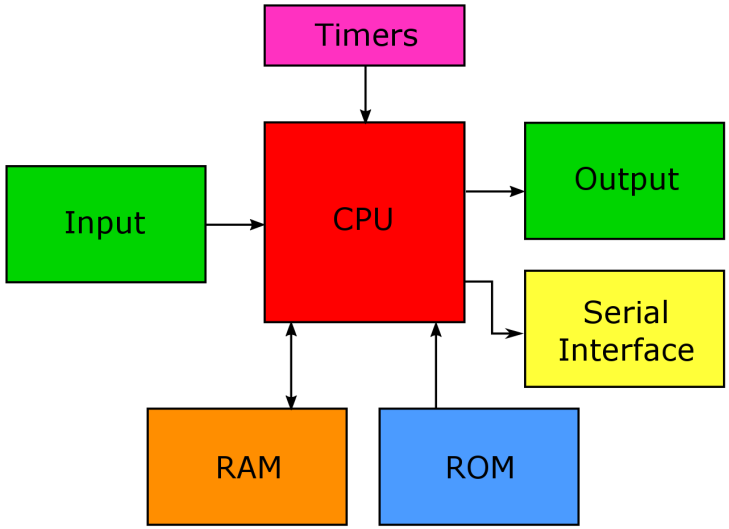
Carnegie Mellon University

95-733 Internet of Things Microcontrollers and WPAN Protocols

Microprocessors and Microcontrollers

Microprocesser: CPU
and several supporting chips.



Microcontroller: CPU
on a single chip.

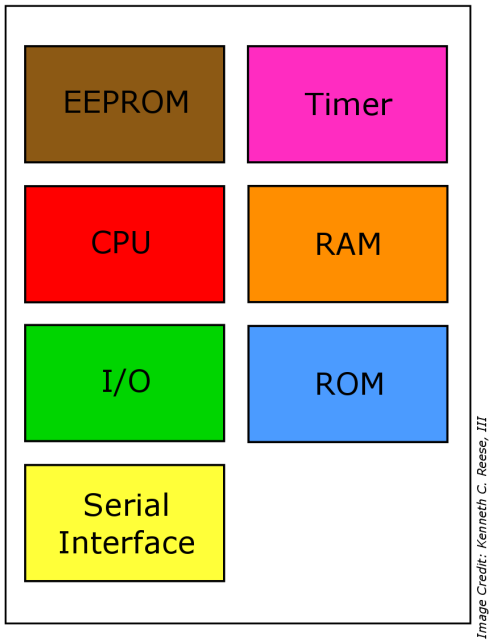


Image Credit: Kenneth C. Reese, III

Microcontrollers from Wikipedia

- A microcontroller (or MCU for MicroController Unit) is a small computer on a single integrated circuit. In modern terminology, it is a system on a chip or SoC. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals.
- Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems.
- By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.
- May be combined with a relay to control motors and machines
- In bulk, may be purchased for .25 USD. These are constrained devices.

Microcontroller from Wikipedia

- The majority of microcontrollers in use today are embedded in other machinery, such as automobiles, telephones, appliances, and peripherals for computer systems.
- Many use Advanced RISC Machine (ARM) processors. British company ARM holdings develops the architecture and licenses it to product design companies.
- Over 100 billion ARM processors produced as of 2017.

An example microcontroller: Particle Photon 2

- Advanced RISC machine (ARM) Cortex M33 CPU, 200 MHZ
- 3 MB of RAM
- 2 MB flash storage
- Dual-band Wi-Fi, BLE,
- 24 GPIO pins
- Web based IDE at particle.build.io (develop code and flash to Photon 2)
- Particle is an open-source platform
- Some devices provide cellular. Others provide WiFi.
- Mesh connectivity no longer supported.
- Has example code for connecting to MQTT , see mqtttest.ino

Particle Microcontroller advertisement

We made more progress on our first day with Particle than we had in months without them, and within six months we began collecting data from thousands of connected brewers in the hands of consumers. Michael Cunningham, CIO, Keurig

This is “usage data”.
Quiz why is usage data valuable?

It can be used to impact future product designs.

We are moving from smart products to smart connected products.

