

# Internet of Things

## Programming

### Week 6 – IoT networking

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Swinburne University of Technology

April 2023

# Individual Practical Assignment

- Development of an IoT edge application using Arduino Uno and/or Raspberry Pi
- You can get ideas from:
  - Lectures
  - Your Survey paper
  - Think what you would like to automatise/improve using IoT at home/work/etc...

# Individual Practical Assignment

You can break down your project with the following tasks:

- Task 1: Define an IoT project.
  - Talk to your tutor
- Task 2: Find the hardware
  - Jaycar, Altronics, Core-electronics...
- Task 3: Develop a database.
- Task 4: Simple edge analytics.
- Task 5: User interface

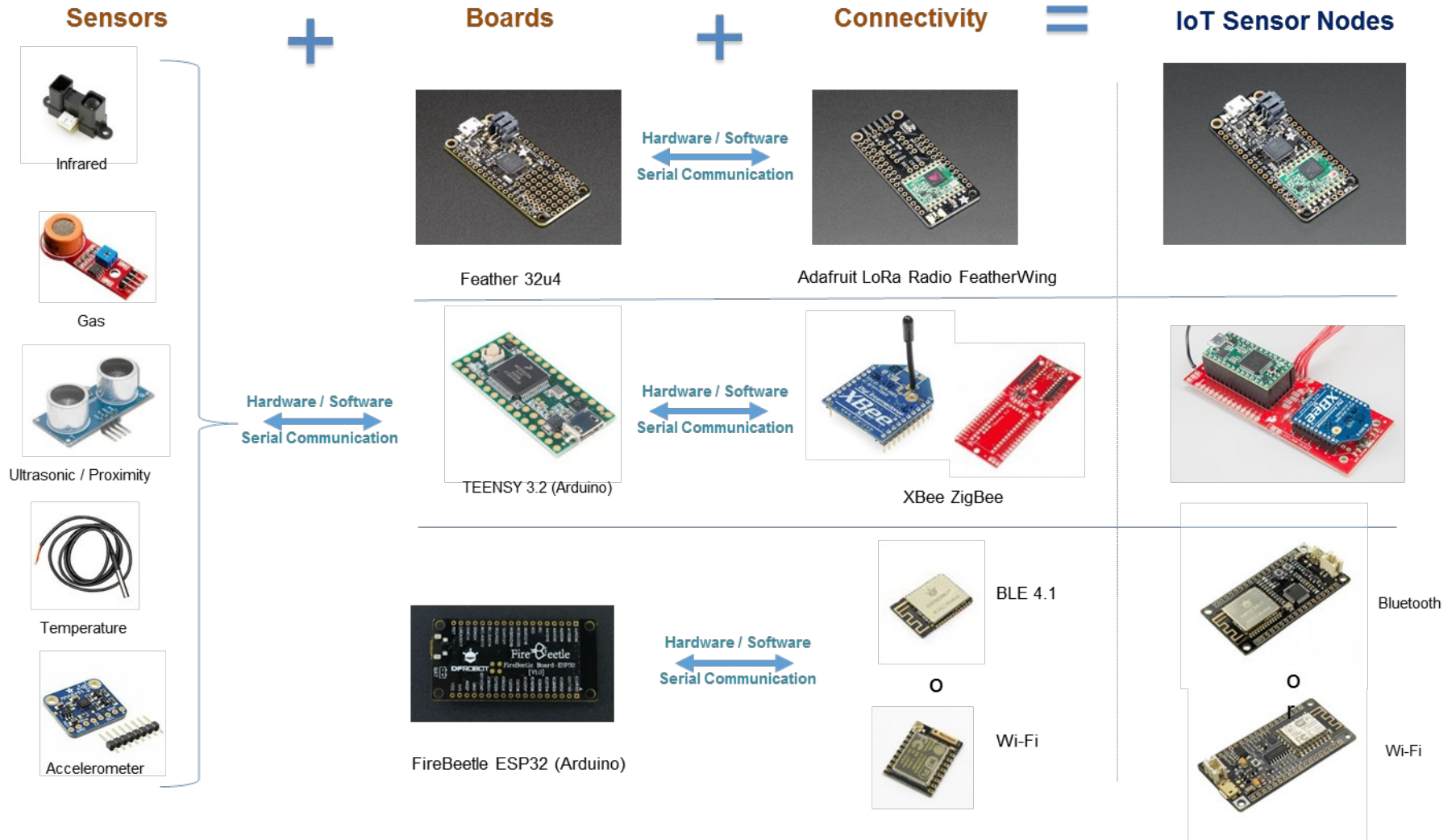
# Individual Practical Assignment

- Check the Rubric to obtain maximum score!
- You must submit (28<sup>th</sup> of April):
  - Source code
  - Report
- You must demonstrate your project in your tutorial (week 8 and 9)

# Individual Practical Assignment

Questions?

