CHAPTER 7. RESULT & ANALYSIS

This chapter focuses on the algorithm design for node localization. The localization algorithm has been tested in specially-designed hardware nodes. This chapter includes the results and analysis and is divided as follows:

1. Design of hardware nodes.
2. Analysis of wireless nodes in terms of its battery consumption, normality curve of the nodes in outdoor as well as in indoor location.
3. Design & analysis of localization algorithm.
4. Performance analysis of nodes in terms of searching pattern of pursuit nodes and also the handshaking behavior of node in disaster prone area.
5. Validation of wireless network.

7. 1 Battery life of nodes

RescOp nodes are subjected to send message packets in CIB and OSA as discussed earlier equipped with lithium-ion 2600 mAh power sources. The RescOp node along with other fixed and movable nodes deployed in CIB location, and then the setup is again deployed in dense forest area OSA (Open Seismic Area). Total 2, 95,651 message packets sent to the receiving nodes in a mesh network. The RescOp node lasts for 13.65 long hours with 2600 mAh Lithium ion power source see Figure 7-1(No. of samples vs battery voltage). The message packets are observed and recorded in X - CTU software as

03-14-2016 18:52:33.833,-,API," ,0013A20040E82D9E,ZigBee Router API,23A7,COM1 - 9600/8/N/1/N,0"

03-14-2016 18:52:34.291,45198,SENT,7E00101001000000000000FFFFFFFE0000686922

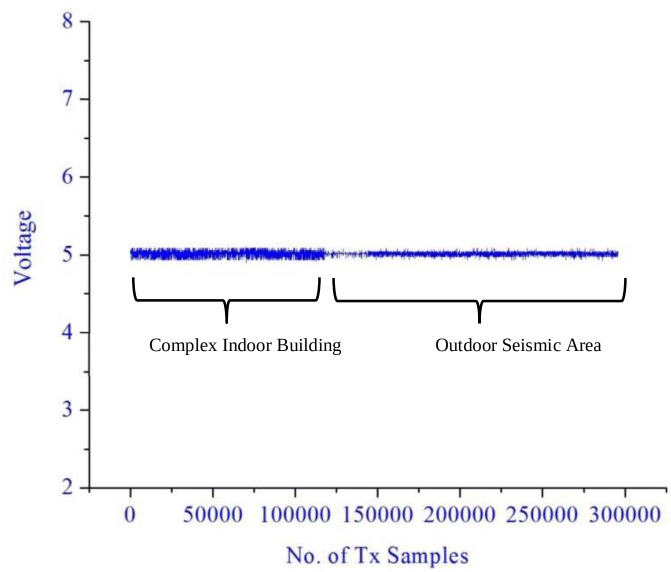

Figure 7-1 Battery Performance

7. 2 Communication Link Capability

The RescOp node is exposed to both CIB (Complex Indoor Building) and OSA (Open Seismic Area) location.as shown in Figure 4-7, Figure 4-8, Figure 4-9, Figure 4-10. The whole setup is already discussed in chapter 4. In the trials, RSSI and throughput values are noticed for the specific time (see Figure 7-2, Figure 7-3, Figure 7-4). It can be observed in Figure 7-2 that the average RSSI value is -65 dBm with minute fluctuation, thereby ensuring an expected high quality performance of the node in post disaster conditions. A packet loss of 3 has been out of 100 packets (97 % availability). Since the packets contain current RSSI information, there subsequent loss is only restricted to RSSI value loss, and that too for a period of few milliseconds. This ensures the reliable network even in complex indoor locations. Throughput values are noted when 100 and 500 message packets are sent to other nodes in unidirectional as well as in bi-directional mode. The unidirectional throughput only send packets when the node gets the transmission status of the message packet received whereas in case of bi-directional throughput the data which is sent, is received back from the remote nodes as an acknowledgement through the cluster ID 0×12. After observing the values in CIB the nodes again deployed in Outdoor Seismic Area (OSA). The behavior is studied for transmitting the 20 bytes of message signal for some specific time.

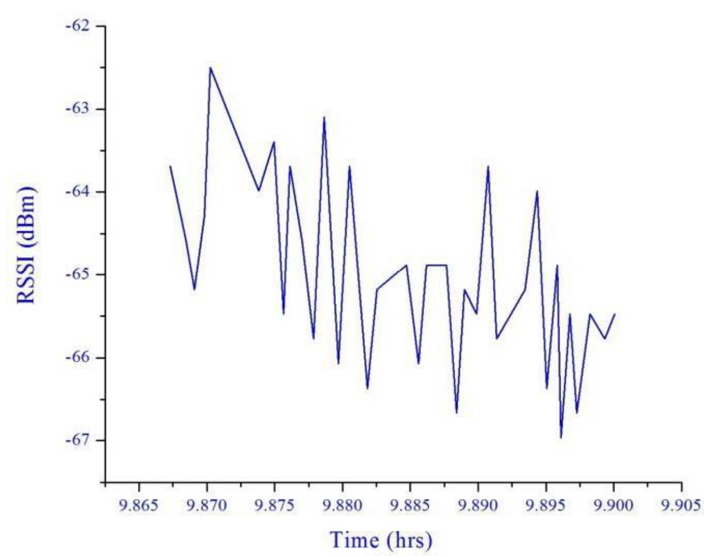

Figure 7-2RSSI (dBm) Complex Indoor Building (CIB)

