Wireless Sensor Network for Intra-Venous Fluid Level Indicator Application

Abstract

Wireless sensor networks use small, low-cost embedded devices for a wide range of applications such as industrial data monitoring and controlling, asset monitoring and tracking, remote metering, automotive networks, wireless data acquisition and processing and home automation. This paper aims to implement a low cost, low power wireless sensor network application inside the hospital premises. More specifically, an automated system will be designed to detect the level of the Intra-Venous fluid and to send this critical data over a wireless transmitter. The data sent will be displayed in a dashboard placed at a nurse station. This state-of-the-art experiment can also be used in the Computer Engineering Technology curriculum for senior level students in the Embedded Systems or Wireless Communication courses. The prerequisites to understand this experiment include wireless sensor networks application classes, popular wireless standards, hardware design with RF transceiver modules, embedded controller and sensor circuits, and embedded software for microcontroller programming.

Introduction

Sensor based technology has invaded medical devices to replace thousands of wires connected to these devices found in hospitals. This technology has the capability of providing reliability with enhanced mobility. In today's hospital scenario, there are more patients but not enough nurses. In these cases, the nurse cannot keep the medical records about every patient. A simple case may be noting the level of the Intra-Venous fluid levels of the patient. The Intra-Venous fluid data is essential to be noted because if the bottle gets fully drained, air enters the tube and in turn into the vein, which may prove disastrous to the patient. Although this checking can be done manually, it is tedious and prone to human errors. So automating this system might prove really helpful. A system can be designed such that if the Intra-Venous fluid reaches a critical level, an alarm like signal is sent to the nurse indicating the patient name and the room number. When this is done, the nurse can easily identify the room and go there directly to change the bottle rather than keep checking every room to notice if the fluid has reached the critical level. This requires the use of wireless sensor networks.

The sensor network application classes can be classified into three categories including data collection, security monitoring, and sensor node tracking. The majority of wireless sensor network deployments will fall into one of these class templates. Hybrid network systems use all three templates and include applications such as vehicle monitoring and/or tracking system. There are at least four types of sensors that can be used for this project. They consist of Ultrasonic Sensor, Capacitive Sensor, Load cell sensor, and Infrared Sensor. Low cost ultrasonic sensor does not differentiate between the bottle surface and the water level. Thus detection becomes very difficult. Better sensitivity ultrasonic sensors cost around $500. In capacitive sensors, reference capacitor values vary with the bottle size and material. Therefore, the calibration becomes tedious. In case of load cell, any slight disturbances to the bottle may cause changes in the output voltage which causes erroneous results. Infrared sensor is the best type of non-contact sensor that can be used for this type of application as shown in Figure 1. In the infrared sensors, an IR emitter and an IR receiver are kept by the side of the intra-venous bottle. The line of sight of the IR sensor passes through the critical level of the bottle. When the liquid level is above the critical level, the IR rays are not received by the receiver. As the liquid level goes below the critical level, IR receiver receives the IR rays and an alarm signal is generated.

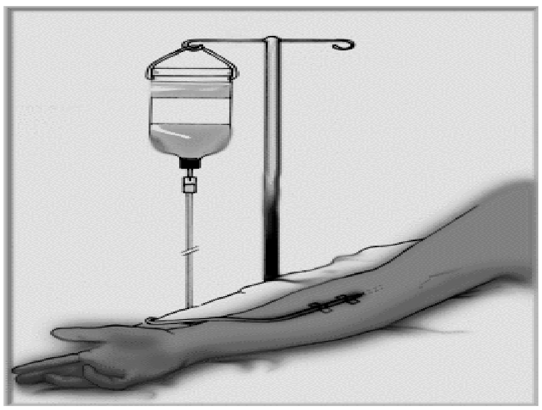

Figure 1. Intravenous Drip Setup in the Hospital

Basic Wireless Sensor Network Setup in the Hospital

The network system shown in Figure 2 consists of ten nodes (slave) that are attached with fluid level sensors and a central node (master) which collects data and displays it.

