
# Distributed & Embedded Real-Time Systems (0640751)

**Lecture (13)**

# Microcontroller-Based Wireless Sensor Networks

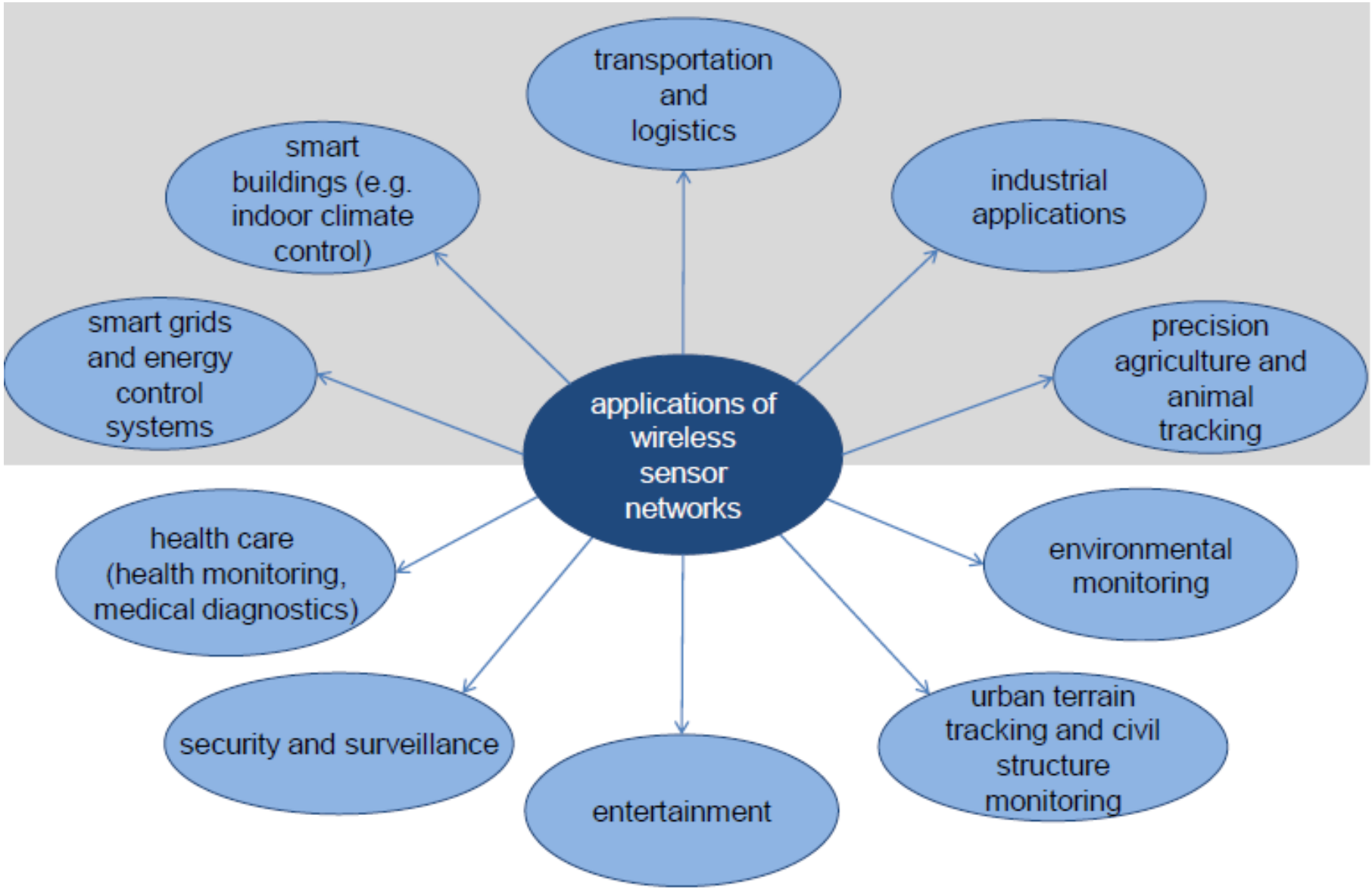
**Prof. Kasim M. Al-Aubidy**
Philadelphia University

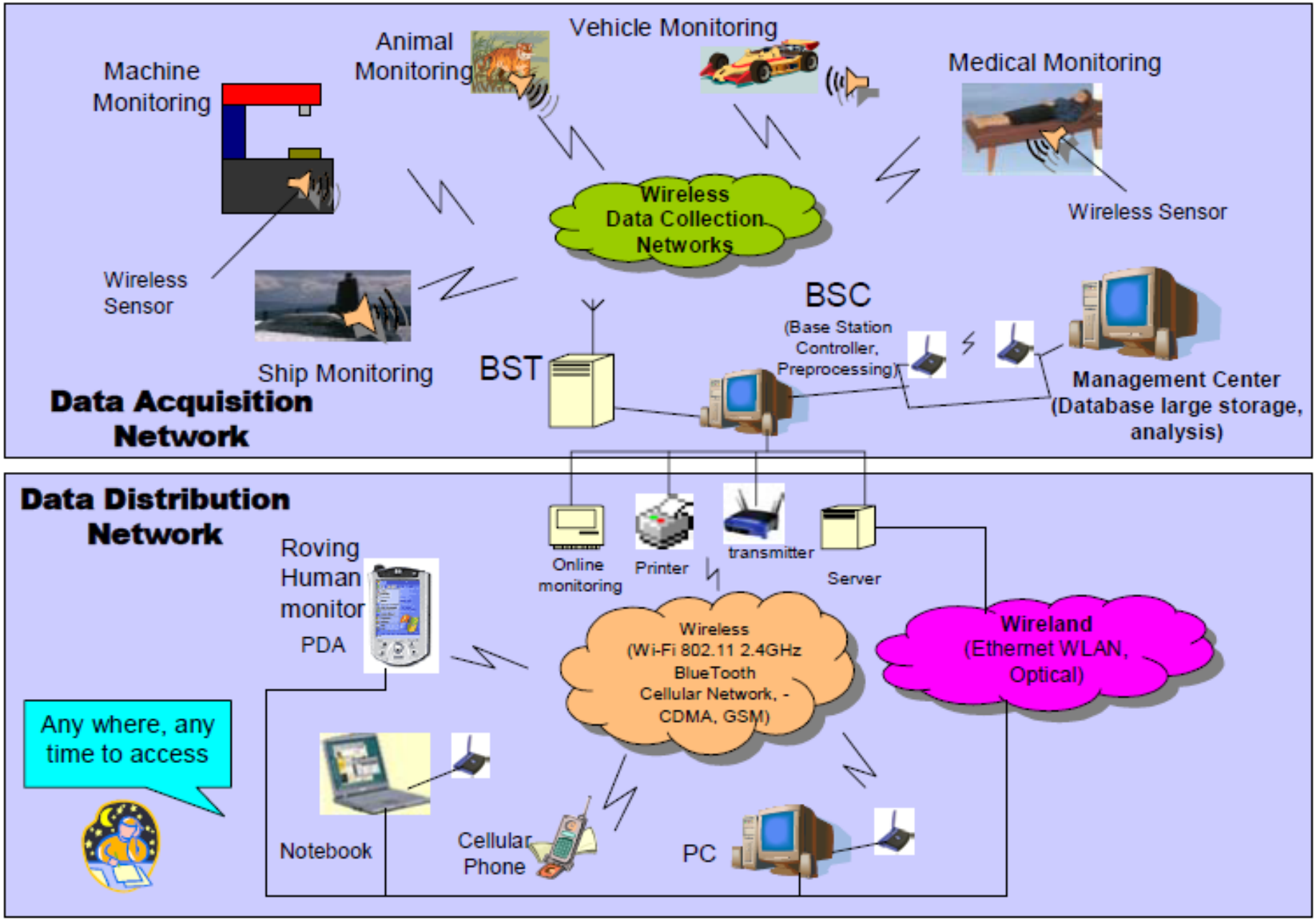
## Introduction:

