# Energy Efficient Localization Techniques in Wireless Sensor Network: A Survey of state-of-the-art


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***Abstract*— Wireless sensor network (WSN) is a particular kind of wireless network which consists of small miniaturized sensors that sense, collect, process and transmit various kinds of data from the area of interest. The sensors can be deployed in any desired manner in order to fully cover the environment of interest. It is important to know the location of sensor node for many applications. Such knowledge can be achieved using localization techniques in WSN. It is highly desired to design inexpensive, flexible, and energy efficient localization schemes for WSNs. Moreover, location accuracy and energy consumption of a node should be balanced simultaneously. To achieve this goal, many research attempts have been made in the past and are still going on. In this paper, we comprehensively survey some of the latest and leading research in efficient localization techniques in terms of both energy consumption and location accuracy to identify and analyze their advantages and limitations. Likewise, we will be able to find out future research directions in this field.**



***Keywords—Wireless Sensor Network (WSN), Energy Efficiency, Localization Techniques.***


## I. Introduction

Wireless sensor network (WSN) is a sub category of wireless network that contains on small autonomous devices which are spatially dispersed in the area of under investigation or monitoring. In some applications the nodes move while in other applications they are static. The nodes have limitation in energy storage. They sense and records various environmental or physical signals such as temperature, acoustic signals, pressure, etc. A WSN usually uses a gateway that provides wireless links between WSN and outer wired world. A sensor node collects and forward data to the gateway for onward delivery towards the destination. Many critical applications require to know the exact locations of nodes in order to better understand the data in the right context and to make appropriate and correct decision upon the received data. On the same time, such applications require to achieve this goal at the cost of minimum energy consumption. To identify location of sensor nodes, localization techniques are used in WSNs. Localization techniques identify location of sensor nodes even if they displace from their initial position with the passage of time.

Restraining energy consumption has been the most critical issue in WSN to prolong the lifespan of sensor nodes [1]. Moreover, keeping energy consumption at minimum level for determining exact and accurate location of nodes is another characteristics WSN is required to have. These two metrics i.e. localization accuracy and power consumption should be balanced and both should be improved at the same time [2]. These challenges indicate that developing energy efficient, simple, flexible and robust localization algorithms in WSN is an exciting area of research [3]. In the past, several attempts of research work have been made to investigate and address this issue. In this paper we comprehensively analyze some of the well-known existing research work conducted to achieve the aforementioned goals. Though, many survey papers already exist in the literature which elaborate many aspects of localization techniques quite aptly, we especially focus on those works which consider energy efficiency as the main objective in localization. Besides, we believe that with the passage of time, those surveys have become outdated and a new review is required to fully cover the new challenges posed by the latest research in this area. Additionally, with the advent of new algorithms and protocols [4]-[9] that have been developed lately in this field, it is now need of the hour to analyze all of them and identify their merits and shortcomings. In this way, we are going to find out future research directions for future researchers as well.

Rest of the paper is organized as follow. Section II presents a review of the latest energy efficient localization techniques. Section III presents summary and discussion. Section IV identifies future research directions. Section V concludes the paper. References are given in section VI.

## II. Review: Energy Efficient Localization Techniques

### A. *Dynamic Transmission power Energy Harvesting based Localization Algorithm*

In [10], a novel localization scheme is proposed for achieving energy efficiency at low cost in wireless sensor network. The scheme is specifically customized for Energy Harvesting (EH) wireless sensor network. EH sensors are assumed to have (i) random power budgets, (ii) random transmission capabilities and (iii) heterogeneous transmission coverage nature. Under these assumptions, a new algorithm is developed to derive the Expected Hop Progress (EHP). Using EHP, the proposed scheme can efficiently find position of the EH sensor node. In addition to the proposed algorithm, a correction mechanism is developed that acts under the heterogeneous coverage nature of EH sensor. It improves efficiency without additional power cost. It is shown in results that the proposed scheme achieves greater efficiency, in terms of power consumption and localization accuracy, than most of the current WSN localization algorithms in EH powering scenario.

### B. *RSSI and Cooperative communication-based Localization Algorithm:*

Cooperative communication between nodes using RSSI and Trilateration method is proposed in [11] for accurately localizing sensor node. Localizing mobile sensor node using graphical representation is faulty, this scheme is promising to overcome this problem. For energy conservation, the number of active nodes is always kept lower than number of sleeping nodes. In this way, both network traffic and loss are mitigated and extra efforts, regarding routing and optimization of paths, are also alleviated. Results show that both time and energy consumption are diminished.

