IoT Security and Forensics

Unit 1 - Introduction

National Forensic Sciences University
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An Institution of National Importance
(Ministry of Home Affairs, Government of India)

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Definition

- Internet of Things is fully networked and connected devices sending analytics data back to cloud or data center.
- The definition of Internet of things :

  "A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, andare seamlessly integrated into the information network, often communicate data associated with users and their environments."

Introduction

- The term Internet of Things was first coined by Kevin Ashton in 1999 in the context of supply chain management.
- Although the definition of ‘Things‘ has changed as technology evolved, the main goal of making computer sense information without the aid of human intervention remains the same.
- IoT technologies allow things, or devices that are not computers, to act smartly and make collaborative decisions that are beneficial to certain applications.
- They allow things to hear, see, think or act by allowing them to communicate and coordinate with others in order to make decisions that can be as critical as saving lives

Characteristics of IoT

Internet of Things

- A dynamic network architecture
- With self configuring capabilities
- Based on various protocols
- Built-up of physical and virtual "Things"
- Use intelligent interface
- Have identity, attribute and virtual personality
- Seamlessly integrated into information network

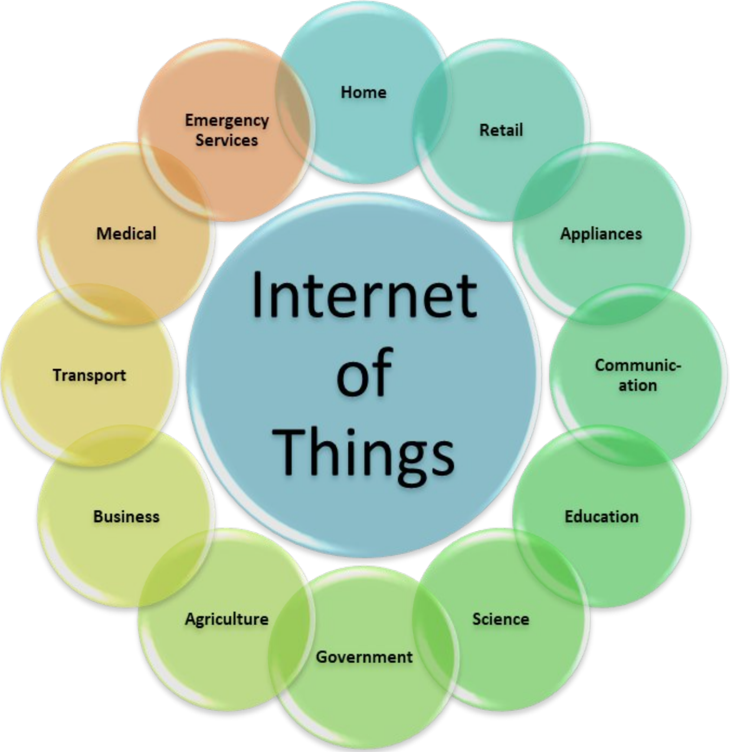
Features of IoT

- **Self-adaptation**: The self-adapting network can make smart decisions according to change in the system without human monitoring.
- **Self-organization**: This type of IoT system can manage its devices and interconnect them as per the network requirement without human intervention.
- **Self-optimization**: The self-optimized IoT system can reserve its resources and increases the durability of network connections.
- **Self-configuration**: The newly connected devices of a self-configurable system can be deployed and configured automatically for interconnection.

Features of IoT (cont..)

- **Self-protection**: The self-protection feature of the IoT system can provide security to connected devices from malicious attacks.
- **Self-healing**: The IoT system with self-healing capacity can be recovered from damage and repair itself without human intervention.
- **Self-discovery**: This feature can help the IoT system to search for neighboring devices and can be accessible for communication.
- **Self-energy-supplying**: The energy supplying IoT system can harvest the energy for its operations and can become independent for power supply.

