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An adaptive ensemble localization approach for sensor nodes in WSN-IoT

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Abstract

Localization is an essential module for most protocols and applications in Wireless Sensor Networks - Internet of Things (WSN-IoT). Among the well-known approaches available for WSN-IoT localization, the algorithm requires at least one, two, or three beacon nodes-based localization approaches. Many other localization protocols use a small set of beacon nodes for the localization of sensor nodes. However, still, the authors are not able to provide an accurate and reliable approach in the field of WSN-IoT. Thus, this work provides an adaptive ensemble localization approach in WSN-IoT. The proposed approach adaptively uses the concept of available single, two, and three beacons nodes-based localization approaches according to the number of available beacon nodes. By comparing available single, two, or three beacons nodes-based localization approaches the simulation results of the proposed work outperformed in terms of fast convergence rate, less erroneous and higher accuracy with reducing the line of sight problem.

Keywords: WSN-IoT, Range Based, Beacon Node, Localization Accuracy, Convergence Rate, Location Error.

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1. Introduction

In the modern era, the use of IoT led to the creation of smart systems. For the less involvement of humans, the IoT system provides machine-to-machine communication [1][2] facilities. On the other hand, the WSN system performs an essential role in places to collect information. The system is designed for remote area applications where humans have rare physical access. The IoT-based WSN system creates an autonomous smart system for efficiently monitoring the remote area [3][4]. Further assessment of the WSN-IoT-based system involves a variety of continuous information from different sources. It integrates sequentially with the framework of various sensor information processing systems to monitor the executive structures, so the possible areas from remote locations can are achieved [5][6].

Sensor nodes in WSN-IoT can provide a collection of real-time data with timestamps and their location information anywhere and anytime. Data is unusable in a system without a known location, so the localization of the sensor node is an essential issue for WSN-IoT. Thus, localization poses a significant challenge for WSN-IoT. The localization approaches are classified into two parts, according to range-based localization and range-free localization approaches [7][8]. The range-based location estimation is much precise compared to range free based location estimation in WSN localization [9]. The range-based approaches, for example, as trilateration, triangulation, and multilateration [10]. The range free based [11] approaches, for example, DV-Hop, improved DV-Hop, centroid, Approximate Point-In-Triangulation (APIT). This work provides the critical analysis of currently available work of range-based approaches such as three beacons, two beacons, and one beacon-based approach for localization in WSN. In the presently available localization works are analysis based on the network parameters such as:

- Network density:
  The total number of beacon nodes are deployed to sensor nodes localization.
- Computation overhead: It analyzes the total number of packets processed for the of sensor nodes localization

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in the network.

- Energy consumption:
  The total amount of energy consumption is required to estimate the sensor node location with higher accuracy,
- Position error:
  The position error is an error, i.e., taken from neighbor reference node for estimation of its sensor node location. If more erroneous reference nodes are involved in the estimate of sensor node location, then less accuracy is achieved by the localization algorithm.
- Response time:
  The response time is referred to as the convergence rate, which means how much time is taken to meet the target value of networking.
- Localization Accuracy:
  The error value difference between the actual position and estimated location of sensor nodes is to define how much accuracy is received by the localization algorithm. If lower mean error, then higher location accuracy and higher mean error, then lower localization accuracy.
- Convergence rate:
  The total number of elapsed time to localized randomly deployed sensor nodes in the networks.

After the critical analysis of existing works in which, most of the researchers focus on localization with a minimum number of beacon nodes or the best selection of beacon nodes, but the least number of researchers are concerned about efficient utilization of available well-known localization approaches in the field of beacon-based localization for the randomly deployed sensor nodes. In randomly deployed sensor nodes scenario, when the sensor nodes are not able to localization itself due to the unavailability of required beacon nodes. Thus, this proposed work based on available beacons-based localization to provides an efficient adaptive ensemble approach of sensor node localization in WSN-IoT. The design approach can provide an efficient adaptive change in its algorithm based upon the received signal at the reference/beacon node of the sensor nodes into the system. The based upon RSSI information received at the beacon node from the sensor nodes, then the beacon nodes will take the decision, which localization approach will be used from the single, two, or three beacons based.

