Cihan University-Erbil Scientific Journal (CUESJ)

Research Article

Solving Isolated Nodes Problem in ZigBee Pro for Wireless Sensor Networks

Nabaa Abdul-Khudhur Hasan*, F. Alaa Kadhim

Department of Computer Science, University of Technology, Baghdad, Iraq

ABSTRACT

Wireless sensor network based on the ZigBee protocol consists of many sensor devices. In some cases, the sensor nodes may turn to isolated node because random distribution, particularly when creating the network. In this research was suggested two cases to overcome on the isolated node problem, the first case had able to overcome this problem by distributing the isolated nodes on the router nodes that carry the least number of sensor nodes, it helps to minimize the computational overhead on router nodes too, while the second one is able to overcome this problem by calculating the distance between the isolated nodes and the routers and then adds these nodes to the nearest routers. Subsequently, this method helps to minimize the energy consumption. The results show our approach able to solve the problem of isolated nodes using these two methods and when compared between them turns out the second method is better In terms of energy consumption. In addition, we are able to make the network larger scale.

Keywords: Isolated nodes, wireless sensor networks, ZigBee Pro

INTRODUCTION

Nowadays, wireless sensor network (WSN) plays an important role because it is used in many applications such as military monitoring, fire control, health observation in patient case, and monitoring of traffic and also used in soil to measure humidity.[1] The demand for the construction of large-scale WSNs has been increasing rapidly; the use of conventional WSNs encounters a number of critical technical challenges such as the network scalability and energy consumption.[2,3] Especially, it must apply a network joining technique that is able to link every node in a big scale WSN with reduced power consumption.[4]

Many of network joining techniques have been suggested to support trusty connection in internet applications (e.g., dynamic host configuration protocol and duplicate address detection).[5-7] Even so, because of the broadcast storm issue, may not be applied this technique and the energy may become not efficient and this will be wasted it,[8] appropriate protocols must be applied to solve the problem of rejoining isolated nodes with conserving energy. To reduce power consumption, ZigBee has applied as communication protocol. Although some papers have been published concerning the problem of communication in ZigBee protocol, but has not been enough and did not cover the problem in complete way when compared with other issues such as routing algorithms[9-11] or data transmission.[12,13] In most of the papers, Clouqueur *et al.*,[14] Dhillon *et al.*,[15] Kumar *et al.*,[16] Rahman *et al.*[17] concerned with the coverage of the sensor network, it assumed that communication in the network is good, but communication in the network is an important and will affect performance, it must focus on.

In this paper, we will focus on connectivity improving by solving isolate nodes problem so the network will be large scale. Moreover, we will solve the problem in two ways. The first method is called load distribution where the isolated nodes are distributed on the router nodes that carry the least number of sensor nodes. The second method is to add the isolated node to the nearest routing node to it. This will help to reduce power consumption.

The remainder of the essay arranged in this way. Part II shows relation works. Part III shows the proposed mechanism where Part IV displays environment and Part V discussed the results of proposed to estimate the efficacy of our suggested. Finally, we deduce this essay in Part VI.

Corresponding Author:
Nabaa Abdul-Khudhur Hasan, Department of Computer Science, University of Technology, Baghdad, Iraq.
E-mail: nabaa_alkhafagi@yahoo.com

Received: Mar 25, 2019
Accepted: Apr 22, 2019
Published: Aug 20, 2019

DOI: 10.24086/cuesj.v3n2y2019.pp31-36

RELATION WORKS

ZigBee Pro

ZigBee is a protocol based on IEEE standard 802.15.4. It is used in WSN because it has the appropriate characteristics of this network such as low-power consumption and low cost. ZigBee is considered a worldwide open standard for wireless radio networks in the monitoring and control fields. The standard was developed by the ZigBee Alliance (a group of international companies).

The ZigBee protocol consists of three devices:[18]

ZigBee Coordinator: The network should include only one and be responsible for several tasks such as network establishment, the allocation of addresses, and the decision-maker regarding the admission or departure of the nodes, in addition to the transfer and processing of messages. It should always be powered on.

