Two Approaches for Implementing & Improving Building Automation System (BAS)

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ABSTRACT

Building Automation Systems (BAS) are used to both improve the indoor climate in buildings and to reduce the operational costs. In this paper, two approaches were used to implement a networked BAS. In the first one, Wireless Sensor Network (WSN) were used as the transporter of the measured samples which are forwarded to a central control room. We have deployed a medium scale WSN consists of 15 nodes and covers 12 rooms in an office building which is currently in-use. The second approach takes a new direction. In this method we suggest the use of an already installed network to carry measurement and control data of a centrally controlled air conditioning system. Our automation system will share the same network devices, transmission media and end points (i.e., PCs) with the traditional users of the network. We build our own programmable data acquisition card based on 8051 microcontroller, developing a LABVIEW based driver for this DAQ which forward the measured data to a LABVIEW based central control and monitoring PC.

Keywords: Building Automation Systems (BAS), Wireless LAN, Data Acquisition Card(DAQ).

طريقتان لتطبيق وتحسين نظام أتمتة المباني (BAS)

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تاريخ الاستلام: 2010/7/8   تاريخ القبول: 2010/11/10

الملخص

تستخدم أنظمة البنايات الذكية من أجل تحسين المناخ الداخلي للبنايات ولتقليل الكلفة التشغيلية. تم استخدام طريقتين في هذا البحث لتنفيذ أنظمة شبكية للسيطرة على البناية المؤتمتة. الطريقة الأولى ترتكز في عملها على شبكة من المتحسسات اللاسلكية لنقل معلومات القياسات المختلفة وتوجيهها إلى غرفة السيطرة حيث تم نصب شبكة متحسسات لاسلكية مكونة من 15 عقدة تغطي 12 غرفة في بناية مستخدمة حاليا. تم استخدام أسلوب آخر وجديد لتنفيذ الطريقة الثانية وذلك بالاستفادة من وجود شبكة حاسبات مشيدة سابقا لتحميلها بالمعلومات الخاصة بالقياسات المختلفة الموجهة إلى غرفة السيطرة. تم تصميم وبناء بطاقة خاصة لجلب البنايات مع برامج القيادة الخاصة بها من أجل تقليل الزخم على حاسبات وأجهزة الشبكة.

الكلمات المفتاحية: أنظمة البنايات الذكية، شبكة محلية لاسلكية، بطاقة جلب البيانات.

1. Introduction:

The term Building automation refers to an intelligent network of programmable controllers and software that monitors and controls mechanical heating, ventilation and air conditioning equipment, and indoor and outdoor lighting in a building, see Figure(1). The primary function of a building automation system or energy management system is to increase the efficiency of a building and reduces energy and maintenance costs. Building Automation systems optimize the performance and maintenance of multiple building control systems including:[1,2,3]

•Heating, ventilation, and air conditioning (HVAC) – These systems include central plants, air handling units, package units and fan coils.

•Lighting systems – including indoor and outdoor systems.

•Metering systems – including electrical meters, gas meters and BTU meters.

There are two major components to build automation systems; the user interface software and the controller. The user interface is typically a computer based graphical software application that allows the user to interface with the system and provides the user full control over the building automation system. A controller is an electronic device that monitors and changes the operations of a specific system. The operational conditions include output variables of the system which can be affected by adjusting certain inputs. The communication between these two components is achieved through special and dedicated network resources[4,5,6].
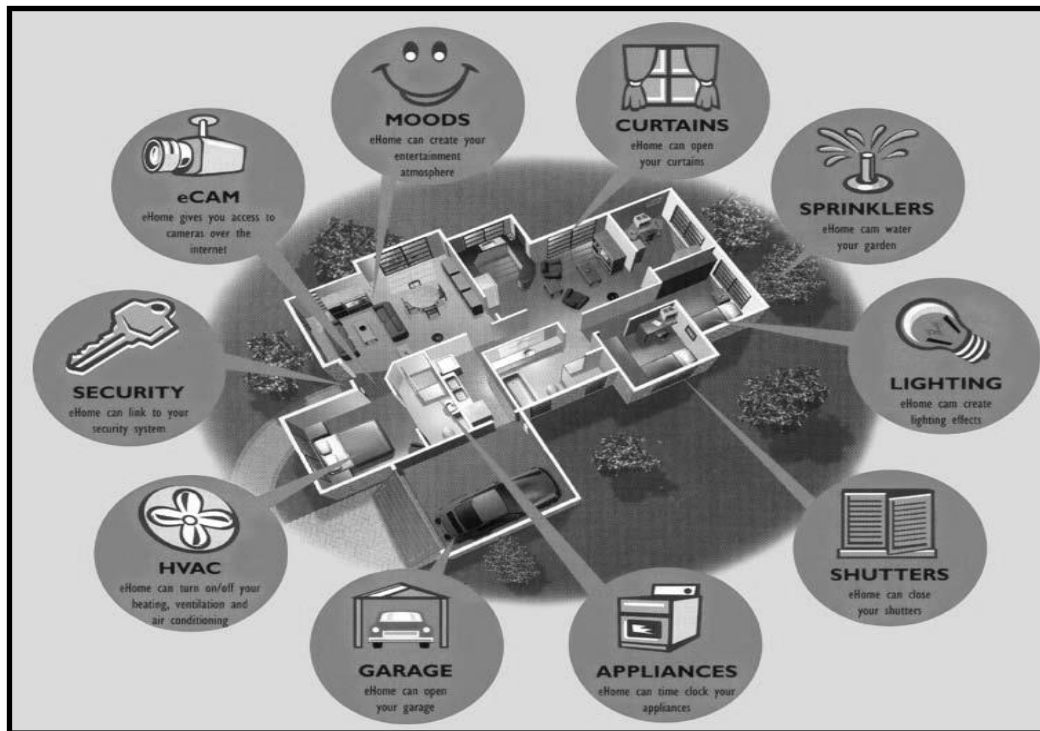

Figure (1): Buildings Automation System (BAS) Functions

2. Description of the First Approach:

In this paper, a testbed is deployed in a realistic setting provided by the office building of the computer engineering department at Mosul university campus. The instrumented area covers 12 rooms of the second floor of the building, using 15 nodes.

