Introduction to the Internet of Things

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Sensors & Devices

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Learning outcomes:

- Overview of Sensors and Devices
- Types of IoT Sensors
- IoT Device Hardware
- Scaling
- Manufacturing & Shipping
- Gateways

Overview of Sensors and Devices

Sensors exist since long before the IoT in its current meaning and are ubiquitous in, for example, buildings, factories, energy and much more. In all these cases sensors are part of the digital data backbone of connected and intelligent solutions. Anything ‘smart’ and IoT-related is built upon sensors and other types of transducers.

A sensor is a device that detects, measures or indicates any specific physical quantity such as light, heat, motion, moisture, pressure, or similar entities, by converting them into any other form which is mostly, electrical pulses.

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Overview of Sensors and Devices

A transducer converts a signal in a form of energy into a signal in another form. In a context of IoT sensors this simply means that sensors are able to sense conditions in or around the IoT device in which they are present and in and around the *(state and environments of)* physical item to which they are attached. Sensors can detect the events or changes in the environments and for the purposes for which they were designed and communicate about these events or changes of specific parameters to systems and other devices which then can use this data for actions, analysis and so forth.

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Overview of Sensors and Devices

Among the environmental parameters, factors and events that **sensors** can ‘sense’ and communicate about are parameters such as **sound, temperature, humidity, presence of specific chemical components or gases, light, occupancy *(e.g. of a room)* and much more.** It is clear that sensors are essential IoT components and need to be very accurate because they are where the data gets captured to begin with.

Overview of Sensors and Devices

As we established in the previous session, sensors/devices are a critical piece of the Internet of Things, serving as system's "senses" and as the means of interacting with the world. Although no complete IoT solution can be built without some kind of hardware, the sensors/devices are often an underappreciated aspect of the system. Choices about the hardware affect everything downstream, from the connectivity you choose, to the analytics you're able to provide, and to the interactions and interfaces that you enable for end-users.

Overview of Sensors and Devices

A sensor can be described using several properties, the most important being:

- Range: The maximum and minimum values of the phenomenon that the sensor can measure.
- Sensitivity: The minimum change of the measured parameter that causes a detectable change in output signal.
- Resolution: The minimum change in the phenomenon that the sensor can detect.

Overview of Sensors and Devices

Sensor Classification:

Sensors can be grouped using several criteria:

Passive or Active. Passive sensors do not require an external power source to monitor an environment, while Active sensors require such a source in order to work.

Another classification is based on the method used to detect and measure the property (mechanical, chemical, etc.).

Analog and Digital. Analog sensors produce an analog, or continuous, signal while digital sensors produce a discrete signal.

Types of IoT Sensors

There are many types of IoT sensors and an even greater number of applications and use cases. Here are 10 of the more popular types of IoT sensors and some of their use cases.

1. Temperature Sensors

Temperature sensors measure the amount of heat energy in a source, allowing them to detect temperature changes and convert these changes to data. Machinery used in manufacturing often requires environmental and device temperatures to be at specific levels. Similarly, within agriculture, soil temperature is a key factor for crop growth

Types of IoT Sensors

2. Humidity Sensors:

These types of sensors measure the amount of water vapour in the atmosphere of air or other gases. Humidity sensors are commonly found in heating, vents and air conditioning (HVAC) systems in both industrial and residential domains.

3. Pressure Sensors

A pressure sensor senses changes in gases and liquids. When the pressure changes, the sensor detects these changes, and communicates them to connected systems. Common use cases include leak testing which can be a result of decay.

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Types of IoT Sensors

4. Proximity Sensors

Proximity sensors are used for non-contact detection of objects near the sensor. These types of sensors often emit electromagnetic fields or beams of radiation such as infrared. Proximity sensors have some interesting use cases. In retail, a proximity sensor can detect the motion between a customer and a product in which he or she is interested. The user can be notified of any discounts or special offers of products located near the sensor. Proximity sensors are also used in the parking lots of malls, stadiums and airports to indicate parking availability.

Types of IoT Sensors

5. Water quality sensor

Water quality sensors are used to detect the water quality and Ion monitoring primarily in water distribution systems. Water is practically used everywhere. These sensors play an important role as they monitor the quality of water for different purposes. They are used in a variety of industries.