ZigBee Router: Could be missing in a network, the network may include just one or more based on the size and topology of the network. It is not found in a star topology. It is often used to expand the ZigBee network (in the tree and mesh). Basically, it executes all tasks of the coordinator, except network establishment (start-up).

ZigBee end devices: It is located in all topologies the purpose of end devices for sending and receiving the packets.

ZigBee consists of three topologies: Star, tree, and mesh topology. In this paper will focus on tree topology, because the isolated nodes problem happens in this topology.

A Connectivity Improving Mechanism for ZigBee WSNs

In 2008, Tian-Wen Song and Chu-Sing Yang,[19] they used the tree topology and modified the connection of nodes, and the joining which succeeded by of a shifting is called extended joining. This operation is specified by three elements nwkMaxChildren, nwkMaxRouters, and nwkMaxDepth which determine if an isolated node is able to add to the network or not this enhancement helps not only the reduction of isolated sensors and wasted costs but also the performance growth of the ZigBee sensor network.

In 2008, Enhancing Node Connectivity by Utilizing RSSI for ZigBee-based WSN

In 2016, Chung *et al.*[20]

They could overcome the isolated node problem, they proposed two methods, Gaussian filtering with averaging and median method based on RSSI samples.

The first way is objective to get high accuracy, while the another way is objective to reduce the computational cost of node connection. The result of the proposed is more effective than the existing approach.

Proposed System

First, we will apply our proposed on the tree topology. An example of connectivity problem in a ZigBee network is shown in Figure 1. There are a number of isolated nodes such as node D; the isolated nodes will cause the expected network operations unreached and waste the deployment costs. Hence, we proposed two methods to solve this problem and we will discuss in the next sections.

However, before that, we must now discover if there are isolated nodes in the network. Hence, we assumed that there is table saved in the coordinator, this table includes the number of routers, end devices, and the links between this device, and shown in Table 1. After network establishment, it will start many operations such as send and receive the packets. We will determine the specific time (15 min), for example, if one node will not do any action, this node will be considered as isolate node and added to the table as isolated. In this way, we will know if there is any isolated node in WSN. Our proposed system is shown in Figure 2.

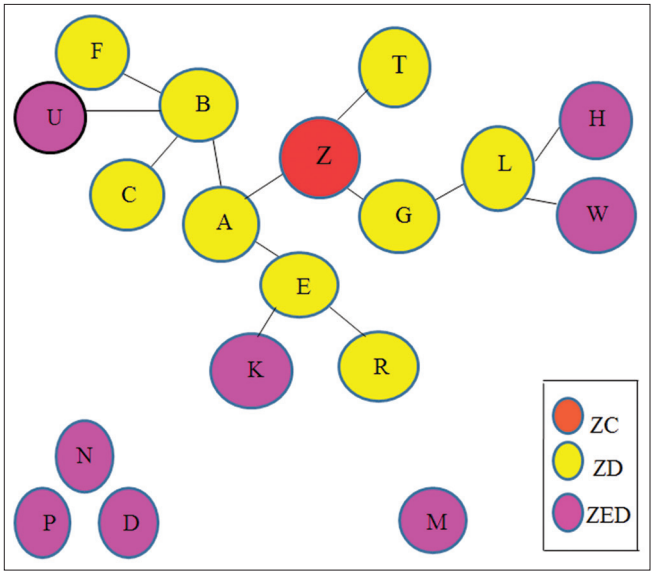

Figure 1: Illustration of ZigBee connectivity issue

Table 1: The table saved in the coordinator (Z)

ZigBee Router	A, B, C, E, F, G, R, L, T
ZigBee end devices	W, H, K, U
Isolated nodes	P, D, M, N
Links	
Z	A, G, T
A	B, E, Z
B	A, C, F, U
C	B
E	A, R, K
F	B
G	L, Z
H	L
L	G, H, W
T	Z
W	L
R	E
K	E
U	B

Case 1

In this case, we will distribute the isolated nodes on the routers that carry least number of end devices. Moreover, this operation starts after the coordinator will know that there are isolated nodes in the network. The coordinator will open the table and search for the least router that carries end devices. For example, Z will send two messages, one of T to tell it that there is new node will join into it, the second message will Tell P that T it is the router appropriate for it. After that will start the communication between P and T to join. If there is more than one isolated node, it will follow the same method. In Figure 3, the node P will be connected to the router T, and the nodes M, N, and D will be connected to F, C, and R, respectively.

