AUTOMATION OF MULTI-STORIED RESIDENTIAL BUILDING

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

in

ELECTRICAL ENGINEERING

(With Specialization in Measurement and Instrumentation)

By

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this dissertation entitled "**Automation of Multi-Storied Residential Building**" in the partial fulfillment of the requirements for the award of the degree of **Master of Technology in Electrical Engineering** with specialization in **Measurement and Instrumentation**, submitted in the **Department of Electrical Engineering**, Indian Institute of Technology, Roorkee, is an authentic record of my own work carried out during a period from May 2007 to June 2008 under the supervision of **Dr. H. K. Verma**, Professor, Electrical Engineering Department, Indian Institute of Technology, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute.

Date: 26 June 2008

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

Dated 26.6.2008

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Chander Kant

Dedicated

To

My Wife

&

My Parents

ABSTRACT

Building Automation (BA) is a network of intelligent devices that monitor and control the electric appliances and mechanical systems of the building, with the triple aim of conserving electricity by efficient use of available resources, giving comfort to the residents and providing safety and security to the residents by incorporating suitable sensors and controls. The integrated BA system can be connected to the Internet or a mobile phone network for remote access. In some cases, with high security requirements, monitoring can be passed on to a private agency for 24x7 hours monitoring of the building.

With a wide range of household devices, BA subsystems put different networking requirements in terms of speed and reliability etc. BA networking technologies can be classified as Powerline, Wired and Wireless technologies. "Powerline" uses the electrical wiring for networking and thus requires no new wires. "Wired technology" is most reliable and secure but requires new cables for networking. "Wireless technologies" although having some disadvantages like interference and security issues, are the most emerging market because they require no wires for networking.

This report analyzes the technologies suitable for Building Automation and describes the Building Automation design based on each of Powerline, Wired and Wireless networking technologies.

The report puts forth an integrated Wired Building Automation design for "Hill-View", the residential multi-storied (RMS) building at IIT, Roorkee. Apart of this Building Automation system has been implemented in Instrumentation & Signal Processing (I&SP) Laboratory and is described here. One of main features of the implemented system is remote access by mobile phone, i.e. events are notified by sending SMS (Short Message Service) on predefined phone numbers and remote control of the devices is possible from the same mobile phone.

An alternative design based on wireless Building Automation and its implemented in I&SP Laboratory using Crossbow's Zigbee wireless modules is described.

A stand-alone safety and security system using microcontroller based controller along with suitable sensors and actuators has been implemented and reported here.

The report concludes that Building Automation System requires a mix of networking technologies, no single technology serves all the requirements of BA.

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Introduction

Building Automation is a programmed, computerized, "intelligent" network of electronic devices that monitor and control the mechanical and lighting systems in a building [1]. An automated building allows for a more efficient use of resources and increases the comfort and security of its occupants. A Building having integrated automation system is also called Intelligent Building.

A definition given by IBDN Intelligent Building Solution is that an Intelligent building is one equipped with the telecommunications infrastructure that enables it to continuously respond and adapt to changing conditions, allowing for a more efficient use of resources and increasing the comfort and security of its occupants. An Intelligent building provides these benefits through automated control systems such as: heating, ventilation, and air-conditioning; fire-safety, security, and energy/lighting management.

The Intelligent building concept takes into consideration the fact that the true cost of a building is not only the cost of construction, but also the costs of operating, maintenance and repairs that come later. An Intelligent building can help reduce the operating and maintenance costs to a great extent by controlling and regulating the systems within the building.

Total life cycle costs for Intelligent buildings are generally lower than costs for conventional buildings due to significant reductions in energy and other cost savings.

1.1 Building Automation Service Requirements

In a fully integrated intelligent building, each device would be capable of communicating with every other device, and all of them would be accessible over the Internet.

Many devices of home are capable of being networked. Some of the categories are as follows [2]:

1. Computers (desktop PC, notebook PC, PDA, shared peripherals).
2. Entertainment (TV, DVD, VCR, Camcorder, Camera, Stereo).

3. Telecommunications (telephone, mobile telephone, intercom, fax).
4. Appliances (microwave, refrigerator, clock, furnace, lights, heater).
5. Telemetry (utility meter, smoke/burglar alarm).

Major requirements for home networks are as follows [3]:

1. **High Bandwidth**: Audio and video streaming required high bandwidth.
2. **Quality of Service**: Home networks should provide guaranteed quality of service, especially for streaming applications.
3. **User Friendliness and Reliability**: Home networking products and solutions target a large number of customers with no computer experience. Thus the technologies and applications should be as consumer friendly as possible. Home networking solutions should be easy to install providing plug 'n' play and/or autoconfiguration features.
4. **Security and Reliability**: Losing a few files to an e-mail virus is one thing; having a burglar disarm security system from his PDA and then plunder the house is something quite different. Hence security is one of major concern.
5. **Reasonable Cost**: Home networking solutions should be provided at reasonable cost, comparable to home appliances.
6. **Low Installation Cost**: Apart from the equipment cost, home networking solutions should take care of installation costs. Thus wireless technologies or power line technologies that reuse existing wiring infrastructure of the home may be preferred, at least for existing households.
7. **Standards and Interoperability**: It is expected that a multitude of home networking products, technologies and solutions from different vendors will coexist in future homes. Hence interoperability and expandability should be there.

1.2 Building Automation Services [4]

Intelligent building services are categorized as follows:

1. Automation
2. Safety
3. Security
4. Information

5. Communication
6. Entertainment

1.2.1 Automation

It broadly includes automation of:

a) HVAC (Heating ventilation and air conditioning) system

b) Lighting System

(a) HVAC System

Improper working conditions like temperature, humidity, ventilation, and indoor air quality usually have significant impacts on the work and health. When we are working in good controlled environment, we can think better and can achieve better results.

In order to provide a good comfort and healthy indoor environment to residents, the building mechanical system must:

- Provide a comfortable temperature and humidity level and reduce air pollutants.
- Proper air ventilation
- Allow the resident to control environment as per his needs.

All this requires control systems for Heating, Ventilating, and Air Conditioning (HVAC). The control system can be based on any of the following criteria [5].

1. Time based control

The heating system is turned ON and OFF at pre-selected time periods. But these periods need to be changed with season change.

2. Optimizer parameter based

Optimizing parameter is selected based on which heating system is turned ON and OFF e.g. temperature. If temperature is low, heating system should be turned ON automatically.

3. PIR based occupancy detection

As soon as person enters, system should be turned ON and should be turned OFF as he leaves.

4. Manual Control.

(b) Lighting System [5], [6]

The principle of lighting controls is to either dim the lights or switch ON/OFF the lighting according to requirements.

The best way to achieve energy-effective design is to add day light in the building. Natural daylight makes people happier, healthier, and more productive. This in addition reduces the energy consumption. The lighting systems can be dimmed with the availability of daylight. Up to 75% of lighting energy consumption can be saved. In addition, by reducing electric lighting and minimizing solar heat gain, controlled lighting can also reduce a building's air conditioning load.

Different control systems exist, again time-based control and optimizer parameter-based where a level of luminance or particular use of lighting is required [5].

- Zones: lights are switched on corresponding to the use and layout of the lit areas, in order to avoid lighting a large area if only a small part of it needs light.
- Time Control: to switch on and off automatically in each zone to a preset schedule for light use.
- Passive Infra-Red (PIR) Occupancy Sensing: In areas which are occupied intermittently, occupancy sensors can be used to indicate whether or not anybody is present and switch the light on or off accordingly.
- Light Level Monitoring: this consists of switching or dimming artificial lighting to maintain a light level measured by a photocell.

The concept behind these controls is to operate lighting automatically according to the function of an area, the time of day, ambient light levels, or occupancy. The single most important aspect is programmability, that is, the ability to remember lighting levels as a series of settings. These settings, also known as scenes, can be recalled automatically by the dimmer system or by the central building control system.

Intelligent lighting controls have many advantages over manual ones, including convenience, creating ambience, increased design flexibility, energy savings, reduced lamp replacement costs and security.

(i) Advantages of Automated Lighting System [6]

1. Scenes, once set up, can be easily recalled manually from wall mounted switch panels or by remote control. They can be recalled automatically by timer, by daylight sensor or according to occupancy. Once a new scene is selected the lighting will fade to the new set of levels at a pre-determined rate.
2. The human eye perceives light non-linearly, it is possible to reduce light levels by over 10% before the reduction in brightness is noticed. This would lead to a near 10% saving in energy consumption.
3. Incandescent lamps tend to fail at this point due to thermal shock of the cold filament. By fading the lamp to the set level, also know as "soft start", a lamp's life is extended considerably.
4. In warm climates and in the summer months when air-conditioning is used, lowering the thermal load of the lighting can also save energy.
5. Energy savings can be derived through occupancy detection. Sensors are mounted in rooms, which detect if there is movement within the room or area. They feed that information back to the controller, which counts a period of time that no movement has been detected for. Each time movement is detected the count will be reset. Once movement has not been detected for a preset period of time the lighting in that room or area can be either switched off or turned down to a low energy saving level. After a further period of no movement they can be turned off altogether.
6. Lighting can play an important part in security, deterring intruders whether the property is occupied or not. Low levels of illumination can be programmed to operate at night in certain rooms or hallways. When the building is unoccupied, levels can be selected that copy normal usage. This can be by time clock or by selecting a vacation mode.

1.2.2 Safety [4]

In Intelligent building safety is one of the most important factors. It includes following sensors/controls:

- Fire detection, alarming and control
  - Manual call points
  - Smoke detector
  - Fire alarm
  - Auto sprinkler system
- LPG leakage detector
- Water supply control
- Wireless emergency pendent for elders
- Emergency button at convenient location

1.2.3 Security [3], [4]

Alarm systems are already a relatively mature market. However, convergence of security systems with home and access networks, along with modern monitoring and sensing devices (e.g. motion detectors, IP cameras), represents a new market potential. Subscribers will be able to monitor their homes remotely via Internet browsers or mobile PDA, or receive automatic e-mail if something happens. Applications may include health care services for elderly and disabled persons. Following are the parts of security system.

- Smart card, finger print based access
- Motion detectors for complete security
- Glass break detectors
- Door/Window sensors
- Alarm notification options
- Hooters to notify society security gate, neighbors.
- View image of visitor at society gate/ apartment door
- Voice communication with visitor
- Video surveillance and remote monitoring-using IP video camera

1.2.4 Information [4]

Now a day, because of the broadband access technology and low cost, number of homes with PC and Internet connectivity is increasing rapidly.

- High speed WiFi connectivity for conveniently using WiFi devices such as PDA, Laptop
- Event tracking system (e.g. Birthdays, anniversaries), greeting with personal voice recording.

1.2.5 Communication [4]

Voice communication is one of the most important requirements and will be in future also. Future communication services will include following applications.

- Universal phone using wireless connectivity
- Free phone calls within society
- Internet telephone VOIP

1.2.6 Entertainment [4]

Earlier people used to have a huge collection of CDs and then DVDs, for MP3 music and movies. Now due to low cost of hard disk, people are maintaining a central library on hard disks instead of CDs and DVDs. This requires high speed protocols to access central library from any part of the building. Future entertainment services include:

- MP3 music download and play from central library
- Movies download and play from central library
- Video on demand

1.3 Building Automation Networking Technologies

Building Automation communication technologies can broadly be classified into three categories as shown in figure 1.1.

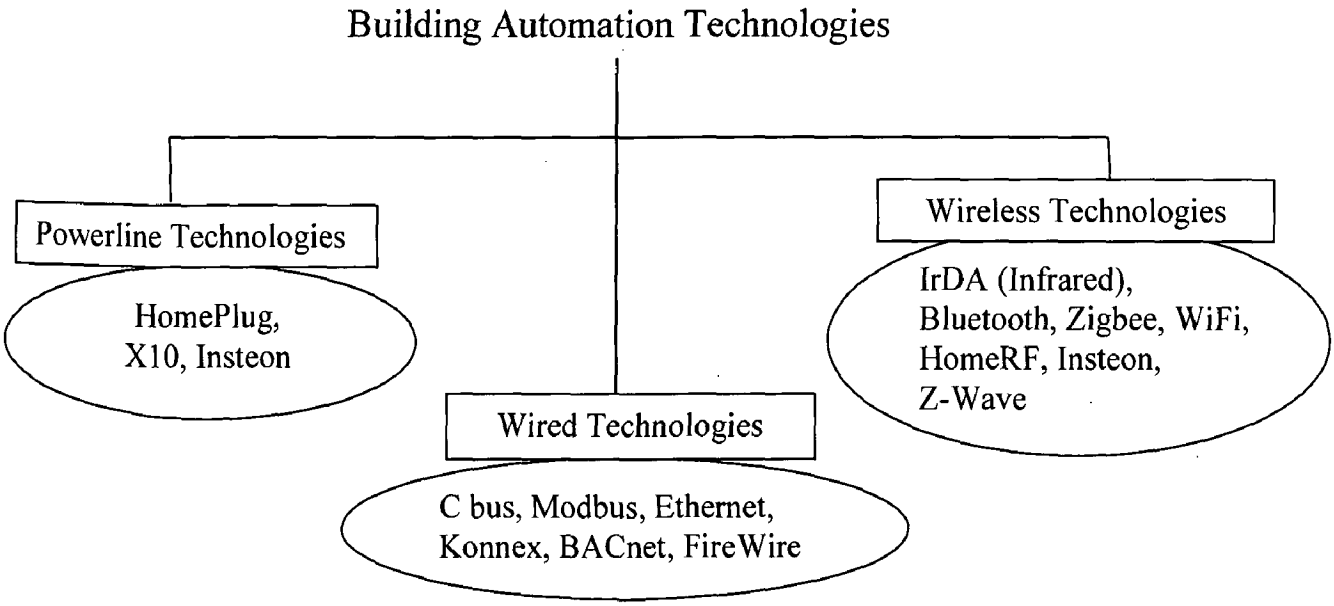


Figure 1.1: Building Automation Networking Technologies

Each networking technology plays an important role for Building Automation and has its merits and demerits. It is necessary to look for all the technologies at the design stage of Building Automation. All these technologies are discussed in the following chapters.

1.4 Organization of Report

The report discusses advantages and disadvantages of each of the networking technology classified as above, describes briefly the networking technologies based on the physical layer, suitable for Building Automation and presents a Multi-Storied Residential Building Automation designs based on each of the physical layer.

Chapter-2 describes the principle of operation of various sensors used for Building Automation. The understanding of this helps to select a suitable sensor for a particular service, as choice and installation of sensor is most important for the reliable operation of Building Automation system.

Chapter-3 describes the Powerline technology, which uses the existing power line wiring for communication in between devices. It also discusses a low cost Building Automation design based on Powerline.

Chapter-4 describes the Wired technology, its advantages and disadvantages and discusses the various available wired technologies briefly. This chapter describes an integrated Building Automation System design proposed for Hill View Building at IIT, Roorkee. This chapter also describes a Building Automation system implemented in I&SP lab.

Chapter-5 describes the wireless technology, its advantages and disadvantages over other two physical layers and available wireless technologies briefly. This chapter also describes an implemented wireless automation system using Crossbow's Zigbee modules.

Chapter-6 describes a standalone security and safety controller for small buildings and Homes. It describes such system implemented using GE's NX8V2 control panel.

Chapter-7 summarizes the dissertation and concludes the networking technologies suitable for Building Automation and gives the future scope for continuing the work.

Chapter – 2
Sensors for Building Automation

Good selection and proper installation of sensors is very much important in any of the BA system. This chapter describes the various sensors which specially are used for BA Subsystems and their operation which will help for the selection of suitable sensors. General sensors used in BA like Door Switch, Water Pressure sensor, Temperature, Humidity etc. are not discussed here.

2.1 Motion Detector

Motion is detected when an infrared emitting source with one temperature, such as a human body, passes in front of a source with another temperature, such as a wall. Motion detectors are used in burglary systems and for energy conservation by switching off the lights if no motion is detected for a set period of time.

The "motion sensing" feature on most lights (and security systems) is a passive system that detects infrared energy, whereas microwave and ultrasonic sensors are active sensors. In case of microwave sensors, microwave source sends out a burst of microwave radio energy and waits for the reflected energy to bounce back. When a person moves into the field of microwave energy, it changes the amount of reflected energy or the time it takes for the reflection. The same thing can be done with ultrasonic sound waves, bouncing them off a target and waiting for the echo. This is used in grocery stores/restaurants for automatic opening of the doors.

Objects that generate heat also generate infrared radiation and those objects include animals and the human body whose radiation is strongest at a wavelength of 9.4μm. Motion detector being a passive sensor and works on principle of detection of infrared, is commonly known as Passive Infrared Sensor (PIR) or pyroelectric sensor.

For detection, an intrusion sensor is sensitive to changes in infrared energy rather than absolute levels. It accommodates itself to the background conditions in the room and perceives the intruder as a change in this state of equilibrium. This change principle is fundamental to the detection process.

The Pyroelectric sensor is made of a crystalline material that generates a surface electric charge when exposed to heat in the form of infrared radiation. When the amount of radiation striking the crystal changes, the amount of charge also changes and can then be measured with a sensitive FET device built into the sensor. Figure 2.1 shows a typical configuration of PIR sensor.

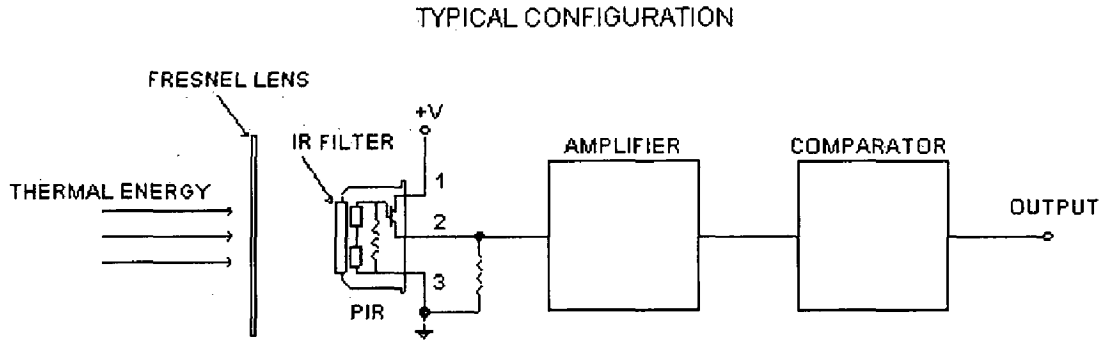


Figure 2.1: A typical Configuration of PIR sensor [7]

The PIR325 sensor has two sensing elements connected in a voltage bucking configuration. This arrangement cancels signals caused by vibration, temperature changes and sunlight. A body passing in front of the sensor will activate first one and then the other element whereas other sources will affect both elements simultaneously and be cancelled. The radiation source must pass across the sensor in a horizontal direction when sensor pins 1 and 2 are on a horizontal plane so that the elements are sequentially exposed to the IR source.

RX-PI 40 and PI-75, PIR sensors are used for motion detection. RX-PI 40 rejects false alarms caused by spot temperature changes such as small to medium sized animals - air conditioners - or moving curtains. Utilizing Quad Zone Logic - the RX-40PI couple signals from its 78 detection zones to determine the size of its target.

Motion detectors often use dual technology comprising of PIR sensor and microwave sensor. The most prevalent reason for using dual technology detectors is the rejection of false alarms, which may be generated by environmental factors, electrical noise, or pets. Security systems that use dual technology sensors to reject false alarms require both sensors to detect an event before an alarm is generated. The dual sensors reduce false alarms due to environmental factors because both sensors will detect an intruder, but only one sensor will react to an event produced by the environment. For instance, a PIR sensor, which detects changes in

temperature, will detect the heating system being turned on, but a microwave sensor will not detect the change in temperature, and therefore there will be no alarm condition.

How pet immunity is achieved?

Dual technology also helps to achieve pet immunity in addition to avoid false triggering from environmental noise. Reduction of false alarms due to pets is dependent on the field of view of the two sensors and the setting of the threshold levels of the comparators. An animal presence is different from a human intruder in that the animal is lower to the ground and the temperature of the animal is lower due to its skin being covered with hair.

A dual-sensing intrusion detection device for detecting an intruder comprises a PIR sensor and a microwave sensor. The device comprises, PIR processing means and microwave processing means, means for summing the processed PIR signal with the processed microwave signal to generate a summed signal, and means for comparing the summed signal to a sum threshold value to determine if an alarm condition exists. The sum threshold value is selected for optimal discrimination between a human intruder and an animal presence.

2.2 Glass Break Detectors

Glass break detectors are used to provide early indication of an attack on glass surface. There are generally two types of detector, on glass and off glass.

Off glass detectors operate when they "hear" the frequency of breaking glass, the advantage of these types of unit is that they can be mounted discretely to the wall or ceiling near the window. On-glass detectors are fixed, (usually with glue), to the actual surface of the window. Glass break detectors used in implementation of Building Automation System are GS-380, GBS-210, and PS 922 Vibration Sensor. Specifications of Glass Break Sensors used are given in Appendix-1.

The GBS-210 glass break detector detects the breaking of glass windows. A dual technology detection method (air pressure and sound analysis) is used. A built in LED indicator allows for easy testing and it also provides an optional alarm memory feature.

2.3 IP Camera [11]

An IP Network Camera is a digital video camera with a computer processor and a web server built-in (making it web addressable), so the camera can connect directly to an IP network without being attached directly to a PC. IP addressability means the video stream can be remotely viewed from anywhere in the world via a standard web browser. A to D conversion and video compression are performed in the IP Camera with video transmission to authorized users over IP Networks.

Video surveillance systems have evolved from analog CCTV systems requiring miles of cables and banks of VCR's and monitors, to fully digital IP Network Video Systems. These Network Video Systems generate video using intelligent Network Cameras, use IP networks for video transmission and record video to hard disks on industry standard PC's located anywhere in the network. Network Video advantages over CCTV include remote viewing, management and recording from any PC, greatly reduced cabling costs, easy scalability, improved operating efficiency and - perhaps most importantly - improved security effectiveness due to advanced features. These benefits will make will make Network Video Systems the solution of choice as the market for video surveillance grows in the post 9/11 world.

A Pheenet model no. MCAC-300PTW IP Camera with remote Pan and Tilt control has been used for video surveillance. Detailed specifications can be found in Appendix-2. A free bundle 16-Channel Software, including Monitor & Playback program, alert with video, save to Internet / HD, Cycle recording and .avi format is available with the same camera. User can monitor 16 different IP cameras on a single screen.