The system consists of many wireless sensor nodes, distributed around the building's second floor, used to measure variouse physical quantities, such as heat, light, humidity and vibration. Based on the measurent process , a central control PC supplied with Labview [7] based GUI program used to receive the data packets from the wireless sensors (via WLAN access point), then taking the different control reactions. The implementation of the control actions into an actuating signals were acheived via PCI-6251M DAQ card [7], see Figure(2).
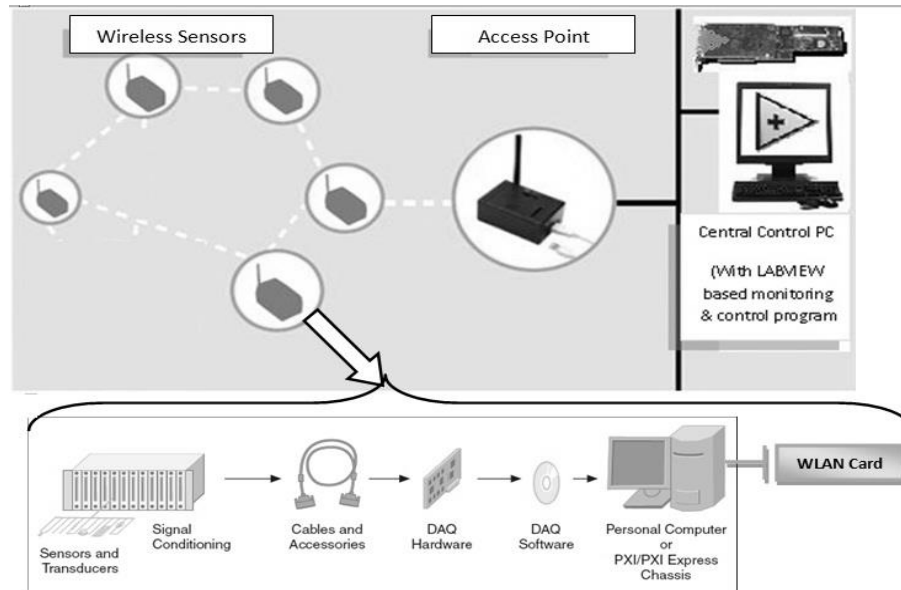
Figure(2): Structure of the Suggested Building Automation System

Each sensor node consists of the following parts:

- Sensors: we used: Temperature, Humidity, Light and motion sensors. Their outputs change linearly with their corresponding inputs (such that: For the temperature sensor, the voltage to temperature transduction ratio is 10mv/C°).
- DAQ System: Standard Industrial PCs can be used with the wide range of PCI modules manufactured by National Instruments. The National Instruments PCI-6251 is a high-speed multifunction M Series data acquisition (DAQ) board optimized for superior accuracy at fast sampling rates. DAQ hardware digitizes signals, performs D/A conversions to generate analog output signals, and measures and controls digital I/O signals[7].
- Personal Computers (PCs): Used for analyzing, presenting, and storing measured data coming from the sensors.
- Software programming language: we used LabVIEW software that is fully visualized (GUI) and it is computable with DAQ card[7].
- Wireless LAN Card: we used a USB wireless LAN from PLANET INC.
- Access Point: used to connect the different sensors to cover the department with (22 Mbps) data rate using IEEE802.11g standard.
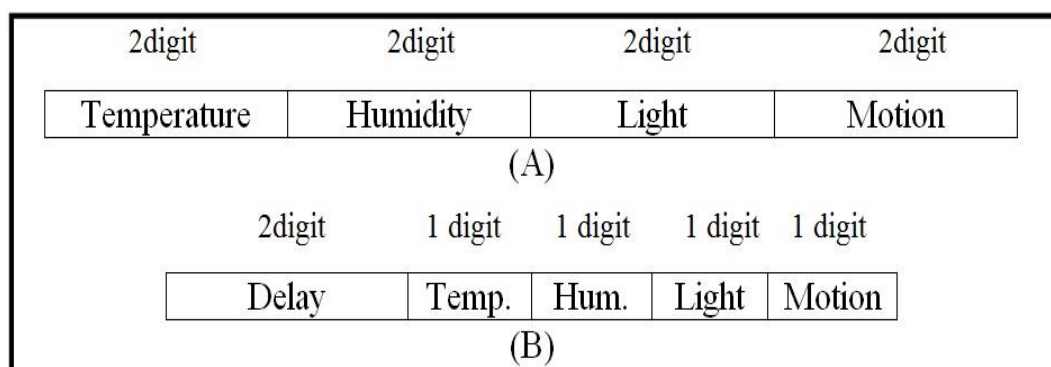
We intend to use the suggested building automation system for the following purposes:

1. Performing air conditioning automation tasks using Temperature sensors distributed around the floor. Actuating signals goes from the central control PC to main air conditioning system to change its states according to previously programmed thermal values.
2. Development of a fire alarm system using the temperature sensors mentioned earlier.
3. Light control function using the measurements provided by light & motion detector sensors. When "No Motion" signal is received from a particular location in the building for a determinate amount of time, the central control PC generate an actuating signal to decrease light intensity in that area.
4. Humidity control using These quantity sensors. Actuating signals are sent to the windows automatic control system.

