

Chapter 3

IoT architecture

ADVANCED TOPICS IN DATA SCIENCE

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Outline

- Introduction
- Level 1: Sensors
- Level 2: Local processing and local storage
- Level 3: Network and Internet
- Level 4: Cloud Processing and Storage

IoT architecture

- IoT (Internet of Things) systems are inherently distributed, heterogeneous, and complicated.
- hence designing architecture plays an important role in determining its functionality and quality in the early phase of development.
- However, designing architecture is not easy, because architects must address a number of system functionalities and quality requirements at the same time.



Level 1: Sensors

- sensors are devices that detect measures from environment.
- sensors:
 - measure values
 - send raw data
 - consume low power



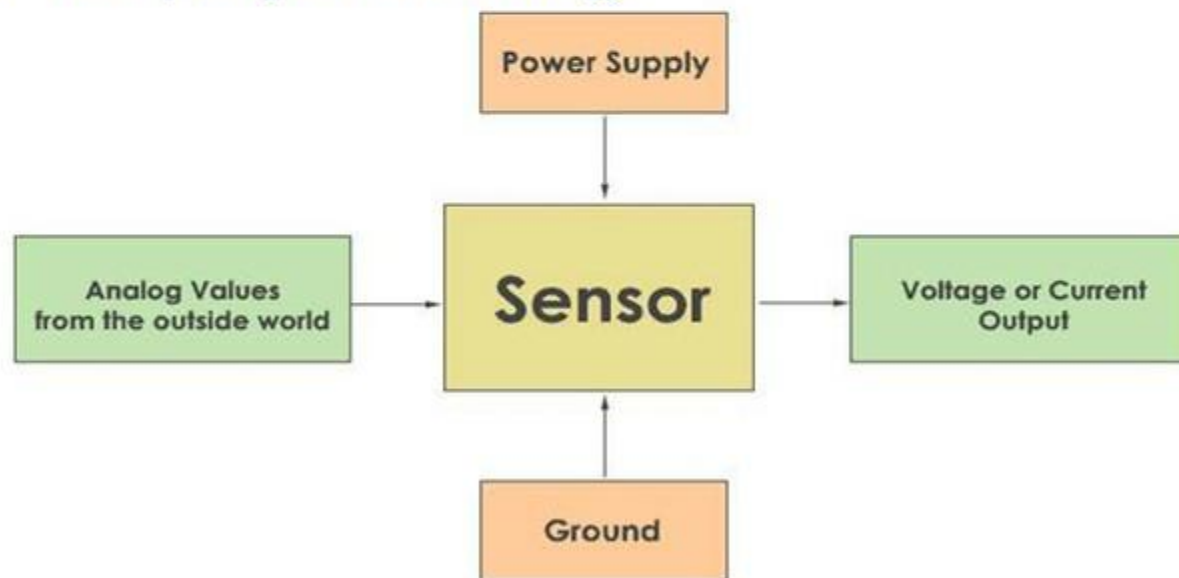
Level 1: Sensors

- Sensors have become an integral part of the embedded system. Right from your mobile to security systems installed at home. They are also becoming important for meteorological stations to predict weather parameters like temperature, pressure, humidity, and many more.
- To interface any sensor to the microcontroller, you have to know the function of the sensor and different types of sensors used in remote sensing, weather systems, security devices, health equipment etc.

