Exploring the Convergence of IoT and AI

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Tashkent, Uzbekistan, 15-19 May 2023

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Introduction to IoT

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1. IoT Introduction and History
2. Architecture
3. Sensors
4. Dev boards
5. Protocols
6. Communication models
7. Edge Computing

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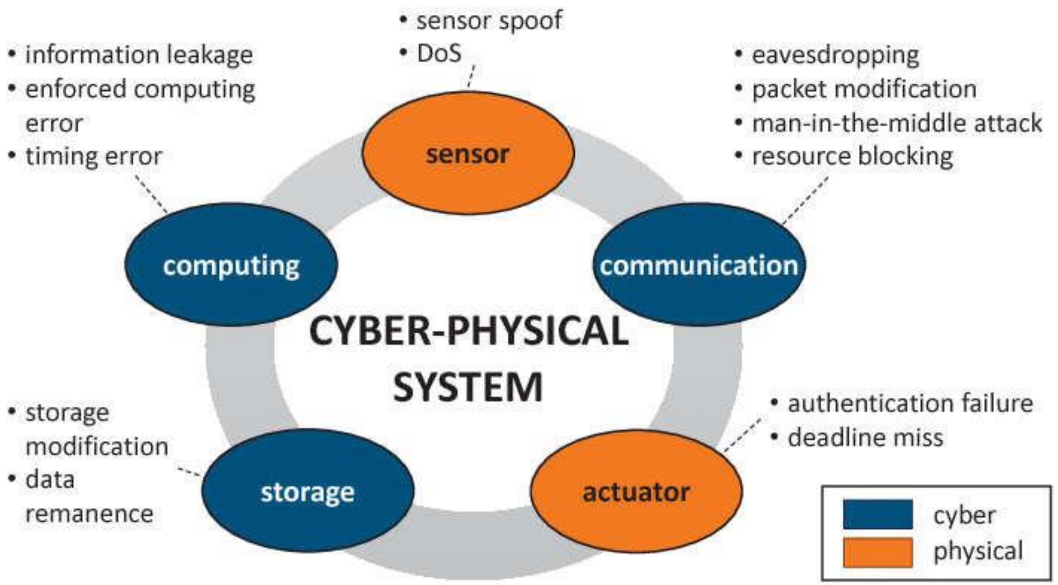
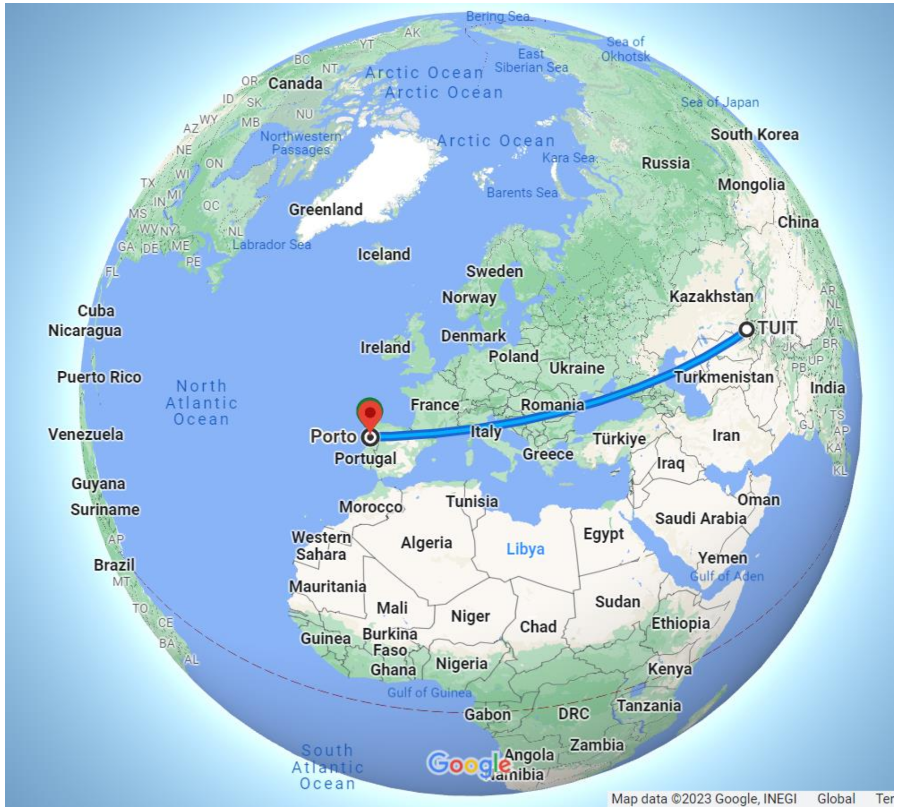
About me.





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Internet of Things.

"IoT is not about connecting Things. It´s about connecting people, processes, and data. It´s about unlocking insights, creating new business models, and improving our quality of life."

Sanjay Brahmawar, CEO at Software AG

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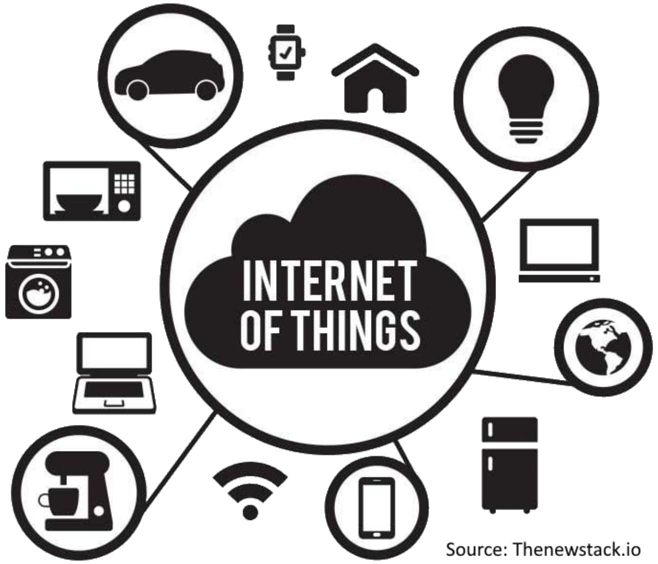
What is IoT?

In simple terms, IoT is a **network** of everyday **physical objects** like smart thermostats, security cameras and even fridges that are connected to the internet and can communicate with each other. These **devices** are equipped with **sensors, software**, and **connectivity**, which allow them to collect and share information with other devices and systems.

The idea is to use technology to **make our lives easier**, more **efficient**, and more **productive** by creating a network of smart services that can automate tasks, gather and analyse data and make decisions based on that data.