- Wireless Sensor Networks (WSNs) have been identified as one of the most important and promising technologies that will allow people and machines to interact with their environment in a simple way. Recently, WSNs play an important role in monitoring and control applications, and will find more applications as computer and communication technologies advances and hardware prices drop.
- WSNs consist of specially distributed devices using sensors to monitor physical or environmental conditions. Application areas of WSNs include geographical monitoring, habitat monitoring, transportation, military systems, business processes, microclimate research, medical care and others.
- Each sensor is attached to battery powered microprocessors combined with a set of specific instrumentation for environmental measurements such as sound, light and temperature. Its advantages include the mobility, simplicity, and low cost in both installation and maintenance.

## Applications of WSNs:

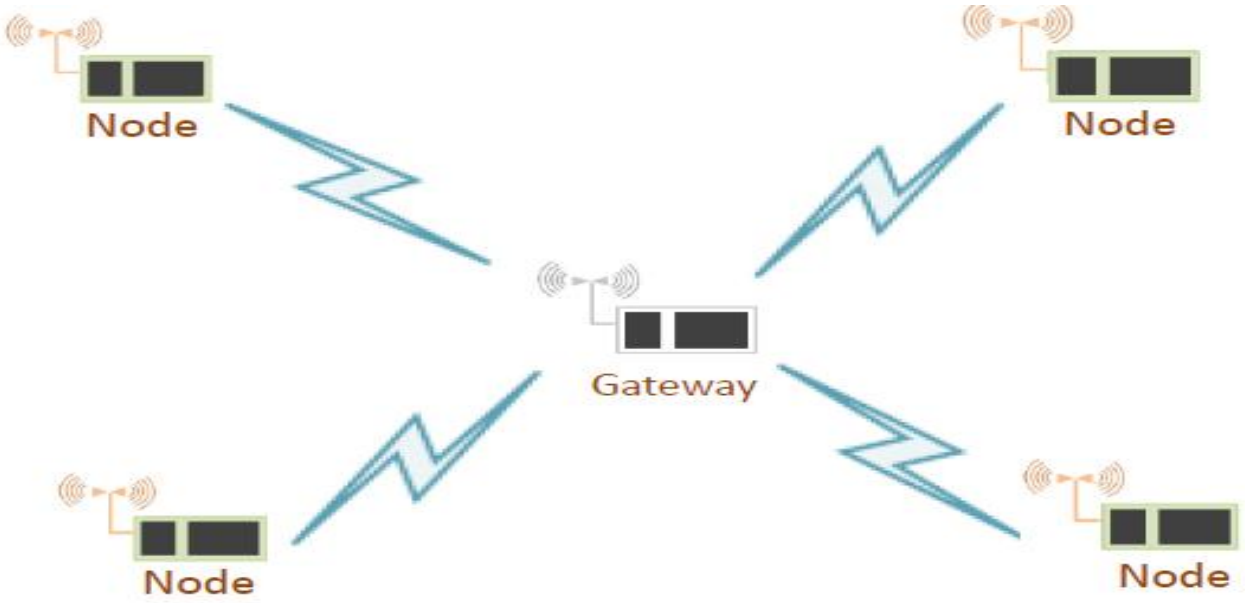
- **Environmental applications:** forest fire detection, biocomplexity mapping of the environment, greenhouses monitoring and control, flood detection, alarming and control, weather forecasting and others.
- **Health applications:** monitoring of human physiological data, monitoring and tracking patients and doctors, drug administration in hospitals and medical stores,.....
- **Smart home applications:** home automation, smart environment by incorporating sensor nodes embedded into furniture and appliances, and they can communicate with each other and the room server, and more.
- **Military applications:** Monitoring friendly forces, "command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting" systems, Battle damage assessment, Nuclear, biological and chemical attack detection and reconnaissance, and more others.
- **Commercial applications:** environmental control in office buildings, Detecting and monitoring car thefts, Managing inventory control in a warehouse, Vehicle tracking and detection, and others


transportation and logistics
smart buildings (e.g. indoor climate control)
industrial applications
smart grids and energy control systems
precision agriculture and animal tracking
applications of wireless sensor networks
health care (health monitoring, medical diagnostics)
environmental monitoring
security and surveillance
entertainment
urban terrain tracking and civil structure monitoring


Machine Monitoring
Animal Monitoring
Vehicle Monitoring
Medical Monitoring
Wireless Data Collection Networks
Wireless Sensor
Wireless Sensor
Ship Monitoring
BST
BSC
(Base Station Controller, Preprocessing)
Management Center (Database large storage, analysis)
Data Acquisition Network
Data Distribution Network
Roving Human monitor
PDA
Online monitoring
Printer
transmitter
Server
Wireless (Wi-Fi 802.11 2.4GHz BlueTooth Cellular Network, - CDMA, GSM)
Wireland (Ethernet WLAN, Optical)
Any where, any time to access
Notebook
Cellular Phone
PC