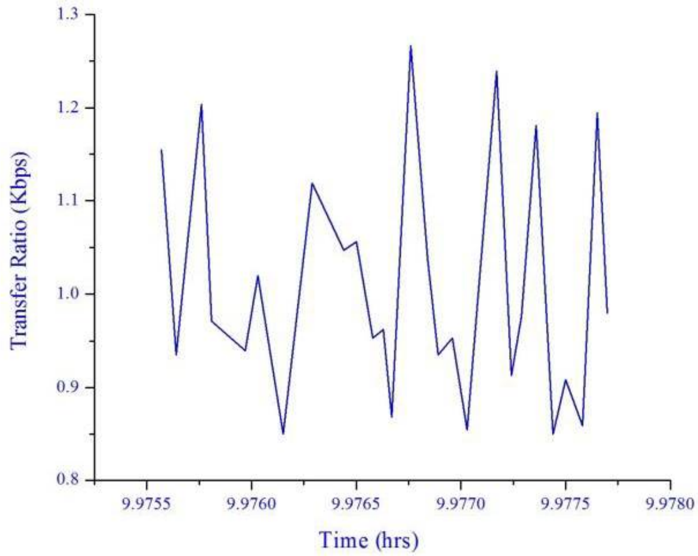

Figure 7-3Throughput RescOp Node with100 Packets

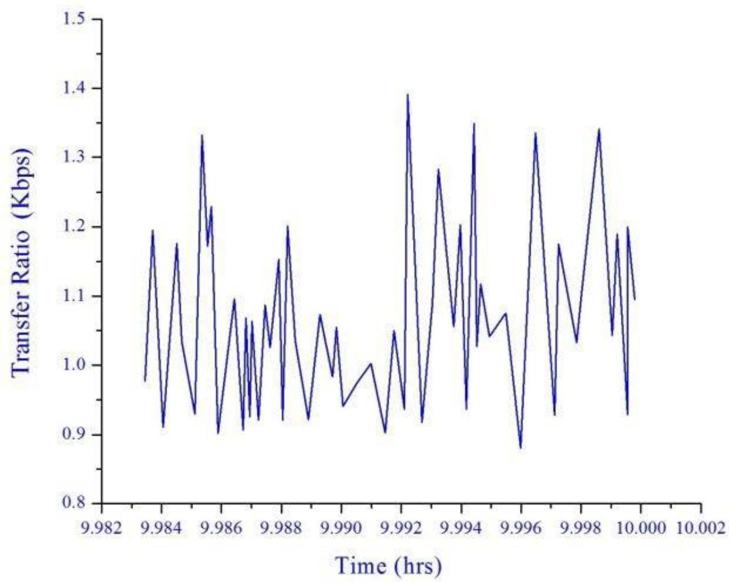

Figure 7-4Throughput RescOp Node with 500 Packets

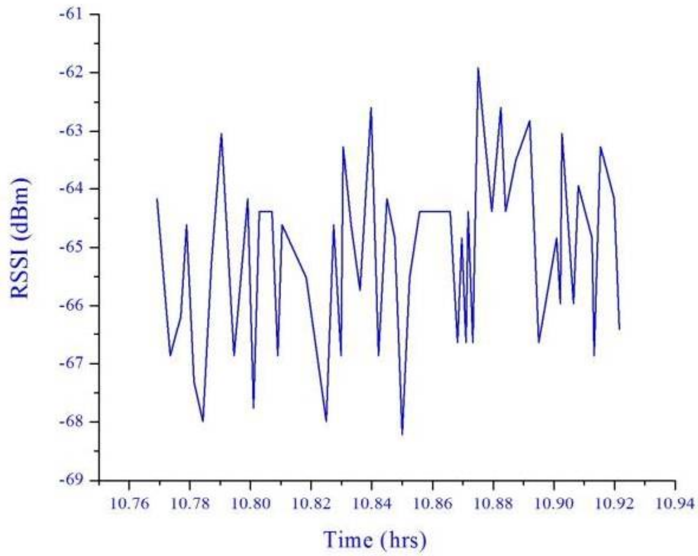

Figure 7-5 RSSI (dBm) in OSA

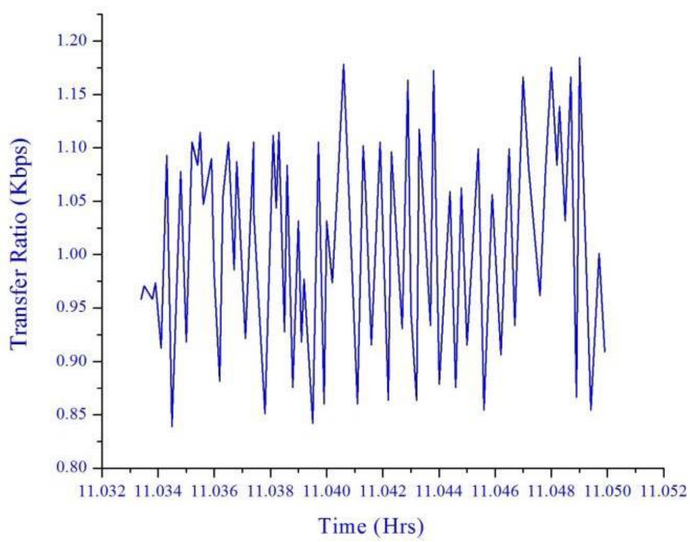

Figure 7-6Throughput unidirectional of RescOp Node

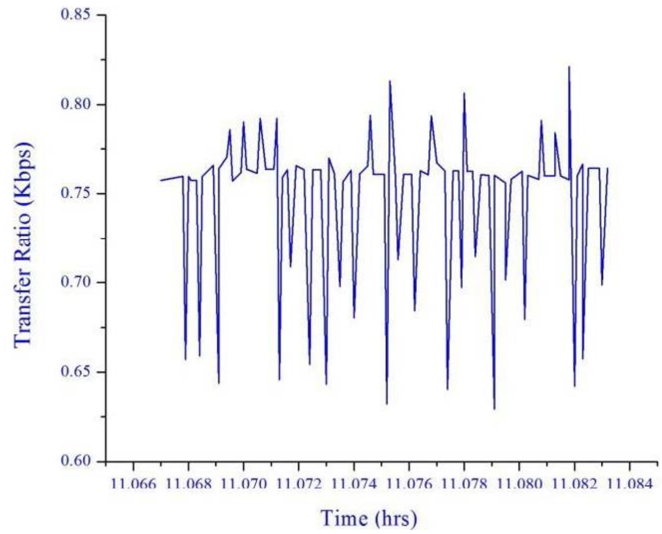

Figure 7-7Throughput bidirectional of RescOp Node

The RescOp nodes have been automated to transmit and receive 20 Bytes of message signal. The packet formation is through X-CTU software. The RSSI and throughput data is gathered in X-CTU as well as in MicroSD card module in different locations. In CIB, 3 packets lost out of 100 is reported as shown in Figure 7-2 whereas the throughput (transfer Ratio) of nodes is 1.12 Kbps (average transfer ratio) for 500 transmission packets and 1.2 Kbps (instant transfer ratio) for 6000 Bytes (see Figure 7-3 and Figure 7-4). In OSA 100 packets are sent in between RescOp node and trapped node. In dense forest area nil packets are lost but 2 packets lost for 500 packets (refer Figure 7-5). Unidirectional throughput (transfer Ratio) is 0.9 Kbps (Instant transfer ratio) for 500 packets and 0.91 Kbps (average transfer ratio) for 6000 bytes (refer Figure 7-6). For Bidirectional throughput instant transfer ratio is 0.77 Kbps for 500 packets and average transfer ratio is 0.76 Kbps for6000 bytes (refer Figure 7-7).

For the values of Table 6-5Normality tests inferences for CIB and OSA locations. Q-Q plot have been obtained (refer Figure 7-8, Figure 7-9, Figure 7-10, Figure 7-11, Figure 7-12, & Figure 7-13) that's show the communication linkage reliability of the RescOp nodes, as signal emanating from the RescOp nodes follow the normally distribution. In CIB location Jarque-Bera normality test, hypothesis H_o accepted at 99.9% confidence level and Shapiro-Wilk normality test, hypothesis H_o accepted at 99% confidence level. In OSA location, the Jarque-Bera normality test, hypothesis H_o accepted at 99.9% confidence level and Shapiro-Wilk normality test, hypothesis H_o accepted at 99% confidence level.

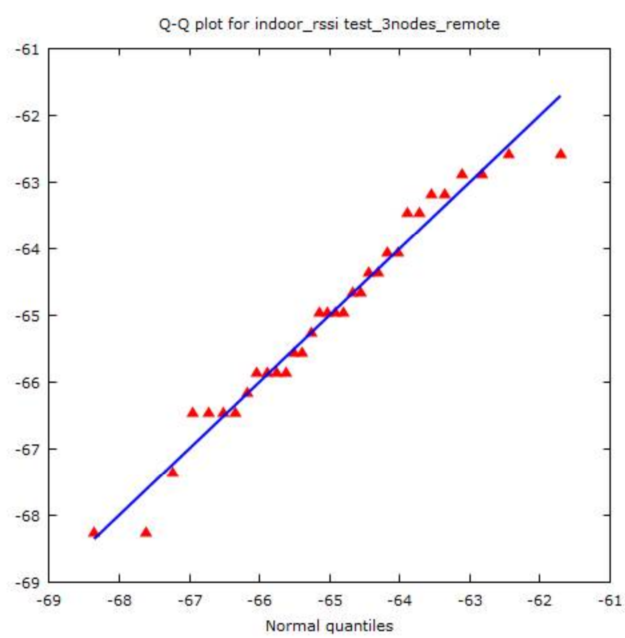

Figure 7-8Q-Q Plot for CIB RSSI

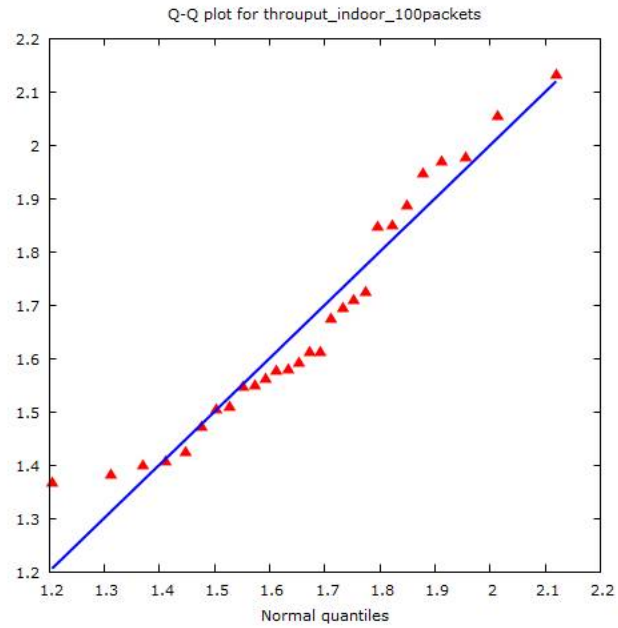

Figure 7-9Q-Q Plot for CIB throughput (100 Packets)

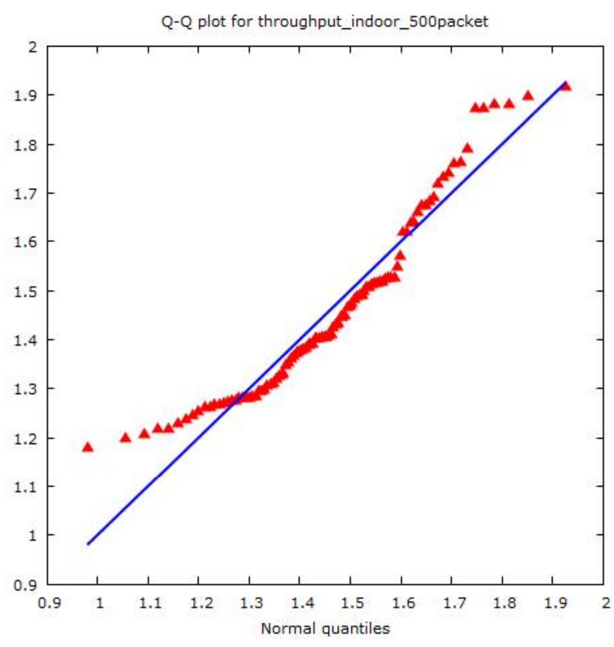

Figure 7-10Q-Q Plot for CIB throughput (500 Packets)

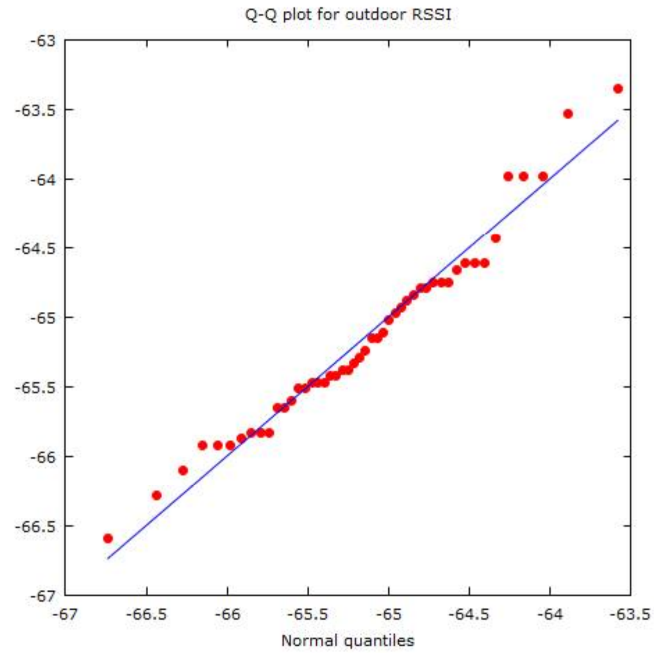

Figure 7-11Q-Q Plot for OSA RSSI

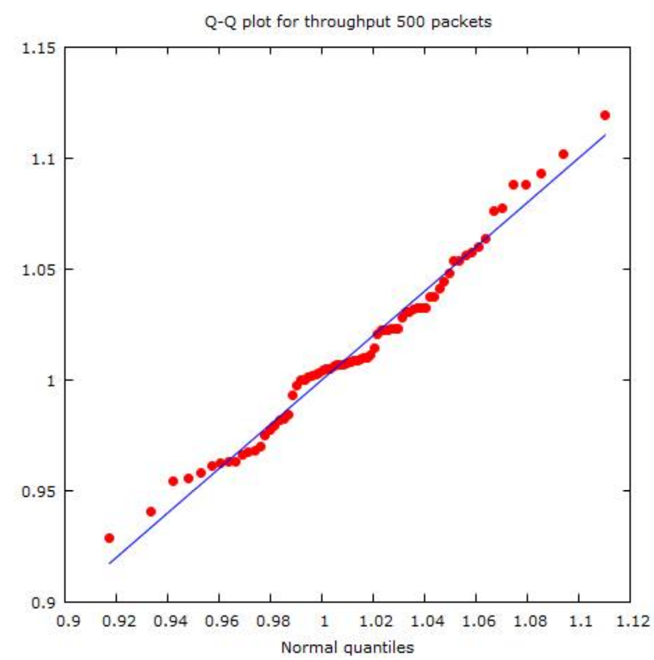

Figure 7-12Q-Q Plot for OSA throughput (100 Packets)

