Development of adaptive and customizable Base Station system in Wireless Sensor Network

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Development of adaptive and customizable Base Station system in Wireless Sensor Network

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Abstract
This paper presents a development of dynamic base station for Wireless sensor network application, which highly capable to adapt itself for any other application in WSN. The proposed base station system has more memory, higher processing and communication capabilities. This system is able to query sensor data, process them, store them and deliver that data to user's cell phone, instantly. The base station system is built around ARM11 architecture microcontroller with Windows Embedded CE 6.0, so that it could possess good processing power, reliability, user friendly GUI and security. For communication purpose, IEEE802.15.4 based ZigBee RF module and GSM modem are used. The data received by base station is processed and stored in memory. The application of Base station is dynamic and customizable. User can change it easily as per the experimental or research requirements.

Keywords: Wireless Sensor Network, Sensors, Base station, Embedded System, System architecture.

Introduction

Wireless Sensor Networks (WSN) have attracted attention of researchers and industries in recent years because of its reliability, easiness, no wiring constraints, easy maintenance, reduced cost, better performance [1]. Now a days, WSN is rigorously used in various applications like environmental monitoring [2], precision agriculture [3], military applications [4], ubiquitous computing [5], etc. While doing research on WSN, generally it is focussed on data routing algorithms [6][7][8], energy conservation algorithms[9][10], optimization of nodes and their positioning [11] and many more. But apart from this, very few researchers are working over development of high end, highly capable and user friendly base station which can easily access and control the whole WSN efficiently.

This paper explains the dynamic base station we have designed. It is designed with ARM11 microcontroller with Windows Embedded CE 6.0 operating system. We tried to make it more functional such that it possesses high processing and communication capabilities with large memory storage It is an hand alone embedded system, which replaces the user computer and server as used in other WSN applications. For communication purpose ZigBee RF module and GSM modem are used.

The architecture of base station is designed such that, the base station can be customized according the changes in the application. Finally, the whole data received from nodes is processed and stored in memory efficiently.

Need of a Dynamic Base Station

While monitoring environment parameters, large number of nodes spread across a wide area. The number of nodes may be in the range of few hundreds to thousands. These nodes usually possesses low processing power and low memory. However to access the data sensed by nodes, a base station is necessary. A base station is a device which possesses higher memory, better communication capabilities and higher processing capacity. If any of node is used as Base Station, it may fail because of limitations of normal nodes. Hence, it might be impossible, if one of general sensor devices become a base station which could manage sensor networks and communication with other network technologies. Hence, base station needs to have enough hardware abilities, strong system and user friendly graphical user interface (GUI), such that capabilities of Wireless sensor networks can be enhanced [17].

Article [12] explained about Industrial graded Base station, which is built on AT91SAM9XE512 controller. Though this base station possesses enough ways of communications with nodes, it seems, it is having limited capabilities because of lack of an Embedded Operating System and high end GUI for users. Also, far remote user did not get any information about the sensor networks.
In the proposed design of Base station, an interactive application with very user friendly GUI is designed for capability enhancement of base station. The application is made dynamic, such that it can be used in any type of WSN applications. Base station is also able to provide sensor data to remote user, through GSM message.

Hardware System Design

The Base Station is designed on Witech OK6410-B-B Development Board, which is a ARM11 microcontroller platform which performs interactive data communication by means of ZigBee and GSM wireless transmission technology. In hardware system design, the interfacing between ARM processing unit with ZigBee RF module and GSM modem as shown in Figure 1.

