Introduction to Internet of Things

LoRa®

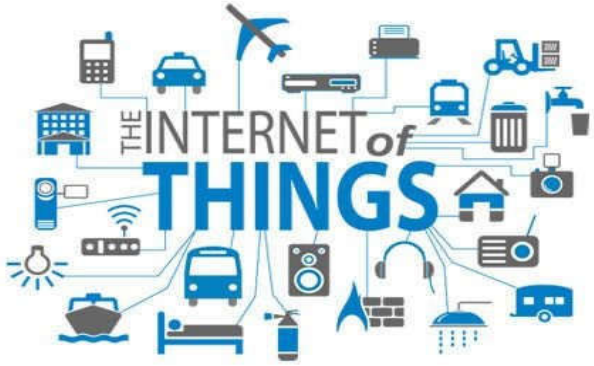
ENGINEERS OF THE PHILIPPINES
INSTITUTE OF ELECTRONICS
1950
RIZAL CHAPTER

Engr. Rally Uminga

SEMTECH

Acsip

Why IoT is Important?



What is Internet of Things (IoT)?

- **inter-networking of physical devices**
- **embedded systems** with **electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data.**

Objectives of IoT.

- **allows objects to be sensed or controlled remotely across existing network infrastructure,**
- **resulting in improved efficiency, accuracy and economic benefit**
- **reduced human intervention.**

sensors and actuators - smart grids, smart power plants, smart homes, intelligent transportation and smart cities.

-IoT will consist of about **50 billion objects** by 2020.

Why IoT is important?

- **convergence of multiple technologies, including wireless communication, real-time analytics, machine learning, commodity sensors, and embedded systems.**
- **wireless sensor networks, control systems, automation** (including **home and building automation**).

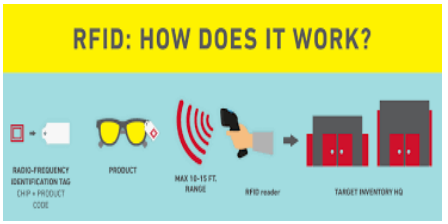
History of IoT

- **Coke machine** in **1982** at **Carnegie Mellon University** becoming the first Internet-connected appliance,
- able to **report its inventory** and whether **newly loaded drinks were cold.**

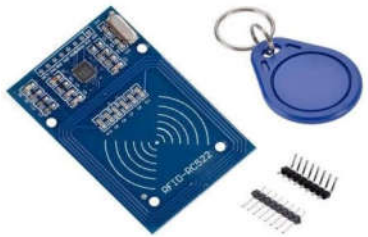
Coke Machine in 1982 – First IoT Device

History

- **Became popular in 1999, through the Auto-ID Center at MIT**
- **Radio-frequency identification (RFID) was seen by Kevin Ashton as a prerequisite for the Internet of things at that point.**



The term "the **Internet of Things**" was coined by **Kevin Ashton** of Procter & Gamble, later MIT's Auto-ID Center, in 1999.



IoT Enabling Technologies

Sensors and Actuators

- **Sensors:**
- **device that converts a physical parameter to an electrical output.**
- **a type of transducer.**
- **can be divided into analog sensors and digital sensors.**
- **Analog sensors give output in the format of voltages and currents.**
- **Digital sensors are excellent for embedded systems, as they bypass the need for ADC, and make the circuit much simpler**
- **Examples include temperature sensors, humidity sensors, pressure sensors, smoke sensors, sound and light sensors**

IoT Enabling Technologies

Sensors and Actuators

- **Actuators:**
- **device that converts an electrical signal to a physical output or motion.**
- **can be controlled by electric voltage or current, pneumatic or hydraulic pressure, or even human power**
- **Actuators can create a linear motion, rotary motion or oscillatory motion**
- **Examples of actuators include electric motors, piezoelectric actuators, pneumatic actuators, step motors, and door lock actuators**

Communications

RFID and NFC (Near-Field Communication)

- **uniquely identify and track tags attached to objects using radio frequency electromagnetic waves.**

- **RFID system typically includes a tag, a reader, and an antenna.**
- **Active RFID-with its own power**
- **Passive RFID-no power on its own**

- **Near-field communication (NFC) is a communication technology that operates at the same frequency (13.56 MHz) as HF RFID. Different from RFID, NFC is based on peer-to-peer communication, which means that a NFC device can be either a reader or a tag**

Communications

RFID and NFC (Near-Field Communication)

RFID Frequency Bands.