6. Chemical sensor

Chemical sensors are applied in a number of different industries. Their goal is to indicate changes in liquid or to find out air chemical changes. They play an important role in bigger cities, where it is necessary to track changes and protect the population.

Types of IoT Sensors

7. Level Sensors

Level sensors are used to detect the level of substances including liquids, powders and granular materials. Many industries including oil manufacturing, water treatment and beverage and food manufacturing factories use level sensors.

8. Accelerometers

Accelerometers detect an object's acceleration i.e. the rate of change of the object's velocity with respect to time. Accelerometers can also detect changes to gravity. Use cases for accelerometers include smart pedometers and monitoring driving fleets.

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Types of IoT Sensors

9. Gas Sensors

These types of sensors monitor and detect changes in air quality, including the presence of toxic, combustible or hazardous gasses. Industries using gas sensors include mining, oil and gas, chemical research and manufacturing. A common consumer use case is the familiar carbon dioxide detectors used in many homes.

10. Gyroscope sensors

Gyroscope sensors measure the angular rate or velocity, often defined as a measurement of speed and rotation around an axis. Use cases include automotive, such as car navigation and electronic stability control (anti-skid) systems.

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IoT Device Hardware

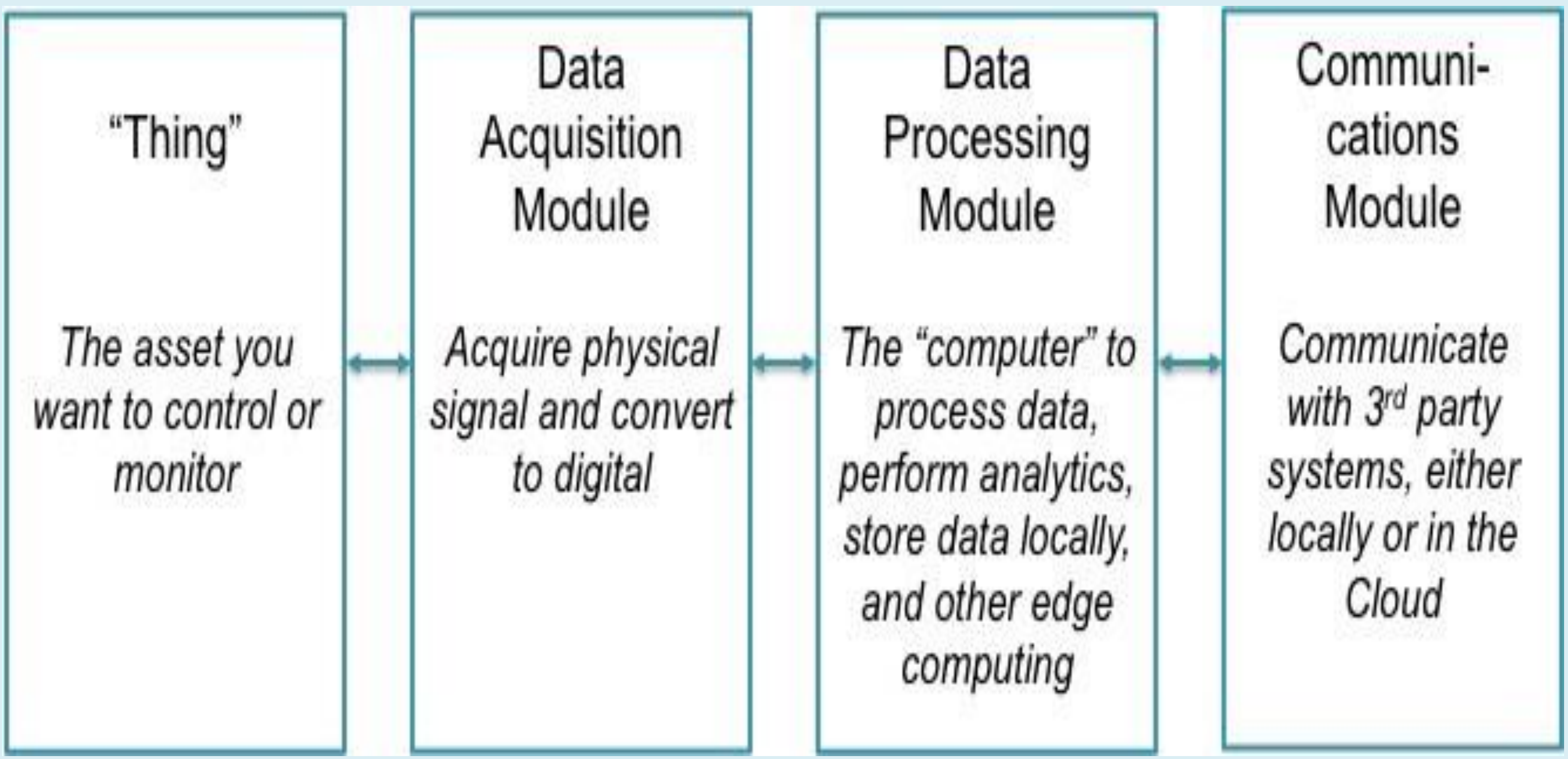
IoT Hardware includes a wide range of devices such as devices for routing, bridges, sensors etc. These IoT devices manage key tasks and functions such as system activation, security, action specifications, communication, and detection of support-specific goals and actions.