A. Witech OK6410-B-B Development Board

For base station development, OK6410-B hardware platform is chosen, which is shown in figure 1. In embedded applications and high end products, ARM11 architecture finds valuable position. The development of microelectronics is one of the reason behind it.
The Witech OK6410-B-B Development Board is based on the Samsung ARM11 microcontroller S3C6410 (667MHz), with the integrated useful interfaces such as TV-out, CAMERA, USB, SD, LCD, Ethernet, and etc., makes the OK6410-B Development Board a powerful device for developing and implementing all kinds of embedded products. The OK6410-B Development Board is the single board version of OK6410, designed in conformity with CE standard with full consideration to high speed signal competence. OK6410-B is compatible for various operating systems like Windows CE6.0, Embedded Linux-2.6, Uc/OS-II and Android 2.1.[13]

B. ZigBee RF module

A ZigBee module with CC2420 chip is used for communication purpose between base station and the nodes in WSN. It is a 2.2 GHz IEEE 802.15.4 compliant and also a low power, short range RF transceiver. ZigBee module is able to transmit data over long distances by passing data through intermediate devices to reach more nodes. Though this module is low power consuming, it can limit the transmission distance depending on power output and environmental characteristics [14].

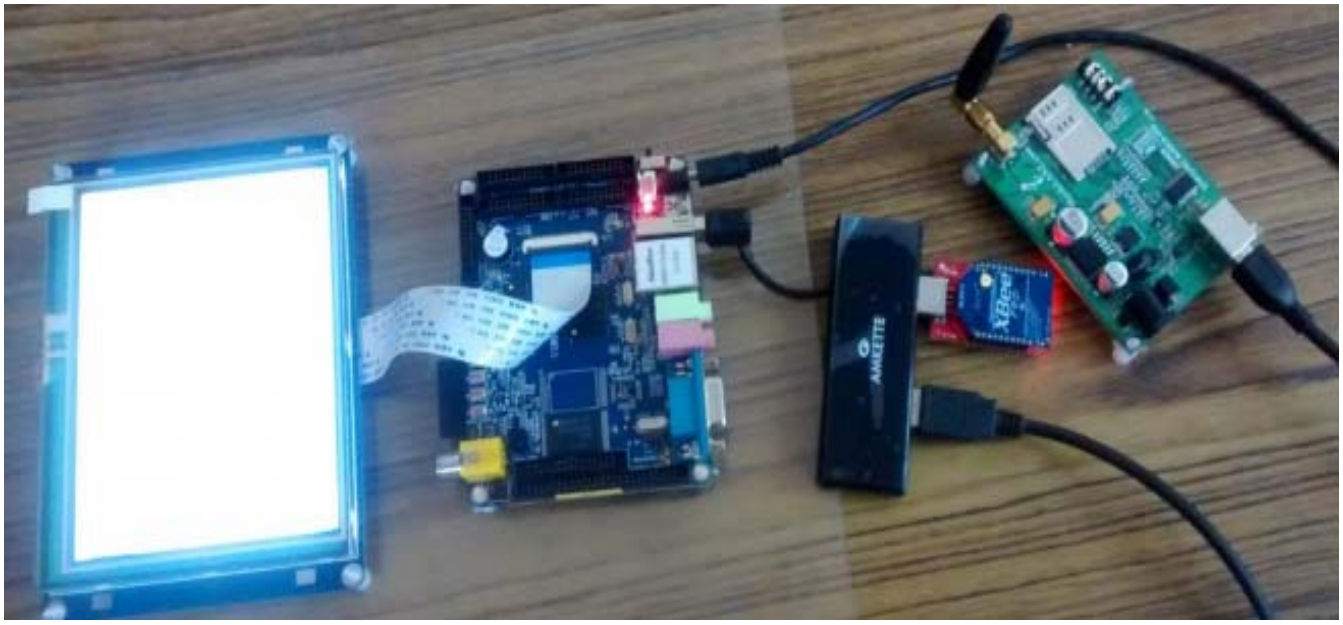


Figure 1: Hardware implementation of Base Station

C. GSM/GPRS module

A GSM/GPRS Modem with USB interface, which allows to connect with PC or any USB supporting interface is used to empower Base Station with high range and reliable communication. Once connected, it will create a virtual serial port for communication. The GSM/GPRS Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS, Voice as well as DATA transfer applications.
While developing Base Station, the GSM modem is connected to the OK6410 development board through USB port. TTL to USB converter is used to connect the GSM modem toTTL Serial port.

