Energy Efficient Communication In Wireless Sensor Network

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Abstract- **Energy efficiency is the most promising approach for addressing the wireless sensor network in communication networks for wireless big data. In wireless sensor network the sensors are powered by battery that drains sooner or later and will have to be taken out and then replaced or recharged. In the existing system nodes have utilized same amount of energy for communication regardless of their distances. To deal with issue the proposed algorithm focused on efficient utilization of an energy based on the node distance. Maintaining the lowest transmission power in wireless sensor network is vulnerable to the interference fluctuations because of the bad signal-to interference-plus-noise-ratio (SINR). The proposed method is to harvest energy from radio frequency. The exact distance between the nodes can be calculated and obtained by RSSI measurement. The parameter of measurement model is determined by anchor nodes, and further corrects the measurement data, which can reduce the measurement error. Each node dynamically adjusts the transmission power and the received signal strength (RSS) target; hence the optimal energy is used for the transmission.**

Keywords: **Wireless Sensor Network, Radio Frequency, Received Signal Strength, Transmit Power Control.**

I.INTRODUCTION

A wireless sensor network (WSN) is a special ad-hoc, multi-hop and self-organizing network that consists of a huge number of nodes deployed in a wide area in order to monitor the phenomena of interest. They can be useful for medical, environmental, scientific and military applications. WSNs mainly consist of sensor nodes or *motes* responsible for sensing a phenomenon and base nodes which are responsible for managing the network and collecting data from remote nodes. However, the design of the sensor network is influenced by many factors including scalability, operation system, fault tolerance, sensor network topology, hardware constraints, transmission media and power consumption.

Currently, wireless sensor networks are beginning to be deployed at an accelerated pace. It is not unreasonable to expect that in 10-15 years that the world will be covered with wireless sensor networks with access to them via the Internet. This can be considered as the Internet becoming a physical network. This new technology is exciting with unlimited potential for numerous application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. Since a wireless sensor network is a distributed real-time system a natural question is how many solutions from distributed and real-time systems can be used in these new systems? Unfortunately, very little prior work can be applied and new solutions are necessary in all areas of the system. The main reason is that the set of assumptions underlying previous work has changed dramatically. Most past distributed systems research has assumed that the systems are wired, have unlimited power, are not real-time, have user interfaces such as screens and mice, 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.

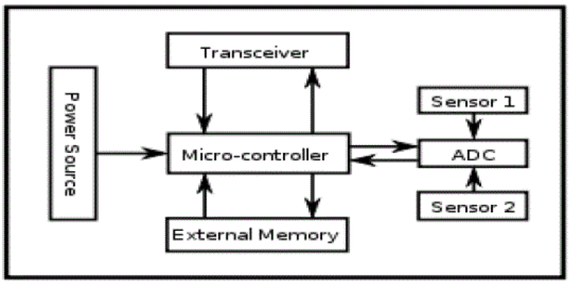

Fig. 1 Structural view of sensor network

Fig. 1. Structure View of Sensor Network

Many wireless sensor networks also utilize minimal capacity devices which places a further strain on the ability to use past solutions.

II. RF BASED WIRELESS CHARGING

RF energy is currently broadcasted from billions of radio transmitters around the world, including mobile telephones, handheld radios, mobile base stations, and television/ radio broadcast stations. The ability to harvest RF energy, from ambient or dedicated sources, enables wireless charging of low-power devices and has resulting benefits to product design, usability, and reliability. Battery-based systems can be trickled charged to eliminate battery replacement or extend the operating life of systems using disposable batteries. Battery-free devices can be designed to operate upon demand or when sufficient charge is accumulated. In both cases, these devices can be free of connectors, cables, and battery access panels, and have freedom of placement and mobility during charging and usage.

