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REAL-TIME MULTI-PATIENT MONITORING SYSTEM USING ARM AND WIRELESS SENSOR NETWORK

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Abstract- Mobile Multi patient monitoring device has become increasingly important in Hospital wards to record real-time data during normal activity for better treatment. However, the current quality and reliability have not been satisfactory due to the size, weight, distance of coverage and also high power consumption. This paper provides a solution for enhancing the reliability, flexibility by improving the performance and power management of the real-time multi-patient monitoring system (MPMS). In the current proposed system the patient health is continuously monitored by the MPMS and the acquired data is transmitted to a centralized ARM server using Wireless Sensor Networks. A ZigBee node is connected to every patient monitor system which will send the patient's vital information .Upon system boot up, the mobile patient monitor system will continuously monitor the patients vital parameters like Heart Beat, body temperature etc and will periodically send those parameters to a centralized server using ZigBee node configured as co-coordinator. If a particular patient's health parameter falls below the threshold value, a buzzer alert is triggered by the ARM server. Along with a buzzer an automated SMS is posted to the pre-configured Doctors mobile number using a standard GSM module interfaced to the ARM server. The Doctor is continuously connected to the ARM server using GSM Module and he/she can get a record of a particular patient's information by just posting a SMS message to the centralized ARM server. This will reduce treatment time, cost and power consumption to a greater extent. At the same time, the efficiency of examining ward will be improved by making the system more real-time and robust.

Keywords- *Mobile Multi patient monitoring system ,ARM, ZigBee .GSM Module*

I. INTRODUCTION

The present patient monitor systems in hospitals allow continuous monitoring of patient vital signs, which require the sensors to be hardwired to nearby, bedside monitors or PCs, and essentially confine the patient to his hospital bed.

Even after connecting these systems to a particular patient, a paramedical assistant need to continuously monitor and note down all the vital parameters of a given patient by keeping track of all of his/her records manually. Adopting such a method is error prone and may lead to disaster in the case of a human error.

In the current proposed system the patient health is continuously monitored by the Mobile multi patient monitoring system and the acquired data is transmitted to a centralized ARM server using Wireless Sensor Networks. A ZigBee node is connected to every patient monitor system that consumes very low power and is extremely small in size. These slave nodes are specifically designed for low power consumption, with minimal circuit components (Aliaksei Kerhet,2007)[18]. They are intended for small packet, long distance range applications and typically consist of a low power processor with minimal resources and interface capabilities. They also have a conservative transceiver that is capable of transmitting 8 bytes of data at a time and has a moderate transmitting range of about 130 m. Therefore, WPANs seem to be a perfect fit for remote patient monitoring. This paper builds an independent system that automatically logs vital parameters of patients for easy access. The data is accessible to doctors through mobile device for convenience. Data of all patients is stored in a common database. Mobility of the equipment is improved by making the equipment more portable.

The literature reviews Diagnosing and continuous record of real-time data by the use of portable patient monitoring system during normal activity would be beneficial for medical practitioners to do proper and better treatment; also it would be useful for health care providers to improve diseases management (Otto, 1999)[11].

This challenge attracts many researchers to invent a new design and deploy comprehensive patient monitoring solutions for hospital health care system (Connor et al., 2001)[6]. Advances in wireless networking have opened up new opportunities in a variety of applications (Pierce, 2001)[8] including healthcare systems (Lorincz et al., 2004; Lubrin et al., 2005; Dayu,` 2010; Dishman, 2004; Jafari et al., 2005).

The advancements of Wi-Fi and Bluetooth have facilitated breaking the cord between the non-invasive patient sensor and the bedside equipment (Lubrin et al., 2005)[8]. These systems do not require the patient to be confined to his bed and allows him

to move around freely in his room but requires him to be within a specific distance from the bedside monitor.

