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Multi-Sensor Wireless Signal Aggregation for Environmental Monitoring System via Multi-bit Data Fusion

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Abstract: This paper uses the ZigBee CC2530 development platform applied to various types of sensors developed for environmental monitoring systems to enhance multi-Sensor wireless signals aggregation via multi-bit decision fusion. ZigBee is a short range wireless transmission standard IEEE 802.15.4-based, formulated by the ZigBee Alliance ZigBee protocol. It is low cost, low power consumption and short-distance transmission at a transmission rate of 250k bps for wireless sensor networks. Its main applications include temperature, humidity and other types of data monitoring, factory automation, home automation, remote monitoring and home device control.

Keywords: Multi-Sensor, Wireless Signal, Environmental Monitoring System, ZigBee, humidity

1. Introduction

Wireless networks have developed very rapidly in recent years. Many related technologies are widely used in the surrounding environment for greater communication and data transfer convenience involving a variety of personal portable digital devices.. Wireless technology has become a hot research topic. The future trend will allow people to use various devices to connect remotely to their home or work environment. Network technology applications will link them closely together to achieve remote wireless monitoring, communication and transmission **[1].**

Wireless sensor networks have already been widely used in the daily life environment. It is applied in many different fields, including health care, digital home, industrial control, environmental monitoring and other fields. The wireless sensor network is a sensor place in the surrounding environment to provide wireless information communication to collect various types of sensor data and information. We use ZigBee CC2503 in this work. ZigBee is characterized by its low power consumption, low price, supports a large number of nodes in sensor applications, such as environmental humidity monitoring, body temperature, blood pressure, heart rate monitoring, bridge vibration detection and structural monitoring **[2].**

This study considers event detection using wireless sensor networks (WSN). As in our previous work **[3][4],** here we focus on the problem of efficient data fusion while reducing the number of bits transmitted in the wireless sensor network. Distributed detection using multiple sensors with various network topologies were considered in **[5] [6]**. Communication requires more power per bit compared to computation and sensing **[7]**. The event of interest could be an intruder crossing the line of control, increase in ambient temperature above some threshold, a camera detecting a burglar in a sensitive area, disaster control applications like detection and prediction of Landslides, Volcanos, Tsunami or Earthquakes. The event detection problem is a binary hypothesis test problem in which the event hypothesis H takes two values {0, 1} indicating event non-occurrence and occurrence. Thus, to improve network lifetime in **[8][9][10]** the observation of each sensor and the communication to its parent was considered to be one bit. In **[11] [12].[13][14]** the authors considered target detection applications in which local sensors had different performance indices, measured in terms of probability of detection (pd) and the probability of false alarm (pf).

2. ZigBee summary

ZigBee is based on the IEEE 802.15.4 protocol network, which is the wireless personal device network standard defined in the IEEE 802.15.4 physical layer section and the media access layer. The ZigBee standard has a higher level such as network application layer and so on. The ZigBee Alliance usually uses IEEE 802.15.4 low data rate. ZigBee communication uses two-way wireless transmission. Its main characteristics are low data rate, low power, low cost, small size, low-rate, short distance transmission using a scalable number of nodes. ZigBee technology is widely used in life.**[15]**

ZigBee can provide transmission rates lower than 1Mbps data transfer. The main advantage is ZigBee is dependent on frequency bands including 2.4GHz, 868MHz, 915MHz and 128-bit encryption technology. When the data transfer has carrier detection ZigBee will exhibit multiple access and sealed packets to avoid collisions between cells resulting in transmission failure. To achieve transmission success, system architecture used in this study is show in Fig.1. It uses a motherboard from the PC connected to receive a variety of ZigBee sensor modules to collect the monitoring data.**[16]**

3. Experimental and simulation platform

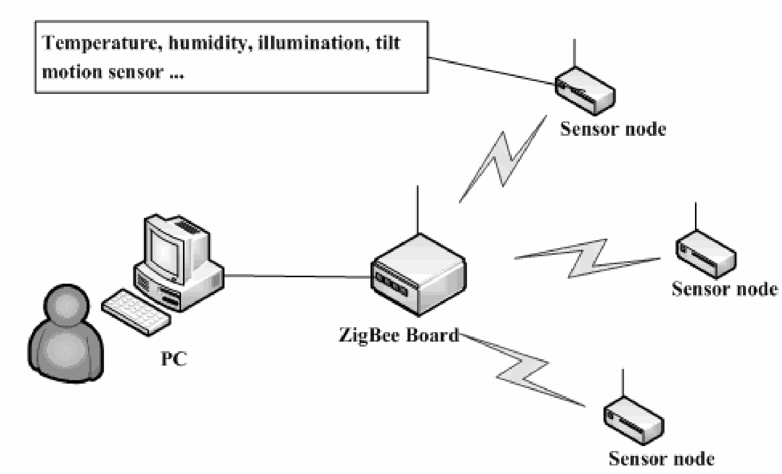


Fig.1. System architecture diagram via using ZigBee

ZigBee CC2530 Module to develop a monitoring system we expect the system flow shown in Fig.2. Computer users make a USB Serial communication interface with the ZigBee board connections, and developing the code to burn in the ZigBee development boards and panels. They both begin with the means of communication to pass the wireless signal transmission, data collection is mainly ZigBee sensor panels connected to the data collection module to the battery board and then transmitted by wireless transmission to the motherboard, motherboard and then receives the final to signal the results back to the USB Serial communication interface to display.