The 4 Building Blocks of IoT Device Hardware:

With as many IoT applications as there are IoT entrepreneurs, it would be impossible to generalize a hardware architecture. But regardless of the application, all IoT devices share some commonalities or “building blocks”, as shown below.

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:



IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 1: Thing

I define "thing" as the asset that you want to control or monitor.

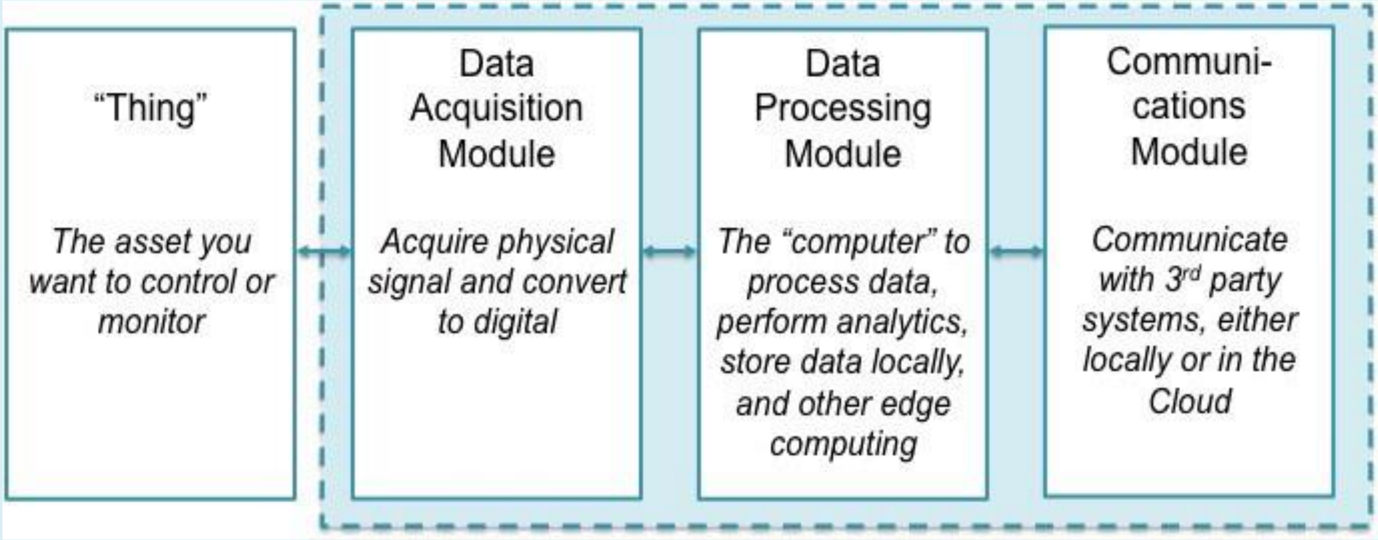
In many IoT products, the "thing" is fully integrated into the smart device. For example, think of products like a smart water pump or an autonomous vehicle. These products control and monitor themselves. In this case, your product includes all four building blocks in a single package as shown in the image.