2.4 Fire Detection, Alarm and Control [8], [9]

When present, humans can be excellent fire detectors. The healthy person is able to sense multiple aspects of a fire including the heat, flames, smoke, and odors. For this reason, most fire alarm systems are designed with one or more manual alarm activation devices to be used by the person who discovers a fire. Unfortunately, a person can also be an unreliable detection method since they may not be present when a fire starts, may not raise an alarm in an effective manner, or may not be in perfect heath to recognize fire signatures. It is for this

reason that a variety of automatic fire detectors have been developed. Automatic detectors are meant to imitate one or more of the human senses of touch, smell or sight. Thermal detectors are similar to our ability to identify high temperatures, smoke detectors replicate the sense of smell, and flame detectors are electronic eyes. The properly selected and installed automatic detector can be a highly reliable fire sensor.

2.4.1 Manual Call points

Manual fire detection is the oldest method of detection. The advantage of manual alarm stations is that, upon discovering the fire, they provide occupants with a readily identifiable means to activate the building fire alarm system. Break glass type are the common one.

Disadvantages

They will not work if the building is unoccupied. And also when occupants are sleeping, by the time they detect fire, fire may have grown to large extent.

2.4.2 Automatic Fire Detectors

a. Thermal Detector
    - Fixed temperature type
    - Rate of rise of temperature type

b. Smoke detector
    - Ionization Type
    - Photoelectric Type

c. Flame Detector

a. Thermal Detector

Fixed temperature devices operate when the room reaches a predetermined temperature (usually in the 135°–165°F/57°–74°C). Rate-of-rise detector identifies an abnormally fast temperature climb over a short time period.

Advantages

1. Thermal detectors are highly reliable.
2. They are also very easy and inexpensive to maintain.

Disadvantages

1. They do not function until room temperatures have reached a substantial temperature, at which point the fire is well underway and damage is growing exponentially. Subsequently, thermal detectors are usually not permitted in life safety applications. They are also not recommended in locations where there is a desire to identify a fire before substantial flames occur.

b. Smoke Detector

Smoke detectors are a much newer technology, having gained wide usage during the 1970's and 1980's in residential and life safety applications. As the name implies, these devices are designed to identify a fire while in its smoldering or early flame stages, replicating the human sense of smell.

(i) Ionization Type Smoke Detector

A typical ionization chamber consists of two electrically charged plates and a radioactive source (typically Americium 241) for ionizing the air between the plates. The radioactive source emits particles that collide with the air molecules and dislodge their electrons. As molecules lose electrons, they become positively charged ions. As other molecules gain electrons, they become negatively charged ions. Equal numbers of positive and negative ions are created. The positively charged ions are attracted to the negatively charged electrical plate, while the negatively charged ions are attracted to the positively charged plate. This creates a small ionization current that can be measured by electronic circuitry connected to the plates ("normal" condition in the detector).

Particles of combustion are much larger than the ionized air molecules. As particles of combustion enter an ionization chamber, ionized air molecules collide and combine with them. The reduction in the ionized particles results in a decrease in the chamber current that

is sensed by electronic circuitry monitoring the chamber. When the current is reduced by a predetermined amount, a threshold is crossed and "alarm" condition is established.

The characteristics of an ionization detector make it more suitable for detection of fast flaming fires that are characterized by combustion particles in the 0.01 to 0.4 micron size range.

(ii) Photoelectric Type Smoke Detector

Smoke produced by a fire affects the intensity of a light beam passing through air. The smoke can block or obscure the beam. It can also cause the light to scatter due to reflection off the smoke particles. Photoelectric smoke detectors are designed to sense smoke by utilizing these effects of smoke on light.

Photoelectric Light Scattering Smoke Detector

Most photoelectric smoke detectors are of the spot type and operate on the light scattering principle. A light-emitting diode (LED) is beamed into an area not normally "seen" by a photosensitive element, generally a photodiode. When smoke particles enter the light path, light strikes the particles and is reflected onto the photosensitive device causing the detector to respond. Figure 2.2(a) shows light scattering detector in normal operation and figure 2.2(b) shows the operation when smoke is detected.

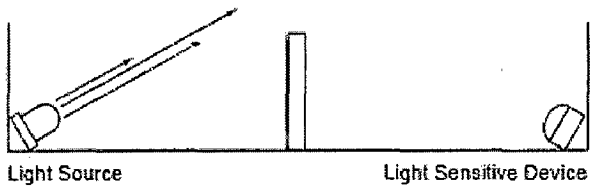


Figure 2.2(a): Light Scattering Detector [9]

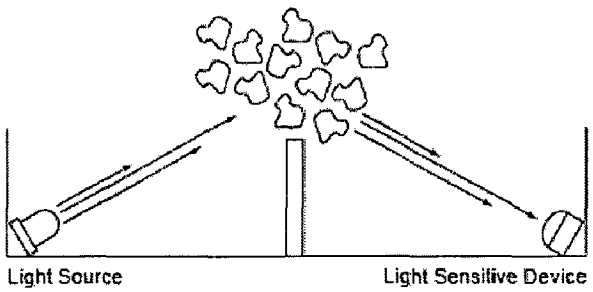


Figure 2.2(b): Light Scattering Detector with smoke [9]

Photoelectric Light Obscuration Smoke Detector

Another type of photoelectric detector, the light obscuration detector, employs a light source and a photosensitive receiving device, such as a photodiode. When smoke particles partially block the light beam, the reduction in light reaching the photosensitive device alters its output. The change in output is sensed by the detector's circuitry, and when the threshold is crossed, an alarm is initiated. Obscuration type detectors are usually of the projected beam type where the light source spans the area to be protected. Figure 2.3(a) shows the light obstruction detector in normal operation and 2.3(b) when smoke is detected.

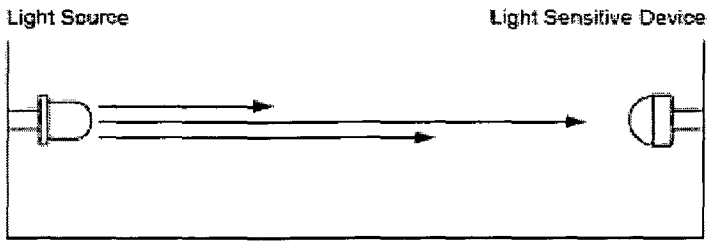


Figure 2.3(a): Light Obscuration Detector [9]

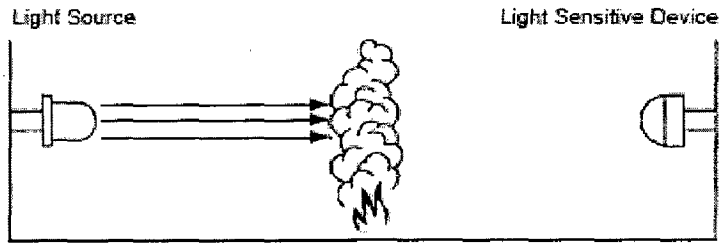


Figure 2.3(b): Light Obscuration Detector with Smoke [9]

Photoelectric smoke detectors are better suited to detect slow smoldering fires that are characterized by particulates in the 0.4 to 10.0 micron size range.

Consider an example of lighted cigarette to see the selection of smoke sensor. A lighted cigarette, for example, will usually produce a slow smoldering fire if it is dropped on a sofa or bed. However, if the cigarette happens to fall upon a newspaper on top of a sofa or bed, the resulting fire may be characterized more by flames than by smoldering smoke.
Photoelectric type smoke detectors are more common in residential complexes.

Advantages

1. The key advantage of smoke detectors is their ability to identify a fire while it is still in its incipient. As such, they provide added opportunity for emergency personnel to respond and control the developing fire before severe damage occurs. They are usually the preferred detection method in life safety and high content value applications.

Disadvantages

1. They are more expensive to install, when compared to thermal sensors.
2. They are more resistant to inadvertent alarms.

Flame detectors are not suitable for residential complexes, hence are not discussed.

System Layout for Smoke Detectors

Smoke detectors are generally categorized as either 2-wire or 4-wire detectors.

Two-wire detectors derive their power directly from the same fire alarm control panel alarm initiating device circuit over which they report an alarm. Because of their dependency on the initiating circuit, 2-wire detectors must be tested and listed for compatibility with the control panel to be used, to ensure proper Operation.

Four-wire detectors are powered from a separate pair of wires, and, like the 2-wire detector, apply an electrical short across the associated alarm initiating device circuit to transmit an alarm. Supervision of the power to 4-wire detectors is mandated through the use of an end-offline power supervision relay. When power is on, the relay contacts of the end-of-line relay are closed and connected in series with the end-of-line resistor beyond the last initiating device. Loss of power at any point in the power supply circuit will cause the relay to de-energize and a trouble condition to occur on the initiating circuit.

2.4.3 Fire Sprinkler System [8]

For most fires, water represents the ideal extinguishing agent. Fire sprinklers utilize water by direct application onto flames and heat, which causes cooling of the combustion process and prevents ignition of adjacent combustibles. They are most effective during the fire's initial flame growth stage, while the fire is relatively easy to control. A properly selected sprinkler will detect the fire's heat, initiate alarm, and begin suppression within moments after flames appear. In most instances sprinklers will control fire advancement within a few minutes of their activation, which will in turn result in significantly less damage than otherwise would happen without sprinklers.

Sprinkler systems are essentially a series of water pipes that are supplied by a reliable water supply. At selected intervals along these pipes are independent, heat activated valves known as sprinkler heads. It is the sprinkler that is responsible for water distribution onto the fire. Most sprinkler systems also include an alarm to alert occupants and emergency forces when sprinkler activation (fire) occurs.

During the incipient fire stage, the heat output is relatively low and is unable to cause sprinkler operation. However, as the fire intensity increases, the sprinkler's sensing elements become exposed to elevated temperatures (typically in excess of 57–107°C (135–225°F), and begin to deform. Assuming temperatures remain high, as they would during an increasing fire, the element will fatigue after an approximate 30 to 120 second period. This releases the sprinkler's seals allowing water to discharge onto the fire and begin the suppression action.

The sprinkler itself is the spray nozzle, which distributes water over a defined fire hazard area (typically 14–21 m2/150–225 ft2) with each sprinkler operating by actuation of its own temperature linkage. The typical sprinkler consists of a frame, thermal operated linkage, cap, orifice, and deflector.

All sprinkler systems require a reliable water source. There should be continuous monitoring of water level and the water pressure, if below than required value, corresponding alarm should be activated.

Some of the Automatic Fire Sprinkler facts are given below [10].

- Automatic fire sprinklers have been in use in the U.S. since 1874.
- Fire sprinklers are widely recognized as the single most effective method for fighting the spread of fires in their early stages - before they can cause severe injury to people and damage to property.
- When one fire sprinkler head goes off to fight a fire the entire sprinkler system does NOT activate. Sprinklers react to temperatures in individual rooms.
- The costs for installing fire sprinkler systems in buildings 6 to 8 stories high ranges from under a dollar to about $2.00 per square foot in most new construction and from about $1.50 to $2.50 per square foot for retrofitting sprinklers in existing buildings.
- The installation of fire sprinklers in new residential construction is estimated to make up around 1% of the total building cost. (Similar to the cost of new carpet)
- According to the National Fire Protection Association, property damage in hotel fires was 78% less in structures with sprinklers than it was in structures without sprinklers during the years 1983-87. (Average loss per fire was $2,300 in sprinklered buildings and $10,300 in unsprinklered buildings.)
- Nearly half of all hotels and motels, according to a 1988 survey by NFPA, have sprinkler systems.
- NFPA has no record of a fire killing more than two people in a completely sprinklered building where the system was properly operating, except in an explosion or flash fire or where industrial fire brigade members or employees were killed during fire suppression operations.

2.5 Standards for Designing Fire Alarm Systems

- National Fire protection Association (NFPA)
- Bureau of Indian standards (National Building Code)

During the selection, installation and maintenance of fire alarm and control system, standards and norms should be followed strictly. Requirements of fire fighting installations can be found in Appendix-2.

Chapter – 3
Powerline Network Technologies

Powerline communications is an emerging networking technology that reuses the house electrical wiring system to link appliances to each other and to the Internet. The idea behind Powerline technology is to control and manage any device that is plugged into an outlet for gathering the electricity they need to operate, including lights, sensors, coffee machines, alarm systems, and television sets. The market potential for such technology is huge, considering that the vast majority of houses worldwide are already wired with electricity lines [4].

Powerline communication carries data on the same wires which are used for electrical power. Typically home-control power line communication devices operate by modulating in a carrier wave of between 20 and 200 kHz into the household wiring at the transmitter. The carrier is modulated by digital signals. Each receiver in the system has an address and can be individually commanded by the signals transmitted over the household wiring and decoded at the receiver. These devices may be either plugged into regular power outlets, or permanently wired in place. Since the carrier signal may propagate to nearby homes (or apartments) on the same distribution system, these control schemes have a "house address" that designates the owner [12].

The Powerline environment is notorious for uncontrolled noise, especially high-amplitude spikes caused by motors, dimmers and compact fluorescent lighting. This noise is minimal during the time that the current on the Powerline reverses direction, a time known as the power line zero crossing. Thus power line communication systems for home networking (e.g. X10 and Insteon) transmit data at zero crossings of A.C. mains.

PLC Advantages

1. Every house/building is equipped with power line wiring. Powerline protocols reuse existing power line wiring. The major advantages of these technologies are that they do not require rewiring of the buildings and are applicable to new and old houses.
2. Low cost.

PLC Disadvantages

1. All devices connected to power line have an adverse effect on communication e.g. TVs, Computers, Vacuum Cleaners, Microwave oven etc.
2. Communication performance may vary between different buildings, neighborhoods, and countries.
3. Impediments to communication are time varying and change throughout the day.

There are number of open specifications for power line networking maintained by different organizations. Still no international standard exists for power line networking. Some of the specifications which are specifically designed for power line networking are discussed in this chapter. Other technologies having power line as one of the physical layer among the multiple physical layers will be discussed in the following chapters.

3.1 X10 [13]

Household electrical wiring—the same which powers lights and appliances—is used to send digital data between X10 devices. This digital data is encoded onto a 120 kHz carrier which is transmitted as bursts during the relatively quiet zero crossings of the 50 or 60 Hz AC alternating current waveform. One bit is transmitted at each zero crossing.

Whether using Powerline or radio communications, packets transmitted using the X10 control protocol consist of a four bit house code followed by one or more four bit unit code, finally followed by a four bit "command". For the convenience of users configuring a system, the four bit house code is selected as a letter from A through P while the four bit unit code is a number 1 through 16.

When the system is installed, each controlled device is configured to respond to one of the 256 possible addresses (16 house codes * 16 unit codes); each device reacts to commands specifically addressed to it, or possibly to several broadcast commands.

Each frame is sent twice in succession to make sure the receivers understand it over any Powerline noise for purposes of redundancy, reliability, and to accommodate line repeaters.

Disadvantages

1. X10 is very slow because X10 uses OOK (on/off keying), where a carrier burst is either present or not present.
2. X10 communication has no built-in mechanism to verify that X10 messages got through—X10 is open loop. Although X10 did eventually define Status Request and Status Response Commands, very few X10 devices actually employ them, and those that do take even more time to send and receive the extra messages.
3. X10 signals usually do not cross power line phases, so you will need some kind of active or passive phase coupler wired into your main electrical panel or plugged into a 220-volt outlet.
4. There are chances that a few times out of a hundred, a controlled light will not go on when you first press the button that you use to control it, called false negative.
5. X10 is also susceptible to false positives, such as lights or appliances going on or off all by themselves, because X10 devices sometimes interpret power line noise as valid X10 commands.
6. There are only 256 combinations of X10 House Codes and Unit Codes, so there can only be 256 logical devices on a power line.

3.2 INSTEON [14] [15]

INSTEON technology is a dual-band mesh topology employing ac-power lines and a radio-frequency (RF) protocol to communicate with and automate home electronic devices and appliances, which normally work independently.

All INSTEON devices are peers, meaning that any device can transmit, receive, or repeat other messages, without requiring a master controller or complex routing software. INSTEON devices repeat one another's INSTEON messages by simulcasting them in precise timeslots synchronized to the power line zero crossing.

Adding more devices not only increases the strength of the simulcast signal, but it also increases the number of available pathways for messages to travel. This path diversity results in highly reliable messaging, so the more devices in an INSTEON network, the better.

On the power line, all messages synchronize to the ac zero crossing via a 131.65-kHz carrier signal as shown in figure 3.1. Other than source and destination code, the messages are of fixed length and contain no other routing information. With standard and extended message sizes of 10 and 24 bytes, respectively, the network provides instantaneous data rates up to13.165 kb/s and sustained speeds to 2.88 kb/s.

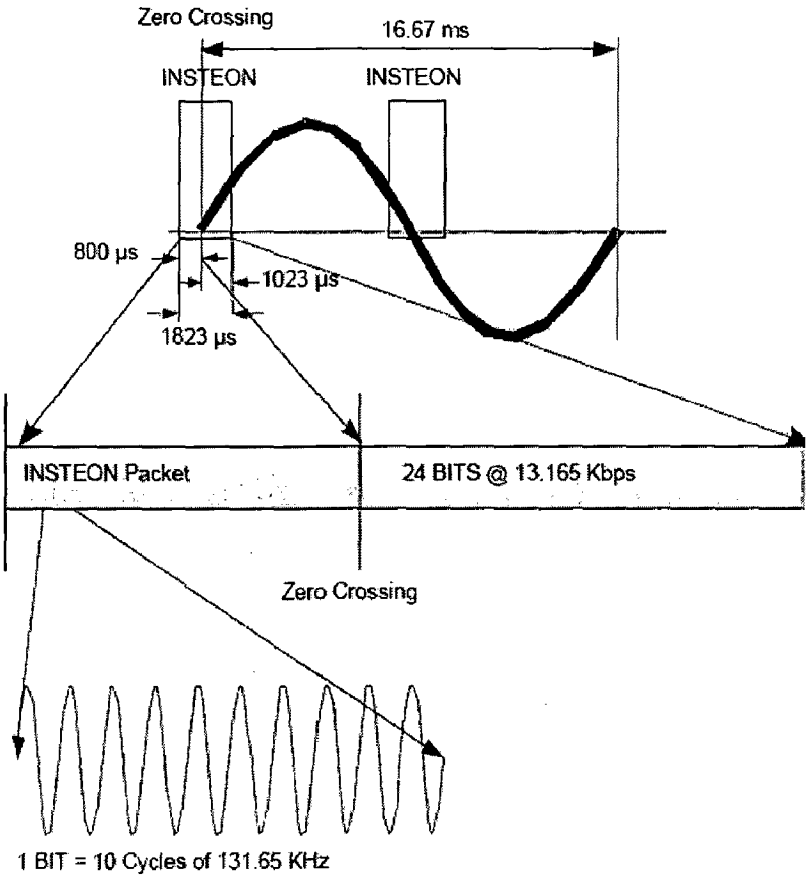


Figure 3.1: Insteon Packet Transmission [15]

3.3 HomePlug [16]

HomePlug is an industry trade group for power line communication. This organization of about 50 companies defines power line communication specifications. HomePlug 1.0 and AV are the two versions of the specification for home networking technology that connects devices to each other through the power lines in a home.

HomePlug Command & Control (*HPCC*) is the latest power line standard released by HomePlug Powerline alliance on October 9, 2007. It's a low-speed; very low-cost technology intended to complement the alliance's higher-speed Powerline communications technologies.

The specification enable advanced, whole-house control of lighting, appliances, climate control, security and other devices

3.4 Design of BA using Powerline [17] [18]

A typical household scenario is shown in Figure 3.2, where various appliances, sensors, utility controls, a telephone interface and a TV screen display are all connected to the power line using power line modem.

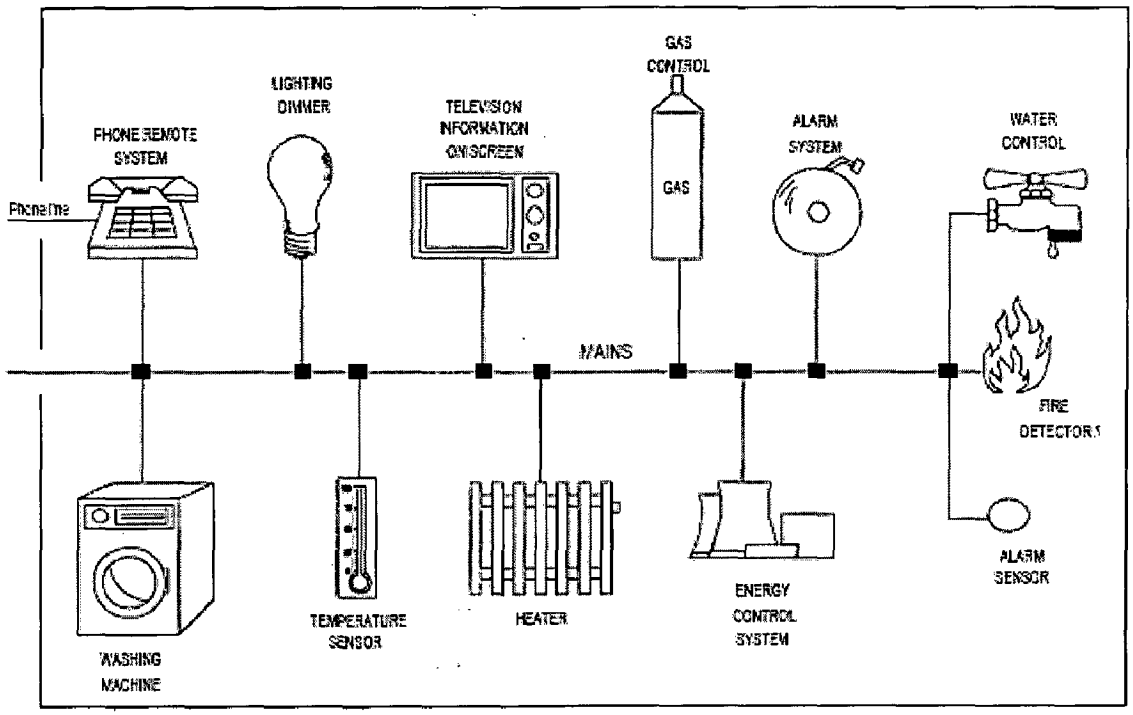


Figure 3.2: Typical Household Scenario on Power Line Communication [19]

The above scenario can be achieved by using power line modems at every electric mains outlet and commands can be issued from a personal computer connected to power line modem using RS232 interface as shown in figure 3.3.

