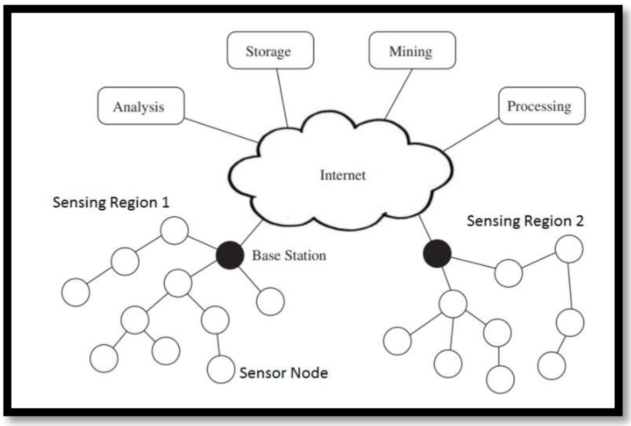
UNIT II

Introduction to Wireless Sensor Network

- A Sensor is a device used to gather information about a physical process and translate into electrical signals that can be processed, measured and analyzed.
- The physical process 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.
- The events can like physical world, an industrial environment, a biological system while the controlling or observing body can be a consumer application, government, civil, military, or an industrial entity.
- Such Sensor Networks can be used for remote sensing, medical telemetry, surveillance, monitoring, data collection etc.
- 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.

Wireless Sensor Networks

- A typical sensor network consists of sensors, controller and a communication system. If the communication system in a Sensor Network is implemented using a Wireless protocol, then the networks are known as Wireless Sensor Networks.

