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CITS 5506
The Internet of Things
Lecture 05

Components of IoT (Continuation)
IoT Applications & Smart Products

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Questions on Guest Lectures

1. The Questions will be uploaded at LMS on Tuesday after the respective Guest Lecture on Monday at folder “Assessment- Qs on Guest Lectures”

2. Question Upload time will be 5:30 pm on Tuesday.

3. Submission Deadline: 6:30 pm on same Tuesday through Turnitin Submission at LMS link “Submissions”

4. Maximum Similarity 10%.

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.

Data Transmission Requirements

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

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

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 International Telecommunication Union, ITU Radio communication Sector (ITU-R)
- States auction spectral blocks for set applications e.g 3G, 4G, 5 G, auctions. Two companies, Optus and Telstra, have won 5 G spectrum in the ACMA spectrum auction.

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.

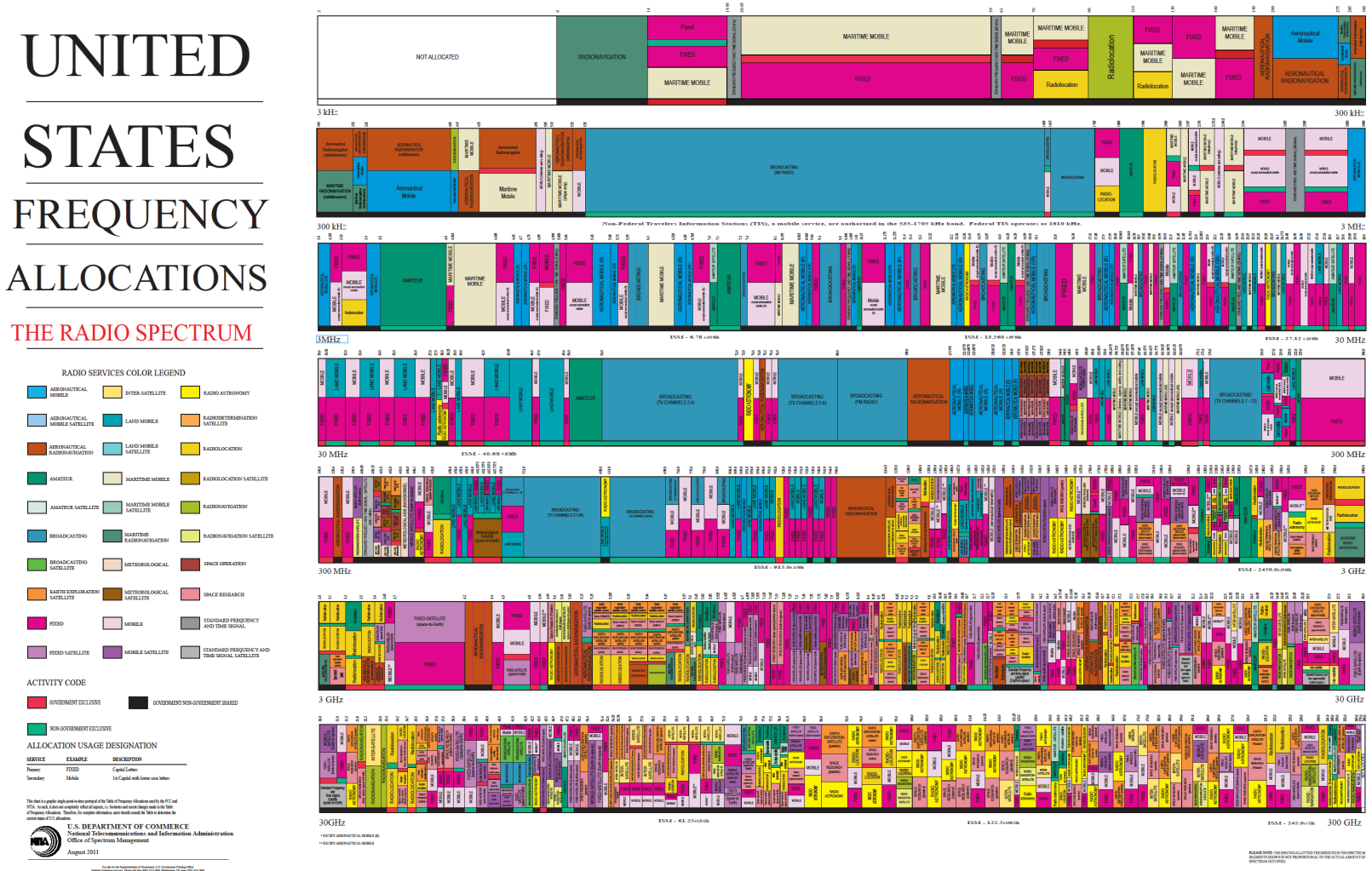
Spectrum Regulations

- A new approach to allow secondary (un-licenced users) to use primary (licenced) spectrum with minimum interference, primarily restricted power transmission, example, UWB, Ultra WideBand.
- Ultra-wideband (UWB, ultra wideband, ultra-wide band and ultraband) is a radio technology that can use a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum.

Ultra-wideband (UWB)

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

- 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

- 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 Mega Hertz - the ISM band.
- Similarly, in the areas of 2.4 Giga Hertz and 5.7 Giga Hertz.
- 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

- 802.11 is a family of evolving specifications for wireless local area networks (WLANs) developed and maintained by a working group of IEEE. There are several specifications in the family, and new ones are added.
- 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. Some reports it having a range of 1 km.

https://www.wi-fi.org/beacon/y-zachary-freeman/wi-fi-halow-and-lorawan-how-do-the-technologies-compare

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 : 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.

