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Investigation on the Incorporation of Internet of Things with Wireless Sensor Networks Based on Path Vector Hop Count and Limited Bandwidth Channel IoT Mechanism †

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Abstract: A Wireless Sensor Network (WSN) consists of sensors with wireless transceivers that link autonomously over many hops. It offers various advantages, including less traffic, more stability, extended wireless communication distances, and broader coverage regions at less money. Combining emerging Limited Bandwidth Channel Internet of Things (LBC-IoT) technologies with wireless sensor networks offers interesting applications in defence, medical, smart conveyance, and marketable sectors. This study initially analyses WSN and LBC-IoT technologies independently before combining them to look into the networking framework of LBC-IoT and WSN, as well as the associated technologies resulting from the fusion. The article describes the typical network node redeployment strategy for wireless sensors, which can lead to poor node connection and inadequate coverage due to a lack of confined subgroup node exploration. The suggested method for localizing WSN nodes, based on the Hop Count Path Vector (HOP-PV) algorithm, enhances and enhances the process for calculating the average hop distance and the number of node hops resulting in the PVHOP-LBCIOT mechanism. Simulation results indicate that the improved PVHOP-LBCIOT algorithm's three deployment methods (square, central uniform, and cross) outperform the two approaches of HOP-PV (Random Deployment) and PVHOP-LBCIOT (border uniform deployment) for an equal number of unknown moving anchor positions (11), disparate number of unspecified nodes (30-13) and fixed communication radius (6), with reduced average error rate of 32.79% from 38% and improved accuracy for obtaining unknown node location. The suggested method for localizing WSN nodes using a single node acting as a mobile anchor point known as the PVHOP-LBCIOT mechanism which enhances and optimizes the process of computing the average hop distance and the number of node hops. A comparison experiment demonstrates that this hopping algorithm has much greater coverage, node power, linkage, and resilience compared to existing method.

Keywords: internet of things; wireless sensor networks; investigation; less traffic; greater coverage; redeployment; robustness

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1. Introduction

A wireless sensor network (WSN) combines integrated systems, desktops, and network interaction techniques into a single integrated circuit capable of collecting, transmitting, and processing data. Mobile operator networks provide good reach of locations. In today's advanced technology society, connectivity innovation is continually changing to increase the excellence and swiftness of data transfer while also providing basic voice call services. However, due to unequal regional installation of mobile cellular networks, low-population areas are not feasible for high-speed data transport nowadays. As a result, it is not feasible to access data in WSN directly using mobile cellular networks. Real-time monitoring involves employing small sensors, processing information with embedded microprocessors, and sending it to remote users over wireless networks. The information is then analyzed according to regulations.

1.1. Benefits of WSN Node Positioning Centered on LBC-IoT Access

LBC-IoT (Limited Bandwidth Channel Internet of Things) is a new technology that uses cellular networks to connect high-demanding and low-power devices. Additionally, it enables ultra-long downtime for implementations that need constant access to the WSN. The correct location of nodes is the most important aspect of wireless sensor networks. After a sensor node has been positioned, WSN may learn the coordinate location of each node and the position connection between nodes, giving each node the necessary conditions for data collection and transmission [1].

The following are the benefits of installing WSN nodes with IoT-LBC access:

- IoT-LBC is a public Utility network that is perfect for a variety of IoT-related applications because of its high signal propagation and low power consumption.
- The LBC-IoT main station locating capabilities may be used. The main station signal allows the network nodes of the IoT-LBC network to precisely determine their position. GPS signals are needed to improve base station placement accuracy in IoT-LBC, as 30m precision is currently not sufficient.
- The IoT-LBC network's backend processing capacity may be utilised. The first computation process may be carried out via the backend, but the calculation technique is more complicated. It involves finding a large number of unknown nodes and being prepared to send the measurements and the results of the calculations via a 4G/LTE-centred IoT-LBC network.

