DESIGN AND IMPLEMENTATION OF AN IEEE 802.15.4 / ZIGBEE BASED STAR NETWORK FOR DATA ACQUISITION AND MONITORING

S. K. Guha#, P. Y. Nabhiraj, T. K. Bhaumik, C. Mallik, VECC, Kolkata, India

Abstract

ZigBee based wireless technology is used to provide a low cost, low power, secured, PAN solution for monitoring of parameters from several distributed vacuum pumping modules installed in the SCC injection line. The parameters include module's pump RPM, input current and pressure reading of different vacuum gauges.

The ZigBee stack is written in a simplified form so that each node can create a network and can join to any established network when powered on. End nodes can be replaced through a little modification in the firmware codes. End node consists of sensors, signal conditioning circuits, microcontroller and ZigBee Transceiver whereas the Central node consists of microcontroller, Transceiver and UART interface. This paper highlights the future approach of utilizing this network for data acquisition related with environmental temperature, relative humidity, noise, water leakage from inaccessible areas of Cyclotron Vault, Pit, Basement and ECR Highbay for the ease of maintenance also the development of an environment monitoring system powered by solar cells covering a wide area.

INTRODUCTION

An Extremely Low Power (XLP) microcontroller based wireless network has been designed for several vacuum pumping modules using 2.4 GHz ZigBee [1] protocol on STAR topology. These pumping modules are installed at different locations of the SCC Injection line in a distributed manner. Two different network devices are designed to operate in this network, one is Coordinator and another is End device. Each End device acquires both analog and digital information from pumping module, generates a Zig Bee data frame for each sample and finally sends to the Coordinator. The frame structures follows IEEE 802.15.4 standards to keep the complexity to a minimum while at the same time making the network sufficiently robust for transmission in a noisy environment.

IMPLEMENTATION OF ZIGBEE

ZigBee is one of the global standards of low data rate wireless communication protocol formulated by the IEEE 802.15.4 working group. The ZigBee protocol has a transfer rate around 250 Kbps and 16 channels in the 2.4 GHz band [2], refer Fig.1, fully hand shakable protocol for transfer reliability, low power consumption (Tx or Rx mode or sleep mode) facilitating remote controlled battery operated systems and sensor network. The Higher Protocol Layers have been defined by ZigBee Alliance

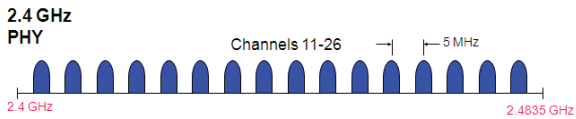

Figure 1: IEEE 802.15.4 PHY overview Operating Frequency band (Industrial, Scientific and Medical).

Group whereas IEEE 802.15.4 working group only utilizes the lowest two layers of OSI which are Physical Layer (PHY) and Data Link Sub Layer (MAC – Media Access Control Sub Layer) refer Fig. 2.

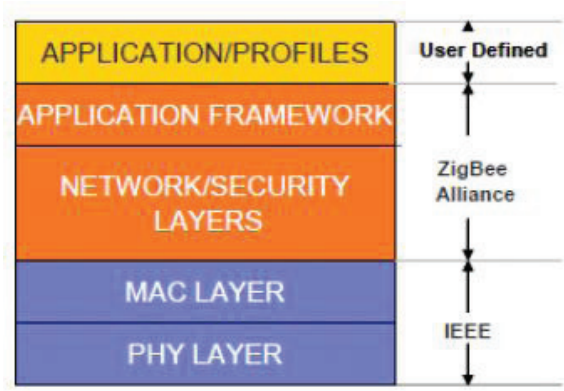

Figure 2: IEEE 802.15.4 Stack Architecture.

IEEE 802.15.4 standard supports several topologies refer Fig. 3 and the intention was to build a medium ranged (70 – 300 mtrs.) low data rate, low complexity wireless Personal Area Network to operate in an unlicensed international frequency range. ZigBee based wireless technology is implemented to provide such a solution.