The protocol clarifying our proposal for the first case is as follows:

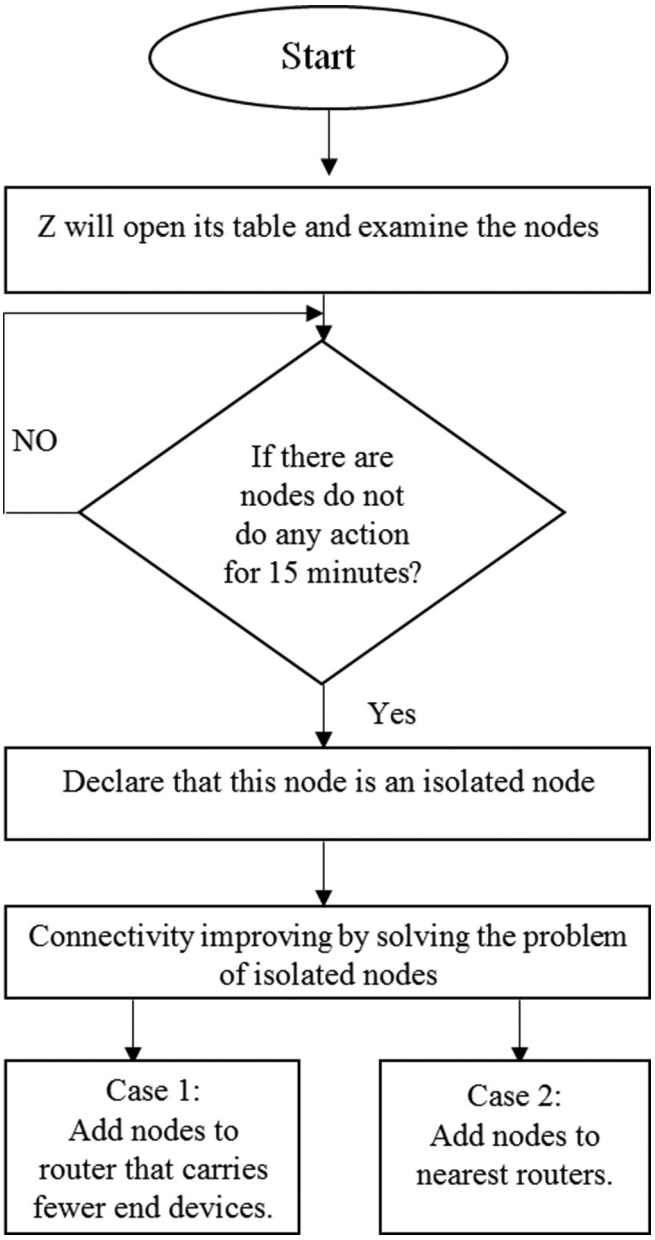

Figure 2: The flow chart of the proposed system

- The coordinator (Z) opens the table stored in it and searches for a router with fewer end devices.
- Then, Z sends a message to that router tells him that there is an isolated node wants to join him by sending the ID of that node.
- And Z sends a message to that node and tells it that there is a router appropriate to it by sending the ID of that router.
- After that, isolated node will send his ID to the router.
- Finally, the router will compare if the ID transmitted by the node matches the ID transmitted by Z, if they match, the router will accept the node, and otherwise, it will ignore the request.