### C. *On-Demand Indoor Localization Algorithm (ODIL).*

In [12], the author proposed an energy efficient localization technique On-Demand Indoor Localization (ODIL) wherein activity durations of sensor nodes are optimized in indoor localization process. The network's accuracy remains intact. Sensor nodes are made to operate with event driven policy and they wake up and operate only when some event occurs. In this way, only those few nodes, which are closed to the target node, are kept active. Data collection from the sensor nodes are also made energy efficient in such a way that nodes are required to transmit only the required data. Implementing the algorithm on real experimentation and observing physical energy enhancement is left for the future work.

### *D. Particle swarm optimization (PSO) based energy efficient localization technique (EELT)*

Exploring unknown environment to find nodes at anonymous location with the help of Location Aware (LA) nodes is considered in [13] and an Energy Efficient Localization Technique (EELT) is proposed. The technique is based on Particle Swarm Optimization. Target nodes are localized by LA nodes using movement patterns (velocity and acceleration), Received Signal Strength (RSS) and Angle of Arrival (AoA) of the target note. Tracking and localizing is performed only through a small number of LA sensors and most them are kept in sleep mode to minimize energy consumption. The proposed scheme is assessed by many kinds of mobility models. It is shown that energy consumption is fairly decreased by increasing accuracy of localization with least estimation errors and overheads. However, sophisticated circuitry is required to compute all parameters like RSS and AoA which makes it cost ineffective.

### *E. (RSS) based localization method using Cramer-Rao Lower Bound (CRLB) for precise estimation of nodes' locations*

A new sensor deployment technique is proposed in [14] to optimize the overall energy consumption of WSN. The technique uses pre-determined Cramer-Rao Lower Bound (CRLB) accuracy model for RSS based localization technique. The relationship between the lower bound of localization estimation and energy consumption is quantitatively analyzed in RSS based localization applications. Regular triangle is chosen to ensure minimum energy consumption when making the specific lower bound after energy efficiency of different coverage cells had been discovered. Optimum beacon scheduling in distributed trick is implemented and simulated. Results show that desired energy efficiency is achieved. However, the scheme assumes regular triangle which is not always possible to happen WSN.

### *F. Ripple Localization Algorithm (RLA)*

The author in [15] proposes an intelligent, energy efficient and distributed localization scheme named ripple localization algorithm (RLA). The scheme is mainly customized for industrial wireless sensor network. It utilizes beacon signals which beacon nodes produce with variable transmission power for localization. The scheme doesn't require any additional hardware resources for ranging. Unknown nodes need not to make communication with other nodes for estimating its location. Rather they intelligently compute their location with the help of beacon signals. It is a kind of distributive property that lets sensors locate their position and thereby reduces communication overhead. The facts that sensor nodes do not use any transmission power for location estimation and beacon nodes do not always transmit at the peak power results in energy efficiency. Simulation and experimental results indicate that the scheme renders substantial accuracy when assessed under different radio conditions.

### *G. Enhanced ALWadHA Algorithm*

Enhanced version of an already proposed algorithm "AlWadHA" is proposed in [16] to optimize energy efficiency. The author utilizes three schemes to achieve the optimization. In the first one, a node estimates its location one time only and keeps that intact. In the second one, reference nodes dynamically control its transmission power according to its distance with the node that broadcasts location request. In the third one, frequency of location request generation is controlled with incremental and exponential requesting rate mechanism. Simulation results show that the latest scheme achieves better results by reducing energy consumption of AlWadHA up to 51.5 % along with high accuracy of location estimation of nodes.

### *H. Kruskal's Approach based algorithm for choosing optimal place for relay node for efficient localization*

An optimal algorithm in [17] is proposed to prolong network life time. The algorithm is based on Kruskal's approach. Locations for relay nodes are calculated in such a way that maximum distance 'δ' between intermediate nodes are maintained where 'δ' represents range of nodes. Distance among nodes is kept small to uphold efficient network topology. In this way, locations for additional nodes are efficiently calculated which in turn guarantees enhanced network lifetime. The author analytically proves the improved results.