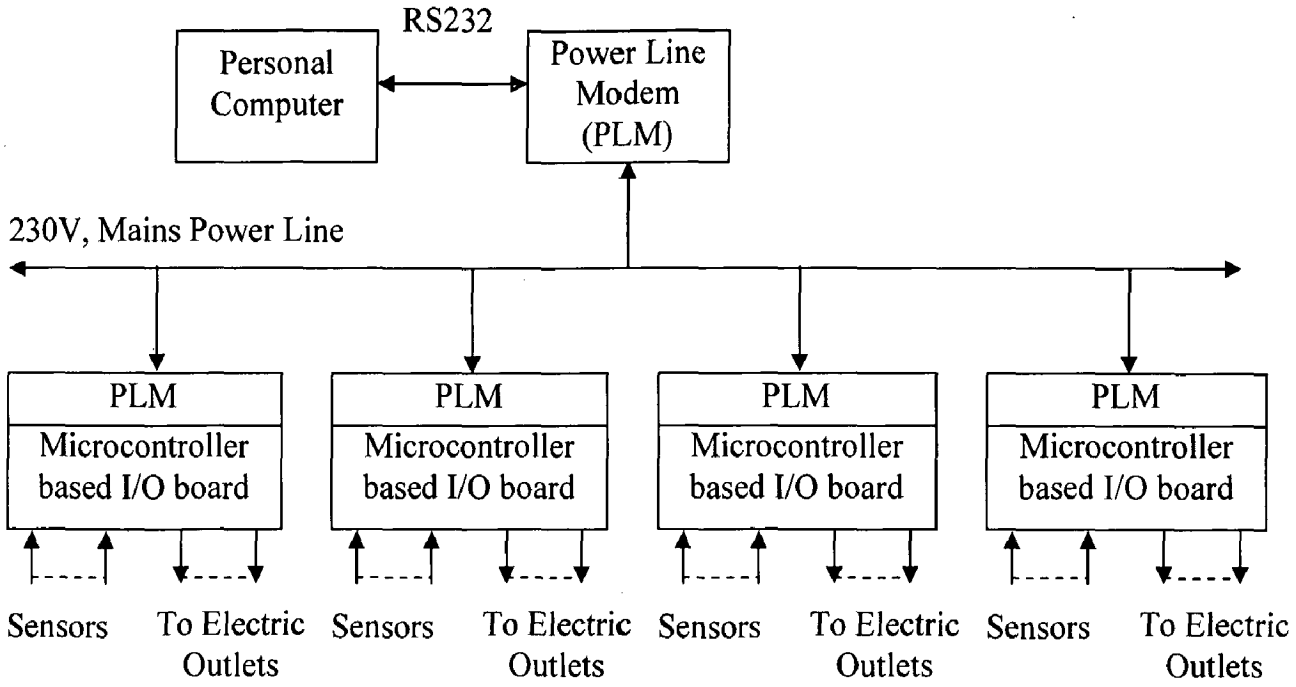


Figure 3.3: Block Diagram of Powerline BA System

The ST7537/ST7538/ST7540 is EHS (European Home System) compliant power line modem from SGS Thomson. The ST7537 transmits and receives data up to 1200bps in half duplex mode using a carrier frequency of 132.45kHz, complying with Europe's CENELEC EN 50065 standard (which specifies the use of 125kHz to 140kHz carrier frequencies for home automation) and US FCC regulations (which specifies the use of carrier frequencies lower than 450kHz). It generates the MFSK modulated signals, supervises the CSMA collision avoidance protocol and provides clock, reset and watchdog to the system.

The CENELEC EN 50065 standard also makes it mandatory the use of CSMA (Carrier Sense Multiple Access) algorithm which allows the coexistence of different systems in this frequency band.

Personal Computer interface with power line modem using RS232 is shown in Figure 3.4 below.

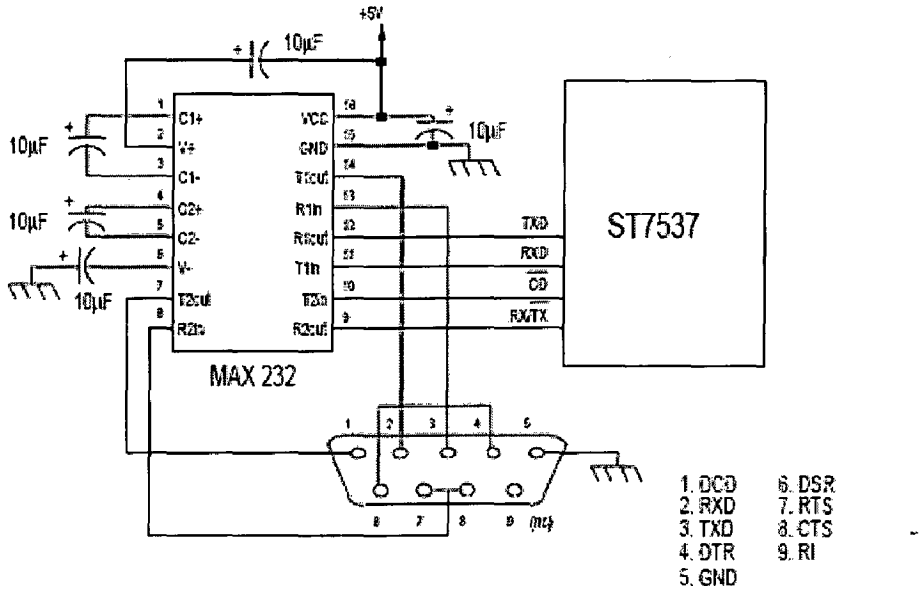


Figure 3.4: ST7537 and RS232 interface [17]

Power line modem board shown in figure 3.5 can be used at mains outlet to control the electric appliances and monitor the digital sensors.

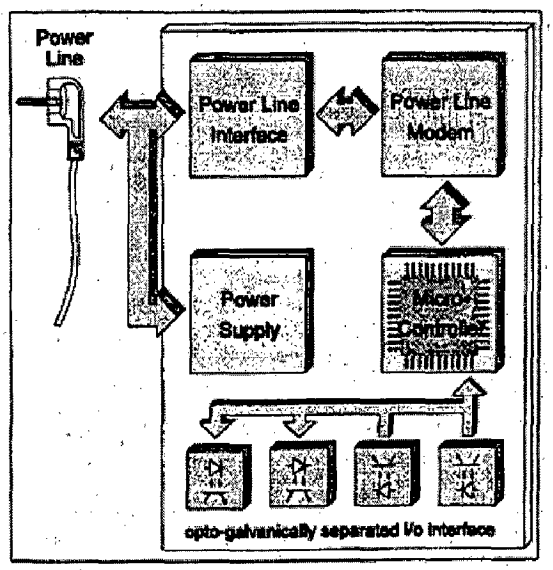


Figure 3.5: Block Diagram of Power Line Modem Board [17]

The common serial data protocols not suitable for power line communication, which use start and stop bits surrounding the data bits for synchronization in between devices. Because of noise on power line these start or stop bits may be lost. Hence protocol like EHS (European Home System) developed for home automation can be used, which uses a leading 16 bit

preamble containing 8 falling and 8 rising edges to synchronize transmitter and receiver instead if using start and stop bits. EHS Powerline datagram is shown in figure 3.6.

EHS defines six different physical medium for exchanging information between electric appliances: Power line, twisted pair (9.6 kBaud), twisted pair 2 (64 Baud, ISDN), coaxial, infrared, and radio frequency. EHS power line defines 2400 half duplex protocol with MFSK (Minimum Frequency Shift Keying).

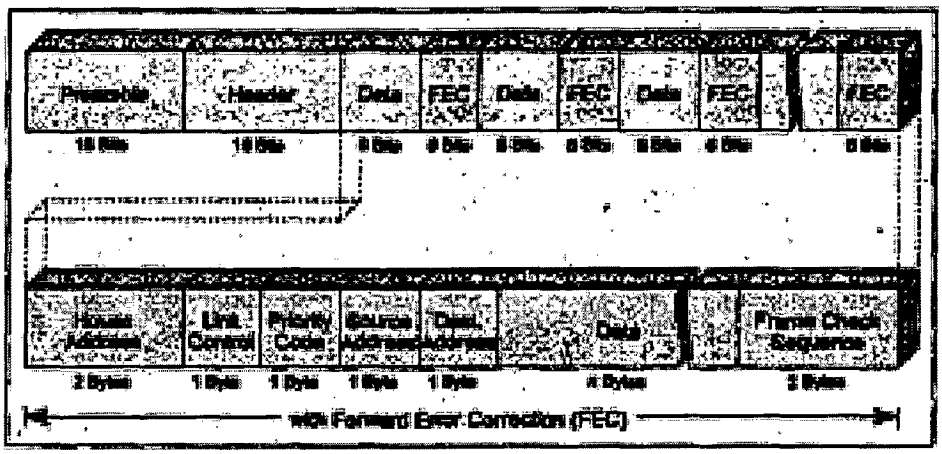


Figure 3.6: EHS Powerline Datagram [17]

A following 16-bit header code allows the reorganization of EHS-datagrams or EHS-acknowledges even if some bits have been destroyed due to noise on the power-line network. Each byte of the following sequence is extended by a 6 bit Forward Error Correction (FEC), hence every 8 data bits are transmitted by a field of 14 bits. The generator polynomial of the FEC (x6+x5+x4+x3+1) is capable to correct up to three succeeding bit-errors within 14 bits. This mechanism is well-suited to compensate disturbances caused by switch mode power supplies or light dimmers, which can generate approximately 1 ms a pulse noise occurring mostly every same phase angle.

Development kits are available from several vendors to quick start with power line modems e.g. EVALST7540-1 reference design board from SG Thomson.

In figure 3.3, although design is shown for a home, but it can be implemented for Building Automation also. In the protocol there should be house address to refer to different house within a building. Distribution transformers block the power line signals. In India, usually

there is one distribution transformer for a small locality. Hence there is no problem of blocking the signal within a building. This is having one adverse affect also. A person from nearby building getting mains power from same distribution transformer may use the same address and can switch ON/OFF the lights of his neighbored residing in nearby building. It is necessary to ensure that power line signal of one building will not interfere with other building (by incorporating some filters in line).

3.5 Automated Home Example

A typical example of automated home is LG Digital Home. It consists of:

- Fridge/freezer
- Microwave oven
- Washing machine
- Air conditioning unit

Fridge is used as a server, as it is always ON and it communicates with other devices via power line (a proprietary protocol known as LNCP).

- TV, music, calendar and recipe books built into fridge
- Recipes can be downloaded from a website and can programme the microwave oven.
- Fridge connects to Internet via DSL.
- Internet grocery shopping
- Microwave oven, Air conditioner and washing machine can be switched on remotely.

Consumer market is very competitive market and the prices of all the appliances have to be low. Addition of automation/networking to the product should not increase its cost substantially. Other wired and wireless technologies may not be suitable at least for consumer electric appliances like Refrigerator, Oven, and Washing Machine etc, because they adds the requirement of wired/wireless protocol along with hardware and also separate cables in case of wired technologies, thus in turn increases the cost of the product. Hence power line communication is expected to be there in home automation system because of its low cost and no need of any additional wiring.

Still there is no world wide standard available for Home Automation on power line; hence there is a strong need of developing such a standard. Companies are developing their own proprietary protocols of power line communication and hence appliances of different make are not interoperable with others on the same network.

Chapter – 4
Implementation of Wired Network for RMS BA

Wired technologies have been tested beforehand for years in the industries, enterprise and business sectors. Wired technologies give highest security and reliability as compared to other technologies. Therefore, it is expected that a large percentage of home networking solutions will be based on these technologies.

Advantages

1. The home networking with special wiring requirements provide a secure way to deploy new services in home networking.
2. Wired protocols support high bandwidth, required for audio and video streaming applications. On the other hand power line and wireless protocols support low data rate.
3. Wired protocols support much higher distances as compared to wireless protocols.
4. Ease, familiarity, accessibility, knowledge, tools are some more advantages of wired protocols.

Disadvantages

1. One of the most daunting costs of home networking is installing new cabling. Putting data cables into new buildings is an expensive and increases the overall cost. On the other hand, rewiring an existing home apartment is difficult and is not a viable solution, especially for brick and stone houses.
2. Maintenance is time consuming as compared to wireless networks.

4.1 BACnet [20], [21]

BACnet is a Data Communications Protocol for Building Automation and Control Networks. BACnet became an ASHRAE/ANSI standard in 1995, and an ISO standard in 2003. It has been designed specifically to meet the communication needs of Building Automation and control systems for applications such as heating, ventilating, and air-conditioning control, lighting control, access control, and fire detection systems and their associated equipment.

This BACnet protocol stack library provides a BACnet application layer; network layer and media access (MAC) layer communications services. It is an open source, royalty-free library for an embedded system, Windows, Linux, or other operating system.

4.1.1 BACnet Architecture

The BACnet protocol is a standard way to send and receive messages on the wire containing data that is understood by other BACnet compliant devices. The BACnet standard defines a standard way to communicate over a number of wires, known as Data Link/Physical Layers: Ethernet, EIA-485, EIA-232, ARCNET, and LonTalk. The BACnet standard also defines a standard way to communicate using UDP, IP and HTTP (Web Services). Figure 4.1 shows the BACnet architecture along with equivalent OSI layers.

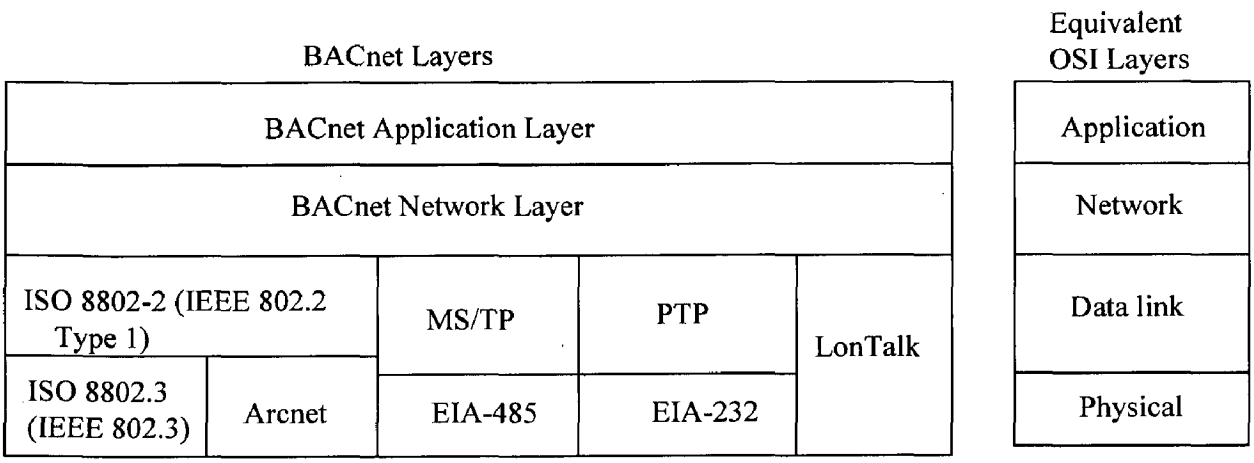


Fig 4.1: BACnet Architecture

The table 4.1 briefly summarizes each physical layer technology. The system cost per node represents the cost of using this technology in a real system including issues like wiring costs, installation costs, the need for repeating devices etc.

Table 4.1: BACnet LAN Configurations Specifications [21]

LAN	system cost per node	speed	pros	cons
Ethernet	high	10-100Mbps	• international standard • already in most buildings • variety of media (UTP, coax, fiber optic) • very fast • easy interface with PCs • no special development tools	• high cost • distance limitations • non-deterministic
ARCNET	med	150K-7.5Mbps	• ANSI standard • deterministic response • scaleable speed • variety of media (UTP, coax, fiber optic) • very fast • no special development tools • high perf for med cost	• single source chip • too costly for low-end unitary controllers • distance limitations
MS/TP	low	9.6K-76Kbps	• ANSI standard • low cost • can be implemented in single chip microprocessor • deterministic response	• single media (EIA-485) • limited speed
PTP	low	9.6K-56Kbps	• only choice for dial-up • specially designed for point-to-point applications • accommodates modern modem standards (V.32bis, V.42)	• point-to-point only • limited speed
LonTalk	low-med	32K-1.25Mbps	• variety of media (UTP, coax, RF, IR, fiberoptic) • scaleable speed	• non-deterministic • distance limitations • single-source chip • special development tools • application size limited

Advantages

- Open Protocol
- BACnet is a software-based protocol so it can run on current and future hardware platforms, making it forward-compatible with future generations of systems. This gives vendor-independence and Using BACnet/IP decouples the logical network from the physical network and provides maximum flexibility of physical network choice, now and in the future.
- BACnet/IP can communicate with different local-area-network (LAN) technology for transporting BACnet application messages via BACnet routers. These types of supplier and LAN choices give the system designer or owner significant flexibility in choosing the best fit among price/performance options that suits each situation.

Disadvantages

- No Standardized Programming language. Proprietary Programming Tools must be bought from each manufacturer.
- No Standardized configuration tools. Proprietary configuration tools must be bought from each manufacturer.
- Expensive for manufacture to develop.

4.2 LonWorks [22]

LonWorks is a networking platform specifically created to address the unique performance, reliability, installation, and maintenance needs of control applications. The platform is built on a protocol created by Echelon Corporation for networking devices over media such as twisted pair, Powerline, fiber optics, and RF. It is popular for the automation of various functions within buildings such as lighting and HVAC.

LonWorks system is distributed control system that enables peer to peer and master/slave communication among the intelligent devices. LonWorks control networks offer a feature called "distributed processing" whereby each device in the network can receive, transmit, and process network information independently of other devices. This means that devices in a LonWorks control network can make decisions and process information without the need for a central processor. Eliminating the need for a central processor reduces the total cost of a

LonWorks control network. It also makes the network more reliable since a failed device does not shut down the rest of the control network. Another key advantage of LonWorks control networks is that the protocol, or language, used to communicate between devices is an open, published protocol accredited by international standards bodies. The major elements of LonWorks are Lontalk Protocol, Neuron chip, Lonwork Transceiver and Network management and applications software.

4.2.1 LonWorks Architecture (ANSI/CEA-709.1)

Key characteristics of the LonTalk protocol include media independence, transaction acknowledgement, peer-to-peer communication, sender authentication, priority transmissions, duplicate message detection, collision avoidance, automatic retries, mixed data rate support, client/server support, foreign frame transmission, data type standardization and identification, unicast/multicast/broadcast addressing, mixed media support, and error detection & recovery.

The LonTalk protocol supports authenticated communications, an essential feature for any home application, automatic meter reading system, security alarms, and remote control devices to prevent unauthorized control of the network. Lontalk protocol defines all layers of OSI model. Physical layer is explained below.

Layer 1-Physical: Electrical Connection

This layer addresses specifics of wiring and connections. The specification of the 78 kbps twisted pair media with 2000 meter range, 64 nodes per network segment, and network isolation characteristics is an example of one physical layer type of media. LONWORKS technology provides many different communications media options including 1.25 Mbps twisted pair, power line, fiber optic, and RF.

The two-wire layer operates at 78 kbit/s using differential Manchester encoding, while the power line achieves either 5.4 or 3.6 kbit/s, depending on frequency.

Advantages

- Standard Programming tools.
- Simple for manufactures to implement through standardized tools and the protocol

which is preconfigured on neuron chip.

- ❖ Permits Reconfiguration within the System.
- ❖ Ensures Communication in Noisy Conditions enhances System Reliability
- ❖ Interoperability
- ❖ Allows for Flexible Topology, and Supports Multiple Media.

Disadvantages

- ❖ Not scalable. Limited by size of neuron chip.
- ❖ Suitable for device level network.
- ❖ No facility for programming complex algorithms
- ❖ Proprietary wiring system and Proprietary Hardware.
- ❖ Neuron chip must be purchased with licensing fee to Echelon.

4.3 KNX [23]

KNX standard is the world's first open and platform independent standard for home & building control, approved as a European (EN 50090 - EN 13321-1) and a Worldwide standard (ISO/IEC 14543).KNX is OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards called the European Home Systems Protocol (EHS), Batibus, and the European Installation Bus (EIB). The KNX standard is administered by the Konnex Association. The standard is based on the communication stack of EIB but enlarged with the physical layers, configuration modes and application experience of BatiBUS and EHS.

The EIB/KNX bus system is useful for measuring, controlling, signaling and monitoring. This system does not require a central station. Its actuators, sensors, switches, displays, control units, interfaces etc. are connected by bus lines on which information can exchange.

4.3.1 KNX Architecture

KNX is OSI-based network communications protocol for intelligent buildings. It defines Physical, Data Link, Network, Transport and Application layers and does not define session and presentation layer. The architecture of KNX is shown in figure 4.2.

