CLUSTER BASED NODE LOCALIZATION TECHNIQUES FOR ENHANCING ENERGY EFFICIENCY IN MOBILE WIRELESS SENSOR NETWORK

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BONAFIDE CERTIFICATE

Certified that this thesis titled **"CLUSTER BASED NODE LOCALIZATION TECHNIQUES FOR ENHANCING ENEGY EFFICENCY IN MOBILE WIRELESS SENSOR NETWORK"** is the bonafide work of **Mr. G. KADIRAVAN** who carried out the research under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion of this or any other candidate.

Place : Puducherry
Date : 31-07-2019

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DECLARATION

I hereby declare that this thesis entitled **"CLUSTER BASED NODE LOCALIZATION TECHNIQUES FOR ENHANCING ENEGY EFFICENCY IN MOBILE WIRELESS SENSOR NETWORK"** submitted to the Department of Computer Science, School of Engineering and Technology, Pondicherry University, Puducherry, India for the award of the degree of **Doctor of Philosophy in Computer Science and Engineering** is the record of bonafide research work carried out by me under the guidance and supervision of **Dr. POTHULA SUJATHA** and that has not formed the basis for the award of any other degree by any University/Institution before.

Place: Puducherry **G. KADIRAVAN**

Date: 31-07-2019

ABSTRACT

Mobile-Wireless Sensor Network (MWSN) is an extended version of wireless sensor network (WSN) has become an important part in day to day life. Actually, the nodes in MWSN are modelled with many supplementary sensors to sense the environment, microcontroller, storage area, communication unit, analog to digital converter (ADC) and power supply. Yet again, the nodes are restricted with inbuilt memory, battery source, processing and radio facility because of its tiny size. In MWSN, movement of sensor node localization is needed to report the initialization of events, helps to request information from specific node, data transmission and so on. Hence, node localization in MWSN is considered as a crucial design issue. MWSN comprises of more number of nodes and GPS would be highly expensive. Most of the localization algorithms are developed based on the natural activity of biological systems and/or physical systems. At the same, cluster based routing protocol is a commonly employed solution to achieve energy efficiency. Though various clustering techniques for MWMSN have been developed, there is still a need to further improve the energy efficiency by considering the different perspectives. Keeping all the above mentioned issues in mind, we organize the research work into several phases and the major contributions are listed below:

- An extensive survey has been made related to the existing node localization and density based clustering in MWSN along with some of the data aggregation and routing techniques particularly developed for MWSN.
- To design and combine BAT and TLBO (BAT-TLBO) based algorithm to resolve node localization problem and attains maximum lifetime.
- To design a Density Based Clustering (DBC)Technique to achieve energy efficiency and maximum lifetime.

- To design a cluster based node localization (CH-NL) and network life time maximization in MWSN. To validate the effectiveness of the proposed algorithms using several performance measures under different scenarios.

A new BAT-TLBO algorithm is presented to resolve the node localization problem. The new solutions are created by the equations inspired from the nature of knowledge exchange among teacher and students in the learning duration. The TLBO has two stages: teaching stage and learning stage. A single hop range based distributed approaches can be employed to localize the nodes in MWSN localization, to determine the coordinates of many sensor nodes by the use of anchor nodes. In the proposed algorithm also used less number of transmissions, location accuracy and handled to dynamic topology.

Next, DBC technique is presented to select CHs it perform energy dissipation and extend the network lifetime. The proposed method operates in three phases: cluster construction phase, data transmission phase and cluster maintenance phase. In the proposed DBC algorithm, it is intended to cluster the sensor nodes which have high energy, less distance and high centrality. Finally, cluster maintenance phase uses cross-level data transmission to enhance the network lifetime significantly and reduce energy consumption.

Finally, a CH-NL protocol is presented to eliminate clustering and node localization problem and extend the network lifetime and energy efficiency. This protocol comprises two phases: Node localization using hybrid BAT-TLBO and Clustering using DBC algorithm. Due to the nature of mobile nodes in MWSN, the CHs tend to move in the sensing field. Then, the node localization algorithm gets executed to determine the location of the sensor nodes. Once the location of the sensor nodes is determined, this information is utilized. By the use of localized nodes, the data transmission will takes place from cluster members to CHs and then to SCHs. Finally, it reaches the BS.

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[G. KADIRAVAN]

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ACRONYMS		ABBREVIATIONS
MWSN	-	Mobile Wireless Sensor Networks
MANET	-	Mobile Ad Hoc Networks
IR	-	Infrared
RF	-	Radio Frequency
AOA	-	Angle-Of-Arrival
TOA	-	Time-Of-Arrival
TDOA	-	Time-Difference-Of-Arrival
RSS	-	Received Signal Strength
FOA	-	Frequency Of Arrival
MLE	-	Maximum Likelihood Estimation
SBE	-	Sequential Bayesian Estimation
KF	-	Kalman Filter
PF	-	Particle Filter
EKF	-	Extended Kalman Filter
SMC	-	Sequential Monte Carlo
RIPS	-	Radio Inter ferometric Positioning System
ROM	-	Read Only Memory
RAM	-	Random Access Memory
RSSI	-	Received Signal Strength Indicator
BS	-	Base Station
LOS	-	Line Of Sight
GPS	-	Global Positioning System
SLAM	-	Simultaneous Localization And Mapping
SLAT	-	Simultaneous Localization And Tracking
LEACH	-	Low Energy Adaptive Clustering Hierarchy

ACRONYMS	-	**ABBREVIATIONS**
CH		Cluster Head
ADC	-	Analog To Digital Converter
GA	-	Genetic Algorithm
SA	-	Simulated Annealing
PSO	-	Particle Swarm Optimization
BA	-	Bat Algorithm
DBC	-	Density Based Clustering
CCA	-	Curvilinear Component Analysis
MCF	-	Maximum Common Nodes First
MAL	-	Mobile-Assisted Localization
MAP	-	Mobile Anchor Point
CDL	-	Color-Theory-Based Dynamic Localization
RGB	-	Red-Green-Blue
MCL	-	Monte Carlo Localization
EMAP	-	Extended Mobile Anchor Point
LEACH-ME	-	LEACH-Mobile Enhanced
CBR	-	Cluster Based Routing
TDMA	-	Time-division multiple access
MSRP	-	Mobile Sink-Based Routing Protocol
MACRO	-	Mobility Adaptive Cross-Layer Routing
MAC	-	Media Access Control
EMMS	-	Energy management algorithm in a WSN with multiple sinks (EMMS)
ABC	-	Artificial Bee Colony
MBC	-	Mobility-based clustering
CIDT	-	Cluster Independent Data Collection Tree
DCT	-	Data Collection Tree

ACRONYMS		**ABBREVIATIONS**
DCN	-	Data Collection Node
HEED	-	Hybrid Energy-Efficient Distributed clustering
DSSS	-	Direct Sequence Spread Spectrum
VELCT	-	Velocity Energy-Efficient And Link-Aware Cluster-Tree
EEDC-TB	-	Energy-Efficient Data Collection Protocol Based On Tree
CREEC	-	Chain Oriented Sensor Network
CTDGA	-	Cluster-Tree Data Gathering Algorithm
TARS	-	Trace Announcing Routing Scheme
ETX	-	Energy Dissipation At The Transmitter
ERX	-	Energy Dissipation At The Receiver
HARP	-	Hierarchical And Adaptive Reliable Routing Protocol
RAHMoN	-	Routing Algorithm For Heterogeneous Mobile Network
HSN	-	Heterogeneous Sensor Network
CBDCR	-	Clue Based Data Collection Routing Protocol
ZEEP	-	Zone Based Energy Efficient Routing Protocol
LASeR	-	Location Aware Sensor Routing
AODV	-	Adhoc On-Demand Distance Vector
TLBO	-	Teaching And Learning Based Optimization Algorithm
MBA	-	Modified Bat Algorithm
SCH	-	Super Cluster Head
MLE	-	Mean Localization Error
NL	-	Number Of Localized Nodes
TEEN	-	Threshold Sensitive Energy Efficient Sensor Network Protocol
M-LEACH	-	Mobile LEACH
CH-NL	-	Cluster Head-Node Localization

ACRONYMS		ABBREVIATIONS
QoS	-	Quality of Service
PDR	-	Packets Delivery Ratio
RE	-	Residual Energy
RF	-	Radio Frequency
WSN	-	Wireless Sensor Networks
ETA	-	Elapsed Time On Arrival
RBS	-	Reference-Broadcast Synchronization
FCC	-	Fast Communications Controller
TDOA	-	Time Difference of Arrival
DDCHS	-	Density and Distance based Cluster Head Selection
DDEEC	-	Developed Distributed Energy Efficient Clustering
SEP	-	Stable Election Protocol

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Mobile wireless sensor networks (MWSNs) are very important in many practical scenarios in that the sensor nodes are movable and not stagnant in nature. MWSNs are flexible to a great extent when compared to WSNs since the sensor nodes undergone deployment in different environments and it manages with fast topological modifications. Mobile sensor nodes comprises microcontroller, variety of sensors to capture the environmental conditions (moisture, acoustics, temperature, movement, etc), a radio transceiver, an inbuilt power unit (El Karl and Willig, 2005). The significant applications of MWSNs are ecological surveillance, weather forecasting, seismic surveillance, acoustic recognition, hospitals, navy, military, smart buildings, and data gathering platforms (Akyildiz et al., 2002). There are two pairs of disputes to MWSNs; hardware and software. The major hardware restrictions are: inbuilt battery source, compact size and installation cost. In addition, the routing protocol decides the effective and reliable data transmission route. Based on the resource availability of the sensor nodes in MWSNs, it can be categorized to homogeneous and heterogeneous MWSNs. The process of deploying nodes in heterogeneous type is difficult than the homogeneous MWSN.The nodes in MWSN should achieve high energy efficiency for the longer network life time (Chelouah et al., 2017). At the same time, the complexity level of the algorithms derived for various tasks like localization, clustering, routing, and so on.

