1) Long Range Networks, LORA
2) Swarm Satellites
3) Message Protocols, MQTT (Maybe)

IOT Freshman Seminar
Tue Oct 17, 2023

Robert Cudmore
rhcudmore@ucdavis.edu

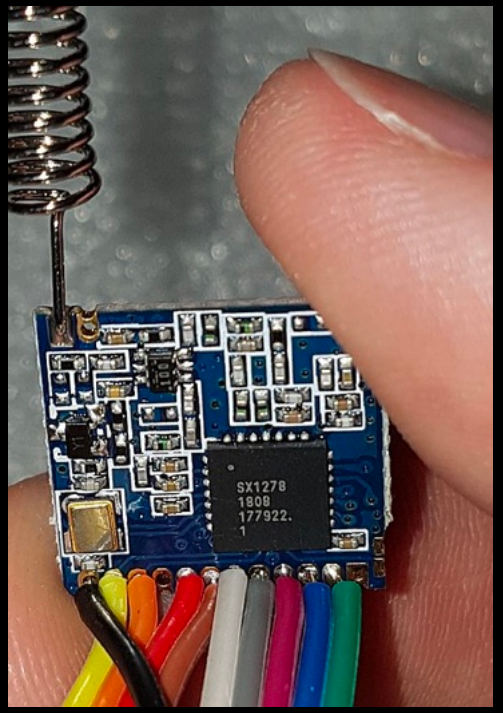
LoRa and LoRaWAN

Long Range Local Area Networks (LoRaWan)

LoRa and LoRaWAN

Long Range Local Area Networks (LoRaWan)

- LoRa is a wireless communication technology owned by SemTech (California)
- Designed for massive-scale IoT deployments
- Sends data in small bursts, similar in size to a text message
- Perfect for devices that need to send plenty of status updates or a regular stream of measurements
- Designed to require **very little power**, so that it does not drain the batteries of IoT devices too quickly
- Similar to other networks (cellular, wifi, bluetooth) requires dedicated hardware but ***it is cheap!***



LoRaWAN

Long Range Local Area Networks (LoRaWan)

Why is it **cheap**?

- Uses license-free sub-gigahertz radio frequency bands

  Like your home WiFi, you are free to transmit a signal

  In contrast to cellular networks that require licensing and $$$

- **Slow data rates** between 0.3 kbit/s and 27 kbit/s

  Versus Wifi with 400 Mb/s to > 1 Gb/s (Wifi is ~1000 times faster)

- **Long distance**, off the shelf LoRa transmitters can reach 10 km

  Versus WiFi which only goes about 90 meters (outdoors)

LoRaWAN

Benefits

- Extremely low power
- Inexpensive to implement
- Can easily transmit many kilometers
- Requires a dedicated gateway (similar to your WiFi router)