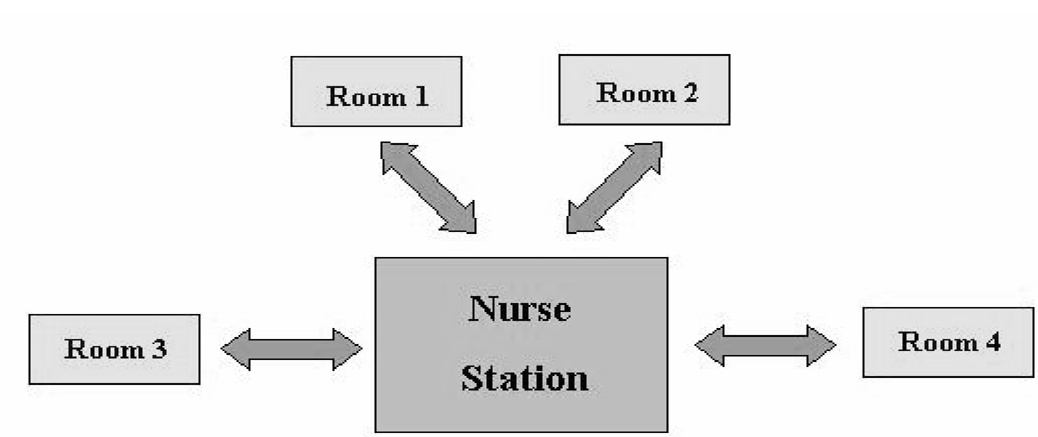

Figure 2. Basic Wireless Sensor Network Setup in the Hospital

In this system, sensor nodes (Figure 3) and display panel (Figure 4) are two major blocks. Every sensor node is equipped with an IR sensor which is used to detect the level of the liquid in the bottle. The sensor is hence placed near the critical level. When the liquid goes below this level it generates an output voltage of 5 V (logic 1) to the RF Transceiver

(CC1100) via controller (AT89S8253). The wireless module then sends this critical information over the air medium to the display station. The display is placed at the common nurse station.

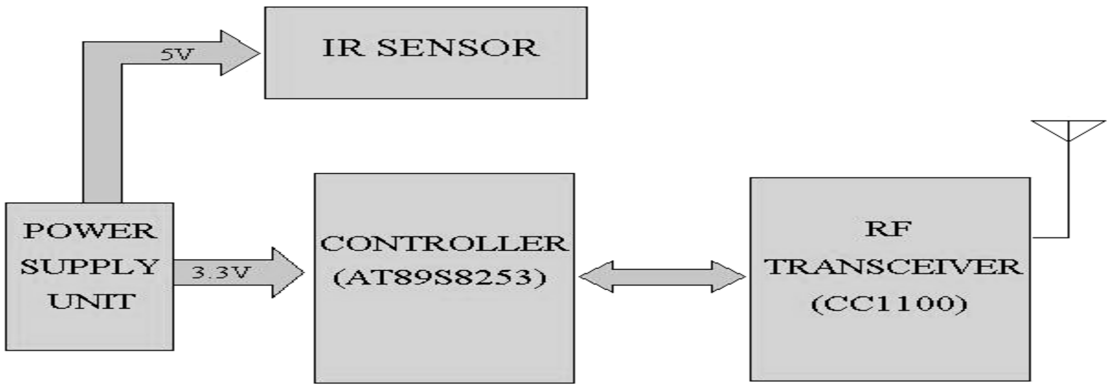

Figure 3. Block Diagram of the Patient Room

The display panel shown in Figure 4 is placed at the nurse station. The display will show all the room numbers in which the critical level is reached along with the option at the slave nodes to reset the circuit.