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 1: Thing

But there are many other applications where the "thing" stands alone as a "dumb" device, and a separate product is connected to it to make it a smart device. In this case, your product only includes the three modules in blue below.



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IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 1: Thing

This is very common in industrial applications where companies have existing assets, and they want to make them “smart” by connecting them to the Cloud. Some examples include wind turbines, jet engines, conveyer belts, etc.

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 2: Data Acquisition Module

The data acquisition module focuses on acquiring physical signals from the "thing" and converting them into digital signals that can be manipulated by a computer.

This is the hardware component that includes all the sensors acquiring real-world signals such as temperature, motion, light, vibration, etc. The type and number of sensors you need depend on your application.

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:
Building Block 2: Data Acquisition Module

The data acquisition module includes more than sensors though. It also includes the necessary hardware to convert the sensor signal into digital information for the computer to use. This includes signal conditioning, analog-to-digital conversion, scaling, and interpretation.

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IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 2: Data Acquisition Module

For the data acquisition module, the important considerations to focus on are:

- What physical signals do I need to measure? (i.e. what type of sensors do I need)
- How many sensors of each type do I need?
- How fast should I measure the real-world signal? (i.e. sample rate)
- How much accuracy do I need in my measurement? (i.e. sensor resolution)

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:
Building Block 2: Data Acquisition Module

The answers to these questions will inform the requirements for your data acquisition module, as well as give you an idea of how much data your device will produce.

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 3: Data Processing Module

The third building block of the device is the data processing module. This is the “computer” that processes the data, performs local analytics, stores data locally, and performs any other computing operations at the edge.

You don’t need to be an expert in computer architecture to have a solid conversation with your engineering team about this module.

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:
Building Block 3: Data Processing Module

Your role should be to understand the overarching goal of the product and ask the right questions that will guide your team to the right decisions. The two most important considerations to focus on are:

- Processing power (i.e. how much processing will you do at the edge?)
- Amount of local data storage (i.e. hard drive size — how much data will you need to store at the edge?)

IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 4: Communications Module

The last building block of your device's hardware is the communications module. This is the circuitry that enables communications with your Cloud Platform, and with 3rd party systems either locally or in the Cloud.

This module may include communication ports such as USB, serial (232/485), CAN, or Modbus, to name a few. It may also include radio technology for wireless communications such as Wi-Fi, LoRA, ZigBee, etc.

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IoT Device Hardware

The 4 Building Blocks of IoT Device Hardware:

Building Block 4: Communications Module

The communications module can be included in the same device as your other modules, or it could be a separate device that is specifically for communications. This approach is often referred to as a “gateway architecture”.

For example, if you have three sensors in a room that need to send data to the Cloud, you might have those sensors connected to a single gateway in that same room, and the gateway consolidates this data and sends it to the Cloud. That way, you only need one communications module, not three.

Scaling

Scale, by definition, refers to *“the capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged in order to accommodate that growth*”. When you hear that definition you might translate it as *“My system needs to be able to handle the data created by my current and future expected customer base”.* While that is certainly part of it, it’s just the tip of the iceberg. It is true that when running a connected business (or really any business for that matter), you need to be able to service your millionth customer just as good as you did your first – latency threshold, connection time, linearly scaling infrastructure, meeting your SLAs, etc.

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Scaling

Scalability means flexibility that allows us to better address and achieves the specific needs as they arise. The main objective of making the device scalable is to meet the changing demands and they can never be static since the interest of people and taste changes with time as well as the environmental conditions. It is vital as it contributes to competitiveness, efficiency and quality.

Scaling

The importance of scalability is that it helps in the system to work gracefully without any undue delay and unproductive resource consumption and makes a good use of the available resources. In a scalable system, if the memory requirements of the system increase as there is an increase in the amount of data then it does not grow to insupportable levels . Moreover, the device operates smoothly and with speed in spite of the fact that whether the device is large or small in size. Hence it is important to make a device scalable to make it more efficient for the present and the future use.

Scaling

Scalability is an absolute necessity for the success of the IoT. Analyst firms and others are predicting that there will be billions of active connected products by 2020. Whether accurate or not, we must prepare for it or risk becoming the victims of our own success.

Scaling IoT projects challenges organizations' approach to such setups and existing architecture. It requires much more than additional sensors attached to more machines. IoT leaders must ensure their team and architecture can handle the increased connected devices and influx of data.

