An Improved Real-Time Surveillance System for Home Security System using BeagleBoard SBC, Zigbee and FTP Webserver

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***Abstract*—Real-time surveillance is an important aspect of an intelligent building with modern security demands. The proposed system implements an embedded system for monitoring wireless sensor nodes and camera installed inside a building for security surveillance. A number of surveillance devices in a Zigbee protocol (IEEE 802.15.4) based wireless network are connected to a BeagleBoard Single Board Computer (SBC) based surveillance management system. Remote alerting on fire and intruder detection are the key features of the system. When smoke or intruder movement is detected, the system sends warning messages through Short Message Service (SMS) to cell phones, starts capturing real-time video for fixed duration and makes the alarm on. The captured video clip is immediately uploaded to an FTP (File Transfer Protocol) webserver so that it can be retrieved later from anywhere around the world. The advantages of the system are that it guarantees reliability by integrating various components of a security system (sensors, alarm, camera, wireless connectivity etc.) and utilizes an FTP server for camera feeds.**

***Index Terms*—Security, Surveillance, Zigbee, BeagleBoard, SBC, Webcam, FTP webserver, PIC microcontroller**

I. Introduction

Nowadays, in the area of digital electronics and intelligent systems, building automation has become one of the fastest developing application-based technologies in the world. Automated security surveillance systems play an important role in providing an extra layer of security to the existing surveillance systems. High-speed data transmission and wireless networking are the common facilities available on an intelligent building or smart home. These facilities together with a camera for remote monitoring can be effectively utilized to build an event based real-time wireless security surveillance system to monitor different state information inside a building.

A. Background study and overview

Several prototypes of automated security surveillance systems built on various platforms have been proposed by different research groups all over the world. Recent progress in wireless technologies has led to the renovation in building automation which makes it possible to upgrade the existing building without destroying the original interior decorations.The Zigbee standard for wireless sensor networks gives more opportunities to build wireless monitoring applications that can guarantee low cost, low power, large range and high reliability.

Jun Hou et.al proposed an intelligent home security system based on Zigbee [1] which can monitor the important positions inside a home through a surveillance camera. The home state SMS and image Multimedia Message Service (MMS) can be sent to mobile phones. Zigbee modules are used to connect the system motherboard with temperature and gas sensors, forming a Wireless Sensor Network (WSN). But this system requires an expensive and high end system mother board for controlling and managing the WSN.

Vivek Nainwal et.al proposed a system which explores WSN for remote surveillance [2]. Sensors are used to detect the presence of objects in the surveillance area and the information is collected over time to extract the event of interest. The events are routed back to a surveillance management subsystem and then it is further processed to trigger the second level of analysis by activating the cameras. The information gathered by the surveillance camera i.e. video or still images could be used for further analysis and detection of the intruding object. Finally by referring to the overall collected information in response to an event, a security breach in the area could be declared by triggering an alarm or relaying this information to the concerned authority. But the proposed system uses the traditional sensor alarm method for user notification and does not utilizing advanced alerting techniques like SMS or MMS.

Yanbo Zhao and Zhaohui Ye proposed the hardware implementation of a low cost Global System for Mobile (GSM) based wireless home security system [3]. Programmable System on Chip (PSoC) microcontroller devices and Zigbee wireless transceiver modules are adopted in the sensor nodes. However the proposed system completely relies on sensors for security surveillance and improved surveillance techniques like camera, webserver etc. are not utilized.

K. Balasubramanian and A. Cellatoglu presented the analysis of different remote control techniques employed in home automation and security systems [4]. Essential schemes for remote control and monitoring of home appliances and security systems are proposed.

