ZigBee Based Wireless Sensor Network for Fire Alarm Monitoring in Naval Vessels

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Abstract— *Wireless Sensor Networks (WSNs) have been developed recently with the ZigBee protocol for different applications. Few papers have been investigated on utilizing WSN into the maritime environment with ZigBee protocol. Many of maritime vessels are required to ensure the reliable fire protection and continuous data monitoring. This work studies a designing of an automated wireless fire alarm system which can continuously monitor the fire status and temperature values of each compartment. The first experiment was conducted in a missile craft to analyze the feasibility of ZigBee protocol for maritime environment. In the second phase, a prototype wireless fire detector unit was created by connecting reliable low power temperature sensor to a ZigBee enabled mote. Each mote is integrated with a Coordinator unit which can process and display sensor values in real time. A supporting Graphical User Interface was generated using python computing language to monitor sensor values. As per the information collected by the sensors, a warning alarm will be activated and a SMS will be sent to the authorized person immediately.*

Keywords— ZigBee, Wireless Sensor Network (WSN), Fire alarm system, Short Message Service (SMS), Coordinator, Maritime

I. INTRODUCTION

A typical naval ship is consisted with thousand numbers of sensors, miles of bulk copper wires and complex architecture of sensor network [1][3]. A regular monitoring and maintenance are required in order to ensure their proper functioning. Huge man hours are needed daily for the functioning. The power has been a major challenge to the network reliability. These aspects have been the major key points to design a wireless sensor network in order to overcome all the above stated factors. Moreover, a significant cost reduction [1] can be achieved using a WSN instead of a wired sensor network. The WSN has already been coordinated with ZigBee protocol for thermocouples, pressure sensors, vibration sensors etc. However, a fire alarm system which should be more reliable has not yet been designed with WSN. Such a system has outstanding advantages like reliable communication, least maintenance, least labor and cost, flexibility of moving fire detectors which are solidly mounted on decks, easy monitoring and

identification, least power failure due to back up system, functioning though power cables are damaged in a fire etc. Also, the risk of failure in damaged wire system can be overcome with a WSN.

In this project, fire status and temperature values are continuously monitored in real time wirelessly, temperature values are plotted as a graph and fire status is displayed as an indicator on a graphical user interface (GUI) which is implemented on a separate embedded system and an operating system (OS). Automatic fire alarm is activated in the smoke situation and SMS will be sent to an authorized person in the particular ship indicating the fire status.

II. ZIGBEE TECHNOLOGY

The project has been designed with Series 2 family XBee modules. The Series 2 uses a microchip from Ember Networks that enables several different flavors of standards-based ZigBee mesh networking. Mesh networking is the heart of creating robust sensor networks, the systems that can generate immensely rich data sets or support intricate human-scale interactions. XBee Pro operating at higher power and having a more sensitive receiver being the major differences of XBee Pro over XBee have become the reason to select XBee Pro.

III. STRUCTURE AND FUNCTIONS OF SENSOR NODES

Sensor nodes typically known as routers and end modules are consisted with a power circuit, an analog temperature sensor, a smoke or a heat detector. A coordinator module is consisted with an Arduino board, a Raspberry Pi board , a LCD touch screen display, a GSM (Global System for Mobile Communication) module and a power circuit as re[resented by figure 1. Two different circuits have been designed for routers and the coordinator. The power circuits have been designed to be flexible to be used with both 230V AC and 24V DC from the ship's voltage supply. Thereby, a 12V battery is charged in each circuit as a backup source in a power failure.

Therefore, either 24V DC or 230V AC is regulated into 12V DC. In the router, 12V DC is utilized by the smoke or temperature detector and is meanwhile regulated into 5V and 3.3V DC for the analogue temperature sensor and the ZigBee module respectively as shown in figure2.

