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We are learning on Noongar land

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CITS 5506
The Internet of Things
Lecture 03

IoT Communication Models
Components of IoT

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Internet of Things Communications Models

Internet of Things Communications Models

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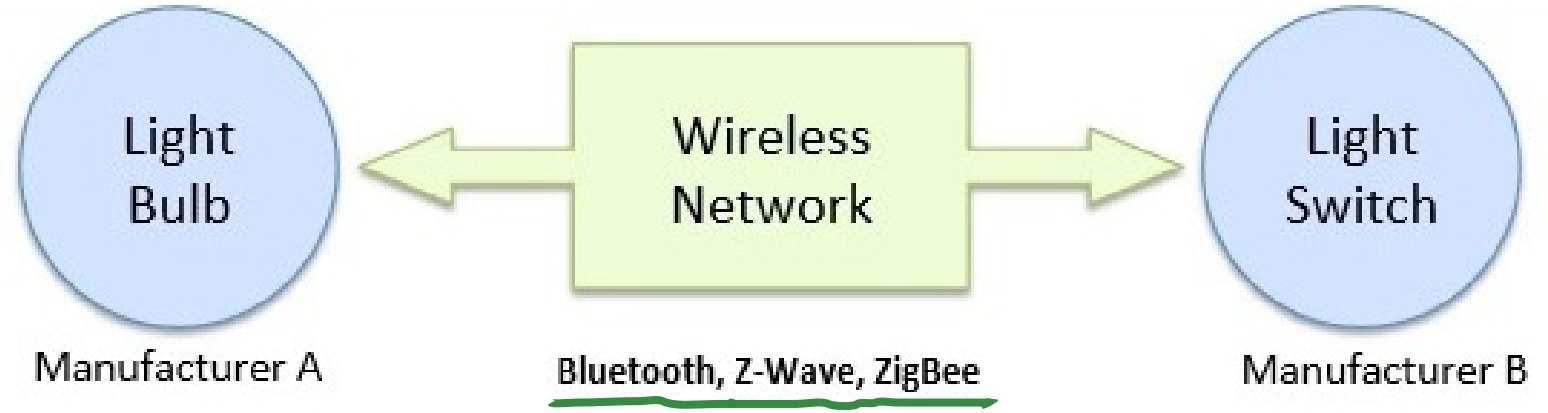
As stated in RFC 7452 Architectural Considerations in Smart Object Networking

- Device-to-Device Communications
- Device-to-Cloud Communications
- Device-to-Gateway Model
- Back-End Data-Sharing Model

Device-to-Device Communications

•The device-to-device communication model represents two or more devices that directly connect and communicate between one another, rather than through an intermediary application server.



Device-to-Device Communications

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•These devices communicate over many types of networks, including IP networks or the Internet.

•Often, however these devices use protocols like Bluetooth, Z-Wave or ZigBee to establish direct device-to-device communications

Bluetooth

Bands → Proprietary
→ Free

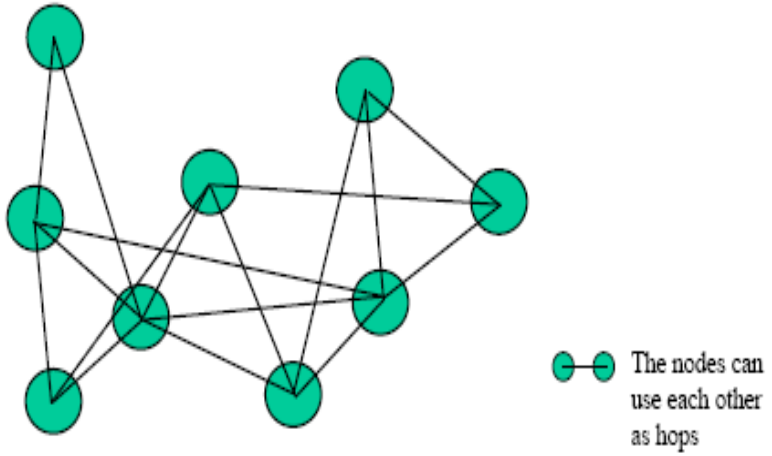
- Bluetooth transmission power is limited to 2.5 milliwatts, giving it a very short range of up to 10 metres (33 ft).
- It employs UHF radio waves in the ISM bands, from 2.402 GHz to 2.48 GHz.
- Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 35,000 member companies.
- The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard.

Z - Wave

- Z-Wave is a wireless communications protocol used primarily for home automation.
- It uses low-energy radio waves to communicate from appliance to appliance, allowing for wireless control of residential appliances and other devices, such as lighting control, security systems, thermostats, windows, locks, swimming pools and garage door openers.
- Z-Wave automation system can be controlled via the Internet

Z - Wave

- Z-Wave use mesh architecture network.



- 232 nodes can be connected to Z-Wave network. Bridging option can increase the number of nodes.

- Z-Wave uses the unlicensed industrial, scientific, and medical (ISM) band operating on varying frequencies globally Europe it operates at the 868-869 MHz band while in North America the band varies from 908-916 MHz

Zigbee

Zigbee is an IEEE 802.15 based specification for a suite of high-level communication protocols used to create personal area networks

It works with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.

Hence, zigbee is a low-power, low data rate, and close proximity (i.e., personal area) wireless mesh ad hoc network.

