Data Acquisition & Control using WSN (Sink Node)

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***Abstract* - Wireless sensor network (WSN) is an infrastructure less network with low cost application oriented & low power, sensing wireless nodes. Wireless Sensor Networks (WSNs) is one of the most important technologies for the twenty - first century. Wireless sensor networks play an important role for information gathering and analysis from remote locations. Advances in development of energy efficient, low-cost, small size hardware components will allow wireless sensor networks to be comparatively more cost-efficient. This paper presents details of one of the application of WSN called Data Acquisition & control using WSN.**

***Keywords* - Wireless Sensor Network, WSN Application, Data Acquisition & Control, Sensor Node**

I. INTRODUCTION

Wireless Sensor Networks is a smart communication network which enables setting up an intelligent network which can handle applications as per user requirements. Wireless Sensor Network (WSN) is an effective solution for a wide range of applications. With the recent technological advances of wireless sensor network, it is becoming an integral part of our lives.

Data Acquisition & Control is one of the applications which can be employed in various fields like variety of industrial, civilian and military applications .In industrial application there are various process parameter like temperature, humidity, gas, light, etc. Traditionally, Data Acquisition is achieved by a small number of expensive and high precision sensing units. Collected data are retrieved directly from the equipment at the end of the experiment and after the unit is recovered. Nodes are equipped with low precision sensors but the network as a whole provides better performance.

Data Acquisition & Control System using wireless sensor networks includes designing and developing of a smart sensor network to record & control Process parameter like temperature, water level & light. It also implements a Visual Data Acquisition System with networking capability using microcontroller. This system allows the control operator to monitor and control Process parameter via centralized control room. The design uses a microcontroller to perform data acquisition & controlling action and uses WSN for data communication. In this way conservation of energy can be made easily possible, giving rise to a completely automated data acquisition & control system

This paper provides an extensive view about WSN details & application of WSN called Data Acquisition & Control System. The paper is organized as follows. In Section II, details of simple data acquisition & control system are given. Section III describes data acquisition & control system using WSN. Section IV gives overview of WSN which includes WSN communication structure, overview of sensor node in WSN, implementation of sink node, components of sensor node & design issues of WSN. Section V Design of Sink node in WSN network, Section VI describes an example of commercially available WSN applications. Section VII contains the advantages of data acquisition & control system using WSN. Section VIII illustration challenges & solution in WSN design. Finally, Section IX concludes the paper.

II. SIMPLE DATA ACQUISITION & CONTROL SYSTEM

A Data Acquisition & control system is one of the most popular control automation applications. In simple Data Acquisition & control system there is only one parameter which is to be monitored & control. Figure1 below shows a simple Data Acquisition & control system.

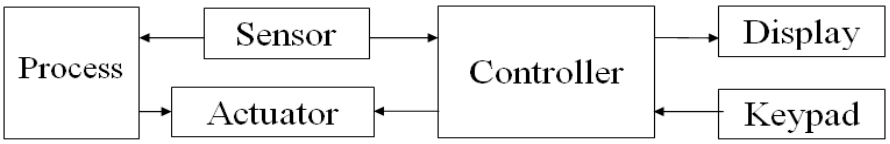

Figure1. Simple Data Acquisition & Control System

Different components of the system are:

1. *Controller*: It is the heart of this project. It controls and synchronizes operation of each and every external peripheral connected to it. System can be implemented using simple 8-bit microcontroller which is used for controlling specific operations. Some of the major features of the microcontroller: flash ROM, RAM, interrupt sources, interrupt priority levels, timers, etc.

2. *Sensor:* It is used in the system to sense the process under monitoring. The sensor senses the process status regularly. The input to the sensor is process parameter & output of sensor is electrical (analog) form. The analog output of sensor will be amplified using signal conditioning circuit.
3. *Actuator (Relay):* A relay is switch which is operated electrically. It can switch AC and DC. Relays can switch high voltages.
4. *Keypad:* Keypad is used for entering set point for the process parameter for controlling process. Continuously monitored parameter is compared with this set point & if monitored parameter exceeds this set point , controller will take corrective action
5. *Display:* LCD means Liquid Crystal Display .It is a display device which displays the information provided to it. Its shape and size varies from application to application.

