Chapter 6

Tracking of Sandalwood trees in forest area: RFID and an IoT Approach

6.1. Introduction:

Sandalwood is a precious commodity and red sandalwood is rarer. In India, illegal cutting and smuggling of sandalwood is controlled by forest department. But illegal cutting and smuggling of sandalwood continues unabated. The Government of India estimates the sandalwood market to be Rs 10,000 Crores annually (approximately US$2 billion) and losing some Crores of rupees in smuggling as reported by police department. Government is designing various methods to control this menace of sandalwood smuggling. In recent days, dogs are used to control and identify theft. But it is not flexible and it needs more skilled manpower and trained pet animals.

For monitoring large areas, the method of using dog is not expected to give satisfactory result. So, there is a need for an automated system for longer lasting solution. Tracking applications, GPS (Brown and Brown, 2005; Clark et al., 2006) are used nowadays but they are facing severe accuracy issues in indoor environment due to satellite visibility problems (Szeto and Sharma, 2007). They are also not cost effective. There is a need for more add-on components like memory device, control device, etc., to work on this module. An application to use RFID and IOT for monitoring and tracking of sandalwood tree is proposed in this work.

Some applications were developed using passive radio frequency identification (RFID) tags (Hakli et al., 2010; Hoyt et al., 2003) for tracking and identification of trees and wood. They are more economical but coverage is limited to 10 cm to 10 metres (Weinstein, 2005). In this method, the tag is cheaper but reader is expensive and it is not possible to integrate sensors.

Moreover, with this system, it is not possible to identify theft at the time of cutting (Kim and Yoon, 2009; Hakli et al., 2010; Hoyt et al., 2003).

So, it is proposed to use active RF tagging method and wireless networks to solve these issues. Customised RF tag with sensors is used in this study. It is expected to offer better results in aspects like long read range (Weinstein, 2005), more sensor integration and less cost than GPS-based tracking. It is possible to get read range up to 500 metres and more than two sensors can be added for triggering applications. The reader cost and number of reader required is very less compared to passive tag method (Weinstein, 2005). A special active RF tag is developed to monitor the trees. It is developed with sensors to alert cutting of the trees. There are two subsystems for data collection. They are link station and data collection/alert server. The tag is designed to transmit data regularly say, once in every hour. If the tree is cut by unauthorised persons, the sensor in the tag will trigger it to transmit tag identity and send alert signal to the central server through link station. Then the server will send alert information to the concerned authorities. To monitor the regular status of the forest range from the remote office, dynamic web page and database is used. In case of emergency, the alert information is transmitted through GSM/GPRS modem as SMS to the forest authorities for fast response and remedial action. In short the main objectives of this work are low cost, integration of sensors, long read range, design of proper base station, link station, data collection centre and alert system. Here we are using cellular structure and frequency planning to give better coverage. The same procedure of cellular mobile communication structure as detailed in chapter 2 is followed here.

6.2. DESIGN AND IMPLEMENTATION

The design is involved three major stages like RF Tag design, RF Link Station design, Data Collection/ Alert Server.

6.2.1. RF Tag Design:

RFID tag design is very important one in this system. It is based on active RFID technology, so external power source is needed to activate. Ultra low power microcontroller, transceiver and sensors are used to give better performance. It is transmitting data in two modes; one is normal mode and the other is alert mode. In the normal mode tag transmits data in every 1 hour and then it will go to sleep mode for energy saving. However, transmit time can be set manually for individual requirement. But battery life depends on the transmitting cycles. So, for longer battery life number of transmissions should be less. Alert mode is used to transmit data about illegal cutting of trees. The sensors inside the RF tag will trigger the transmitter to send alert information and ID to the link station and central server. Then SMS will be sent to the registered cell numbers for rescue. RF tag construction is represented as block diagram in figure 6.1.

