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Improved Energy-Aware Indoor WSN Localization Using Range-Based Genetic Algorithm

Satendra Ahirwal, Jitendra Singh
Department of EC
Babulal Tarabai Institute of Research & Technology, Sagar, MP, India
Satendra0601@gmail.com, jitendra.btirt@gmail.com

Abstract: This study focuses on improving energy-efficient indoor localization in Wireless Sensor Networks (WSNs) using a Range-based Genetic Algorithm (RBGA) based on Received Signal Strength Indication (RSSI). WSNs consist of a multitude of sensor nodes deployed in an area to monitor remote locations. These sensor nodes comprise various components that sense, process, and transmit data collaboratively. WSNs find applications in diverse fields, ranging from indoor to outdoor deployments, including medical health, environmental and agricultural monitoring, intelligent home automation, military operations, space exploration, and marine research. Many wireless device network applications necessitate sensor localization techniques and awareness of each node's physical location. The localization process involves utilizing range measurements and the received signal strength for precise positioning.

Ensuring both network security and energy conservation in WSNs is a challenging task. In order to address these concerns, this research investigates RSSI-based localization methods. The study is divided into two components. Firstly, exact positioning is based on the RSSI received from nodes, which leads to higher energy consumption. The distribution movement of RSSI is examined in this experiment, followed by the loss model of signal broadcast processing experimental data. Secondly, individual RSSI measurements are processed at various distances to improve localization accuracy. The RSSI range-based technique faces challenges due to its low positioning accuracy, low energy efficiency, and high error rate. The proposed RBGA is employed to overcome these issues, which optimizes the localization process by minimizing error rates and providing the most likely solution satisfying all factors.

Keywords: Wireless Sensors, Wireless Sensor Networks, Range-based, Localization Algorithms, RSSI, Error Minimization, Energy Efficient Network, Optimization, Sensor Network.

I. INTRODUCTION

The introduction discusses the development of Wireless Sensor Networks (WSNs) based on the Wireless Personal Area Network (WPAN) standard, aiming for low power consumption in various applications. Localization is a significant application, both for indoor and outdoor scenarios. Initially, indoor localization was discussed using the GSM system, achieving an error distance of 5 meters in multi-floor indoor buildings. However, GSM-based indoor localization was deemed inaccurate due to the large scale of Received Signal Strength Indication (RSSI). Later, using RSSI measurements in WSNs based on the Zigbee standard was introduced. Still, it faced challenges like a larger variety of RSSI values due to fading and shadowing effects indoors, resulting in an error of more than 2 meters. The growth of wireless communication technology enabled the development of economical and low-power sensors. The general goal is to create WSNs capable of sensing, computing, and communicating to achieve various objectives like monitoring phenomena, target tracking, forest fire detection, and battlefield surveillance. In many WSN applications, the location information of each node is essential. However, as sensor nodes are often randomly deployed, determining their physical location becomes crucial for identifying the origin of sensor readings, energy-aware geographic routing, self-organization, and self-configuration of networks.

Furthermore, in various applications, the location information itself holds significant value. Manual configuration is impractical for large-scale WSN deployments; hence, GPS receivers are unsuitable due to their line-of-sight requirement, high cost, and power consumption. As a result, various localization algorithms have been introduced, where only a limited number of sensor nodes are equipped with GPS receivers, and others derive their locations using localization techniques.

1.1 Elements of WSN

The typical WSN consists of the Sensor Node and the Network Architecture. (i) Sensor Node: A Sensor Node in a WSN comprises four basic components - Power Supply, Sensor, Processing Unit, and Communication System. The sensor collects analogue data from the physical world, converted to digital data using an Analog-to-Digital Converter (ADC). The processing unit, usually a microprocessor or microcontroller, performs intelligent data processing and manipulation. The communication system comprises a short-range radio for data transmission and reception. All components are low-power devices; a small battery powers the entire system. Despite the name, a Sensor Node encompasses more than just the sensing component; it also includes processing, communication, and storage units. The structure of a sensor node aims to reduce cost, increase flexibility, provide fault tolerance, improve development processes, and conserve energy. The sensing unit contains various sensors to measure different environmental phenomena, and the analogue signals from the sensors are converted to digital signals using the ADC.