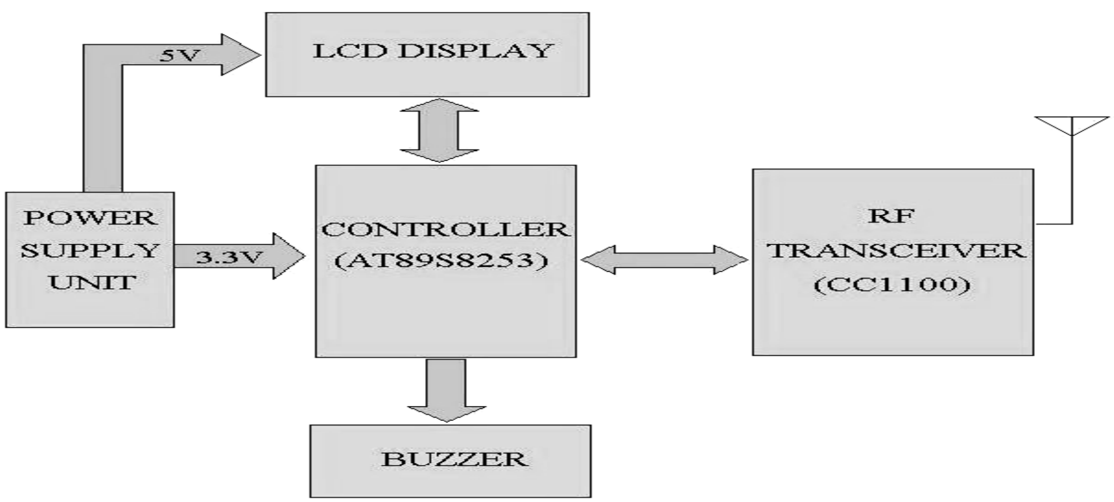

Figure 4. Block diagram of the Nurse Station

As seen in Figure 3 and 4, the major hardware parts used in our system are RF Transceiver module, an embedded controller[1], and a sensor circuit (emitter and receiver). The wireless transceiver [2] (chipcon RF radio CC1100) module fits perfectly to avoid any catastrophic medical side-effects for the end application. In our case, CC1100 is configured via a simple 4-wire SPI compatible interface. This interface is also used to read and write buffered data. The wireless transceiver (CC1100) module operates at the voltage level of 3.3 V. To meet this operating voltage requirement, an 89S8253 controller from Atmel [3] with operating voltage from 2.7 V to 6 V was chosen. This contains a hardwire SPI which can be exploited for data transfer between the controller and the wireless module.

In this case to implement Figure 6, an IR sensor HS 0038[4] was chosen, which is a line of sight sensor where IR waves are generated by an IR emitter at one end and is received by a receiver placed along the same line on the other side. These types of sensors are non contact type and used in applications like interruption identifier, burglar alarms, interruption counters and level measurement. HS0038 operates at 38 kHz frequency and the receiver gives the output voltage depending on the presence or absence of the IR rays emitted by the transmitter.

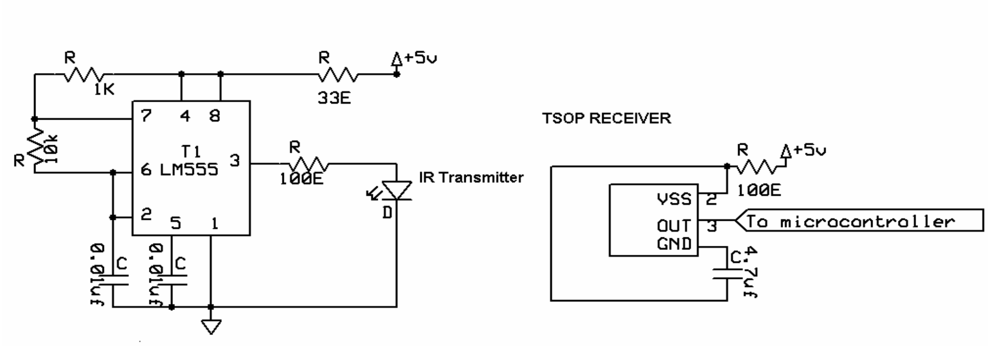

Figure 6. Schematic of the IR sensor

Nurse Station Circuit Diagram

The master circuitry shown in Figure 7 is placed at the nurse station. Its basic job is to be in the receive mode and collect the data sent by the slave nodes. The value of the data depends on whether the sent information is the original critical data or the data stating the slave node has been reset. The master circuitry collects it, decodes its nature and if it is the data then sends back an acknowledgement to the transmitter. The room number of the patient is obtained from the address of the slave node. This address is then displayed using an LCD module. Any arrival of the critical data is notified using a buzzer and the corresponding room numbers are displayed.

