UNIT 2

HARDWARE FOR IOT

SENSORS:

- Sensors are the electronic devices that sense the physical conditions.
- Sensor is a device that detects and measures physical properties or environmental conditions such as temperature, humidity, light , motion, sound or pressure.
- A sensor converts **physical energy** like heat, sound, strain, pressure, vibrations and motion into **electrical energy**. An **electronic circuit** connects to the input at a sensor. The circuit receives the output of the sensor. The output is according to the variation in physical condition. A smart sensor includes the electronic circuit within itself, and includes computing and communication capabilities.

- Technology that facilitates such changes due to sensing is also used in **mobile phone.**
- A mobile phone can sense surrounding conditions.
- The touchscreen of a mobile phone can senses a finger touch and gestures.
- The sensors enable the functioning of applications and games.
- A **microcontroller** is an associate **computing device** with a sensor circuit which calculates the **touched position** and maps it to a user command when a resistive-based touchscreen is used.
- Then the mobile phone takes further actions as per the command.

Touch sensor: This is the primary sensor that detects the physical contact of a user's finger on the screen. It allows users to interact with the device by tapping, swiping, or pinching gestures.

Proximity sensor: This sensor detects the presence of nearby objects, such as the user's face during a phone call. It helps in automatically turning off the screen during calls to prevent accidental touches and saves power by dimming the screen when the device is not in use.

Accelerometer: An accelerometer measures the acceleration of the device along its X, Y, and Z axes. It enables features such as screen rotation (changing from portrait to landscape mode) when the device is rotated, and motion-based gaming.

Gyroscope: A gyroscope measures the device's orientation and angular velocity. It enhances the accuracy of motion tracking and gesture recognition, especially in gaming and augmented reality applications.

Ambient light sensor: This sensor measures the ambient light level surrounding the device. It automatically adjusts the screen brightness to optimize visibility and conserve battery life based on the lighting conditions.

Fingerprint sensor: Many modern smartphones incorporate fingerprint sensors for biometric authentication. These sensors capture and store unique fingerprint patterns to unlock the device or authenticate transactions securely.

Types of sensors based on how they **process and output data**.

1.**Analog Sensors**

2.**Digital Sensors.**

Analog sensors measures continuous physical quantity .

The first type gives **analog inputs** to the control unit.

Examples are thermistor, photoconductor, pressure gauge and Hall sensor.

The second type gives **digital inputs** to the control unit.

Digital sensors give discrete values or digital signals as output.

Examples are touch sensor, proximity sensor, metal sensor, traffic presence sensor.

Analog Sensors:

Analog sensors produce output signals that are continuous and proportional to the physical quantity being measured.

Examples:

- Temperature sensors that **output** a **voltage** or **current** proportional to the temperature.
- Pressure sensors that produce a voltage or current proportional to the pressure applied.
- Light sensors that generate an analog voltage or current corresponding to the intensity of light.

Analog sensors typically require analog-to-digital conversion (ADC) to convert their output into digital format for processing by microcontrollers or digital devices.

Digital Sensors:

Digital sensors produce discrete output signals that represent specific states or values.

Examples:

- Switches that detect the presence or absence of an object and output a binary signal (on/off).
- Digital temperature sensors that output temperature readings in digital format.
- Motion sensors that output digital signals indicating motion detection events.

Digital sensors often incorporate built-in analog-to-digital converters and microcontrollers to process the sensed data and provide digital output directly.

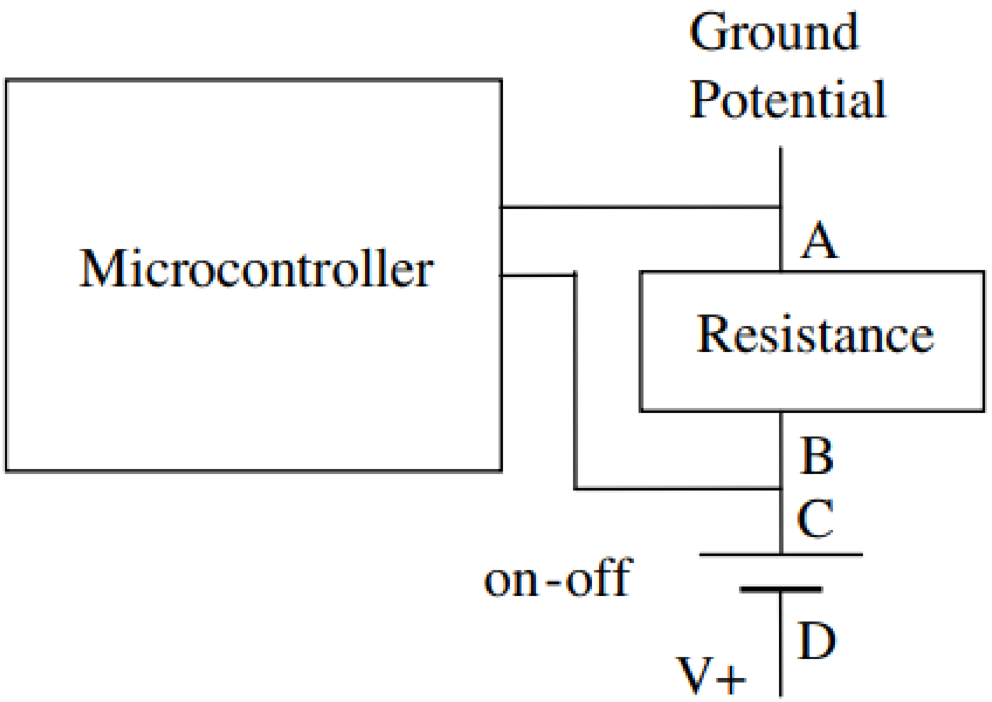
Analog System	Digital System
Analog signals	Digital signals
Analog signals are difficult to get analysed at first.	Digital signals are easy to analyse.
Analog signals are more accurate than digital signals.	Digital signals are less accurate.
Analog signals take time to be stored. It has infinite memory.	Digital signals can be easily stored.
To record an analog signal, the technique used, preserves the original signals.	In recording digital signal, the sample signals are taken and preserved.
There is a continuous representation of signals in analog signals.	There is a discontinuous representation of signals in digital signals.
Analog signals produce too much noise.	Digital signals do not produce noise.
Examples of analog signals are Human voice, Thermometer, Analog phones etc.	Examples of digital signals are Computers, Digital Phones, Digital pens, etc.

Sensing of an On-Off State

How is the switch on state sensed? How does one-bit digital output, 1 or 0 generate?

Figure shows that the circuit consists of one end A of the resistance connected to ground potential (negative end of the supply). The other end B connects to the end C of the switch. A switch can have two states on or off and gives two outputs 1 or 0. The other end D connects to the supply voltage V+ (= 5V) terminal. Microcontroller port pins connect C and A.

The circuits give 1s and 0s at port pins when switch state is off and on.



Microcontroller electronic circuits for sensing On and Off states on generation of output 1 and 0 for the port pin.

Types of Sensors:

There are numerous types of sensors, each designed to measure specific physical properties and environmental conditions.

1. Temperature Sensor
2. Humidity Sensor
3. IR Sensor (Distance)
4. Ultrasonic Sensor
5. Pressure Sensor
6. Light Sensor
7. Sound
8. Electrical Sensor
9. Gyroscope

Different Types of Sensors

1. **Temperature Sensors:**

- Devices which monitors and tracks the temperature and gives temperature's measurement as an electrical signal are termed as temperature sensors .
- These electrical signals will be in the form of voltage and is directly proportional to the temperature measurement.
- They detect a temperature change and convert the findings to data.
- Temperature sensors are used in various industries, including manufacturing, healthcare, and agriculture.
- **Examples :** Resistance temperature detectors(RTDs), and thermistors.
- 2 main types of Thermistors:
  NTC (Negative Temperature Co-efficient)
  PTC(Positive Temperature Co-efficient)

Humidity Sensor:

- Humidity sensors measure the **moisture content in the air**.
- Humidity is measured in percentage.
- It is the relative percentage ratio (RH%) of content of water vapours in air compared to one in a situation of maximum possible water vapour content for the air temperature at the instance of measurement.
- Greater than 90% humidity signifies it is a rainy day.
- The common application of the humidity sensor is in HVAC(Heating, ventilation and air conditioning) system to monitor and control indoor air quality.

3. Infrared Sensor (IR Sensor):

- IR Sensor is a device that detects infrared radiation emitted by objects in its field of view.
- Infrared (IR) sensor is useful for a 0.15 m to 0.8 m range of object.
- The distance can be measured for object from 0.1 m to 0.8 m. Above 0.8 m, the reflected intensity may be insufficient for detection and below 0.15 m, the time interval is less than 1 ns, which inhibits the detection.
- These sensors are widely used in various application including proximity sensing , object detection and motion detection.
- One common example of IR Sensor is the passive infrared sensor. (PIR).
- PIR sensors are commonly used in automatic door opening systems, occupancy detection in smart building and energy saving application.

4. Ultrasonic Sensor:

- Ultrasonic sensor is a device that uses ultrasonic sounds waves to detect the distance to an object and measure its proximity.
- Ultrasonic sensors are commonly used in applications such as object detection distance measurement and robotics.
- One common example of an ultrasonic sensor is the **ultrasonic ranging module.**

  Example: Parking assistance system in automobiles.
- Ultrasonic sensors are also used in robotics for navigation and obstacles avoidance and in home automation for the presence detection and gesture recognition.

5. Light Sensor:

- A light sensor, also known as photodetector or photosensor is a device that detects the intensity or presence of light in its surroundings.
- These sensors are used in wide range of applications, including automatic light control ,photography and ambient light sensing in electronic devices.

Example:

- Light dependent resistor or LDR,Photodiode
- The property of LDR is that its resistance is inversely proportional to the intensity of the ambient light i.e when the intensity of light increases, it’s resistance decreases and vise versa.