The further part of this work is covered as section 2 provide the literature survey of available vital work in the field of wireless sensor node localization in WSN, section 3 provides the proposed work of ensemble adaptive sensor node localization for random sensor node deployment scenario in the form of flow chart and algorithm, section 4 presents the work analysis of the proposed ensemble adaptive localization approach with their example, section 5 presents the simulation-based analysis of proposed work and comparison analysis with the one, two and three beacon-based localization algorithms and section 6 states the conclusion of the proposed work.

2. Literature Survey

Recurrence Position Estimation (RPE) approach for localization of unknown nodes with the help of at least three beacon nodes in the WSN [12]. This work geometrical problem is solved through a non-linear regression approach and has developed a reliable approach to estimate the location of an unknown node. A designed model was presented, while the deployment of sensor nodes requiring 5% beacons of nodes. The accuracy of this approach is 90% in while estimation of the location of unknown nodes within 3% ranging distance.

An efficient Directed Position Estimation (DPE) for the WSN is constructed with the help of at least two beacon nodes [13] as shown in Figure 1. The presented known direction recursion approach to choose between two known possible solutions, and it also solved the geometric problem. The model introduced a low-density network of unknown node localization in WSN. This work reduces the requirements of three beacon nodes for the estimation of unknown nodes location. It reduces network density deployment, communication overhead, computational error, algorithm complexity, and energy depletion of a node.

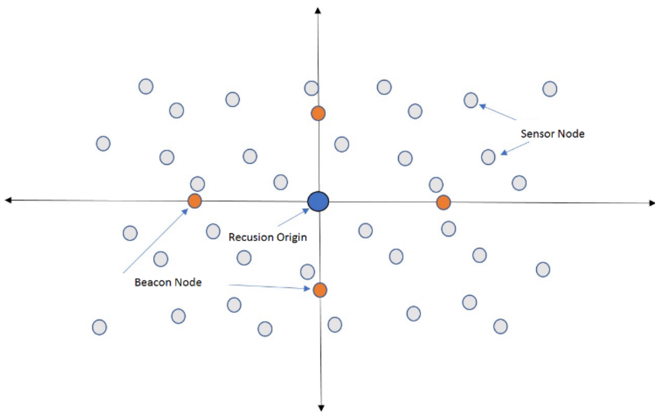
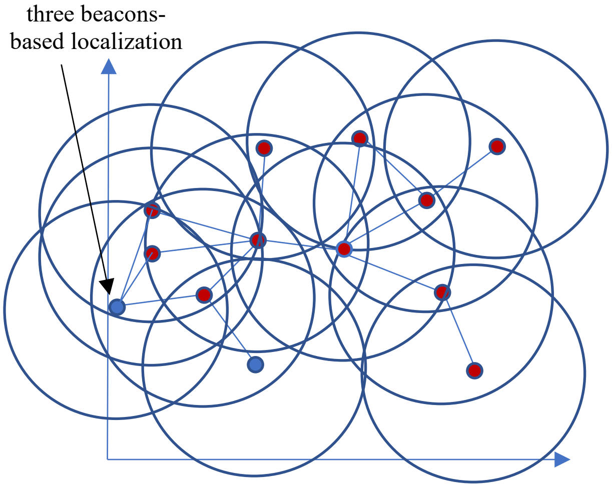


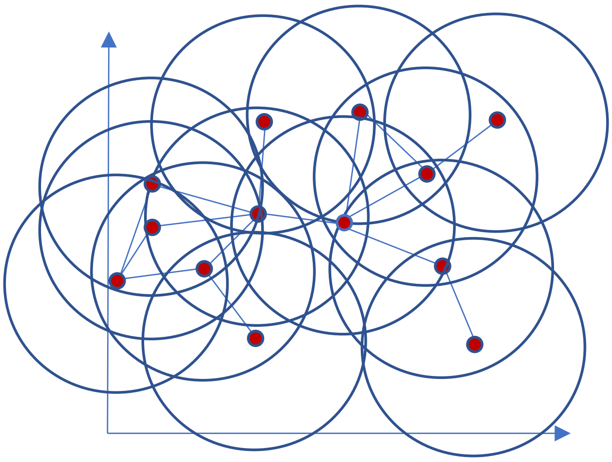
Figure 1. For directed localization recursion using beacon structure