Level 1: Sensors

How sensors work

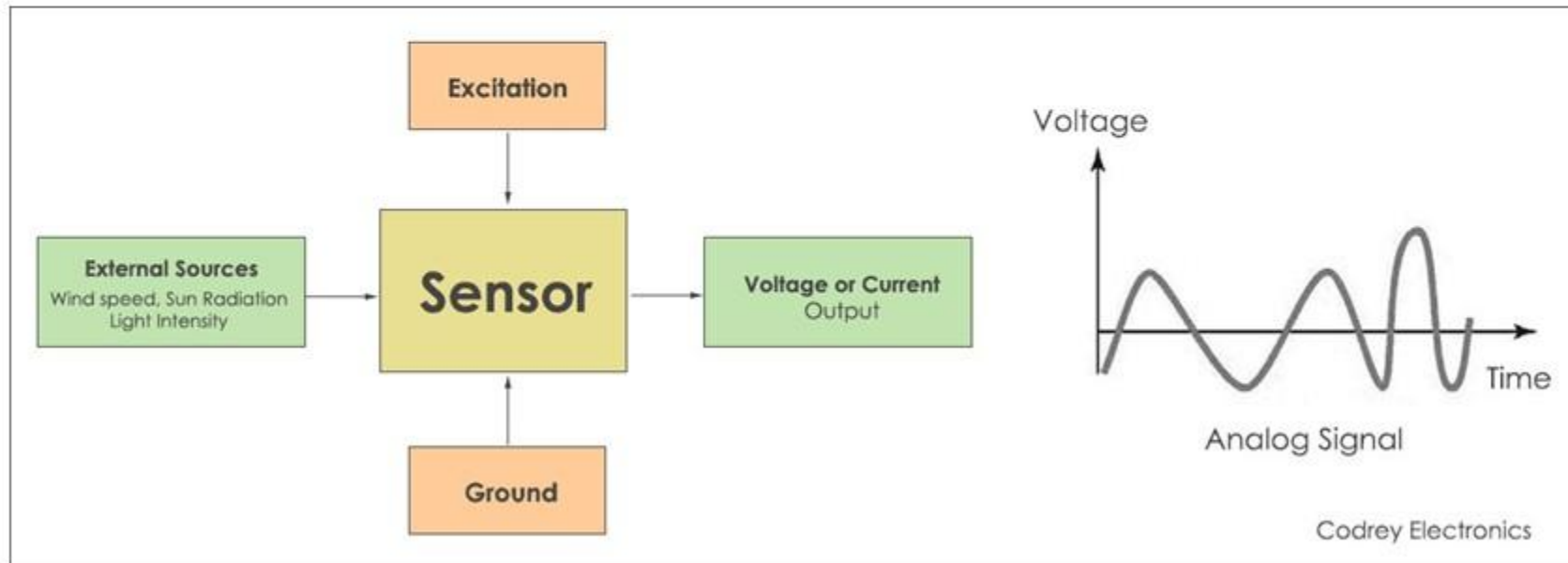
- Sensor is a module or chip that observes the changes happening in the physical world and sends the feedback to the microcontroller or microprocessor. Excitation (Power supply) and Grounding must be provided to the sensor for the proper working.