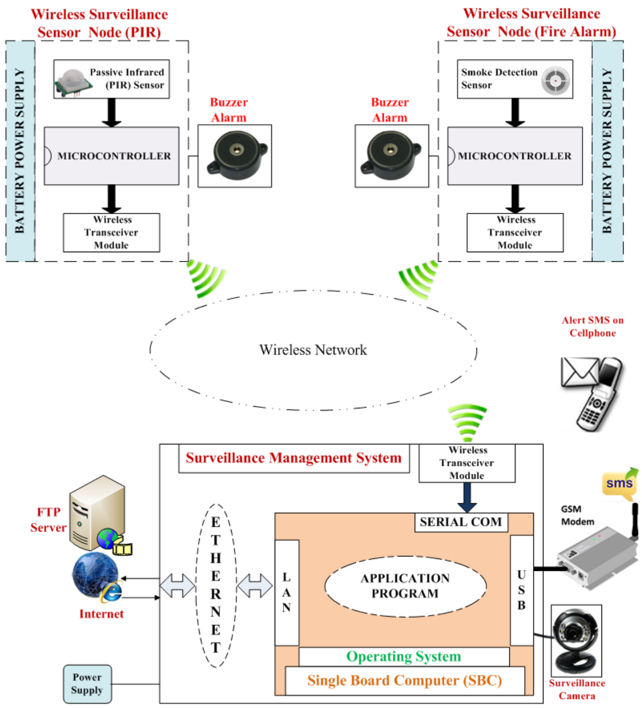

Fig. 1. System architecture

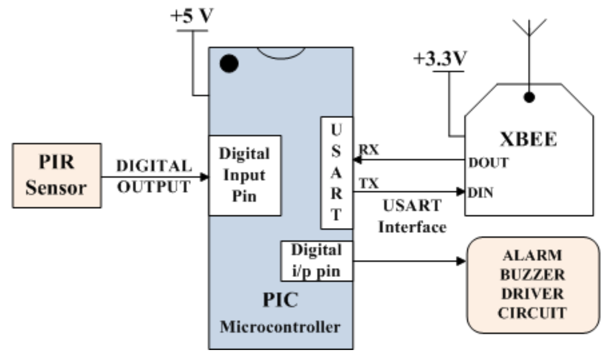

Fig. 2. PIR node

II. Proposed System

The overall architecture of the proposed surveillance system is shown in Fig. 1. The system is built on embedded system which includes two parts.

1) Wireless surveillance sensor nodes
2) A surveillance management system

Modular design is adopted throughout the system by which wireless surveillance sensor nodes can be added and removed from the system without affecting the normal working.

A. Wireless surveillance sensor nodes

A WSN consists of a number of sensor nodes as 'end devices' and a 'master node' as the network coordinator. Each sensor node in a WSN has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing the sensors and activating the alarm and an energy source, usually a battery or an embedded form of energy harvesting.

There are two kinds of sensor nodes in the proposed system. They are

1) Passive infrared (PIR) nodes
2) Fire alarm nodes

PIR node is used to sense the presence of intruders and this node can be placed in the main entrances of rooms and other suitable areas. The fire alarm node is used to detect the presence of fire.

A microcontroller is used in each node to process the sensor outputs. An electronic buzzer is connected to the microcontroller to generate the alarm sounds. Wireless capability can be given to the sensor nodes by interfacing a Zigbee wireless transceiver module to the microcontroller. This assures the wireless transmission of the sensor state information inside the WSN. All the sensor nodes are configured as 'end devices' and a Zigbee protocol based wireless network is the communication medium between them. The node which controls the communication between the other nodes is called the 'network coordinator' or the 'master node'. Here the 'master node' is connected to an SBC based surveillance management system. The sensed data from different nodes are forwarded to the master node.

