

A Proposed System for Real-Time Early Warning for Building Fire Detection Based on Embedded XBee-PRO RF Modules with Data Accuracy Appropriation

Azmi Shawkat Abdulbaqi , Abd Abraham Mossлах , Reyadh Hazim Mahdi

Abstract--In the recent years, and because of the rapid growth of mobile technology, the Wireless Sensor Networks (WSNs) have become very important topics and as one of the most important research areas with the rapidly impact on technology enhancement. These networks such as Zigbee WSN has become one of the most promising technologies for different applications. In the Zigbee WSN, the individual nodes of these networks operate autonomously. The active application of fire detection in the large buildings, describes the application of these wireless networks to detect smoke or fire early by discovering the parameters of fire or smoke to the main server side to take activate the necessary action in the event. This paper present design of fire remotely monitoring and controlling system using Zigbee WSNs for building environment based on embedded higher power XBee-Pro 802.15.4 RF module with Data Accuracy Appropriation (DAA). The parameters of the building environment include, alcohol, gas, petroleum, and any inflammable materials can be detected using specific sensors and the sensed data are then transferred to the microcontroller. The design of the system depends mainly to initialize the device and receive or send the parameters. This system experimentally proved that can be detected the fire or smoke and early alarm for an event.

Index Terms -- Wireless Sensor Networks, Tracking System, Fire Alert Detection System, XBee Module.

I. INTRODUCTION

The technological development in various modern science has increased in recent years. This development has led to increased interest of people in fire controlling.

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Most of old fire detection technologies used wire technology to activate these technologies. This technology is very expensive and affects the appearance of this technology. To fix this problem, wireless sensor networks that have been created using wireless transmission can be used to transfer data easily (for action) and receive easy-to-data (for reaction). This technology is more flexible to use and avoids the problems of network cabling and the infrastructure and eliminated the wires in many old technologies. Zigbee WSNs technologies are the most technologies are growth witnessed in this century. These technologies have been widely considered as one of the most important technologies in this century [1]. It consist of independent nodes or terminals, which connect with each other by forming a multi-hop radio network which is continuously connected in a decentralized manner. Lately, WSNs play important role to observe hazardous phenomenons include alcohol, gas and fire. One of the most important developments in hazardous phenomenon response technology is multi-sensor with intelligent methods [2].

Zigbee WSNs have been used in many critical applications such as tracking system, remote patient health monitoring system, fire and smoke detection and home automation. Zigbee is appointed for a set of networking and application software layers by using low-power, small and low data rate communication technology. These networks are based on IEEE 802.15.4 standard for personal area networks [3]. In order to effectively Zigbee WSN in building fire detection, these networks, divide into nodal units called clusters, the nodal units deployed on each building's floor, according to the crowded floor, and each nodal unit sends data from current node of the sensor to the head of clusters, in turn, transfers the data to the main station (central server) [3] [4]. In Zigbee WSNs the role of sensors is to add the information from the environment (temperature,

smoke, fire) and process data and perform appropriate actions. Zigbee WSNs of the building are consist of mainly two parts: (1) Nodes well-known information. (2) The head of the cluster nodes.

The greatest threat that facing buildings and homes are inflammable materials and its components. Many methods were implemented to prevent these man-made disasters. Early warning of the fire is the most important issue in building fire detection systems in which Zigbee WSN can provide real time fire detection with high accuracy. This threat causes economic damage as well as endangering people's and animal's lives [4]. The main requirement to control the fire inside large buildings is fire's data. This data must up to the center of the fire-control event of a fire, for the purpose of control fire directly without any damage in the buildings [5].

II. LITERATURE REVIEW

Most of the research work on wireless sensor network is done towards enhancing and increasing the lifetime of sensor networks by proposing new energy efficient ways. Jiang Linyang et.al. [6] proposed a system which aims at complete monitoring of a variety of real-time data and the status of a laboratory, judging the environmental index automatically, and detecting intrusions from outside which accompanied by sound and light alarm. This system achieves the intelligent management of the laboratory. The laboratory monitoring system can communicate with PC, either by wired or wireless means and realize telemetry, meeting the needs of unmanned laboratory. Christian Trodhandl et.al [7] proposed a system in which the data in the target system were gathered with a time triggered sensor network, which transmits the measured values to the local target server. The target server is directly connected by sensor network, which communicates with the visualization and programming tools through the web server. The visualization client provides the live display (parameter) of the observed system. The target server acts as a gateway between the target system and the monitoring clients, which provides security and authentication salient features for connecting the observe clients. One target server is able to serve for multiple target systems. This method makes the system easily adaptable to different embedded target systems. Liu Yang Linying et.al [8] proposed a system, which supplied the software and hardware design solution of an embedded web-based remote laboratory environment monitoring system. This proposed system builds an embedded web server to publish the sensor network data and video images to realize remote observing, which is based on proposed architecture. Administrators can be controlled the