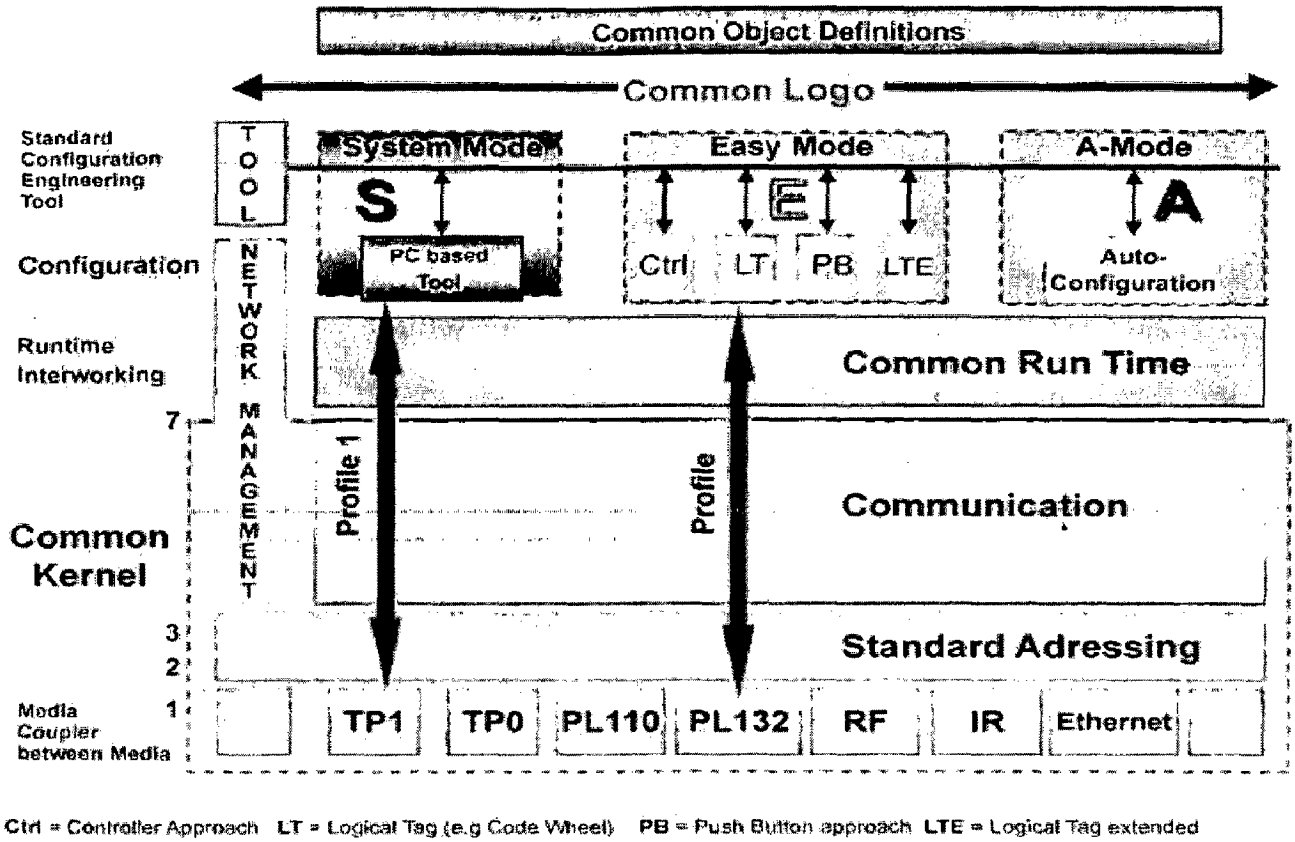


Figure 4.2: KNX Architecture [23].

Physical Layer

a) $\mathbf{TP_0}$,(Twisted pair, type 0)inherited from BatiBUS, and $\mathbf{TP_1}$, (Twisted pair, type 1) basic medium of EIB, provide both improved solutions for twisted pair cabling.

Main characteristics are:

- data and power transmission with one pair (devices with limited power consumption may be powered by the bus),
- Asynchronous character oriented data transfer and half duplex bi-directional communication.
- $\mathbf{TP_0}$, transmission rate is 4.8kbits/s while $\mathbf{TP_1}$ is 9.6 kbits/s.
- Both media implement CSMA/CA collision avoidance.
- All topologies may be used and mixed (line, star, tree)

b) $\mathbf{PL_{110}}$, (Power-line, 110 kHz) from EIB, and $\mathbf{PL_{132}}$, (Power-line, 132 kHz) from EHS, enable communication over the mains supply network.

Main characteristics are:

- Spread frequency shift keying signaling,
- Asynchronous transmission of data packets
- Half duplex bi-directional communication.
- Data rate: $\mathbf{PL}_{110}$=1200 bits/sec; $\mathbf{PL}_{132}$= 2400 bits/sec.
- Both media implement CSMA

c) RF has been fully specified within KNX, and enables wireless communication in the 868 MHz bandwidth.

Main characteristics are:

- Frequency shift keying signaling.
- Asynchronous transmission and half duplex bi-directional or unidirectional communication.
- Data rate: 38.4kbits/s.
- Medium access is based on CSMA mechanism.

d) Ethernet (KNXnet/IP)

This widespread communication medium can be used in conjunction with the "KNXnet/IP" specifications, which allow tunneling of KNX frames encapsulated in IP frames.

e) IR has been taken over from EIB as associated standard and shall serve as basis for future implementations.

Advantages

- International Standard CELENEC, CEN, ISO/IEC, ANSI
- KNX simplifies electrical installation and reduces cable lengths(reduced fire risk)
- Interoperability
- Installation is possible in small and large buildings.
- Save Energy
- Platform Independent: KNX can be realized on any micro processor
- Flexibility for future extend

4.4 MODBUS [24] [25]

MODBUS is a serial communications protocol published by Modicon in 1979 for use with its programmable logic controllers (PLCs). It has become a de facto standard communications protocol in industry, and is now the most commonly available means of connecting industrial electronic devices.

4.4.1 Architecture

MODBUS is an application layer messaging protocol, positioned at level 7 of the OSI model that provides client/server communication between devices connected on different types of buses or networks.

- TCP/IP over Ethernet
- Asynchronous serial transmission over a variety of media (wire: EIA/TIA-232-E, EIA-422, EIA/TIA-485-A; fiber, radio, etc.)
- MODBUS PLUS, a high speed token passing network.

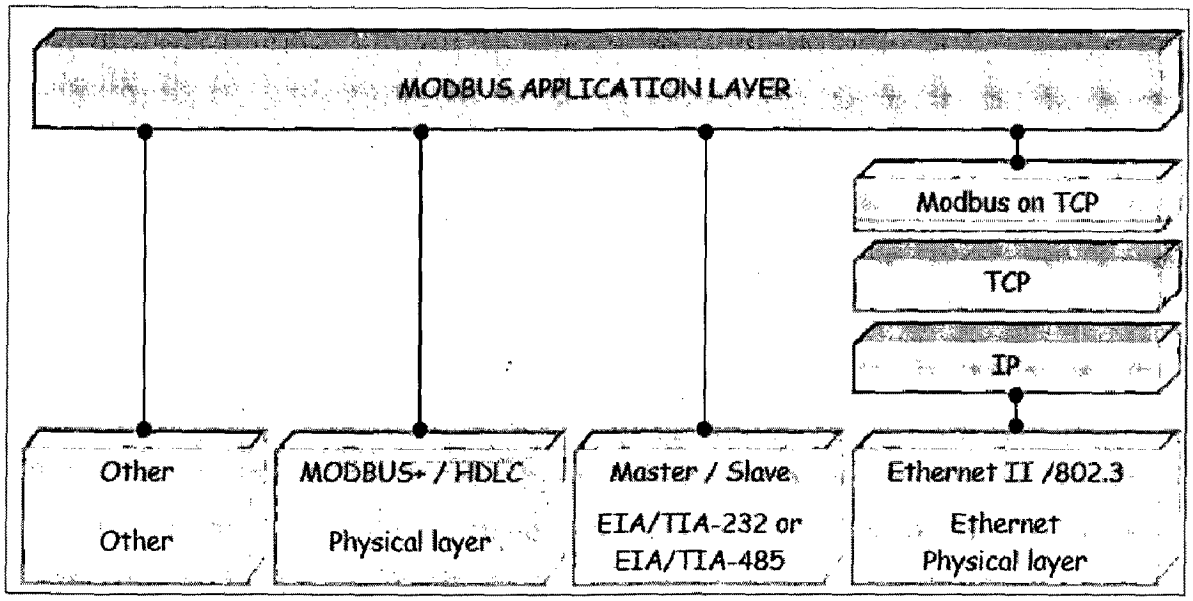


Figure 4.3: MODBUS Communication Stack [25]

The MODBUS protocol allows an easy communication within all types of network architectures.

Advantages

- Simple protocol
- Interoperabilty
- Multiple media
- MODBUS on Ethernet allows High Speed performance

Disadvantages

- MODBUS on serial network is not fast.
- Does not support for advanced Building Technology needs.
- Since MODBUS is a master/slave protocol, there is no way for a field device to "report by exception" (except over Ethernet TCP/IP, called open-mbus)- the master node must routinely poll each field device, and look for changes in the data. This consumes bandwidth and network time in applications where bandwidth may be expensive, such as over a low-bit-rate radio link.
- MODBUS is restricted to addressing 254 devices on one data link, which limits the number of field devices that may be connected to a master station (once again Ethernet TCP/IP proving the exception).

4.5 C-Bus [26] [27]

C-Bus is a home and Building Automation protocol that is used primarily in Australia, although it is also currently used throughout Asia, Russia, USA, South Africa and the UK. C-Bus was created by Clipsal Integrated Systems division for use with its brand of home automation and building lighting control system. C-Bus is a microprocessor-based control and management system for Buildings and Homes. It is used to control lighting and other electrical services such as pumps, Audio Visual Devices, Motors, etc. To ensure fast and reliable operation, each C-Bus device has its own in-built microprocessor and "intelligence", allowing units to be individually programmed.

The C-Bus system is available in a wired version and a wireless version. There is a gateway to allow messages to be sent between wired and wireless networks.

4.5.1 C-Bus Network Wiring

- The wired C-Bus system uses a standard category 5 UTP (Unshielded Twisted Pair) cable as its network communications cable. The category 5 C-Bus network wiring uses free topology architecture. The Bus not only provides the means of communication between units, but also the small amount of power needed to operate the circuitry within each C-Bus unit.
- The maximum length of cable used on a C-Bus network is 1000 metres, however this is easily extended using C-Bus Network Bridges. Up to 100 units can be installed on a C-Bus network and this can also be extended using Network Bridges.
- The maximum number of C-Bus networks in one installation is 255 (note that this limitation does not apply if a C-Bus Ethernet Interface is utilised, the system size is then limited to IP Addressing only). The maximum number of networks connected in series to the local network via Network Bridges is seven (i.e. using six network bridges).
- Each standard C-Bus unit requires 18mA @ 36Vdc to operate. However some C-Bus units require up to 40mA.
- More than one C-Bus power supply can be connected to a C-Bus network to provide sufficient power to the C-Bus units, the C-Bus power supplies will share the load evenly.
- Each C-Bus network requires a network burden. A Network Burden (1,000 Ohm resistor in series with 10uF 50V electrolytic capacitor) must be connected across each network to ensure the correct electrical characteristics. This Network Burden acts as an a.c. filter. A Network Burden has been built in to certain C-Bus units.
- Each C-Bus network requires at least one system clock generating unit for data synchronization.
- The isolation between the mains supply circuitry and the 36V dc C-Bus circuitry is greater than 3.5kV. This is achieved using double wound transformers and opto isolators. This means the C-Bus wiring, connections and circuitry can be considered Extra Low Voltage.

The C-Bus Open Protocol is available at no-cost through the C-Bus Enabled Program, however it is necessary to agree to a license agreement. It is also possible to become a C-Bus enabled partner; this requires payment but provides a greater level of support for product development and certification.

Advantages

- Highly robust and reliable control system
- A single C-Bus cable connection can control an unlimited number of devices.
- Ultimate flexibility in switching and control – functions can be changed, added, removed, moved, reprogrammed, at any position on the network, at any time without any bulk hard-wiring.
- C-Bus is simple to install and less cost.
- C-Bus can control any type of load, digital and analog.

4.6 Comparison of Wired Network Technologies

Table 4.2 shows the comparison in between all the previously discussed networking technologies. Most of new technologies designed for Building Automation support multiple physical media i.e. power line, wire and wireless networking e.g. BACnet. LonWorks and KNX. Modbus is the oldest networking technology, low cost and easy to implement.

Table 4.2: Comparison of wired Network Technologies [28]

Parameter	BACnet	Lonwork	KNX	C-bus	Modbus
Abbrevation	Building Automaton Network	Local Operating network	Konnex	Clipsal-bus	_
Available since	1995	1988	During 1980's EIB. KNX: 1999	During 1990's	1979
Maintained by	ASHREA	Echelon	Konnex Association	Clipsal's Integrated Systems	Modicon
Standards	ASHRAE/ANSI In 1995. ISO in 2003	Lontalk: ANSI/CEA-709.1, Lonwork/IP	ISO/IEC 14543, EN 50090, EN 13321-1	No inter-national standard	No inter-National Standard

		ANSI/CEA-852.			
Parameter	**BACnet**	**Lonwork**	**KNX**	**C-bus**	**Modbus**
Level	Management, Automation, Field.	Only for device level.	Management, Automation, Field.	Device level	Device Level
Layers of OSI model	1,2,3,7	1,2,3,4,5, 6,7	1,2,3,4,7	----	1,2,7
Open	Yes	Yes	Yes	Yes	Yes
Media	ARCnet, PTP, MS/TP, LON-Talk, Ethernet	TP, PL, RF, Coaxial, Fiber Optics	Twisted Pair, PL, RF, IF, Ethernet	Cat5-UTP	RS-485, RS-232, Ethernet, Fiber, RF
Topology	No Fixed. Bus, Hierarchically	Bus, star, Ring & other combination	Linear, star, Ring, and Combination	Free	Bus
Message Destination	Unicast, Broadcast	Unicast, Multicast, Broadcast	Unicast, Multicast, Broadcast	Unicast, Broadcast	Unicast, Broadcast
Error Detection	CRC	CRC	CRC	----	RTU:CRC ASCII:LRC
Speed (bps)	TP:76kbps ARCnet:156 Kbps, Ethernet:10 Mbps.	TP:78kbps PL:5.4 or 2.6kbps Based on frequency	RF:16.4kbps (FSK) @868.3Mhz. TP0:4.8kbps TP1:9.6kbps PL110:1.2kbps PL132:2.4kbps	500 bps	Not specified. Mostly 19.2kbps, 9.6kbps
Inter-operability	Yes	Yes	Yes	Yes	Yes
Central Controller	Yes	Not required	Not Required	Not Required. Used for Additional Features.	Yes
Lighting, HVAC, security	ALL, but mostly For HVAC	Yes	Yes	Yes	Yes

4.7 Design of Residential Multi-Storied BA System

The Hill-View Building at IIT, Roorkee has four complexes (each having 28 apartments), two of which were constructed in June 2005 and other two in January 2006. The building has all framed structure duly designed for earthquake resistance, electrical installation Ethernet cabling, telephone cabling and power points. Presently all residents access Internet by using ADSL modem on telephone line. Hence the cables provided for Ethernet are not used presently.

The following section describes the design proposed for the automation of Hill-View Building at IIT, Roorkee.

4.7.1 Design Objectives

In almost all the residential buildings, there is large electricity wastage because of not switching OFF the lights in the common area (Corridors, Lawn, and Parking) during the day time. Either switching of lights is manual or in some cases it is time based. Timer based will switch ON/OFF the lights at specified times only. They will not switch ON the lights in cloudy scenes even though it is required. And also timer needs to be reset during season change since sunrise and sunset times are changing. The N.C. Nigam Guest House (IITR) lights are also timer based. So, optimum design is to switch the lights based on the ambient light level. This saves lot of electricity. Design objectives of Hill View Building Automation system are as follows.

1. Energy Conservation by switching OFF the lights when not required.
2. To provide security to the occupants from intruders.
3. To provide safety against fire (fire detection, alarming and control), Gas leakage detection etc.
4. Remote operation i.e. control of any electric appliance from central location within the building or from outside building.
5. Access to Digital Entertainment library
6. Simple and user friendly HMI
7. Low Cost solution
8. Simplicity of solution
9. Future expandability

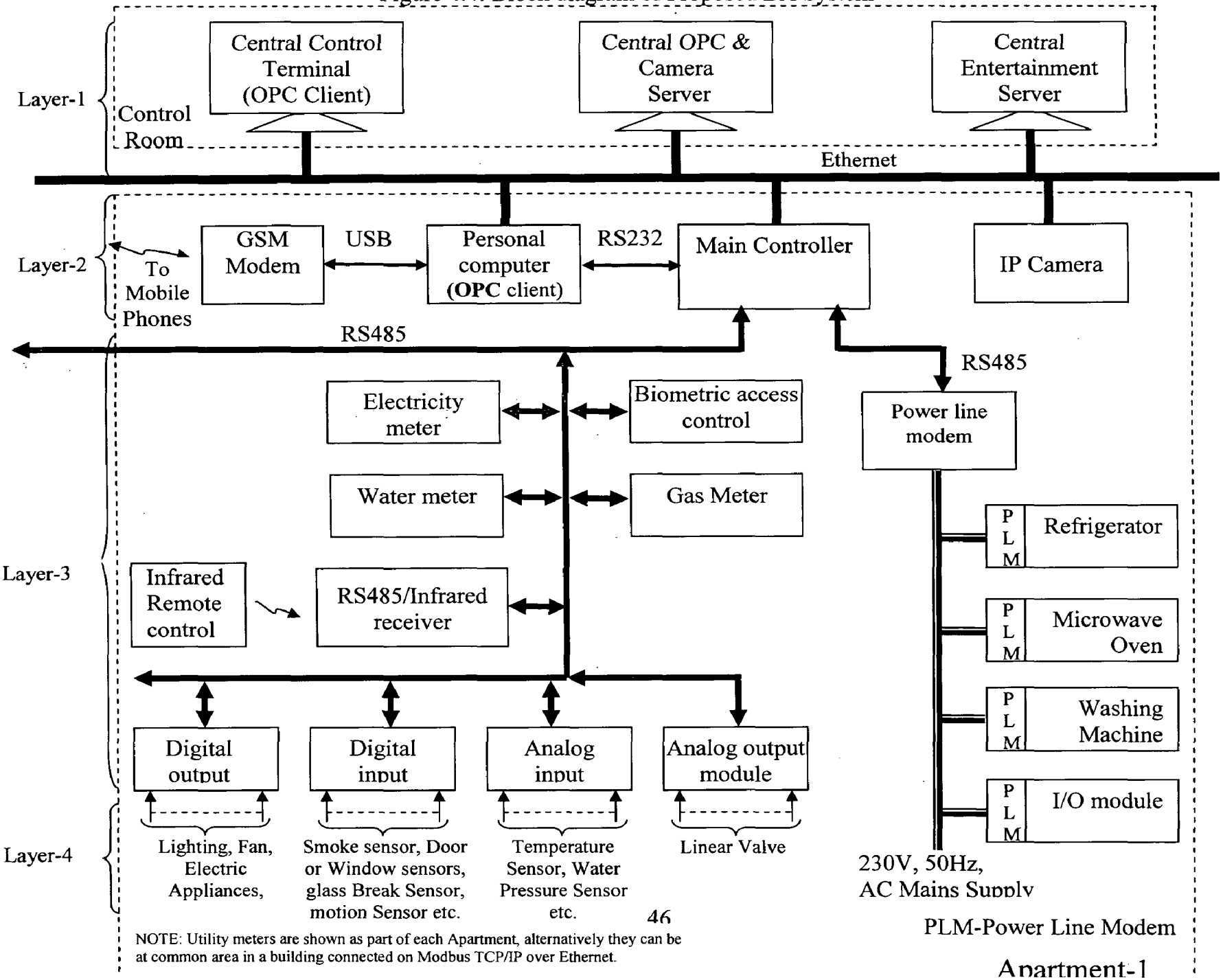
4.7.2 Hardware Design

Building Automation network is divided into four layers. The central server and workstations having HMI are on the top layer (Layer-1) and are connected on Ethernet. Layer -2 is having Main Controller (ADAM-6500), IP camera and Personal computer within each apartment again connected on Ethernet. Hill View Building is already having Ethernet cabling which gives network connectivity at Layer-1 and Layer-2. Layer-3 consists of Analog and Digital I/O modules connected to main controller on RS485 network, Powerline network (discussed in Chapter-3) connected to main controller by RS485 line. The Layer-4 consists of all the sensors (Motion Detector, Glass Break detector, Door/Widow sensor, Ambient light sensor etc.), controls (230V, 5A Relay modules to Switch ON/OFF fans, electric appliances) and their interface circuitry. Figure 4.4 shows the block diagram of the proposed Hill View Building Automation system.

Modbus is selected for layer-3 because it is the oldest networking technology and most widely used in industries. Modbus products are available in a wide range almost for every industrial application and cost is low when compared to other networking technologies. Modbus being oldest one, lot of expertise is available as compared to latest technologies. It is very easy to extend the system in future by just adding the modules in multi drop manner on RS485 network. Hence for buildings automation Modbus is a good choice at device level because high speed is not a requirement at layer-3. Modbus modules form a RS485 network in half duplex manner using a single twisted pair cable.

A remote control adds luxury of controlling the appliances connected to network from anywhere within the room. An IR remote control and receiver combination is proposed in the design. IR receiver should be able to interpret the commands sent from remote control device, translate the commands to MODBUS protocol and sent them on the RS485 network. A simple microcontroller based IR receiver and remote control device combination can be designed easily if not available in the market.

Figure 4.4: Block diagram of Proposed BA System



NOTE: Utility meters are shown as part of each Apartment, alternatively they can be at common area in a building connected on Modbus TCP/IP over Ethernet.

ADAM-6500 integrates the power line network and Modbus network. Power line network is connected to ADAM-6500 on a separate RS485 port as the protocol of power line network has to be different than Modbus protocol because of the reasons discussed in Chapter-3. ADAM-6500 monitors the Input modules on both networks and generates control signals as programmed.

a) Features of Main Controller (ADAM-6500)

- Provides web connectivity
- TCP/IP support RJ45 connector
- Integrated web server
- Integrated OPC server
- Fault and event notification vie Email or pager
- On line alarm viewing
- 5 Serial communication ports (3-RS232 and 2-RS485)

Each apartment is having a PC, one ADAM-6500, one IP camera (for 24X7 video surveillance), all connected on Ethernet. ADAM-6500 have integrated OPC server. OPC client (developed in LabVIEW) is on PC and resident can issue commands from PC to control each electric appliance connected on network.

Remote operation of Building Automation system can be based on Internet or on wireless network such as GSM. Main control room is connected to Internet by using a Public IP. Hence control is possible from Internet by using web publishing tools. Remote operation and event notification is provided by GSM network, which has a very vast coverage and almost everyone is connected to GSM network by mobile phone. SMS (Short Message service) provided by GSM, is a very low cost service and hence is used for remote operation.

b) Apartment Automation

Automation of apartment lies at layer 2, 3 and 4. All the apartments are connected to control room by Ethernet. Main features of apartment automation are explained below.

(i) Lighting control of apartment is integrated to network as compared to standalone lighting control of corridors. Residents can remotely control the electric appliances from anywhere within the building and from mobile phones from outside. Residents can define the various light scenes to create a particular environment. Within an apartment, lights/exhausts in toilets are controlled automatically depending on occupancy. Resident can set the duration of ON time.