### *I. Euclidean and hop distance-based algorithm to enhance efficiency of DV-hop algorithm*

The author in [18] proposes a semi-analytical approach to enhance a well-known localization method DV-hop. The large overhead associated with DV-hop is mitigated by eliminating unnecessary recalculation of nodes' positions on receiving of beacon broadcast. Performance of original DV-hop and varied DV-hop is compared through simulation results that favors the latter scheme. The author further presents a new paradigm of research regarding distance dependence performance of nodes in wireless sensor network. However, the author assumes uniformly-distanced sensor distribution and regular circular area which is applicable only to small cases in real-worlds.

### *J. Homogenous distribution-oriented algorithm for randomly deployed Mobile Sensor Network*

In WSN, it is often desirable to fully cover required area with minimum number of sensors. The author in [19] proposes a scheme to achieve high energy efficiency with minimum number of mobile nodes required to cover a given area. The mobile sensor nodes are randomly deployed in homogenous distribution. Base station is used to communicate with all sensors to guide them to find pertinent locations for deployment. As such, inter sensor communication and sensor movement is minimized and energy consumption is reduced as a result. Simulation results show that the proposed scheme outperforms earlier work because (i) number of nodes required to cover a given area is smaller, (ii) average node movement made by mobile sensor nodes to set themselves at pertinent location is smaller and (iii) energy efficiency of the whole network is more enhanced. However, the scheme has assumed circular regular and smooth area which is impractical in real world scenario.

### *K. Movement-adaptive report scheduling combined with Ratiometric Vector Iteration (RVI) based algorithm*

A large portion of energy consumption results from unsuccessful communication attempts between node-node and/or node-gateway. One of its major causes is erroneous localization of nodes. In [20], author proposes an approach to reduce the number and collision of messages happening among nodes. At the same time, optimal accuracy of node location is maintained. The scheme has three ingredients. First is Ratio- metric Vector Iteration (RVI) which mainly deals with distance ratio estimates. In RVI, three sensors falling nearest to the target broadcast their RSS. RVI iteratively uses such estimates to accurately locate a sensor. After exact calculation, the location information is sent to the node of interest. Depending on moving or stationary node, frequency of location calculation is determined so that little location estimation is performed if node is stationary. This is termed as movement adaptive report. By combining RVI with movement adaptive report, simulation results show that localization error is mitigated and overall number of transmitted messages are cut by half of those counted for earlier approaches. However, determining the three closest neighbor is quite tricky task that often leads to fallacy.

*L. RSSI ranging and GPS back-offs based algorithm for energy efficiency.*

The author in [21] proposes a scheme that promises to prolong network lifetime by balancing node's GPS on-off time with its position accuracy. So, energy consumption and localization accuracy is balanced. Short-range radio contact logging is used with GPS to lower energy consumption while achieving desirable accuracy of node's location. Additionally, RSSI and GPS back-offs are utilized to further lower energy consumption. Given constraints like life-time, acceptable accuracy and acceptable error, contact radius of nodes and beacon period for any Mobile Sensor Network (MSN) application is adapted. Beacon signal generation is made event driven for energy saving. Though the scheme performs better than several contemporary schemes, however, it is based on GPS which is itself a big source of energy consumption and, thus, energy efficiency is not optimized.

*M. A Simple and regular movement-based algorithm of Mobile anchor nodes to enhance efficiency*

The author in [22] proposes a range-free localization technique which locates a blind node with the help of anchor and reference nodes. Ring overlapping and mobile anchor nodes are used for this purpose. For effective localization of the blind node, the reference node should be centered in the ring of interest. The identification is achieved by comparing RSSI values among nodes. The ring is further shrunk by using multiple mobile beacons for reducing probing area. Ring overlapping is then utilized to efficiently estimate the node's position. Simulation results show that the scheme is not only highly accurate in the calculation of node's exact location but the associated energy consumption is also comparatively smaller than the existing approaches. The technique, however, uses simple, plain and regular pattern of mobile anchor node movement which is unrealistic in real world application.

*N. Smart reference-selection method and clustering based algorithm to enhance efficiency of ALWadHA.*

Another improvement to AlWadHA algorithm is proposed in [23] that combines AlWadHA with Distributed Uniform Clustering Algorithm (DUCA) clustering technique for low energy consumption. Nodes perform data aggregation to reduce channel occupancy. Simulation results show that the proposed scheme achieves accuracy commensurate to AlWadHA along with reduction in energy consumption. However, the technique is only applicable to static sensor nodes.

