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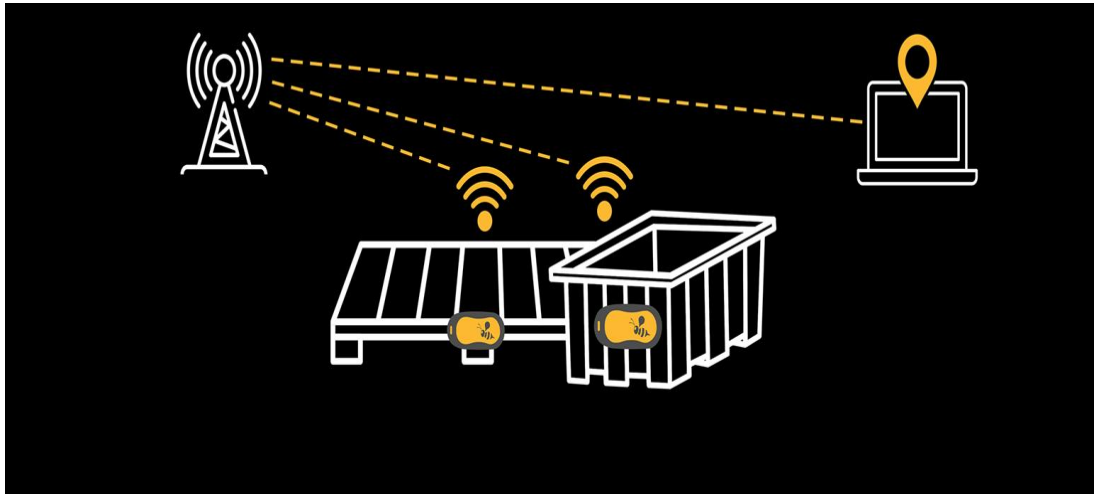
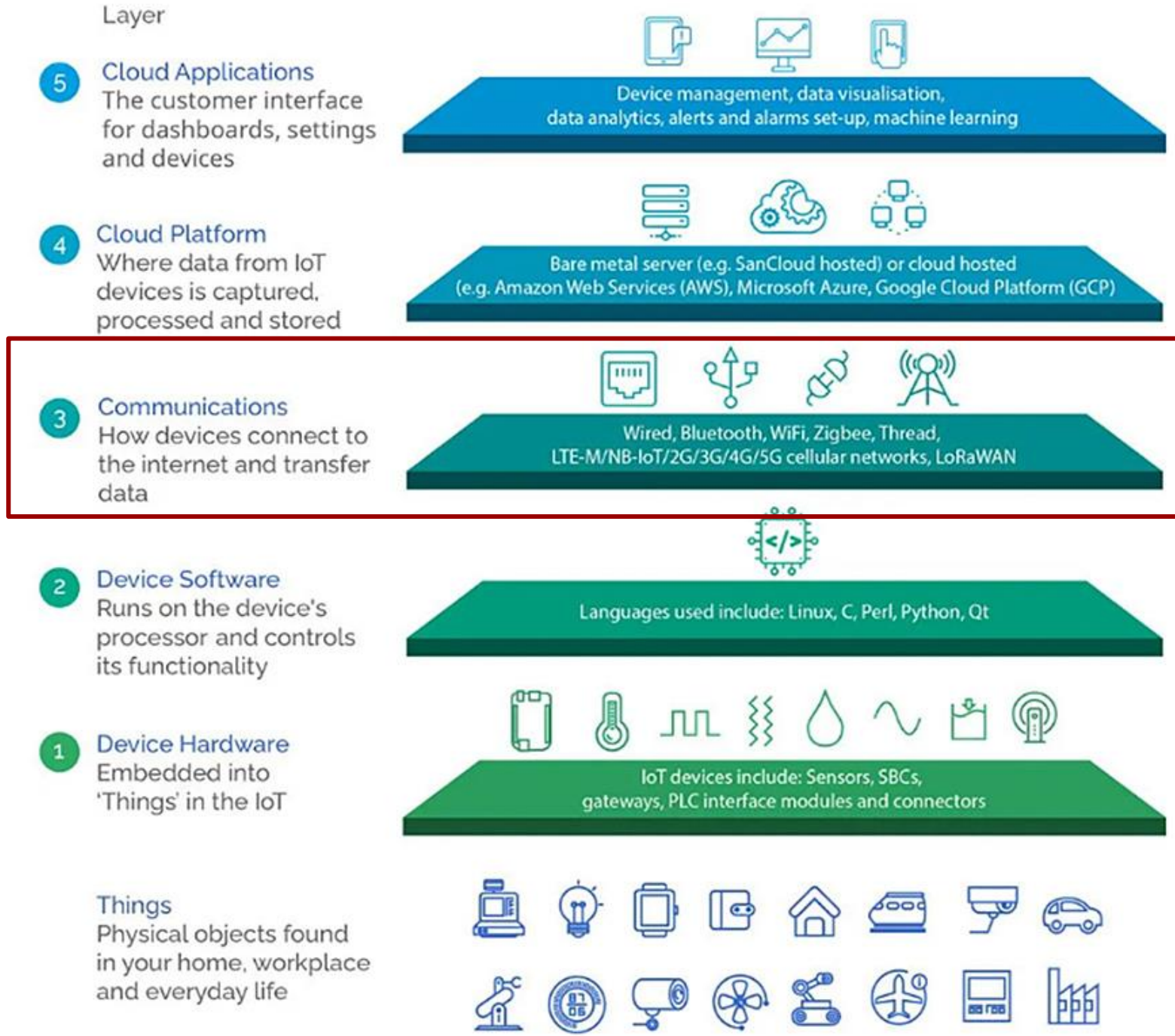
Intro to LPWAN Technologies

Objectives

- Exploring LPWAN Technologies (LoRa, Sigfox, NBIoT)
- IoT Device-to-Cloud Communication
- Cloud Computing Services
- Cloud for IoT Applications

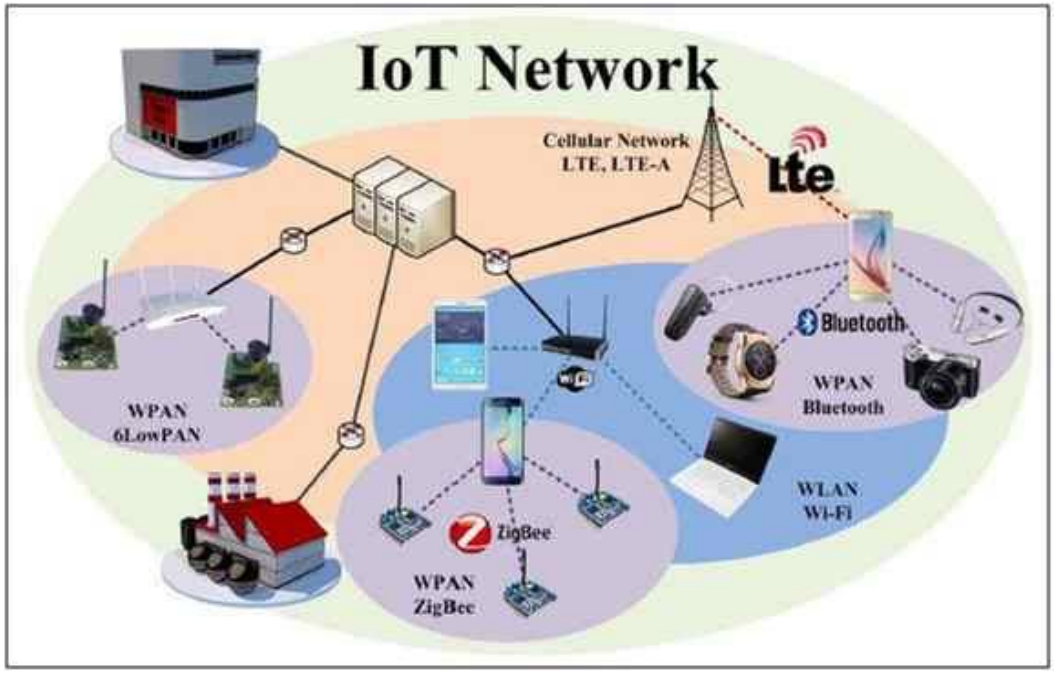




Source: https://iotbusinessnews.com/WordPress/wp-content/uploads/2022/07/IoT-technology-stack-diagram.jpg

IoT Network

- Refers to the communication technologies
- Acts as a communication channel to transfer data between devices, applications and services
- Choosing the proper networking protocol for given requirements



Source: https://www.c-sharpcorner.com/UploadFile/f88748/internet-of-thingsiot-part-4-network-protocols-and-arc/