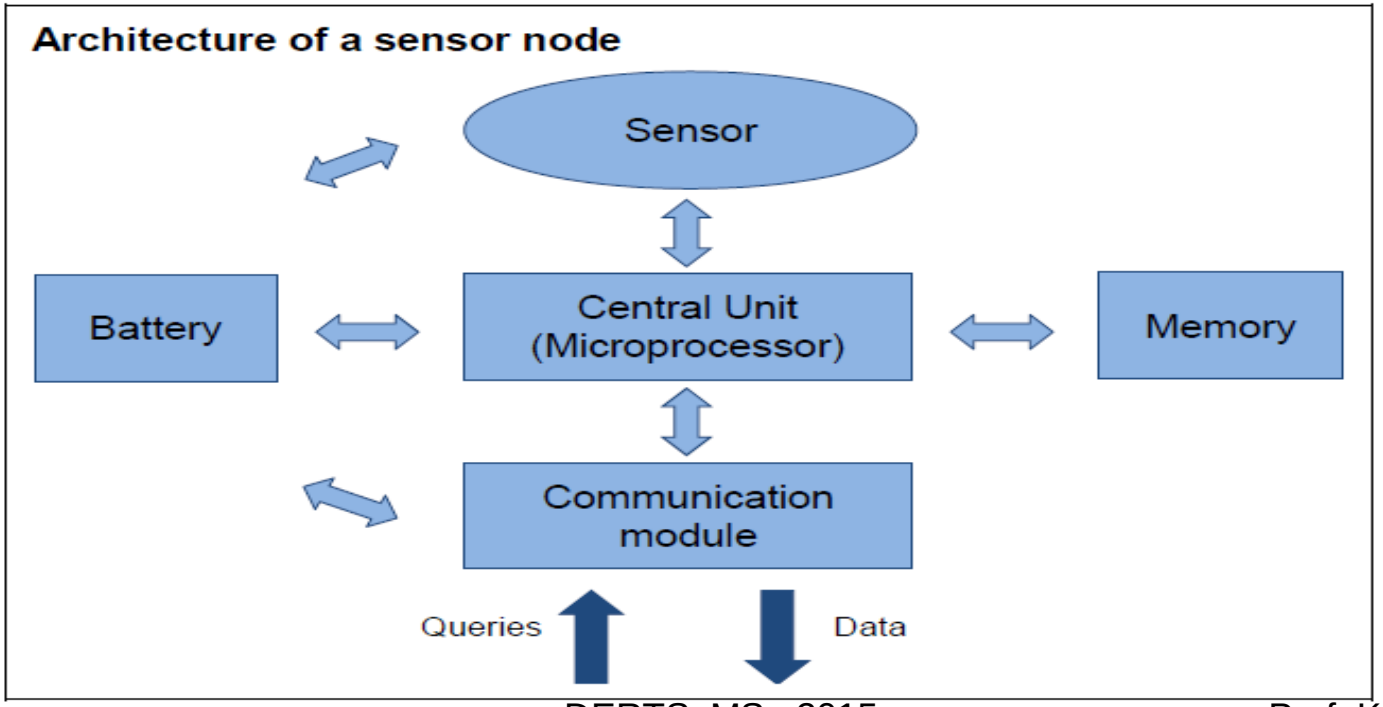
## WSN Architecture:

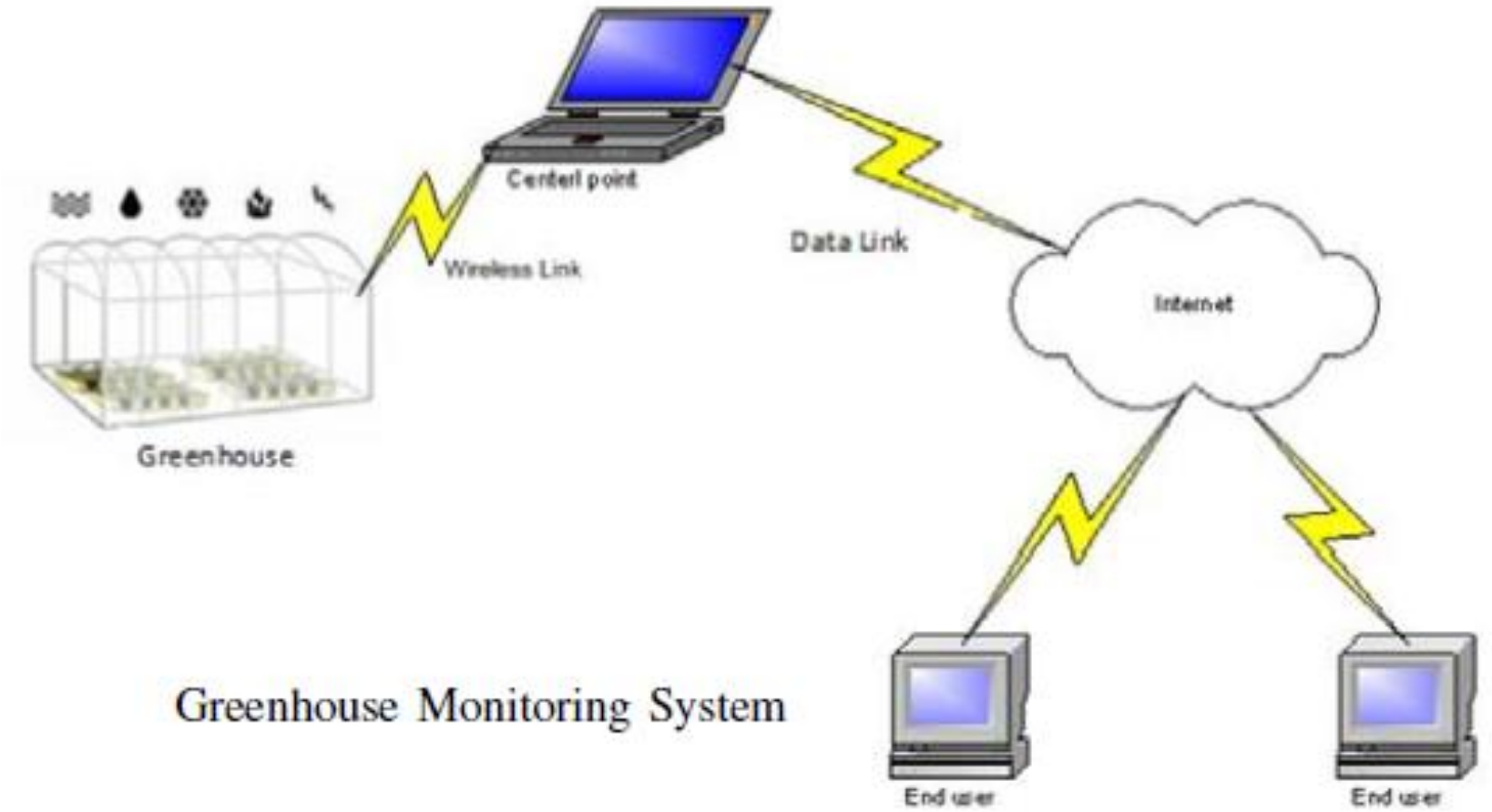
- Nodes in the WSN are classified into two types according to their function:
- Source node: It is any entity in the network that can provide information. It could be a sensor node, or an actuator node that provides feedback information about an operation.
- Sink node: It is the entity where information is required. It could be another sensor/actuator node used to interact with sensor network or as a gateway to interact with another larger network such as the Internet.