PAN from Wikipedia

- A personal area network (PAN) is a computer network for interconnecting devices centered on an individual person's workspace. PANs can be used for communication amongst the personal devices themselves, or for connecting to a higher level network and the Internet where one master device takes up the role as gateway. A PAN may be carried over wired computer bus such as USB.
- A wireless personal area network (WPAN) is a low-powered PAN carried over a short-distance wireless network technology such as IrDA, Wireless USB, Bluetooth and ZigBee. The reach of a WPAN varies from a few centimeters to a few meters.
- Some PAN implementations (e.g., Bluetooth Low Energy with tiny sensors) can behave like constrained environments.
- Constrained Networks (per RFC 7228)

  Limited bandwidth, energy, and processing power

  Often battery-operated sensors or actuators

  Examples: 6LoWPAN, LoRaWAN

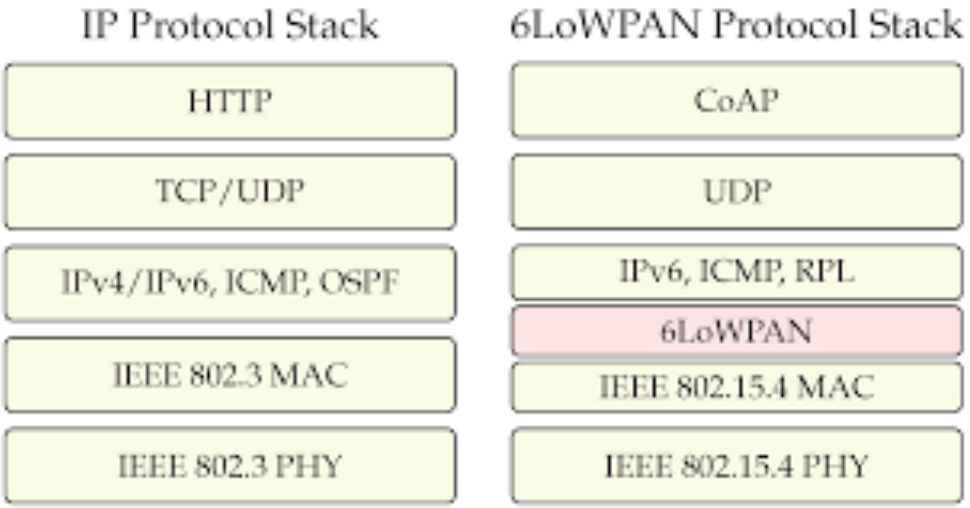
Important WPAN Protocols

Name	Battery Usage	Indoor Range	Mesh networking	Openness	Internet Integration	Comment
EnOcean	Very low energy harvesting	< 30 m	No	Low	No	Full stack. Buildings and industrial solutions
ZigBee	low	< 50 m	Yes	Low	No	Full stack. Based on 802.15.4
Thread	low	< 50 m	Yes	Medium (used by Google Nest)	Yes	6LoWPAN over 802.15.4
Bluetooth	Low with BLE	< 50 m	Yes pub/sub mesh networking over BLE	Medium	No but coming	Full stack. Not based on 802.15.4
Wi-Fi	High and Low variations	< 30 m	No (Star topology)	High	Yes	LAN

From "Building the Web of Things by Guinard and Trifa.
If your device will be plugged in, use Ethernet or Wi-Fi or both.

Notes on 6LoWPAN

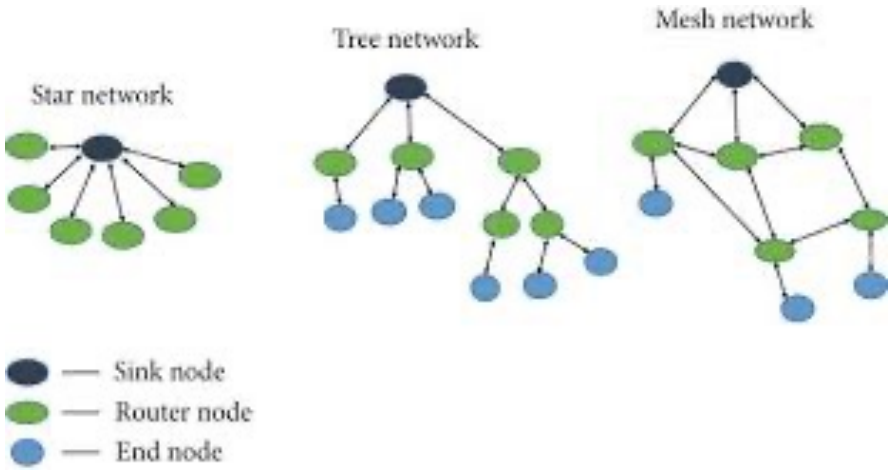
Standard IPv6 packets are too large for the small frame sizes of low-power wireless technologies like IEEE 802.15.4.