- LoRaWAN transmitter

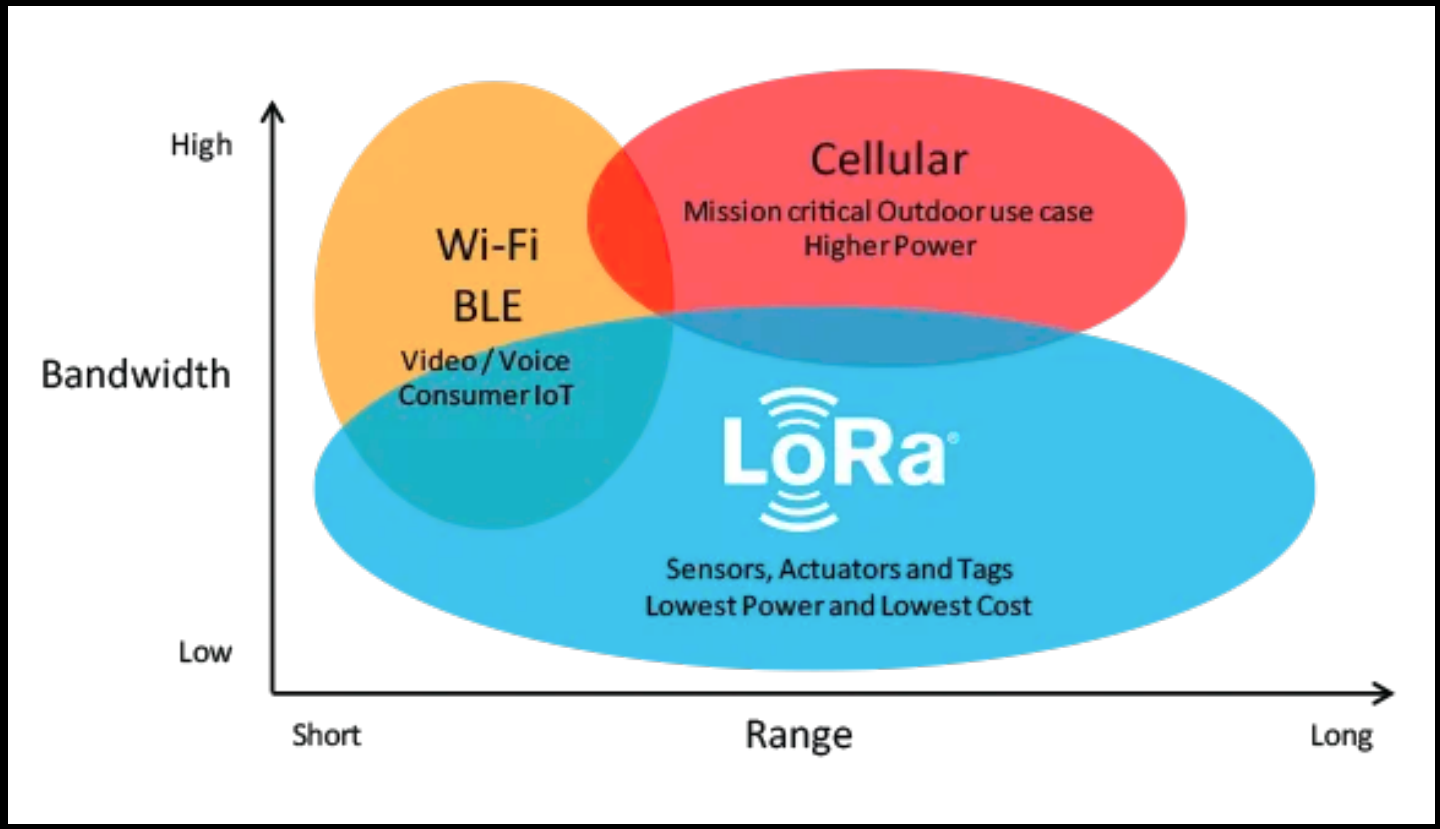
- LoRaWan Gateway

  To get sensor data onto the internet

  ~ $120

LoRa

Range versus bandwith of different network technologies



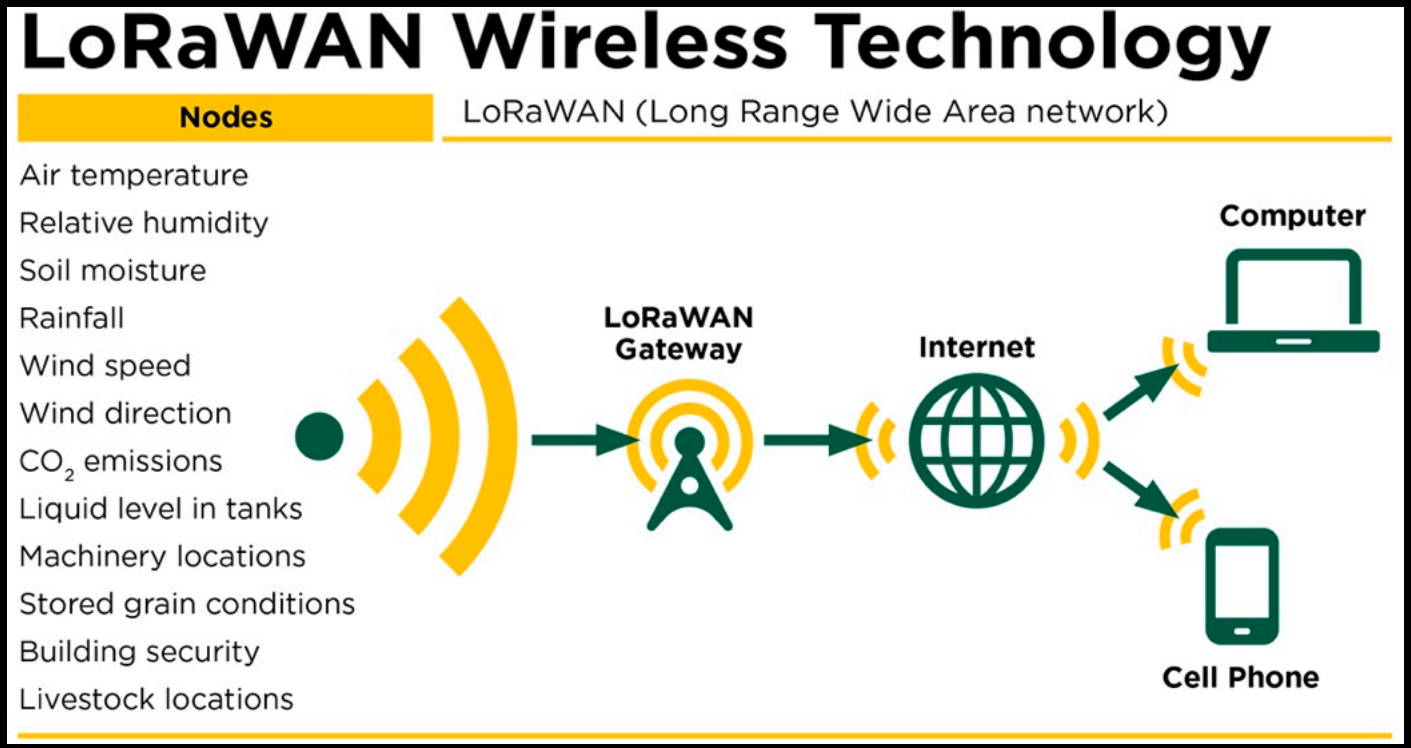
LoRa

Use in agriculture

LoRa

Use in agriculture

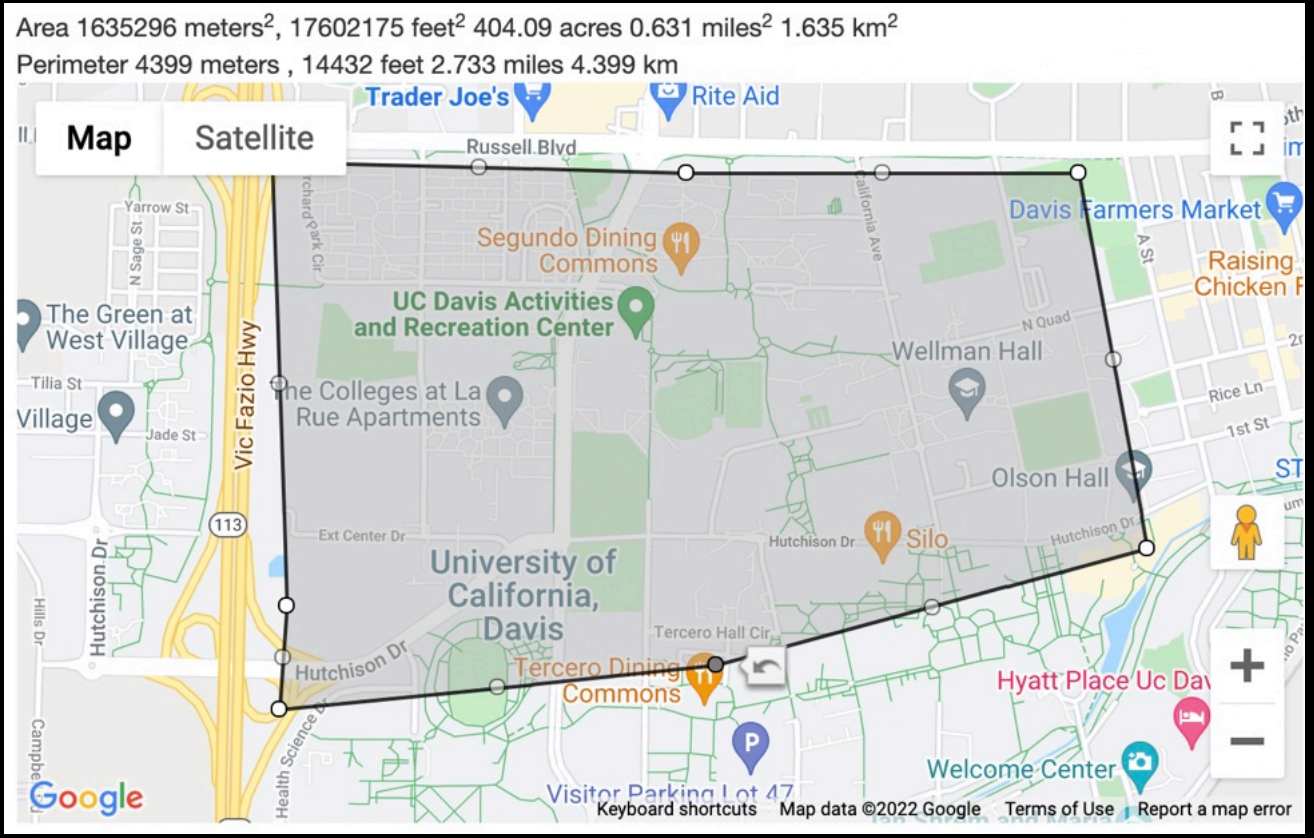
The usual sensors but now at a distance



LoRa

Use in agriculture

- The average CA farm size is about 400 acres
- Highlighted region is 404 acres
- Davis campus is bigger
- Still, hope you can appreciate, a farm has a lot of area to manage



LoRa

Use in agriculture - Lots of people to feed and money to make

- If an inexpensive and reliable IOT network could be used to **optimize** farming/ livestock this would have a large impact on efficiency of food production to feed a growing planet
- Farming In California