B. Surveillance management system

The surveillance management system manages SMS alerts, wireless feeds, camera feeds, video file uploading to FTP webserver etc. It is realized on an SBC with an operating system (OS) installed into it. The system consists of a stationary Universal Serial Bus (USB) webcam to capture real-time video clips and wired Local Area Network (LAN) connection for video file uploading to FTP server. Any events happened on the sensor nodes are routed back to the surveillance management system using the Zigbee wireless transceiver connected to the surveillance management system. Upon detecting an event, the system generates alert SMS to selected recipients using a GSM modem. The camera unit will switch to active state when the occurance of an event at the WSN is notified. The real-time video is captured for a fixed duration of time and the video clips are uploaded to an FTP server using an OS application program written in a high level language.

III. Detailed System Design

The whole system design can be broken down in to two sections: wireless surveillance sensor node design and the surveillance management system design.

A. Wireless surveillance sensor node design

The block schematic of the PIR node and fire alarm node are shown in Fig. 2 and Fig. 3 respectively.

The surveillance sensor node consists of a 28-pin PIC microcontroller (PIC16F873A) device for sensor interfacing and an XBEE module as the Zigbee wireless transceiver. The XBEE Series-2 module from Digi [5] is the Zigbee module

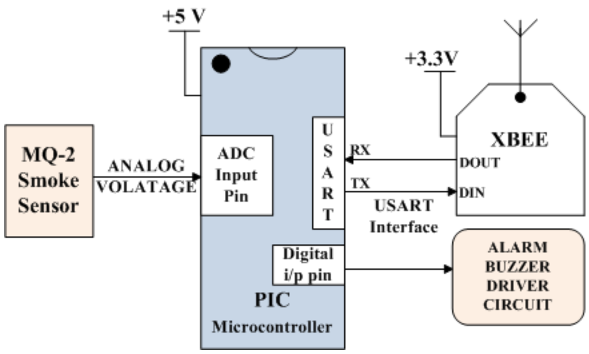

Fig. 3. Fire alarm node

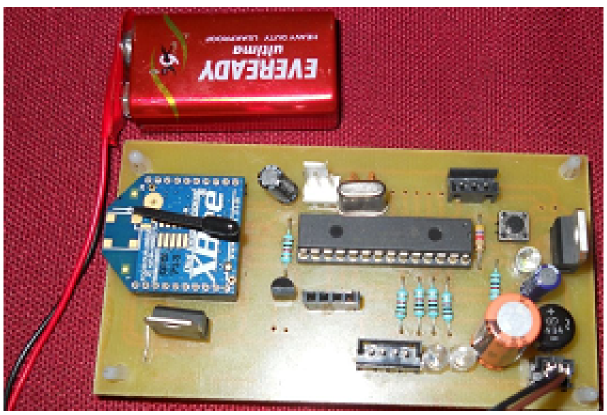

Fig. 4. Wireless surveillance sensor node

selected. The PIC microcontroller works with 5 Volts(V) power supply; and XBEE module with 3.3V. So a separate regulated power supply of 3.3V is generated using a variable voltage regulator IC. The XBEE module can be directly interfaced to the Universal Synchronous Asynchronous Receiver/Transmitter (USART) module of PIC microcontroller. The XBEE modules used at the sensor nodes are configured as a 'Zigbee End-Device'. The electronic buzzer driving circuit is implemented using a BC547 NPN transistor.

The PIR node adopts a PIR sensor for intruder detection. PIR sensors contain a pyroelectric device that responds only to the infrared radiation emitted by a living body whose radiation is strongest at wavelength between 9.4 Micrometers to 10.4 Micrometers. PIR sensor module has digital output [6], so it is directly connected to a digital input pin of PIC microcontroller.

The fire alarm nodes consist of smoke sensors for detecting the presence of fire. MQ-2 smoke sensors are used in the proposed system [7]. MQ-2 has analog voltage output and this analog voltage is connected to an Analog to Digital Converter (ADC) input pin of the PIC microcontroller.

The circuit is designed in a generalized manner so that the same node can be used to connect both PIR sensor and smoke sensor. LED indications are provided for indicating sensor output status, power on status etc. Fig. 4 shows a surveillance sensor node.

