International Journal of Advanced Computer Technology
ISSN: 2319-7900 www.ijact.org Volume-X, Issue-VI, December 2020

Enhanced Performance Cooperative Localization Wireless Sensor Networks Based on Received-Signal-Strength Method and ACLM

Pavan Bharti[1], Ashutosh Gupta[2]
Department of EC, KNPCST, RGPV, Bhopal, M.P., India

Abstract - There has been a rise in research interest in wireless sensor networks (WSNs) due to the potential for his or her widespread use in many various areas like home automation, security, environmental monitoring, and lots more. Wireless sensor network (WSN) localization is a very important and fundamental problem that has received a great deal of attention from the WSN research community. Determining the relative coordinate of sensor nodes within the network adds way more aiming to sense data. The research community is extremely rich in proposals to deal with this challenge in WSN. This paper explores the varied techniques proposed to deal with the acquisition of location information in WSN. In the study of the research paper finding the performance in WSN and those techniques supported the energy consumption in mobile nodes in WSN, needed to implement the technique and localization accuracy (error rate) and discuss some open issues for future research. The thought behind Internet of things is that the interconnection of the Internet-enabled things or devices to every other and human to realize some common goals. WSN localization is a lively research area with tons of proposals in terms of algorithms and techniques. Centralized localization techniques estimate every sensor node's situation on a network from a central Base Station, finding absolute or relative coordinates (positioning) with or without a reference node, usually called the anchor (beacon) node. Our proposed method minimization error rate and finding the absolute position of nodes.

Keywords: Wireless sensor network, sensor nodes, localization algorithm, range-based, Received-Signal-Strength Method, range-free algorithm.

I. Introduction

In WSNs, there are often some GPS-enabled mobile nodes, called seeds, which may offer location information needed by other mobile nodes. But the number of seeds can't be too many thanks to economic reasons. In some earlier localization researches, seed information is flooded to the entire network. Still, this is often not efficient in mobile WSNs, because communication cost is just too high. After an extended propagation, the knowledge could also be out of Date or suffer from accumulated errors. Thus, we propose a unique localization approach, called Dynamic Reference Localization (DRL), which improves the DV-hop approach by deploying it locally. Rather than flooding everywhere, the WSN, DRL reduces the overhead of flooding by dynamically limiting flooding during a local area and keeps good performance by dynamic referencing. Dynamic referencing makes DRL a strong approach that will adapt to a good range of node conditions, like node speed, seed density, and node density. Since DRL runs in a DV-hop manner, it doesn't need special (or expensive) hardware capable of detecting distance or angle required in Moreover, DRL allows all of the nodes to be mobile and move freely. At the same time, there are only a limited fraction of nodes having the self-positioning capability.

In summary, DRL has subsequent characteristics: Efficiency: Localization information is dynamically updated and flooded efficiently. Robustness: Basically, DRL locates nodes by the triangulation technique; however, it also allows the situations not to collect enough triangulation seeds. Special hardware-free: DRL doesn't need any hardware of special capability. Free mobility: DRL allows mobile nodes to move free. Localization approaches are often classified into range-based approaches, such as, and range free approaches, such as. The most difference between them is that thanks to getting the space information. The previous relies on distance or angle measurement with radio signals, like TDoA and AoA, and wishes expensive measurement hardware.

The latter uses special protocols to eliminate the necessity Localization approaches are often classified into range-based approaches, such as, and range free approaches, such as. The most difference between them is that the way to get the space information [1]. The previous relies on distance or angle measurement with radio signals, like TDoA and AoA, and wishes expensive measurement hardware. The latter uses special protocols to eliminate them may be a range-based approach for mobile WSNs, which use only local information. It uses a range of measurements between nodes to create a network frame of reference. It's shown that despite possible range measurement errors and motion of the nodes, the algorithm provides enough stability and site accuracy. However, the quantity of data exchange and graph calculation is huge, and it needs hardware capable of supporting the TOA to get the range between two mobile nodes.

