WIRELESS SENSOR NETWORK USING ZIGBEE

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Abstract

A wireless sensor network (WSN) consists of sensors which are densely distributed to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. The sensor data is transmitted to network coordinator which is heart of the wireless personal area network. In the modern scenario wireless networks contains sensors as well as actuators. ZigBee is newly developed technology that works on IEEE standard 802.15.4, which can be used in the wireless sensor network (WSN). The low data rates, low power consumption, low cost are main features of ZigBee. WSN is composed of ZigBee coordinator (network coordinator), ZigBee router and ZigBee end device. The sensor nodes information in the network will be sent to the coordinator, the coordinator collects sensor data, stores the data in memory, process the data, and route the data to appropriate node.

***Index Terms:** WSN, ZigBee.*

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1. INTRODUCTION

Wireless sensor network is a technology for wide range of wireless environments. Recently more research work has been done in direction to develop wireless network that works on low power, low data rate, low cost personal area network. Many organization has develop WSNs for smart home, smart farm, smart hospital for patient monitoring, for traffic monitoring in VANET, fire monitoring in smart cities. The importance and application has been increased by the recent delivery of the IEEE 802.15.4 standard and the forthcoming ZigBee standard. The ZigBee Alliance has developed very low-cost, very low-power consumption, wireless communications standard for network and application layer to fulfill the demand of automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later for physical and MAC sub layer. Then the ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology.

ZigBee is expected to provide low cost and low power connectivity for equipment that needs very long battery life as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth. Also ZigBee can be implemented larger networks than is possible with Bluetooth. ZigBee compliant wireless devices are operate in the unlicensed RF worldwide (2.4GHz global, 915MHz Americas or 868 MHz Europe). The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz.

2. WSN

A wireless sensor network is a collection of nodes. Each node consists of processing capability (one or more MCUs or DSP chips), multiple types of memory (program, data and flash memories), a RF transceiver, a power source (batteries), and accommodates various sensors and actuators [11]. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. A WSN is a distributed real-time system. Most past distributed systems research has assumed that the systems are wired, have unlimited power, are not real time, have a fixed set of resources, treat each node in the system as very important and are location independent. In contrast, for wireless sensor networks, the systems are wireless, have scarce power, are real-time, utilize sensors and actuators as interfaces, have dynamically changing sets of resources, aggregate behavior is important and location is critical. Many wireless sensor networks also utilize minimal capacity devices which places a further strain on the ability to use past solutions. Usually these devices are small and inexpensive, so that they can be produced and deployed in large numbers, and so their resources in terms of energy, memory, computational speed and bandwidth are severely constrained. There are different Sensors such as pressure, accelerometer, camera, thermal, microphone, etc. They monitor conditions at different locations, such as temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects, the current characteristics such as speed, direction and size of an object. Normally these Sensor nodes consist there components: sensing, processing and communicating.

Wireless Sensor Networks (WSNs) are traditionally composed of multiple sensor nodes that sense environmental phenomena and generate sensor readings that are delivered, typically, through multi-hop paths, to a specific node (called the sink) for collection [6].

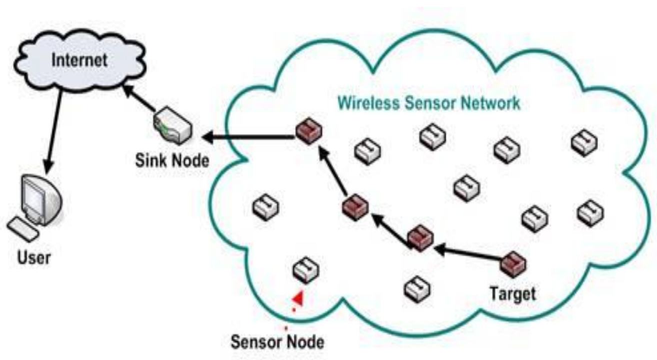

Fig -1: Traditional Wireless Sensor Network [9]

3. SENSOR AND SENSOR NODE

Sensor is a device that receives and responds to a signal or stimulus. It is an element that senses a variation in input energy to produce a variation in another or same form of energy. A sensor (also called detector) is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. For example thermocouple converts temperature to an output voltage which can be read by a voltmeter. For accuracy, most sensors are calibrated against known standards. A sensor is a device which receives and responds to a signal when touched. A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. Sensors that measure very small changes must have very high sensitivities. Sensors need to be designed to have a small effect on what is measured; making the sensor smaller often improves this and may introduce other advantages. Technological progress allows more and more sensors to be manufactured on a microscopic scale as micro sensors using MEMS technology. In most cases, a micro sensor reaches a significantly higher speed and sensitivity compared with macroscopic approaches [10].

