Unit II:
Wireless Sensor Network

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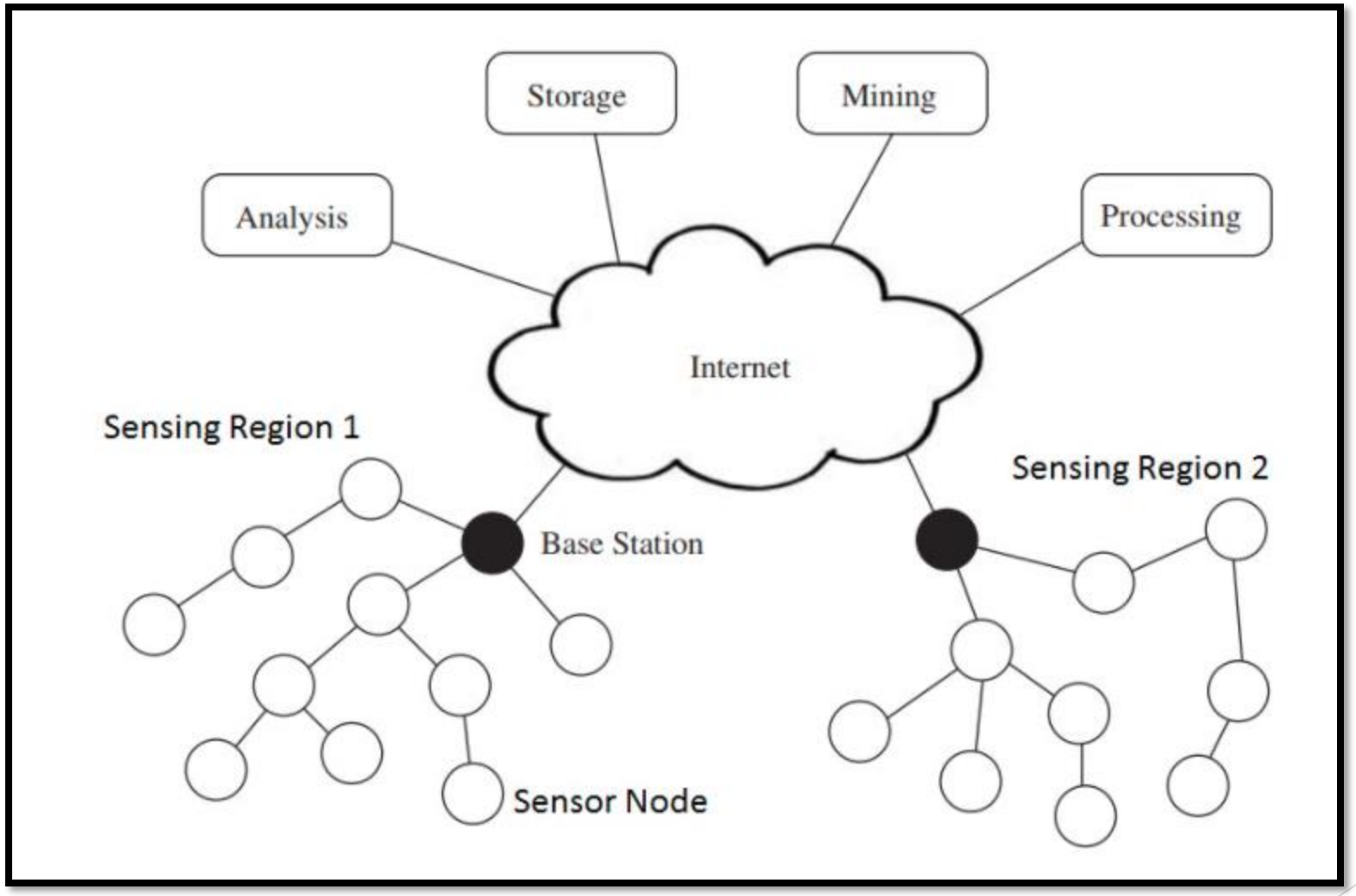
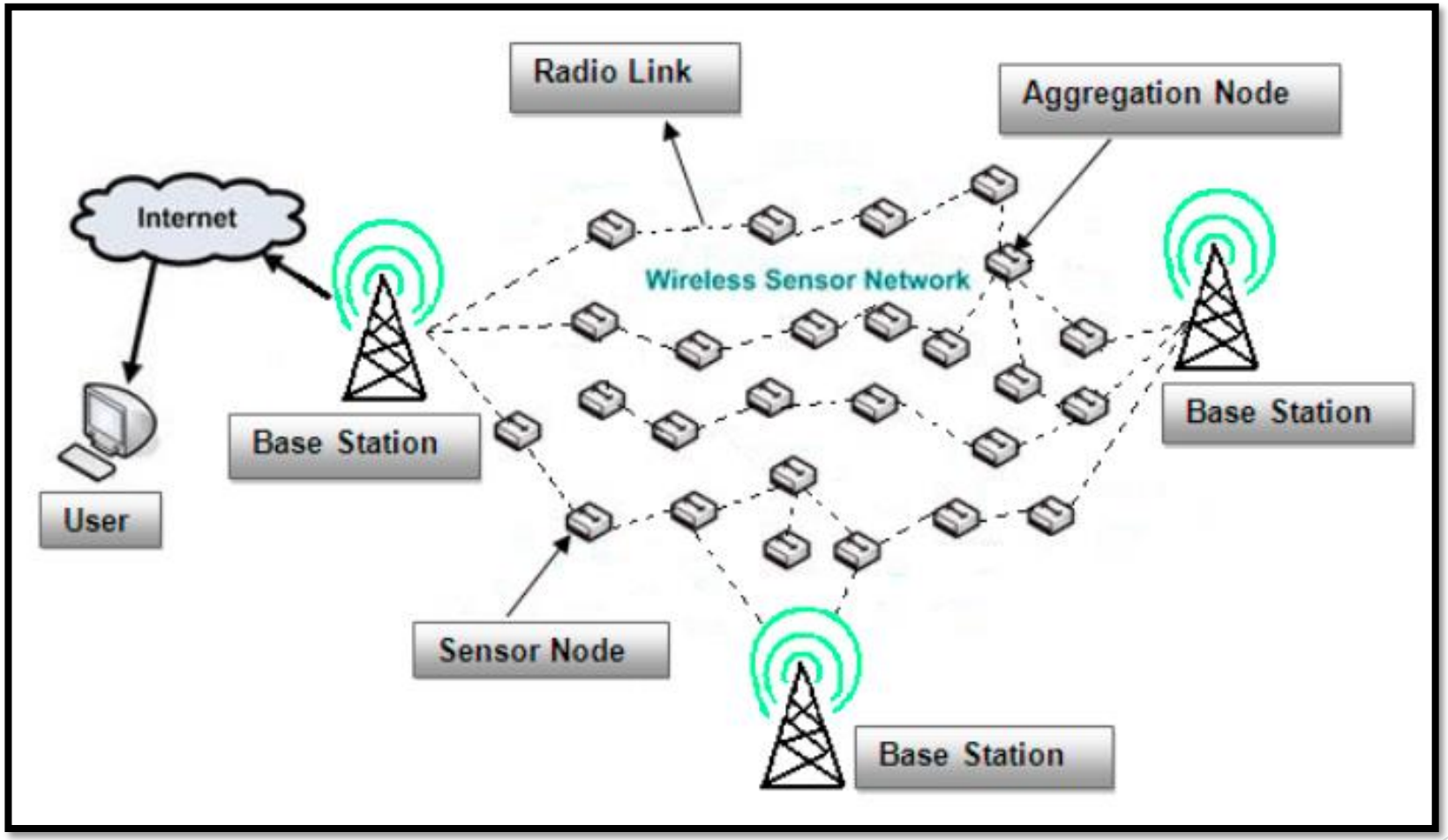
Wireless Sensor Network