D. Software Platforms, Tools and Operating System

In Base Station, software part is designed in C# language. C# is simple, powerful, type-safe, and object-oriented language. The continuous innovations in C# language enable rapid application development[16]. Also, it retains the expressiveness of C-style languages. While developing Base Station applications, Windows Embedded CE 6.0 operating system and Visual Studio with .NET Framework is used.

i. Windows Embedded CE 6.0

Windows Embedded CE 6.0 (WinCE) is an open 32 bit embedded operating system developed by Microsoft. It was

designed only for embedded system applications. Windows CE is a distinctly different operating system and kernel, rather than a trimmed-down version of desktop Windows. Unlike the previous versions, the platform builder for Windows Embedded CE6.0 is no longer independent program but a plug-in in the Visual Studio 2005. That is to say, the Visual Studio 2005 is now the development environment for Windows Embedded CE 6.0.

ii. Visual Studio and .NET Framework

While choosing a programming language and platform for the development of the base station, various demands for such implementation are to be considered. These demands arise from the behaviour of WSN, the base station's type and our requirements. It may contain demands like application to be able to communicate with the gateway node through a serial port, store gathered values in a database, develop a graphical user interface (GUI) and much more. Visual Studio is a framework which allows to meet these demands easily. It contains a set of tools for developing GUI application, supports multithreading.

E. Implementation of Base Station

The base station implementation includes following subsections.

i. Hardware Implementation

The aim of the research is to design a dynamic base station for wireless sensor network, which will be ported on Development board. Figure 1 shows the experimental setup for the project.

The base station is the combination of the various hardware, which includes Witech OK6410-B-B Development board, USB ZigBee RF module and USB GSM Modem. Windows Embedded CE 6.0 OS is installed on Witech OK6410-B-B Development board. Also, the base station application is installed on it. The base station possesses touch screen interface TFT LCD display. The inbuilt Real Time Clock (RTC) in development board is used for real time processing and handling of base station. The USB ZigBee is used to establish the wireless network between base station and nodes. Whereas the USB GSM modem is used to share data with the remote users. The Witech OK6410-B-B Development board consists of only one USB On-The-Go connector. Hence to connect two USB devices, i.e. GSM modem and ZigBee both, a USB hub is used. For the sake of USB interfacing as On-The-Go device, the suitable driver is needed to install on the development board.

ii. Software Implementation

In software point of view, the aim of the project is to create an application for Base Station, which is having various functions necessary for wireless sensor networks. The base station application is developed in Visual Studio using C# .NET considering ARM11 Development board as a hardware platform. Figure 2 shows the front end of the base station application installed on the development board.

The application front end GUI contains various user controlled functions, text displays and menus. Few of these menus as discussed:

1. Date Selector: It enables user to select date, on which the base station should start working.

2. Current time: This text box displays the current date and time. This date and time is chosen from the Real time clock (RTC) available on the OK6410 Development board.

