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Zigbee Based At-Home Medical Equipment for Natural Disasters

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Abstract:
Electricity-operated durable medical equipment (DME), such as ventilators, dialysis machines, and patient monitoring devices, are life-supporting machines used extensively by patients at home. While convenient and economical, at-home use of DME is susceptible to power outages, especially the ones caused by natural disasters that often occur in large area and for a long duration. There is little existing technology allowing hospitals to monitor DME-dependent patients without using the current infrastructure, such as the landlines, the cell towers, Ethernet cable or the Internet. Reported herein is a novel wireless system that utilizes a radio ad hoc network to automatically report the patient's information and location, and the DME information and status to a nearby hospital when a power outage is detected.

This system consists of two parts: a hospital-based receiving device, called the Base Station node, and multiple transmitting devices, called User Nodes, each connected to the DME at patients' homes. The Base Station and User Nodes is each built with a Teensy® microcontroller, a GPS receiver module, and an Xbee® radio implementing the Zigbee® protocol.
Additionally, each User Node contains a status LED and an internal lithium-ion battery connected by a charge controller. User Nodes are programmed to obtain the GPS location of the patient, monitor the DME status, communicate with nearby nodes, transmit the data and relay information to the Base Station through the radio ad hoc network the nodes form in the case of a power outage.

The Base Station device is programmed to receive and convey the information transmitted from the User Nodes to a nearby hospital's patient monitoring computer through a USB connection. This system works without relying on the infrastructure, and allows hospital staff to know the information and locations of DME and their users and provide help needed during power outages.

I. INTRODUCTION:

Durable medical equipment (DME) is any medical device used at home by patients for monitoring and/or treating diseases [1]. There are two types of DME: passive equipment and active equipment, the latter reliant on electricity to operate. Life-supporting active DME include dialysis machines, ventilators, oxygen concentrators, etc. [2]. At-home use of DME is not only convenient and economical, but also leads to a better quality of life for the patient. In a 2013 survey, the World Health Organization (WHO) estimated that in Japan alone, there are 13,000 DME in use, namely 101 DME users per million population [3]. DME are heavily used in the United States although a specific number is not available due to privacy laws [3]. Despite aforementioned benefits, at-home DME are susceptible to power outages, especially those caused by natural disasters. During difficult times like this, the DME dependent patients had to face the life-threatening situation because their machines had stopped functioning. While most at-home DME are equipped with integrated batteries to keep them functioning during power outages, their rechargeable batteries typically last only 1 hour with lead-acid batteries and 2-3 hours with newer lithium-ion batteries [4].

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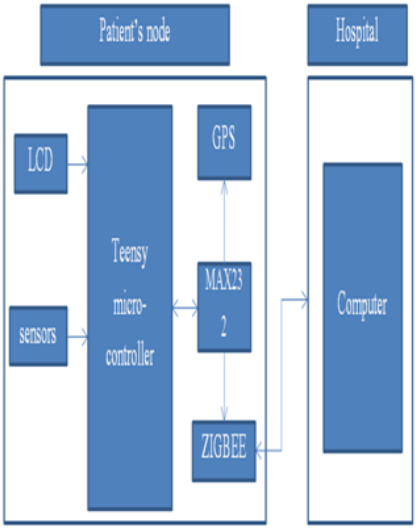
Thus, there is a critical need for a means of communication between the medical staff at a hospital and patients at home during natural disasters without needing current infrastructure such as landlines or cell towers that are often unavailable during natural disasters. Aware of the severity of this problem, the Assistant Secretary for Preparedness and Response (ASPR) of the U.S. Department of Health & Human Services through its partner, www.innocentive.com, launched a challenge in 2013 to seek ideas that might solve this communication issue [5]. Although there are several commercially available general purpose trackers or locators [6], [7], and some DME even have integrated reporting units, none of these are operable when the infrastructure is disabled, because they all rely on the cell phone services and/or Internet connectivity. Hence, there needs to be a means of communication, which does not use the current infrastructure, between the at-home DME-dependent patients and the hospital staff during natural disasters.