- A Sensor is a device that is used to gather information about a physical process or a physical phenomenon and translate it into electrical signals that can be processed, measured, and analyzed.
- The term physical process used in the above definition of a Sensor can be any real-world information like temperature, pressure, light, sound, motion, position, flow, humidity, radiation, etc.
- A Sensor Network is a structure consisting of sensors, computational units, and communication elements for the purpose of recording, observing, and reacting to an event or a phenomenon.
- If the communication system in a Sensor Network is implemented using a Wireless protocol, then the networks are known as Wireless Sensor Networks or WSN
- A Wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless Ethernet.

WSN


Storage
Mining
Analysis
Processing
Internet
Sensing Region 1
Sensing Region 2
Base Station
Sensor Node

Basic Architecture of Wireless Sensor Network



Classifications of WSN

- Wireless Sensor Networks are extremely application-specific and are deployed according to the requirements of the application.
- Hence, the characteristics of one WSN will be different from that of another WSN.
- Irrespective of the application, Wireless Sensor Networks, in general, can be classified into the following categories.
  - Static and Mobile WSN
  - Deterministic and Nondeterministic WSN
  - Single Base Station and Multi Base Station WSN
  - Static Base Station and Mobile Base Station WSN
  - Single-hop and Multi-hop WSN
  - Self – Reconfigurable and Non – Self – Configurable WSN
  - Homogeneous and Heterogeneous WSN

Classification continued

Static and Mobile WSN

- In many applications, all the sensor nodes are fixed without movement and these are static networks.
- Some applications, especially in biological systems, require mobile sensor nodes. These are known as mobile networks. An example of a mobile network is animal monitoring.

Deterministic and Nondeterministic WSN

- In a deterministic WSN, the position of a sensor node is calculated and fixed. The pre-planned deployment of sensor nodes is possible in only a limited number of applications.
- In most applications determining the position of sensor nodes is not possible due to several factors like harsh environments or hostile operating conditions. Such networks are non-deterministic and require a complex control system

Classification continued

Single Base Station and Multi Base Station WSN

- In a single base station WSN, only a single base station is used which is located close to the sensor node region. All the sensor nodes communicate with this base station.
- In the case of a multi-base station WSN, more than the base station is used and a sensor node can transfer data to the closest base station.

Static Base Station and Mobile Base Station WSN

- Base stations can be either static or mobile. A static base station has a fixed position usually close to the sensing region.
- A mobile base station moves around the sensing region so that a load of sensor nodes is balanced.

Classification continued

- **Single-hop and Multi-hop WSN**
- In a single-hop WSN, the sensor nodes are directly connected to the base station.
- In the case of multi-hop WSN, peer nodes and cluster heads are used to relay the data so that energy consumption is reduced.

Self – Reconfigurable and Non – Self – Configurable WSN

- In a non – Self – Configurable WSN, the sensor networks cannot organize themselves in a network and rely on a control unit to collect information.
- In most WSNs, the sensor nodes are capable of organizing and maintaining the connection and work collaboratively with other sensor nodes to accomplish the task.

Homogeneous and Heterogeneous WSN

- In a homogeneous WSN, all the sensor nodes have similar energy consumption, computational power, and storage capabilities.
- In the case of heterogeneous WSN, some sensor nodes have higher computational power and energy requirements than others, and the processing and communication tasks are divided accordingly.

WSN Architecture

Elements of WSN

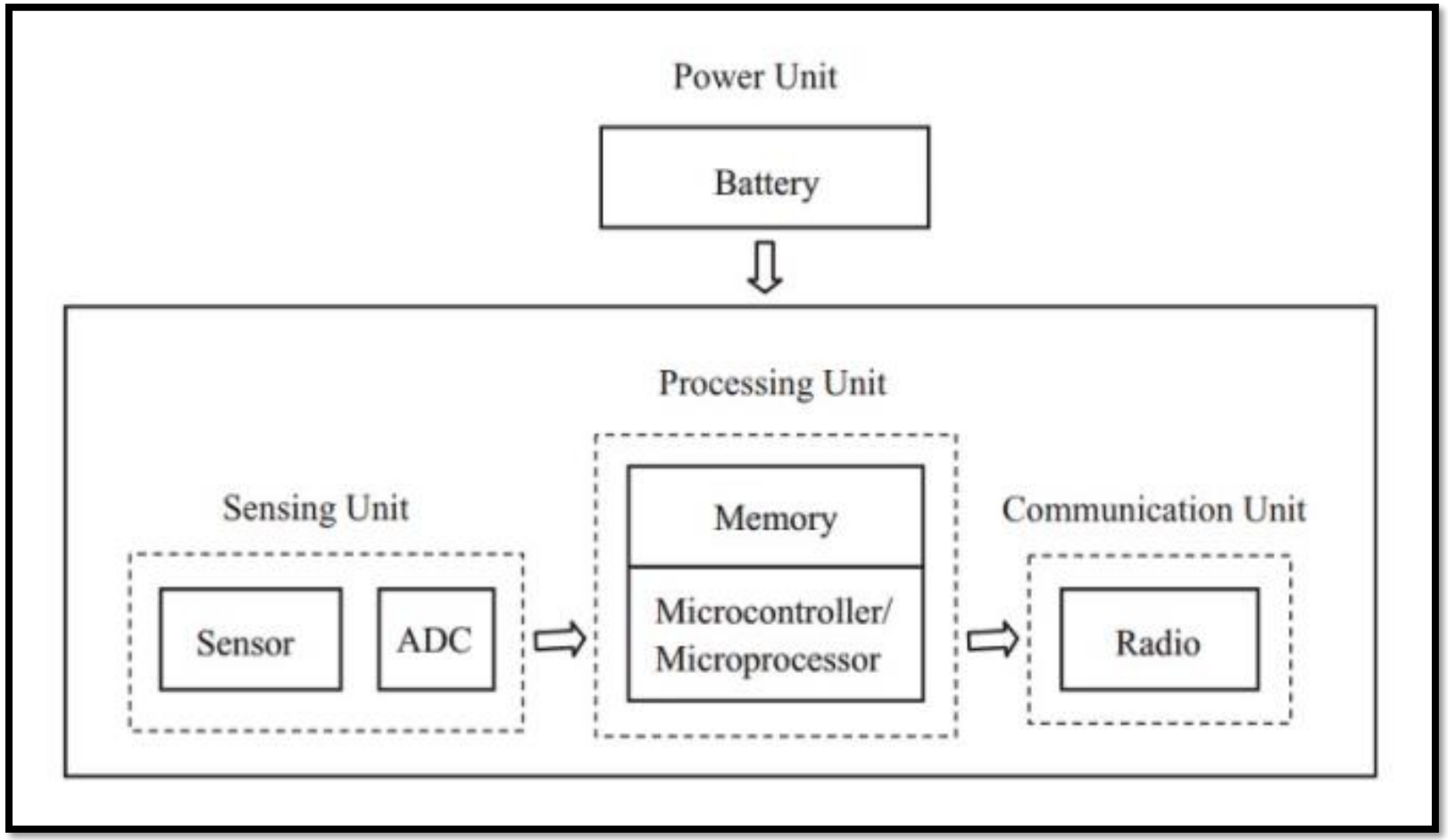
A typical wireless sensor network can be divided into two elements. They are:

- Sensor Node
- Network Architecture

Sensor Node

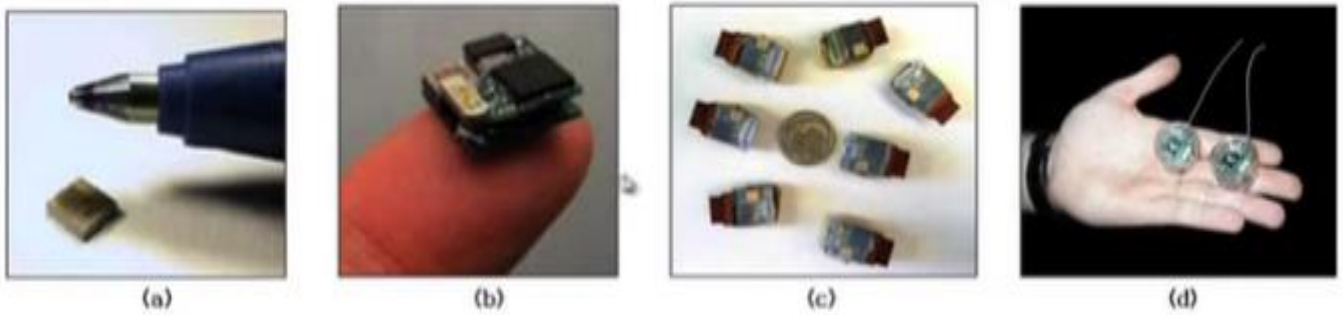
- A Sensor Node in a WSN consists of four basic components. They are:
  - Power Supply
  - Sensor
  - Processing Unit
  - Communication System

Sensor node


Power Unit
Battery
Processing Unit
Sensing Unit
Sensor
ADC
Memory
Microcontroller/
Microprocessor
Communication Unit
Radio

Sensor nodes

Sensor Nodes (Different Sizes & Shapes)



(a) Xbow mica mote [ZESS] (b) Eco [CHOU] (c) Eco [MOTE] (d) dots [BERK]

- Multifunctional
  - The number of sensor nodes used depends on the application type.
- Short transmission ranges
- Have OS (e.g., TinyOS).
- Battery Powered – Have limited life.

