CHAPTER 4

AN ENHANCED WIRELESS DAQ SYSTEM

4.1 INTRODUCTION

Most of the industrial automations and control systems nowadays are based on semiconductor technology, embedded systems and computer science. The control systems can be operated either by simple or in a very complex manner depending upon the requirements and the usage. Some of the changes are made through the hardware and software modifications, and modifications may be either expanding or reducing controlling devices to increase the adaptability and flexibility of the specific application. The DAQ system based on the fast developing embedded systems are mainly used in the field of industrial automation and controlling plant functions.

Modern control system operation and design methodology are very complex one. Under these circumstances, the hardware must be expanded and programmed, which reduces the equipment usage to increase the adaptability and flexibility to the specific applications (Shaik 2011). The input and output capabilities are expandable to maximize the operation and function of the systems used for industrial and Real-time environments (Andrade et al 2011). Real time embedded systems and industrial control systems are the most important areas in the research on embedded control applications. For low level factory automation, the system uses wireless technology, which is a more flexible method for distributed control and DAQ system. Wireless
technology comparatively is best to wired technology in terms of cost, transmission efficiency, data reliability (Luo et al 2002).

The proposed system describes an embedded system uses a Wireless method with advanced Wi-Fi technology allowing remote device control and data acquisition with respect to existing systems. By using ARM9 processors the execution speed is comparatively faster than the existing microcontroller. This embedded device plays the major role in building networked manufacturing systems that show a very promising prospect for industrial applications like gas plant and power plant applications (Andrade et al 2011).

4.2 RELATED BACKGROUND

The Real-world signals to be analyzed are physical phenomena. Nowadays computers with EISA, ISA, PCI or PCMCIA bus is used for DAQ in testing, measuring, laboratory applications, industrial automation environments and research by the scientists and engineers. Many applications used plug-in boards to acquire data and transfer it directly to computer memory. In some cases DAQ hardware can be incorporated within the PC and communicated to the external world by parallel or serial communication protocols. Typically DAQ plug-in boards are general purpose DAQ devices that are well suited for measuring voltage signals. The integration of multiple components on a single package is allowed in modern high capacity FPGA which includes processing, storage and input-output capabilities that is necessary for DAQ systems. Therefore it is not scalable.

4.3 OVERALL DESIGN OF THE PROPOSED DAQ SYSTEM

Depending upon the functions and utilities of an embedded system it has various designs to interact with its environment continuously and to
carry out various tasks with its timing constraints for meeting the requirements of system performance (Gori et al 1999). The processors had a great impact on embedded system design (Hua Fang et al 2011). The system's hardware mainly consists of a DAQ, a controller and the data transmission module (Gan-ping Li 2010). Each sensor of the DAQ part gets the input signal that is transmitted to the ARM9 through wireless medium and the ARM processes that data and transmits to mobile handheld devices or PC machine or laptop through the Wi-Fi for ease of monitoring. The overall system design is shown in Figure 4.1.

Figure 4.1  Block diagram of wireless data acquisition system using ARM9 and Wi-Fi

4.4  IMPLEMENTATION OF THE SYSTEM

The system is implemented using the ARM processor which acquires the Real-world data and communicate the same with the PC through wireless protocol Wi-Fi. Here the DAQ system is implemented for the gas industry applications. In which the data are acquired by sensors and
monitored. The monitored value is converted to a digital value by inbuilt ADC in ARM9. However the major considerations were the space and power consumption and the ADC has been designed with high resolution measurements as per the requirement of an application. The acquired data are transmitted through the Wi-Fi modules and the values are stored in the system (PC or Laptop or any handheld devices) (Alkar & Karaca 2009). The Real-time data that are acquired from the acquisition system can be realized by the system and refreshes the data whenever needed. Hence the system can carry out high efficient DAQs and enhance the Real-time performance of a complex control process. The hardware and software implementation are discussed as follows.

4.4.1 Hardware Requirements

The hardware used to design and implement the DAQ system is S3C2440A processor with ARM920T core.