  $50 billion in revenue in 2018

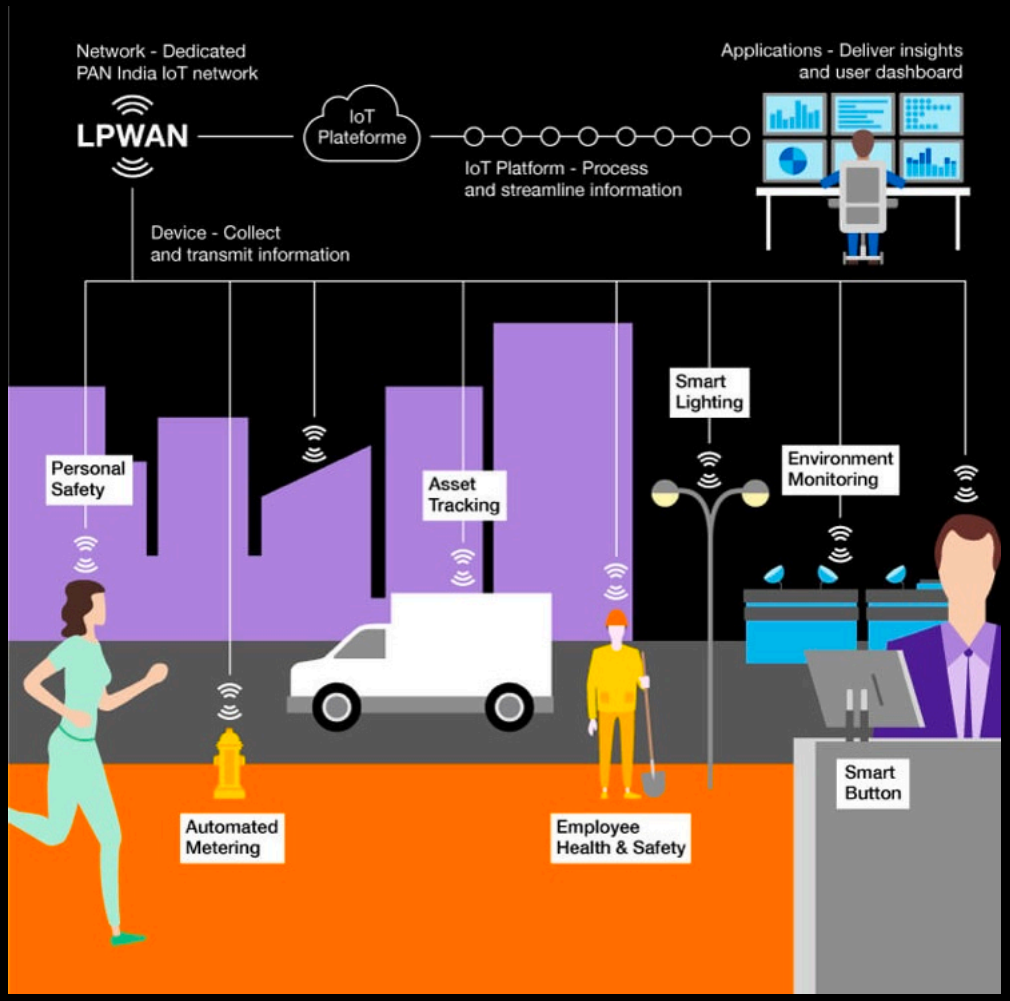
  In 2017, there were 77,100 farms and ranches in the state

  Operating across 25.3 million acres of land
- Increase in **efficiency** will increase revenue for farmers

LoRa

Public LoRa networks

- Although not common in North America
- LoRa networks are being installed by cities and telecommunication providers world wide
- South America, India, Africa, Europe
- Idea is this will enable a “smart city” by allowing low-cost sensors to transmit and receive small packets of information



https://hellofuture.orange.com/en/developing-countries-lora-network-bearer-progress/

LoRa

Public LoRa networks

Basically, all our current IOT things but now communication is **easier** and **cheaper**

- Smart meters to track gas, electricity and water consumption
- Connected accessories for improving health and security in the workplace
- Environmental sensors
- Smart lighting
- A connected alert button that can be activated to report an aggression

LoRa

Public LoRa networks

- South Africa and India: “smart metering” offering aimed at public water, electricity, and gas providers
- Africa: Can pay for drinking water (with a phone) because of smart water meters

Smart Water

Plan for 1 million Sigfox-enabled smart water meters in Mexico

Jonathan Spencer Jones • Sep 19, 2023 Share

Yes, “smart water”

LoRa

Public LoRa networks - Africa

- In Rwanda, The Akagera National Park has launched a "**smart park**" system based on LoRaWan.
- Effectively combat poaching
- One hundred solar sensors have been installed within the park
- These regularly send signals that are relayed to a control room thanks to LoRaWAN gateways placed at high altitude around the site
- Track the localization of animals, park staff, and tourists' vehicles
- Check the state of the electric fencing and other security equipment.
- The facility has several advantages:

  More secure than traditional radio systems (researchers realized that the poachers were intercepting the radio signals used by the park's agents and scientists to track endangered species),

  Less costly than satellite positioning systems, and connection to the LoRa network inside the park is highly reliable.

LoRa

Public LoRa networks

- How does this compare to the current system of shared rideables? Like scooter and bike sharing?
- How does this compare to our home and cellular internet?

LoRa

Public LoRa networks

- Key word is “**public**”, new LoRa networks are being installed more like a “public utility” like water, gas, and electric
- You still pay, but it is hopefully reasonable
- We did not achieve this with home and cellular internet
- Allows our billions of things to send/receive sufficient data to function (even a lime scooter).