Band	Range	Data Speed	Tags
Low frequency (LF): 125–134.2 kHz	10 m	low	passive
High frequency (HF): 13.56 MHz	10 cm–1 m	low to moderate	passive
Ultra high frequency (UHF): 433 MHz	1–100 m	moderate	passive or active
Ultra high frequency (UHF): 856 MHz–960 MHz	1–12 m	moderate to high	passive or active
Microwave: 2.45–5.8 GHz	1–2 m	high	active
Microwave: 3.1–10 GHz	<200 m	high	active

Communications

Bluetooth Low Energy (BLE)

BLE also operates in the 2.4 GHz ISM band, but uses a simpler modulation system. BLE remains in sleep mode constantly except for when a connection is initiated, and it therefore consumes much less power

BLE applications:

- **Heart rate monitors**
- **Blood pressure monitors**
- **Blood glucose monitors**
- **Fitbit-like devices**
- **Industrial monitoring sensors**
- **Geography-based, targeted promotions (iBeacon)**
- **Proximity sensing**

Communications

LiFi

- **Light Fidelity (LiFi) is a novel, wireless, bidirectional, high-speed communication technology based on rapidly modulated visible light. It is a type of Visible Light Communications (VLC) system. Similar to WiFi, LiFi transmits data using electromagnetic waves. But instead of using radio waves (MHz – GHz), it uses visible light (~THz).**
- **LiFi has a huge advantage in term of infrastructure, as LED light bulbs are increasingly used in buildings, streets, and vehicles. It can operate at an impressive speed of up to 224 gigabits per second, and it is insensitive to electromagnetic interference.**
- **LiFi cannot penetrate walls, which means it can only operate at a short range, but at the same time, this makes it less likely to be hacked. There are already products on the market that can provide light and connectivity at the same time**

Communications

6LowPAN

6LoWPAN stands for IPv6 (Internet Protocol Version 6) over Low power Wireless Personal Area Networks (WPAN).

- **It is a basically a low-power, low data rate, wireless mesh network based on IEEE 802.15.4 standards, using IPv6 as the communication protocol.**
- **6LoWPAN has a distinct advantage, i.e., it is based TCP/IP open standards, including TCP, UDP, HTTP, COAP, MQTT, and websockets**
- **It has end-to-end IPv6 addressable nodes, and can be easily connected to the Internet directly. It is also self-healing because of mesh routing. 6LoWPAN has been used in wireless sensor networks, lights,and meters.**

Communications

ZigBee

ZigBee is a high-level communication technology for low-power, low-data-rate personal area networks, such as sensor networks, home automations, and medical Devices

ZigBee is based on IEEE 802.15.4 standard.

It has a transmission distance of 10–100 meters and needs to be line of sight. It operates in the industrial, scientific, and medical (ISM) radio bands, i.e., 868 MHz in Europe, 915 MHz in the United States and Australia, 784 MHz in China, and 2.4 GHz in the rest of the world. ZigBee has a data rate ranging from 20 kbit/s (868 MHz band) to 250 kbit/s (2.4 GHz band). It is a basically a low-power, low data rate, wireless mesh network based on IEEE 802.15.4 standards, using IPv6 as the communication protocol.

Communications

ZigBee

ZigBee networks are normally cheaper than other wireless networks such as Bluetooth or WiFi. ZigBee has been used for wireless light switches, electrical meters (smart grid, demand response, etc.), and industrial equipment monitoring etc.

ZigBee has been around longer, and therefore has been adopted more widely than 6LoWPAN. ZigBee is no doubt still the most popular low-cost, low-power wireless mesh networking standard available today. However, 6LoWPAN is catching up and becoming more attractive, since it is IP-based, particularly with IPv6 support.