4.4.1.1 S3C2440A processor with ARM920T core

The target board contains the SAMSUNG’s S3C2440A IC with 16/32-bit RISC microprocessor. This SAMSUNG’s S3C2440A is designed to provide in the handheld devices mainly for the reduced power consumption with the kit when compared to the other processor. This kit is mainly used in the low power application with a high performance processor of reduced size. For further reduction in the cost of the system the S3C2440A has included and developed using ARM920T core with 0.13µm CMOS standard cells with an enhanced memory compiler (Jian Ge et al 2010).

The device is advantageous because of low power, simple usage, maintenance free and fully in the format of static design which is particularly used for the cost effective and power sensitive applications. It also adopts the
new method of bus architecture called as Advanced Microcontroller Bus Architecture (AMBA). The enhanced SAMSUNG’s S3C2440A includes outstanding features of CPU core and 16/32-bit ARM920T RISC processor (Mo Guan & Minghai Gu 2010). The ARM920T contains Memory Management Unit (MMU), Harvard Cache Architecture and AMBA BUS uses separate 16KB data caches and 16KB instruction of 8-word line length. The Target Board is illustrated in Figure 4.2.

![Figure 4.2 ARM9 Mini2440 target board](image)

### 4.4.1.2 Wi-Fi modem

The market for wireless communication has grown rapidly since the introduction of 802.11b Wireless Local Area Networking (WLAN) standards which offer performance more nearly comparable to that of Ethernet. WLAN (or) Wi-Fi was created specifically to operate as a wireless Ethernet (Li Nan et al 2010). It is an open standard technology that enables wireless connectivity between equipments and LANs. Public access WLAN services are designed to deliver LAN services over short distances typically 50 to
150m. In these cases WLANs are connected to a local database and give the end user access through a kiosk or portable device.

Internet access through public WLANs is a new and very hot trend providing many benefits and conveniences over other types of mobile Internet access. Performance is 50 to 200 times faster than dial up Internet connections or cellular data access. The users do not have to worry about cords, wires or sharing an access point such as a phone jack. A global directory that would provide users with a search engine to locate the closest access point. Even without the directory WLAN devices make it very easy to connect. Most WLAN enabled devices have a software utility that indicates a user’s proximity to a WLAN access point. Service providers place an antenna or access point at a designated hot spot. The antenna transmits a wireless signal to the adapter card present in a user’s computer or device. Users connect to the WLAN through a page in their Internet browser.

Coverage extends over a 50 to 150m radius of the access point. Connection speeds range from 1.6Mbps which is comparable to fixed DSL transmission speed to 11Mbps. New standards promise to increase speeds to 54Mbps. Today’s WLANs run in the unlicensed 2.4GHz and 5GHz radio spectrums. The 2.4GHz frequency is already crowded. It has been allocated for several purposes besides WLAN service. The 5GHz spectrum is a much larger bandwidth, providing higher speeds, greater reliability and better throughput.

4.4.2 Software Requirements

The softwares used as a front end and back end design tools which are utilized to simulate the DAQ system are given and explained.
4.4.2.1 Front end design

Visual Basic (VB) is a third-generation event-driven programming language and Integrated Development Environment (IDE) from Microsoft for its Component Object Model (COM) programming model first released in 1991. VB is designed to be relatively easy to learn and use. VB was derived from BASIC and enables the Rapid Application Development (RAD) of Graphical User Interface (GUI) applications (Qiu & Gooi 2000), access to databases using Data Access Objects, Remote Data Objects, or ActiveX Data Objects and creation of ActiveX controls and objects. The scripting language VBScript is a subset of VB.

A programmer can create an application using the components provided by the VB program itself. Programs written in VB can also use the Windows API but doing so requires external function declarations. Though the program has received criticism for its perceived faults and version 3 of VB was a runaway commercial success and many companies offered third party controls greatly extending its functionality. The final release was version 6 in 1998. Microsoft's extended support was ended in March 2008 and the designated successor was VB.NET (now known simply as VB). A dialect of VB, VB for Applications (VBA) is used as a macro or scripting language within several Microsoft applications including Microsoft Office. Like the BASIC programming language VB was designed to be easily learned and used by beginner programmers.