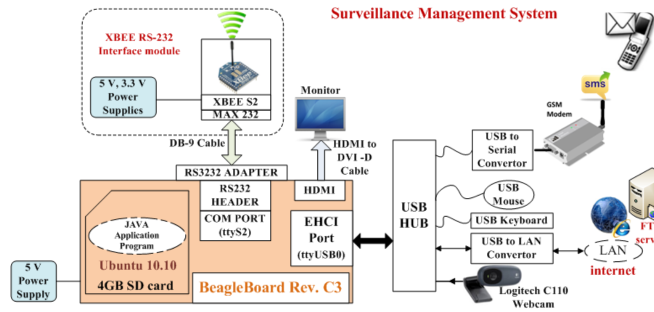

Fig. 5. Surveillance management system

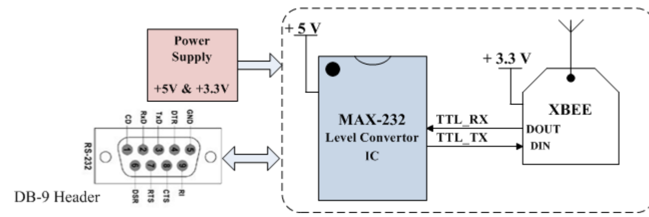

Fig. 6. Block Diagram of XBEE RS-232 interface module

B. Surveillance management system design

The surveillance management system is implemented on BeagleBoard SBC. BeagleBoard is a low-power, low-cost open source hardware, which uses a dual core microprocessor developed by Texas Instruments (TI OMAP-3). The ARM Cortex-A8 CPU of TI OMAP-3 can run open source embedded OS like Ubuntu Linux. High level programming language selected for writing the OS application program for the surveillance management system is Java. The block diagram of the surveillance management system is shown in Fig. 5.

The Ubuntu Linux OS image for BeagleBoard [8] is extracted to an SD card [9]. The BeagleBoard's video output is connected to a monitor. An external USB hub device is connected to the BeagleBoard and to this hub USB devices like keyboard, mouse, and webcam etc. are directly connected. The necessary OS configurations such as login details, LAN settings etc. can be easily done through this set up.

The Zigbee wireless network connectivity must be established on the BeagleBoard to manage the wireless surveillance sensor nodes. The XBEE modules cannot be directly connected to the serial communication port of BeagleBoard as voltage levels are not compatible to each other. The XBEE modules have TTL output and input; but BeagleBoard needs RS-232 interface voltage levels. This issue is solved by designing a XBEE RS-232 interface module which acts as a voltage level converter between the BeagleBoard and the XBEE module. The block schematic of XBEE RS-232 interface module is shown in Fig. 6.

The XBEE RS-232 interface module can be tested by accessing the serial communication port of the BeagleBoard. The wireless data from Zigbee network can be accessed through the serial port of BeagleBoard and the received data can be viewed on the 'minicom' terminal window (a Linux

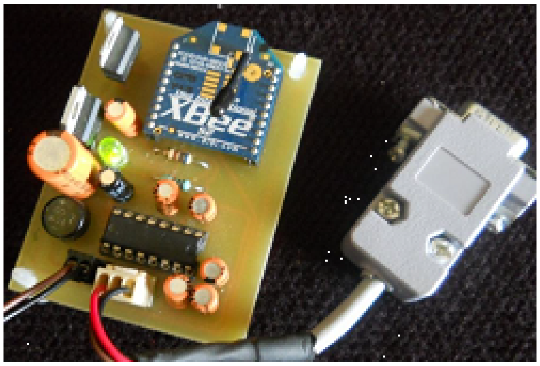

Fig. 7. XBEE RS-232 interface module

serial communication terminal similar to 'hyper terminal' of Windows OS) of Ubuntu Linux OS. Fig. 7. shows the XBEE RS-232 interface module.

IV. System working

The total system working can be divided into three sections.