5. Implementing a building security system using motion detectors localized in suitable locations.
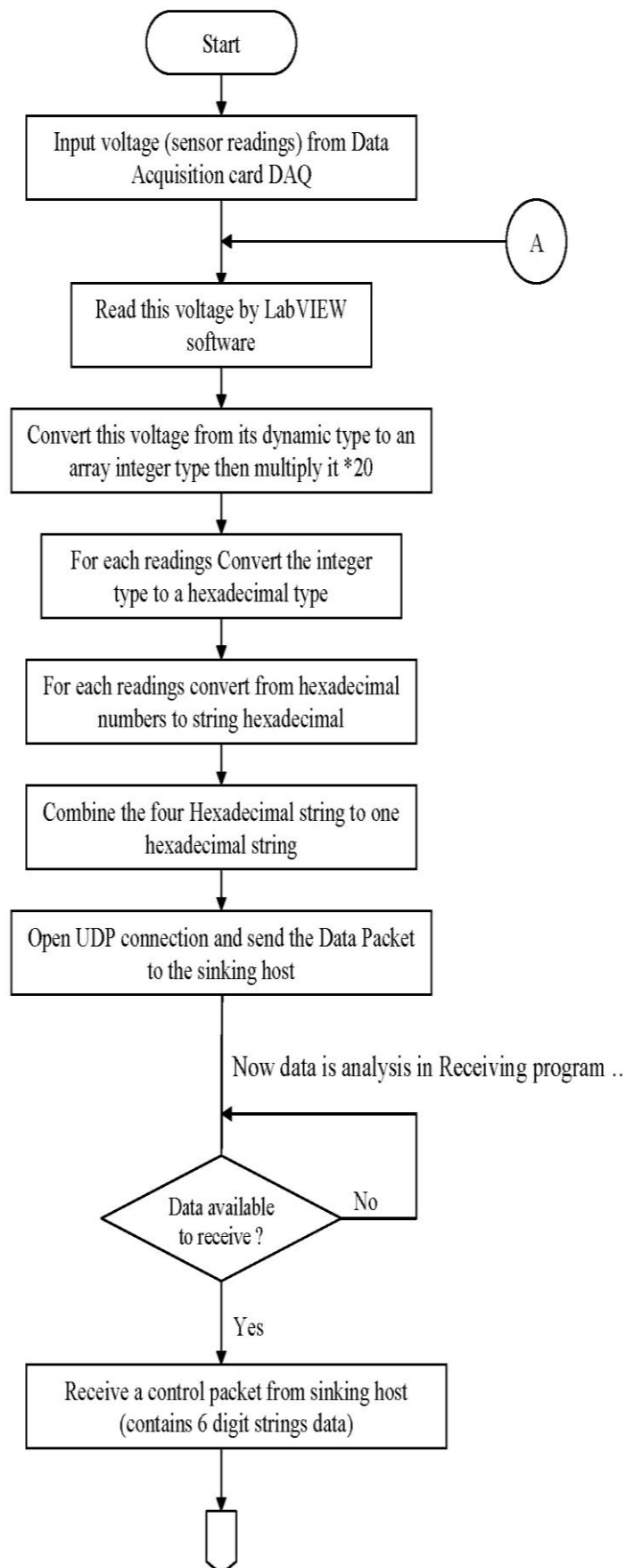
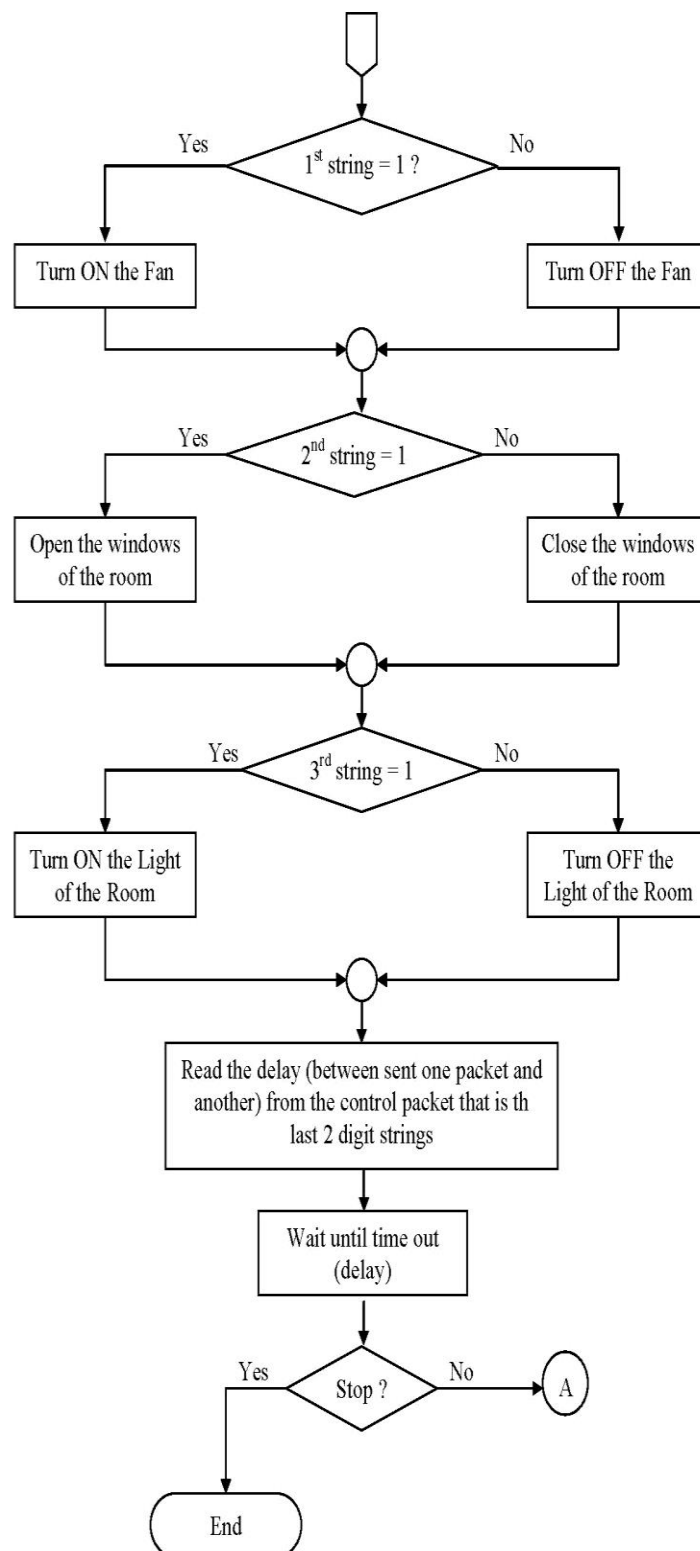Two types of programs were used to achieve automation task:

1.The sender program (Nodes Program): It is responsible for managing input data (sensor readings), then creating a *data packet* and send it to the control server over a wireless LAN using a UDP connection. Finally, the sender program is responsible for receiving *control packet* from the control server which is used to reconfigure these nodes. The packets format are shown in Figure(3) and the flowchart of the sender program is shown in Figure(4).