equipment in the laboratory during a web browser which is a cross platform. Embedded database manages the data collected by sensor networks and achieving a local management of the environmental data.

The results show that the designed system perform a secure and appropriate remote observing and local management of the laboratory environment. The system has high permittivity, precision and generalization. Gupta et.al. [9] has proposed a system, where small embedded wireless sensors in a big number of applications such as, Internet-capable smart phones devices, cameras, cars, toys, medical instruments, home appliances and energy counters which produce an enormous volume of small bits of data. The real value of this data has been in its analysis, which leads to considerable Visions and actions that can enhance the veracity of our planet and its people. The author has improved a web-based infrastructure made of sensor network for saving, participate, searching, visualizing and analyzing data from varied devices. The proposed system facilitates are simple interaction between end-users and H/W components of the system through an open, REST-based API. A.K. Singh and Harshit Singh proposed system to detect a fire by using WSN and fuzzy type-2 logic [10]. Fuzzy gives the best result in such cases as the gathered data acts as input data for the system on which Fuzzy logic was implemented to calculate the probability of the forest fire. Yunus Emre Aslan et al. [11] proposed a comprehensive framework for the use of WSN to detect a fire in the forest and monitoring. The framework considers all parts of the life cycle of a WSN system that is specialized for fire detection of the forest. And as a major key to detected forest fire early, the system is constructed which concerns the low energy capacity of sensor nodes and the hard ecological situations which may adversely affect the accuracy of the network and operation.

III. AUTOMATIC RESPONSE SYSTEMS (ARS)

ARS are self-response systems responsible for specific action in a certain time for a specific reason. Any emergency system must be suited for important and essential for the purpose of detecting disasters rapidly and correctly. This requires the availability of real-time data about the disaster in addition to predict to what extent will this disaster [12]. The parameters of fire such as temperature and humidity in the each building or office can be monitored in real time. Fire factors composed mainly oxygen, material and heat. The fire may occur in any form of activities such as short circuit in the electrical wires, petrol, gas stoves and smoking nearby them will cause fire accidents. To

control fire, a system of having an automatic sensor monitoring, fire alarm warning and fire extinguishing are based on Zigbee wireless sensor network technology with XBee Pro Wireless Module [13].

IV. E-SAFETY BEHAVIOR

E-safety is a term for saving people and properties supported by electronic processes and communication. It's utilizing technologies of information and communication in a secure, safe and responsible way. It is interested with the safeguarding of individuals in the digital world and making sure they feel secure when accessing novel technology [17].

V. REAL-TIME DETECTION ALGORITHM BEHAVIOR

It is desirable and applicable algorithm use to detect anomalies in real-time or near real-time. To ensure data integrity and reduce the delay time, the system prefers to connect directly online to detect anomalous objects immediately. This is momentous for the sensors in the Wireless Networks. Those sensors are monitoring hazardous natural phenomena (e.g., toxic gas spread, fume spread), where immediate detection and reaction to these events can be essential for reducing loss of life and money [16] [18].

VI. SENSORS NODES BEHAVIOR

Zigbee WSN consists of many sensor nodes. It's the main units of the network. These nodes can monitor sense and collect information about parameters (temperature, smoke or fire) of different locations and send this information to the Coordinator (Sink Node). These sensors consist of parts below:

1. Processing Module.
2. Sensor Module.
3. WSN Module.
4. Driver Display Module. This part responsible of three parts above.

When the parameter of temperature is occurring and increased, the node sense this parameter and transmits the signal to the engine driver through Zigbee WSN. The Zigbee wireless module is responsible for receiving a reliable signal and transmit signals to the server to get the desired action and turn on water engine to push water during building pipes to control fire. The display module driver observed the three modules and control the fire by using a fire sprinkler system [14] [7].