For example, adopting a wireless technology like Bluetooth has a range of transmission about ten meters. Beyond this distance, it is not possible to acquire data. Patient mobility beyond his hospital room can be incorporated by using a network of such nodes placed at appropriate distances in order to transfer data to the monitoring station. However, network nodes that use protocols such as Bluetooth require a larger volume and higher power consumption. This indirectly indicates a higher cost per node and a fairly high burden on its power source, further increasing its size and cost. Depending on the size of the hospital, several such nodes might be required resulting in a much higher system infrastructure cost. Secondly, a typical Bluetooth Personal Area Network (PAN) has a limitation of 8 Nodes per PAN which will limit the expansion of such systems. Moreover, such protocols are meant for moderate to high bandwidth applications where relatively large packets of data need to be transmitted and received. In the case of patient vital sign monitoring, the data packet size is much smaller and could be in tens of hundreds of bytes, which seems to suggest that networks using such protocols might seem impractical and it's obvious that we need a low power, low cost network nodes for such applications.
To improve the accuracy and to increase the efficiency of the above processes a real time patient monitoring system based on Wireless Sensor Networks (using IEEE 802.15a) and a centralized ARM Server integrated with GSM module is designed. ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth. ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking. ZigBee has a defined rate of 250 kbps best suited for periodic or intermittent data or a single signal transmission from a sensor or input device.

The present paper is organized as follows. The section 2 gives overview of the system, section 3 introduces the System Architecture and the hardware design . The section 5 deals with software implementation of the architecture ,section 6 covers results and discussions and section 7 deals with conclusions.

II. OVERVIEW OF THE SYSTEM

To build an independent system that automatically logs vital parameters of patients for easy access. The data is accessible to doctors through mobile device for convenience. Data of all patients is stored in a common database. Mobility of the equipment is improved by making the equipment more portable. In the current proposed system the patient health is continuously monitored by the Mobile Multi Patient Monitoring System and the acquired data is transmitted to a centralized ARM server using Wireless Sensor Networks. A ZigBee node is connected to every patient monitor system that consumes very low power and is extremely small in size. These slave nodes are specifically designed for low power consumption, with minimal circuit components[15]. Therefore, WPANs seem to be a perfect fit for remote patient monitoring. Upon system boot up, the mobile patient monitor system will continuously monitor the patients vital parameters like Heart Beat, body temperature etc and will periodically send those parameters to a centralized server using ZigBee node configured as co-coordinator. If a particular patient's health parameter falls below the threshold value, a buzzer alert is triggered by the ARM server. Along with a buzzer an automated SMS is posted to the pre-configured Doctors mobile number using a standard GSM module interfaced to the ARM server. The Doctor is continuously connected to the ARM server using GSM Module and he/she can get a record of a particular patient's information by just posting a SMS message to the centralized ARM server. This will reduce treatment time, cost and power consumption to a greater extent. At the same time, the efficiency of examining ward will be improved by making the system more real-time and robust. If a particular patient's information is required by the doctor, then he/she can send a SMS to the ARM server mentioning the record number of a particular patient. The ARM server will first check for a valid doctor's mobile number which is provided to the GSM module during system boot up time. If the mobile number requested by the doctor matches with the one present in the ARM server then a SMS response will be sent back to the doctor based on the request.

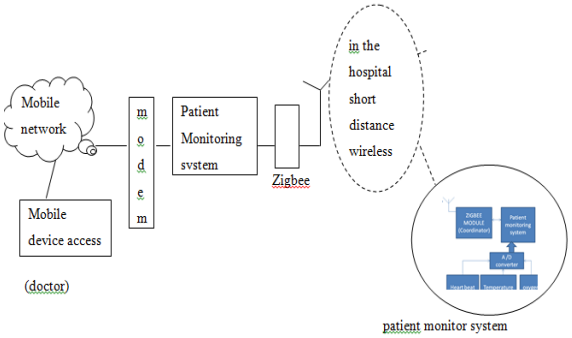

Fig:1 Overview of system

2.1 TECHNICAL APPROACH

A serial interface program is implemented to collect the data from different WSN's to the central mobile

monitor station running on Linux with ARM9 controller. The received data from different wireless sensors are processed by the controller periodically. SMS alerts are generated by the controller based on the preconfigured threshold values of the monitoring parameters of a particular patient. Another serial interface program is implemented to interface with a standard GSM module on the controller. The SMS send and receive functionality is also implemented and is interfaced with a serial interface for a standard GSM mobile module.