Communications

Z-Wave

Z-Wave is a wireless communication technology that is primarily used for home automation, such as controlling and automating lights and appliances. It can be used as a security system or to monitor and control your property remotely. Z-Wave operates at unlicensed industrial, scientific, and medical (ISM) band, i.e., 868.42 MHz in Europe, 908.42 MHz in the United States and Canada, and other frequencies in other regions.

Z-Wave is designed to provide reliable, low-latency transmission at a range of about 100 meters, with data rates up to 100 kbit/s. A Z-Wave network normally includes a primary controller and a collection of devices (up to 232).

Communications

LoRa

LoRa is a long-range communication technology that is intended for low-power, long-distance communications of battery powered IoT devices—that is, low-power wide area network (LPWAN). It supports secure bidirectional communications of networks with millions and millions of devices.

Communications

Comparison of Different Technologies.

	Standard	Frequency	Range	Data Rate
LiFi	Similar to 802.11	400–800 THz	<10 m	<224 Gbps
WiFi	802.11a/b/g/n/ac	2.4 GHz and 5 GHz	~50 m	<1 Gbps
Cellular	GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G), 5G	900, 1800, 1900, and 2100 MHz 2.3, 2.6, 5.25, 26.4, and 58.68 GHz	<200 km	<500 kps (2G), <2 Mbps (3G), <10 Mbps (4G) <100 Mbps (5G)
Bluetooth	Bluetooth 4.2	2.4 GHz	50–150 m	1 Mbps
RFID/NFC	ISO/IEC 18000-3	13.56 MHz	10 cm	100–420 kbps
6LowPAN	RFC6282	2.4 GHz and ~1 GHz	<20 m	20–250 kbps
ZigBee	ZigBee 3.0 based on IEEE802.15.4	2.4 GHz	10–100 m	250 kbps
Z-Wave	Z-Wave Alliance ZAD12837 / ITU-T G.9959	868.42 MHz and 908.42 MHz	<100 m	<100 kbps
LoRa	LoRaWAN	868 MHz and 915 MHz	<15 km	0.3–50 kbps

Protocols

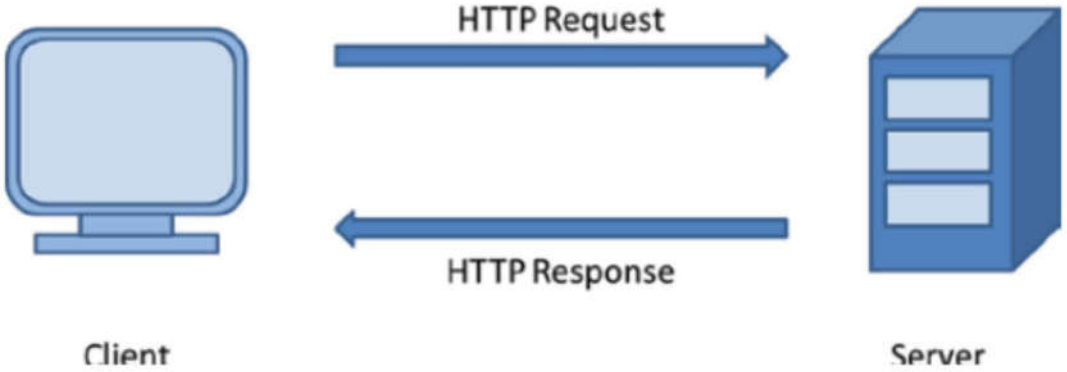
Protocols, or communication protocols, are a set of rules that allow devices to communicate with each other. Protocols define the syntax, semantics, and synchronization

of communication. A close analogy to protocols is human languages. There are many communication protocols available for IoT applications.

Protocols

HTTP

The Hypertext Transfer Protocol (HTTP) is the communication protocol behind the World Wide Web (WWW). It is based on client–server architecture, and operates in a request and response fashion.



The HTTP protocol.