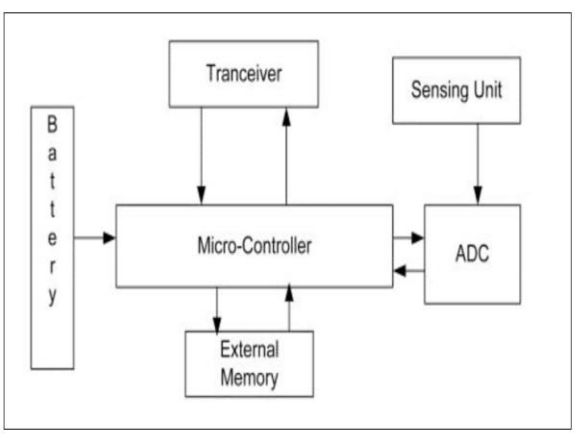

Figure 1 Structure of a sensor node

The processing unit comprises a microcontroller, storage (RAM), operating systems, and a timer. It collects and processes data from various sources, and the timer is used for sequencing tasks. The communication unit includes a transceiver with a transmitter and receiver, communicating through various network protocols using suitable methods such as radio, infrared, or optical communication. The power unit provides energy to the sensor node, and the sensor's life depends on the connected battery or power generator, aiming for efficient battery usage [4].

1.2 Network Architecture

When a large number of sensor nodes are deployed in a vast area to monitor a physical environment cooperatively, the networking of these sensor nodes becomes crucial. In a Wireless Sensor Network (WSN), a sensor node communicates with other sensor nodes and a Base Station (BS) using wireless communication.

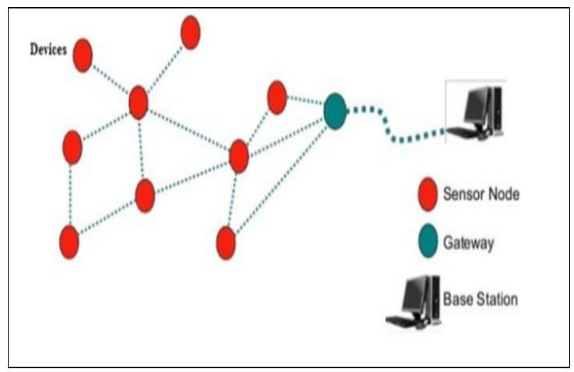

Figure 2: Wireless sensor network architecture

The base station sends commands to the sensor nodes, and the sensor nodes collaborate to perform tasks. After collecting the necessary data, the sensor nodes send the data back to the base station. The base station also acts as a gateway to other networks through the internet. Once it receives data from the sensor nodes, the base station performs simple data processing and sends the updated information to the user via the Internet [5].

1.3 Characteristics of WSN

WSNs are used to measure numerous parameters in real-world unattended physical environments. Consideration of the following characteristics is essential for the efficient deployment of the network: Low cost: in order to reduce the overall cost of the network, the cost of individual sensor nodes must be kept as low as possible, considering that hundreds or thousands of sensor nodes are typically deployed in a

WSN. Energy-efficient: Sensor nodes consume energy for computation, communication, and storage, with communication being a major energy-consuming process. Efficient protocols and algorithms should be designed to minimize power consumption to avoid sensor nodes becoming invalid due to power depletion. Computational power: Sensor nodes usually have limited computational capabilities to balance cost and energy considerations. Communication capabilities: WSNs typically communicate using radio waves over a wireless channel with short-range, narrow, and dynamic bandwidth. Communication hardware and software must consider robustness, security, and resiliency, especially in unattended and hostile operational environments. Security and privacy: Sensor nodes should have sufficient security mechanisms to prevent unauthorized access, attacks, and unintentional data damage.