The low cost sensors are densely deployed in WSN, which collect environmental data. The environment can be monitored and controlled by the use of sensors and actuators in WSN. Sensor nodes have various energy and computational constraints because of their inexpensive nature and ad-hoc method of deployment [8].

Recently research has been developed at energy efficient routing. The sensor nodes are small and distributed, which are capable of local processing and wireless communication. Each sensor node is capable of only a limited amount of processing. But when coordinated with the information from a large number of other nodes, they have the ability to measure a given physical environment in great detail. Thus, a sensor network can be described as a collection of sensor nodes which co-ordinate to perform some specific action. Unlike traditional networks, sensor networks depend on dense deployment and co-ordination to carry out their tasks. The multiple sensor nodes are required to overcome environmental obstacles like obstructions, line of sight constraints etc. The environment to be monitored has an ad-hoc infrastructure for communication. Another requirement for sensor networks would be distributed processing capability because communication is a major consumer of energy [8].

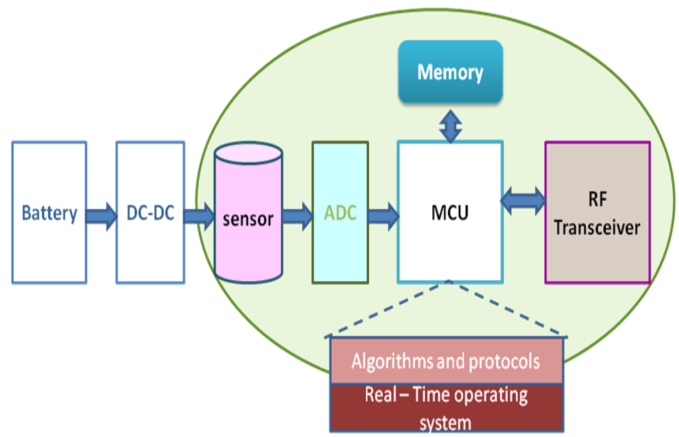

Fig.-2: System architecture of a typical wireless sensor node

A sensor node consists of four sub-systems [8]:

3.1 Computing Subsystem

It consists of a microcontroller unit. This controls the sensor data and executes communication protocols. MCU's are operated under various operating modes of power management, for long battery life purpose.

3.2 Communication Subsystem

It consists of a short range radio frequency transceiver, which is used to communicate with neighboring nodes within cluster and the outside the cluster. The transceiver can operate under the Transmit, Receive, Idle and Sleep modes. Power consumed by the node can be reduced by keeping the node in sleep mode when it is not transmitting or receiving.

3.3 Sensing Subsystem

This subsystem has wireless sensor nodes and actuators that form the WSN. In addition it is having a sink node that connects WSN to internet or another network.

3.4 Power Supply Subsystem

This subsystem consists of battery that supplies power to the node. A battery should be used at rated current capacity is lesser than the minimum energy consumption required for sensor node that leads to the lower battery lifetimes. The battery lifetime can be increased by reducing the current and turning node off when not transmitting and receiving. Also the power consumed by the sensor nodes can be reduced by applying energy efficient routing algorithm for networks.

4. BLOCK DIAGRAM OF WSN

The block diagram of wireless sensor network of the project is as shown figure below. The ultrasonic proximity sensor is connected to SPI of a controller 89v51 through buffer IC74LS125. The ZigBee module-1 (Tarang F4) is also connected to SPI via buffer. They are communicating alternatively via buffer IC. The temperature sensor LM35 is connected to port-1 via ADC-0804. The LCD is connected to port-2 of MCU. ZigBee module-1 is communicating to ZigBee module-2 (Tarang F4) via wireless radio link. The ZigBee module-2 is connected to PC via RS-232 cable. The sensing data is displayed on the LCD then to PC Hyper-terminal.