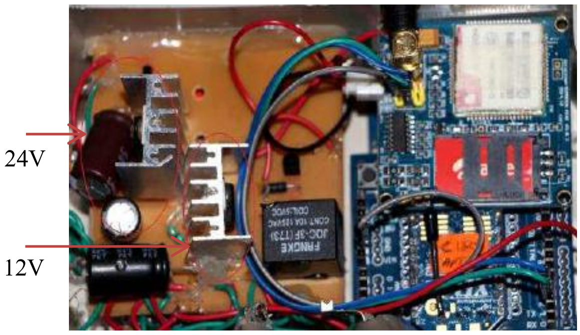

Figure1. Experimental Setup of the Coordinator

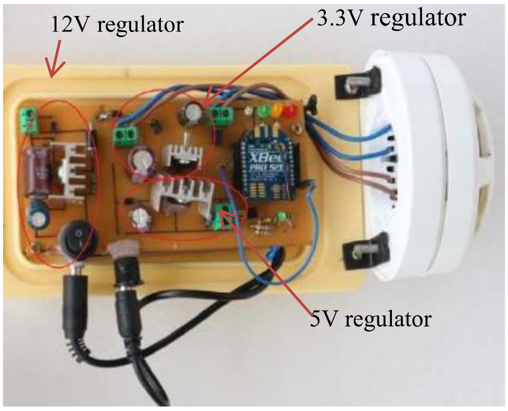

Figure2. Experimental Setup of Router/End device

12V DC in the coordinator module is used for the activation of the fire alarm. 5V is utilized by the Arduino board, Raspberry Pi board and the GSM module. 3.3V DC needed by the ZigBee module in the coordinator is utilized through a ZigBee shield connected to the Arduino board. The experimental setup and the block diagram of the network are shown in figures 3 and 4 respectively.

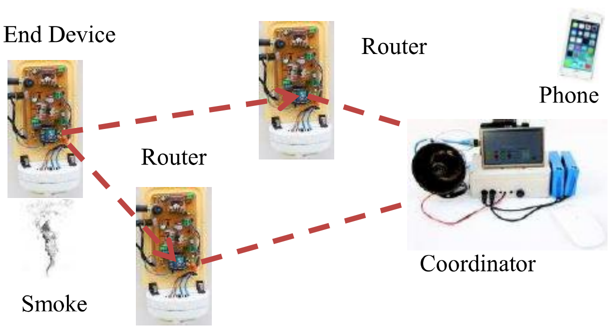

Figure3. Experimental setup of the WSN

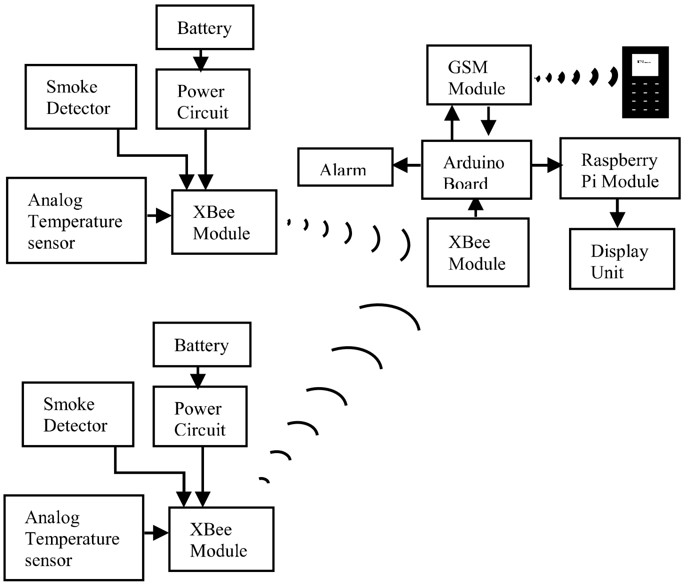

Figure 4. Block Diagram of WSN

A. *The Cordinator*

A ZigBee network always has been involved with a single coordinator device [23]. This radio is responsible for forming the network, handing out addresses and managing the other functions that define the network, secure it and keep it healthy. The coordinator module is connected with the Arduino board where data is classified as per the sensor node and the temperature value is calculated. An array of data is developed and those are sent to the Raspberry Pi board. Fire alarm activation and GSM module function have also been programmed in the Arduino board.

B. *The Router*

A router is a full-featured ZigBee node. It can join existing networks, send information, receive information and route information. Routers are attached with a conventional smoke or heat detector with an analogue temperature sensor (LM35) and signals have been routed to the coordinator. Routing means acting as a messenger for communications between other devices that are too far apart to convey information on their own. Routers are typically plugged into an electrical outlet because they must be turned on all the time. A network may have multiple router radios [23] where three numbers have been used in the project.