Additionally, privacy mechanisms must be included to protect sensitive data. Distributed sensing and processing: In WSNs, each node is capable of collecting, processing, aggregating, and sending data to the sink or base station. This distributed sensing approach provides robustness to the system. Dynamic network topology: WSNs are dynamic networks where sensor nodes can fail due to battery exhaustion or other circumstances, and communication channels can be disrupted. The frequent changes in the network topology require nodes to have reconfiguration and self-adjustment capabilities. Self-organization: In WSNs, sensor nodes are deployed in an unknown fashion in an unattended and hostile environment. They must be able to self-organize, adjust themselves to distributed algorithms, and form the network automatically. Multi-hop communication: As many sensor nodes are deployed, communication with the sink or base station may require multiple hops through intermediate nodes in the routing path, especially if the destination is beyond the direct radio frequency range.

1.4 Localization Methods

This section discusses range-based and range-free techniques for localization:

(i) Range-Based Localization: Range-based schemes involve distance and angle estimation techniques. Important techniques used in range-based localization include Received Signal Strength Indication (RSSI), Angle of Arrival (AOA), Time Difference of Arrival (TDOA), and Time of Arrival (TOA).

a. Received Signal Strength Indication (RSSI): RSSI is a technique used to estimate the distance between a transmitter and receiver by measuring the signal strength at the receiver. The propagation loss is also calculated, and this information is converted into a distance estimation. As the distance between the transmitter and receivers increases, the power of the signal strength decreases.

II. LITERATURE SURVEY

Sangthong et al. [8]: The authors present a new method for evaluating indoor localization technology in wireless sensor networks (WSNs). They use weighting algorithms called the weight range localizer (WRL) and relative span exponential weight range localizer (RS-WRL) based on the received signal strength indicator (RSSI) to estimate the position of target nodes. The results show that this method can increase the precision of range-based localization in indoor environments. A. Kulaib et al. [9]: This paper surveys distance-based localization techniques for WSNs. They classify the techniques into distributed, distributed-centralized, or centralized categories based on their characteristics. Centralized algorithms generally produce better location estimates but consume more energy due to higher communication overhead. Distributed-centralized algorithms balance accuracy and energy consumption and are suitable for cluster-based WSNs. Jyothi N S et al. [10]: The paper discusses the importance of localization techniques in WSNs for determining the location of sensor nodes and collected data. It highlights the need for low-cost, scalable, and efficient localization mechanisms in WSNs and provides an overview of different localization techniques. Ms Sunita et al. [11]: This paper explores the application areas of sensor networks beyond military operations and surveillance. It discusses how low-cost and robust sensor nodes allow their use in various fields like environmental sensing, industrial applications, healthcare, and home automation. Sakshi Aggarwal et al. [12]: The paper emphasizes the significance of localization in WSNs, especially for critical operations like coverage, deployment, routing, target tracking, and rescue missions. It provides an overview of different localization techniques and surveys various aspects such as localization error, accuracy, energy consumption, and schemes proposed by different authors for improving localization. Sudha H. Thimmaiah et al. [13]: The authors propose an RSS-based localization technique to reduce localization errors in WSNs. They compare their proposed localization model with existing protocols and analyze its efficiency. SH. Hong et al. [14]: This paper describes a localization algorithm for building a small-sized network's position coverage system using wireless sensor networks. The proposed algorithm allows position estimation even with a few anchor nodes and utilizes RSSI and acceleration device measurements for distance estimation.

III. SIMULATION TOOL

The performance analysis in this thesis is implemented using MATLAB version (R2008a). MATLAB provides processor-optimized libraries for quick execution and computation, and the analysis is conducted on an input cancer dataset. MATLAB utilizes JIT (just-in-time) compilation technology to achieve execution speeds comparable to traditional programming languages. It also uses multi-core and desktop computers, offering several multi-threaded algebraic and numerical functions. Throughout this thesis, all data retrieval and analysis are efficiently carried out in MATLAB.

