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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.

Keywords: zigbee technology, wireless sensor network

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 [5].
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 [10].

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].

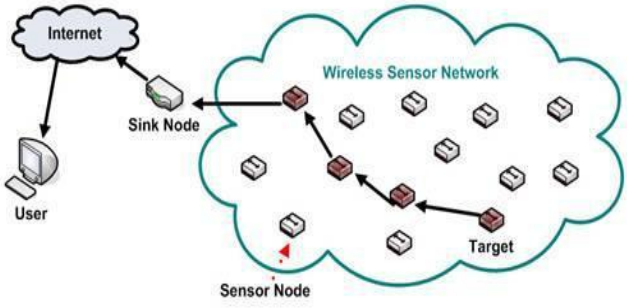

Fig 1: Traditional Wireless Sensor Network [9]

3. Zigbee technology

Zigbee is based on IEEE 802.15.4 Standard with capacity coordinating mutual communication among thousands of tiny sensors is a new wireless communication technology with short length, low complexity, low energy consumption, slow data rate and low-cost. The sensors can send the data from single sensor to another with small energy cost and high-efficiency through the radio waves. Zigbee technology has the lowest energy consumption and price when compared with various existing wireless communication technologies. Zigbee technology is extremely suited for agricultural field which has a small amount of data flows because of the slow data rate and the small range of communication. Zigbee makes it as the best choice for the wireless sensor networks because of the technical characteristics in its technology. Hence, it has the practical significance when applied in the crop environmental monitoring system.

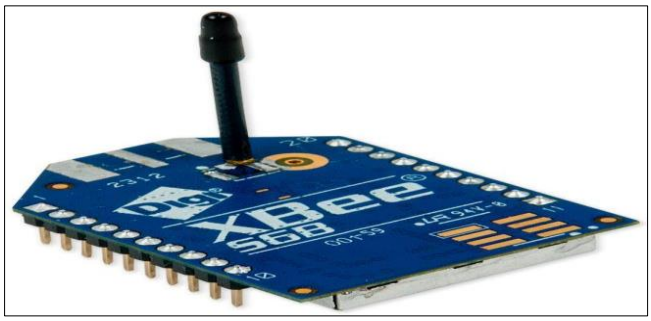

Fig 2: Zigbee

A. Features of Zigbee Technology

1. Zigbee uses a kind of power-saving modes to guarantee that it could be used for 6 months to two years powered by two AA batteries.
2. The avoidance collision mechanism in CSMACA is used by Zigbee and pre-set a prior particular time slot for a fixed bandwidth communications service in order to ward off competition and conflict when sending data. MAC layer adopts a fully confirmed the data transport mechanism, and each packet sent by the recipient must wait for confirmation.
3. Zigbee has self-supported features that one node can sense other ones without any human interventions, and connect with each other automatically to produce a completed network. It also obtains self-recovery function that the network can repair itself when a node is added or deleted, then the place of a node been changed, or a breakdown occurred.
4. It also can adjust the topology structure to guarantee that the system can work normally without any human interventions.
5. Zigbee is a fresh open-standard wireless protocol developed by the Zigbee Alliance (consisting of over 270 companies).
6. Zigbee is particularly targeted at low-power, low-cost and low data rate wireless sensor and control networks, for interoperability, it is easy to make and can hold up to 65,000 nodes depending on the type of topologies used.

B. Architecture of Zigbee Wireless Network

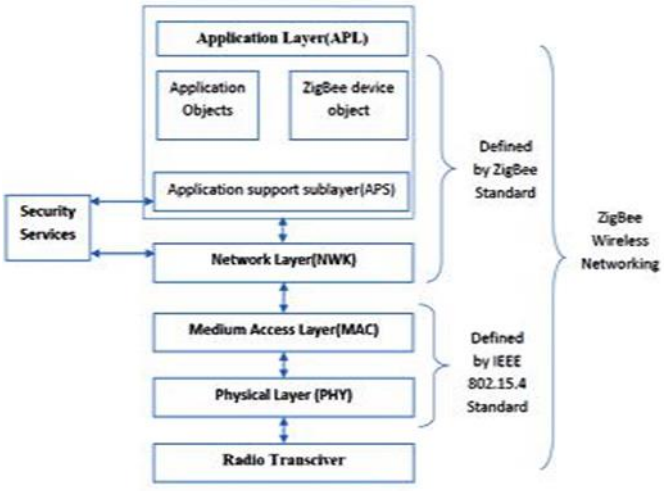

Fig 3: Architecture of Zigbee

4. 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].

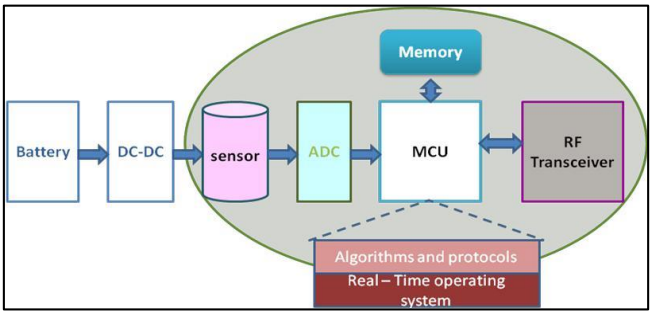

Fig 4: System architecture of a typical wireless sensor node a sensor node consists of four sub-systems [8]:

4.1 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.