III. Data Acquisition & Control System Using WSN

Why Wireless?

In most industrial plant, control system is used to monitor & control different parameters in processing plants. Since many plants are big in size and controlled by a few operator, so it become difficult to manage multiple processes data. In many applications like chemical plant, operator has to work in hazardous conditions, where person is not advisable to go. In such cases monitoring the control system from a remote place within the plant/ outside the plant is the best option.

In many situations it is desirable to make measurements in locations where the use of cabled sensors cannot be done. In some applications long cables decrease the quality of the measurement or it may become too expensive. Sometime it is important to increase the number of measurements but the data logger doesn't have enough available channels remaining for attaching additional sensor cables. A WSN provides an efficient solution to implement all such wide variety of application.

Introduction to Data Acquisition System Using WSN

Data Acquisition System Using WSN contains number of sensor nodes which has four basic components such as sensor, processing unit, transceiver unit & power supply unit as shown in Figure2. It may have application specific additional components. Sensing units is a combination of sensor and analog to digital converter (ADC). The analog output of sensors is converted in digital form using ADC, and then it is processed using processing unit. A transceiver unit connects the node to the network.

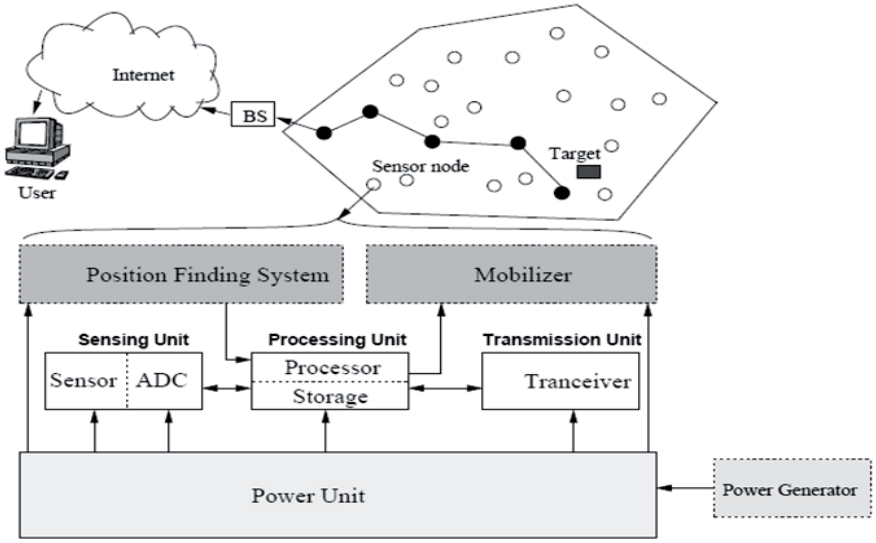

Figure2. Sensor Node Components

IV. Wireless Sensor Network (WSN)

A WSN can be generally described as a network of nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment. This section provides an overview of WSNs Communication Structure, Overview of Sensor Node in WSN, Implementation of Sink Node, and Components of Sensor Node.

WSN Communication Structure

A typical sensor network contains a number of sensor nodes which processes the data and communication it to network. The sensor nodes communicate the received data via radio transmitter, to a sink node either directly or through other nodes. Figure3 shows the communication architecture of a WSN.

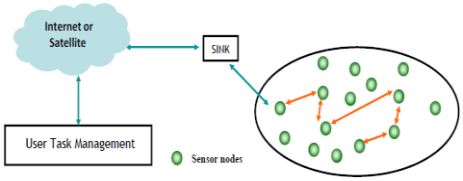

Figure3. General Communication Structure of a WSN

Overview of Sensor Node in WSN

A functional diagram of a wireless sensing node is shown in Figure4. Depending on parameter to be sense, sensor and required signal conditioning can be used. Radio link can be used for wireless connectivity of network. Flash memory helps the remote nodes to acquire data. The microprocessor has a number of functions including:

a) Managing sensor data collection.
b) Power management
c) Sensor data interfacing