# IoT hardware and Software

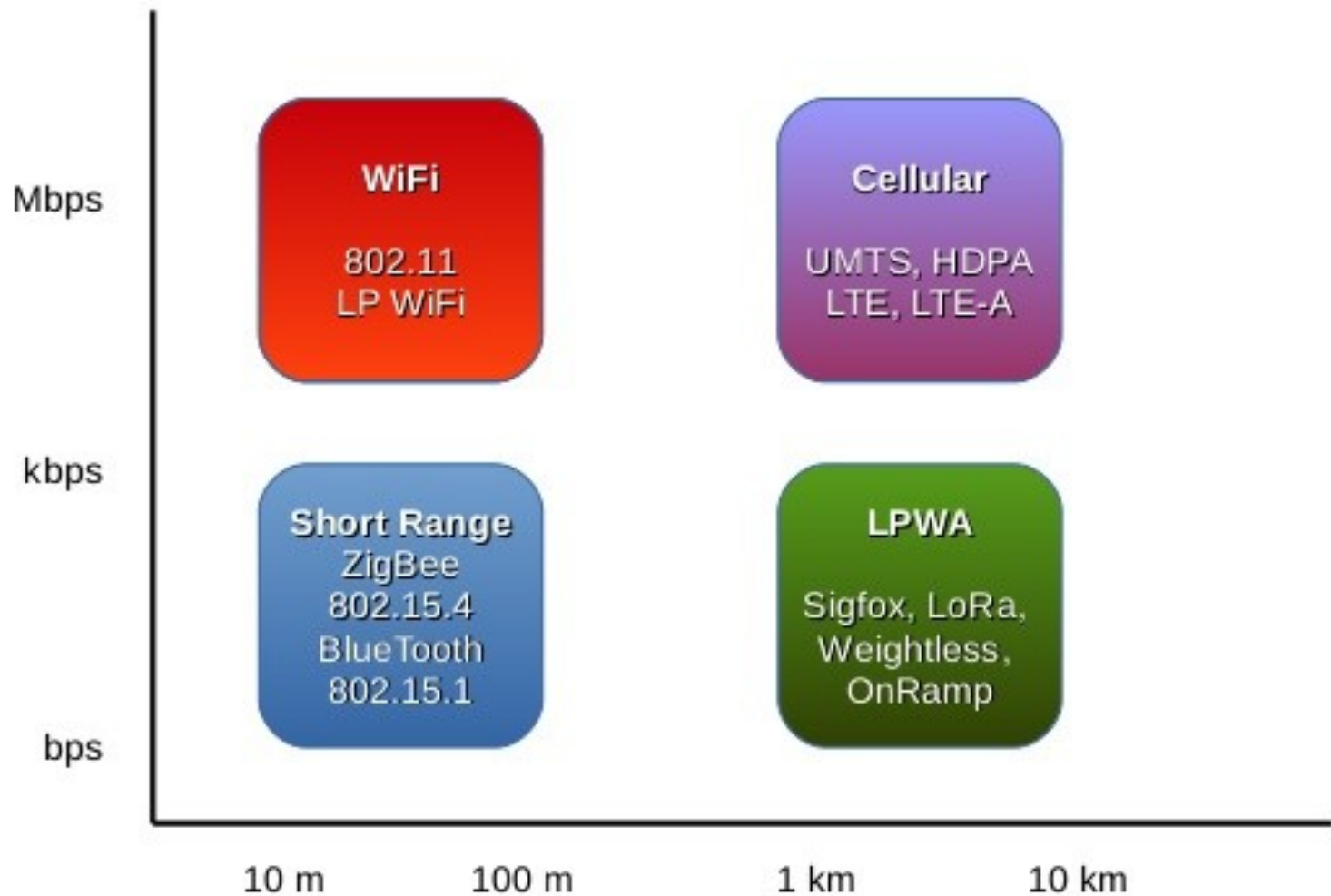


# IoT Networks



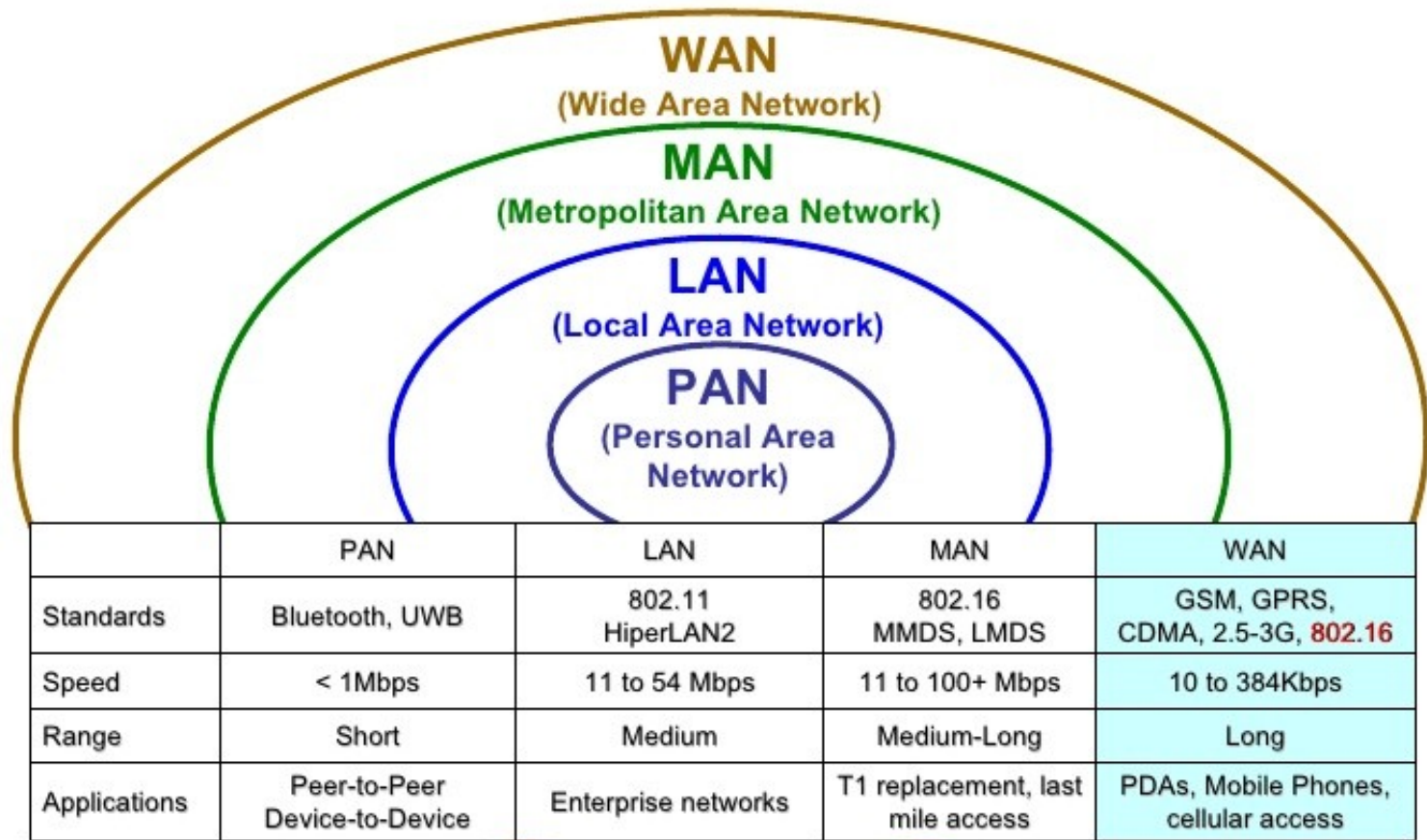
	Local Area Network Short Range Communication	Low Power Wide Area (LPWAN) Internet of Things	Cellular Network Traditional M2M
	40%	45%	15%
☺	Well established standards In building	Low power consumption Low cost Positioning	Existing coverage High data rate
☹	Battery Live Provisioning Network cost & dependencies	High data rate Emerging standards	Autonomy Total cost of ownership
	Bluetooth 4.2	LoRa	GSM 3G+ / H+ 4G

# M2M Technologies - Overview





# Background: Wireless Technologies



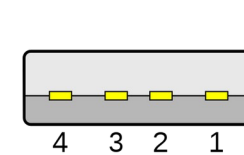
# Personal area network (PAN)

PANs can be wired, such as USB or FireWire, or they can be wireless, such as infrared, ZigBee, Bluetooth

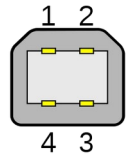
The range of a PAN typically is a few meters

# PAN Wired - USB

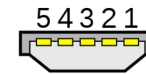
- Universal Serial Bus (USB).
- Industry standard maintained by the USB Implementer Forum (USB-IF).
- Four generations of USB specifications: USB 1.x, USB 2.0, USB 3.x, and USB 4.
- USB 1.0 specified 12 Mbit/s (Full Speed); USB 4.0 supports 40 Gbit/s.
- Cable maximum length:
  - USB 1.0: 3m
  - USB 2.0: 5m
  - USB 3.0: 3 m
  - USB 4.0: 0.8 m



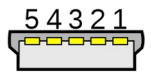
Type-A



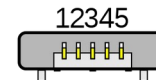
Type-B



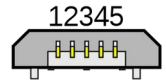
Mini-A



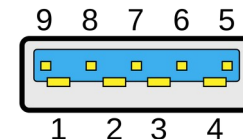
Mini-B



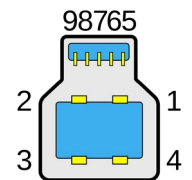
Micro-A



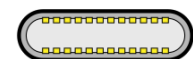
Micro-B



Type-A  
SuperSpeed



Type-B  
SuperSpeed



Type-C

# WPAN: Bluetooth

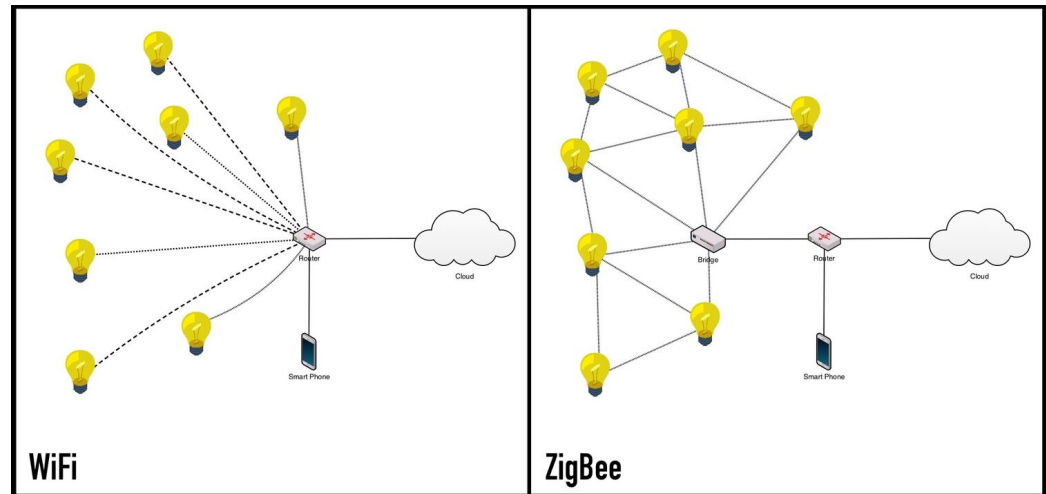
- Short range wireless technology (<10m)
- 2.4 GHz
- Speed up to 3 Mb/s
- IEEE 802.15.1
- Point-to-point, Broadcast, or Mesh
- BLE stands for Bluetooth Low Energy