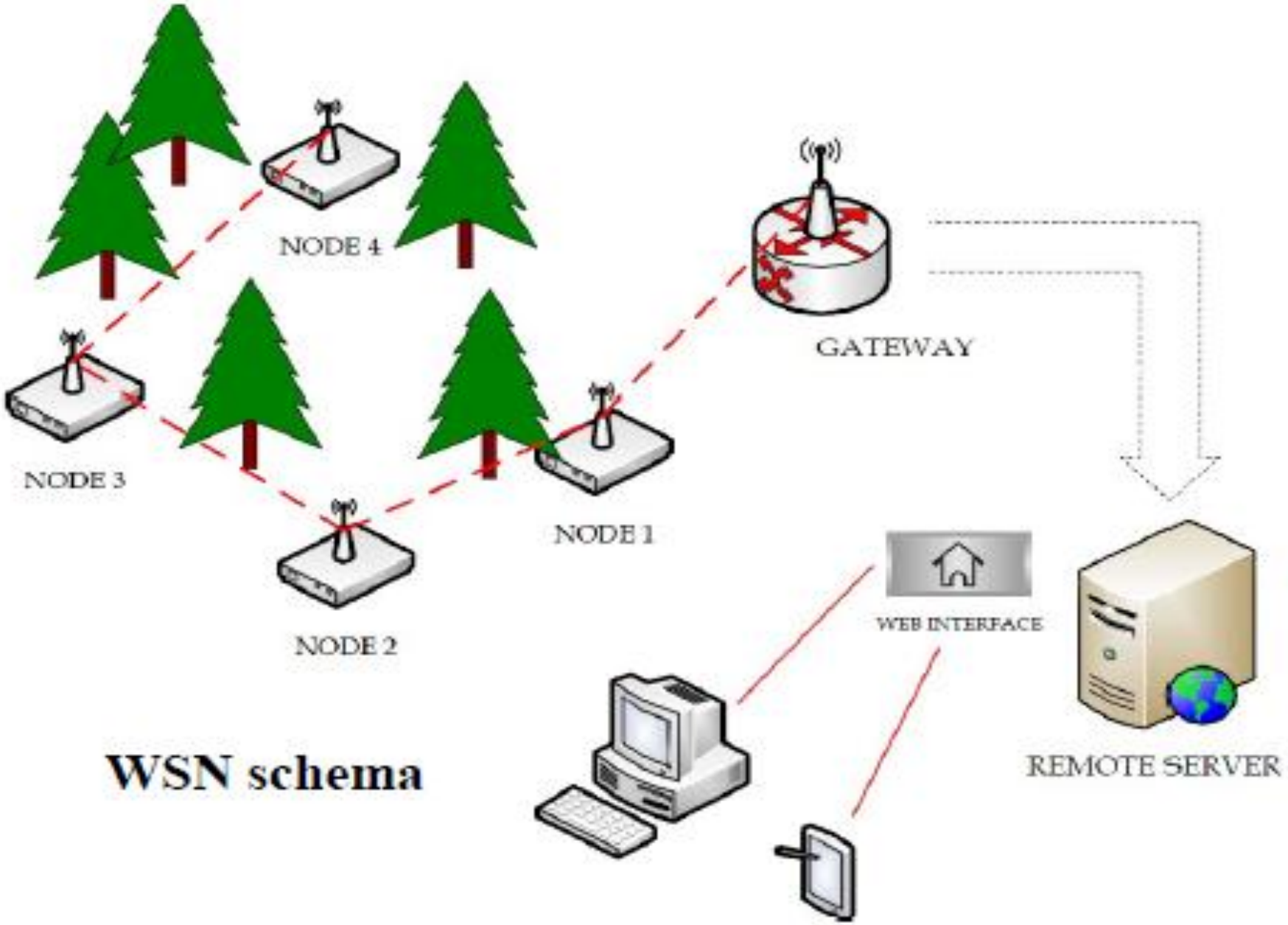
**Each sensor node comprises five main components:**

- **Controller:** A microcontroller to process data received from sensors or other nodes.
- **Memory:** storage unit of the controller to store programs and intermediate data.
- **Sensors:** set of devices required to interface controller with physical parameters of the environment, such as temperature sensors.
- **Communication Link:** Connecting nodes into a network requires a device for sending and receiving information over a wireless link.
- **Power Supply:** An energy source, such as solar cell or batteries is required.

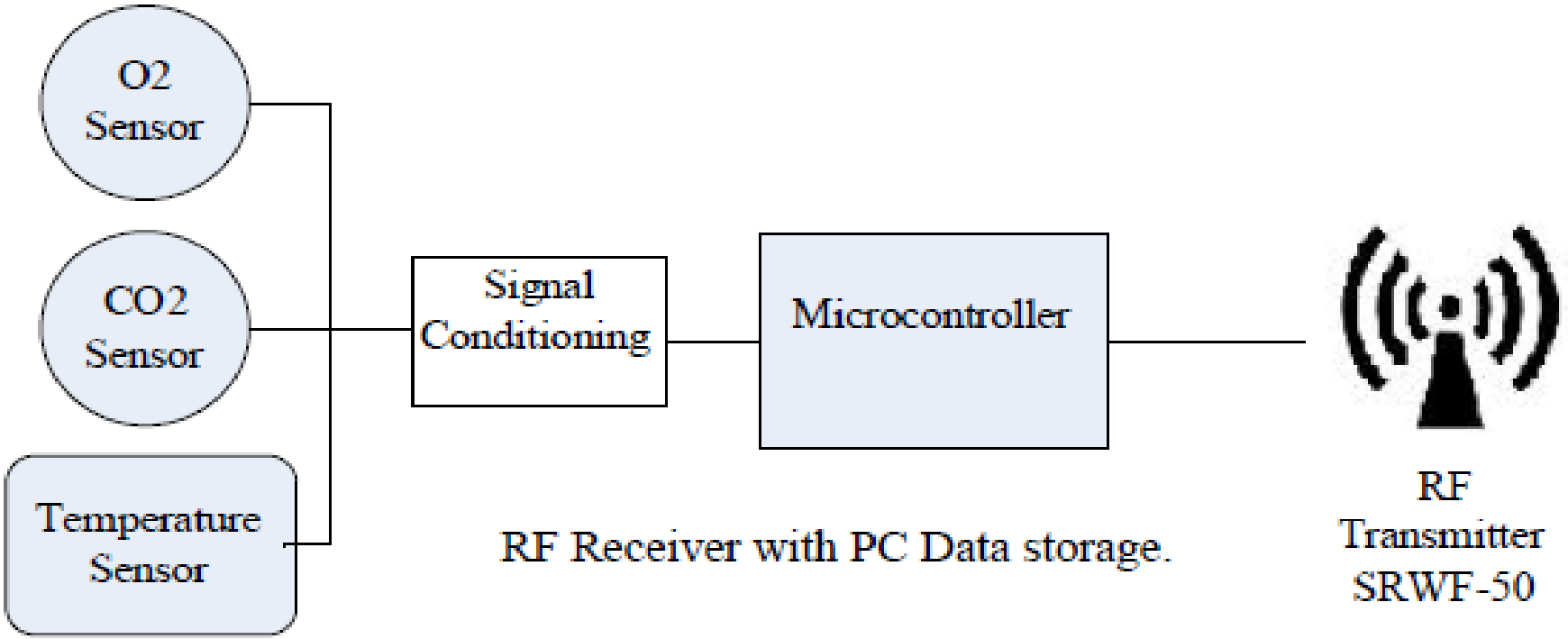





Greenhouse Monitoring System


NODE 4
NODE 3
NODE 2
NODE 1
GATEWAY
WEB INTERFACE
REMOTE SERVER

**WSN schema**




Wireless system hangs at plant

❑**Each individual node in the WSN can monitor its local region and communicate through a wireless channel with other nodes.**