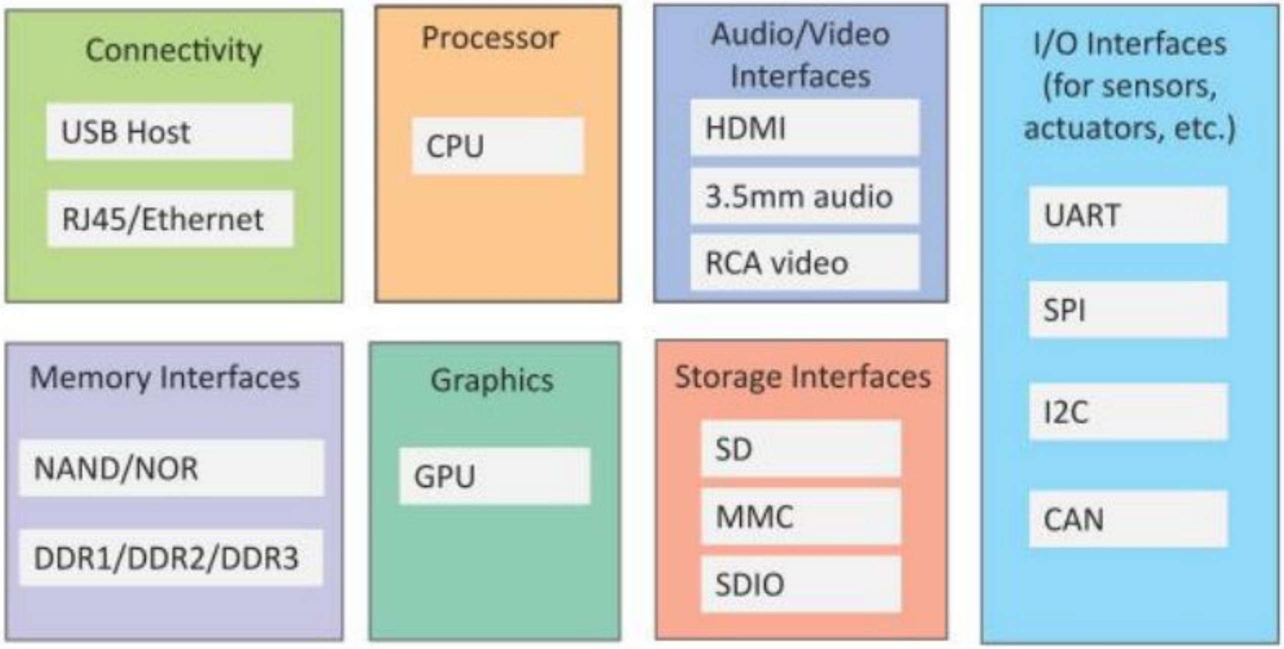
Application Domains of IoT



Physical Design of IoT

- The "Things" in IoT usually refers to IoT devices which have unique identities and can perform remote sensing, actuating and monitoring capabilities.
- IoT devices can:
  - Exchange data with other connected devices and applications (directly or indirectly), or
  - Collect data from other devices and process the data locally or
  - Send the data to centralized servers or cloud-based application back-end for processing the data, or
  - Perform some tasks locally and other tasks within the IoT infrastructure, based on temporal and space constraints