2digit	2digit	2digit	2digit
Temperature	Humidity	Light	Motion

(A)

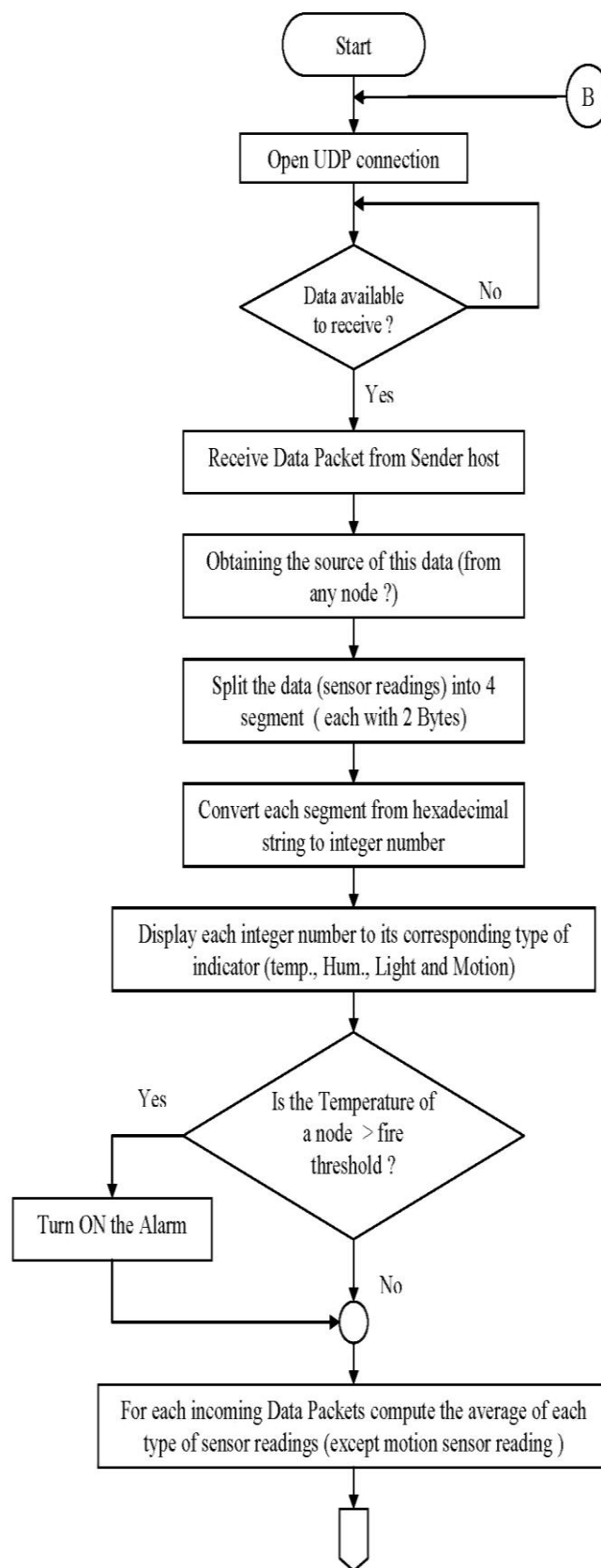| 2digit	1 digit	1 digit	1 digit	1 digit
Delay	Temp.	Hum.	Light	Motion

(B)