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The obvious appeal of harvesting ambient RF energy is that it is essentially “free” energy. The number of radio transmitters, especially for mobile base stations and handsets, continues to increase. ABI Research and iSupply estimate the number of mobile phone subscriptions has recently surpassed 5 billion, and the ITU estimates there are over 1 billion subscriptions for mobile broadband. Mobile phones represent a large source of transmitters from which to harvest RF energy, and will potentially enable users to provide power-on-demand for a variety of close range sensing applications. Also, consider the number of WiFi routers and wireless end devices such as laptops. In some urban environments, it is possible to literally detect hundreds of WiFi access points from a single location. At short range, such as within the same room, it is possible to harvest a tiny amount of energy from a typical WiFi router transmitting at a power level of 50 to 100 mW. For longer-range operation, larger antennas with higher gain are needed for practical harvesting of RF energy from mobile base stations and broadcast radio towers. In 2005, Powercast demonstrated ambient RF energy harvesting at 1.5 miles (~2.4 km) from a small, 5-kW AM radio station.

An important performance aspect of an RF energy harvester is the ability to maintain RF-to-DC conversion efficiency over a wide range of operating conditions, including variations of input power and output load resistance. For example, Powercast’s RF energy-harvesting components do not require additional energy-consuming circuitry for maximum power point tracking (MPPT) as is required with other energy-harvesting technologies. Powercast’s components maintain high RF-to-DC conversion efficiency over a wide operating range that enables scalability across applications and devices. RF energy-harvesting circuits that can accommodate multi-band or wideband frequency ranges, and automatic frequency tuning, will further increase the power output, potentially expand mobility options, and simplify installation.

RF energy can be used to charge or operate a wide range of low-power devices. At close range to a low-power transmitter, this energy can be used to trickle charge a number of devices including GPS or RLTS tracking tags, wearable medical sensors, and consumer electronics such as e-book readers and headsets. At longer range the power can be used for battery-based or battery-free remote sensors for HVAC control and building automation, structural monitoring, and industrial control. Depending on the power requirements and system operation, power can be sent continuously, on a scheduled basis, or on-demand. In large-scale sensors deployments significant labor cost avoidance is possible by eliminating the future maintenance efforts to replace batteries.

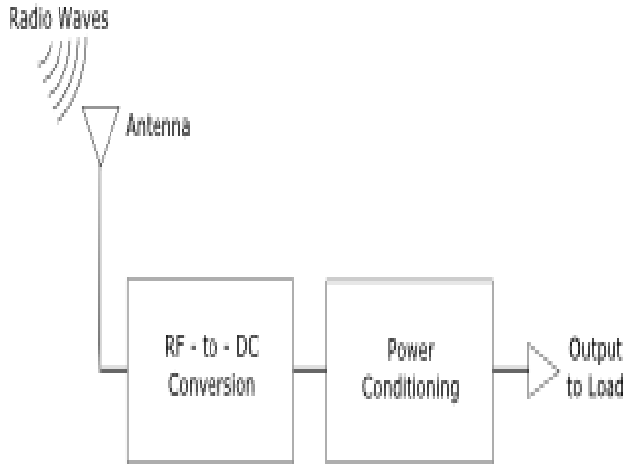

Fig. 2. RF Based Energy Harvesting Structure

Ambient radio waves are universally present over an ever-increasing range of frequencies and power levels, especially in highly populated urban areas. These radio waves represent a unique and widely available source of energy if it can be effectively and efficiently harvested. The growing number of wireless transmitters is naturally resulting in increased RF power density and availability. Dedicated power transmitters further enable engineered and predictable wireless power solutions. With continued decreases in the power consumption of electronic components, increased sensitivity of passive receivers for RF harvesting, and improved performance of low-leakage energy storage devices, the applications for wire-free charging by means of RF-based wireless power and energy harvesting will continue to grow.