6. Pressure Sensor:

- A pressure sensor is a device that measures the presence of gases or liquids and convert this measurements into electrical signal.
- The sensor is called pressure transducer, pressure transmitter, pressure sender or pressure indicator.
- Application of pressure sensor can be explained as, a **tyre pressure monitoring system(TPMS)** uses the pressure sensors on each tyre. The sensors communicate the tyre pressure in each tyre, and a corresponding monitoring circuit sends alerts on the dashboard of the vehicle.

7.Sound

- A microphone is used to sense sound.
- A readily available electronic board with a microphone connects to the microcontroller, which can control an actuator for actions based on the sensed sound, or recognize the voice and then take required action, such as dialing a number using the actuator circuit or switching on the car

8.Electrical Sensor:

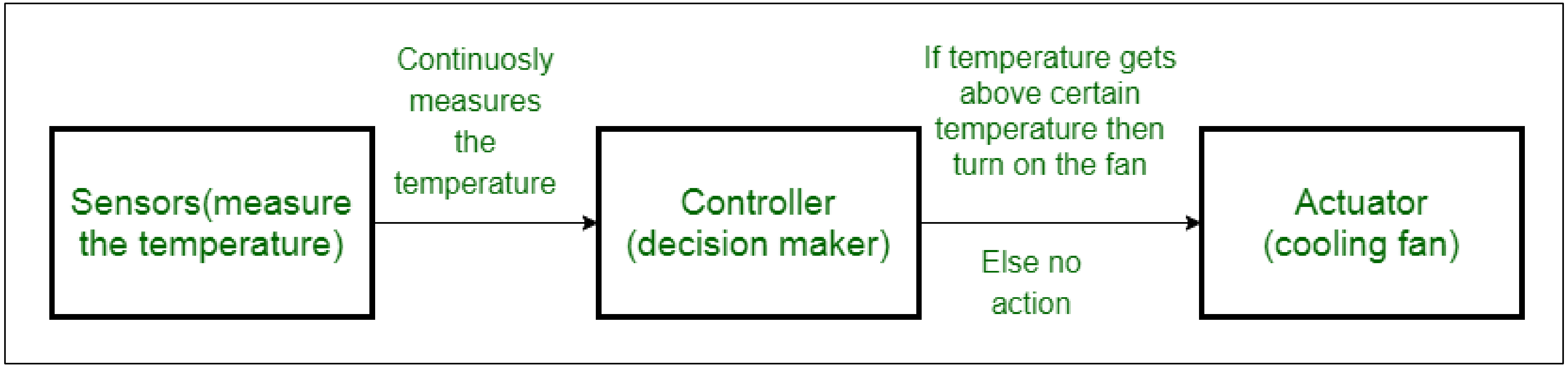
- An electrical sensor is a device that detects or measures electrical properties or signals.
- These sensors can be used to monitor various aspects of electrical system , such as voltage ,current ,resistance, capacitance or frequency.
- Electrical sensors play a crucial role in numerous application across different industries ,including automotive , aerospace, telecommunication and energy management.

9. Gyroscope:

- A gyroscope is a device which is used to measure or maintain orientation and angular velocity.
- It consists of spinning mass or rotor ,which will freely rotate in multiple axes.
- Gyroscope are commonly used in navigation systems, stabilization systems, robotics and consumer electronics.
- One of the common example of a gyroscope is the MEMS (Micro-Electro-Mechanical Systems) gyroscope.

ACTUATOR

- An actuator is a device that takes actions as per the input command, pulse or state (1 or 0), or set of 1s and 0s, or a control signal.
- An attached motor, speaker, LED or an output device converts electrical energy into physical action.
- The actuator are device that convert **electrical**, hydraulic or mechanical energy into **motion**.



Examples of applications of actuators are:

- Light sources
- Relay switch
- LEDs
- Solenoids
- Piezoelectric vibrators and sounders
- Servomotor
- Switching on a set of streetlights Application of brakes in a moving vehicle Ringing of alarm bell
- Speakers
- Switching off or on a heater or air-conditioner or boiler current in a steam boiler in a thermal plant

Sensor | Control Center | Actuator

Temperature sensor detects heat.

Sends this detect signal to the control center.

Control center sends command to sprinkler.

Sprinkler turns on and puts out flame.

Sensor to **Actuator** Flow

Light Source

Traffic lights are examples of function of light sources as actuators controlled by the inputs.

LED (Light Emitting Diode)

- An LED can be considered as actuator when it is used to produce light in response to an input signal.
- LED is an actuator which emits light or infrared radiation.
- Uses of different colour LEDs, RGB (Red-Green-Blue) LEDs, intensity variation of LED and colours, graphic and text display using big screens are actions which are controlled using the inputs.

Piezoelectric Vibrator

The piezoelectric vibrator is a device that uses the piezoelectric effect to generate **mechanical vibrations** when the **electric signal** is applied. Piezoelectric crystals when applied in varying electric voltages at the input generate vibrations.

Example: Piezoelectric lighter

Piezoelectric Speaker

A piezoelectric speaker enables synthesized music tunes and sounds. The appropriately programmed pulses generate the music, sounds, buzzers and alarms when they are the input to the speaker.

Example: Piezoelectric Buzzer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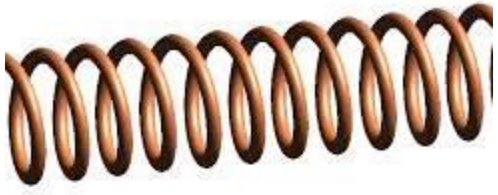


Solenoid:

- A solenoid is an actuator consisting of a number of cylindrically wound coils.
- A solenoid is an electromechanical device that converts **electrical energy** into **linear motion**.
- It consists of a coil of wire (typically copper) wound around a cylindrical or rod-shaped core made of ferromagnetic material, such as iron.
- When an electric current passes through the coil, it creates a magnetic field that induces a force on the core, causing it to move axially within the solenoid.

Applications of Solenoids as Actuators:

Locks: Solenoid locks use solenoids to actuate the locking mechanism. When a current is applied, the solenoid engages or disengages the locking mechanism, allowing or preventing access.

Motor

- A motor is a common type of actuator that converts electrical energy into mechanical motion.
- There are various types of motors, including DC motors, AC motors, stepper motors, and servo motors.
- Each type has its specific characteristics and applications.
- A motor can be DC (direct current controlled) or AC (alternating current controlled).
- IO modules are readily available to receive the control digital inputs of 1s and 0s and deliver high currents.

Example: DC Motor in an Electric Fan

Consider an electric fan powered by a DC motor:

1. **Electrical Input:** When you switch on the electric fan, an electrical current is supplied to the DC motor.

2. **Conversion of Electrical Energy:** The DC motor converts the electrical energy from the power source into mechanical motion.

3. **Rotation of Motor Shaft**: The electrical energy causes the motor shaft to rotate. The direction and speed of rotation depend on the polarity and magnitude of the electrical current supplied to the motor.

4. **Fan Blade Movement:** As the motor shaft rotates, it drives the fan blades attached to it. The blades move through the air, creating airflow and producing the cooling effect.

5. **Control of Motor Speed:** The speed of the fan can be controlled by adjusting the voltage or current supplied to the DC motor. Lower voltage or current results in slower fan speed, while higher voltage or current increases the fan speed.

In this example, the DC motor serves as an actuator by converting electrical energy into mechanical motion, which drives the fan blades, thereby producing airflow and providing cooling.

Servomotor:

- A servo motor is a type of motor commonly used as an actuator in control systems to precisely control the position, speed, and acceleration of mechanical systems.
- It consists of a DC or AC motor coupled with a sensor and a feedback control system.
- Servo motors are widely used in robotics, automation, aerospace, and other applications where precise motion control is required.
- The shaft of the motor can be controlled and positioned or rotated through 180° (+90°) degrees.
- The shaft's angular position is controlled through 180°, between –90° and +90° degrees.

Example: Servo Motor in a Robotic Arm

Consider a robotic arm with multiple joints controlled by servo motors:

1.Controller Input: The controller sends commands specifying the desired positions or angles for each joint of the robotic arm.

2. Feedback System: Each servo motor in the robotic arm is equipped with a feedback mechanism, such as an encoder, that continuously monitors the position of the motor shaft.

3.Comparison: The feedback system compares the actual positions of the motor shafts with the desired positions specified by the controller.

4. Error Signal: Any discrepancies between the actual and desired positions generate error signals for each motor.

5. Control Input: The controller adjusts the control inputs (PWM signals) to each servo motor based on the error signals, driving the motors to move the robotic arm joints towards the desired positions.

Relay Switch

- Relay switch is an electromechanical device that allows a low-power signal to control high-power circuit.

- An electronic switch can be controlled by the input 1 or 0 from the port pin of a microcontroller or through a push button switch and battery.

- The current flows through the switch or voltage applies through the switch depending upon the input state 1 or 0.

RADIO FREQUENCY IDENTIFICATION TECHNOLOGY

RFID, or Radio Frequency Identification, is a technology that uses **radio waves** to wirelessly identify and track objects or people.

It consists of three main components:

1. RFID Tags
2. RFID Readers
3. Backend System

- RFID technology is widely used in various industries, including retail, healthcare, logistics, and manufacturing.
- It offers benefits like improved efficiency, accuracy, and visibility in tracking and managing items or people.

RFID IoT Systems:

1.RFID Tags:

- These are small electronic devices that contain a **microchip** and an **antenna**. The **microchip** stores information about the tagged item, such as its unique identifier or other data.
- The **antenna** enables the tag to transmit this information to an RFID reader via radio waves.
- Tags can be **passive** which is powered by the readers electromagnetic field during communication
- Tags can be **active** which contain their own power source ,enabling longer read ranges and more data storage capability.

2. RFID Readers:

- These are devices that send and receive radio signals to communicate with RFID tags. Readers are used to read the information stored on the tags.
- The reader circuit of an ID can use UART or NFC protocol to identify the tag, when the RFID tag is at a distance less than 20 cm.
- An active NFC device/mobile generates an RF field which induces the currents in RFID and generates enough power for RFID.
- Using that power, the RFID transmits the identification of tag contents.

3.Backend System:

- This is the software and database infrastructure that manages the data collected by RFID readers.
- It processes and stores the information, allowing users to access and analyze it for various purposes, such as inventory management, asset tracking, or access control.