III. SYSTEM ARCHITECTURE

The hardware design of Wireless Sensor Network Gateway is based on ARM microprocessor. Through expanding ZigBee and GSM modules, the platform can realize the function of wireless sensor network nodal data collection and transmission. In this the zigbee modules are considered as zigbee transceivers. Zigbee modules can communicate and send the information from one place to another. Zigbee is connected to center core ARM processor in which the application runs. This ARM processor acts as the gateway to zigbee and GSM module. ARM is connected to GSM module through which text messages like SMS alerts are sent to the doctor's mobile number which is configurable. A set of pre-configured AT commands are required to prepare a SMS and send it to the configured mobile number which is implemented used a program for the GSM module. The design is made flexible so that the doctor's number can be changed during the system bootup time (Zhou Pengshuo,2008)[14]. Structure of the system is shown in figure below.

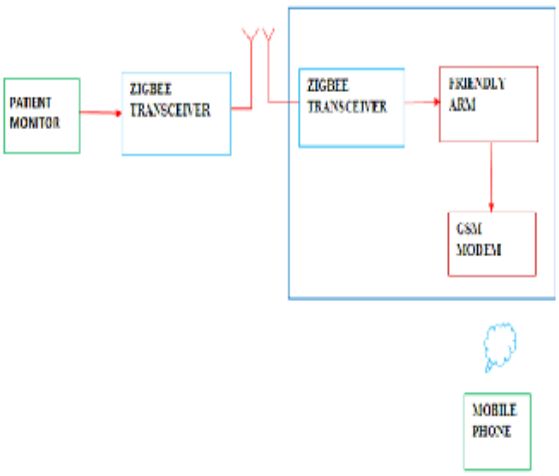

Fig 2 S3c2440 Block Diagram

The hardware design has an embedded ARM platform, with S3C2440 from Samsung Electronics as the center core which is built upon the Linux operating system and its maximum frequency may be up to 533 MHz. The Controller has a high level of integration and the simplified hardware design; it helps to improve the reliability of the whole system. S3C2440 hardware resources are as follows: 2MB NOR flash, 256MB NAND flash, 64MB SDRAM, one IIC, one IIS,3 TTL, 4 USB interfaces,130 GPIO interfaces and one Ethernet network card. In addition, S3C2440 supports many kinds of Network protocols, such as TCP, UDP and other protocols for firmware upgrade.

The serial driver in the Linux operating system is used to interface with a standard mobile having a GSM module. The hardware has another TTL interface which is used to interface with the Zigbee Module. This makes the ARM system as a centralized WSN gateway which is used to get the data from the Patient Monitor System periodically.

The multi patient monitoring system consists of an 8 bit ATMEL micro controller. An 8/1 multiplexer is used to connect different sensors. A/D converter is cascaded to the multiplexer to get the data from different sensors. The multiplexed digital data is processed by the micro controller and converted into a string format. The string format message mentioning patient ID along with the monitored parameters is prepared as a string format by the microcontroller and is sent wirelessly to the ARM SERVER using zigBee co-coordinator.

3.1 Temperature Sensor:The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full -55 to +150°C temperature range.

3.2 Heart Beat Sensor:A simple heart beat transducer is made from an infrared LED and an infrared phototransistor. It basically works as the skin acts as a reflective surface for infrared light. The IR reflectivity of skin depends on the density of blood in it. Blood density rises and falls with the pumping action of the heart. So the intensity of infrared reflected by the skin proportionally gives us the heartbeat.

