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A Review of Range-based RSSI Algorithms for Indoor Wireless Sensor Network Localization

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Abstract: The secure localisation of unknown nodes in Wireless Sensor Networks (WSNs) is a crucial research topic due to the vast range of applications of WSNs. These applications drive the development of WSNs, as real-world obstacles typically motivate them. WSN technology is rapidly evolving, and this paper provides a brief overview of WSNs, including key research findings on energy conservation and node deployment. The paper discusses the applications of WSNs in medical health, environment and agriculture, intelligent home furnishing and construction, and military, space, and marine exploration. The paper focuses on the research of RSS-based locating algorithms in WSNs and is divided into two sections. Firstly, accurate location depends on the accurate RSSI received from nodes. This experiment analyses the distribution trend of RSSI and derives the loss model of signal propagation by processing experimental data. Secondly, Gaussian fitting calculates the distance between receiving and sending nodes by processing individual RSSI at different distances. The primary challenge in studying this RSSI range-based technique is the low positioning accuracy, low energy, and high error rate. To solve this problem, a recommended GA is used to find the optimal site by minimising error, providing the best feasible solution, and being energy-sensitive, with accuracy based on the least error inside the network. The proposed approach aims to optimise sensor placements for improved performance.

Keywords: Wireless Sensors, Wireless Sensor Networks, Range-based, Localization Algorithms, RSSI, Error Minimization

I. Introduction

In the field of short-range communications, Wireless Sensor Networks (WSN) have been developed based on the Wireless Personal Area Network (WPAN) standard to utilise sensors in various applications with low power consumption. One of the important applications of WSN is localisation, which includes both wireless indoor and outdoor scenarios. Currently, indoor localisation has been discussed using the Global System for Mobile Communications (GSM) system, achieving an accuracy error of a distance of 5 meters in multi-floor indoor buildings. The key idea of localisation is the use of received signal-strength fingerprints. However, the discussion claimed that GSM-based indoor localisation is inaccurate due to the large scale of RSSI. In the later years, using the RSSI measurement of WSN based on the Zigbee standard was introduced. The result showed that the RSSI has a larger variety due to the harmful effects of fading or shadowing indoors, resulting in an error of more than 2 meters, which is unacceptable.

Wireless communication technology has enabled the growth of comparatively economical and low-power sensors, and the general goal is to make WSN capable of sensing the surroundings, computing some tasks, and communicating with each other to attain objectives such as monitoring phenomena, target tracking, forest fire detection, and battlefield surveillance [1]. In most applications, location information for each node in the network is necessary. However, sensor nodes are often deployed randomly throughout a region, which makes finding their physical location a crucial problem in WSN operations. This is important for identifying the origin of sensor readings, enabling energy-aware geographic routing, facilitating self-organisation and self-configuration of networks, and providing location information in various applications. Manual configuration is an easy but impractical solution for large-scale deployment. Sensor node location information is crucial for many reasons, as sensed data often has no value without it. Location information is used in routing protocols, algorithms, and services. Equipping nodes with GPS receivers is unsuitable due to GPS's cost, power consumption, and the requirement for line-of-sight to GPS satellites. As a result, various localisation algorithms have been introduced for randomly deployed sensor networks. Only a few sensor nodes are equipped with GPS receivers, and other sensor nodes derive their locations using localisation techniques [2].

1.1 Elements of WSN

A typical wireless sensor network can be divided into two main elements: Sensor Node and Network Architecture. A Sensor Node in a WSN consists of four basic components: Power Supply, Sensor, Processing Unit, and Communication System.