Wireless sensor network (WSN) applications typically involve observing some natural phenomenon by sampling the environment. Mobile wireless sensor networks (MWSNs) are a specific class of WSN during which mobility plays a key role within the execution of the appliance. In recent years, mobility has become a crucial area of research for the WSN community. Although WSN deployments were never envisioned to be fully static, mobility was initially considered to have several challenges that needed to be overcome, including connectivity, coverage, and energy consumption, among others. However, recent studies are showing mobility during a more favorable light [2]. Instead of complicating these issues, it's been demonstrated that mobile entities' introduction can resolve a number of these problems.

Additionally, mobility enables sensor nodes to focus on and track moving phenomena like chemical clouds, vehicles, and packages. One of the foremost significant challenges for MWSNs is that the need for localization. To know sensor data during a spatial context or for correct navigation throughout a sensing region, the sensor position must be known. Because sensor nodes could also be deployed dynamically (i.e., dropped from an aircraft) or may change position during run-time (i.e., when attached to a shipping container), there could also be no way of knowing the situation of every node at any given time. For static WSNs, this is often not the maximum amount of a drag because once node positions are determined, they're unlikely to vary. On the opposite hand, mobile sensors must frequently estimate their position, which takes time and energy and consumes other sensing applications' other resources. Furthermore, localization schemes that provide high-accuracy positioning information in WSNs can't be employed by mobile sensors because they typically require centralized processing, take too long to run, or make assumptions about the environment or topology that don't apply to dynamic networks.

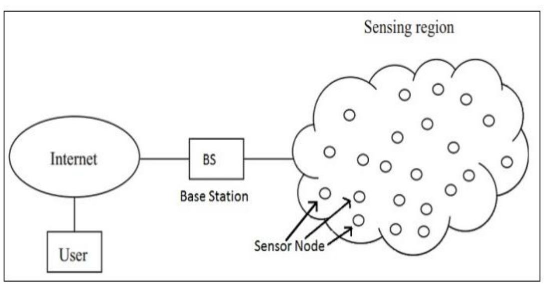

Fig1. Basics of Wireless Sensor Networks

When an outsized number of sensor nodes are deployed during a large area to co-operatively monitor a physical environment, the networking of those sensor nodes is equally important. A sensor node during a WSN communicates with other sensor nodes and a Base Station (BS) using wireless communication. The bottom station sends commands to the sensor nodes, and therefore the sensor node performs the task by collaborating. After collecting the required data, the sensor nodes send the information back to the bottom station. A base station also acts as a gateway to other networks through the web. After receiving the info from the sensor nodes, a base station performs simple processing and sends the updated information to the user using the Internet. If each sensor node is connected to the bottom station, it's referred to as Single-hop specification. Although long-distance transmission is feasible, the energy consumption for communication will be significantly above data collection and computation [2].

Received (Radio) Signal Strength (RSS): RSS based localization is far and away a really popular technique employed by the wireless sensor network community. This system involves measuring the facility of an incoming signal at a receiving node, supported by the known transmitted power; the effective propagation loss is often calculated. Theoretical and empirical models are wont to translate the loss in measured power into distance estimate for localization. In some ways, radio wave strength (RSS) is popular and a perfect modality for range estimation of sensor nodes in wireless networks. Its use comes at no additional cost in fixing the network. RSS is particularly appealing for localization thanks to its simplicity in implementation that doesn't introduce additional cost, energy, and size constraints into the network. Despite its appealing nature, RSS does yield very noisy range estimations since it suffers from reflection and attenuation within its application environment. These effects can have a much larger impact than the loss of signal strength due to traveling a longer distance, making it difficult to infer from measure losses without a really good environment model. Because of the relatively high noise in measurement, there are proposals to scale back the margin of error, which will reduce the extent to which the measurement errors affect the estimation of absolutely the or relative positional coordinate of the sensor nodes within the network. Several proposed techniques are using RSS information without the necessity for timing and synchronization, a number of them being formulated within the context of maximum likelihood (ML). A formulation for RSS-based localization within the context of maximum chances is nonlinear and non-convex. Linear least square (LLS), multidimensional scaling (MDS), and semidefinite programming (SDP) relaxation are methods that are proposed to unravel the issues of localization, where the SDP method has been found to offer the simplest performance with higher computational complexity [3].