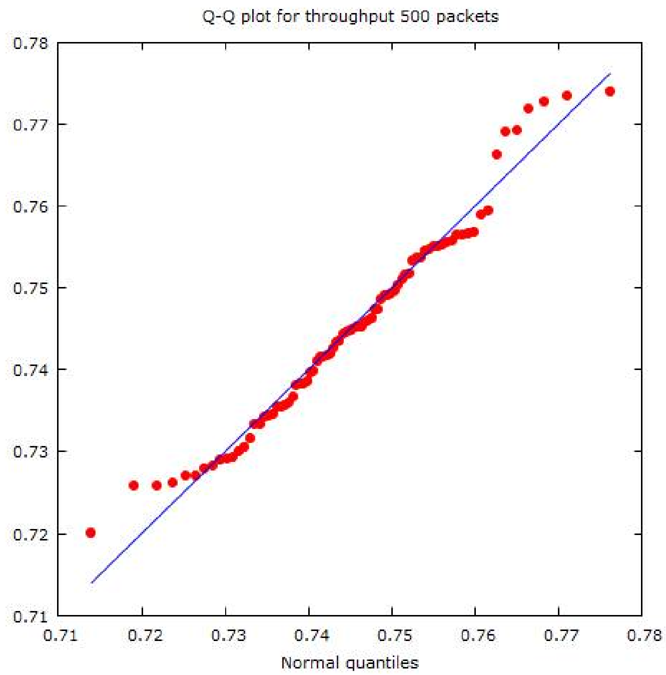

Figure 7-13Q-Q Plot for OSA throughput (500 Packets)

7. 2. 1 CONCLUSION ON NORMALITY

The RescOp wireless node designed is discussed and the performance is observed in Indoor CIB and Outdoor OSA locations. The nodes performance, in terms of communication linkage reliability and power consumption is outstanding as expected. It has been noted that the wireless nodes parameters like RSSI and throughput go along with normal distribution straight line and the nodes can be modelled with fix mean and variance. Also the power consumed by the wireless nodes was examined in outdoor and indoor locations. And the nodes withstand for long hours with 2600 mAh battery source (can be extendable).

7. 3 Results & Discussions of Searching pattern

Figure 7-14, Figure 7-15 & Figure 7-16 shows the searching pattern of pursuit node while searching for anchor node in outdoor location. The results in Figure 7-14, Figure 7-15 & Figure 7-16 are for outdoor locations show the path followed by pursuit node towards anchor node. The paths followed are simulated in SCILAB. The results listed below is expressed in a format of all the RSSI values in a test field in upper half and lower half shows the path followed by pursuit node. As seen in the Figure 7-14 the pursuit node gets the first RSSI value of -117 dBm. The pursuit node after getting the first trails received the -121dBm, -109dBm, -112dBm, -111dBm, -120dBm RSSI values from nearby location. According to the algorithm, the pursuit node moves to the new location of -109dBm because -109dBm is the largest value among all other values. Now the pursuit node learns to move to the largest value. This is the way teacher gets the best learner that is moving towards the largest value. Now Similarly -109dBm gets eight new RSSI values from the nearby location but it will choose a new location of -107dBm and the process continues till the pursuit node received -40dBm value. In Figure 7-15, the pursuit node received the -121dBm RSSI value and subjected to move to new location of -105dBm and node keep on following the same rule and reaches to the anchor node where it will receive -40dBm RSSI value. Same is the case of Figure 7-16for dense forest outdoor location. In Figure 7-15 & Figure 7-16 there is a deviation in path but finally reaches to the anchor node. As the RSSI values fades and follow multipath in real environment, so is the path become deviated. But the pursuit node is trained in a way to reach to the anchor node in any situation. This makes the anchor node fully discoverable in any outdoor location.

−116	−121	−119	−120	−122	−119	−117	−119	−115	−122	−118	−120	−118	−119	−120	−120	−118	−119	−121
−118	−112	−114	−112	−110	−112	−112	−115	−110	−109	−109	−111	−108	−113	−111	−112	−109	−109	−118
−117	−110	−107	−104	−105	−105	−108	−106	−107	−104	−107	−107	−108	−105	−109	−105	−103	−113	−117
−117	−111	−102	−98	−97	−97	−99	−96	−99	−99	−98	−101	−96	−99	−102	−98	−106	−109	−119
−121	−110	−105	−100	−95	−90	−90	−94	−90	−90	−90	−91	−91	−88	−92	−99	−106	−116	−116
−119	−114	−103	−98	−89	−82	−75	−79	−81	−80	−83	−84	−85	−85	−93	−99	−107	−111	−120
−118	−110	−107	−96	−89	−79	−75	−70	−67	−70	−70	−69	−69	−80	−89	−98	−102	−107	−116
−119	−110	−101	−97	−92	−80	−70	−58	−62	−55	−60	−59	−69	−79	−92	−95	−106	−109	−118
−117	−111	−105	−99	−89	−84	−71	−61	−50	−50	−50	−60	−69	−80	−92	−100	−106	−112	−117
−119	−110	−106	−94	−93	−81	−73	−63	−53	−40	−50	−60	−71	−79	−92	−99	−108	−109	−118
−123	−114	−102	−98	−91	−82	−74	−57	−50	−53	−52	−60	−71	−80	−90	−97	−104	−108	−119
−119	−115	−102	−96	−97	−80	−71	−62	−57	−55	−62	−63	−71	−82	−90	−95	−107	−112	−119
−123	−115	−108	−96	−90	−84	−73	−68	−69	−72	−69	−71	−69	−79	−86	−94	−109	−110	−117
−117	−111	−111	−95	−88	−83	−80	−83	−79	−85	−80	−82	−81	−79	−90	−97	−108	−109	−121
−119	−110	−105	−97	−91	−88	−92	−89	−92	−87	−89	−90	−90	−87	−92	−101	−107	−112	−117
−121	−110	−109	−98	−100	−97	−97	−95	−101	−95	−98	−100	−99	−99	−98	−98	−107	−111	−120
−119	−111	−109	−105	−106	−104	−106	−105	−109	−105	−108	−107	−105	−108	−104	−102	−102	−111	−120
−115	−111	−113	−109	−111	−112	−111	−110	−110	−108	−113	−112	−111	−110	−115	−110	−112	−111	−119
−115	−118	−114	−118	−115	−116	−116	−120	−119	−119	−120	−118	−120	−120	−120	−120	−119	−119	−121
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−116	−121	−119	−120	−122	−119	−117	−119	−115	−122	−118	−120	−118	−119	−120	−120	−118	−119	−121
−118	−112	−114	−112	−110	−112	−112	−115	−110	−109	−109	−111	−108	−113	−111	−112	−109	−109	−118
−117	−110	−107	−104	−105	−105	−108	−106	−107	−104	−107	−107	−108	−105	−109	−105	−103	−113	−117
−117	−111	−102	−98	−97	−97	−99	−96	−99	−99	−98	−101	−96	−99	−102	−98	−106	−109	−119
−121	−110	−105	−100	−95	−90	−90	−94	−90	−90	−90	−91	−91	−88	−92	−99	−106	−116	−116
−119	−114	−103	−98	−89	−82	−75	−79	−81	−80	−83	−84	−85	−85	−93	−99	−107	−111	−120
−118	−110	−107	−96	−89	−79	−75	−70	−67	−70	−70	−69	−69	−80	−89	−98	−102	−107	−116
−119	−110	−101	−97	−92	−80	−70	−58	−62	−55	−60	−59	−69	−79	−92	−95	−106	−109	−118
−117	−111	−105	−99	−89	−84	−71	−61	−50	−50	−50	−60	−69	−80	−92	−100	−106	−112	−117
−119	−110	−106	−94	−93	−81	−73	−63	−53	*	−50	−60	−71	−79	−92	−99	−108	−109	−118
−123	−114	−102	−98	−91	−82	−74	−57	−50	−53	*	−60	−71	−80	−90	−97	−104	−108	−119
−119	−115	−102	−96	−97	−80	−71	−62	−57	−55	−62	*	−71	−82	−90	−95	−107	−112	−119
−123	−115	−108	−96	−90	−84	−73	−68	−69	−72	−69	−71	*	*	*	−94	−109	−110	−117
−117	−111	−111	−95	−88	−83	−80	−83	−79	−85	−80	−82	−81	−79	−90	*	−108	*	−121
−119	−110	−105	−97	−91	−88	−92	−89	−92	−87	−89	−90	−90	−87	−92	−101	*	−112	*
−121	−110	−109	−98	−100	−97	−97	−95	−101	−95	−98	−100	−99	−99	−98	−98	−107	−111	−120
−119	−111	−109	−105	−106	−104	−106	−105	−109	−105	−108	−107	−105	−108	−104	−102	−102	−111	−120
−115	−111	−113	−109	−111	−112	−111	−110	−110	−108	−113	−112	−111	−110	−115	−110	−112	−111	−119
−115	−118	−114	−118	−115	−116	−116	−120	−119	−119	−120	−118	−120	−120	−120	−120	−119	−119	−121

Figure 7-14 Path as Computed by Hybrid TLBO -Unilateral Algorithm for Outdoor Location