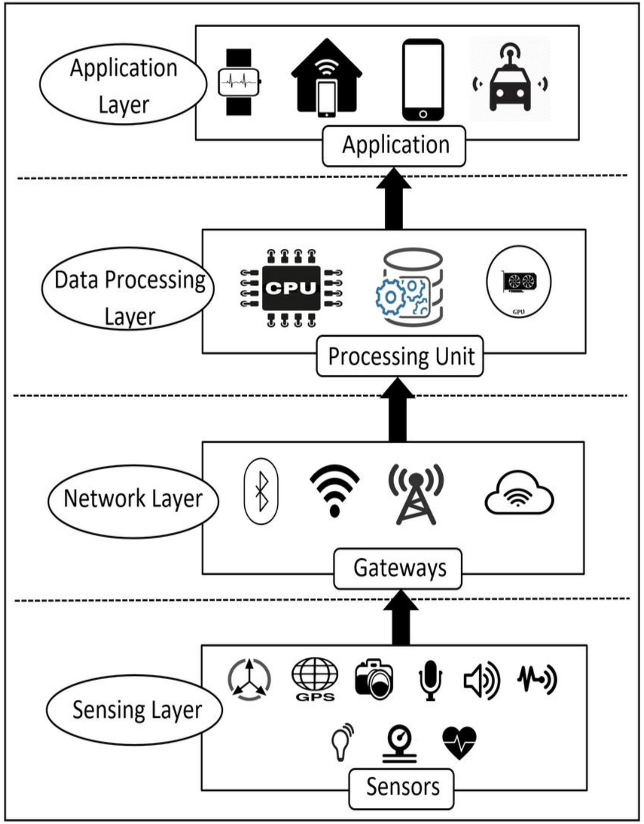
Block Diagram of IoT System



IoT Connectivity

- An IoT device may consist of several interfaces for connections to other devices, both wired and wireless.
  - I/O interfaces for sensors
  - Interfaces for internet connectivity
  - Memory and storage interfaces
  - Audio/video interfaces

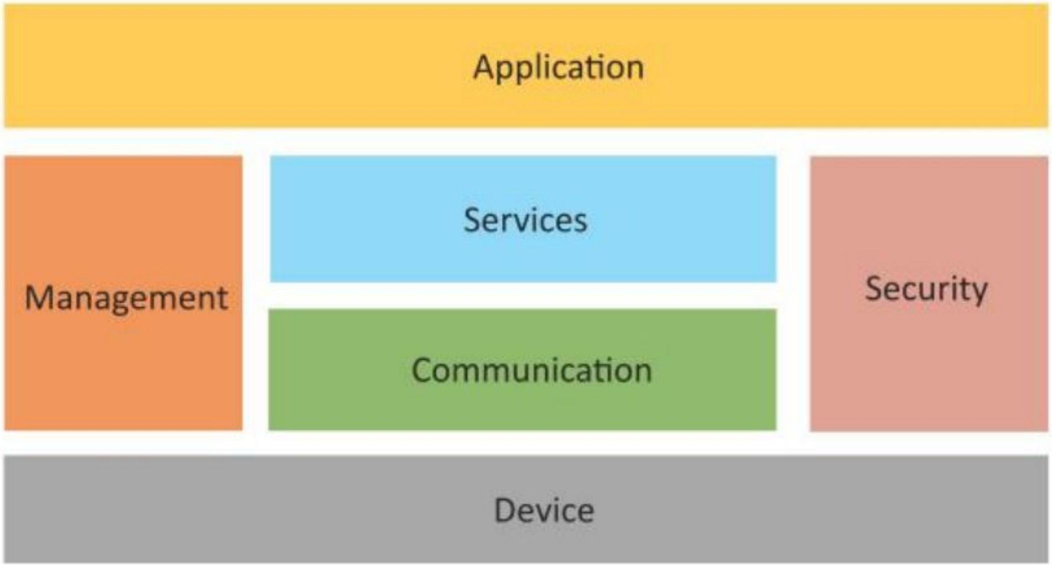
Architecture of IoT



Architecture of IoT (cont..)

- Sensing Layer
  - It deals with hardware devices like sensors, actuators, and trans-receivers.
- Network Layer
  - It consists of connecting technology like gateways and middleware applications for providing communication between hardware devices and storage/ processing units.
- Data Processing Layer
  - It facilitates data storage and processing that is to be used in IoT applications.
  - The data are collected by hardware devices.
  - The collected data are processed and stored in a local or cloud data storage unit according to the requirement for decision making.
- Application layer
  - It deals with user interactions by providing a graphical or textual interface.
  - It also handles data formatting and semantics related conversation for the presentation of data.

Logical Design of IoT



Logical Design of IoT (cont..)