# WPAN: ZigBee



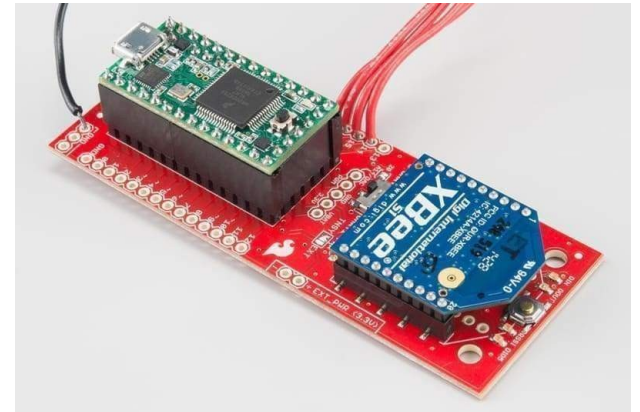
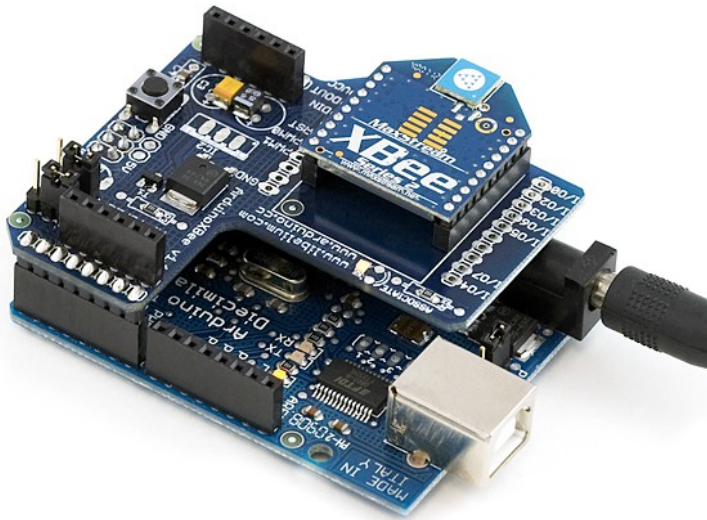
- Designed for low data-rate and battery-powered applications.
- 2.4 GHz
- IEEE 802.15.4 standard
- 250 Kbits/s
- Supports encryption
- Range: up to 30 meters
- Star, Mesh and Tree network topology
- Supports up to 65,000 devices
- Cheaper than Bluetooth and WiFi; however, it requires a gateway for internet access
- Nodes can stay in sleep mode most of the time, drastically extending battery life
- The most popular, low-cost, low-power wireless mesh networking standard



<https://linkdhome.com/articles/what-is-zigbee-guide>

<https://zigbeealliance.org/solution/zigbee/>

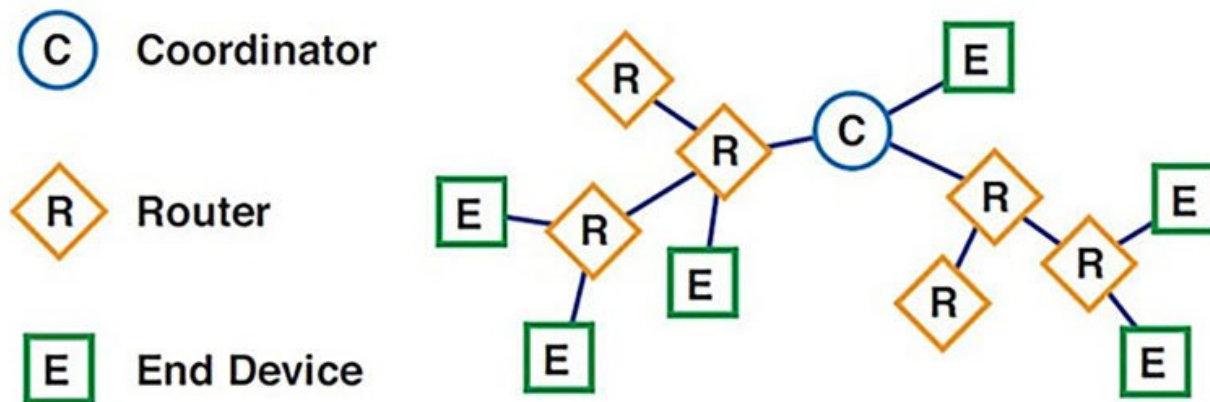




<https://www.digi.com/products/embedded-systems/digi-xbee/digi-xbee-tools/xctu>

# WPAN: ZigBee - Types of devices

- End device: can not route traffic
- Router: routers can route traffic
- Coordinator: in addition to routing traffic, is responsible for forming the network in the first place, might bridge to other networks.



# WPAN: Infrared



- Infrared (IR) is a wireless mobile technology used for device communication over short ranges
- IR communication has major limitations because it requires line-of-sight, has a short transmission range and is unable to penetrate walls
- IR-enabled devices are known as IrDA devices because they conform to standards set by the Infrared Data Association (IrDA)
- Data transmitted between IrDA devices is normally unencrypted



# Local Area Network (LAN)

- It covers a local area. This usually includes a office or home
- Technologies: Ethernet (LAN) or WiFi (WLAN)



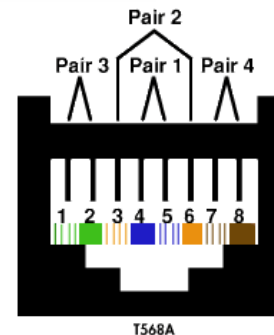
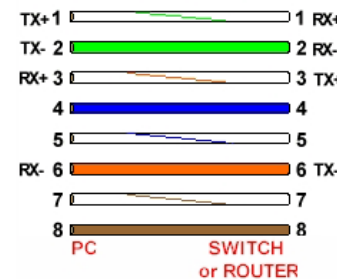
# Ethernet

- Wired computer technology for LAN.
- Ethernet Alliance is a non-profit industry consortium to promote and support Ethernet
- Original Ethernet used coaxial cable, modern Ethernet uses twisted pair and fibre optics.
- IEEE 802.3
- Speed
  - Cat 6: 5000 Mbits/s
  - Cat 6e: 10000 Mbits/s
- Ethernet cables: Straight-through or Cross-over
- Modern Ethernet ports detect if connection requires cross-over or straight-through (Auto MDI-X)



## STRAIGHT-THROUGH

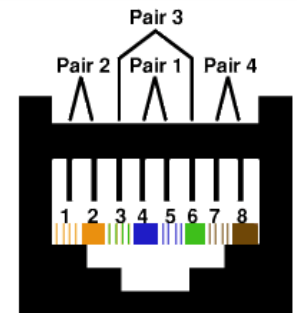
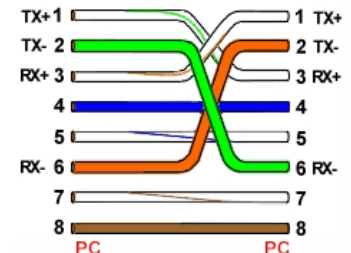
Wiring Standards Used  
T568A T568A



T568A

## CROSS-OVER

Wiring Standards Used  
T568A T568B



T568B

# Wi-Fi



Wireless Fidelity



Wi-Fi is a trademark of the Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing



Wireless Ethernet



Initial standard for wireless local area networks



Reliable



High speed



High power consumption



Different versions

IEEE 802.11a

IEEE 802.11b

IEEE 802.11g

.....

# Wi-Fi Operating Frequency

- Wi-Fi most commonly uses the 2.4 gigahertz UHF and 5 gigahertz SHF Industrial, Scientific and Medical (ISM) radio bands
- 2.4 GHz
  - Comprises 14 channels (3 non-overlapping: 1,6,11) each with a bandwidth of approximately 20 to 22 MHz operating in the ISM band.
  - It is a crowded frequency because many devices other than 802.11 devices operate in it. E.g., Bluetooth, microwaves, telephones, garage door openers, baby monitors, etc.
- 5 GHz
  - Comprises 24 non-overlapping channels, each with a bandwidth of approximately 20 MHz.
  - this band is less crowded than 2.4 GHz