Protocols

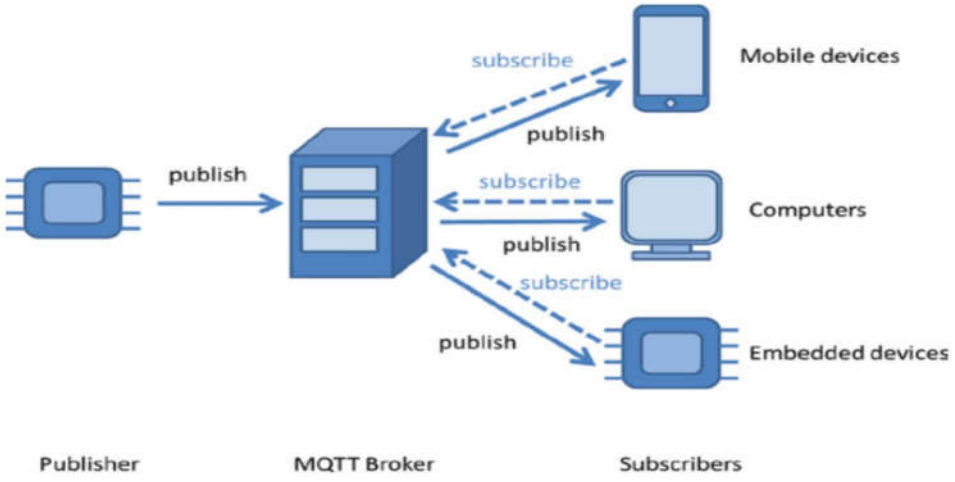
WebSocket

WebSocket is a communication protocol designed for web browsers and web servers, but unlike HTTP, WebSocket provides full-duplex communication over a single TCP connection. WebSocket is stateful, as the client and server do maintain a connection during the communication.

Protocols

MQTT

MQ Telemetry Transport (MQTT) is a lightweight, machine-to-machine communication protocol designed for IoT devices by IBM. MQTT is based on a publisher–subscriber model, where the publisher publishes data to a server (also called broker), and the subscriber subscribes to the server and receives data from the server. The MQTT broker is responsible for distributing messages and can be somewhere in the Clouds.



The MQTT protocol.

Protocols

CoAP

Constrained Application Protocol (CoAP) is a specialized application layer protocol for constrained IoT devices, i.e., devices with limited computing power, power consumption, and network connectivity, etc. It is based on request and response messages, similar to HTTP, but it uses UDP (user datagram protocol) rather TCP (transmission control protocol). Although UDP does not provide reliable transmissions, it is much simpler, has much smaller overhead, and hence it is much faster. CoAP is designed for machine-to-machine (M2M) applications such as smart energy and home / building automation.

Protocols

XMPP

Extensible Messaging and Presence Protocol (XMPP) is an open standard, real-time communication protocol based on XML (Extensible Markup Language). It can provide a wide range of services including instant messaging, presence and collaboration. It is decentralized and has security features. It is also extensible, which means it is designed to grow and accommodate changes. XMPP software includes servers, clients, and libraries.

Protocols

Node-RED

Node-RED is a web-based open source software tool developed by IBM, which can be used to connect hardware devices over the Internet.

For example, with Node-RED, you can connect your embedded development board to the Internet, read the sensor values, display it in a chart, in a web page, in an email, or a Twitter message. You can also send commands back to the development board to perform some control. It is a graphic-based programming tool, which uses functional blocks called nodes to build the program. All you need to do is to wire up the nodes and configure them. This makes many programming tasks remarkably simple and easy to implement.

IoT Architecture Summary

- ***Things*** **equipped with sensors to gather data and actuators to perform commands received from the cloud.**
- ***Gateways*** **for data filtering, preprocessing and moving it to the cloud and vice versa, – receiving commands from the cloud.**
- ***Cloud gateways*** **to ensure data transition between field gateways and central IoT servers.**
- ***Streaming data processors*** **to distribute the data coming from sensors among relevant IoT solution's components.**
- ***Data lake*** **for storing all the data of defined and undefined value.**
- ***Big data warehouse*** **for collecting valuable data.**
- ***Control applications*** **to send commands to actuators.**
- ***Machine learning*** **to generate the models which are then used by control applications.**
- ***User applications*** **to enable users to monitor control their connected things.**
- ***Data analytics*** **for manual data processing.**

What is LoRa, Why is it Popular???