The language not only allows programmers to create simple GUI applications and also to develop complex applications. Programming in VB is a combination of visually arranging components or controls on a form specifying attributes and actions of those components and writing additional lines of code for more functionality. Since default attributes and actions are defined for the components and a simple program can be created without the
programmer having to write many lines of code. Performance problems were experienced by earlier versions but with faster computers and native code compilation this become less of an issue.

Although VB programs can be compiled into native code executable from version 5 onwards they still require the presence of runtime libraries of approximately 1MB in size. Runtime libraries are included as default in Windows 2000 and later. The VB window for developing the embedded based applications are illustrated in Figure 4.3.

![Visual Basic code window](image)

**Figure 4.3 Visual Basic code window**

4.4.2.2 Back end design

The backend design is implemented with embedded Linux. Porting of Real-time OS with the ARM processor is one of the basic implementation for developing the application. This section describes about the initial installation of ARM target to develop the Real-time application.

The tasks are created and ported in the ARM processor. It must be ensure that the Mini2440 is powered off and is not placed on any conductive
Before starting to download files or images to the Mini2440 user needs to have a serial and a USB cable connected between the PC and the Mini2440. If the USB drivers are not installed for the Mini2440 then the user has to install on the PC and can download any files to the Mini2440 (Mo Guan & Minghai Gu 2010). Then the user finds the driver in the download section.

- The serial cable to be connected between the Mini2440 serial port and the serial port of the PC. The required serial port connection settings on the PC are;
  
  - Bits per second $= 115200$
  - Data bits $= 8$
  - Parity $= \text{None}$
  - Stop bits $= 1$
  - Flow control $= \text{None}$

- A USB cable is connected between the PC and the Mini2440. To download images to the Mini2440 initially the user should set the Mini2440 to NOR by moving the slide switch to the NOR position. The Mini2440 NOR flash is used by the bootloader program and contains a program inside the NOR memory that interfaces with the PC via the serial and USB ports (Li Nan et al 2010). When the slide switch is set to the NOR position the Mini2440 will run the bootloader program contained in the NOR flash boot area, when the board is powered up or the reset button is pressed.

- Downloading the program Using DNW (dnw.exe)

- The program called “dnw.exe” to be run on the PC, the screen will display the information as in Figure 4.4.
Figure 4.4 DNW window to transfer window

- Clicking on the “Configuration” tab and selecting “Options”, setting the baud rate to 115200bps and selecting the com port number which the user using for the download that is if the serial cable is plugged into the COM 1 port on the PC then select COM 1. From the enlisted instructions the user will refer to all serial connections as “COM 1”. Set the USB Port download address to 0x30000000. PC screen displays the information as in the Figure 4.5.

Figure 4.5. Baud Rate set window

- Then the user to click “OK”.

- Clicking the “Serial Port” tab on the top left and selecting “Connect”, the screen will now show that DNW is connected
to the serial port to [COM1, 115200bps] by displaying this information in the top title bar. If the user does not have this message then the user needs to recheck the serial settings and/or serial cable connections. If the user's USB connection is correct the message [USB: x] will be displayed, if not it is needed to check the USB is properly configured.

- The downloading procedure begins.

- Power up the Mini2440 ensures the power LED is ON because of using the NOR flash bootloader the Mini2440 LCD will not display any information. However the PC will now be displaying the message as in Figure 4.6.

![Figure 4.6](image)

**Figure 4.6** Target board information to download the application and bootloader
• The bootloader program on the users Mini2440 is now communicating with the PC using the serial connection. If the user does not see the above screen then there is a problem with the serial connection. Instruct the boot loader program with commands inside the Mini2440 via the PC keyboard and observe the results on the screen of the PC. Maximize the DNW screen so that the user can see all the boot loader command options available.

• Pressing the “x” key and then returning/entering on the PC the screen will displays the information.

• Pressing the “v” key and then returning to the PC the screen will display “USB host is connected. Waiting a download.” The Mini2440 is now ready to receive a file via the USB. Click the USB Port from the menu at the top of the window and select the Transmit/Restore option. The screen will now ask the user to select a file to transmit, Select the “supervivi_Mini2440” file (if the file is not displayed ensure that the user to have the “all files *.∗” option selected). Then click OPEN.