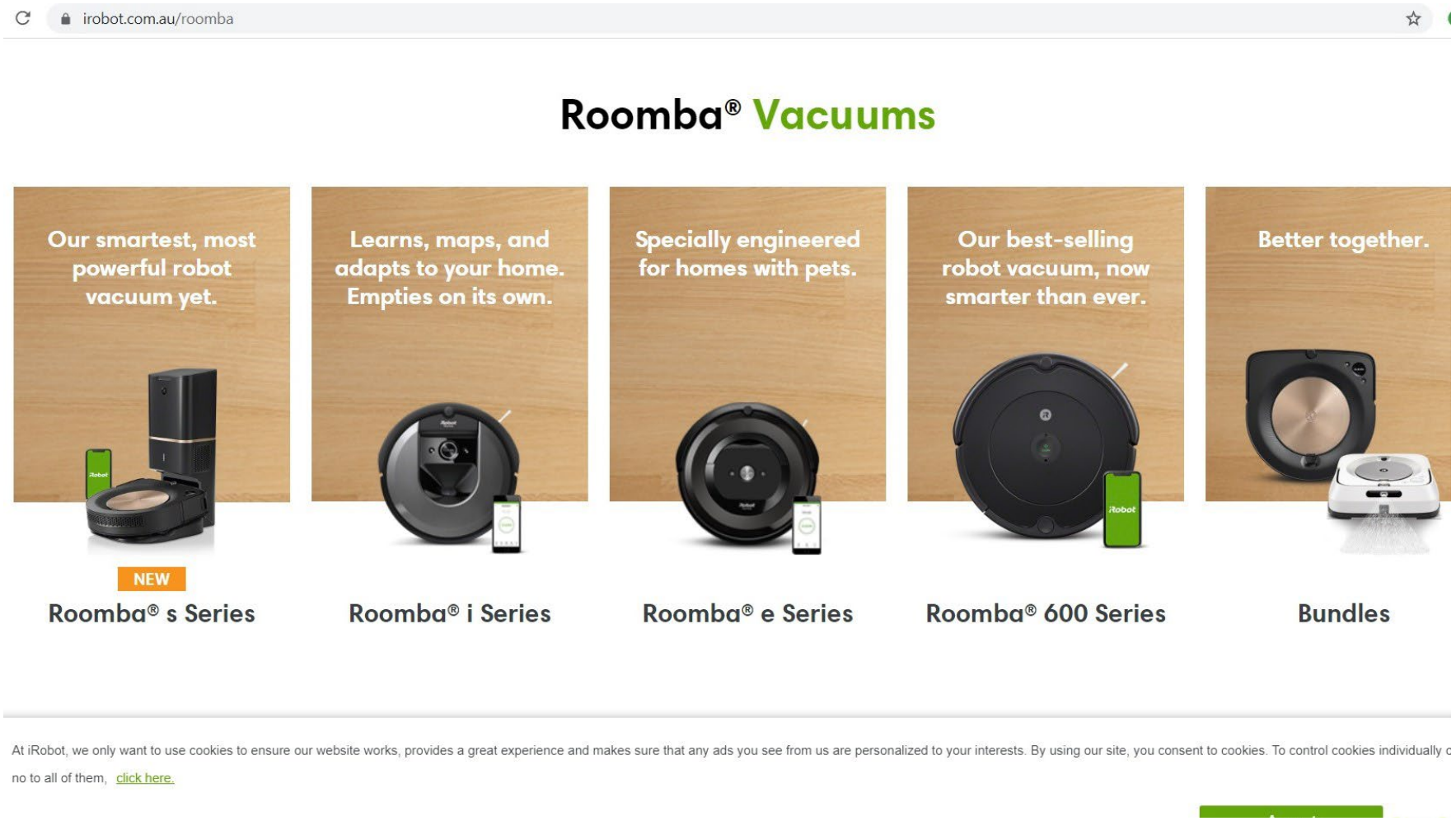
Connectivity : Zigbee

- ***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.

Robotic Vacuum Cleaners