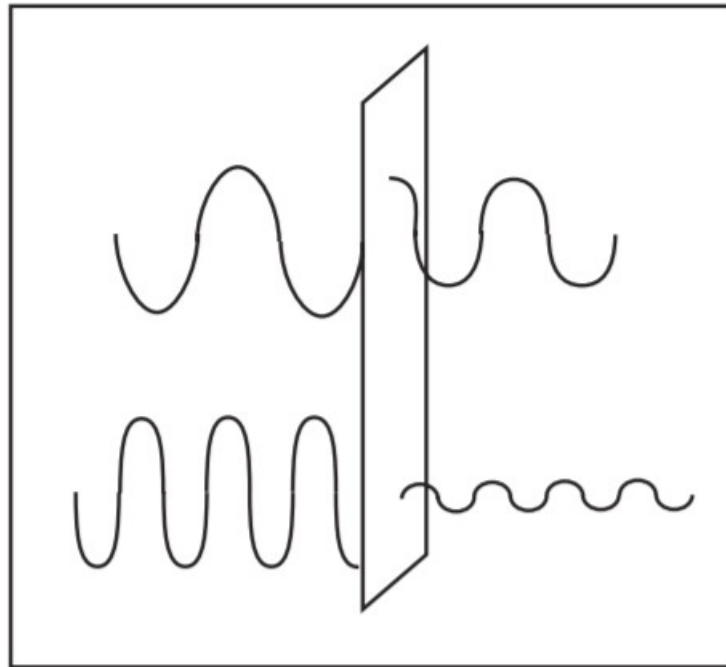
# Wi-Fi Standards Characteristics

Technologies	Indoor/ Outdoor	Bitrate	Freq. bands	License	Bandwidth	Modulation	MIMO
<b>IEEE 802.11</b>	20m /100m	2 Mbps	2.4GHz	Unlicensed	20 MHz	FHSS and DSSS	—
<b>IEEE 802.11b</b>	35m/ 140m	11 Mbps	2.4GHz	Unlicensed	20 MHz	HR-DSSS	—
<b>IEEE 802.11a</b>	35m/ 119m	54 Mbps	5GHz	Unlicensed	20 MHz	OFDM	—
<b>IEEE 802.11g</b>	45m/ 90m	54 Mbps	2.4 GHz	Unlicensed	22 MHz	OFDM/ DSSS/ CCK	—
<b>IEEE 802.11n</b>	70m/ 250m	600 Mbps	2.4 GHz/ 5 GHz	Unlicensed	20 MHz/ 40 MHz	OFDM	4 X 4
<b>IEEE 802.11ac wave</b>	70m/ 250m	7000 Mbps	5 GHz	Unlicensed	80 MHz	64-QAM	MU-MIMO
<b>IEEE 802.11ad</b>	10m/ n/a	7000 Mbps	60 GHz	Unlicensed	2.16 GHz	Single Carrier/ OFDM	10 X 10
<b>IEEE 802.11ac wave 2</b>	70m/ 250m	7000 Mbps	5 GHz	Unlicensed	80 MHz/ 160 MHz	256-QAM	MU_MIMO 8 X 8

Garcia, Laura & Jimenez, Jose & Taha, Miran & Lloret, Jaime. (2018). Wireless Technologies for IoT in Smart Cities. Network Protocols and Algorithms. 10. 23. 10.5296/npa.v10i1.12798.

# Electromagnetic waves attenuation

- Higher frequency signals have higher attenuation passing through obstacles than do lower frequency signals. This is because some of the energy of the electromagnetic field transfers into the material of the obstacle (cement walls, foliage, etc.) which reduces the strength of the signal.



# Wi-Fi Hardware

- Access Point
- Wireless Adapter
- Router
- Bridge: Connects two wired networks together over Wi-Fi
- Embedded System

# Wi-Fi Raspberry Pi

*sudo iwlist wlan0 scan*

```
pi@raspberrypi:~ $ sudo iwlist wlan0 scan | grep ESSID
      ESSID:"TP-LINK_9687"
      ESSID:"NETGEAR70"
      ESSID:"iiNet4E8787"
      ESSID:"NETGEAR70-5G"
      ESSID:"TP-LINK_85F3_5G"
      ESSID:"TP-LINK_9687_5G"
      ESSID:"Optus_99D903"
```

*sudo nano /etc/wpa\_supplicant/wpa\_supplicant.conf*

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=AU

network={
    ssid="TP-LINK_9687"
    psk="12345687"
    key_mgmt=WPA-PSK
}
```

*sudo wpa\_supplicant -i wlan0 -c /etc/wpa\_supplicant/wpa\_supplicant.conf*

Or restart the pi...



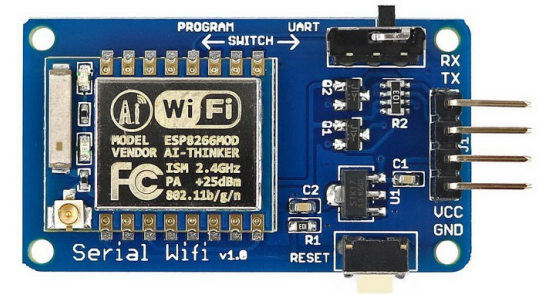
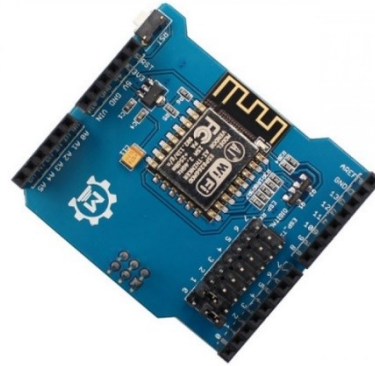
# Wi-Fi Raspberry Pi - eduroam

*sudo nano /etc/wpa\_supplicant/wpa\_supplicant.conf*

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=AU

network={
    ssid="eduroam"
    scan_ssid=1
    key_mgmt=WPA-EAP
    eap=PEAP
    identity="fmarti@swin.edu.au"
    anonymous_identity=""
    password="INSERT_PASSWORD_HERE"
    ca_cert=""
    phase2="auth=MSCHAPV2"
}
```

*[https://github.com/oleks/eduroam-wpa\\_supplicant](https://github.com/oleks/eduroam-wpa_supplicant)*



# WiFi Modules

# Arduino Wi-Fi

- `#include <WiFi.h>`
- `char ssid[] = "IoTProgramming";`
- `status = WiFi.begin(ssid);`
- `IPAddress ip = WiFi.localIP();`
- `IPAddress subnet = WiFi.subnetMask();`
- `IPAddress gateway = WiFi.gatewayIP();`

# Wide Area Network (WAN)



Network that covers an area wider than a LAN



Distances can range from a network connecting multiple buildings on a corporate or college campus



The most popular WAN is the internet

# Low Power Wide Area Network (LPWAN)



Designed to allow long range communications at a low bit rate among things



The LPWAN data rate ranges from 0.3 kbit/s to 50 kbit/s per channel



Long Range: The operating range of LPWAN technology varies from a few kilometres in urban areas to over 10 km in rural settings. It can also enable effective data communication in previously infeasible indoor and underground locations.



Low Power: Optimized for power consumption, LPWAN transceivers can run on small, inexpensive batteries for many months



Low Cost: LPWAN's simplified, lightweight protocols reduce complexity in hardware design and lower device costs



- Sigfox is a French global network operator founded in 2009
- Builds wireless networks to connect low-power objects such as electricity meters and smartwatches
- 868 to 869 MHz and 902 to 928 MHz depending on regions
- Designed for devices that need to be continuously on and emitting small amounts of data
- Industrial, Scientific and Medical ISM radio band
- Sigfox partner in Australia is Thinxtra



USABLE WORLDWIDE



ALL INCLUSIVE



MULTI HARDWARE  
DEVELOPMENT PLATFORMS



TECHNICAL SUPPORT



SCALABLE

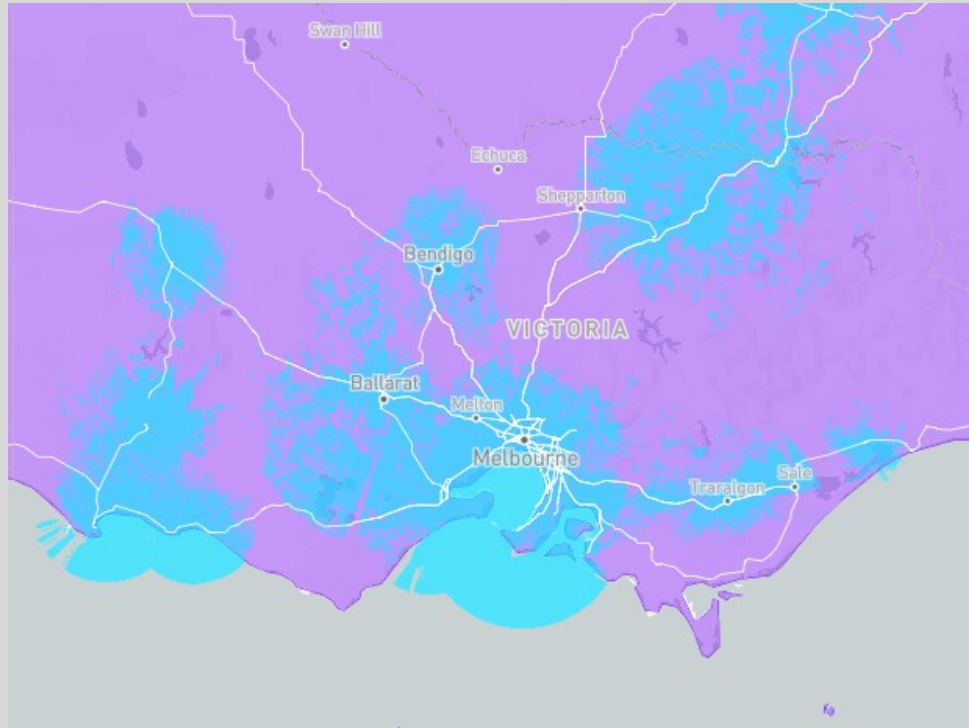


COST EFFECTIVE

#### THE FIRST COMPLETE SIGFOX READY DEVELOPMENT KIT BY THINXTRA

The perfect way to get started with Sigfox, the Thinxtra devkit Xkit boasts a full suite of features and accessories to empower anyone to set up an IoT solution, even with very little hardware experience. Perfect for start-ups, design houses, universities and schools, the kit has everything you need to hit the ground running using the globally available Sigfox network.