*O. Performance analysis of some existing protocols for cluster head location*

To find optimized location of Cluster Heads (CHs) in heterogeneous WSN, three clustering schemes are analyzed in [24]. The schemes are Regular Grid (RG), Minimax Grid (MG) and K-Medoids (KM). Performance of the schemes are compared with the well-known approach 'LEACH' [30]. The schemes minimize communication overheads generated and required by nodes for CH selection in previously proposed clustering schemes. Network area is divided into cells. In RG approach, CH is positioned at the center of each cell. In MG, CH is placed at the center of the smallest circle. In KM, network is divided into clusters and Energy Harvesting nodes are found and assigned the role of CHs. Simulation results show that all the three discussed schemes outperform LEACH in energy consumption and can enhance network lifetime by 200 %.

*P. Robot-based deployment Scheme for sensor nodes using Zigbee*

ZigBee based scheme is proposed in [25] which is especially designed for disaster-stricken areas. Nodes are deployed by mobile robots in a manner to minimize energy consumption in communication. Robots make coordination and communication among themselves in order to accurately localize, explore and create the network. Some of the deployed nodes act as anchor nodes and relays information to help accurate localization. Such nodes do not need to send beacon signals to signify their positions. So, energy is saved. The scheme is practically implemented and results show that the proposed scheme yields precise localization, reduced redundant nodes and quicker exploration with multiple robots. However, the assumed area (less than 10m*10m) for the network is too small to be realized in real world scenario.

*Q. Ripple Localization Algorithm: Performance Analysis in Randomly Deployed Wireless Sensor Network*

A distributed localization scheme is proposed in [26] where beacon-signal generating nodes control and adapt its transmission power to the required range. The transmitted signals are received by other nodes using only radio connectivity to estimate their ranges and positions. No additional hardware is used, saving cost, energy and size. Sensor nodes distributively define their locations leading to reduced communication overheads. Beacon nodes don't always transmit with maximum power. Unknown nodes don't need extra transmission for its localization. Results indicate that the algorithm yields high accuracy under changing channel conditions and under the employment of even small number of beacon nodes. Further, 66.67% of energy is saved in the transmission of beacon signal compared to other existing schemes that transmit beacon signals at maximum power constantly.

*R. Midpoint Algorithm for uniform distribution of sensors*

The author in [27] proposes sensor placement pattern to reduce inter node communication in WSN. For this purpose, the author uses Manhattan grid technique to deploy sensor uniformly in same spaced rows and columns. To achieve such placement of nodes, the author proposes a decentralized 'Midpoint Algorithm'. Sensor placement is made on choice, not randomly. Results show that Manhattan grid networks outperform randomly distributed networks in provisioning of improved accuracy versus energy tradeoff. Also, it comes out that the proposed Midpoint Algorithm provides more energy savings than existing algorithms.

*S. Range-based Monte Carlo boxed (RMCB) Algorithm*

The author in [28] proposes a distributed Range-based Monte Carlo Boxed (RMCB) scheme that supports both static and mobile nodes. The scheme considers both ranging and non-ranging capabilities-holder nodes. The scheme also evaluates performance of range-based localization and range-free localization. Through empirical measurements and simulation results it is proved that RMCB outperforms range-free algorithms in terms of localization error at the cost of the same computational complexity. However, the scheme is very sensitive to the quality of range estimation and a little deviation, that usually results from environmental obstacles, leads to a large error.

### *T. Adaptive localized algorithm-based self-configuring localization system*

An energy efficient scheme that uses a mobile anchor node is proposed in [29]. The scheme is inspired from the Self- Organizing Medium Access Control algorithm for Sensor Networks (SMACS). Distance measurement is made through dedicated hardware. Ultrasonic transmitter, radio frequency and GPS receiver is installed in mobile node. Stationary node is provided with Radio Frequency (RF) and ultrasonic receiver. The mobile nodes broadcast its location over specific interval of time using RF and ultrasonic. The static nodes take that locations for granted as virtual anchor nodes. In this way, sensor location is computed locally by measuring distance to the virtual anchor node. For such measurement, Time Difference of Arrival (TDoA) technique is used. Rest of the non-localized sensors calculate their distance and, thus, their locations by measuring their distance to the localized nodes. Results demonstrate that the scheme performs better in energy, cost and accuracy than any other localization scheme employing mobile anchor nodes. However, complex circuits are installed in mobile nodes which reduces simplicity in WSN.