Source: Thenewstack.io

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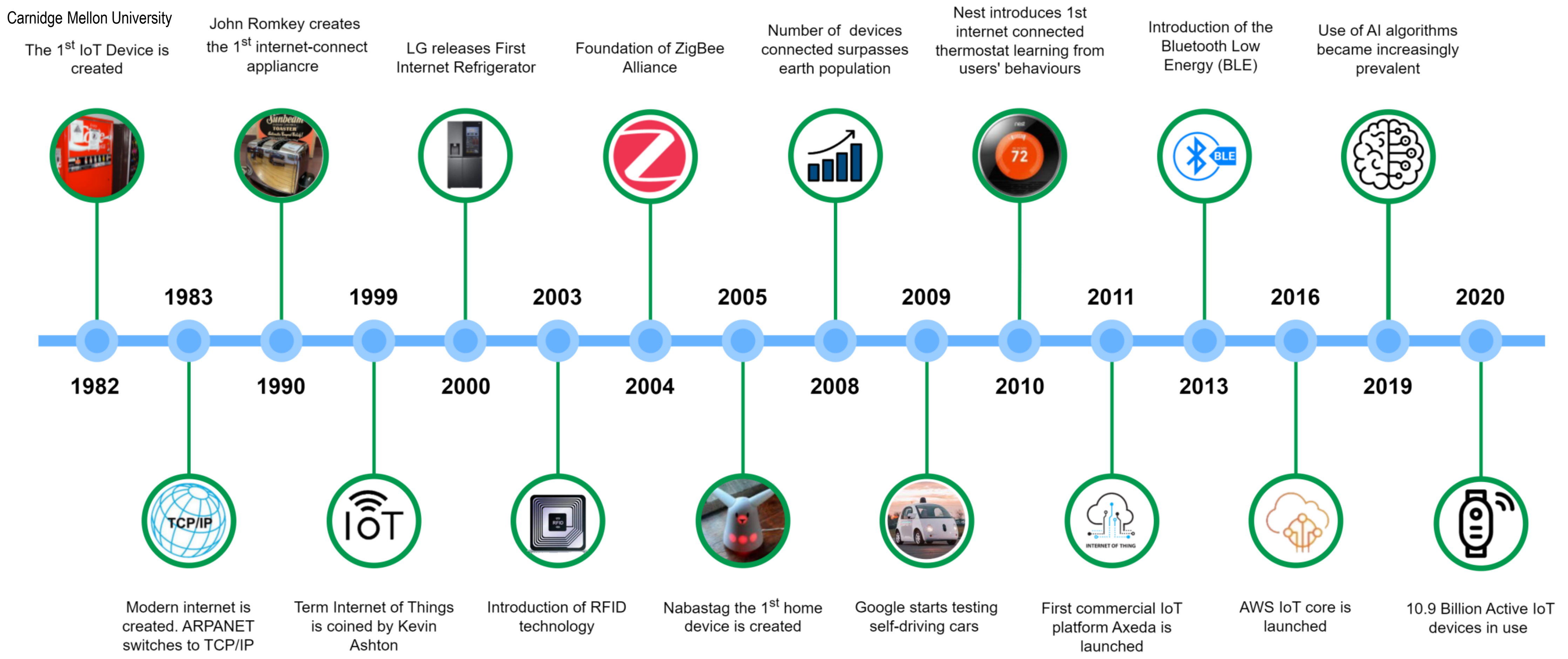
History of Internet of Things



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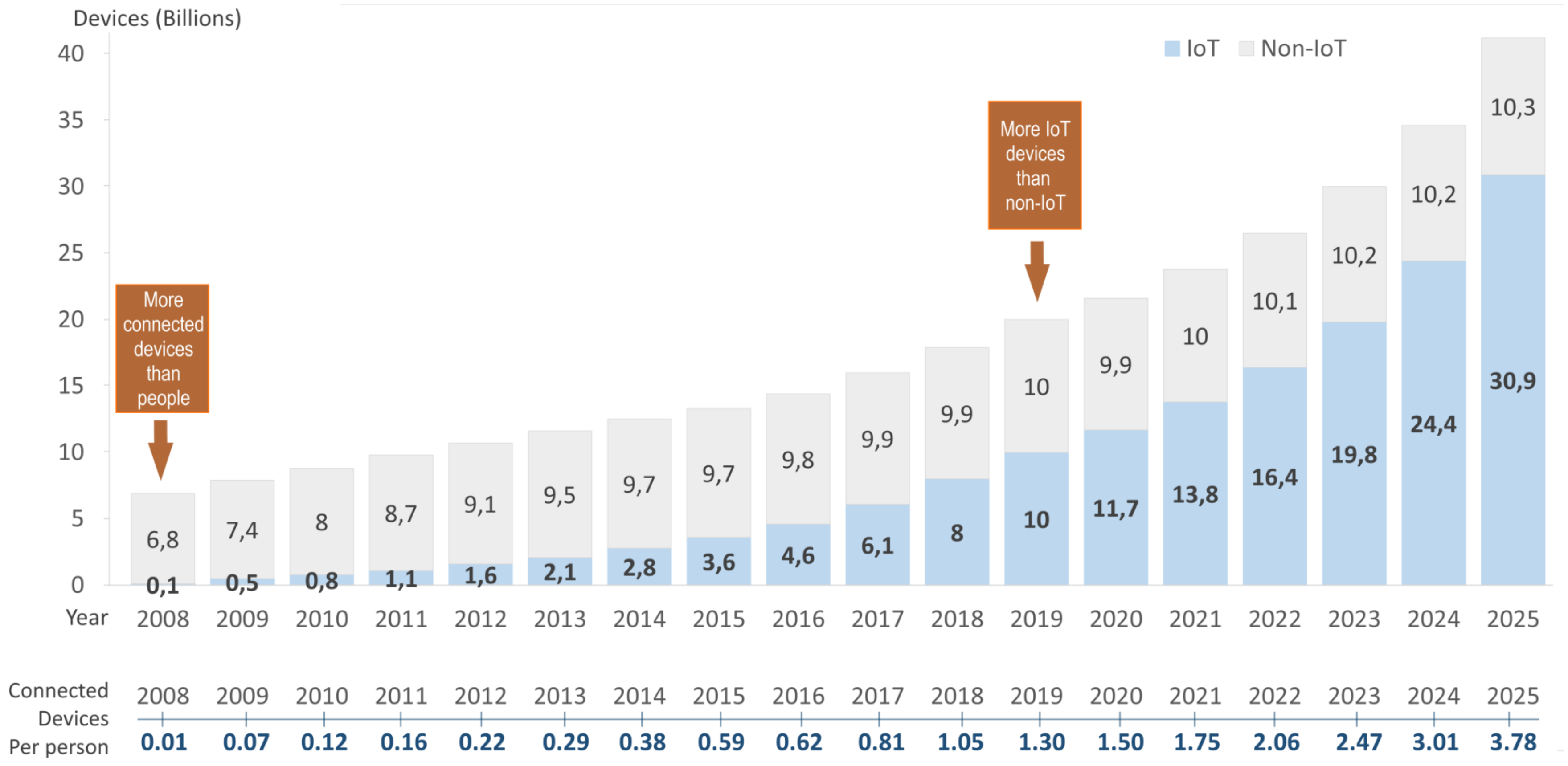
Active IoT Devices