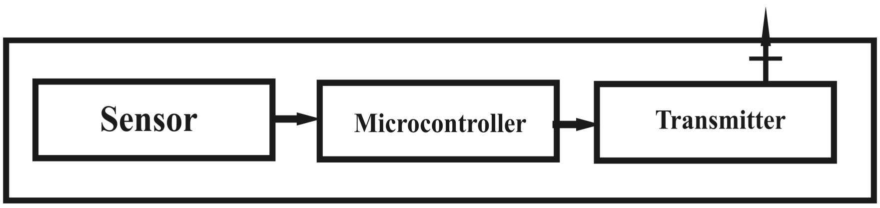

Figure 6.1: RF Tag Block Diagram

6.2.2. Sensor:

Here acceleration sensors and vibration sensors are used to identify unauthorized cutting and movements of trees in the forest. The acceleration sensor is a polysilicon surface-micro machined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using differential capacitors that consist of independent fixed plates and plates attached to the moving mass. Acceleration deflects the beam and unbalances the differential capacitor, resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation is used to determine the magnitude and polarity of the acceleration**.** Activity and inactivity sensing detects the presence or absence of motion and whether the acceleration on any axis exceeds a user-set level. The pin diagram of acceleration sensor is shown in figure 6.2.

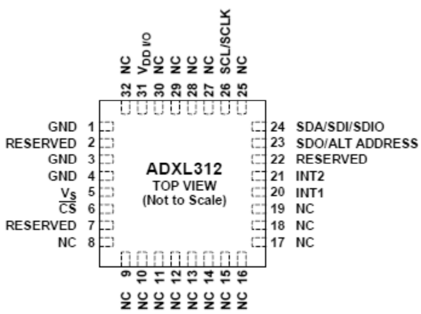

Figure 6.2: Pin Configuration (Top View) of Acceleration Sensor

6.2.3. RF Tag Circuit Connection and Operation:

The circuit diagram of RF tag is given by figure 6.3. Here Tarang wireless module is used to develop an RF tag. It is based on Freescale MC1321X SIP device, operates within ISM 2.4 GHz frequency and suitable for adding wireless capability to any product with serial interface. This module requires minimal power and provides reliable delivery of data between devices. The I/O interfaces provided in this module directly fit into many industrial applications. It requires 3.3 V DC, fed to pin 1. Acceleration sensors x, y and z output are connected to AD0, AD1 and AD2. Position changes and even vibration can be identified by this sensor. If it is needed we can use separate vibration sensor as shown in figure. In normal mode operation the tag will transmit its ID information in every one hour and whenever acceleration sensor inputs x, y and z data exceeds the threshold value, RF tag will be triggered to transmit the emergency alert information.