VII. PROPOSED SYSTEM BACKGROUND

A. System Based on Classification of Data accuracy

Data classification is very important approach in data accuracy appropriation. In the classification model, the set of data are classified into normal or anomalous class, depending on learning. The techniques based-on supervised classification are no need for knowledge, training data and learn the classification model which suitable for the most of the data state during the training phase.

B. A System based on Zigbee WSN

Zigbee its a technology of wireless that developed as an OGS (open global standard) to address the unique needs of low-power wireless M2M networks. The standard of Zigbee is operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed and unaccredited bands including 2.4 GHz, 900 MHz and 868 MHz [14]. The facilities of this technology are low cost, low power, reliable, security-enabled and point to multipoint transmit/receive. The applications of Zigbee are including non-permanent electronics (consumer-electronics), energy management and efficiency, healthcare, home-automation, system of driving, services of telecommunication, building automation and industrial automation [18][15]. Fig. 1 show the above Zigbee protocol description.

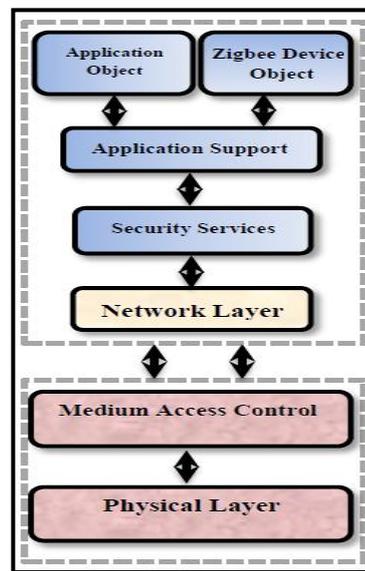


Fig.1 Zigbee Protocol Architecture

There are several reason leads to choose Zigbee networks instead of other networks describe below [19]:

1. Zigbee is the standards based wireless technology designed to address the needs of low-power wireless sensor and low-costs.
2. Zigbee can be used almost anywhere, is easy to implement and needs little power to operate and uses the 2.4 GHz radio frequency to deliver a variety of reliable and easy-to-use standards anywhere in the world.
3. Allows be widely deployed in wireless control, deployment in large areas and monitoring applications.
4. The technology defined by the Zigbee details and specifications means to be simple and low expensive than other WAPNs, such as Bluetooth.
5. With reliable wireless performance Zigbee gives you the freedom and flexibility to do more.
6. Zigbee offers a variety of innovative standards smartly designed to help people be green and save money.

C. A System based on Microcontroller and Sensors

A microcontroller can be considered a self-contained system with a processor, memory, peripherals and can be used as an embedded system. The majority of microcontrollers in use today are embedded in other machinery, such as motorcars, telephones, home appliances, and peripherals for computer systems. Microcontrollers are used in goods and products devices that controlled automatically, such as automobile engine control systems, implantable medical devices, remote controls, office machines, home appliances, power tools, and toys [19].

D. A System based on Back propagation Neural Networks technique

An intelligent system build by using Artificial Neural Networks. This system has ability to identify the received signals that are sent to the server and get the action, i.e. not every signal is sent, only signals that are concerned.

E. A System based on Embedded XBee-PRO 802.15.4 RF modules

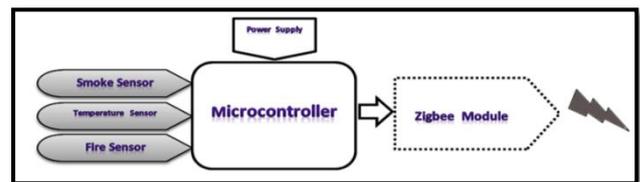
XBee is tiny units that authorize to implement a separate-wireless connection between two real projects (server and client) such as carry out connection between two microcontroller units [16]. XBee-PRO 802.15.4 RF modules are embedded solutions providing wireless end-point connectivity to devices. It's small units that permit to carry out a separate-wireless connection between two actual projects (client and server) such as implement connection connection between two microcontroller units. These modules use the IEEE 802.15.4 networking protocol from point-to-multipoint rapidly

or peer-to-peer networking [16]. This connection technology based on RF (Radio Frequency) that have range 1 km or more. The XBee-PRO designed for applications of high-throughput that required a low latency and expected communication timing. XBee modules are ideal for low-power, low-cost applications and power-amplified versions for extended-range applications. To assurance connection between server and client through the highway, XBee units must be installed along the highway in equal distances during Zigbee protocol [17].