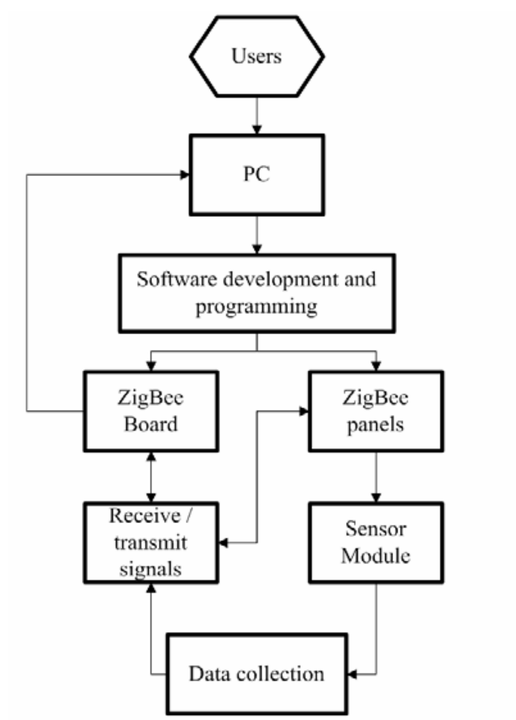


Fig.2. System flowchart

This paper utilized a wireless sensor network technique consisting of multiple devices in particular area such as a factory, house, or even a large area such as a freeway traffic system or battlefield. This technique contains sensor equipment called nodes, used in different amounts depending on the kind of wireless sensor network application. This paper also inserted a variety of sensors in the system terminal to monitor the acquired information. The sensor hardware design consists of three basic parts shown in figure 1. The system flowchart is shown in figure 2.

4. Multi-bit Data Fusion Method for Decision Modeling

This paper focuses on an efficient multi-bit decision fusion approach for a decision modeling. In order to get a better comprehension of this multi-bit approach, this paper indicate an elongation of the multi-bit decision fusion method, requiring one bit transmission for decision modeling. This study considers an equiprobable binary event with hypothesis $I \in \{0,1\}$ in the application area. Let *S* number of sensor nodes be deployed with uniform distribution in the application area where an event may or may not occur. Consider that each sensor B_i is capable of observing one bit of quantized data $O_i \in \{0,1\}$ about the occurrence of event *I* with some known probability of detection pd_i and probability of false alarm pf_i.

Here $pd_i = P(O_i = 1 \mid I = 1)$ and $pf_i = P(O_i = 1 \mid I = 0)$.

The multi-bit decision fusion decision modeling is presented as the optimum fusion approach for star type. Fusion center B_0 makes a one bit decision D_0 about the occurrence of event *I* based on one bit decision OP_received from every sensor node. The multi-bit decision fusion decision modeling is a threshold test for eq-1

$$P_{CV} = \sum_{i=1}^{N}\left[D_i \log\frac{Pd_i}{Pf_i} + (1-D_i)\log\frac{1-Pd_i}{1-Pf_i}\right] \tag{1}$$

The decision D_0 of B_0 can be obtained using.

$$\mathrm{P}_{CV} \underset{D_0=0}{\overset{D_0=1}{\gtrless}} \theta \tag{2}$$

We calculate pd_i and the probability of false alarm pf_i at any node B_i having N_i children $B_1, B_2, \ldots, B_{N_i}$. The probability of detection pd_i and pf_i for the decision D_i can be computed using

$$Pd_i = \sum_{D}\prod_{j=1}^{N_i}(D_j Pd_j + (1-D_j)(1-Pd_j)) \tag{3}$$

And

$$Pf_i = \sum_D \prod_{j=1}^{N} (D_j Pf_j + (1 - D_j)(1 - Pf_j)) \tag{4}$$

In this decision modeling, every node is a fusion center. This paper has two options; fix the threshold for all the nodes or have variable thresholds for different nodes.

(1) Multi-bit decision fusion with Fixed Threshold (multi-bit decision fusion -FT): Here the threshold θ at every node is fixed and can be decided based on the point in the pd_i and pf_i plots curve in which we want to operate.

(2) Multi-bit decision fusion with Variable Threshold (multi-bit decision fusion -VT): Here every sensor node D_i throughout the tree uses a different threshold θ_i. The optimum thresholds $\theta = [\theta_1, ..., \theta_N]$ are those which result in maximum system accuracy. This also has an impact on an overall increase in system accuracy.