III. ZIGBEE PROTOCOL AND ITS ARCHITECTURE

Given the IEEE 802.15.4 specifications on PHY and MAC layer, the ZigBee Alliance defines the network layer and the framework for the application layer. The responsibilities of the ZigBee network layer include: mechanisms to join and leave a network, frame security, routing, path discovery, one-hop neighbors discovery and neighbor information storage. The ZigBee application layer consists of the application support sublayer, the application framework, the ZigBee device objects, and the manufacturer-defined application objects. The responsibilities of the application support sublayer include: maintaining tables for binding (defined as the ability to match two devices together based on their services and their needs) and forwarding messages between bound devices. The responsibilities of the ZigBee device objects include: defining the role of the device within the network (e.g., PAN coordinator or end device), initiating and/or responding to binding requests, establishing secure relationships between network devices, discovering devices in the network, and determining which application services they provide.

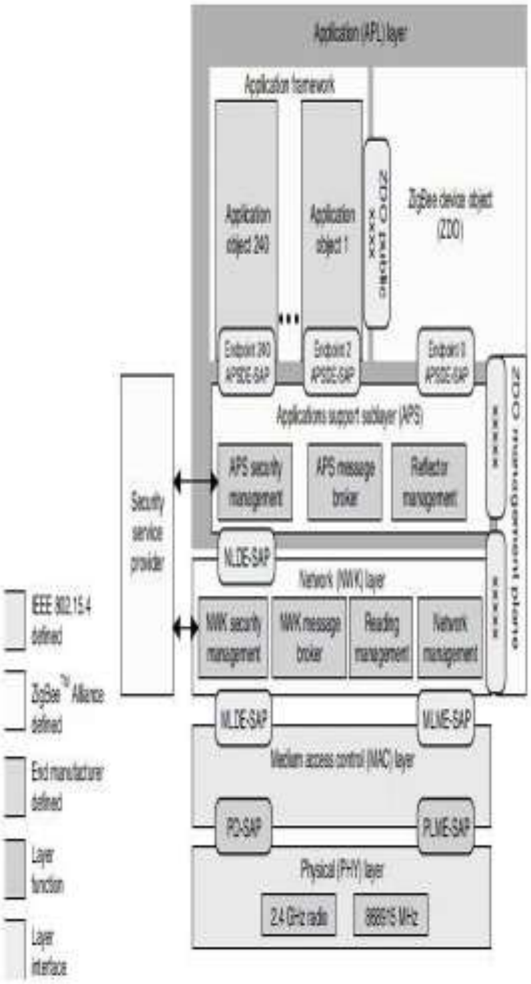

Fig. 3. A detailed overview of ZigBee stack Architecure

ZigBee specifications define a beacon-enabled tree-based topology, as a particular case of the IEEE 802.15.4 peer-to-peer network. This topology consists of one root device which is PAN coordinator (generally the sink of the scenario) and the nodes of the tree. The nodes of the tree are divided into two categories: routers and leaves. Routers must be FFDs; they receive data from children, aggregate them, and transmit the packet obtained to their parents.

The application of ZigBee protocol is mesh topology/networking. In mesh topology, ZigBee network will have a single coordinator device and at least one other device, either router or end device. ZigBee networks always have a single coordinator device for forming the network, handing out the address, securing the network and keeping it healthy. A router is a full-featured ZigBee node. It can join existing networks, send information, and receive information and route information. An end device always needs a router or coordinator to be their parent device.

IV.XBEE

XBee is a brand of radio that supports a variety of communication protocols. XBee is a feature-rich RF module which makes it a very good solution for WSN designers; the implemented protocols on the modules like IEEE 802.15.4 and ZigBee can significantly reduce the work by the programmer for ensuring data communication. Besides the capability of these modules to communicate with Microcontroller through UART serial communication, it also has additional pins which can serve for XBee standalone applications.

