Real Time Incubator Monitoring System Using Wireless Sensor Network

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Abstract *- Although the Infant Mortality Rate of preterm babies has improved dramatically, they still remain vulnerable to many complications. The high rate of pathogenic infections in preterm babies addresses the need for a better prevention, detection and treatment facility. Modern Pediatrics Hospitals are equipped with incubators for post-delivery infants by providing them ambient environmental conditions which are essential and crucial for the healthy growth of the neonatal which was available only from experimental techniques owing to the complex human physiological phenomena till now. Pediatricians need real time data to monitor various parameters of the infants in these incubators for periodic medical requirements. Performance evaluation of this MANET based real time incubator monitoring system is simulated on NS2 considering each incubator as an access point equipped with various sensors which is analyzed with the Enhanced-Adhoc Ondemand Distance Vector(E-AODV) protocol. Tests have been carried out in the pediatrics hospitals to monitor new born infants during post-delivery complications. This paper proposes miniaturized sophisticated intelligent wireless sensors networks to provide real time monitoring of parameters like ECG, Blood Pressure, Oximetry, Pulse, and Temperature of the infant/patient and the humidity of the incubator. The simulation results are encouraging enough to warrant their use as a real time information delivery system that would greatly help Pediatrics consultants and particularly infants and can rely on this extremely potential Intelligent Sensors Network that provides accurate pathological parameters.*

Keywords: Access points, Wireless Sensor Networks, E-AODV, Incubators

1 Introduction

Infant primary defense against the pathogens is its immune systems which are underdeveloped in its first 6 months of gestational period. The only defense mechanism it has are the immunoglobulin antibodies being passed by mother through the placenta in the blood stream recognizing the pathogenic bacteria, virus, fungi entering the body, helps in preventing infections to the fetus which has a considerable amount of antibodies in its blood stream and they continue to receive them through breastfeeding and are passively immunized. Neonates tend to produce antibodies at a slow rates compared to adults for the first 6 months as new-borns are highly vulnerable of catching unwanted infections if not given proper care. It is advocated for the use of a monitoring system wherein real time physiological parameters of the new-borns are kept track of and facilitated with required conditions. New-borns are usually housed in an incubator system which requires a nurse or a physician to overlook it constantly. Babies that are born under less than 37 weeks of gestation period are generally considered to be premature. Neonates are susceptible to many diseases owing to the fact that their organs and immune systems are not matured. It has been studied that neonates tend to become ill severely mainly during and after birth. Such neonates who are vulnerable to attacks from foreign agents or in case of a self-system collapse are usually housed in a Neonatal Intensive Care Unit (NICU). Early detection and prevention of any complications arising reduces the Infant Mortality Rate. A better health can hence be provided to neonates by reliable and friendly monitoring systems and have found success in the health sector.

Premature babies are usually prone to physiological diseases apart from congenital diseases. Common problems are the ones related to Respiratory system like the Apnea, Anemia, Chronic Lung Disease, Cardiovascular system, the Bradycardia, and many others including Hernia, Hemorrhages, Jaundice, and Sepsis and Feeding intolerance. Thus it is critical to keep a real time tab on the baby's physiological parameters so that doctors and physicians can initiate the necessary procedures to save the baby.

A real time incubator system wherein the new-borns are constantly monitored is proposed. This real time monitoring of incubators and emergency notification is very useful and is relied upon by the Neonatologists as well as Pediatricians. It is of prime importance that the baby' vital signs are monitored continuously. Wide ranges of available physiological monitoring hardware help us get the biometric values in analog format and the system we propose transmits this data to the main base station in digital format. Each proposed incubator will have a set of six sensors which will provide the ECG, Blood Pressure, Oximetry, Pulse and Temperature of the infant in the incubator. Data collected from all the sensors is stored temporarily in the node provided in the Incubator itself and transmits the data to the Base Station over a wireless channel for analysis. The doctor or the nurse can access the data of a particular incubator on request for analyzing an irregularity found in the readings of any of

the parameters, and then an emergency notification is sent to the concerned pediatrician/consultant and family members.

2 SENSING PRINCIPLES

2.1 Blood Pressure

The Blood Pressure of the baby is measured using a CMOS Blood Pressure Sensor kept on the skin of the patient to monitor continuously. It measures the displacement of a surface caused by the movement of the blood vessel walls, due to its over pressure inside known as tonometry, Fig. 1.

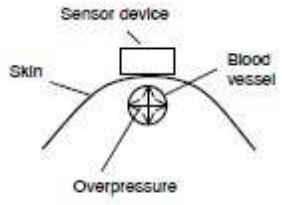

Fig. 1 Blood Pressure Sensor Schematic

Array of such force sensors are used to increase the accuracy applied on to the skin surface, the array which gives the highest value is considered. Each of these force sensors has suspended elastic membrane with a top electrode for capacitive read out of deflection of the surface made of CMOS technology where there will be reference element with respect to which the sensors will calculate the displacement, Fig. 2.