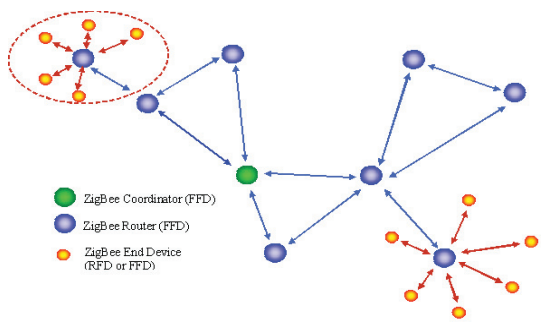

Figure 3: IEEE 802.15.4 standard Combined Topology, Highlighting STAR.

SCHEME OF THE SYSTEM

The star network has been developed by using two kinds of Zigbee nodes. Several End nodes are designed for each of the vacuum pumping modules and one

#suman@vecc.gov.in

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Network Coordinator it also interfaces with control PC refer Fig. 4.

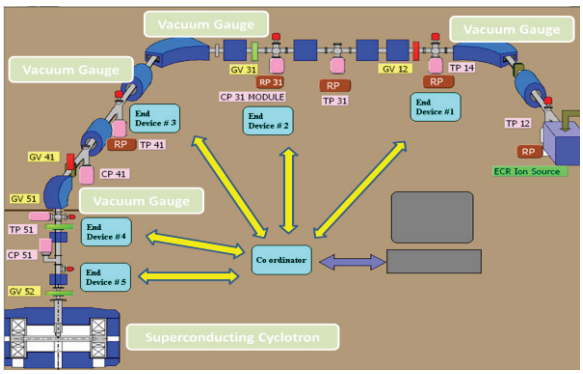

Figure 4: Schematic of the network along with other beam line elements.

Each End node receives information regarding DC current drawn by the turbo pump, pumping speed and the pressure information as read by the adjacent vacuum gauges. The information is being sent to the coordinator against a request being received from it. At the coordinator end, after successful receiving of a frame from different end nodes the data part is being separated from the complete frame and the data bytes are being sent to Lab VIEW user end application program through serial communication.

HARDWARE CONFIGURATION

Both the nodes are using Microchip 8 bit PIC 18F46J50 MCU [3] a member of nano watt extremely low power (XLP) technology microcontroller family with 64K program memory and IEEE 802.15.4 standard compliant RF transceiver module which is based on 2.4GHz RF Transceiver IC MRF24J40, [4] 20 MHz Integrated Crystal, Internal Voltage regulator, Matching Circuitry and PCB Antenna refer Fig. 5.

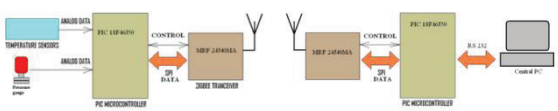

Figure 5: Block diagram of End node and Coordinator.

The RF Transceiver communicates with MCU via 4 wire serial SPI protocol along with Interrupt, Wake and Reset Signal refer Fig. 6. While configuring RF transceiver the operation channel, data rate, address and other related issues has been specified by accessing the different Short address and Long address control registers through SPI interface. The end node acquires analog signals (0 – 10 V DC) from turbo pump controller and vacuum gauges. After being passed through the signal conditioning circuit the three analog data are fed to the ADC of the MCU through different channels. These three analog signals are sequentially sampled and the 10 bit digital equivalent data are stored in 6 subsequent memory locations of an array which are appended in the Data frame in the MAC Sub layer by the stack program.

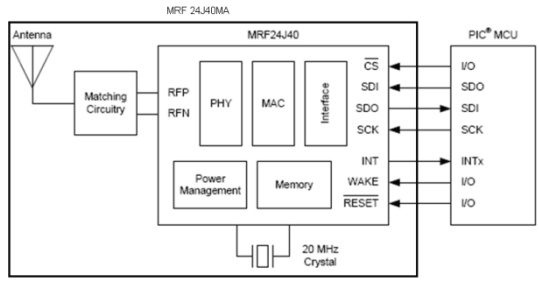

Figure 6: Connection details between RF Transceiver and MCU.