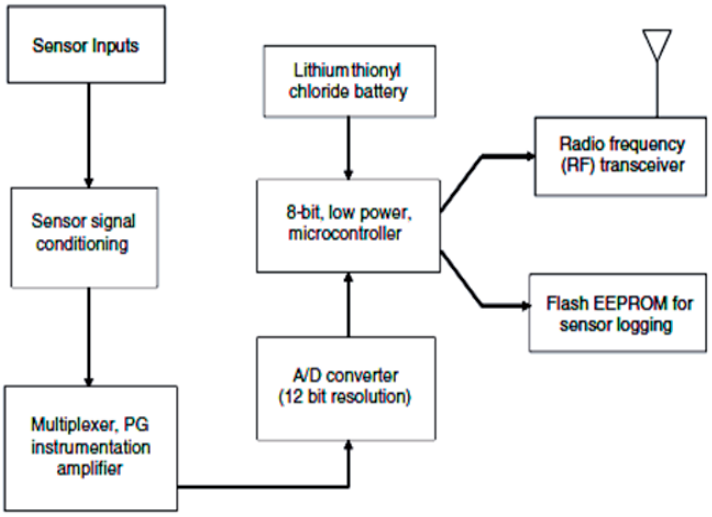

Figure4. Functional diagram of a sensor node

Implementation of Sink Node

Sink node is the final node near control room or data retrieving end. All the sensor nodes in sensor field communicate their data to sink node either directly or multi hop data transmission to sink node through other nearby node. There are two way to implement the sink node.

1. *Using Discrete Component* : In this method final sink node which is combination of discrete component such as sensor, data acquiring circuit, microcontroller & transceiver unit is shown in figure 5
2. *Using Integrated Component* : In This Method integrated component like Mica2 mote (which itself is having inbuilt sensors, transceiver and processing unit) & Interface Board is used, as shown in figure 6

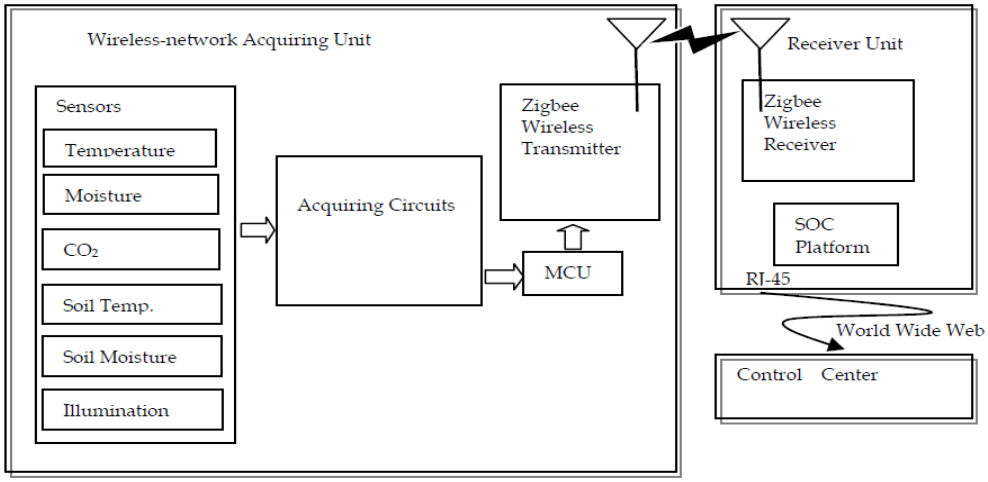

Figure5. Sink Node Arrangement using discrete components

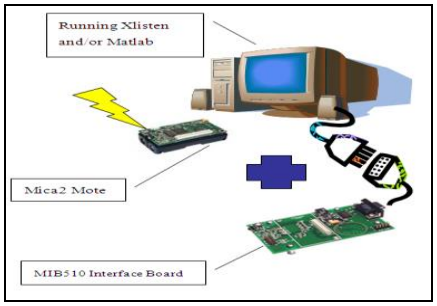

Figure6. Sink Node Arrangement using Integrated Component

V. DESIGN OF SINK NODE

Introduction

The proposed system is use to design a sink node of data acquisition & control system, particularly using wireless sensor network. It includes designing and developing of a *smart sensor network node* to record & control Process parameter like temperature & water level. This system will also include a Visual Data Acquisition System with networking capability using microcontroller. The proposed system monitors particular process parameter continuously. The system allows the control operator to monitor and control process parameter via centralized control room. The design uses a microcontroller to perform data acquisition & controlling action and uses RF module for data communication. In this way a completely automated data acquisition & control system can be designed.