MATLAB is a high-level language and interactive environment widely used by engineers and scientists across various disciplines. It facilitates exploration, visualization, and collaboration in signal and image processing, communication, and computation of results. With MATLAB, researchers can collect, analyze, and visualize data, gaining insights in a fraction of the time it would take using spreadsheets or traditional programming languages. The results can be documented and shared through plots, reports, or printed MATLAB code.

Matrix Laboratory (MATLAB) is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB enables matrix manipulation, plotting functions, data analysis, rule implementation, and user interface construction. It also provides access to symbolic computing capabilities through the optional MuPAD symbolic engine.

For this work, MATLAB is simulated on an Intel 2.4 GHz machine running Windows 7 or Windows XP operating system. It is a high-level technical computing language and interactive environment for rule development, data visualization, record analysis, and numeric computation. The software program allows data manipulation and visualization, scientific calculations, and programming tasks, both simple and complex. Additionally, it offers support for database analysis, visualization, and rule development. The tool cabinet in MATLAB includes multi-threaded functions to leverage the power of multi-core and desktop computers. Moreover, there is an additional package, Simulink, for natural network simulations.

IV. RESULT ANALYSIS

One of the primary challenges in Wireless Sensor Networks (WSNs) is the accurate localization of sensor nodes and the high error rate in RSSI-based positioning. WSNs find applications in a wide range of fields, and their popularity is attributed to various advantages they offer, such as cost-effectiveness due to cable replacement, flexible network topologies, scalability, and lower maintenance requirements. WSNs are self-organizing networks with numerous microsensors deployed in a region for surveillance, interconnected through wireless communication. These networks have significantly contributed to communication and computer research advancements and are extensively utilized in military surveillance, medical assistance, logistical management, environmental monitoring, agriculture, and various commercial domains. In order to address these challenges and enhance performance, Genetic Algorithms (GA) are employed. GA helps achieve objectives like achieving a low error rate in sensor node localization, providing reliable output, and obtaining the best feasible solutions.

(a) Set wireless network configuration

Table 1 Set Network configuration

Description	Parameter
Network Dimension	102mX102mX102m
Number of Nodes	15,24,34
Approximate Distance	6
Approximate Angle	6

Population size	65
Maximum iteration	72

(b) Results Analysis
(1) Error Analysis based on Case 15 Node

Table 2 Error Analysis between RSSI and RBGA in Case 15 Node

Algorithm	No. of Nodes	Error (in %)
RSSI	15	6.7819
RBGA	15	5.3415

Error Analysis between RSSI and RBGA in a 15-Node Case: In the case of 15 nodes, the error analysis was conducted to compare the performance of the existing algorithm RSSI with our proposed algorithm RBGA. The results indicated that the existing RSSI algorithm had a higher error rate than our RBGA algorithm.

(ii) Result Graph for Error Analysis in a 15-Node Wireless Network:
The error analysis results for the 15-node wireless network are depicted in Figure 3. The graph clearly illustrates that the RSSI-based algorithm showed higher errors, while the RBGA algorithm demonstrated lower errors, indicating its superior performance in node localization.

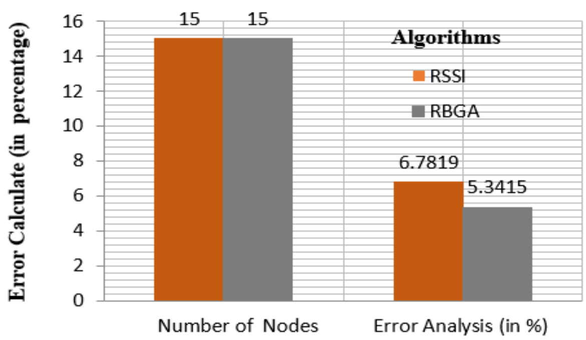

Figure 3 Error analysis based on case 15 nodes in wireless network

Table 3 Nodes position sensing time between RSSI and RBGA in Case 15 Node

Algorithm	No. of Nodes	Node Position Sensing Execution Time (in sec)
RSSI	15	0.34617
RBGA	15	3.219

Nodes Position Sensing Time Analysis between RSSI and RBGA in a 15-Node Case: For 15 nodes, a time analysis was conducted to compare the nodes' position sensing time between the existing algorithm RSSI and our proposed algorithm RBGA. The results indicated that the existing RSSI algorithm took more time for position sensing, while our RBGA algorithm required less time.