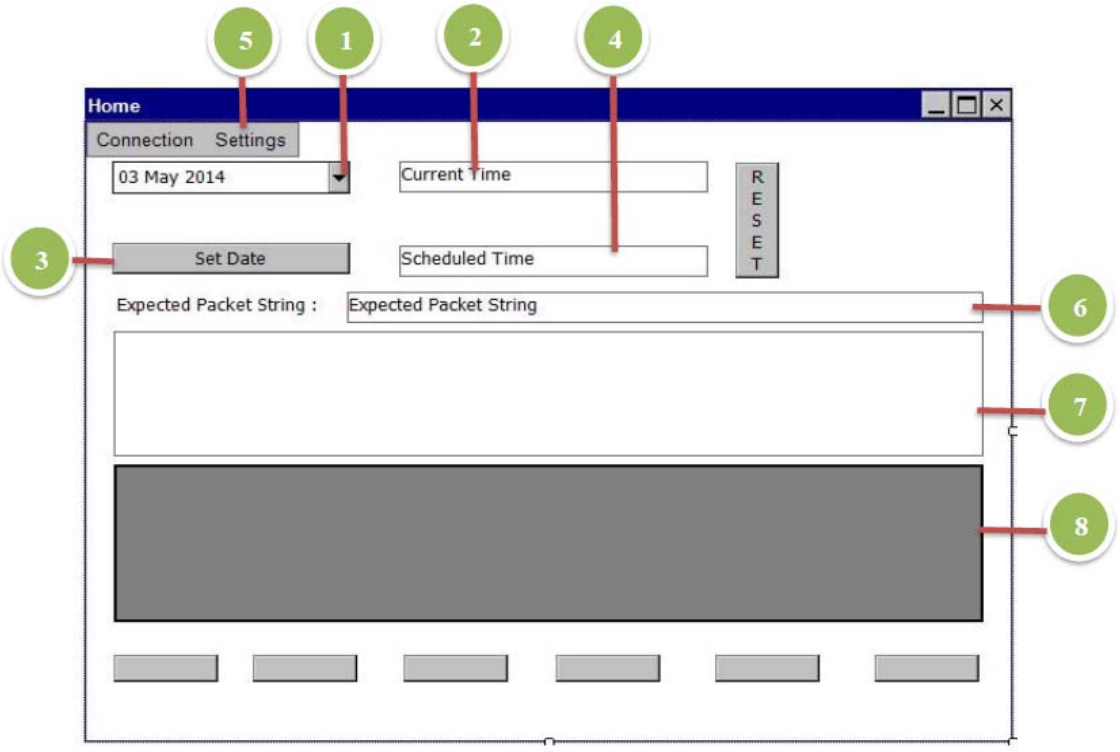


Figure 2: Front End of Base Station application

3. Set Date/Set Period menu: Set Date menu is used to set the date selected from date selector. Once date is set, the Set Date menu will be changed to Set Period menu and two selection boxes pop up as shown in Figure 3, which represents Hour and Minutes selection boxes.

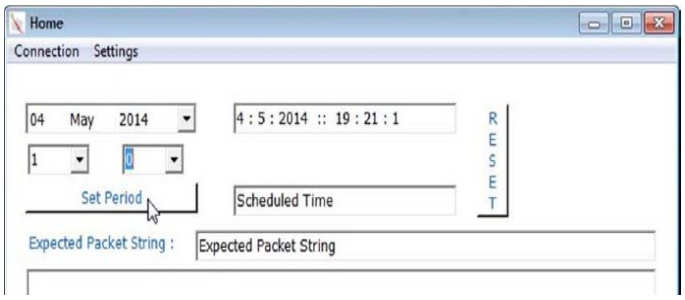


Figure 3: Set Date/Set Period menu

4. Scheduled time: Once Hour and Minute are selected, and Set Period menu is pressed, the scheduled time is updated. This scheduled time represents the future time at which base station initiates itself. The scheduled time is determined by adding current time with period entered by user.

5. Setting: The Setting menu is further subdivided into three sub menus as:

a) Change Sensors: After the network is being established by base station, it receives the data from all the nodes in specific string format, which includes the two digit initials for the sensors and data related to specific sensors with proper precision. But, being a customizable application, the user should be facilitated to change the sensors and its corresponding data format. When user clicks on "Setting > Change Sensors" menu, a new window will pop up, where user have to set the number of sensors to be entertained in application as shown in Figure 4.

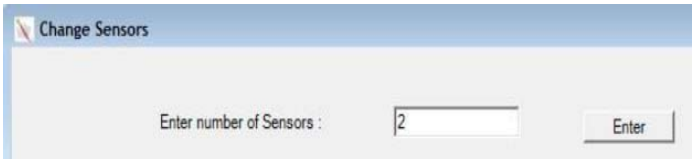


Figure 4: Change Sensor menu

As per entered value of number of sensors, the user have to fill the relative data for the same, like name of sensor, two digit initials, X and Y shown in Figure 5. Where, X represents the precision digit numbers to be used before decimal point, whereas Y represents the post decimal digits.

