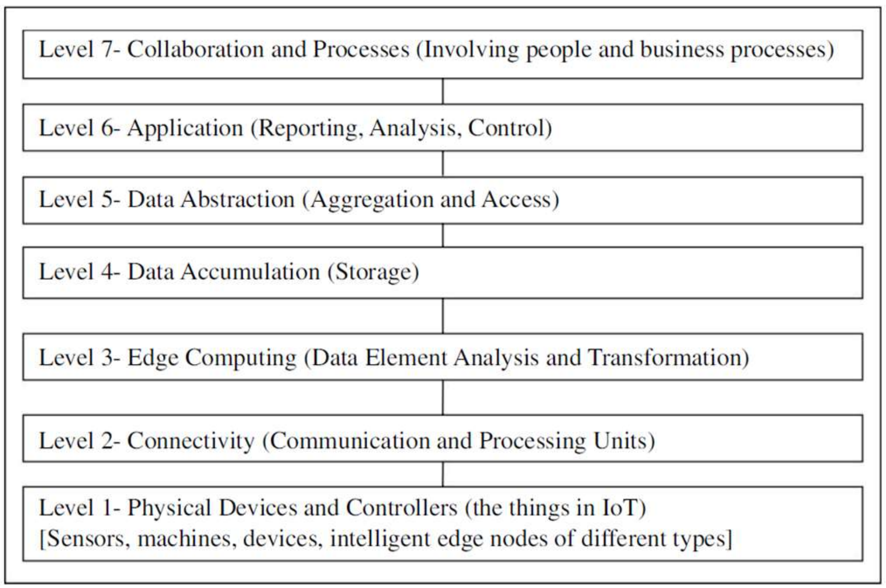
IoT Architecture

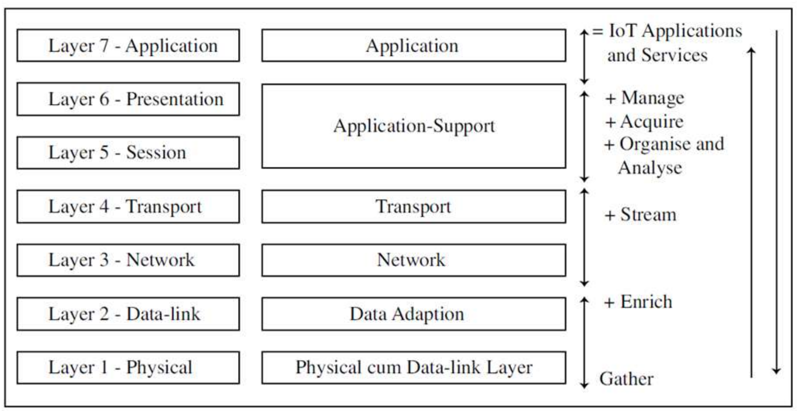
IoT Architecture: Levels

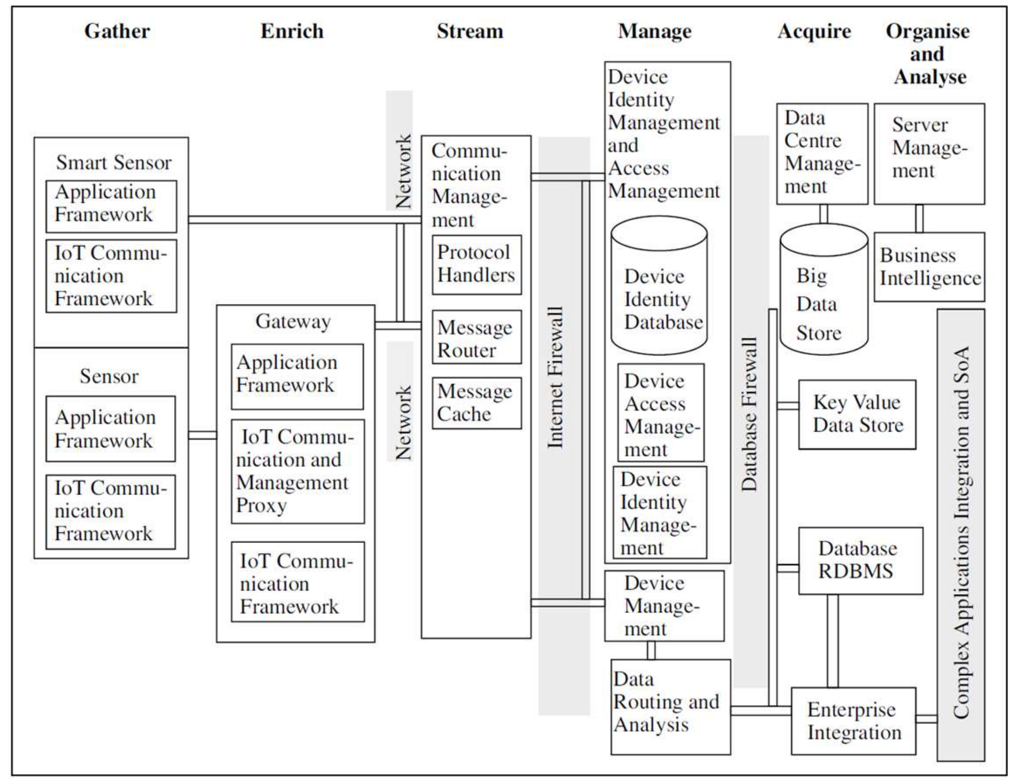


1. **Device platform** Consists of device hardware and software using a microcontroller (or SoC or custom chip), and software for the device APIs and web applications
2. **Connecting and networking** (connectivity protocols and circuits) enabling internetworking of devices and physical objects called things and enabling the internet connectivity to remote servers
3. **Server and web programming** enabling web applications and web services
4. **Cloud platform** enabling storage, computing prototype and product development platforms
5. **Online transactions processing,** online analytics processing, data analytics, predictive analytics and knowledge discovery enabling wider applications of an IoT system

IoT Architecture: Application & Services

Gather + Enrich + Stream + (Manage + Acquire + Organise +Analyse) = IoT Applications nd Services





IoT Architecture: Major Components

Major components of IoT devices are:

1. **Physical objects** with embedded software into a hardware.

2. **Hardware** consisting of a microcontroller, firmware, sensors, control unit, actuators and communication module.

3**. Communication module**: Software consisting of device APIs and device interface for communication over the network and communication circuit/port(s), and **middleware for creating communication stacks** using 6LowPAN, CoAP, LWM2M, IPv4, IPv6 and other protocols.

4. **Software** for actions on messages, information and commands which the devices receive and then output to the actuators, which enable actions such as glowing LEDs, robotic hand movement etc.