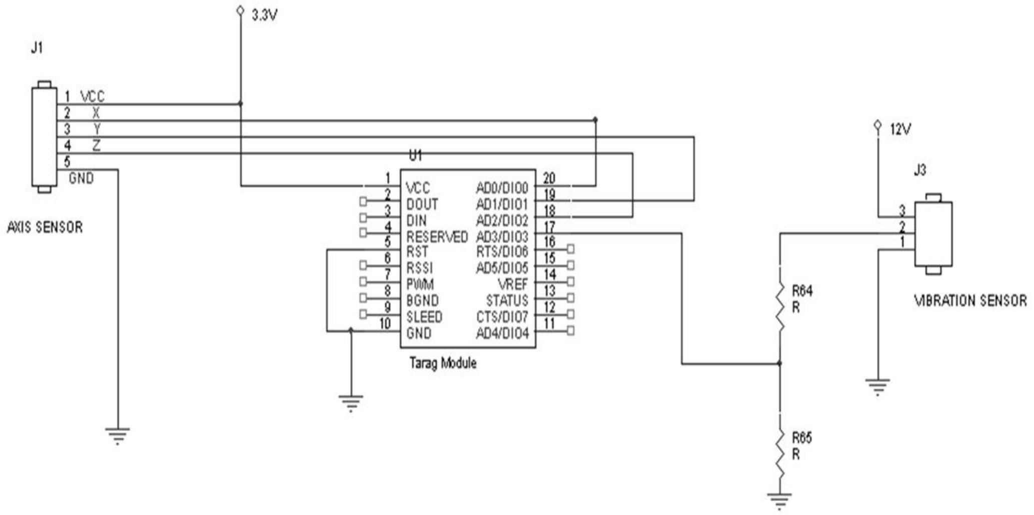

Figure 6.3: Circuit Diagram of RF Tag

6.2.4. RF Link Station:

Cellular architecture is used for implementing RF link station antenna. It gives greater coverage for larger areas. The read error probability and antenna cabling issue are solved in this method. The physical area is divided by hexagonal cells and reader antenna is placed in this cell by shortest route. For the given physical area, the number of cells, number of antennas and number of readers are calculated by following procedures that is regularly used in mobile communication.

$\mathbf{Cn} = \mathbf{Fa} / 2.59\ \mathbf{D}^2$

D is radius of hexagon;

Cn is Number of cells and **Fa** is total farm area;

Area of the hexagon = $2.59\ D^2$

Proposed reader read range = 100 Meters;

So, **D** = 100 Meters;

If **Fa** = 160000 Square meters,

Cn = 4 X 100 X 4 X 100/ 2.59 X 100X100 = 6.1

No of Hexagon Cells = 6 and No of link stations required are 6.

So, approximately 6 link stations are required to cover 160000 square meters area. Proper division of land area and antenna placement will lead to good results. Special directional antennas are to be chosen for better results in tough terrains. The model for cellular structure was simulated using numerical computing software Matlab. The model is given by figure 6.4. But, in real time the experiment is conducted with 2 link stations.

Reader antennas are placed in cellular base stations and the output is mapped by selection switch. For normal operation mode by selecting particular switch we can get information about the local trees through their tag data. For emergency cases like cutting of tree can be identified by blinking light of that particular cell and by displaying proportionate tag. Transmitted RFID tag information and received reader signals. The link performance is simulated for the given distance range and yielding better response.

In the Real-time link station module the following elements are used for connecting ID and alert signals to the central tracking server. They are RF reader, Microcontroller and ZigBee. Reader antenna is placed in hexagon center to collect the data. Tag transmits data to the reader and port number where it is collected. Based on the received tag number, it is possible to identify proper cell and location of the tree. This data is carried to microcontroller link unit and then it is given to the ZigBee module to connect with the central server. The cellular structure is represented in figure 6.5 and link station block diagram is given figure 6.6.