- A hotspot consists of a wireless transceiver or Wi-Fi transceiver for Internet connectivity.
- It receives signals from a number of RFID tags in an organization and transmits the data to the web server over the Internet.
- The hotspot connects to the Internet for IoT services, applications and business processes.
- A mobile or wireless nearby the device can also function as a hotspot. RFIDs form an IoT network.
- They connect to the Internet and then to an IoT server.
- An IoT server consists of RFID identity manager, device manager, data router, analyser, storage and database server and services.

Principle of RFID

- A tag is an electronic circuit which transmits its ID using RF signals.
- The ID transmits to a reader, then that transmits along with the additional information to a remote server or cloud connected through the Internet.
- An RFID tag has an advantage over a barcode or QR code in terms of simpler processing of the RFID data.

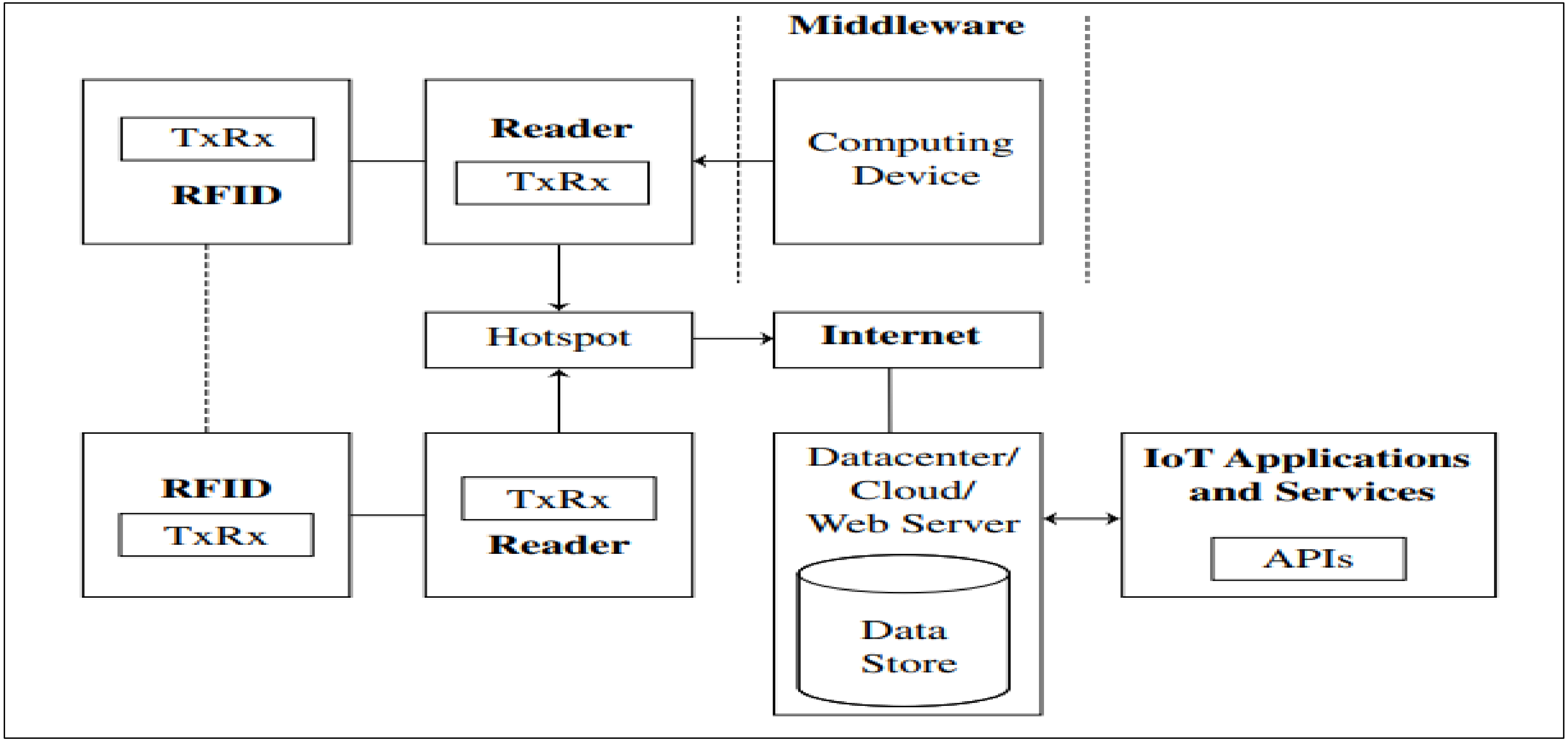
RFID IoT Network Architecture

- The four layered ITU-T reference model for the Internet of RFIDs, individual capabilities of the layers and data interchange.
- Fourth layer capabilities are for IoT/M2M services and applications. RFID technology has many applications.

RFID IoT Applications

Examples are tracking and inventory control of goods, supply chain systems, business processes such as for payment, leasing, insurance, and quality management, access to buildings and road tolls or secured store centre entries, and devices such as RFID based temperature or any other parameter sensor.

Components of an RFID System



RFID (Radio Frequency Identification) systems consist of several key components that work together to enable the identification and tracking of objects or assets. Here are the main components:

1.RFID Tags:

Microchip: Each RFID tag contains a microchip that stores data, such as a unique identifier or additional information about the tagged item.

Antenna: Tags also include an antenna, which is used to transmit and receive radio signals to and from RFID readers.

Enclosure: The microchip and antenna are typically housed within a protective enclosure, which can vary in size and shape depending on the application and environment.

Types: RFID tags can be **passive** (powered by the reader's electromagnetic field during communication), **active** (contain their own power source for longer read ranges and more data storage capacity), or **battery-powered passive**.

2.RFID Readers:

- **Transceiver:** RFID readers include a transceiver, which generates radio signals and receives signals from RFID tags.
- **Antenna:** Like RFID tags, readers also have an antenna to transmit and receive radio waves.
- **Power Source:** Readers require a power source to operate, which can be battery-powered or connected to a power outlet.
- **Interrogation Zone:** Readers create an interrogation zone or read range within which RFID tags can be detected and read.

3. Backend System:

- **Database:** The data collected by RFID readers is typically sent to a backend database for storage and retrieval.
- **Software:** Backend systems include software applications for processing and analyzing RFID data, as well as for managing and integrating it with other systems.
- **Connectivity:** These systems often have connectivity options, such as Wi-Fi, Ethernet, or cellular, to communicate with RFID readers and other devices.

4. Middleware:

- **Interface:** Middleware serves as a bridge between RFID readers and backend systems, providing an interface for data exchange and integration.
- **Filtering and Processing:** Middleware can filter and process RFID data before it is passed on to the backend system, helping to manage large volumes of data more efficiently.
- **Customization:** Middleware may offer customization options for specific RFID applications and requirements.

Middleware: Middleware are software components used at the reader, read manager, data store for the transaction data store and APIs of the applications.

5. Application Software:

- **User Interface:** Application software provides a user interface for interacting with RFID data, allowing users to view, analyze, and manage information related to tagged items or assets.

Applications and services and other associated applications software use the data store at the cloud or web server.

Overall, these components work together to create RFID systems that enable the automatic identification, tracking, and management of objects or assets in various applications and industries.

Issues

- **Design issue:** Designing a unique ID system needs a standard global framework.

- **Security issue:** A tag is read only. It can thus interact with any reader and thus allows automated external monitoring. A tag can thus be tracked without authority. A privacy issue arises when a tag and reader need not to be authenticated before their use. Full implementation of privacy and security needs data processing at the tag and reader with access encryption and authentication algorithms. Another issue is that the RFID system can be vulnerable to external virus attacks.

- **Cost issue:** RFID tag and reader become costly with data processing and security enhancing technology.

- **issue:** The tag needs protection from the adverse weather condition which may damage the tag.

- **Recycling issue:** Recycling of the tags can be an environmental concern.

- **Active life issue:** Active RFID, which consists of battery, has limited life of up to 2 to 4 years.

Technological Challenges

RFID technology challenges are as follows:

- ✓ **Interference:** When an organization uses a number of wireless systems, since RFID hotspot also requires wireless installation, the frequencies may interfere among the systems. The systems require effective mitigation from interference.
- ✓ Effective implementation at data processing subsystem consisting of reader and tag protocols, middleware architecture and EPC standards.
- ✓ Need of low cost tags and RFID technology
- ✓ Design robustness
- ✓ Data security

Security Challenges

The issues associated with RFID security are:

- ✓ Discovery of foreign attacks (intrusions) and maintain overall data integrity. Unauthorized disabling of a tag by a reader which is external, thus making the tag useless.
- ✓ Unauthorized tag manipulation by a reader which is external, thus making the tag useless
- ✓ Cloning of the tag by an unauthorized entity
- ✓ Man-in-the-Middle attack: When an external object pretends to be either a tag or reader between system tags and readers.

Solutions can be encryption, tag deactivation on detection of intrusion, mutual authentication between the tag and reader, detection of the tag owner, use of read data analyser and data cleaning.

<u>Problem:</u>

How does an RFID tag securely communicate and read by a reader?

How is an RFID tag secured?

<u>Solution:</u>

Method 1: An RFID tag may have a processor and memory. Then it computes one-way hash function called meta ID on tag. When the RFID reader uses the meta-ID, then only the tag communication unlocks and the tag becomes readable. After the reader finishes reading, the tag gets locked. This disables reading by unknown entities to the system.

Method 2: The tag can self-destruct if under attack.

Wireless Sensor Networks

- **Wireless Sensor Networks (WSNs)** are networks of small, low-power devices (sensors) that collect and transmit data wirelessly.
- These networks are used in various applications such as environmental monitoring, healthcare, industrial automation, and smart cities.
- Each node of the WSN has an RF transceiver. The transceiver functions as both, a transmitter and receiver.

Definition

- WSN is defined as a network in which each sensor node connects wirelessly and has the capability of computation, for data compaction, aggregation and analysis.

- Each one also has communication as well as networking capabilities.