Classification of Wireless Sensor Networks

Static and Mobile WSN: In many applications, all the sensor nodes are fixed without movement, and these are static networks. Some applications, especially in biological systems, require mobile sensor nodes. These are referred to as mobile networks. An example of a mobile network is animal monitoring.

Deterministic and Nondeterministic WSN: In a deterministic WSN, a sensor node position is calculated and fixed. The pre-planned deployment of sensor nodes is feasible in just a limited number of applications. In most applications, determining sensor nodes' position isn't possible because of several factors like harsh environment or hostile operating conditions. Such networks are non-deterministic and need a complex system.

Single Base Station and Multi Base Station WSN: In a single base station WSN, only one base station is employed, which is found near the sensor node region. All the sensor nodes communicate with this base station; just in case of a multi-base station WSN, a quiet base station is employed, and a sensor node can transfer data to the closest base station.

Static Base Station and Mobile Base Station WSN: Like sensor nodes, even base stations are often either static or mobile. A static base station features a fixed position, usually near to the sensing region. A mobile base station moves around the sensing region so that a load of sensor nodes is balanced.

Single-hop and Multi-hop WSN: In a single-hop WSN, the sensor nodes are directly connected to the bottom station. Just in the case of multi-hop WSN, peer nodes and cluster heads are wont to relay the information to reduce energy consumption.

Self – Reconfigurable and Non – Self – Configurable WSN: In a non – Self – Configurable WSN, the sensor networks cannot organize themselves during a network and believe an impact unit to gather information. In most WSNs, the sensor nodes can organize and maintain the connection and work collaboratively with other sensor nodes to accomplish the task.

Homogeneous and Heterogeneous WSN: In a homogeneous WSN, all the sensor nodes have similar energy consumption, computational power, and storage capabilities. Just in the heterogeneous WSN, some sensor nodes have higher computational power and energy requirements than others, and therefore the processing and communication tasks are divided accordingly [4].

Applications of Wireless Sensor Networks

Theoretically speaking, the possible applications of Wireless Sensor Networks are unlimited. A number of the commonly used applications of wireless sensor networks are listed below [5].

- Air control (ATC)
- Heating Ventilation and air-con (HVAC)
- Industrial production line
- Automotive Sensors
- Battlefield Management and Surveillance
- Biomedical Applications
- Bridge and Highway Monitoring
- Disaster Management
- Earthquake Detection
- Electricity Load Management
- Environment Control and Monitoring
- Industrial Automation
- Inventory Management
- Personal Health Care
- Security Systems
- Tsunami Alert Systems
- Weather Sensing and Monitoring

II. Literature Survey

Klogo et al. [6] present the gap in the Frequency Domain, and Spatial- Wireless Sensor Network (WSN) localization is an important and fundamental problem that has received a lot of attention from the WSN research community. Determining the absolute and relative coordinate of sensor nodes in the network adds much more meaning to sense data. The research community is very rich in proposals to address this challenge in WSN. This paper explores the various techniques proposed to address the acquisition of location information in WSN. The paper also evaluates these techniques' performance based on energy consumption, the skill, and person-hours needed to implement the technique and localization accuracy (error rate) and discuss some open issues for future research.

Nawaz et al. [7], Determining nodes' localization in a Wireless Sensor Network is a very important task, which involves collaboration between nodes. Localization is a fundamental service since it is relevant to many applications and the network's main functions. Collaboration is essential to self-localization so that that localization can be accomplished by the nodes themselves, without any human intervention. In this paper, we first analyze the key aspects that have to be considered when designing or choosing a localization problem. Then, we present the types of current localization algorithms, making a broad comparison among the most relevant algorithms. With this comparative analysis, we aim at identifying a complete algorithm able to adapt itself to a wide variety of possibilities (number and density of nodes, obstacles and terrain irregularities, network topology, node mobility, etc.