- Logical design of an IoT system refers to an abstract representation of the entities and processes without going into the low-level specifics of the implementation.
- An IoT system comprises of a number of functional blocks that provide the system the capabilities for identification, sensing, actuation, communication, and management.

Components of IoT

- There are three IoT components which enable seamless communication:
  - Hardware - made up of sensors, actuators and embedded communication hardware
  - Middleware/ Connecting Technology- on demand storage and computing tools for data analytics
  - Presentation/ User Interface - novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms and which can be designed for different applications.

Sensors

- A sensor detects (senses) changes in the ambient conditions or in the state of another device or a system, and forwards or processes this information in a certain manner.
- Definition: “A device which detects or measures a physical property and records, indicates, or otherwise responds to it”
- They perform some input functions by sensing or feeling the physical changes in characteristics of a system in response to a stimuli.
- For example heat is converted to electrical signals in a temperature sensor, or atmospheric pressure is converted to electrical signals in a barometer.

Transducer

- Transducers convert or transduce energy of one kind into another.
- For example, in a sound system, a microphone (input device) converts sound waves into electrical signals for an amplifier to amplify (a process), and a loudspeaker (output device) converts these electrical signals back into sound waves.
- The word “Transducer” is the collective term used for both Sensors which can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy etc., and Actuators which can be used to switch voltages or currents

Features of Sensors

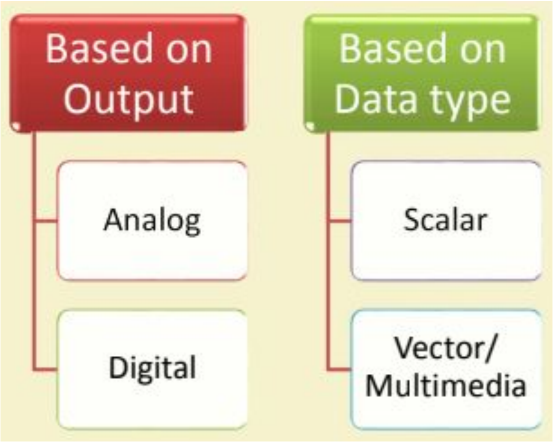
- It is only sensitive to the measured property (e.g., A temperature sensor senses the ambient temperature of a room.)
- It is insensitive to any other property likely to be encountered in its application (e.g., A temperature sensor does not bother about light or pressure while sensing the temperature.)
- It does not influence the measured property (e.g., measuring the temperature does not reduce or increase the temperature).

Sensor Resolution

- The resolution of a sensor is the smallest change it can detect in the quantity that it is measuring.
- The resolution of a sensor with a digital output is usually the smallest resolution the digital output it is capable of processing.
- The more is the resolution of a sensor, the more accurate is its precision.
- A sensor's accuracy does not depend upon its resolution.

Sensor Classes

- Analog Sensor
  - Analog Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured.
  - Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc. are all analog quantities as they tend to be continuous in nature.
  - For example, the temperature of a liquid can be measured using a thermometer or thermocouple (e.g. in geysers) which continuously responds to temperature changes as the liquid is heated up or cooled down.



Sensor Classes (cont..)

- Digital Sensor
  - Digital Sensors produce discrete digital output signals or voltages that are a digital representation of the quantity being measured.
  - Digital sensors produce a binary output signal in the form of a logic “1” or a logic “0”, (“ON” or “OFF”).
  - Digital signal only produces discrete (non-continuous) values, which may be output as a single “bit” (serial transmission), or by combining the bits to produce a single “byte” output (parallel transmission).

Sensor Classes (cont..)