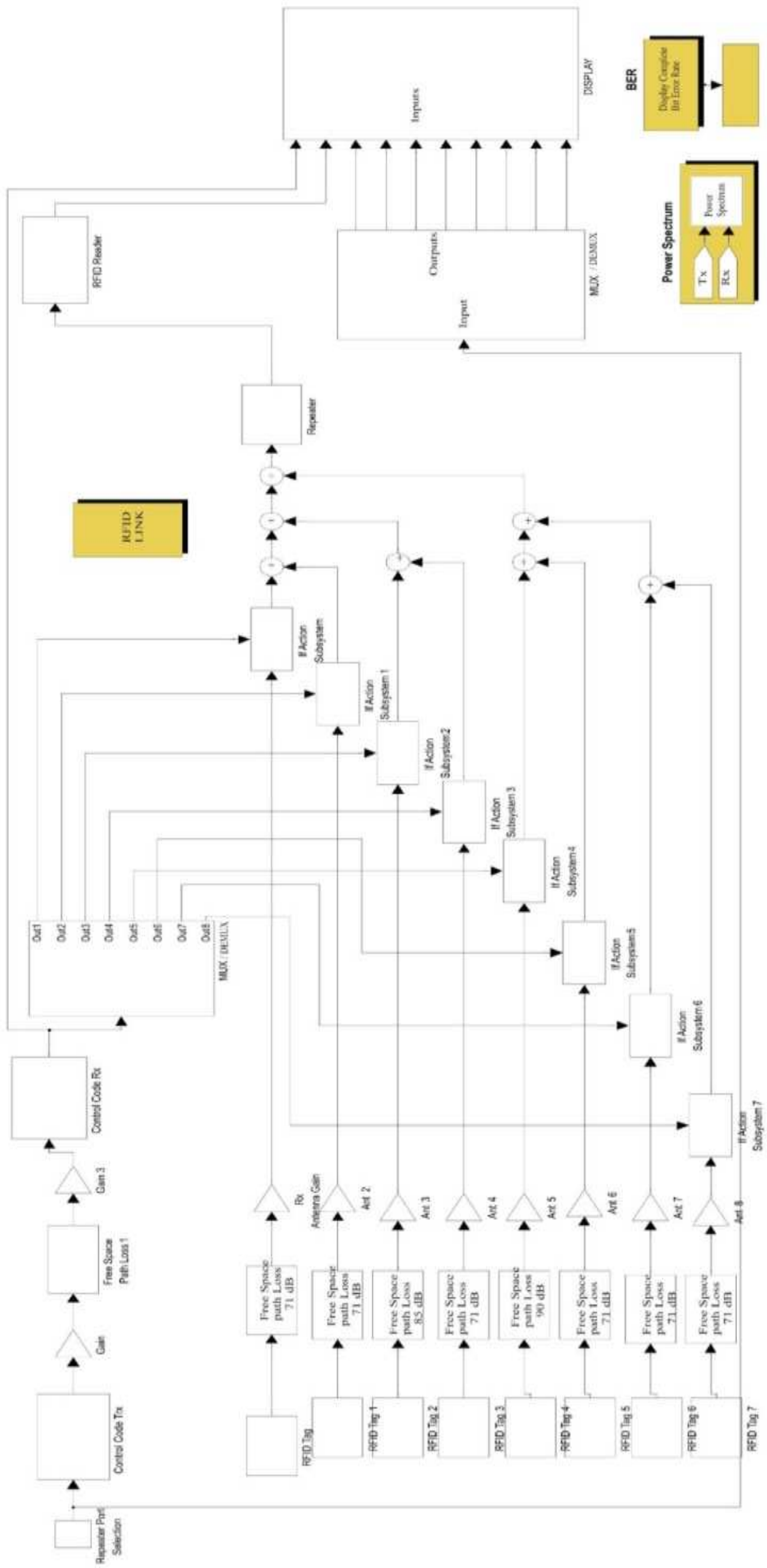

Figure 6.3: Matlab Model of Cell Based Base Station Set Up

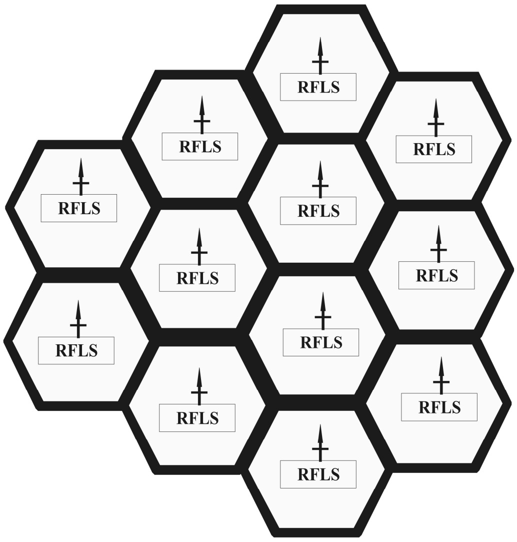

Figure 6.5: Cellular Structure of RF link Station

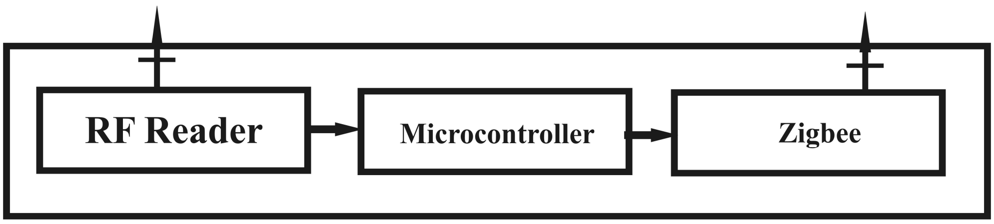

Figure 6.6: RF Link Station Block Diagram

6.2.5. RF Link Unit Circuit Connection and Operation:

The circuit diagram is given in figure 6.7. Here Atmel Microcontroller 89c52 is used as central processing unit in this unit. The major components in sections are Tarang wireless module based RF reader and ZigBee module link data transmitter. Here MAX 232 is used as adapter for RS 232 logic and TTL.

It is used to connect ZigBee and RF reader module with the controller. Both microcontroller and MAX 232 are operated in 5V. RF reader output is connected to R1IN (13^{th} pin) of MAX232 and ZigBee is connected to T1OUT. R1OUT of MAX232 is connected to RxD of microcontroller and it gives reader data to the microcontroller. TxD of Microcontroller is connected to T1IN of MAX 232 transmits data to ZigBee.

Whenever RF reader receives data from RF tag it will be send to the microcontroller through MAX 232 convertor. Microcontroller is used as Linker central processing unit and it decides rout to the server and send the data to ZigBee unit. If the server is very next to the cell then it will directly connected through ZigBee. Otherwise it routed through ZigBee linker units to reach destination server unit.