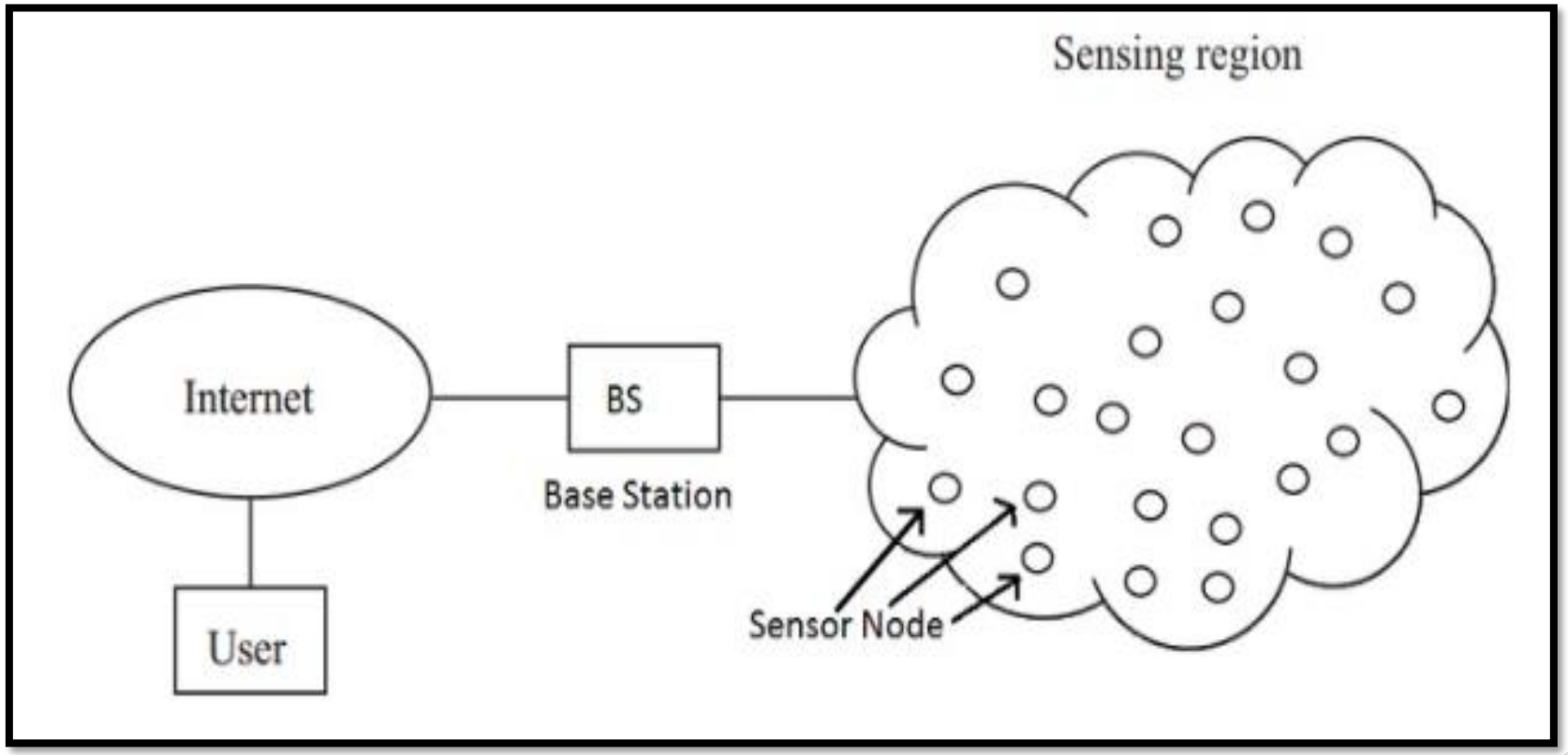
Explanation

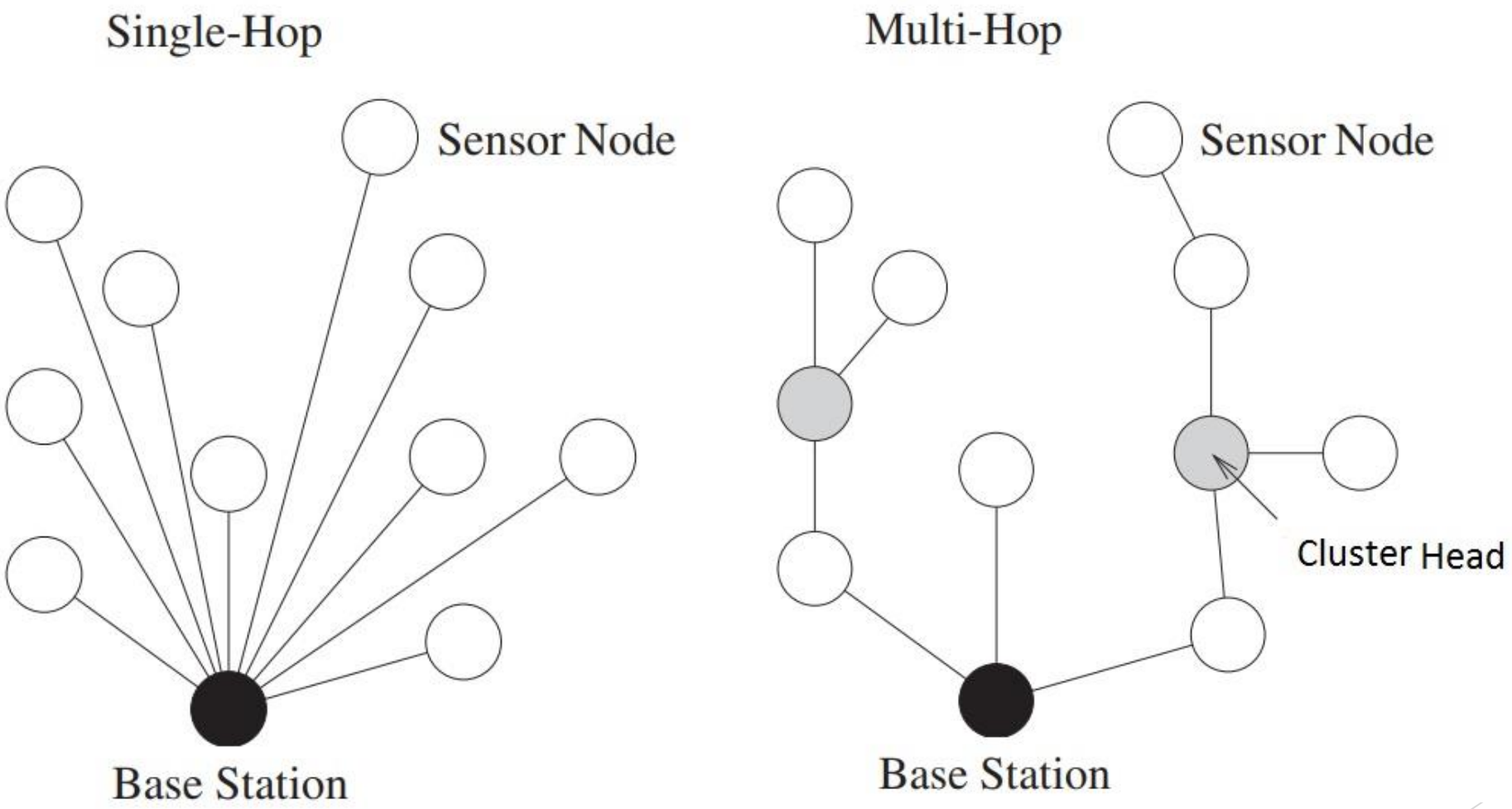
- The sensor collects the analog data from the physical world and an ADC converts this data to digital data. The main processing unit, which is usually a microprocessor or a microcontroller, performs intelligent data processing and manipulation.
- Communication system consists of the radio system, usually a short-range radio, for data transmission and reception. As all the components are low-power devices, a small battery like CR-2032, is used to power the entire system.
- A Sensor Node consists of not only the sensing component but also other important features like processing, communication, and storage units.
- With all these features, components, and enhancements, a Sensor Node is responsible for physical world data collection, network analysis, data correlation, and fusion of data from other sensors with its own data.

Network Architecture

- When a large number of sensor nodes are deployed in a large area to co-operatively monitor a physical environment, the networking of these sensor nodes is equally important.
- A sensor node in a WSN not only communicates with other sensor nodes but also with a Base Station (BS) using wireless communication.
- The base station sends commands to the sensor nodes and the sensor node perform the task by collaborating with each other.
- After collecting the necessary data, the sensor nodes send the data back to the base station.
- A base station also acts as a gateway to other networks through the internet.
- After receiving the data from the sensor nodes, a base station performs simple data processing and sends the updated information to the user using the internet.
- If each sensor node is connected to the base station, it is known as Single-hop network architecture. Although long-distance transmission is possible, the energy consumption for communication will be significantly higher than data collection and computation.