4.2 Communication Subsystem
It consists of a short range radio frequency transceiver, which is used to communicate with neighbouring 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.

4.3 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.

4.4 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.

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:

1. Low cost
2. Ultra-low power consumption
3. Use of unlicensed radio bands
4. Cheap and easy installation
5. Flexible and extendable networks
6. 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 [18].

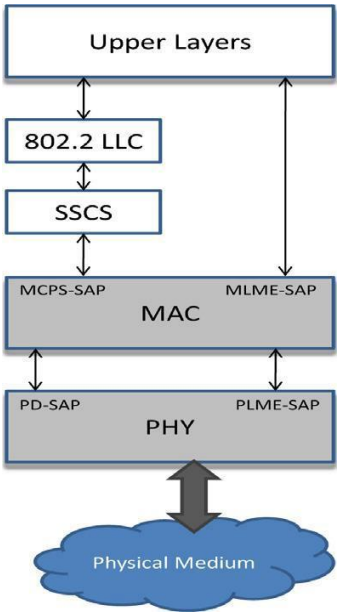

Fig 5: Node architecture of LR-WPAN device [1, 7]

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 [15]:

- 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) [16].

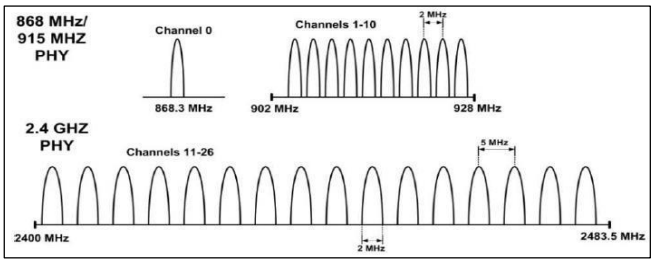

Fig 6: Frequency band and channel assignment

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 [11].

6. Zigbee network topologies

The message is routed from one network node to another depends on the network topology. A Zig Bee 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.

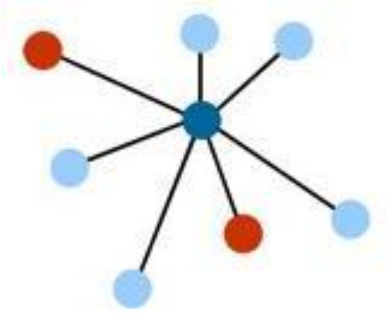

Fig 7: Star topology [4]

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.

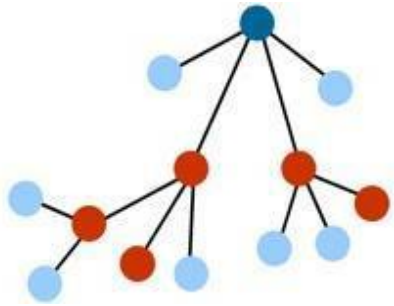

Fig 8: Tree topology [4]

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.

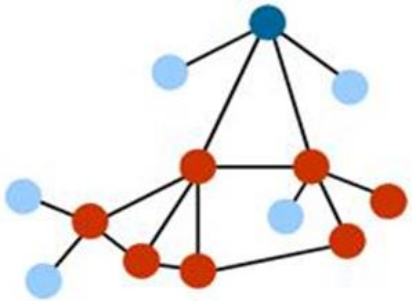

Fig 9: Mesh topology [4]

7. Applications of zigbee

It is of greater use in many areas like

- Lighting & Energy Management
- Smart Home
- Healthcare
- Intelligent Transport
- Manufacturing
- Telecom Services
- Environmental Monitoring and
- Retail Stores

Fig 10: Zigbee Applications

8. Conclusion

In this paper, a Zigbee interface aimed to reset the control system for resetting network devices to their original settings. Zigbee is used in several applications such as monitoring, sensor interconnecting, and automating different systems at manufactories, home, hospitals, and agriculture as a new attractive wireless technology.

9. Future scope of Zigbee

Fig 11

Zigbee has a really promising future in front of it. Research guarantees that Zigbee fuelled by the fast ascent in home networking administration. In the forthcoming years Zigbee would give reforming statistics which would absolutely change the wireless world.

a) Revenue: In next four years Zigbee revenues would increase by astonishing 3400%.
b) Sales: In 2008 Zigbee sales would reach a remarkable figure of 700m$.
c) Zigbee in every home: A minimum of 100-150 Zigbee chips would present in every family within the next two to three years.
d) Cost: Zigbee would cost only $5 for a single chip. But the small storage size of protocol stack Zigbee chip will further lower the price to around $2 per chip.

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