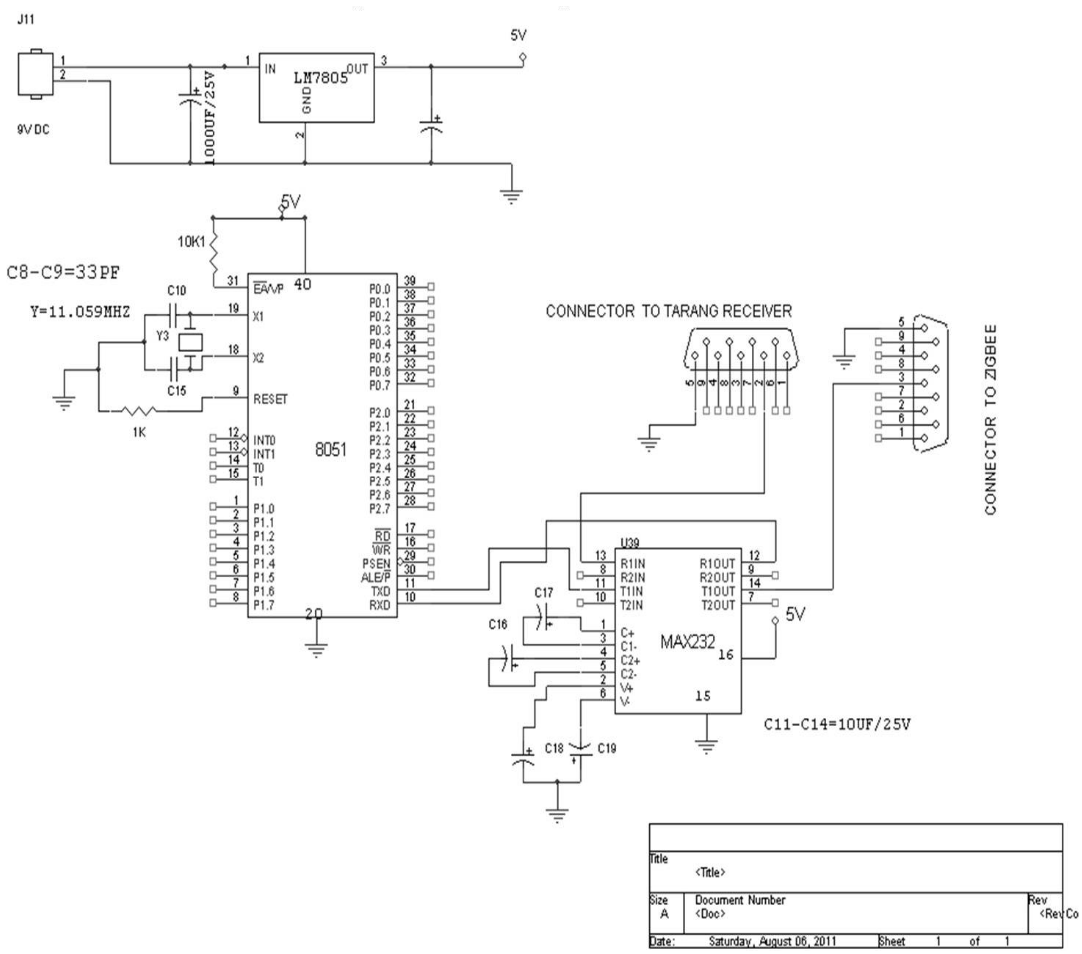

Figure 6.7: Circuit Diagram of Link Station

6.2.6. Data Collection/Alert Server:

The trees data base is stored in Centralized data collection/Alert Server. Specific software is developed to store the details. Tree's information is updated automatically by reader and ZigBee module. The GSM/GPRS module is connected with the system to transfer tracking and alert information to supervisors. Whenever the tree is cut alert will be sent by SMS. The block diagram of this section is represented in figure 6.8 and real time hardware setup is given by figure 6.9.

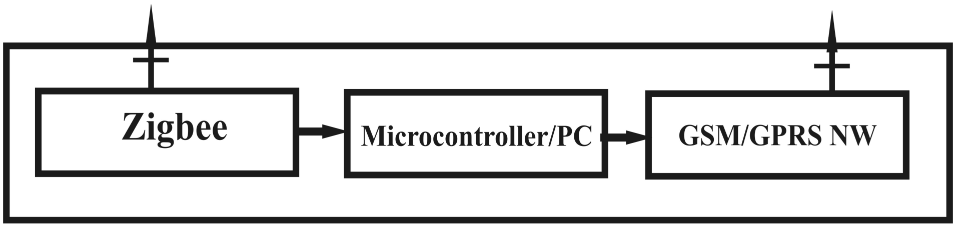

Figure 6.8: Block Diagram of Data Collection Centre

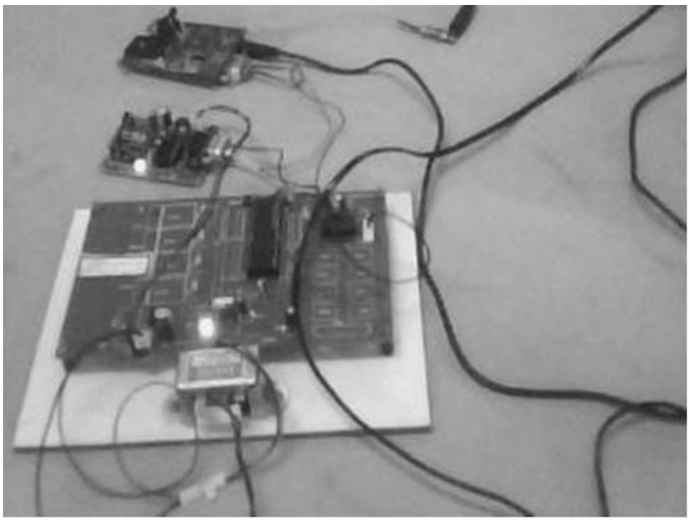

Figure 6.9: Data Collection/Alert Server Hardware Setup

6.2.7. Circuit Connection and Operation:

It is very important unit in this work. RFID reader and linker unit transmit the Tag information to this unit through ZigBee module for alert. We have developed microcontroller based system for our experiment as given by figure 6.10. The important elements in this section are Microcontroller ATMEL

89c52, MAX232, ZigBee and GSM modem. ZigBee is connected to receive port and GSM is connected to transmit port for alert signal transmission. ZigBee is connected to R1IN and GSM is connected to T1OUT of MAX 232. Then T1IN and R1OUT of MAX 232 are connected to microcontroller Pins RxD (10) and TxD (11).