1.2 ARCHITECTURES OF MWSN

MWSN can be divided into 2-tier, 3-tier or flat hierarchical structure (Munir et al., 2007), as demonstrated in Fig. 1.1.

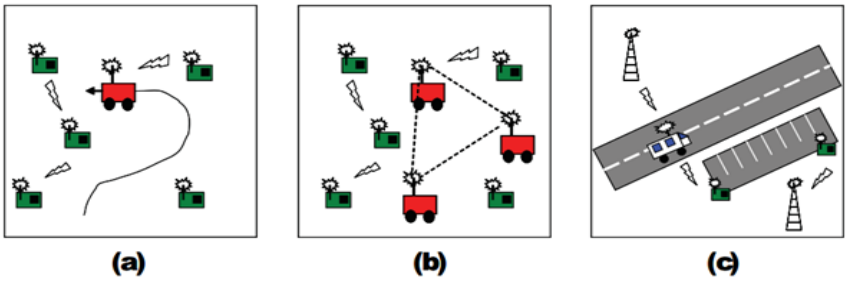


Fig.1.1. (a) Flat, (b) 2-Tier, and (c) 3-Tier MWSN architectures

A planar or flat, network framework contains a heterogeneous set of devices which communicate in ad hoc way. The devices might be of stationary or mobile, however, the entire communication takes place over the similar network. The fundamental navigation systems adopt (Amundson et al., 2008) flat architecture, as pictured in Fig. 1.1(a)

A set of mobile nodes and stationary nodes are comprised in two-tier architecture. An overlay network is formed by mobile nodes or acts as data mules to aid to shift data over the network (Yuan et al., 2017). Mobile devices involve overlay network which comprises superior processing ability, higher bandwidth, and long communication range. Overlay network density is usually associated additionally, or network might be disjoint. Mobile entities might locate itself with a view to ensure network packets that attains the destination or to re-establish connectivity. The 2-tier architecture is illustrated in Fig 1.1(b).

The static sensor node set broadcast the data in three-tier architecture and mobile devices set passes that data to access points set. A heterogeneous network is employed to cover a wide network area and is compact with numerous applications at the same time. For instance, assume a sensor network application which controls the parking garage for the availability in parking space. To the compact mobile devices like PDAs (Personal Digital Assistant) or cell phones, the sensor network transmits the availability updates which it passes through. Cell phone passes this data availability to access points like towers of cell phones and the data is uploaded towards the database server that is centralized. By accessing the database, the user need to find the parking space that is available. Fig.1.1(c) illustrates the 3-tier architecture.

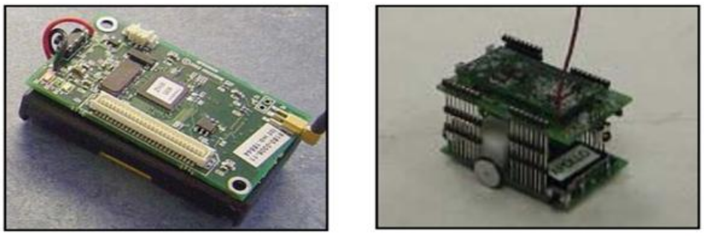
In the network, mobile wireless sensors might be divided depending on the role at node level:

Mobile Embedded Sensor: Own movement cannot be controlled by the Mobile embedded nodes; rather, its motion is projected through few external force like when linked with shipping container (Kus´y et al., 2007) or tethered to an animal (Juang et al., 2002). XSM (Dutta et al., 2005), Mica2, MicaZ and Telos (Polastre et al., 2005) are specialized embedded sensors, Fig.2(a).

Mobile Actuated Sensor: Locomotion ability is contained through the sensor nodes that allows it to shift over a sensing area (Amundson et al., 2008). With this kind of controlled mobility, coverage might be enhanced, certain phenomena might be targeted and pursued, deployment specification might be highly specific. Mobile sensor is demonstrated in Fig. 2(b) (Shah et al., 2003).

Data Mule: Sensors are not been mobile some times, however to collect the data and deliver to base station, it might need a mobile device. These mobile entities kinds are known as data mules (Shah et al., 2003). It is considered that the data mules can recharge automatically from power source.

Access Point: The mobile nodes can locate itself to manage connectivity (Shah et al., 2003), (Wang et al., 2005) in sparse networks while the node drops down the network. They act as network access points in this case.



(a) (b)

Fig. 1.2. (a) The Mica2 sensor node. (b) The USC Robomote mobile actuated sensor.

1.3 ADVANTAGES OF MWSNs OVER WSNs

Through application, deployments of sensor networks are frequently determined. Randomly, the nodes can be positioned in grid, over interesting objects or in other arrangements that is countless. Until the sensor node begins to process and gather data, an optimal deployment is unknown in numerous circumstances. The node location rearranging is commonly improbable for wide or remote area deployments (Elhoseny et al., 2017). The redeployment is probable while the nodes are mobile. The coverage in WSNs is enhanced by the mobile entities integration into WSNs and therefore, uses the sensor network deployment (Wang et al., 2005), (Liu et al., 2005), (Elhoseny et al., 2014). The highly versatile sensing applications are enabled by mobility. For instance, mobile sensor network is demonstrated by Fig. 1.3 which monitors wildfires. The mobile sensors are capable to manage from the fire perimeter, safe distance and keep updating the fire fighters which denote wherever the perimeter is located currently.

Fig.1.3. A MWSN that monitors wildfires.

As the fire spreads, the mobile sensors can track it, as well as stay out of its way. Mobile nodes can moves towards connecting the weak or lost communication pathways in disjoint or sparse networks. With static WSNs, this is not probable that the data from disconnected or dead nodes will be lost simply. The nodes move towards the BS might die while network sinks are static at the same time as it must transmit higher data messages when compared to the one that are far away. This issue is removed by employing mobile base stations and network lifetime is prolonged (Gandham et al., 2003).

The higher channel capacity is enabled by mobility and managed data integrity through generating numerous communication pathways and minimizes the hop message count that transmits prior to attaining the destination (Kansal et al., 2004).

1.3.1 Difference between WSNs and MWSNs

The variation between the general considerations of the WSNs and MWSNs are given below.

- **Localization:** The position of the node is determined in statically deployed networks in the initialization phase. As it passes by sensing area, these nodes which are mobile should gain its location continuously. Extra energy, time and rapid localization availability service is needed by localization.

- **Dynamic Network Topology:** Conventional routing protocols of WSN (Al-Karaki and Kamal, 2004) depends mostly over recent route histories or routing tables to pass the messages by network to their respective destination. The table data might be quickly outdated in dynamic topologies and route discovery is iteratively done at considerable cost by means of time, bandwidth and power. Frequency, there is an active research given to Mobile Ad Hoc Network (MANETs) routing and MWSNs fortunately (Abolhasan et al., 2004).
- **Power Consumption:** The models of power consumption greatly vary among MWSNs and WSNs. Wireless communication acquires a considerable energy cost and should be efficiently employed for both network kinds. Mobility power is needed by mobile entities and is frequently equipped with huge energy reserve, or comprises self-charging ability which allows it to plug to power resources for recharging the batteries.
- **Network Sink**: The sensor data passed towards the BS in centralized WSN applications wherever it might be processed by employing resource-intensive techniques. Major overheads might be caused by data aggregation and routing. Mobile base stations (Gandham et al., 2003) employ few MWSNs that traverse the sensing area to gather data, or locate itself in order to the transmission hop counts are reduced for sensor nodes.

1.4. CHALLENGES IN MWSN

In this section, some of the challenges present in the field of MWSN are explained below.

Energy Efficiency

As the sensor nodes operate on inbuilt battery, the available energy should be spent efficiently. Hence, the requirement of energy efficient techniques such as clustering, routing, and so on should be designed for MWSN.

Dynamic topology

Due to the nature of mobile nodes in MWSN, the network topology undergo modifications at any time. So, the techniques developed for MWSN should consider the feature of dynamic topology, i.e. the techniques should be adaptable to the modifications in the network topology.

Type of service

The service type provided by the traditional communication network is apparent that it shifts data from source to destination. In MWSN, shifting data is not the actual intention instead it is needed to offer useful information about the given process. In addition, concepts such as scoping of interactions to particular geographic regions or to time intervals become mandatory. So, novel model of using such a network are needed, along with new interfaces and new ways of thinking about the service of a network.

Quality of Service (QoS)

The characteristic which is highly related to the type of a network's service is the QoS. The conventional QoS requirements comes from multimedia-type applications such as bounded delay or limited bandwidth are not related when the applications are delay tolerant or the bandwidth of the transmitted data is very small in the first place. Sometimes, only infrequent transmission of data is also enough. At the same time, some real time applications are highly sensitive to delay. So, adapted quality concepts like reliable detection of events or the approximation quality of a, say, temperature map is important.