Case 2

In this case, the distance will measure between all isolated nodes and every router, and select, the less distance between them to join. We will use the distance Equation (1) to calculate the distance between them.[21]

$$Di = \sqrt{(x1 - x2)^2 + (y1 + y2)^2} \quad (1)$$

The protocol clarifying our proposal for the second case is as follows:

- The coordinator (Z) opens the table stored in it and searches for the number of routers and isolated nodes.
- Then, z will calculate the distance between the isolated nodes and all routers.
- After that, z will compare the distance and select least distance between them (node will be added to the router closest to it).
- These nodes are added by sending Z two messages; one of them to the router containing the ID of isolated node and the other one is sent to the node and contains the ID of the router.
- Finally, the router will compare if the ID transmitted by the node matches the ID transmitted by Z, if they match, the router will accept the node, and otherwise, it will ignore the request.

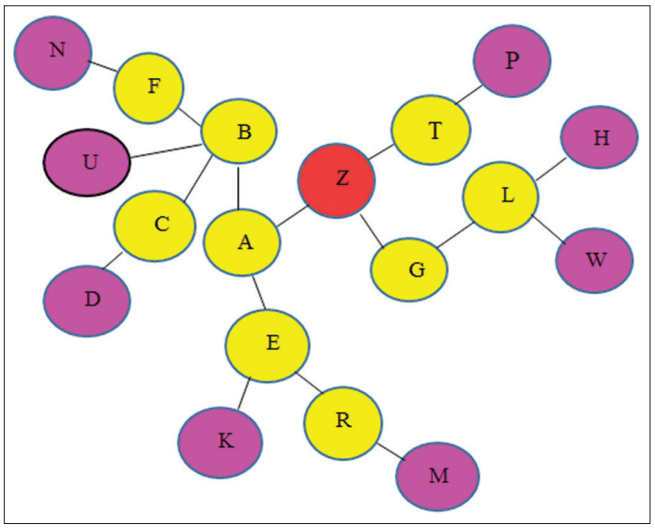

Figure 3: Illustration to resolve the connection problem in the ZigBee protocol by Case 1

Figure 4 displays the coordinates of nodes.

Applying the distance formula for finding the every node distance value with the help of sensors, nodes coordinate as showing in Figure 5, for example, distance between Z (coordinator) and T node.

Z=(5, 4)

T=(2, 4)

$$d1 = \sqrt{(5-2)^2 + (4-4)^2}$$

$$d1 = \sqrt{(3)^2 + (0)^2}$$

$$d1 = \sqrt{9}$$

d1=3

Similarly, the value of all remaining distance is also calculated, which is also shown in Figure 4, that is, d2=2, d3=1, d4=2, d5=2, d6=1, d7=2, d8=4, d9=5, d10=4, d11=5, d12=1, and d13=2, using sensor nodes coordinate and distance measurement formula we able to measure the distance between each node in a WSN area.

After calculating the distance between the all nodes within the network, now we will calculate the distance between the isolated nodes and the routers only, Table 2 explain that, for example, the distance between node P and router A is 8.1 and between node P and router B is 6. Moreover, on this basis, we will compare and choose the nearest router to this isolated node to join, show that in Figure 6.

To measure the energy consumption[22] and compared it in the two cases used. We will use Equations (2, 3):

$$ETx(k, d) = Eelec*k + \varepsilon amp*k*d^2 \quad (2)$$

$$ERx(k) = Eelec*k \quad (3)$$

Where, Eelec is the energy to run circuitry=50 NJ/bit, εamp is the energy for radio transmission=100 PJ/bit/m^2, ETx energy for sending k bits over distance D, and ERx energy for receiving k bits.

PROGRAMMING ENVIRONMENT

The proposed system was written in c# language version 2013 on Windows10.

PERFORMANCE EVALUATIONS

We suggested two cases to solve the problem of isolated nodes, and during the execution turns out, the method two is better than method one. The first method depends on added the isolated nodes to the routers that carry the least number of sensor nodes. The second method depends on the distance measure way, where the distance of the path between the isolated nodes and the routers is measured. Then, the appropriate router is then selected for the node to join based on the least distance between the router and the isolated node. The second method was chosen as the best after measuring and analyzing the results for energy consumption; Figure 7 shows the energy consumption in the first and second method.