LoRa

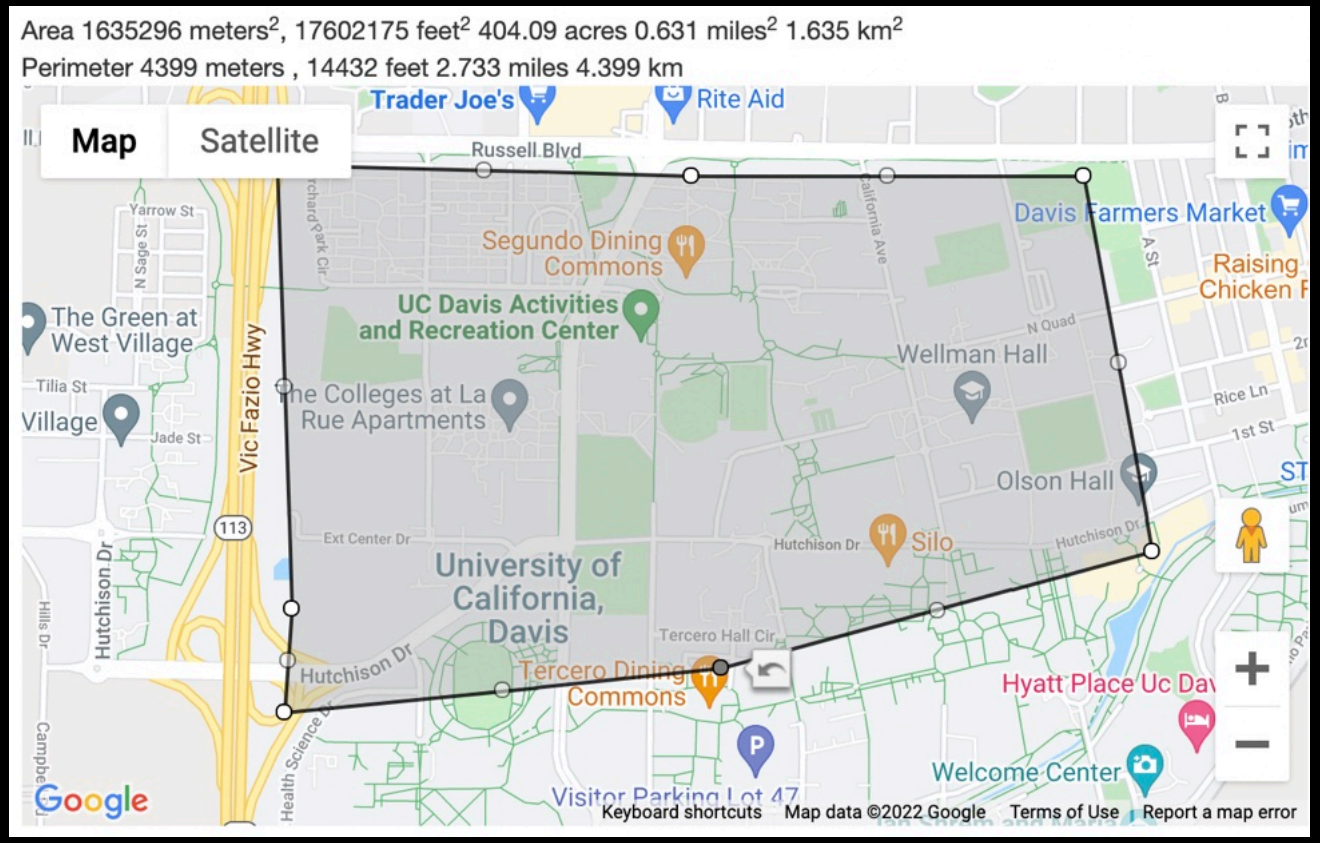
Review

- License free spectrum - no frequency spectrum license fees to deploy.
- Ultra low power - LoRaWAN end devices can last up to 10 years on a single coin cell battery.
- Long range - LoRaWAN gateways can transmit and receive signals over a distance of over 10 kilometers in rural areas and up to 3 kilometers in dense urban areas.
- Deep indoor penetration - LoRaWAN networks easily cover multi floor buildings.
- Geolocation - A LoRaWAN network can determine the location of end devices using triangulation without the need for GPS (need 3 gateways)
- High capacity - LoRaWAN Network Servers handle millions of messages from thousands of gateways.
- Public and private deployments - It is easy to deploy public and private LoRaWAN networks using the same hardware and software.
- End-to-end security- From end device to gateway using **AES-128 encryption**.
- Firmware updates over the air - Remotely update code for a single end device or group of end devices.
- Roaming- LoRaWAN end devices can perform seamless handovers from one network to another (like WiFi/Cellular)

LoRa

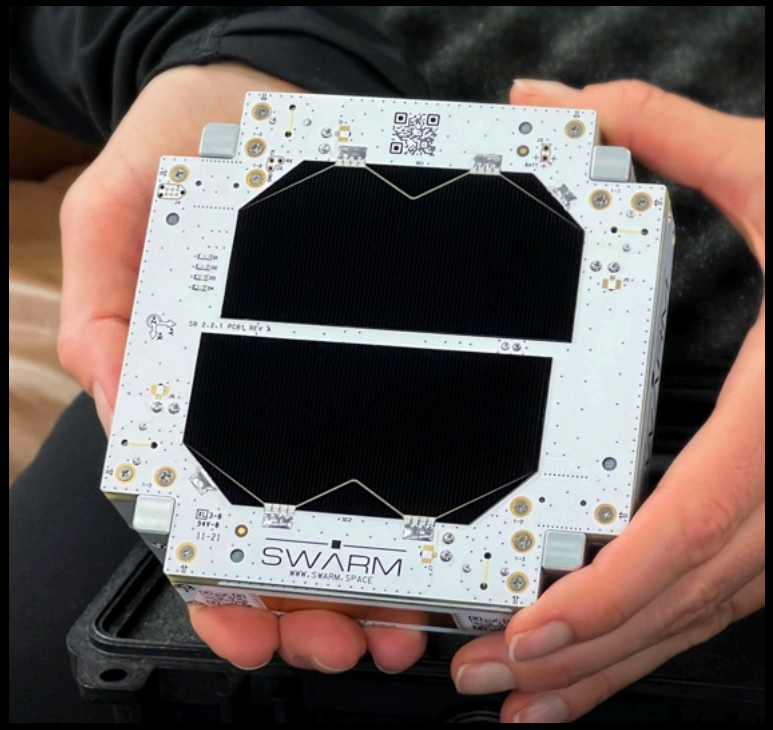
Set up a LoRa network for a relatively small area.

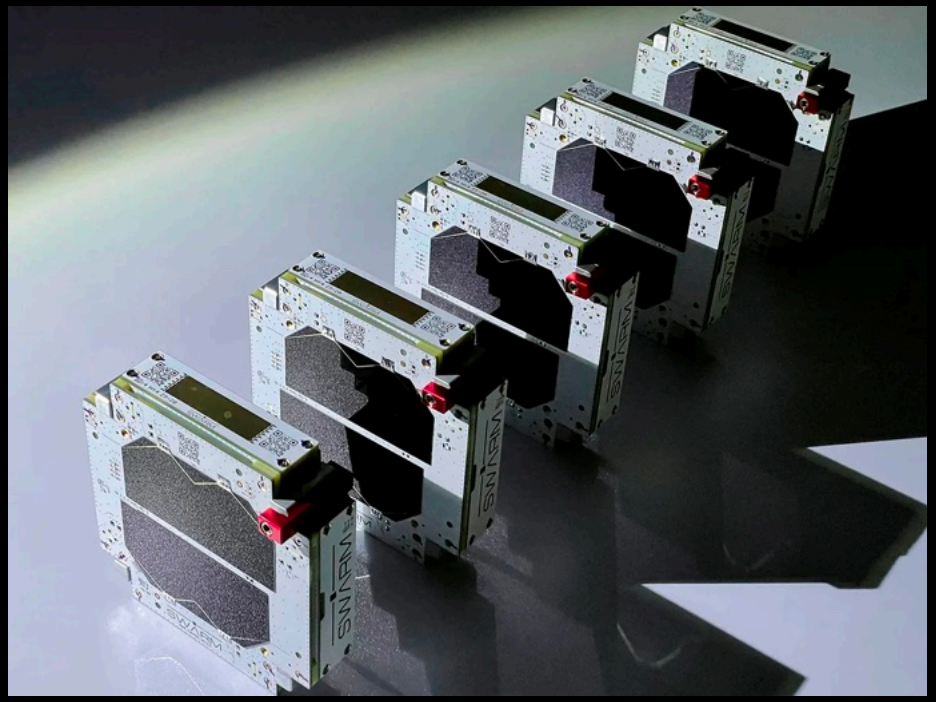
How can we make this work on a state or country or world scale?