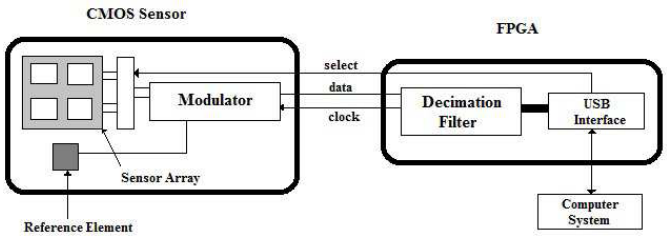

Fig. 2 Blood Pressure Sensor

2.2 Pulse Oximetry

Pulse Oximetry uses light wavelengths to measure oxygen saturation. Light is emitted from light sources/emitters which goes across the pulse oximeter probe and reaches the light detector. A finger is placed in between the light source/emitter and the light detector; the light will have to pass through the finger to reach the detector. Part of the light will be absorbed by the finger (the blood within) and the part not absorbed reaches the light detector, Fig.3.

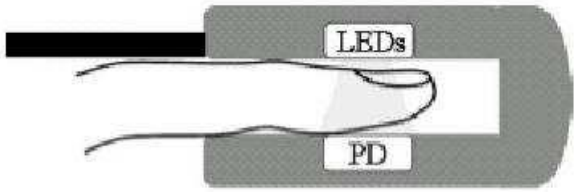

Fig. 3 Pulse Oximetry Sensor

The amount of light absorbed by the finger depends on the following factors:

1) The light absorbing substances (Hb in Blood) concentration.

2) The light paths length in the absorbing substance.

3) Oxyhemoglobin and Deoxyhemoglobins differential absorption of red and infrared wavelengths. Hence we will be using red light and IR light LEDs in the sensor probe.

It is observed from experiments that Oxy Hb absorbs more infrared wavelength than red wavelength and Deoxy Hb absorbs more red wavelength than infrared wavelength. In the finger, its not just the blood that absorbs the light, skin and other tissues also do absorb some light. Blood is pulsating and hence any variation in absorption must be due to blood in the finger being the properties of the Human Blood, the red and infrared wavelengths in measuring the Blood Oxygen Saturation.

A basic Oximetry Sensor uses 2 LEDs; one being a red LED and another IR LED and these are lit up in a particular timed sequence. A detector is used at the other end inner wall of the finger probe where the varying light is received. The readings from these sensors are continuously fed to a computer and are available in the form of a graph called the plethysmographic trace (pleth) using complex calculations by the computer.

2.3 Temperature

Sensors widely used in the medical applications to measure the temperature of the infant are generally of the Contact Sensors type. While using these sensors, one infers the readings by considering the sensors and the body in contact are in thermal equilibrium.

2.4 ECG

ECG, electrocardiogram is a recording of the electrical activity of the heart (cardiac) muscle as obtained from the surface of the skin. Electrocardiograph (ECG) is one of the most widely used biomedical sensing procedures to date. The heartbeat is the definitive indicator for a wide range of physiological conditions. Current flows in the form of ions in

the body and signals contraction of cardiac muscle leading to the heart's pumping action. Quasar's sensor is a compact and most commonly used ECG sensor that does not require skin preparation, gels, or adhesives. It includes not only a sensing device, but also signal conditioning circuitry such as low noise amplifiers and voltage reference chips.

2.5 Humidity

Humidity sensors are used to find the amount of water vapor content in its surroundings. The capacitive humidity sensors consist of a substrate on which a thin film of polymer or metal oxide is deposited between two conductive electrodes. The sensing surface is coated with a porous metal electrode to protect it from contamination and exposure to condensation. The substrate is typically glass, ceramic, or silicon. The Humidity is measured by virtue of the dielectric constant of this material varying according to the variations of the environment.

3 Communication Channel

This paper focuses on establishing Enhanced AODV protocol based communication between the Doctors/consultants and the incubators. A communication channel is created between each of the nodes housed on each incubator and the base station where all the data is received and stored. 3 routing tables are used by Enhanced-AODV. The 3 tables being Routing Table, Distance vector table and Path memory table for each node. This protocol uses 4 types of messages, the ping message (PNG) will be broadcasted by the nodes to know the direction and distance of the neighboring nodes, the router request message (RREQ) will be sent from each node once the direction and distance of the neighboring nodes are determined, the RREQ message will decide the final path for the packets and the Route Reply Message (RREP) will confirm the path and ensures that the connection is established. The Acknowledgement (ACK) message is transmitted by the receiving node after the reception of each packet. The Distance Vector Table contains the information about the direction and distance of the neighboring nodes. The Path memory table deals with the number of nodes per sector and help is creating the path for the packet. The Enhanced-AODV ensures optimized communication between the nodes and the base Station. The Data received by the Base Station is stored, analyzed and compared with the standard values. Each concerned authority is provided with a PDA using which they can access the readings as and when required. When the authority wants to access the data, they can send a request using their PDA. The request message will contain the node (Incubator) IP address. Depending on this request, the Base Station will send the reading to the PDA of the authority. The actual biometric parameters will be available on the PDA after this.