(ii) Entertainment: Each resident can view video movies and listen songs on PC in his apartment from the Digital Entertainment library in control room. Each apartment is connected to control room by high speed Ethernet at Layer-1, hence video downloading is not a problem.

(iii) Security: Each apartment is having Motion Detectors, Glass Break Detectors, Door/ Window Sensors and an IP camera. Two modes are there for each apartment Stay and Exit. In Stay mode, security sensors are bypassed and in Exit mode, if any event is detected a signal is sent to control room within building and messages are sent on selected mobiles numbers giving the type of event. IP camera is having I/O connector and can start recording immediately when triggered either by an external event connected on Input pin or by internal motion detector. Similarly one can generate alarm remotely connected to IP camera on Output pin.

An IP camera is also provided at main entrance of the building along with security person so that each resident can see the persons wanted to meet him and even can talk to them.

A biometric access control at main entrance of each apartment is proposed in the design. Door should be opened either by Key or by biometric (finger print) recognition.

(iv) Safety: Smoke sensors are provided on the ceiling in each room and manual call points are given in corridors and stairs. Safety system is integrated to Building Automation system. If any smoke sensor is activated, alarm is generated and messages are sent to selected mobile numbers and signal goes to control room. Smoke sensors only gives a warning signal on fire detection, whereas sprinkler system controls the fire automatically. A sprinkler system is designed for each apartment to control the fire.

Water level sensors and water pressure sensors are integrated to automation system to ensure sprinkler system gets sufficient water at required pressure when required. Figure4.5 shows a typical sprinkler system designed for the apartment.

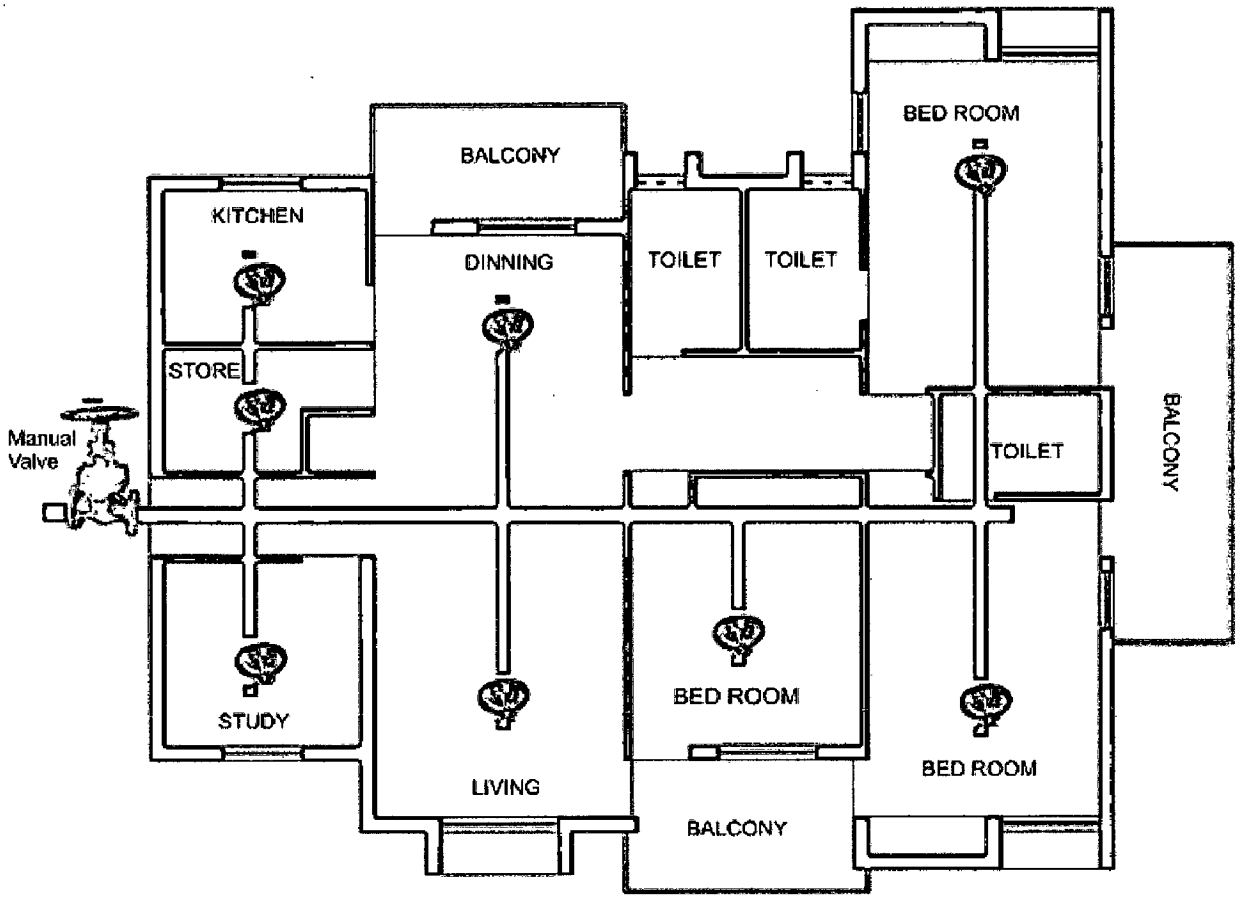


Figure 4.5: Layout of Fire Sprinkler System for Hill View Building Apartment

c) Common Areas Automation

Common areas include all the corridors, parking space and Lawns. Main features of common area automation are explained as follows.

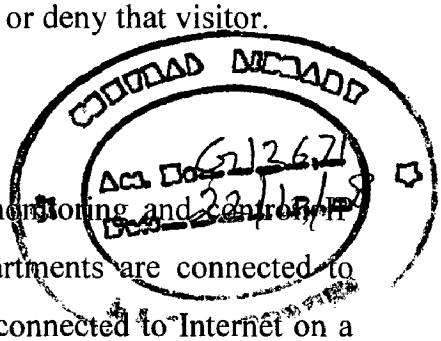
(i) Lighting Control: Use of photo sensors (LDR in our case) to sense ambient light and use of motion detectors to sense any motion in corridors.

Lights are divided into zones and are having two modes, dim mode and bright mode. When ambient light is low e.g. during evening/night, some of the lights will be switched ON automatically in the corridors giving dim light. When any motion is detected in a zone along with low ambient conditions then only all lights of that zone will be switched

ON i.e. bight mode. After set time has been elapsed, lights will again come back to dim mode as one can pass easily from corridors in a short time. Lighting control of corridors is standalone and need not be connected to network. Lighting control of Lawns is controlled based on ambient light level.

(ii) Safety: Manual call points and hooters are given in all corridors and stairs. There is no need of sprinkler system in these areas as there is not any combustible material in stairs or corridors.

(iii) Security: An IP camera having microphone and speaker is provided at main entrance of the building along with security person. Whenever any visitor comes at security office, security person will call the respective resident for whom visitor has come. Then resident can see the visitor on his PC, can do the conversation (as main gate IP camera supports voice communication), and can tell the security person to allow or deny that visitor.



d) Control Room

Control room is having a server machine, workstation for monitoring and control, IP Camera server and Digital entertainment server. All the apartments are connected to control room by Ethernet and Main server in control room is connected to Internet on a public IP so that Building Automation system can also be accessed from Internet. Workstation has HMI (OPC client) by which supervisor can monitor smoke sensors of all the apartments, monitor apartments in exit mode and issue control commands to the apartment for which he has authorization. A supervisor in control room can monitor all the events of corridors. Each apartment resident can give access of controls and monitoring of his apartment to the supervisor depending on his choice.

IP camera server will start recording of the zone for which IP camera has been triggered by event detection. Any resident can monitor his home from Internet as server machine is connected to Internet on public IP.

4.7.3 Software Design

a) OPC (OLE for process control)

OPC is used as a communication standard because of the following advantages of OPC:

- OPC standardizes the communication of process control data
- OPC standardizes on a technology rather than a product
- OPC provides true interoperability and scalability
- OPC provides a fully scalable system for the future.
- OPC considerably minimizes the effort involved in software development and maintenance.
- OPC is powerful, flexible and user-friendly.
- OPC is established around the world with millions of installations.
- OPC follows the client/server approach.
- OPC enables communication between several servers and clients at the same time.
- The OPC client and OPC server can run on the same or different computers.
- OPC enables remote access via DCOM or XML/HTTP.

OPC is a published industrial standard for system interconnectivity. The OPC Foundation maintains all the OPC specifications. OPC stands for OLE for Process Control. It uses Microsoft's COM and DCOM technology to enable applications to exchange data on one or more computers using client/server architecture. OPC defines a common set of interfaces. So applications retrieve data in exactly the same format regardless of whether the data source is a PLC, DCS, gauge, analyzer, software application or anything else.

b) OPC for Modbus

OPC servers for Modbus are installed on PC. OPC client can be made in VB, in LabVIEW (giving good graphical user interface) or in any other supported platform. Another advantage of using OPC is that each apartment owner can choose the client depending on his budget; he may go for a low cost client or a high ended client depending on his requirements and budget.

All the Modbus modules within an apartment are connected to personal computer through OPC server.

Client of each apartment has to be password protected and can't be accessed remotely without password.

c) Human Machine Interface (HMI) in LabVIEW

HMI acting as OPC client is developed using LabVIEW graphical software. The aim was to design a HMI which should be user friendly. From the graphical panel user should be able to control and easily identify the type of event and location of event. For that a LabVIEW library for building controls and indicators like FAN, CFL (Compact Fluorescent Lamp), Door sensor, Smoke sensor, Motion Detector etc. has been created. By implementing these controls and indicators on apartment floor plan, a user friendly graphical interface is developed. Figure 4.7 shows the client HMI for Building Automation.

4.8 Laboratory Implementation

During the implementation of Building Automation system, aim was to satisfy most of objectives of the design proposed for Hill View Building. The Building Automation is implemented in Instrumentation and Signal Processing Lab (I & SP Lab). System is a four layer model. At top layer (Layer-1), client machines are connected on Ethernet LAN. Layer-3 consists of a PC acting as mains controller, having OPC server and OPC client on same system and an IP camera connected on LAN. At layer-2 Data acquisition and control modules are connected on RS485 network in half duplex manner. And at lowest layer Layer-4, field devices are connected e.g. smoke sensors, Motion detectors, Glass Break Sensors, Door/Window Switches, LDR, Relays etc. Remote control and event notification is provided by GSM network. Main features are:

1. CFLs and Fans are connected to the implemented Building Automation system. CFLs are programmed to be automatically ON depending on the ambient light level to give dim mode.
2. CFL at main entrance is programmed to be ON when motion detection is there and as well ambient light level is low i.e. bright mode.
3. Smoke sensors give fire detection notification on selected mobile numbers.

Block diagram of implemented automation system is shown in figure 4.6.

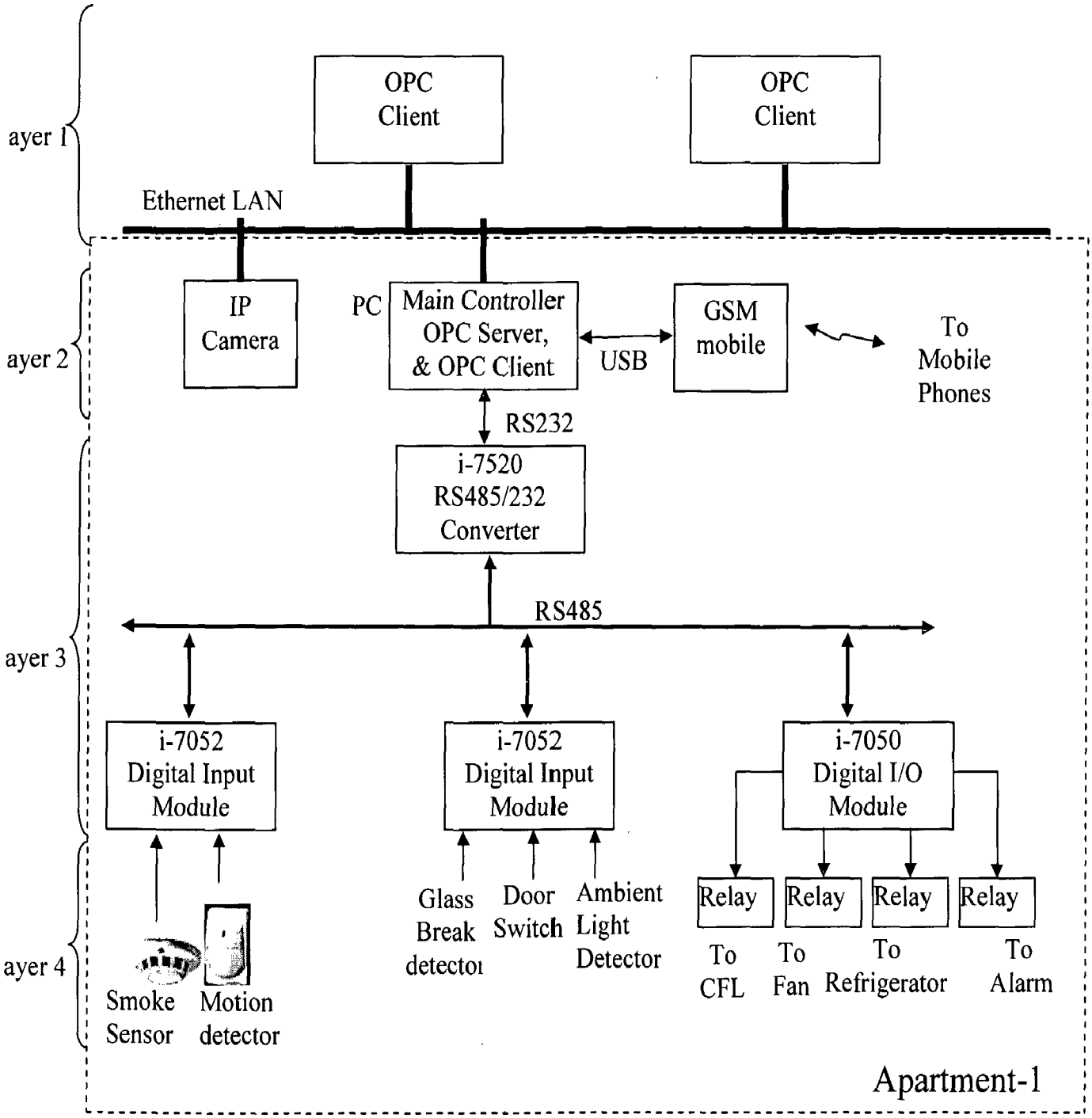


Figure 4.6: Block diagram of Implemented Wired BA System

a) Hardware and Software Design

Following is the list of the hardware modules and sensors used to implement the Building Automation system.

1. i-7050D Digital input and Output Module
2. i-7052D isolated digital input module
3. i-7520 RS485 to Rs232 converter
4. Motion detector RX-40
5. Smoke Sensors
6. Door/Window sensors
7. Glass break detector
8. Micro push button switches to simulate input sensors not available
9. LDR and interfacing circuit
10. 230V, 5 Amp relays and LEDs.

Specifications of Data Acquisition and Control modules are given in Appendix-3.

(i) Lighting System of Corridor

Corridor lights of I&SP LAB are controlled automatically on motion detection. They however have manual override also. To automatically switch ON/Off the corridor lights based on motion, we have used two LC-780 motion detectors one on each side of the corridor. Detailed specifications of LC-780 are given in Appendix-2.

(ii) Human Machine Interface (HMI)

HMI is made in LabVIEW acting as OPC DA client. At Layer-1, OPC clients are connected to LAN and one can access the Building Automation system from LAN by OPC clients. Remote operation is given by GSM modem/mobile connectivity. A Motorola L6 mobile set was used to connect the Automation System to GSM RF link. GSM mobile interfacing code is written in LabVIEW using AT commands. If any event is detected e.g. smoke detector is activated, a message is transmitted on predefined mobile numbers. And also user can control appliances by giving commands from his mobile phone remotely. Front panel of graphical user interface is shown in figure 4.7.

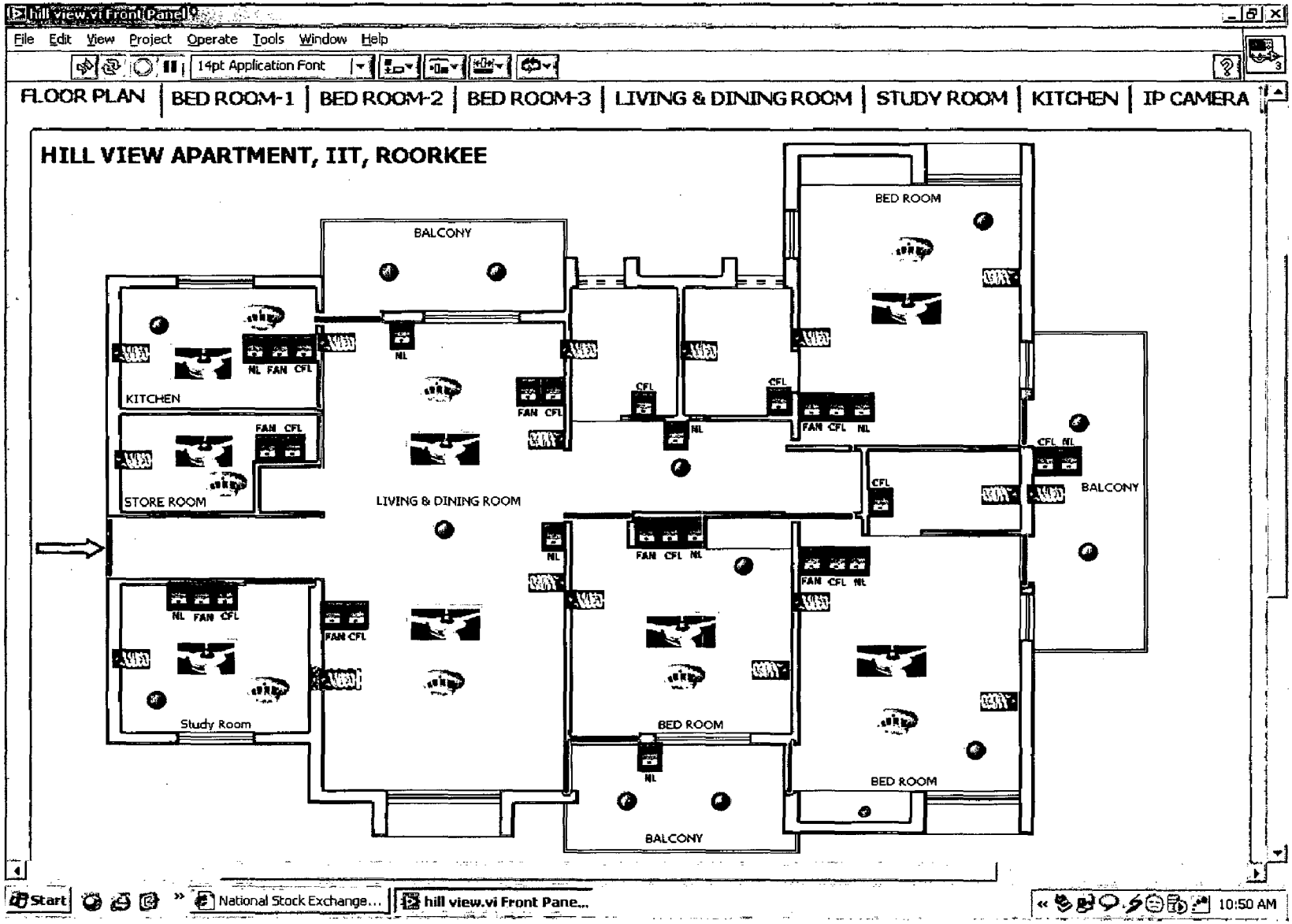


Figure 4.7: GUI designed for Hill View Building Automation

b) Using AT Commands

AT commands are the instructions given to control/access the GSM mobile or modem. AT stands for Attention. All the commands issued to GSM modem starts with AT. Modem sends a response back against every command it receives. Modem can be connected to PC on a serial cable, Bluetooth or Infrared link. Hyperterminal is a good application software to check communication, issue commands and observe responses if modem is connected on serial cable. Following is list of commands and responses used for setting up communication in between PC and mobile.

AT <Enter>
To setup communication in between PC and mobile.

AT+CMGF =1 <Enter>
To select SMS text mode

Send Message from PC

AT+CMGS="+919219532375" <Enter>

Send mobile number on which SMS should be sent. In response modem sends >. Then type the SMS to be sent terminated by **ctrl Z (1AH)** character.

Receive message on PC

AT+CNMI=3,1,0,0,0 <Enter>
To instruct the mobile as soon as it receives any new message, transmit the location of the message to PC. Read new message location sent by mobile on Hyperterminal.

AT+CMGR= 2000 <Enter>
To read message at location number 2000 (assume 2000 is the location of new message).

There is another command to receive any new message on PC directly rather than first receive the location number and then read message on that location number.

AT+CNMI=3,2,0,0,0 <Enter>
This command was not working when tested with Motorola L6 mobile.

All these commands were implemented using LabVIEW.

The wired technologies require.physical media (copper, twisted pair, coaxial). The major barrier to wide deployment has been installation and maintenance costs, especially for existing houses. Pulling wires in an existing house is in most cases is quite difficult, and most consumers are unwilling to invest in or cannot afford a large scale home rewiring, thus the solution is not amenable to mass market. And also, wired technology does not give mobility, i.e. access is limited to the wired outlet.

WiFi access points for Internet connectivity are already implemented in large number of Educational institutions, Hotels and commercial buildings e.g. all the Departments, Hostels and library at IIT, Roorkee are WiFi enabled.

Thus, wireless solutions, the no-wires technologies are expected to be widely adopted for in building networking.

Advantages of Wireless Technologies

1. Wireless networks provide an additional level of transmission security using a technique know as spread spectrum.
2. Cables are vulnerable to accidental or intentional damage, whereas wireless networks provide integrity.
3. Cables are difficult to locate and may take hours to repair. During a widespread event such as weather related outage, repairs may have to wait for several days.
4. Newer wireless technologies support mesh networking, giving higher reliability.

Disadvantages of Wireless Technologies

1. Wireless networks operate on the ISM band 2.8GHz, which is already very overcrowded.
2. Multipath interference, transmission collisions and physical obstruction may degrade system performance. In comparison to outdoors transmission, indoor RF signal propagation conditions are harsher and more dynamic.