The ultrasonic proximity sensor is used to measure the distance of any stationary object. The sensor data is captured at serial port of an MCU. This data is stored in MCU memory as well as displayed on LCD. The sensor can measure distance minimum 10cm and maximum 400cm (4m). If distance is less then 10cm the message is displayed on LCD that distance is lesser then min range. The data pin of ultrasonic proximity sensor is connected to RXD pin of MCU through buffer. The data received on RXD pin by the MCU is in ASCII format at data rate of 9600 baud rate. The received data format is XXX.XXcm<CR>, where X is '0' to '9' ASCII character and <CR> is carriage return where the string terminates.

The temperature sensor LM-35 is used to sense the environmental temperature. The Vout pin of LM-35 is connected to Vin pin of ADC for analog to digital conversation. The 8 bit digital output DB0 to DB7 is connected to port1 of MCU. The temperature reading of 8 bit stored inside MCU memory. The LM35 is precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. This will require a voltmeter to sense the temperature. Vout can be measured by voltmeter. The output voltage is converted to temperature by a simple conversion factor. The sensor has a sensitivity of 10mV/ $^{\circ}C$. Hence conversion factor is the reciprocal, and that is 100 $^{\circ}C$/V. The general equation used to convert output voltage to temperature is:

$$\text{Temperature}(^{\circ}C) = \text{Vout} * (100\ ^{\circ}C/V)$$

So if Vout is 1V, then, Temperature = 100 $^{\circ}C$. The output voltage varies linearly with temperature. Temperature reading is also displayed on LCD with the distance reading.

ZigBee module1 is connected to MCU via SPI. The Dout pin of ZigBee module is connected to RXD pin of MCU via buffer IC and Din pin of ZigBee module is connected to TXD pin of MCU. Both the sensor data can be transfer to Zigbee module1 through wired connection. This sensor data is transferred to ZigBee module to via radio link. ZigBee module2 is connected to COM port of PC via RS232 cable. The same sensors reading displayed on the LCD can be displayed on PC in hyper terminal. Here the network formed by both the ZigBee module is unicast network, communication between two nodes only. For unicast network it needs to assign source address and destination address for both of the ZigBee module. The Zigbee module used in this project is Tarang-F4 module, which works on 3.3v to 3.6v operating voltage and ISM 2.4 GHz band of frequency.

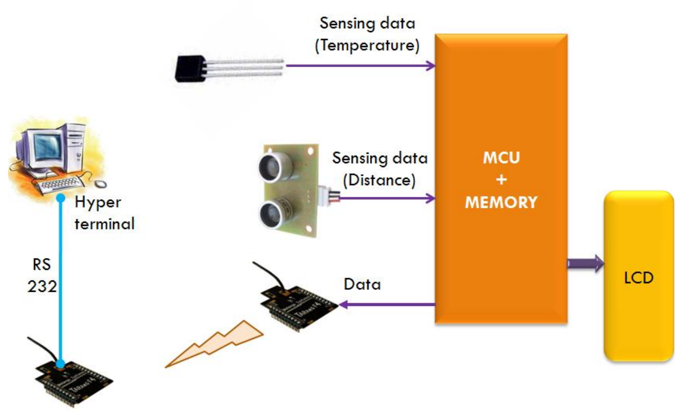

Fig- 3: Block diagram of wireless sensor network

5. ZIGBEE/IEEE STANDARD 802.15.4

ZigBee is a worldwide open standard for wireless radio networks in the monitoring and control fields. The standard was developed by the ZigBee Alliance (an association of international companies) to meet the following principal needs:

- Low cost
- Ultra-low power consumption
- Use of unlicensed radio bands
- Cheap and easy installation
- Flexible and extendable networks
- Integrated intelligence for network set-up and message routing

Some of the above requirements are related - for example, the need for extremely low power consumption is motivated by the use of battery-powered nodes which can be installed cheaply and easily, without any power cabling, in difficult locations.