Network Layer

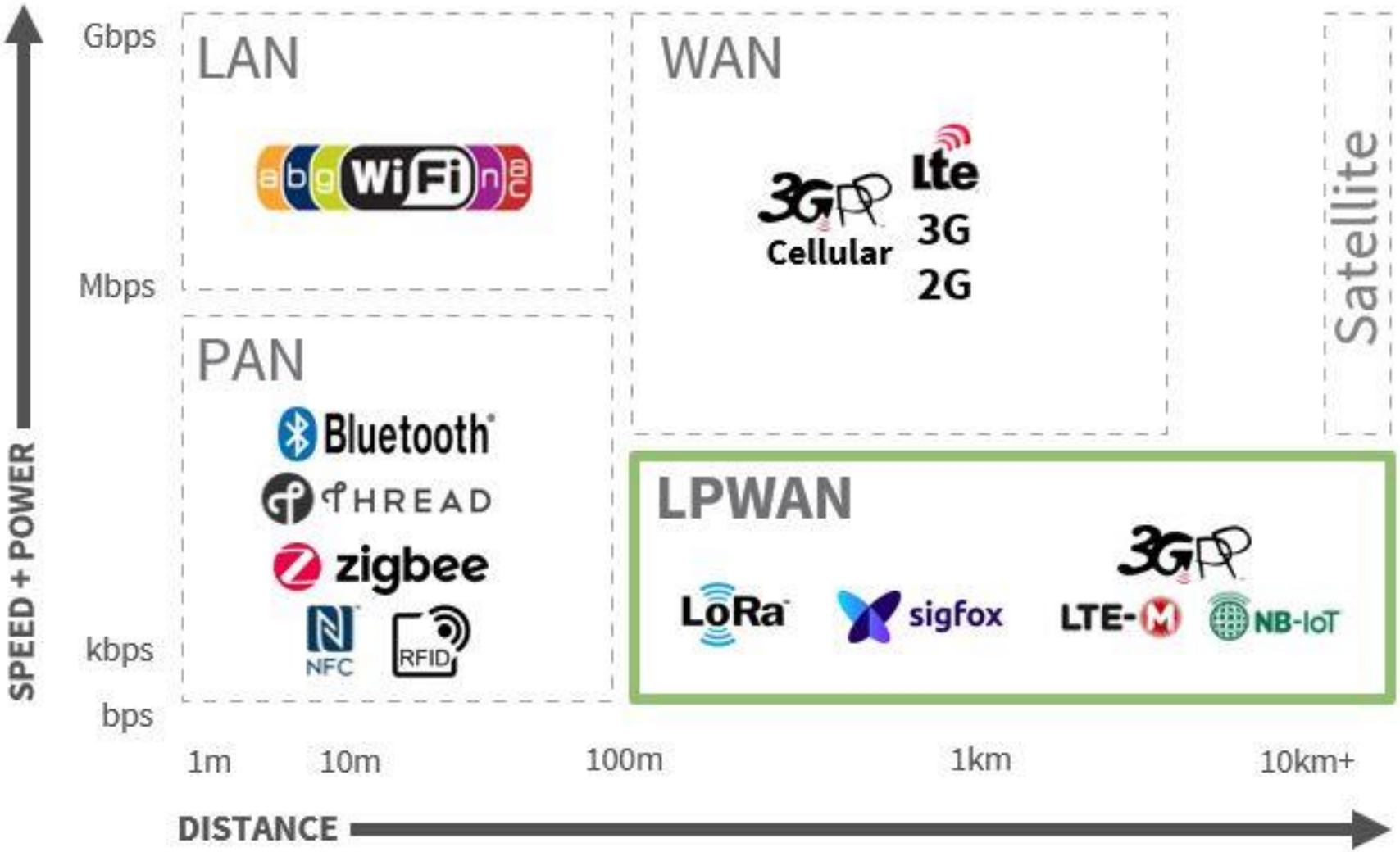
Licensed vs Unlicensed Spectrum Band

Licensed Band

- Reserved bands for radio stations, Mobile Network providers for 2G/3G/4G/5G
- License fee is required for using these bands, cost is high

Unlicensed Band

- Free and open for anyone to use
- No licenses and fees are required



source:https://www.allion.com/iot-lpwan/

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LPWAN Technologies

LPWAN

- LPWANs are designed for **low power** consumption and **long battery life**.
- LPWANs transmit data **over wider areas** than many traditional wireless networks (tens of kilometers).
- **Low cost**, LPWAN's simplified, lightweight protocols reduce complexity in hardware design and lower device costs

Key characteristics of LPWAN technology

Low Bandwidth, Long Range: Interconnects low-bandwidth, battery-powered devices over long distances.

Cost-Effective and Power-Efficient: Operates at lower costs and greater power efficiency compared to traditional mobile networks.

High Device Capacity: Supports a large number of connected devices over expansive areas.

Packet Flexibility: Accommodates packet sizes from 10 to 1,000 bytes for diverse data types.

Uplink Speeds: Offers uplink speeds up to 200 Kbps, suitable for low data rate applications.

Long-Range Capability: Ranges from 2 km to 1,000 km, depending on the specific LPWAN technology.

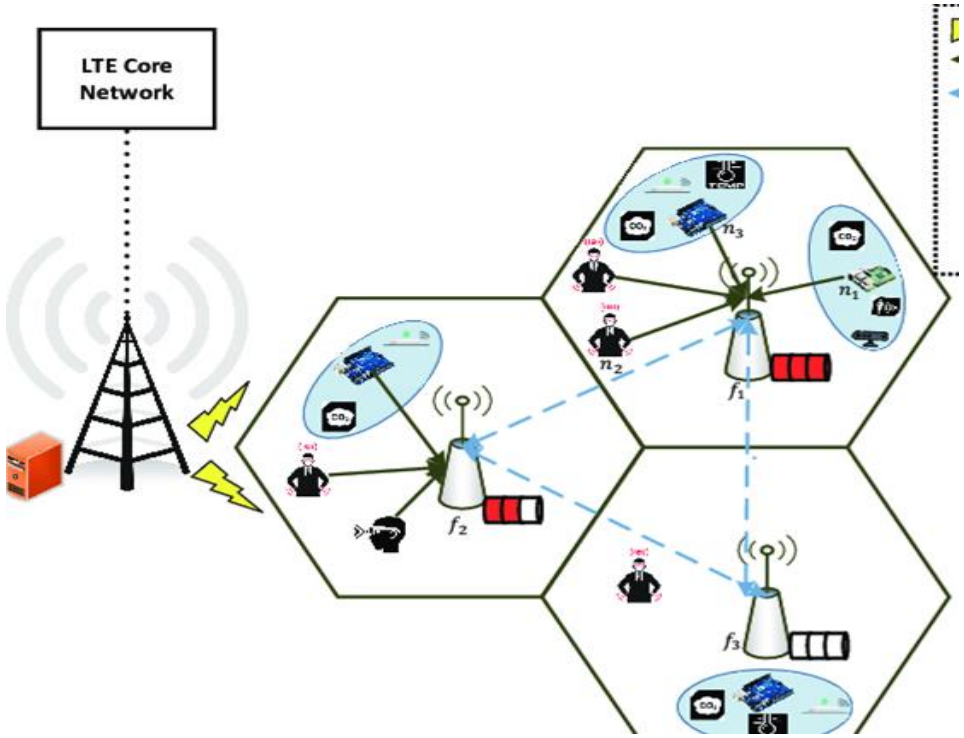
Unlicensed vs Licensed

Unlicensed band LPWAN: Sigfox, LoRa

Licensed band LPWAN: EC-GSM-IoT, LTE-based cellular IoT technologies (LTE-M, NB-IoT)

NB-IoT (Narrowband IoT)

NB-IoT is a standardized cellular technology tailored for low-power, wide-area IoT communication within the 3GPP (3rd Generation Partnership Project) framework. NB-IoT, also known as CAT-NB1, operates on existing LTE and Global System for Mobile (GSM) infrastructure. It offers uplink and downlink rates of around 200 Kbps, using only 200 kHz of available bandwidth.



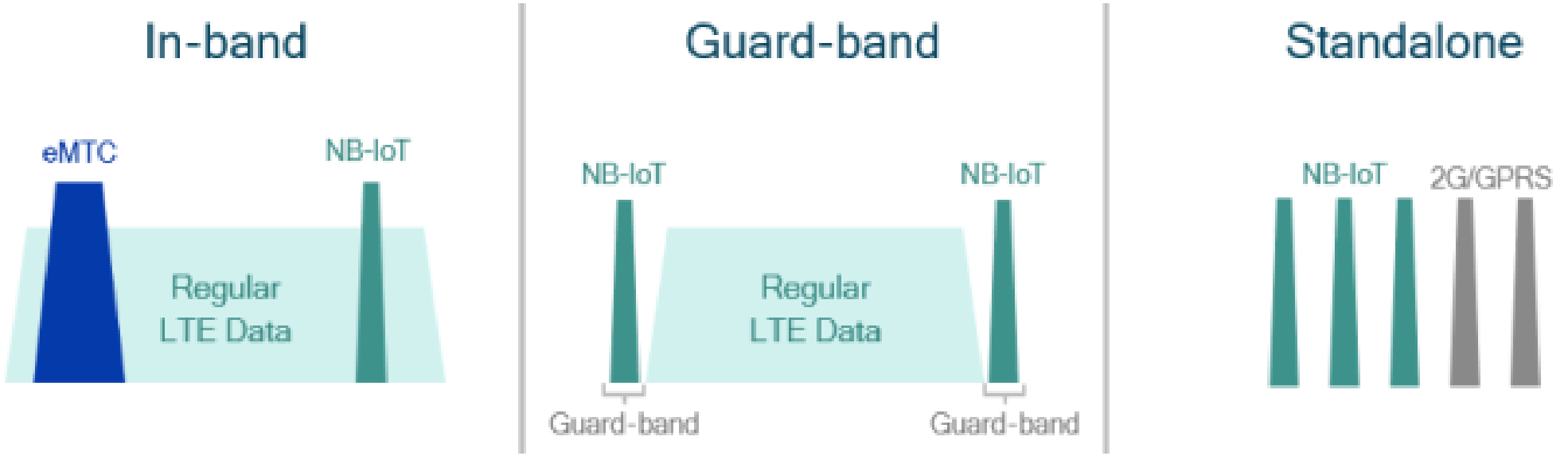
https://www.researchgate.net/figure/Fog-system-model-with-NB-IoT-devices_fig1_329953543

3GPP Release 13 NB IoT Frequency Band Details :