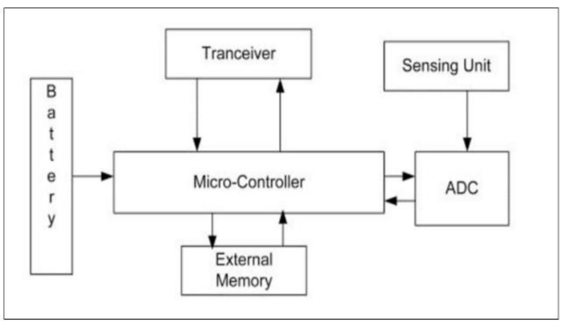

Figure 1. Structure of a sensor node

The sensor collects analogue data from the physical world, which is then converted to digital data by an ADC. The main processing unit, usually a microprocessor or a microcontroller, performs intelligent data processing and manipulation. The communication system consists of a short-range radio for data transmission and reception. Since all components are low-power devices, a small battery powers the entire system. Despite its name, a Sensor Node comprises the sensing component and other important features like processing, communication, and storage units. With all these features, components, and enhancements, a Sensor Node is responsible for physical world data collection, network analysis, data correlation, and fusion of data from other sensors with its own data. It is dynamic and can consist of various types of sensor nodes. The environment is heterogeneous in terms of both hardware and software. The construction of the sensor node focuses on reducing cost, increasing flexibility, providing fault tolerance, improving the development process, and conserving energy. The structure of the sensor node consists of a sensing unit (sensor and analogue-to-digital converter), a processing unit (processor and storage), a communication unit (transceiver), and a power supply unit. The major blocks are shown in Figure 1, and a concise description of different units is as follows [3]. The sensing unit is comprised of a collection of various sensors that are necessary for measuring different physical phenomena in the environment. The sensors are carefully selected based on their intended application. The sensor's output is an analogue electric signal, which is then converted to digital using an analogue-to-digital converter (ADC) to communicate with the microcontroller. The processing unit includes a microcontroller, RAM for storage, an operating system, and a timer. Its responsibilities include collecting data from various sources, processing it, and storing it. The timer is used to sequence events in a predetermined order. The communication unit uses a transceiver with a transmitter and receiver to communicate through channels using a network protocol. Suitable methods such as radio, infrared, or optical communication are used depending on the application requirements and relevance. The power unit is responsible for providing energy to the sensor node for monitoring the environment at a low cost and in less time. The sensor's life depends on the battery or power generator connected to the power unit. The power unit is essential for efficiently using the battery [4].

1.2 Network Architecture

The networking of sensor nodes is of great importance when many nodes are deployed in a vast area to monitor a physical environment cooperatively. In a Wireless Sensor Network (WSN), a sensor node communicates with other sensor nodes and a Base Station (BS) using wireless communication. The base station sends commands to the sensor nodes, and the sensor nodes collaborate to perform the required tasks. Once the necessary data is collected, the sensor nodes return it to the base station. Additionally, a base station serves as a gateway to other networks via the Internet. After receiving data from the sensor nodes, the base station performs simple data processing and transmits the updated information to the user via the Internet [5].

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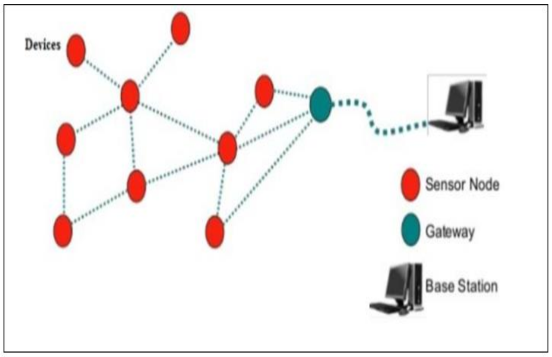