❑ **Wireless communication can be achieved using one of the following technologies:**

- **Bluetooth.**
- **Zigbee**
- **WiFi**
- **GPS**

❑ **It is useful to use mobile communication in the remote monitoring and control to avoid all disadvantages of the above technologies.**

# Comparison between ZigBee and Bluetooth:

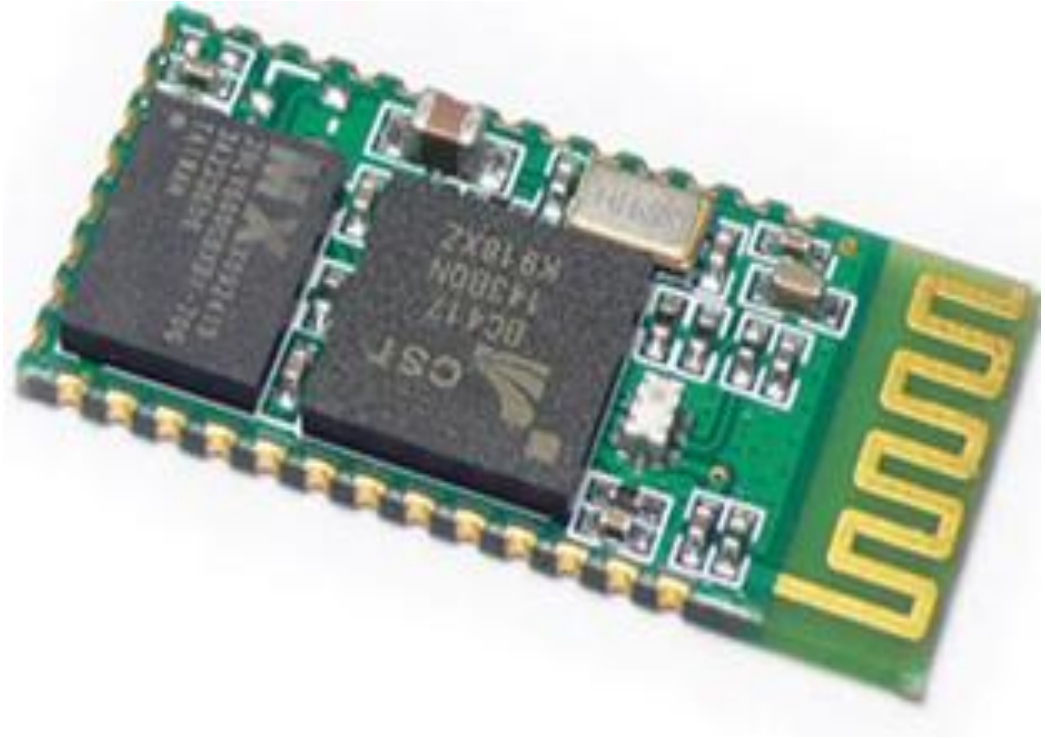
| System | ZigBee™ 802.15.4 | Bluetooth™ 802.15.1 |
|---|---|---|
| Application | Monitoring and control | Cable replasment |
| System resources | 4-32 KB | 250 KB |
| Battery life (days) | 100-1000+ | 1-7 |
| Nodes in network | 255 / 65K+ | 7 |
| Baseband(Kb/s) | 20-250 | 720 |
| Distance (meters) | 1-75+ | 1-10+ |
| Key characteristics | stabitity, low consumption, low cost | price, easy to use comfort |

# Comparative table between different wireless standards

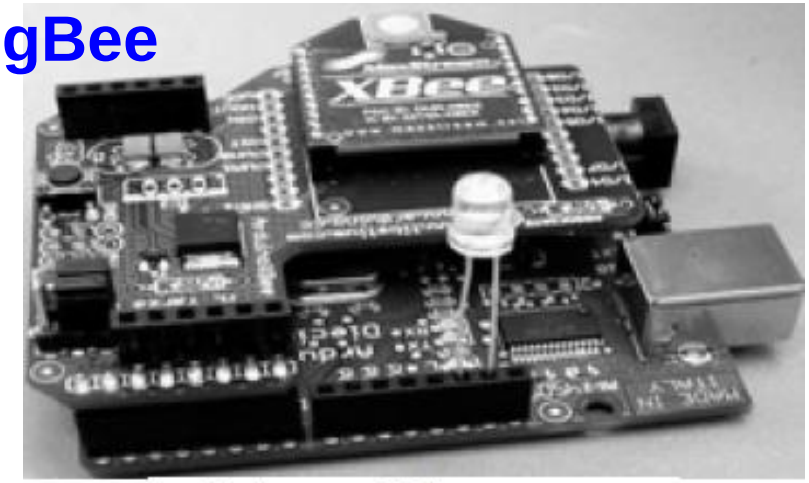
| Criterion | 802.11b | 802.11g | 802.11a | 802.11n draft | 802.16 ( WIMAX) | GSM (GPRS,UMTS) | Bluetooth |
|---|---|---|---|---|---|---|---|
| Maximum Operation Area (theoretical | 550 m/ 55m | 300m/ 30m | 500m / 50m | 800m / 80m | 5Km - 100Km according to standard | 20Km-30Km | 100m / 10m |
| Transfer Rate (maximum / real) | 11 Mbps / 4-6 Mbps | 54 Mbps / 25-30 Mbps | 54 Mbps / 25-30 Mbps | 300 Mbps / 30 Mbps | According to implementation 15-150Mbps | According to operator and coverage: 6-144 Kbps | According to manufacturer and standard 115-1000 Kbps |
| Frequency Band | 2.4 GHz | 2.4 GHz | 5 GHz | 2.4 GHz | 0.7-66 GHz | 0.8, 0.9, 1.8, 1.9, 2 GHz | 2.4 GHz |
| Mobility | Low up to 10Km/h | | | | | Higher | Low up to 10Km/ h |
| Advantages | Easy adaptability to hardware, easy programming | | | | Large communication distance | Almost global coverage, low energy consumption | Low energy consumption, relatively high communication speed |
| Disadvantages | Low communication speed | ------- | High energy consumption | | | High costs /minute, or for sent data when used frequently | Small distance, high interference |