Table1: Comparison between wireless devices

Characteristics	Bluetooth	Wireless USB	WiFi
Standard / Reference	IEEE 802.15.1	Certified USB-IF compliance	IEEE 802.11 B-G and others
Distance (max)	100m (class1)	10m (110Mbps)	100m
Data rate (max)	3Mbps	480Mbps (3m)	54Mbps
Connections	Ad hoc, max 8 devices	127 devices (max)	Point-to-hub
Line of sight	No	No	No
Relative power consumption	Medium	Low	High
Typical application	Voice and data applications for consumer electronics and personal computing devices	Data applications for consumer electronics and PC peripherals	Data and voice applications, wireless LAN, broadband internet access
Security	Authentication and encryption	Authentication and encryption	Authentication and encryption (WEP/WPA)
Characteristics	**WiMax**	**ZigBee**	**IrDA Infrared**
Standard / Reference	IEEE 802.16a	IEEE 802.15.4	IrDA specifications
Distance (max)	50km	100m nominal	1m
Data rate (max)	70Mbps	250kbps (2.4Ghz)	16Mbps
Connections	Point-to-hub, mesh	Ad hoc, Peer-to-peer, star	Point-to-point
Line of sight	No	No	Yes
Relative power consumption	High	Very low	Low
Typical application	Wireless metropolitan area network or last mile technology for rural areas	Sensing and controlling applications in home automation	Remote controls, mobile phones
Security	Authentication and encryption	Several measures, 128-bit AES encryption	n/a

For example, a router node can be built without the need for a microcontroller. XBee has digital input/output pins that can be used to read a digital value by a sensor or to control a motor. XBee also has PMW/analog pins; a 10-bit PWM pulse width modulated output may be sent to another XBee. One important feature is line passing where a digital input on one XBee can be reflected on the digital output of another, thus controlling the output of the second XBee.

The experiments will be done based on the ZigBee protocol which is considered one of the most common protocols in personal WSN of low bandwidth, low cost, high level of security and low power consumption. An example of a module which includes ZigBee protocol is CrossBowMicaZ. The inability to customize proprietary communication protocols or develop custom software makes the area of research for additional power consumption reduction narrowed. CrossBowMicaZ provides the ability to customize the communication protocol, but it has some disadvantages relating to the size, range and different hardware for different network functions. The author draws a comparison of the available wireless technologies, mainly in terms of less frequent battery replacement, and then concludes that XBee (ZigBee) modules are the most efficient solution. To analyze the power consumption of two different firmwares (Router and End Node) against three different hardware modules (XBee PRO 60mW, XBee PRO S2B and XBee Series 2) in two modes (Transmitting and Idle).

V. RECEIVED SIGNAL STRENGTH INDICATOR

In telecommunications, received signal strength indicator(RSSI) is a measurement of the power present in a received radio signal. RSSI is usually invisible to a user of a receiving device. However, because signal strength can vary greatly and affect functionality in wireless networking, IEEE 802.11 devices often make the measurement available to users. RSSI is often done in the intermediate frequency (IF) stage before the IF amplifier. In zero-IF systems, it is done in the baseband signal chain, before the baseband amplifier. RSSI output is often a DC analog level. It can also be sampled by an internal ADC and the resulting codes available directly or via peripheral or internal processor bus.

VI.METHODOLGY AND ITS BLOCK DIAGRAM

This is the methodology and its block diagram for energy efficient data transfer in communication networks for wireless big data.