- Scalar Sensor
  - Scalar Sensors produce output signal or voltage which is generally proportional to the magnitude of the quantity being measured.
  - Physical quantities such as temperature, color, pressure, strain, etc. are all scalar quantities as only their magnitude is sufficient to convey an information.
  - For example, the temperature of a room can be measured using a thermometer or thermocouple, which responds to temperature changes irrespective of the orientation of the sensor or its direction.
- Vector Sensor
  - Vector Sensors produce output signal or voltage which is generally proportional to the magnitude, direction, as well as the orientation of the quantity being measured.
  - Physical quantities such as sound, image, velocity, acceleration, orientation, etc. are all vector quantities, as only their magnitude is not sufficient to convey the complete information.
  - For example, the acceleration of a body can be measured using an accelerometer, which gives the components of acceleration of the body with respect to the x,y,z coordinate axes.

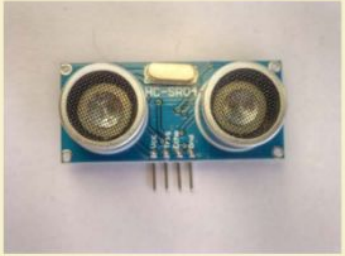
Sensor Types

Light	• Light Dependent resistor • Photo-diode
Temperature	• Thermocouple • Thermistor
Force	• Strain gauge • Pressure switch
Position	• Potentiometer, Encoders • Opto-coupler
Speed	• Reflective/ Opto-coupler • Doppler effect sensor
Sound	• Carbon Microphone • Piezoelectric Crystal
Chemical	• Liquid Chemical sensor • Gaseous chemical sensor

Sensors

Pressure Sensor

Source: Wikimedia Commons



Ultrasonic Distance Sensor

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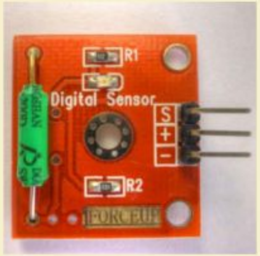

Tilt Sensor

Source: Wikimedia Commons

Infrared Motion Sensor

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Analog Temperature Sensor

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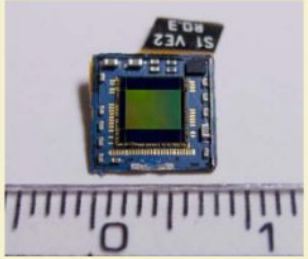


Camera Sensor

Source: Wikimedia Commons

Sensorial Errors

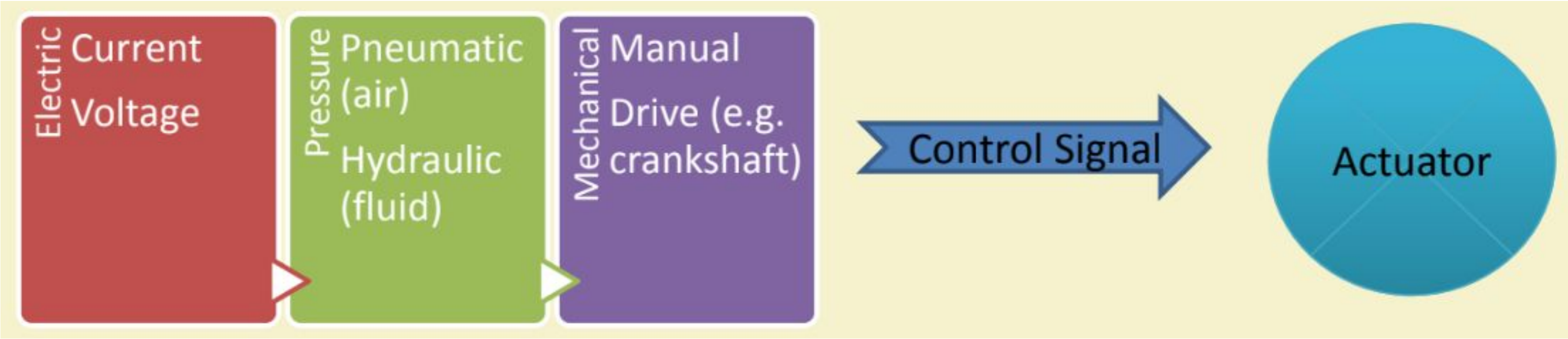
- Since the range of the output signal is always limited, the output signal will eventually reach a minimum or maximum, when the measured property exceeds the limits.
- The full scale range of a sensor defines the maximum and minimum values of the measured property.
- If the output signal differs from the correct value by a constant, the sensor has an offset error or bias.
- The sensitivity of a sensor under real conditions may differ from the value specified. This is called a **sensitivity error**.
- Nonlinearity is deviation of a sensor's **transfer function (TF)** from a straight line transfer function.