System Architecture Overview & working

Sink Node in Data Acquisition & Control System Using WSN implements a Data Acquisition System with wireless Networking capability using microcontroller & RF module. Figure 7 shows system block diagram. It implements an interface to a temperature sensor, water level sensor, & data communication module. The Temperature level in the area will be continuously monitored via the temperature sensor. The temperature levels will be logged at predefined intervals and will be transferred to the main station via the wireless link. As long as the temperature level is within set limits fan is off. As soon as the level increases beyond the set limits, Fan will be ON. Figure 8 shows system flow.

On the main station the data will be captured and will be stored in a database for further temperature analysis (temperature level records) and in case if any increase is detected an alarm will be raised on the PC for urgent attention. Same operation may be performed in case of water level. Water level increase alarm will also be given. The software architecture is based on Ad-Hoc model. Software on the PC acts as a terminal and will continuously keep polling for messages. When data is received from the terminal, it will immediately log all data acquired into the data base. The server program will analyze the data and take action accordingly. This system will not only be useful in industry field, but also has great future in smart-data acquisition & control system.

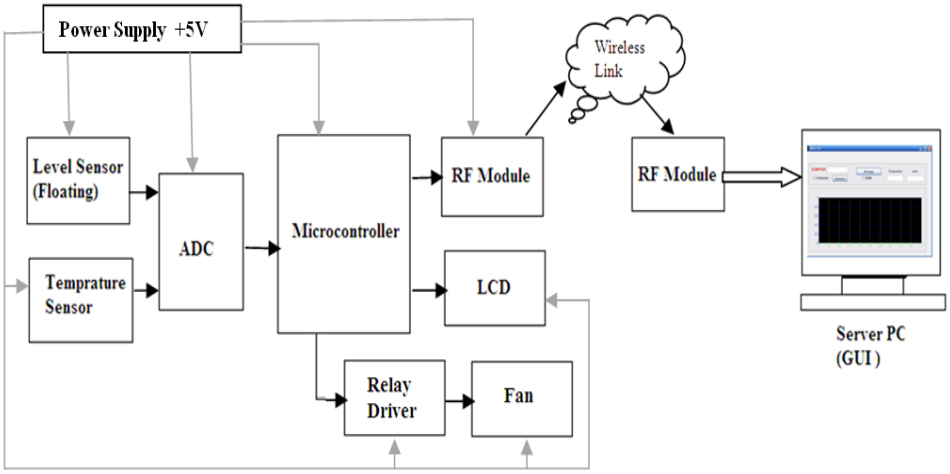

Figure7. System Block Diagram

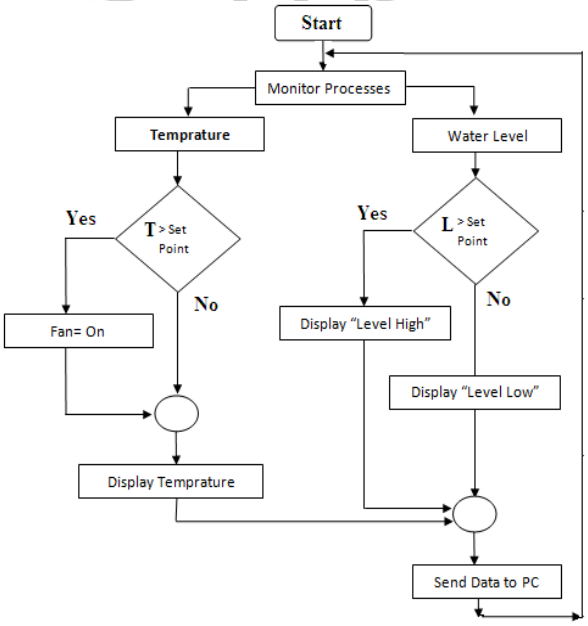

Figure8. System Flow

Results

In proposed system as I have designed a sink node in data acquisition & control system using WSN, there are two processes-temperature & water level. Set point given for temperature is 50°c. LCD will continuously show current temperature & water level either (High /Low). Initially Fan is off, but as temperature increases above 50°c it will become ON. Simultaneously the temperature & level data is continuously sent through RF module to Server PC. GUI is built using MATLAB software. On server PC we can see graphical representation of temperature with respect to time.