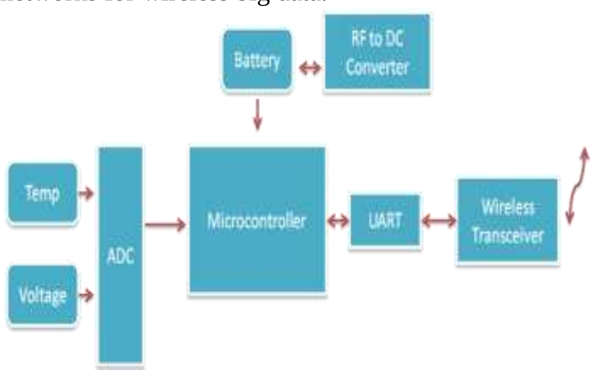

Fig 4: Block Diagram

The wireless temperature sensor node was implemented in this paper based on a PIC microcontroller that Utilizes XBee-Pro S2B to create sensing phenomena. Thus implementing a WSN model in which we study some factors which affect the design of such networks. Although the design of sensor nodes is different for different applications, but the basic structure is similar. The architecture of sensor nodes consists of a processing unit which is responsible for collecting and processing the data sensed by a sensor. A radio transceiver works as the communication unit among sensors and a battery is the power supply unit in this system.In this section, we will study the capabilities of each chosen item in implementing the sensor node. Moreover the constraints and designing issues along with troubleshooting will be discussed as well. Figure shows our embedded wireless sensor node.

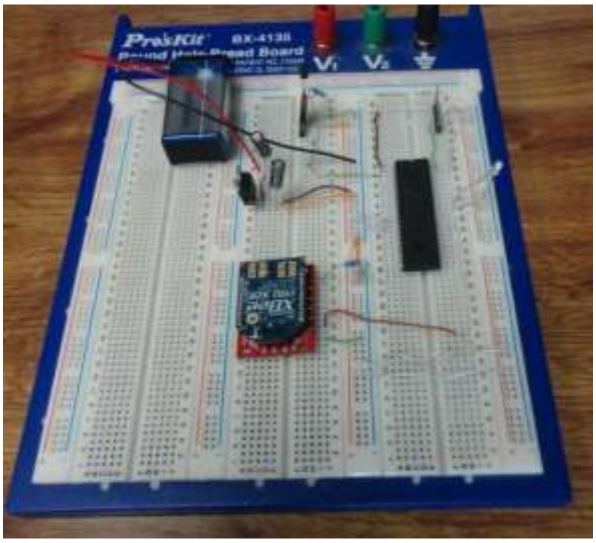

Fig 5:Wireless Temperature Sensor Node

After investigating the available temperature sensors, we found the DS18B20 digital thermometer to be an adequate element in our design. In [39], DS18B20 digital thermometer has an operating temperature range of -55°C to +125°C and resolution from 9 to 12 bits, and the accuracy is ±0.5°C over the range of -10°C to +85°C. DS18B20 communicates over 1-wire bus which means it only requires one data line for communication, this helps the design to have as few port pins as possible for communication. The power supply range is 3.0V to 5.5V with the capability of deriving the power directly from the data line, eliminating the need for an external power supply. For our design, since the XBee module uses 3.3V, we try to select the elements which are compatible with this voltage supply such as DS18B20. Moreover, each DS18B20 has a unique 64-bit serial code which allows multiple DS18B20s to function on the same 1-Wire bus.Since DS18B20 is a 1-Wire bus sensor, the microcontroller has to control the sensor and receive the sensed data on the same line which requires very precise timing. The delays among commands and received data by the microcontroller have to be set very carefully.

In this work PIC18 microcontroller is used due to its popularity, availability and available development tools. The requirements for the microcontroller in this design are: The Xbee module works with a supply voltage of 3.3V, so it is more flexible for the design to have the process unit using the same voltage. Hence, a second regulation circuit is not needed. Power usage should be as low as possible. Two UART interfaces are needed. UART1 to send data to XBee module. UART2 for further development such as serial interface with computer. The software programmed on the microchip is about 5 KB of program memory. After investigating microchip comparison utility, we found that PIC18F46K22 has the capabilities to meet all our requirements. In order to achieve the lowest possible power consumption, we choose the frequency of the oscillator to be 1 MHz. Since the default baud rate of XBee module is 9600, we have to configure the setting of the Microcontroller to function on baud rate 9600 with the frequency 1 MHz. Thus we follow the following setting :Set the value of register BRGH to 1, Set value of register SPBRGH to 0 and SPBRG to 25.The Microcontroller is connected to DS18B20 via pin RA0**,** UART interface is connected to XBee. The Microcontroller sends data through UART to XBee.The PIC is programmed using MPLABX software which utilizes C language using C18 compiler. The program is developed to receive the reading temperature from DS18B20 and send this data through UART to XBee which is configured as an end device to the coordinator.