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 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.

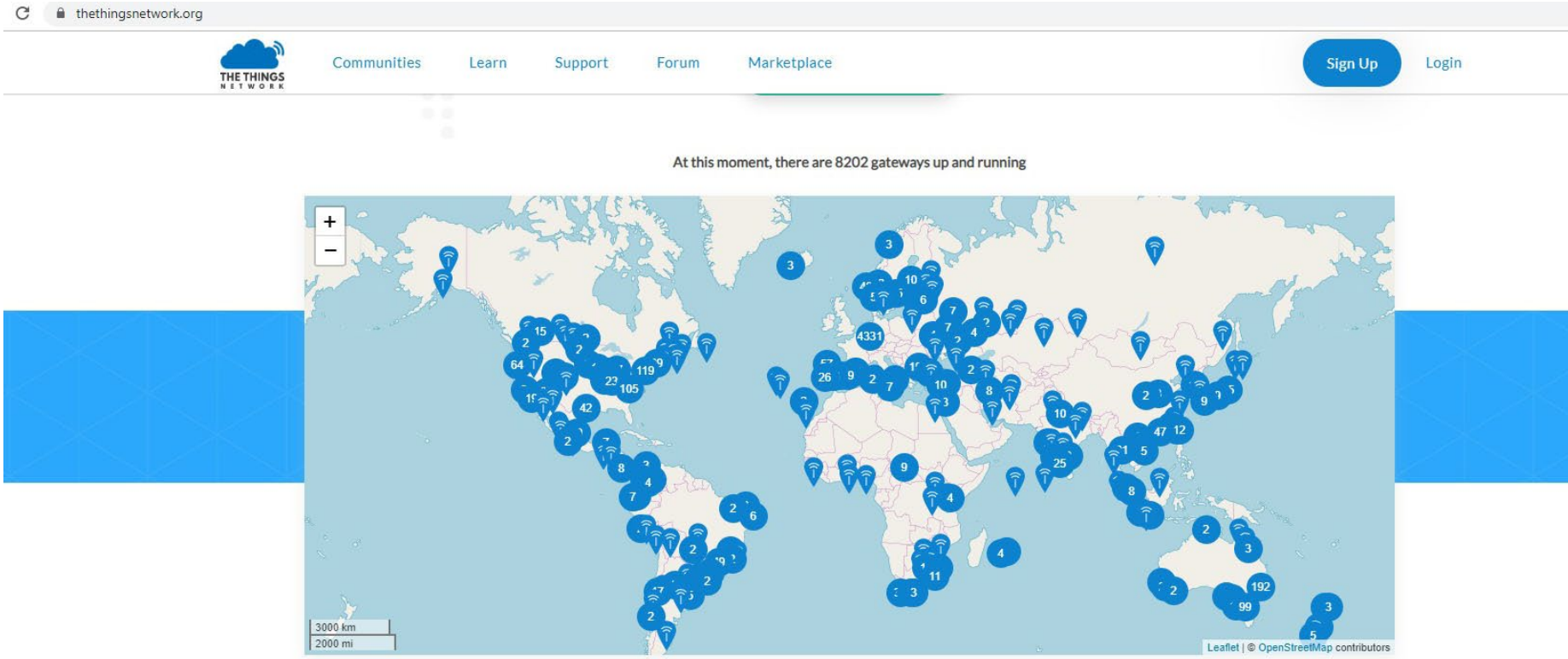
Connectivity : Low Power Wide Area Networks