3. Wireless networks are susceptible to interference from Wi-Fi hotspots, microwave ovens, cordless phones etc.
4. Wireless networks are less secure as compared to wired networks.
5. Health hazards.

Wireless technologies can broadly be categorized into following classes:

Wireless PANs (Personal Area Networks): Bluetooth is suitable for personal area networking where one can connect PC and all the peripherals wirelessly using Bluetooth.

Wireless LANs (Local Area Networks): IEEE802.11x also called Wi-Fi is suitable for local area netwoks where data rate required is very high i.e. browsing and multimedia streaming applications (802.11n supports high data rate for multimedia streaming).

Wireless PANs/LANs for Building Automation: In application like wireless Building/Home automation, the device mostly stays in deep-sleep mode and only sends a short burst of information if a trigger event occurs. The main requirements for devices in such types of networks are:

- extremely low power consumption
- the ability to sleep for a long time
- simplicity
- low cost

HomeRF, Z-Wave and Zigbee come under this category.

This chapter describes the wireless networking technologies for Building Automation briefly and also discusses the wireless network implemented using Crossbow's wireless modules.

5.1 Wireless Ethernet (Wi-Fi) Technology

Ethernet being most mature and reliable technology, with simple and low cost installation and configuration, still shares one disadvantage with other buses (like MODBUS, Profibus, and others). It needs to run on a cable. There is a solution to this problem-wireless Ethernet. Wireless Ethernet provides the benefit of Ethernet without the need to

run cables. Wireless Ethernet also called WiFi, is IEEE 802.11x standard (x being the variant e.g. a, b, g, n,).

5.1.1 IEEE 802.11 Standard [29]

The 802.11 standard defines a local area network that provides cable free data access for clients that are either mobile or in a fixed location at a rate of either 1 or 2Mbps.

Like all IEEE 802 standards, the 802.11 standards focus on the bottom two levels of the OSI model, the physical layer and link layer as shown in figure 5.1. Any LAN application, network operating system, protocol, including TCP/IP and Novell NetWare, will run on an 802.11-compliant WLAN as easily as they run over Ethernet. Figure 5.1 shows the architecture of IEEE 802.11.

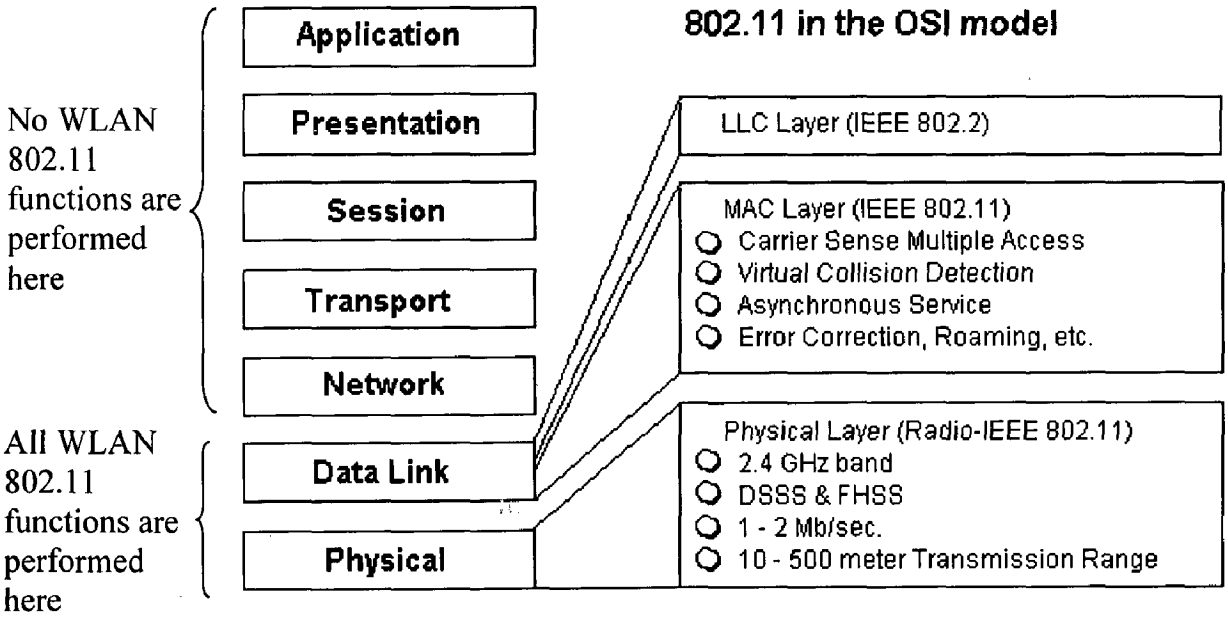


Figure 5.1: IEEE 802.11 Architecture [30]

5.1.2 IEEE 802.11a Standard [31]

When 802.11b was developed, IEEE created a second extension to the original 802.11 standard called 802.11a. Due to its higher cost, 802.11a fits predominately in the business market, whereas 802.11b better serves the home market.

802.11a supports bandwidth up to 54 Mbps and signals in a regulated 5 GHz range. Compared to 802.11b, this higher frequency limits the range of 802.11a. The higher frequency also means 802.11a signals have more difficulty penetrating walls and other obstructions. Because 802.11a and 802.11b utilize different frequencies, the two technologies are incompatible with each other. Some vendors offer hybrid 802.11a/b network gear, but these products simply implement the two standards side by side.

Operating Frequency : 5.8 GHz Unlicensed National Information Infrastructure (UNII)
Transfer Rate (theoretical) : Up to 54Mbps
Transfer Rate (throughput) : 20 - 36 (approximate average)
Mechanism : Orthogonal Frequency Division Multiplexing (OFDM)
Channels Available : 12 (all non-overlapping)
Maximum Range : 80ft. (average)

Advantages - fastest maximum speed; supports more simultaneous users; regulated frequencies prevent signal interference from other devices.

Disadvantages - highest cost; shorter range signal that is more easily obstructed.

5.1.3 IEEE 802.11b [31]

In September 1999, a new 802.11b high rate was amended to the 802.11 standard. The 802.11b standard added two higher speeds, 5.5Mbps and 11Mbps, to the original 1 or 2Mbps 802.11 standard. With the faster data rates, 802.11b, also known as Wi-Fi, quickly became the standard for WLANs. The 802.11b standard made changes only to the Physical layer of the original 802.11 standard.

Operating Frequency : 2.4GHz ISM
Transfer Rate (theoretical) : 1, 2, 5.5, 11Mbps
Transfer Rate (throughput) : 4Mbps (average)
Mechanism : Direct Sequence Spread Spectrum (DSSS)
Channels Available : 11 (3 non-overlapping)
Maximum Range : 175ft. (average)

The available frequency spectrum (2.412 to 2.484 GHz) is divided into 11 channels in U.S.A. Because there must be 25MHz passband, only three non-overlapping channels are available for simultaneously operation.

Advantages - lowest cost; signal range is best and is not easily obstructed.

Disadvantages - slowest maximum speed; supports fewer simultaneous users; appliances may interfere on the unregulated frequency band.

5.1.4 IEEE 802.11g Standard [31]

In 2002 and 2003, WLAN products supporting a new standard called 802.11g began to appear on the scene. 802.11g attempts to combine the best of both 802.11a and 802.11g. 802.11g supports bandwidth up to 54 Mbps, and it uses the 2.4 GHz frequency for greater range. 802.11g is backwards compatible with 802.11b, meaning that 802.11g access points will work with 802.11b wireless network adapters and vice versa.

Operating Frequency	: 2.4 GHz
Transfer Rate (theoretical)	: 54Mbps
Transfer Rate (throughput)	: 20 - 30 (average)
Mechanism	: Complimentary Code Keying (CCK), OFDM
Channels	: 3 (1, 6, 11)
Maximum Range	: 175ft (average)

Advantages - fastest maximum speed; supports more simultaneous users; signal range is best and is not easily obstructed.

Disadvantages - costs more than 802.11b; appliances may interfere on the unregulated signal frequency.

5.1.5 802.11n Draft (2.0) [32], [33]

The 802.11n amendment has introduced substantial enhancements in Wireless Local-Area Network (WLAN) performance, efficiency and robustness of the 802.11 physical (PHY) and medium access control (MAC) layers. The 802.11n standard promises to

achieve as much as 5x the throughput and up to double the range over legacy 802.11 a/b/g technology.

Release date	: October 2008 (est.)
Op. Frequency	: 5 GHz and/or 2.4 GHz
Data Rate (Typ)	: 74 Mbit/s
Data Rate (Max)	: 248 Mbit/s (2 stream)
Range (Indoor)	: ~70 meters

At this level of throughput and range performance, 802.11n is expected to support multimedia applications in the home, with the ability to transport multiple high-definition (HD) video streams through the house, while at the same time accommodating Voice over Internet Protocol (VoIP) streams and data transfers for multiple users with high Quality of Service (QoS) and latest generation security protections in place. In enterprise, campus and municipal networks, 802.11n offers the robustness, throughput, security and QoS capabilities that IT managers have come to expect from wired Ethernet networks.

Advantages in home networking

1. Wi-Fi CERTIFIED 802.11n wireless routers or access points have a much better capability to blanket the whole home in a strong signal, delivering up to twice the range of previous-generation Wi-Fi networks.
2. An 802.11n Wi-Fi signal can reach all the places a consumer might want to connect. "Dead spots" are dramatically reduced.
3. Applications that require a lot of bandwidth, such as high-definition video, can run effortlessly throughout the house.
4. Moving large files around the home network seems effortless. For example, an entire family can enjoy a movie stored on a PC by streaming it to the flat screen TV in the living room. Parents can finally back up a large library of music and photos to an external storage device in minutes instead of hours.

Today's homes have numerous devices connected to the network- a shared PC, a digital library having a hard drive that stores thousands of MP3 songs and pictures, a digital camera, a printer and many more. Wi-Fi CERTIFIED 802.11n draft 2.0 lets everyone

connect at the same time and still enjoy things like digital music, streaming video, online gaming without compromising on the user experience.

5.1.6 Comparison of IEEE 802.11x Variants

Table 5.1 summarizes the specifications of WLAN standards discussed so far in this chapter.

Table 5.1: Primary IEEE 802.11 Specifications [34]

Protocol	**Release Date**	**Op. Frequency**	**Throughput (Typ)**	**Data Rate (Max)**	**Range (Radius Indoor)**	**Range (Radius Outdoor)**
Legacy	1997	2.4-2.5 GHz	1 Mbit/s	2 Mbit/s	~20 Meters	~100 Meters
802.11a	1999	5.15-5.25 5.25-5.35 5.49-5.725 5.725-5.85 GHz	25 Mbit/s	54 Mbit/s	~35 Meters	~120 Meters
802.11b	1999	2.4-2.5 GHz	6.5 Mbit/s	11 Mbit/s	~40 Meters	~140 Meters
802.11g	2003	2.4-2.5 GHz	20 Mbit/s	54 Mbit/s	~40 Meters	~140 Meters
802.11n	(estimated, currently at Draft 2.0)	2.4 GHz and/or 5 GHz	74 Mbit/s	248 Mbit/s (2x2 antenna)	~70 Meters	~250 Meters

5.2 Bluetooth Technology

Bluetooth serves as a universal low-cost, user friendly air interface that aims to replace the plethora of proprietary interconnect cables between various personal devices.

Bluetooth operated in the unlicensed frequency range of 2.4 to 2.4835GHz, with channel spacing of 1 MHz. Bluetooth is an FHSS system with 79 channels, a hopping rate of 1,600 hops per second and a different hopping sequence per piconet.

Bluetooth Applications

1. Bluetooth headsets and hands free kits
2. Computer peripherals, such as keyboards, mice, printers, and faxes. Now laptops are available with Bluetooth port.
3. Transferring images from still and video cameras to computers.
4. Communications between PC or PDAs and a cell phone. A laptop in briefcase can download email via the cell phone in the user's pocket.
5. Ad hoc networking between PCs and PDAs.

5.3 HomeRF [35]

HomeRF is a wireless networking specification (Shared Wireless Access Protocol-SWAP) for home devices to share data. It was developed by the HomeRF Working Group, a consortium of mobile wireless companies that included Siemens, Motorola and more than 100 other companies. The group was disbanded in January 2003 after Wi-Fi 802.11b networks became accessible to home users and Microsoft began including support for Bluetooth, a standard the HomeRF competed with, in its Windows operating systems. As a result HomeRF has fallen into obsolescence. Thus, HomeRF became obsolete and there is currently no group developing the standard further.

HomeRF used frequency hopping spread spectrum (FHSS) in the 2.4 GHz frequency band and could achieve a maximum of 10 Mbit/s throughput; its nodes can travel within a 50 meter range of an access point while remaining connected to the personal area network (PAN).

5.4 Z-Wave [36]

Z-Wave is the interoperable wireless communication protocol developed by Danish company Zensys and the Z-Wave Alliance. It is designed for low-power and low-bandwidth appliances, such as home automation and sensor networks. The Z-Wave Alliance is a consortium of more than one hundred independent manufacturers who have agreed to build wireless home control products based on the Z-Wave standard. Principal members include Danfoss, Intel, Intermatic, Leviton, Monster Cable, Universal Electronics, Wayne-Dalton and Zensys.

Z-Wave Radio Specifications

Bandwidth : 9,600 bit/s or 40 Kbit/s, fully interoperable

Modulation : GFSK

Range : Approximately 100 feet (or 30 meters) assuming "open air" conditions, with reduced range indoors depending on building materials, etc.

Frequency band: The Z-Wave Radio uses the 900 MHz ISM band. In the US this is 908.42 MHz and in Europe 868.42 MHz.

5.5 Zigbee Technology [37]

Zigbee is a technological standard based on the IEEE 802.15.4 specification for low data rates in the Industrial, Scientific, and Medical (ISM) radio bands. The technology allows for devices to communicate with one another with very low power consumption, allowing the devices to run on simple batteries for several years. Home automation is one of the key market areas for Zigbee.

The Zigbee 1.0 specification was ratified on December 14, 2004.

a) Zigbee/IEEE 802.15.4 – General Characteristics [38]

- Dual PHY (2.4GHz and 868/915 MHz)
- Data rates of 250 kbps (@2.4 GHz), 40 kbps (@ 915 MHz), and 20 kbps (@868 MHz)
- Optimized for low duty-cycle applications (<0.1%)

- CSMA-CA channel access
    - Yields high throughput and low latency for low duty cycle devices like sensors and controls
- Low power (battery life multi-month to years)
- Multiple topologies: star, peer-to-peer, mesh
- Addressing space of up to:
    - 18,450,000,000,000,000,000 devices (64 bit IEEE address)
    - 65,535 networks
- Optional guaranteed time slot for applications requiring low latency
- Fully hand-shake protocol for transfer reliability
- Range: 50m typical (5-500m based on environment)

b) Architecture [39]

For purposes of this discussion, three areas of architectural responsibility are in a ZigBee engineering effort (Figure 5.2).

- The 802.15.4 specification describes a peer-to-peer radio using direct sequence spread spectrum (DSSS). The specification also calls out the data rates, channelization and modulation techniques to be employed.
- The ZigBee Alliance specifies the logical network, security and application software, which are implemented in a firmware stack. It is the ZigBee networking stack that creates the mesh networking capability.
- The application layer is defined by profiles, of which there are two types: public profiles are those certified by the ZigBee Alliance for interoperability purposes, and private profiles are for use in closed systems.

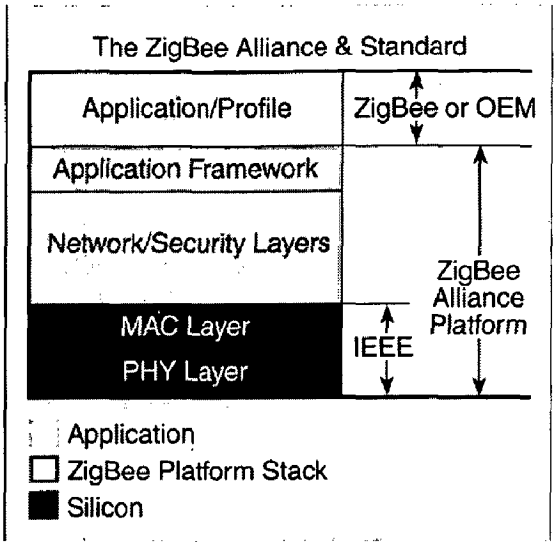


Figure 5.2: Zigbee Architecture [39]

Zigbee protocol supports multi network topologies such as:

- Star (one coordinator to many nodes, theoretical up to 65,536)
- Cluster tree (multi-hop network from beaconing node)
- Mesh (allows for routing to any connected device on the network).

Zigbee seems to be most promising wireless technology for Building Automation because of open architecture based on IEEE 802.15.4 standard, mesh networking, long battery life and also supported by large number of companies. The following section describes the implementation of a wireless network using Crossbow's wireless Zigbee modules.

5.6 Z-Wave Vs Zigbee Comparison [40]

As Zigbee and Z-wave both focuses on home automation and sensor network, hence a comparison of both technologies is given below in table 5.2.

Table 5.2: Z-Wave Vs Zigbee

	Z-wave	**Zigbee**
Standard	proprietary	based on IEEE 802.15.4
Data rate	40 kbps (PHY rate, ~10 kbps, overhead removed)	250 kbps (10 kbps to 115 kbps, overhead removed)
Frequency	900 MHz area	900 MHz regional bands and globally in 868 MHz and 915 MHz and 2.4 GHz
Proven interoperability	yes (within alliance)	yes (within IEEE 802.15.4 standard)
Range	30 meters point-to-point, unlimited with mesh networking	10 meters to 75 meters point-to-point, typically 30 meters indoors, unlimited with mesh networking
Purpose	Remote monitoring and control for light industrial and home applications	remote monitoring and control for light industrial and home applications – ultra-low-power for wireless personal area networks
Applications	Mostly home applications, lighting, security, access, entertainment control, PC, window coverings, smoke detectors	home automation, building automation, industrial automation, lighting, security, access, entertainment control, PC, window coverings, smoke detectors, industrial process control
Developer	Zensys	Freescale, TI
Industry Association	Z-Wave Alliance	ZigBee Alliance
Key members	Intel, Logitech, Cisco, Intermatic	Ember, Freescale, Honeywell, Philips, Samsung, TI – 70+ members

5.7 Laboratory Implementation

For situations where implementation of wired network is not an easy or is a costly solution e.g. rewiring an existing building, wireless networks offer a good choice. A network of wireless nodes for Building Automation has been implemented in I & SP LAB, for monitoring various conditions like Ambient light, Temperature, Humidity,

Pressure, Door Switches, Glass Break detector, Motion Detector and Smoke Sensors. Figure 5.3 shows the diagram of implemented wireless network.

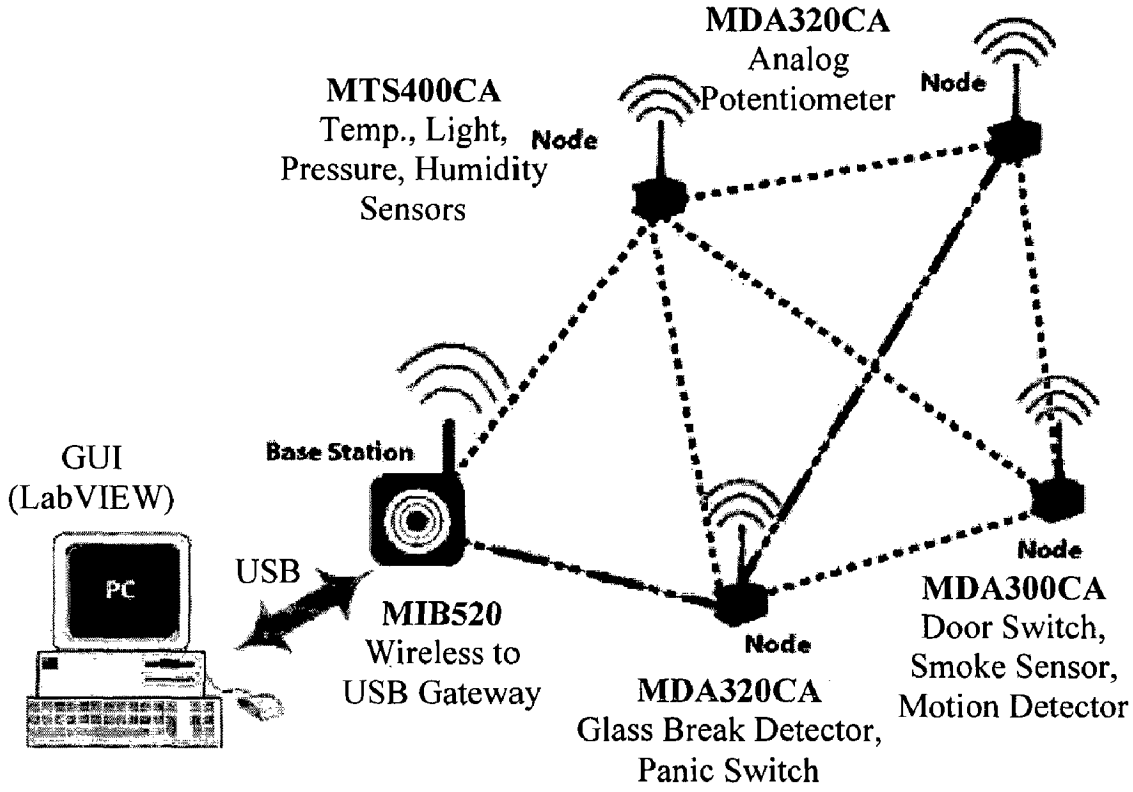


Figure 5.3: Diagram of Implemented Wireless Network

Main features of the network are:

- Uses 2.4 GHz ISM band for communication
- Self healing using mesh networking
- Large distance, intermediated nodes act as routers.
- Use of general instrumentation wireless modules e.g. MDA300/MDA320, which in turn gives flexibility of addition of any external sensor for specific requirements. Similarly any digital input sensor can be added to same module.
- Graphical User interface in LabVIEW.

A LabVIEW based Graphical User Interface (shown in figure 5.4) was developed to acquire data from wireless nodes MTS400, MDA300CA and MDA320CA. Nodes were programmed having mesh topology feature using MoteConfig utility from Crossbow.