Scalability

As a MWSN comprises of massive number of sensor nodes, the proposed model and algorithms should be able to operate will in varying number of sensor nodes.

Fault tolerance

As sensor nodes may exhaust its energy completely or damaged, or the wireless link between two nodes is lost, it is essential that the MWSN has the ability to tolerate the faults. For the tolerance of node failures, repetitive node deployment might be useful, using many nodes than would be highly needed when all the nodes are operated properly.

Lifetime

The nodes in different situations depend on a available usage of limited batteries. The replacement of power sources in this scenarios is impractical, and the MWSN should work for an intended duration or as long as possible. So, network lifetime is also a major issue in the design of MWSN. It is evident that the energy efficient MWSN is essential for a longer lifetime. Alternatively, a rechargeable power sources can also be placed to recharge the inbuilt battery.

Wide range of densities

In MWSN, the node count per unit area, i.e. the node density is significantly varying. Diverse applications have varying number of nodes. In some cases, for specific applications, the density changes over time and space because the nodes may fail or in mobile. The nodes do not seem to be monotonous in the whole network and the network should be adaptable to the modifications.

1.5 LOCALIZATION IN MWSN

For MWSN, we offer localization taxonomy techniques in this section and review selected works demonstrate the general MWSN localization. In previous decade (Hightower and Borriello, 2011; Mao et al., 2007), a broad review of WSN localization study had been published. The extensive methods, signal modalities and hardware are employed by localization method that might be divided over various dimensions. We began through defining the three steps employed specifically in localization (Brooks et al., 2002), (Moore et al., 2004), (Girod et al., 2006): i) measurement ii) coordination iii) computation of position. We aim at other MWSN-based localization aspects like mobility effects, distributed vs. centralized processing, and environment.

Fig. 1.4 Denotes the MWSN localization, a node group combine to begin the localizing and synchronize its clocks when needed. Numerous nodes emit the signal and few signal features are examined through more number of receivers. Through transforming signal measurements, the position of the node is determined to estimates the position in terms of localization technique. It is highly needed to compute the position and to enlist the support of associating sensor nodes that had been placed in environment at known locations as priori. These devices are known as infrastructure, seed nodes or anchor nodes. For instance, the infrastructure nodes are satellites which moves around the planet. The position computation might be related to a static set of anchor nodes at known locations in local coordinate system, or absolute parameters might be derived when the anchor node positions are known with respect to some global coordinate system.

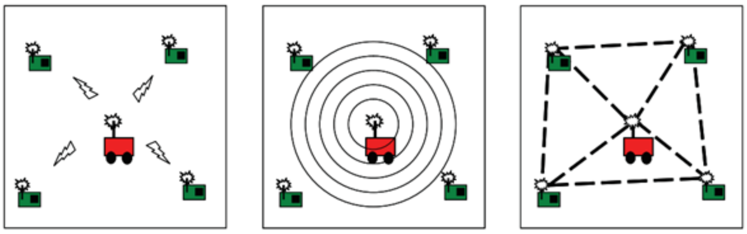


Fig. 1.4: Localization phases: (a) coordination, (b) measurement, and (c) position estimation

Coordination Phase.

Nodes involved in localization, coordinate typically with each other before transmission of signal. Notification is included in that coordination when the localization procedure is about to start and clock synchronization that allows attained signal data to be examined in a general timeframe. Coordination by employing synchronization methods like ETA (Kus´y et al., 2006) and RBS (Elson et al., 2002) might encapsulate both clock synchronization and notifications into single message. These techniques comprise microsecond accuracy and need transmission in a distinct message. For instance, Sync Event which is the ETA primitives determine the upcoming time to start the procedure of localization. The message sender timestamp is encoded in message that is embedded into immediately message prior to transmission, thus minimizes the sum of non-deterministic latency included in synchronization. The nodes in transmission range would get the message at the similar time approximately and considering the negligible transit time of radio signal by air, would be capable to convert the sender timestamp into local timescale. In numerous localization schemes, this method is employed (Mar´oti et al., 2005), (Kus´y et al., 2006), (Fanget al., 2005), and (Amundson et al., 2008).

1.5.1 Measurement Phase

Specifically, the measurement phase includes the signal transmission through at least one node subsequent to signal processing on other nodes that is participating.

Signal Modalities

For precise location, the signal modality choice employed through sensor nodes is significant and based on environment, application and node hardware. It is commonly undesirable to use extra hardware as the WSNs are built to offer inexpensive extensive area of observation capability as it enhances cost, utilization of resource and weight. In several environments, the techniques of localization will differently perform. For instance, when compared to acoustic signals, radio signals perform worst in environments as moisture in air absorbs and reflect better frequency radio waves however it affects little towards vibration sound waves. At the end, few limitations are placed by application itself over signal modality. For instance, the nodes should localize in stealth conditions in a military application will be superior by employing silent modality like radio frequency instead of audible one like acoustic.

Either audible or ultrasound wave propagation is specifically employed by acoustic modality. Various methods had been used. Cricket (Priyantha et al., 2000) and Active Bats (Harter et al., 1999) are two generally and early cited ultrasound localization methods. An ultrasound technique involves a review over ultrasonic positioning and difficulties. Numerous new localization systems had been built in audible acoustic band that involves sniper detection system (L´edeczi et al., 2005), beam forming (Chen et al., 2002), and generalized sound source localization (Williams et al., 2006).

Infrared (IR) signal attenuation needs closer proximity among the receiver and transmitter. For most of the indoor localization approaches, this is acceptable, but, localization in outdoor is complex, not only because of proximity problem however due to complexity in reading during sunlight. Active Badge system (Want et al., 1992) is one the earlier mobile localization systems which make use of a small electronic device to transfer IR identification signal periodically. Through infrastructure nodes, the signal is retrieved and processed centrally through enabling the position of the data that has to be accessed through authorized users. IR localization techniques can be reviewed by (Brassart et al., 2000) and (Kemper et al., 2008).

For localization, propagation Radio Frequency (RF) is highly popular method where every node in WSN comprises of onboard radio hardware. To extract range otherwise bearing data for computation of position, phase, frequency or strength are the signal properties that have been examined. One advantage of RF is that even in sparse networks (Kus´y et al., 2006) it is used to attain accuracy in localization by means of centimetres. At the same time, at frequencies among 400 MHz to 2.4 GHz, sensor node radios broadcast usually by raw signal sampling for phase otherwise for frequency that is done with resource-limited hardware. To produce low frequency beat signal, techniques like radio interferometer (Mar´oti et al., 2005) have to be employed as demonstrated in Fig.1.5. Through examining continuously the attained signal strength indicator, the phase and frequency of beat signal can be measured over radio chip.

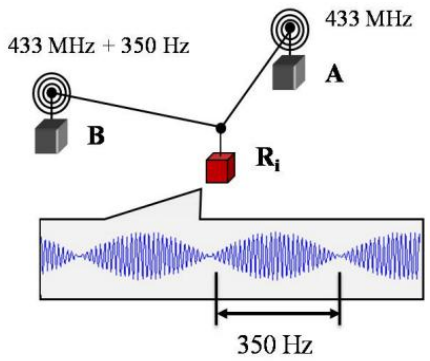


Fig. 1.5: Radio Interferometry

Two nodes transmit a sinusoidal signal at slightly different frequencies, which interfere to create a low-frequency beat signal that can be measured using resource constrained sensor nodes.

To decide the node position, the Spotlight (Stoleru et al., 2005) and Lighthouse (omer, 2003) approaches employs a light beacon. They need powerful light source and line of sight, though both the techniques claim for higher accuracy which would perform good in customized hardware for the light source and light region.

Measurement Techniques

For deriving range, proximity or bearing data depending on signal measurement, many approaches were used.

The Angle-of-Arrival (AOA) technique (Bekris et al., 2004), (Niculescu and Nath, 2003), (Friedman et al., 2008), (Chen et al., 2002) include determining the angular separation among single or two beacons and fixed axis. Through angulation technique, position might be determined through particular sensor node counts in subsequent section.

Time-of-Arrival (TOA) (Priyantha et al., 2005), (Caffery, 2000), (Wang et al., 2003) localization measures signal time that it takes to reach the few sensors. It need to know the signal time that was transmitted and considers tight time synchronization among receiver and sender. This signal comprises feature of known propagation like speed by air at sea level.

The major disadvantage of this method is that it is complex to record accurately the radio signal arrival time as it travels nearby light speed. Hence, with acoustic source, it works superior. By the use of round-trip TOA technique, communication overhead needs to be eliminated (Gunther and Hoene, 2005), whereas Node A broadcast the signal towards Node B. The Node B passes back the signal over signal reception and round-trip time is observed through Node A that accounts for deterministic delay while in the procedure of communication.

Time-difference-of-arrival (TDOA) localization (Kus´y et al., 2007), (Williams et al., 2006) enhances the TOA method through removing the requirement to know when the transmission of signal occurred. A signal is received by numerous time-synchronized nodes and look at variance in arrival time over certain time period. The source location can be determined easily when there exist an enough participating node counts.