NB Band	*Uplink (UL) Operating Band BS Receive / UE Transmit* F_{UL_low} – F_{UL_high}	*Downlink (DL) Operating Band BS Transmit / UE Receive* F_{DL_low} – F_{DL_high}	*Duplex Mode*
B1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	HD-FDD
B2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	HD-FDD
B3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	HD-FDD
B5	824 MHz – 849 MHz	869 MHz – 894 MHz	HD-FDD
B8	880 MHz – 915 MHz	925 MHz – 960 MHz	HD-FDD
B12	699 MHz – 716 MHz	729 MHz – 746 MHz	HD-FDD
B13	777 MHz – 787 MHz	746 MHz – 756 MHz	HD-FDD
B17	704 MHz – 716 MHz	734 MHz – 746 MHz	HD-FDD
B18	815 MHz – 830 MHz	860 MHz -875 MHz	HD-FDD
B19	830 MHz – 845 MHz	875 MHz – 890 MHz	HD-FDD
B20	832 MHz – 862 MHz	791 MHz -821 MHz	HD-FDD
B26	814 MHz – 849 MHz	859 MHz – 894 MHz	HD-FDD
B28	703 MHz – 748 MHz	758 MHz – 803 MHz	HD-FDD
B66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	HD-FDD

Indian operators mostly utilise B8 for NB-IoT applications

NB-IoT Deployment Strategies

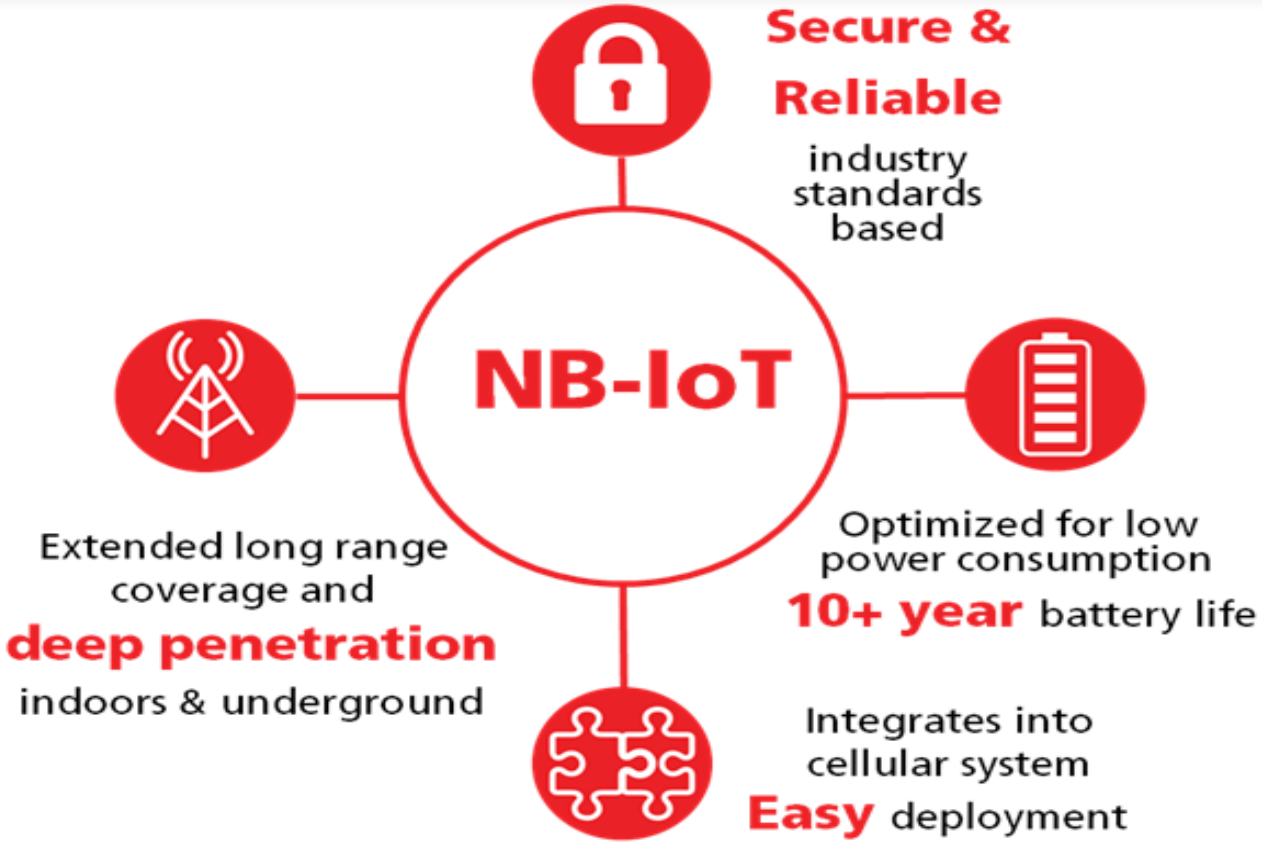


source: https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/whitepaper_-_leading_the_lte_iot_evolution_to_connect_the_massive_internet_of_things_v1.0.pdf

Features of NB-IoT

- **Key Features:**
  - Narrowband spectrum utilization for efficient data transmission.
  - Deep coverage, making it suitable for challenging environments.
  - Extended battery life for devices with sporadic communication needs.
- **Advantages:**
  - Utilizes existing cellular infrastructure.
  - Global standard ensures interoperability
- **Disadvantages:**
  - Higher power consumption compared to non-cellular options.
  - Deployment costs may be influenced by reliance on cellular infrastructure.

NB-IoT in Nutshell



Source: https://www.u-blox.com/en/narrowband-iot-nb-iot

LoRA (from "long range")

LoRa is a low-power WAN transmission technology, mainly used in the Internet of Things. LoRa is the abbreviation of long-range, and long-range is also the core advantage of LoRa, with a long transmission distance of over 15 km in open areas.

Frequency Band for LoRa

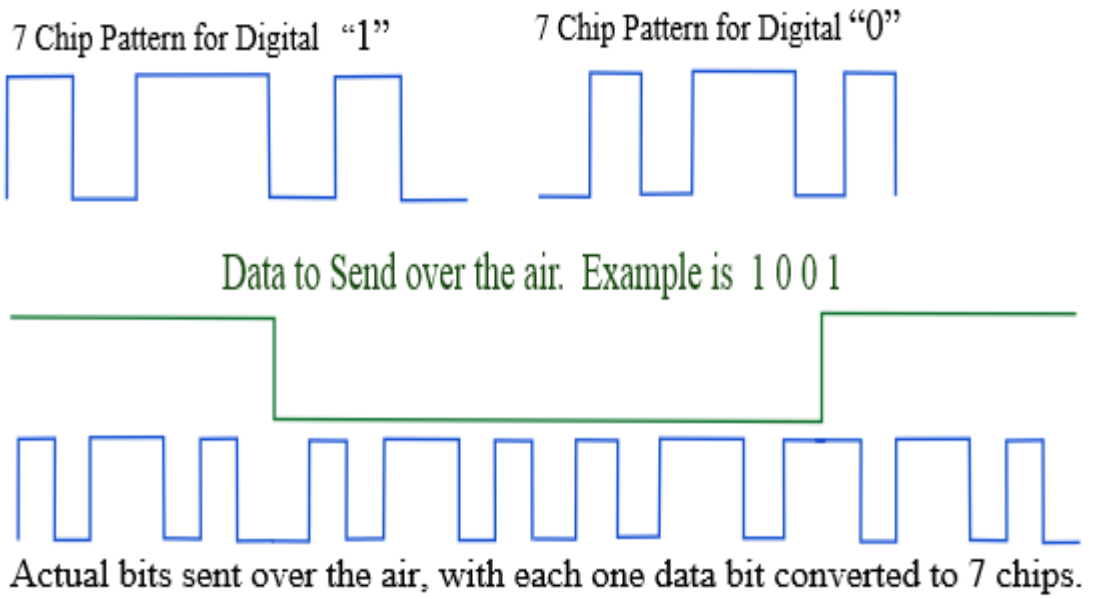
LoRa Frequency Bands (ISM)

Uplink (MHz)	Downlink (MHz)	Channel Bandwidth Uplink (kHz)	Channel Bandwidth Downlink (kHz)	Geographical Area
863	870	125/250	125	Europe
433	434	-	-	Europe
902	928	125/500	500	Region 2 - America, Greenland, eastern Pacific Islands
470	510	-	-	China
779	787	-	-	China
915	928	-	-	Australia, New Zealand
920	923	-	-	South Korea
920	925	-	-	Hong Kong
920	925	-	-	Singapore, Thailand, Vietnam
920	928	-	-	Japan
922	928	-	-	Taiwan
923	925	-	-	Brunei, Cambodia, Indonesia, Laos
865	867	-	-	India

source:https://haltian.com/resource/frequency-bands-for-ten-most-popular-iot-protocols/

LoRA Modulation

- LoRa uses Direct Sequence Spread Spectrum (DSSS) they call Chirp Spread Spectrum (CSS).
- Each bit is spread by a chipping factor.
- The number of chips per bit is called the spread factor.
- The larger the spreading factor, the slower the over-the-air data rate.
- Slower the data rate, the better the receiver sensitivity and the longer the potential communication range.