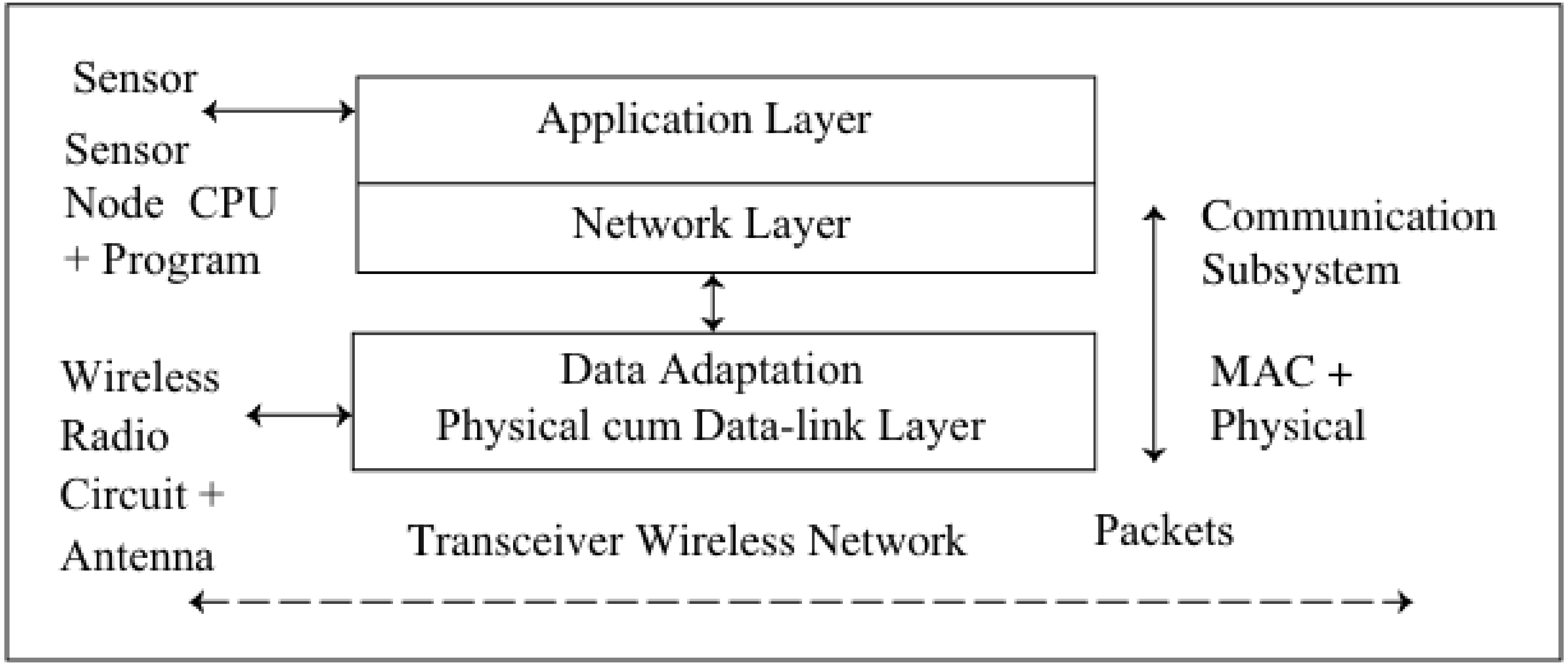
- A WSN consists of spatially distributed autonomous devices (sensors).

Key Components of WSNs

- **Sensors** – Devices that measure environmental conditions like temperature, humidity, motion, or pressure.
- **Nodes** – Small computing devices with sensors, a processor, and a communication module (e.g., Zigbee, Bluetooth, Wi-Fi).
- **Base Station (Sink Node)** – Collects data from sensor nodes and sends it to a server or cloud for processing.
- **Communication Protocols** – Methods for wireless data transmission (e.g., IEEE 802.15.4 for low-power networks).

WSN Architecture

WSN Node Architecture shows the three-layer architecture of a node. The three layers are application layer, network layer (serial link with data-link MAC), physical cum data-link layer (MAC + Physical Layer).



Architecture of a wireless sensor node

- The application layer software components are sensor management, sensor query and data dissemination, task assignment, data advertisement and application-specific protocols.

- Sensor, CPU and program sensor node constitute the application and network layers.

- Network layer links serially to the data-link layer, and may include the coordination or routing software.

- A serial link interconnects the layers to a wireless radio circuit and antenna. The radio circuit is at physical cum data-link layer.

- Communication subsystem uses MAC and physical protocols.

PARTICIPATORY SENSING

- Information collected from sensors of multiple heterogeneous sources can lead to knowledge discovery after analytics and data visualisation.

- Participatory sensing is a method of data collection that involves individuals or communities actively participating in the process of gathering information using their personal devices, such as smartphones or wearable sensors.

- This approach improves the presence of mobile devices and the capabilities they offer, such as GPS, cameras, accelerometers, and microphones, to collect various types of data, including environmental, social, and urban information.

- A **participant** of a PS process can be sensors used in mobile phones.

- Mobile phones have camera, temperature and humidity sensors, an accelerometer, a gyroscope, a compass, infrared sensors, NFC sensors, bar or QR code readers, microphone and GPS.

- Mobiles communicate on the Internet the sensed information with time, date and location stamps.

- Figure 7.9 (a) shows the sources of data in the PS process for IoT applications.

- Figure 7.9 (b) shows the phases of a PS process.

Phase 1 is coordination, in which the participants of a PS process organise after identifying the sources.
Next two phases, i.e. phases 2 and 3 involve data capture, communication and storage on servers or cloud.
Next two phases, i.e. phases 4 and 5 involve PS data processing and analytics, visualisation and knowledge discovery.
Last phase, i.e. phase 6 is for initiating appropriate actions.

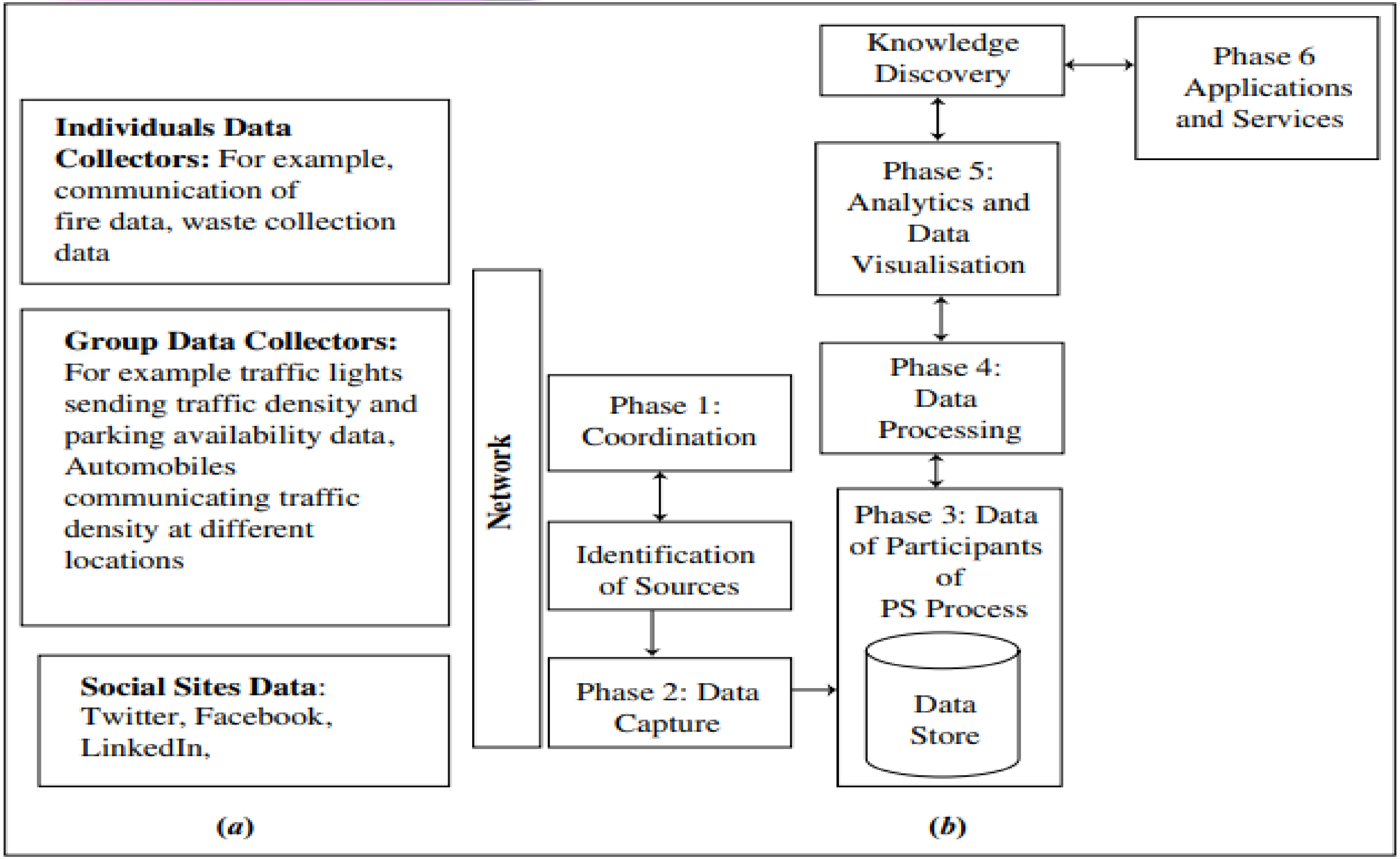


Figure 7.9 (a) Sources of data in the PS processes and (b) Phases of a participatory sensing process for IoT applications and services

Industrial IoT

- Industrial Internet of Things (IIoT) involves the use of IoT technology in manufacturing.
- IIoT involves the integration of complex physical machinery M2M communication with the networked sensors and use of software, analytics, machine learning and knowledge discovery.
- IIoT applications are in the manufacturing, railways, mining, agriculture, oil and gas, utilities, transportation, logistics and healthcare services.

Problem

How is IIoT technology used in optimising the bicycle manufacturing process?

