CHAPTER 6. ANALYSIS OF HARDWARE NODE

This chapter focuses on the analysis of hardware node. The main aim is to determine the communication link capability and the battery life time of the nodes for both trapped node (visitor node) and pursuit node (RescOp node). As the wireless nodes are to be deployed in the disaster prone region, it is very important to resolve issues of reliability in terms of communication link. For model testing, two normality tests have been used known as Jarque- Bera and Shapiro- Wilk normality test. These tests are performed to compute the confidence level of nodes in OSA (Open seismic area) and CIB (Complex Indoor building) locations. The nodes are equipped with Xbee module which is communicating through ZigBee protocol. When the communication link in between trapped node and pursuit node gets established, the parameters like RSSI and throughput values are calculated for both OSA and CIB locations. And the same values are used to validate the nodes communication link reliability by Q-Q plots. The backbone of any wireless sensor network depends on the capability of the nodes to send the message signal in a more optimized way and also depends upon the power consumption by the node. To increase the life of the nodes, the power consumption has to be less. The performance analysis of the wireless nodes is very much necessary to overall improve the performance by rescue operation teams post disasters.

The chapter is structured as

(i) Design aspects of Mobile sensor node (RescOp)

(ii) Reliability tests using Jarque-Bera and Shapiro Wilk normality test.

(iii) Obtaining Normality plots of CIB and OSA locations

(iv) Analysis with respect to sustainable development of the region.

6. 1 MOBILE SENSOR NODE- RescOp

The mobile sensor node RescOp provides the reliable communication and is the important device in the designing of wireless network for disaster prone areas. Xbee is used as a wireless device along with micro SD card module, 16×2 alphanumeric LCD, and 2600mAh power supply, these all devices are integrated in a RescOp node.

Xbee –S2 series is a latest transceiver device and it is best known for its minimal cost, high performance and minimal power consumption. The Xbee-S2 series module transmission range is 2.4 kms. The transceiver module transmitting power is 2 mW at 3 dBm, with receiver peak current of 40 mA at 3.3 V and its receiver sensitivity is -96 dBm. On the contrary Xbee-S2 Pro module is the advance version of Xbee- S2 with transmitting power of 50 mW at 17 dBm and 10 mW at 10dBm. The receiver sensitivity for the module is -102 dBm [108, 112]. The receiving peak current is 45 mA. Xbee module is able to form a point to point as well as mesh network. The network comprises of coordinator node, router node and end device nodes and is programmed using API command set mode using X-CTU (testing and configuration software) but when used with microprocessor/ microcontroller, it will switch to AT command mode. Xbee-S2 module is very secure to design the wireless network as it is having advanced secure features. Xbee- S2 is able to form 6500 unique addresses using DSSS (Direct sequence spread spectrum).

The implemented nodes are classified in two types: trapped node and locator node (Mobile Sensor Node- RescOp). The detailed hardware/Control Architecture of Mobile Sensor Node (RescOp) is shown in Figure 6-1 and actual hardware node in Figure 6-2. The main central processing unit is AT Mega 328P. These boards are connected with Xbee-S2 using ZigBee protocol, and are driven with 2600 mAh battery source (extendable). The battery source is connected via A to B type cable. The RescOp nodes can also be powered through AA batteries type. Using IC 7805 and LM 1117 voltage regulators, the output voltage is regulated to +5 V and +3.3 V respectively. A separate SPI based interface is available on-board for boot loading purpose (Note: Some time processors are not boot loaded properly). On board FTDI port is also available to load the firmware on the node. RescOp node has digital switches and LEDs to check the pullup and pull down of the pins of ATMEGA 328P using f-to-f connector. 16×2 LCD (Optional 20×4) is available on board and the backlight of LCD can be adjusted via preset. RescOp nodes are having on board presets to check the ADC operation. Xbee S2 module is fitted to the on board shield and all pins of Xbee-S2 are remained open so as to connect the pins externally to microcontroller. Micro SD card module is also clipped to fetch the RSSI values of the nearby nodes.