Network Architecture

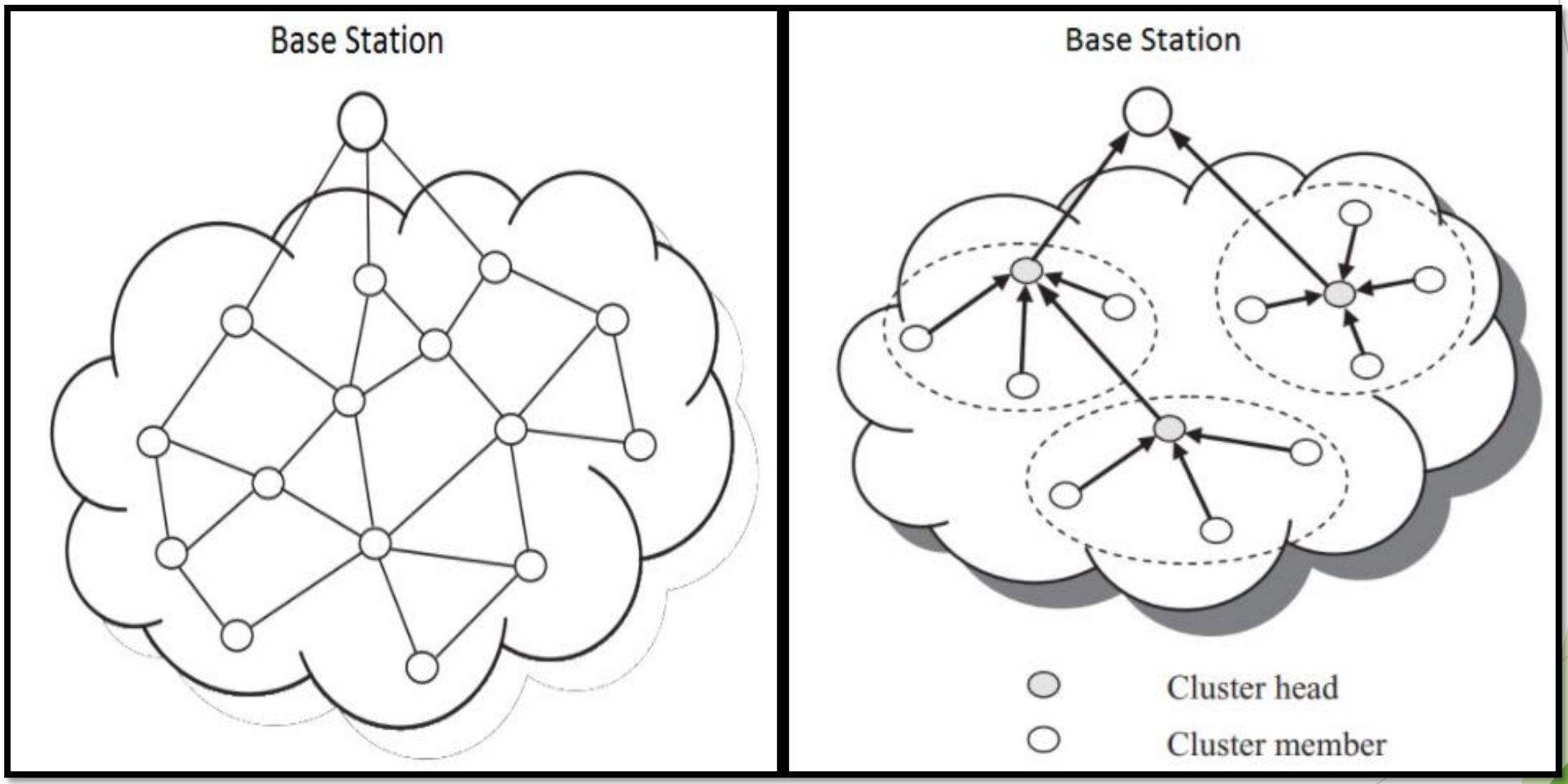



Single-Hop
Sensor Node
Base Station
Multi-Hop
Sensor Node
Cluster Head
Base Station

Continued

- Hence, Multi-hop network architecture is usually used. Instead of one single link between the sensor node and the base station, the data is transmitted through one or more intermediate nodes.
- Multi-hop can be implemented in two ways.
  - Flat network architecture and Hierarchical network architecture.
- In flat architecture, the base station sends commands to all the sensor nodes but the sensor node with matching query will respond using its peer nodes via a multi-hop path.
- In hierarchical architecture, a group of sensor nodes are formed as a cluster and the sensor nodes transmit data to corresponding cluster heads.
- The cluster heads can then relay the data to the base station.

Flat and Hierarchical architecture



Applications of Wireless Sensor Networks

- The possible applications of Wireless Sensor Networks are unlimited. Some of the commonly used applications of wireless sensor networks are listed below.
  - Biomedical Applications
  - Bridge and Highway Monitoring
  - Disaster Management
  - Earthquake Detection
  - Electricity Load Management
  - Environment Control and Monitoring
  - Industrial Automation
  - Personal Health Care
  - Security Systems
  - Tsunami Alert Systems
  - Weather Sensing and Monitoring

WSN Vs. IOT

WSN

- Nodes are not directly connected to the Internet, nodes routes traffic to reach the sink node.
- WSN are not necessarily connected to the Internet
- In WSN, the sensor gathers all the information.
- Example: A large collection of sensors used to monitor precipitation on an acre of land, if in fact, all the sensors are wireless. This system may or may not be connected to an IoT system.

IOT

- Sensors send their data directly to the Internet as they have an internet connection.
- IOT always connected to the Internet
- Things can be anything- sensors, humans, cameras, PCs, and phones. These devices may upload their data to the Internet so that other users may use them.
- Example: A fridge with the capability of sending temperature reading to the internet

Types of Sensors

1. Thermal Sensors

- Thermometer – measures absolute temperature
- Thermocouple gauge– measures temperature by its affect on two dissimilar metals
- Calorimeter – measures the heat of chemical reactions or physical changes and heat capacity

2. **Mechanical Sensors**

- Pressure sensor – measures pressure
- Barometer – measures atmospheric pressure
- Altimeter – measures the altitude of an object above a fixed level
- Liquid flow sensor – measures liquid flow rate
- Gas flow sensor – measures velocity, direction, and/or flow rate of a gas
- Accelerometer – measures acceleration

continued

3. Electrical Sensors

- Ohmmeter – measures resistance
- Voltmeter – measures voltage
- Galvanometer – measures current
- Watt-hour meter – measures the amount of electrical energy supplied to and used by a residence or business

4. **Chemical Sensors**

- Chemical sensors detect the presence of certain chemicals or classes of chemicals and quantify the amount and/or type of chemical detected.
- Oxygen sensor – measures the percentage of oxygen in a gas or liquid being analyzed
- – detects the presence of CO2

5. **Proximity sensor**

continued

6. **Optical**

- Light sensors (photodetectors) – detects light and electromagnetic energy
- Photocells (photoresistor) – a variable resistor affected by intensity changes in ambient light.
- Infra-red sensor – detects infra-red radiation

7. **Acoustic**

- Seismometers – measures seismic waves
- Acoustic wave sensors – measures the wave velocity in the air or an environment to detect the chemical species present

8. **Other sensors**

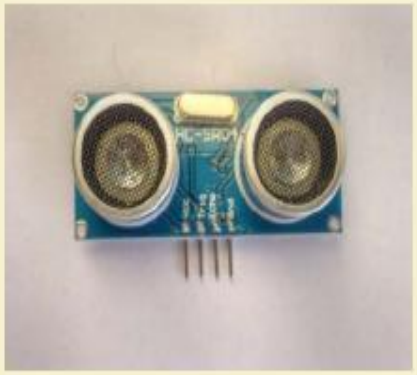
- Motion – detects motion
- Speedometer – measures speed
- Geiger counter – detects atomic radiation
- Biological – monitors human cells

Continued

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor
- Color Sensor
- Humidity Sensor
- Tilt Sensor
- Flow and Level Sensor