Manufacturing & Shipping

The most important consideration is that it’s going to take a while. Do not expect to go from a few prototypes to multiple thousands of production units within a couple months.

Expect several months to a year to go through the entire process. And scale also factors in here; a manufacturer will be much more willing to move quickly if they know they’ll be producing hundreds of thousands of units than they will to produce just a few thousand.

Manufacturing & Shipping

This process takes a considerable amount of time for a number of reasons.

With software, if there are bugs or areas of improvement, you can update the system after it's live. And with the connectivity layer, you might be using proven standards and existing infrastructure that carry relatively low risk (like WiFi or Cellular). Even if you're using a relatively new standard, making updates to the network can also be performed after-the-fact.

Manufacturing & Shipping

With hardware, you are not making changes to your sensors/devices once they've been produced. This is why having a small scale pilot is absolutely critical, it allows you to rigorously test your prototypes to identify any bugs or weaknesses in the hardware so that the final units can as purpose-built for the specific use case as possible. And manufacturing usually involves building injection molds, which help reduce per-unit costs but have massive upfront fixed-costs, meaning that it's extremely costly and time-intensive to make changes.

Manufacturing & Shipping

Another reason that the manufacturing process can take a while, is that you need to source all the materials. For a given sensor/device, there may be dozens or into the hundreds of individual components necessary to build the full device.

The manufacturer will need to set up production lines too. This involves setting up all the equipment and assembly lines to actually manufacture the sensors/devices, as well as setting up the testing processes for each important stage.

Finally, once the units have been produced, they'll need to be shipped to wherever they're needed.

Gateways

Gateways act as bridges between sensors/devices and the cloud. Many sensors/devices will “talk” to a gateway and the gateway will then take all that information and “talk” to the cloud.

An Internet of Things (**IoT**) **gateway** is a physical device or software program that serves as the connection point between the cloud and controllers, sensors and intelligent devices.

An IoT Gateway is a solution for enabling IoT communication, usually **device -to-device communications** or **device-to-cloud communications**.

Gateways

The gateway is typically a hardware device housing application software that performs essential tasks. At its most basic level, the gateway facilitates the connections between different data sources and destinations.
A simple way to conceive of an IoT Gateway is to compare it to your home or office network router or gateway. Such a gateway facilitates communication between your devices, maintains security and provides an admin interface where you can perform basic functions. An IoT Gateway does this and much more.