# Sigfox Coverage



<https://www.sigfox.com/en/coverage>

# Sigfox Application Example

## Next Generation Keg Tracking from Kegstar



The Kegstar team has spent several years developing this potentially game-changing tracking technology, which not only provides the exact real-time location of every keg, but also gives detailed information of what's inside it.

<https://thinextra.com/2020/11/next-generation-keg-tracking-from-kegstar/>





LoRa transceiver chips

# LoRa (Long Range)

- ▶ LoRa (Long Range) is a non-cellular long range and low power wireless technology
- ▶ LoRa is a proprietary (patented) wireless radio frequency technology
- ▶ LoRa competes against other low-power wide-area network (LPWAN)
- ▶ LoRa achieves its extremely long range connectivity, possible 10km+
- ▶ Data rates are below 50kbps
- ▶ 868 MHz 433MHz and 915MHz (Unlicensed frequencies)



Long distance communication



Small amounts of data (low bandwidth)

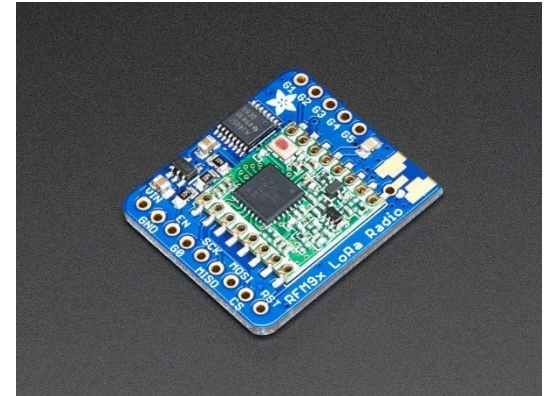