Solution

- The sensors at each manufacturing stage in a bicycle industry communicate information on completion at each stage for each bicycle.
- An IIoT application analyses that data on completion of each activity at each stage, including data of breakdowns, work stoppages and failures at the stages. The application enables the company to take steps and synchronises various actions to remove any bottlenecks due to the components supply or the manufacturing stage machinery or human failures.
- Bicycle manufacturing is thus optimised.
- Figure 7.10 shows IIoT phases in the bicycle manufacturing process.

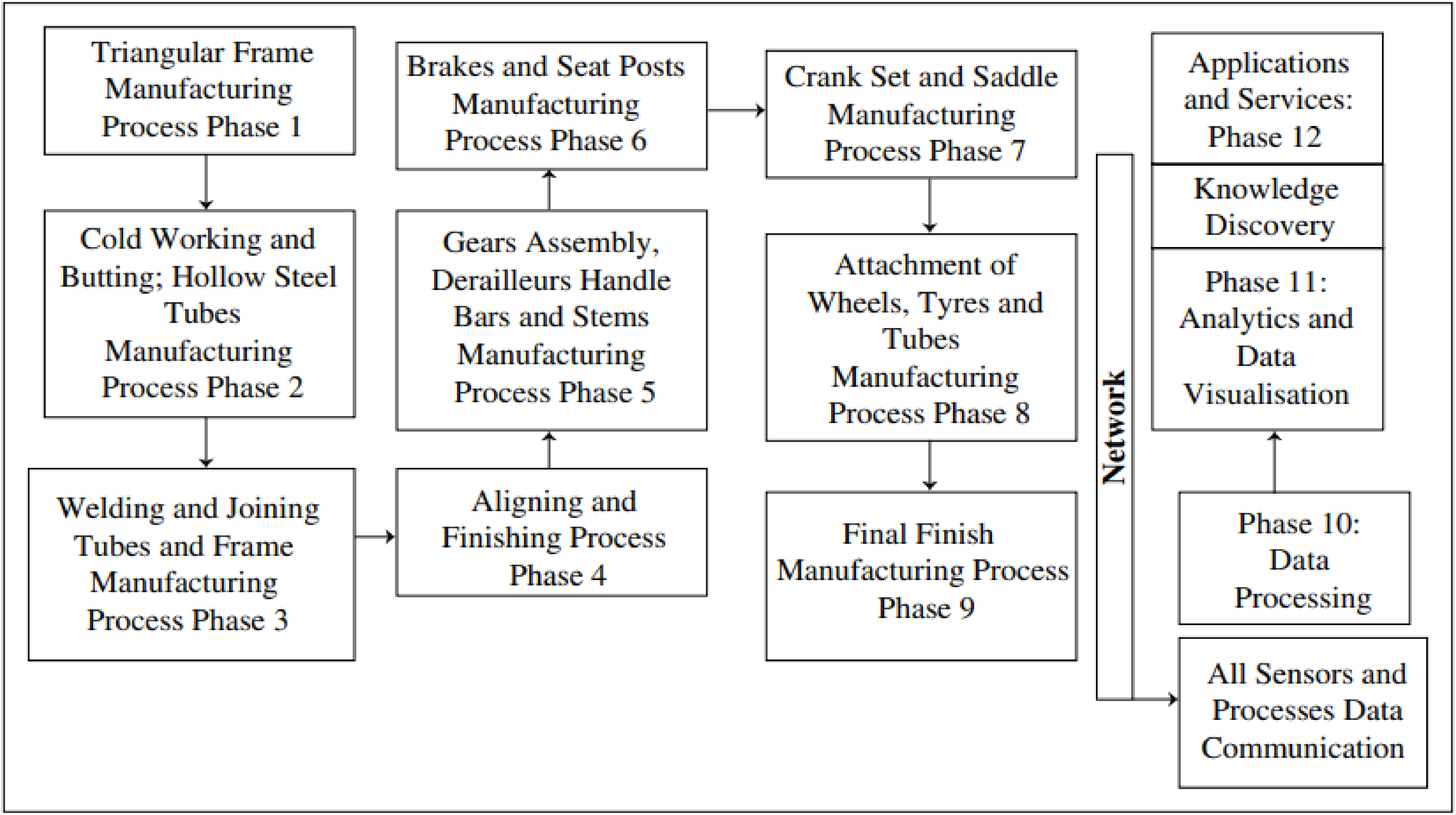


Figure 7.10 IIoT phases in the bicycle manufacturing process

Embedded platforms for IOT

Embedded system denotes a system that embeds software into a computing platform.

Embedded device refers to a device, which embeds software into a computing platform and performs the computations and communication for specific systems.

Microcontroller unit (MCU) means a single-chip VLSI (Very Large Scale Integration) unit (also called microcomputer), which may be having limited computational capabilities.

Timer device or feature in electronic systems that measures time intervals.

Port refers to a device that enables input output (IO) communication between the MCU and another device such as a sensor or actuator or keypad or with an external computing device.

USB port connects the device hardware to a computer .

GPIO pins refer to General Purpose Input-Output pins. A pin that can be used in addition to digital input and output for other purposes, such as Rx (receive) and Tx (transmit) or SDA (serial data line) and SCK (Serial Clock), PWMs (Pulse Width Modulation), analog inputs, outputs or timer outputs.

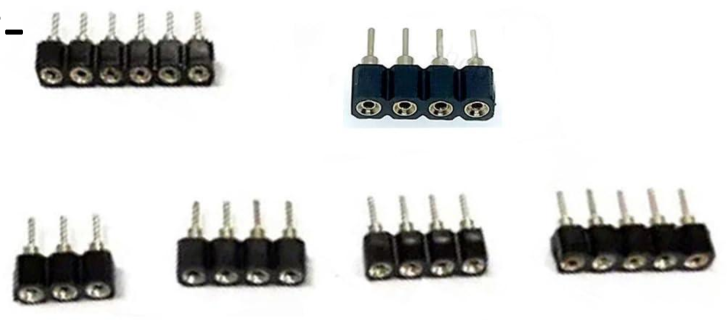
Board is an electronic hardware—an electronic circuit board with MCU or SoC (System-on-a-Chip), circuits and connectors, which provide the connections to other ICs and circuit components.

Platform denotes a set consisting of computing and communication hardware, software and operating system (OS).

Module (hardware) is smaller form-factor hardware which can be placed onto a board. The module may embed the software.

Shield means a supporting circuit with connection pins, socket(s) and supporting software.
Usage of the supporting circuit provides extra features, such as connectivity to wireless devices, such as ZigBee, ZigBee IP, and Bluetooth LE, Wi-Fi or GSM or RF module or to a wired device, such as Ethernet shield.

Header means plastic-coated strip or plastic-capped plug-in which is placed on top of the pin holes when making connection of the wires without electronic soldering.



Jumper denotes a wire with a solid tip at each end which is normally used to interconnect the components on an electronic-circuit breadboard.

Interrupt means an action in which a running program interrupts an hardware signal, such as timer timeout or on execution of a software instruction for interrupt.

Integrated Development Environment (IDE) means a set of software components and modules which provide the software environment for developing and prototyping.

Operating system (OS) is a system software which facilitates the running of processes, allocation of memory etc. The OS enables many system functions using the given computing device hardware.

EMBEDDED COMPUTING BASICS

Embedded Software :Software consists of instructions, commands and data. A computing and communicating device needs software.

Bootloader: Bootloader is a program which runs at the start of a computing device, such as an MCU. A bootloader initiates loading of system software (OS) when the system power is switched on, and power-on-self test completes.

Real-Time Operating System

Real-Time Operating System (RTOS) is an OS that enables real-time execution of processes on computing and communication hardware.

Simulator

Simulator is software that enables development on the computer without any hardware, and then prototyping hardware can be connected for embedding the software and further tests.

APIs: Application Programming Interfaces. It is a set of rules , protocols and tools that allow different software application to communicate with each other.

Device Interfaces : These are special types of APIs that enable communication between software and hardware devices.

Selection of Embedded Platform

Hardware

- Processor speed
- RAM need which may be 4 kB or higher depending upon the OS and applications.
- Connection needs to ZigBee, ZigBee IP, Bluetooth LE, Wi-Fi or Wired Ethernet for networking using a supporting circuit (shield)
- Sensor, actuator and controllers interfacing circuits, such as ADC etc
- Power requirements, V- and V+, 0 V and 3.3 V or 0 V and 5 V or other.
- Software Platforms and Components

Software Platforms and Components

Selection among a number of different available software depends on hardware platform, open source availability of software components, cost of availability or development of other required components for applications and services.

The choice of embedded software

IDE with device APIs, libraries, OS or RTOS, emulator, simulator and other environment components, middleware with communication and Internet protocols, and Cloud and sensor-cloud platform for applications development, data storage and services.

EMBEDDED PLATFORMS FOR PROTOTYPING

Several standard popular boards, modules and supporting circuits (shields) are available from a number of sources.

Following are some of the development boards:

- Arduino,
- Raspberry Pi
- Intel® Galileo
- Edison
- Beagle Bone
- mBed boards.