−116	−117	−121	−119	−117	−121	−121	−115	−119	−115	−121	−121	−118	−117	−120	−117	−119	−119	−121
−122	−112	−111	−108	−112	−112	−105	−110	−109	−111	−108	−113	−110	−111	−111	−109	−108	−114	−117
−115	−109	−111	−106	−102	−105	−106	−105	−106	−104	−104	−102	−104	−104	−107	−108	−99	−111	−121
−119	−112	−105	−101	−98	−101	−97	−99	−99	−100	−95	−98	−101	−99	−98	−98	−107	−109	−118
−119	−111	−110	−100	−91	−88	−90	−90	−87	−86	−90	−92	−89	−91	−91	−99	−109	−111	−120
−119	−112	−106	−98	−89	−80	−83	−82	−80	−82	−76	−85	−83	−81	−93	−101	−108	−115	−118
−115	−112	−103	−101	−89	−84	−75	−70	−67	−75	−69	−71	−71	−80	−90	−99	−103	−115	−120
−119	−108	−105	−98	−86	−80	−68	−62	−61	−57	−55	−64	−72	−81	−89	−98	−105	−113	−118
−115	−111	−105	−100	−92	−78	−72	−60	−48	−54	−50	−60	−66	−81	−87	−95	−108	−109	−117
−118	−109	−105	−97	−91	−83	−72	−63	−51	−40	−49	−62	−74	−79	−94	−97	−104	−108	−119
−117	−111	−106	−97	−91	−79	−70	−61	−52	−48	−52	−59	−70	−79	−90	−100	−109	−110	−118
−117	−110	−108	−100	−90	−82	−71	−62	−59	−63	−59	−63	−70	−83	−93	−96	−106	−111	−117
−118	−113	−105	−100	−92	−81	−72	−68	−71	−68	−71	−68	−70	−82	−90	−95	−106	−109	−119
−119	−109	−104	−97	−88	−81	−79	−83	−79	−83	−79	−85	−80	−77	−87	−102	−103	−109	−120
−115	−108	−107	−99	−90	−91	−88	−95	−90	−94	−90	−89	−86	−91	−89	−100	−106	−108	−117
−117	−112	−107	−95	−98	−97	−98	−99	−99	−98	−101	−101	−97	−96	−100	−101	−102	−109	−119
−119	−112	−105	−103	−103	−108	−103	−103	−106	−108	−104	−107	−105	−107	−106	−105	−105	−113	−117
−117	−111	−114	−109	−109	−113	−107	−110	−109	−112	−110	−111	−110	−110	−112	−108	−114	−108	−115
−121	−116	−117	−119	−121	−120	−120	−120	−119	−119	−118	−115	−118	−116	−118	−120	−117	−120	−120
−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
−116	−117	−121	−119	−117	−121	*	−115	−119	−115	−121	−121	−118	−117	−120	−117	−119	−119	−121
−122	−112	−111	−108	−112	−112	*	−110	−109	−111	−108	−113	−110	−111	−111	−109	−108	−114	−117
−115	−109	−111	−106	−102	*	−106	−105	−106	−104	−104	−102	−104	−104	−107	−108	−99	−111	−121
−119	−112	−105	−101	−98	−101	*	−99	−99	−100	−95	−98	−101	−99	−98	−98	−107	−109	−118
−119	−111	−110	−100	−91	*	−90	−90	−87	−86	−90	−92	−89	−91	−91	−99	−109	−111	−120
−119	−112	−106	−98	−89	*	−83	−82	−80	−82	−76	−85	−83	−81	−93	−101	−108	−115	−118
−115	−112	−103	−101	−89	−84	*	−70	−67	−75	−69	−71	−71	−80	−90	−99	−103	−115	−120
−119	−108	−105	−98	−86	−80	−68	*	−61	−57	−55	−64	−72	−81	−89	−98	−105	−113	−118
−115	−111	−105	−100	−92	−78	−72	−60	*	−54	−50	−60	−66	−81	−87	−95	−108	−109	−117
−118	−109	−105	−97	−91	−83	−72	−63	−51	*	−49	−62	−74	−79	−94	−97	−104	−108	−119
−117	−111	−106	−97	−91	−79	−70	−61	−52	−48	−52	−59	−70	−79	−90	−100	−109	−110	−118
−117	−110	−108	−100	−90	−82	−71	−62	−59	−63	−59	−63	−70	−83	−93	−96	−106	−111	−117
−118	−113	−105	−100	−92	−81	−72	−68	−71	−68	−71	−68	−70	−82	−90	−95	−106	−109	−119
−119	−109	−104	−97	−88	−81	−79	−83	−79	−83	−79	−85	−80	−77	−87	−102	−103	−109	−120
−115	−108	−107	−99	−90	−91	−88	−95	−90	−94	−90	−89	−86	−91	−89	−100	−106	−108	−117
−117	−112	−107	−95	−98	−97	−98	−99	−99	−98	−101	−101	−97	−96	−100	−101	−102	−109	−119
−119	−112	−105	−103	−103	−108	−103	−103	−106	−108	−104	−107	−105	−107	−106	−105	−105	−113	−117
−117	−111	−114	−109	−109	−113	−107	−110	−109	−112	−110	−111	−110	−110	−112	−108	−114	−108	−115
−121	−116	−117	−119	−121	−120	−120	−120	−119	−119	−118	−115	−118	−116	−118	−120	−117	−120	−120

Figure 7-15 Path as Computed by Hybrid TLBO-Unilateral Algorithm for Indoor Location

−124	−121	−118	−119	−122	−116	−119	−121	−116	−122	−116	−120	−121	−120	−120	−120	−122	−116	−120
−116	−112	−107	−109	−115	−109	−112	−113	−110	−108	−114	−110	−112	−113	−112	−109	−107	−112	−114
−121	−110	−106	−109	−106	−106	−107	−107	−105	−104	−106	−105	−104	−105	−109	−104	−103	−110	−119
−116	−110	−106	−98	−99	−97	−98	−98	−98	−99	−98	−103	−98	−97	−95	−99	−107	−110	−117
−116	−111	−104	−99	−89	−90	−92	−91	−93	−90	−89	−91	−88	−87	−89	−97	−108	−112	−117
−120	−106	−105	−96	−92	−78	−85	−80	−82	−79	−82	−83	−78	−80	−92	−100	−104	−112	−125
−117	−106	−106	−99	−91	−83	−75	−69	−72	−67	−69	−71	−70	−81	−87	−96	−101	−113	−114
−118	−108	−104	−101	−91	−78	−71	−61	−59	−61	−59	−61	−72	−77	−90	−96	−107	−110	−118
−117	−112	−105	−97	−90	−77	−71	−61	−48	−46	−55	−62	−70	−79	−85	−97	−106	−112	−119
−122	−112	−106	−100	−95	−79	−72	−65	−49	−40	−52	−64	−69	−79	−92	−100	−106	−108	−118
−118	−108	−103	−96	−91	−80	−72	−61	−51	−49	−51	−60	−72	−79	−93	−98	−104	−112	−118
−120	−112	−104	−103	−88	−79	−67	−61	−60	−61	−62	−62	−70	−79	−91	−102	−106	−110	−120
−118	−106	−105	−99	−91	−80	−71	−68	−72	−69	−72	−70	−72	−81	−93	−97	−105	−109	−120
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−117	−109	−102	−97	−92	−90	−91	−89	−90	−92	−90	−89	−90	−91	−91	−100	−107	−110	−116
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−116	−110	−104	−107	−105	−103	−107	−108	−110	−105	−106	−104	−106	−105	−104	−106	−105	−108	−116
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−118	−116	−122	−121	−118	−119	−118	−120	−118	−119	−123	−118	−118	−117	−119	−117	−117	−120	−117
−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
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−124	−121	−118	−119	−122	−116	−119	−121	−116	−122	−116	−120	−121	−120	−120	−120	−122	−116	−120
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−117	−112	−105	−97	−90	−77	−71	−61	−48	−46	−55	−62	−70	−79	−85	−97	−106	−112	−119
−122	−112	−106	−100	−95	−79	−72	−65	−49	*	−52	−64	−69	−79	−92	−100	−106	−108	−118
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−120	−112	−104	−103	−88	−79	−67	−61	*	−61	−62	−62	−70	−79	−91	−102	−106	−110	−120
−118	−106	−105	−99	−91	−80	−71	−68	−72	*	−72	−70	−72	−81	−93	−97	−105	−109	−120
−117	−108	−104	−98	−85	−79	−79	−84	−78	−79	*	−83	−83	−83	−91	−98	−105	−109	−118
−117	−109	−102	−97	−92	−90	−91	−89	−90	−92	−90	*	−90	−91	−91	−100	−107	−110	−116
−116	−111	−106	−98	−100	−101	−97	−101	−95	−95	−98	−99	*	−102	−96	−101	−104	−108	−119
−116	−110	−104	−107	−105	−103	−107	−108	−110	−105	−106	*	−106	−105	−104	−106	−105	−108	−116
−116	−114	−112	−111	−112	−115	−112	−113	−111	−110	−109	*	−110	−110	−108	−106	−111	−112	−120
−118	−116	−122	−121	−118	−119	−118	−120	−118	−119	*	−118	−118	−117	−119	−117	−117	−120	−117

Figure 7-16 Path as Computed by Hybrid TLBO-Unilateral Algorithm for Dense Forest Outdoor Location

7. 3. 1 Conclusion on Unilateral method

In this subsection, a novel approach for localization of nodes in disaster area test field has been explained and then the experiments on test field is shown. The modules have been tested for omnidirectional radiation pattren and then using these modules a state of the art unilateral technique has been introduced over trilateration algorithm. The unilateral technique become more efficient and less dependent on the network to localize the trapped node. Following the selection of sensor module, a new approach to localize has been introduced that uses RSSI as a parameter. The algorithm designed is tested and the trapped node is fully discoverable.

The advantage of this technique is its simplicity of getting embedd into most of electronics embedded platform.

7. 4 Results & discussions on LNSM & Hybrid TLBO-Unilateral

This section consists of LNSM results and Teaching Learning Optimization Algorithm results.