Existing Method:

In this method, zigbee protocol technology usage is done. By which patient's condition is sent from various transmitter sections to receiver section. i.e The transmitter sections are arranged at each and every patient. At the receiver PC need to be monitored continuously by a doctor/staff in the hospital.



Draw Backs:

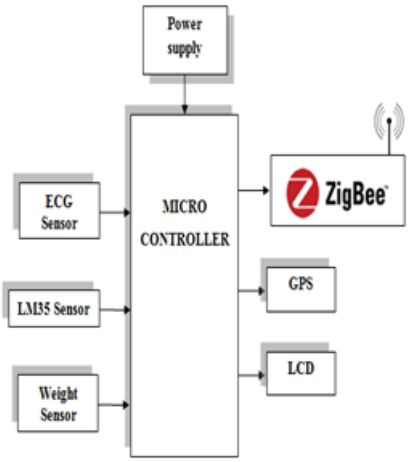
- Limit range
- Requires a computer system
- Low efficiency

Proposed Method:

This system consists of two parts: a hospital-based receiving device, called the Base Station node, and transmitting devices, called User Nodes, each connected to the DME at patients' homes. The Base Station and User Nodes is each built with a microcontroller, a GPS receiver module, and an Wireless Communication implementing the ZigBee protocol. User Nodes are programmed to obtain the GPS location of the patient, monitor the DME status, communicate with nearby nodes, transmit the data and relay information to the Base Station through the ad hoc network the nodes form in the case of a power outage. The Base Station device is programmed to receive and convey the information transmitted from the User Nodes to a nearby hospital's patient monitoring computer through Serial communication. This system status is display on LCD.

Block Diagram:

Patient Section:



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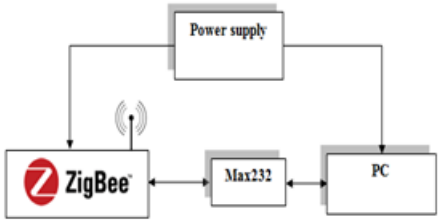
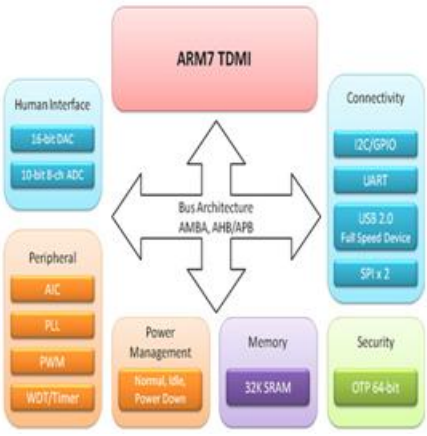
Monitoring Section:



II. MODULE DESCRIPTION:

ARM7TDMI Processor Core:

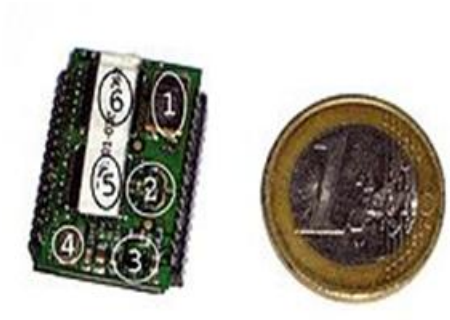
- Current low-end ARM core for applications like digital mobile phones
- TDMI
  - T: Thumb, 16-bit compressed instruction set
  - D: on-chip Debug support, enabling the processor to halt in response to a debug request
  - M: enhanced Multiplier, yield a full 64-bit result, high performance
  - I: Embedded ICE hardware
- Von Neumann architecture



Global Positioning System:

The **Global Positioning System** (**GPS**) is a U.S. space-based global navigation satellite system. It provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth which has an unobstructed view of four or more GPS satellites.