ICMP for error reporting
OSPF for route optimization
MAC for media access control
RPL for IOT routing
802.3 Ethernet
802.15.4 Low-rate wireless

Wireless Sensor Network Topologies

- Star
- Tree
- Mesh
- Hybrid



- A sink node acts as a gateway between a constrained network (e.g., sensors using 6LoWPAN, Zigbee) and a more capable network (e.g., Ethernet, Wi-Fi, or cellular)
- Router Node = Intermediate device (data source + forwarding capability)
- End Node = Leaf device (data source only)

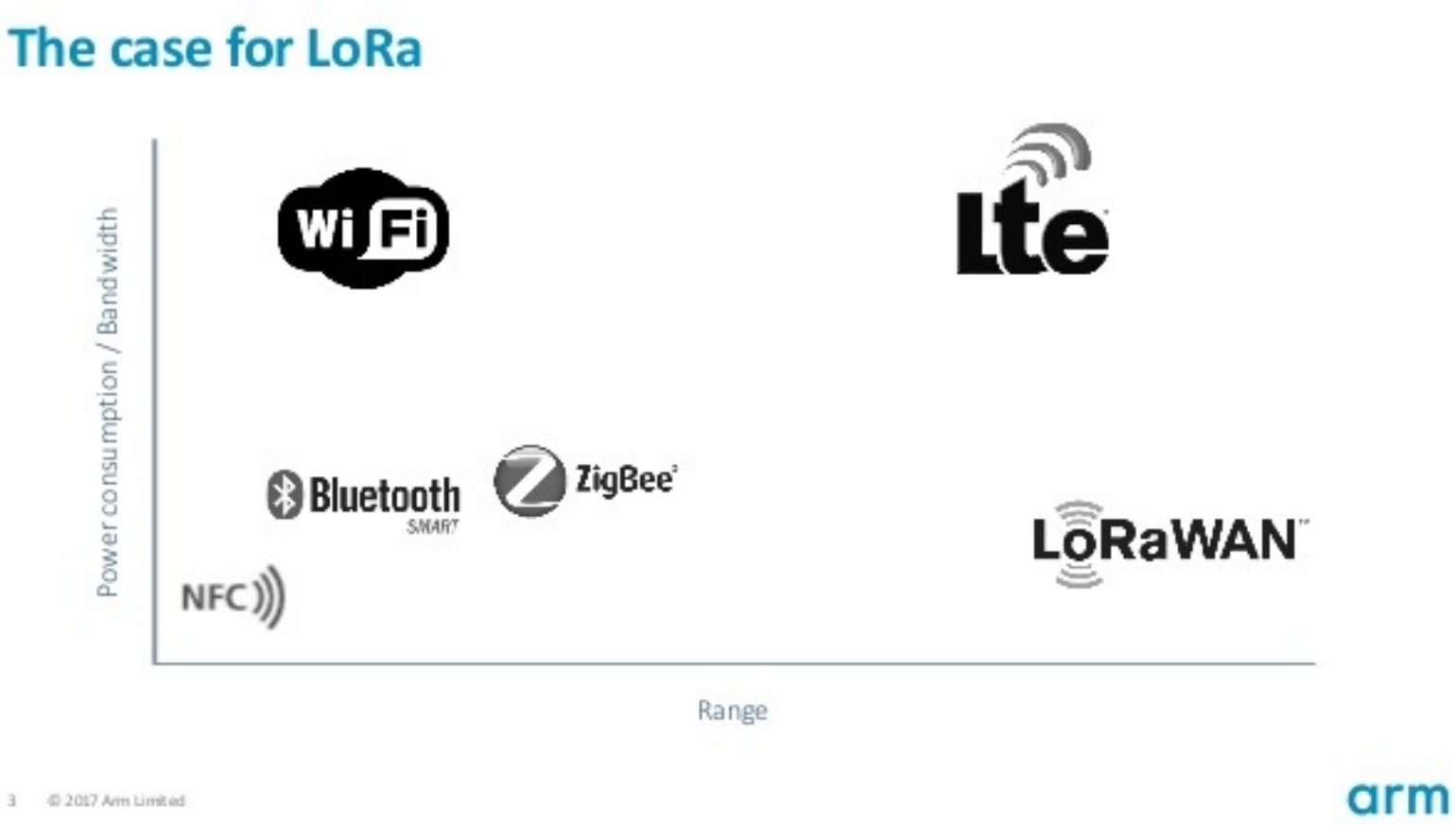
Mesh Networking

- Very much like peer-to-peer with routing.
- Turn lights off if no motion for 10 minutes.
- Turn heat down if no motion for 1 hour.
- No WiFi, ethernet, or celluar. Each device has an address.
- Devices:
  M = Motion Detector
  L = Light Control
  H = Heat Control
  D1 = Door Lock
  S1 = Sensor in another room
  L2 = Second Light Control
- Suppose M cannot directly reach H
  A mesh network can automatically find a path:
  M → **L** → **D1** → **H**

Low Power Wide Area Networks (LPWAN)

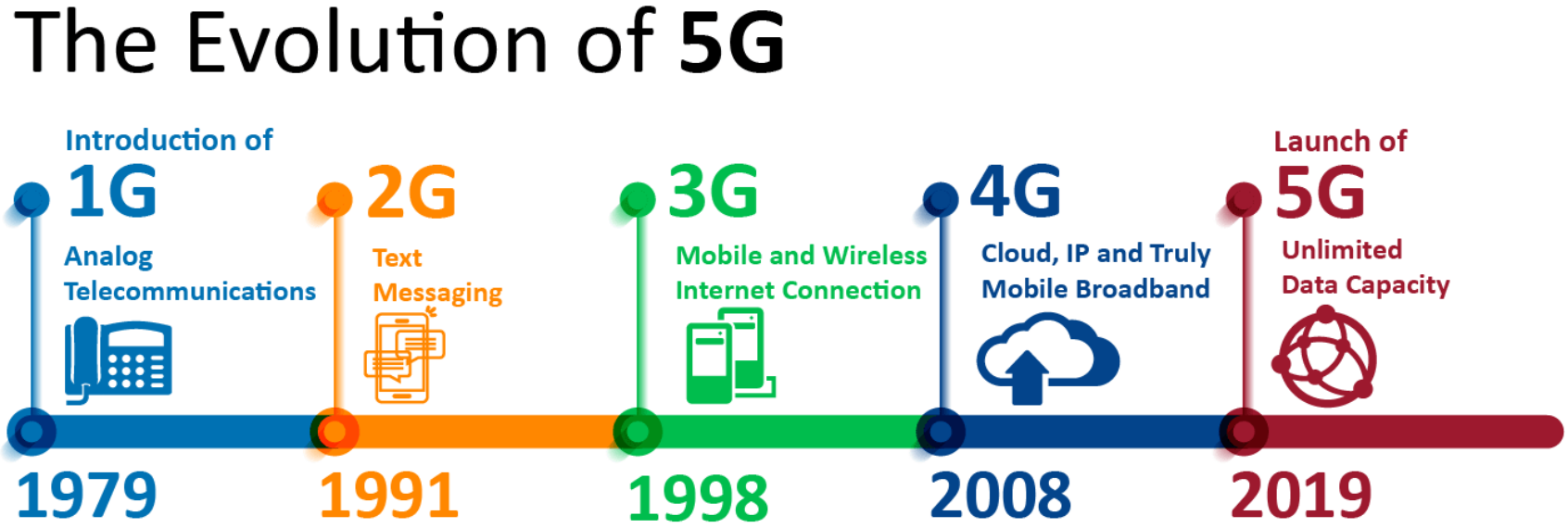
- LoRa (short for Long Range) is an important player – many others exist
- LoRa is at the physical layer and for long range communications
- Very low bandwidth 250 bps – 11 kbps (not JSON or ASCII) typically raw binary and small < 243 bytes
- Low battery use – transmit rarely
- May be mobile
- Talks to a gateway that connects to the internet
- LoRaWAN is a communications protocol above LoRa
- 128-bit AES key for encryption
- Adopted at CMU, see OpenChirp

Low Power & Low bandwidth & Long range



From ARM presentation 2017

Wireless Wide Area Network



1G was all about voice.
2G was about voice and texting
3G was about voice, texting, and data (use the web)
4G was everything in 3G but faster
5G fast enough to download a full-length HD movie in seconds.
2020 Verizon deploys 5G in several cities
2025 Wide adoption, about 1/3 of all mobile subscriptions, worldwide