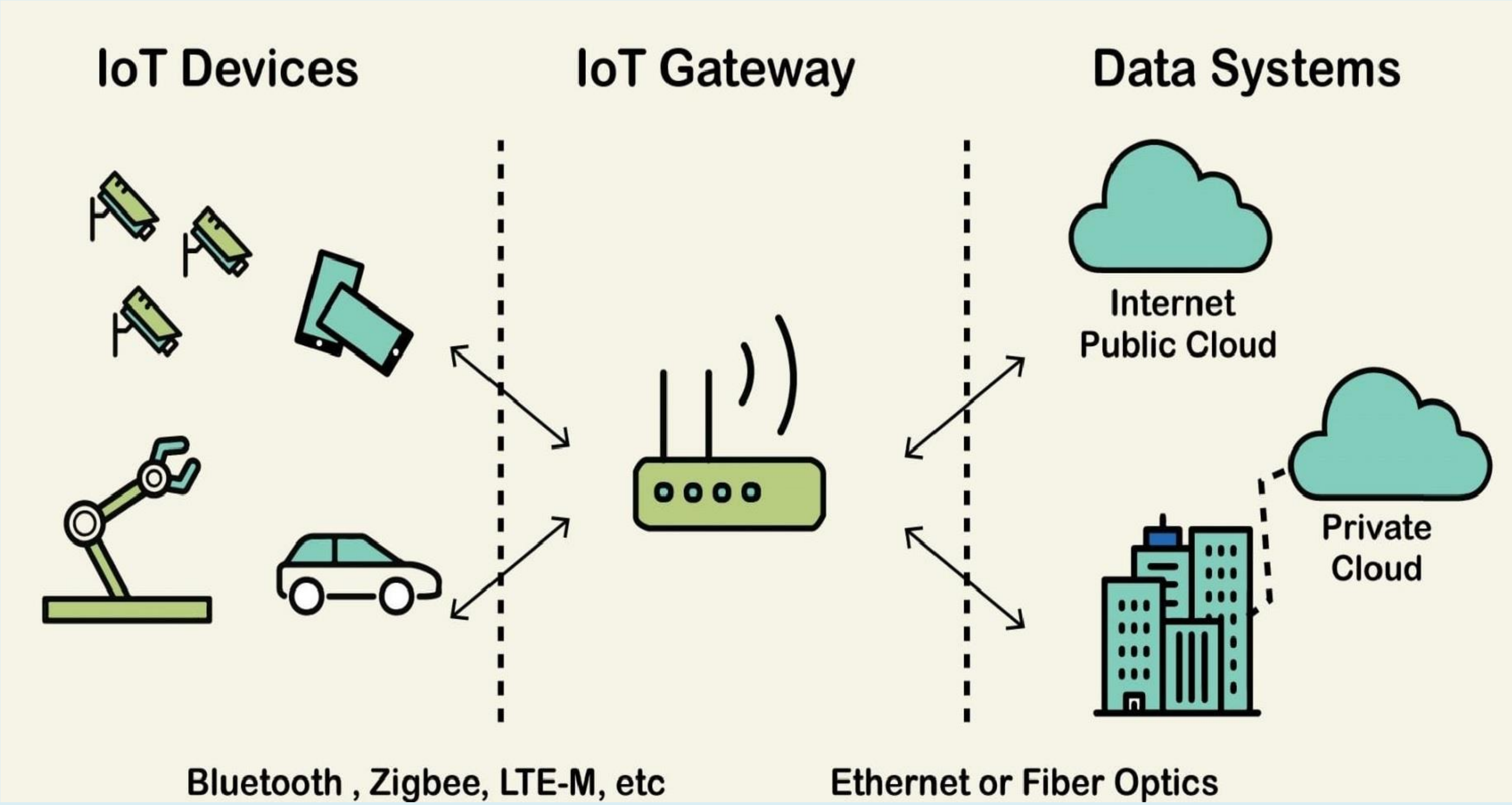
Gateways

What functions does an IoT gateway perform?
IoT Gateways have evolved to perform many tasks, from simple **data filtering** to **enabling visualization** and **complex analytics**. These smart devices are helping power the current wave of IoT expansion.
The IoT Gateway stands as one of the key elements in this ecosystem. It handles all communication with all sensors and remote connections such as the Internet, applications, or users.

Gateways

The IoT Gateway follows the same principle of bridging communications for different technologies. It creates a bridge between the IoT sensors/actuators and the Internet. The IoT gateway aggregates all data, translates sensor's protocols, and pre-process the data before sending it. The IoT devices connect to the IoT Gateway using short-range wireless transmission modes such as Bluetooth LE, Zigbee, Z-wave, or long-range like LTE, LTE-M, WiFi, and then it links them to the Internet (Public Cloud) through Ethernet LAN or Fiber Optics WAN (HDLC/PPP).

Gateways



The IoT gateway understands these transmission modes and data protocols and can translate them to other protocols that the data systems needs.

Gateways

IoT Gateway Key Features

- Communication bridging and M2M communication.
- Serves as a data cache, buffer, and streaming device.
- Offline services and real-time control of devices.
- Aggregates data.
- Pre-processes, cleans, and filters data before sending it.
- Additional intelligence for some IoT devices.
- It provides additional security.
- Device configuration and change management.

Gateways

How does an IoT Gateway work?

Most IoT devices in networks nowadays are capable of aggregating data. For example, sensors in car traffic can aggregate data and send it to an AI analysis service in the cloud. But to reach the cloud, the sensors must first send all this raw data to the IoT Gateway.

The IoT Gateway follows this simple process.

1. Pre-processes, cleans, and filters raw data.
2. Translates protocols for encryption and communication.
3. Sends data to a destination on the Internet or Intranet.

Gateways

Not all IoT applications will need a gateway, but they’re an important class of hardware that’s often a requirement for certain use cases because they’re needed to provide the connectivity to the sensors/devices.

In the next section we’ll explore connectivity as a whole for IoT as well as specific connectivity and network standards that you may need to consider.

Thank you