- 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)



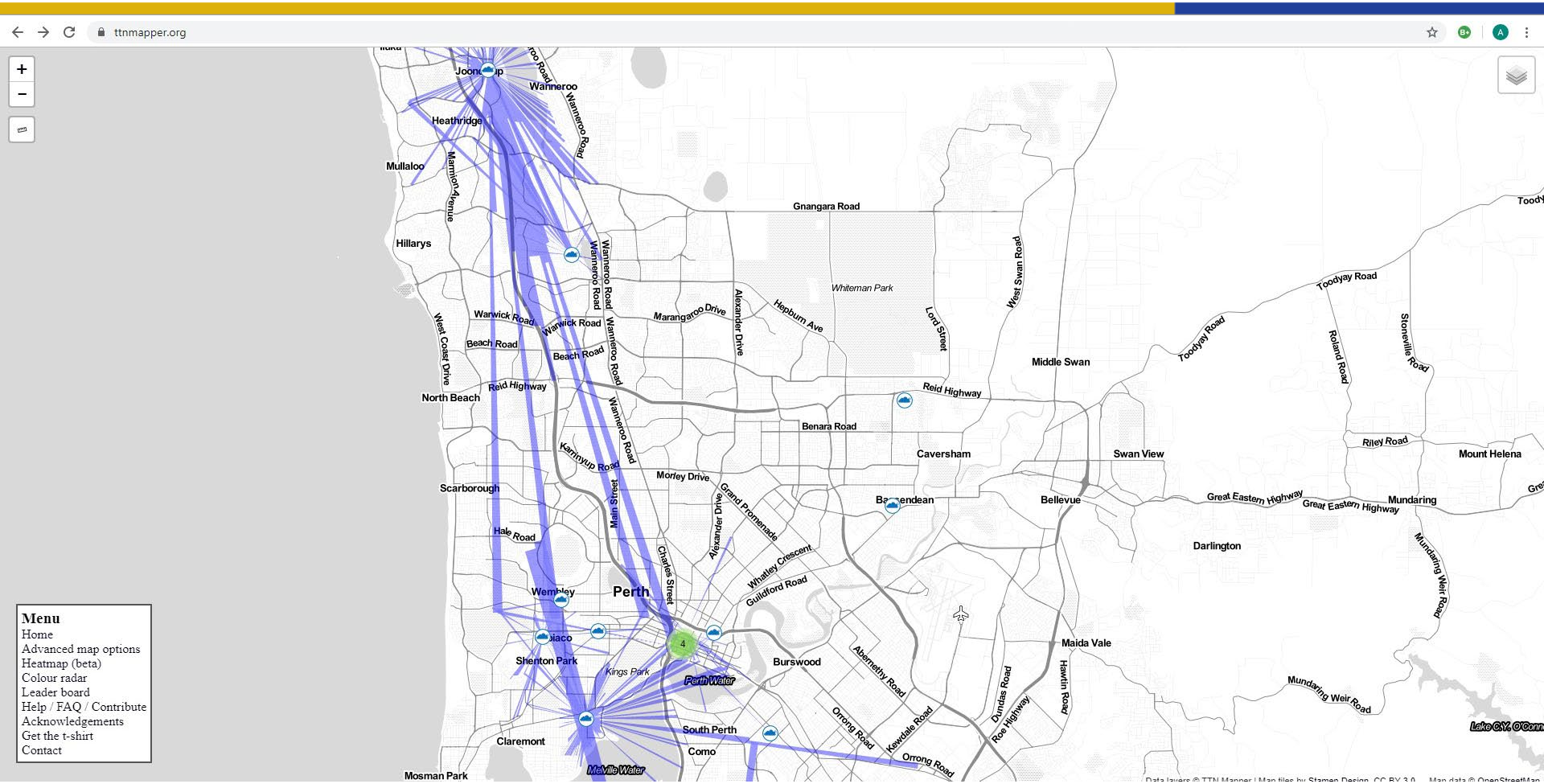
www.thingsnetwork.org

80953 MEMBERS

8202 GATEWAYS

141 COUNTRIES

LP-WAN Coverage – ttnmapper.org



- **SIGFOX**

Sigfox is a French company founded in 2009 that builds wireless networks to connect low-energy objects such as electricity meters, smart watches and washing machines, which need to be continuously on and emitting small amounts of data.

- Learn and Build your own Iot Product utilizing Sigfox

  https://build.sigfox.com/

Connectivity : Low Power Wide Area Networks

- Sigfox employs a proprietary technology that enables communication which uses 868MHz in Europe and 902MHz in the US.
- It utilizes a wide-reaching signal that passes freely through solid objects, called "ultra narrowband" and requires little energy, being termed "Low-power Wide-area network (LPWAN)".
- The signal can also be used to easily cover large areas and to reach underground objects.
- Sigfox has partnered with a number of firms in the LPWAN industry such as Texas Instruments, Silicon Labs and ON Semiconductor (produce IoT development kits).

LoRa: Long Range Low Power Wireless platform

- LoRa is a proprietary, chirp spread spectrum (CSS) radio modulation technology for LPWAN used by LoRaWAN, Haystack Technologies, and Symphony Link.

- LoRa is a patented technology developed by Cycleo (Grenoble, France) and acquired by Semtech in 2012.
- LoRa uses license-free sub Gigahertz radio frequency bands like 169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America).
- Claims 30 miles connectivity in rural area

NB-IoT

- NarrowBand IoT (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio technology standard developed to enable a wide range of devices and services to be connected using cellular telecommunications bands

- NB-IoT is a narrowband radio technology designed for the Internet of Things (IoT) and is standardized by the 3rd Generation Partnership Project (3GPP)

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Weightless (Wireless Communication)

- Weightless is the name of a set of LPWAN open wireless technology standards for exchanging data between a base station and thousands of machines around it. These technologies allow developers to build Low-Power Wide-Area Networks (LPWAN).

- Cambridge, UK based company

https://www.iotglobalnetwork.com/companies/single/id/954/weightless

Weightless (Wireless Communication)

- Weightless is managed by the Weightless SIG, or Special Interest Group.
- The intention is that devices must be qualified by the Weightless Special Interest Group to standards defined by the SIG.
- Patents would be licensed to those qualifying devices; thus, the protocol whilst open, may be regarded as proprietary.