Hu, Lingxuan, et al. [8] in research, many sensor network applications require location awareness, but it is often too expensive to include a GPS receiver in a sensor network node. Hence, localization schemes for sensor networks typically use a small number of seed nodes that know their location and protocols. Other nodes estimate their location from the messages they receive. Several such localization techniques have been proposed, but none of them consider mobile nodes and seeds. Although mobility would appear to make localization more difficult, we introduce the sequential Monte Carlo Localization method in this paper. We argue that it can exploit mobility to improve the accuracy and precision of localization. Our approach does not require additional hardware on the nodes and works even when the movement of seeds and nodes is uncontrollable. We analyze the properties of our technique and report experimental results from simulations. Our scheme outperforms the best known static localization schemes under a wide range of conditions.

Ji, Xiang et al. [9] Sensor Positioning is a fundamental and crucial issue for sensor network operation and management. In the paper, we first study some situations where most existing sensor positioning methods tend to fail to perform well, an example being when a sensor network's topology is anisotropic. Then, we explore the idea of using dimensionality reduction techniques to estimate sensor coordinates in two (or three) dimensional space. We propose a distributed sensor positioning method based on a multidimensional scaling technique to deal with these challenging conditions. Multidimensional scaling and coordinate alignment techniques are applied to recover positions of adjacent sensors. The estimated positions of the anchors are compared with their true physical positions and corrected. The positions of other sensors are corrected accordingly. Our method can overcome adverse network and terrain conditions with iterative adjustment and generate an accurate sensor position. We also propose an on-demand sensor positioning method based on the above method.

Zhenjie et al. [10] Sensor localization is a fundamental and crucial issue for wireless sensor networks operation and management. In this paper, we present a new localization scheme with a mobile beacon for wireless sensor networks. The scheme relies on TDoA (time difference of arrival) of the mobile beacon RF signals measured locally at a sensor to detect range differences from the sensor to the mobile beacon's different position. We analyze our scheme's performance and identify possible sources of position errors, and suggested measures to avoid them. We conduct simulations to test our scheme's performance; the obtained results show that the scheme is an effective scheme for localization in wireless sensor networks.

Han et al. [11] Location discovery problem in wireless sensor networks (WSN) is the process that sensor nodes collaborate to determine their positions. To solve this problem, high-cost sensor nodes with known locations, called anchors, are required. We propose a novel bilateration location algorithm and an associated anchor deployment scheme to reduce the required anchors and location errors. The bilateration algorithm's novelty generally requires only two neighbor sensors with known locations to determine a node's location. To make this algorithm effective in practice, we propose to deploy three anchors as a group. Therefore, sensors around the anchors can first locate themselves, and then sensors that are far away can gradually determine their locations. We conduct theoretical analysis and extensive simulations. Comparing with the state-of-the-art location discovery approaches, our algorithm provides higher accurate location estimations with fewer anchors and lower communication costs.

Di Stefano et al. [12]. In this paper, we propose a distributed algorithm for solving the positioning problem in ad-hoc wireless networks. The method is based on the nodes' capability to measure the angle of arrival (AOA) of the signals they produce. The distributed algorithm's main features are simplicity, asynchronous operations (i.e., no global coordination among nodes is required), ability to operate in disconnected networks. Moreover, each node can join the computation at any time. Numerical results obtained by simulating several scenarios show that the algorithm can reach a good convergence level even when the number of communications is limited.

Yoo et al. [13] this paper proposes a novel scheme for positioning error mitigation in orthogonal frequency division multiplexing (OFDM)-based wireless location systems. The proposed scheme combines the cell ID and the time-difference-of-arrival (TDoA) schemes. These two schemes have a mutually complementary characteristic. In the proposed scheme, one of the two schemes is selected and used for positioning error mitigation, according to the received signal strength (RSS) due to Delta, where Delta denotes the distance between a base station (BS) and a mobile station (MS).