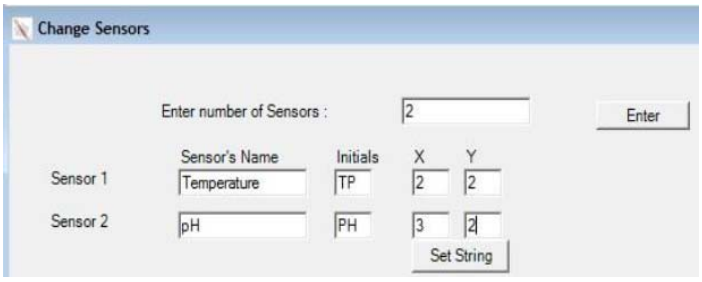


Figure 5: Change Sensor menu with sensor information

Once the data shown in Figure 5 is filled, the packet string is now set to new one as shown in Figure 6.

Figure 6: Pop-up indicating expected packet string

b) Current time Samples: Once the current time and scheduled time is matched, the base station will establish the wireless sensors network and proceed as per routine and collects data from the nodes present in network. But, suppose the user wants to collect sensor samples at the current/present time, the user can start base station routine by pressing "Setting > Current time Samples" menu as shown in Figure 7.

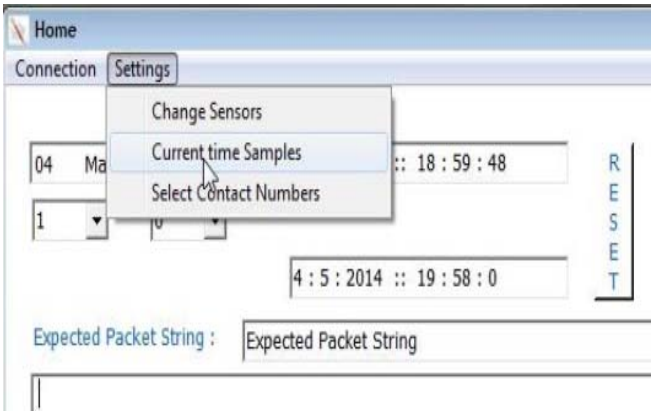


Figure 7: Setting menu

c) Select Contact Number: The application also provides facility to connect GSM Modem to the base station, which will be used to route the relevant data to the user, whenever base station receives the data from nodes. As GSM modem is used, it is also needed to mention the 10 digit SIM number, where the data is to be sent. Figure 8 shows, how to set the contact number in the application.

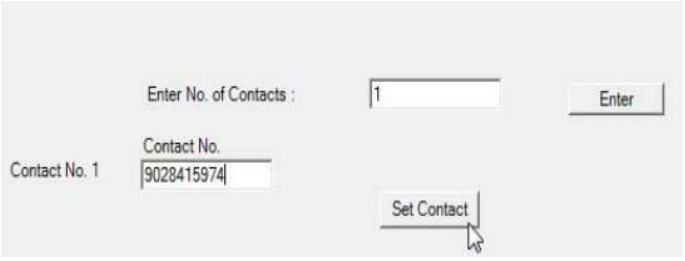


Figure 8: Set Contact menu

6. Expected Packet String: This text box displays the String related to sensors and their corresponding reading in specific format. The expected packet string is also get updated as the sensors and its corresponding precision is changed by user.

7. Base station information text box: This text box displays the information about the internal processes happening in base station application such as information of nodes present in network and its relevant data. As time passes, this text box gets updated according to the status of base station.

8. On board output display: This sheet displays the output information of the nodes present in the network as shown in Figure 9. This sheet includes information about the node identifier, MAC id, sensors and time stamp. This table gets updated every time as base station receives data from nodes present in network.