Figure 2 Wireless sensor network architecture

1.3 Characteristics of WSN

Wireless Sensor Networks (WSN) are currently utilised to measure various parameters in real-world unattended physical environments. Therefore, it is crucial to consider the characteristics of WSNs to deploy the network efficiently. The significant characteristics of WSNs are outlined below. Low cost is essential in WSN since hundreds or thousands of sensor nodes are typically deployed to measure any physical environment. In order to reduce the overall cost of the network, the cost of each sensor node must be kept as low as possible. Energy efficiency is another vital factor in WSN, as energy is utilised for different purposes, such as computation, communication, and storage. Sensor nodes consume more energy than any other component for communication, and if they run out of power, they often become invalid. Therefore, the protocols and algorithm development must consider power consumption during the design phase. Computational power is typically limited in WSN nodes, as cost and energy must be considered. Communication capabilities in WSNs typically use radio waves over a wireless channel. Communication occurs in a short range, with narrow and dynamic bandwidth. The communication channel can be either bidirectional or unidirectional. Due to the unattended and hostile operational environment, running WSN smoothly is challenging. Therefore, the hardware and software for communication must consider robustness, security, and resiliency. The security and privacy of each sensor node in a WSN (wireless sensor network) is crucial. It is essential to have adequate security mechanisms to prevent unauthorised access, attacks, and unintentional damage to the information stored within the sensor node. Privacy mechanisms should also be included to ensure that sensitive data remains secure. Distributed sensing and processing are vital aspects of WSNs. With many sensor nodes deployed, they are distributed uniformly or randomly throughout the network. Each node can collect, sort, process, aggregate, and send data to the sink. This distributed sensing provides robustness to the system, allowing it to function efficiently even if a few nodes fail. WSNs are dynamic networks, and the network topology changes frequently. Sensor nodes can fail due to battery exhaustion or other circumstances, communication channels can be disrupted, and additional sensor nodes may be added to the network. In order to address these issues, WSN nodes must be embedded with the function of reconfiguration and self-adjustment to adapt to these changes. Self-organisation is another essential aspect of WSNs. Sensor nodes in the network must be able to organise themselves as they are deployed in an unknown and hostile environment. They must collaborate to adjust to the distributed algorithm and automatically form the network. Finally, multi-hop communication is feasible with the sinker or base station, given that many sensor nodes are deployed in WSNs. In this approach, an intermediate node helps to establish a routing path to communicate with the sink or base station. If a node needs to communicate with another node or base station beyond its radio frequency, it must use the multi-hop route by an intermediate node.

1.4 Localisation Methods

This section delves deeply into range-based and range-free techniques used for localisation. Range-based localisation schemes utilise distance estimation and angle estimation methods. Some important techniques used in range-based localisation include received signal strength indication (RSSI), angle of arrival (AOA), time difference of arrival (TDOA), and time of arrival (TOA). Among these, RSSI is a technique where the distance between the transmitter and receiver is estimated by measuring the signal strength at the receiver. Propagation loss is also calculated and converted into distance estimation. As the distance between the transmitter and receiver increases, the power of the signal strength decreases.