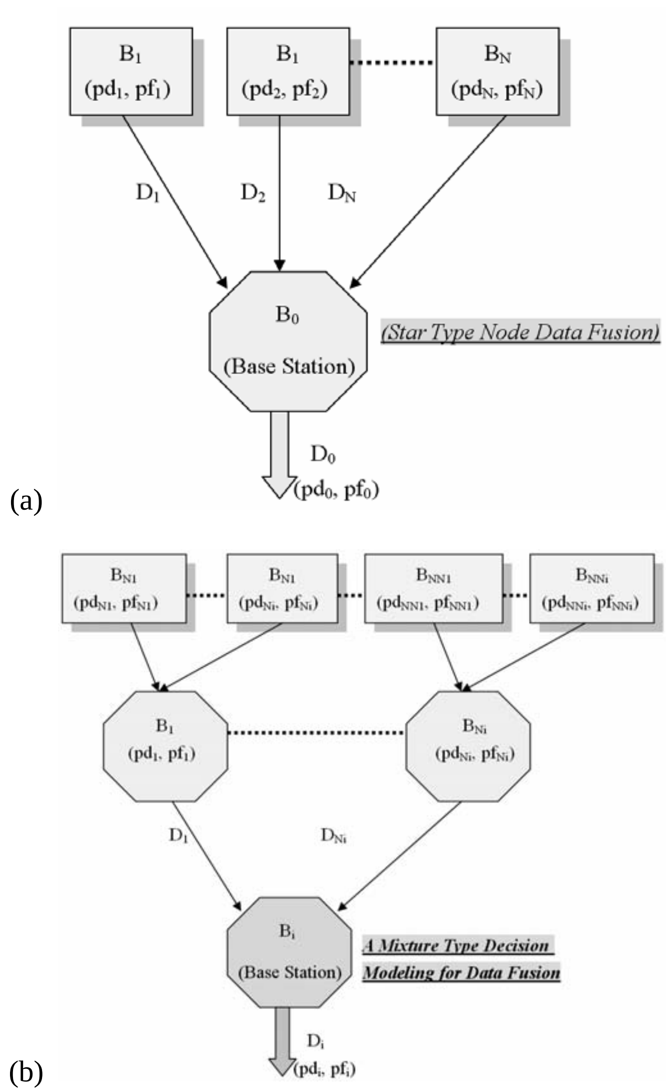


Fig.3. (a) Star Type Node (b) a Mixture Type Decision Modeling

4. The first experimental simulation

Using a ZigBee CC2530 single-chip development board (Fig.4), two ZigBee panels (Fig.5) use three sensor modules MK-M160 LED dimming (Fig.6 (a)), MK-M240 adjusted full-color LED Light (Fig.6 (b)), MK-M180 tilt motion detection (Fig.6(c)).

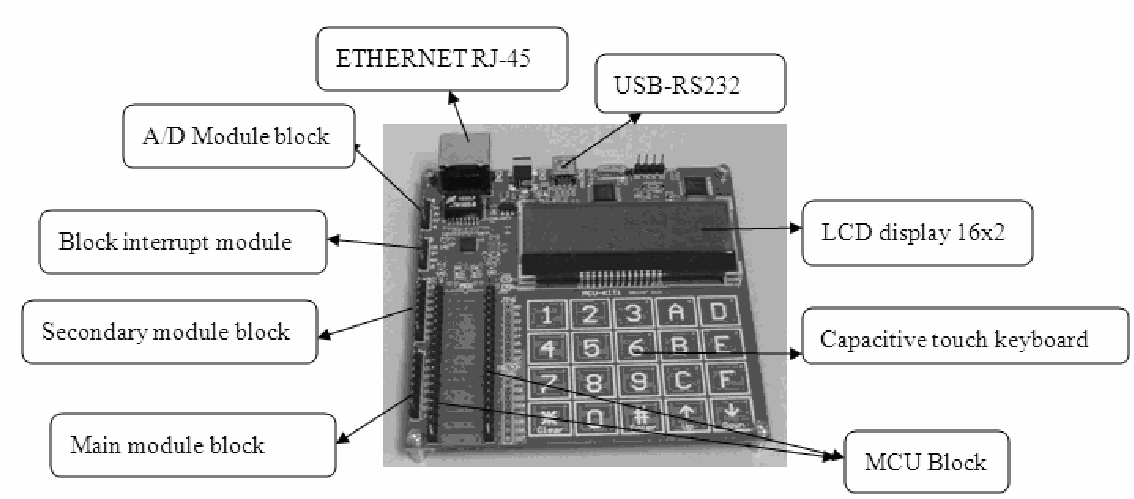


Fig.4. ZigBee CC2530 single-chip development board

Fig.4 development board single-chip ZigBee CC253020 has a communications network ETHERNET RJ45 connector, USB switch to Serial (RS232 Mini-USB) cable connector, capacitive touch keyboard group, LCD display 16x2, 3.3Vvoltage regulator IC, connected to the CC2530 MUC board and debug burner (Fig.8). With the IAR development environment to compile the design program to burn to the development board, draw a line on the A / D module blocks, the interrupt module, primary and secondary modules to achieve the program's design.