LoRa

Swarm Satellites





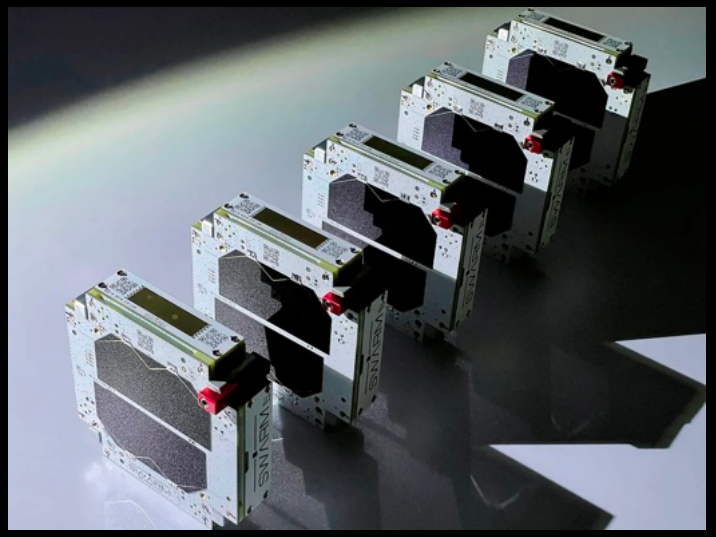
LoRa

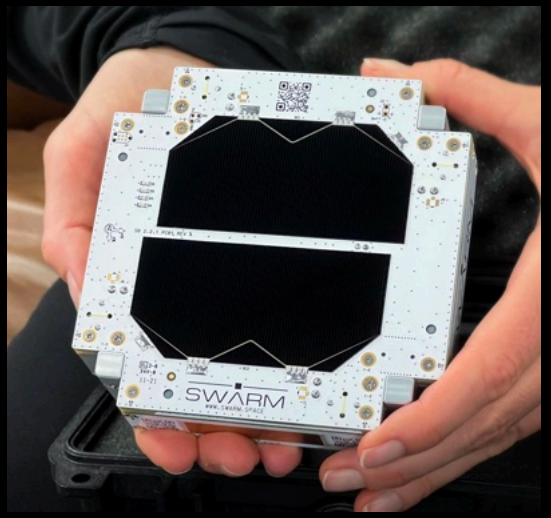
Swarm Satellites

Each sattellite is the size of a grilled cheese sandwich

The FCC had denied Swarm the right to launch the satellites because of the agency's concerns that the satellites were too small to be effectively tracked—but still large enough to cause serious damage if they collided with another object in orbit

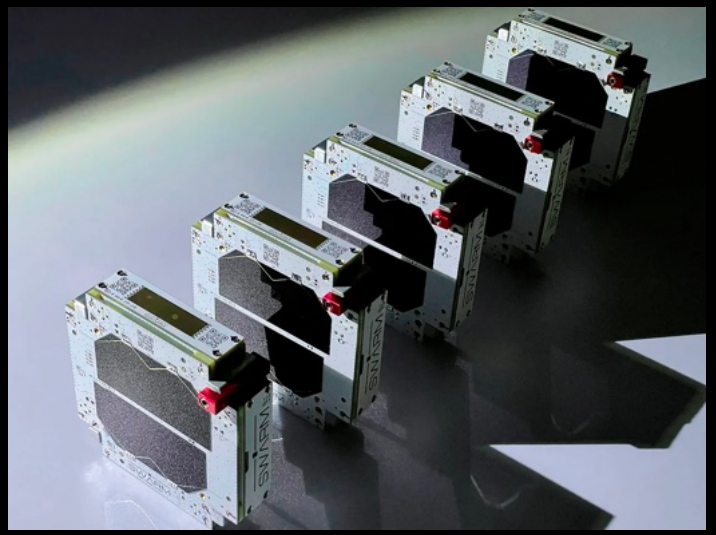
Historically, the first illegal satellite. After a US $900,000 fine for the illegal launch, Swarm has **begun to realize its LoRa-based satellite network**.

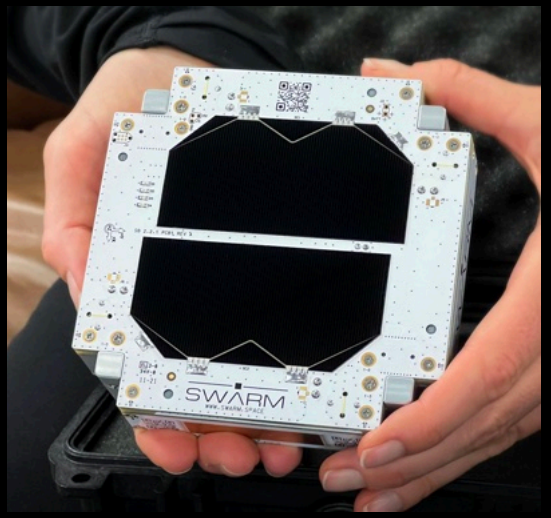




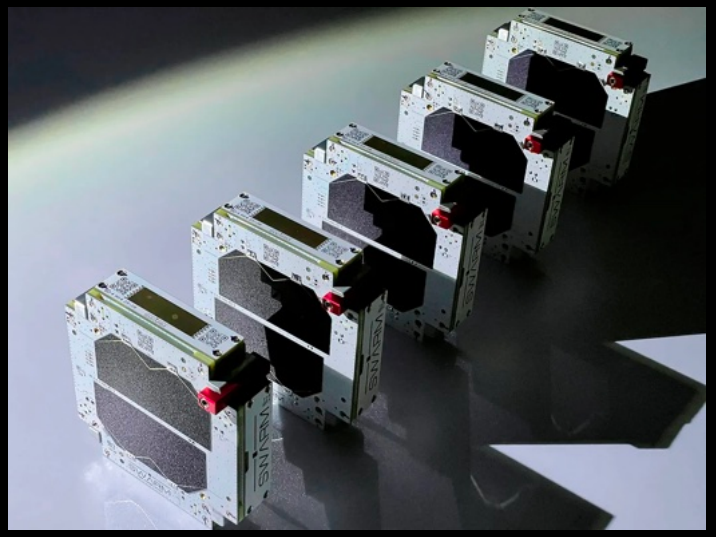
LoRa
Swarm Satellites

- Altitude of 550 kilometers (when a satellite is directly overhead)
- If your looking at an angle or at the horizon this distance can become ~3000 kilometers
- “That’s like from Los Angeles to Chicago.”
- **Using the amount of signal power used in a wireless garage door opener**
- Required a lot of serious engineering but it seems to work
- Goal is to provide remote, low power IOT sensors a direct connection to the cloud
- And at a low cost, small fraction of current cell phone connections





LoRa
Swarm Satellites

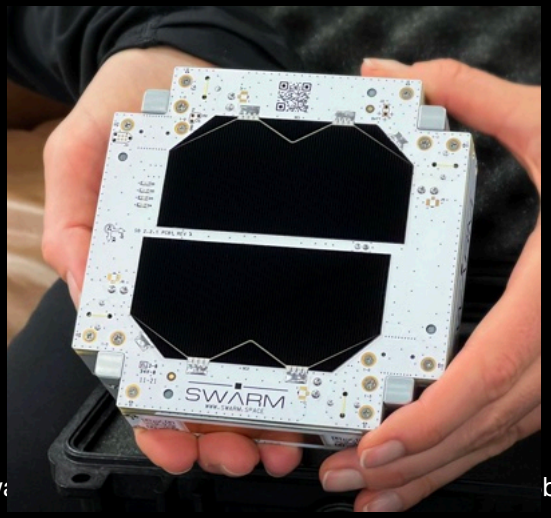


- https://swarm.space/swarm-tile/
- $120 for transmitter/receiver
- $5 a month via an annual subscription
- The subscriber receives 750 packets (200 bytes each) per month

  One character is 1 byte, so you get 150,000 characters per month

  In contrast, Twitter Tweet is limited to 280 character (Blue account is 10,000)

  So with Swarm LoRa, you can send about 537 tweets of data per month!
- Considerably cheaper than rival satellite data services.