Zigbee

- Transmission distances to 10–100 meters (30' to 300') line-of-sight, depending on power output and environmental characteristics.
- Zigbee networks are secured by 128 bit symmetric encryption keys.
- Zigbee has a defined rate of up to 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Zigbee

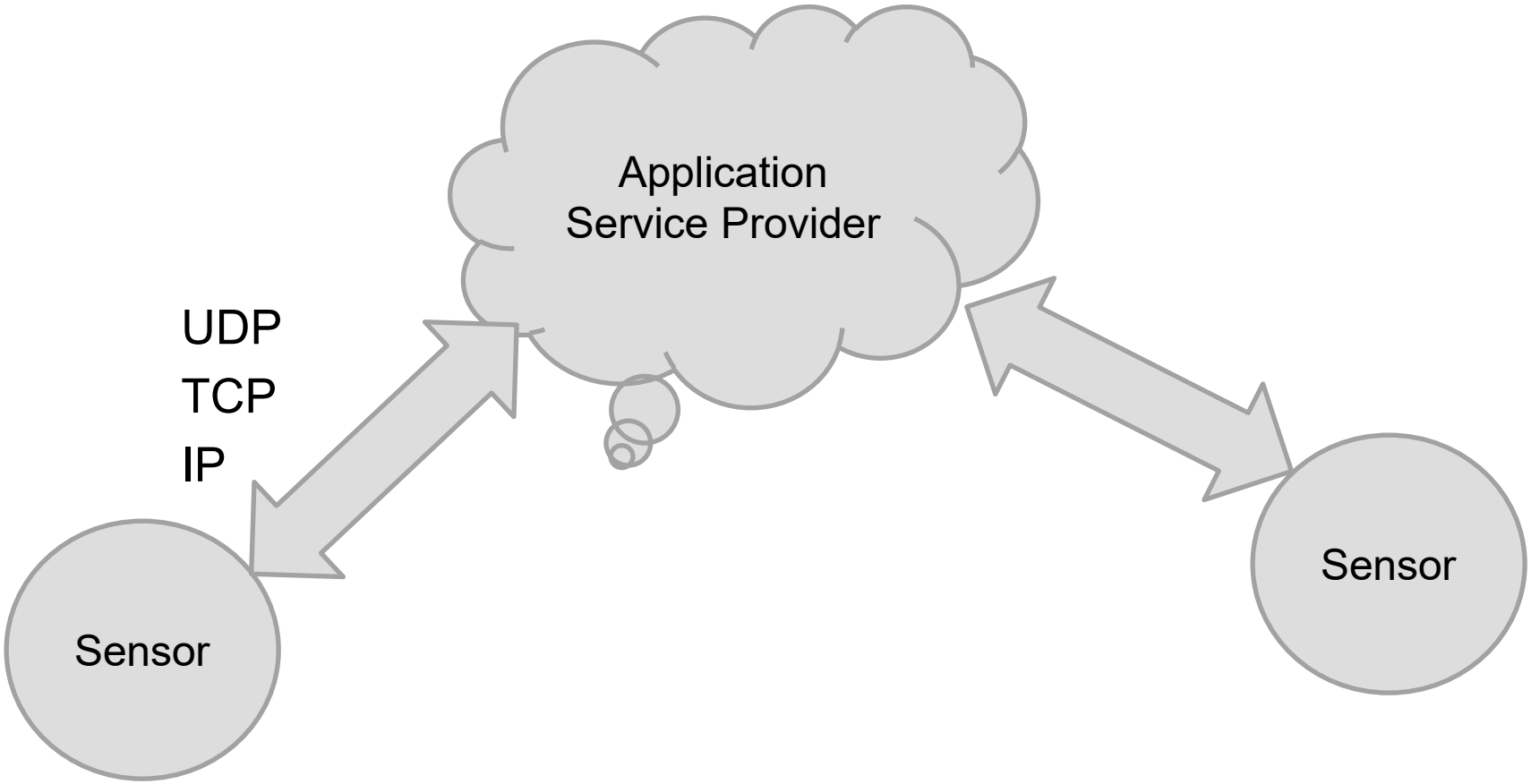
- Zigbee operates in the industrial, scientific and medical (ISM) radio bands, including 2.4 GHz in most jurisdictions worldwide.
- Some devices also use 784 MHz in China, 868 MHz in Europe and 915 MHz in the US and Australia, even those regions and countries still use 2.4 GHz for most commercial Zigbee devices for home use.
- Data rates vary from 20 kbit/s (868 MHz band) to 250 kbit/s (2.4 GHz band).

Device-to-Cloud Communications

- In a device-to-cloud communication model, the IoT device connects directly to an Internet cloud service like an application service provider to exchange data and control message traffic

- This communication model is employed by some popular consumer IoT devices like the Nest Labs Learning Thermostat and the Samsung SmartTV

Device-to-Cloud Communications



Device-to-Cloud Communications

- In the case of the Nest Learning Thermostat, the device transmits data to a cloud database where the data can be used to analyze home energy consumption.

- Further, this cloud connection enables the user to obtain remote access to their thermostat via a smart phone or Web interface, and it also supports software updates to the thermostat.

Nest Labs Learning Thermostat

- Nest lab's Learning Thermostat is not the only smart thermostat on the market e.g ecobee smart Thermostat
- Google's purchased Nest Labs for a reported $3.2 billion in January 2014.
- Nest works with many existing HVAC (Heating, Ventilation and Air Conditioning) systems.
- It means smart thermostat is to be installed in place of an existing thermostat.

