# Design and Implementation of a Low Cost Wireless Sensor Network using Arduino and nRF24L01(+)

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## Abstract

Wireless communication is rapidly growing, making it possible to design wireless network systems that can constantly collect, analyze, evaluate and validate our environment to get more control of the factors that influence it. With over a decade of intensive research and development, wireless sensor network technology has been emerging as a viable solution to many innovative applications. In this paper, we describe a wireless sensor network system that we have developed using open-source hardware platform, Arduino. The system is low-cost and highly scalable both in terms of the type of sensors and the number of sensor nodes, which makes it well suited for a wide variety of applications related to environmental monitoring. Unlike wired network designs, wireless network designs create more flexibility in handling these environmental issues. For this reason, a wireless sensor network system that is capable of handling this situation is implemented. Overall system architecture and the design of hardware and software components are presented in details in this paper.

***Keywords***— *Arduino; nRF24L01 transceiver; Wireless Sensor Network; Coordinator node; Super node; Sensor node; Serial Peripheral Interface (SPI)*

## I. INTRODUCTION

The identification of the various factors affecting the environment can help in the development of better intervention methods for finding solutions to our environment. Building wireless sensor networks is one way to help identify some of these environmental problems. The environment in which human operate is capable of affecting its activities in many ways depending on many factors, such as, the amount of temperature, moisture, light, vibration, humility, smoke/fire, sudden car engine failure, etc. The main objective of this paper is to develop alternate and low cost methods. One of the methods involve in creating a wireless sensor network (WSN) in which every sensor is wirelessly transmitting the data or the value of that particular sensor to its superior node[2]. In general the architecture of the network is in hierarchical form. The network architecture includes several nodes such as child nodes, super nodes and one coordinator node. Here all the data from the sensors of child nodes are transmitted to its parent or super node. Multiple super nodes are further hierarchically connected to the main coordinator.

Wireless communication is rapidly growing, making it possible to design wireless network systems that can constantly collect, analyze, evaluate and validate our environment to get more control of the factors that influence it. The system is developed based on the open source hardware platform Arduino. The system is low cost and highly scalable, making it well suited for environmental monitoring. For our requirements, the sensor nodes are made small as possible.

## II. SYSTEM DESIGN

The core of the Wireless sensor network (WSN) consists of the base node (coordinator) and super nodes. The nRF24L01(+) is capable of acting as a multi-ceiver, listening to 6 other devices. This functionality of the device is exploited and used in the creation of a wireless sensor network.

The node numbered 00 is the coordinator node as depicted in figure 1. The main objective of this node is to collect the information from all the other nodes of the network. This is the top most node in the tree topology of the network hierarchy [7]. The super nodes (01-06) are the children of the coordinator node. The mission critical sensor are advised to be used at this level as the transmission lag is minimum. The sensor nodes are the children of the super node or the other sensor nodes. The sensors that are less critical are used here for example, temperature sensors, humidity sensors etc.

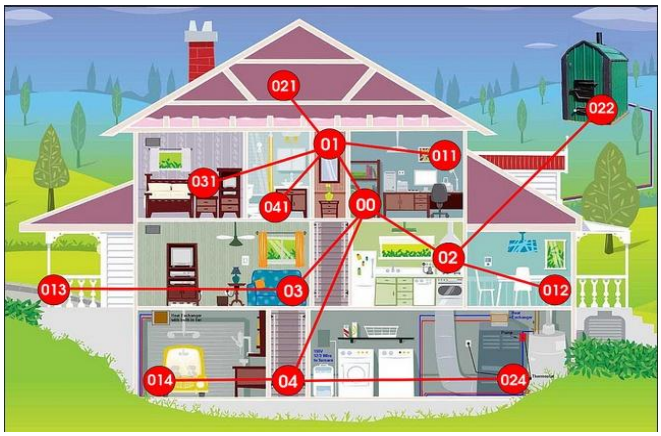


Figure 1: Wireless sensor network topology

## III. IMPLEMENTATION

Building a wireless sensor network system requires development and integration of many hardware and software components. Figure 1 shows the overall network structure of an environmental monitoring wireless sensor network system that we have developed.

Each node consists of an Arduino [3], an nRF24L01(+) module and a sensor. The nodes are identified by their number (00, 01,011 etc.) depending on their position in the network. The node 00 is the coordinator node. This is Base node to which all the other nodes in the network send their information to. Each node in the network can be powered up using a battery. However, it is not advised for the coordinator or the

super nodes [6] to be powered by battery. The radio communication between the nodes is shown below in figure 2.