(iv) Result Graph for Time Analysis in a 15-Node Wireless Network:
The time analysis results for the 15-node wireless network are depicted in Figure 4. The graph clearly illustrates that the RSSI-based algorithm had a longer processing time, whereas the RBGA algorithm exhibited minimal processing time, highlighting its efficiency in nodes' position sensing.

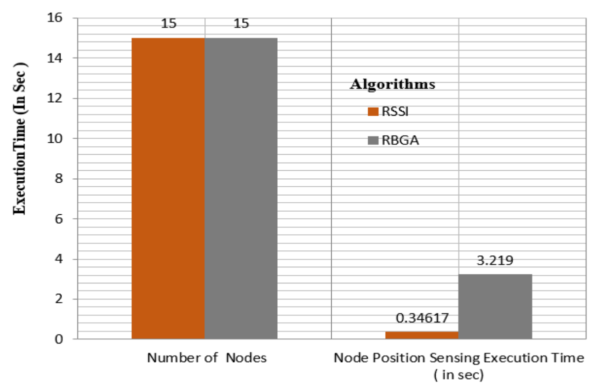

Figure 4: Time Analysis based on 15 Nodes in Wireless Network

The overall result analysis for different cases, including 15 nodes, 24 nodes, and 34 nodes, indicates that our proposed algorithm (RBGA) exhibits minimal processing time compared to the existing algorithm (RSSI). Similarly, the error analysis for these cases shows that our proposed algorithm (RBGA) has less error than the existing algorithm (RSSI). These findings demonstrate the efficiency and accuracy of RBGA in position sensing for wireless sensor networks.

Conclusion
The proposed range-based genetic algorithm (RBGA) has significantly improved energy-aware indoor localization for wireless sensor networks (WSNs). By addressing the drawbacks and issues of the existing RSSI-based methods, the RBGA efficiently increases the lifetime of sensor nodes, reduces energy

consumption, and minimizes errors in position sensing.

The RBGA optimizes the localization process by finding the optimal solution for sensor node locations using anchor nodes. Energy conservation becomes critical for sensor nodes, and the RBGA contributes to this goal. In a wireless sensor network, mobile sensor nodes self-organize to form a network with one-to-many wireless transmissions (multi-hop). The network consists of sensor nodes, sink nodes, and user nodes.

Localization in WSNs presents new challenges due to the integration of resource-limited wireless sensors on a mobile platform. While previous algorithms like WRL and RS-WRL based on RSSI localization for short-range communication showed acceptable results with higher error rates and limited accuracy in indoor localization, the proposed RBGA algorithm has demonstrated significantly improved accuracy and lower error rates for indoor localization.

The proposed RBGA algorithm has proven its efficiency, accuracy, and energy awareness in indoor localization for wireless sensor networks through experimental validation. It minimizes errors, enhances network performance, and provides more accurate position estimates, making it a valuable addition to WSNs. The results of the analysis further support the effectiveness of our proposed RBGA algorithm.

References

[1]. Mao, G., Fidan, B., & Anderson, B. D. O. (2007). Wireless sensor network localization techniques. Computer Networks: The International Journal of Computer and Telecommunication Networking, 51(10), 1389-1286.

[2]. Shang, Y. (2004). Localization from connectivity in the sensor network. IEEE Transactions on Parallel and Distributed Systems, 15(11), 961-974.

[3]. Hightower, J., & Borriello, G. (2001). Location systems for ubiquitous computing. Computer, 34(8), 57-66.