High immunity to interference

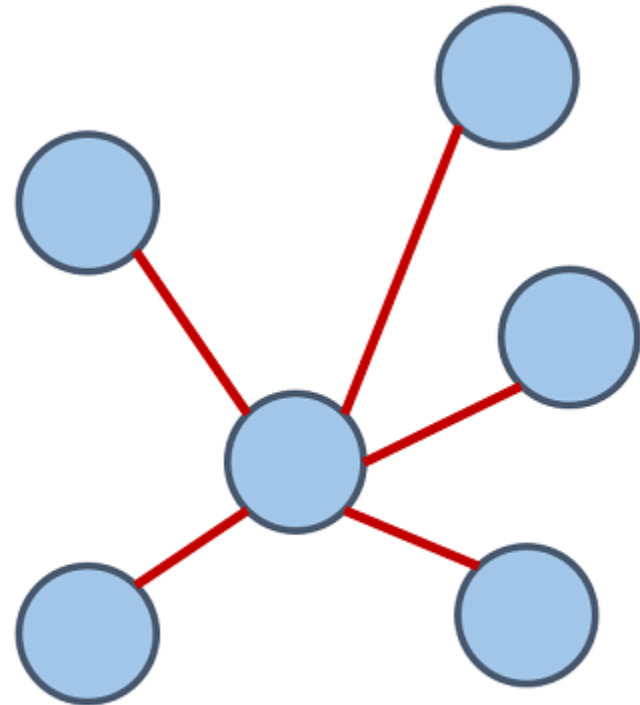


Low power consumption

# LoRa topologies



Point to point  
communication



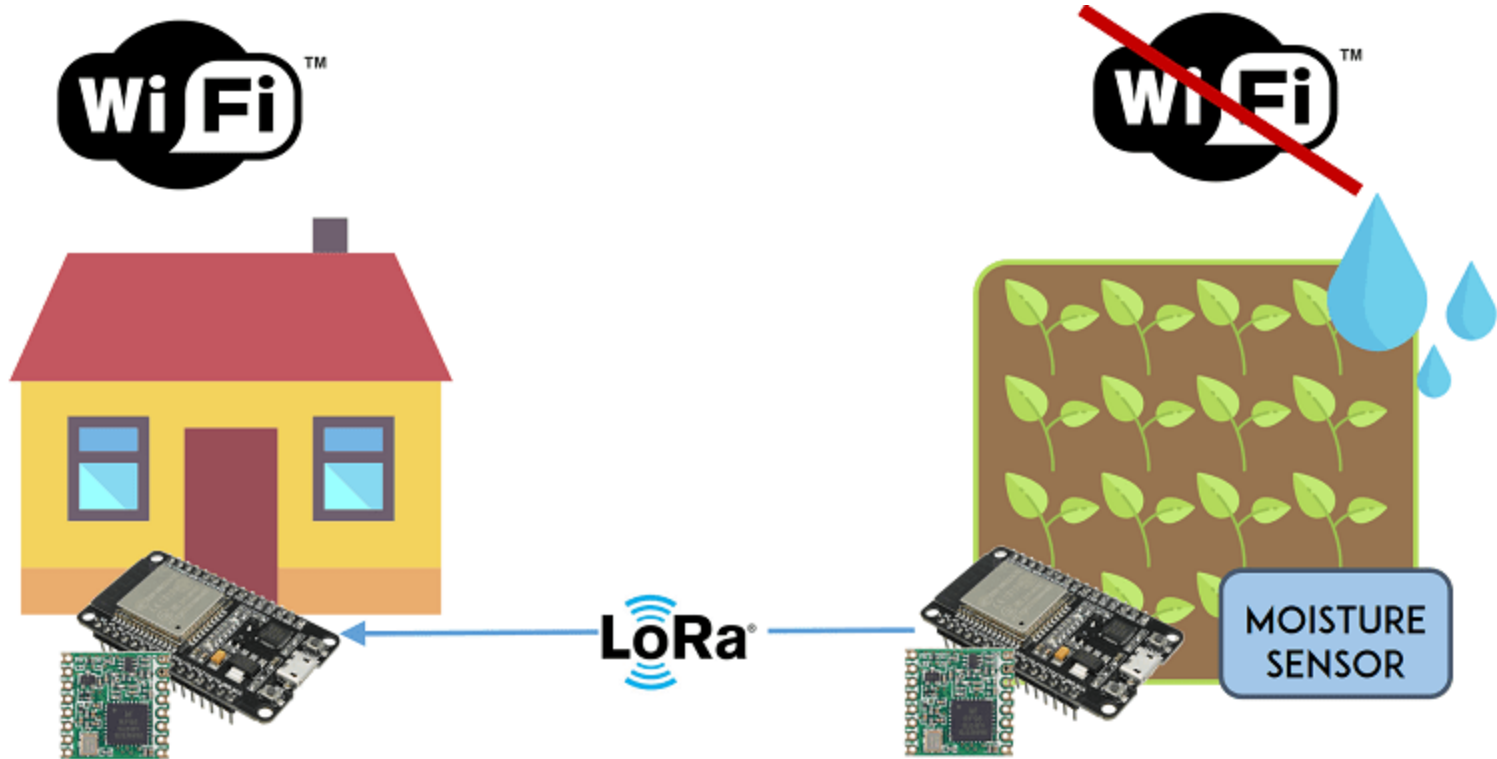
Network

```
#include <LoRa.h>
```

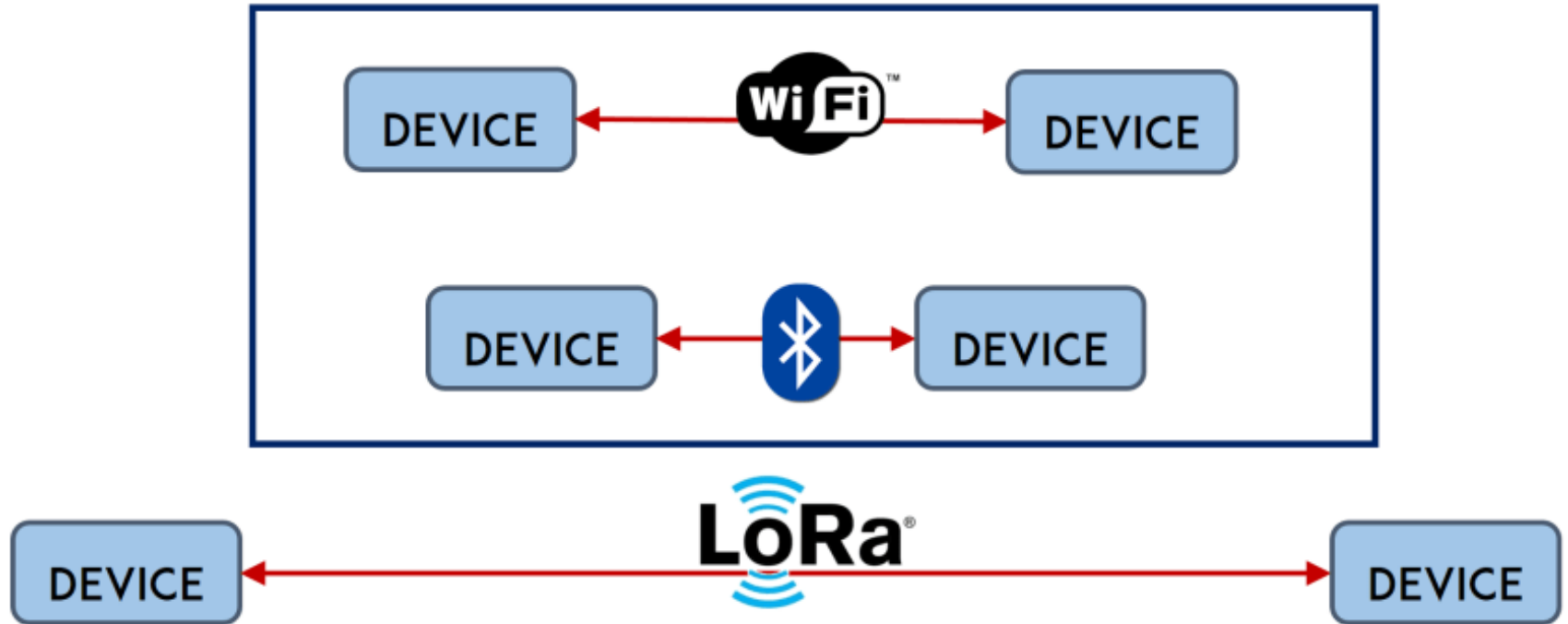
```
lora.init();
```

```
lora.receivePackage(rxBuf)
```

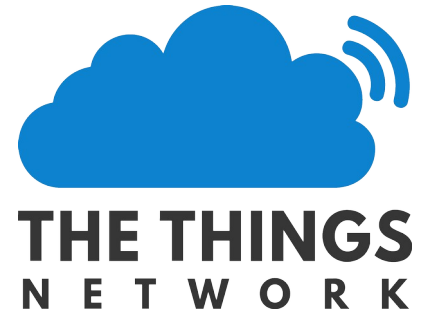
```
lora.readRSSI();
```



SHORT DISTANCE



<https://randomnerdtutorials.com/esp32-lora-rfm95-transceiver-arduino-ide/>



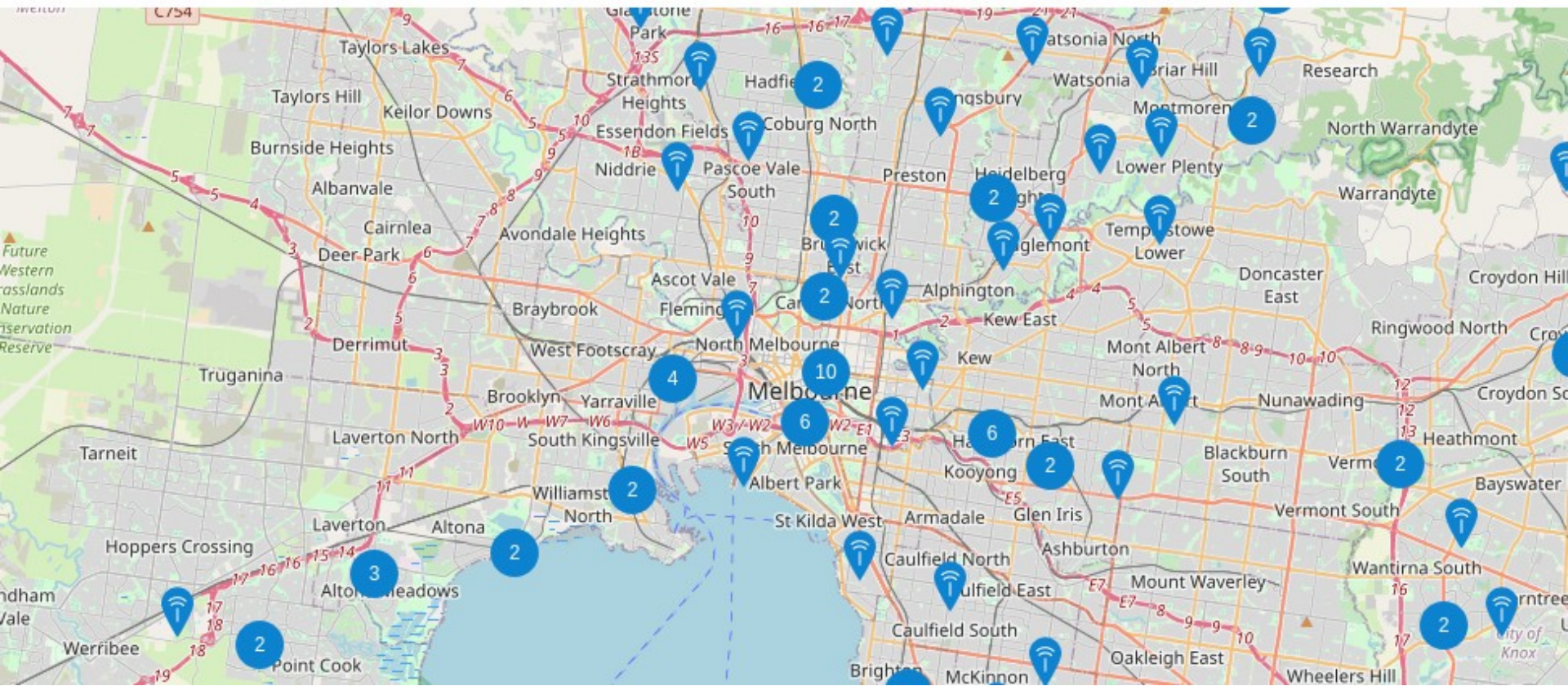
- LoRaWAN (Long Range Wide Area Network) is a network (protocol) using LoRa (RF Technology).
- Developed and maintained by the LoRa Alliance, LoRaWAN defines the communication protocol and system architecture for the network
- Network options:
  - Private (your own gateway, network server, etc.).
  - Public Networks (telecom, community).
- The Things Network is a global community building an open-source and decentralized LoRaWAN network.