We use the XBee module configured as an XBee end device in this sensor node. Communication between XBee and Microcontroller is done by UART interface. We connect the DIN Pin3 of XBee to UART2 TX2 of microcontroller, VCC Pin1 to power supply and GND Pin10 to the ground. Since we are using AT mode no register setting is required for the communication with the microcontroller.

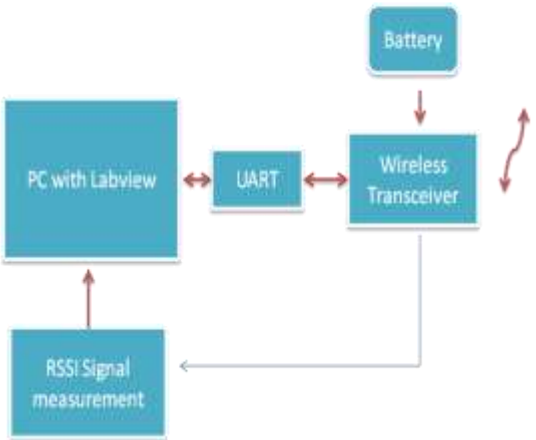

Figure 6: Receiver Side

Figure 7 describes the flowchart of the working procedure of the sensor node. The microcontroller reads the data from the sensor node, and then sends the temperature via XBee end device to XBee coordinator which presents the reading temperature on X-CTU terminal screen.

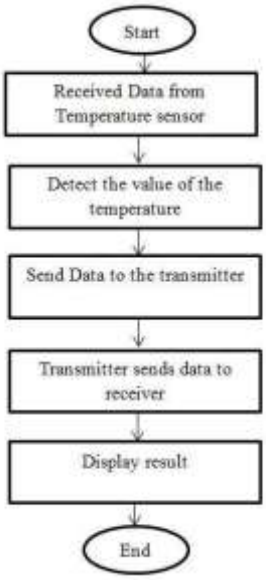

Figure7: Flow chart of the system

VII. TRANSMIT POWER CONTROL

Transmit Power Control (TPC) or sometimes called Dynamic Power Control (DPC) is a mechanism used in radio communications to reduce the power of a radio transmitter to the minimum necessary to maintain the link with a certain quality.TPC is used to avoid interferences into other devices and/or to extend the battery life.

VIII. EXPERIMENTAL RESULT ANALYSIS

According to this measurement, the XBee PRO 60mW among the other modules exhibits the highest power consumption in different modes of operation. In XBee PRO 60mW, the router consumes just 8.5% less power in idle mode than in transmitting mode. With XBee PRO S2B, the router reduces the power consumption in idle mode to 6% while the ratio between the idle and transmitting mode is constant in the case of XBee Series 2. The power consumed by the end device in the idle mode is considered to be a very important parameter in WSN mode. The measurement shows that the XBee S2 uses less than 500uA reducing the consumption in transmitting mode by 95%, while XBee PRO S2B needs 1.1mA in idle mode. XBee PRO 60mW presents the best ratio between transmitting and idle mode since their difference is large.

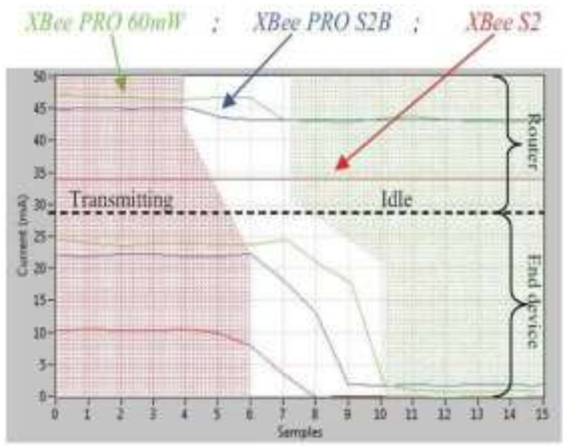

Fig 8:XBee modules power consumption vs various operation modes.