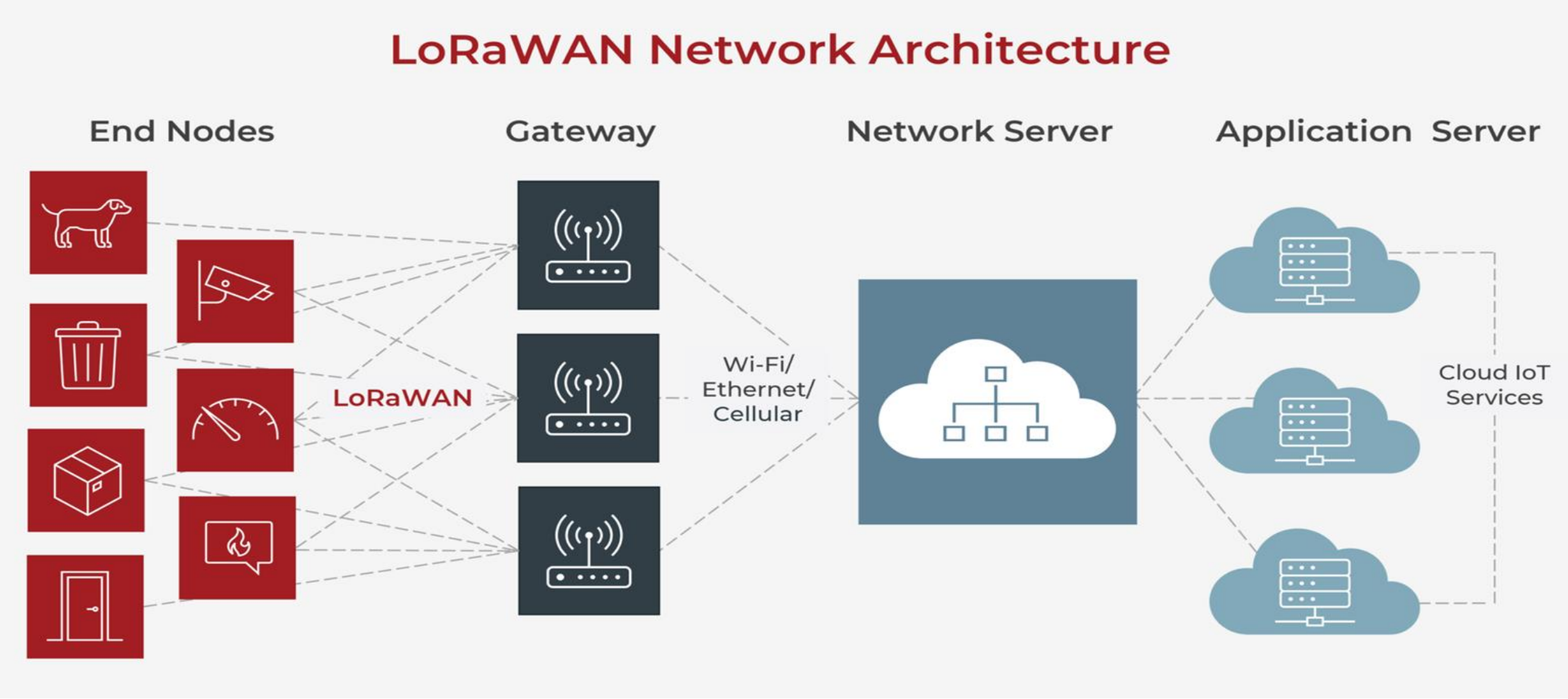
Advantages of LoRA

- **Long transmission distance**: communication distance up to 15 kilometers
- **Low working energy consumption**: Only connects when there is data, and the battery can work for several years
- **Multiple network nodes**: In flexible networking mode, multiple nodes can be connected
- **Low cost**: unlicensed spectrum, low node/terminal cost
- **Strong anti-interference**

Disadvantages of LoRA

- **Spectrum interference**: With the continuous development of LoRa, LoRa equipment, and network deployment continue to increase, and certain spectrum interference will occur between each other.
- **Need to build a new network**: During the LoRa deployment process, users need to build their own network.
- **Small payload**: The payload of LoRa transmission data is relatively small and has a byte limit.

Overview of LoRaWAN Network Arch.



source: https://www.cardinalpeak.com/blog/setting-up-a-lora-gateway-to-view-iot-device-data

SigFox

Sigfox is a long range cellular wireless communication that offers custom solutions primarily for low-throughput Internet of Things (IoT) and M2M applications by availing its end-to-end IoT connectivity services using it's patented technologies.

The Sigfox network protocol has patented base stations that are integrated with software defined radios.

Sigfox service operates in the ISM and SRD bands worldwide from **862 to 928** MHz.

Advantages of SigFox

✅ **low power consumption**: Ideal for simple devices that transmit data infrequently, as it can send small amounts of data at a slow pace.

✅ provides **wide coverage** in the areas where it is available.

✅ It is **simple to set up** and does not require cables or complicated installation procedures.

Sigfox can significantly reduce energy consumption and expenses related to connected devices.

This platform is ideal for low-power applications that transmit small amounts of data at irregular intervals across long distances.

Disadvantages of SigFox

❌ It is not deployed everywhere, so it won't work for a large number of use cases currently.

❌ Communication is better headed up from the endpoint to the base station. It has bidirectional functionality, but its capacity from the base station back to the endpoint is constrained, and you'll have less link budget going down than going up.

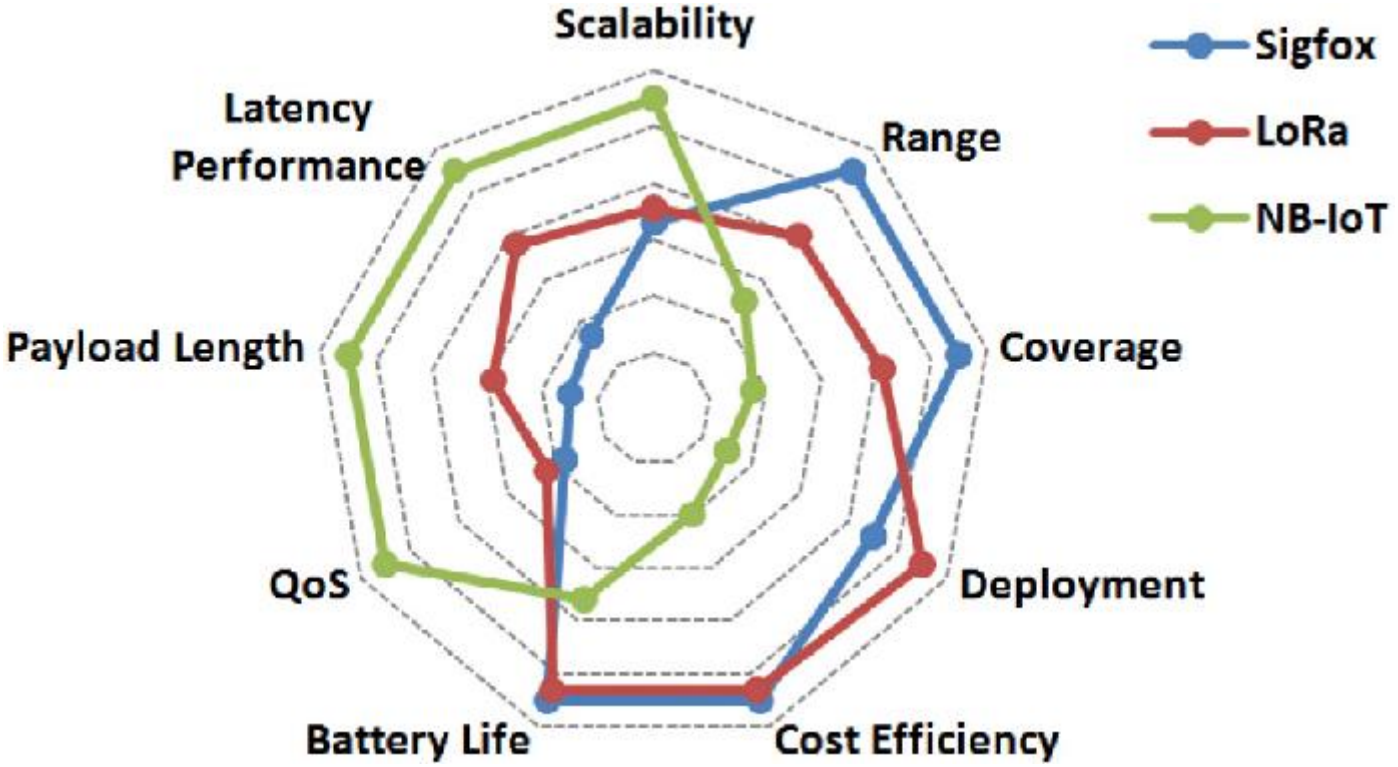
❌ Mobility is difficult with Sigfox devices.

Comparison of different Technologies

	LoRa	Sigfox	NB-IoT
Bandwidth	250 kHz	100 Hz	200 kHz
Data rate	20 kbps	100 bps	200 kbps
Communication range	1 km (urban), 20 km (rural)	10 km (urban), 40 km (rural)	1 km (urban), 10 km(rural)
Private network	YES	No	No
Energy consumption	Low	Low	Low
Standardisation	LoRa-Alliance	ETSI	3GPP

source: Industrial Internet of Learning (IIoL): IIoT based pervasive knowledge network for LPWAN—concept, framework and case studies

Comparison contd..



source: A comparative study of LPWAN technologies for large-scale IoT deployment, Mekki et. al

	2G	LTE-M	NB-IoT	sigfox	LoRa
Netwok coverage	●●●	●●●	●●○	●●○	●●○
Bandwidth	●●○	●●○	●○○	●○○	●○○
Battery life	●●●	●●●	●●●	●●●	●●●
Building penetration	●●○	●●○	●●●	●●○	●●○
Roaming	✓	✓	✓	restricted	very difficult
Real-time tracking	✓	✓	×	×	×
Licensed frequency spectrum	✓	✓	✓	×	×
Hardware independent	✓	✓	✓	×	×
Suitable for emergency systems	✓	✓	×	×	×
Usage examples					

Source: https://powunity.com/en/sigfox-lora-independent-radio-networks-for-data-exchange

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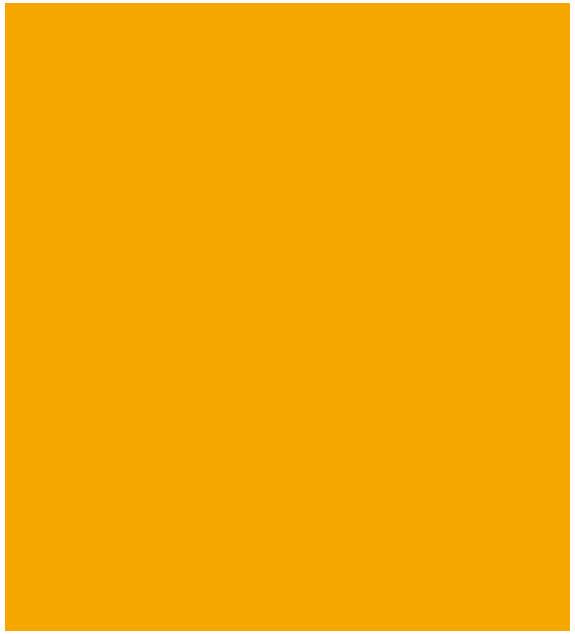
IoT Communication Introduction



Introduction

Communication forms the heart of the Internet of Things. It enables the seamless interaction between devices, creating a network that offers real-time data and insights. The importance of communication in IoT lies in its ability to facilitate immediate action and decision-making based on the data shared.