3.3 Zigbee Sensor :Tarang wireless modules are low to medium-power devices and suitable for adding wireless capability to any product with serial data interface. The modules require minimal power and provide reliable delivery of data between devices. The I/O interfaces provided with the Module help to directly interface with any standard serial devices. (Jianliang Zheng)17

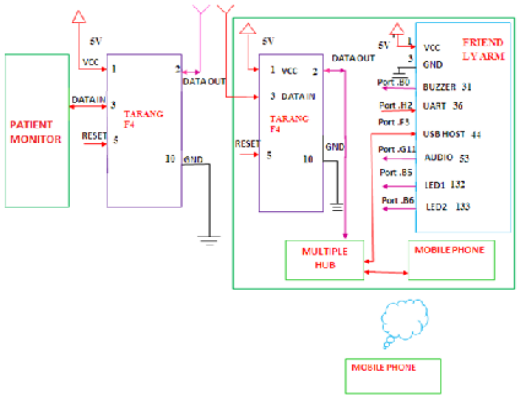

Fig:3 Interfacing Diagram

IV. SOFTWARE MODEL

The basic application software architecture of the system is split into 3 major modules.

1. GSM module for interaction of the ARM server with the external world.
2. ZigBee module for interaction of the patient monitor system
3. Patient monitoring system for processing the patient's information and maintaining a log file

Upon system boot up, the mobile patient monitor system will continuously monitor the patients vital parameters like Heart Beat, body temperature etc and will periodically send those parameters to a centralized server using ZigBee node configured as co-coordinator along with the patient ID (like Bed No).

The patient information will be received by a centralized server (ARM) to which a ZigBee node is connected in a ASCII string format. The received data from the patient monitoring system is parsed and the first parameter of the string is obtained which is the patient ID (Bed No) from the data. The rest of the parameters include the patients vital parameters like HeartBeat/Temperture/Oxygen etc. All these parameters are first logged in a standard log format in a file in JFFS file format which is the part of flash file system and then processed accordingly. Every log message consists of a patient's information along with the time stamp of the message received followed by the particular patient's parameters (like Heart Beat/Temperate Etc)

If a particular patient's health parameter falls below the threshold value, a buzzer alert is triggered by the ARM server. Along with a buzzer an automated SMS is posted to the pre-configured Doctors mobile number using a standard GSM module interfaced to the ARM server. The Doctor is continuously connected to the ARM server using GSM Module and he/she can get a record of a particular patient's information by just posting a SMS message to the centralized ARM server. This will reduce treatment time, cost and power consumption to a greater extent. At the same time, the efficiency of examining ward will be improved by making the system more real-time and robust.

If a particular patient's information is required by the doctor, then he/she can send a SMS to the ARM server mentioning the record number of a particular patient. The ARM server will first check for a valid doctor's mobile number which is provided to the GSM module during system boot up time. If the mobile number requested by the doctor matches with the one present in the ARM server then a SMS response will be sent back to the doctor based on the request made. The response includes the complete patient record of the requested patient. If the mobile number doesn't match with the one configured in the system then such request requests will be ignored and the GSM module will go back to the wait mode for the next valid request. (Pietro.V,2007) [16]

4.1 Device Driver Program

The Zigbee module interfaces with the ARM server using a serial device driver program and on the other end the GSM module interfaces with the ARM server using a USB Device interface. Both the serial and the USB device drivers are enabled by default as a part of standard Linux Kernel that is embedded within the ARM system.

A standard JFFS file system support is provided for event logging and error logging during the system's operation. To support this functionality, JFFS file support is enabled as a compile option during the Linux Kernel compilation.

4.2 Serial Exchange Protocol

A proprietary Serial Exchange Protocol (SEP) is designed and implemented for data processing between the wireless patient monitoring system and the centralized ARM server. The data exchanged between the patient monitoring system and the server will be of a string format containing individual vital patient parameters like heart beat etc separated by a delimiter. The typical format a SEP includes character string followed by related parameter value separated by delimiter. An example of this format is given For Ex: H20 T40 O80. (Cheng Xingguang,2006)[19]

V. SOFTWARE IMPLEMENTATION

The software system implementation is divided into 3 basic modules.