Sensorial Errors (cont..)

- If the output signal slowly changes independent of the measured property, this is defined as **drift**.
- Long term drift over months or years is caused by physical changes in the sensor.
- **Noise** is a random deviation of the signal that varies in time.
- If the sensor has a digital output, the output is essentially an approximation of the measured property. This error is also called **quantization error**.
- If the signal is monitored digitally, the sampling frequency can cause a dynamic error, or if the input variable or added noise changes periodically at a frequency proportional to the multiple of the sampling rate, **aliasing errors** may occur.

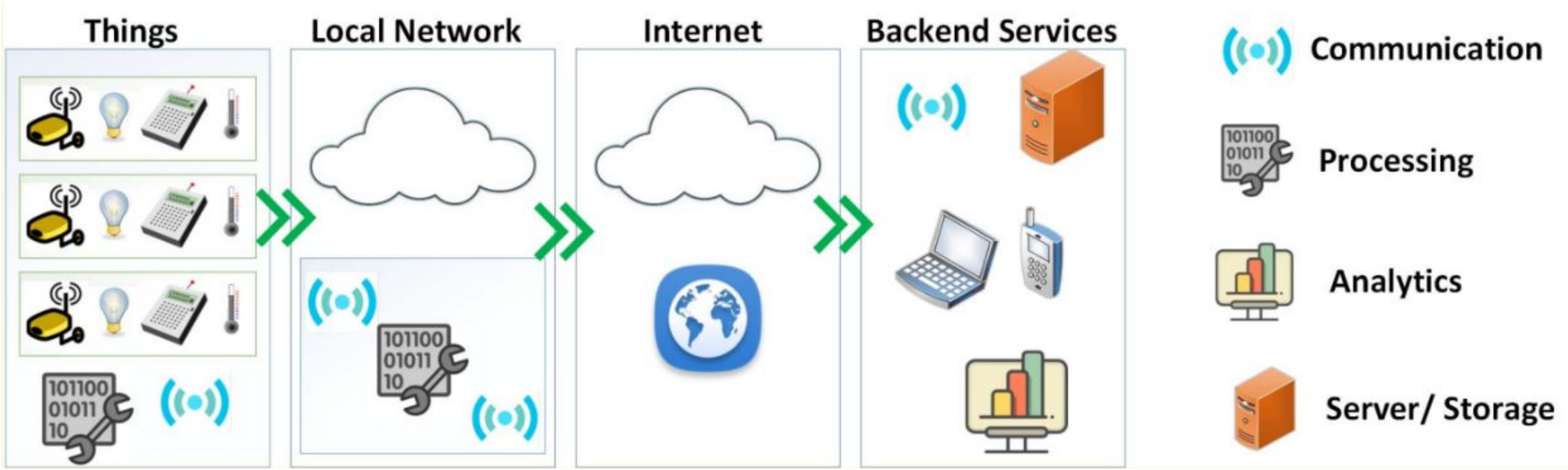
Actuator

- An actuator is a component of a machine or system that moves or controls the mechanism or the system.
- An actuator is the mechanism by which a control system acts upon an environment
- An actuator requires a control signal and a source of energy.
- Upon receiving a control signal, the actuator responds by converting the energy into mechanical motion.
- The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other input.