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Table 2: Type of address in ZigBee Network

Type	Example	Unique
64- bit	0013A200403E0750	Yes,onthe earth
16-bit	23F7	Yes, only within network
Node Identifier	Node1	Uniqueness not guaranteed

Fig 9:Node position for coverage range test inside the building

The experiment, we are interested in measuring the RSSI level when the distance changes between two XBee modules. Therefore, we measure the change in the level of RSSI in relation to the change in distance between the XBee modules. This measurement is implemented for the various transmit powers of the remote node and constant transmit power of coordinator.We use a non-line-of-sight (NLOS) setting in the faculty of informatics building by placing the coordinator node in our laboratory in front of the door and the remote node in the corridor outside the room, both of them approximately at a height of 2 meters. We move the remote node gradually to the locations B, C, D, E and G in order to increase the distance by 10m from the coordinator as show in figure 5. In this experiment we don't consider the factors which may affect the strength of the signal such as the Wi-Fi routers and cordless phones.

In outdoor test we measure the RSSI level when the distance varies according to the line-of-sight settings. We setup two nodes; coordinator and remote node in Luzanky Park in Brno. As in the previous section we progressively increase the distance between the two nodes by 20 meters in order to measure the change in RSSI level.In outdoor test, many factors may reduce the coverage range such as altitude of radio antenna, atmospheric conditions, terrain sensitivity, reflection, absorption of signals and interference.

IX. Coverage Range Test

The x-axis represents the distance between the two nodes and the y-axis represents the RSSI value in –dBm.

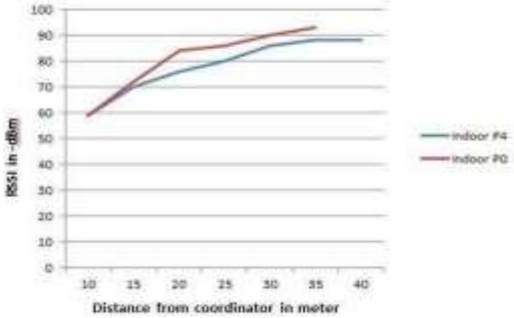

Fig 10:Measurement of RSSI value vs. distance at transmit power level P0 and P4.

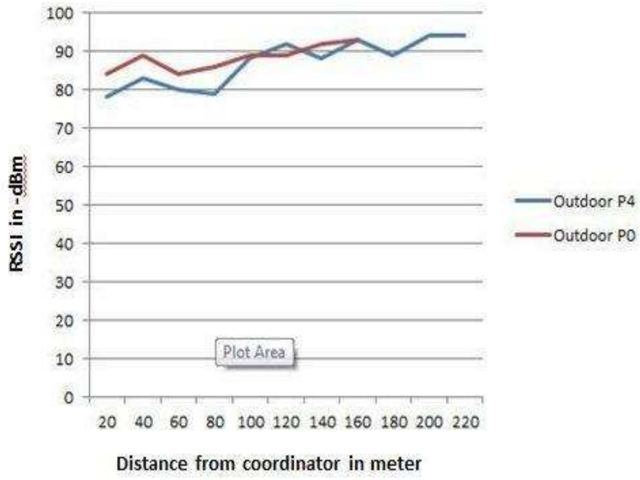

Fig 11:Measurement of RSSI value vs. distance at transmit power level P0 and P4.

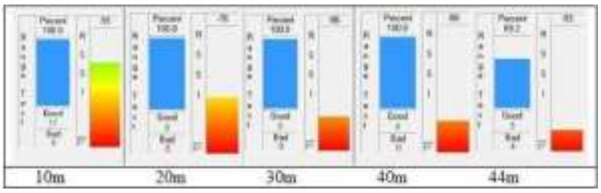

Fig 12:X-CTU screen for indoor Measurement of RSSI value at transmit power level P4.