Device-to-Device (D2D)

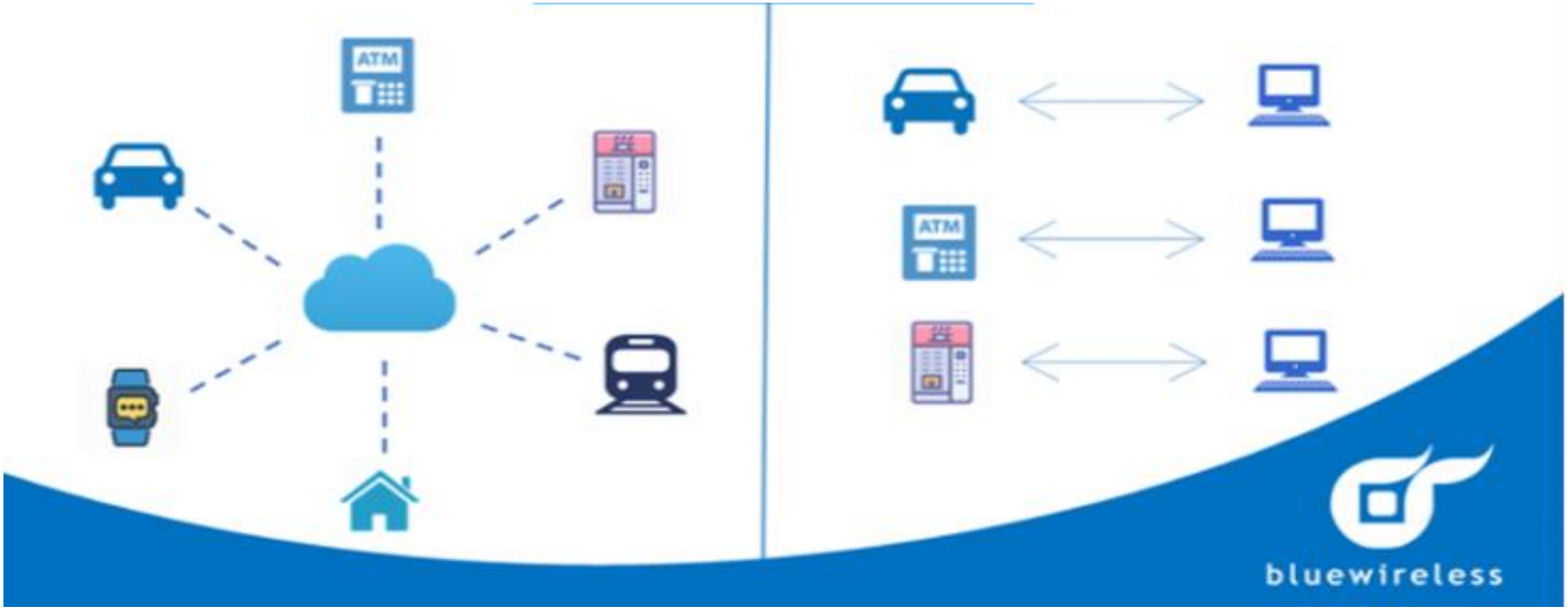
- allows direct communication between IoT devices without the need for a central hub or network infrastructure
- useful in scenarios where devices are in the close proximity of each other and can exchange data directly, reducing latency and network load
- enhances the efficiency of IoT systems, facilitating real-time data exchange and immediate responses

Device-to-Cloud (D2C)

- allows IoT devices to send data to cloud-based applications for storage, analysis, and further action
- essential where cloud analytics can provide valuable insights for decision making or where remote access to the device's data is required
- MQTT and HTTP protocols are commonly used due to their robustness and reliability over the internet
- Scalability and flexibility make it a powerful tool for handling vast volumes of data generated by IoT devices

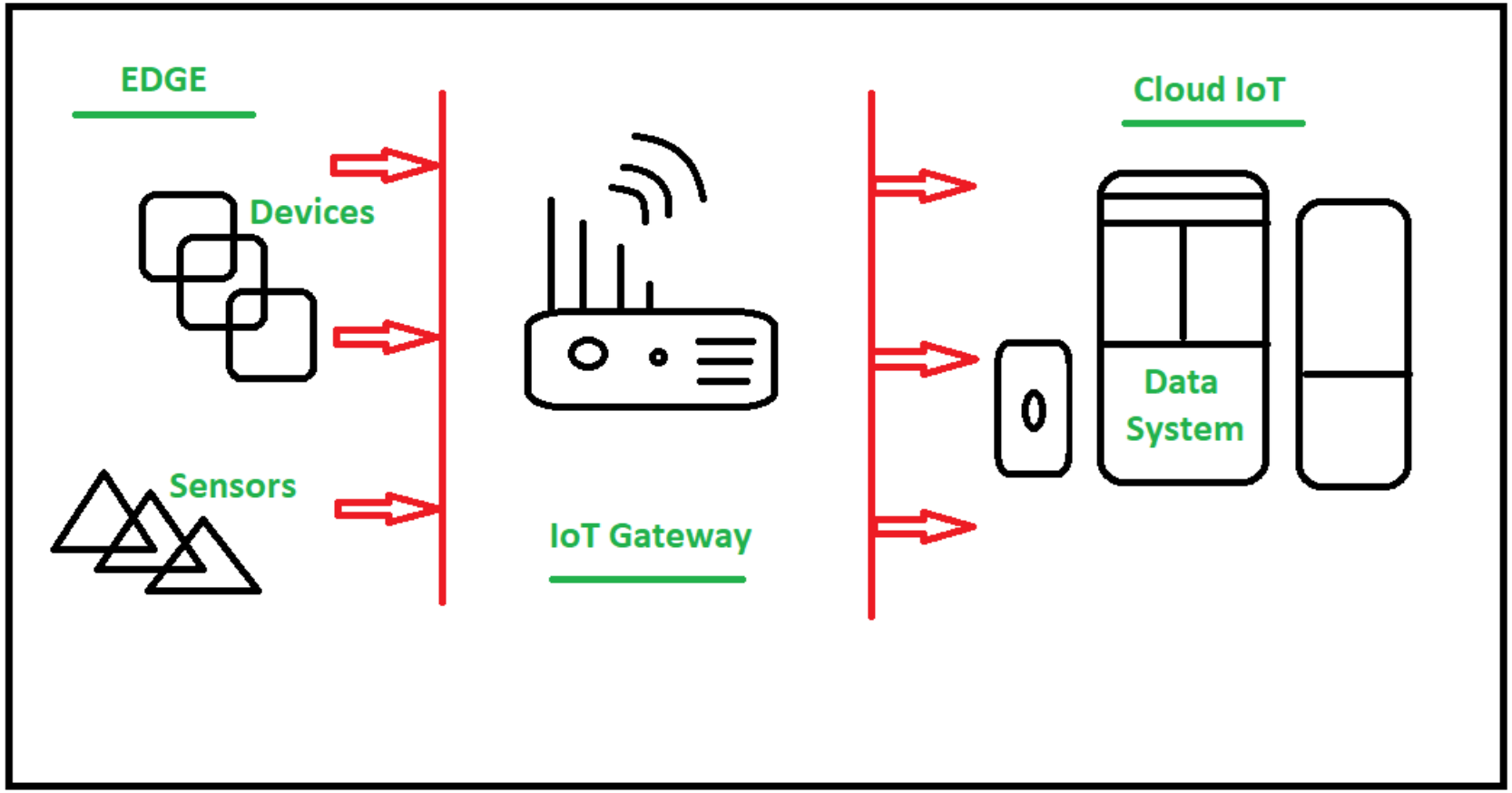
Device to Cloud

Device to Device



source: https://www.speranzainc.com/what-is-machine-to-machine-device-to-device-internet-of-things/

Device to Gateway



source:https://www.geeksforgeeks.org/internet-of-things-iot-gateways/

Device-to-Gateway (D2G)

- IoT device connects to an intermediary device called “gateway”
- Gateway is a bridge between devices and cloud or central system
- Gateway device collects the data, processes it and sends it forward
- Useful in scenarios where devices may not be able to connect directly to network
- Power conservation is also an advantage
- Gateway can provide additional processing power, security