1.2. WSN Node Location Techniques and Algorithms

WSN node positioning techniques are divided into 2 types namely (i) Ranging technique of positioning and (ii) Non-ranging technique of Positioning [2].

- Ranging-based positioning strategies involve measuring angular data and straight-line lengths between nodes, followed by calculating undetermined node coordinates using trilateral and triangulation methods of positioning [3].
- Non-ranging technique of Positioning does not rely on node measurement of distance and may calculate undetermined node coordinates due to network connection. The center-of-mass technique, the Distance Vector calculating procedure HOP-PV, and other approaches are widely used [4].

Performance criterion for positioning systems is based on Anchor nodes which are associated with the arithmetic approach of localization. The computation procedure becomes increasingly difficult as the number of anchor node sites increases. The node uses energy that is directly connected to the zone of Coverage [5].

2. Materials and Methods

2.1. PV-HOP Algorithm for Node Location

PV-HOP (Path Vector-Hop), technique for non-ranging, is commonly used for WSN node positioning. All nodes are easily accessible to one another and identical to their neighbouring nodes; four black circles show stationary anchor points at confirmed locations; every vacant point circle in the two-dimensional area of the X and Y axes indicates an unidentified node; and the positioning calculation procedure is split into two stages [6].

1. The first stage is to calculate the minimum quantity of bars that separate each anchors point from the unknown node point.
2. The second stage is to determine the distance that lies among each anchored node and the location node.
3. The Location Marker of the other anchored nodes recorded in the database, along with a total number of hops, may be used to compute each anchored node using a mean hop separation value of 1 [7]. The expression for mean hop separation among all anchor nodes is given by Equation (1).

$$S_i = \frac{\Sigma_{j \neq i} \sqrt{(a_i - a_j)^2 + (b_i - b_j)^2}}{\Sigma_{j \neq i}\, h_{ij}} \quad (1)$$

where (a_i, b_i) and (a_j, b_j) represents the location marker of the anchored nodes with numbers corresponding to *i* and *j*, respectively.

h_{ij} symbolizes the quantity of hop divisions from anchored node from *i* to *j*.

S symbolizes the mean hop separation among all anchor nodes.

It is possible to transmit the mean hop length and calculation result to all unidentified nodes after ensuring that the nodes receive information from anchor nodes on the shortest path. The unknown node is able to calculate how far it is from the corresponding anchored node [8].

2.2. Positioning Technique for Shifting Anchored Point Multi-Position Change

The following positioning techniques are used for shifting an anchored point.

2.2.1. LBC-IoT Mobile Access Based Wireless Sensor Network

The versatility and robustness of the IoT-LBC mobile communication solution make WSN suitable for a variety of applications. The IoT-LBC admittance node serves as a mobile reference point with a simple movement rule inside the same aggregate, and the HOP-PV calculates the number of transitions to the endpoint node in the background.

2.2.2. Optimization Technique for LBCIOT-PVHOP

The number of transitions that each moving anchored point stays at various reference locations must be determined using the HOP-PV method, and the leap values may be checked among two points as shown in Equation (2) [9].