Source: IoT Analytics Research 2018

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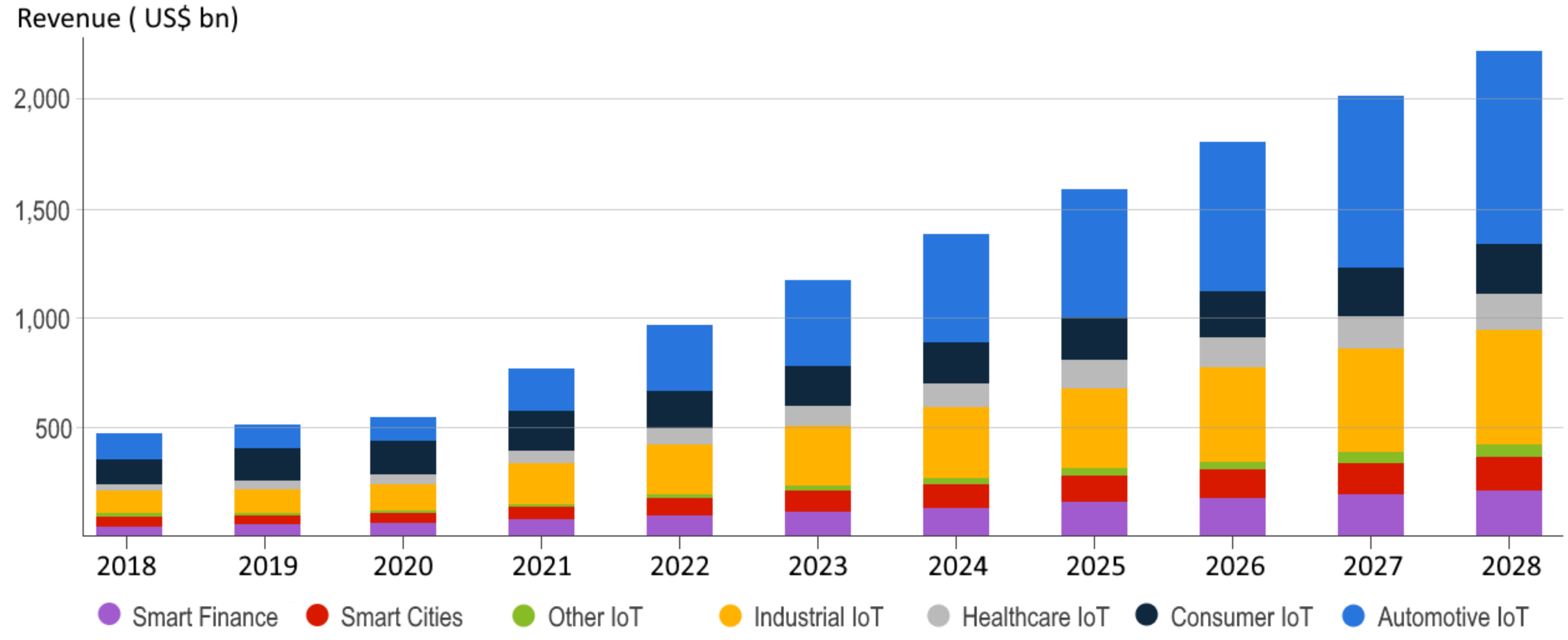
Internet of Things Worldwide

- Revenue in the IoT market to reach US$1,177.00bn in 2023
- The market´s largest segment is Automotive with a market volume of US$397.20bn in 2023
- Revenue annual Growth rate of 13.6% (CAGR 2023-2028) resulting in a market volume of US$2,227,00bn in 2023



Source: Statista

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How IoT is transforming industry and every day life?

Healthcare: Wearable fitness trackers and smartwatches monitor vital signs, track physical activity, and provide real-time health data.

Agriculture: IoT sensors in fields and on livestock can monitor soil moisture, temperature, and crop growth, enabling farmers to optimize irrigation, fertilizer usage, and overall crop health.

Smart Homes: IoT devices in smart homes can be controlled remotely via smartphones or voice assistants, allowing homeowners to adjust temperature, lighting, and security settings for enhanced energy efficiency, convenience, and security.

Manufacturing: IoT enables interconnected machines in manufacturing, collecting real-time data on performance, inventory, and energy. This allows for predictive maintenance, efficient resource allocation, and streamlined production processes in smart factories.

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How IoT is transforming industry and every day life?

Transportation: Sensors and communication technologies in cars enable features like GPS navigation, real-time traffic updates, automated safety systems and optimize supply chain management.

Retail: IoT devices in retail stores, such as beacons and RFID tags, enable personalized shopping experiences, inventory management, and targeted advertising

Energy Management: IoT devices can monitor and control energy consumption in homes and buildings, helping to optimize energy usage, reduce waste, and lower costs. Smart grids enable better management of electricity distribution and integration of renewable energy sources.

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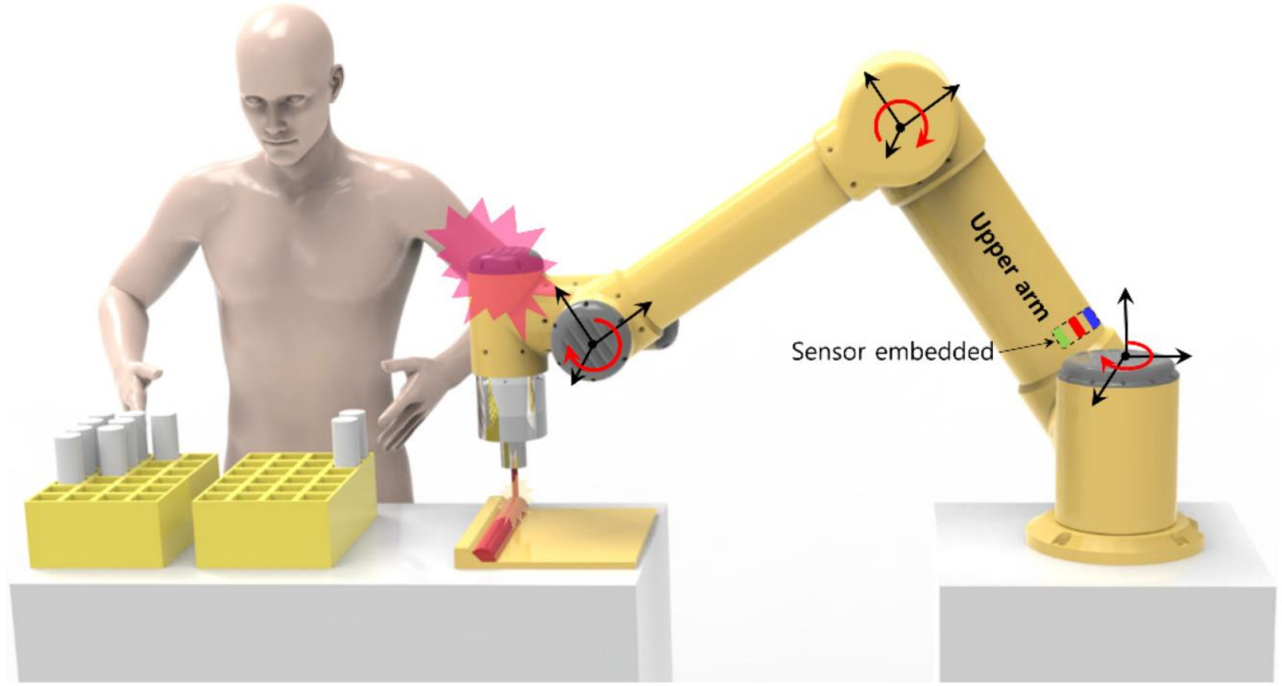
Why IoT is important in Robotics?



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How IoT Works?

Data ingestion 1

IoT decices/sensors collect data from the environment. The data can be as simple as temperature/humidity or it can be as complex as a full video feed.

Data Transmission 2

The data is transmitted to the cloud via Gateways (Telemetry devices).
The gateway use both the cellular as well the satellite or cable communication to transmit the data.
To ensure data security, protocols such as Bluetooth, LoRa, ZigBee, REST, MQTT, NB-IoT etc. are used

Data Processing 3

Once the data gets to the cloud, IoT platform processes it. The processing can be as simple as checking if the temperature is within the acceptable range or could be much more complex, such as using computer vision on video to identify objects.

Data Visualisation 4

The processed data (information) is made useful to the end-user by providing alerts to the user (e-mails, text, notification).
The user might have an application (interface) that allows him to proactively chek-in to the system .

Data Analysis and Prediction 5

To use the data collected over the time, data analytics makes use of the historical data to provide insights that can be used to forecast future trends.
You cam make intelligent business decisions based on the insights and predictions generated from the data.