Level 1: Sensors

Analog Sensors

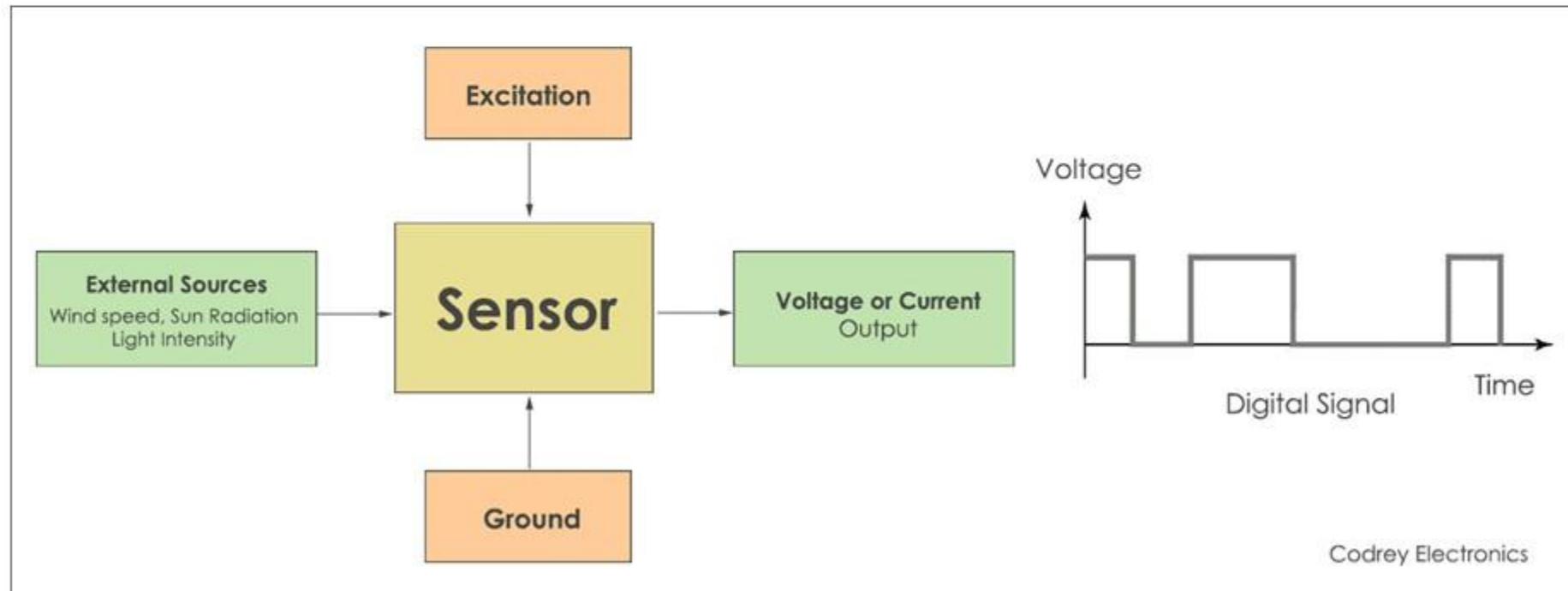
- Analog sensor senses the external parameters (wind speed, solar radiation, light intensity etc.) and gives analog voltage as an output. The output voltage may be in the range of 0 to 5V.



Level 1: Sensors

Digital Sensors

- Unlike analog sensor, Digital Sensor produce discrete values (0 and 1). Discrete values often called digital (binary) signals in digital communication.



Level 1: Sensors

How to choose a Sensor?

- To select a sensor, it's important to know about analog and digital circuits.
- Analog circuits are made up of analog components like resistor, capacitor, diodes and transistors... Whereas digital circuits consist of logic gates and microcontroller chips.
- Analog signals are much affected by external noise and create errors in the output signal. But digital signals are susceptible to noisy environments and hence digital sensors are preferred over analog ones.
- **Analog** I/O is used when you need to detect or control an event which involves a range of values.
Digital I/O is used when you need to detect or control an event which is binary (yes/no, on/off, etc).

Level 1: Sensors

ADC: Analog to Digital converters

- Analog-to-digital converters, abbreviated as “ADCs,” work to convert analog (continuous, infinitely variable) signals to digital (discrete-time, discrete-amplitude) signals.