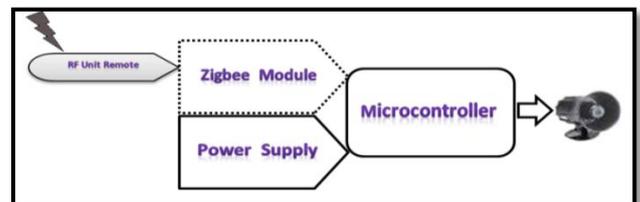
VIII. SYSTEM COMPONENTS

Component of proposed system which is called (Firefighting System) that based on Zigbee WSN with Embedded XBee-PRO RF modules consists of several sensors connected with each other in order to transfer data between distributed nodes in real time. Firefighting System with both Zigbee WSN environment and Embedded XBee-PRO RF modules consist of mainly below hardware units:

1. Central Server (main station)
2. Sensor nodes (nodes of fire sensor detection, smoke sensor detection and temperature sensor detection) equivalent to the Data Acquisition Unit.
3. Router nodes (to connect a set of sensor nodes with each other) equivalent to the data transmission unit.
4. Coordinator, equivalent to the data processing unit
5. RF transceiver (RF transmitter, RF receiver), fig. 2: (a, b)
6. Unit of Battery-Powered responsible of sensors always wake-up



(a)



(b)

Fig.2 Transceiver infrastructure
(a). Transmitter node
(b). Receiver node

The main station (central server) is responsible for incoming data, combining from all detection nodes (sensors) to a central server in order to process these data and achieved reaction depend on the incoming action. The function of sensors equivalent to detectors in Zigbee WSN. Depending of incoming data, these detectors (sensors) determine the type of factor is fire or smoke or temperature. The sensors monitor the factors within buildings and provide external alarms or water sprinkler system or both together when these sensors detect the factor . There are many types of sensors, some of them responsible to detect fire, and another to detect smoke or temperatures. Each sensor network node in Zigbee WSN has the below parts: (1) A Radio Transceiver (RT) with an Internal Antenna (IA) or connection to an External Antenna (EA) (2) A microcontroller (3) An Electronic Circuit for interfacing with the sensors (4) A Source of energy, usually a battery or an embedded form of energy harvesting. RF Transceiver consists of RF Transmitter and RF Receiver and used to modulate and demodulate transmission of RF signals. The RF transmitter carries the RF signal, and the RF receiver receives it. RF transceivers feature an antenna to receive transmitted signals, a tuner and detector to locate desired frequencies. The RF transceiver uses RF modules for high speed data transmission. The function of coordinator (Sink Node) in the system generates and receives lots of radio packets when it remains always active because it connected to the power supply through a central server (main station) to make all operations of the network is active. The coordinator is relaying the control instruction from server to nodes through an RF communication to achieve a full control of switch node port and then controls the switch of the water engine. The power supply unit is responsible for providing each node in Zigbee WSN with the energy to be always active. The function of routers is: (1) Data storage and delivery (2) Discovery the connection with the devices of the

Zigbee WSN (3) Data forwarding, and (4) Maintenance of network link if fail occurred.

IX. PROPOSED SYSTEM IMPLEMENTATION

Fire-fighting System detection is one of the object tracking systems implemented in three essential stages, the required environment protection, Zigbee WSNs with embedded XBee-PRO 802.15.4 RF modules and Artificial Neural Network . The objective of the proposed system is to save people's life inside building, indoor, government property and the focus on detecting and control the fire accidents inside these large buildings. The proposed Zigbee WSNs system consists of a set of autonomous distributed sensors .These sensors that are called nodes are installed along the building's floors that need to be controlled and capable of performing some processing such as monitor data of pressure, smoke, fire and temperature in these floors, pass these gathering data through the connected nodes of the network to the server location. The monitoring center (server location) is responsible for monitoring the operation condition of the system and making decision about events. The system design is mainly used to initialize receive or send the parameters or command of pressure, smoke, fire and temperature to the device. The system starts information processing by data acquisition from the sensor nodes when the sensor acquires data from a specific event (fire, smoke or temperature), monitors the data, analyzes the events, sending data to a central server via a gateway node to gain proper decisions by XBee-PRO 802.15.4 RF modules, and sends alerts to notification system following an alarm. All nodes in the Zigbee WSN are always inactive and become active on demand when sensor nodes senses the data according to the sensing frequency that depends on the type of incoming data. The network has become active when the connection between three mainly parts: Data transmission unit, Router and the Coordinator (Sink Node), Fig. 3.