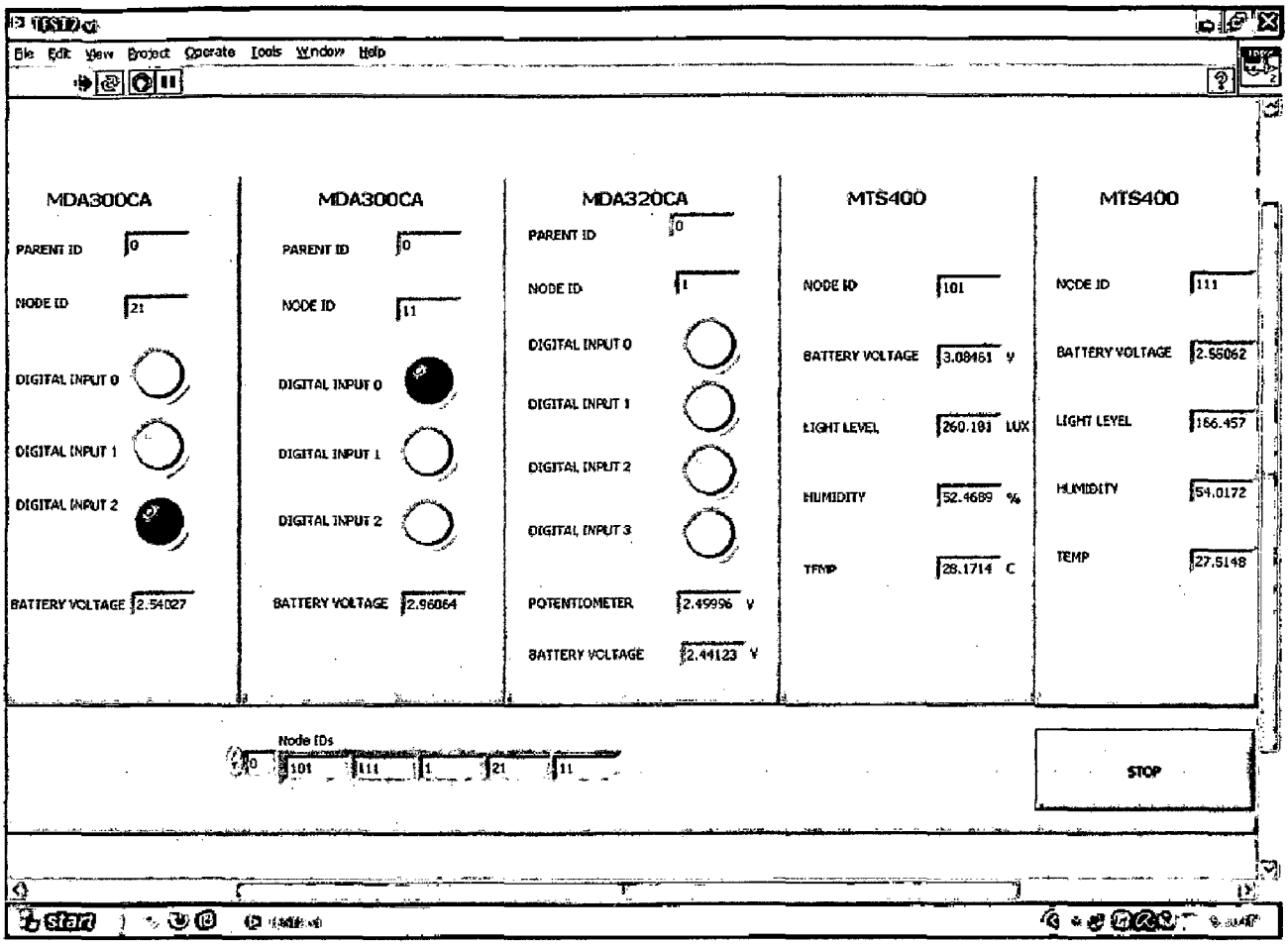


Figure 5.4: GUI for Implemented Wireless Network

Micro push button switches were used to simulate digital input sensors and analog potentiometer was used to simulate analog input sensor. In wireless sensor networks it is important to monitor battery voltage of each wireless node. Parent ID of a node is the ID of node to which it is connected. Gateway ID is always 0. The sensor nodes which are connected to gateway directly have 0 Parent ID. Let us say node ID 1 is connected to node ID 11 in mesh topology, then parent ID of node ID 1 is 11.

Figure 5.5 shows the online data acquired using MoteView (a user interface from Crossbow), from the wireless network of Crossbow's 2.4 GHz wireless modules. On left side the nodes connected to network are in green color and on right side, sensor data from all the modules connected is shown with date and time stamp. Preprogrammed nodes having MTS400 sensor board were used in this wireless network.

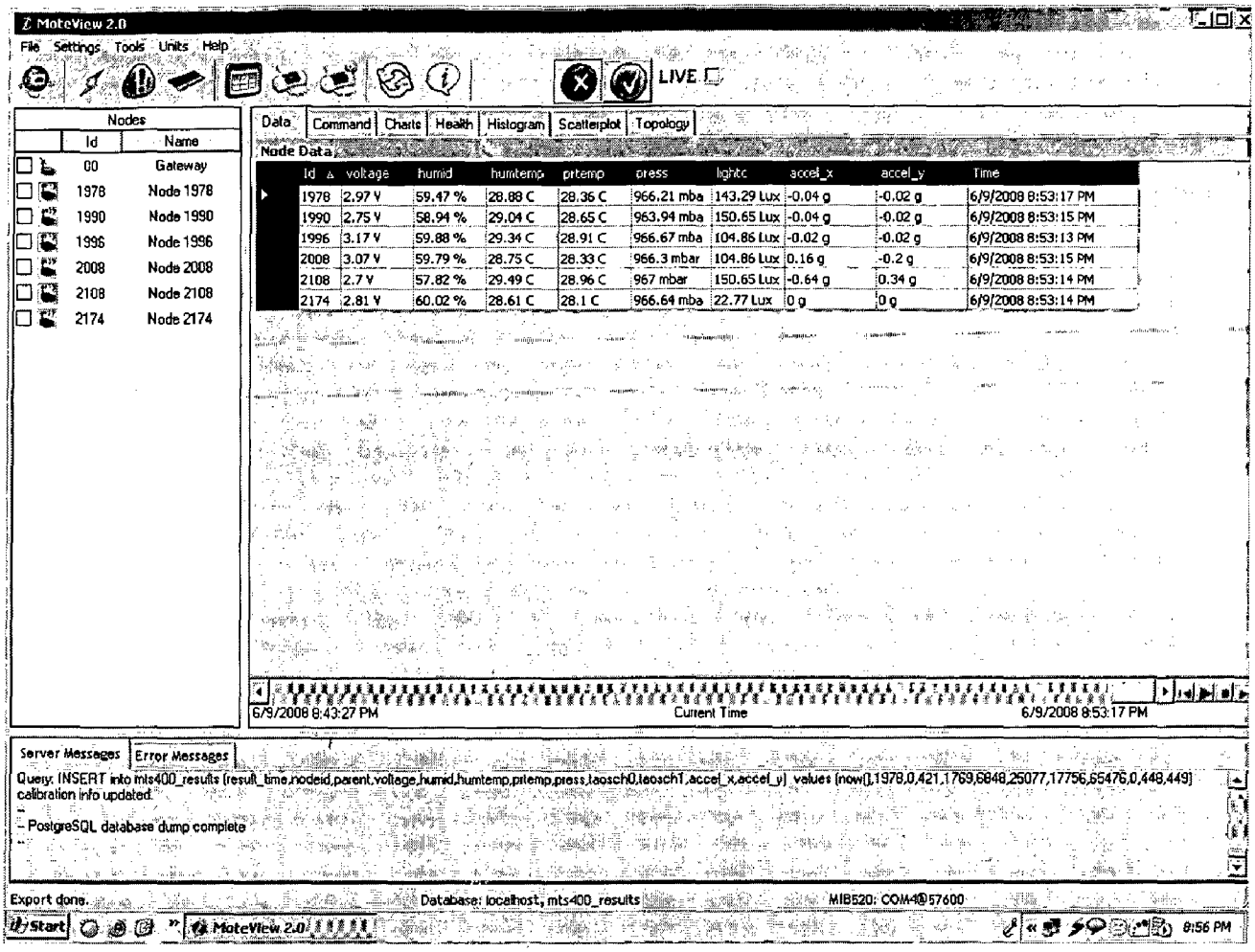


Figure 5.5: Front Panel of MoteView Showing Real Time Wireless Nodes

This network supports star as well as mesh networking topology. Each node tries to find the gateway first and connects in a star topology with gateway in single hop as shown in figure 5.6.

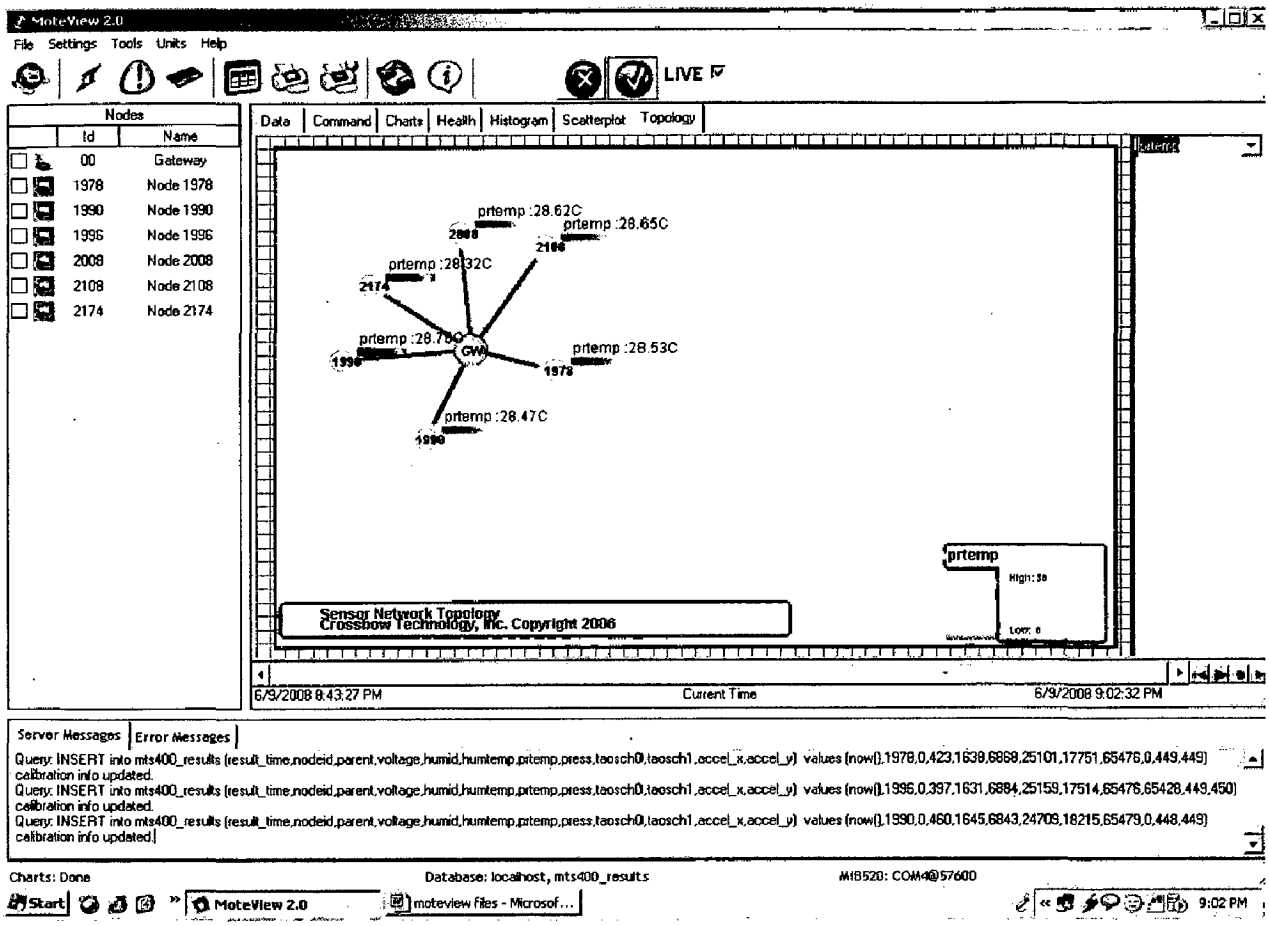


Figure 5.6: Wireless Nodes in Start Topology

Moteview, a user interface has features to plot single and multiple graphs, draw histograms, to send alarms via email notification if programmed event has exceeded the limits.

If any node does not find direct RF link with gateway either because it is moved out of range or an obstruction has come in between node and gateway, it finds the nearest neighbor and sends its data to it. This forms a mesh networking topology. In this way data reaches to gateway in a multi hop manner. Figure 5.7 shows the different mesh topologies of nodes formed automatically during testing.

Chapter – 6
Implementation of Standalone Safety and Security Controller

Now a day, people are more concerned than ever about safety and security system to protect the human beings and the valuable things. A typical safety and security system provides following functions:

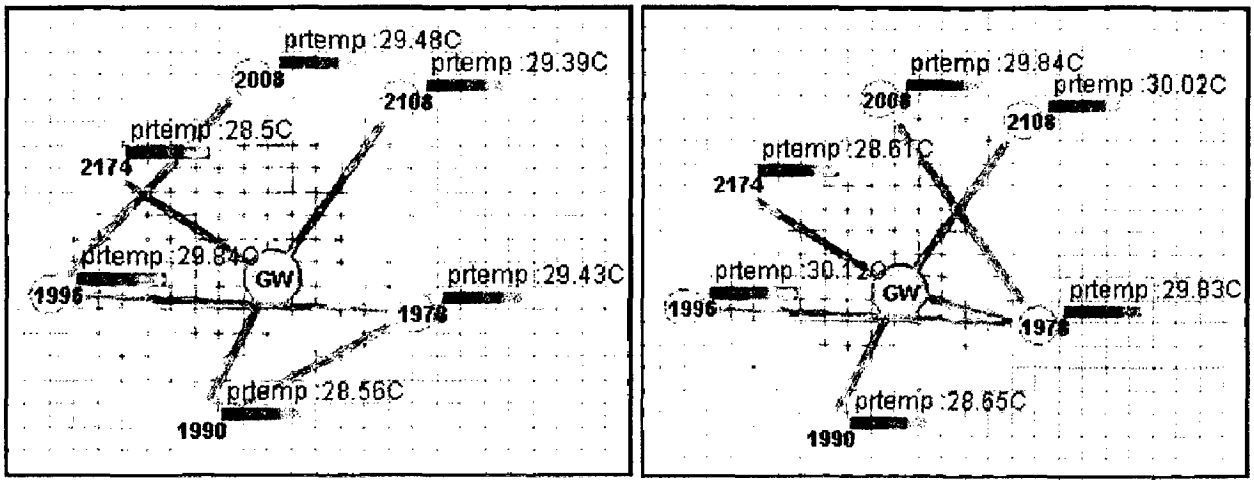
- ❖ Fire detection and alarming
- ❖ Intruder detection and alarming
- ❖ Access control System

Safety includes following sensors and controls:

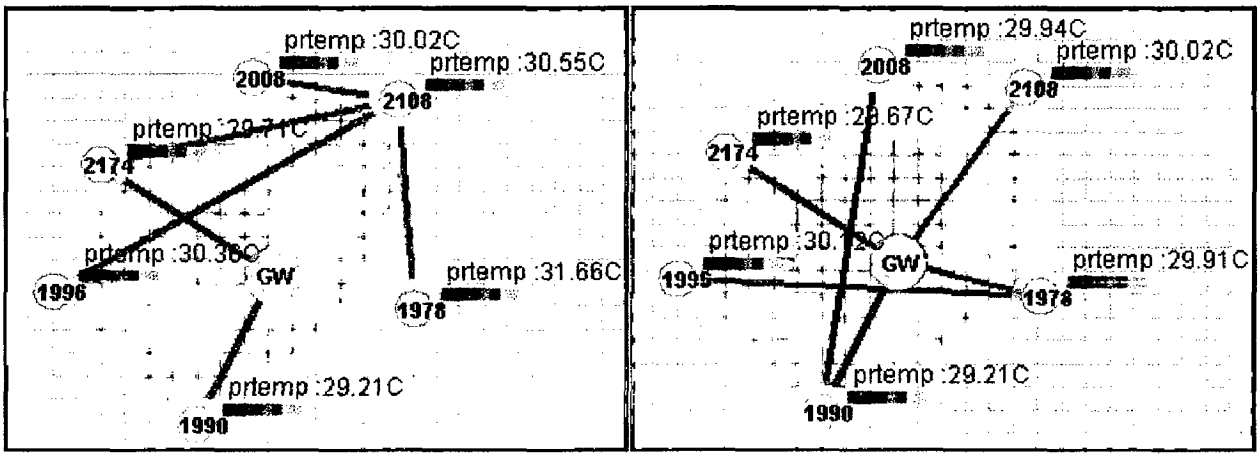
- ❖ Fire detection, alarming and control
  - Manual call points
  - Smoke detector
  - Fire alarm
  - Auto sprinkler system
- ❖ LPG leakage detector
- ❖ Wireless emergency pendent for elders
- ❖ Emergency button at convenient location

For intruder detection PIR motion sensors, Glass break sensors, Door/Window sensors are most commonly used. Access control system can be card swipe based or biometric type, biometric type being more secure. And for video surveillance of buildings, CCTV cameras are used along with DVR for recording.

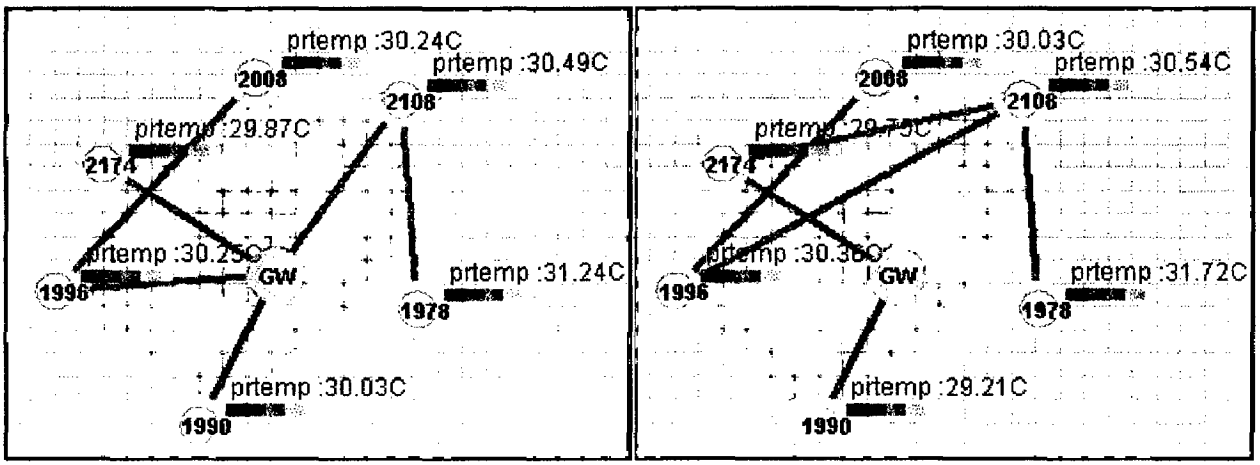
For people who just want to secure his home from intruders and alarming against fire detection, standalone safety and security systems are good solutions for them. They are very cheap and easy to install. Such standalone safety and security system using GE NX-8V2 control panel has been installed, which can be extended easily by adding expansion modules.



(a) (b)



(c) (d)



(e) (f)

Figure 5.7: Picture of Network Topologies Formed Online

6.1 NX-8V2 Control Panel and Expansion Modules

The NetworX NX-8V2 represents a new approach to security systems design being most flexible, durable, and user-friendly control. Featuring sophisticated software, which allows up to 99 users to interface with 48 zones, 8 partitions, and a host of integrated fire, access, verification, and input/output modules, all reported with the most comprehensive and fast SIA and Contact ID formats. The NetworX design allows a fully loaded system to be housed in one single metal enclosure. The most advantage of NX-8V2 is that up to 32 modules can be added to expand the capabilities of the NX-8V2. Following are some of the expansion modules that can be attached to NX-8V2 control panel.

1. NX-216 : 16 Zone hardwire expander module
2. NX-408E : 8-zone wireless expander module
3. NX-416E : 16-zone wireless expander module
4. NX-448E : 48-zone wireless expander module
5. NX-584E : Home/Automation/Access Control
6. NX-534E : Two way voice audio module with speaker and microphone
7. NX-507E : Relay module, X10 compatible, 7 Form C relays
8. NX-508E : 8-output module, parallel printer module, X10 compatible
9. NX-591E : Cellemetry interface module
10. NX-1700 : Smart reader door access control
11. NX-592E : NetworX GSM module
12. NX-108E : 8-zone LED keypad
13. NX-1192E : 192 zone LCD keypad

6.2 NX 8V2 Features

1. Sensors can be connected in many different configurations to NX8V2 control. Figure... below shows a double zone configuration. Control panel generates an alarm if there is any short circuit in the wires or any of the zone is opened i.e. it monitors the current fed into E.O.L. (End of Line) resistance. If current increases or decreases then it detects the condition and gives alarm.
2. NX8V2 supports 16 zones and 8 partitions.

3. Each partition is protected by user code.
4. Supports 2-wire and 4-wire smoke sensor.
5. Three different phone numbers can be stored and for each phone number there are two programming locations to select which events are reported to that phone number.
6. User can select any zone type for each zone out of the available 30 zone types.
7. Control panel generates alarm on mains AC fail or low battery condition.
8. If anyone tampers with control panel or cuts the phone line, an alarm is generated.
9. 4-Auxilliary outputs are there on control panel and each output can be programmed for particular events or partitions.
10. The control panel gives the scheduling feature, i.e. user can program on which day partition will autoarm.

There are 200 programming locations, each location is divided into segments and each segment is of 1-byte. Each segment can store 8 different conditions. User can program each of the location and segment depending on his requirement.

6.3 Implementation of Standalone Safety and Security System

Following sensors were connected to 8 zones of NX8V2 control:

Door/window sensors, Glass break detector, Vibration detector, Motion Detectors, Smoke detector. A 12V, 7 AH battery backup is provided to power the control panel and sensors in case mains AC fails. A 12V hooter was connected to make siren on event detection.