### *U. Distributed and range free localization scheme (BLI) using directional antenna.*

Using small gain directional antenna, location of randomly deployed sensor is estimated in [31] along with reduction in interference and noise. Highly accurate, energy efficient, distributed, simple, range free and cheap localization technique, named ‘BLI’, is proposed where mobile anchor is provided with a directional antenna. The scheme can support any size and density of WSN. The scheme is basically Inspired by the Self- Organizing Medium Access Control for Sensor Networks (SMACS). It is proved that location can be fairly estimated using geometric features on 2-dimensional plane. Localization estimation is performed locally using beacon signals. Results show that high accuracy and energy efficiency can be achieved with the scheme. However, directional antenna requires more sophistication in MAC protocols which increases complexity.

### *V. Greatest gain direction line intersection (GGDI)*

In [32], the author proposes an accurate, energy efficient and range independent localization scheme called GDDI. The scheme uses mobile anchor nodes which have directional antenna. No extra hardware and computation is required by sensor nodes since they can compute their location using minimum beacon points. Location is computed using intersection points of the largest gain direction of antenna. Results show that the proposed technique is highly accurate and energy efficient than other localization schemes. However, the nodes have to use intersection points which is an added complexity.

### *W. RSSI-and-range-free based minimized radio communication algorithm*

In [33], a range free and simple localization scheme is proposed for localized nodes using limited RF communication and using no RSSI. No beacon or RSSI support is available. Hence no calibration measurement is needed. The simplicity of the scheme lets applications to run on simple hardware for in- network localization. It enables decrease in power consumption of localized nodes. The scheme is practically implemented in office environment that contains on many rooms. Nodes require a total of 1900 Bytes of memory for all operations. For the storage of data only, memory occupation ranges from 18 Bytes to 180 Bytes. Accordingly, power consumption ranges between 345 micro Watt and 2.48 micro Watt. According to the results, the room area is successfully analyzed with 96% of the total time while maximum value of point-based error is 8.7 meters. For sub rooms, the values are 100% and 4.2 meters.

### *X. A trilateration combined with compass-based algorithm*

In [34], a new technique is presented to accurately locate mobile sensor nodes. An enhanced Trilateration scheme is utilized to identify the initial position of a node and keep that updated by using digital compass as and when the nodes move. Simulation results show that higher enhancement in terms of energy efficiency is achieved as compared to simple Trilateration method. Further, location accuracy is also found to be the same as that of the simple Trilateration scheme. However, additional complexity introduces since node has to measure its velocity and acceleration and has to keep compass.

### *Y. Flip-ambiguity mitigation-oriented algorithm using Particle Swarm Optimization (PSO)*

The author in [35] proposes flip ambiguity mitigation technique. Flip ambiguity is an important problem in localizing blind nodes in wireless sensor network. The proposed scheme solves this problem using (i) topological constraints of neighboring anchor node and (ii) distance-based constraint in combination with (iii) Particle Swarm Optimization (PSO) technique. All the above three techniques are used iteratively in distributed manners to spot blind nodes in WSN. With the utilization of very few resources, the problem is solved aptly and is demonstrated by simulation results. As compared to the previous techniques, the proposed scheme mitigates flip ambiguity by 95 to 100 percent with consequent energy efficiency of up to 87 percent. However, noise and other signal impairments are supposed to be static by the author which is unrealistic in real world scenario. Moreover, sometimes large number of iterations are required to localize all the nodes which adds delay to complete network configuration.

### *Z. Anchor nodes’ beacons’ average energy based optimized algorithm*

In order to minimize estimation error-based energy consumption, the author proposes a scheme in [36] which allocates optimal power to anchor node. The scheme computes distance between anchor node and the unknown node using Received Signal Strength Indicator (RSSI) and average energy of the beacon signal. In this way, squared position error bound, which is an accuracy indicating parameter, is derived and used in decision making. In addition to this, localization performance is maximized by proposing another optimization problem in which anchor nodes can accurately estimate their own locations using the derived optimal power allocation policy. Optimal power allocation policy is derived for anchors with and without uncertainty in their locations. Simulation results show that considerable amount of power consumption is reduced by provisioning optimal transmission power to anchor. However, high power consumption results if error occurs in the anchor node position which is its main drawback.