Level 1: Sensors

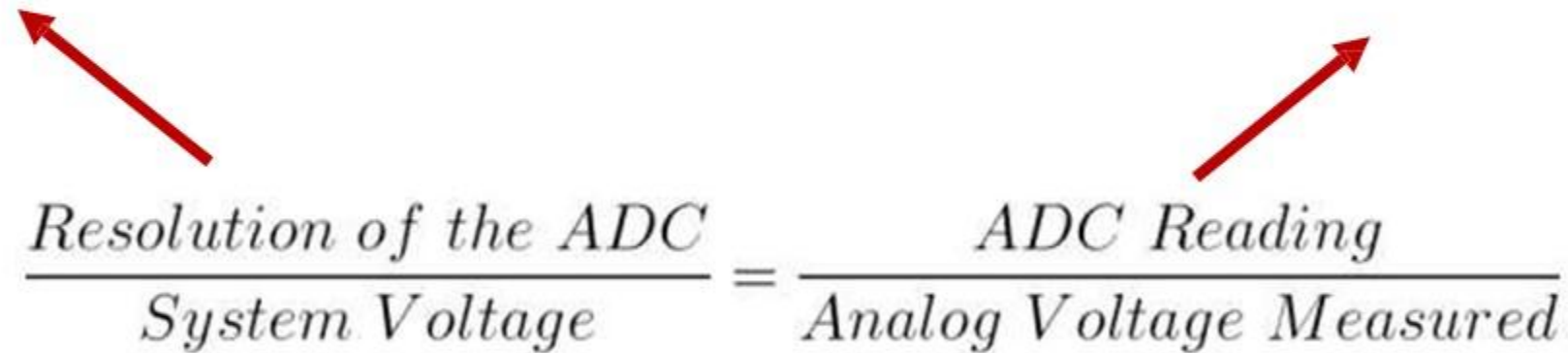
ADC: Analog to Digital converters

- Relating ADC Value to Voltage

The ADC reports a **ratiometric** value. Analog to digital conversions are dependant on the system voltage.

Usually 1023 (since most of ADCs are 10-bits)

??????



The diagram features a central equation with four red arrows pointing from its components to explanatory text. The equation is:
$$\frac{\text{Resolution of the ADC}}{\text{System Voltage}} = \frac{\text{ADC Reading}}{\text{Analog Voltage Measured}}$$
 The arrows point from 'Resolution of the ADC' to 'Usually 1023 (since most of ADCs are 10-bits)', from 'System Voltage' to 'Usually 5V', from 'ADC Reading' to '??????', and from 'Analog Voltage Measured' to 'The input value in Volt'.

Usually 5V

The input value in Volt

Level 1: Sensors

Analog Pressure Sensor

- Analog Pressure Sensor is a 5V sensor that can measure pressures up to 200 PSI. It outputs an analog voltage that is proportional to the measured pressure.



Analog pressure Sensors (Barometric)

Level 1: Sensors

Digital pressure sensor

- Digital pressure sensor has inbuilt signal processing unit such as ADC that converts the analog input to digital pressure output.
- Some of the applications of the Barometric pressure sensor are:
 - Leak detection in gas pipes and cables
 - Measuring pressure for environmental purpose
 - Tyre pressure monitoring
 - Respiration analytics
 - Industrial and process control
 - Medical devices
 - Airflow monitoring
 - Drones
 - Water level measurement



Level 1: Sensors

Analog temperature sensor

- Analog temperature sensor measures the temperature of the current location based on the resistance in variation. The value of resistance changes with temperature.
- Applications:
 - water temperature measurement
 - Air temperature measurement
 - Air conditioning
 - Food processing



Level 1: Sensors

Wind speed / Wind direction Sensor

- Wind speed/wind direction sensor commonly called anemometer uses the ultrasonic technique to get wind speed and direction.
- Applications:
 - Environmental weather stations
 - Oceanographic and meteorological stations
 - Harbours and seaports
 - Road tunnels



Level 1: Sensors

Reflex sensor

- A simple reflex sensor has transmitter and receiver sections. The transmitter sensor emits a light beam and when an object is detected the receiver captures and process this as changeover signal.
- Applications:
 - Monitors flow of material process
 - Level measurement
 - Recording level of liquid quantities



Level 1: Sensors

Fork sensor

- Fork sensors are quite close to the reflex sensor but efficient in picking and detecting very small objects with a size of micrometers (μm).
- Applications:
 - Placing and sorting small components
 - Gap monitoring and control
 - Recognize holes



Level 1: Sensors

Analog Hall effect/Magnetic Sensor (Position Sensor)

- The Hall Effect sensor works on the magnetic field. It senses the magnetic field and gives the output voltage. When the magnetic field is positive output voltage increases above the null voltage (no magnetic field and zero current).
- Applications of Hall sensor are:
 - GPS positioning
 - Current sensing
 - Speed movement detection
 - Metal detector



Level 1: Sensors

Radar Sensor

- Radar transmit short microwave signals that travel at the light speed. Radar sensors are used for measurement of liquid levels.