The message broadcast received signal strength (RSS) is examined through other localization technique from known location (Lee et al., 2008), (Madigan et al., 2005). As the model of free-space signal strength is controlled through inverse-square law, localization by accurate is probable. Any hardware change is not included by measuring RSS additionally as most of the chips offer software access towards received amplitude signal. Profiling is the other use for RSS (Bahl and Padmanabhan, 2000), (Ladd et al., 2004), in that a RSS map values are build while in primary training phase. By the use of RSS values with training data, the sensors determine its positions.

There exist numerous published methods which determine the node position depending on the examined frequency of arrival (FOA) of a signal (Ledeczi et al., 2008), (Chang et al., 2008) recently. Doppler-shift is carried out by signal frequency while the receiver and transmitter move relative to each other. To extract the mobile node velocity and position, the examined Doppler-shift at numerous infrastructure nodes might be employed.

The highly precise position estimations are provided by the above method; but, it is adequate sometimes to localize it towards the area. This region may be a office floor, city block or room in house. This localization kind might be proximity-based as the node is positioned in Region A, when the Region an anchor is capable to find it. By employing hop count (Niculescu and Nath, 2003) is the other method. As the node radio approximate transmission is known, by examining the count of message hops towards the anchor node set would limit the target node towards a certain area.

1.5.2 Localization Phase

To find the approximate target node position, the derived signal data in the phase of measurement can be used. General MWSN localization methods depends on ranging whereas angle or distance approximations are derived. Since the data range could be corrupted easily, optimization techniques can be employed to filter noise and it leads to more precise position computation.

Lateration

Lateration is employed to compute position (Manolakis, 1996), (Genchev et al., 2008; Maxim et al., 2008) while the range among mobile nodes and landmarks might be determined. This technique is illustrated by Fig. 1.6(a). Three range metrics from known locations are needed for two-dimensional localization. Every range might be demonstrated as circle radius with anchor node positioned at centre. Three circles will intersect at one point exactly without measurement noise and target node location. The three circles get overlap in the noise existence and target node might probably be comprised in this region.

Angulation

It might be employed to decide the mobile node position (Esteves et al., 2003; McGillem and Rappaport, 1989; Betkeand Gurvits, 1997), while the angular separation or anchor bearings among mobile and anchors node might be gained as demonstrated in Fig. 1.6(b). While two anchors are employed for triangulation, the target position would be recognized as third point of two known angles in a triangle and one side length. Through the bearings intersection, the position of target is determined; more than two anchor bearings are employed. At precise similar point, the bearings would not intersect in the measurement noise existence however it would describe an area wherever the target node is probable to be.

Cellular Proximity

Range-free method (Want et al., 1992), (Shang et al., 2004), (Niculescu and Nath, 2003) is the alternative technique where the node is located to the area in which it is found. Additional course-grained position estimate is provided commonly by this technique and it is based on infrastructure node density.

Dead Reckoning

Dead reckoning (Hu andEvans, 2004), (Zhang and Martonosi, 2008), (Fang et al., 2005) is the extensively employed method for localization for mobile robots. From wheel encoders, the robots gains its present velocity or other means, and employs this data in conjunction with time which had been elapsed as the final update to extract present heading and position. The main disadvantage of this method is that the position computation acquires error in time, basically due to noisy encoder data because of wheel slippage, other factors, uneven surfaces and dust.

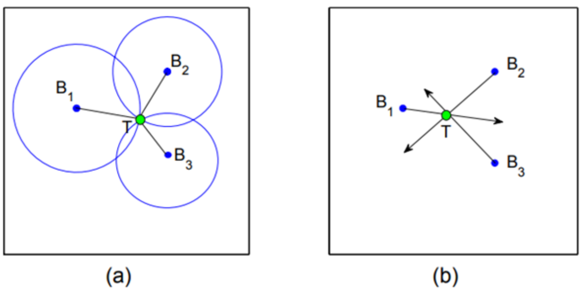


Fig. 1.6. The position of a target node (T) is estimated based on the known positions of beacons (B_i) using (a) lateration or (b) angulation.

Estimation Methods

Generally, state estimation techniques are applied in case of noisy data measurement. There present a huge count of estimation methods however the two major methods are: i) maximum likelihood estimation (MLE) (Zhang and Martonosi, 2008), that computes the rates of state based over measured data only, and no previous data of state is employed and ii) sequential Bayesian estimation (SBE) computes the state values depends on measurements and prior data.

Through maximization of measured data likelihood, MLE techniques like (Kuang and Shao, 2006) and (Mendalka et al., 2008) search the system state estimates. MLE takes the system parameter values which creates the examined data “more probably" when comparing with other parameter values. By employing measurement model, the data likelihood is estimated which relates the data towards the system state.

By employing recursive Bayes rule, system state is computed iteratively in SBE. By employing measurement model, the likelihood of data is estimated. The SBE solution is intractable generally and it cannot be determined analytically. Grid-based filters and Kalman Filter (KF) are the restrictive cases set which present optimal solutions. The highly common suboptimal solutions present like Particle Filter (PF) and Extended Kalman Filter (EKF) which approximate the optimal Bayesian estimation.

By approximating the posterior density using a random sample set, the technique of sequential Monte Carlo (SMC) is presented PF which offers suboptimal solution through random samples set with linked weights. When the particle count becomes huge, the techniques of particle filter give optimal solution.

The Radio Interferometric Positioning System

The radio interferometric positioning system (RIPS) (Mar´oti et al., 2005) is an RF-based localization technique in that the work is depended. A detailed RIPS overview is provided here. For precisely finding the relevant position of sensor node set over an extensive region, Radio Interferometric Positioning System was built by employing onboard radio hardware. The randomness in primary stage of local oscillators over receiver and transmitter nodes restricts the use of RF carrier phase for distance measurements. For the interference signal generation, transmitter pairs are used by RIPS at close frequencies. The interference signal envelope phase is independent by the receiver phase. Through employing couple of receivers for phase offset measuring among receiver pairs, the phase ambiguity is eliminated at the transmitter.

In the framework of COTS Mica2, RIPS was implemented generally. 128 KB program Read Only Memory (ROM), ADC with 9 kSPS sampling rate, 7.4 MHz processor, 4 kB Random Access Memory (RAM), CC1000 tunable radio transceiver (Instruments, 2007) are comprised by resource limited devices which works in 433 MHz ISM band. Though the radio hardware is versatile for cost and size, 433 MHz is very high to examine directly the received signal. By the use of received signal strength indicator (RSSI) reading, the frequency and phase of envelope signal might be measured. With sufficient accuracy, the low-frequency signal phase might be computed which might be less than 5% error, by employing constrained processing power and currently available through the approaches of time-synchronization(< 5μs) as demonstrated in Fig. 1.7. At corresponding frequencies f_A and f_B, A and B are the two nodes that passes pure sinusoids in a way that $f_B < f_A$. With frequency $|f_A - f_B|$, the inference of two signals occurs in beat signal.

The phase offset among the receiver pairs is measured that is a distance linear combination among four node participation:

$$\Delta\varphi = \frac{2\pi}{\lambda}(d_{AD} - d_{BD} + d_{BC} - d_{AC})\ (mod\ 2\pi) \quad (1)$$

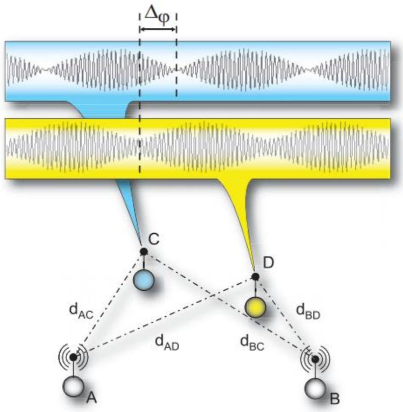


Fig. 1.7. The radio interferometric positioning system

Raw RSSI signal cannot be passed towards Base Station (BS) because of bandwidth limitations and hence it should be processed over mote. It is non-trivial to analyze the signal over resource-constrained node hardware that includes both post-processing and online steps. Into a 256-byte buffer, the RSSI signal is placed while in online processing phase, one instance at time every A/D converter interrupt. The clock sampling and clock speed rate constraint the processing to 820 CPU cycles approximately for each instance. To filter the signal noise, the raw sample is used into average over every interrupt. From primary 10% of the buffered samples, amplitude is decided through gathering maximum and minimum peak values, adequate to cover the least period. The amplitude is employed as indicator of signal quality and for threshold determination for detection of peaks. In post-processing phase, peaks are indexed and are employed to find the signal phase and frequency.

When the buffer is filled, post-processing is executed. To find out the signal period, the indexed peaks are employed and outlying peaks are ignored. Through considering the average period length reciprocal, signal frequency is found. Through deriving the phase average of filtered peaks, signal phase is computed simultaneously. The estimated phase, frequency and amplitude are passed towards BS after the post processing completion wherever the localization method is executed. The post-processing phase and frequency computation of RIPS methods derive lower than 10,000 cycles per measurement and comprises linked phase measurement error of 0.09 radian.

Quad-range is known as the distance measurement $(d_{AD} - d_{BD} + d_{BC} - d_{AC})$. An ambiguity presents wherever the examined signal phase variance with respect to respective wavelength and RIPS samples at numerous frequencies distinguished through 5 MHz to solve this. To decide four nodes positions, a single quad-range is not adequate that includes radio interferometric measurement. Genetic optimization technique is employed when the entire node participate in a sensing area. This technique is capable to eliminate simultaneously bad measurements when computing accurately the sensor positions. The quad-ranges among adequate count of participating nodes limit every node towards distinct sensing area position. RIPW was assumed to comprise 3 cm accuracy and160 meters range. RIPS is highly accurate localization method which might be carried out over WSN with extra support of sensor hardware.