1. GSM modem interaction with the ARM server using serial interface.
2. ZIGBEE coordinator interaction with the patient monitor system using TTL Interface
3. Multi patient monitor system operations and management.

4. All of the above modules are explained below along with the flowcharts.
5. GSM Module Implementation

Upon system boot up, the GSM process is triggered by the Linux system. The GSM process will then register with the serial driver to which a standard GSM Modem is connected. A welcome message is sent to the doctor's mobile number which is pre-configured during the system runtime.

Whenever the patient monitor system wants to send a message to the doctor's mobile number, a message corresponding to the appropriate patient is prepared in a string format which includes the patients vital parameters (like Heartbeat/Temperature/Oxygen intake etc.) in a string format and is then posted to the GSM module using a standard POSIX message queue. The GSM module will be waiting on that particular message queue on a different thread context and upon receiving of a message from the centralized patient monitor system, an SMS alert is posted to the GSM module by following the sequence of AT commands for sending a SMS alert.

Whenever a particular patient's information is needed by the doctor an SMS request is posted to the mobile number sending the particular patients name or number. Upon reception of the message an interrupt is generated by the mobile module. The GSM module will be constantly waiting on another POSIX message queue for a SMS request. The doctors mobile number is compared with the pre configured mobile number which is provided during the boot up time for security reasons. Once after successful validation, the particular patient's requests are then forwarded to the centralized patient monitor module.

5.1 Zigbee Module Implementation

The Zigbee module is implemented using a standard TTL interface which is connected to a zigbee router module. The router module will be continuously getting data from the multiple patient monitor systems which are fixed for every patient inside the hospital.

Upon reception of a string message from a particular patient monitor device, the message is posted to the centralized using a message queue. The internal module will take it for further processing. Both the Zigbee router and the coordinator operate at 2.4GHz frequency with a preconfigured PAN ID's to communicate with.

5.2HIGH LEVEL DESIGN

There are two main programs in the project

- The GSM logic will be in main.c
- The patient monitoring system logic will be in PatientMonitor.c

The GSM framework will be in GSMfrmwrk_v5.c.sms_gsm.h will have macros and structures related to GSMframework. Patient Monitoring system will have logic related to patientmonitor. This file contains logic for interaction with patient monitor device over Zigbee. A text based parser is implemented in this file which will parse the text string and will store the parameters based on particular patient in a structure.

Whenever a message comes from zigbee interface the logic inside Patient_Monitor.c will get the data that will be processed further.SMS messages from the PatientMonitor.c file will be posted to the GSM process using a message Queue.Whenever a message comes from the GSM framework like doctor's request a message will be posted by gsmfrmwrk_v5.c using another message queue.The patientmonitor will be waiting for such a message using PThread. Similarly the patientmonitor will be waiting for another message from zigbee interface(zbfrmwrk).

There will be four threads running inside each process

1. SerialRXTask will reserve the data over serial interface and will put the message in a message queue.
2. SerialTxTask sends a message over serial interface which it has over a message queue.serialRxQueue.
3. The last two threads mQZbTxTask and mQZbRxTask will process the message received from the serialRxTask thread serialTxTask and will act upon the message (like sending SMS alert/triggering the alarm) based on the program.

5.3 Steps for connecting target and the host system

- As we don't have a development environment like compiler and editor inside the target kit because of resource limitations like less CPU frequency and less RAM and ROM we will develop our program on a host machine and copy it to the target using a network (LAN).
- Once after successful copy we will execute the program in the same way as host system.
- To copy the file from host to target over LAN we use a file transfer protocol called TFTP(Trivial File Transfer Protocol).
- We use LAN based file copy because that is one of the very popular method and most of the embedded kits these days comes with a default LAN port(interface) nothing but ethernet interface
- Development kits like friendly ARM comes with one default serial interface which is used to interact with the kit.
- A null modem is used for interaction between the kit and the host system.

- The Ethernet cable is used for communication between the host and the target for file transfer while the null modem is used for interaction with the kit and the programmer.
- TCP/IP protocol suit (TCP/UDP/IP) runs on both the target kit and the host system. We can connect a LAN cable using -Ethernet interface for data transfer.
- RS232 protocol is used for serial communication.