• The file will be sent to the Mini2440 what the user has done is load the Mini2440 NAND boot with the supervivi file loader program. The PC screen will revert back to the main boot page.

The user need to install the Linux kernel press the “k” key and then return to the PC the screen will display “USB host is connected. Waiting a download”. Click the USB Port from the menu and select the Transmit/Restore option. The screen will now ask the user to select a file to transmit, Select the “zImage_a35” if the user has a 3.5” LCD, or
“zImage_a70” if the user had a 7” LCD or “zImage_1024x768” if the user is using the VGA adapter. Each Linux kernel is different depending upon which LCD he is using. Then click OPEN.

The file will now be downloaded via the USB to the Mini2440 after it has been downloaded and configured the PC screen will revert back to the bootloader menu. The next step is to install yaffs, press the “y” key and then return to the PC the screen will display “USB host is connected. Waiting a download”. Click the USB Port from the menu and select the Transmit/Restore option. The screen will now ask the user to select a file to transmit. Choose the “root_qtopia.img” file. Then click OPEN.

The file will now be downloaded into the Mini2440 it will take some time so just wait until it is completed and the PC screen reverts back to the bootloader screen. Now to boot the Linux system first power off the Mini2440. Then move the flash select slide switch to NAND Boot. Power up the Mini2440 and Linux will boot up if the user leaves the cables to the PC attached will display the LINUX debug messages while the Linux system on the Mini2440 is booting.

4.5 **AN ENHANCED DAQ SYSTEM**

Much important aspect is data should be stored as a record for the future reference and requirements. In the conventional model of DAQ system, the routing of data from different sensors is done through the discrete IC devices along with the ADC and an input multiplexer (Shaik 2011). In the proposed work, the DAQ system is implemented in the gas industry applications. Acquired data from the sensor are to be monitored. The monitored value is converted to a digital value by inbuilt ADC in ARM9. The major considerations were the space and power consumption, the ADC has been designed with high resolution measurements, as per the requirement of an application.
The Real-time data which are acquired from the acquisition system can be realized by the system and refreshes the data whenever needed. Hence, the system can carry out high efficient data acquisitions and enhance the Real-time performance of a complex control process (Shaik 2011).

4.6 IMPLEMENTATION OF THE PROPOSED SYSTEM

An enhanced DAQ system is an efficient system to acquire and transmitting data in an embedded system by using Wireless technology. It has simultaneously been acquiring information from channels and supplies the standard signal for the DAQ system and is transmitted to the global system. This method of embedded systems can be used for diverse applications involved in the Real-time controls and DAQs. The circuit diagram of sensor connections is depicted in Figure 4.7.

Figure 4.7 Circuit diagram of sensor connections
The proposed system is implemented using the Wi-Fi technology in a DAQ system (Li Nan et al 2010). Sensor input is acquired by ARM 9 and monitored. If the data value exceeds the reference (pre defined value) limit, warning message with alarm signal is sent. Gas and temperature are assumed to be input parameters and the corresponding sensors acquires the input. The acquired data is sent through Wi-Fi. Circuit diagram of Wi-Fi module connection is shown in Figure 4.8.

![Circuit diagram of Wi-Fi module connection](image)

**Figure 4.8 Circuit diagram of Wi-Fi module connection**
4.7 PERFORMANCE COMPARISON OF WIRELESS PROTOCOLS

Performance comparison of Bluetooth, ZigBee and Wi-Fi protocols with respect to their specifications and properties are given below:

a) **Bluetooth**

Bluetooth Low Energy (LE) started life as a project in the Nokia Research Centre with the name Wibree. In 2007 the technology was adopted by the Bluetooth Special Interest Group (SIG) and renamed Bluetooth Ultra-Low-Power and then Bluetooth LE. The aim of this technology is to enable power sensitive devices to be permanently connected to the Internet. LE sensor devices are typically required to operate for many years without needing a new battery. LE technology is primarily aimed at mobile telephones where it is envisaged that a star network topology, similar to Bluetooth, will often be created between the phone and an ecosystem of other devices (Anitha et al 2011).