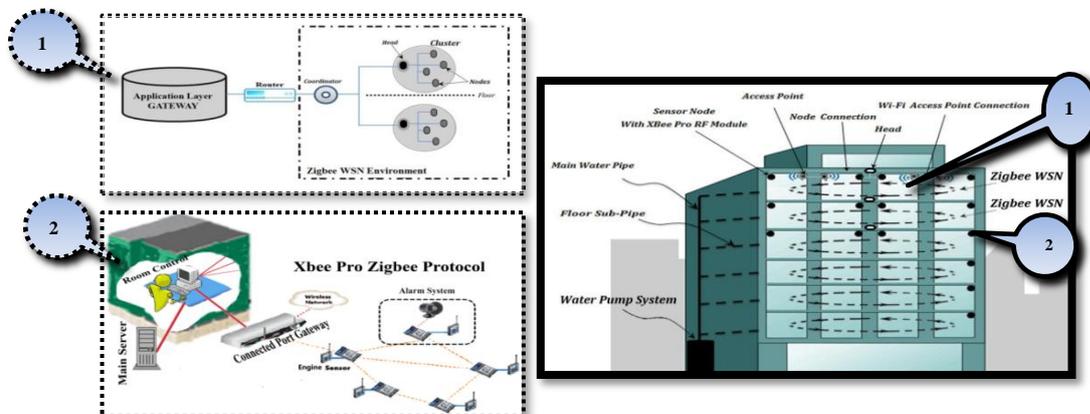


Fig. 3 A complete structure of proposed Fire-Fighting System

In this section, an algorithm description of the proposed system is:

Start;

Input Temperature parameter (TP), Smoke Parameter(SP), Fire Parameter (FP)

Output: Fire Alarm, Fire Sprinkler System(FSS)=ON, Water Engine(WE)=ON

The Procedure

Initialization (TP), (SP), (FP)

(10) Acquisition the input signals (Parameter of TP or SP or FP);

Checking the data from sensing unit to the data processing unit

Convert the input parameter signals (TP or SP or FP) into digital data to Compare with DataBase

Read (TP) and/or (SP) and/or (FP)

If TP=1 or SP=1 or FP=1 (i.e **ACTIVE**) then

(20) Compare the digital input data with DataBase

Apply Back Propagation Neural Network in the Server Station to confirm signals

Transmit Signal to Engine Driver Using Zigbee WSN. WE=ON and FSS=ON

Confirm the Action from the Server Station

While (TP), (SP), (FP) =1 then

Repeat (20)

Else (10)

End

X. RESULTS AND ANALYSIS

Below table (1) show the simulated sensor nodes and data rates, transferring during the training phase and system parameters training by Zigbee WSNs.

Table (1)
Contents of system parameters, training by the system

Parameters (i)	Type of (i)	Data Rates (Kb/s)	Status Monitor	Power Consumption	Max of Detection Range
Smoke Concentrat	Fume	175	Abnormal	Low	10-15 m
O2 Concentrat	Gas	150	Abnormal	Low	10-15 m
Co Concentrat	Gas	600	Abnormal	Low	10-15 m
Humidity Concentrat	Vapor	180	Abnormal	Low	10-15 m
Temperature	Heat	198	Abnormal	Low	10-15 m

Table (2) shows the characteristic of Zigbee WSNs used in the proposed system

WSN Type	Transmission Range	Max number of nodes	Standard	Max Signal Rate	Cost Price	Protocol complexity
Zigbee	10–100 m	65,000	IEEE standard	250 kb/sec	Low Cost	Low

XI. CONCLUSION

The Zigbee WSNs that built in proposed system play an important role in event detection, time controlling and place determining of the fire starting-ending, depending on the wireless sensor network separation within the area of sensors to monitor these events. The structure of Zigbee WSN are minimize the amount of cables that used with traditional fire-fighter methods by using new fire-fighting technologies. The system is efficient to detect fire from the collected information by sensor system and the decisions of fire-fighting depend on the fire factor. After receiving a signal of danger, the system of water sprinkler can be made faster by the relevant system or engine driven.

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