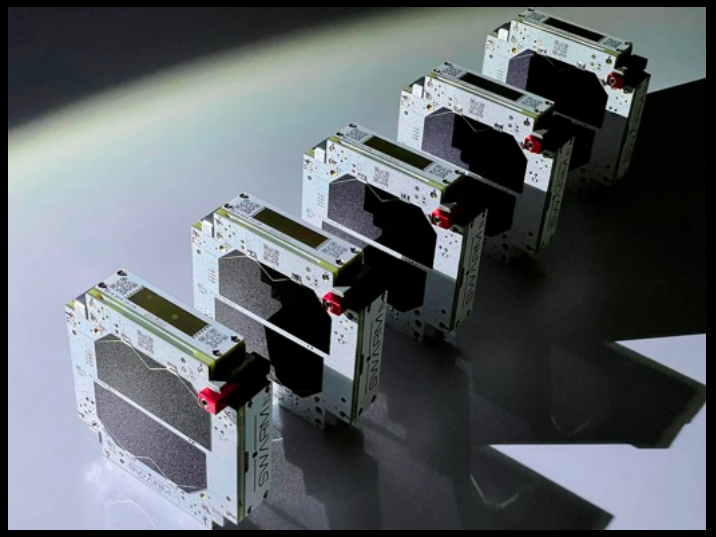
https://www.hackster.io/news/satellite-iot-connectivity-startup-swarm-releases-pricing-for-the-swa

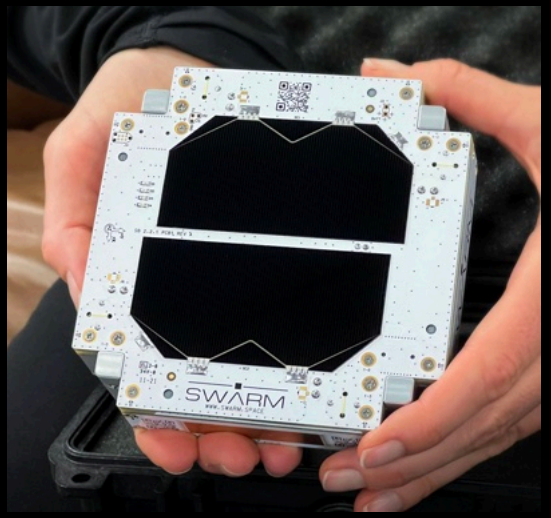
LoRa

Swarm Satellites

- Swarm company is now owned by Space-X (2021)
- Elon Musk
- Oh no, low-cost low-power IOT might be heading in same direction as the traditional internet with just a few very large and powerful gate-keepers

Amazon, Apple, Google, Facebook, **Space-X**





Star Link - Space X

A fast internet connection from anywhere in the world

Star Link - Space X

A fast internet connection from anywhere in the world

- $500 for satellite dish
- $100 per month for fast internet
- Can be anywhere on the earth, no wires
- Starlink constellation is authorized for 4,408 satellites
- In orbits at around 550 kilometers
- Seeking a Federal Communications Commission (FCC) license for a second-generation system of approximately 30,000 satellites

Star Link - Space X

A fast internet connection from anywhere in the world

- Could see original starlink with your naked eye
- This is what it looked like
- You can subscribe to notifications when it is visible based on your location

  https://findstarlink.com/

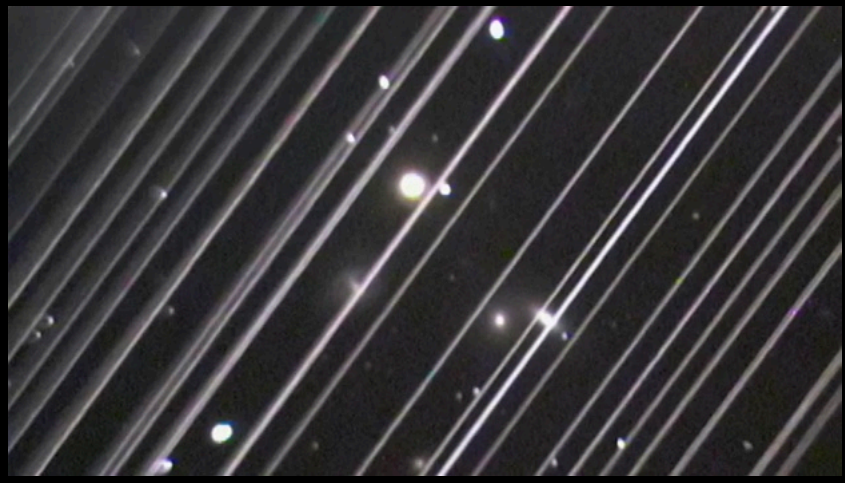
Star Link - Space X

Disrupting ground based telescopes

Astronomers ask UN committee to protect night skies from megaconstellations

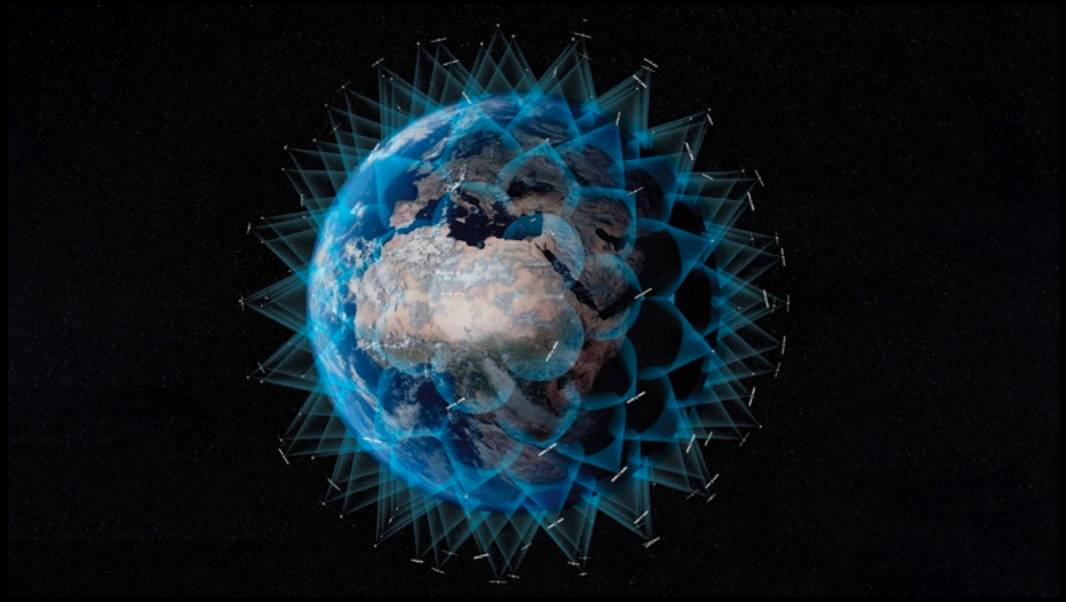
By Tereza Pultarova published April 27, 2021

A United Nations committee will discuss whether pristine night sky should be protected against Starlink trains.