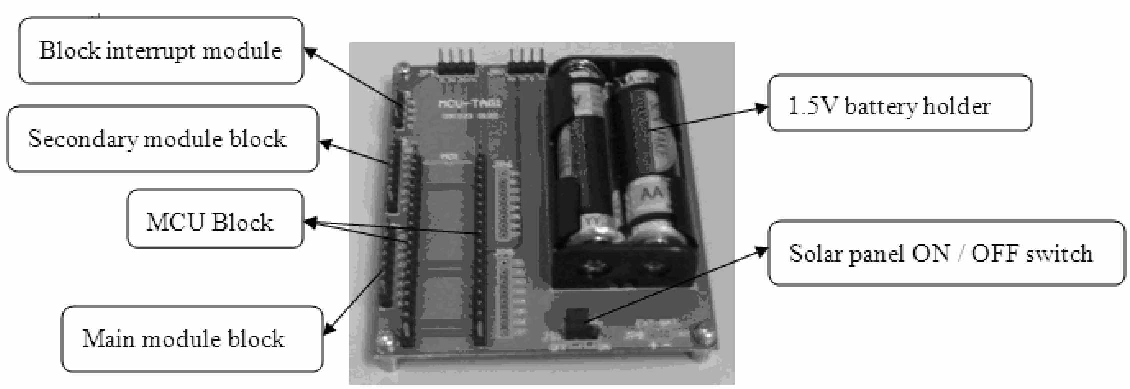


Fig.5. ZigBee panels

Fig.5 panels can be used with ZigBee development board, connect the CC2530 MUC board and debug the code writer to burn ZigBee panels. ZigBee panels draw a line on the A / D module blocks, the interrupt module, primary and secondary modules, solar panels will receive the signal sent to the ZigBee board, board to receive the signal transmitted back to the interface to perform the computer monitor action .

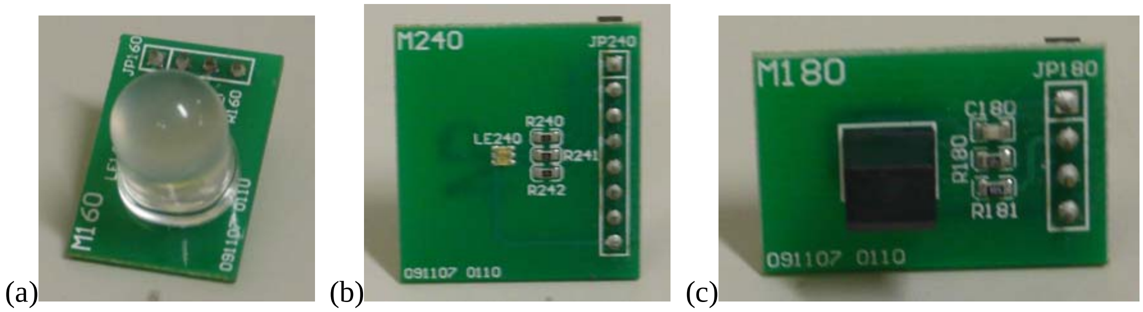


Fig.6. (a) MK-M160 LED dimming (b) MK-M240 full-color LED dimming (c) MK-M180 tilt motion detection

Fig.6 (a) MK-M160 LED dimming the main function module, LED dimming control to adjust the PWM to achieve changes in the brightness of LED lights can also be used as the warning lights application. Fig.6 (b) MK-M240 full-color LED dimming module main function, R / G / B Full Color LED dimming can adjust the color change, namely red, blue, and green, the color can be adjusted to the required applications, Fig.6(c) MK-M180 tilt motion detection module by module mainly hit the ball moves, detect whether there are tilt or vibration sensor, usually used in the tilt or vibration.

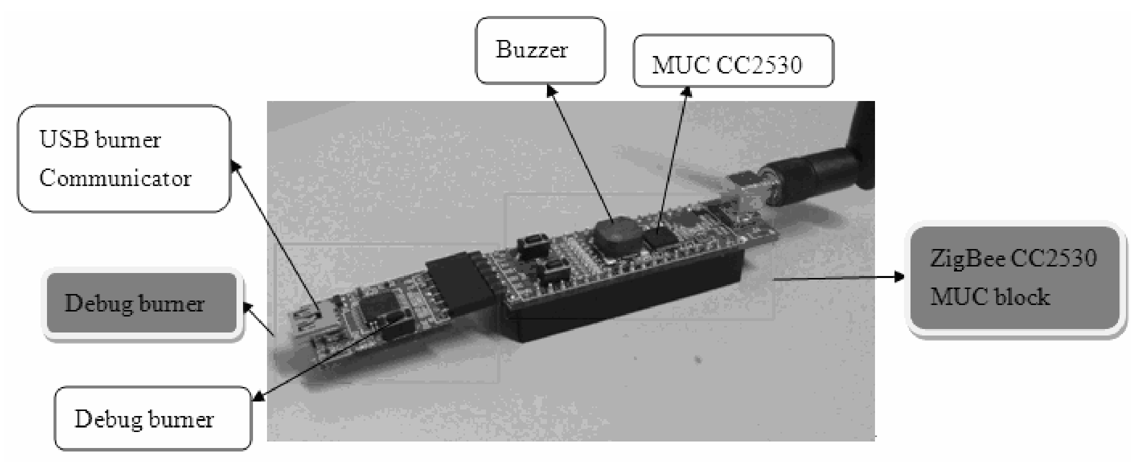


Fig.7. ZigBee CC2530 MUC board, debugging burner

Fig.7 ZigBee CC2530 MUC board, debugging burner, mainly connected to the ZigBee CC2530 MUC board seat, MUC board has MUC CC2530, eight LED, button switch two, a buzzer, debug burner Communication devices on USB burner, a RESET button.