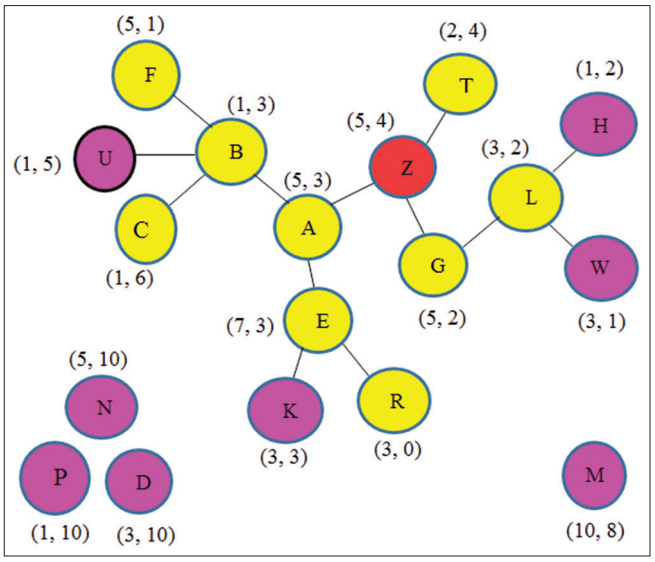

Figure 4: Show nodes coordinate

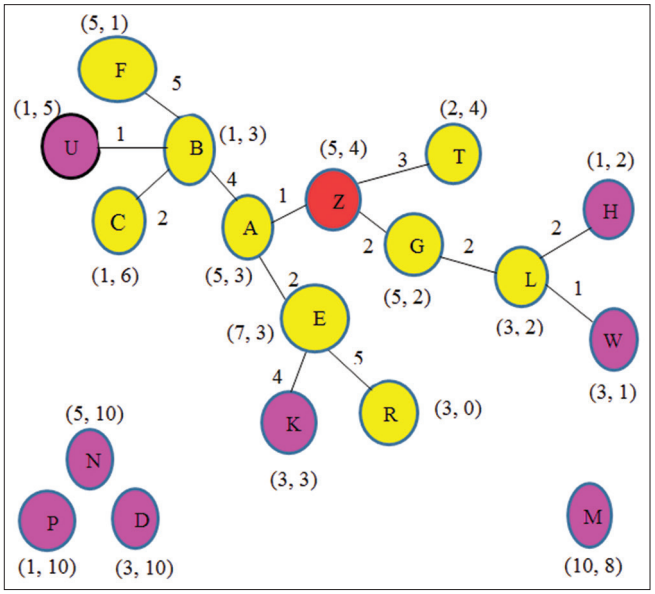

Figure 5: Display the distance measurement for the nodes

Table 2: Explain the distance between isolated nodes and routers

ISOLATE	Routers								
	A	B	C	E	F	G	L	T	R
P	8.1	6	4	9.2	9.8	8.9	8.2	6	10.2
M	7.1	9.8	9.2	5.8	8.6	7.8	9.2	8.9	10.6
N	7	7.2	5.7	7.3	9	8	8.2	6.7	10.2
D	7.3	6.3	4.5	8.1	9.2	8.2	8	6.1	10

The results show that there is a significant difference in energy consumption between the two methods when the isolated nodes added to the network where the amount of energy consumed in the first method when joining the node M to the router R is 181.4 mJoule, and node N to F