[4]. Veljo, O., Alex, V., & Anthony, L. (2005). Accurate GSM indoor localization. UbiComp 2005, 141-158.

[5]. Masashi, S. (2006). Indoor localization system using RSSI measurement for wireless sensor network based on Zigbee standard. Target, 538, 050.

[6]. Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cyirci, E. (2002). Wireless sensor networks: A survey. Computer Networks, 38(4), 393-422.

[7]. Bulusu, N., Heidemann, J., & Estrin, D. (2000). GPS-less low-cost outdoor localization for very small devices. IEEE Personal Communications, 7(5), 28-34.

[8]. Sangthong, J., Thongkam, J., & Promwong, S. (2020). Indoor wireless sensor network localization using RSSI-based weighting algorithm method. In 2020 6th International Conference on Engineering, Applied Sciences and Technology (ICEAST) (pp. 1-4). IEEE.

[9]. Kulaib, A., Shubair, R., Al-Qutayri, M., & Ng, J. W. (2011). An overview of localization techniques for wireless sensor networks. In Innovations in Information Technology (IIT), International Conference on (pp. 167-172). IEEE.

[10]. Jyothi, N. S., & Mundada, M. R. (2015). Localization technique for wireless sensor networks. International Journal of Engineering and Technical Research (IJETR), 3(1).

[11]. Ms. Sunita, Malik, J., & Mor, S. (2012). A comprehensive study of applications of the wireless sensor network. International Journal of Advanced Research in Computer Science and Software Engineering, 2(11).

[12]. Aggarwal, S., & Gupta, V. (2016). Localization in wireless sensor networks. International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), 5(5).

[13]. Thimmaiah, S. H., & Mahadevan, G. (2016). An adaptive localization error minimization approach for wireless sensor network. IEEE.

[14]. Hong, S. H., Kim, B. K., & Eom, D. S. (2009). Localization algorithm in wireless sensor networks with network mobility. Manuscript received September 20, IEEE.

[15]. Chiang, D., Lin, C., & Chen, M. (2011). The adaptive approach for storage assignment by mining warehouse management system data for

distribution centres. Enterprise Inf. Syst., 5(2), 219-234.

[16]. Bandyopadhyay, D., & Sen, J. (2011). Internet of Things: Applications and challenges in technology and standardization. Wireless Personal Communications, 58(1), 49-69.

[17]. Tan, L., & Wang, N. (2010). Future internet: The internet of things. In 2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE) (Vol. 5, pp. V5-376). IEEE.

[18]. Heinzelman, W. B., Chandrakasan, A. P., & Balakrishnan, H. (2002). An application-specific protocol architecture for wireless microsensor networks. IEEE Transactions on Wireless Communications, 1(4), 660-670.

[19]. Kongluan, L. (2011). Improving the energy efficiency of LTE networks by applying genetic algorithms. In IEEE Ninth International Conference on Dependable, Automatic and Secure Computing (pp. 593-597).

[20]. Namvar, G. O., & Vikram, K. (2010). Coalition formation for bearings-only localization in sensor networks-A cooperative game approach. IEEE Transactions on Signal Processing, 58(8), 4322-4338.

[21]. Li, B., Li, H. X., Wang, W. J., Yin, Q. Y., & Liu, H. (2013). Performance analysis and optimization for energy-efficient cooperative transmission in the random wireless sensor network. IEEE Transactions on Wireless Communications, 13(9), 4647-4657.

[22]. Tomic, S., Beko, M., & Dinis, R. (2017). 3-D target localization in wireless sensor networks using RSS and AoA measurements. IEEE Transactions on Vehicular Technology, 66(4), 3197-3210.

[23]. Tomic, S., Marikj, M., Beko, M., Dinis, R., & Orfao, N. (2015). Hybrid RSS-AoA technique for 3-D node localization in wireless sensor networks. In Proc. Int. Wireless Commun. Mobile Comput. Conf. (IWCMC) (pp. 1277-1282).