5.4 Steps for interaction with the kit

If a programmer wants to communicate with the kit then he or he will run a terminal emulator software on a host machine. The terminal emulator will internally use RS 232 protocol for interaction

Software development platform is Linux 2.6.32 and the Cross-compiler environment is arm-linux-gcc-4.4.3. Programs design mainly includes two parts, one is device driver program, and another is application program. Driver program runs in the kernel space and it is the basis which is called by the application program to achieve the function of system.

VI. RESULTS AND DISCUSSIONS

The patient monitor system is first interfaced with a Zigbee co-ordinator using a TTL Interface. After power up the current patient monitor system uses a timer program which runs on an ATMEL based microcontroller along with the attached interfaces given below.

1. Heart Beat Sensor
2. Temperature Sensor
3. Oxygen Sensor.
4. ZigBee Transceiver

Fig :4- ZigBee Transceiver

5. Interfacing of the GSM AND MPMS Module

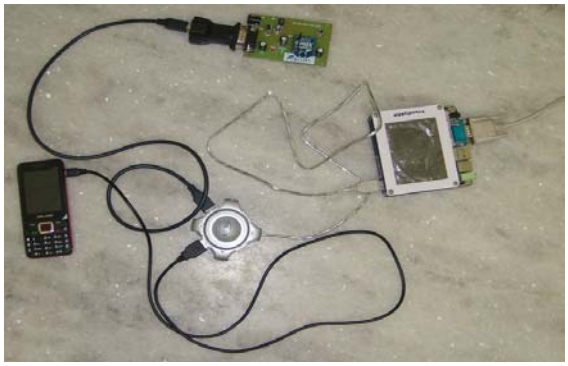

Fig :5- Interfacing of the GSM AND MPMS Module

The timer program will run for every 10 seconds and will be periodically collect the data from a particular patient. Once the timer expires, this system prepares a messages which contains the patients vital parameters and is sent over the air using the zigbee co-ordinator module.

A test setup is developed with a patient monitor system sending the patients information periodically for every 10 sec's. The data transferred by the system is processed using the centralized ARM server and whenever a particular patients Heartbeat or temperature drops below a certain threshold an automated SMS is sent to the pre-configured mobile number.

6. Interfacing of the patient monitor and Zigbee

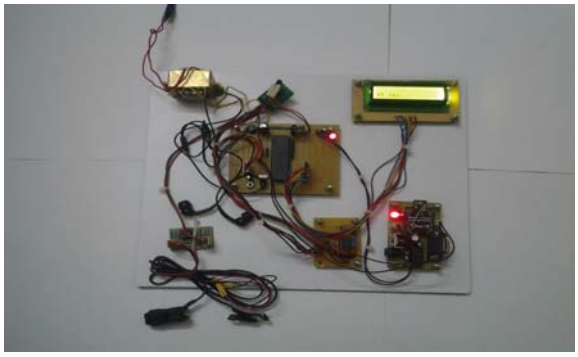

Fig:6- Interfacing of the patient monitor and Zigbee

The above experiment is performed with four different patients with different alert parameters. A message from a valid mobile number is sent to the ARM server requesting for a record of a particular patient, and the response of the message contained the requested patient's information.

VII. CONCLUSIONS

The present system can support up to twenty patients with real-time, low-power, low-cost, long-distance, and dual-mode monitoring, which is suitable for poor people in the Third- World countries, where there are

no telephone lines, web-based systems, and GPS. The use of the S3c2440 and the ZigBee Tarang modules communications processor for building blocks of the monitoring system has the benefits of intelligence, compact size and reliability. By the aid of this highly-integrated chips, external components and hence wirings are kept to a minimum. A reliable wireless personal area networks (WPANs) has been introduced and described, and also a solid software implementation method has been used to develop this DSP-based system. Further advantage of this system is its low-power consumption, which is attractive for portable applications.

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