Level 1: Sensors

Solar radiation sensor

- Global radiation sensor (solar radiation) uses photo voltaic diode for measuring solar radiation.
- Applications:
 - Meteorological stations
 - Energy applications
 - Irrigation



Level 1: Sensors

Humidity sensor

- Humidity sensor calculates the humidity of the present location. Humidity is an important parameter for environmental observance, consumer electronics and medical diagnostics.
- Applications:
 - Humidity transmitter
 - Handheld devices
 - Refrigerators
 - Air compressors
 - Weather stations
 - Medical systems
 - Dew measurement



Level 1: Sensors

Air Quality Sensor [Gas sensor]

- This sensor monitors the number of gases in the air like CO₂ (carbon dioxide), SO₂ (sulfur dioxide), CO (carbon monoxide) etc.
- Applications:
 - Meteorological institutes
 - Health agencies
 - Homes and Hospitals
 - Industrial applications
 - Ventilation systems
 - Air cleaning



Level 1: Sensors

Light sensor

- Light sensor captures the ambient light (dark/bright) and converts it to current.
- Applications:
 - Display backlight in Mobiles and LCDs
 - TVs, Cameras
 - Toys
 - Automatic street light control



Level 1: Sensors

Rainfall sensor

- Meteorological agencies use rain gauge sensor to measure the amount of rainfall falls in a particular location. Rainfall is measured in mm.



Level 1: Sensors

Soil moisture sensor

- Soil moisture measures the amount of salt and moisture in the soils. It also measures the temperature in the soil.



Level 1: Sensors

Water level sensor

- Water level sensor calculates the depth of water in lakes, dams and rivers. There are various analog and digital based water level sensors.
- Applications:
 - Water level monitoring
 - Environmental applications
 - Groundwater tanks
 - Surface water applications



Level 2: Local processing and local storage

- Local processing devices are the second level and third in IoT. At this point, data is locally stored and processed, ideally not sent forwards unless relevant (example, sensor that detect emotions...)
- This part is explained in detail in the hardware section, as said devices are nothing more than microcontrollers and embedded boards, which handle the data they receive from the sensors.



Level 2: Local processing and local storage

Microcontrollers

- Microcontrollers are **small computing devices, easily connectable to hardware**. The development tools were, however, an obstacle and made using them very complicated.
- The first easy to use microcontroller was Arduino. It is a small programmable device, on which you can run a simple, open source software called firmware. The only fault was that it didn't have enough processing power and, as a result, no more than 4 network connections were supported. Its RAM being of 2KB. Shortly, the Arduino does not run an Operating System, what it runs is called Firmware. Basically, it runs only one program. The result is that you can estimate what program sequence gets executed at a certain time. Program written to the Arduino remain there until they are replaced with another program. Even when powered off, Arduino stores its software.

Level 2: Local processing and local storage

Arduino

- Small programmable device
- Easily connectable
- Open source
- Has a software that looks very easy !
- RAM of 2KB
- The Arduino does not run an Operating System, what it runs is called Firmware.



Level 2: Local processing and local storage

Rasberri Pi

- Like a computer
- Runs Linux
- you can run multiple programs on it
- You can run applications that use Internet services
- Full Networking system
- Very cheap !