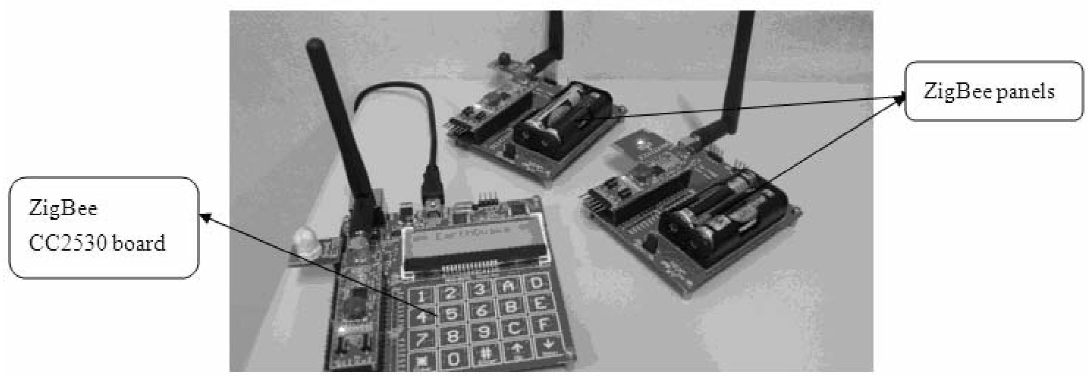


Fig.8. ZigBee CC2530 simulation platform bridge vibration detection

The experimental simulation to develop the ZigBee CC2530 bridge vibration detection and vibration related application. This experiment is based on bridge design vibration monitoring with a computer-interface to improve monitoring ease. CC2530 development board will be collected from the state or the data back to the computer USB Serial communication interface as shown in Fig.8. Motherboard connection with the host computer, the USB Serial communication interface to open the board PORT. You can detect whether abnormal bridge vibration state or no abnormal vibration. The USB Serial communication interface displays the received data "0 ". If the battery panel tilt motion detection module is influenced or interfered by the shock. This time the USB Serial communication interface will display the received data " 1 ", when receiving data " 1 ", CC2530 LED board Dimming module warning lights start immediately, and the LCD display board will display "Warning" to remind, buzzer noises along with the warning lights, LED on the motherboard if the CC2530 dimming bulb does not work, the first The upper two panels will replace light bulbs LED full color LED on the motherboard dimming light bulbs to continue warning.

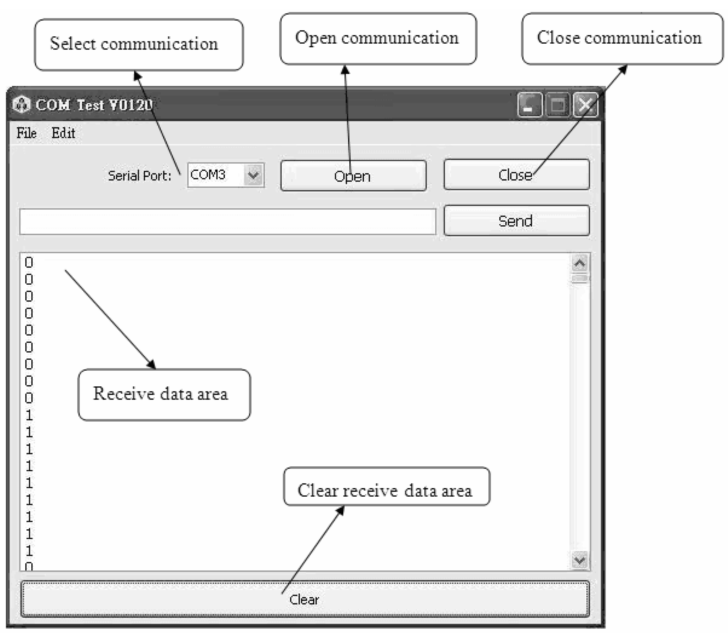
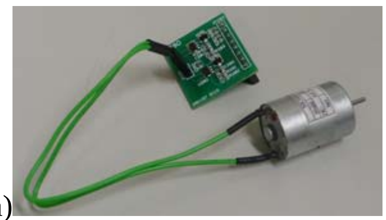


Fig.9. USB Serial communication interface

5. The second experimental simulation

The second experiment simulated a main greenhouse control environment. The environmental control equipment required in addition to the greenhouse ZigBee CC2530 board and outside panels includes a sensor module that uses the MK-M160LED dimming module (Fig.6(a)), MK-M280 motor control module (Fig.10(a)), MK-M170 illumination light detection module (Fig.10(b)), MK –M200 temperature and humidity detection module(Fig.10(c)), the above four groups of sensors can be used to control the green house environment to achieve the goal.