Nazir et al. [14] Localization is an active field of research in wireless sensor networks WSNs. The exact physical location of the sensor nodes in WSNs is useful for various applications, e.g., intrusion detection, target tracking, environmental monitoring, network services, etc. In this paper, we present the classification and comparative study of localization algorithms. The goal of our consideration is to analyze how these localization algorithms work to increase the life span of network nodes in harsh environments like oil fields, gas fields, forests, chemical factories, and underground mines, etc. and how to find the position of the mobile node with Distributed, Range-based and Beacon-based Localization technique in harsh environments. Furthermore, this paper also highlights some issues experienced by these localization techniques.

Niu et al. [14] in this paper, an overview of recent developments in received-signal-strength (RSS)-based localization in wireless sensor networks is presented.

Several important practical issues and their solutions are discussed. A maximum-likelihood estimator based on quantized data is presented along with its corresponding Camera lower bound and optimal quantization design schemes to save communication bandwidth and sensor energy. An iterative sensor selection approach is presented to activate only the most informative sensors for further system resource savings by maximizing the mutual information or minimizing the posterior iteration. For a resource-constrained WSN with imperfect wireless channels, channel-aware target localization is described. The channel model is incorporated into the localization scheme itself, thereby improving performance without increasing communication overhead. Another practical issue involving malicious sensors called Byzantines is discussed, and mitigation schemes are provided. A recent coding-theory based approach which is both computationally inexpensive and robust to such malicious attacks is also discussed.

III. Simulation Setup Tool and Simulation Result

(a) Simulation Setup Tool: The Performance analysis of experimental set-up (MATLAB) used for this thesis Implementation of knowledge mining provides processor optimized libraries for fast execution and computation and performed on input cancer dataset. It uses its JIT (just in time) compilation technology to supply execution speeds that rival ancient programming languages. It should additional advantage of multi-core and computer computers, MATLAB provide much multi-rib mathematics and numerical perform. These functions automatically execute multiple procedure threads during a} very single experimental set-up to execute faster multicourse computers. Throughout this thesis, all inflated economical data retrieve results were performed in an experimental set-up. The experimental set-up is that the high-level language and interactive surroundings utilized by numerous engineers and scientists worldwide. We explore and visualize ideas and collaborate across entirely different disciplines with signal and image methods, communication, and computation of results. The experimental set-up provides tools to accumulate, analyze, and visualize info, modify you to induce insight into your info during a} very division of the time it might take exploitation spreadsheets or ancient programming languages. It should document and share the results through plots and reports or as unconcealed experimental set-up code. Experimental set-up (matrix laboratory) could be a multi-paradigm numerical computing situation and fourth-generation communication. A branch of data work develops it; experimental set-up permits matrix strategy, plotting of performing and data, implementing the algorithm, and user interfaces with programs. MATLAB is meant primarily for mathematical computing; associate no mandatory toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing capabilities

(b) **Simulation Result:** In range-based localization method is an active field of the research area in wireless sensor networks. Range-based localization RSS and our proposed method minimization error rate and very best solution.

Table 5.1 WSN Range Based Configuration

Parameter Name	Set Parameter Values
Length(m) x Height(m) x Width(m)	105x105x105
Approximate Distance Calc. (approx.)	5
Approximate Angle Calc. (approx.)	5
Population Size	67
Maximum Iterations	79
Number of Nodes	10,15,21

(a) Error Rate Analysis:

Comparing error rate analysis between two methods, the first old method (RSSCLM) and the second proposed method (ACLM). The proposed method error rate analysis finds less error, but the old method error rate analysis finds a high error rate. Finally, show that figure 2 our proposed method best and reliable.