If any sensor activates, an alarm signal is generated and keyboard displays the activated zone number. User can program custom messages to be displayed on keyboard for each zone. NetworX is connected to phone line and makes a call to the phone/mobile number programmed at corresponding location. Figure 6.1 shows the picture of implemented standalone safety and security controller.

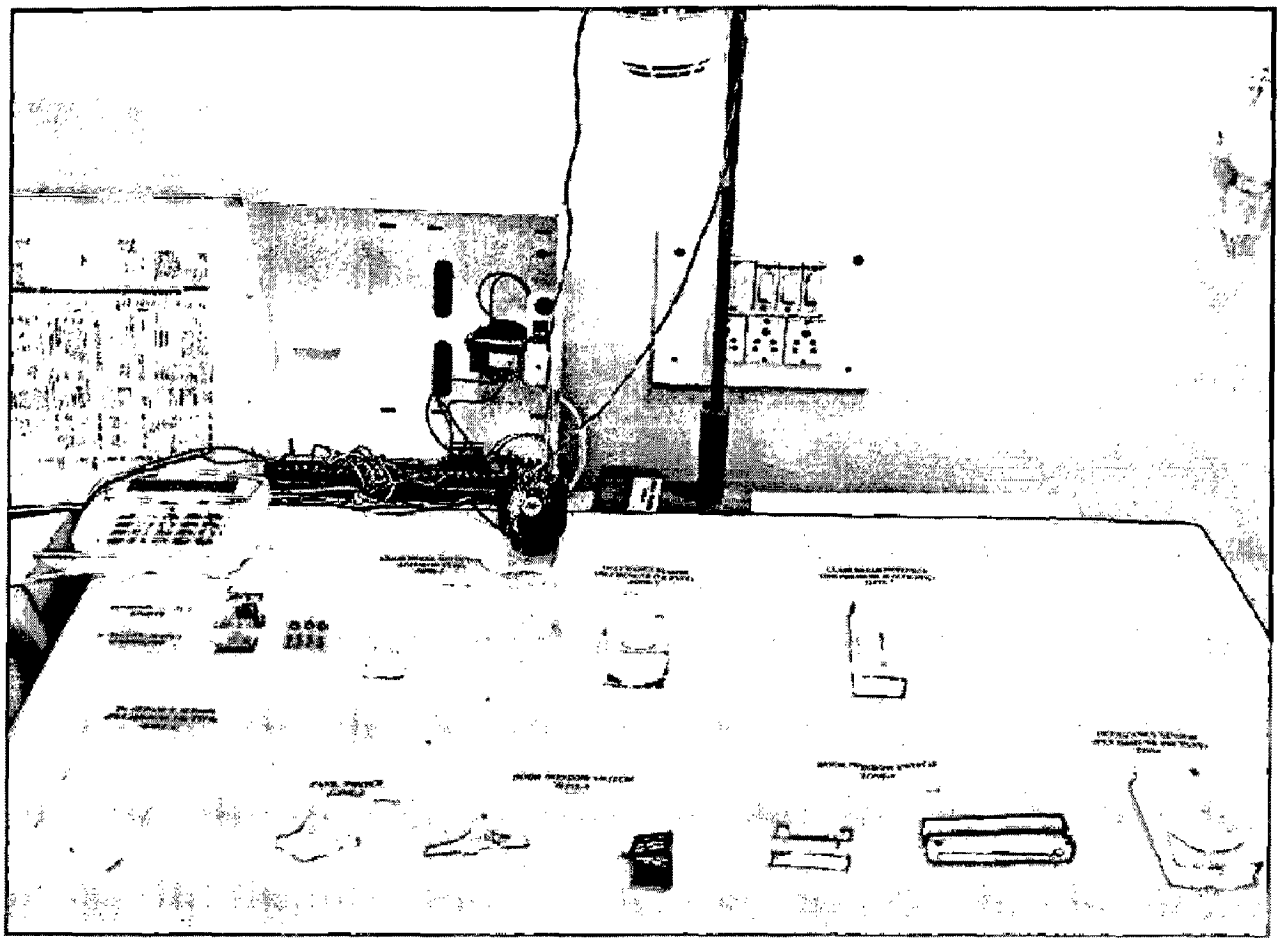


Figure 6.1: Picture of Implemented System

Keyboard has three special buttons: Fire, Police and Emergency. Each button has a different type of alarm associated with it. Two external relays were connected, one programmed to be activated for Fire button and other programmed for Police button. If Fire button is pressed, relay corresponding to it will activate sprinkler system and if Police button is pressed, relay will switch ON a halogen lamp and make a siren. Usual practice is if any intruder is detected, switch ON the lights and make siren automatically.

7.1 Conclusion

In a fully integrated intelligent building, each device is capable of communicating with every other device, and all of them are accessible over the Internet. Building Automation technologies are organized in two groups:

1. Technologies that require new wiring.
2. Technologies with "no new wires".

The first group offers a very secure way to deploy new services, as technologies tested in enterprises and business sector are now brought to the home environment. Ethernet being high speed is one of the major alternatives for the Building Automation. MODBUS because of an industrial proven, simple, lot of products available, easily expandability and low cost, is good at device level.

Second group, "no new wires" is further split into two parts: first, technologies based on existing power line wiring and second, wireless technologies. Powerline technologies are expected to play an important role mainly for control and automation applications because every house/building is already equipped with power line wiring.

The emerging wireless technologies have overcome their own limitations of low bandwidth, low transmission range and higher cost. Among wireless technologies, IEEE 802.11b as established; proved and mature technology is suitable for wireless local area networking. And 802.11n (estimated) would have a very high speed. Bluetooth being cheap, short distance cable replacement is suitable for personal area networking. Zigbee technology having advantage of mesh structure and very low power consumption is one of the best candidates for Building Automation.

Each of the Powerline, wired and wireless technology has its own advantages as well as disadvantages. A complete Building Automation system will have multiple technologies.

The proposed design for Hill View Building Automation shows Wired and Powerline networking technologies. Ethernet being a high speed network is used at layer 1 & layer 2. Within apartment MODBUS on RS485 twisted pair and Powerline network are proposed at layer-2 to interface with devices. MODBUS and Powerline network are used at layer 3. Electronic appliances like washing machine, Oven, refrigerator etc. are not supposed to have a separate communication port because it will increase cost and need separate wiring for automation. Hence Powerline network is supposed to be there in Building Automation to communicate with these consumer devices. A fire sprinkler system is proposed for each apartment to control fire automatically.

Even though Zigbee seems to be most promising wireless technology, it is not considered in proposed design because it is a new technology, not well established, and requires a lot of expertise. And also there are not many application oriented products available in the market for Building Automation.

The implemented Building Automation system is based on wired as well as wireless technology. Ethernet is used for connecting OPC clients to each other and data acquisition and control modules are connected on RS485 network. A wireless network has been implemented using Crossbow's Zigbee modules.

7.2 The Future of BA

Building Automation represents a quickly growing arena. After deployment of current emerging technologies, new applications will appear, turning digital networked houses into smart adaptable homes. More intelligent and autonomous consumer electronic devices are expected to communicate with each other, take their own initiatives, and handle specific every-day tasks without human intervention. Smart networked automation and security systems will provide advanced services and secure the house from all kinds of thugs, hooligans, and terrorists. Broadband in home networks will interconnect devices, provide adequate bandwidth capabilities, and hide any heterogeneity in home segments. Science fiction films are expected to be reality soon. As they say, the only limit is the human imagination [41].

7.3 Future Scope of Work

The development of proposed design for RMS BA can be taken up as future work. Presently wired system has been implemented using PC as a main controller, instead ADAM-6500 or equivalent can be used as main controller. Because PC in homes is used for entertainment purpose, may be affected by virus while internet surfing and PC need not to be ON every time for controlling. The presented Power Line Modem based Building Automation system can be taken up as a development work. And also RS485 based infrared remote/receiver pair can be developed in future.

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Appendix – A
Sensor Specifications

1. Pet Immune Infrared Detector RX-40PI

Specifications

Detection Method	PIR
Coverage	40 x 40ft. 85° wide (12 x 12m)
Optional Lens / Detection range	FL-60N 60 x 6ft. (18 x 1.8m)
Detection Zones	78
Mounting Height	5 - 8ft. (1.5 - 2.4m)
Pulse Count	2 / 4
Power Input	9.5 - 16V DC
Current Consumption	11mA max.
Alarm Output	N.C. 28V DC 0.2A max.

2. Passive Infrared Motion Detector LC-780

Specifications

Power supply	100-250 VAC
Maximum load	10A
Delay time	8 sec.~8 min
Photocell sensor	CdS
Infrared sensor	Dual element
Detection speed	0.15-3 m/sec.
Mounting height	1.8-3.0 m (6-10 ft)
Temperature	-20°C - 50°C (4°F - 122°F)
Dimensions	125 x 105 x 62 mm

3. Glass Break Sensor GS-380

Specifications

Detection Range	Radius of 180 cm
Detection Method	Piezoelectric
Alarm Period	0.5 second - 6 second (0.3 second minimum)
Alarm Output	Semiconductor style switch, polarity, DC24V/40mA. Resistance at 13 ohm (max) when normal
Operating Temperature	-4° F to + 131° F (-20° C to +55° C)
Mounting Position	indoor, surface of glass materials
Weight	0.46 oz (13 grams)
Dimension (Inches/mm)	1.4" Ø x 0.43" (36.5 Ø x 11mm)
Wiring Terminal	Direct Style/stripped bare wire

4. Acoustic Glass Break Detector GBS-210

Specifications

Power supply	12 V DC ± 25%
Power consumption (LED off)	max.10 mA
Maximum consumption (LED on)	max. 35 mA
Terminals size	1 mm2
Alarm output	normally closed, max. 60V / 50 mA internal resistance max.16 Ohm
Tamper output	normally closed, max. 60 V / 50 mA internal resistance max.16 Ohm
Detection range	max. 9 m
Minimum glass dimensions	0.6 x 0.6 m
Initialization	max. 60 s
Security level	grade 2, EN 50131-1
Environment	II. - general indoor, (EN 50131-1)
Operating temperatures	-10 to +40 °C

5. Vibration Sensor PS922

Specifications

Physical Parameters	
Mounting	: Window Frames, Door, Walls, Roofs
Casting	: White ABC Body

Dimensions	: 86mm X 26mm X 25mm
Electrical Parameters	
Supply Voltage	: 9V To 16 VDC
Current	: 10mA Typical
Alarm Output	: Normaly closed potential free contacts. Having rating as 200 VDC, 500mA
Alarm Period	: 2-4 seconds(typical)
Detection LED	: Internally linked to enable/disable using jumper setting
Detection Method	: Piezo Electric Transducer

6. Photoelectric Smoke Detector KL731

Specifications

Operating voltage	9 to 28 VDC
Current consumption Alarm at 24 VDC	< 100 mA
Radio-active source	Average activity
Remote alarm output	Remote alarm output
Operating temperature	Operating temperature
Humidity (non-condensing)	95%
IP rating	IP42
Number of detectors per zone	20
Approvals	Approvals

KZ705R is a 5 contact detector base. In addition to the normal base and remote indication connectors, the KZ705R also has an additional earth terminal connector to allow for easy terminations of a possible cable screen. A built in 12 V relay makes it ideal for use on low voltage intrusion systems.

7. IP Camera

MCAS300PTW - Specifications	
1. Free Bundle 16-Channel Software, including Monitor & Playback program, for instance, alert with video, save to Internet / HD, Cycle recording, .avi format available. 2. Support 802.11g 54Mbps wireless LAN and 10/100Mbps Ethernet 3. Advanced Video & Audio Synchronization 4. Fast Pan / Tilt Ability 5. Direct Ethernet / Wireless Network Connectivity 6. Alarm I/O & Motion Detection with three windows 7. Password protection 8. Automatic transfer of snapshots via email and FTP with event triggering 9. Allows remote access from web browser for live image viewing 10. Utilized in a mixed operating system environment such as Windows and MAC 11. Broad range of applications for monitoring homes, offices, banks, hospitals and a variety of industrial and public monitoring	
Voice	24kbps, 8kbps(option) Build-in microphone External microphone connector Audio / Video output connector
Video Specification:	
Resolution:	640 x 480 pixel
Sensor:	Sensor:
Electronics Shutter:	1/60 ~ 1/100,000 sec
Minimum Illumination:	Minimum Illumination:
Lens:	4.3mm, F2.0
Focus Extent:	20 cm ~ 8
Focus Extent:	20 cm ~ 8
Image(Video Setting):	
Image Compression:	MPEG4
Frame Rate:	30fps@CIF, 10fps@VGA
Compression Rate Selection:	Medium/Standard/good/detailed/excellent
Frame Rate Setting:	30/25/20/15/10/5/3/2/1
Video Resolution:	NTSC: Up to 30 Frames at 640 x 480 PAL: Up to 25 Frames at 640 x 480
Control:	Brightness control Contrast control Saturation control Hue

Wireless Specification:	
Standard:	IEEE 802.11g
Frequency:	2.400~2.4835GHz
Security:	64 / 128-bit WEP
Antenna:	Dual Detachable Antenna (Reverse SMA Connector)
Pan / Tilt:	Pan: range ± 135°, 10°~50°/sec Tilt: range +90°~-45°, 7°~25,°/sec Auto pan mode Auto patrol mode
LAN Port:	One RJ-45 port to connect to 10/100Mbps Ethernet, auto-sensing
Generic I/O Port:	1 sensor input(max. 12VDC 50mA) 1 relay output(max. 24VDC 1A, 125VAC 0.5A)
LED Indicator:	Power/microphone and activity
Weight:	336.6g
Power Supply:	12VDC,1.5A external power supply
Management:	
IP Assignment:	Static IP, DHCP Client
Communication Protocol:	TCP/IP, HTTP,SMTP, FTP, Telnet, NTP, DNS, DHCP, DDNS, UPnP
Management Utility:	Web-based System Log FTP Application
Utility Function:	Live image viewing Remote management Snap shot Video recording
Temperature:	Operation:0 °C ~ 40 °C Storage:-20 °C ~ 70 °C
Certificate:	FCC,CE

Appendix – B
Fire Fighting Installation Requirements

REQUIREMENT OF FIRE FIGHTING INSTALLATION (AS PER NBC-2005)

S. No.	Type of Building Occupancy	Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Spinkler	Capacity		Pump Capacity, Type, Number	
							UG Tank Litres	Terrace Tank Litres	Near UG Tank lpm	Near Terrace Tank lpm
1	2	3	4	5	6	7	8	9	10	11
(1)	**Residential**									
	(i) Less than 15 m in height.	R	NR	NR	NR	NR	NR	5000 (5000)	NR	450 (450)
	(ii) 15 m and above but not exceeding 35 m in height	R	NR	R	NR	NR	NR	25000	NR	900
	(iii) Above 35 m but not exceeding 45 m in height	R	R	NR	NR	NR	75000	5000 (5000)	1620 lpm (E-1) (D-1)	NR
	(iv) Above 45 m but not exceeding 60 m in height	R	R	NR	R	R	75000	10,000	2280 lpm E-1 D-1	NR
	(v) Above 60 m in height.	R	R	NR	R	R	100,000	25,000	2280 lpm E-2 D-1	NR
(2)	**Educational (Other than Hospitals)**									
	(i) Less than 15 m in height.									
	(a) Ground plus one storey	NR	NR	NR	NR	NR	NR	5000(☆)	NR	450(☆)
	(b) Ground plus two or more storeyes	R	NR	NR	NR	NR	NR	10,000 (5000)	NR	450 (450)
	(ii) 15 m and above but not exceeding 30 m in height	R	NR	R	NR	NR	NR	25000	NR	900

S. No	Type of Building Occupancy	Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler	Capacity		Pump Capacity, Type, Number	
							UG Tank Litres	Terrace Tank Litres	Near UG Tank lpm	Near Terrace Tank lpm
1	2	3	4	5	6	7	8	9	10	11
(3)	**Hospital & Nursing Home.**									
	(i) Less than 15 m in height with plot area upto 1000 m^2									
	(a) Upto ground plus one storey with no beds	R	NR	NR	NR	NR	NR	2500 (2500)	NR	NR
	(b) upto ground plus one storey with beds	R	NR	R	NR	NR	NR	5000 (5000)	NR	450 (450)
	(c) Ground plus two or more storeys with no beds.	R	NR	R	NR	NR	NR	5000 (5000)	NR	450 (450)
	(d) Ground plus two or more storeys with beds	R	R	NR	NR	NR	50,000	5000 (5000)	1620 lpm E-1 D-1	NR
	(ii) Less than 15 m in height with plot area more than 1000 m^2	R	R	NR	R	NR	100000	10000	1620 lpm E-1 D-1	NR
	(iii) 15 m and above but not exceeding 24 m in height	R	R	NR	R	R	100000	20000	2280 lpm E-1 D-1	NR
	(iv) Above 24 m but not exceeding 30 m in height.	R	R	NR	R	R	150,000	20,000	2280 lpm E-2 D-1	NR

S. No	Type of Building Occupancy	Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler	Capacity		Pump Capacity, Type, Number	
							UG Tank Litres	Terrace Tank Litres	Near UG Tank lpm	Near Terrace Tank lpm
1	2	3	4	5	6	7	8	9	10	11
(4)	**Assembly Building.**									
	(i) Less than 10 m in height									
	(a) Upto 300 persons	R	NR	R	NR	NR	NR	10,000 (5000)	NR	450 (450)
	(b) More than 300 persons	R	NR	R	NR	NR	NR	15,000 (5000)	NR	900
	(ii) Above 10 m but not exceeding 15 m in height	R	R	NR	NR	NR	50000	5000 (5000)	2280 lpm E-1 D-1	450 (450)
	(iii) Above 15 m but not exceeding 24 m in height	R	R	NR	R	R	75,000	10,000	2280 lpm E-1 D-1	NR
	(iv) Above 24 m but not exceeding 30 m in height.	R	R	NR	R	R	100,000	20,000	2280 lpm E-2 D-1	NR
(5)	**Business Building**									
	(i) Less than 10 m in height	R	NR	R	NR	NR	NR	10,000 (5000)	NR	450 (450)
	(ii) Above 10 m but not exceeding 15 m in height	R	R	NR	NR	NR	50000	5000 (5000)	2280 lpm E-1 D-1	450 (450)
	(iii) Above 15 m but not exceeding 24 m in height	R	R	NR	R	R	75,000	10,000	2280 lpm E-1 D-1	NR

S. No	Type of Building Occupancy	Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler	Capacity		Pump Capacity, Type, Number	
							UG Tank Litres	Terrace Tank Litres	Near UG Tank lpm	Near Terrace Tank lpm
1	2	3	4	5	6	7	8	9	10	11
	(iv) Above 24 m but not exceeding 30 m in height	R	R	NR	R	R	100,000	20,000	2280 lpm E-2 D-1	NR
	(v) Above 30 m in height	R	R	NR	R	R	200,000	20,000	2850 lpm E-2 D-1	NR

Legend :

R- Required to be provided

NR- Not required to be provided

E-1- One electrically operated main fire pump.

E-2- Two electrically operated main fire pump.

D-1- One diesel engine main fire pump.

Note:

(1) (*) To be provided if basement area exceeds 200 m²

(2) Value given in paranthesis shall be added if basement area exceeds 200 m²

(3) The buildings indicated in Col.(2) shall include the following buildings.

(A) Residential Buildings	:	Apartments, Dormitories, Hostels, Barracks (Does not include Hotels.)
(B) Educational	:	Schools and Institutions.
(C) Hospital and Nursing Home	:	Hospital, Nursing Home, Sanatoria.
(D) Assembly Buildings	:	Buildings used for Recreations, Social, Religious purpose e.g. Theatre, Motion Picture Houses, Assembly Hall, Auditorium, Exhibition Hall, Museum, Restaurant, Place of Worship, Station, Terminals of Air etc.

(E) Business Buildings	:	Office, Banks, Professional Establishments, Laboratories, Research Establishments, Libraries, Test House. Computer installation, Telephone Exchanges etc.

(4) Buildings at B,C and D in Note 2 are not permitted more than 30 m. in height.

(5) ***Automatic Sprinkler.*** Automatic Sprinkler shall be provided in basement if area is 200 m^2 and above.

(6) Typical system with one electric and one diesel fire pump shall be as shown in Fig 1 and 3

(7) Typical system with two electric and one diesel fire pump shall be as shown in Fig 2 and 4.

Appendix – C
Data acquisition and Control Modules Specifications

1. i-7050 Digital Input Output Module

Specifications

Digital Input

Channels	7 (Sink)
Digital Input status Logic Level 0 Lofic level 1	 +1V max. +3.5V ~ +30V
D/I can be used as counter channels Input Frequency 16 bit	7 100Hz 0 ~ 65535

Digital Output

Channels	7 (NPN, Sink) Open collector to 30V, 30mA max. load
Power Dissipation	300mW

2. i-7052 Isolated Digital Input Module

Specifications

Digital Input

Channles	8 6 fully independent channels 2 common ground channels
Digital input status Logic level 0 Logic level 1	 +1V max. +3.5V ~ +30V
D/I can be used as counter channels Input Frequency 16 bit	8 100Hz 0 ~ 65535
Input Impedance	3KW, 0.5W
Isolation Voltage	5000Vrms

3. i-7520 Isolated RS232 to RS485 converter

Specifications

Serial Interfaces

1. RS-232 Interfaces are full-duplex and require just data signals Signals TX, RX
2. Baud Rates Std Windows rates up to 115.2 kbaud
3. Data Bits 7 or 8 bits
4. Parity None, odd or even
5. Stop bits 1 or 2
6. Flow Cntl None
7. RS-485 Interface is half-duplex and includes self tuner and network protection Signals TX/RX pair
8. Baud Rates Std Windows rates up to 115.2 kbaud.
9. Data Bits 7 or 8 bits
10. Parity None, odd, or even
11. Stop bits 1 or 2
12. Distance 1200 M
13. RS-422/RS-485 Interface is fullduplex and includes self tuner and network protection Signals TX pair, RX pair
14. Baud Rates Std Windows rates up to 115.2 kbaud.
15. Data Bits 7 or 8 bits
16. Parity None, odd, or even
17. Stop bits 1 or 2
18. Distance 1200 M

CE Certification

EMC Directive 89/336/EMC

Emission EN 55022

Noise immunity EN 50082-2C