1) Working of surveillance sensor nodes utilizing a Zigbee based WSN and PIC microcontroller.
2) Working of BeagleBoard based surveillance management system running a Java based application program on Ubuntu Linux OS.
3) FTP web server storing the real-time information from the surveillance management system.

The Zigbee modules used in the surveillance sensor nodes are configured to work as 'Zigbee End-Device'. The network topology used is star topology, with the 'Zigbee Network Coordinator' or 'Master node' resides at the BeagleBoard based surveillance management system.

Each sensor node uses a PIC microcontroller for processing the sensor output and to each PIC either a PIR sensor or a smoke sensor is connected. The embedded C application program for the PIC microcontroller is written in such a way that upon detecting a sensor output, the alarm buzzer starts to make 'beep' sound and the Zigbee module connected to the microcontroller will send a code number to the surveillance management system. This code number indicates the location (typically, the floor number) at which the event has occurred. For example, the PIC used in the PIR node placed at first floor is programmed to send the code number '1' if the PIR sensor connected to PIC detects a human presence. Similarly, the PIC microcontroller in the PIR node at second floor will send the code number of '2'.

A maximum of ten PIR nodes can be added to the WSN in which the PIC microcontroller used in a PIR node is programmed to send the corresponding floor number at which it is being placed. If the surveillance sensor node is a fire alarm node, the sensor used is a smoke sensor. Here the code words allotted to floors are 'A', 'B', 'C' etc. For example if smoke is present at first floor and if it is detected by the sensor, the PIC microcontroller used in that node will send the code word of 'A' via the Zigbee module indicating that smoke has occurred at the first floor. Similarly, code word of 'B' is allotted for second floor and code word of 'C' for third floor and that alphabetic order continues. Here also up to ten fire alarm nodes can be added to the WSN which means that the last code word allotted is 'J'; indicating the tenth floor. This method of assigning a code number to a sensor node has the advantage of a modular design i.e. wireless sensor nodes can be added or removed without affecting the normal working of the entire system. The designer has to program only the sensor node; not the surveillance management system.

The surveillance management system is expected to be placed in the main room of the building, e.g. inside the locker room. This system is built on a BeagleBoard SBC which runs a Java based application program on Ubuntu Linux OS. This Java code manages the inputs/outputs associated with serial and USB port of the BeagleBoard, SMS generation using GSM modem, real-time video capturing using webcam and video clip uploading to FTP server. The following Java classes are added to a main Java program in which each Java class will do a particular task and a main class will manage all the other classes. (A java class can be considered as a working Java program).

1) Beagle Board serial port reading.
2) Alert SMS generation using GSM modem.
3) Video capturing using webcam.
4) Video file renaming using timing information.
5) Video file uploading to the FTP server.
6) Video file deletion.

The Zigbee coordinator module connected to the BeagleBoard can receive the code number sent by the sensor nodes. The Java application program running on BeagleBoard will decode this code and will generate an alert SMS to a user mobile number indicating the floor number at which the event occurred. For example if an intruder presence is detected at first floor the SMS sent to the user mobile will be an alert message indicating that an intruder found on floor no. 1. If smoke is found on floor no. 1; the alert SMS sent to user mobile will indicate presence of fire on floor no. 1.

A USB webcam is connected to the BeagleBoard based surveillance management system and it is in off state normally. Whenever a person enters the room in which the surveillance management system is placed, the webcam starts to capture real-time video of 30 Seconds duration. This video clip is then renamed with the current year, month, date and time and the captured video clip is immediately uploaded to an FTP server namely ftp.technologiesoftomorrow.com. After a successful upload the same file is deleted from the SD card for effective memory utilization. If the uploading is unsuccessful, the file will not be deleted from the SD card. Uploading files to an FTP web server ensures worldwide access to the video clips. Also even if any damage happens to the surveillance management system, the captured video clips are safe.