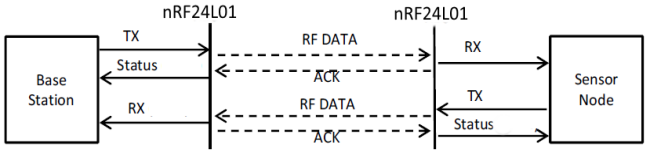


Figure 2: Radio communication taking place between nodes

### A. Hardware Implementation

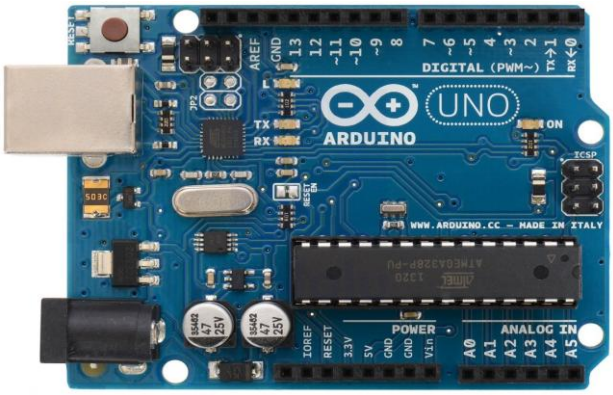


Figure 3: Arduino Uno

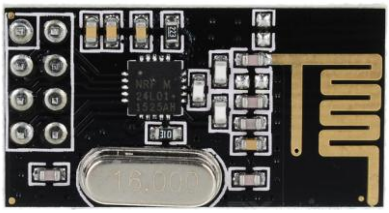

Figure 4: nRF24L01 (+)

The nRF24l01 is a 2.4 GHz radio transceiver with a max data rate of 2 Mbps and the range is 1km in open area and 70-100 meter in closed areas. To get an increased range, the data rate can be set to 256 kbps. The pin out for the nRF24L01 [fig. 4] shown in table 1. The nRF24L01 is an ultra low power consumption device which runs on 3.3V but the SPI pins on the device are 5V compatible. When it starts to transmit, the current peaks to 150ma which is 3 times the current supplied the Arduino [fig. 3]. To overcome this, a 10uf capacitor is used between VCC and Ground of the transceiver module.
The sensors connected to the Arduino are supposed to consume low power if the node is a leaf node. For the Arduino Uno we are using the Arduino Pro mini 3.3V firmware. Choice of battery used in the proposed system involves Li-ion and Li-Po which has the supply voltage of 3.7V whereas the capacity is 4000mAh each, however even 3.0V coin cell battery rated at 540mAh can be used.

| MODULE PIN | DESCRIPTION | UNO | MEGA |
|---|---|---|---|
| 1 | GND | GND | GND |
| 2 | VCC | 3.3V | 3.3V |
| 3 | CE | DIO 8 | DIO 8 |
| 4 | CSN | DIO 7 | DIO 7 |
| 5 | SCK | DIO 13 | DIO 52 |
| 6 | MOSI | DIO 11 | DIO 51 |
| 7 | MISO | DIO 12 | DIO 50 |
| 8 | IRQ | | |

Table 1: nRF24L01-Arduino pin out

### B. Software Implementation

After the connections are made, Arduino can be programmed using the Arduino IDE. For communications between Arduino and nRF24L01, Maniacbug's and tmhio RF24 library is used. The CE and CSN pins of the nRF24L01 can be connected to any free digital I/O pin on the Arduino but must be specified in the Arduino program.

The RF Transceivers can behave as a transmitter and a receiver but the trick in creating a sensor network lies in the synchronization of the switching between the receiver and transceiver mode of the RF modules. To tackle this problem, the nodes need to be calibrated. The transmission delay between the sensor leaf node and the coordinator node is calculated and all nodes use this to set their time outs.

### C. Security Implementation

Wireless sensor networks are highly vulnerable to security attacks when compared to a wired or infrastructure based network. So the nodes must have an effective yet low overhead security module.

The information from the leaf node does not reach directly to coordinator or root node. The message is passed by various sensor nodes. The number of hops taken for the message to reach the root node is known by the sender. For this reason an Onion protocol can be implemented. In this method, the sender will encrypt the data in layers according to the number of hops. For example, if it takes 3 hops to reach the root node, the sender will encrypt the data 3 times successively and then send the data to the root node. When the data is received by a node, it will remove one layer of encryption as shown in figure 5.