Arduino

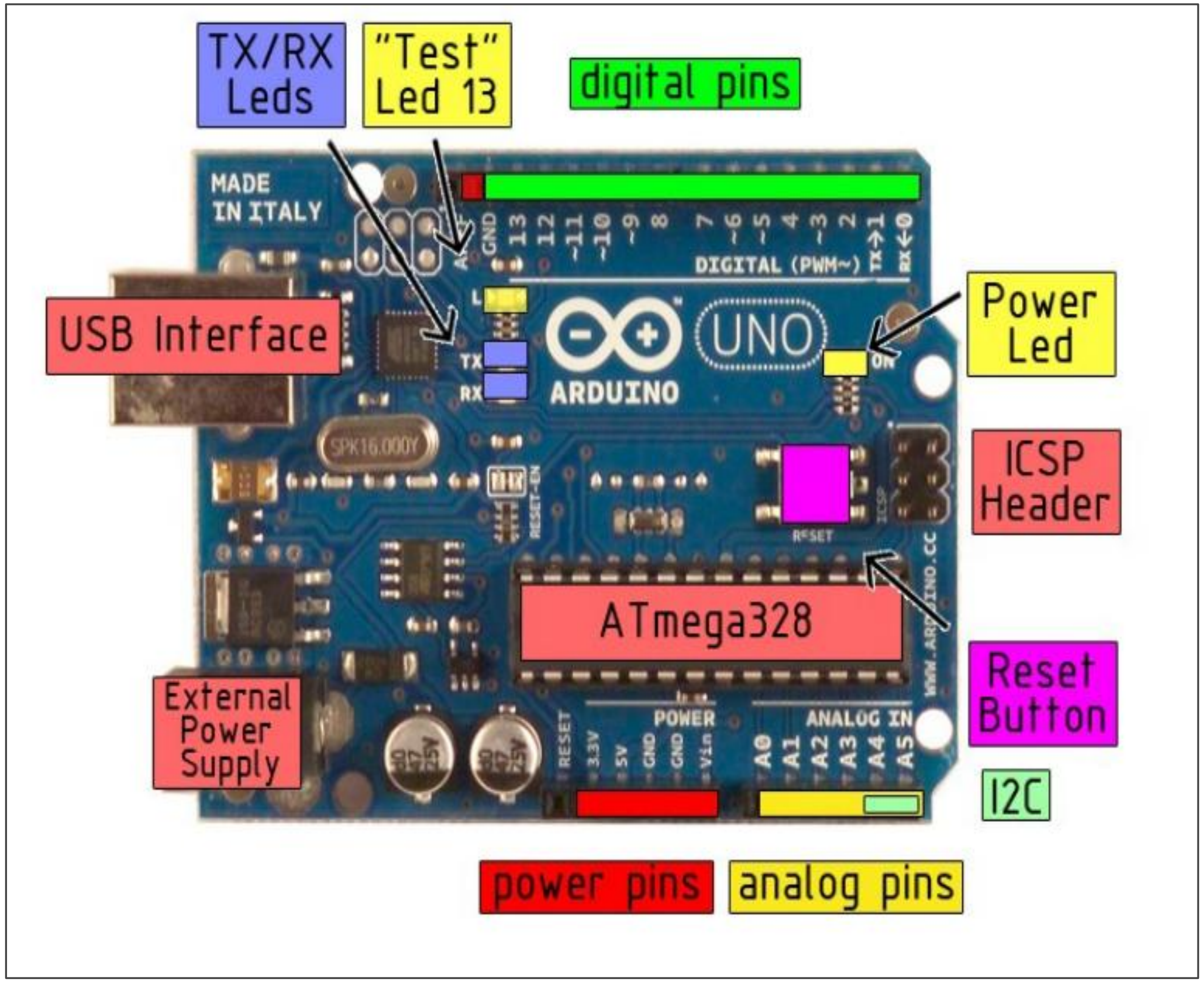
An Arduino board is a microcontroller based development platform that allows to create electronic projects.

Arduino Uno board is a robust as well as widely used board to get started with electronics and coding. Uno is most used and documented board of the whole Arduino family at present.

It includes the following components:

- Microcontroller
- Input /Output (I/O)Pins
- Power Supply
- Reset Button
- Crystal Oscillator
- LEDs
- Voltage Regulator
- Serial Interface
- USB Port

Technical Specification



Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

IoT Applications

- An Arduino application can be an embedded-device data-connectivity to the Internet and data store on cloud.
- Example of an Arduino application for IoT is Internet of streetlights.
- Arduino board find applications where the device does not require intensive computing and graphics.
- The applications are using things which are light emitting devices, wearable devices, health monitoring or fitness devices, watches, sensors and actuators connected smartly through the Internet.

Table 8.1 Features of UNO and other IoT device and wearable device boards

Board/ Shield	Application	AVR® Micro-controller/ Clock	Operating/ input V	EEPROM/ SRAM/ Flash	Analog In/ Out/Digital IOs/*n*-bit PWM	USB/ UART	Ether-net/ Wi-Fi/ GSM
Due	Fast computations, ARM based MCU	ATSAMSX8I	3.3 V/ 7 V–12 V	0 kB/ 96 kB/ 512 MB	12/2/54/ 12	2 micro/4	0/0/0

UNO	Getting started with electro-nics and coding	ATMega328/ 16 MHz	5 V/7 V–12 V	1 kB/2 kB/ 32 kB	6/0/14/6	Standard/ 1	0/0/0
Yun	IoT	(i) ATmega 32U4/ 16MHz (ii) AR9331 Linux/ 400 MHz	5 V	(i) 1 kB/ 2.5 MB/ 32 MB (ii) 1 kB/ 16 MB/ 64 MB	(i) 20/7/ 12/0	Micro/1	0/0/0
Ethernet	IoT	ATMega328/ 16 MHz	5 V/ 7 V–12 V	1 kB/2 kB/ 32 kB	6/0/14/4	Standard/ 0	1/0/0
Fio	IoT	ATMega328P/ 8 MHz	3.3 V / 3.7 V–7 V	1 kB/2 kB/ 32 kB	8/0/14/6	Mini/1	0/0/0

Gemma	Wearable	ATtiny85/8 MHz	3.3 V/ 4–16 V	512 B/512 B/8 kB	1/0/3/2	Micro/0	0/0/0
LilyPad	Wearable	ATmega168V/ 8 MHz ATmega328P/ 8 MHz	2.7–5.5 V/ 2.7–5.5 V	512 B/1 kB/ 16 kB	6/0/14/6	0/0	0/0/0
LilyPad SimpleSnap	Wearable	ATmega328P/ 8 MHz	2.7–5.5 V/ 2.5–5.5 V	512 B/ 512 B/8 kB	4/0/9/4	0/0	0/0/0
LilyPadUSB	Wearable	ATmega32U4/ 8 MHz	3.3 V/ 3.8–5 V	1 kB/ 2.5 kB/32 kB	4/0/9/4	Micro/0	0/0/0

Table 8.2 lists the features of ARM based Arduino for IoT devices and wearable devices board, 'due' for fast computations and communication.