Examples of Sensors

Pressure Sensor
Source: Wikimedia Commons

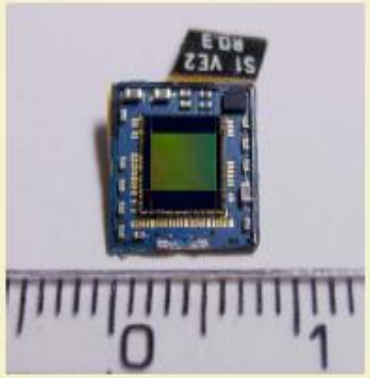


Ultrasonic Distance Sensor
Source: Wikimedia Commons

Tilt Sensor
Source: Wikimedia Commons

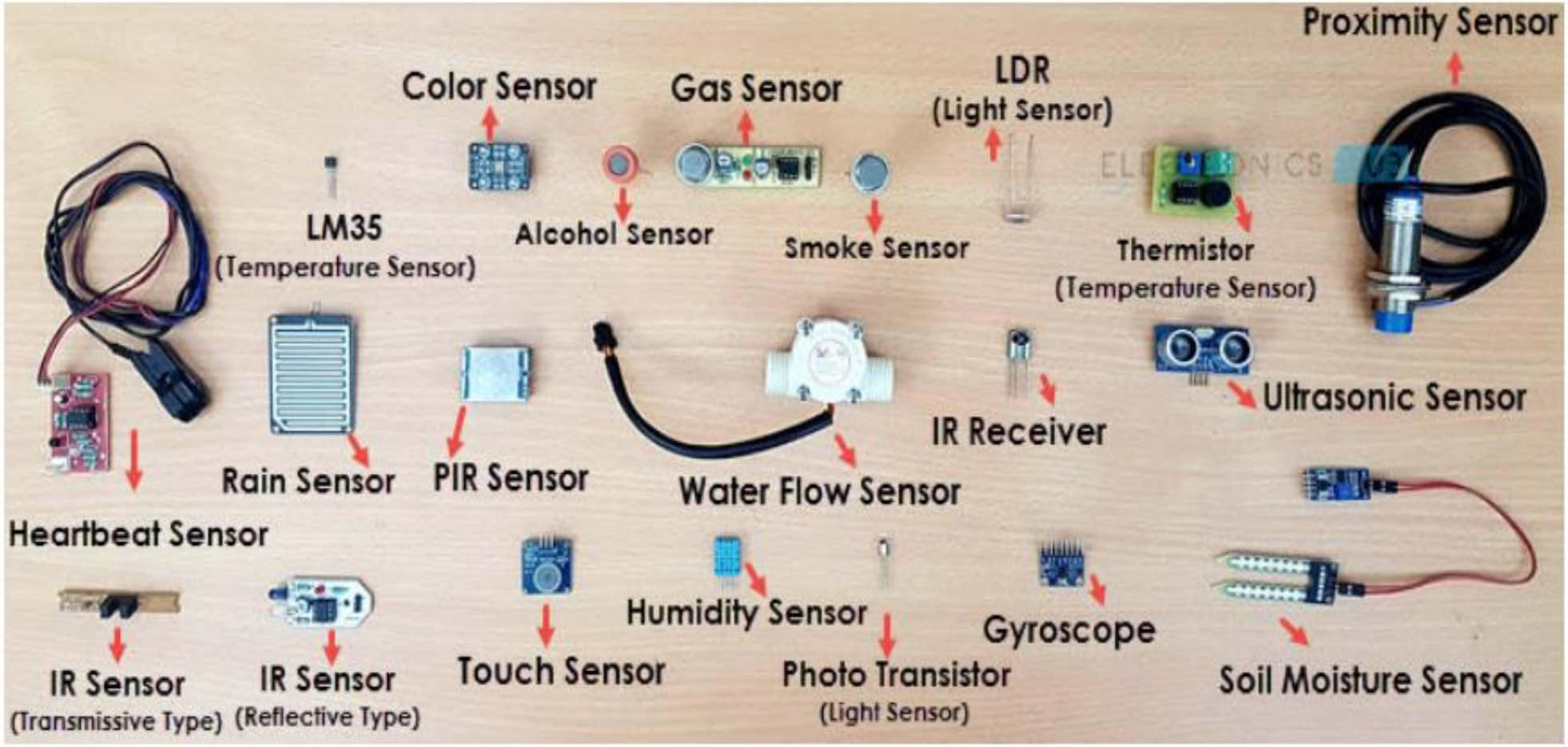
Infrared Motion Sensor
Source: Wikimedia Commons

Analog Temperature Sensor
Source: Wikimedia Commons



Camera Sensor
Source: Wikimedia Commons

List of Sensors



List of Sensors

Classification of Sensors

Passive and Active sensors

- A passive sensor does not need any additional energy source and directly generates an electric signal in response to an external stimulus, i.e., the input stimulus energy is converted by the sensor into the output signal.
- The power required to produce the output is provided by the sensed physical phenomenon itself.
- Eg: Thermometer
- The active sensors require external power for their operation, which is called an excitation signal. That signal is modified by the sensor to produce the output signal. The active sensors sometimes are called parametric because their own properties change in response to an external effect and these properties can be subsequently converted into electric signals.
- Eg: Strain guage

analog and digital

Sensors are classified as *analog and digital* based on the type of output signal.

- Analog sensors produce continuous signals that are proportional to the sensed parameter and typically require analog-to-digital conversion before feeding to the digital controller.
- Eg: Temperature sensor, LDR, analog pressure sensor
- Digital sensors on the other hand produce digital outputs that can be directly interfaced with the digital controller.
- Often, the digital outputs are produced by adding an analog-to-digital converter to the sensing unit. If many sensors are required, it is more economical to choose simple analog sensors and interface them to the digital controller equipped with a multi-channel analog-to-digital converter.
- Eg: Passive infrared sensor(PIR) and digital temperature sensor

Scalar and Vector sensor

Scalar Sensor: Detects the input parameter based on its magnitude

- The response of the sensor is a function of magnitude of the input parameter.
- Not affected by the direction of the input parameter.

Example: temperature, gas, strain ,color and smoke sensors

Vector Sensor: The response of the sensor depends on the magnitude of the direction and orientation of input parameter.

Example: Accelerometer, gyroscope , motion detector sensor

Selection of sensors for Practical Applications

The accuracy of selecting a sensor depends on the knowledge about the application type, the variable choice of product, and the condition in the operating environment.

Measuring range

- While selecting a sensor (temperature sensor, proximity sensor, accelerometer sensor, etc.), the measuring range should directly correspond with the physical measuring range to obtain the most precise reading and optimal sensor lifespan.

Environment

- We must be aware of environmental conditions while installing a product. Numerous sensors can be affected by environmental conditions (such as temperature variation, gas, humidity, chemicals, etc.)

Flexibility

- While selecting a sensor, we need to check if it can provide flexibility, like features that can adapt to changing the products.

Continued

Digital lowers costs.

- It is always better to use a sensor which gave gives a digital output. It is better to avoid using analog field devices, even though they minimize the cost because converting from analog to digital can produce errors. A digital output equivalent sensors are more worth it.

Intelligent sensors

- It is better to adopt intelligent sensors that can be scaled, calibrated**,** or configured remotely. Smart sensors are those which take up data from the environment and use the predefined function to perform some actions.

Sudden temperature changes

- The sensor must be in such a situation that it can overcome the sudden temperature changes and work properly without producing errors.

Continued

Excitation

- Many transducers require power to produce an output signal and it is important to provide a power source that will not introduce additional errors.

Accuracy and Precision

- Accuracy is the quality or state of being correct and precision is the ability of the devices to notice small changes.
- Too high precision can give a wrong indication that the value is too accurate. Similarly, a sensor with good accuracy will be expensive. The error can affect both precision and accuracy.

Signal Conditioning

- Electrical noise is always present, often more so on production floors, and can cause erroneous readings.
- Signal conditioners and other protection circuits can provide some protection from these effects before conversion.