Table 6-1 RescOp Node Specification

S.No	**Components**	**Component Description**	**Power Consumption**
1	Display	16×2 alphanumeric Display	200 mA
2	Power Supply	Constant voltage supply	10000 mAh
3	8 SPST	Soft touch	-
4	RF Based Xbee	50mW (Tx) -102 dBm (Receiver Sensitivity)	295 mA (Tx) 50 mA (Rx)
5	Antenna	Omnidirectional	2 dBi gain
6	SD Module	8GB memory extend to 32 GB	-

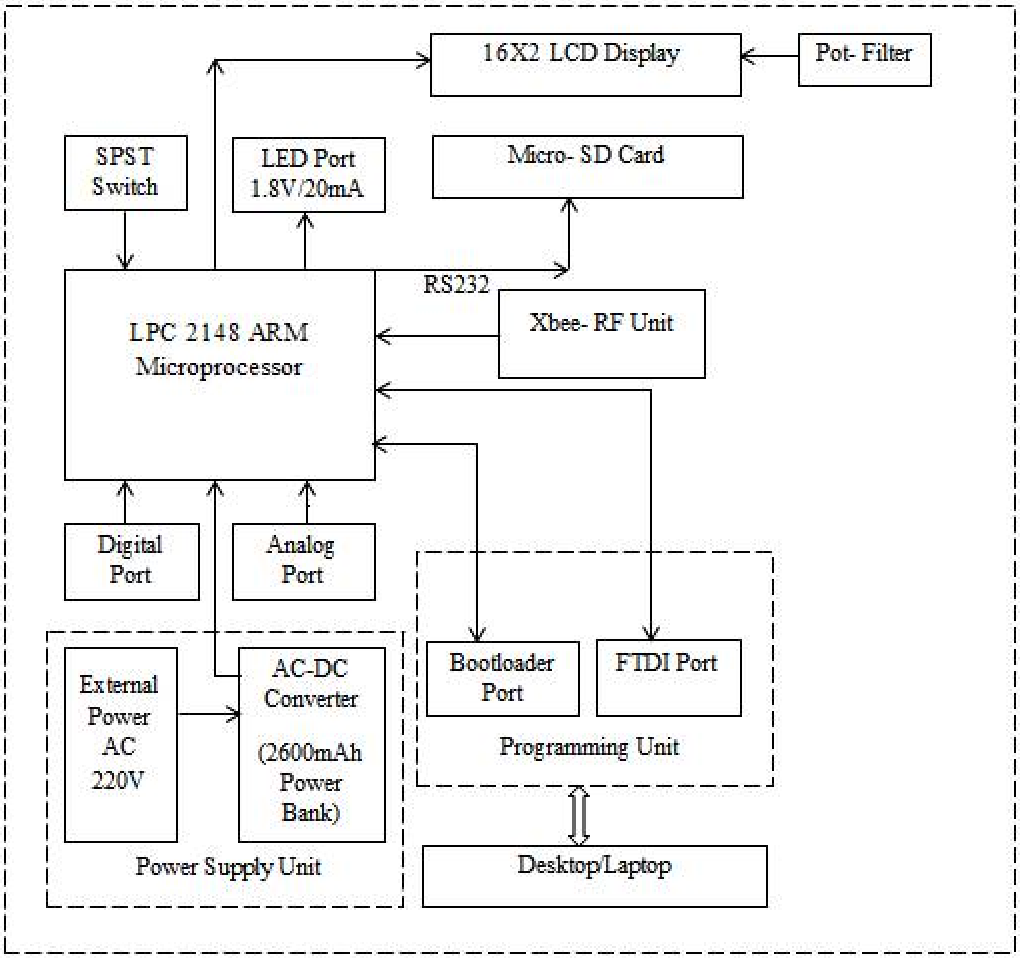

Figure 6-1 Detailed hardware/Control Architecture of Mobile Sensor Node (RescOp)

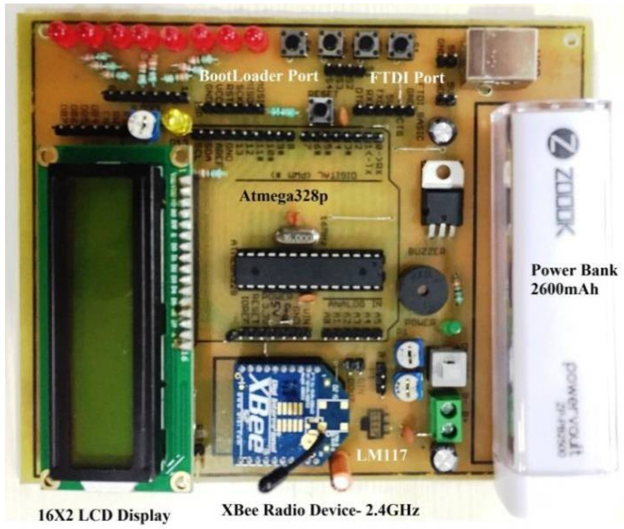

Figure 6-2 Mobile Sensor Node

EXPERIMENTAL SETUP

Several extensive experiments have been performed in Indoor environments (Complex Indoor Buildings-CIB) and outdoor environments (Open Seismic Area-OSA). All experiments considered the influence of nearby surroundings on the nodes, its battery life and communication link reliability.