Figure shows hardware implementation of proposed system. Figure shows LCD display which shows temperature & level & Figure shows GUI which shows graphical representation of temperature with respect to time.

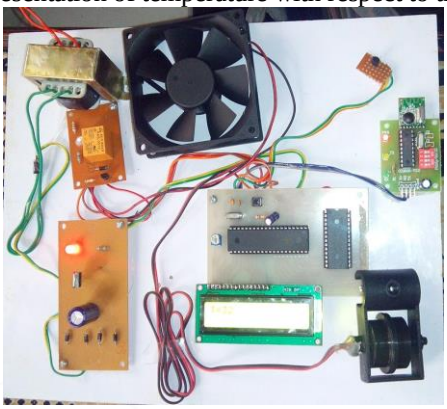

Figure9. Hardware Implementation

Figure10. Hardware output on LCD

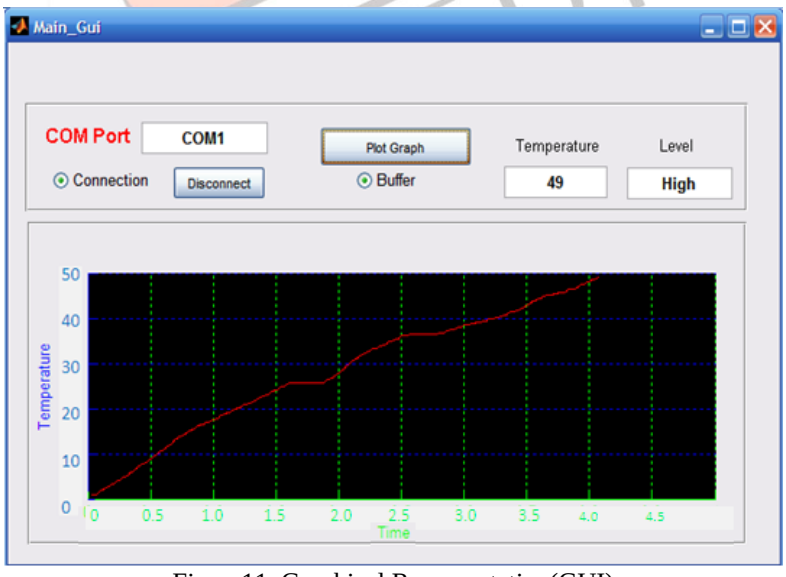

Figure11. Graphical Representation(GUI)

VI. Commercially Available Wireless Sensor Network Applications

There have been lots of successful applications all over the world. A wireless self-organizing mesh field network has been applied to monitor wellhead annular pressure and heat exchanger pressures on an offshore platform in the ocean. Even though the wellhead area is crowded with metal obstructions everywhere, remote monitoring is achieved successfully in this harsh, difficult

to reach area. Continuous monitoring of pressures eliminates the need for daily visits to the wellhead to manually record gauge readings and enables unusual readings to be identified earlier and action taken to investigate and rectify faults before they develop into serious problems. What's more, the installation took about two hours compared with up to two days for a conventional wired installation. Another exciting application is the temperature monitoring on a rotating drier to ensure that the proper temperature is reached and maintained during the drying process. The cost of wiring for temperature measurement on a rotating drier is prohibitive. With the savings introduced by using wireless transmitters, more temperature transmitters can be located on each drum to increase the amount of process information. Additionally, the five year battery life for each unit lessens the need for periodic transmitter maintenance.