4 Implementation

A simplified network environment is created wherein the sensors on the infant are feeding the real time physiological parameters to the Physicians on their PDAs routed via a common base station housed at the hospital's data center. Each Incubator is fitted with an on-board module referred to here as node, whose only job is to collect the data from the various sensors, convert them into digital signals and transmit wirelessly using E-AODV routing protocol to the next immediate node or to the base station directly. The sensors are wired to the incubators module. These modules are equipped with a small memory storage capacity and are used to temporarily store the collected parametric data. The module communicates with the base station and upon successful establishment of communication channel begins the transfer of data. The Base Station is a server set up on the hospital premises which handles all the incoming information about the infants and maintains a database which is equipped with a state of the art application that does the actual monitoring of the infants parameters. It is pre-fed with standard levels of a healthy infant which it uses to compare with the incoming data from all the incubators and generates alerts the concerned doctor and the nurse station notifying immediately about the emergency generated to the Doctors cell phone and family members from the Base Station.

The proposed system will have the doctor PDAs be installed with an application which assists them in the treatment process. The application stalls all the current processes running on the PDA and receives the messages from the Base Station seeking attention from the doctor. The doctor can as well access the database maintained by the Base Station whenever in need to monitor real time readings of the infant parameters and pleth.

5 Simulation and Results

Network Simulator-2 was used to simulate the communication network in the proposed system. The environment is simulated in a 2-D topology system using E-AODV Protocol considering 6 nodes as constituted by 6 different sensors, the data from each of these nodes is sent over wired channel to the module housed on the incubator. The data from each of these nodes is sent to the Base Station over a wireless channel with a packet size of 5kB and an interval arrival time of 10 packets per second. The data traffic generation is performed using File Transfer Protocol (FTP) Model and is sent over a multiplexed wireless channel of 1ms duration per node.

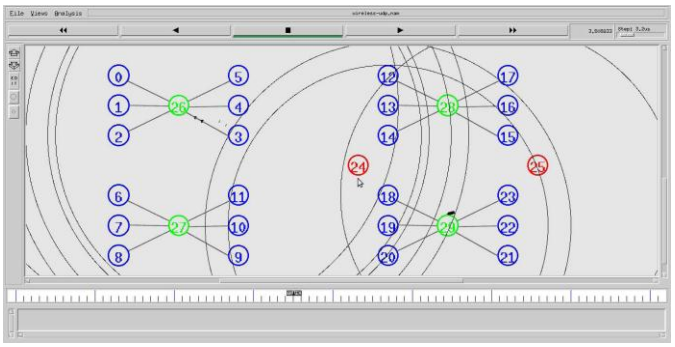

Fig. 4 Simulation showing the data transfer from individual sensors to the incubator node

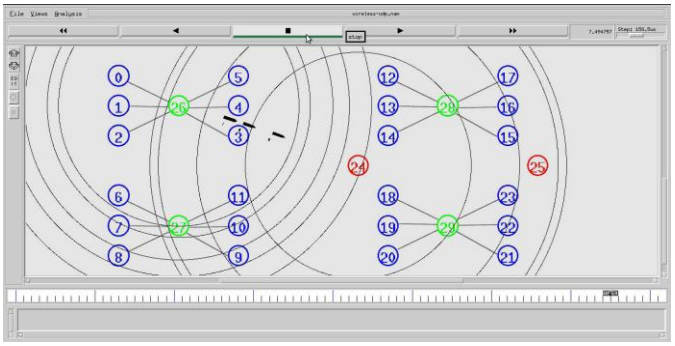

Fig. 5 Simulation showing the data transfer from incubator node to the nearest access point.

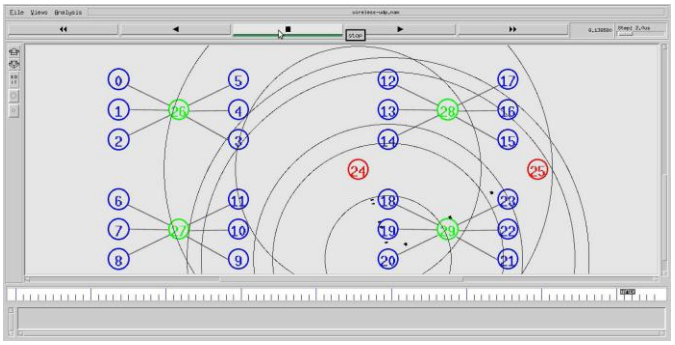

Fig. 6 Simulation showing the data transfer from access point to the main base station.

6 Conclusion and Future Work

The proposed Real time incubator monitoring system collects various biometric parameters of the infant in the incubator and sends this over a wireless network to the Base Station. The proposed system ensures proper monitoring of the infants and helps in case of emergencies as well using enhanced-AODV protocol.

The future work is focused on the implementation of the monitoring system to monitor all the pathological parameters of infants in all the hospitals with common physician/consultant.

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