Level 2: Local processing and local storage

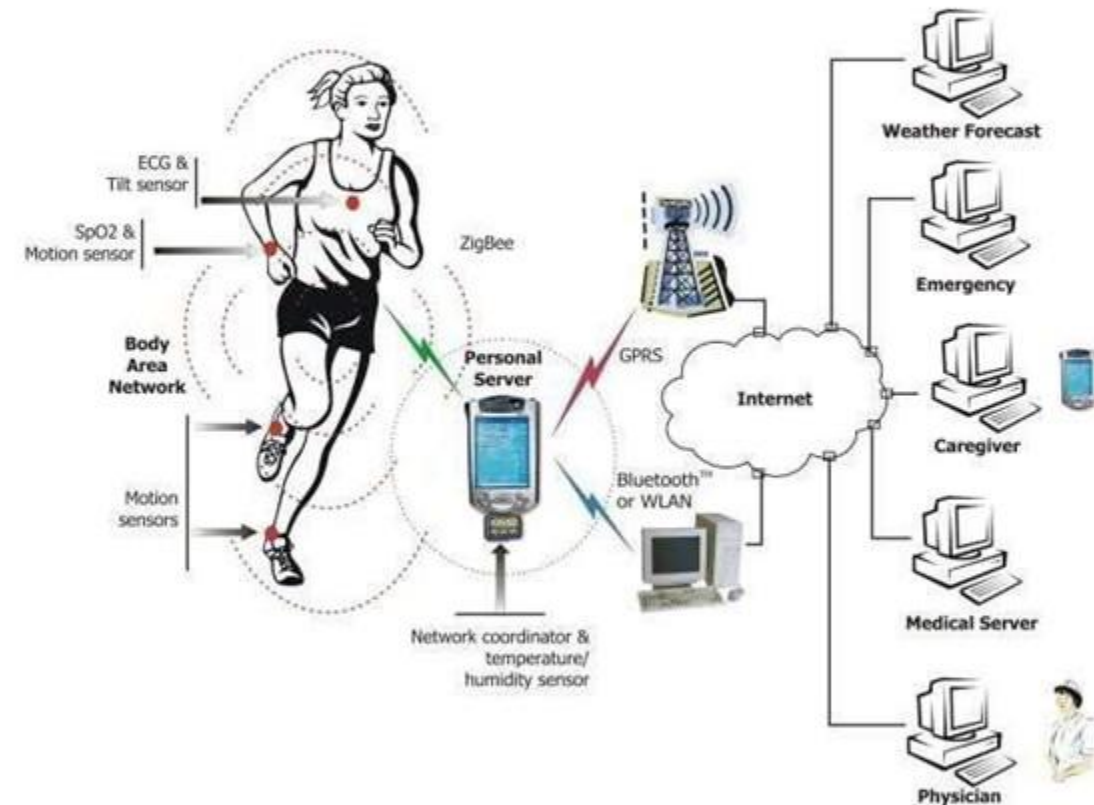
Wearable

- Wearable technology is a smart electronic device with microcontrollers. The device can be worn on the body as an implant or as an accessory. These wearable devices can perform many of the same computing tasks as mobile phones and laptop computers; however, in some cases, wearable technology can outperform these hand-held devices entirely.
- While wearable technology tends to refer to items which can be put on and taken off with ease, there are more invasive versions of the concept as in the case of implanted devices such as micro-chips or even smart tattoos. Ultimately, whether a device is worn on or incorporated into the body, the purpose of wearable technology is to create constant, convenient, portable, and mostly hands-free access to electronics and computers.

Level 2: Local processing and local storage

Wearable

- First Layer – this layer is the sensor(s). The sensors are placed closest to the body. The sensors monitor elements such as temperature, movement and pulse.
- Second Layer – this layer is the connectivity and control layer. The Bluetooth Low Energy (BLE) protocol is the most commonly used to connect wearable devices to a smartphone or home network.
- Third Layer – This layer is the cloud where the wearable supplies and reads data.



Level 2: Local processing and local storage

Wearable

- Wearable devices such as activity trackers are a good example of the Internet of Things, since “things” such as electronics, software, sensors and connectivity are effectors that enable objects to exchange data through the internet with a manufacturer, operator and/or other connected devices without requiring human intervention.

Level 3: Network and Internet

- There is hardware which connects to the previously described devices, pulls out data and sends it to the cloud to be stored.
- There are 4 protocols used at this level:
 - CoAP (less secure and designed for machine to machine communication),
 - MQTT (less secure and designed for machine to machine communication),
 - HTTP (web protocol)
 - XMPP which functions as a chat.

Level 4: Cloud Processing and Storage

- In the cloud, data is collected and the main goal is for it to reach the point of making predictions based on the stored information.
- Mainly, at this level:
 - Data is aggregated
 - Data is stored
 - Inference from data



Questions