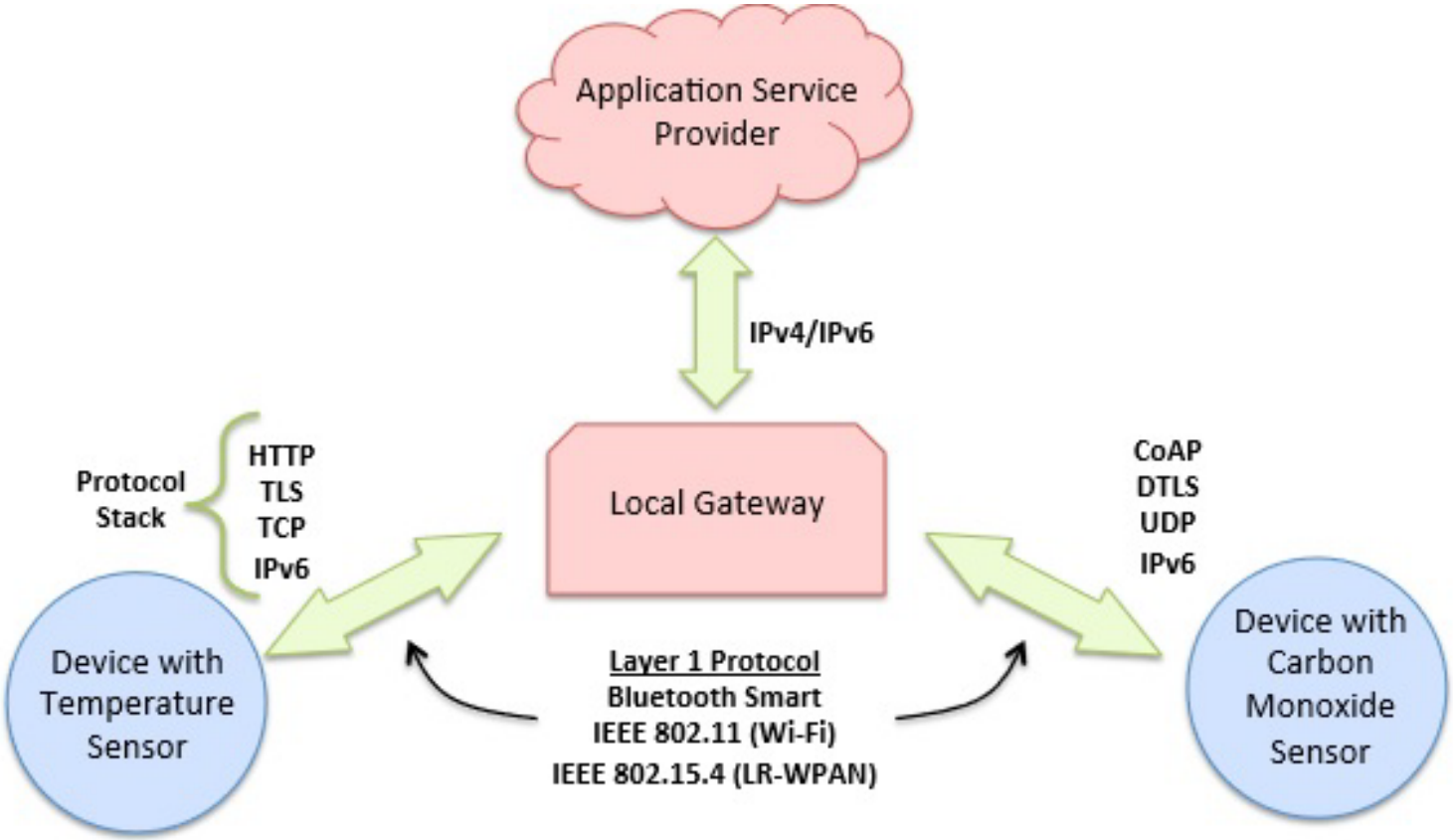
Nest Labs Learning Thermostat

Device-to-Cloud Communications

- Frequently, the device and cloud service are from the same vendor.

- If proprietary data protocols are used between the device and the cloud service, the device owner or user may be tied to a specific cloud service, limiting or preventing the use of alternative service providers. This is commonly referred to as "vendor lock-in"

Device-to-Gateway Model



LR-WPAN is Low Rate Wirless Personal Area Network

Device-to-Gateway Model

In the device-to-gateway model, or more typically, the device-to-application-layer gateway (ALG) model, the IoT device connects through an ALG service as a conduit to reach a cloud service.

In simpler terms, this means that there is application software operating on a local gateway device, which acts as an intermediary between the device and the cloud service and provides security and other functionality such as data or protocol translation

Device-to-Gateway Model

- Several forms of this model are found in consumer devices. In many cases, the local gateway device is a smartphone running an app to communicate with a device and relay data to a cloud service.

- This is often the model employed with popular consumer items like personal fitness trackers. These devices do not have the native ability to connect directly to a cloud service, so they frequently rely on smart phone app software to serve as an intermediary gateway to connect the fitness device to the cloud

Device-to-Gateway Model

- The other form of this device-to-gateway model is the emergence of “hub” devices in home automation applications.

- These are devices that serve as a local gateway between individual IoT devices and a cloud service, but they can also bridge the interoperability gap between devices themselves.

Device-to-Gateway Model

- SmartThings hub is a stand-alone gateway device that has Z-Wave and Zigbee transceivers installed to communicate with both families of devices.

- It then connects to the SmartThings cloud service, allowing the user to gain access to the devices using a smartphone app and an Internet connection

RFID enabled Smart Refrigerator

Back-End Data-Sharing Model

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- Back-End Data-Sharing essentially extends the single device-to-cloud communication model so that IoT devices and sensor data can be accessed by authorized third parties.

- Under this model, users can export and analyze smart object data from a cloud service in combination with data from other sources, and send it to other services for aggregation and analysis.