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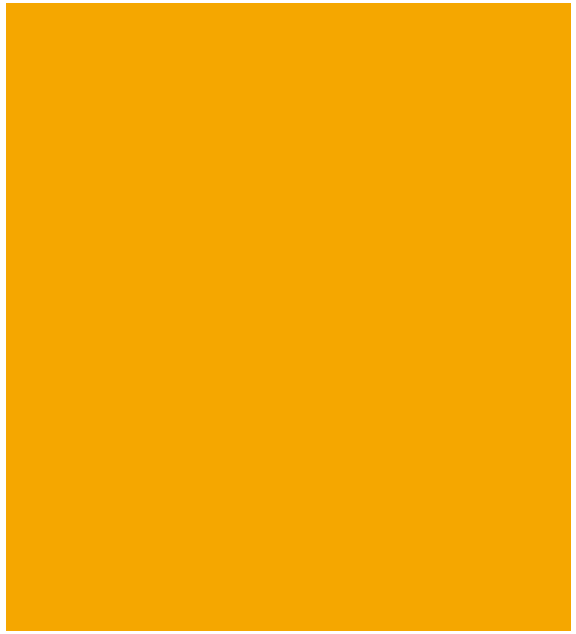
Cloud Computing Services

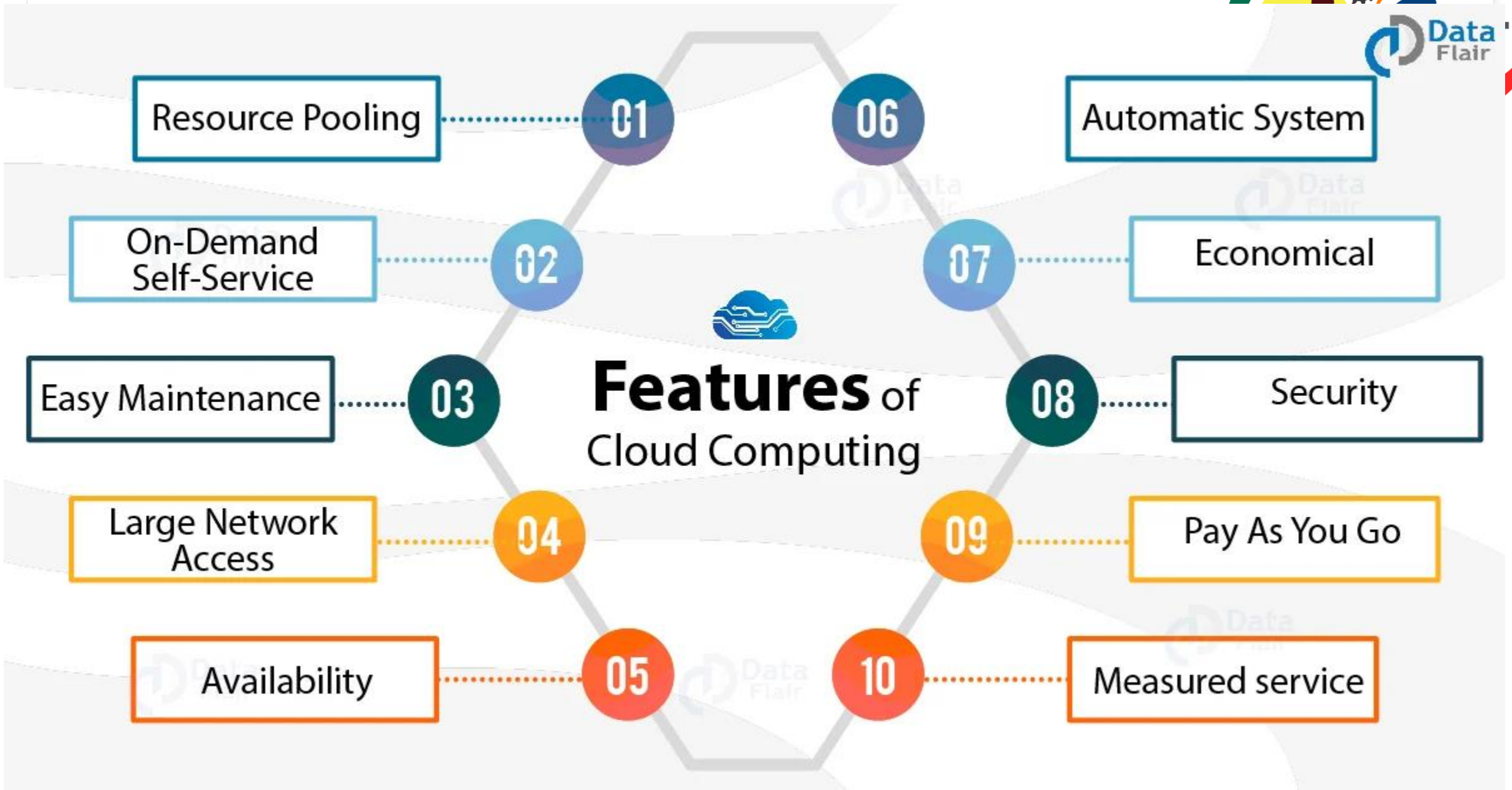


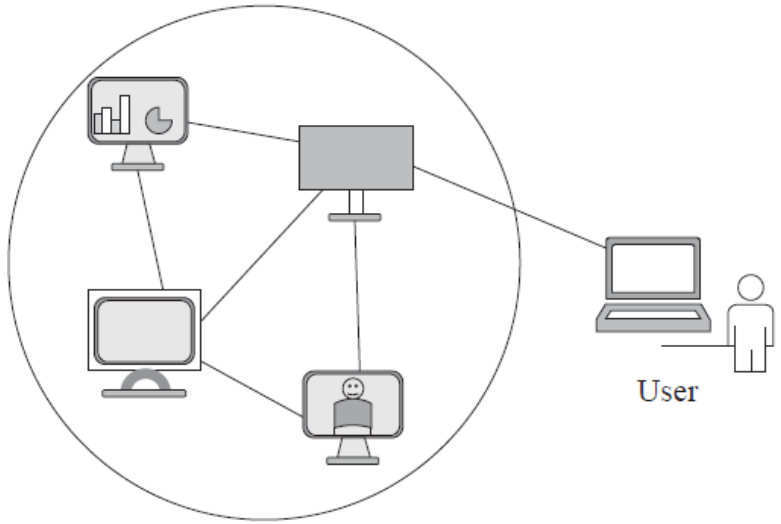
What is cloud computing?

- Cloud computing is a technology paradigm that involves delivering various computing services, including storage, processing power, networking, databases, analytics, software, and more, over the internet. Instead of relying on local servers or personal devices to handle applications and store data, users can **access and utilize these services remotely through the internet**.

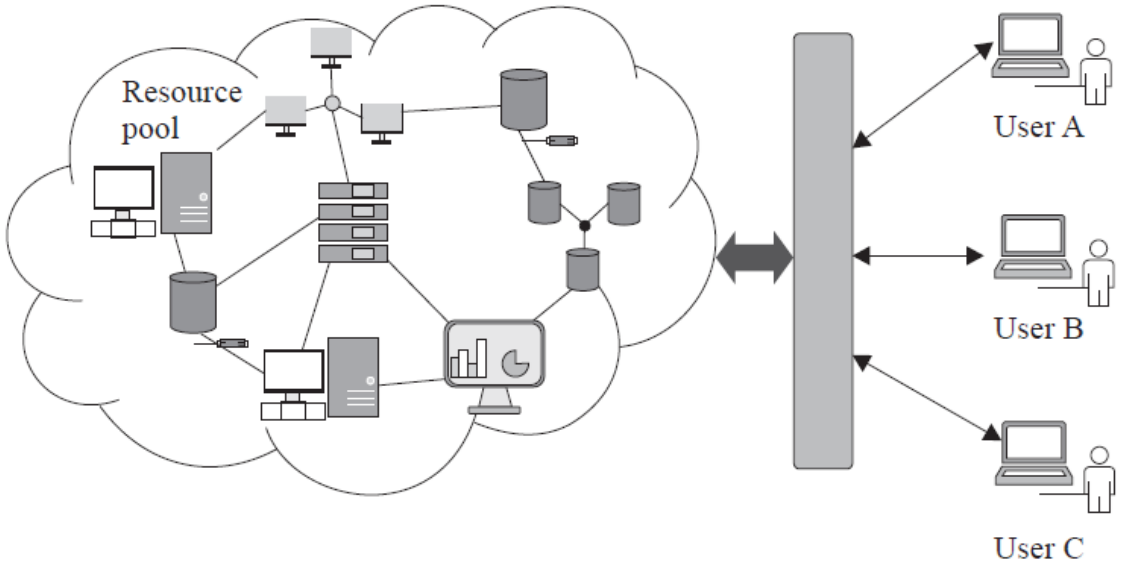
Features of cloud computing

- **On-Demand Self-Service:** Users can provision and manage computing resources as needed without requiring human intervention from service providers.
- **Broad Network Access:** Cloud services are accessible over the internet from a variety of devices, such as laptops, smartphones, and tablets.
- **Resource Pooling:** Cloud providers consolidate computing resources and serve multiple customers, allowing them to benefit from economies of scale.
- **Rapid Elasticity:** Cloud resources can be quickly scaled up or down to accommodate changes in demand. Users only pay for the resources they consume.