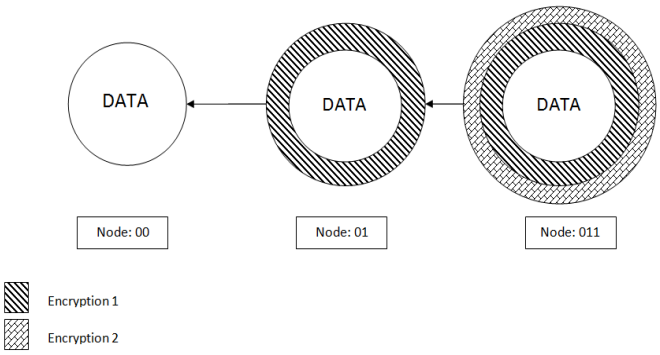


Figure 5: Onion Encryption

## IV. APPLICATION

The wireless sensor network attained with the implementation of RF transceivers and Arduino has many applications:

i. *Home automation*: Home automation is the use and control of home appliances remotely or automatically. The overall wired setup of home automation system can be costly and complex. By implementing wireless sensor network we can overcome the cost problem while attaining a flexible and scalable system.

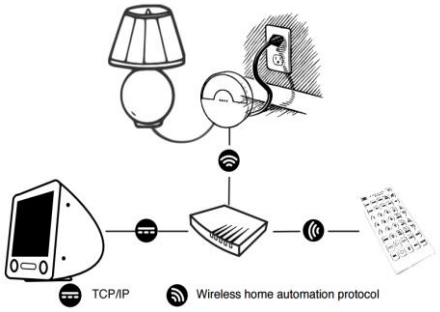


Figure 6: Home automation

ii. *Wireless body sensor network*: In a hospital healthcare monitoring system it is necessary to constantly monitor a patient's physiological parameters. The monitoring system has a coordinator node attached on a patient's body that collects all information from wireless sensors and sends them to the base station to be evaluated. These attached sensors on the patient's body forms a wireless sensor network.

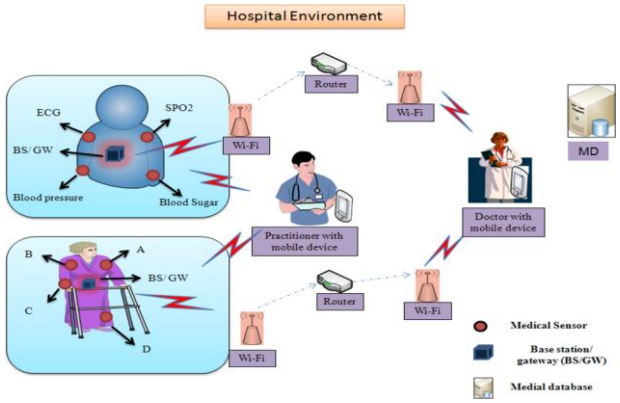


Figure 7: Hospital Body Monitoring system

iii. *Factory Monitoring System*: For factory automation, devices and machines consume a lot of space and make it a crowded place. As the pipelining space is limited, the labors working in the environment become more accident prone [4]. The combination of embedded systems on wireless technology has an enhanced quality of industrial safety.

iv. *Internet of Things (IoT)*: Today smart grid, smart home, smart water network as well as intelligent transportation are infrastructure systems that connect our world. The common vision of search system is associated with one single concept i.e. IoT, where through the use of sensors the entire physical infrastructure is closely coupled with information in communication technology [1]. The wireless sensor networks are the key technology IoT.

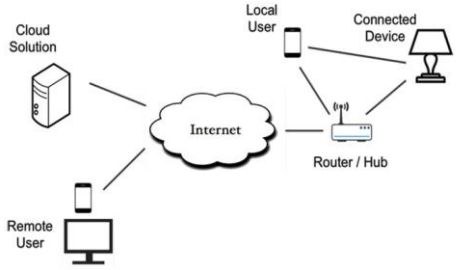


Figure 8: An overview of the Internet of Things (IoT)

## V. CONCLUSION

In this paper, a design concept of wireless sensor network is obtained using low cost transceivers and open source microcontroller, Arduino. The system is well suited for environmental monitoring. For our requirements, the sensor nodes are made as small as possible. The proposed system is secure; each node has its own data buffer identified by a 64 bit address along with Onion protocol which enhances the data encryption among nodes. This in turn makes the sniffing of the packet very difficult. On the other hand, an ultra low power consumption setup with proper Arduino optimization, 3000mAh Li-Po or Li-ion batteries can support a node for more than fifteen months. This makes nRF4L01(+) module a cheaper alternative to Xbee modules.

## ACKNOWLEDGEMENT

This paper is based on B.E. graduation project under review at SJB Institute of Technology, VTU, under the guidance and supervision of Prof. Ramya B.K., Faculty of Information Science and Engineering, 2016.

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