Whenever ZigBee receives data, it will be send to microcontroller through MAX232 ports. Then microcontroller will analyze the data whether it is normal mode or emergency data. If it is emergency mode data, microcontroller will send SMS to stored numbers through GSM modem. Here SIM 300 GSM modem is used for sending message.

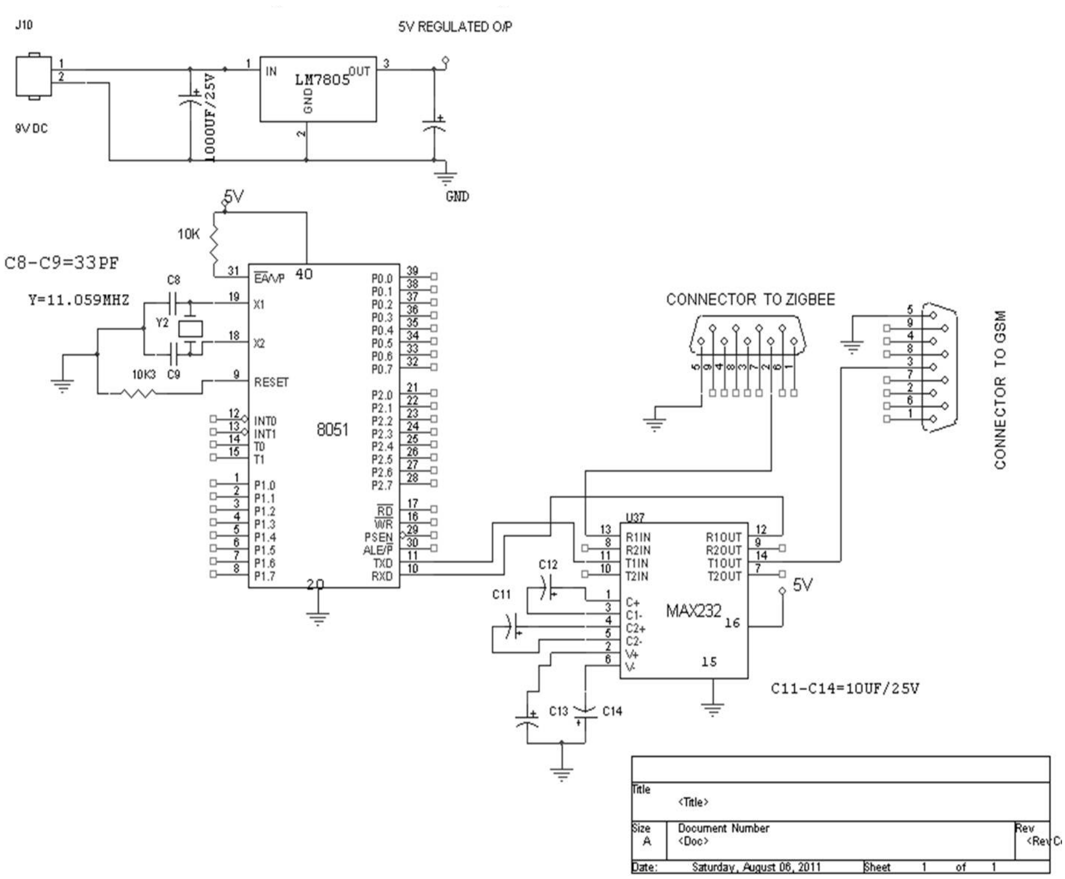

Figure 6.10: Circuit Diagram of Data Collection Unit

6.3. IMPLEMENTATION

Hexagonal cell structure is used for placing antenna tower. It is very efficient method for calculating number of antennas and readers for area mapping. It gives perfect solution for coverage issue. That is, the visibility will be more compare with mapping methods. In the above mentioned calculation totally 6 readers are needed to cover 160000 Square meters area. It is the most economical. Closed loop algorithm is used to track the objects. Here active RF tags are used because of long range requirement and sensor management. For long range, life and low cost application UHF tags are more suitable. The tag is generally internally attached to the tree. As Mobile communication systems, cellular structure is used to fix reading point antennas for successive read rate. Every cell has one reader as a base station. It collects the section trees' information and it is transmitted to the central data collection/alert server using microcontroller and ZigBee switching unit. The updates are transmitted to central server. The tracking central data collection server has the entire database. Its major job is to maintain trees count and to send alert information in case of theft. In general the tag transmits regular presence data to the link station in every one hour and then it will move to the sleep mode. Whenever the tree is cut by unauthorized person, the sensors will trigger the system to transmit the tag ID and alert information to the central data collection server through RF link station. The data collection center will send SMS alert to the registered numbers.

6.4. RESULTS

The real time model was developed with 6 tags and two link stations with microcontroller based server and result is observed for both modes. Various tests were conducted for read range radiation pattern and various tree movement simulations. SMS alert was obtained for all second mode tests. Acceleration changes are created and output voltage variations from the sensor are observed with SMS reception being checked. Some of the readings are tabulated in table 6.1. The cellular structure setup was simulated using Matlab software for 8 cells and performance analyzed.