II. Literature Survey

Sangthong et al. [8] have proposed a method to evaluate wireless sensor network (WSN) technology for indoor localisation. Nowadays, achieving accurate indoor positioning in wireless networks can offer a plethora of interesting services and applications. However, several factors in the indoor environment can lead to imprecise localisation and increased distance error. To estimate the position of a target node, the authors have employed two weighting algorithms, namely the weight range localiser (WRL) and relative span exponential weight range localiser (RS-WRL), based on the received signal strength indicator (RSSI). The results have shown that the cumulative distribution function (CDF) probability accurately indicates the distance error, thereby increasing the precision of range-based localisation in indoor environments. In their study, A. Kulaib et al. [9] have comprehensively reviewed distance-based localisation techniques for Wireless Sensor Networks (WSNs). The authors have selected and presented ten representative distance-based localisation algorithms with diverse characteristics and methods, given the vast number of published algorithms. The localisation techniques are classified into distributed, distributed-centralised, or centralised based on a tiered classification mechanism outlined by the authors. Centralised localisation algorithms generally produce better location estimates than distributed and distributed-centralised algorithms. However, the energy consumption in centralised algorithms is much higher due to high communication overheads for packet transmission to the base station. Distributed-centralised localisation algorithms are often used in cluster-based WSNs as they produce more accurate location estimates than distributed algorithms without significantly increasing energy consumption or sacrificing scalability. The localisation of sensor nodes is a crucial aspect of WSNs. This paper provides an overview of major localisation techniques, including centralised and distributed approaches, while highlighting the factors that must be considered when selecting a localisation technique. Additionally, the authors discuss the advantages and limitations of various techniques and highlight future research directions and challenges in this field. Jyothi N S et al. [10] highlight the significance of localisation techniques in wireless sensor networks (WSNs) as they play a vital role in determining the location of sensor nodes that collect and forward data to the destination. The authors discuss the importance of designing low-cost, scalable, and efficient localisation mechanisms for WSNs as it is an interesting research area with numerous works being done so far. The paper elaborates on sensor node architecture, applications, and localisation techniques. Sunita et al. [11] emphasise that while sensor networks were initially deployed for military operations and surveillance, they have become a potential solution for other fields such as environmental sensing, industrial sensing, health, and home applications. The authors have studied the various application areas of sensor networks. The low-cost small sensor nodes and the robustness of the network make it an ideal solution for numerous fields. Sakshi Aggarwal et al. [12] emphasise the significance of localisation in wireless sensor networks (WSNs), particularly in critical operations such as coverage, deployment, routing, target tracking, and rescue operations. The accuracy of the sensor nodes is crucial for providing the best solution with accurate results. This paper provides an overview of different approaches to node localisation discovery in WSNs, including a survey of various aspects or techniques of localisation, such as localisation error, localisation parameters, accuracy, bit error probability, and energy consumption. The authors also highlight various schemes proposed by different authors to improve localisation in WSNs. Sudha H. Thimmaiah et al. [13] proposed wireless sensor-based communication systems are an ever-growing sector in the communication industry. A wireless infrastructure is a network that enables correspondence between various devices associated with an infrastructure protocol. Localising the position or location of sensor nodes is essential in a sensor network for providing efficient service to the end user. The existing techniques proposed so far suffer from estimating the likelihood of localisation error. The authors propose an RSS (Received Signal Strength) based localisation technique and adaptive information estimation to reduce or approximate the localisation error in a wireless sensor network to address this issue. The authors compare our proposed localisation model with existing protocols and analyse its efficiency. Hong et al. [14] describe a localisation algorithm for building a small-sized network's position coverage system using a wireless device network. In existing device networks, much of the localisation algorithm is dedicated to creating position estimations by learning at least three position values of anchor nodes aware of absolute position value under the setting where device nodes are mounted. The proposed algorithm has an indefinite travelling direction and has shown, in performance analysis, that it's possible to estimate positions even with a small number of anchors. Also, using the implemented board, usefulness has been tested with the implementation of realistic distance measurements through distance measurement using RSSI (Received Signal Strength Indication) and travelling distance measurement using acceleration devices.

III. Expect Outcome

The inability to accurately sense node positions and the increased error rate in RSSI are fundamental issues in the field of WSN. WSNs have a wide range of applications, and many monitoring applications rely on them due to their benefits, such as cheaper costs, flexible network topologies, scalability, and lower maintenance. A Wireless Sensor Network (WSN) is a self-organised network comprising many microsensors randomly deployed for regional surveillance via wireless communication. WSNs have advanced communication and computer research and are widely used in military surveillance, medical aid, logistics management, environmental monitoring, agriculture, and other commercial domains. One approach to improving performance in WSNs is to use GA to solve problems, such as reducing the error rate in sensor positions, producing dependable output, and obtaining the best possible solution.

Conclusion

The objective of a wireless sensor network is to enable the detection, processing, and transmission of monitoring information for objects within the network's coverage area. A wireless sensor network comprises many static or mobile sensor nodes that form a self-organising network using multi-hop wireless transmissions. These sensor networks have three components: sensor nodes, sink nodes, and user nodes. In this study, we investigated location technology based on received signal strength indicators (RSSI) in WSNs. A large amount of experimental data is required to obtain an accurate RSSI value that can replicate the real experimental environment. We determined the parameters of the shadowing model and analysed the RSSI value at a given distance using Gaussian fitting during the localisation process. Moreover, we developed an RSSI-based interpolation model of the node and investigated the effect of the number of nodes. The proposed algorithms were validated using an empirical model, which produced an acceptable result with a higher error rate in indoor localisation. As a result, the proposed GA algorithm for range-based localisation in this study can estimate positions with greater precision. Our approach minimises error, provides the best possible result, and is energy-efficient.

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