The FTP server used is 'ftp.technologiesoftomorrow.com' and the web page for this server can be accessed by simply typing the URL, 'ftp://ftp.technologiesoftomorrow.com', on any of the commonly available web browsers.

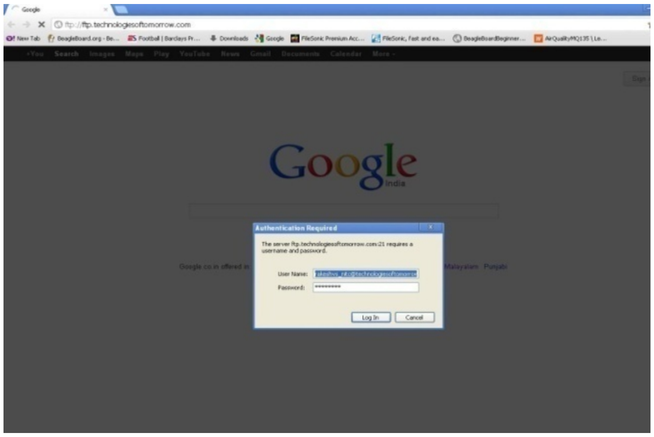

Fig. 8. FTP webserver login page

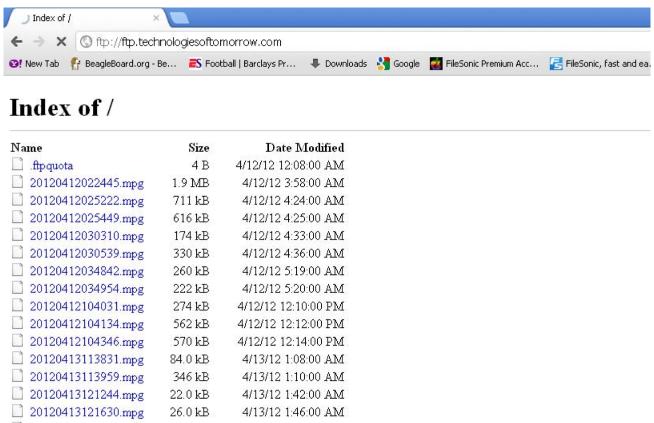

Fig. 9. FTP webpage with video files listed

User login ID and password are provided to access this web page. The uploaded video clips are listed on this page and it can be easily downloaded by simply clicking onto it. Fig. 8 and Fig. 9 show the screen shots of the web page ftp.technologiesoftomorrow.com.

V. Future enhancements

A number of future enhancements can be given to the proposed security surveillance system by making it more energy efficient and scalable. Scalability can be increased by deploying the Zigbee based WSN in the form of clusters rather than catering for a single huge star network topology. Mesh network topology and multi-hoping can be deployed for increasing the range. In order to minimize the energy consumption of the sensor nodes and to increase network lifetime low-voltage microcontrollers can be used in the sensor nodes. There a number of possible extensions to user notification can be done such as user notification through MMS, converting an SMS into email, user alert through landline phone, live-streaming of real-time video etc. Reporting of a faulty node through user notification is also a future enhancement.

VI. Conclusion

The system proposes the design and implementation of an event based security surveillance system for an intelligent building or a smart home. A WSN, a camera and an FTP server are utilized for the better security surveillance inside a building. The traditional system is modified to a new type of smart security system with SMS alerting on intruder detection and fire detection. Zigbee technology used in the WSN achieves a low-cost, low-power wireless communication network. A low-cost, low-power SBC and an open source operating system are effectively utilized to manage the entire security surveillance including a WSN, a GSM module and a camera. The camera connected to a BeagleBoard SBC captures real-time video with the help of a Java application program running on Ubuntu Linux OS. The video clips captured are uploaded to an FTP server namely ftp.technologiesoftomorrow.com and the web page of this FTP server is worldwide accessible. A working model of the proposed security surveillance systems is realized and various features are successfully tested.

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