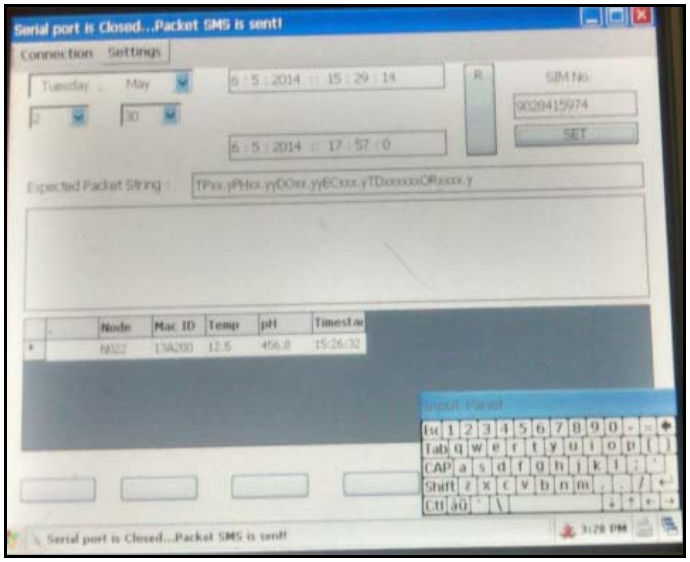


Figure 9: Base Station Framework

Apart from this, user's smart device, this can be a smart phone, tab or Cell phone is also a part of the system. User's smart device is always updated by base station through GSM. Base station regularly sends the processed data through SMS on SIM number entered by the user. After experimental setup is established and various parameters are being set, the application starts System and Communication Check. The application checks whether all hardware devices including ZigBee, GSM modem, microcontroller, etc are working properly or not. If it finds any problem or error in any part of system, it shows a message regarding the same. On successful completion of System and Communication check, the application follows following steps.
The initialization of the system is done through interfacing all peripherals to the development board and installing the base