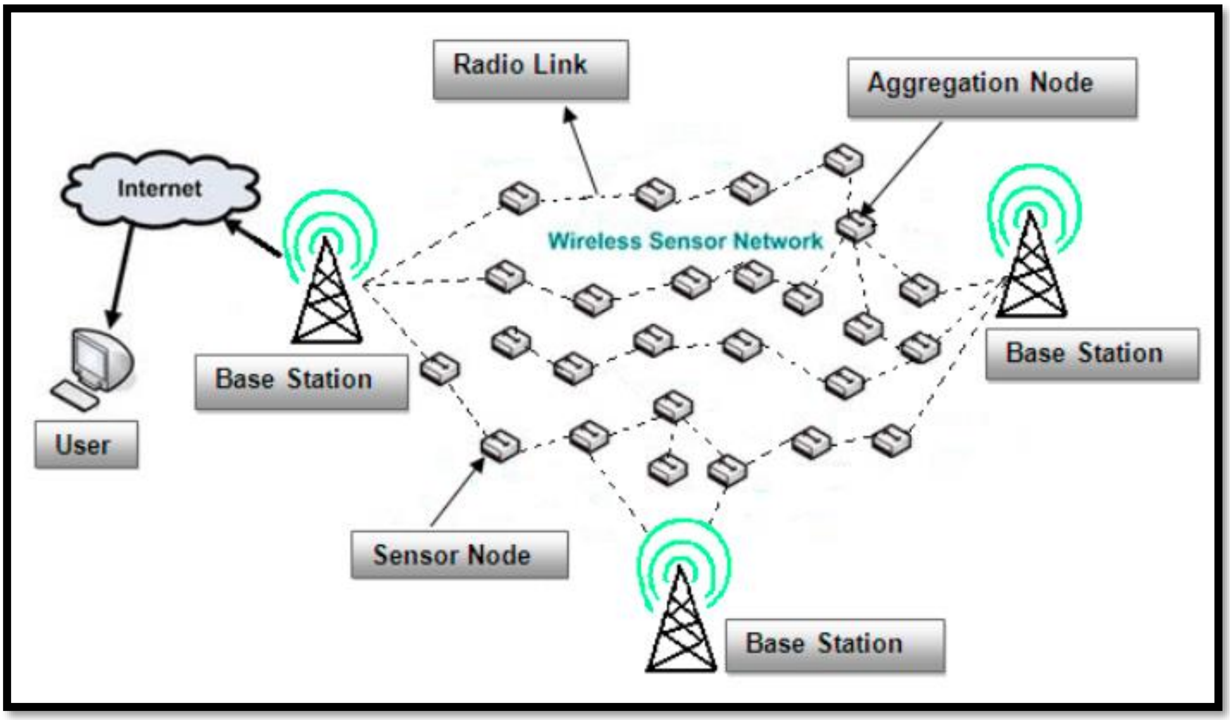


- According to technologists, Wireless Sensor Networks is an important technology for the twenty first century.
- Recent developments in MEMS Sensors (Micro Electro Mechanical System) and Wireless Communication has enabled cheap, low power, tiny and smart sensors,

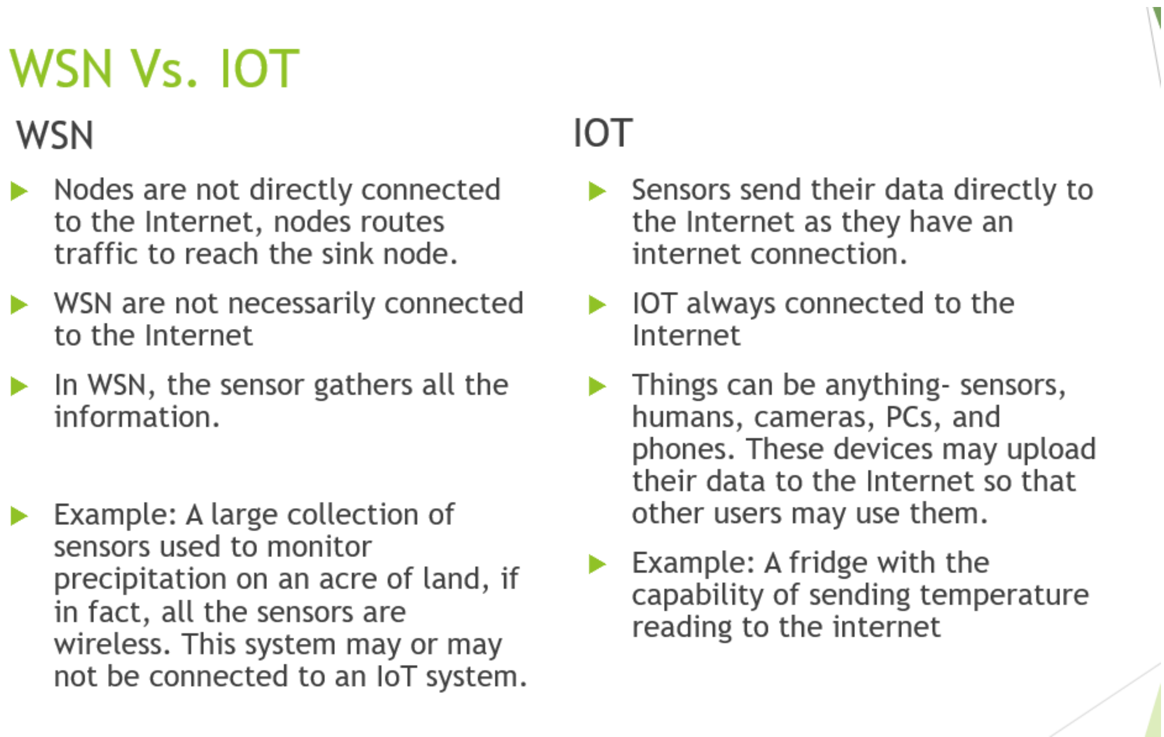
deployed in a wide area and interconnected through wireless links for various civilian and military applications.

- A Wireless Sensor Network consists of Sensor Nodes deployed in large quantities and support sensing, data processing, embedded computing and connectivity.

Basic Architecture of Wireless Sensor Network



- 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.



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

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

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.