RPMA

- Random phase multiple access (RPMA) is the trade name given to a low-power wide-area channel access method product being sold by the company Ingenu, formerly On-Ramp Wireless.
- It is meant to be used for machine-to-machine (M2M) communication on the Internet of Things (IoT).
- RPMA covers rural Texas oilfields with 400 square miles per tower (from RPMA website).

https://www.ingenu.com/

https://www.ingenu.com/technology/rpma/

RPMA

- RPMA is currently used in dozens of private networks worldwide. The 2.4 GHz spectrum is available worldwide and is cost-free to use.

- RPMA access points may cover up to 300 square miles. It would take 30 cellular towers to cover the same area.

- Ingenu, who owns RPMA, reportedly has some access points covering as many as 450 square miles each.

Emerging 5 G Networks

- The biggest input to IoT may come from cellular community. 3 GPP is now working on 5G standardization. The group has the experience of standardizing 3 G and 4 G.

- Cellular is becoming increasingly attractive for supporting large-scale IoT installations due to:
  - wide coverage
  - relatively low deployment costs
  - high level of security
  - access to dedicated spectrum
  - simplicity of management

Emerging 5 G Networks

- However, LTE networks have not been designed keeping in view IoT devices, which can be event driven.
- Therefore, several improvements have been initiated in 3GPP aiming to augment LTE to become more suitable for IoT applications.
- The number of connected machines are expected to grow dramatically-- up to 30,000, maybe 60,000 devices in a single cell– so LTE technologies require respective mechanisms to handle a very large number of devices.

** LTE (Long Term Evolution) is a 4 G wireless standard for high Bandwidth.*

Emerging 5 G Networks

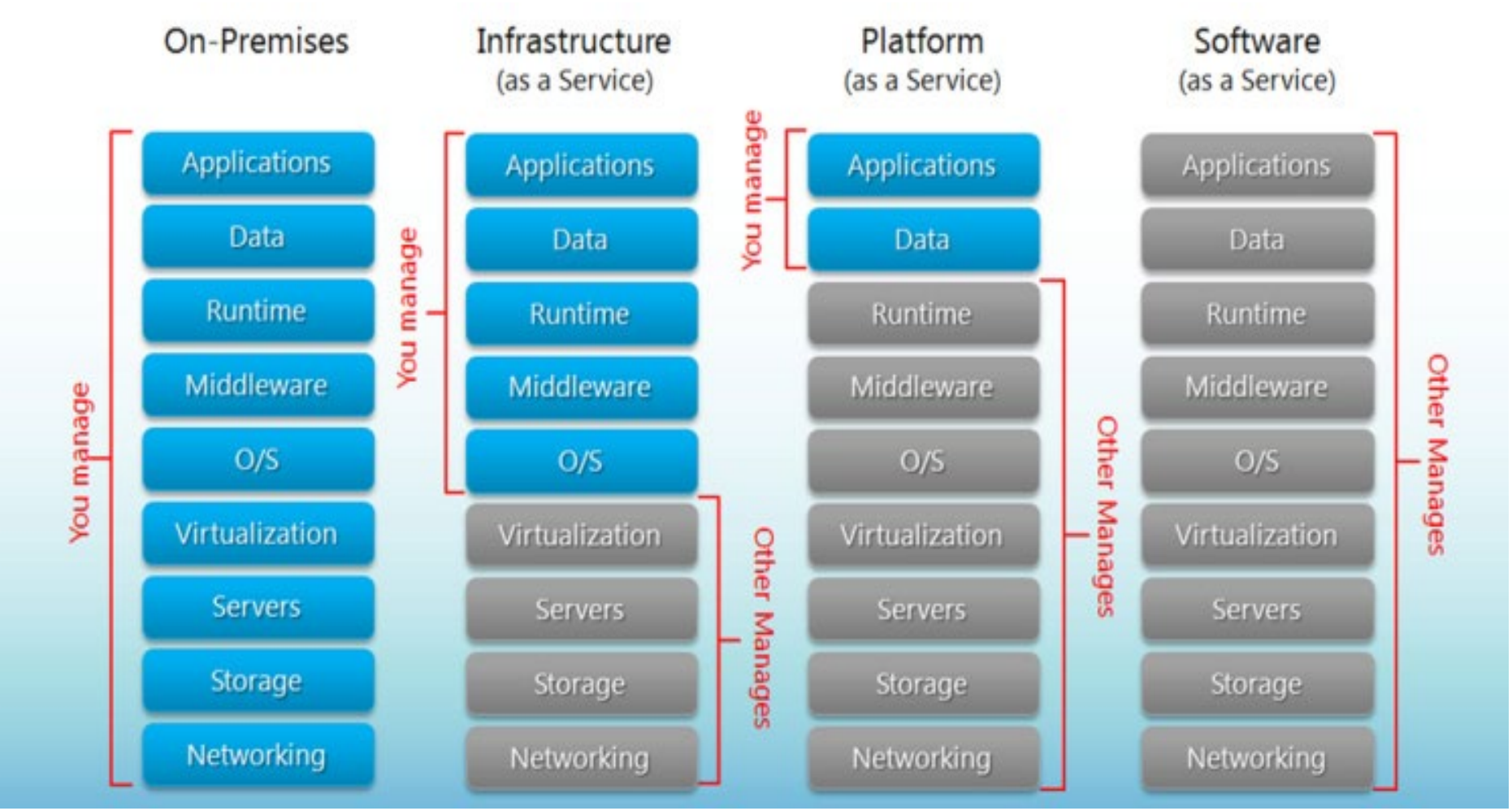
- Typical IoT data transmissions are infrequent, small, and require simplified *signaling* procedures for connection establishment to offer energy consumption saving for such devices.