The CIB is complex indoor building which is already been discussed in previous chapter. The RescOp established the point to point and point to multipoint communication network with other nodes. RescOp node is transmitting and receiving 20 byte of data and sharing the each other RSSI values (see Table 6-2 & Figure 6-3). The trials on these test areas include assessment of RSSI (Received Signal Strength Indicator) and throughput measure (transfer ratio) between two radio modules with respect to time. It will evaluate both transfer ratios as well as average transfer ratio.

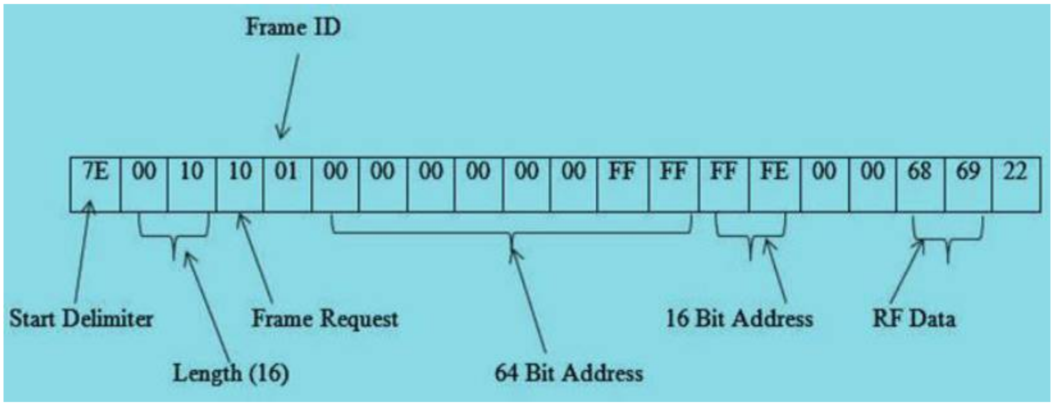

Figure 6-3 Frame Type

Table 6-2 Description of Nodes in Indoor and outdoor locations

Summary of experiments

Experiments Area	Descriptions	Type of Nodes	Battery Type	Transmission bit
CIB- complex indoor Buildings	20 chambers, 8 Full length Chambers and 12 Half chambers	RescOp	2600mAh Li-ion Based Power Bank	7E001010010000 00000000FFFFFF FE0000686922
OSA- Outdoor Seismic Area	Seismic area with dense forest.	RescOp	2600mAh Li-ion Based Power Bank	

6. 2 ANALYSIS OF NODES

Communication link reliability of RescOp node is subjective to two factors. First is the consumption of power and second is the communication link reliability when it is exposed to transmit the message signal in indoor as well as outdoor location and both are disaster prone area.

6. 2. 1 Power consumption of RescOp

Power consumption of the wireless node is one of the essential concerns while designing wireless network. RescOp nodes are designed in keeping the facts in mind that they are used in disaster prone areas. Power consumption can also be managed by activating sleep mechanism as well as by managing multi hopping technique.

The average power consumption[74] of the RescOp node is expressed as:

$$P_{Xbee} = P_{Sleep\ Mode} + \frac{P_{Rx}\,(T_{S-F}+T_{FS}+T_{CP})}{T_{ST}+T_{FS}} + \frac{P_{Tx}\,T_{CP} + P_{Rx}(T_D+2T_T)}{L} \qquad 6.1$$

$P_{Sleep\ Mode}$ = Power consumption of node in a sleep mode

P_{Rx}= average power consumption of receiving node

P_{Tx}= average power consumption of transmitting node

T_{S-F}= Time of state of transceiver module from sleep to free

T_{FS}= Time of Free State

T_{CP}= Controlling packet

T_D= Transmission time of packet

T_T=shifting time in between sending and receiving

L= time of every node receiving a packet

T_{ST} =sleeping time in sleep state

T_{FS}= time in free state.

From the above expression, it is clear that if the transmissions delay time is less the greater is the power consumption. The condition happens when there is an overlapping of the two frames sending at the same time. Most of the time, there is request for resending the same frame. This leads to the power wastage in the wireless network. This has to rectify by making proper balancing in between the transmission delay and power consumption while maintaining the quality of the wireless channel.

The other type of solution for less power consumption is through the firmware to be written in wireless node. This can be addressed as:

1. Code length should be small.

2. No use of else-if loops as these commands consume more power than dedicated if loops.

3. Debouncing problem to be rectified that will execute the loops in firmware for one time only thus having less power consumption. The firmware written in wireless nodes takes care of above mentioned points.

6. 2. 2 Communication link reliability

Jarque-Bera and Shapiro-Wilk normality tests are analyzed for the assessment of wireless node in wireless sensor network. The tests are assessed for the normality distribution in different locations of CIB and OSA.