C. *The End Device*

There are many situations where the hardware and full-time power of a router are excessive for what a particular radio node needs to do. End devices are essentially stripped-down versions of a router. End devices have been also attached with a conventional smoke or heat detector along with an analogue temperature sensor (LM35) and the signals have been routed to the coordinator directly or through a router. End devices act as messengers between any other devices. Therefore, less expensive hardware is required and end devices can be powered down intermittently in order to save energy by going temporarily into a nonresponsive sleep mode. End devices always need a router or the coordinator to be their parent device. The parent helps end devices to join the network and stores messages for them when they are asleep. ZigBee networks may have any number of end devices. In fact, a network can be composed of one coordinator, multiple end devices and no routers at all [23][24]. But, in the project two numbers of routers and an end device have been used along with a coordinator represented by figure 5.

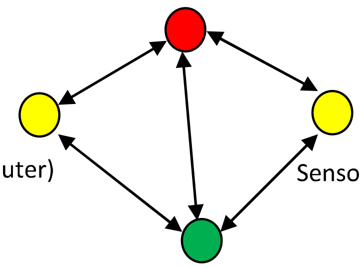

Figure 5. Mesh Network topology

IV. CIRCUIT CONNECTION DIAGRAM

As per the figure 6, the basic wiring diagram of the WSN coordinator module which consists with embedded such as Arduino module, Arduino shield, Xbee module, Raspberry pi module, GSM module, LCD Display unit and Siren system along with relay circuit.

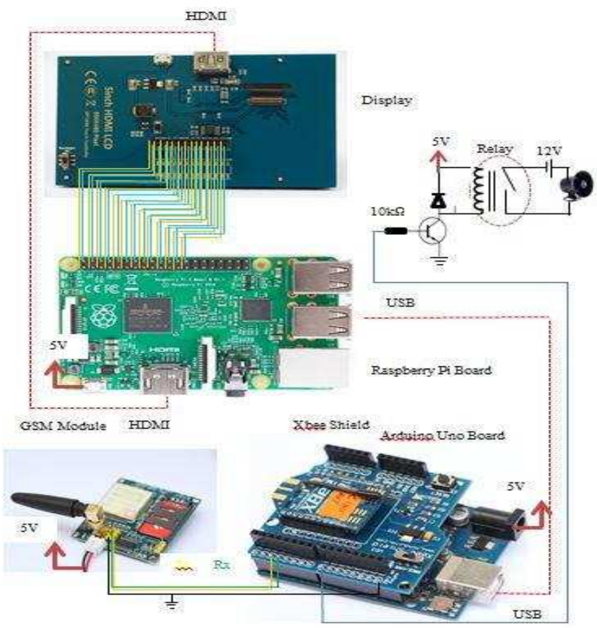

Figure 6: Cordinator Connection Diagram

Xbee module of the coordinator circuit is responsible for the functioning of all the information received and sent according to the Zigbee protocol which is a kind of RF module that performs the data integration function when it is programmed as a coordinator unit. All those programming can be done with pre defined user friendly software such as XCTU [24] ect. All other routers and end devices are addressed to the coordinator module to form a reliable mesh network by interconnecting all sensor motes with each other (either Router or End device).

Received data will be analyzed by the Arduino module which can be programmed with Arduino programming language where data will be categorized as per their addresses. Temperature values are calculated and the data will be passed to the data array and then sent to the Raspberry pi module through serial communication. As per the received digital data from the temperature or smoke sensors, Arduino will send the signal to the relay unit for activation of siren alarm. Simultaneously, a SMS will be sent via GSM module which is connected to the Arduino module. GSM module is required to be powered separate 5Vsupply . Tx, Rx pins and receiving mobile phone contact number should be defined on Arduino program where pre defined library can be used which should be installed prior on raspberry pi module separately.

Raspberry pi module will further process the received data array in order to display on the graphical user interface. All those instructions can be programmed on python platform which is officially introduced to the raspberry pi embedded. Raspberry pi module GPIO pins are connected with the display unit by set of wires and HDMI ports should be connected separately as shown in figure 6. This has to be powered with 5V power supply through micro USB cable. Raspberry pi unit should work on Debian platform and hence Arduino software should be installed on the Debian OS where initial settings has to be done prior to the installation such as Booting the debian , IP address settings, Python installation, Library installation for both Arduino and python. [16][17][18][19][20][21][23]

V. PROCESS OVERVIEW

A. Real Time Data Monitoring

Calculated temperature values and fire status values are printed as an data array as per their sensor addresses as shown in figure 7. They will be sent to the Raspberry Pi interface and processed on python domain to be plotted in real time. Each of the values are displayed in a text box which is updated in real time.