# Bluetooth Adapter Interfacing:

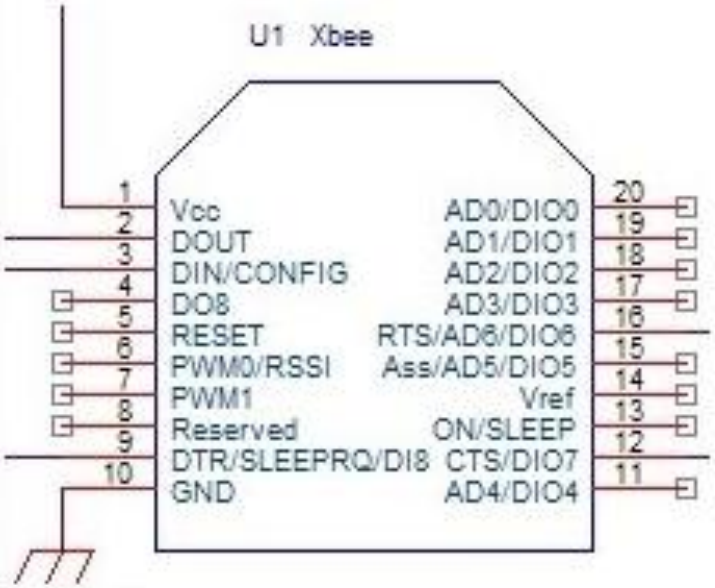
- **The Bluetooth adapter (HC06) has been used to connect the Arduino UNO board embedded in the designed system such that it can be accessed by any Bluetooth device within the area.**
- **Two data lines (TxD & RxD) for serial communication.**
- **Once the connection to the Bluetooth module is established, a terminal program can be used for this purpose.**