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Architecture of an IoT System

Application Layer	The application consists of application that use the data collected by the sensors. These applications can be dashboards, analytics tools, or machine learning algorithms that provide insights and predictions based on the data collected.
Middleware Layer	The middleware layer provides a platform for managing the data and services in the IoT system. It consists of various components such as message brokers, application servers, and API gateways.
Data layer	The data layer is responsible for storing and processing the data collected by the sensors. This layer can use different databases such as SQL, NoSQL, and Time-series databases.
Network Layer	The network layer is responsible for transmitting data between the sensors and the cloud ot the edge devices. This layer can use different communication protocols such as Wi-Fi, Bluetooth and LoRaWAN.
Sensing Layer	The sensing layer is the bottommost layer of the IoT architecture and consists of sensors and actuators that collect data from the physical world. Sensors can collect data such as temperature, humidity and pressure, while actuators can control devices such as motors, valves and switches.

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IoT Devices

IoT devices refer to a diverse range if computing devices that can connect wirelessly to a network and equipped with the ability to transmit data. These devices are part of the growing network of the Internet of Things (IoT), which includes a wide variety of interconnected devices.

The Internet of Things (IoT) expands internet connectivity beyond traditional devices like desktops, laptops, smartphones, and tablets, to encompass a wide range of everyday physical objects and devices that were previously non-internet-enabled. These devices are equipped with embedded technology that enables communication and interaction over the internet, allowing them to be monitored and controlled remotely.

In theory, you can make any device an IoT device by adding internet connectivity and the ability to transmit data.

To create an IoT appliance, a combination of hardware and software components is need, including development boards, sensors , actuators , cloud services and programming languages.

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SBC, Microcontroller, SoC & Development boards

There are several types of development boards for IoT, each with its own set of features and capabilities. The most common types are:

- **Microcontroller boards:** These are small, low-power devices that are used for embedded systems development. Microcontroller boards typically feature a single microcontroller chip and a limited amount of memory and input/output pins. (Arduino Uno, Raspberry Pico and STM 32)
- **System-on-chip (SoC) boards:** These are more powerful than microcontroller boards and feature a complete system on a single chip. SoC boards typically include a microprocessor, memory, and a variety of communication interfaces. (ESP32, ESP8266, Nordic nRF52 and Raspberry Pi).
- **Single-board computers (SBC):** These are powerful computers that are built on a single circuit board. SBCs typically feature a processor, memory, storage, and a variety of input/output interfaces. (Raspberry Pi , Jetson Nano, Asus Tinker Board and BeagleBone Black).

The choice of board will depend on the specific requirements of your project, such as processing power, memory, and connectivity options.

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Development board and SBC for IoT

Raspberry Pi 2

64 bit quad-core ARMv8 , 1.2GHz CPU
1 GB RAM
802.11n Wireless LAN, Bluetooth 4.1,BLE
40 GPIO , Camera and Display Interface
Linux

$50-60

Omega 2

MT7688 SoC 580MHz MIPS CPU
802.11 b/g/n WiFi ,
16MB Flash, 64MB DDR2 DRAM
32 pins (18 GPIO)
Linux

$20

Particle Photon

STM32F205 120MHz ARM Cortex M3
802.11 b/g/n WiFi
1MB Flash, 128 KB RAM
18 GPIO
Free RTOS

$20

Beagle Bone

1GHz AM3350 Sitara ARM Cortex-A8
802.11 b/g/n Ai-Fi, BLE
512MB DDR, 4GB eMMC
65 GPIO
Linux

$50

Jetson Nano

Quad-core ARM Cortex A57
128 VIDIA CUDA cores
4GB DDR4, 16GB eMMC
40 GPIO
Linux

$150

$15-20

ESP 32

ESP32-WROOM -32E Soc
4MB flash, 4MB SRAM
802.11b/g/n, BLE
34 pins GPIO
Arduino IDE

$12

Banana Pi

A20 Dual-core 1.0 Ghz CPU
1GB DDR3
26 pins GPIO
Linux

$50-60

Arduino Nano

ARM Cortex M0- 32 bit
448Kb ROM, 520KB SRAM
22 pins GPIO
Arduino IDE

$30

Arduino uno R3

ATmega328p
32KB Flash, 2KB SRAM
20 pins GPIO
Arduino IDE

$30

i.MX8

Cortex A53
2GB DDR4 SDRAM
802.11b/g/n, BLE
40 pins GPIO
Linux

$150

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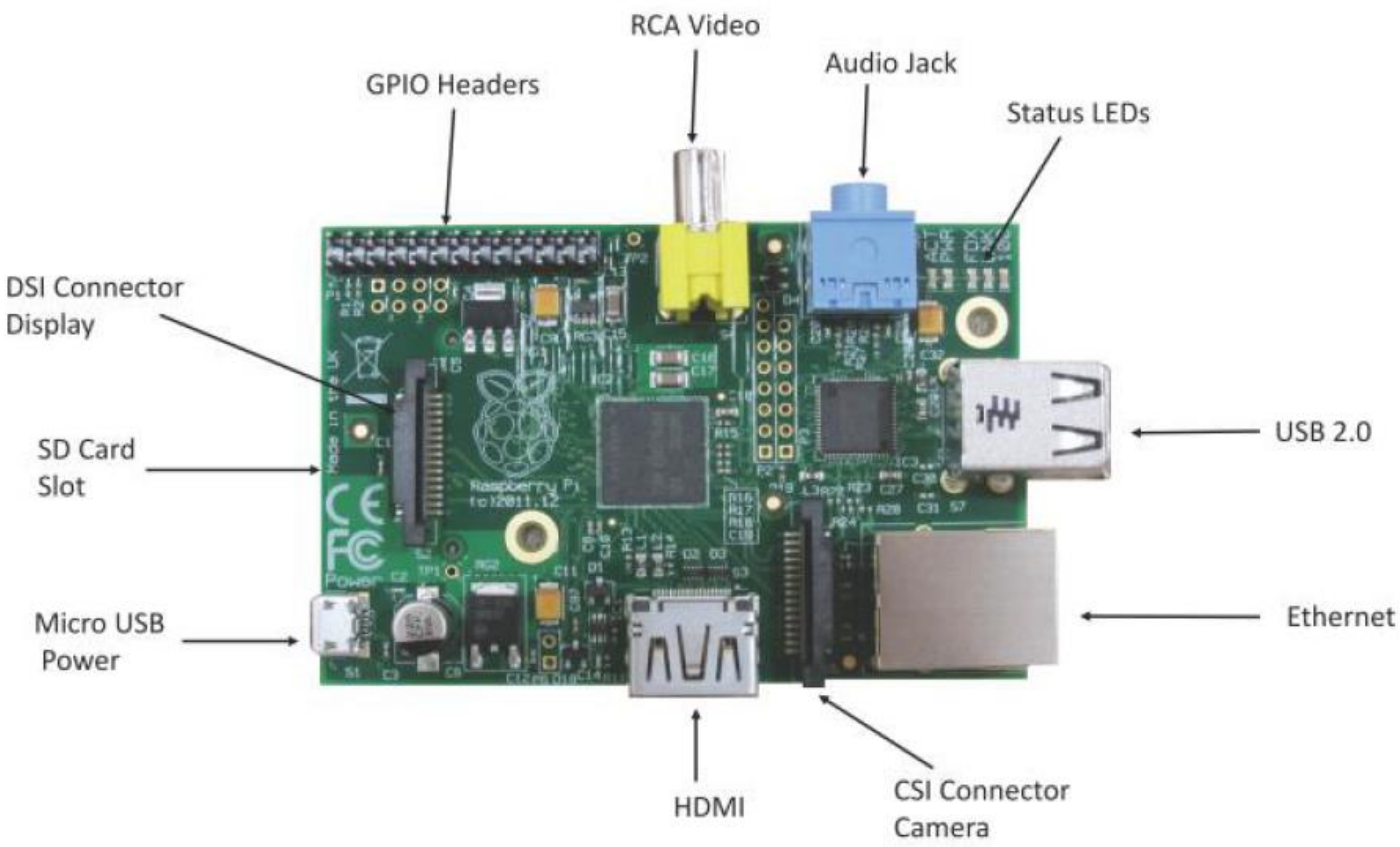
Raspberry Pi



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Raspberry Pi Interfaces

- **Serial**

  The serial interface on Raspberry Pi has receive (Rx) and transmit (Tx) pins for communication with serial peripherals.