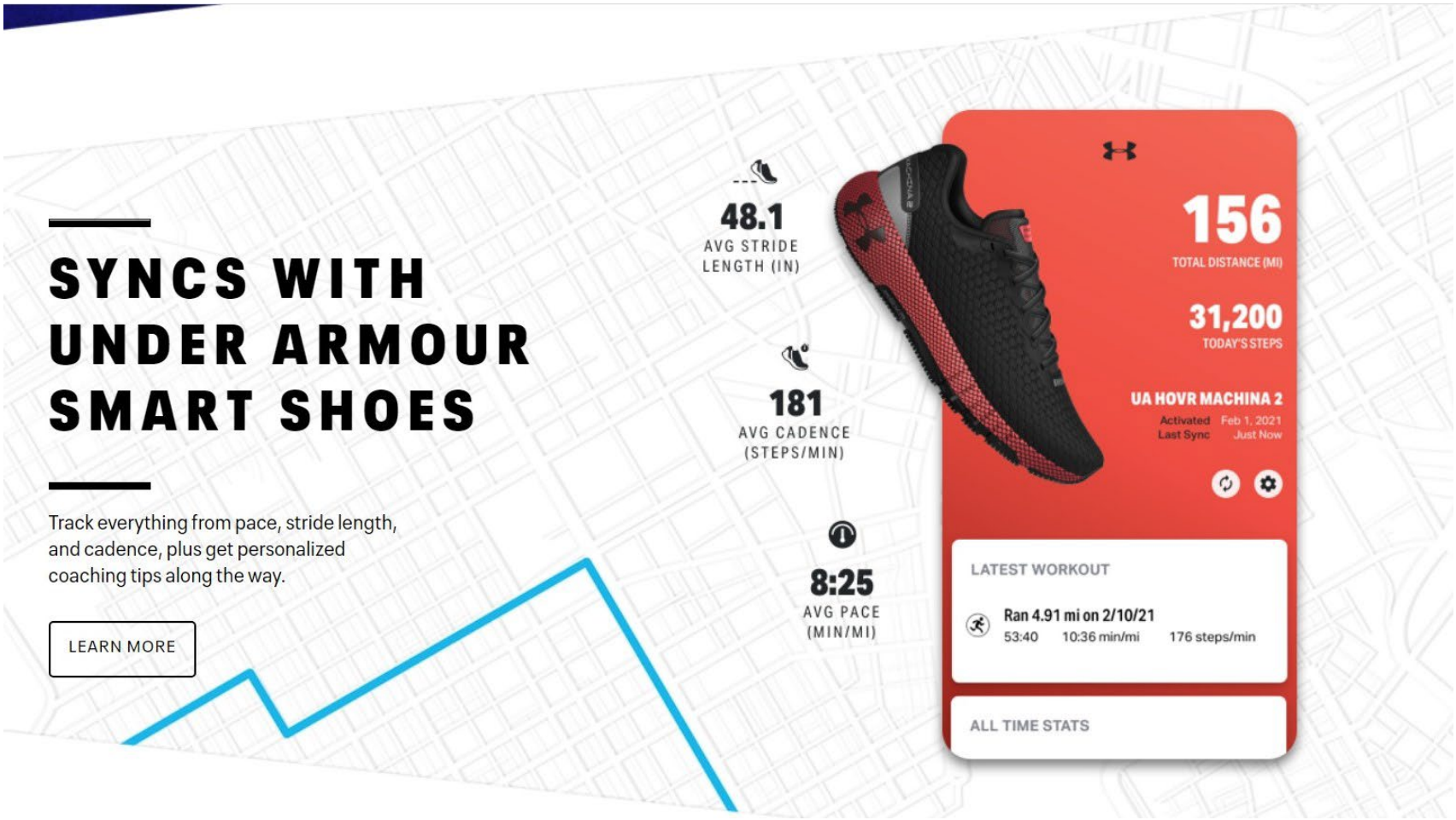
Back-End Data-Sharing Model

The app Map My Fitness is a good example of this because it compiles fitness data from various devices ranging from the Fitbit to the Adidas miCoach to the Wahoo Bike Cadence Sensor.

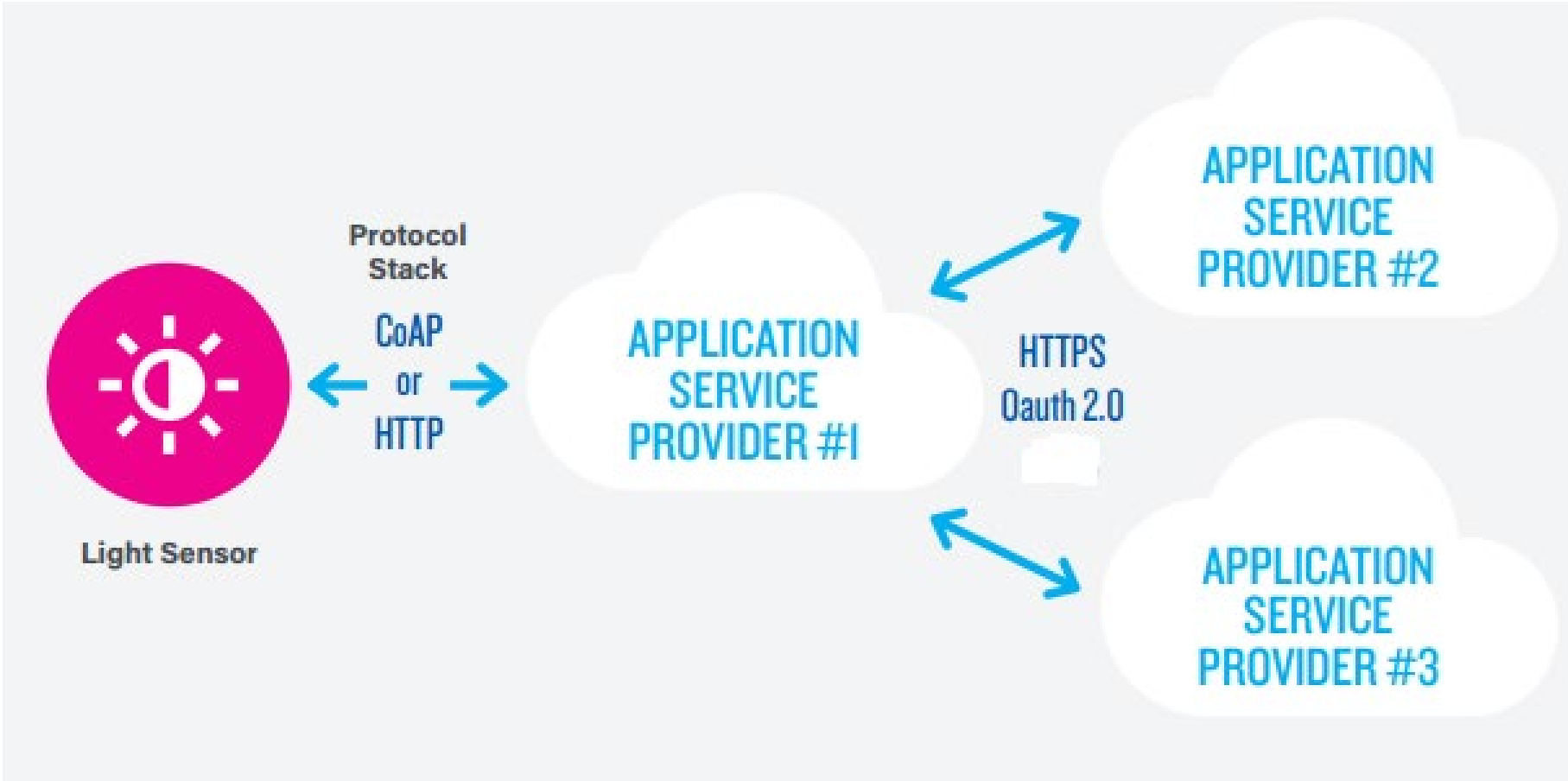
This means an exercise can be analyzed from the viewpoint of various sensors.