Figure(3): Packets format:(A) Data Packet, (B) Control Packet
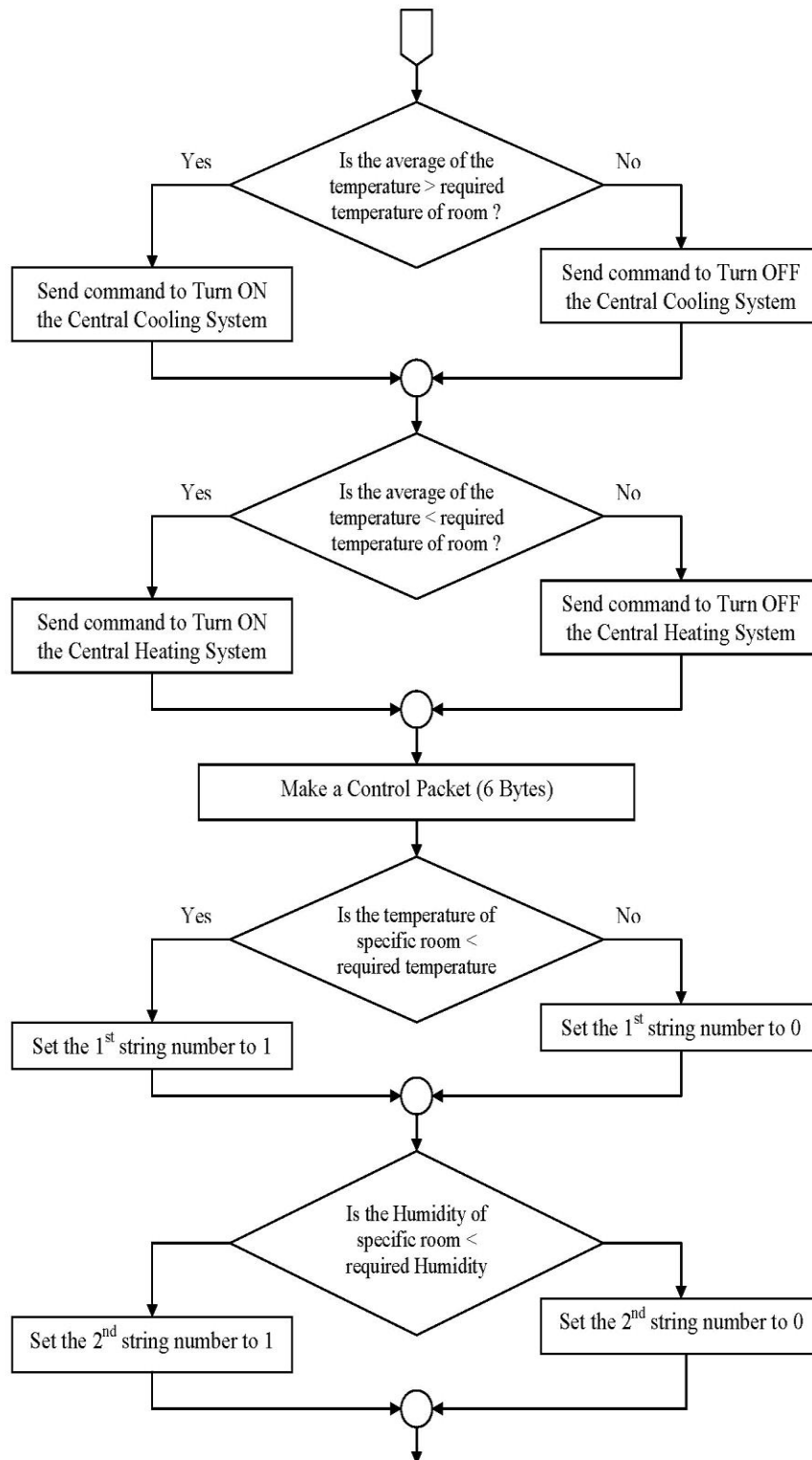
6. The receiver program (Control Server Program): It is responsible for receiving *data packets* from sender program, displaying the sensors readings, Performing a control decision then send a *control packet* back to the sender node to adjust their readings, see Figure(5).
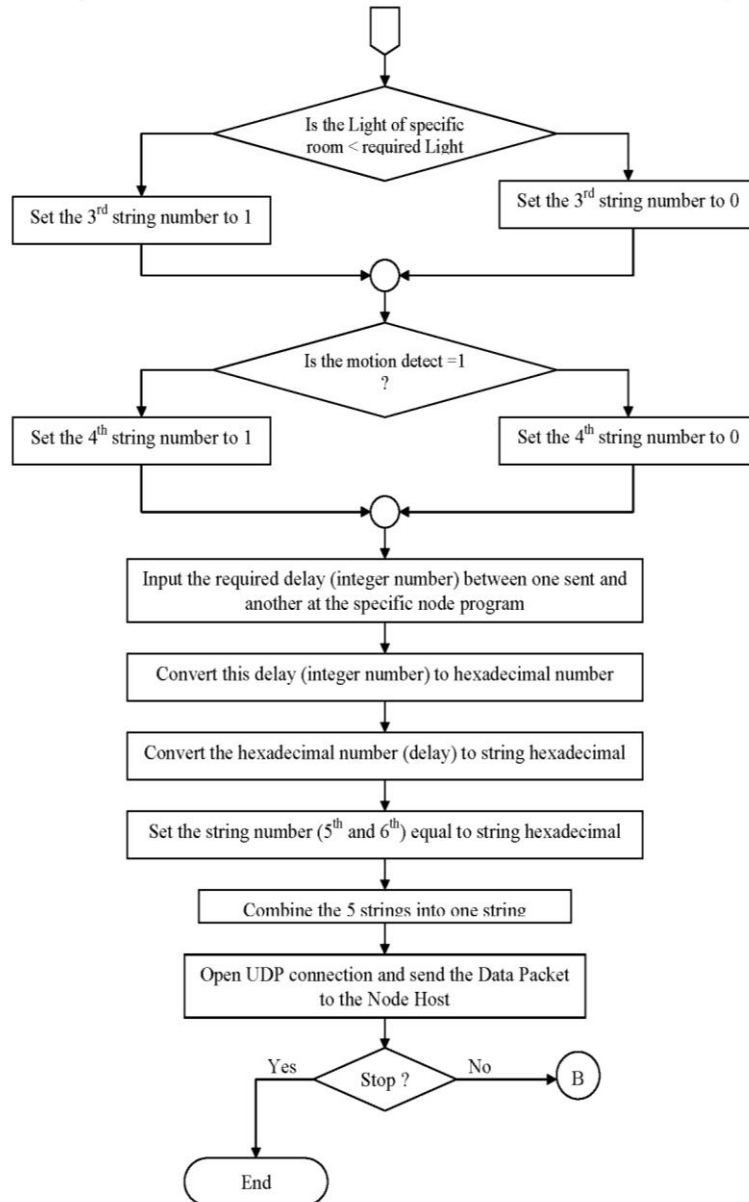
```
                    ┌─────────────┐
                    │    Start    │
                    └──────┬──────┘
                           │
                           ▼
        ┌──────────────────────────────────────┐
        │ Input voltage (sensor readings) from  │
        │ Data Acquisition card DAQ             │
        └──────────────┬───────────────────────┘
                       │                          ┌─────┐
                       │◄─────────────────────────│  A  │
                       ▼                          └─────┘
        ┌──────────────────────────────────────┐
        │ Read this voltage by LabVIEW          │
        │ software                              │
        └──────────────┬───────────────────────┘
                       ▼
        ┌──────────────────────────────────────┐
        │ Convert this voltage from its dynamic │
        │ type to an array integer type then    │
        │ multiply it *20                       │
        └──────────────┬───────────────────────┘
                       ▼
        ┌──────────────────────────────────────┐
        │ For each readings Convert the integer │
        │ type to a hexadecimal type            │
        └──────────────┬───────────────────────┘
                       ▼
        ┌──────────────────────────────────────┐
        │ For each readings convert from        │
        │ hexadecimal numbers to string         │
        │ hexadecimal                           │
        └──────────────┬───────────────────────┘
                       ▼
        ┌──────────────────────────────────────┐
        │ Combine the four Hexadecimal string   │
        │ to one hexadecimal string             │
        └──────────────┬───────────────────────┘
                       ▼
        ┌──────────────────────────────────────┐
        │ Open UDP connection and send the Data │
        │ Packet to the sinking host            │
        └──────────────┬───────────────────────┘
                       │
        Now data is analysis in Receiving program ..
                       │
                       ▼
                  ◄────────
                 ╱          ╲
                ╱  Data      ╲    No
                ╲  available  ╱────────
                 ╲ to receive?╱
                  ╲          ╱
                   ────────
                       │ Yes
                       ▼
        ┌──────────────────────────────────────┐
        │ Receive a control packet from sinking │
        │ host (contains 6 digit strings data)  │
        └──────────────┬───────────────────────┘
                       ▼
```

Figure(4): Flowchart of the Sender Program

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Figure(5): Flowchart of the Receiver Program

Figure (6) shows the deployment layout for the second floor of the building. All the sensor nodes have wireless connection to the gateway server and send their data periodically every (10 seconds).

In the initial phase of the deployment, the tested only supports in-building monitoring of the mentioned physical quantities. In the future, actuators will be added and a control algorithm will be developed to achieve full building automation.
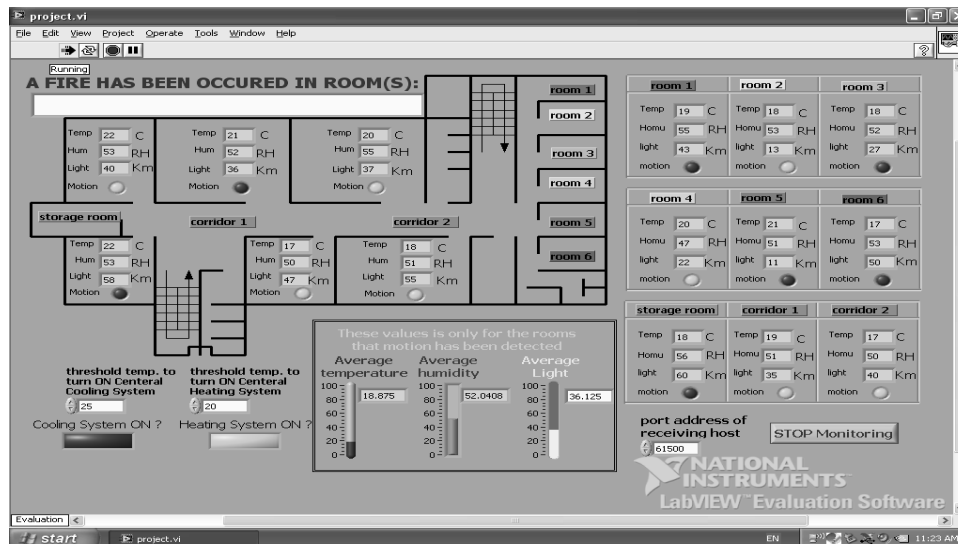
Figure (6): LabVIEW™ GUI of the Suggested Building Automation System