- **SPI**

  Serial Peripheral Interface (SPI) is a synchronous serial data protocol used for communicating with one or more peripheral devices.

- **I2C**

  The I2C interface pins on Raspberry Pi allow you to connect hardware modules. I2C interface allows synchronous data transfer with just two pins - SDA (data line) and SCL (clock line).

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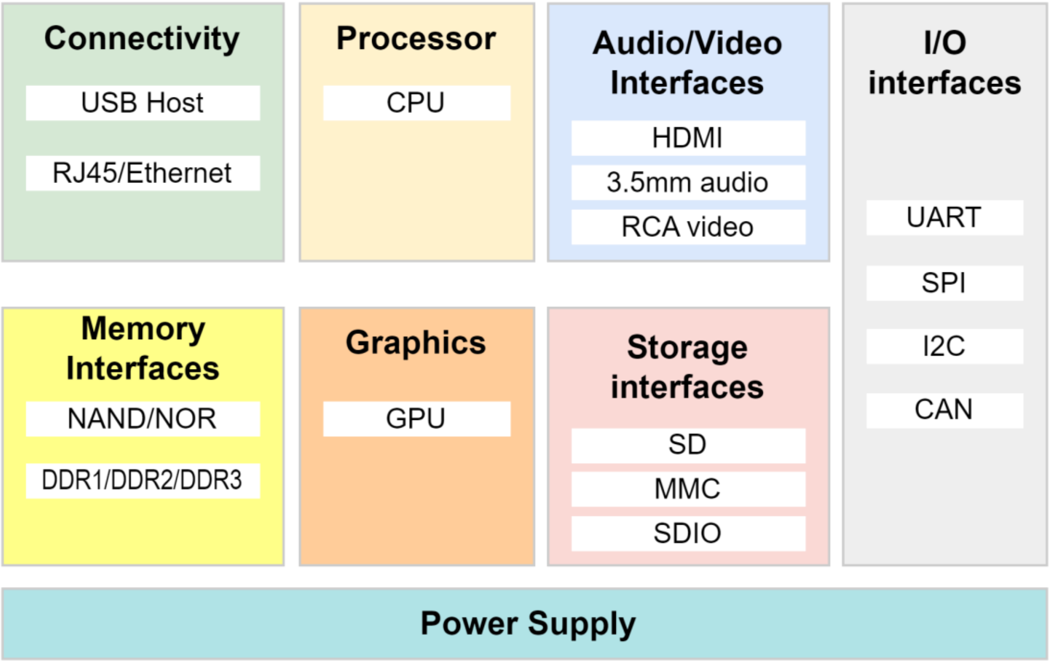
Generic block diagram of an IoT Development Board

The basic block diagram on an IoT devices is summarized as follow:

- **Processor** which often is a microcontroller.
- **Connectivity** component to communicate with other devices using Wi-Fi, Bluetooth or cellular network.
- **Memory** that is used for storing device´s firmware, settings, readings and logs.
- **User interface** to provide a way for user to interact with the device (audio/video)
- **I/O interfaces** for sensors or actuators
- **Power supply** that can be a battery, solar panel, or external power source.



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Sensors

IoT sensors ate classified into two categories:

- **Analog Sensors:** These sensors measure physical parameters such as temperature, pressure, and humidity, and convert them into electrical signals that are analog in nature. The analog signals are then processed by an analog-to-digital converter (ADC) to convert them into digital signals that can be processed by a computer or microcontroller.

- **Digital sensors:** These sensors directly generate digital signals that can be read by a computer or microcontroller. Digital sensors are often used for measuring motion, proximity, and environmental conditions. They are also more accurate and less susceptible to noise compared to analog sensors. Some examples of digital sensors include GPS sensors, motion sensors, and light sensors

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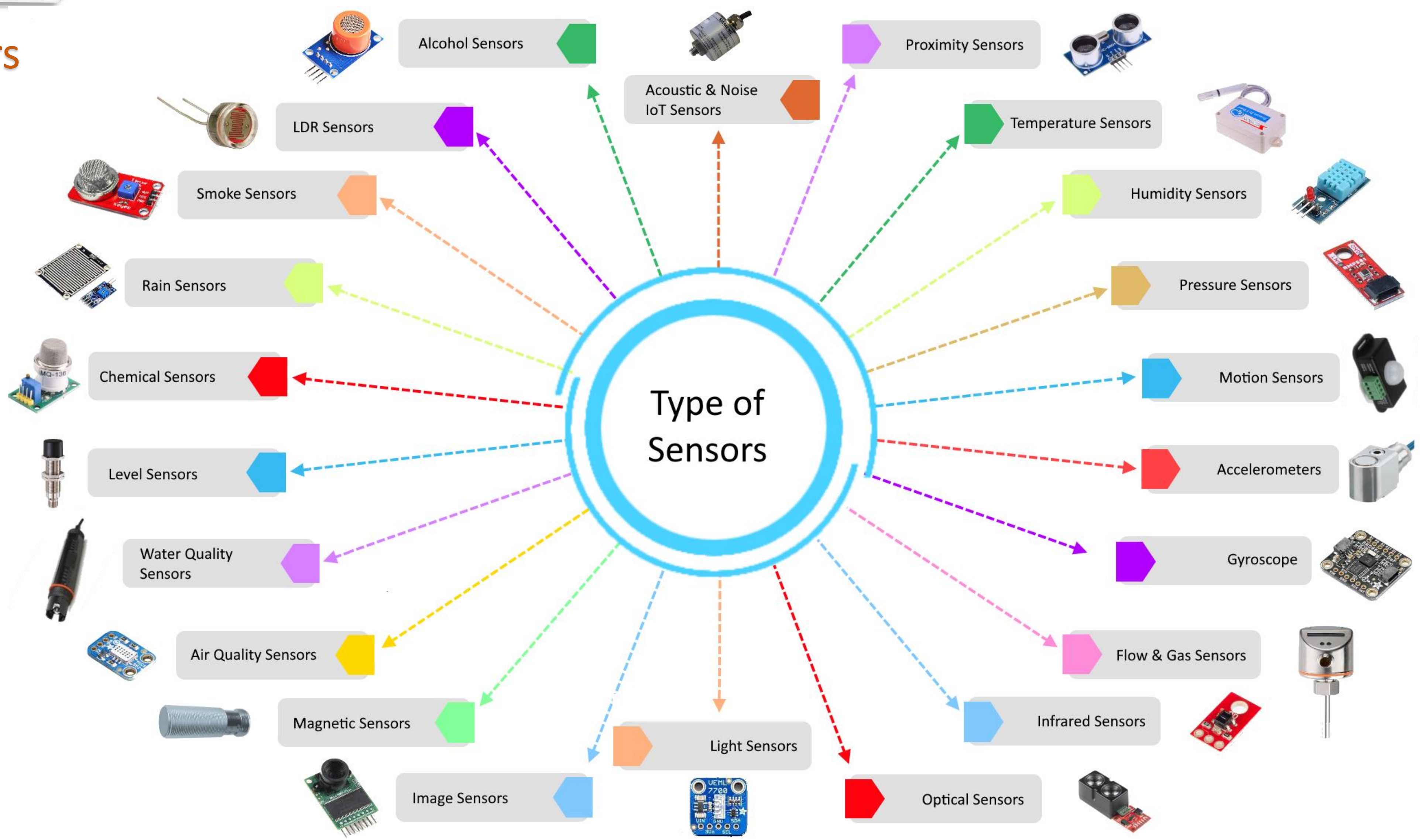
Sensors