SOFTWARE STACK PROGRAM

The software protocol stack is modified by using MPLab C18 Compiler for both types of devices in a simplified form. It is basically based on MAC and PHY layers of IEEE 802.15.4 specification. This Stack provides a feature to find an existing network, form a new network or to join in a network. Specific 8 byte Extended Organizationally Unique Identifier (EUI) or MAC address and 2 byte PAN address have been loaded into respective control registers of the RF chip. It also enables to identify Received Signal Strength (RSSI) for all the received frames. Refer Fig. 7 for ZigBee Data frame format as used.

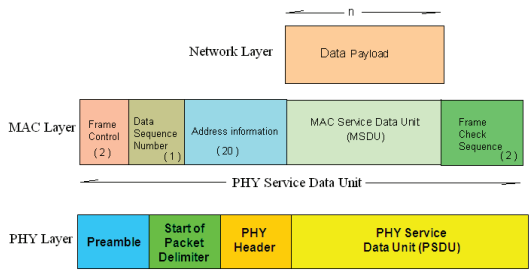

Figure 7: Data Frame format in MAC and PHY Layer.

The MAC layer program provides the information of the channel to be accessed (here in this case channel 24 has been utilized), generates the address information and append the data bytes into the MAC layer data frame. The protocol stack also supports the broadcast or unicast addressing mode. The network coordinator access each end node by pointing different arrays of the Destination address field sequentially only after receiving the response form an end node it address the next one. Because of the less number of nodes the entire network is designed in such a way that all the nodes are having same PAN (Personal Area Network) ID field. For simplicity only Data frames are utilized here. In case of changing any defective node, only 8 numbers of Extended Address Registers (EAD) has to be configured. User end Lab VIEW application program receives data bytes from a particular end node via the network coordinator through

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RS 232 serial (19200,N,8,1 format) bus. The program flow diagram has been shown in Fig. 8.

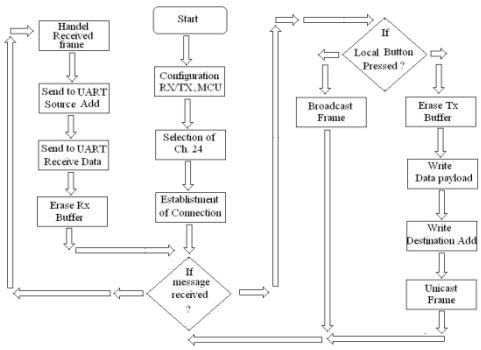

Figure 8: Flow chart of the Firmware program.

THE OPERATOR INTERFACE

The user interface is being performed by application program developed using Lab VIEW [5] software (version 7.1) refer Fig. 9.

Figure 9: Operator GUI.

The front panel shows the vacuum information as received from the coordinator. It displays the actual voltage signal as collected and transmitted by the end node. Fig. 10 shows the block diagram of the program.

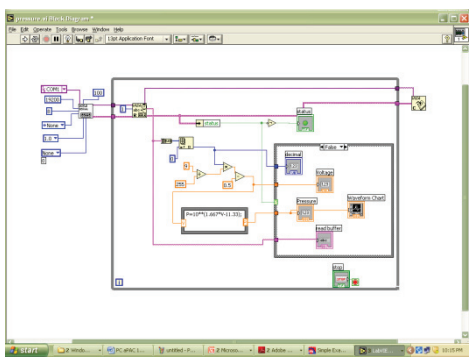

Figure 10: Block diagram of GUI program.

CONCLUSIONS

The present network has been tested with the vacuum pumping modules kept at a distance of 150 ft. in a closed, non line of sight environment of SCC (Superconducting Cyclotron) Highbay area. The transmitted data has been checked with local vacuum gauge reading in an un interrupted manner and found working satisfactorily. As extension of the present job, we are engaged in the Design of 802.15.4 / ZigBee based Personal Area Network for data acquisition of environmental temperature, relative humidity, noise, water leakage from the inaccessible areas of Cyclotron Vault, Pit, Basement and ECR Highbay for the ease of fast fault finding and decrease of down time of both Cyclotron and ECR Ion source.

REFERENCES

[1] ZigBee_Specification, http://www.zigbee.org/en/spec_download/download_request.asp
[2] IEEE 2003 version of 802.15.4 MAC & Phy standard.
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