Jarque-Bera Tests[113] is

$$JB=\frac{n}{6}\left(S^2+\frac{(K-3)^2}{4}\right) \qquad 6.2$$

S= sample skewness $\widehat{\mu_3} / \widehat{\mu_2}^{\frac{3}{2}}$. It is an estimator of $\beta_1 = \frac{\mu_3}{\mu_2^{\frac{3}{2}}}$

K= sample kurtosis $\widehat{\mu_4} / \widehat{\mu_2}^{2}$. It is an estimator of $\beta_2 = \frac{\mu_4}{\mu_2^{2}}$

Where $\widehat{\mu_j} = \frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^{2}$, j=2, 3, 4……

Shapiro –Wilk normality test [113, 114] is

$$SW = \frac{\left(\sum_{i=1}^{n} a_i X_{(i)}\right)^2}{\sum_{i=1}^{n} (X_i - \bar{X})^2} \quad 6.3$$

$X_{(i)} = X_{(1)}, X_{(2)}, X_{(3)} \ldots\ldots\ldots X_{(n)}$ is the vector for random variable

$\bar{X} = (X_1 + X_2 + X_3 \ldots\ldots\ldots\ldots + X_n)/n$ is the sample mean and a_i is the constant.

The brief and concise result of both tests is shown in Table 6-3 and Table 6-4. The Jarque - Bera normality test assumes the null hypothesis H_o, that the data is normally distributed. The hypothesis H_o is accepted if and only if the test score W is below the critical value W_α at some confidence level of 90%, 95%, 97.5%, 99% or 99.9 % which corresponds to 4.61, 5.99, 7.38, 9.21, or 13.82 respectively. Shapiro- Wilk normality test on the other hand presumes the hypothesis H_o, and the hypothesis is accepted if the test score W is above critical value W_α at some confidence level like 90%, 95%, 98%, or 99.9% which corresponds to 0.9555, 0.947, 0.938, or 0.93 respectively

These two tests have been performed for CIB and OSA locations. The RSSI values are gathered and stored in MicroSD card which is inbuilt in RescOp wireless node and results are observed for RSSI and throughput (refer Table 6-5). Based on the data acquired from the nodes the Q-Q plots have been obtained which are discussed in further chapter.

Table 6-3 Test Statistics of Jarque-Bera Normality Test

	Jarque-Bera normality test				
Hypothesis H_o	Data is from a normally distributed set				
Rule	H_o is accepted if test score W is below critical value W_α at a particular confidence level ($W < W_\alpha$)				
Confidence level	90 %	95 %	97.5 %	99 %	99.9 %
Critical value (W_α)	4.61	5.99	7.38	9.21	13.82

Table 6-4Test Statistics of Shapiro-Wilk Normality Test

	Shapiro-Wilk normality test			
Hypothesis H_o	Data is from a normally distributed set			
Rule	H_o is accepted if test score W is above critical value W_α at a particular confidence level ($W > W_\alpha$)			
Confidence level	90 %	95 %	98 %	99 %
Critical value (W_α)	0.955	0.947	0.938	0.93

Table 6-5Normality tests inferences for CIB and OSA

Cases	Normality test	test score for RSSI data		test score 100 packets	test score 500 packets	Inference
		local	remote	throughput data	throughput data	
CIB-Complex Indoor Building	Jarque-Bera	2.53	0.643	2.124	11.75	H_o is accepted at 99.9 % confidence level.
	Shapiro-Wilk	0.95	0.964	0.934	0.924	H_o is accepted at 99 % confidence level
OSA-Outdoor Seismic Area	Jarque-Bera	0.81	0.528	132.368	2055.88	H_o accepted at 99.9 % confidence level
	Shapiro-Wilk	0.974	0.982	0.684	0.712	H_o accepted at 99 % confidence level

6. 3 Conclusion

The RescOp node design and performance criteria of the nodes are discussed for both CIB and OSA locations. The node performances have been studied under different circumstances. The wireless network involving the RescOp nodes would be easy to deploy in a remote or disaster prone area.

The battery source equipped with RescOp was also studied for both OSA and CIB locations. The power required for a single node to operate in the network comes around 4.8 watt hours. A 5W solar panel will be sufficient to power up the nodes. Or, the same solar panels can be used to recharge the batteries.

The active devices in the node are as follows:	
Display (16 × 2)	3 mA
Microcontroller- Atmega328	16.32 mA @ 16 MHz
ZigBee- CC2500	2 mA
LED (red)	20 mA
Total current consumption	41.32 mA i.e. 4.8 watt hour