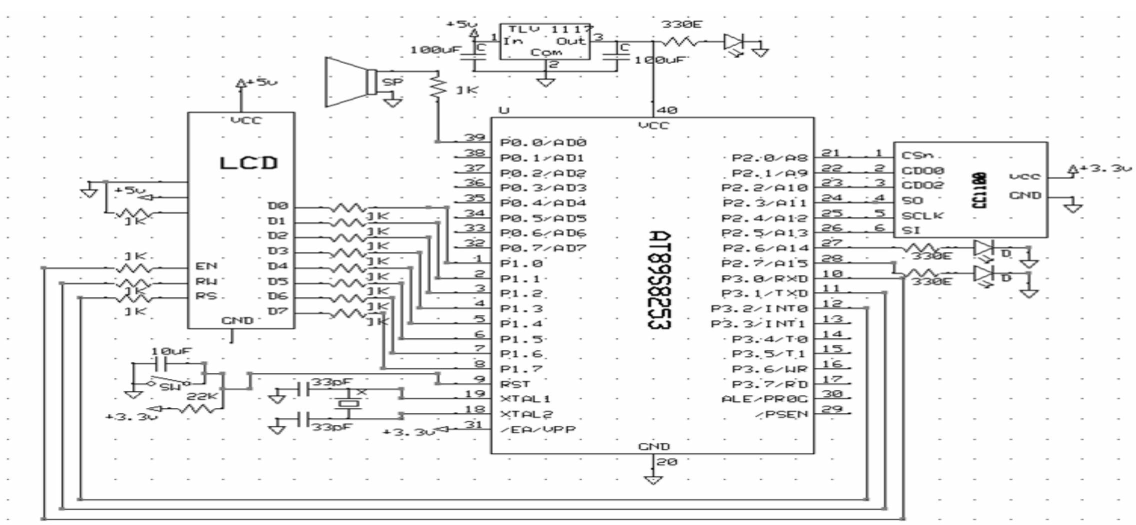

Figure 7. Nurse Station Schematic Diagram

Patient Room Circuit Diagram

The slave circuitry as shown in Figure 8 is present at the nodes in the patient room. The transceiver is normally in the transmit mode and whenever the critical level is reached, the information is sent to the master and immediately after sending the data, the transceiver at the slave node comes to the receiver mode in order to get the acknowledgement from the master. Once the signal is received, it confirms that the nurse has been informed about the critical level. If the signal is not received, then the transceiver goes back into the transmit mode and re-transmits the data until it correctly receives the signal.

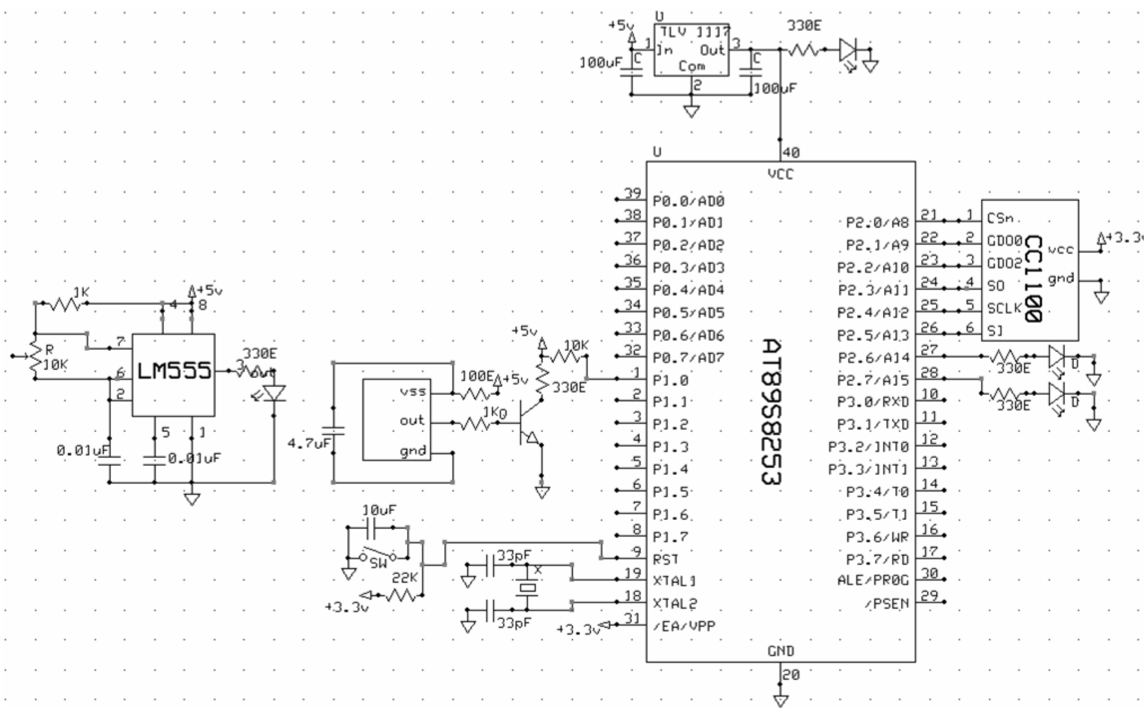

Figure 8. Patient Room Schematic Diagram

Embedded Software Programming

The embedded software used for programming the AT89S8253 controller in Figure 7 and 8 is KEIL compiler. The standard library known as REG8253 is used and the library for LCD Display, SPI, and CC1100 transceiver were written. To program the microcontroller AT89S8253, in the patient room we followed the flow chart shown in Figure 9. In the central nurse station we followed the follow chart shown in Figure 10.