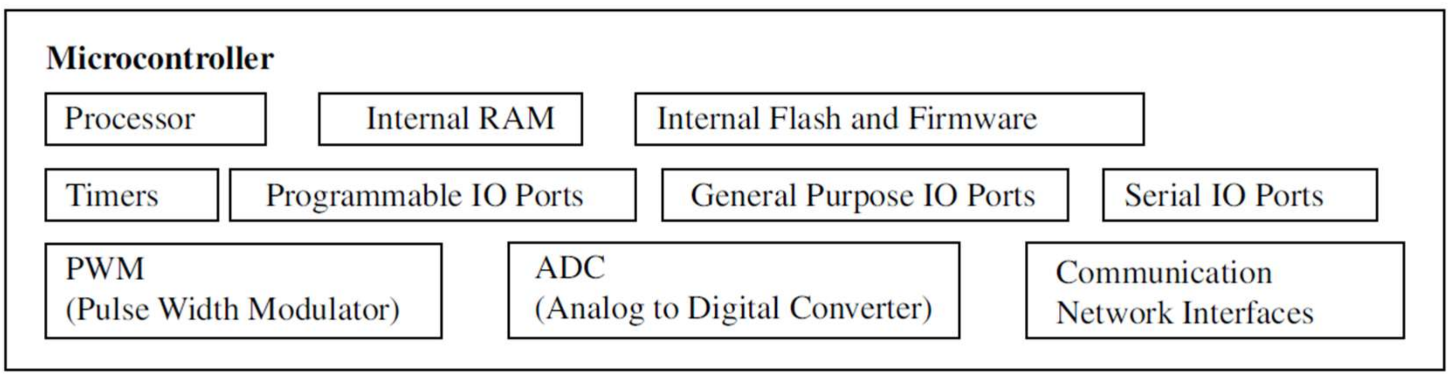
Technologies Behind IoT

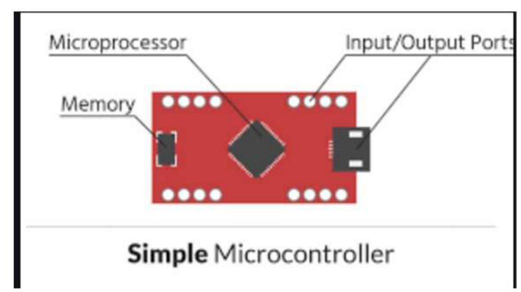
- **Hardware** (Arduino Raspberry Pi, Intel Galileo, Intel Edison, ARM mBed, Bosch XDK110, Beagle Bone Black and Wireless SoC)
- **Integrated Development Environment** (IDE) for developing device software, firmware and APIs Protocols [RPL, CoAP, RESTful HTTP, MQTT, XMPP (Extensible Messaging and Presence Protocol)]
- **Communication** (Powerline Ethernet, RFID, NFC, 6LowPAN, UWB, ZigBee, Bluetooth, WiFi, WiMax, 2G/3G/4G)
- **Network backbone** (IPv4, IPv6, UDP and 6LowPAN)
- **Software** (RIOT OS, Contiki OS, Thingsquare Mist firmware, Eclipse IoT)
- **Internetwork Cloud Platforms/Data Centre** (Sense, ThingWorx, Nimbits, Xively, openHAB, AWS IoT, IBM BlueMix, CISCO IoT, IOx and Fog, EvryThng, Azure, TCS CUP)
- **Machine learning algorithms and software.** An example of machine-learning software is GROK from Numenta Inc. that uses machine intelligence to analyse the streaming data from clouds and uncover anomalies, has the ability to learn continuously from data and ability to drive action from the output of GROK's data models and perform high level of automation for analysing streaming data

Technologies Behind IoT

1. Control Units