An example network is shown in Figure 6-. It depicts a precision agriculture deployment- an active area of application research. Hundreds of nodes scattered throughout a field assemble together, establish a routing topology, and transmit data back to a collection point. The application demands for robust, scalable, low-cost and easy to deploy networks are perfectly met by a wireless sensor network. If one of the nodes should fail, a new topology would be selected and the overall network would continue to deliver data. If more nodes are placed in the field, they only create more potential routing opportunities.

Figure 6: Possible deployment of ad-hoc wireless embedded network for precision agriculture. Sensors detect temperature, light levels and soil moisture at hundreds of points across a field and communicate their data over a multi-hop network for analysis.

VII. Advantages Of Process Parameter Monitoring System Using Wireless Sensor Network (WSN)

WSNs bring several advantages over traditional wired industrial monitoring and control systems as expressed in the following:

1. *No Wiring Constraints*
   Without the wiring constraints, devices can be utilized in applications that previously are either physically unreachable or cost prohibitive. Furthermore, the industrial process system becomes highly scalable and flexible due to the device autonomy. In addition, newly added devices can be installed at any location without running power supply and data communication wires.
2. *Easy Maintenance*
   After the installation of wired device, control engineers have to deal with various wiring maintenance problems. Wireless device is almost carefree, only a battery change is necessary after years of operation. In addition, it is also possible to relocate current wireless devices or include additional wireless devices on the control system after it has been installed with minimal changes to the existing configuration.
3. *Reduced Cost*
   Going wireless eliminates the wiring and installation cost. What's more, for some applications, sensing nodes can put their radio in off mode when necessary, this will save lots of energy compared to wired devices, which requires constant power supply.
4. *Better Performance*
   Industrial WSNs has higher data transmission speed. Secondly, unlike wired control systems, where devices share a single bus, multiple wireless communications can act simultaneously if there is no mutual radio interference. Thirdly, more sensors/data points can be used to beat the performance of traditional wired control system.

VIII. Challenges And Solutions

Even though adopting WSN technology to process control systems is attractive, there exists a lot of challenges. The transition from wire to wireless can be beneficial only if related issues are resolved by the combined efforts from both academy and industry.

The following actions can be taken to improve the accuracy, integrity, and freshness of data.

1. *Radio transmission technology:*
   For physical layer radio transmission, the Direct Sequence Spread Spectrum (DSSS) or Frequency Hopping Spread Spectrum (FHSS) technology has been utilized to significantly reduce noise interference. Also, higher gain or directional antenna can be used to improve signal strength.
2. *Diversity technique:*

Different radios may be utilized for operation of various ranges. Also, a sensor's radio transceiver can be capable of changing its transmission power to achieve different transmission ranges.

3. *Multi-path technique:*
   Signals may be routed through multiple wireless nodes. In mesh network, multiple paths are used for delivery a single message to guarantee its reliability to 99.9%. For example, if one path is block by obstacle, the data can still be transmitted through other paths.
4. *Evaluation and estimation technique:*
   A WSN self-test technique is introduced to deal with the dynamic RF environment. It indicates that unlike wired channels, where errors come from faulty cables, connector or other hardware components are occur, transmission errors occur on wireless channels. By evaluating parameters from a feedback loop, the RF environment characteristics can be estimated and they are used to predict the performance and adapt the operational characteristics of the WSNs to meet the specific application goal.
5. *Redundant technique:*
   Components in WSN can be redundant to increase its reliability. Also, if we can use two or more different frequencies to communicate at the same time, data transmission will continue even if there is interference on one of the frequencies.

IX. CONCLUSION

WSN is a technology with promising future and it is presently used in a wide range of applications to offer significant advantages over wired system. The demanding constraints for process monitoring and control applications has many challenges to the implementation of WSNs to the industrial field. In this paper we have surveyed various issues relating to implementing the WSN technology to process monitoring and control.

Future research and development may continue to be focused on further improvements of the reliability and responsiveness, and technology advancements on energy saving, power management, fault tolerance, and smart routing. Research can also be done to improve overall system performance, predict potential problem, and provide suggestions for meeting the desired customer requirement. Also, control over wireless is still an emerging research area.

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