LE is also known as Bluetooth v4.0 and is part of the public Bluetooth specification. As a result of being a standard LE benefits from all the advantages of conformance and extensive interoperability testing at unplug fests. A device that operates Bluetooth v4.0 may not necessarily implement other versions of Bluetooth; in such cases it is known as a single-mode device. Most new Bluetooth chipsets from leading Bluetooth silicon manufacturers will support Bluetooth and the new LE functionality.

b) **Zigbee**

ZigBee is a low-power wireless specification based on the Institute of Electrical and Electronics Engineers (IEEE) Standard 802.15.4-2003 and
was established in 2002 by a group of 16 companies. It introduces mesh networking to the low-power wireless space and is targeted towards applications such as smart meters, home automation and remote control units. Unfortunately ZigBee's complexity and power requirements do not make it particularly suitable for unmaintained devices that need to operate for extended periods from a limited power source. ZigBee channels are similar to those for LE in that they are 2MHz wide. However, they are separated by 5MHz thus wasting spectrum somewhat. ZigBee is not a frequency hopping technology and therefore requires careful planning during deployment in order to ensure that there are no interfering signals in the vicinity (Hemanth Kumar & Manjunath Iakkannavar 2012).

c) Wi-Fi

In recent years a number of improvements have been made to the Wireless-Fidelity (Wi-Fi) IEEE Standard 802.11 wireless networking standard which may be able to reduce its power consumption including IEEE Standard 802.11v and other proprietary standards. Although Wi-Fi is a very efficient wireless technology, it is optimized for large data transfer using high-speed throughput and is not really suitable for coin cell operation. Some companies are attempting to use Wi-Fi for HUD devices. Special proprietary driver software is required, however and only limited functionality can be achieved (Li Nan et al 2010).

In Table 4.1 a comparison of the various parameters related to the above discussed wireless communication protocols is presented.
Table 4.1 Comparison of wireless communication protocols

<table>
<thead>
<tr>
<th>SPECIFICATIONS/ WIRELESS PROTOCOLS</th>
<th>BLUETOOTH (Anitha et al 2011)</th>
<th>ZIGBEE (Xiangyang Li et al 2012)</th>
<th>Wi-Fi 802.11a/b/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Standard</td>
<td>802.15.1</td>
<td>802.15.4</td>
<td>802.11a/b/g</td>
</tr>
<tr>
<td>Sampling rate (MHz)</td>
<td>11MHz</td>
<td>8MHz</td>
<td>44MHz</td>
</tr>
<tr>
<td>Range of transmission (m)</td>
<td>10</td>
<td>10-80</td>
<td>10-300</td>
</tr>
<tr>
<td>Operating frequency (GHz)</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4, 5</td>
</tr>
<tr>
<td>Coding efficiency (%)</td>
<td>94.14</td>
<td>76.5</td>
<td>97.18</td>
</tr>
<tr>
<td>Data Protection</td>
<td>16 bit CRC</td>
<td>16 bit CRC</td>
<td>16 bit CRC</td>
</tr>
<tr>
<td>Power consumption (battery life)</td>
<td>Medium</td>
<td>Very low</td>
<td>High</td>
</tr>
</tbody>
</table>

It is observed that the Wi-Fi communication protocol is advantageous one compared with other protocols with respect to their specification and properties. So, it used for the experimental setup.

4.8 EXPERIMENTAL RESULTS

The implementation of the system consists of two units: DAQ unit and data storage unit. The DAQ unit consists of the ARM9 processor that collects all the analog data and process them. The processed data transfer from the DAQ unit to the PC via enhanced wireless communication protocol using Wi-Fi. Figure 4.9 depicts the overall system hardware implementation. The VB is used to acquire the data in the PC via Wi-Fi module.