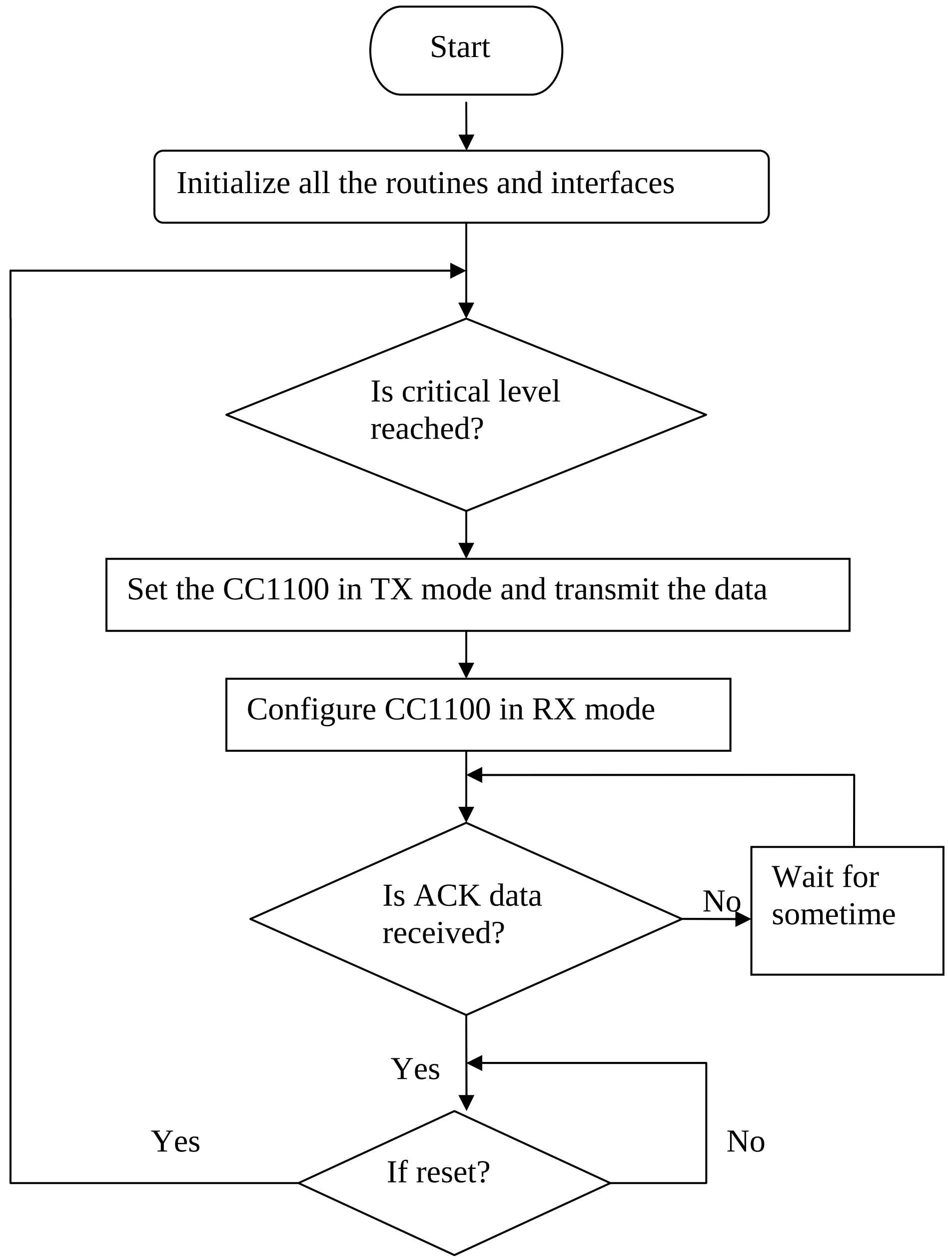

Figure 9. Flowchart to Program the Patient Room Microcontroller

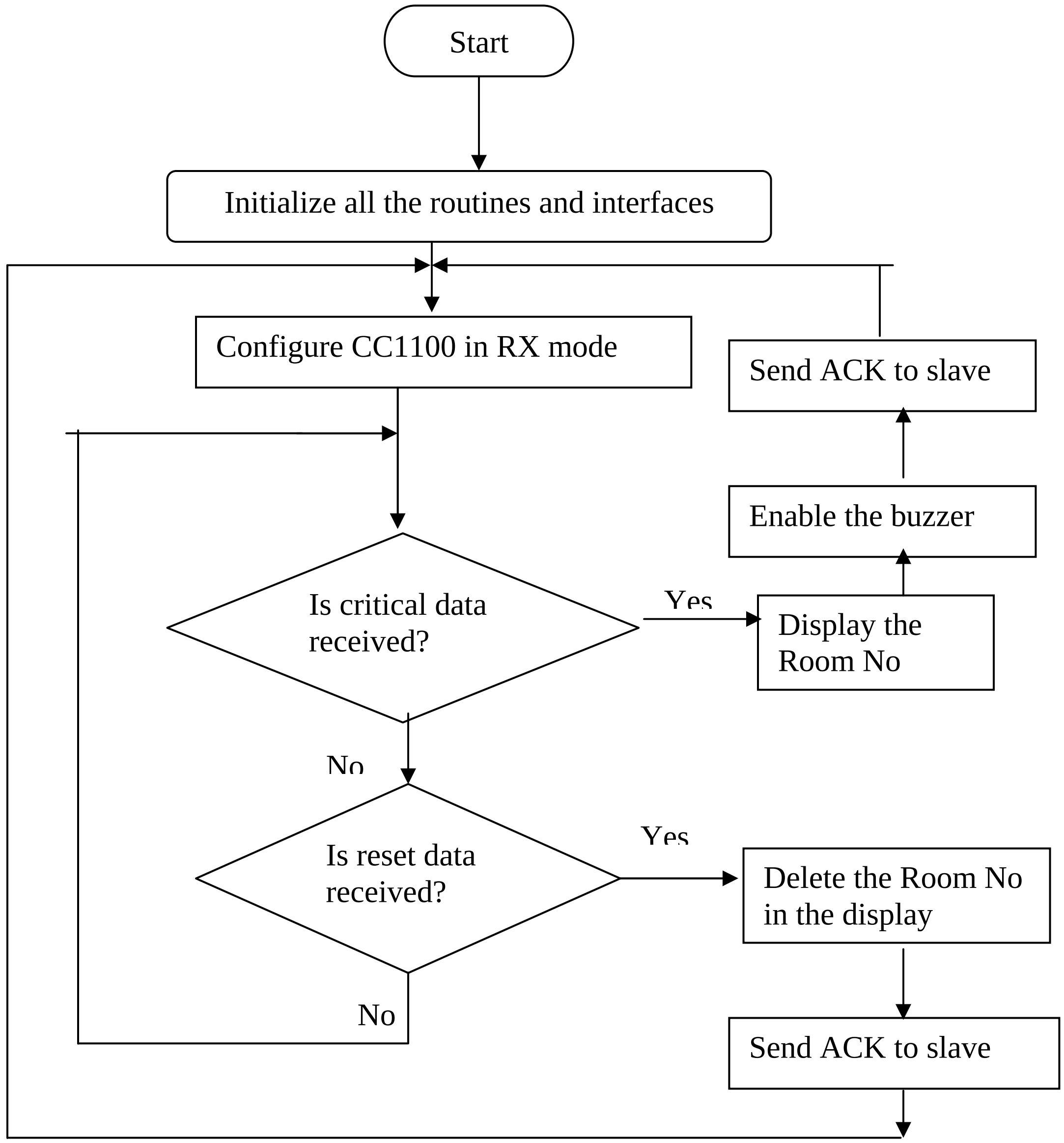

Figure 10. Flowchart to Program the Nurse Station Microcontroller

Experimental Results and Conclusion

The setup in Figure 11 shows the Intra-Venous fluid bottle with the sensors placed on either side. The Infra Red emitter is placed in line of sight of the Infra-Red receiver. When the bottle is present with the fluid between the transmitter and the receiver, the fluid, by its property, absorbs all the IR rays from the transmitter and hence the receiver gives an output of 5 V continuously. When the level of the fluid goes down the line of alignment of the Tx-Rx pair, the output goes to 0 V. The change in the output is detected using the controller to which the receiver is connected.