- SpaceX has reduced visible reflection but not eliminated it
- Will also affect ground-based radio wave telescopes that are super sensitive to interference
- Basically all this electrified metal in our atmosphere is disrupting these sensitive receivers
- Radio telescopes are usually surrounded by a zone where no cell phone or wifi is allowed. They even limit diesel engines !

Do we have too many satellites???



Do we have too many satellites???

- We have already made a bit of a mess of our land, oceans, and atmosphere.
- Do you think we are making a mess of near-earth orbit?
- Will collisions become common? (like the movie Gravity)
- Collisions at 11,000 km per hour are usually serious
- **Near-Earth orbit is becoming commercial**. For example NASA is getting out of that space by 2030 to focus on the moon and mars.

Network Protocols
MQTT

Network Protocols
MQTT

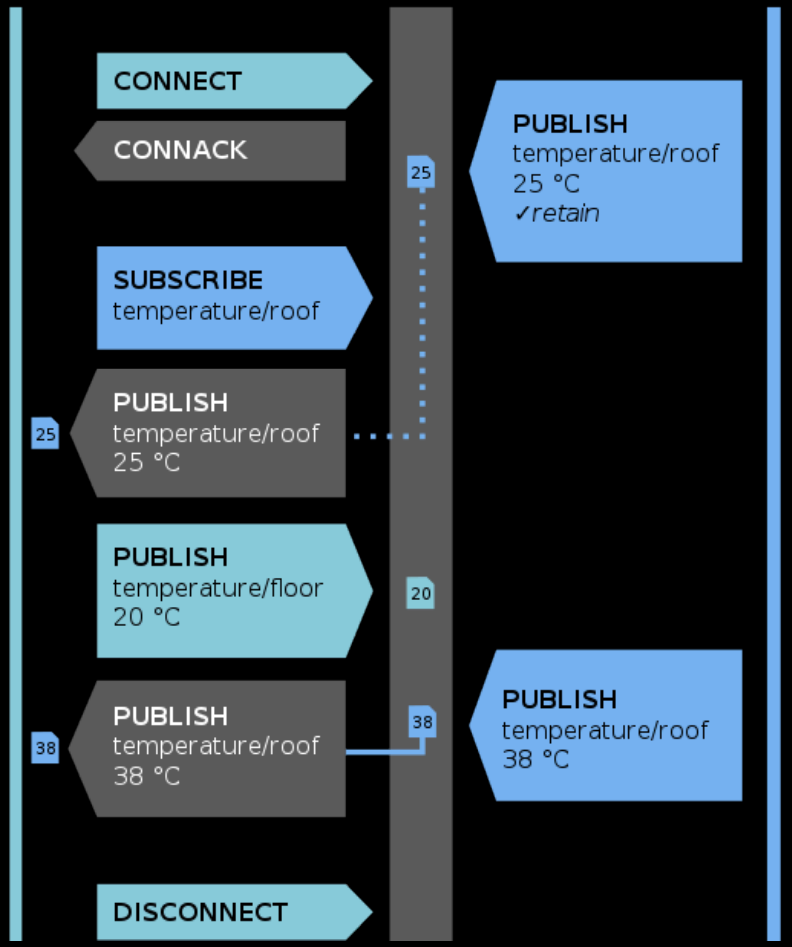
- MQTT: MQ Telemetry Transport. The MQ part is no longer an acronym, referred to some internal software when this was being designed at IBM.
- Designed as an extremely lightweight publish/subscribe messaging transport
- Ideal for connecting remote devices with a small code footprint, limited resources, and minimal network bandwidth.
- MQTT today is used in a wide variety of industries, such as automotive, manufacturing, telecommunications, oil and gas, etc.
- The protocol is an open OASIS standard and an ISO recommendation (ISO/IEC 20922).

MQTT

- Requires a server call an “MQTT Broker”
- Devices with sensors and actuators can either “subscribe” or “publish” to a “topic”
- A topic is uniquily identified using a string, usually of the form:

  huzzah1/led1

  huzzah2/temperature1
- The broker is very light-weight and just sits and waits for other devices to either “subscribe” or to “publish”
- When broker receives “publish” data it sends it to all who have “subscribed”
- Important: Publishers don’t need to know who has subscribed or the number of subscribers



MQTT

MQTT software is available most everywhere

- Because MQTT is an open standard, a number of client and broker software are available
- Can be installed on anything:

  macOS, Windows, Linux

  microcontroller (Arduino)

  Raspberry Pi computer (Linux)

  Smart Phone

Todays Review

- Long Range Local Area Networks (LoRaWan)
  - To transmit sensor data 10’s of Km (beyond WiFi and Bluetooth)
  - Low cost transmission compared to cellular
  - Satellite network is being built ($5 per month for a sensor in the middle of know where!!!)
- Messaging protocols
  - Messaging protocols
  - MQTT, software to transmit small amount of sensor data
  - Simple, low energy, open standard and is available on most devices

Next Class

- Demo of Arduino rp2040 microcontrollers with sensors
- Transmit and receive data to and from the cloud

Is your data transmission safe?

AES-Encryption

Is your data transmission safe?
AES-Encryption

- Short answer - Yes, if systems are set up properly
- AES uses very long public and private keys to encrypt data from the sender (a cypher) and then decrypt by the receiver
- Keys can be 128 or 256 characters long
- So how long would it take a super-computer to try and guess the public/private keys?
- Rougly 0.5 billion billion years (yes, that is billion billion)
- Because, for 256 bits (AES) there are 1.1 x 10^77 possible keys
- That is a number with 77 zeros!
- 10^77 is called “one hundred quattuorvigintillion” ???

Is your data transmission safe?
AES-Encryption

- “Moore’s Law” predicts that computing speed will double every two years
- This has been generally true for about 60 years
- A rough estimate is that computer speed could allow AES-Encryption to be broken around the year 2080 !
- But, we may be reaching the end of this speed increase as computer chips need to get smaller for this to hold
- We are hitting a physical limit of chip size because our nano-meter manufacturing are pushing up against the size of an atom

Is your data transmission safe?
AES-Encryption - Will Quantum Comping Crack It?

- Quantum Computing !!! Currently lots of hype on this !!!!
- Can quantum computing break aes encryption?
- My opinion: No, it can only make it weaker
- With the right quantum computer, you could crack AES encryption in …

  AES-128 would take about 2.61*10^12 years

  AES-256 would take 2.29*10^32 years
- For reference, the universe is currently about 1.38x10^10 years old (13.8 billion)
- …. cracking AES-128 with a quantum computer would take about 200 times longer than the universe has existed.

Is your data transmission safe?

What data transmissions gets encrypted?