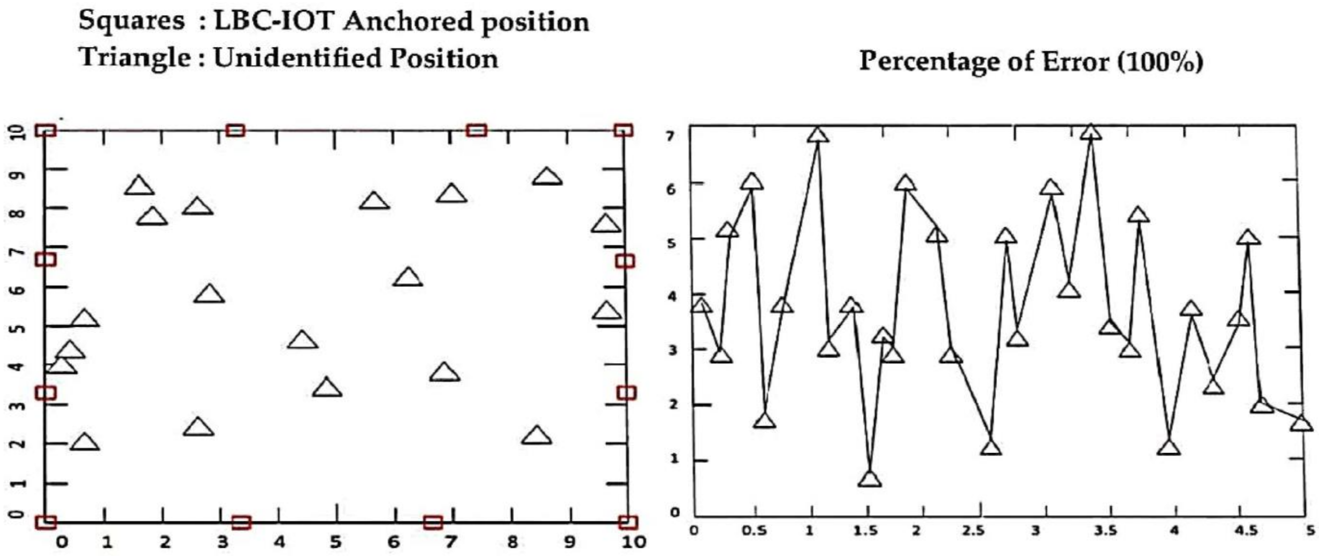
$$g = \frac{\Sigma_{j \neq i} \sqrt{(a_i - a_j)^2 + (b_i - b_j)^2}}{\Sigma_{j \neq i} \min\,(h_{ik} + h_{jk})} \quad (2)$$

The number of transitions from any location on the k node to the anchored points *i* and *j*, respectively, is represented by the formula's variables h_{ik} and h_{jk}. The reference value for the number of transitions among two anchored positions are determined by taking the lowest value of the sum of transitions from every position of nodes to two anchor locations [10-16].

3. Results and Discussion

3.1. Simulation Results

With the side length of the square set to 10 m, 40 static nodes are arbitrarily placed inside a square using the MATLAB 2015 software. Starting at point 1 (0, 0), one mobile node approaches this cluster and proceeds to the following positions as planned: 2 (3.2, 0), 3 (6.5, 0), 4 (10, 0), 5 (10, 3.5), 6 (10, 6.7), 7 (10, 10), 8 (6.7, 10), 9 (3.3, 10), 10 (0, 10), 11 (0, 6.7), and 12 (0, 3.2). With a beginning node transmission radius R of 6 m, the 12 (0, 3.2) procedure sends the shortest path, the least one-node hop and registers the single or multi-transition content when every node remain at each place as shown in Figures 1 and 2.