(a) 
(b) 

(c) 

Fig.10. (a)MK-M280 motor control module(b) MK-M170 illumination light detection module(c) MK-M200 module temperature and humidity detection

Fig.10(a) motor control module can be a sprinkler to reduce the indoor temperature or a cooling fan, cooling air bulk temperature in accordance with the environment to determine the fan speed. Fig.10(b) illumination light detection module can determine whether there is ambient light or abnormal illumination. The brightness illumination detection module can sense the degree of illumination brightness. If the illumination is not enough a sensing module send a message to the CC2530 motherboard, motherboard to increase the illumination. These sensors can be used in environments requiring long-term light illumination monitoring, for example, fruit storage or road lighting. Fig.10(c) temperature and humidity detection module sensing the environmental temperature, humidity used in greenhouse.

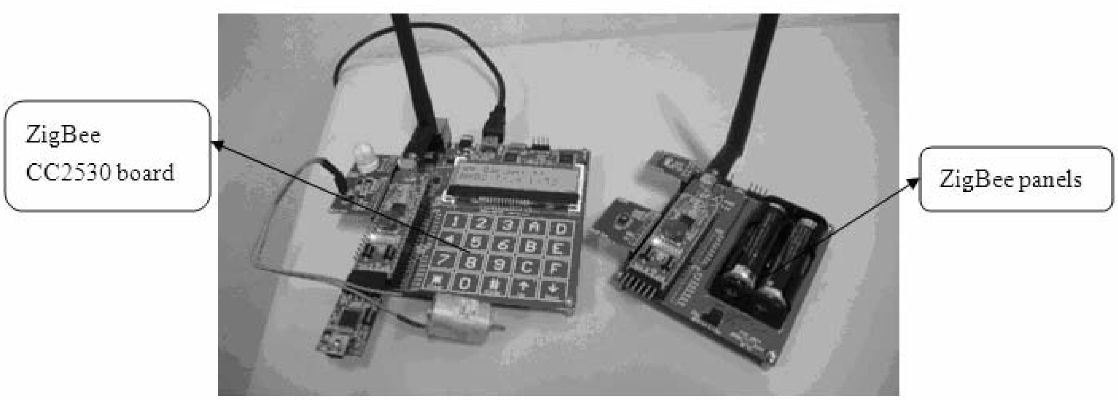
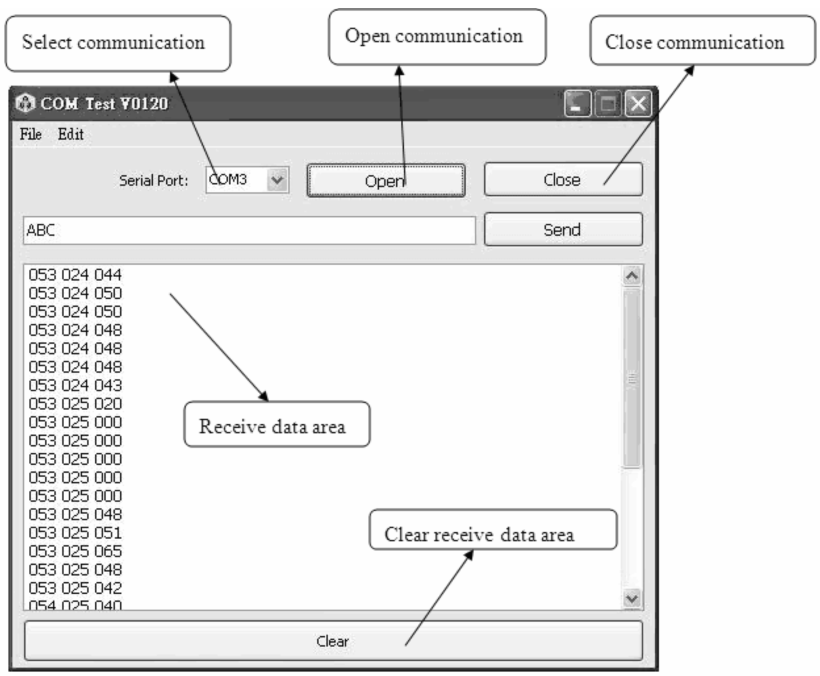


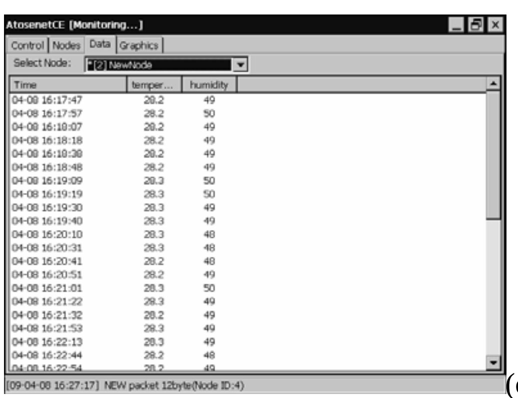
Fig.11. ZigBee CC2530 simulation platform for environmental monitoring of greenhouse