Figure 4.9 Overall hardware setup using Mini2440 ARM9 processor
Wireless technology helps the user to improve the processes by adding new measurements to the systems that were previously impossible or impractical with a cabled solution. Real-time data acquisition is commonly required in a diversity of areas such as power grid, healthcare, industrial production, water conservancy, meteorology and agriculture. The use of phone lines or cables in these areas for data transfer would get half the result with twice the effort, while wireless networks could cover all the data acquisition points with much lower cost and less effort for installation and maintenance than wired networks. As the wireless communication and RF technologies keep evolving, wireless data acquisition systems present remarkable advantages in terms of easy and fast installation with low cost, and are gradually replacing the traditional wired systems.

4.8.1 Simulation Outputs

The proposed DAQ system hardware part is designed by using sensors, ARM9 Mini2440 and Wi-Fi modules with an alarm and the output must be monitored on the PC screen. The proposed concept is implemented in gas industry. The gas sensor, temperature sensor monitors the input value and monitored value of temperature is displayed on the PC using ARM9 kit. If the monitored temperature value exceeds the threshold value an alarm signal is raised. The warning message with the exceeded temperature with gas leakage percentage value is monitored and that also transmitted through Wi-Fi. By this way gas plant accidents are easily identified and eliminated with an effective manner.

Figure 4.10 and Figure 4.11 illustrates the monitored value of the DAQ system when the data exceeds the reference level.
It is observed that, when the displayed output value exceeds the reference level of the temperature and gas pressure level necessary actions are taken. Figure 4.12 shows the transmitted data monitored on the screen when the value is in normal condition. If the display observes output within the
reference level no actions will be taken but the informations are stored in the device memory for further reference.

Figure 4.12 Wireless transmitted data monitored on the screen, if value in normal condition

4.9 PERFORMANCE COMPARISON OF EMBEDDED PROCESSORS

Table 4.2 Comparison of various processors with ARM9

<table>
<thead>
<tr>
<th>SPECIFICATIONS/PROCESSORS</th>
<th>PIC MICRO CONTROLLER (Andrade et al 2011)</th>
<th>ARM7 (Yujun Bao &amp; Xiaoyan Jiang 2010)</th>
<th>ARM9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>1.8 V to 5.5V</td>
<td>3.6 V</td>
<td>3.3V</td>
</tr>
<tr>
<td>Operating Frequency</td>
<td>20 MHz</td>
<td>55MHz</td>
<td>300MHz</td>
</tr>
<tr>
<td>Maximum Frequency</td>
<td>40 MHz</td>
<td>85MHz</td>
<td>400 MHz</td>
</tr>
<tr>
<td>Maximum Latency</td>
<td>20 cycles</td>
<td>29 cycles</td>
<td>28 cycles</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-45°C to 85°C</td>
<td>-40°C to 85°C</td>
<td>-40°C to 80°C</td>
</tr>
</tbody>
</table>
From the Table 4.2, it is observed that the ARM9 core gives better performance compared with PIC Microcontroller and ARM7 processors and hence it is best suited for DAQ applications. Some of the discussions about ARM9 processor over PIC Microcontroller and ARM7 processors are as follows;

- ARM9 is flexible, highly integrated MCU and it is designed to optimize system control, user interface management and ease of use.

- ARM9 based MPUs range from entry-level devices to advance highly integrated devices with extensive connectivity, refined interfaces and ironclad security which makes the design process easier and reduce time to market.

- Innovative direct memory access (DMA) and memory implementations, which enable high-speed data transfers while freeing the processor for the application

**4.10 SUMMARY**

The design of a data-acquisition system based on an ARM 9 processor is presented as a new method for wireless transmissions through Wi-Fi technology and data acquisition. It offers necessary functions to develop an application for Real-time controls. The existing system is designed only for the specific application on Ethernet where the data loss is minimal. The proposed new DAQ system integrates signal conditioning, data acquiring, data collecting and processing function into the single board based embedded system with wireless technology using Wi-Fi. The Wi-Fi system is an efficient way of transmitting and receiving of the data value in a secured manner. Almost the system is efficient, simple design, fast in transmission and monitoring of data and data loss is less.
The VB is a front end tool to interact between the PC and DAQ system. The comparison of various wireless communication protocols and processors with ARM9 is given and the implementation is made in the well known protocol that gives the overall system an added advantage.