The estimation of the unknown node location is directional through the recursion origin that leads to communication holes. Thus, this problem was solved [14] with the Non-directed Bilateral Position Estimation algorithm (NBPE) presented for WSN with communication holes. This approach for localization provides the omnidirectional (i.e., any 360 ° direction) location estimation for unknown node and also resolves communication holes such as O and C type holes that arise during the localization in WSN. The approach uses the estimation of two possible solutions and the selection of a possible solution based on a common beacon node between two beacon nodes. The NBPE work results have shown that the position error, energy depletion and response time are slightly better than DPE and RPE. The mathematical model for estimation of the two possible solutions for unknown node coordinates are (x2, y2) and (x3, y3) as shown below:

$$(x2, y2) = ((x1 + L * \cos(\alpha - 30)), (y1 + L * \sin(\alpha - 30)))$$
$$(x3, y3) = ((x1 + L * \cos(\alpha + 30)), (y1 + L * \sin(\alpha + 30)))$$



(c)



(d)

Figure 4. (a) Initial one beacon-based localization, (b) One and two beacon-based localization, (c) One and three beacon-based localization, (d) Localized sensor network

5. Simulation Results and Analysis

The performance analysis of the proposed approach is presented with a comparative analysis of single [15], two [13][14], and three [12] beacon-based localization approaches. The performance was analyzed using Matlab [23] on a PC with an Intel Core i7 processor, 3.40 GHz CPU and 4 GB of RAM.

5.1. Simulation Scenario

In the simulation configuration, the communication range of the sensor node is set at 25 m. The sensor nodes are randomly distributed over a target area of 100 x 100 m^2. The network model considered free space path loss and fading, RSSI measurement technique, and multihop propagation technique for localization of sensor nodes. The 10% standard deviation is taken to simulate noise in the distance estimation phase using the RSSI measurement technique.

5.2. Performance Evaluation Criteria

Performance evaluation of the proposed work based on localization accuracy, convergence rate, computational overhead, and energy consumption. The suggested work results are compared with single, two, and three beacon-based localization techniques.

Localization Accuracy

Localization accuracy is analyzed by measuring the error rate, i.e., the average difference between the actual coordinate value and the estimated coordinate value of the sensor nodes in the network. If the error rate is low, then high accuracy is achieved by the localization algorithm.

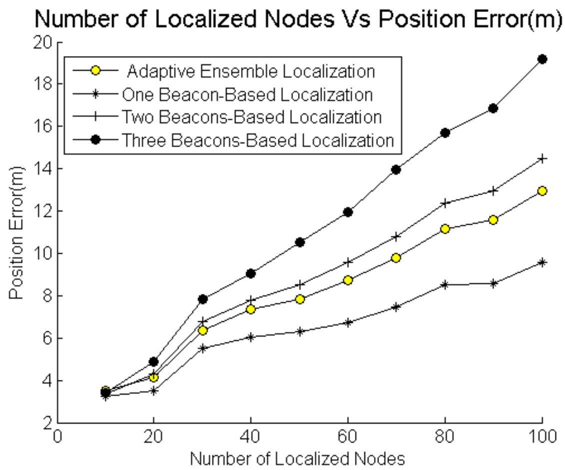


Figure 5. Number of localized nodes vs position error (meter)

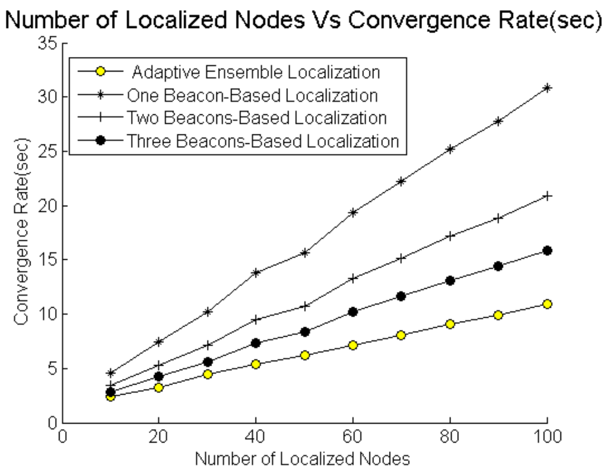


Figure 6. Number of localized nodes vs convergence rate (second)

The localization accuracy of the adaptive ensemble approach is superior to one beacon, and two based localization approaches, as shown in Figure 5. The position error may increase when the number of physical nodes interactions is increasing for sensor node localization. Therefore, the adaptive localization approach provides higher accuracy at lower convergence rates than other beacon-based localization approaches.