Smart Sensor

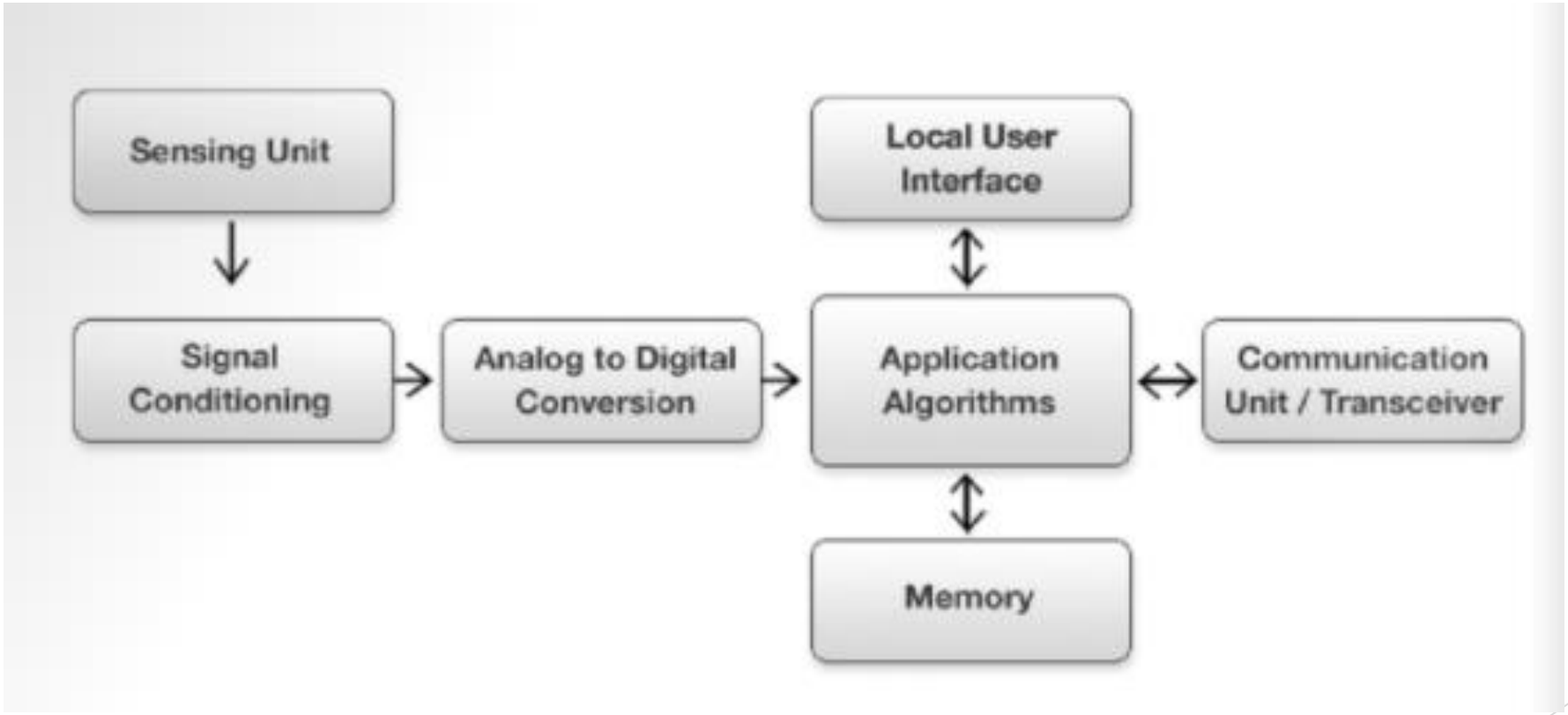
- A smart sensor is a device that takes input from the physical environment and uses built-in compute resources to perform predefined functions upon detection of specific input and then process data before passing it on.
- Smart sensors enable the more accurate and automated collection of environmental data with less erroneous noise amongst the accurately recorded information.
- A smart sensor might also include several other components besides the primary sensor.
- These components can include transducers, amplifiers, excitation control, analog filters, and compensation.
- A smart sensor also incorporates software-defined elements that provide functions such as data conversion, digital processing, and communication to external devices.

Continued

- Smart sensors provide the features - self-identification, smart calibration and compensation, digital sensor data, multi-sensing ability, sensor communication for remote monitoring and remote configuration, etc.
- Smart sensors are the sensors with integrated electronics that can perform data conversion, bidirectional communication, take decisions, and perform logical operations.

- **Examples of smart sensors**
  There are all kinds of smart sensors, but the most commonly used ones are level sensors, electric current sensors, humidity sensors, pressure sensors, temperature sensors, proximity sensors, heat sensors, flow sensors, fluid velocity sensors, and infrared sensors.

A Smart Sensor



Signal Conditioning

- Signal conditioning is an electronic circuit that manipulates a signal in a way that prepares it for the next stage of processing.
- Many data acquisition applications involve environmental or mechanical measurement from sensors, such as temperature and vibration.
- These sensors require signal conditioning before a data acquisition device can effectively and accurately measure the signal.
- For example, thermocouple signals have very small voltage levels that must be amplified before they can be digitized.
- Other sensors, such as resistance temperature detectors (RTDs) accelerometers, and strain gauges require excitation to operate. All of these preparation technologies are forms of signal conditioning.
- Signal conditioning is one of the fundamental building blocks of modern data acquisition