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.

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

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

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

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

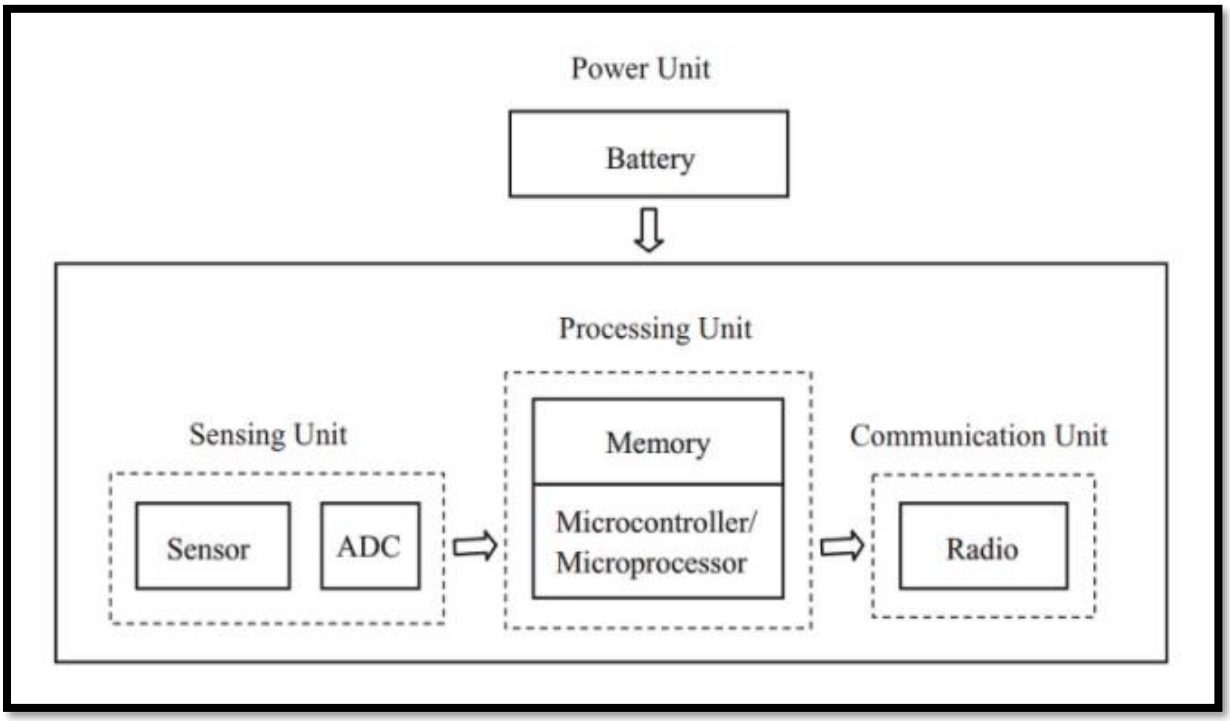
7. Acoustic

- 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

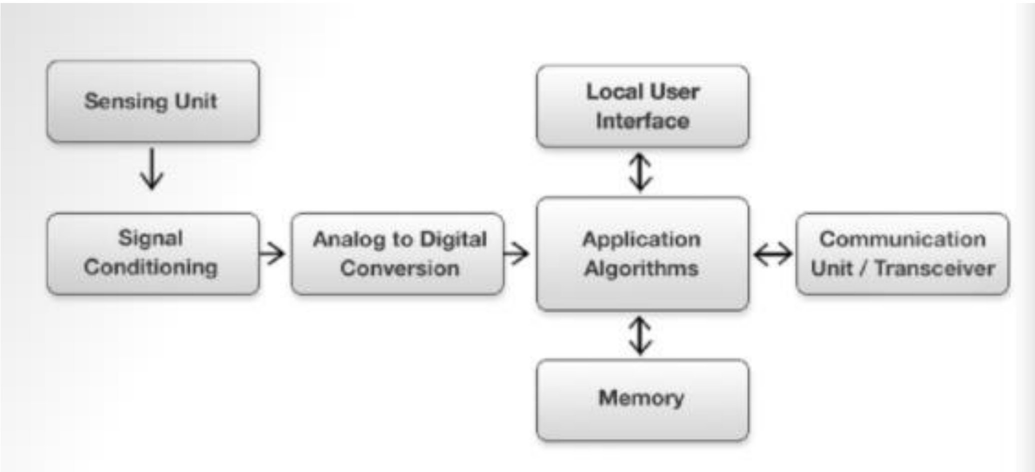
Architecture of Sensor Node



- Figure above shows the different units of a wireless sensor node and the different integration techniques.
- **Sensing Unit :**
  - The sensing unit integrates one or more physical sensors and provides one or more analog-to-digital converters as well as the multiplexing mechanism to share them. The sensors interface the virtual world with the physical world.

- **Processor Unit:**
  - The processor unit brings together all the other units and some additional peripherals.
  - Its main purpose is to process (execute) instructions pertaining to sensing, communication, and self-organization.
  - It consists of a processor chip, a nonvolatile memory (usually an internal flash memory) for storing program instructions, an active memory for temporarily storing the sensed data, and an internal clock, among other things.
- **Communication Unit:**
  - As the selection of the right type of processor is vital to the performance as well as the energy consumption of a wireless sensor node, the way the subcomponents are interconnected with the processor subsystem is also vital.
  - Fast and energy-efficient data transfer between the subsystems of a wireless sensor node is critical to the overall efficiency of the network it sets up.
  - However, the practical size of the node puts a restriction on system buses.
  - Whereas communication via a parallel bus is faster than a serial bus, a parallel bus needs more space.
  - Moreover, it requires a dedicated line for every bit that should be transmitted simultaneously while the serial bus requires a single data line only.
  - Owing to the size of the node, parallel buses are never supported in node design. The choice, therefore, is often between serial interfaces such as the serial peripheral interface (SPI), the general purpose input/output (GPIO), the secure data input/output (SDIO), the inter-integrated circuit (I2C), and the Universal Serial Bus (USB). Among these, the most commonly used buses are the SPI and the I2C

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.
- 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.

Need of Sensor

- Sensor technologies have improved the everyday life of human beings through their applications in almost all fields.
- Sensors are devices that detect changes in the source/environment and collect signals, and accordingly, the reaction is designed. T
- here is a range of sources, including light, temperature, movements, and pressure etc., which may be used.
- A wide range of applications is utilised using innovative sensor technologies in lifestyle, healthcare, fitness, manufacturing, and daily life.