# Single-Board Microcontroller + ZigBee

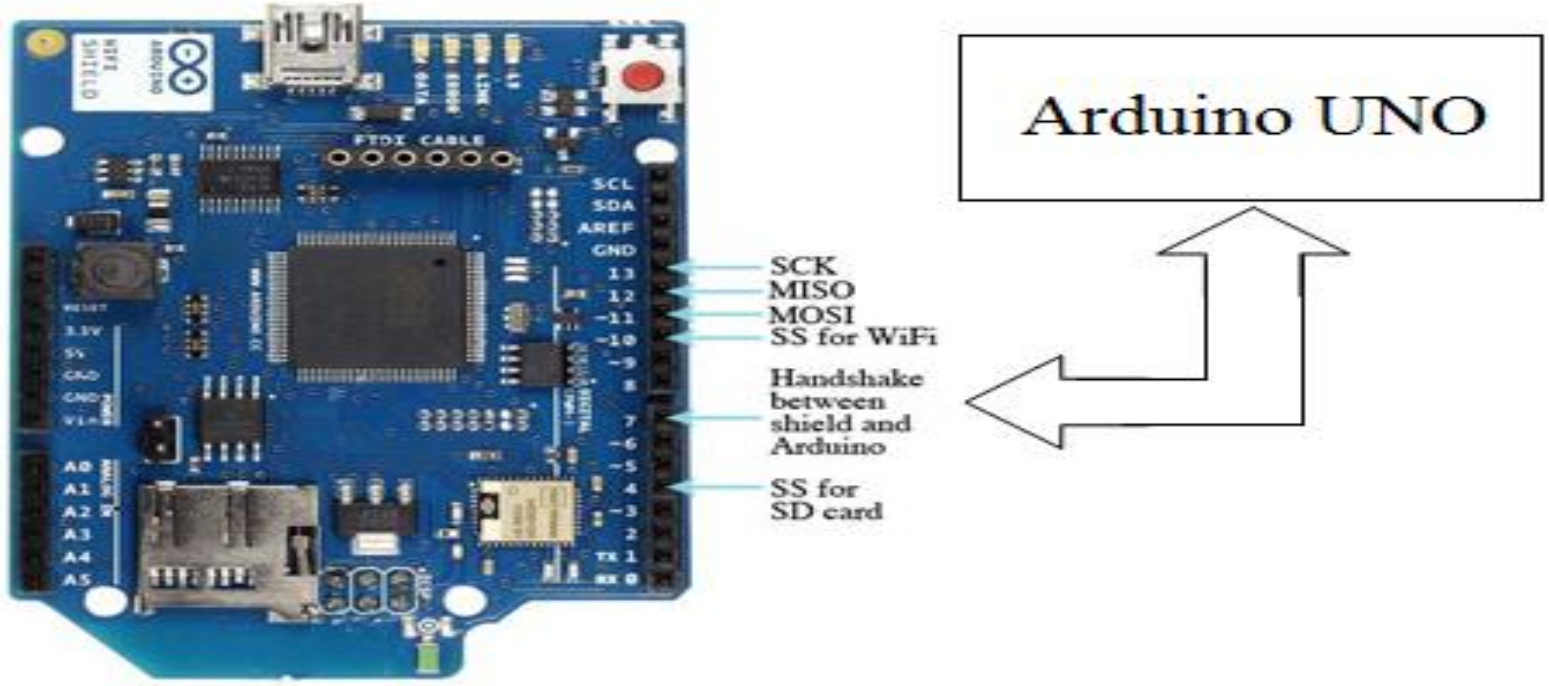


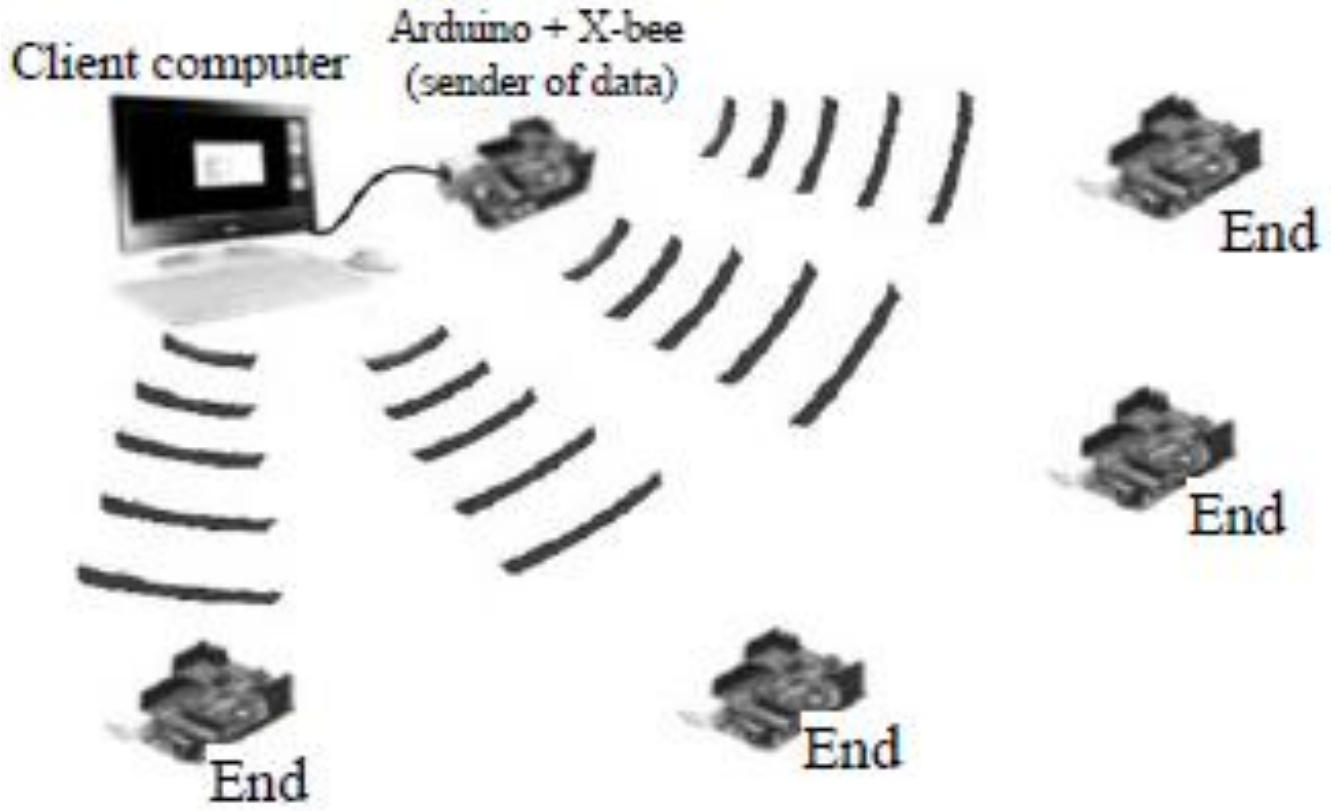

Arduino + X-bee.

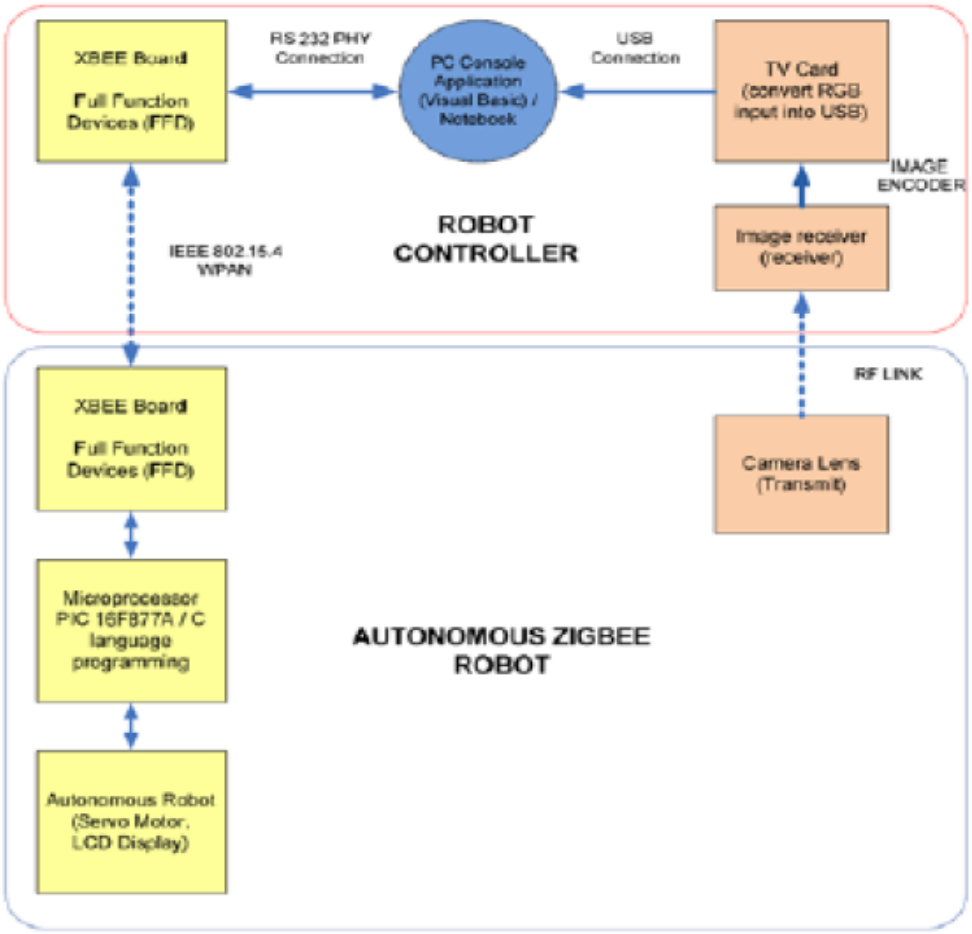
# Arduino WiFi Shield Interfacing:

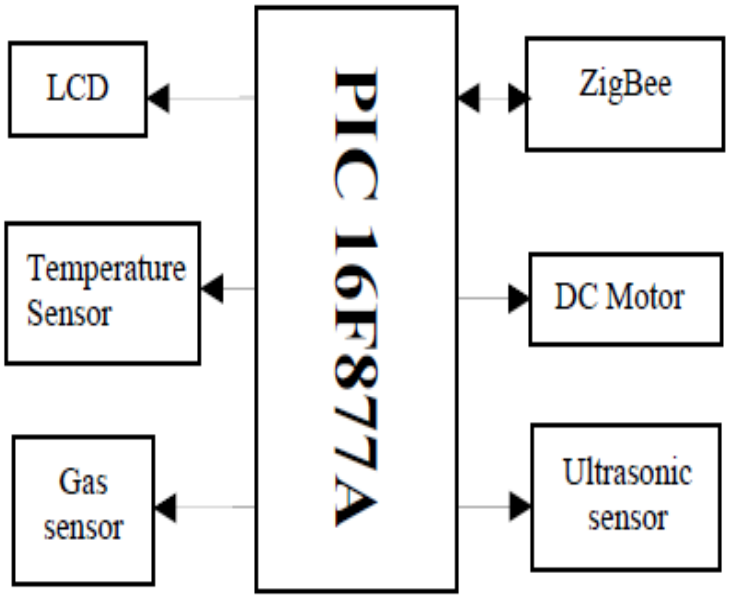
- Through this module, the remote station can be connected to the local network wirelessly using the 802.11 wireless specification.
- The WiFi Shield is mounted on top of the Arduino UNO board using SPI port.
- Six lines are required for WiFi interfacing.
- In this case, the unit equipped with WiFi shield can be accessed directly through the network.