https://list.ly/list/JHQ-devices-supported-by-mapmyfitness

Smart Shoes


SYNCS WITH UNDER ARMOUR SMART SHOES
Track everything from pace, stride length, and cadence, plus get personalized coaching tips along the way.
LEARN MORE
48.1
AVG STRIDE LENGTH (IN)
181
AVG CADENCE (STEPS/MIN)
8:25
AVG PACE (MIN/MI)
156
TOTAL DISTANCE (MI)
31,200
TODAY'S STEPS
UA HOVR MACHINA 2
Activated Feb 1, 2021
Last Sync Just Now
LATEST WORKOUT
Ran 4.91 mi on 2/10/21
53:40 10:36 min/mi 176 steps/min
ALL TIME STATS

Back-End Data-Sharing Model



Back-End Data-Sharing Model

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•**Constrained Application Protocol** (**CoAP**) is an Internet Application Protocol for constrained devices (defined in RFC 7228). It enables those constrained devices to communicate with the wider Internet using similar protocols.

•The Internet Protocol Suite is increasingly used on small devices with severe constraints on power, memory, and processing resources, creating constrained-node networks.

Back-End Data-Sharing Model

OAuth is an open standard for access delegation, commonly used as a way for Internet users to grant websites or applications access to their information on other websites but without giving them the passwords

This mechanism is used by companies such as Google, Facebook, Microsoft and Twitter to permit the users to share information about their accounts with third party applications or websites.

Components of IoT

Components of IoT

- **Sensors**
- **Connectivity**
- **Platform**
- **Analytics**
- **User Interface**

Sensors

- Different sensors available to measure temperature, humidity, light, noise, pollution, pressure, torsion, tension, acceleration, position, images, magnetic fields, electric fields, etc etc.

- Sensors are now invisible and energy efficient, whilst maintaining a high measurement precision.

- Miniaturization is trending and hopefully the Internet of Things by 2025 will be a healthy mix of sensors measuring things and robots acting on the insights.

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Key Requirements

- Availability
- Reliability
- Viability

Connectivity: Wireless System

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Frequency Band

Licensed

With Infra-structure, based upon traditional cellular network

- Cellular
- Paging
- Fixed Wireless
- Satellite

Unlicensed

Infra-structure less, Adhoc and Peer to Peer, Self- Organizing

- Cordless
- WLAN
- Bluetooth, UWB(Ultra-wideband)
- M2M
- PAN

Wireless Channel

- Wireless communications is highly variable.
- Data sent over those channels is
  - error-prone
  - unreliable
  - latency issues
- The lesson is that wireless channels require aggressive management.

Wireless System Requirements

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System Requirements

- Capacity: Bits flowing reliably (bps)
- Latency: Delay in delivering bits
- Coverage: % of geographical locations with minimum level of service
- Cost of service

Additional Requirements on Transceiver:

- Power Consumption: Battery life, Complexity
- Portability: Size and weight
- Cost of Transceiver

Data Transmission Requirements

→ Bit error rate

Application	Data Rate	BER	Latency	Traffic
Voice	Low	Medium	Low	Continuous
Messaging	Very Low	Very Low	High	Bursty
Pictures	Medium	Low	High	Bursty
Video	High	Medium	Medium	Continuous
Web Browse	Low	Very Low	Medium	Bursty
File Transfer	Low to High	Very Low	High	Bursty
Gaming	Low	Very Low	Very Low	Bursty
IoT	Low	Low	Low-High	Bursty

Spectrum Regulations

- In Australia frequency spectrum is controlled by ACMA, Australian Communications and Media Authority
- FCC, Federal Communications Commission in USA
- ETSI (European Telecommunications Standards Institute) in Europe.
- World wide spectrum is controlled by ITU Radio communication Sector (ITU-R)
- Auction spectral blocks for set applications e.g expensive 3G, 4G Auctions.