1.5.3 The Effect of Mobility on Localization

Mobile sensors localization is carried out with a view to track them for navigational uses specifically. We use extra difficulties while the sensors are mobile and should design approaches to solve it.

Localization latency is difficult: The sensor might modify position significantly when time to carry out localization as measurement takes place. For instance, periodic position estimates need robot navigation to extract accurate wheel angular velocity control outputs. The localization technique needs 5 seconds to finish when robot is travelling at 1 m/s, from computed position, the robot may be 5 meters off.

Mobility might affect the signal localization: Mobility may also impact the localization signal itself. The signal frequency might undergo a Doppler shift, through error initialization into measurement. While signal transmitter is relatively moving towards the receiver, the Doppler shifts occur as demonstrated in Fig. 1.8(a)(b). The resultant shift is frequency which is relative to relevant speed and positions of two nodes. This Doppler Effect is considered by m-Track and employs to tune the position estimate. To resolve directly the velocity and position, other methods use Doppler Effect.

There exist a probability that mobile sensor, shift from that position with better LOS when localization approach needs line of sight (LOS), towards the poor position LOS. A dense node network is needed when a LOS exist between mobile nodes.

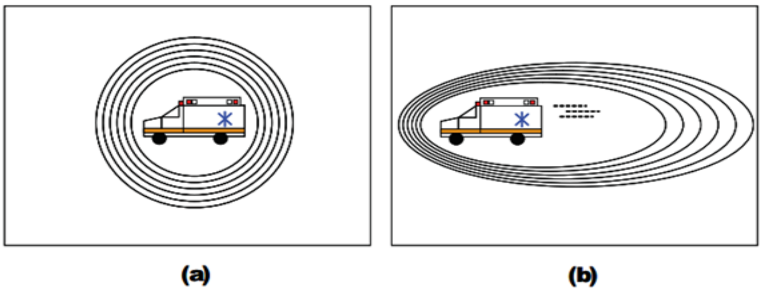


Fig. 1.8. (a) The frequency of a signal does not change when the transmitter and receiver are moving at the same velocity. (b) However, when the transmitter and receiver are moving relative to one another, the signal will undergo a Doppler shift.

1.5.4 Centralized vs. Distributed Algorithms

The resource limitations inherently gives difficulties while implementing particular localization techniques, as it need wide processor bandwidth and memory, mainly while tending with huge sensor counts otherwise while employing composite statistical techniques to compute position or range (Mao et al., 2007). A centralized localization technique executes over BS and entire node that is participating has to pass the measured data towards BS. The benefits of centralized techniques are these might be modelled which comprise additional precision and accuracy. The processing of BS affects from general centralization disadvantages like single point of failure, greater power utilization and poor scalability. It is better to use distributed or centralized processing while the nodes are mobile and it is highly significant. Rapid and continuous localization is required by mobility. Through there exist centralized localization approaches for mobile sensors they are always not fast for particular applications, like navigation. For instance, m-Track offers approximately 5 seconds latency. It is distributed at the same time and derives less than 1 second over return velocity and position estimates.

1.5.5 The Impact of Environment on Localization.

In localization technique effectiveness, the environment acts as a main role. One technique of localization will not be suitable for entire circumstances. The environmental factors are given below:

Pressure, humidity and Ambient temperature can affect the accuracy of localization as these factors impact directly the crystal oscillator in transceiver. Through precipitation, it is established with radio wave propagation involving air moisture additionally, hence localization method employs RF measurements might be impaired in the conditions.

The huge problems with Global Positioning System GPS is that it does not reliably work indoors, under water or cloudy. This is due to that the GPS receivers need LOS to four satellites moving around the planet.

To build precise localization methods, there is a significant effort in indoor situations. Indoor applications which need estimation of node position are difficult due to most propagation techniques and measurement approaches suffer from multipath effects (Hashemi, 1993), whereas obstacles cause signal reflections. Numerous existing localization methods that offers good accuracy in outdoor environment, however, it does not perform well in indoor environment.

1.6 MWSNs Applications with Localization Requirements

Various application kinds have been built already in that the localization act as an integral portion though MWSNs are in their infancy still. In four major types, the applications fall such as environmental, military, commercial and civil

Commercial

We desire that several applications in commercial field need few positioning data type as MWSNs is developed by popularity.

Service Industry

It is one of those domains which make use of MWSNs. For service robots, various organizations have begun to develop software which carries out tasks like fundamental patient care, security and maintenance in office buildings, and concierge and food service in hotels and restaurants. For estimation of position, these applications need a mechanism. Visual localization system is used by different organizations depending on pattern matching.

Objects are employed as landmarks and loaded as priori into system and execute dynamically. Through matching video images with landmark data, the robot learns the position.

Housekeeping

For domestic usage, iRobot is a vacuum cleaning robot that is automated. The iRobot generates a room map when it moves through, employing feedback from optical and bumper sensors. To recharge automatically its batteries, the iRobot employs self-docking station.

Environmental

For environmental monitoring, MWSNs become a precious asset and it has the capability to collect data over extensive regions of interest.

Wildlife Tracking

Zebra Net is that mote-scale wireless devices were given to zebras for the movement tracking purpose which is an early MWSNs. There exist no cell phone coverage, data was routed by peer-to-peer network towards mobile base stations because it uses remote region. The zebras were not limited to particular domains and except small devices attached with it, left undisturbed. Without using MWSNs, this tracking level is not probable.

Pollution Monitoring

(V¨olgyesi et al., 2008) projects a mobile air quality monitoring model. Sensor nodes which measure certain air pollutants are placed over vehicles. The sensors test the air when the vehicles move over the roadways and it records different pollutants concentration with time and location. The data are uploaded towards the server and provided into web, while the sensors are in access point's proximity.

Civil

Civil services are the domain which comprises huge MWSNs utility potential. It involves the non-military municipal applications which maintain the society securely and efficiently.

Pothole Detection

A model is built to find potholes over city streets in (Eriksson, 2008). When this is placed on taxi cabs, accelerometer is contained by the sensor nodes and it is communicated by employing cellular networks or opportunistic WiFi.

Wireless E-911

Enhanced 911 emergency telecommunications service in North America or E911, was introduced to associate callers with emergency services in a way that it will link physical location with caller phone number. E911 service is second phase through FCC, that need cellular devices that is wireless to offer user location automatically while the service is called. Wireless E-911 is significantly needed to employ various techniques involving multi lateration, multi angulations and embedded GPS chips depending on cell towers known locations.

Military / Aerospace

It is one among huge funders and promoters of wireless sensor technology. There exist an absolute distinction of hostile entities and tracking friendly, autonomous robots navigation, localization services, and intensive study is performed in this domain.

- **Shooter Detection / Weapon Classification:** Soldier-wearable sensor model is built which recognizes the enemy sniper location and the fired weapons are recognized.

Every sensor comprises microphone array placed over soldier helmet. Both muzzle blast and projectile shock wave is observed by sensor and depending on TDOA and acoustic signal features and is capable to triangulate the enemy location to categorize the type of the weapon.

- **Autonomous Deployment:** For sensor network repair and deployment, unattended aerial vehicle is employed. Those support the battlefield surveillance for military and it also helps by field operations in command and control manner.

1.7 MOBILE SENSOR NAVIGATION

Navigation systems have existed for decades, and it conventionally depend over celestial examination like measuring the angle among sun and horizon, correlative luminous star positions. Navigation has been used to mobile robots that are autonomous whereas the robot is dependable for travelling to area B from area A. The procedure of maintaining and determining trajectory or course towards a target location is described as navigation.

A target location does not refer to end mobile entity destination as they might not be one in this definition. A bounded area is defined through goal location to whereas the mobile entities have to proceed the subsequent one.

When comparing with historical nautical counterparts, the navigation techniques have a long history. The difficulties which are presented to answer below three questions are given: 1)" with respect to me, where are other places?"; 2) "From here, how can I go other places"; 3) "Where am?" However it does not need to give solution to all to navigate accurately to a area, the contemporary navigation systems have the capability to give a solution to one at least. To find the path among the target and present locations, it is needed to use extra navigational tools like search algorithms and obstacle avoidance.

A sensory input forms are needed which ultimately be converted to motion vector to forward a mobile entity to its target position.

Laser rangefinders, sonar and cameras are some common sensors employed for robot navigation. Fig. 1.9 demonstrates the equipped robot with the devices. They are precise extremely but they are bulky and take a considerable sum of energy sum and comprise substantial processing needs. For resource limited mobile sensors, they are inappropriate subsequently. But, sensors present which suits with mote-scale devices.

Digital compasses, wheel encoders, accelerometers and gyroscopes are involved in those sensors. As defined below, numerous navigation methods have been built which employed for deriving data from these sensor kinds.