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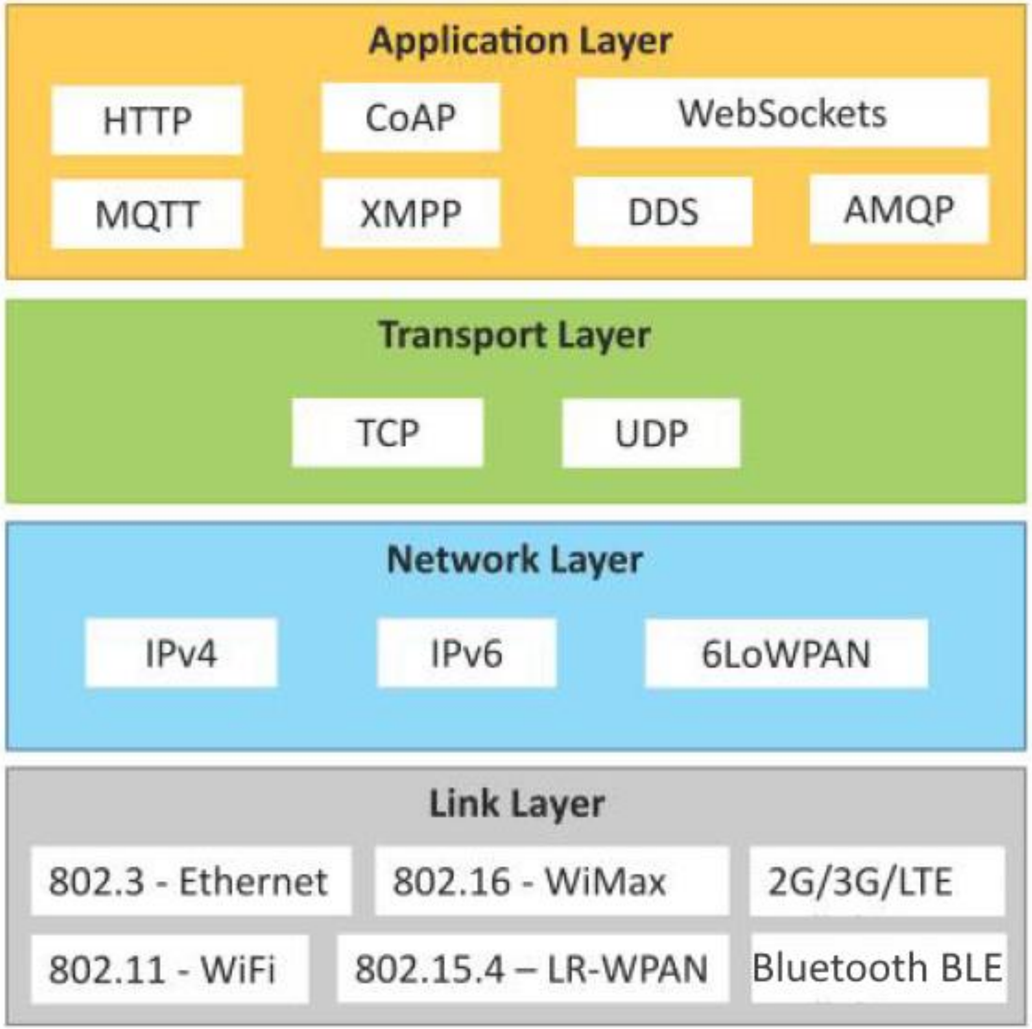
IoT Protocols

IoT protocols can be mapped to different layers of the OSI (Open Systems Interconnection) model, which is a conceptual framework used to understand and describe network protocols and their interactions. Here's a breakdown of common IoT protocols.



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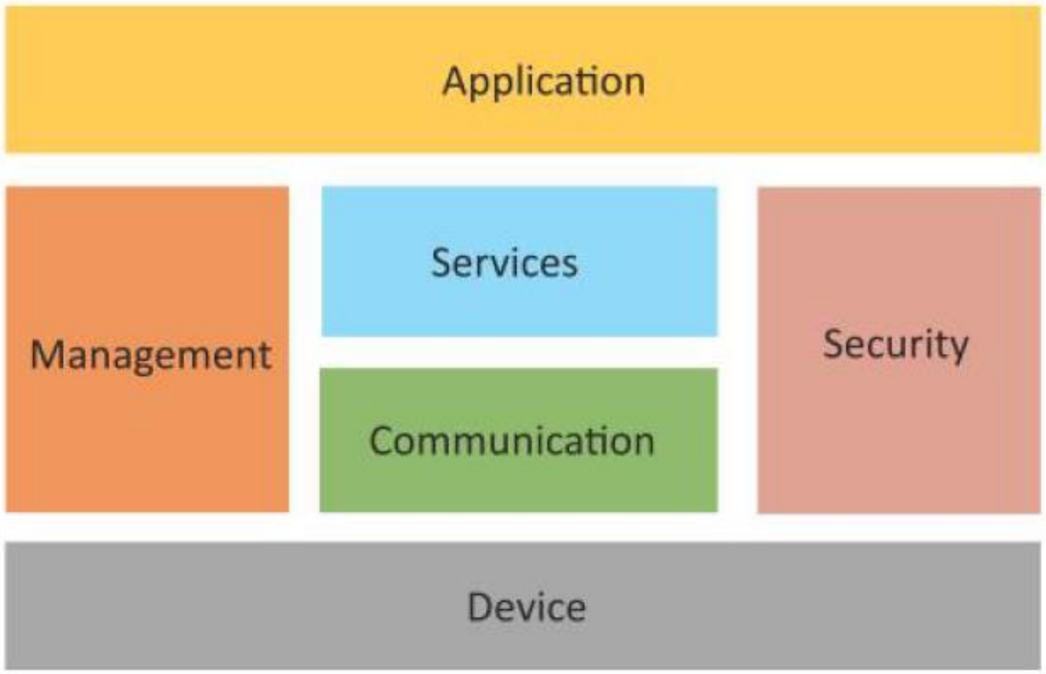
Logical Design of IoT

- Logical design of an IoT system refers to an **abstract representation** of the entities and processes without going into the low-level specifics of the implementation.

- An IoT system comprises of a number of **functional blocks** that provide the system the capabilities for identification, sensing, actuation, communication, and management.



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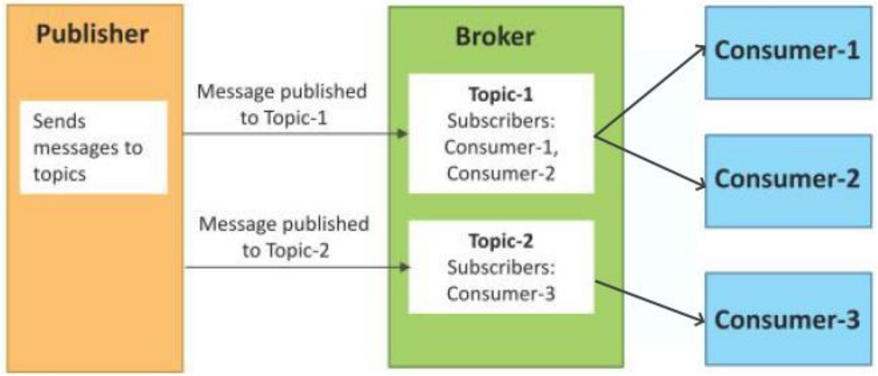
Publish-Subscribe communication model

- Publish-Subscribe is a **communication model** that involves publishers, brokers and consumers.