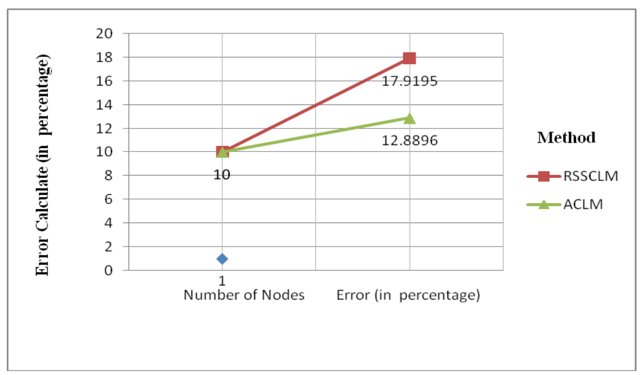

Fig2 Error Rate Analysis based on number of 10 nodes using in WSN

(b) TE. Time Analysis: Comparing TE. Time Analysis between two methods, here first old method (RSSCLM) and second proposed method (ACLM). Proposed method time analysis find out not less time but old method time analysis find out less time. Finally, show that figure 5.3 our proposed method best and reliable.

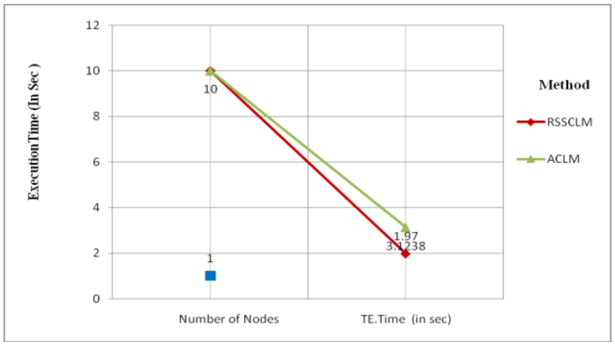

Fig3 TE. Time Analysis based on number of 10 nodes using in WSN

IV. Conclusion

Enhanced performance cooperative localization wireless sensor networks supported received-Signal-Strength method and advanced cooperative localization method (ACLM). These techniques were also considered relative to some performance parameters, especially the energy constraints that best these techniques (ACLM). Most localization techniques in WSN determine the situation of unknown nodes (static or mobile) during a 2D plane/space. However, sensor nodes are mostly deployed in 3D space. There's the necessity then to explore location determination techniques in 3D space. Means of communication requirements of these techniques are major contributors to the sensor nodes' ability consumption within the network; hence the localization techniques that depend on wireless communication heavily have a high power consumption of node. To point out some issues, those are received much attention from the WSN research. This comparative analysis to point out in the result section complete localization solution, within the sense that it adapted to an honest kind of conditions and proposed work realize good results in localization WSN. It also allowed us to go looking out for a localization solution to be applied within the precise supported WSNs for wireless environmental monitoring in range base area. The overall wireless communication network has been proposed method (ACLM). Proposed work is management sensor position in localization WSN; there are still several other challenges that need being minimization error and also an effective wireless network. Implementation of the advanced cooperative localization method (ACLM) in mat lab and proposed method best compared to the existing method.

References

[1]. Priyantha, Nissanka Bodhi, Hari Balakrishnan, Erik D. Demaine, and Seth Teller. "Mobile-assisted localization in wireless sensor networks." In Proceedings IEEE 24th Annual Joint Conference of the IEEE Computer and Communications Societies. vol. 1, pp. 172-183. IEEE, 2005.

[2]. Rudafshani, Masoomeh, and Suprakash Datta. "Localization in wireless sensor networks." In 2007 6th International Symposium on Information Processing in Sensor Networks, pp. 51-60. IEEE, 2007.

[3]. Patwari, Neal, and Alfred O. Hero III. "Using proximity and quantized RSS for sensor localization in wireless networks." In Proceedings of the 2nd ACM international conference on Wireless sensor networks and applications, pp. 20-29. 2003.

[4]. Deif, Dina S., and Yasser Gadallah. "Classification of wireless sensor networks deployment techniques." IEEE Communications Surveys & Tutorials 16, no. 2 (2013): 834-855.