7. 4. 1 LNSM Parameters

LNSM parameters obtained are included in the algorithm to be designed and used to find the distance and RSSI values. The RSSI values are obtained in outdoor locations as mentioned in previous chapter 4. 500 Samples of RSSI are measured for outdoor locations. The RSSI data measured is shown in Figure 7-17. The deviation in outdoor environment is from -64 dBm to -68 dBm. This is due to the environmental parameters like fading of channel, interferences from trees, building etc. The wireless channel is modeled using LNSM and obtained RSSI by node and should pass the normality test. The experiments follow Shapiro-Wilk [115]& Jarque-Bera test [113]for normality.

Based on the RSSI values measured for different locations, the parameters of LNSM can be measured. The regression line can be obtained as shown in Figure 7-17

$Y_{outdoor} = -57.848\ X_{outdoor} + 506.8$ (7.1)

Note: $Y_{OUTDOOR}$ is average RSSI and $X_{OUTDOOR}$ logarithmic scale of distance in meters

So we can write the above equations as

$RSSI_{outdoor} = -57.848 \log (d/d_0)_{outdoor} + 506.8$ (7.2)

Comparing equations 6.1 and 6.2 with LNSM theoretical equation of

$P_{L(d)}\ dBm = P_{L(d0)} + 10n \log10 (d/d_0) + X_\sigma$.

We can calculate the path loss exponent and standard deviation as

$10n = 57.848$ and $P_t\ (dBm) - P_{L0} + X_\sigma = -506.8$ (Outdoor) (7.3)

Therefore with these equations we can find the LNSM parameters. And further the distance can be measured with the following equations:

$d = d_0 10^{-(RSSI + 506.8)/57.848}$ (in mtrs) Outdoor (7.4)

The equation 6.4 is used to calculate the estimated distance by putting in equation of RMSE (Root Mean Square Error)

$$RMSE = \sqrt{\left(\frac{1}{n}\sum_{i=1}^{n}(Error)^2\right)} \qquad (7.5)$$

Error= Actual Distance (d_A) - Estimated Distance (d_E)

The RMSE is observed as 35 mtrs in outdoor locations. Also the anchor as well as pursuit node RSSI values are not normally distributed. In Jarque-Bera normality test, H_o is the null hypothesis. In Jarque Bera test, W is the critical value for the acceptance of hypothesis and W_α is the critical value. The confidence levels mentioned 90%, 95%, 97.5%, 99%, 99.9% corresponds to 4.61, 5.99, 7.38, 9.21, and 13.82 respectively. And same for Shapiro- Wilk normality test the critical value W_α the confidence level for 90%, 95%, 98%, and 99.9% corresponds to the 0.9555, 0.947, 0.938, and 0.93 respectively. The RSSI data obtained by modelling of wireless channel using LNSM the H_o for Jarque-Bera and Shapiro-Wilk is not much acceptable at 99% confidence level. This shows the data is not normally distributed. The Q-Q plot shows the normality behavior of nodes in outdoor location shown in Figure 7-18. The results are not satisfactory by just modeling of the wireless channel through LNSM. The performances of the nodes in outdoor location are shown in terms of throughput also in Figure 7-18 and Figure 7-19. It has been observed that the output throughput is not satisfactory, which motivates and leads to the use of Hybrid TLBO- Unilateral technique.

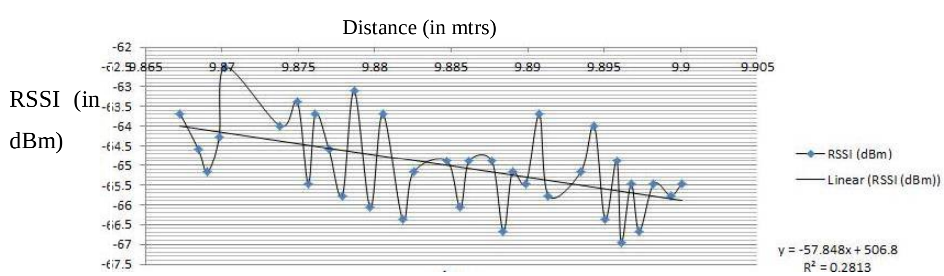

Figure 7-17 Measured data in Outdoor Location

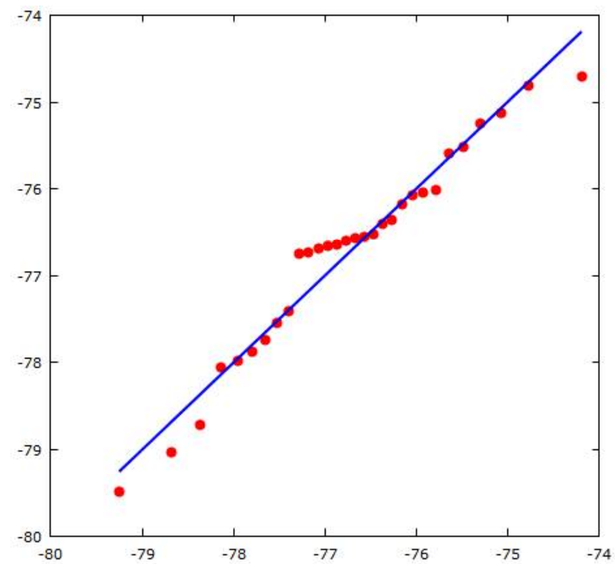

Figure 7-18 Plot for Outdoor Location for Normality

Check – using LNSM

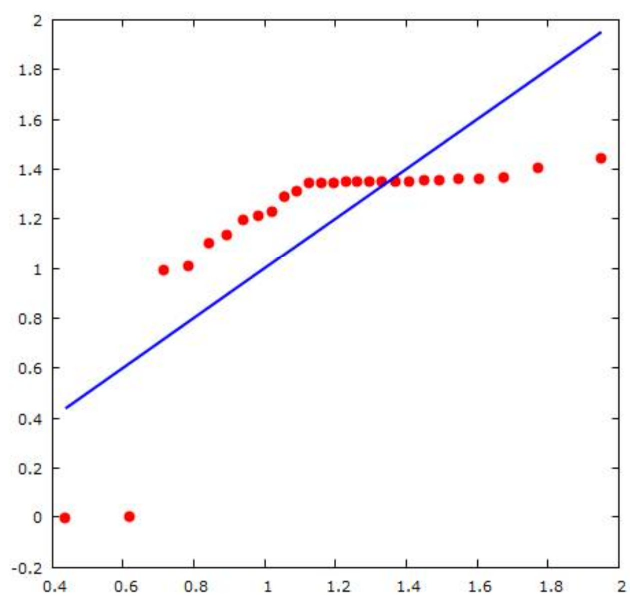

Figure 7-19 Plot for throughput of Outdoor Location for Normality Check – using LNSM

7. 4. 2 Hybrid TLBO– Unilateral Technique Results

In hybrid TLBO- Unilateral technique, the wireless channel is modeled using equation 5.17 in chapter 5. And again the normality tests Jarque-Bera and Shapiro Wilk have been performed. Using Hybrid technique, H_0 is accepted for both test at 99.9 % confidence level shows the normally distribution of the data. As stated in Table 7-1, the parameter is calculated after obtained RSSI values. The standard deviation is 1.01 and the RMSE calculated using equation 5.17 is obtained about 0.7 mtrs. The results in Figure 7-20 shows the normality behavior of the pursuit node and in terms of throughput the normality has been shown in Figure 7-21. The plots show that the nodes performed well in outdoor locations as compared to the LNSM technique.

TABLE 7-1 PARAMETERS OBTAINED FROM HARDWARE NODE

Parameters	Outdoor Location
Mean	-59.192
Median	-58.990
Minimum	-63.052
Maximum	-56.754
Standard Deviation	1.0183
C.V	0.017203
Skewness	-0.87642
Ex. Kurtosis	2.1473
5%	-61.066
95%	-57.77

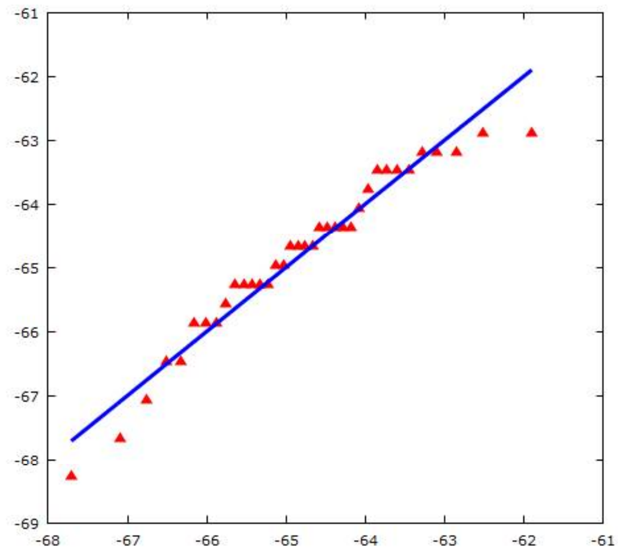

Figure 7-20 Plot for Outdoor Location for Normality Check -Hybrid TLBO Unilateral Algorithm

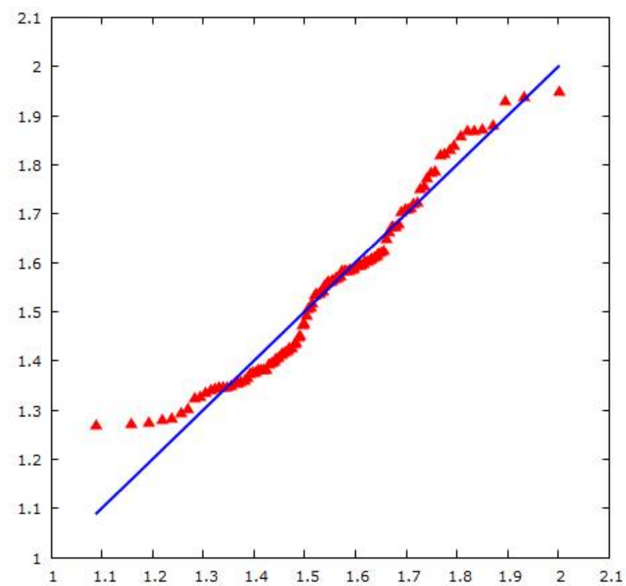

Figure 7-21 Plot for throughput of Outdoor Location for Normality Check - Hybrid TLBO Unilateral Algorithm

7. 4. 3 Conclusion on LNSM & Hybrid-TLBO unilateral Method

Two approaches of localization are discussed here. These methods are aimed to localize the anchor node by pursuit node. The first method is traditional LNSM technique and second method is hybrid TLBO- unilateral technique. In LNSM technique the wireless channel is modeled. After modeling, the new equations of finding estimated distance have been derived for outdoor locations. The node signals are found to be not fully normally distributed using Shapiro Wilk and Jarque Bera tests. In the other method Hybrid TLBO- unilateral technique the pursuit node is trained as teacher and learner to follow the path of greater RSSI value than the previous RSSI value received from the anchor node. The tests have been conducted for outdoor location and found that the anchor node is fully discoverable by pursuit node. The nodes signals now become normally distributed tested by Shapiro Wilk and Jarque Bera tests. The standard deviation is also found to be in range for outdoor locations. The Hybrid TLBO- unilateral is a flexible and easy to use algorithm that can be applied to any mobile node or fixed node. The localization problem in WSN can be dealt with hybrid TLBO- unilateral Algorithm.