- **Publishers are the source** of data. Publishers send the data to the **topics** which are managed by the broker. Publishers are **not aware** of the consumers.

- **Consumers subscribe** to the topics which are managed by the broker.

- When the broker receives data for a topic from the publisher, it sends the data to all the **subscribed consumers.**



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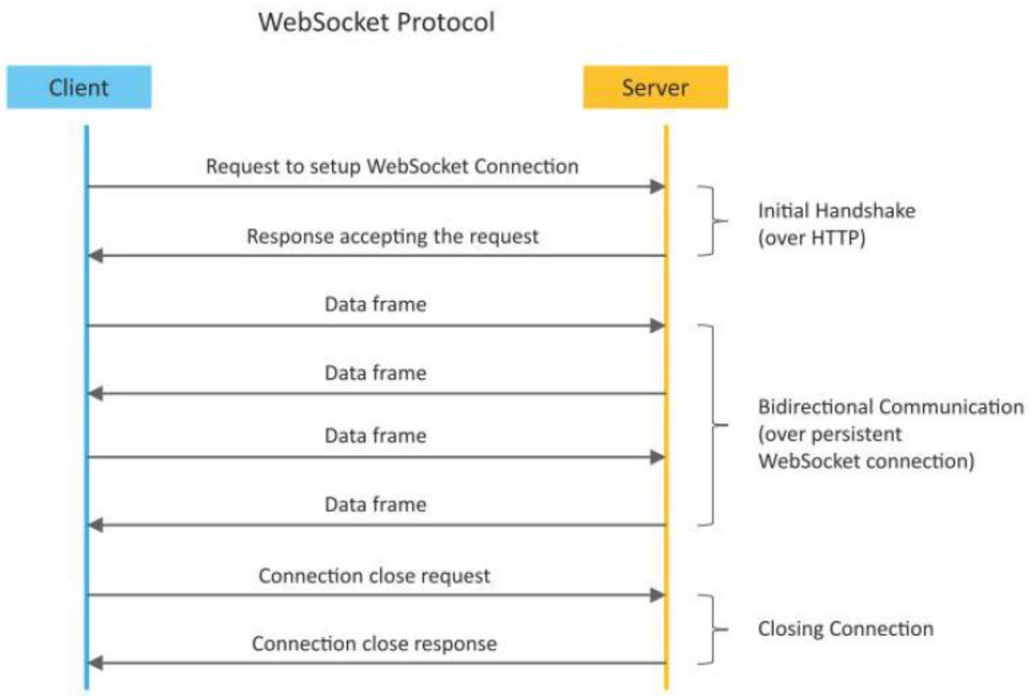
WebSocket-based Communication API

- WebSocket APIs allow **bi-directional**, full duplex communication between clients and servers.

- WebSocket APIs follow the exclusive **pair communication** model



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Other communication models

- Request-Response communication model
- Push-Pull communication model
- Exclusive Pair Communication model
- REST-based communication API
- Exclusive Pair communication model

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Challenges of IoT

- **Security risks:** With the increased number of connected devices, the risk of cybersecurity threats and breaches increases.
- **Interoperability issues:** With the multitude of devices available in the market, ensuring interoperability can be challenging.
- **Privacy concerns:** IoT devices can collect sensitive data, leading to privacy concerns.
- **Complexity:** The complexity of IoT devices and their interconnectedness can make it challenging to manage and maintain them.
- **Cost:** IoT devices can be expensive, and the cost of implementing and maintaining them can be prohibitive for some businesses and individuals.

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Benefits of IoT

- **Increased efficiency and productivity**: IoT devices can automate various tasks and processes, leading to increased efficiency and productivity.
- **Improved decision-making:** IoT devices can provide real-time data, enabling businesses and individuals to make informed decisions quickly.
- **Enhanced customer experience:** IoT devices can personalize the customer experience by providing customized services and products.
- **Cost savings:** IoT devices can reduce costs by optimizing processes and reducing waste.
- **Improved safety and security:** IoT devices can monitor and control environments, making them safer and more secure.

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Physical Design of IoT

To **get data from a toaster**, you can follow the steps outlined below:

1. **Choose** a suitable **temperature sensor** or a thermocouple that can withstand high temperatures. For example, a K-type thermocouple can measure temperatures up to 1,200 degrees Celsius and is ideal for use in a toaster.
2. **Connect** the temperature **sensor to a microcontroller board** such as an Arduino or Raspberry Pi. You can use a breakout board or a shield that is compatible with your microcontroller board to connect the temperature sensor.
3. **Program the microcontroller** board to read the temperature data from the sensor and record it. You can use programming languages like C++ or Python to write the code for your microcontroller board.
4. **Place** the temperature **sensor inside** the toaster. Ensure that the sensor is not in contact with the heating element or any moving parts inside the toaster.
5. **Run a test** cycle on the toaster and monitor the data being recorded by the microcontroller board. The microcontroller board should be connected to a computer or a mobile device so that you can view the data being collected.
6. **Analyze the data** collected and use it to improve the toaster's performance. For example, you can use the data to optimize the heating element's temperature or adjust the cooking time to achieve better results.

It's important to note that modifying a toaster or any other household appliance can be dangerous and should only be attempted by qualified professionals with the proper training and expertise. Always follow safety guidelines and take necessary precautions when working with electrical appliances.

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Edge Computing

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What is edge computing?

Edge computing is a **distributed** computing model that brings computation and data storage **closer to the devices** or endpoints where it is needed, rather than relying on a central location or a remote data center. By contrast, IoT systems based on a cloud architecture rely on a centralized or cloud based servers to process data.

Without an edge architecture, data needs to me transmitted from distributed IoT devices to a central location for processing, and the results are then used to transmit commands back to the IoT devices to adjust their operating parameters.

What are IoT Edge devices

IoT **edge devices** are physical devices such as sensors, cameras, and other type of hardware, that gather data about a particular environment or system.

IoT **edge gateways** are intermediary devices between edge devices and the rest of an IoT network. Edge gateways process and filter data from edge devices as well as transmit the data to a central location or cloud platform.

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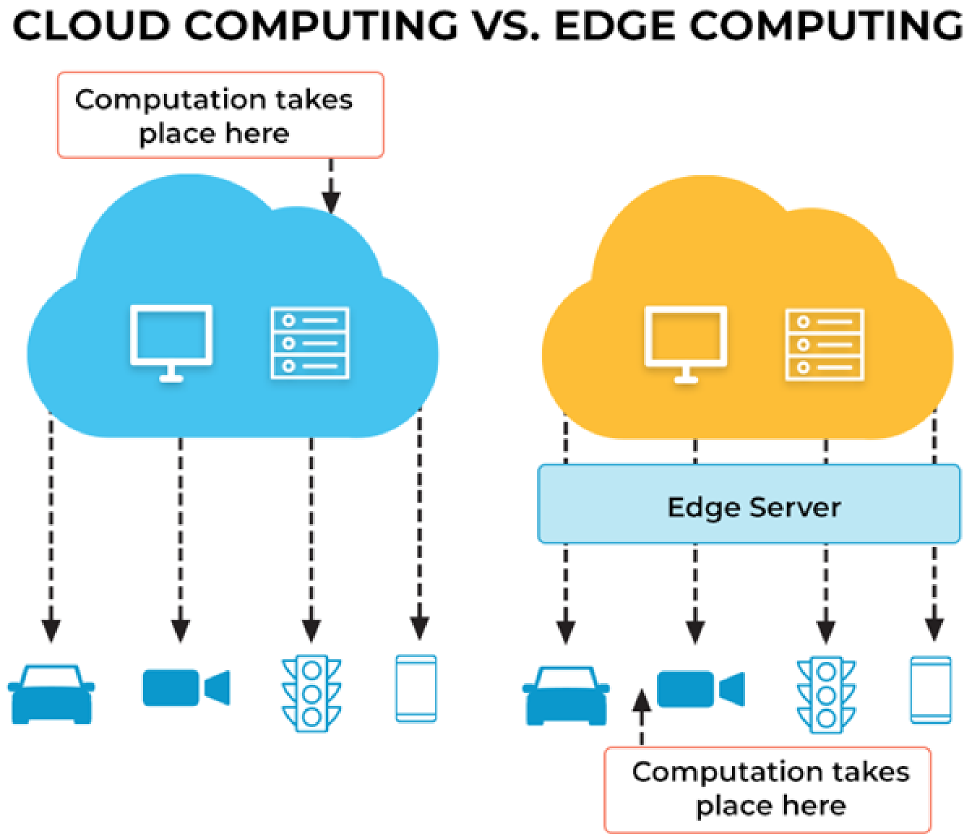