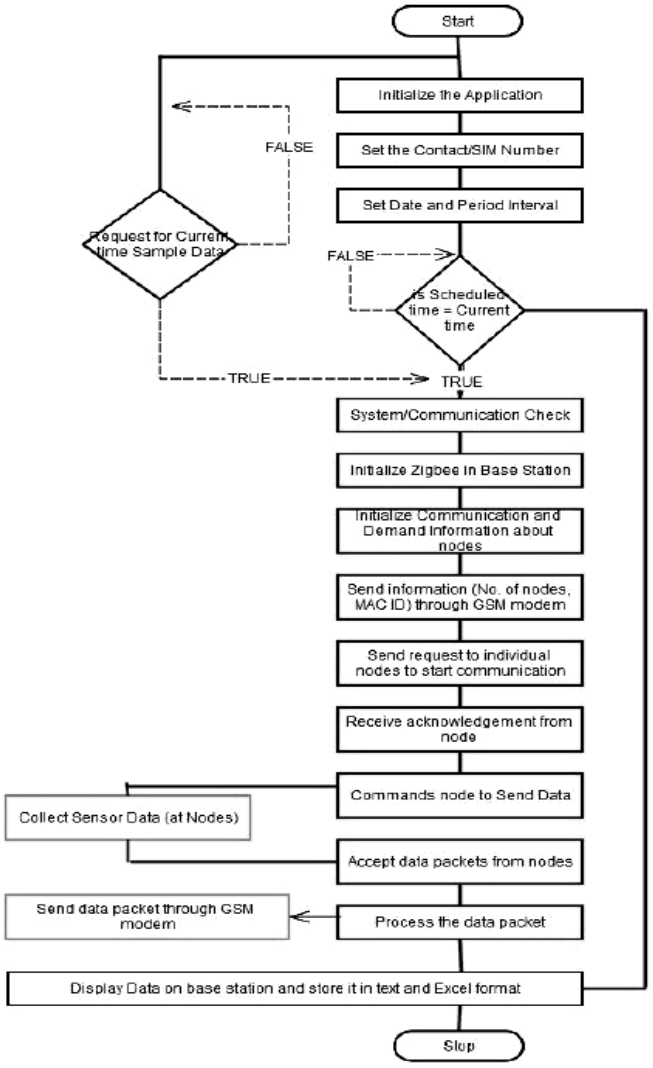


Figure 10: Architectural Workflow diagram of Base station

station application on the same board. Once hardware and software initialization is done, the onetime configuration has to be done in the base station application by the user. This configuration includes setting of COM port, baud rate, etc for serial port, sensor's information like sensor name, and its precision, as shown in Figures 4, 5 and 6.
The workflow shown in Figure 10 can be explained with various steps involved in the functioning of the base station. Initially, the base station will be in broadcast mode and it will order all nodes present in network to send their information i.e. MAC Id, signal strength and Node Identifier. In reply to this, all nodes present in network will send their information to Base station. Then few steps are dedicated for hand shaking between Base station and the individual node. In these Steps, Base station act in Unicast mode. After hand shaking and its acknowledgement, Base station command each node to send their data. In reply to this command, all nodes send their data towards Base station, one by one. Actually, this data is nothing but sensor data sensed by sensors present in each node. This data is assembled in a specific format, such that after received by Base station, it can process it in suitable format. The format of the data received is as shown in Figure 11.

TP50.1PH14.01DO50.01EC200.0TD100000OR2000.1

Where-

TP – Temperature
PH - pH level
DO – Oxygen
EC – Electric Conductivity
TD – TDS
OR – ORP

Figure 11: Data string format sent by a node

In the received data string, each sensor is abbreviated by two alphabets, as shown in red color text. And next subsequent green colored numerical value indicates the sensor data sent by sensor nodes.

Results & Discussions

The main application of the base station is to receive the data from nodes present in the network and to process the data in specific format. The received data is processed and displayed in application, and then saved in various ways as discussed below.

The processed data in base station is forwarded through a SMS to user's smart device via GSM modem. This SMS includes number of active nodes present in the network and their information such as MAC Id., signal strength, node identifier, etc as shown in Figure 12.

CSIR-NEERI WSN SYS
* Developed By AID *
15:05:14 15:20 Nodes:2
v13A2004090DFAC31N022v13A200405C725C24N092

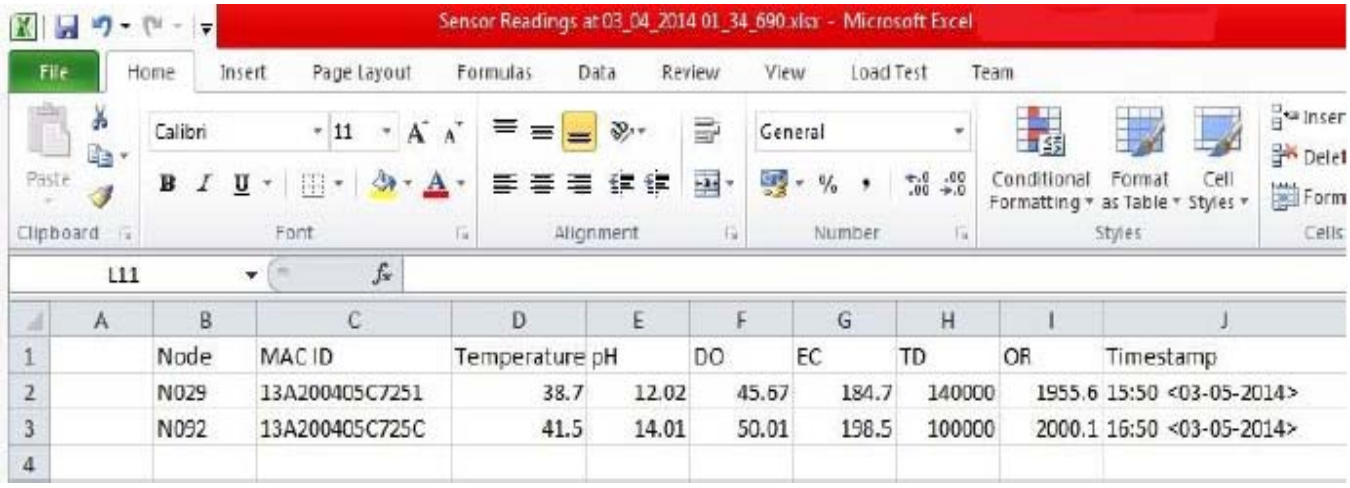
Figure 12: SMS indicating nodes information