7. 5 VALIDATION OF THE WIRELESS NETWORKS

The network is deployed in CIB & OSA locations as mentioned earlier in chapter 4, and RSSI values with respect to time has been recorded when the visitor node is moving across the fixed nodes. As shown in Figure 7-22, the RSSI variation with time represents the distance between visitor and fixed nodes respectively. For example, for node-1 the RSSI value gradually increases till -40 dBm (max. signal strength) and then decreases. The same behavior is experienced while the visitor node follows the same reverse path while returning. It is to be noted that order of appearance of nodes on path is node-1, node-2, node-3 and then node-4 in last. Figure 7-23 also shows the same behavior in outdoor location

A wireless network has been deployed at the site selected as already discussed in chapter 4. Some experiments are conducted for location fingerprinting algorithm and some experiments have been conducted for unilateral algorithm. For location fingerprinting AN1 (Anchor Node) nodes for location1, location2, location3, location4, location5, location6, location7, and location8 were communicating with MN1 (Movable node) nodes. The MN1 nodes are subjected to move from disaster prone area many times and RF signatures were captured. The failure ratio in terms of not capturing the RF signature is very less. Vehicle is subjected to move in different speeds of 20 Km/h, 40 Km/h and 50 km/h. The packet loss at speed more than 45 Km/h is more as compared to speed less than 40 Km/h. As the terrain is hilly so vehicle cannot move more than 50 Km/h. There is loss of one or two packets only at speed more than 45 Km/h. Vehicle is also subjected to handshake between two AN1 say location1 to location2 and to location3 and so on. Results were captured for these conditions also. The handshaking was smooth and continuous signal sharing of RF values were captured in location fingerprinting algorithm. The same data in excel format is captured in SD card module and same data is routed to main center node. In Figure 7-24 RF signature is captured by ANI (Anchor Node) node location1 while vehicle carrying MN1 (Movable Node) node moving towards the AN1. The signal varies from-90dBm to -48dBm. And the same node MN1 when move away from the AN1 node then the signal varies from -40 dBm to -90dBm as shown in Figure 7-25. Same scenario has been shown in location 2, location 3, and location 4 in Figure 7-26, Figure 7-27 and Figure 7-28 respectively. In Figure 7-29 handshaking in between location 1 and location2 with AN1 has been shown. The handshaking mode is smooth enough at speed 32km/h. In Figure 7-30 it can be observed that if speed of the vehicle goes more than 45km/h then packet loss takes place. The peak in the Figure 7-31 shows the packet loss during retrieving RF signatures. Figure 7-32 Figure 7-33 show the behavior of AN1 and MN1 node at various speeds. The results show the exceptional behavior of reliability of AN1 and MN1 node.

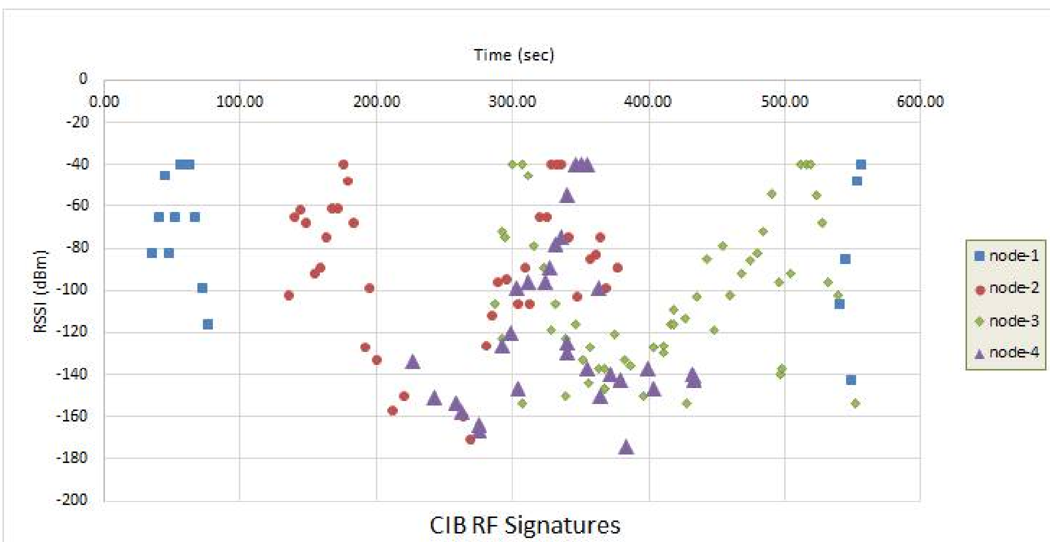

Figure 7-22RSSI (dBm) Complex Indoor Building (CIB)

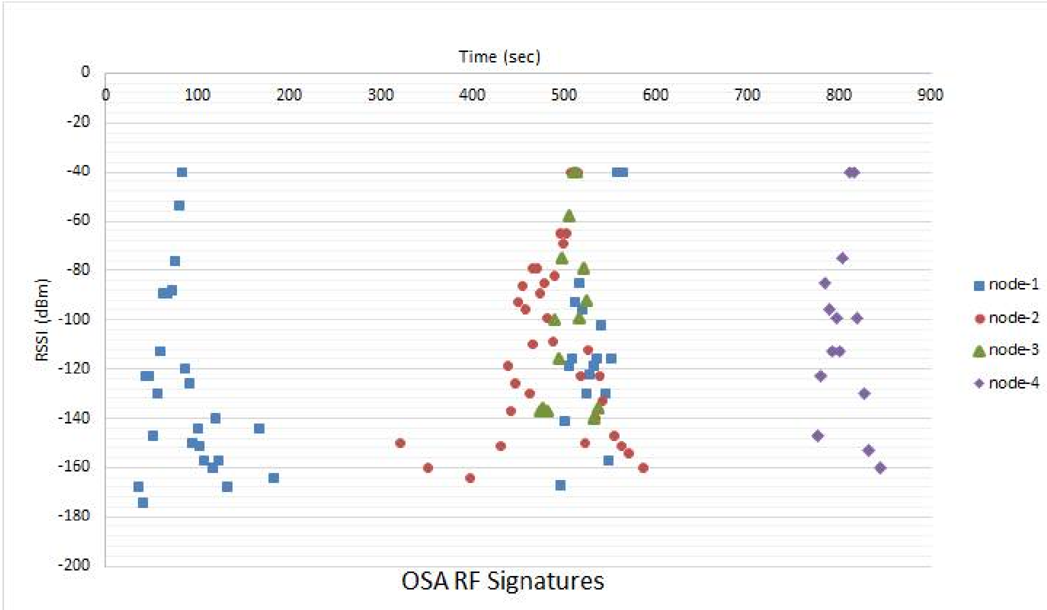

Figure 7-23RSSI (dBm) OSA

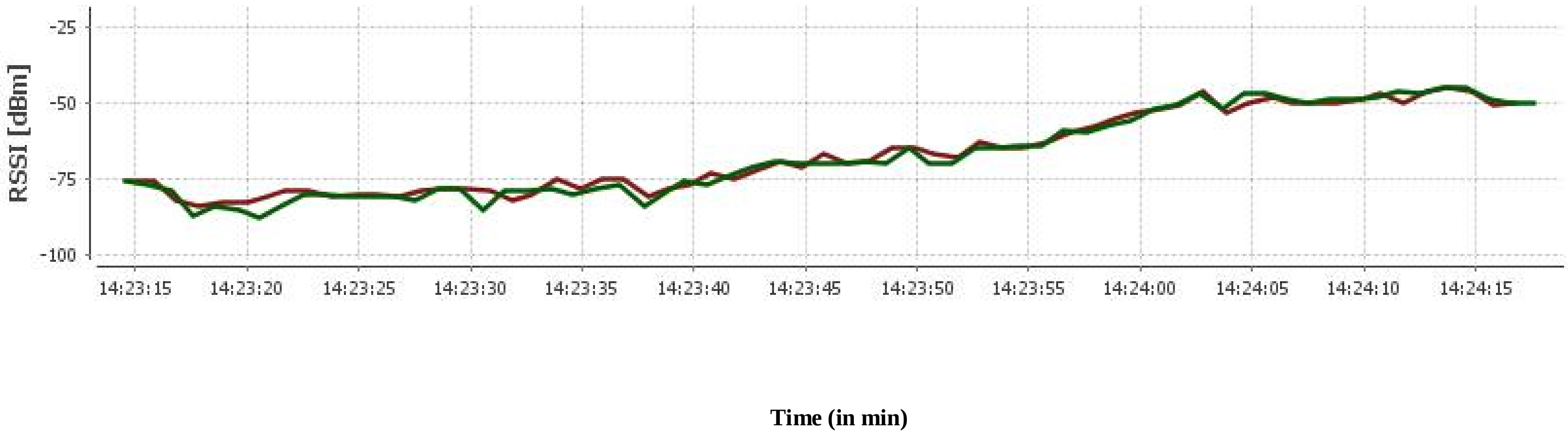

Figure 7-24 RF signature capturing by AN1 location 1 (vehicle carrying MN1 moves toward AN1)