### *AA. Energy-efficient LOcalization and Tracking (eLOT) system*

| Ref. # | D/C | SSN/MSN | RB/RF | AF/ AD | GF/ GD | Power usage | NSOM | Complex | Scala ble | Multi hop | Acc. | SND | Comp. cost | Comm. Cost | Hardware cost | Physical measurement | Deploy ment | Implem- ntation | In/Out |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1] | C | MSN | RB | AD | GF | MOD | O | H | H | YES | H | Mod | L | H | Mod | RSS | UNF/RND | Prac | In/Out |
| [14] | D/C | MSN | RB | AD | GD | L | M | Mod | H | No | H | Mod | Mod | Mod | L | RSS | RND | Sim | Out |
| [29] | D/C | MSN | RB | AD | GD | Mod | O | Mod | H | Yes | H | H | H | L | H | TDoA | RND | Sim | Out |
| [31] | D | MSN/SSN | RF | AD | GD | L | O | Mod | H | Yes | H | H | L | Mod | L | RSSI | RND | Sim | Out |
| [32] | D | MSN/SSN | RF | AD | GF | L | O | Mod | H | Yes | H | H | L | Mod | L | RSSI | RND | Sim | Out |
| [33] | D | MSN/SSN | RF | AF | GF | L | O | L | L | Yes | H | L | L | L | L | | UNF | Prac | In |
| [34] | C | MSN/SSN | RB | AD | GF | H | O | H | L | No | H | L | Mod | MOD | H | RSSI | RND | Sim | Out |
| [35] | D | SSN | RB | AD | GF | | O | H | Mod | NO | H | L | H | H | H | | RND | Sim | Out |
| [36] | C | SSN | RB | AD | GD | L | O | Mod | L | No | H | L | Mod | Mod | L | RSSI | RND | Sim | Out |
| [10] | | SSN | RF | AD | GD | L | | Mod | H | YES | H | H | Mod | L | H | No. of hops | RND | Sim | In/Out |
| [11] | D | MSN | RB | AD | GF | L | O | L | H | YES | | H | Mod | Mod | Mod | RSSI | RND | Sim | Out |
| [12] | C | MSN | RB | AD | GF | L | M | H | L | NO | H | Mod | Mod | Mod | Mod | RSSI | UNF/RND | Sim | In |
| [13] | C | MSN | RB | AD | GF | L | O | H | H | Yes | H | Mod | H | H | L | RSSI, AoA | RND | Sim | In |
| [2] | C | SSN | RB | AD | GF | H | O | H | H | No | H | H | H | H | H | RSS, DRSS, DoA | UNF | Sim | Out |
| [15] | D | MSN | RF | AD | GF | L | O | L | H | NO | Mod | H | L | L | L | RSS | RND | Prac | Out |
| [16] | D/C | SSN | RB | AD | GF | Mod | O | H | H | NO | H | H | Mod | H | L | RSSI | RND | Sim | Out |
| [18] | C | SSN | RF | AD | GF | L | O | L | H | Yes | Mod | H | H | L | L | | UNF | Sim/Anal | Out |
| [19] | C | MSN | RF | AD | GF | L | O | Mod | H | Yes | H | L | Mod | Mod | L | | RND | Sim | Out |
| [20] | D | MSN/SSN | RB | AF | GF | H | M | Mod | L | Yes | Mod | L | Mod | L | L | RSS | RND | Sim | Out |
| [21] | D | MSN | RB | AF | GD | H | M | H | H | Yes | H | H | H | L | H | RSSI | RND | Sim/Prac | Out |
| [22] | C | MSN | RF | AD | GD | Mod | M | Mod | L | No | H | H | H | H | Mod | RSSI | RND | Sim | Out |
| [23] | C | SSN | | AD | GF | Mod | M | Mod | L | No | H | Mod | H | Mod | L | RSSI | RND | Sim | |
| [24] | C | SSN | RF | AD | GD | Mod | | Mod/L | H | Yes | Mod | H | H | L | L | | UNF | Sim | Out |
| [25] | C | MSN/SSN | RF | AD | GF | Mod | O | Mod | L | Yes | H | Mod | L | L | H | RSS | RND | Prac | Out |
| [26] | D | SSN | RF | AD | GF | L | M | L | H | Yes | H | Mod | L | L | L | RSS | RND | Sim | Out |
| [27] | D | SSN | RF | AF | GF | H | O | H | H | Yes | H | H | H | L | Mod | RSS | UNF | Sim | Out |
| [28] | D | MSN | RB/RF | AD | GD | Mod | O | Mod | H | No | H | Mod | Mod | H | Mod | RSS | RND | Sim/Prac | Out |
| [4] | C | MSN | RF | AD | GF | H | O | Mod | H | Yes | Mod | H | H | Mod | H | RSSI | RND | Sim | Out |
| [5] | | MSN/SSN | RB | AD | GF/ GD | Mod | O | Mod | H | Yes | H | H | H | L | L | RSSI | RND | Sim | Out |
| [6] | D | SSN | RF | AD | GF/ GD | Mod | M | H | H | Yes | H | L | H | L | H | No. of hops | RND | Sim | In/Out |
| [7] | D/C | SSN | RB | AD | GF/ GD | Mod | O | Mod | Mod | No | Mod | Mod | Mod | L | Mod | RSSI | RND | Sim | In/Out |