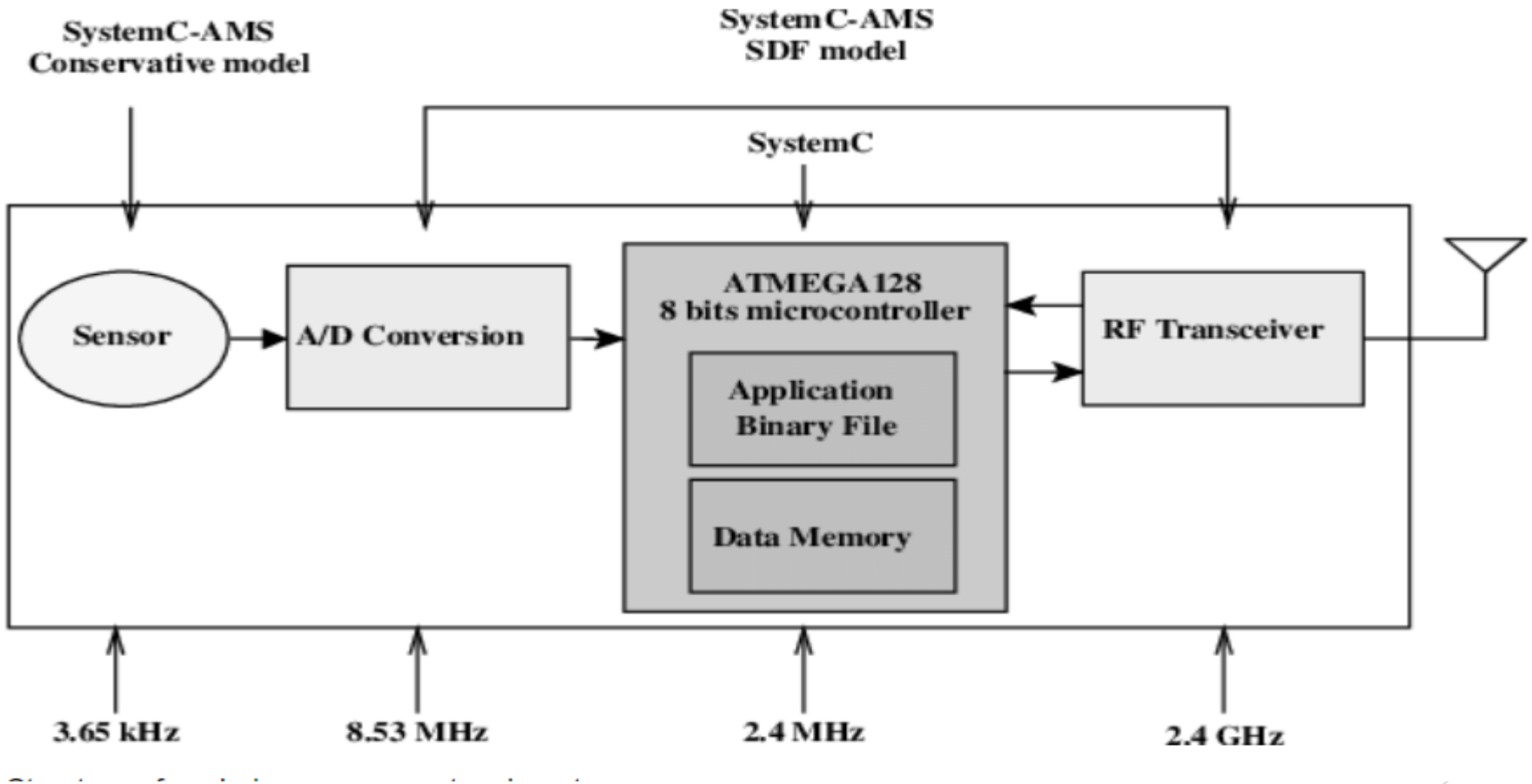
Continued

- Data acquisition systems need to connect to a wide variety of sensors and signals in order to do their job. Signal conditioners take the analog signal from the sensor, manipulate it, and send it to the ADC subsystem to be digitized for further processing (usually by computer software).

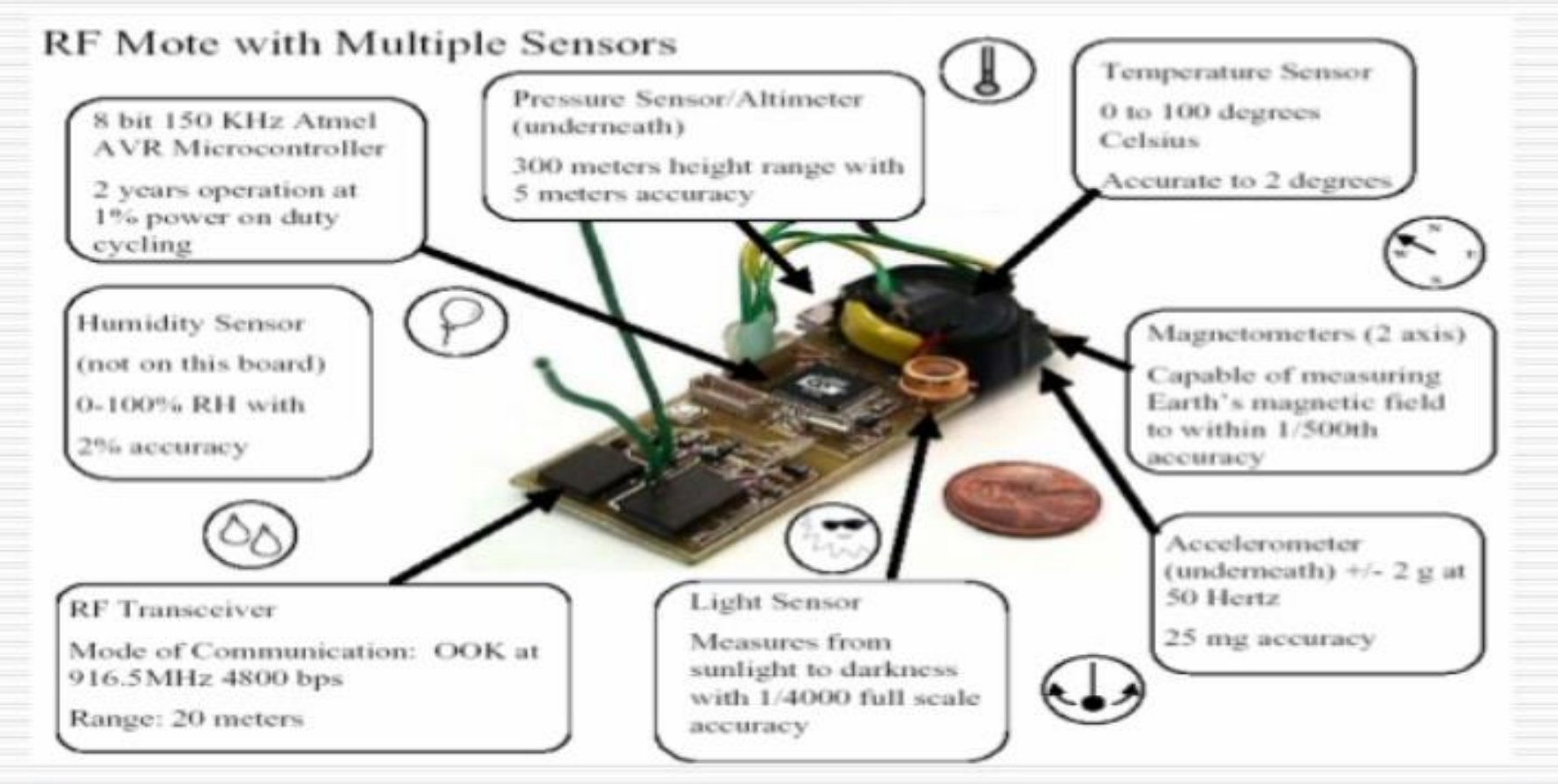
Today common types of signal conditioners are:

- Voltage and high-voltage signal conditioners
- Current signal conditioners
- AC signal conditioning
- DC signal conditioning
- Digital signal conditioners
- Thermocouple signal conditioners
- Strain gauge signal conditioners

MOTE in WSN


SystemC-AMS
Conservative model
SystemC-AMS
SDF model
SystemC
Sensor
A/D Conversion
ATMEGA128
8 bits microcontroller
Application
Binary File
Data Memory
RF Transceiver
3.65 kHz
8.53 MHz
2.4 MHz
2.4 GHz

MOTE is a node in sensor network that is capable of performing some processing, gathering, sensing information and communicating with other connecting nodes in the network



Nodes

- A wireless mote contains a small number of integrated circuits, or “chips”, connected together onto a circuit board and powered by a battery.
- The heart of a mote is its micro-controller: a tiny processor into which all the other chips connect.
- The micro-controller typically coordinates the sampling of the sensor chips and the communication through the radio chip.
- The radio chip sends the packets it receives from the micro-controller to an antenna.
- The sensor chips come in many sizes, packages and types, and deliver sensed data either through digital (as a series of 0s and 1s) or analog (as a voltage) ports.

Localization

- The task of determining physical coordinates of sensor nodes in WSNs is known as localization or positioning
- Localization is extensively used in Wireless Sensor Networks (WSNs) to identify the current location of the sensor nodes.
- This gives rise to a problem where the sensor nodes must identify its current location without using any special hardware like GPS and without the help of manual configuration.
- In centralized localization technique, all the inter-sensor measured distances are sent to the central location where the positions of each and every sensor node are calculated.

Routing protocol

- The routing protocol is a process to select a suitable path for the data to travel from source to destination.
- The process encounters several difficulties while selecting the route, which depends upon, the type of network, channel characteristics, and performance metrics.

Thank You