The second experiment used illumination light detection module, temperature and humidity detection module, the motor control module to simulate the greenhouse environment control systems, extensive application of this monitoring system involves flowers, fruits and vegetable environmental control. When the system begins to detect the greenhouse environmental state, if the ambient light illumination is good, the interface (Fig.12) displays it as normal. If the light environment lacks sufficient illumination, the sensor module will increase the ambient light illumination until it returns to normal. The system is connected to a sensor that detects the ambient temperature and humidity module. When the ambient temperature or humidity reaches the maximum value set by the system threshold, the system will start the motor driven fan or sprinklers to cool the environment to the standard range.



(a)

(b)



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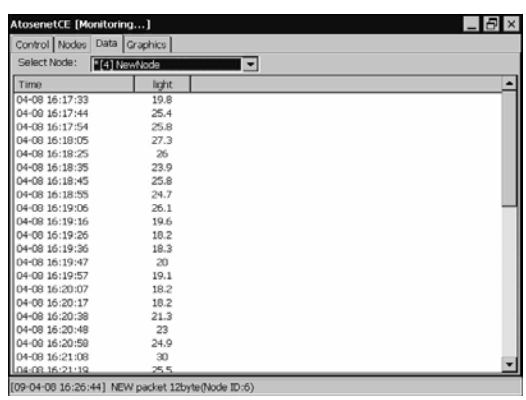


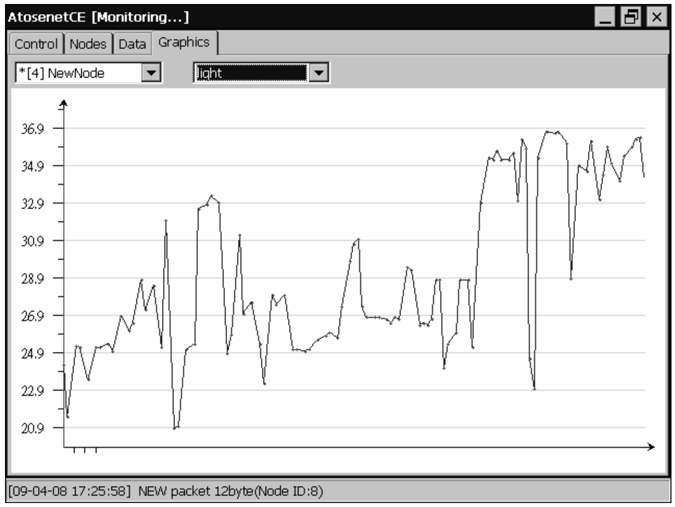
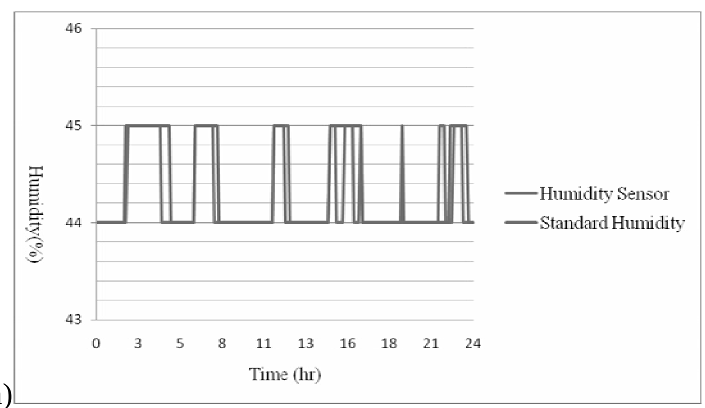
(d) 

Fig. 12. (a) Greenhouse environmental control USB Serial communication interface (b) receiving sensor node signal (c) The temperature and humidity database (d) The illumination database (d) the light sensor node display with waveform. It also displays information from each sensor.

6. Experiment Result Discussions

Finally, the greenhouse environment control data to the chart using sensors to detect the temperature data with standard data (Fig.13(a)), humidity (Fig.13(b)) and illumination (Fig.13(c)) data collection comparison, the environment Condition is set in a normal-like environment, the observed sensor data module with the standard error of the data, humidity and illumination are displayed as a percentage, the temperature is the Celsius temperature display.