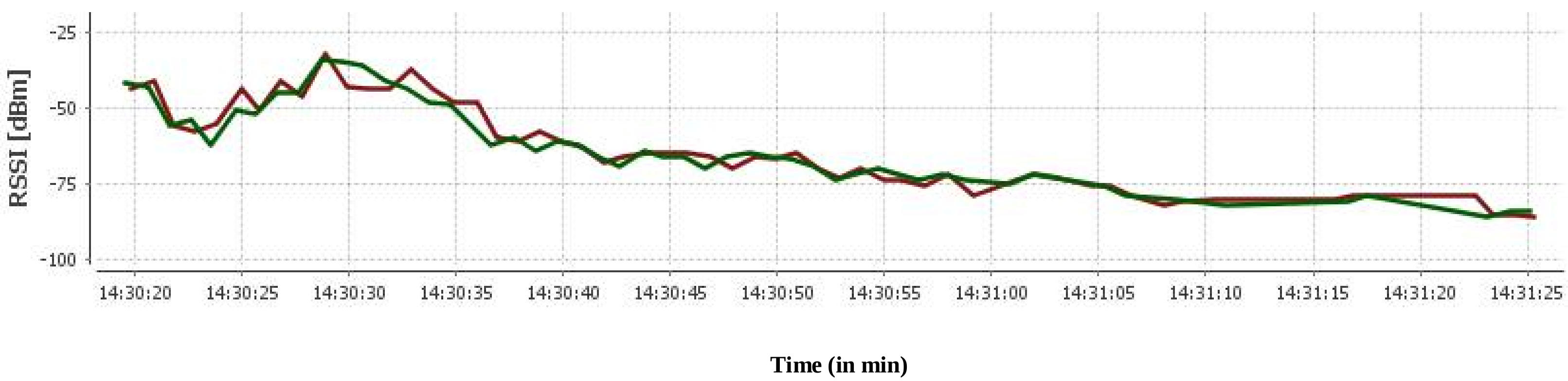

Figure 7-25 RF signature capturing by AN1 location 1 (vehicle carrying MN1 moves away from AN1)

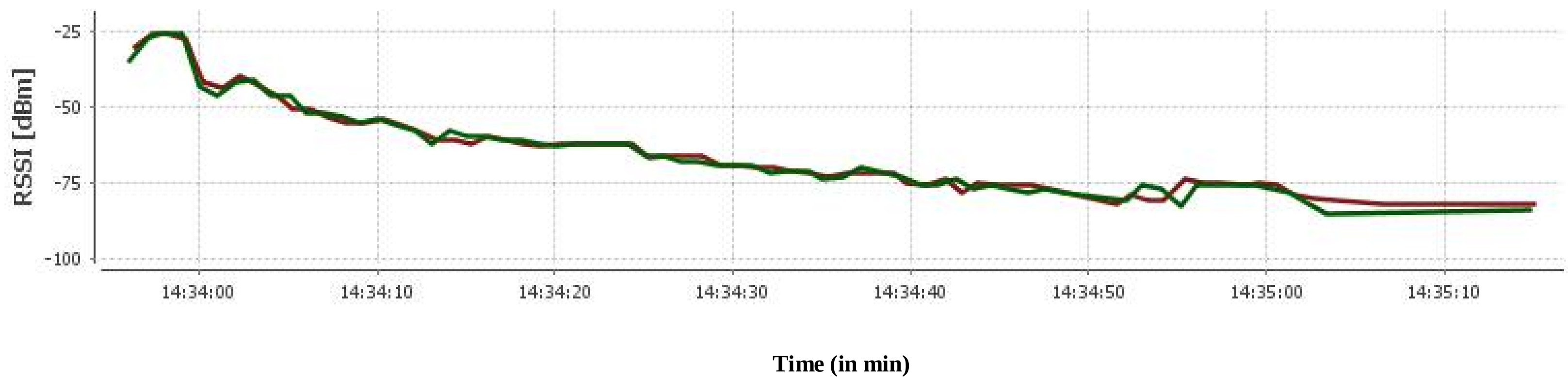

Figure 7-26 RF signature capturing by AN1 location 2 (vehicle carrying MN1 moves away from AN1)

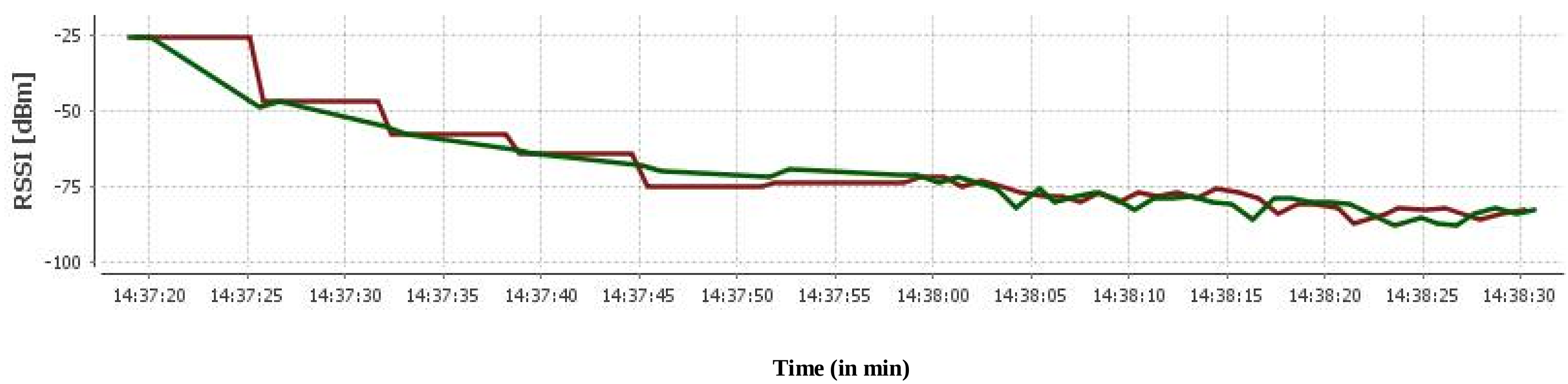

Figure 7-27 RF signature capturing by AN1 location 3 (vehicle carrying MN1 moves away from AN1)

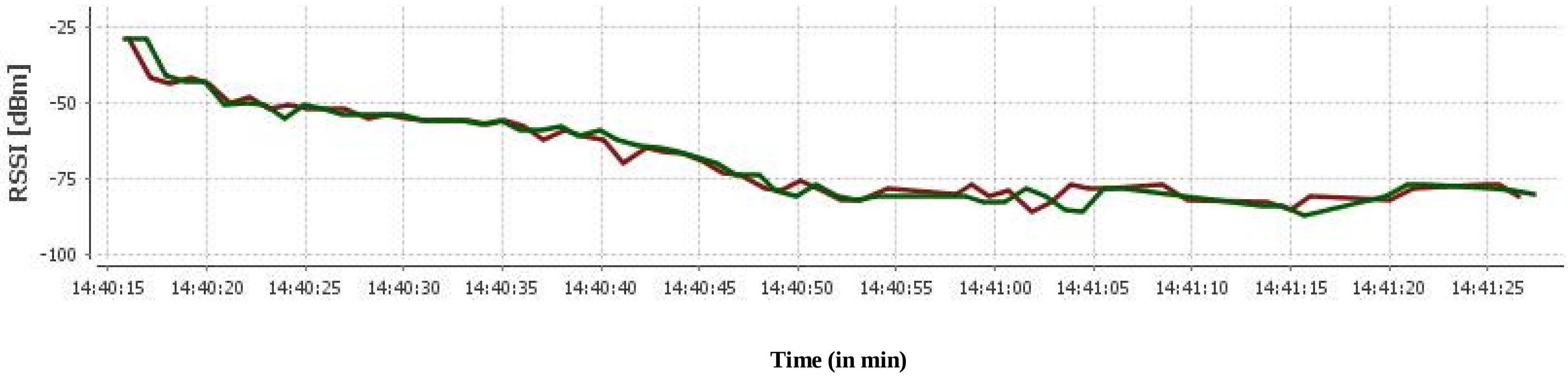

Figure 7-28 RF signature capturing by AN1 location 4 (vehicle carrying MN1 moves away from AN1)