Convergence Rate

The total number of computation times required for localized randomly deployed sensor nodes in the network is known as the convergence rate. Figure 6 shows that the convergence rate of a very high rate compared to all localization approaches due to low overhead calculation.

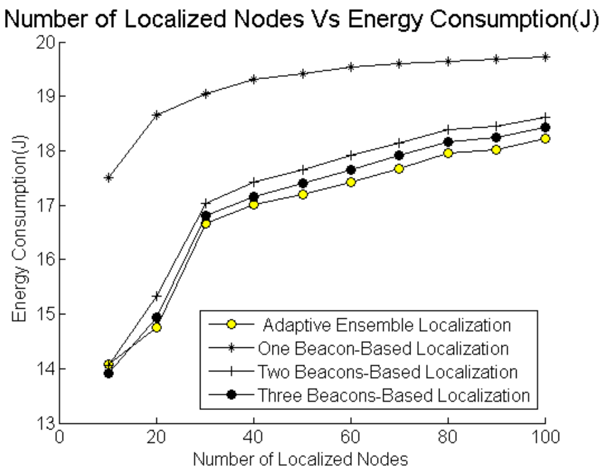


Figure 7. Number of localized nodes vs energy consumption (joule)

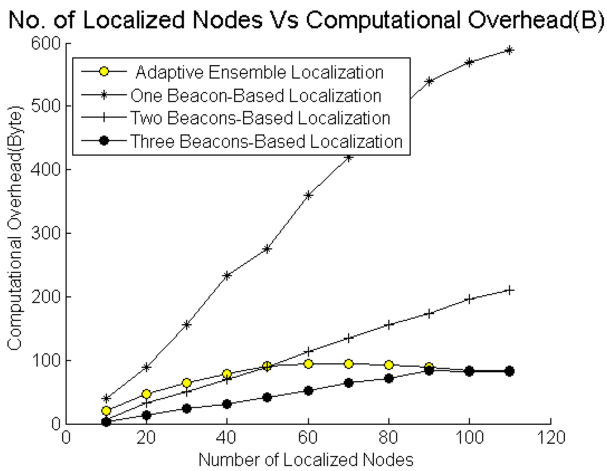


Figure 8. Number of localized nodes vs computational overhead (byte)

Energy Consumption

Total energy consumption of the sensor by the localization nodes of the localized sensor node in the network. Figure 7 shows that a beacon-based localization approach consumed a larger amount of energy than all localization approaches. The proposed approach has an adaptive nature to provide efficient use of energy resources of sensor nodes.

Computational Overhead

The total number of communication packets is processed for the localization of the sensor node in the network known as computational overhead. Figure 8 states that the computational overhead of a single anchor is higher than all localization approaches due to additional virtual node computations. The adaptive ensemble localization approach uses one, two or three beacon-based approaches according to their availability. Initially, the localization process starts with a deployed beacon node in the center of the target area, and then the localization process begins. Therefore, the initial stage of computation overhead is higher than that of two and three beacon-based localization approaches. Depend upon the number of beacon nodes availability of the two or three beacon-based localization approach is selected. The computational overhead degrades gradually at the phase of localized sensor nodes density are increased as shown in Figure 8.

6. Conclusion

Localization became a challenging task for WSN-IoT to provide efficient and reliable monitoring of real-time systems. Without the location of sensor nodes, the information gathered is of less importance. In the context of indoor applications where GPS technology is not capable of working efficiently, a range-based localization approach plays an important role. The proposed adaptive ensemble localization approach is designed for WSN-IoT using single beacons, two beacons, and three beacon-based localization approaches. The adaptive localization approach changes according to the number of available beacon sensor nodes. The simulation results and analysis section have shown that the proposed approach presenting the eminent performance over to three other approaches of sensor node localization to provide the fast convergence with higher accuracy, and it also balanced the network resources.

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