Sensor 1 Fire status	Sensor1 temp. Value	Sensor 2 Fire status	Sensor 2 temp. Value	Sensor 3 Fire status	Sensor3 temp. Value

Figure 7. Data Array of Fire Status and Temperature Values

B. Results on the GUI

Each sensor note output is displayed on the GUI as a numerical value of the temperature. In addition, the fire indication is displayed to the user by conversion of the green coloured label into red with the detection of a fire or smoke. Figure 8 indicates the aforementioned details. The "Display Graph" button leads to the real time temperature graph shown by figure 9. It has been programmed to store twenty sample values which can be modified as per the requirement.

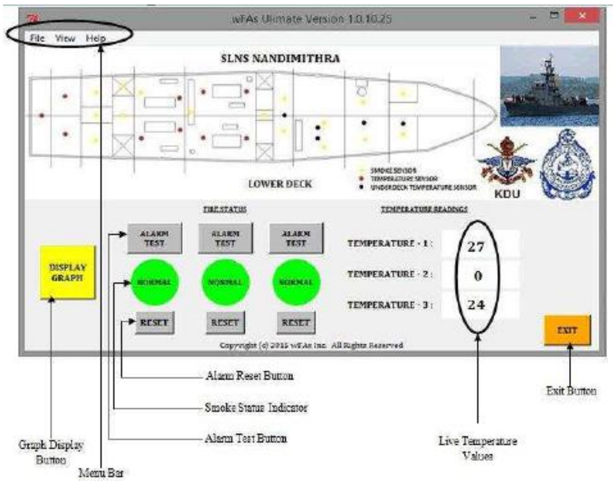

Figure 8. GUI on Windows Platform

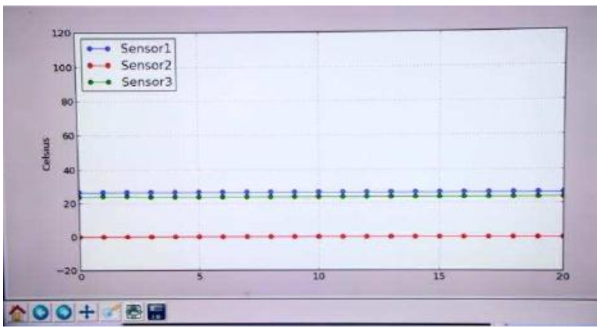

Figure 9. Real Time Temperature Graph

C. Automated Fire Alarm System

The relay circuit will activate the 12V fire alarm if any of above figure fire status becomes true.

D. SMS Alert Function

If any of the above fire status in figure becomes true, SMS will be sent to the authorized person through a GSM module which is connected with the Arduino interface.

V. CONCLUSION

The work has been a final outcome of a designing of an automated wireless fire alarm system which can continuously monitor the fire status and temperature values of each compartment. The WSN has been based on ZigBee protocol. An initial experiment has been conducted in a missile craft to analyse and clarify the feasibility of ZigBee protocol for maritime environment. In the WSN, each mote has been integrated with a coordinator unit which can be processed and displays sensor values in real time. A supporting GUI has been generated to monitor sensor values where Raspberry Pi module is used and python computing language used on Debian platform. Finally, a prototype wireless fire detector unit has been designed by connecting reliable low power temperature sensors to a Zigbee enabled mote. As per the information collected by the sensors, warning alarm has been activated, fire alarm has been indicated in the GUI and SMS has been sent to the authorized person simultaneously.

VI. FUTURE WORK

The work conducted is considered to be an initial feasibility test and a demonstration of a prototype test to show the ability to work on a shipboard setting well. Further, testing is necessary to demonstrate that the system will operate being more reliable over an extended period of time on a shipboard setting. Also hardware development is required to extend battery life to sufficient levels in order to prevent additional workload on ship's force from battery replacement while the ship is in operation. PCB design should be miniaturized as much as possible to increase the efficiency, achieve significant savings in power and cost and also to allow greater flexibility and space utilization. Further software development is required in order to minimize the delay responses.

Rather than the data monitoring, the system can be further developed as a smart fire protection system by isolating fire zones with the tripping of the miniature circuit breakers and activating fire extinguishers in relevant fire zones. System monitoring capabilities can be increased by developing remote login facilities and remote manipulating system over the internet. Raspberry Pi module supports well such applications. Moreover, integrating other sensor modules which are often used in ship environment will reduce the work force, save time and make the operation routine of the ship more flexible.

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