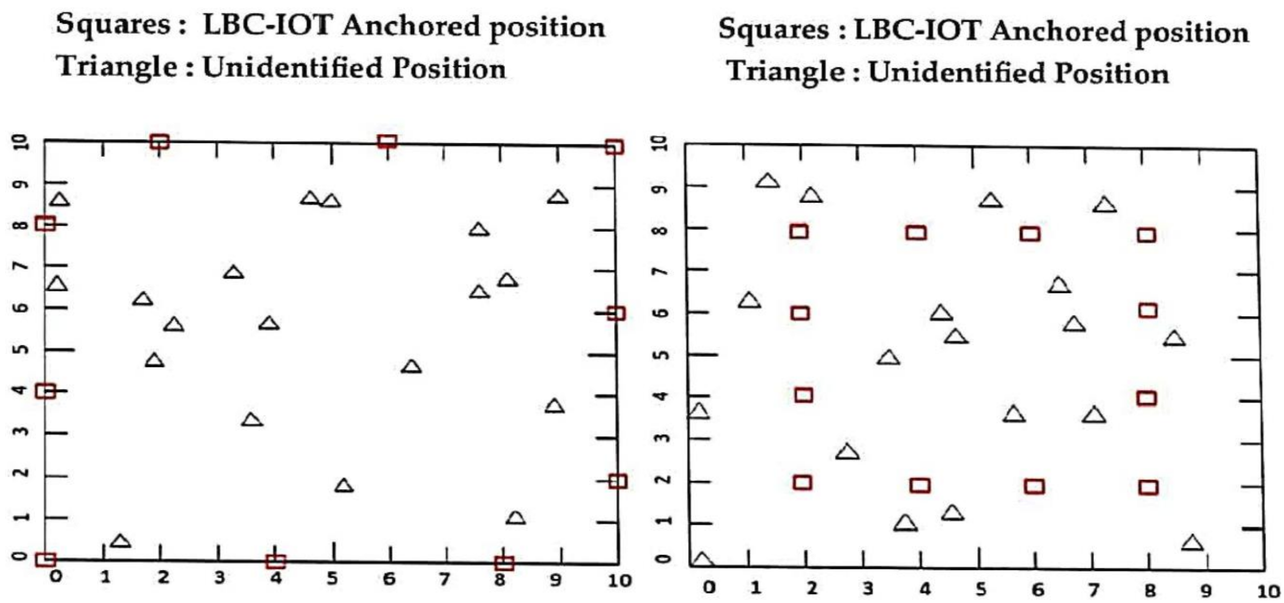
(**a**) (**b**)

Figure 1. (**a**) MATLAB simulation to calculate the distribution of anchor point locations and unknown node locations. (**b**) Error rate of the results of the unknown node position calculation by MATLAB.

The IoT-LBC mobile cluster's initial localization is shown by □ in the schematic diagram, while the location of the localized node that has to be identified is indicated by Δ.

3.2. Effect of the Quantity of Unexplored Nodes on the Results

The number of sites where IoT-LBC anchor nodes may be found influences the complexity of the calculation procedure as well as the time it takes to do the position calculation.



(**a**) (**b**)

Figure 2. (**a**) The schematic distribution of ten movable anchored position nodes (MATLAB simulation) (**b**) To determine the twelve shifting anchor locations in accordance with the square deployment design (simulation).

From the above Table 1, it is observed that increase in the anchored point displacement count, lowers the average error rate.

Table 1. Changing the number of anchored places and its impact on the mean error rate.

Anchored Point Displacement Count	Error Rate (Average) %
2	41.3
4	38.75
6	36.83
8	34.6
10	33.05
11	32.79

3.3. The Impact of Allocation Rules of the Anchored Position on the Outcomes

The placement of IoT-LBC anchor nodes follows specific regulations, and the dispersion of anchor sites affects the results produced. This work compares and analyses experimental results using four deployment methods: square method, border uniform method, Centre uniform method, and cross method. The findings are displayed in Figure 3.