The IEEE 802.15.4 standard defines the characteristics of the physical and MAC layers for Low-Rate Wireless Personal Area Networks (LR-WPAN). The figure shows a generic LR-WPAN node architecture. The node architecture is defined into a number of structural blocks called layers. Each layer implements a subset of the LR-WPAN standard and offers services to its upper layers and gets services from its lower layers. The layered architecture of each network node comprises Physical (PHY) layer and Medium Access Control (MAC) sublayer. On top of these layers is the Service Specific Convergence Sublayer (SSCS) which interfaces the MAC sublayer to the logical link control sublayer and other upper layers such as the networking layer which provides network configuration, manipulation and message routing,and application layer, which provides intended function of device. The LR-WPANs standards are defined only for the physical layer and medium access control sublayer while other layers' specifications are undefined in the standards [1].

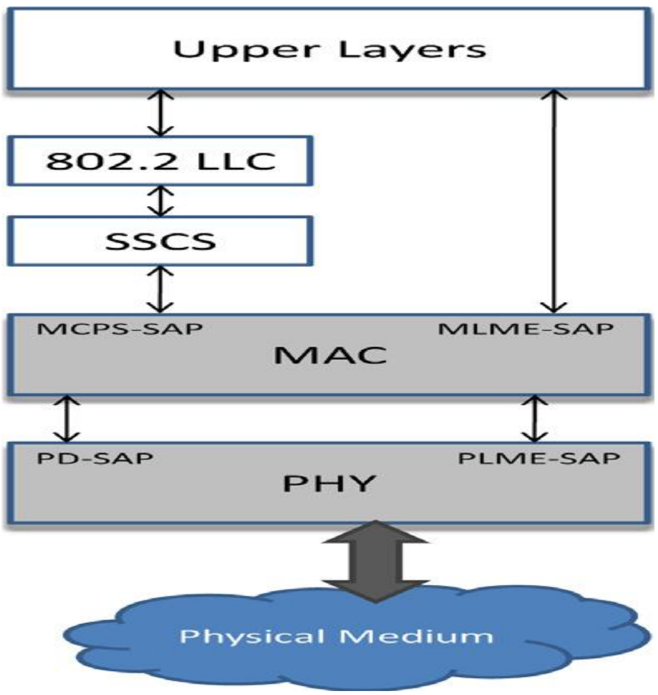

Fig. -4: Node architecture of LR-WPAN device [1, 7]

The physical layer provides two services: the PHY data service and PHY management service interfacing to the Physical Layer Management Entity (PLME). The PHY data service enables the transmission and reception of PHY Protocol Data Units (PPDU) across the physical radio channel.

The physical layer of IEEE 802.15.4 is in charge of the following tasks [5]:

- Activation and deactivation of the radio transceiver
- Energy Detection (ED)
- Link Quality Indication (LQI)
- Clear Channel Assessment (CCA)
- Channel Frequency Selection

The IEEE 802.15.4 offers three operational frequency bands: 2.4 GHz (worldwide), 915(North America) MHz and 868(Europe) MHz. There is a single channel between 868 and 868.6 MHz (20 kbit/s) 10 channels between 902 and 928 MHz (40 kbit/s), and 16 channels between 2.4 and 2.4835 GHz (250 kbit/s). The protocol also allows dynamic channel selection, a channel scan function in search of a beacon, receiver energy detection, link quality indication and channel switching. All of these frequency bands are based on the Direct Sequence Spread Spectrum (DSSS) spreading technique. The 2450 MHz band employs Offset Quadrature Phase Shift Keying (O-QPSK) for modulation while the 868/915 MHz bands rely on Binary Phase Shift Keying (BPSK) [2].