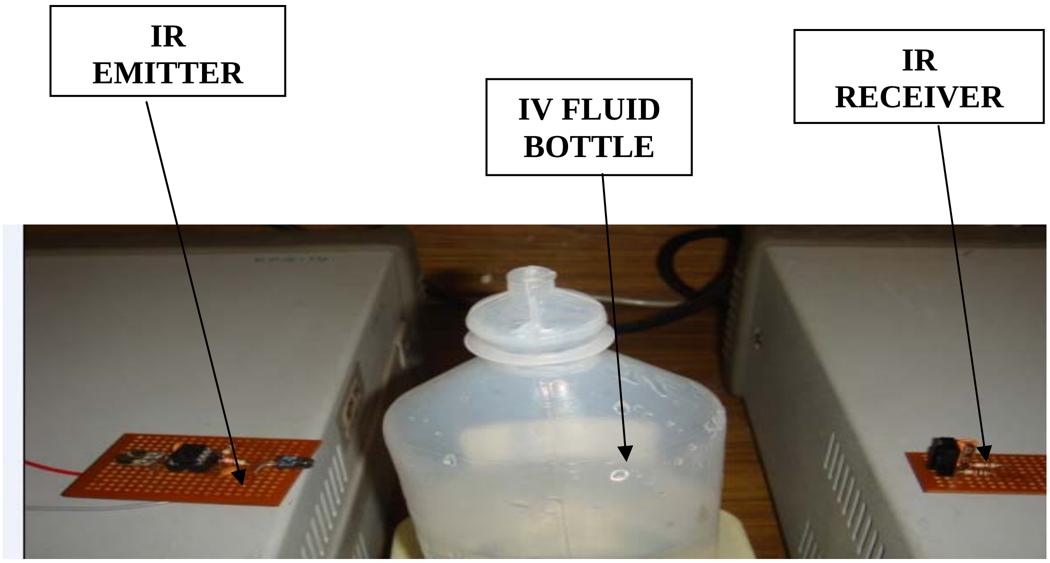

Figure 11. Sensor Setup in Patient Room

Figure 12 shows the display board which contains the central node at the nurse station. The transceiver in this node receives the signal from the various slave nodes of the patient rooms. The patient room slave board in Figure 13 and 14 is directly connected to the sensor through the microcontroller's port pins.

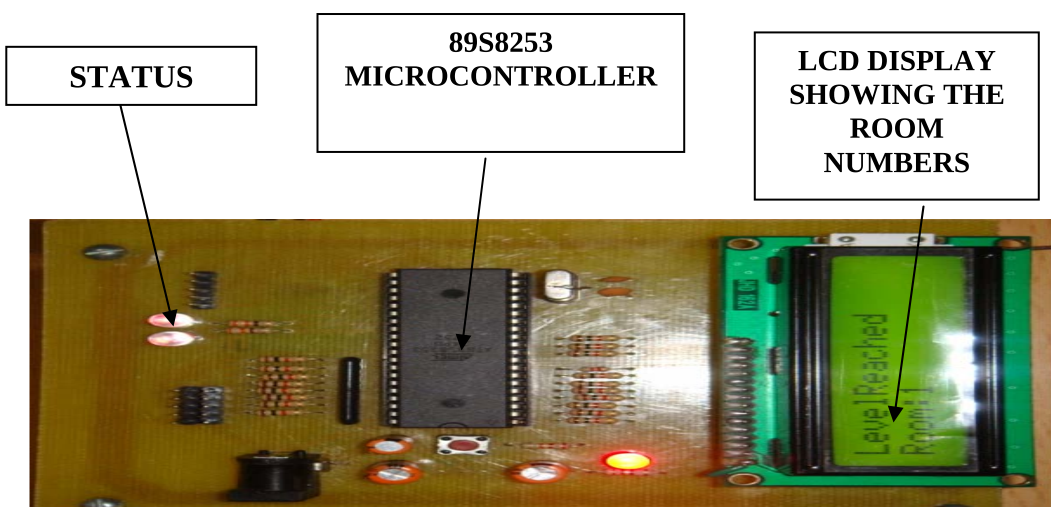

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Figure 12. Display Board in the Nurse Station