**Ref;**Reference**, D/C;**Distributed/Centralized**, MSN/SSN;**Mobile Sensor Nodes/Static Sensor Nodes**, RB/RF;**Range Based/Range Free**, AF/AD;**Anchor Free/Anchor Dependent**, GF/GD;**GPS Free/GPS Dependent**, Mod;**Moderate**, L;**Low**, H;**High**, M;**Multiple kinds**, O;**One kind**, Acc;**Accuracy**, Comp.;**Computational**, Comm.;** Communication**, In/Out;**Indoor/Outdoor, **NSOM**;Node stores One kind or Many kinds of data, **RB**;Range Based, **GPF**;GPS Free, **Ind/Out**;Indoor/Outdoor, **SND**=Supported Node Density, **RND**;Random, **UNF**;Uniform, **Sim**;Simulation,

**Table 1: Comparative analysis of the literature**

An energy efficient Zig-bee based technique "Localization and Tracking (eLOT)" is proposed in [1] that utilizes low cost and transportable hardware for accurate tracking and localization of nodes. The scheme is deployable in both indoor and outdoor environments. Mobile nodes prompt access to the network and network can locate it with minimum power consumption. Resultant, energy efficiency and localization accuracy is balanced in the proposed scheme. Energy efficiency is further enhanced by coordinating collision and interference of signals among nodes. Once mobile node is located, it is promptly associated with specific channel frequency in an area. The node then makes no needless transmission leading to energy saving. Results show that eLOT is workable under every condition with unified mechanism and that it provides energy efficiency with high localization accuracy. Extension of the network to include roads and buildings is left for the future.

### *BB. A Multi-objective Optimization Algorithm*

It is observed that using multiple parameters for localization e.g. Received Signal Strength (RSS), Difference RSS (DRSS), Direction of Arrival (DoA) leads to high accuracy. In [2], the author proposes a novel analytical approach that can evaluate the maximum achievable performance, regarding localization of nodes, under the combined effect of the above three parameters. The aim is to improve localization accuracy and reduce energy consumption simultaneously. The scheme uses Carrier Sense Multiple Access/Collision Avoidance (CSMA/CS) along with 'Request to Send' and 'Clear to Send' (RTS/CTS) as transmission process. In case where CSMA/CS RTS/CTS is not applicable, Cramer-Rao Lower Bound (CRLB) is derived for target node that equally utilizes measurements from DRSS and DoA to estimate node's location as the objective function of localization error. The proposed optimization approach is further fortified with Non-Dominated Sorting Genetic Algorithm (NSGA-II) which is an optimization algorithm to find Nash Equilibrium or Pareto optimal solutions effectively. Simulation results show that location accuracy is enhanced and energy consumption is reduced.

| Technique | Cost | Accuracy | Energy Efficiency | Hard ware size |
|---|---|---|---|---|
| GPS | High | High | Less | Large |
| GPS free | Low | Med | Med | Small |
| Centralized Base | Depends | High | Less | Depends |
| Decentralized Base | Depends | Low | High | Depends |
| APIT | Med | Med | high | Med |
| DV hop | Low | Med | High | Small |
| AOA | High | Low | Med | Large |
| RSSI | Low | Med | High | Small |
| TDOA | Low | High | High | Large |
| TOA | High | Med | Less | Large |