In order to examine the operation of the network, a network analyzer software *"Wireshark"* was used. Wireshark[8] is a GUI network protocol analyzer used for interactively browse packet data from a live network or from a previously saved capture file. Different statistics were collected after running this package to monitor our network. The network operation can be viewed from different points as shown in Figure (7). The collected statistics proves that system operation was as expected and can be summarize as follows:

1. CPU utilization for sensor nodes (using Windows Task Manager) was 15%, while it was 33% for the control server.
2. Packets rate was 10 packet/sec. for each node leading to total utilized network bandwidth of (1 Mbit/sec.).
3. The average latency value(time needed for each packet to travel from the source to the destination) was (6 msec.).
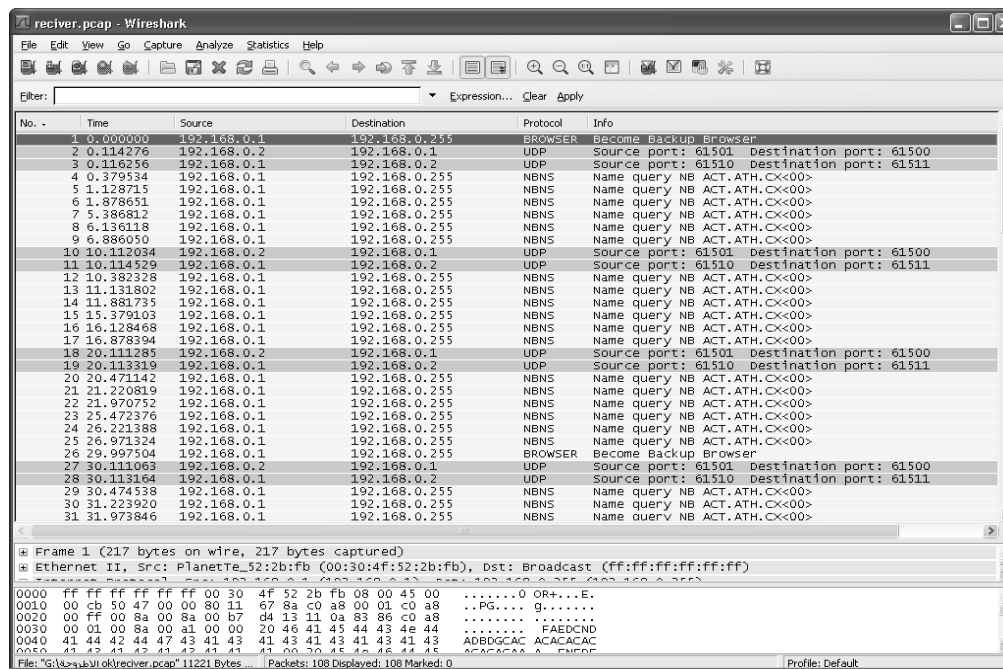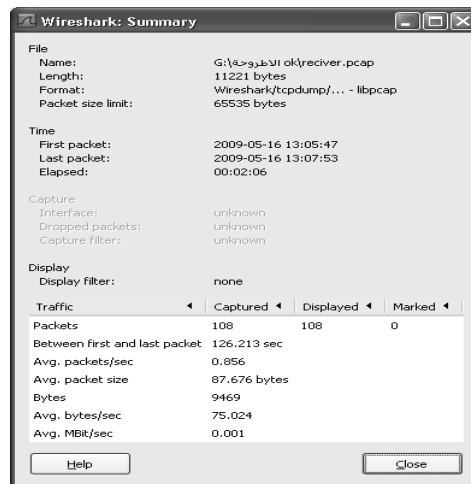
Figure(7): Different Network Statistics
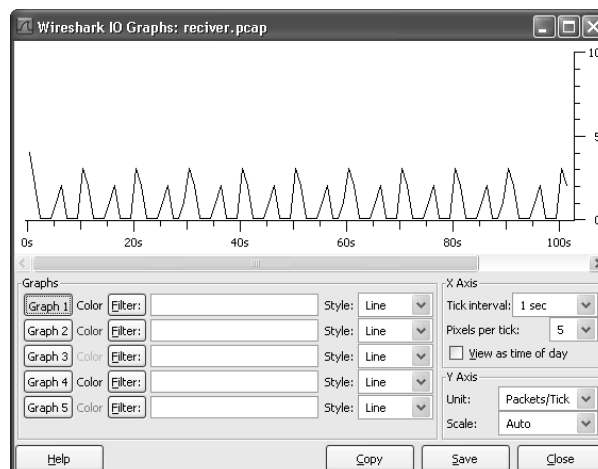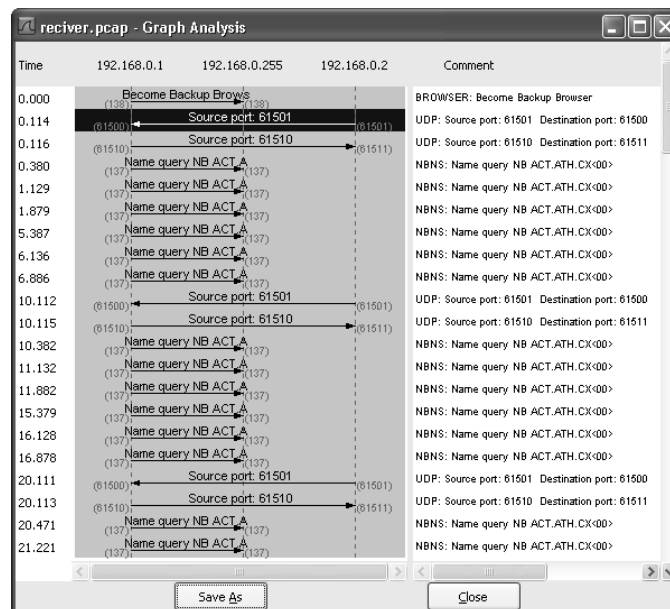
3. Description of the Second Approach:

The buildings automation concept presented in this section provides a reasonable and cost effective solution. The main structure of the suggested system can be shown in Figure (8).
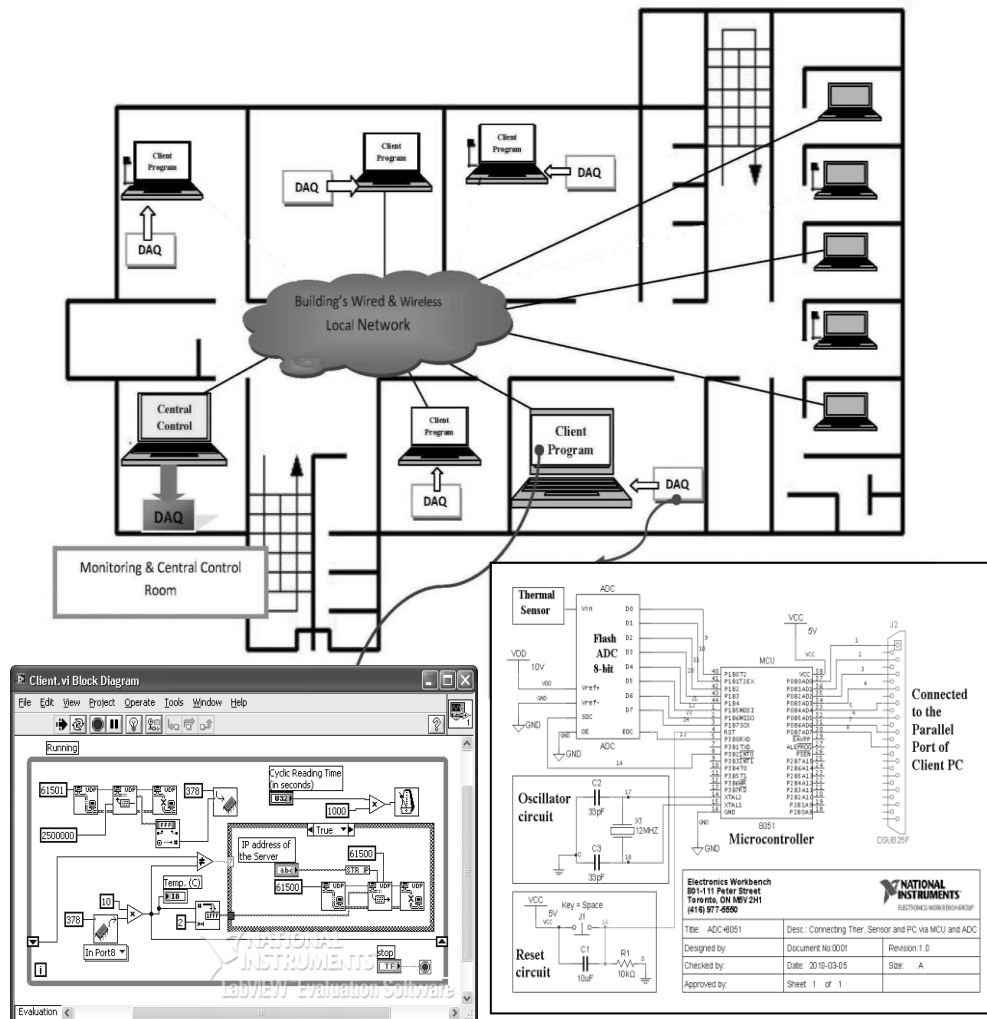

Figure (8): The Layout of the Suggested Buildings Automation System

The main components of the system are: a programmable input Data Acquisition Cards (DAQ), a Labview based client program, a Labview based central control software and output Data Acquisition Card (DAQ). The actions of these components can be explained as follows:

1. The input Data Acquisition Cards (DAQ) has the responsibility of gathering the required measured quantities from the environment. The phrase "Stealth mode" can precisely describe the operation of this card. Our idea state that we make use of the ordinary PCs, distributed within the building, to be the bridge between the input DAQ and the building's local network. However, this task must be achieved while adding minimum load on these PCs and the local network. What we need here is an intelligent DAQ capable of processing the data then selecting the non redundant one and passing them to its computer through the bus between them. Also, this DAQ must be programmable in order to cover the different needs and to serve against multiple conditions. In order to realize these needs, we decide to build our own

prototype DAQ (this card was designed and checked using NI Electronics WorkBench Ver.10). The heart of the card was an 8051 microcontroller connected (via ADC) to a thermal sensor from one side and to the computer bus (through parallel port) from the other side. The memory of this microcontroller was filled with different subroutines (to reflect the different situations) and one of them is chosen every time to achieve certain task, see Figure(9). The card is reconfigured remotely by the administrator over the building's LAN, making use of the host IP to be reachable. In order to guarantee the continuity of its functioning, the card keeps its work even if the PC was in standby mode.
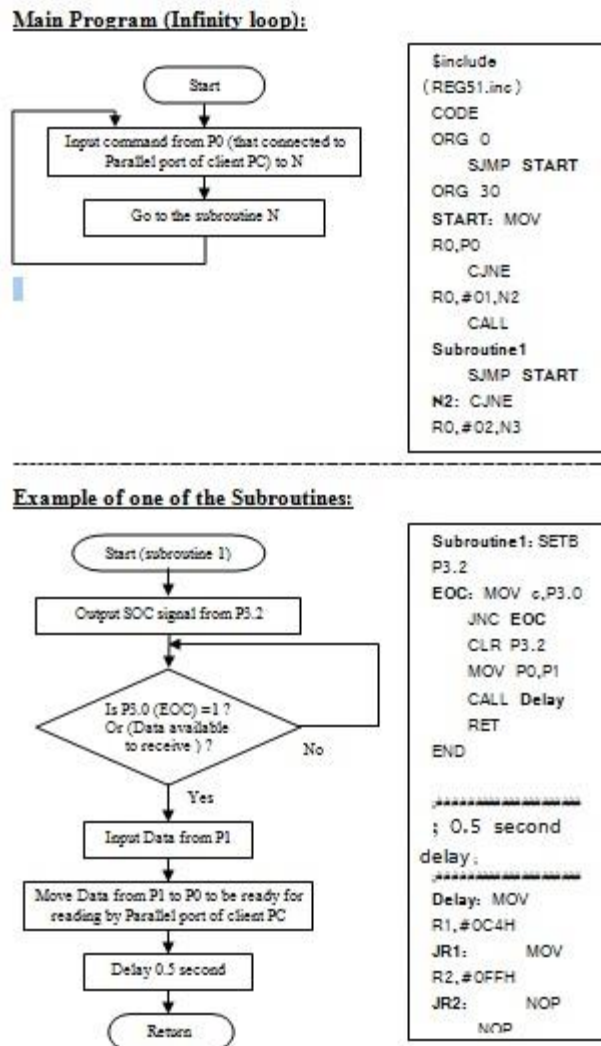
Figure(9); Flowcharts and Sample Codes of the Sensors Subroutines