Signal Conditioning

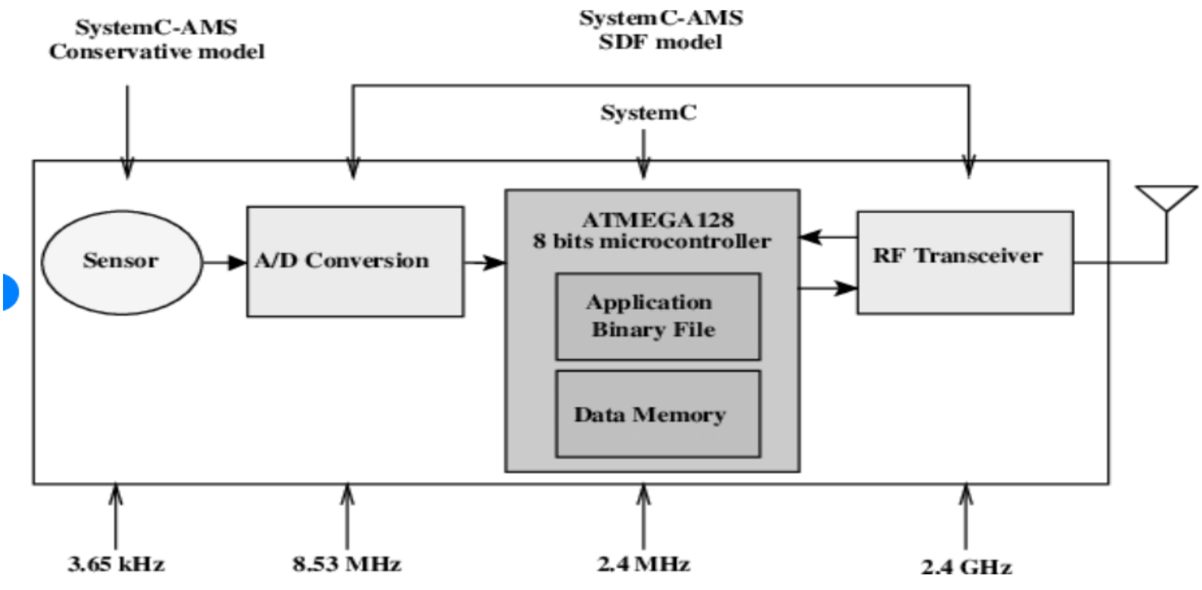
- Modern sensor wireless communication devices are digital in nature, but the inter-communication between them is done via analog signals. For example, in an IoT sensor setup, the communication between a sensor and the central processor is wireless and it is usually done through Wi-Fi. Wi-Fi or WLAN (**IEEE 802.11)** communicates in various frequencies, including but not limited to 2.4 GHz, 5 GHz, and 60 GHz frequency bands.

- In cases like these at the receiver end it is essential to condition the input analog signal. Signal conditioning ensures proper retrieval of data, by efficient conversion of analog signal into digital data. Signal conditioner is an essential component of a system that interfaces with a sensor.
  The steps in signal conditioning and data acquisition are listed below.
  - Amplification
  - Linearization and Cold junction compensation
  - Filtering
  - Sampling and Digital conversion
  - Isolation
  - Data Acquisition

- **Steps in signal conditioning**
  - The input from transducer contains all the required data. This signal is very low in power, distorted with noise. It is important to amplify the signal initially to start the conditioning process. Amplification is preceded by calibration of the signal.

1. Amplification
   - Amplification is done to increase the voltage of the incoming signal.
   - Typical voltage range for the data acquisition hardware will be 0 to (+ or -) 10V.
   - If the signal is lower than this range it is amplified
2. Linearization and Cold Junction Compensation
   - Linearization is required when the signals produced by a sensor do not have a proportionally direct relationship with the physical measurement.
3. Filtering
   - After amplification and linearization stage of signal conditioning, signal must be filtered and optimized for the analog and digital converter (ADC) to read it. Filtering reduces noise errors in the signal.
   - Typically for most of the applications a low-pass filter is used for filtering. This allows the lower frequency components to pass through but attenuates the higher frequencies

Architecture of MOTE



- Mote sensor node architecture is a multipurpose architecture that consists of a power management subsystem, a processor subsystem, a sensing subsystem, a communication subsystem, and an interfacing subsystem.
- The sensing subsystem provides an extensible platform to connect multiple sensor boards.
- One realization of the sensor board contains a 12-bit, 4-channel ADC; a high resolution temperature/humidity sensor; a low-resolution digital temperature sensor; and a light sensor.
- These devices are interfaced to the processing subsystem through the SPI and I 2C buses. The I2C bus is chosen to connect low data rate sources whereas the SPI bus is used to interface high data rate sources
- A mote needs to use wireless communications to talk with others.
- The wireless signals are actually raw electro-magnetic signaling primitives.
- A RF transmitter should use digital modulation to modulate the data to RF carrier.
- A RF receiver then performs demodulation and data extraction.
- In WSNs, a mote mainly sends out two types of data: (1) sensor data collected from environment; (2) control data such as wireless network protocols.
- Those data are encapsulated into “packets” from network protocol viewpoint.