- Most commonly used control unit in IoT consists of a Microcontroller Unit (MCU) or a custom chip. A microcontroller is an integrated chip or core in a VLSI or SoC. Popular microcontrollers are ATmega 328, ATMega 32u4, ARM Cortex and ARM LPC.





Simple Microcontroller

Technologies Behind IoT

1. The Control Unit

- A Micro Controller Unit (MCU) comprises a processor, memory and several other hardware units which are interfaced together. It also has firmware, timers, interrupt controllers and functional IO units.
- Additionally, an MCU has application-specific functional circuits designed as per the specific version of a given microcontroller family. For example, it may possess Analog to Digital Converters (ADC) and Pulse Width Modulators (PWM).

Technologies Behind IoT

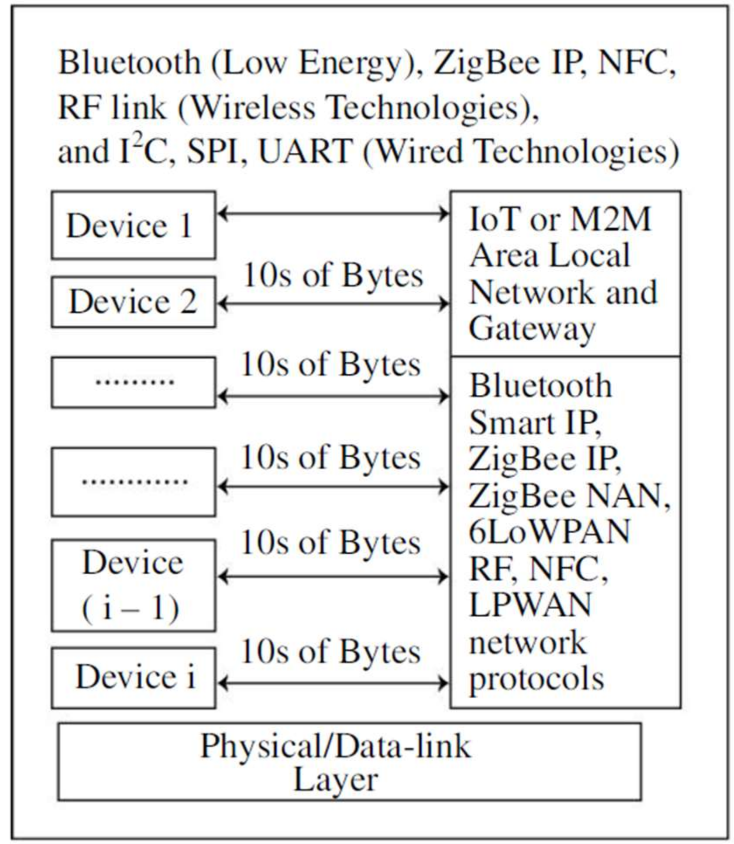
2. Communication Module

- A communication module consists of protocol handlers, message queue and message cache. A device message-queue inserts the messages in the queue and deletes the messages from the queue in **a first-in first-out** manner.
- A device message-cache stores the received messages. Representational State Transfer (REST) architectural style can be used for HTTP access by GET, POST, PUT and DELETE methods for resources and building web services.