ZIGBEE:



ZigBee module. The €1 coin, shown for size reference, is about 23 mm (0.9 inch) in diameter. ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for wireless personal area networks (WPANs), such as wireless headphones connecting with cell phones via short-range radio. 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. The ZigBee Alliance is a group of companies that maintain and publish the ZigBee standard.

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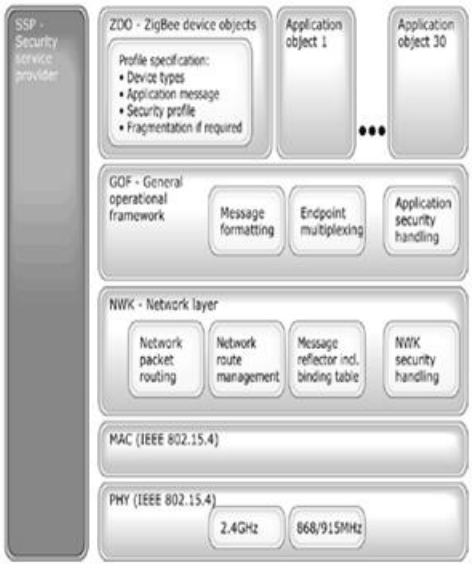
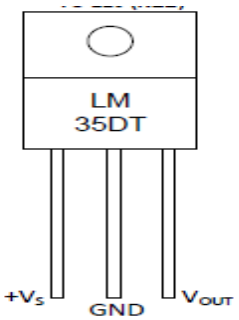
Architecture:



Temperature sensor (LM35):



Pin Definition:

The definition of gray-scale sensor pin is

1. Signal Output
2. GND
3. Power

Features Of Temperature Sensor:

- Calibrated directly in Celsius (centigrade)
- 0.5^0 C Ensured accuracy (at $+25^0$ C)
- Suitable for remote applications
- Operate from 4 to 30 V
- Low cost due to wafer-level trimming

Specifications:

- Type: Analog
- Sensitivity: 10mV per degree Celcius
- Functional range: 0 degree Celsius to 100 degree Celsius

ECG SENSOR:

The ECG Beat Sensor provides a simple way to study the heart's function. This sensor monitors the flow of blood through ear lobe. As the heart forces blood through the blood vessels in the ear lobe, the amount of blood in the ear changes with time. The sensor shines a light lobe (small incandescent lamp) through the ear and measures the light that is transmitted. The clip can also be used on a fingertip or on the web of skin between the thumb and index finger. The signal is amplified, inverted and filtered, in the box.

WEIGHT SENSOR:

The weight sensor is designed to automatically raise an alarm should any of the following situations arise:

• If a person has not gone to bed by a predetermined time.

• If a person has not got out of bed by a predetermined time.

• If a person gets out of bed during the night and does not return within the predetermined time period.

The solution can be tailored to suit the specific daily activities of the individual. There is an optional facility available to automatically turn on a light to minimise the risk of falling should the person get out of bed.

Software Tools:

Keil compiler is a software used where the machine language code is written and compiled. After compilation, the machine source code is converted into hex code which is to be dumped into the microcontroller for further processing. Keil compiler also supports C language code.