**Table 2: Comparison of various localization techniques**

## III. SUMMARY AND DISCUSSION

In WSN, many critical applications require to know the exact locations of nodes in order to better understand the nodes' data in the right context and to make appropriate and right decision upon the received data. To achieve this task, applications require to minimize energy consumption as much as possible. Localization techniques are used in WSNs to identify location of sensor nodes. For instance, line of sight communication among nodes, which is a desirable feature in WSN, can be achieved through effective localization. Localization techniques identify location of sensor nodes even if they displace from their initial position with the passage of time. However, developing energy efficient localization technique for WSN is a strenuous task since there are many constraints like limited power supply, low processing power, low memory, meager data rate and size etc. to consider. Cost effectiveness in hardware, power consumption and deployment are considerable factors in designing localization algorithm. Moreover, high accuracy in localization is the main requirement of WSN. Additionally, density of nodes in a locality also matters in designing such algorithm. In mobile WSNs, nodes are mobile and require recomputation of their new exact locations in real-time. So, topological changes occur frequently. Increase in beacon nodes increases accuracy but it also adds to cost. Some schemes are only applicable to indoor environment while others are specifically designed for outdoor environment. Moreover, Localization techniques are classified as anchor dependent or anchor free, centralized or distributed, fine grained or coarse grained, GPS based or GPS free, static or mobile sensor nodes, and range based or range free. All these factors contribute to complexity of localization techniques and algorithms. In the literature, many algorithms and schemes have been proposed to address the various challenges associated with the localization techniques. In this paper, we studied some of the latest attempts in this regard and identified some insights into future work which is presented in the next section. Characteristics of various techniques are summarized in table 1 and 2.

## IV. FUTURE RESEARCH DIRECTIONS

There is still great scope to develop efficient localization algorithms for WSNs. Here we identify some future research directions which we believe can lead to further enhancement in efficiency in WSNs.

### A. LINE OF SIGHT COMMUNICATION WITH THE HELP OF DIRECTIONAL ANTENNA.

Directional communication with the help of directional antenna is a great tool for minimizing energy consumption. Further work in this direction may lead to reduced interference, reduced MAC issues and minimum nodes' movement requirements.

### B. MOVEMENT OF RESERVED MOBILE NODES IN SPECIFIC PATTERN

Making movement of small number of reserved mobile nodes in specific patterns may considerably simplify localization algorithm. Such mobile nodes may be mobilized in a specific movement pattern throughout a WSN's coverage area in order to mitigate probability of holes creation in WSNs.

### C. SDN-BASED WSN LOCALIZATION

Initially proposed for wired networks, SDN has now been proposed in various kinds of wireless networks including WSN. SDN based WSN is perceived to be more energy efficient since only controller has to send broadcast messages for topology discovery. Likewise, SDN-based WSN localization is envisaged to enhance energy efficiency. This research direction is still unexplored and potentially advantageous in terms of energy efficiency in localization in WSNs.

### D. DRONE ASSISTED LOCALIZATION

With the ubiquitous use of drones in various applications of communications and networking, it is envisaged that their use may facilitate WSN localization in new ways. Those WSNs that are deployed in hard to reach areas, drones may assist especially in such scenario. Further research in this direction is required.

## V. CONCLUSION

WSN consists of small independent devices which are spatially separated and deployed in a given area to monitor physical or environmental conditions. The nodes in WSN sense, gather, store, process and forward data to destination. It is necessary to know about the location of sensor node collecting data. Localization techniques are used to locate the sensor nodes in WSNs. It is of paramount importance to design inexpensive, efficient, and scalable localization schemes for WSNs. Localization accuracy and energy consumption of a node should be balanced at the same time. To achieve these goals, many research attempts have been made in the past. In this paper, we surveyed some of the leading and state of the art research contributions in designing localization techniques that efficiently achieve high location accuracy and low energy consumption. It is concluded that there is much potential to enhance efficiency in WSN especially with the advent of new applications and algorithms. Our work facilitates understanding various techniques employed in WSN for achieving localization precision and energy efficiency and promotes further research in WSN by presenting future directions.

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