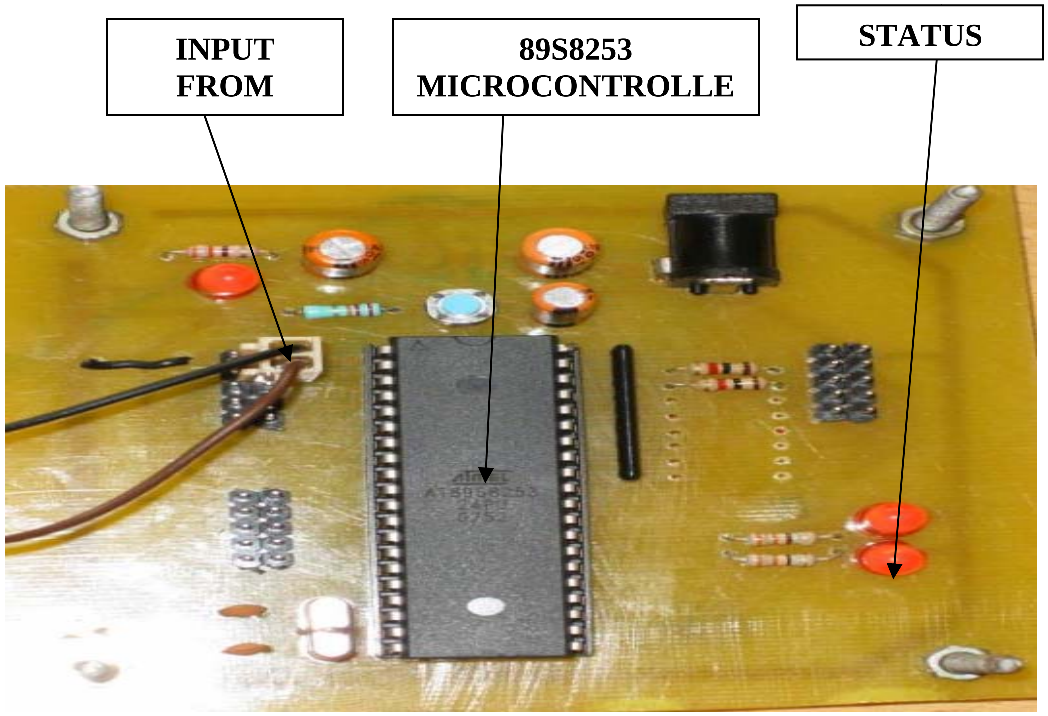

Figure 13. Front of Slave Board in Patient Room

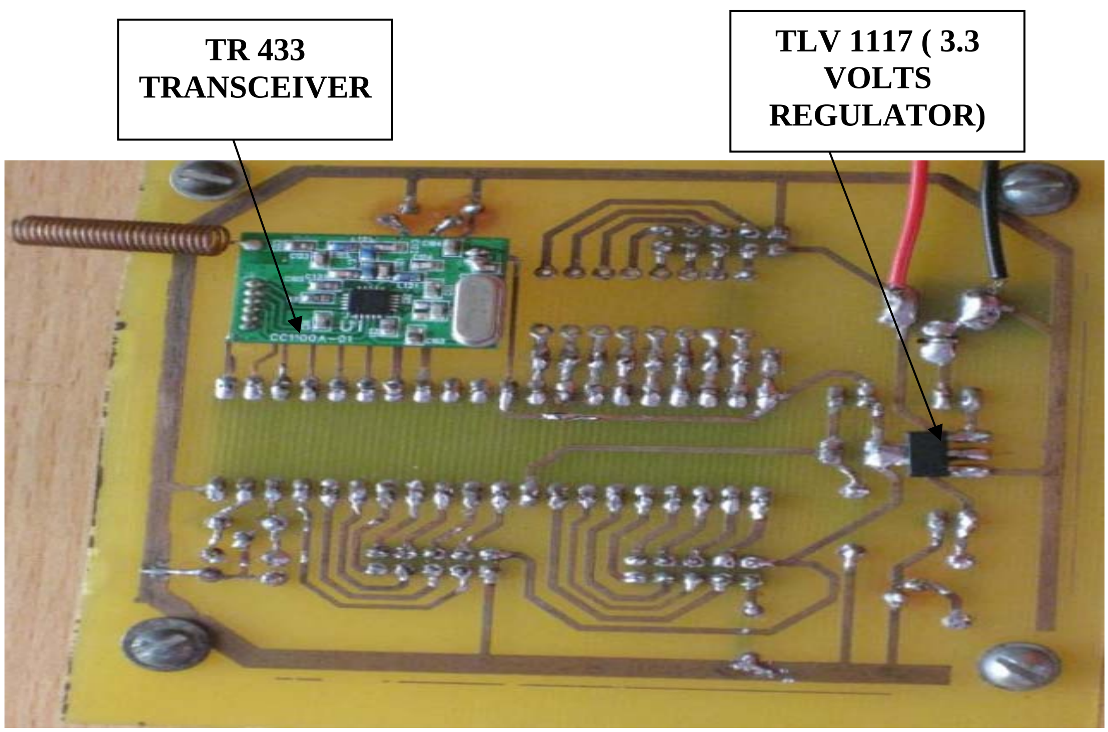

Figure 14. Back of the Slave Board in Patient Room

In this paper, we demonstrated low cost wireless sensor network system which monitors and detects the level of the Intra-Venous fluid and sends critical information within the hospital premises. There is still wide scope future expansion of this project in the medical field. For example, other vital parameters of the patient such as blood pressure and temperature can be sent remotely to the nurse desk or directly to the doctor's computer to monitor the patient's health condition any time.

Bibliography

1. K.J. Ayala, "The 8051 Microcontroller ", 3rd Edition, Microcontrollers Pros Corporation, 2004.
2. Single –Chip Low Cost Low Power RF Transceiver CC1100 Data Sheet, Texas Instruments, http://focus.ti.com/docs/prod/folders/print/cc1100.html, May 2009.
3. Atmel AT89S8253 is an 8051 based Full Static CMOS controller Data Sheet, Atmel Corporation, http://www.atmel.com/dyn/resources/prod_documents/doc3286.pdf, July 2009.
4. HS0038A Photo Modules for PCM Remote Control Systems Data Sheet, , Vishay Siliconix, http://www.alldatasheet.com/datasheet-pdf/pdf/215919/VISAY/HS0038A2.html, July 2009