Table 6.1 Acceleration Sensor position, output voltage & SMS status observation

S. No	Position (Angle in Degrees)	Voltage	SMS Status
1	Y axis Ref Point(0)	2.2 V	No SMS
2	20	2.8 V	No SMS
3	40	3.2 V	SMS Received
4	90	3.4 V	SMS Received
5	-90	3.6 V	SMS Received
	X axis		
6	20	2.9 V	No SMS
7	40	3.3 V	SMS Received
8	90	3. 6V	SMS Received
9	180	3.9 V	SMS Received

6.5. Comparison of Various Methods:

GPS, Animal (Dog), Manual, and RFID tag

The cost of one GPS based Tag system is approximately INR. 5000 (http://www.futurlec.com/GPS.shtml) and for tracking 20 trees approximate budget is INR 1, 00,000. It is basic GPS tag cost and for intermediate device (receiver, link station and supporting hardware) cost will be approximately 50,000. Cost of active RFID based tag is approximately INR 1000 and tracking 20 trees approximate budget is INR 25000 including all system components. Another drawback in GPS based track tag that it is not possible to monitor illegal cutting and smuggling of trees in the presently available GPS track tag system. Size, flexibility and accuracy are the next important factors in GPS track tag. The size of the device is not small and will not give accurate position in deep forest areas due to visibility issue of satellites. But RFID based system will give accurate result, they are compact and portable. In the present scenario in India trained Dogs and skilled manpower are used to track illegal deforestation. But it will not give permanent solution. Error probability is high and sometimes threatening is major issue in this method.

6.6. CONCLUSION

In this work a system to give complete solution for tracking sandalwood tree theft using the latest RFID based IoT technology is designed and implemented. It is proposed as a low cost optimized solution using RF tag, ZigBee and GSM technology. It involves less manpower in maintaining special forest zones like sandalwood forest. The real time model was developed with 6 tags and two link stations with microcontroller based server and result is observed for both modes. Various tests were conducted for read range radiation pattern and various tree movement simulations. It shows better performance for both modes and SMS alert was obtained for all second mode tests. Acceleration changes are created and output voltage variations from the sensor are observed with SMS reception being checked.