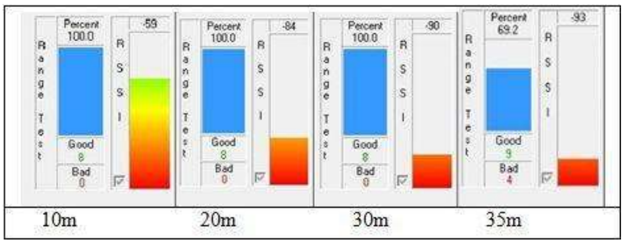

Fig 13:X-CTU screen for indoor Measurement of RSSI value at transmit power level P0

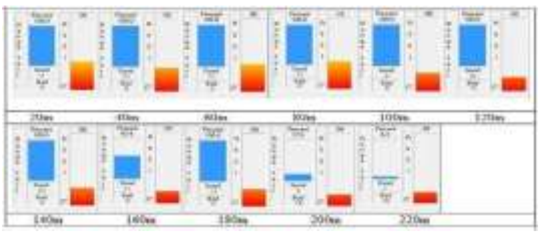

Fig 14:X-CTU screen for outdoor Measurement of RSSI value at transmit power level P4.

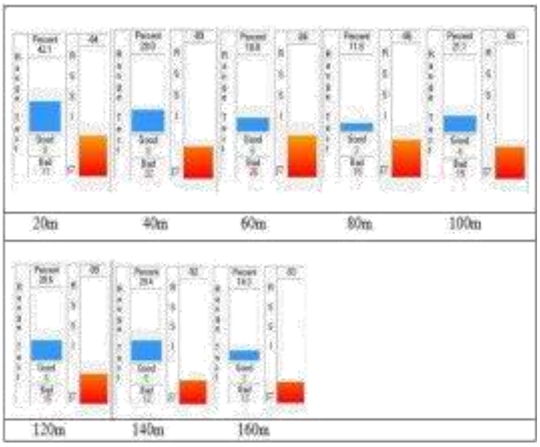

Fig 15:X-CTU screen for outdoor Measurement of RSSI value at transmit power level P0.

Table 3: Power consumption of XBee-Pro S2B in different operational modes at different transmit power levels

Power Level	Router and Coordinator				End Device			
	Transmitting		Listening		Transmitting		Idle	
	mVosc	mA	mVosc	mA	mVosc	mA	mVosc	mA
P4	172	95	92	51	160	88	20	12
P3	168	93	92	51	152	84	20	12
P2	156	91	92	51	148	82	20	12
P1	152	84	92	51	144	80	20	12
P0	148	82	92	51	144	80	20	12

Table 4: Measured coverage range of XBee-Pro S2B

Transmission power level	Indoor Coverage range	Outdoor coverage range
P0	35m	160m
P4	44m	220m

X.CONCLUSION

In this paper, the different architectural aspects and requirements for designing WSNs. The investigated different technologies and protocols of WSNs including a comprehensive study of XBee, ZigBee modules capabilities, an analysis of the power consumption of XBee, ZigBee modules as well as a comparison with other wireless devices.The structure of ZigBee protocol in order to design a multi-hop wireless sensor network including addressing, ZigBee devices operational modes and communication modes. Then, the embedded temperature wireless sensor node using a PIC microcontroller utilizing an XBee-Pro S2B module to create a sensing phenomenon in the network. Using our sensor node along with other development kits and software tools we were able to design a self-organizing WSN. The series of experiments to measure different parameters in our WSN. The measured power consumption in ZigBee protocol devices; coordinator, router and end device during their different operational modes. The estimated power consumption of these devices at different transmit power levels (P4, P3, P2, P1, P0) which are supported by XBee-Pro S2B. The difference in the power consumption of end devices and router/coordinator is large.

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