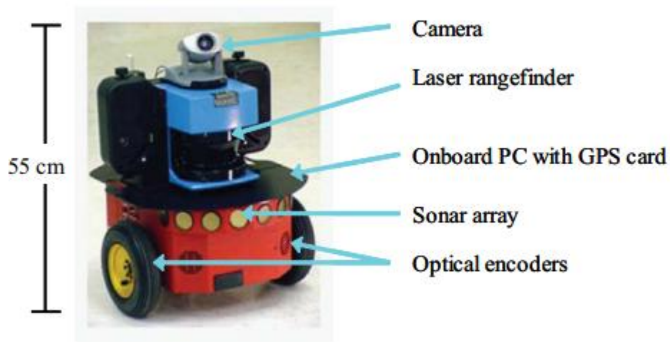


Fig.1.9. A mobile robot equipped with camera, laser rangefinder, sonar panels, GPS, and optical encoders.

1.7.1 Navigation Taxonomy

Way-finding and local are two categories of Navigational behaviour (Franz and Mallot, 2000). For attaining the target location, everyone demonstrates a strategy. To attain the target position, local strategy allows mobile entity through sensor input and area knowledge probably. In the present scenario, the entire sensor input is required to attain the target position.

At the same time, to attain the target, way-finding needs sequential examination of various landmarks. It might shift to local navigation methods to attain at precise orientation and position when the mobile entity is closer to the target.

A set of four behaviours are involved in local navigation which are listed below.

- **Searching**: This is fundamental local navigation behaviour that needs the ability for identifying the target. Mobile entity randomly moves or depends on few motion patterns; however, it will find the target through, rescue and search operation is the behaviour instance.
- **Direction-following**: The target can be searched through the path following in numerous circumstances. The path can be a compass point, celestial cue or magnetic field. An instance is travelling by ship from Europe towards New World through heading west. Along an applied axis, this needs mobile entity to itself align. The mobile entity does not comprise target in the domain view every time through path following, the target would be reached.
- **Aiming**: Mobile entity follows the path towards target position in direction-following method. The mobile entity is needed by aiming behaviour.
- **Guidance**: Frequently, the target location might not be visible towards mobile entity and depending on sensory input combination and known spatial relationship among present position, it should be guided the surrounding environment and target position.

The below three behaviors are involved in way-finding. These behaviors suit hierarchy depending on complexity such as local navigation.

- **Recognition-triggered Response:** To associate two locations, this behavior allocates local navigation method. Depending on either target or start position, the local strategy is chosen and known route among two. The responses to target and present position are fixed, which is, the similar local strategy would be employed always for navigating among two positions.

- **Topological**: Topological behavior avoids the limitation of recognition-triggered response. For instance, when route includes passing from one room to other and through closed door, the passage is blocked, at the door, mobile entity that navigates through recognition-triggered response will get stuck. To attain the target position, topological behavior uses mobile entity through complimentary strategy which might allow sidestepping the blocked doorway and giving modified route to room.
- **Survey Navigation:** To attain the target position, the two way-finding methods are limited towards travelling. Survey navigation take entire known data of environment into consideration and allows extra uncharted routes while needed.

1.7.2 Navigation Approaches

For navigation (Borenstein et al., 1997), there are two major techniques are available. The primary one is dead reckoning that was initialized in this chapter earlier. To learn position and orientation, the next is reference-based, that needs specifically a framework which might be examined through mobile entity. The specific reference-based navigation class is known as angle-based navigation that is extensively employed in this work. Onboard sensors are used by dead reckoning to decide the travelled distance on a target time interval. By employing odometer through encoders, distance will be determined by inertial navigation method like gyroscopes and accelerometers. The major advantage of employing dead reckoning model is that no external framework is needed. Through combining doubly integrating acceleration or velocity, position might be inferred in order to time; but, error would accrue unbounded except mobile entity might tune the error periodically through employing known reference positions. Dead reckoning is used by navigation methods (Elwel, 1999).

Mobile entities employ landmarks in reference-based systems in area for precise orientation and positioning. Landmarks might be active beacons like satellites, lighthouses, structures or sensor nodes in circumstance like buildings and trees. Model-matching is general usage for reference-based systems and known as mapping. To find landmarks, mapping needs capability in environment and combines it towards environment representation which was derived priori as well as saved in mobile entity memory. Landmarks are found typically for mobile robots employing cameras. But, the landmarks need not be structural. RSS profiling is a model-matching method type. Simultaneous Localization and Mapping (SLAM) is mapping type in that the mobile entity constructs a environment map on the other hand it decides the position. For the mobile entity localization, Simultaneous Localization and Tracking (SLAT) (Taylor et al., 2006) is method which follows the path when it takes to arrive at current position.

1.8 CLUSTERING TECHNIQUE IN MWSN

Clustering mechanisms have been applied to MWSN with hierarchical structures to enhance the network performance while reducing the necessary energy consumption. Clustering is a cross - cutting technique that can be used in nearly all layers of the protocol stack. The primary idea is to group nodes around a cluster head that is responsible for state maintenance and inter-cluster connectivity. In conventional cellular networks, fixed BSs are connected through wired backbones. Communications between two mobile nodes that are only 1 - hop away from their respective BSs can be established through the fixed BSs and the wired backbone. In this case, clustering is used to select and allocate channel groups to all the BSs within a system and to achieve efficient frequency reuse.

In multi-hop wireless networks, node clustering is a technique that aggregates nodes into groups (clusters) to reduce the routing overhead and to provide a convenient framework for efficient resource (e.g., bandwidth or code) allocation, energy management, fault- tolerant routing, and high end-to-end throughput.

In clusters without any CH, a proactive strategy is used for intra-cluster routing while a reactive strategy is used for inter-cluster routing. However, as the network size grows, there will be heavy traffic overhead within the network. Therefore, normally one node is selected as the cluster head of a cluster, and it acts as the local coordinator of transmissions within its cluster.

A hierarchical routing or network management protocol can be more efficiently implemented with cluster heads. As compared to the BSs used in current cellular systems, the cluster head does not have any special hardware, and is in fact dynamically selected among the set of nodes.

However, a cluster head performs additional functions as a central administration point, and a CH failure would degrade the performance of the entire network; it may become the bottleneck of the cluster. An efficient node- clustering mechanism tends to preserve its structure when a few nodes are moving and the topology is slowly morphing.

The objective of the node clustering procedure is to find a feasible interconnected set of clusters that covers the entire node population. The cluster contains a CH and cluster members. The cluster members sense the data and forward it to BS. In some cases, the data collector node is also placed that has the capability to gather data from CHs and forwards to Base Station.

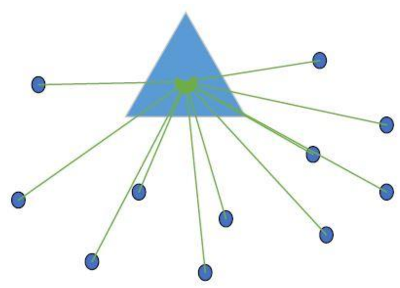


Fig.1.10(a). single-hop communications

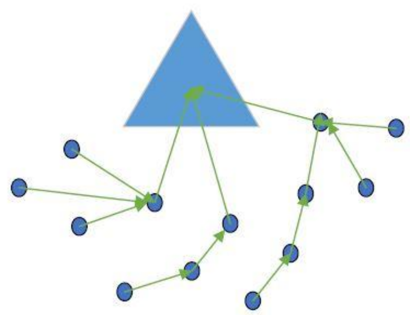


Fig.1.10(b). multi-hop communications

In MWSN, there is a possibility that numerous sensor nodes undergo deployment and the nodes are found to be deployed on the same region. As shown in Fig.1.10 (a). , the sensor nodes directly send the data to the BS. At the same time, Fig.1.10 (b). shows the multi-hop communications which utilizes intermittent nodes to transmits data. In case, when the nodes are not closer to BS, more energy will be used to transmit the data that leads to energy exhaustion (B. Mukherjee,2001). In case of multi-hop communication, the energy spent for transmitting data is distributed so that network lifetime can be improved. Since the network lifetime and energy resources are restricted, there is a requirement of energy efficient techniques for maximizing the results of the relay system. To this end (K. R. Dayananda, 2016), clusters are constructed that is employed for coordinating data transmission and reducing energy utilization.

In MWSN, the network is partitioned into a number of clusters using a clustering technique. Every node transmits the data to its local CH which is responsible to forward the data to BS for further computation. . In MWSN, data collector performs to collect the data from cluster head or nearby nodes and transmit to the BS. The BS plays a role of gateway to link the MWSN to the external environment, shown in Fig. 1.11.