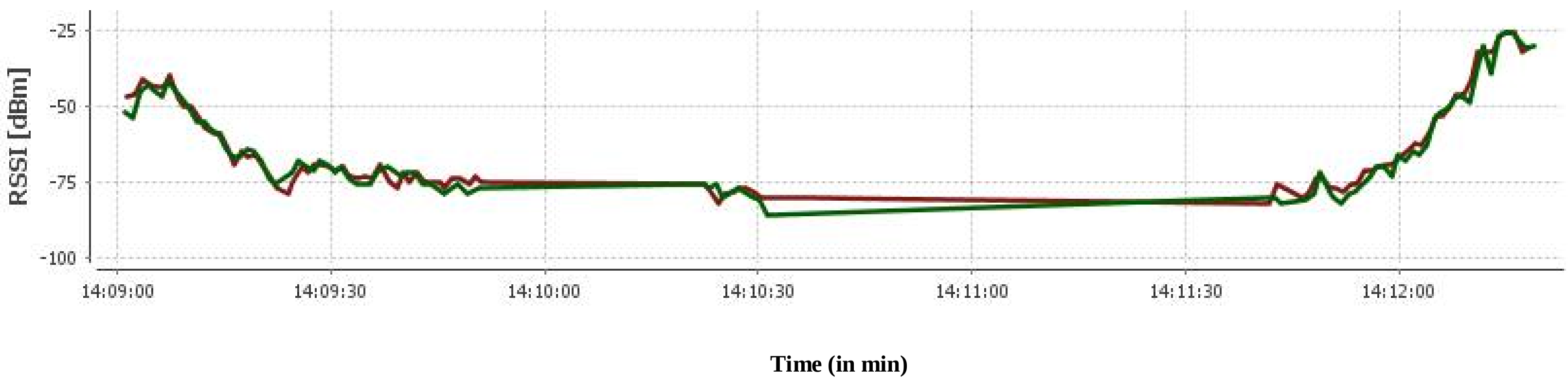

Figure 7-29 Handshaking of MN1 from AN1 location 1 to AN1 location 2

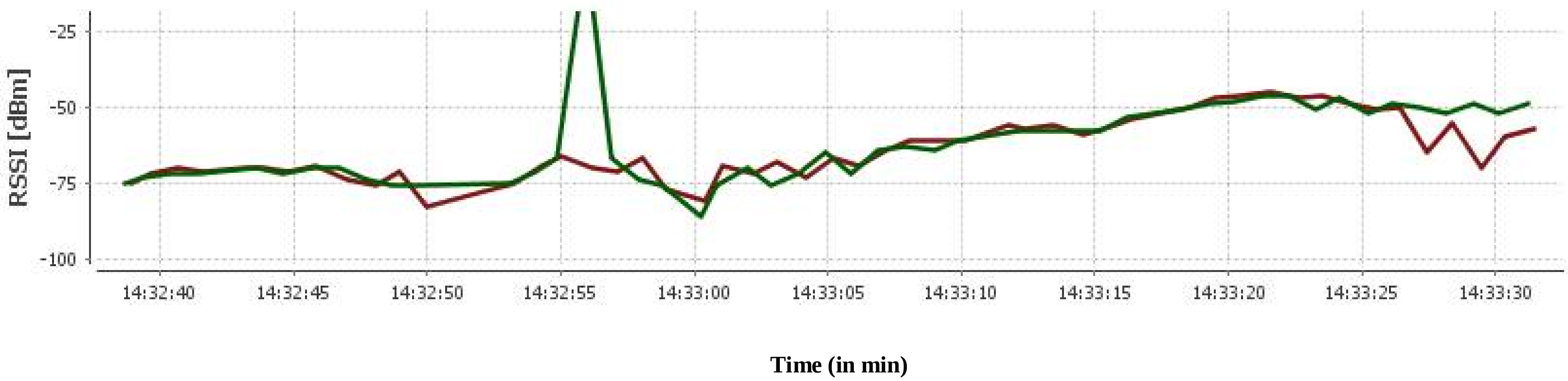

Figure 7-30 RF signature capturing by AN1 location 6 (vehicle speed is 48 km/h)

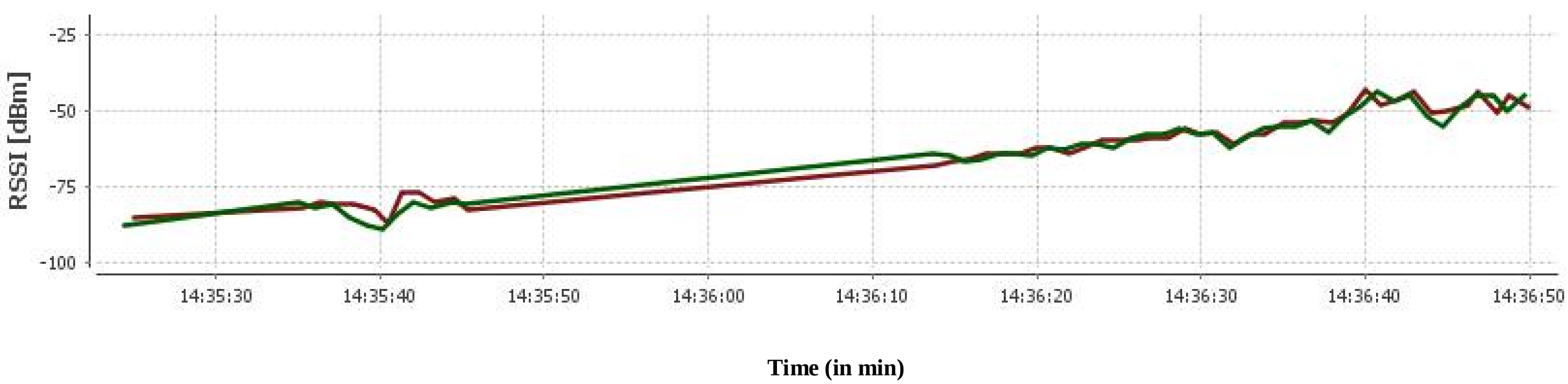

Figure 7-31 RF signature capturing by AN1 location 8 (vehicle speed is 25 km/h)

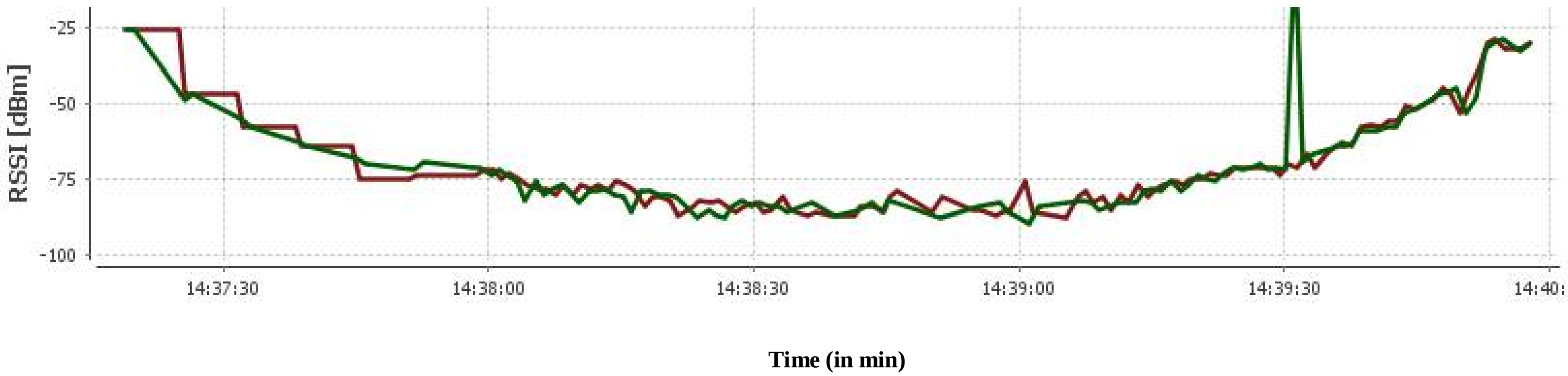

Figure 7-32 Handshaking of MN1 from AN1 location 7 to AN1 location 8 (vehicle speed is 46 km/h)

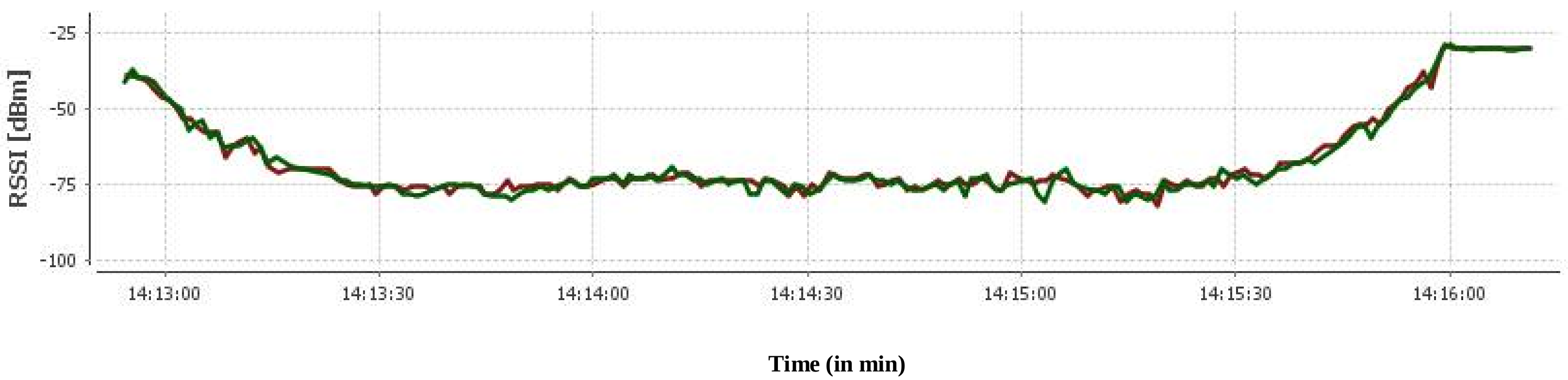

Figure 7-33 Handshaking of MN1 from AN1 location 3 to AN1 location 4 (vehicle speed is 34 km/h)

Comparison Chart

Reference	Technology used/ Framework	Algorithm Used	Metric	Environment	Parameter to be estimated	Type of Study	Area	Average Localization
[98]	MATLAB	PSO	RSSI	NA	location	Simulation	NA (only no. of nodes vary to no. of iterations)	NA
[99]	MATLAB	LM	RSSI	NA	location	Simulation	100 ×100 m	1.18m
[100]	ZigBee (FT-6250/FT-6251)	RBFN	LQI	Indoor	location	Experimental	7.26 × 16.6 m	2.8 m
[101]	ZigBee (Telosb)	BR and GD	RSSI and LQI	Indoor	location	Experimental and offline ANN training	12.19 ×20.12 m	1.65 m
[102]	MATLAB	NN	RSSI and Hop count	NA	Distance	Simulation	50 ×50	6-7 m

[103]	N/A	MLP and GR	Wavelet based features	Indoor	Distance and location	simulation	Positions	2m
[104]	ZigBee (CC2431)	MLP	RSSI	Indoor	Distance	Experimental and ANN simulation	5 × 5 m	2m
Finding of this research	**ZigBee (Xbee S2)**	**Hybrid TLBO-Unilateral Algorithm**	**RSSI**	**Outdoor**	**Distance and location**	**Experimental and simulation**	**150 × 100 mtrs**	**0.7 m**