Features of
Cloud Computing
01
Resource Pooling
02
On-Demand
Self-Service
03
Easy Maintenance
04
Large Network
Access
05
Availability
06
Automatic System
07
Economical
08
Security
09
Pay As You Go
10
Measured service



(a) Network computing

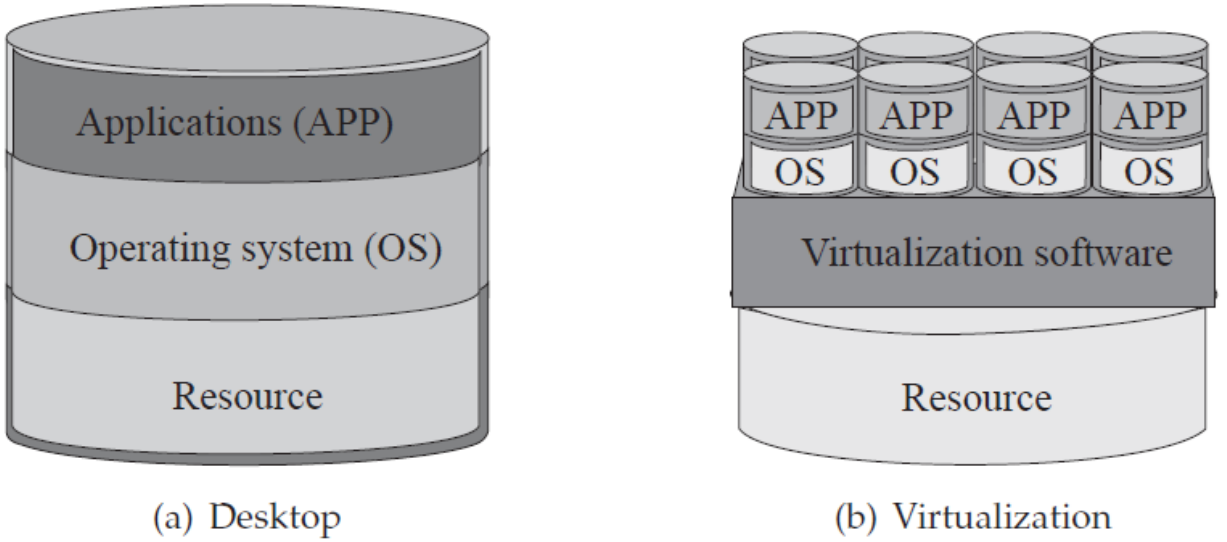


(b) Cloud computing

Network computing vs Cloud computing, source: Misra et al. Introduction to IoT

Virtualization

- **The technique of sharing a single resource among multiple end user organizations or end users is known as virtualization.**



Traditional desktop vs Virtualization, source: Misra et al. Introduction to IoT

Services

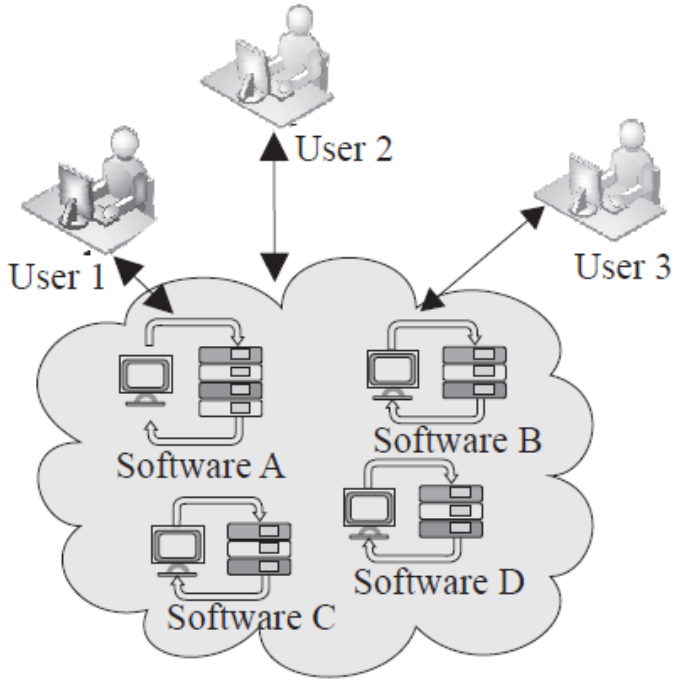
There are different types of service models in Cloud computing:

- **Software as a service (SaaS)**
- **Platform as a service (PaaS)**
- **Infrastructure as a service (IaaS)**

Software as a Service

- **This service provides access to different software applications to an end user through Internet connectivity.**
- **For accessing the service, a user does not need to purchase and install the software applications on his/her local desktop.**

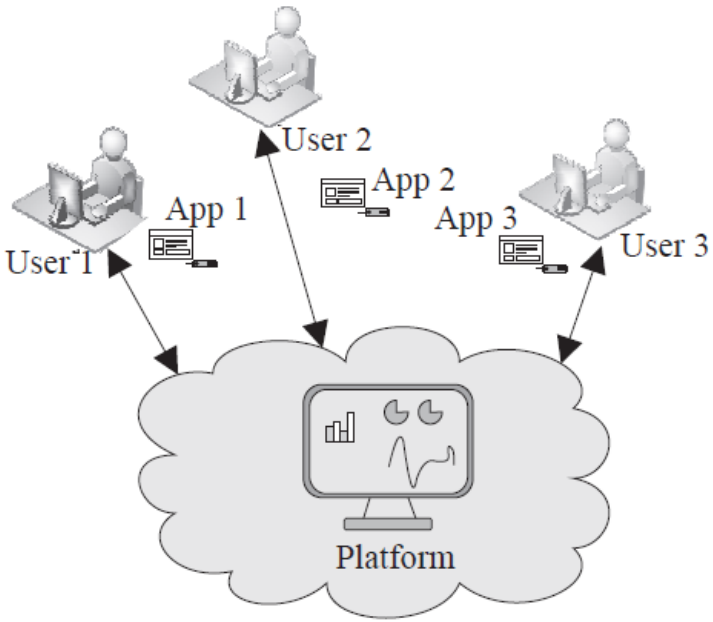
- **Ex:- Microsoft Office 365**



Software as a service, source: Misra et al. Introduction to IoT

Platform as a Service

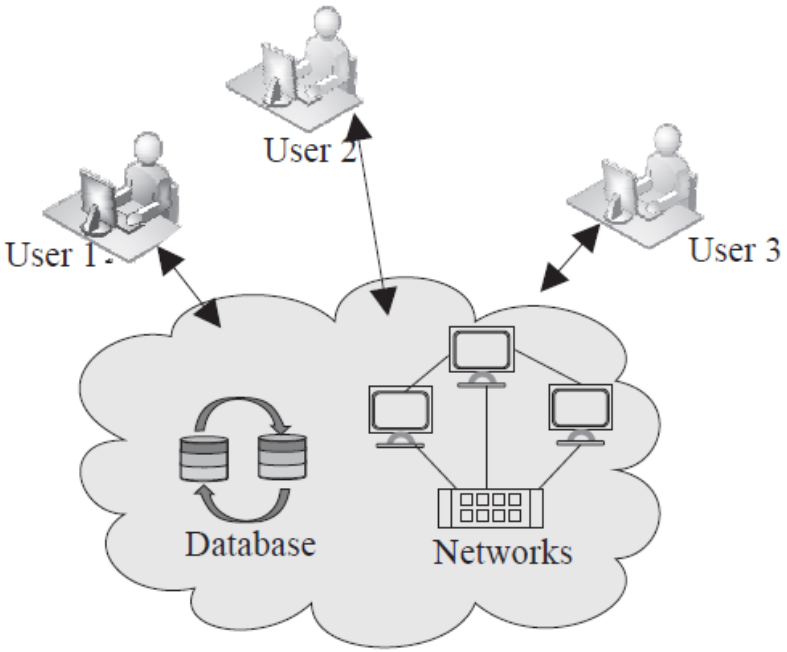
- **PaaS provides a computing platform, by which a user can develop and run different applications.**
- **The cloud user need not go through the burden of installing and managing the infrastructure such as operating system, storage, and networks.**
- **Example: Windows Azure**



Platform as a service, source: Misra et al. Introduction to IoT

Infrastructure as a Service

- **IaaS provides infrastructure such as storage, networks, and computing resources.**
- **A user uses the infrastructure without purchasing the software and other network components.**
- **Example: Storage space**



Infrastructure as a service, source: Misra et al. Introduction to IoT

Examples

Platform Type	Examples
SaaS	Shopify, MailChimp, Dropbox, Hubspot, Google Applications (G Suite)
Paas	AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Google App Engine, Apache Stratos, OpenShift
IaaS	Amazon Web Services (AWS), Microsoft Azure, Google Compute Engine (GCE), IBM Cloud, Rackspace, Digital Ocean, Oracle Cloud