[5]. Arampatzis, Th, John Lygeros, and Stamatis Manesis. "A survey of applications of wireless sensors and wireless sensor networks." Proceedings of the 2005 IEEE International Symposium on, Mediterranean Conference on Control and Automation Intelligent Control, 2005., pp. 719-724. IEEE, 2005.

[6]. Klogo, Griffith S., and James D. Gadze. "Energy constraints of localization techniques in wireless sensor networks (WSN): A survey." International Journal of Computer Applications 75, no. 9, 2013.

[7]. Nawaz, Sarfaraz, and Sanjay Jha. "Collaborative localization for wireless sensor networks." Proceedings of the 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC07). 2007.

[8]. Hu, Lingxuan, and David Evans. "Localization for mobile sensor networks." In Proceedings of the 10th annual international conference on Mobile computing and networking, pp. 45-57. 2004.

[9]. Ji, Xiang, and Hongyuan Zha. "Sensor positioning in wireless ad-hoc sensor networks using multidimensional scaling." In IEEE INFOCOM 2004, vol. 4, pp., 2652-2661. IEEE, 2004.

[10]. Zhenjie, Xia, and Chen Changjia. "A localization scheme with mobile beacon for wireless sensor networks." In 2006 6th International Conference on ITS Telecommunications, pp. 1017-1020. IEEE, 2006.

[11]. Han, Guang, Gang Qu, and Shaoxiong Hua. "A new approach towards solving the location discovery problem in wireless sensor networks." In MILCOM 2006-2006 IEEE Military Communications Conference, pp. 1-7. IEEE, 2006.

[12]. Di Stefano, Gabriele, and Alberto Petricola. "A Distributed AOA Based Localization Algorithm for Wireless Sensor Networks." JCP 3, no. 4: 1-8, 2008.

[13]. Yoo, Seung Hwan, Seungsoo Yoo, Chulho Lee, Sun Yong Kim, and Seokho Yoon. "A novel scheme for positioning error mitigation in OFDM-based on wireless location systems." In The 9th International Conference on Advanced Communication Technology, vol. 2, pp., 1267-1270. IEEE, 2007.

[14]. Nazir, U., N. Shahid, M. A. Arshad, and S. Hussain Raza. "Classification of localization algorithms for wireless sensor network: A survey." In 2012

International conference on open source systems and technologies, pp. 1-5. IEEE, 2012.

[15]. Niu, Ruixin, Aditya Vempaty, and Pramod K. Varshney. "Received-signal-strength-based localization in wireless sensor networks." Proceedings of the IEEE 106, no. 7 (2018): 1166-1182.

[16]. Buratti, Chiara, Andrea Conti, Davide Dardari, and Roberto Verdone. "An overview of wireless sensor networks technology and evolution." Sensors 9, no. 9: 6869-6896, 2009.

[17]. Bekmezci, Ilker, Ozgur Koray Sahingoz, and Şamil Temel. "Flying ad-hoc networks (FANETs): A survey." Ad Hoc Networks 11, no. 3: 1254-1270, 2013.

[18]. Rubinstein, Marcelo G., Igor M. Moraes, Miguel Elias M. Campista, Luis Henrique MK Costa, and Otto Carlos MB Duarte. "A survey on wireless ad hoc networks." In IFIP International Conference on Mobile and Wireless Communication Networks, pp. 1-33. Springer, Boston, MA, 2006.

[19]. Rodoplu, Volkan, and Teresa H. Meng. "Minimum energy mobile wireless networks." IEEE Journal on selected areas in communications 17, no. 8: 1333-1344, 1999.

[20]. Choffnes, David R., and Fabián E. Bustamante. "An integrated mobility and traffic model for vehicular wireless networks." In Proceedings of the 2nd ACM international workshop on Vehicular ad hoc networks, pp. 69-78. 2005.

[21]. Akyildiz, Ian F., and Xudong Wang. "A survey on wireless meshes networks." IEEE Communications Magazine 43, no. 9: S23-S30, 2005.

[22]. Kim, Han-sung. "Communication system and method in wireless infrastructure network environments." U.S. Patent 7,266,374, issued September 4, 2007.