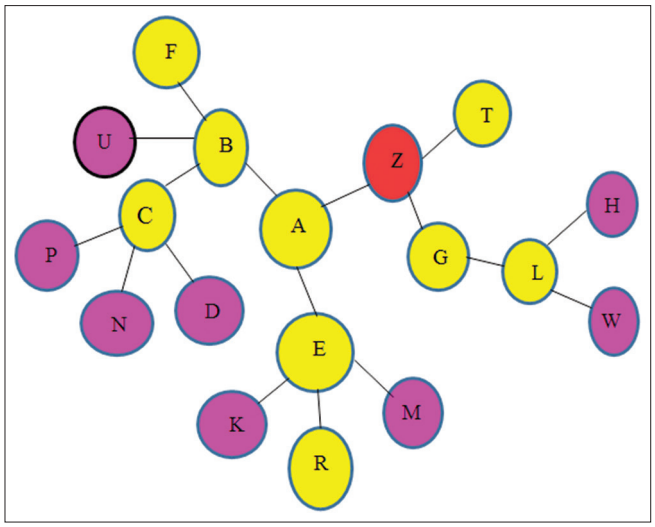

Figure 6: Illustrates the way of connection to the nodes by case two (minimum distance)

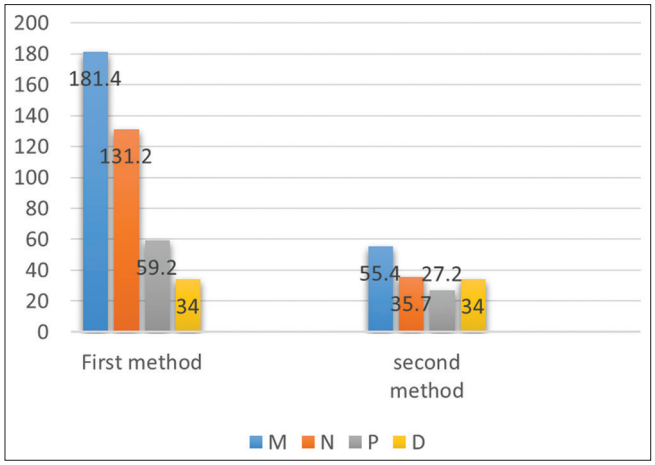

Figure 7: Illustration the energy consumed in the two methods it used

is 131.2 mJoule, node P to T is 59.2 mJoule, and finally, the amount consumed in node D to C is 34 mJoule.

As for the amount of energy consumed in the second method when add the node M to the router E is 55.4 mJoule, and node N to router C is 35.7 mJoule, node P to router C is 27.2 mJoule, and finally, the amount of energy that consume for add node D to router C is 34 mJoule.

CONCLUSION

This work proposed an enhanced the connectivity of ZigBee using two ways for solving the problem of isolated nodes in WSN. We have applied the first way by making the isolated nodes join to router who carries the least number of end devices and as for the second way by calculating the distance and added this node to nearest routers.

We proved our scheme could overcome the problem of isolated nodes. After that, we compared between the two ways where the second method provides efficiency by achieving less energy consuming compared to the first method. Furthermore, our scheme applied to make the network larger scale.