Spectrum Regulations

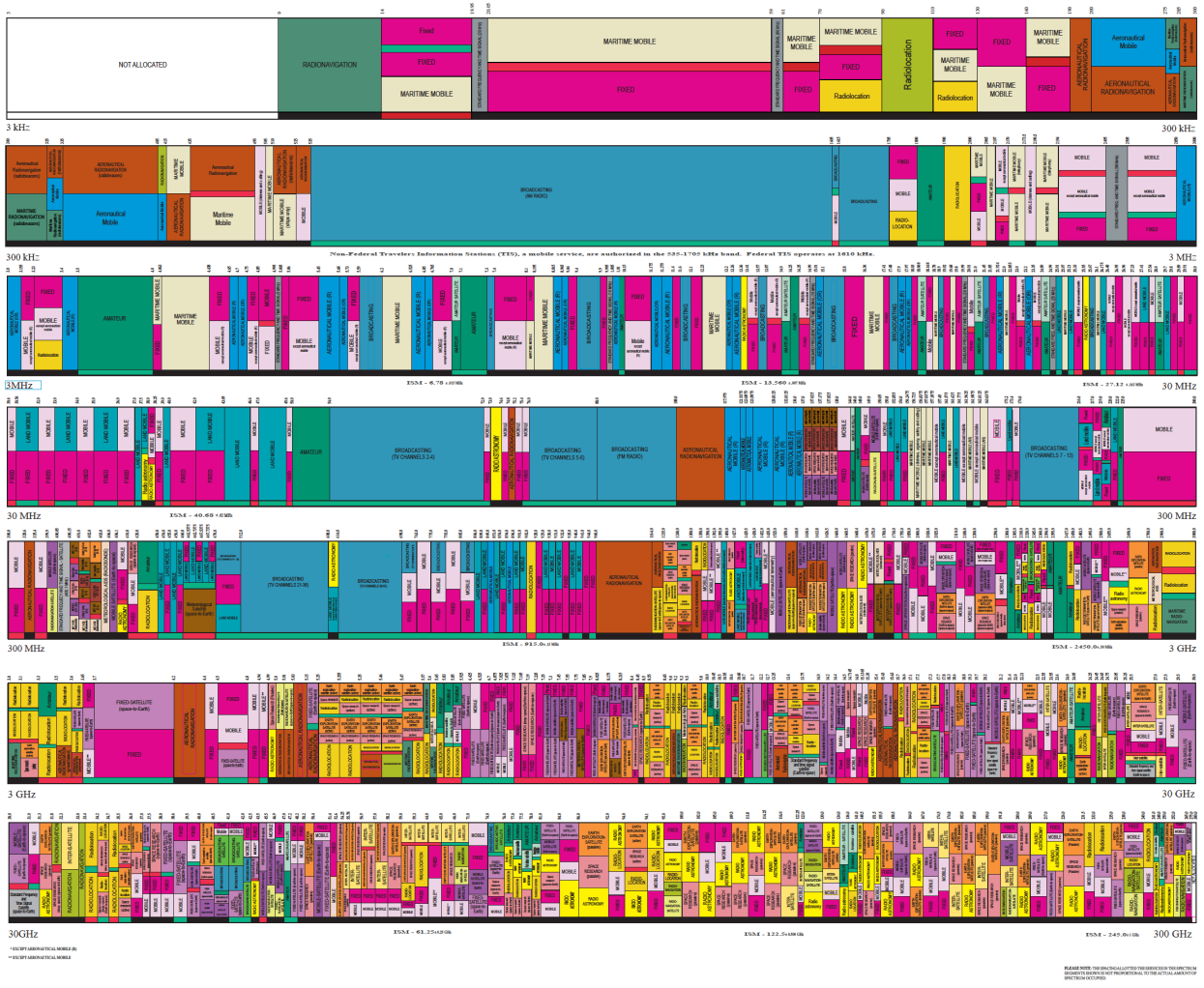
- Some spectrum for unlicensed use, which means that no one has to pay for leasing or buying that spectrum.
    - Minimal rules on how can the spectrum be used, the so-called etiquette rules, e.g power spectral density of the emission at a particular point, most often, the antenna.

- These bands may become congested.

Spectrum Regulations

- A new approach to allow secondary (un-licenced users) to use primary (licenced) spectrum with minimum interference, primarily restricted power transmission, example, UWB (Ultra Wide Band)
- Ultra-wideband is a technology for transmitting information across a wide bandwidth (>500 MHz). This allows for the transmission of a large amount of signal energy without interfering with conventional narrowband and carrier wave transmission in the same frequency band.

US – Frequency Allocations



Connectivity

- Key Requirements
  - Availability
  - Reliability
  - Viability
- Mobile phone technology is probably the best business proposition
- Furthermore, an exciting class of Low Power Wide Area networking technologies is also emerging
- Low Power Wifi, a new system, is also a contender [1]

1. https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-introduces-low-power-long-range-wi-fi-halow

ISM Band

- The industrial, scientific and medical radio bands (ISM bands) are radio bands reserved internationally for the use of radio frequency energy for industrial, scientific and medical purposes other than telecommunications.

- Examples of applications in these bands include microwave ovens, medical diathermy machines etc.

- Communications equipment operating in these bands must tolerate any interference generated by ISM applications, and users have no regulatory protection from ISM device operation.

Frequency Band for IoT

For IoT, some bands are of particular interest,

- Band between 900 & 928 megahertz - the ISM band.
- Similarly, in the areas of 2.4 gigahertz and 5.7 gigahertz.
- There are some bands at lower frequencies that are also appealing.
- These bands are essentially license-free operation so that a very large number of IoT devices can be deployed without having to pay for the usage of the band.

Wireless LAN

- The 802.11 working group currently documents use in five distinct frequency ranges: 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, and 5.9 GHz bands.

- Each range is divided into a multitude of channels of bands.

- Countries apply their own regulations to the allowable channels, allowed users and maximum power levels within these frequency ranges.

Connectivity

- Wi-Fi Alliance introduces low power, long range Wi-Fi HaLow™ (pronounced “HAY-low”) in 2016

- Wi-Fi HaLow extends Wi-Fi into the 900 MHz band, enabling the low power connectivity necessary for applications including sensor and wearables. Wi-Fi HaLow’s range is nearly twice that of today’s Wi-Fi.

Connectivity

- As the 2.4 GHz band becomes more crowded, many users are opting to use the 5 GHz ISM band. This not only provides more spectrum, but it is not as widely used by Wi-Fi as well as many other appliances including items such as microwave ovens, etc.