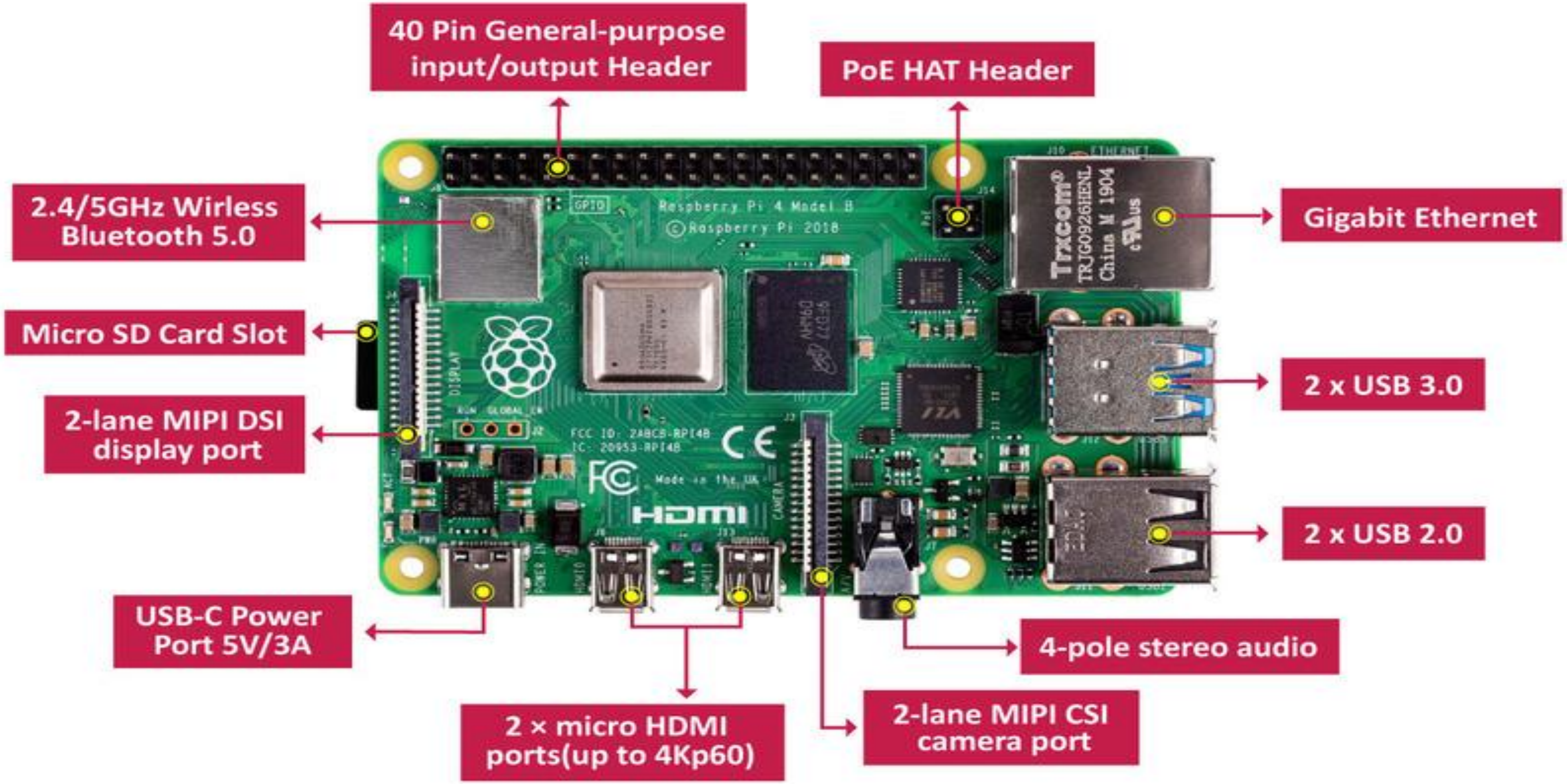
Raspberry Pi

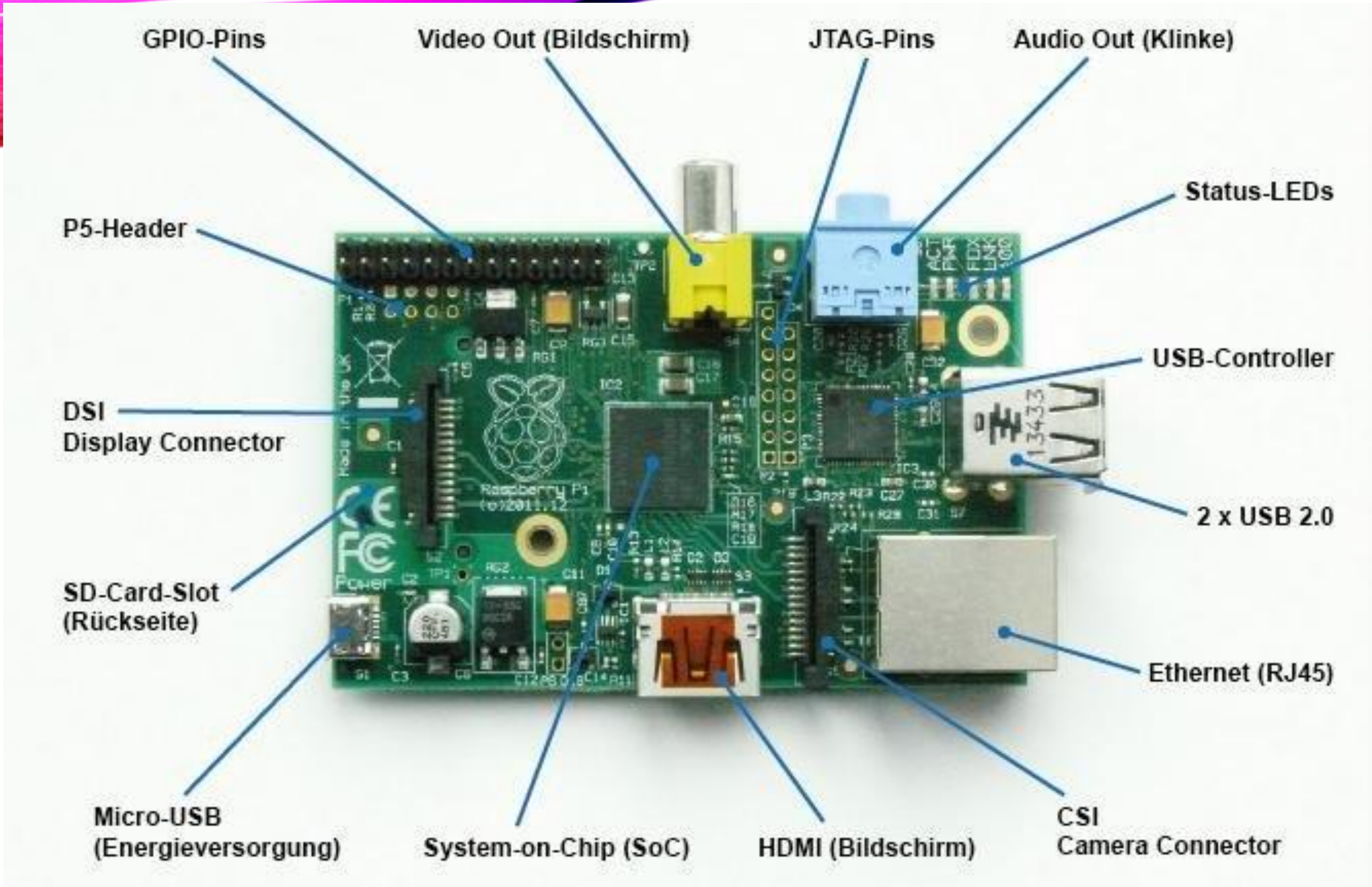
Raspberry Pi 3 (RPi 3) model B is the latest (February 2016) single board SoC based computing and communication board.

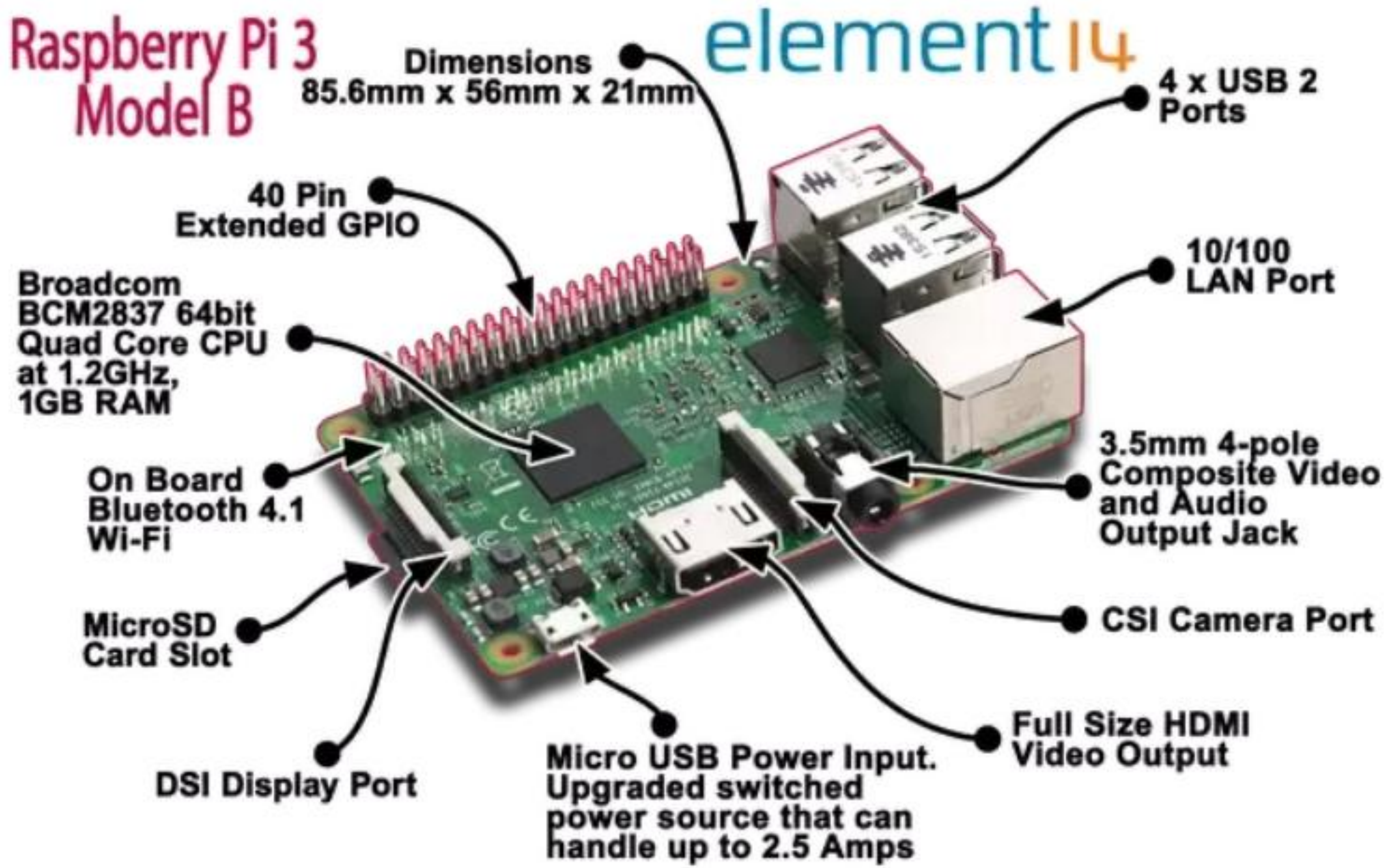
RPi is for home automation and drones, for devices which need an OS that is different from that of traditional PCs, such as Ubuntu Core (also known as Snappy).

Components of Raspberry Pi Board:

- Processor
- Memory (RAM)
- Input/Output (I/O) Pins
- USB Ports
- HDMI Port
- Ethernet Port/Wi-Fi
- MicroSD Card Slot
- Camera and Display Ports
- Audio Jack
- Power Port
- Onboard LEDs


40 Pin General-purpose input/output Header
PoE HAT Header
2.4/5GHz Wirless Bluetooth 5.0
Gigabit Ethernet
Micro SD Card Slot
2 x USB 3.0
2-lane MIPI DSI display port
2 x USB 2.0
USB-C Power Port 5V/3A
4-pole stereo audio
2 × micro HDMI ports(up to 4Kp60)
2-lane MIPI CSI camera port


GPIO-Pins
Video Out (Bildschirm)
JTAG-Pins
Audio Out (Klinke)
Status-LEDs
P5-Header
USB-Controller
DSI
Display Connector
2 x USB 2.0
SD-Card-Slot
(Rückseite)
Ethernet (RJ45)
Micro-USB
(Energieversorgung)
System-on-Chip (SoC)
HDMI (Bildschirm)
CSI
Camera Connector


Raspberry Pi 3
Model B
element14
Dimensions
85.6mm x 56mm x 21mm
4 x USB 2
Ports
40 Pin
Extended GPIO
10/100
LAN Port
Broadcom
BCM2837 64bit
Quad Core CPU
at 1.2GHz,
1GB RAM
3.5mm 4-pole
Composite Video
and Audio
Output Jack
On Board
Bluetooth 4.1
Wi-Fi
MicroSD
Card Slot
CSI Camera Port
Full Size HDMI
Video Output
DSI Display Port
Micro USB Power Input.
Upgraded switched
power source that can
handle up to 2.5 Amps

IoT Applications

- An RPi application is media server IoT devices.
- RPi board functions as a personal computer.
- Its applications are in networked security camera systems in home automation or ATMs applications and services.
- Example 8.4 gives Raspberry Pi applications in IIoT.