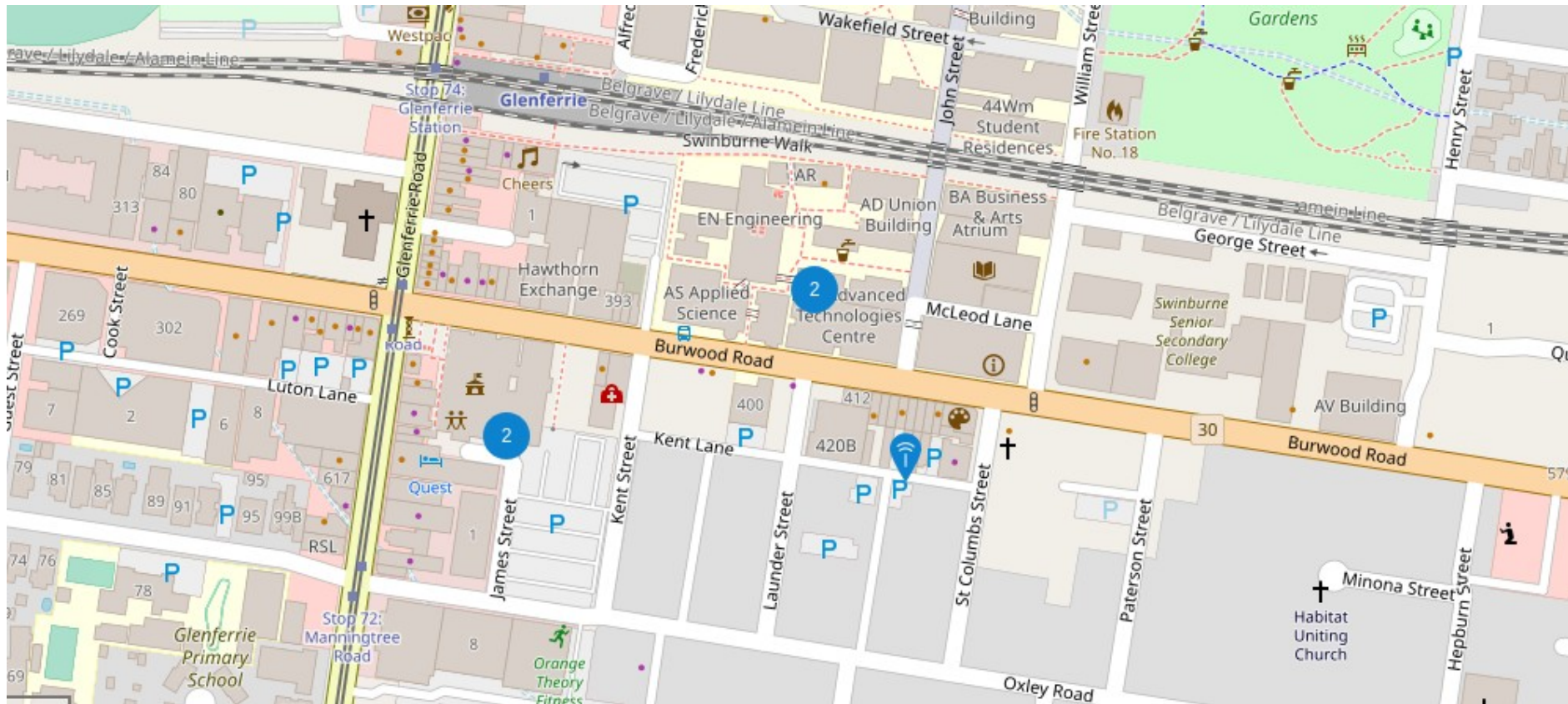




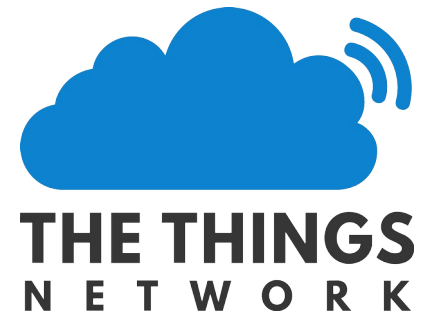
<https://www.thethingsnetwork.org/>

At this moment, there are 19218 gateways up and running

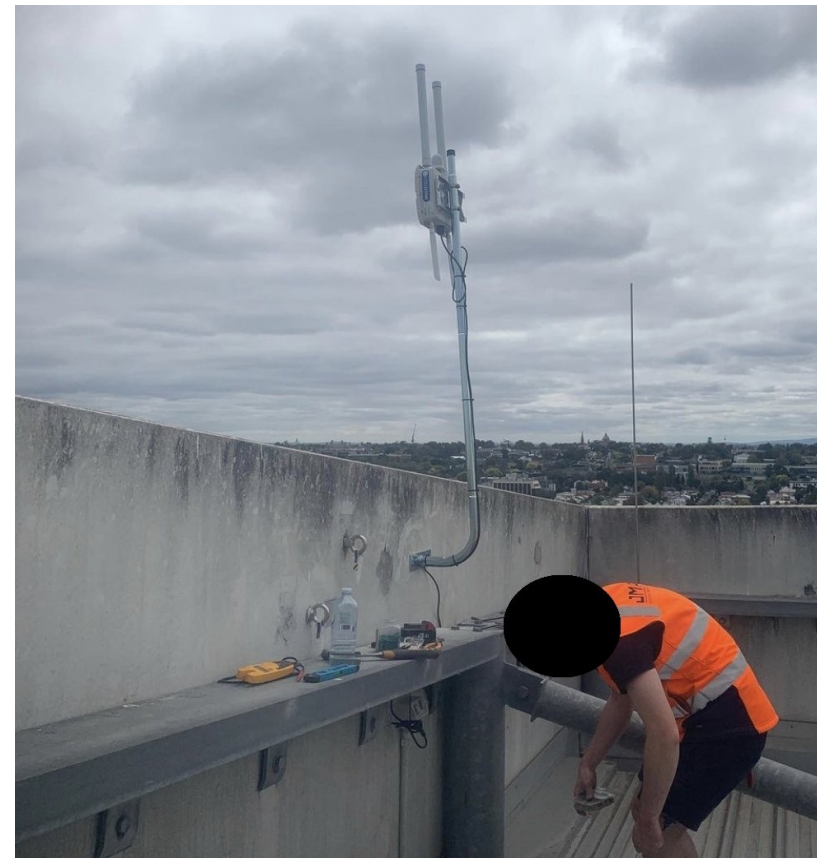








ATC gateway installed in March 2021





# Narrowband IoT (NB-IoT)

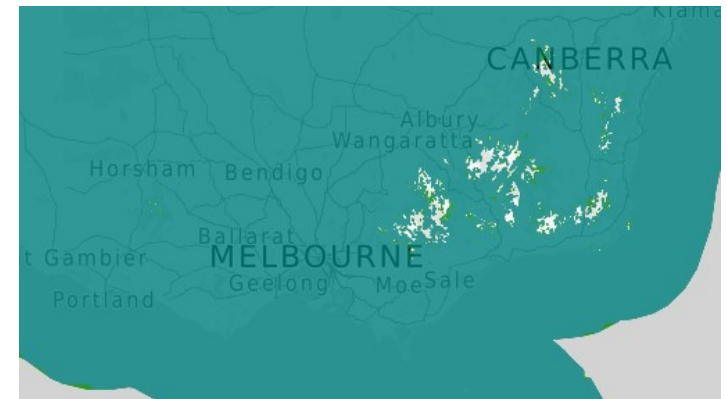
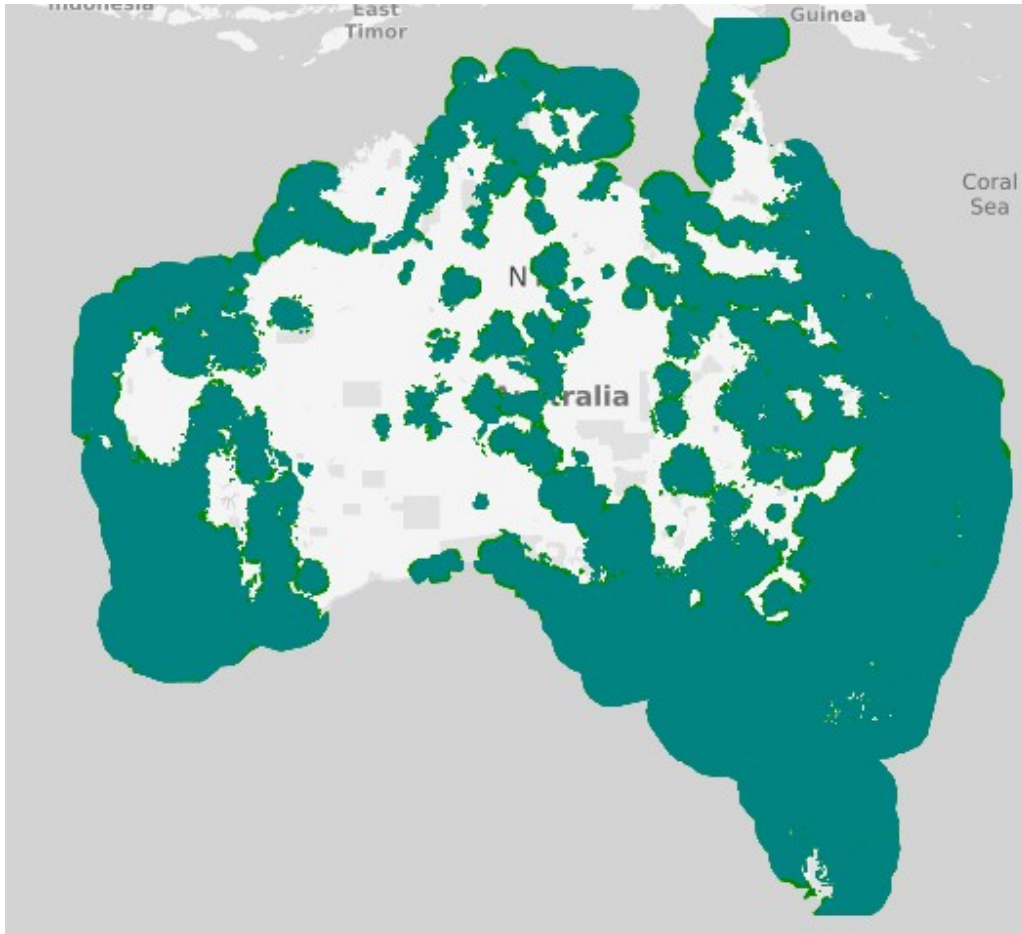