REFERENCES

1. J. Sen. "A Survey on Wireless Sensor Network Security". *International Journal of Communication Networks and Information Security*, vol. 1, no. 2, pp. 59-82, Aug 2009.
2. M. S. Pan, C. H. Tsai and Y. C. Tseng. "The orphan problem in ZigBee wireless networks". *IEEE Transactions Mobile Computing*, vol. 8, no. 11, pp. 1573-1584, Nov. 2009.
3. S. Hur, J. Kim, J. Choi and Y. Park. "An efficient addressing scheme and its routing algorithm for a large-scale wireless sensor network". *EURASIP Journal Wireless Communications and Networking*, vol. 2008, pp. 765803, Sep. 2008.
4. F. Ye and R. Pan. "A Survey of Addressing Algorithms for Wireless Sensor Networks". In Proceeding IEEE WiCOM, Sep. 2009.
5. R. Droms. "Dynamic Host Configuration Protocol". Internet RFC 2131, Mar 1997.
6. R. Droms, J. Bound, B. Volz, T. Lemon, C. Perkins and M. Carney. "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)". Internet RFC 3315, Jul. 2003.
7. N. H. Vaidya. "Weak Duplicate Address Detection in Mobile Ad Hoc Networks". In Proceeding of ACM MobiHoc, Jun. 2002.
8. J. L. Lu, F. Valois, D. Barthel and M. Dohler. "Low-energy Address Allocation Scheme for Wireless Sensor Networks". In Proceeding of IEEE PIMRC, Sep. 2007.
9. T. Kim, D. Kim, N. Park, S. Yoo and T. S. Lopez. "Shortcut Tree Routing in ZigBee Networks". 2nd International Symposium on Wireless Pervasive Computing (ISWPC'07), San Juan, Puerto Rico, Feb. 5-7, 2007, pp. 4247.
10. P. Ran, M. H. Sun and Y. M. Zou. "ZigBee Routing Selection Strategy Based on Data Services and Energy Balanced ZigBee Routing". IEEE Asia-Pacific Conference on Services Computing (APSCC'06), Guangzhou, China, Dec. 2006, pp. 400-404.
11. K. K. Lee, S. H. Kim and H. S. Park. "Cluster Labelbased ZigBee Routing Protocol with High Scalability". 2nd International Conference on Systems and Networks Communications (ICSNC'07), Cap Esterel, France, Aug. 2007, p. 12.
12. G. Ding, Z. Sahinoglu, P. Orlik, J. Zhang and B. Bhargava. "Tree-based data broadcast in IEEE 802.15.4 and ZigBee networks". *IEEE Transactions on Mobile Computing*, vol. 5, no. 11, pp. 1561-1574, 2006.
13. G. Ding, Z. Sahinoglu, B. Bhargava, P. Orlik and J. Zhang. "Reliable Broadcast in ZigBee Networks". 2nd Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks (SECON'05), Santa Clara, USA, Sep. 2006, p. 510.
14. T. Clouqueur, V. Phipatanasuphorn, P. Ramanathan and K. K. Saluja. "Sensor Deployment Strategy for Target Detection". 1st ACM International Workshop on Wireless Sensor Networks and Applications (WSNA'02), Atlanta, USA, Sep. 2002, pp. 42-48.
15. S.S. Dhillon, K. Chakrabarty and S. S. Iyengar. "Sensor Placement for Grid Coverage under Imprecise Detections". 5th International Conference on Information Fusion (FUSION'02), Annapolis, USA, Jul. 2002, pp. 1581-1587.
16. S. Kumar, T.H. Lai and J. Balogh. "On K-coverage in a Mostly Sleeping Sensor Network". 10th Annual International Conference on Mobile Computing and Networking (MobiCom'04), Philadelphia, USA, Sep-Oct, 2004, pp. 144-158.
17. O. Rahman, A. Razzaque and C. S. Hong. "Probabilistic Sensor Deployment in Wireless Sensor Network: A New Approach". 9th International Conference on Advanced Communication Technology (ICACT'07), Phoenix Park, South Korea, Feb. 2007, pp. 1419-1422.
18. O. G. Aju. "A survey of ZigBee wireless sensor network technology: Topology, Applications and challenges".

International Journal of Computer Applications, vol. 130, no.9, pp. 975-8887, Nov 2015.

19. T. W. Song and C. S. Yang. A connectivity improving mechanism for ZigBee wireless sensor networks". IEEE/IFIP International Conference on Embedded and Ubiquitous Computing, 2008.
20. S. M. Chung, K. T. Kim, J. Song and Y. Youn. "Enhancing Node Connectivity by Utilizing RSSI for ZigBee-based WSN". International Conference on Information and Communication Technology Convergence, 2016.
21. V. V Madhav and J. Nigam. "Ensuring uniform energy consumption in non-deterministic wireless sensor network to protract networks lifetime". *International Journal of Electronics and Communication Engineering*, vol. 11, no. 9, pp. 1005-1009, 2017.
22. T. Kumar, J. Davinder, S. Saini and S. V. Bhooshan. "Cluster head selection in a homogeneous wireless sensor network ensuring full connectivity with minimum isolated nodes". *Hindawi Publishing Corporation Journal of Sensors*, vol. 2014, p. 8, 2014.