- **LoRa(Long Range)**
- **Digital wireless data communication developed by Cleo of Grenobie, France**
- **Acquire by Semtech in 2012**
- **Uses sub GHz license free RF bands (169MHz, 433MHz, 868MHz (Europe) and 915MHz (North America)**
- **Typically more than 10km with low power consumption**

What is LoRaWAN

- **Network layer protocol for managing communication between LPWAN gateways and end-node devices as routing protocol maintained by LoRa Alliance.**
- **Lora is the physical layer and LoraWAN is the network/upper layers**

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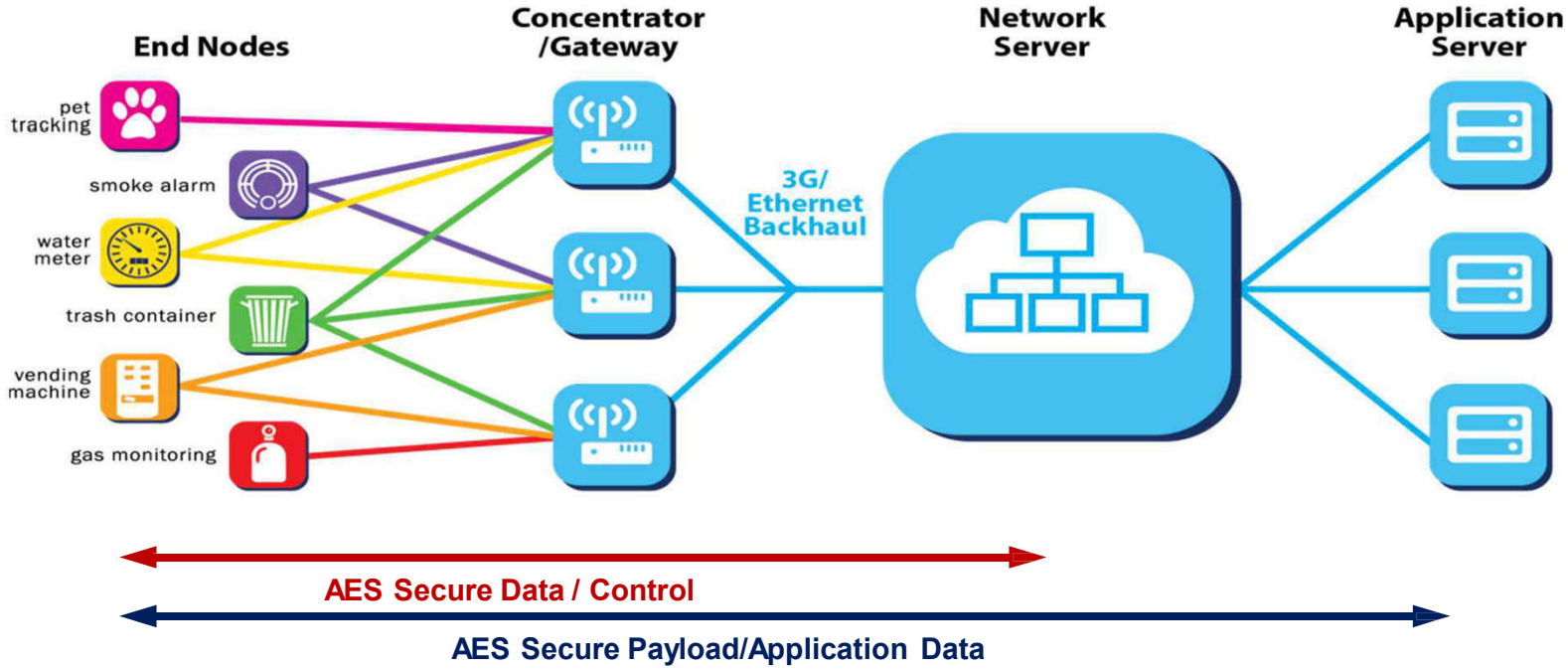
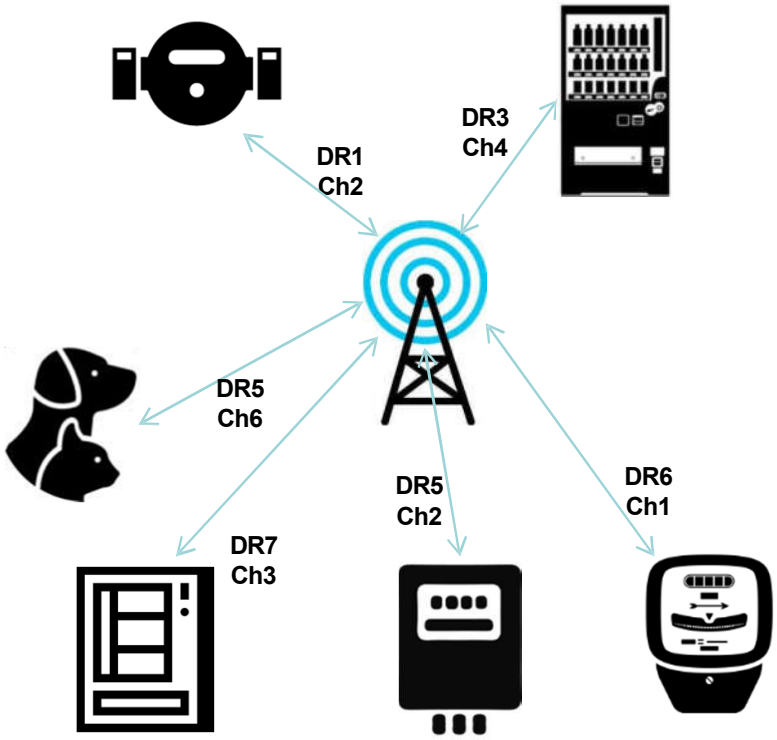
What is LoRaWAN