- In theory - all transmissions
- Any time you connect to a network (wifi, cellular, lora, etc)
- To and from: Your phone, laptop, desktop
- Moving forward, all IOT devices

    2018 - 22 billion

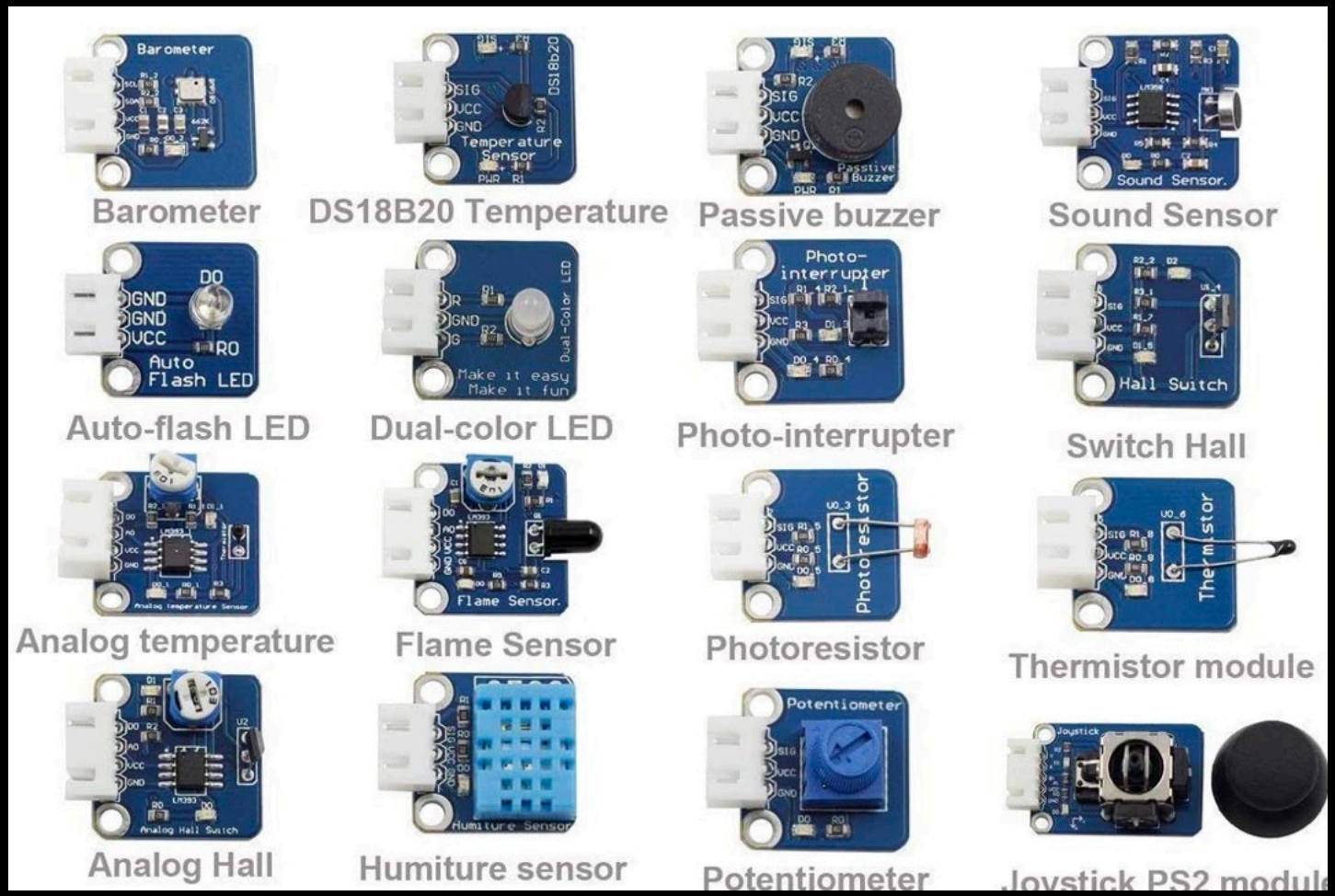
    2025 - 38 billion

    2030 - 50 billion

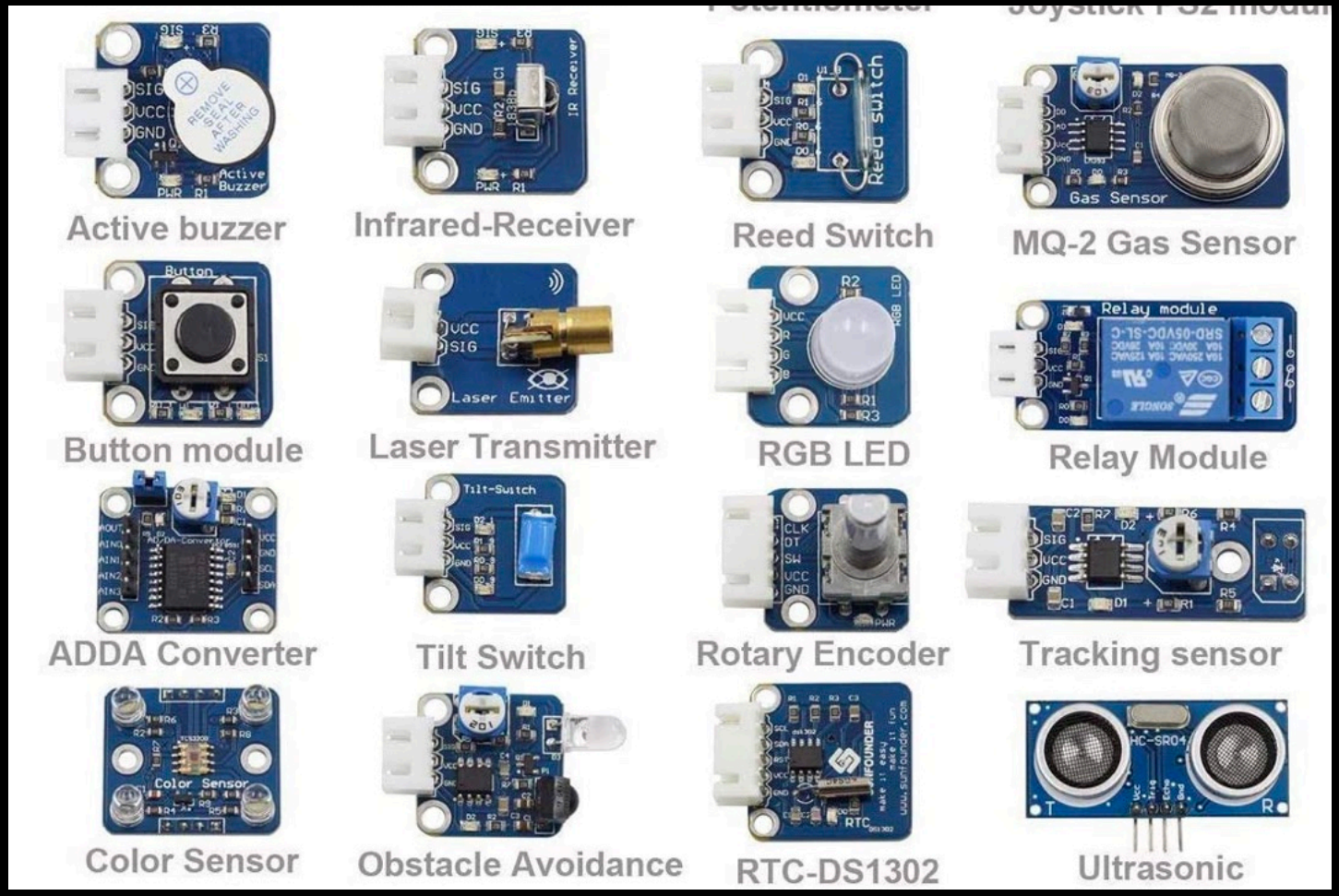
    This is a ridiculously large number

Sensors and Actuators

Sensors and Actuators



Sensors and Actuators



Sensors and Actuators

- Soil humidity/moisture
- PIR motion sensor

- Motors
- Capacitive touch (triggers when touched, like your smart phone screen)
- Pressure sensor (analog signal representing pressure)