- In a cloud architecture, IoT devices send data to the cloud where it is processed, analyzed and stored, and the results are sent back to the devices as needed.
- In Edge computing, IoT devices process and analyze data locally or near the source of data Generation, reducing latency na minimizing data transfer to the cloud.

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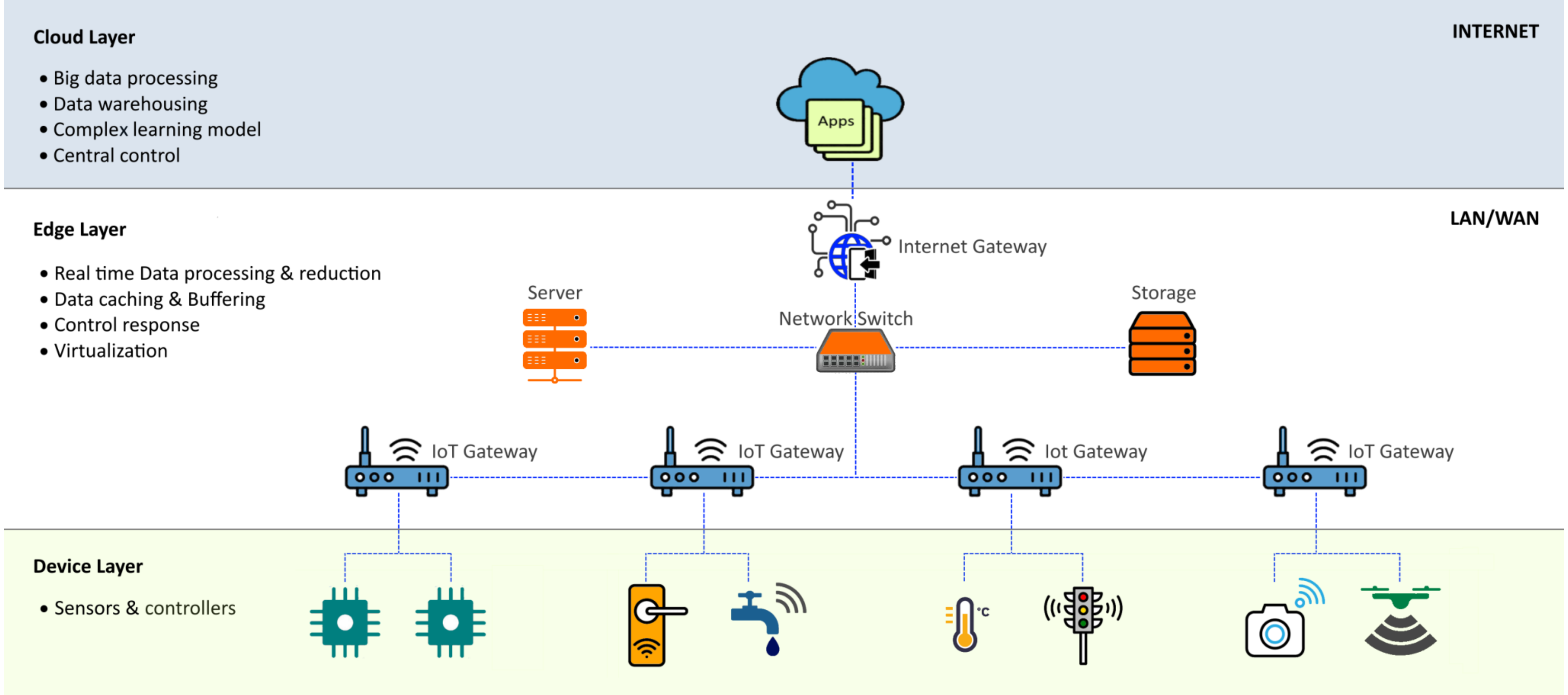
Edge Computing Architecture



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Key Benefits of edge computing

- **Reduced latency**: By processing data closer to the source, edge computing reduces the latency or delay in data transmission, enabling faster response times and better real-time performance.
- **Improved reliability**: Edge computing can improve reliability and availability by reducing the dependence on a centralized data center and enabling redundancy and failover at the edge.
- **Increased scalability:** Edge computing allows for distributed computing and storage resources, making it easier to scale up or down as needed.
- **Improved data privacy and security**: Edge computing can enhance data privacy and security by enabling data to be processed and analyzed locally, reducing the risk of sensitive data being transmitted over the network.
- **Lower network bandwidth usage**: By processing data locally, edge computing can reduce network bandwidth usage, leading to lower costs and more efficient use of resources.
- **Cost savings:** Edge computing can help reduce costs associated with data transmission, storage, and processing, by leveraging local resources and minimizing the need for expensive centralized infrastructure.

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Autonomy

Autonomy refers to the ability of a system or device to operate independently, without human intervention or control. These are the applications that require autonomy:

Autonomous vehicles
Smart cars need autonomy to improve safety, increase efficiency, and reduce the need for human input while driving.

Drones
Drones need autonomy to fly efficiently and safely, and adapt to changing environment without requiring constant human control.

Robotics
Autonomy makes robots smarter, more flexible and safer.

Smart Home
Autonomy enables smart homes to operate automatically and intelligently, providing convenience, energy efficiency, and adaptability.

Agriculture
Autonomy enables automated farming operations, optimized resource usage, remote monitoring and control, and increased productivity.

Healthcare
Autonomy facilitates remote patient monitoring, improves patient outcomes, reduces errors, and enhances the efficiency of healthcare delivery.

Latency

IoT deveices are designed to collect and transmit data in real-time and transmit the data to other devices or systems with very little delay. Low latency is important for:

Real-time decision making
Low latency allows faster and more efficient processing of data, resulting in faster response times and improved real-time performance.
Real-time processing is critical in robotics to enable quick and accurate changes in the environment.

Safety
In some applications , such as autonomous vehicles or medical devices, low-latency is critical to ensure safety. For example if an autonomous vehicle detetcs an obstacle in the road, it needs to be able to respond quickly to avoid collison.

Efficiency
Low latency can also improve the efficienty of IoT systems. For example, in a smart home, low latency can ensure that appliances are turned on and off quickly and responsively, can save energy and improve user experience.

Bandwidth

While all the IoT devices generate data that needs to be transmitted over a network, some devices can increase bandwidth more than others such as:

High-resolution cameras
A high-resolution camera can generate several gigabytes of data per hour, which can quickly consume available bandwidth.

Wearable devices
Smartwatches, fitness trackers or medical monitoring devices that collects vital signs data every few seconds can generate a large amount of data overtime.

Industrial sensors
Industrial IoT sensors used in manufacturing or transportation can generate a significant amount of data that needs to be transmitted over a network.

Smart home devices
Smart home IoT devices such as smart thermostats, security systems and entertainment systems generate a significant amount of data.

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