Electric
Current
Voltage
Pressure
Pneumatic (air)
Hydraulic (fluid)
Mechanical
Manual
Drive (e.g. crankshaft)
Control Signal
Actuator

Actuator Types

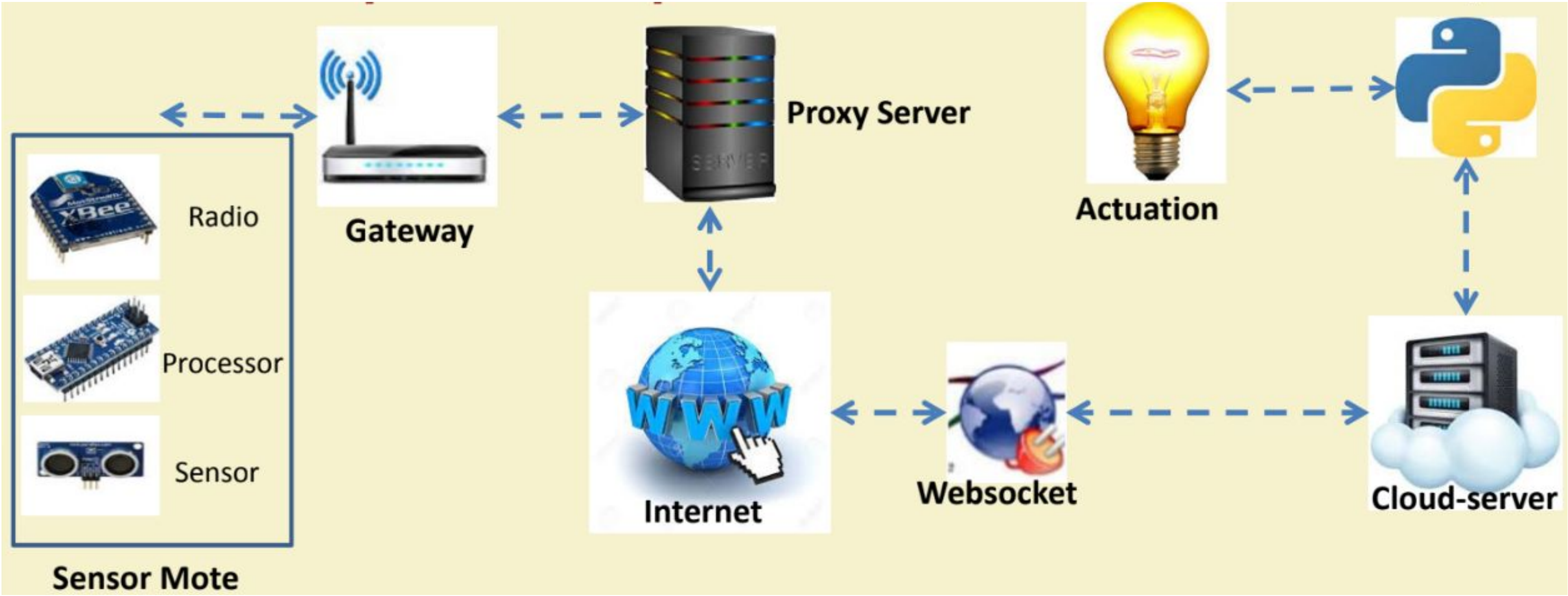
Working of IoT System



Functional Components of IoT System

- Component for interaction and communication with other IoT devices
- Component for processing and analysis of operations
- Component for Internet interaction
- Components for handling Web services of applications
- Component to integrate application services
- User interface to access IoT

IoT Implementation Example



IoT Categories

- Industrial IoT
  - IoT device connects to an IP network and the global Internet.
  - Communication between the nodes done using regular as well as industry specific technologies.

- Consumer IoT
  - IoT device communicates within the locally networked devices.
  - Local communication is done mainly via Bluetooth, Zigbee or WiFi.
  - Generally limited to local communication by a Gateway

Challenges of IoT

- Security
- Scalability
- Energy efficiency
- Bandwidth management
- Modeling and Analysis
- Interfacing
- Interoperability
- Data storage
- Data Analytics
- Complexity management