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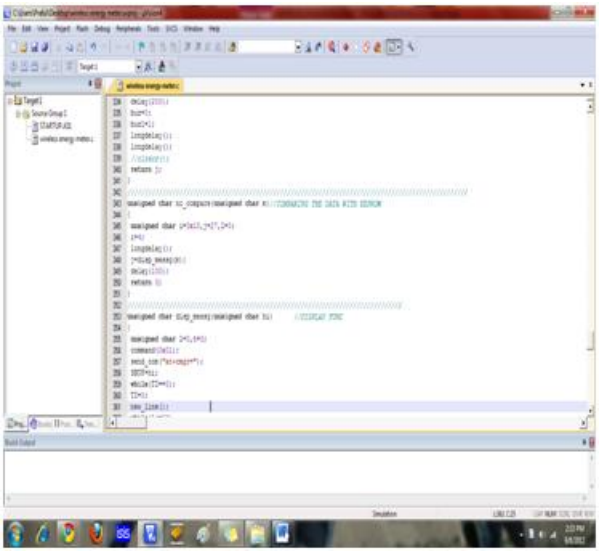
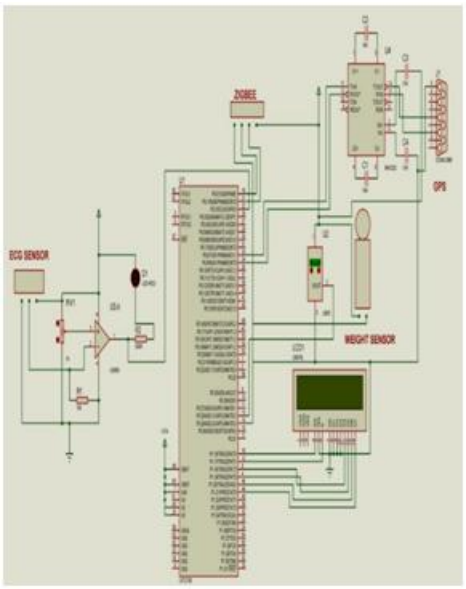
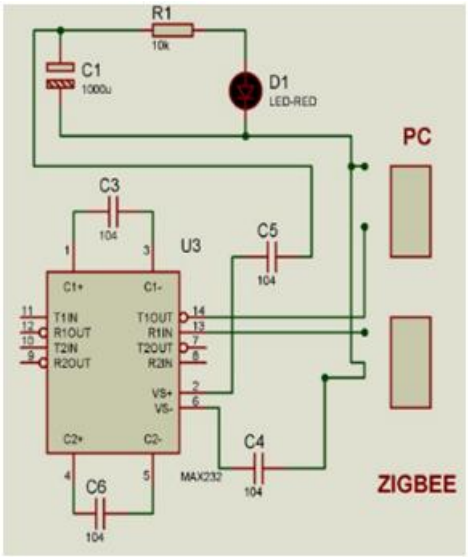




Flash Magic:

Flash Magic is a tool which is used to program hex code in EEPROM of micro-controller. It is a freeware tool. It only supports the micro-controller of Philips and NXP. It can burn a hex code into that controller which supports ISP (in system programming) feature. Flash magic supports

Schematic Diagrams:



III.RESULTS:

Fig:Patient section

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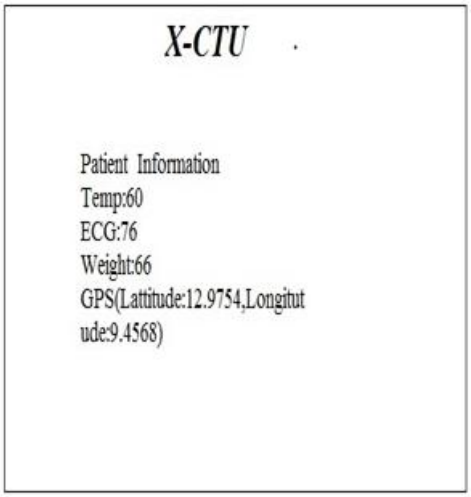

Fig: patient information

IV.CONCLUSION:

Given testing data, it was found that the prototype design of the DME tracking system was feasible to implement and would meet the requirement for securely transmitting patient data, location information, and the status of DME to a nearby hospital during power outages. Although the maximum radio range for the current pilot prototype was found to be 90 m, the advantage of modular design allows this proof- of-concept system to be easily scalable by simply employing more powerful radio modules or having specially placed forwarding nodes to facilitate the forwarding of information from more distant homes. In a medium patient density situation, for instance, a radio with an indirect (i.e. non line-of-sight) range of >4.70 km could be employed. Additionally, the implementation of this DME tracking system is relatively inexpensive, utilizing commercially available low cost general-purpose microcontrollers and general-purpose radios. When produced in one circuit in mass production, the cost will be even lowered.

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