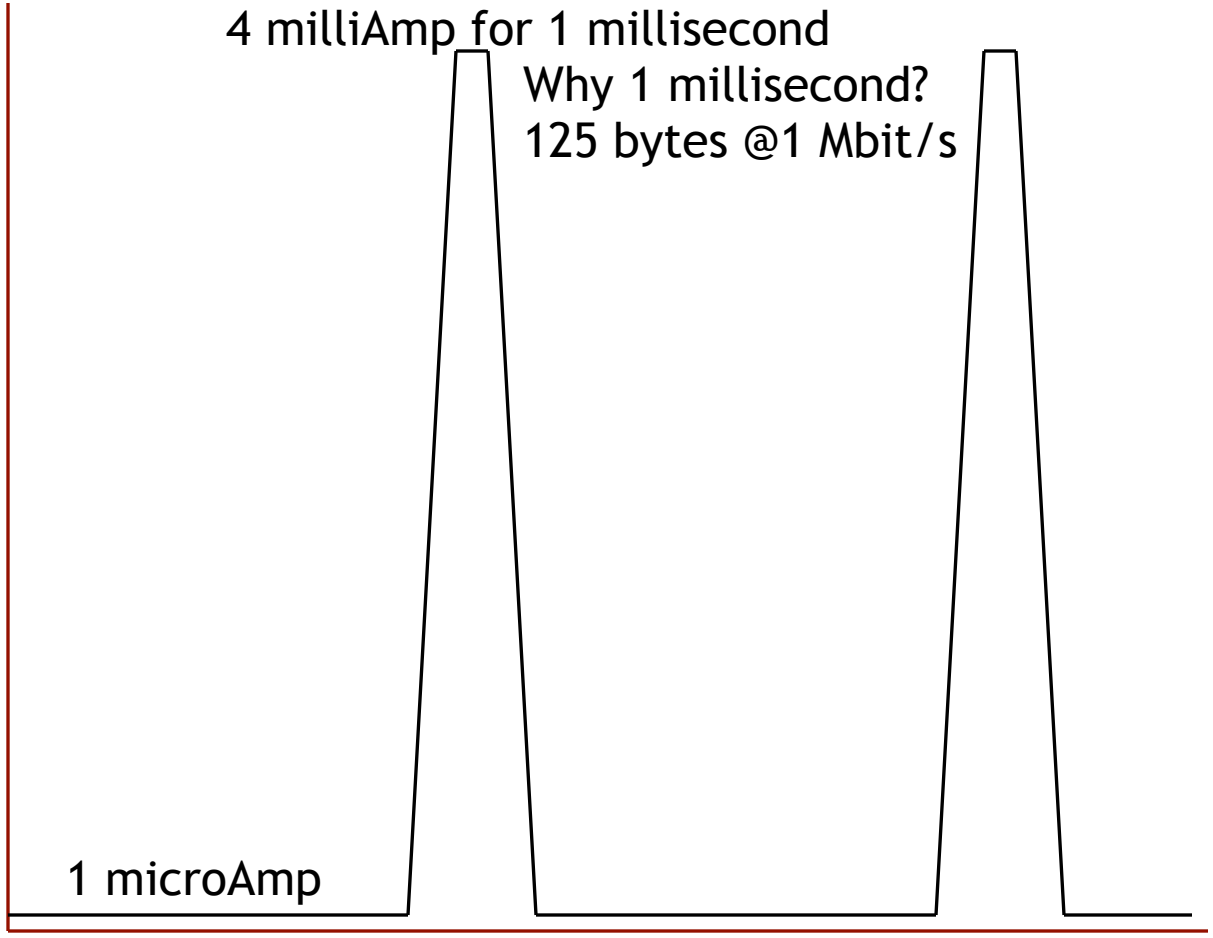


BATTERY CALCULATION (CONT.)



Battery capacity: 250 mAh (milliAmp-hours)
Ramp-up and down: 1 milliAmp for 5 milliseconds

Average current drawn is:
4 microAmps (xmit) +
5 microAmps (ramping) +
1 microAmp (standby)
= 10 microAmps

Therefore, battery lifetime
= 250 mAh / 10 microAmps
= 250 mAh / 0.01 mA
= 25,000 hours
= 2 years and 10 months

Saves energy because it’s sleeping most of the time!

“THE IOT GATEWAY PROBLEM” PAPER

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Usually need a smartphone app to interact with IoT data/devices
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The authors propose that smartphones become generic BLE gateways
Any phone talking with any peripheral device via BLE

- Phone as IPv6 router for peripheral device
- Phone proxies a device’s Bluetooth profile to cloud servers

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Value is in the data, not connectivity
Incentives are a problem
    For device makers?
    For app developers?
    For smartphone users?

EXTENDING COMMUNICATION RANGE