(a) 

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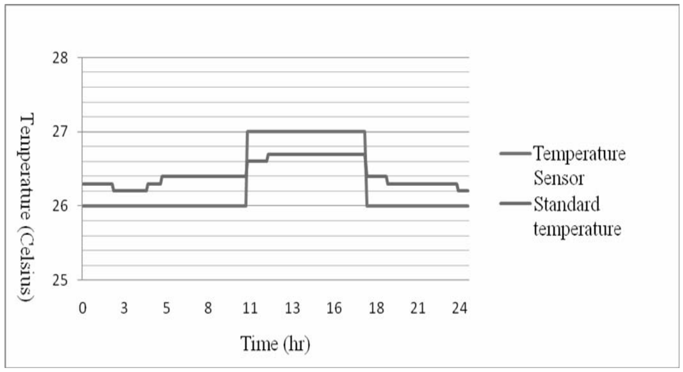

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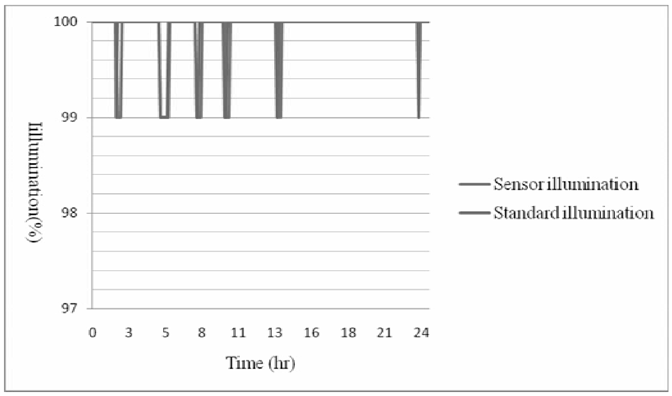

Fig.13.(a) Humidity data comparison (b) Temperature data comparison (c) Illumination data comparison

The fig.13(a)(b)(c) using standard sensors and ZigBee sensors measured the comparison chart, with the standard value in the sense of space both in the same comparison of the measured data error is extremely small, but because of changes in the external environment by Errors. Fig.13 (a) placing the sensor data is measured from the same space. Fig.13 (b) standard in the measurement of temperature data beat minor, so the temperature sensor data is rounded results. Fig.13(c) day of illumination is required under continuous lighting conditions.

In figure 14, when the estimated time approached 300hr above the actual value, the measurement value tended to match. The experiment compared the multi-bit decision fusion based; standard measurement and general data fusion methods based on parallel data fusion methods. The standard measurement based cited the literature from our pervious researches in the **[17]** reference list. According to the training error curves, the multi-bit decision fusion based method was better than the other methods in training process.

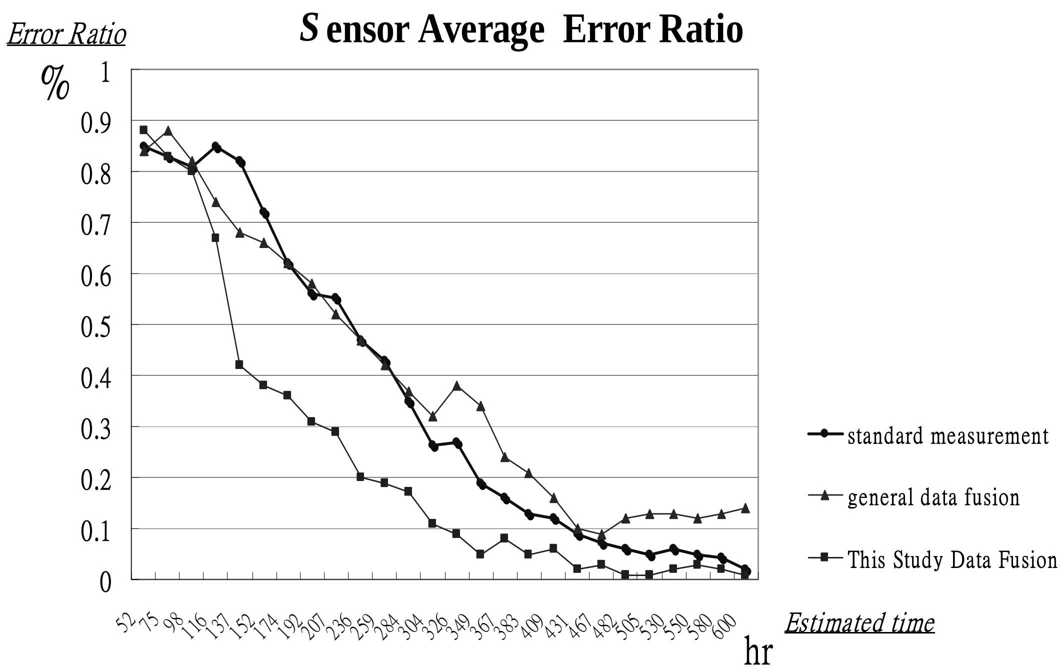

Fig. 14. Comparison of innovative standard measurement based, multi-bit decision fusion and general data fusion methods based on parallel data fusion methods.

7. Conclusion and Future Work

The ZigBee CC2530 Texas Instruments chip and the IAR development software compiler tested a bridge safety monitoring vibration system. In abnormal conditions before the user can receive messages, for strain anomalies, the bridge vibration monitoring is an early warning system. Advanced preventive measures will minimize the damage to protect the safety of users. In the experimental greenhouse environment control is required for state standards. If the environmental state has changed, ZigBee CC2530 sensor module can monitor the environment at any time; send data to the computer interface for Monitoring and surveillance. ZigBee applications are not limited to this type of monitoring and can be applied to other Types of monitoring and control.

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