LoRaWAN™ Network



What is LoRaWAN

LoRaWAN™ Network



Multi-channel gateway

- Simultaneous reception of messages
- Scalable capacity
- Indoor or outdoor
- Adaptive data rate
- Supports geo-location

Fast time to market

- Commercial products available today
- Reference HW and MAC provided
- Reference design available

History

LoRa® - Brief history

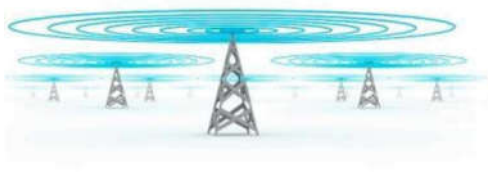
2013
- Launch of first LoRa radio by Semtech

2014
- First mobile network operator trials

2015
- Launch of LoRa Alliance: 130 members in 6 months
- Multiple sensors, gateways, modules available
- Public, private, viral network deployments worldwide

2016
- Over 400 LoRa Alliance members today
- Over 100 regions with deployments or trials
- Low power geolocation introduced
- Comcast announces US LoRaWAN network trial

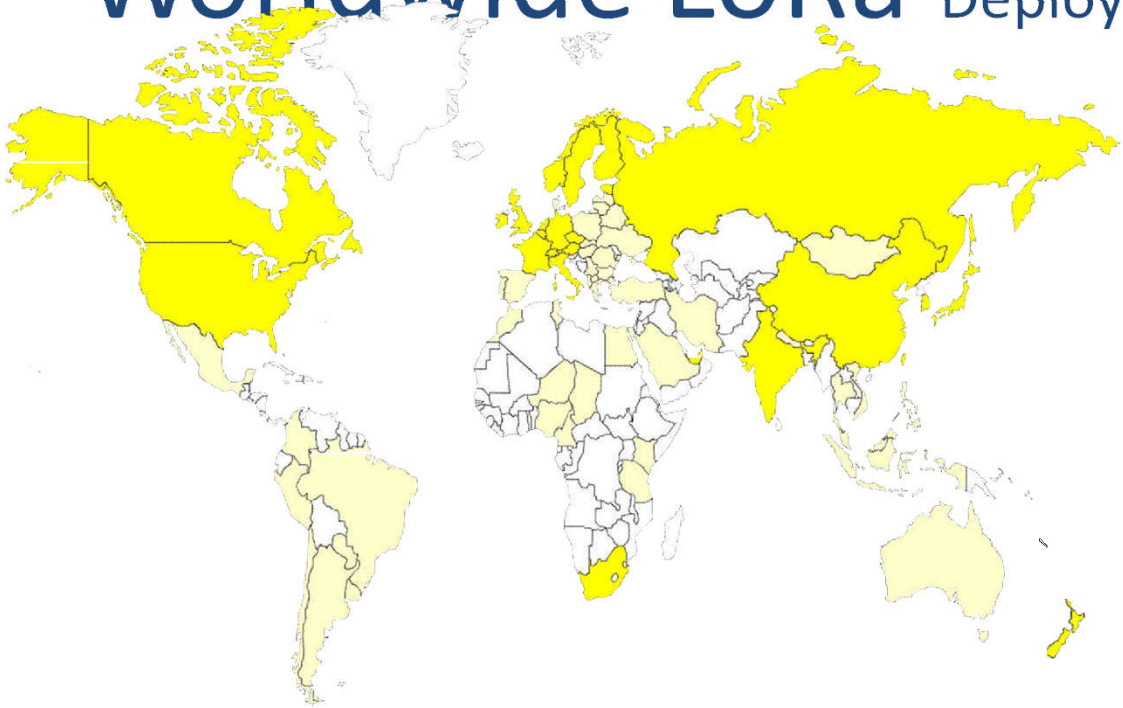
LoRa® Key Features



Long Range	Low Power	Multi Usage	Low Cost
15-30 miles outdoor	10-20yr lifetime	Scalable capacity	Minimal infrastructure
Deep indoor coverage	>10x vs cellular M2M	Multi-tenant	Low cost end-node
		Public or private	Open source software

LoRa® Key Features

Worldwide LoRa® Deployment



- 34 Publicly Announced Operators
- 150+ on-going trials & deployments
- 400+ members in the Alliance

Legend:

Publicly Announced

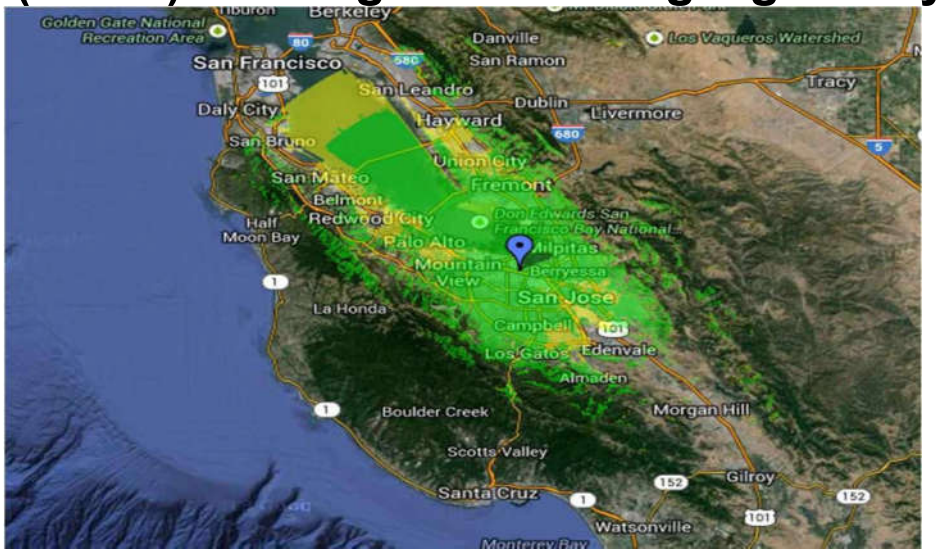
Other deployments

LoRa® Key Features

Coverage map from a single gateway

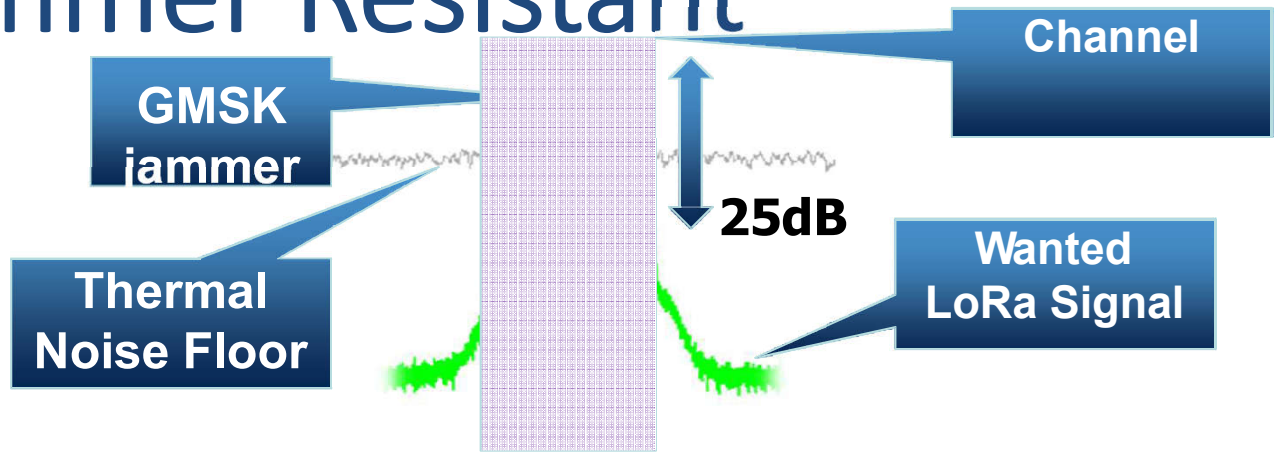
Cisco Webex building in San Jose

>20 miles (32Km) coverage from a single gateway



LoRa® Key Features

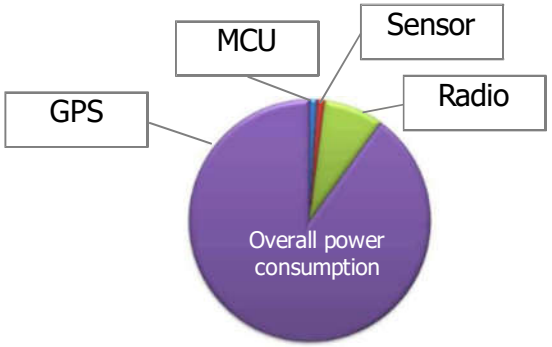
Jammer Resistant



Jammer type	LoRa Co-channel Signal to Interferer ratio	Existing FSK Co-channel Signal to Interferer
CW / FSK / GMSK	-25dB	+8 to 12dB
FDM AWGN	-21dB	15dB
LoRa at different data rate	-25dB	

LoRa® Key Features

Geolocation with LoRaWAN™



Low Power

GPS free location

Optimize operations

- All base stations share a common timebase
- A LoRaWAN sensor transmits a packet
- Algorithms compare the time of arrival and other signal parameters

LoRa Use Cases

Agriculture with LoRa

- Animal health monitoring
- Crop yield
- Water conservation

Asset management with LoRa

- Utilization Of Resources
- Asset tracking and monitoring
- Energy and land use

LoRa Use Cases

Smart City with LoRa

- Energy conservation
- City or neighborhood coverage
- Operational efficiency

Smart Buildings with LoRa

- Deep indoor penetration
- Safety and security
- Operational efficiency

Smart Metering

- Electric Utility
- Water Utility

Thank you

- Any question or comment?