Technologies Behind IoT

2. Communication Module

- **Physical cum data-link layer** in the model consists of a local area network/personal area network. A local network of IoT or M2M device deploys one of the two types of **technologies—wireless or wired communication technologies.**



Technologies Behind IoT

3. Sensors

- Data is generated using sensors, embedded devices and systems at the physical layer in the IoT architecture
- Sensors are electronic devices that sense the physical environments. An industrial automation system or robotic system has multiple smart sensors embedded in it.
- Sensor-actuator pairs are used in control systems. **A smart sensor includes computing and communication circuits.**
- Sensors are of two types. 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**. Examples are touch sensor, proximity sensor, metal sensor, traffic presence sensor, rotator encoder for measuring angles and linear encoders for measuring linear displacements.

Technologies Behind IoT

1. Sensors

- **Data is generated using sensors**, embedded devices and systems at the physical layer in the IoT architecture. Thereafter, the data communicates through the data-link, data adaptation, network, application-support and application layers to the applications of IoT.
- Data is used for analytics, visualization, intelligence and knowledge discovery or controls and monitoring.
- **Control systems use the sensors for monitoring and the actuators for actions.**

Technologies Behind IoT

The Sensor technology

- Used for designing sensors and associated electronic readers, circuits and devices.
- A sensor can sense a change in physical parameters, such as temperature, pressure, light, metal, smoke and proximity to an object, acceleration, orientation, location, vibrations or smell, organic vapors or gases. A microphone senses the voice and changes in the sound, and is used to record voice or music.
- 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. The circuit receives energy in form of variations through currents, voltages, phase angles or frequencies. Analog sensors measure the variations in the parameters with respect to a reference or normal condition and provide the value of sensed parameter after appropriate calculations.
- The change of states with respect to a reference or normal condition senses the states in the form of 0s and 1s in digital sensors.
- **Analogue sensors** convert data into digital signals through Analogue to Digital Convertor (A-D-C)

Technologies Behind IoT

Example of Sensors

- **Motion Sensors:** Motion or speed is measured in m/s. The sensor measures delay between successive reflected IR light pulses. An LED source is an IR light source and a phototransistor is an IR sensor. Alternatively, ultrasonic wave echoes can be used to sense the motion of light. The sensor measures the delay between successive echoes.
- **Pressure Sensors:** Pressure can be sensed in a number of ways. The sensor is called pressure transducer, pressure transmitter, pressure sender or pressure indicator. Piezometer pressure transducer uses a piezoelectric object between two surfaces. The compression creates electric charges on the opposite surfaces of the object. The flow of charges generates current and voltages, which provide the measure of pressure. A resistive sensor also measures variation of resistance with force.
- **Humidity Sensors:** 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. A capacitor sensor shows change in capacitance as a percentage of relative humidity changes.

Technologies Behind IoT

Example of Sensors

- **Environment Monitoring Sensors:** Environment parameters are temperature, humidity, barometric pressure and light. A collective use of these parameter sensors enable monitoring of the environment. The data of these sensors adapts to the requirement and sends communication on the Internet to the cloud or web for the environment monitoring applications.
- **Image Sensors:** The camera uses CCD, which consists of a large number of pixels, exposed to the light from the image. It accumulates charges on each of the pixel present at a large number of horizontal and vertical coordinates. The charge accumulation is as per the intensity of light at the corresponding pixel coordinate in the image. Colored camera has set of R, G and B (Red, Green and Blue) light intensity components at each pixel coordinate.
- **Temperature Sensors:** A component called thermistor, shows larger changes in resistance within narrow environment temperature range (120°C to –90°C). An NTC thermistor shows negative temperature coefficient which means a drop in the resistance value with rise in temperature.

Technologies Behind IoT

Example of Sensors

Distance Sensors:

- Infrared (IR) sensor is useful for a 0.15 m to 0.8 m range of object. IR sensor works on the principle that when a narrow beam IR LED sends radiation at an inclined angle, the nearby phototransistor FPT receives the reflected radiation after travelling two times the object distance.

“Things” Sensors:

- **A barcode** is a representation of data. The data relates to the object where the printed code strip is attached. The code is read by an optical scanner.
- **QR code** is an abbreviation for Quick Response Code. It was first used in automotive industry. Its applications are product identification, tracking, marketing and document management.
- The QR code consists of black square dots arranged in a square grid format on a white background. The required data is at patterns in both horizontal and vertical components of the image. A scanner or camera reads the code and the data is processed using an error-correction method called Reed Solomon method. The processing takes place till the process results in appropriate interpretation of the data.

Summary of IoT Architecture