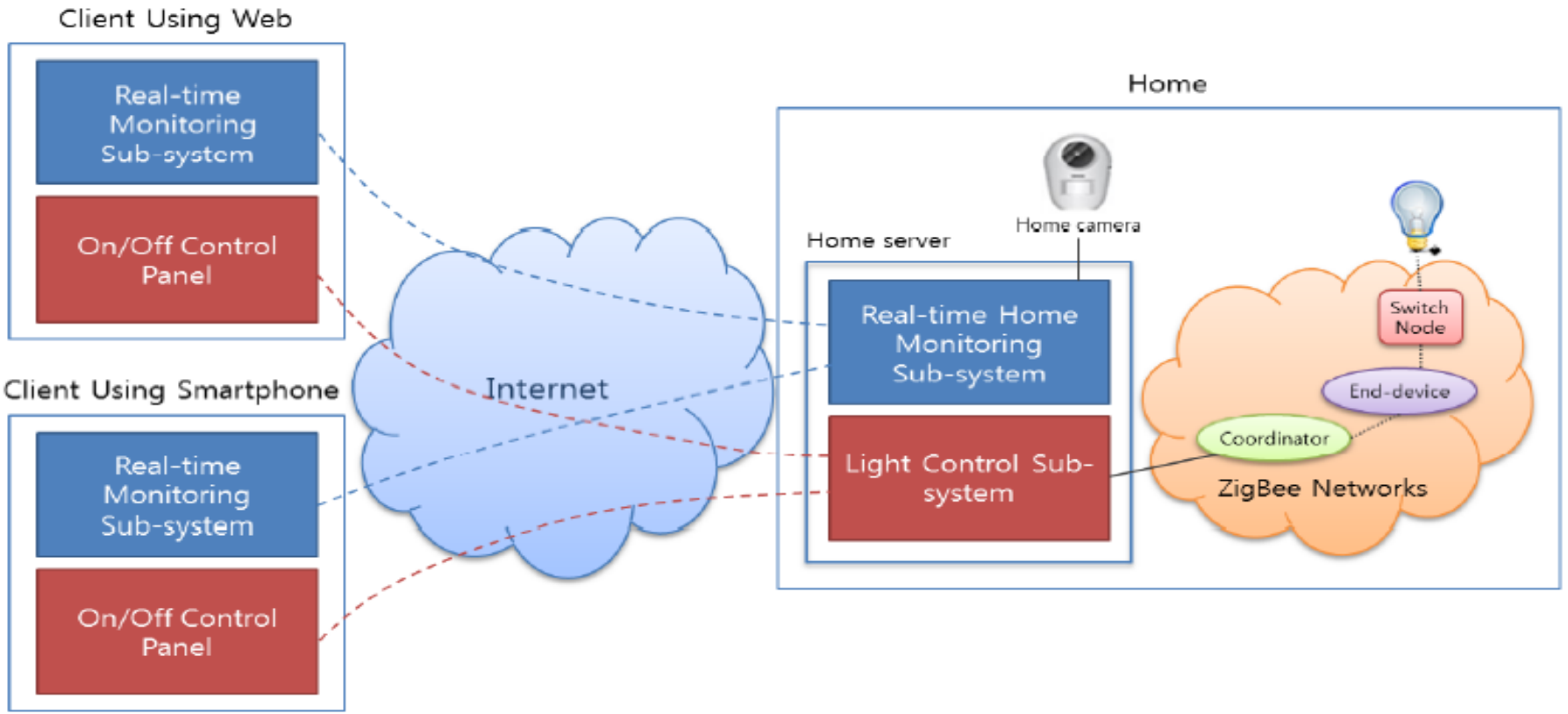

Client computer
Arduino + X-bee
(sender of data)
End
End
End
End

# Example: Mobile Robot control using Zigbee Technology

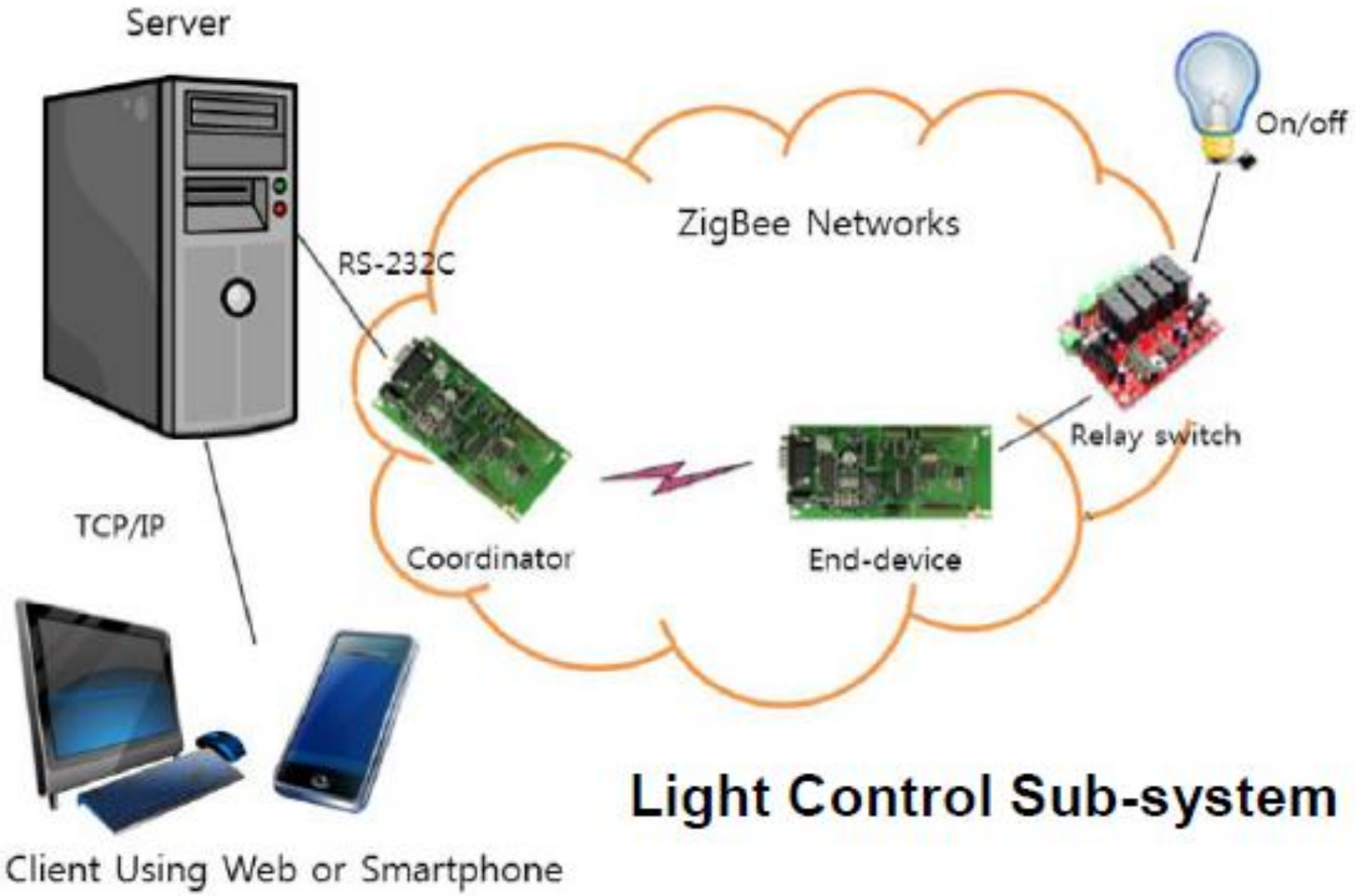


# Example: Smart Home




The system consists of a real-time home monitoring sub-system and a light control sub-system. A home server with a home camera caters for home status through video to client. It also works as a home gateway to provide interoperability between the heterogeneous ZigBee and Internet and local and remote control over the home's light devices through the light control sub-system.


Server
RS-232C
ZigBee Networks
On/off
Relay switch
TCP/IP
Coordinator
End-device
Client Using Web or Smartphone
Light Control Sub-system

## References: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