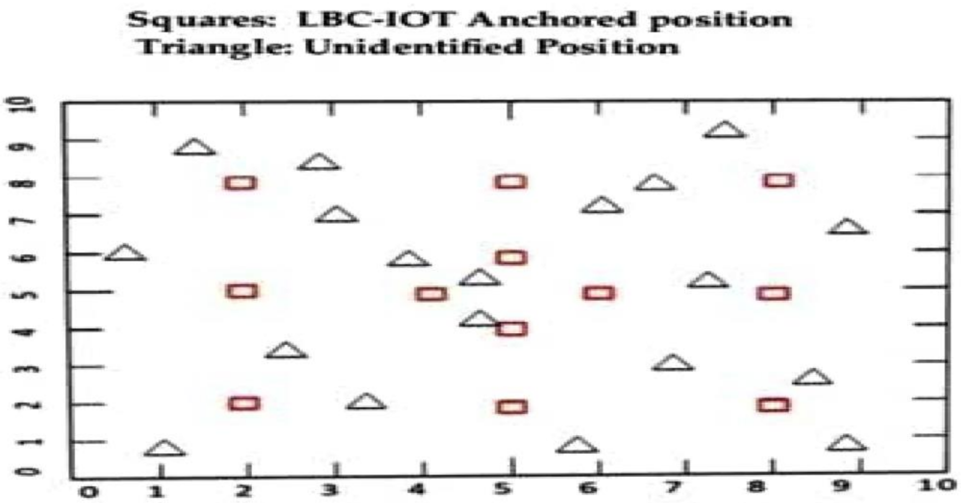


Figure 3. Twelve movable anchor locations are determined (MATLAB simulation) in accordance with a consistent deployment design.

The Simulation results indicate that our improved PVHOP-LBCIOT algorithm's three deployment methods (square, central uniform, and cross) outperform the two approaches of HOP-PV (random deployment) as well as PVHOP-LBCIOT (border uniform deployment) for an equal number of unknown moving anchor positions (12), Constant Communication range (6), and unequal number of unidentified nodes (31-13) with reduced average error rate of 32.79%. Additionally, the obtained unidentified node location's accuracy is increased. The findings are shown in Figure 4.

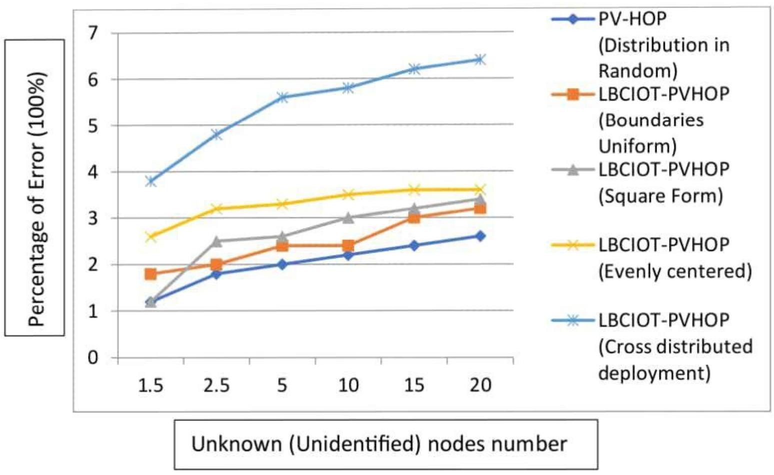


Figure 4. Comparing the impact of various anchor point relocation techniques on the error rate.

3.4. Evaluation Analysis

The PVHOP-LBCIOT analytical technique utilizes LBC-IoT's self-positioning and background calculation capabilities, as well as deployment optimization to calculate unknown node locations. A comparison to the original PV-HOP method shows significant error reduction. The PVHOP-LBCIOT enhancement algorithm improves both hop distance and hop number using approaches developed in related research. Simulation experiments are performed using the MATLAB platform and the standard moving anchored position deployment approach demonstrate a significant reduction in average positioning error rates, indicating the efficiency of the modified methodology.

4. Conclusions

The deployment of network units for sensors that are wireless has advanced significantly as a result of networks' rapid growth. Traditional methods, however, are not very effective in big quantities and have a restricted covering area. This article integrates IoT-LBC technology and WSN which focuses on the IoT-LBC-based WSN topology and associated information integration approaches. The proposed WSN node localization technique, based on the Hop Count Path Vector (HOP-PV) algorithm, enhances the process for calculating the mean hop separation and the number of node hops, resulting in the PVHOP-LBCIOT mechanism. The result of a comparative experiment shows that this hopping algorithm outperforms the old technique in terms of reach, power of the node, connection, and endurance. This work provides fresh perspectives on node redeployment techniques for wireless sensor networks, stimulates further in-depth examination of research findings, and provides a strong framework for specialists and scientists to carry out further research in this field.

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