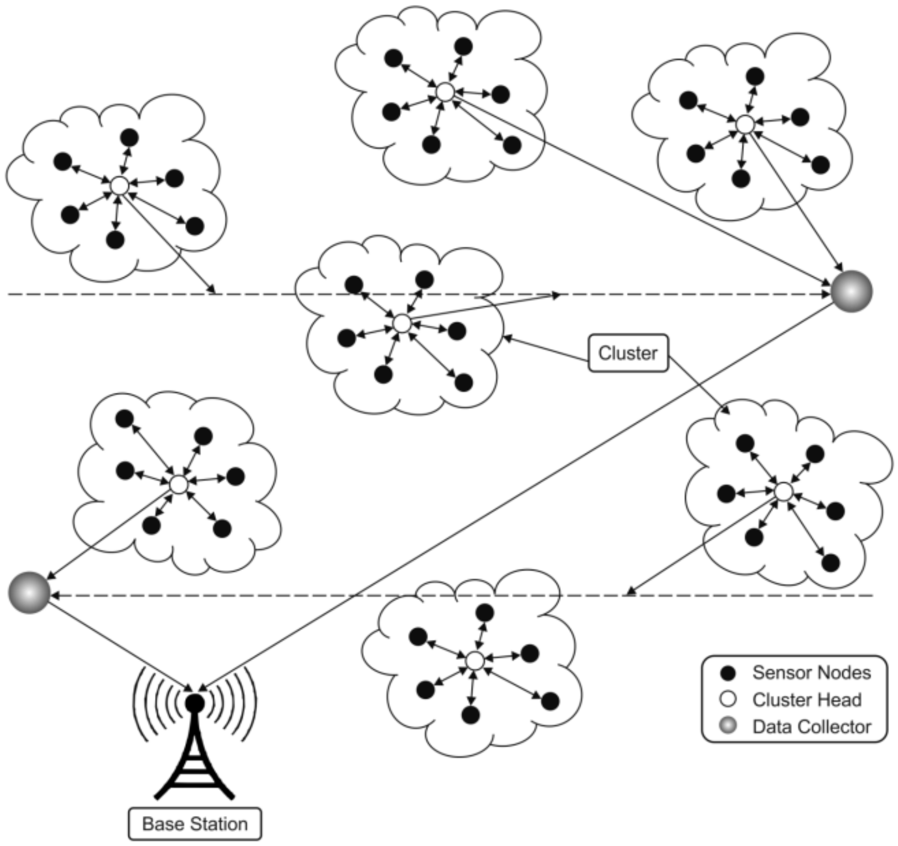


Fig.1.11. The overall clustering process in MWSN

1.9 MOTIVATION AND RESEARCH CONTRIBUTIONS

Actually, the nodes in MWSN are modelled with many supplementary sensors to sense the environment, microcontroller, storage area, communication unit, analog to digital converter (ADC) and power supply. Yet again, the nodes are restricted with inbuilt memory, battery source, processing and radio facility because of its tiny size. And, the mobile sensor node structure is nearly analogous to the actual sensor node. In addition, few supplementary units are included in mobile sensor nodes like location finder like GPS, mobile unit, and power generator. Location finder unit is employed to recognize the coordinates of the sensor node and the mobile unit makes the sensor node movable. The power generator unit is liable to produce energy for satisfying additional energy needs of the sensor node using explicit methods like solar cell.

In a few more processes like that, node localization acts a key enabling role. Node localization is needed to report the initialization of events, helps to request information from specific node, data transmission and so on. Hence, node localization in MWSN is considered as a crucial design issue. In a network, there would be a huge count of sensor nodes closely dispensed at locations that might be movable. In most of the MWSN, the data grouped through these sensors would be pointless if not the position out off wherever the data is acquired is well-known. This creates the localization capability of a network more important.

Hypothetically, a localization determining gadget like GPS might be able to be employed for a sensor to position itself. Although, it is unrealistic to employ GPS in every sensor node as a MWSN comprises of more number of nodes and GPS would be highly expensive. Notwithstanding, GPS do not work ever in indoor environment, so alternate solutions must be used. To resolve the issue, numerous localization approaches has been evolved. In spite of availing GPS to every node in MWSN, the localization methods simply consider that the minimum number of nodes contain GPS hardware. These nodes are frequently known as anchor nodes and they can easily recognize its locations.

In other way, some localization algorithms can be employed to determine the distance between the anchors and the actual sensor able to converse with some close by sensors and it examine distances between them by employing few localization algorithms, (For example, received signal strength (RSS), time of arrival (ToA)) and then obtain its location using the distance.

MWSN is considered as a multi-model and multidimensional optimization issue and it can be resolved by population dependent stochastic methods. Some localization algorithms using Genetic Algorithm (GA) are employed, which the estimated optimum node positions of every one-hop neighbour nodes. A two phase centralized localization method which employs Simulated Annealing (SA) Algorithm and GA is introduced. Particle Swarm Optimization (PSO) based approach is projected to improve the localization accuracy. Each of these heuristic and meta-heuristic optimization algorithms is dominant for resolving the localization issue. Most of the localization algorithms are developed based on the natural activity of biological systems and/or physical systems. For instance, PSO is proposed depending upon the swarm activities of birds and fish in addition SA depends on annealing process of metals whereas GA was stimulated from through natural activities like inheritance, mutation, selection and crossover. Every algorithm has its pros and cons.

A Bat Algorithm (BA) is projected depending upon echolocation activities of bats. BA has been introduced is stimulated through the fantastic activities of echolocation of micro bats. BA to a great extent efficient compared to other approaches in terms of precision and efficiency. The BA suffers from low success rate due to the fact that bat is not capable to discover each and every way in the search space. Consequently, to conquer this issue, the existing BA has been changed.

At the same, the energy utilization of transmitting images and videos is a main concern in MWSN, there is a need to develop big data processing technique in smart sensor environment like MWSN. Among the diverse solutions exists, cluster based routing protocol is a commonly employed solution. Though various clustering techniques for MWSN have been developed, there is still a need to further improve the energy efficiency by considering the different perspectives. To overcome the limitations of the existing algorithms, A new DBC algorithm for CH selection has been derived.

Most of the existing works are concentrated on energy efficiency. But, in this work, we incorporated both energy efficient clustering and include a concept of super CH (SCH) for inter-cluster data transmission.

Keeping all the above mentioned issues in mind, we organize the research work into several phases and the major contributions are listed below:

- An extensive survey has been made related to the existing node localization and density based clustering in MWSN.
- To design and combine BAT and TLBO (BAT-TLBO) based algorithm to resolve node localization problem and attains maximum lifetime.
- To design a Density Based Clustering (DBC) Technique to achieve energy efficiency and maximum lifetime
- To design a cluster based node localization (CH-NL) and network life time maximization in MWSN. To validate the effectiveness of the proposed algorithms using several performance measures under different scenarios.

1.10 THESIS ORGANIZATION

From the above mentioned research contributions, the overall thesis is formulated in seven chapters and the thesis organization is listed as follows:

- Chapter 2 discusses the various localization techniques, clustering protocols and also classifies the existing methods under several aspects. In addition, this chapter reviews the state of art methods of data aggregation techniques in WSN

- Chapter 3 portraits the overall system design of the research work and enlighten the research contributions for the proposed work as per the derived research objectives.
- Chapter 4 introduces the proposed BAT and TLBO (BAT-TLBO) based algorithm to resolve node localization problem and analyzes the experimental results of the proposed method under several aspects.
- Chapter 5 discusses the proposed density based Clustering and multi-hop data transmission protocol to achieve energy efficiently and maximum life time and involves the detailed experimental analysis under three different scenarios.
- Chapter 6 explains the cluster based node localization (CH-NL) and network life time maximization MWSN and is tested using differ performance measures.
- Chapter 7 concludes the research work of node localization based clustering technique and the future enhancements of the research are given.

1.11 SUMMARY

In this chapter, a brief overview of MWSN and its application areas are provided. In addition, the variation of MWSN and WSN is given in detail. Furthermore, node localization concepts and basic techniques are discussed briefly. In addition, the motivational factors and the research objectives of the thesis are given. At the end, the outline of the thesis is provided in a chapter wise manner. The next chapter deals with detailed discussion regarding the literature work carried out in the respective problem with its existing challenges.

CHAPTER 2

LITERATURE SURVEY

2.1 OVERVIEW

MWSNs act as a major part in practical scenarios in that the sensor nodes are movable and not stagnant in nature. MWSNs are flexible to a great extent when compared to WSNs since the sensor nodes undergone deployment in different environments and it manages with fast topological modifications. And, the mobile sensor nodes have the nature of changing their location often in the provided sensing region. The process of node localization in MWSN is a challenging task which intends to determine the location coordinates to every device with unknown positions in the target region. Presently, different meta-heuristic based optimization algorithms for node localization have been devised. In addition, various clustering techniques for MWSN are also introduced. This chapter reviews the existing node localization, clustering and routing techniques which are relevant to the proposed research.

2.2 REVIEW OF NODE LOCALIZATION TECHNIQUES

In MWSNs, a standard technique for localization is discussed. Primarily, the localization techniques classification is offered. The final section discusses other techniques which are modelled to deal with mobile anchor nodes and mobile nodes.

2.2.1 Classification of Localization Techniques in WSNs

A detailed classification of localization techniques are discussed in this section. They are classified into distributed and Centralized methods, range-based and range-free methods, anchor-based and anchor-free techniques. Finally, stationary and mobile localization methods are presented.

2.2.1.1 Centralized versus Distributed Localization Algorithms

Localization techniques might be divided into distributed (Shang andRuml, 2004; Priyantha et al., 2008; Ihler et al., 2005) or centralized (Doherty et al., 2001; Shang et al., 2003) methods depending on its computational environment. Nodes transmit data towards main location in centralized methods wherever every node location and computation is carried out and transmitted back again towards nodes. The disadvantages of centralized methods are its intrinsic delay and higher communication costs. When the network node count increases, the intrinsic delay also increases and it creates centralized method is ineffective for massive networks in most of the cases. Distributed techniques that disperse over the network the computational load to minimize the delay and sum of inter-sensor communication had been presented (Shang et al., 2003). Through communicating with the adjacent nodes, every node decides the position in distributed techniques. As every node decides the location locally with the adjacent support, distributed techniques are highly energy efficient and robust without the requirement to receive and transmit the location data from and to a main server. For implement, it might be highly composite and also at some time not probable because of the constrained abilities of sensor node computation.