There are few steps dedicated for hand shaking between Base station and the individual node. In these Steps, Base station acts in Unicast mode. After hand shaking and its acknowledgement, Base station command each node to send their data. In reply to this command, all nodes send their data towards Base station, one by one. This data includes sensor data sensed by sensors present in each node. This data is assembled in a specific format, after received by Base station. Finally, this data is forwarded as a SMS to user's smart device through GSM modem. The message will be displayed as shown in Figure 13.

The data is also displayed on the screen of base station and saved in text and excel format at specified location. Figure 14 and Figure 15 shows the data saved in excel and text format respectively. Where first column represents the node identifier, which is a name given to the node. Second column represents the MAC id of the nodes. The last column represents the time stamp, which is the time at which sensor node senses the data from various sensors interfaced to it. And all other in between columns indicates the sensors and its relevant data received from sensor nodes.

15:05:14 15:20 Nodes:2
N022TP52.1PH14.01DO50.01EC200.0TD100000OR2000.1
N092TP62.1PH14.01DO50.01EC200.0TD100000OR2000.1

Figure 13: SMS indicating data sensed by nodes



	A	B	C	D	E	F	G	H	I	J
1		Node	MAC ID	Temperature	pH	DO	EC	TD	OR	Timestamp
2		N029	13A200405C7251	38.7	12.02	45.67	184.7	140000	1955.6	15:50 <03-05-2014>
3		N092	13A200405C725C	41.5	14.01	50.01	198.5	100000	2000.1	16:50 <03-05-2014>
4										

Figure 14: Data stored in Excel format

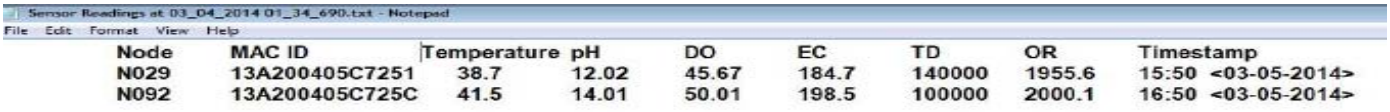


Figure 15: Data stored in Text format

All the steps discussed above, repeats whenever the current time matches with the updated scheduled time, which is determined by the repetition period mentioned by user. Also the user gets SMS accordingly and data backup is stored and updated in

memory in text and excel format. In between, the user can also update that period suitably, according to the need of application.

Conclusion & Future Work

The implementation section summarizes the work carried out for the base station in wireless sensor network. We have successfully designed a hand alone embedded system, which replaces the user computer and server as used in other WSN applications. The findings and observations can be used as a guide for future research projects using this technology.

The outcome of this project is an application for base station in wireless sensor networks. Now, being a dynamic base station is ready, it can be easily used in any wireless sensor networks experiment. This application can also be changed according to change in project requirement. Also, its GUI can be enhanced, such that the nodes and its position can be observed from base station only by using GPS technology.

Till now, the processed data is stored in specific memory location and also sent it as a SMS through GSM modem. In future, the data can be directly saved to data server using techniques like GPRS, cloud computing, etc. Also the various routing protocols can be tested and studied on the present platform. Research towards energy optimization can be done.

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