- Many of the 5 GHz Wi-Fi channels fall outside the accepted ISM unlicensed band and as a result various restrictions are placed on operation at these frequencies.

Connectivity

- How to connect these billions of Things

- Wireless appears to be a feasible solution due to:
  - Flexibility / Things can move around
  - Scalability
  - Cost Efficiency

- Already experience of successful wireless system i.e., Cellular network

Connectivity

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- In Cellular Technology, we face the problem of battery discharge

- In IoT, we want that sensor runs on a small battery may be for years

- IEEE standard 802.15.4 intends to offer the wireless personal area network (WPAN) which focuses on low-cost, low power, low-speed communication between devices.

Connectivity : Zigbee

- Zigbee technology is based on this standard, IEEE 802.15.4 developed by Zigbee Alliance

- Zigbee is good for short range (10 to 20 meters approx) but it requires large number of nodes to cover larger range, and maintenance cost increases manifold

- While designing the standard, the emphasis was on low power instead of low energy. Low power results in short range, thus increasing number of nodes and maintenance cost.

Connectivity : Zigbee

- Energy = Power x Time , so a better design could have worked on high power for very short amount of time and hibernating for rest.

- An undue emphasis on cost, instead of looking at a bigger model affected the standard. With high number of nodes covering a larger area, the maintenance cost surpasses the Zigbee hardware cost manifold.

Connectivity : Low Power WiFi

- Wifi, despite higher power consumption, is a good candidate for IoT

- Wifi has achieved greater success and is nowadays has ubiquitously much higher presence

- Wifi has not been fairly suitable for sensor communication due to high energy consumption

- Wifi community started installing IC for duty cycle, whereby it remain in dormant mode if no sensing or transmission happening, thus making it energy efficient

Connectivity : Low Power WiFi

- Further wifi can provide data rates from few Kbps to Mbps

- IEEE started working on IEEE 802.11ah, a wireless networking protocol published in 2017 to be called Wi-Fi HaLow (pronounced "HEY-Low"), where thousands of devices can be connected

- Applications
  - Industrial Automation and Control
  - Smart Metering
  - Health Care Applications

Connectivity : Low Power WiFi

- 6 thousands sensors can connect to single access point
- Can Communicate at 100 Kbps
- Default transmission power of 200 milli watt
- Range of about 1 KM compared to 10 meter or so of Zigbee
- Industrial, scientific, and medical radio **band** (**ISM band**) in the range of sub GHz

Connectivity : 3 GPP

- The 3rd Generation Partnership Project (3GPP) is a collaboration between groups of telecommunications associations, known as the Organizational Partners.

- The initial scope of 3GPP was to make a globally applicable third-generation (3G) mobile phone system specification based on evolved Global System for Mobile Communications (GSM) specifications within the scope of the International Mobile Telecommunications-2000 project of the International Telecommunications Union (ITU).

Connectivity : 3 GPP

The scope was later enlarged to include the development and maintenance of :

- GSM and related "2G" and "2.5G" standards, including General Packet Radio Service (GPRS is a packet oriented mobile data service on the 2G and 3G cellular_communication) and EDGE (Enhanced Data rates for GSM Evolution)

- Related "3G" standards and related "4G" standards, including LTE (Long-Term Evolution) Advanced and LTE Advanced Pro and related "5G" standards

Connectivity

- 3 GPP working on cellular IoT for 5 G
- Narrowband Internet of Things (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio technology standard developed by 3GPP.
- NB-IoT focuses specifically on low cost, long battery life, and high connection density.
- NB-IoT uses a subset of the LTE standard

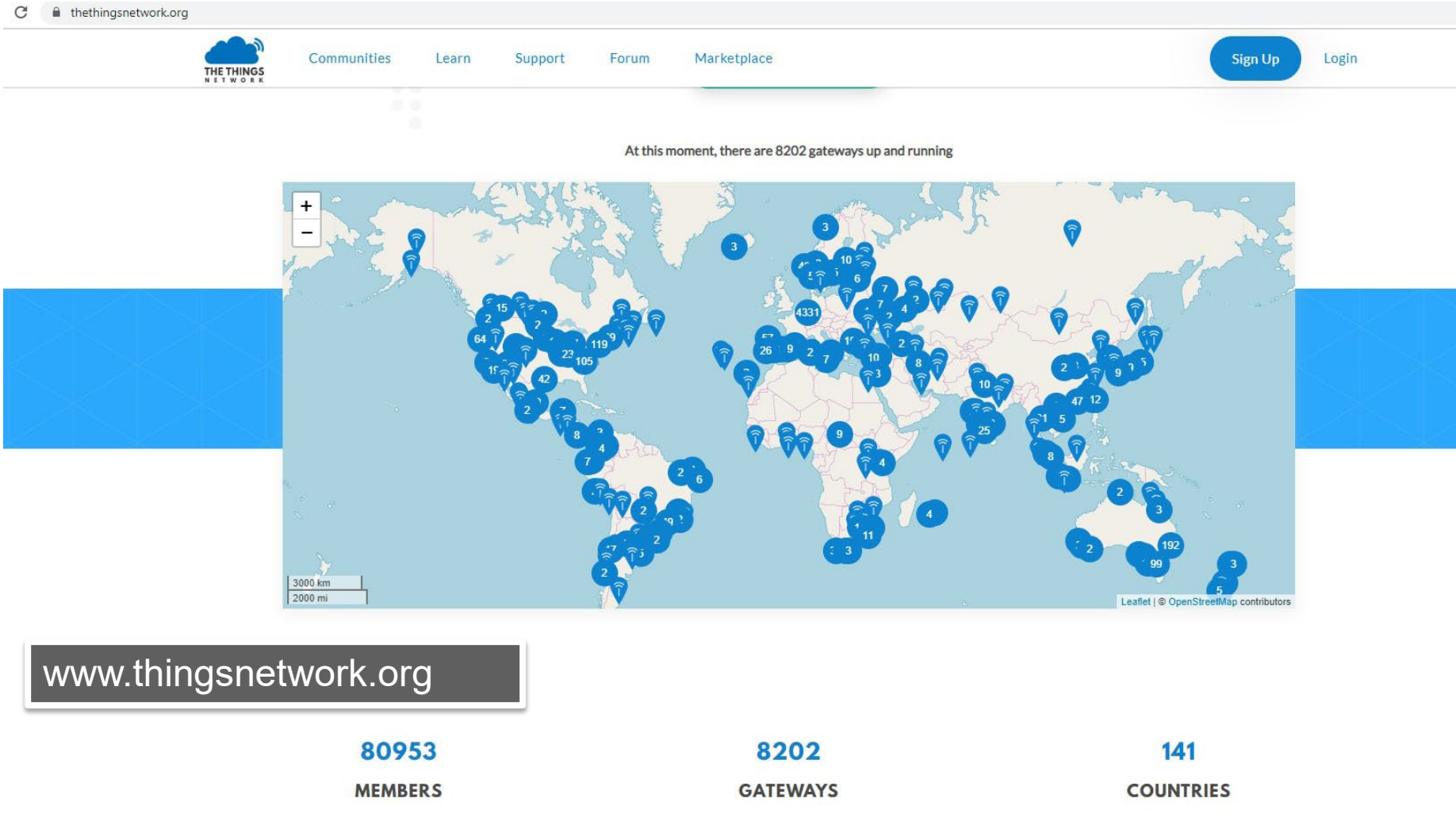
Connectivity : Low Power Wide Area Networks