- Low Power Wide Area Network (LPWAN) radio technology standard to enable a wide range of cellular devices and services
- NB-IoT focuses specifically on indoor coverage, low cost, long battery life, and high connection density
- Major AUS and NZ Telecom providers such as Telstra, Optus and Vodafone use their cellular networks to offer NB-IoT technologies
- Stationary use (with Cat-NB2 allowing for limited mobility)
- Extremely low cost per device
- Low data rate connections
- B28 (700 MHz)



Arduino MKR NB 1500

# Telstra Coverage NB-IoT



## Boards Manager



Type All ▼

NB 1500

### Arduino SAMD Boards (32-bits ARM Cortex-M0+) by Arduino version 1.6.21 **INSTALLED**

Boards included in this package:

Arduino MKR Vidor 4000, Arduino MKR NB 1500, Arduino MKR WiFi 1010, Arduino/Genuino Zero, Arduino/Genuino MKR1000, Arduino MKRZERO, Arduino MKR FOX 1200, Arduino MKR WAN 1300, Arduino MKR GSM 1400, Arduino M0 Pro, Arduino M0, Arduino Tian, Adafruit Circuit Playground Express.

[Online help](#)

[More info](#)

Close

# Long Term Evolution for Machines (LTE-M)

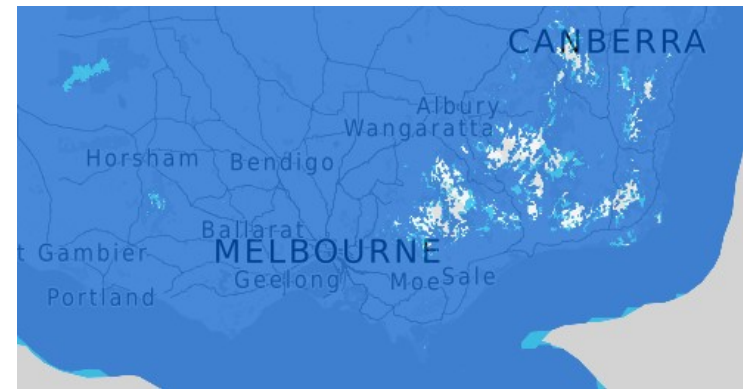
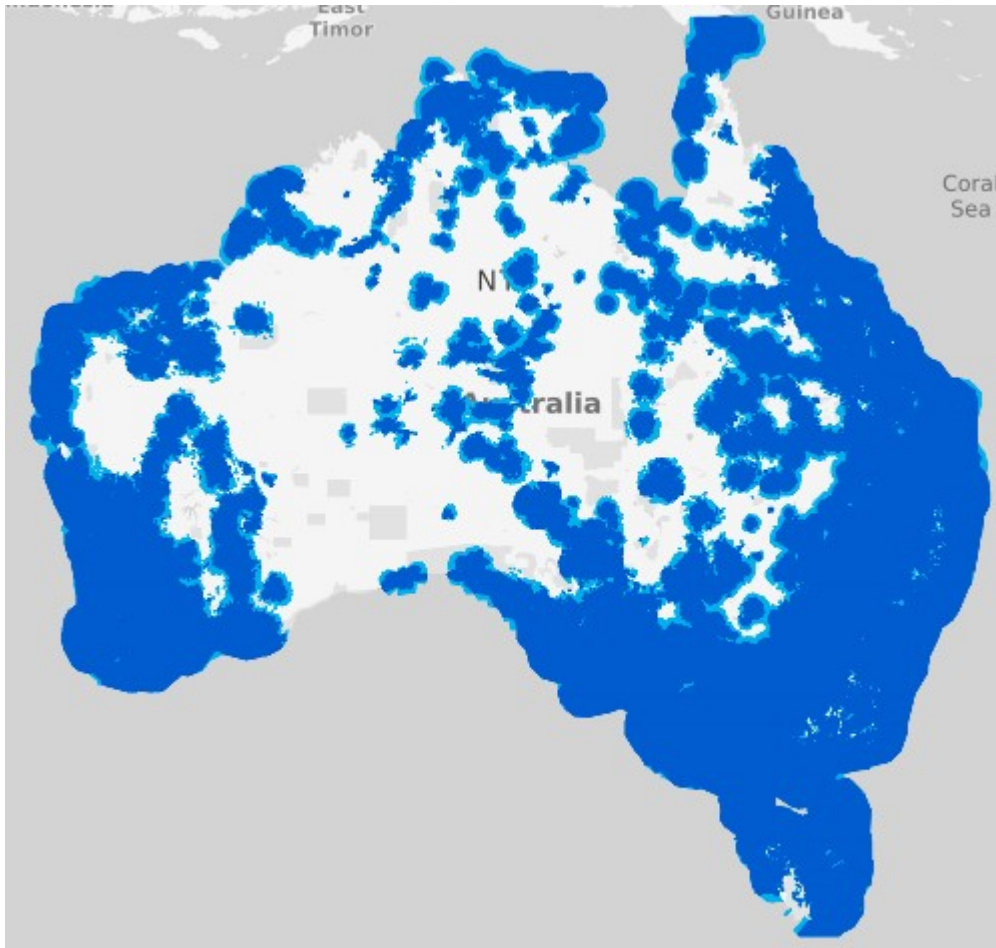
- Low Power Wide Area Network (LPWAN) radio technology standard developed by 3GPP to enable a wide range of cellular devices and services.
- Major AUS and NZ Telecom providers such as Telstra, Optus and Vodafone use their cellular networks to offer NB-IoT technologies
- High bandwidth data rates
- Mobility (asset tracking, vehicles, etc.)
- Voice connectivity through VoLTE technology
- B3 (1800 MHz) B28 (700 MHz)



Arduino MKR NB 1500

# Telstra Coverage LTE-M

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# Low Power Wide Area Network (LPWAN)



NB-IoT



	LoRa / LoRaWAN	Sigfox	NB-IoT	LTE-M
<b>Origin</b>	France	France	USA (Global)	USA (Global)
<b>Proprietary or open</b>	LoRa – proprietary LoRaWAN – open	Net – proprietary Devices – open	Open	Open
<b>Cellular</b>	No	No	Yes	Yes
<b>Spectrum</b>	Unlicensed	Unlicensed	Licensed	Licensed
<b>Range, km</b>	urban: 2-5 rural: 15	urban: 3-10 rural: 30-50	urban: 1-5 rural: 10-15	urban: 2-5
<b>Speed, uplink / downlink</b>	50 kbps / 50 kbps	300 bps / –	250 kbps / 250 kbps	1 Mbps / 1 Mbps
<b>Power consumption</b>	●●●	●	●	●●●
<b>Security</b>	●●	●●	●●●	●●●
<b>Availability of devices</b>	●●	●●●	●●	●
<b>Price*</b>	●●	●	●●	●●●
<b>Areas of application</b>	Precision farming, manufacturing automation, pipeline monitoring	Predictive maintenance, capacity planning, demand forecasting	Electric metering, manufacturing automation, retail PoS	tracking objects, wearables, energy management, utility metering, city infrastructure
<b>Supporting companies</b>	IBM, Semtech, Cisco, HP, Orange, Kerlink, Actility	STMicroelectronic, Texas Instruments, Atmel, Silicon Labs	Huawei, Ericsson, Qualcomm, Vodafone	Verizon, AT&T, Nokia

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# Questions?

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