2. The second component in our system was the client program. This Labview base software represents the driver of the input DAQ. This executable software is installed on the PC and reads the data coming from the parallel port (i.e., the input DAQ), then converting them to an appropriate network packet to be sent to the central control server using UDP protocol. This software has another task during the DAQ's reconfiguration process, in which it passes the administrator commands to choose one of the programs stored in the microcontroller's memory.

3. The last part of the system is the central control & monitoring room. It consists of a networked PC supplied with a Labview based program and connected to a PCI-

6251M DAQ card. This server reads the data coming through the building's LAN from the various input DAQs, monitors them on its GUI and gives the proper commands to the central air conditioning system via PCI-6251M DAQ card. As seen in Figure (10), the GUI provides both monitoring and programming functions to its user. The remote DAQs can all be reconfigured with the same program or individually using different programs.
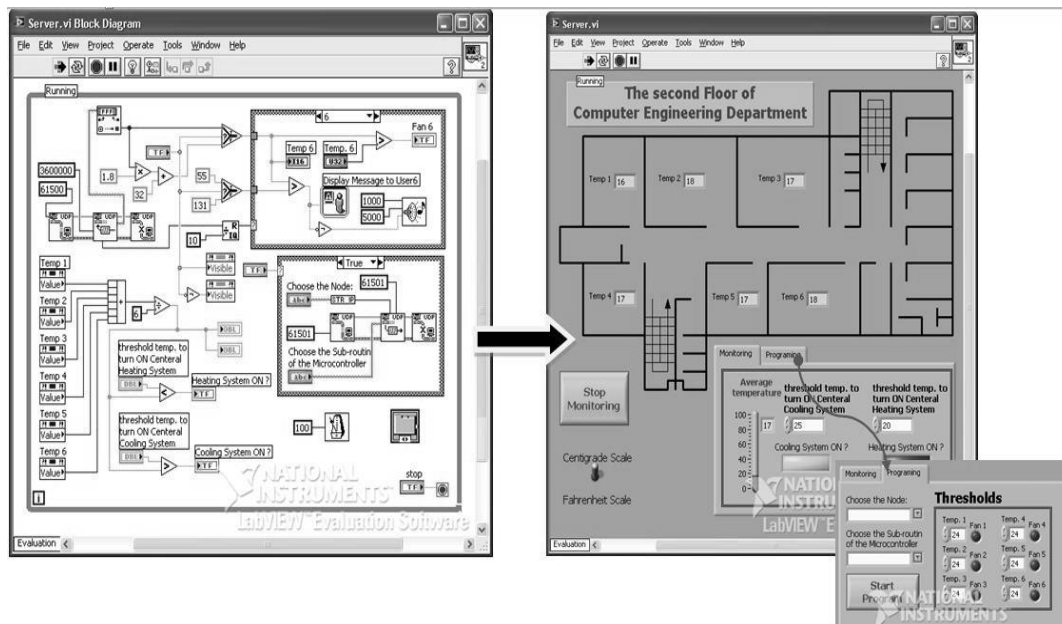
Figure(10): Details of the Central Control & Monitoring Software

Our implementation of the system was very easy and timely efficient. We connect the input DAQ to few PCs on the second floor of computer engineering department/ Mosul university campus, and then we supply these nodes with the client program. After awhile, we began to receive the data from these nodes which affect on the decision taking by the server towards the central air conditioning system. Also, the reprogramming task was very efficient and needs little efforts. Our measurement on the computer's CPU (using Windows Task Manager) shows that the maximum load afforded by the input DAQ does not exceed (2%) and (8%) for the control server. On the other hand, the load provided to the network was less than (0.13 Mbit/sec). This result proves that the suggested method adds minimum load on both the network and the end nodes.

4.Conclusion:

This paper demonstrate two design approaches for implementing Buildings Automation Systems(BAS). The first approach follows the direct method in which PCs supplied with the necessary data acquisition cards and networking capabilities were used to achieve the automation tasks. The second approach optimize resources (both CPU and Network utilization) usage using a new procedure called "Stealth Mode". This approach decreases CPU utilization of sensor nodes by 80% and 75% for the control server. Also, the needed network bandwidth was lowered by 87%. On the other hand, the cost of the custom made DAQ was(15$) compared to (500$) for the first option. From these results, it is obvious that the second approach can be considered as a cost effective solution and gives better performance than the first one.

REFERENCE

[1].   W. Granzer, W. Kastner, G. Neugschwandtner, and F. Praus, "A modular architecture for building automation systems," in *Proc. 6th IEEE WFCS*, 2006, pp. 99–102.

[2].   Q. I. Ali, "An Efficient Implementation of Wireless Sensor Network (WSN) for Buildings Automation Purposes", 11'th Scientific Conference of Babel University,2009.

[3].   Fl Lewis, "Wireless Sensors Networks, Smart Environments: Technologies, Protocols, and Applications', ed. Cook DJ, Das SK, John Wiley, New York, 2004; 1-18.

[4].   J. Reerink; C. Deroussent, "Preliminary Based Service Evaluation for Elderly People and Healthcare Professionals in Residential Home Care Units",Digital Society, 2008.

[5].   A. Willig, K. Matheus, and A. Wolisz, "Wireless technology in industrial networks," *Proceedings of the IEEE*, vol. 93, no. 6, pp. 1130–1151, 2005.

[6].   Q. I. Ali, "Design & Implementation of a Buildings Automation System Working in Stealth Mode", 2010 Virtual Instrumentation Academic Paper Conference, Lebanon, 2010.

[7].   "Measurement and Automation Catalog", National Instruments, 2007.

[8].   Wireshark Web site: http//:www.Wireshark.com.