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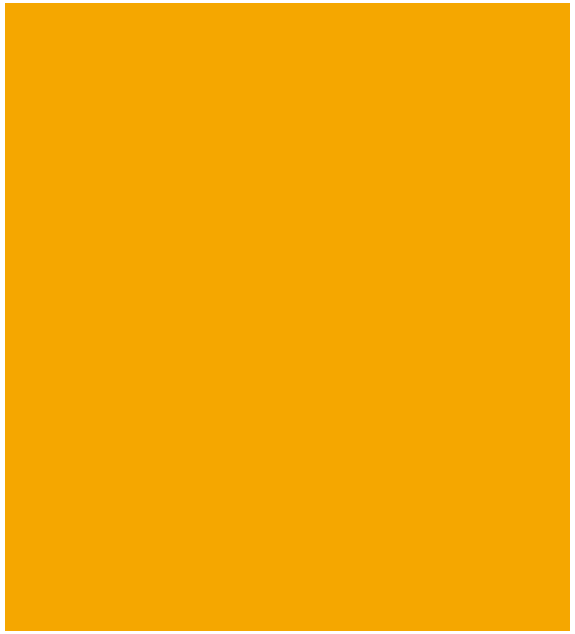
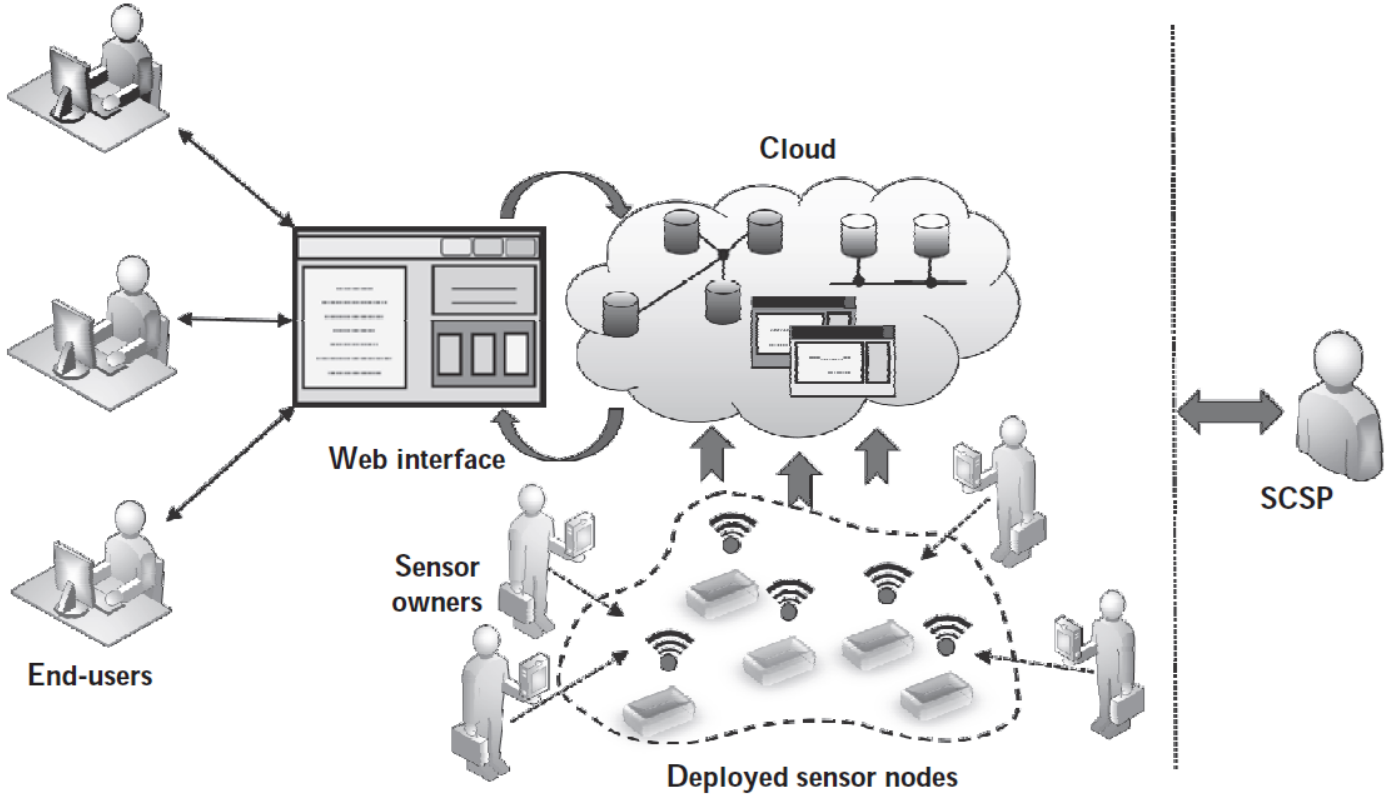
Cloud for IoT applications



Sensor cloud

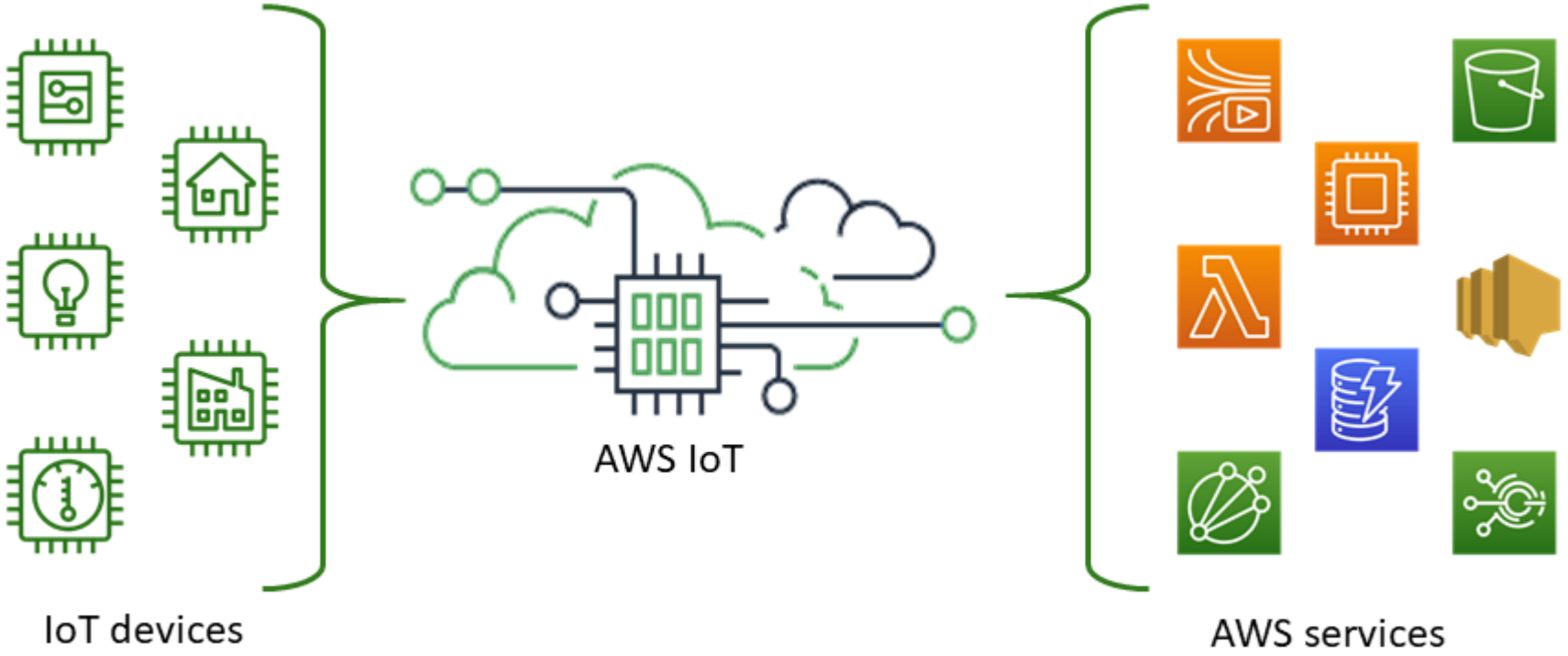
- **In a sensor-cloud, virtualization of sensors plays an essential role in providing services to multiple users.**
- **Typically, in a sensor-cloud architecture, multiple users receive services from different sensor nodes, simultaneously.**

Sensor cloud architecture



Sensor-cloud architecture, source: Misra et al. Introduction to IoT

AWS IoT Core



AWS IoT services offering

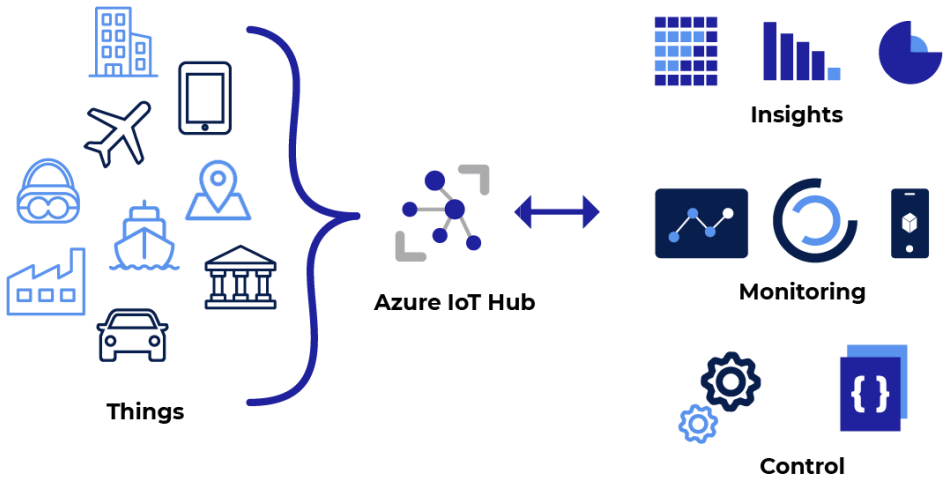
Source : https://docs.aws.amazon.com/iot/latest/developerguide/what-is-aws-iot.html

AWS IoT

- cloud services that connect IoT devices to other devices and AWS cloud services
- Provides device software to integrate devices into IoT-based solution
- AWS supports various protocols
- Provides different services as per requirements

Azure IoT Hub

- **IoT Hub is Microsoft's Internet of Things (IoT) platform as a service (PaaS) solution that acts as a gateway between connected objects and the cloud platform.**
- **IoT Hub enables two-way communication between the cloud and connected objects.**
- **IoT Hub keeps an identity register of all devices connected to the platform. It stores information about the devices, their authentication details, and access rights.**



Azure IoT hub

source :https://dev.to/lanreogunlade1998/creating-an-iot-hub-on-azure-portal-and-authenticate-using-raspberry-pi-587a

Programming Exercise

Link for Colab

We will cover basics of strings, lists, index, slicing, tuples.

Homework

- Define various characteristics of LoRA and NB-IoT?
- What is cloud computing?
- What is virtualisation in cloud computing?
- What is meant by licensed and unlicensed spectrum?

Summary

- We explored different LPWAN technologies
- Overview of NB-IoT, LoRA, Sigfox
- IoT Device-Communications
- Cloud Computing Services

Thank you!