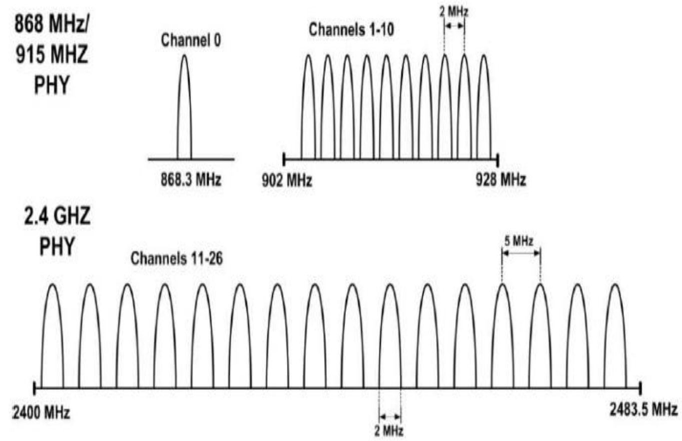

Fig. -5: Frequency band and channel assignment

The MAC sub layer provides two services: the MAC data service and the MAC management service interfacing to the MAC sub layer Management Entity (MLME) Service Access Point (SAP) (MLME-SAP). The MAC data service enables the transmission and reception of MAC Protocol Data Units (MPDU) across the PHY data service. The features of MAC sub layer are beacon management, channel access control through the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) scheme, collision-free time slots management, frame validation, acknowledged frame delivery and node association and disassociation [1]

6. ZIGBEE NETWORK TOPOLOGIES

The message is routed from one network node to another depends on the network topology. A ZigBee network can adopt one of the three topologies: Star, Tree, and Mesh.

6.1 Star Topology

A Star network has a central node, which is linked to all other nodes in the network. All messages travel via the central node.

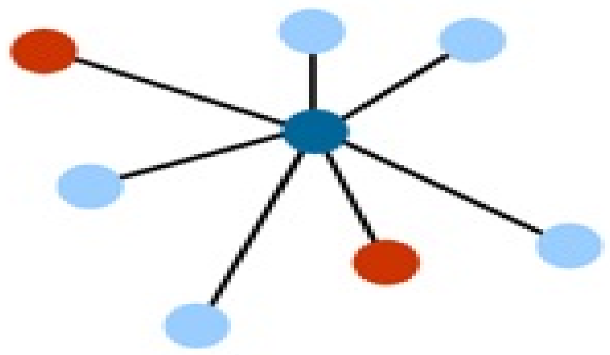

Fig. -6: Star topology [4]

6.2 Tree Topology

A Tree network has a top node with a branch/leaf structure below. To reach its destination, a message travels up the tree (as far as necessary) and then down the tree.

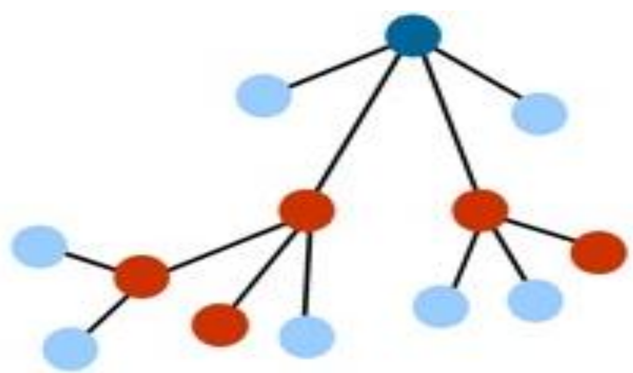

Fig. -7: Tree topology [4]

6.3 Mesh Topology

A Mesh network has a tree-like structure in which some leaves are directly linked. Messages can travel across the tree, when a suitable route is available.

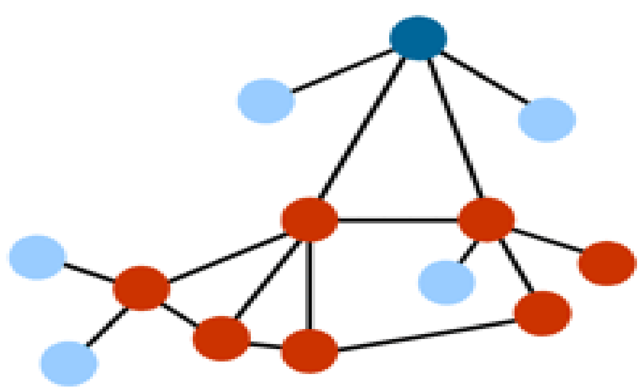

Fig. -8: Mesh topology [4]

CONCLUSIONS

A Wireless sensor network is flexible in nature and has very good features like fault tolerance, High sensing fidelity, low cost etc. which can be very useful to develop exciting applications for remote sensing but the realization of sensor networks needs to satisfy the constraints introduced by factors such as fault tolerance, scalability, cost, hardware, topology change, environment and power consumption. As we know these constraints are highly stringent and specific for sensor networks, some new wireless ad hoc networking techniques are required.

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