Table 8.4 Features of Raspberry Pi 2 model B + board

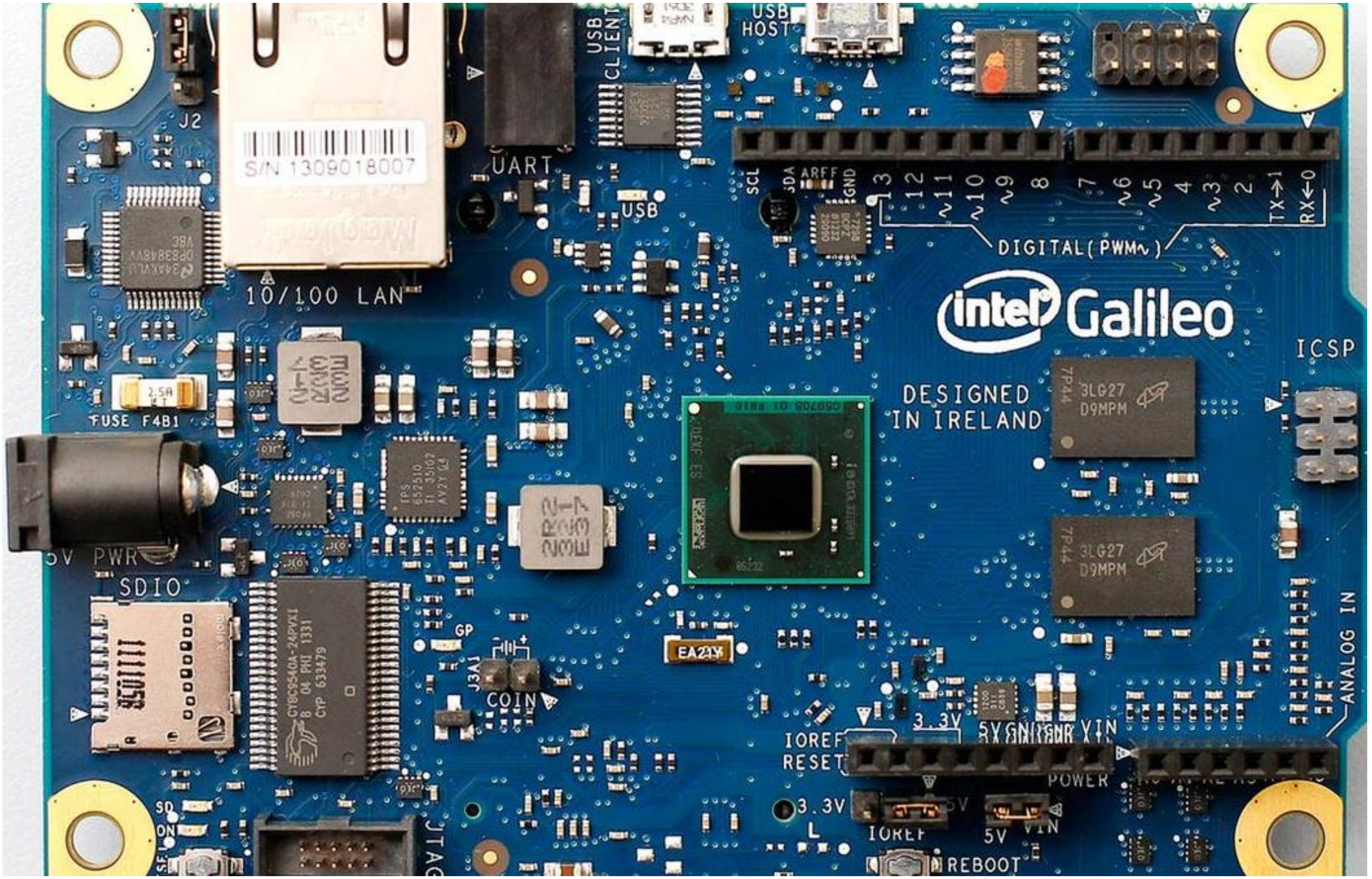
Board/ Shield	Application	SoC Processor/ Clock	Opera-ting/ Input V	L1 Cache/ L2 Cache/ RAM	Digital IO/ PWM/ Micro SD/	USB hosts/ UART Rx and Tx/I2C SDA-SCK/ SPI	Ether-net port/ HDMI out/ Camera Port/ GSM
Raspberry Pi 2 model B+	Advanced compute, and graphic and network connectivity functionality like a single board computer	Quadcore ARM Cortex-A7/ 900 MHz	5 V/ 7 V–12 V	16 B/ 128 kB/ 1 GB RAM	40/1/1	Standard hosts 2/ 1 pair/1 pair/1 with two chip select signals	1/ 1 /1/0

Intel Galileo

- Intel Galileo is a line of Arduino-certified development boards. Galileo is based on **Intel x86 architecture**.
- It is open-source hardware that features the **Intel SOC X1000 Quark based Soc** which gives it power and versatility to create awesome embedded system.

Components:

- Processor
- Memory (RAM)
- Input/Output (I/O) Pins
- USB Ports
- Ethernet Port
- MicroSD Card Slot
- Power Port
- Serial Port


intel Galileo
DESIGNED
IN IRELAND
10/100 LAN
S/N 1309018007
UART
USB
USB CLIENT
USB HOST
J2
FUSE F4B1
5V PWR
SDIO
COIN
DIGITAL (PWM~)
ICSP
ANALOG IN
IOREF
RESET
POWER
REBOOT
JTAG

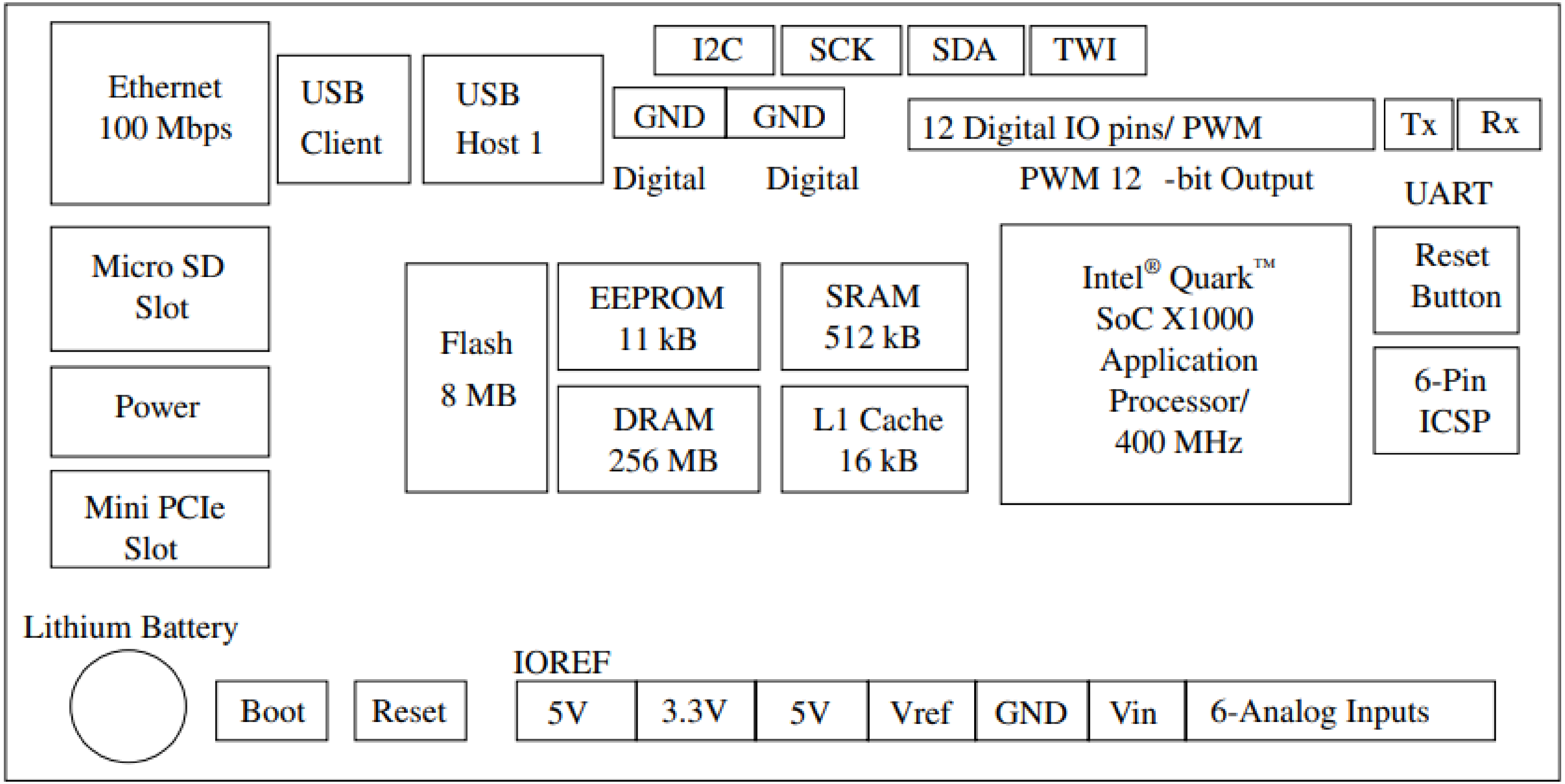


Figure 8.3 Architecture of Intel Galileo Gen 2 board for advanced computer functionalities with network connectivity for development of IoTs

Intel Edison

- Intel Edison is a compute module.
- The Intel Edison module includes built in Wi-Fi and Bluetooth connectivity.
- RAM is 1 GB in size.
- It has higher performance.

Beagle Bone

- Beagle Bone based board has very **low power** requirement.
- It is a card-like computer which can run **Android** and **Linux**.
- Both the hardware designs and the software for the IoT devices are **open source**.
- Memory on-board is 2 GB

<u>Features:</u>

- high performance
- Single-board computer and communication board
- Prototyping ease for media

ARM mBed

- open source
- The board enables the use of an open version of modules, support of software library for peripheral components, sensors, radios, protocols and cloud service APIs under the Apache License 2.0.

IoT Applications

- An mBed community ecosystem enables the development of the secure and efficient IoT applications.
- A platform includes an online web-browser-based programming and development environments
- for IoT devices.
- mBed applications use IBM IoT Foundation for Internet cloud data storages and IoT applications

THANK YOU