- If technology and data plans are affordable, cellular technology can support IoT due to its global availability and considerable reliability.

Platform

- The collected data needs to be stored and processed somewhere. Known as IoT platforms, these are typically cloud-based infrastructures which:
  - receive and send data via standardized interfaces, known as API (Application Programming Interface)
  - store the data; and
  - process the data
- Many commercial platforms are available today, e.g, Amazon Web Services (AWS), Microsoft Azure, IBM Watson, Google Cloud Platfrom, Oracle, Bosch, CISCO IoT cloud Connect, SAP etc etc

Comparison of Cloud Services



Software as a service (SaaS)

Recommended is scalable cloud solutions in a software-as-a-service (SaaS) model for IoT

Software as a service (SaaS) is a software distribution model in which a third-party provider hosts applications and makes them available to customers over the Internet like office365, Canva etc

SaaS is one of three main categories of cloud computing, alongside infrastructure as a service (IaaS) and platform as a service (PaaS).

PaaS (Platform As A Service)

- Used for applications, and other development, while providing cloud components to software.

- What developers gain with PaaS is a framework they can build upon to develop or customize applications.

- PaaS makes the development, testing, and deployment of applications quick, simple, and cost-effective

IaaS (Infrastructure As A Service)

- Self-service models for accessing, monitoring, and managing remote data center infrastructures, such as compute (virtualized or bare metal), storage, networking, and networking services (e.g., firewalls).

- Instead of having to purchase hardware outright, users can purchase IaaS based on consumption,

Analytics

- Data analytics needs to be applied to the data to get the insight from data.

- Big data analytics tools are generally available today, which stretch from simple statistical tools to more sophisticated machine learning approaches, with deep learning being the latest trend.

- Think of statistical tools finding you the known knowns in the data; machine learning finding the known unknowns; whilst deep learning is able to find the unknown unknowns.

User Interface

- User Interface is the component that how the data is presented to the final users.
- IoT product needs to have a very appealing user interface, both web based as well as smart phone or tablet based.
- There are many open-source as well as paying front-end products available today e.g, OpenRemote

  - OpenRemote is an open-source project, which integrates many different protocols and solutions available for smart building, and smart city automation, and offers visualization tools. (Wikipedia)
  - https://www.openremote.io/