- Low-Power Wide-Area Network (LPWAN) or Low-Power Network (LPN) is a type of wireless telecommunication wide area network designed to allow long range communications at a low bit rate among things (connected objects)

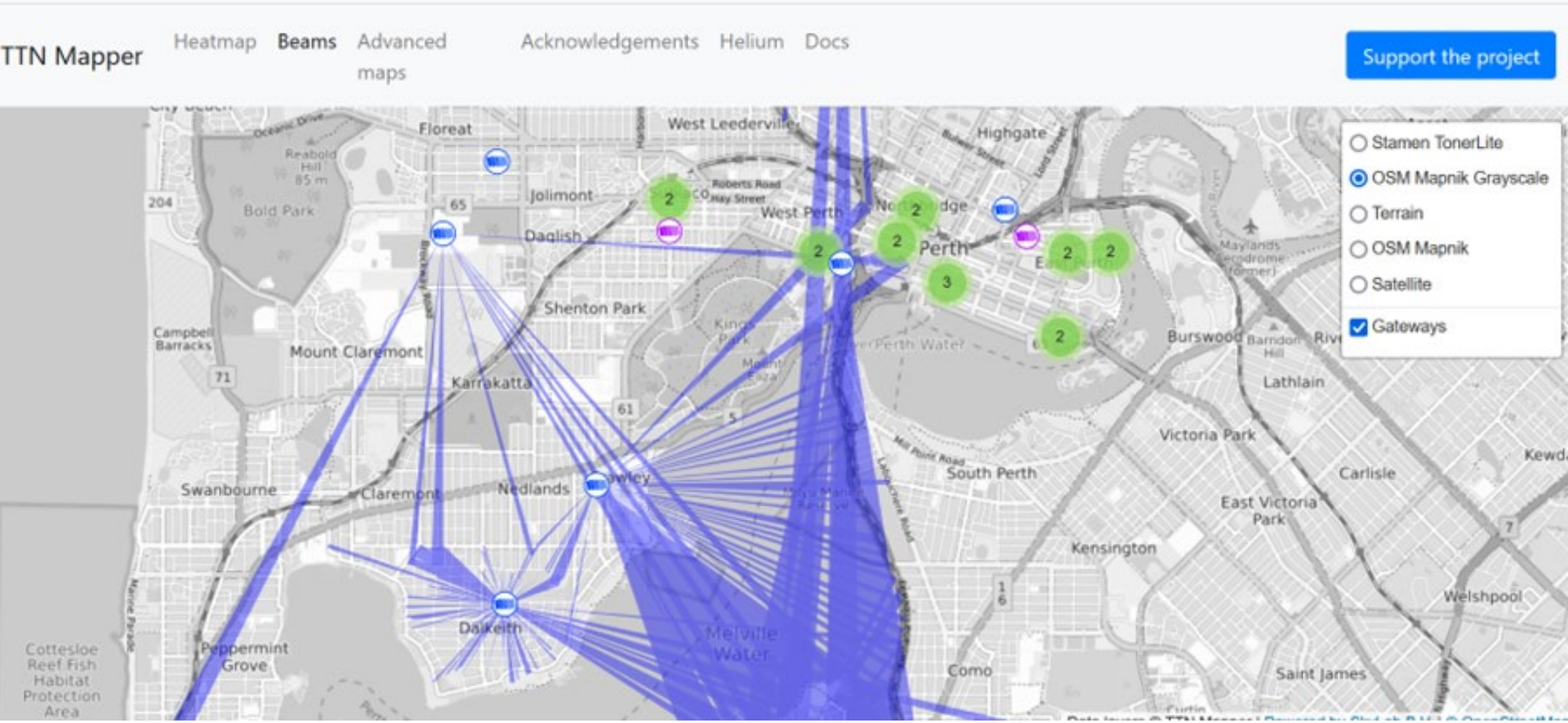
- 25 mW transmission power

- 15-50 km rural outdoor / 2-3 km urban indoor

LP-WAN (LoRa Gateways in World)



LP-WAN Coverage – ttnmapper.org



dbm

- A power level of 0 dBm corresponds to a power of 1 milliwatt.

- To express an arbitrary power *P* in mW as *x* in dBm, the following expression is used:

$$x = 10 \log_{10}(P/10mw)$$

Or conversely

$$P = 1\ mw\ .\ 10^{(x/10)}$$