2.2.1.2 Range-Free versus Range-Based Localization Techniques

Two kinds of techniques are presented in order to decide the sensor node location: range-based (Bahl andPadmanabhan, 2000) (Priyantha et al., 2000) (Chen et al., 2006) (Alippi and Vanini, 2004) and range-free (Bulusu et al., 2000) (Huang et al., 2003) (Niculescu and Nath, 2003). To compute the position of the node, the data connectivity is employed by Range-free techniques among the adjacent nodes whereas to compute the distance among two adjacent nodes, ranging data might be employed by range-based techniques.

Extra hardware is not needed by the range-free techniques and to compute the node location, it employs proximity data in WSN and it have constrained precision. range measurements like angle of arrival (AoA), time difference of arrival (TDoA), time of arrival (ToA), and received signal strength indicator (RSSI) are used by range-based techniques to measure the distance among the nodes with a view to node location estimation at the same time. The various ranging methods are discussed as below:

Time of Arrival

With a predetermined velocity, the whole sensors send a signal towards its adjacents in the method of Time of Arrival (ToA). A signal is passed back to its adjacent by every node by employed the count of received and transmission and computes its distance towards the adjacent.

Received Signal Strength Indicator

The sum of power exist within a received radio signal is called as Received Signal Strength Indicator (RSSI). When radio propagation distance increases, there will be a decrease in received signal strength (RSS) because of the path loss of radio-propagation. at the receiver, by employing the rate of RSS, the two sensor nodes distance might be compared, through considering the sender transmission power is fixed or known either (Stojmenovic, 2005).

One among the benefits of this method is no extra hardware is needed and it employs features in wireless devices such as attained signal strength indicator. It does not affect size of the sensor or local power utilization and cost. Inaccuracy is the drawback of this method. For instance, the method precision is highly affected when the sensor network is placed in walls, indoors because of the noise, absorption, nonlinearities and interference.

Time Difference of Arrival

The technique of Time Difference of Arrival (TDoA) need a node to pass two signals that transmit over various speeds. Every node is equipped with speaker and microphone in this method. Many models employs ultrasound when few employ audible frequencies. Through a transmitter, radio message is passed in TDoA which wait for a certain time interval and creates some chirps pattern over the speaker. The radio signal is heard through the nodes in listening mode and denotes the present time and for the chirp pattern detection, they turn over the microphones and denote the present time again. The nodes might estimate the distance among itself when they had various times and transmit as the radio waves passes in high speed when compared to sound (Stojmenovic, 2005).

TDoA techniques carry out accurately when conditions such as line-of-sight are faced and also when there is echo friendly environment. Specialized hardware is the main drawback of those models that have to be constructed into sensor nodes. With humidity and temperature in air, the sound speed differs that gives inaccuracies. To satisfy the conditions of line-of-sight, it is highly complex in numerous circumstances like in mountains or inside construction.

Angle of Arrival

By employing microphone arrays or radio, the method of Angle of Arrival (AoA) collect the data. This array enables a receiver node that decides the transmitting node direction. To collect AoA data, the method of Optical communication must be employed. Through numerous spatially separated microphones, distinct transmitted signal is heard. The time difference or phase among signal’s arrival at various microphones is computed and therefore signal AoA is found.

To some extent, this method is accurate, one of the drawbacks is when compared to TDoA ranging hardware, AoA hardware is big in size and costlier, as every node should comprise one speaker and numerous microphones. Other significant factor is the requirement for spatial separation among speakers that might be complex to contain the sensor nodes size when decreases (Stojmenovic, 2005). Highly accurate outcomes might be offered through range-based method however it need costly hardware, like antenna arrays and ultrasound devices for AoA and TDoA respectively. A drawback of range-based method is distance data might be composite to adopt by real time because of the problems like obstacles and omni-directional ranging absence that avoid line-of-sight.

2.2.1.3 Anchor-Based versus Anchor-Free Localization Techniques

For WSNs, other localization algorithms, classification depends whether the exterior reference nodes are required. Anchor nodes are known as the nodes either know its location through physical set up or comprise an installed GPS receiver. To offer coordinates, they are employed through other nodes as reference nodes in complete reference model that are employed.

Anchor nodes are used by (Shang et al., 2004) (Shang andRuml, 2004) (Boukerche et al., 2007) (Li and Kunz, 2009) anchor-based techniques to translate, rotate and scale the relevant coordinate system few times as it with a strong coordinate system. Anchor nodes of three non-collinear are used for at least two dimensional spaces. In order to the global coordinate system otherwise another coordinate system, the end coordinate sensor node assignments are suitable. A disadvantage of anchor-based technique is the requirement of positioning technique to decide the position of anchor node. For example, for GPS-based anchors position in regions when the other positioning model is engaged wherever there is no clarity, the method might not properly function. Other disadvantage for anchor-based techniques is they are expensive and they need a GPS receiver to place over it. Hence, the methods that need numerous anchor nodes are not cost-effective highly. Location data might be solid towards the anchor nodes but cautious anchor node deployment is needed that might be highly improbable and costly in terrains that are inaccessible.

Anchor-free localization techniques do not need anchor nodes. This technique offers relevant node locations only, that are location of node that shows the sensor node position relevant to every other. Those relevant coordinates are adequate for those applications. For instance, the subsequent forwarding node is selected always in geographic routing protocols depending on the distance measure which need the subsequent hop to be near physically towards the destination that might be demonstrated perfective with relevant coordinates.

2.2.1.4 Mobile versus Stationary Node Localization

In WSNs, the mobility problem had attracted many people interest recently when the application count needs mobile sensor nodes. Researches has been presented over mobility introduction offers a whole network enhancement and it not only enhances the whole lifetime of the network, however, it enhances the network data capacity and governs latency and delay problems (Liu et al., 2005) (Wang et al., 2005). To support the static sensor nodes (Priyanthaet al., 2005) (Sichitiu and Ramadurai, 2004)(Galstyan et al., 2004) localization, few researchers have presented methods in that the mobile anchor nodes are employed; an instance of the application is inventory management which is the benefit of that technique. All or few sensor nodes are mobile in other circumstances. This is why "the tracking and locating problem is created through mobility and moving sensors in real situation". For searching static sensor node locations, mobile anchor nodes are used by algorithms which position the mobile sensor nodes that are surveyed.

2.2.2 Localization Algorithms Proposed for Stationary WSNs: CCA-MAP

For static WSNs, numerous localization techniques had been projected. The aim is at CCA-MAP technique that is the foundation for the projected iCCA-MAP. For static WSNs, the technique of CCA-MAP is one of the high performing method to the best of our knowledge. CCA-MAP is a technique of cooperative node localization that is projected through (Li andKunz, 2009) that uses an effective method of non-linear data mapping known as Curvilinear Component Analysis (CCA) (Demartines and Hérault, 1997), for node localization within WSN. The localization problem can be formed as Cooperative localization method and to extract location coordinates, optimization method are used by assuming the entire conditions over inter-node distances, instead of assuming the conditions among anchor and sensor nodes. CCA was projected actually for multidimensional data sets representation and dimensionality reduction which is also a self-organizing NN. input space vector quantization is carried out by self-organizing NN and quantized nonlinear projection vectors to the output space, through data sets mapping in high dimension towards low one.

CCA is used by CCA-MAP to construct local maps at each probable network node and combines together to formulate the global map. Local data is used by every node to estimate the local map. For node coordinate computation in local map, CCA is used. For networks with lower nodes than 1000 in CCA-MAP technique, adjacent in two hops are involved in local map construction for every node. Neighbours in one hop suffice for networks higher than 1000 nodes. The shortest local map distance matrix is estimated and employed as rough distance matrix. By employing lowest hop counts, the shortest distance matrix of every local map is extracted from each node to each other node when the CCA-MAP range-free version is used in local map otherwise it might be extracted from distance measures among node when the range-based CCA-MAP version is employed.

CCA algorithm is applied to every node through the relevant coordinate generation of every node within its local map. $O(k^2)$ is the computing complexity of every local map, wherever k refer the average count of two hop neighbours. The local maps are combined then. Depending on the anchor node locations, an absolute map is transformed by the combined map. Three anchor nodes are needed minimally for a two dimensional space, CCA-MAP experimental outcomes demonstrates that the technique can attain highly accurate localization performance by employing the reduced three anchor node set (Li and Kunz, 2009). The randomly chosen local map node is employed in merging phase for giving the map. The adjacent node who shares the local map nodes with present map is chosen to combine the local map into present map. Two maps are combined by employing the general node coordinates. For combining the novel local map to a present map, linear transformation is employed. When CCA-MAP is executed within a distributed manner, this method enables local maps to be combined in various network parts, or the maps are combined in series. $O(k^3n)$ is the map merge complexity, wherever average count of two hop adjacent is denoted through k and sum of node is n.

When combining the map, anchor nodes are not needed. But, to derive the fixed node coordinates, an absolute map might be estimated by employing anchor node coordinates to derive the clear node coordinates while three anchor nodes exist within the sub network patched map. $O(a^3 + n)$ is the complexity for anchor nodes. In a distributed manner, CCA-MAP technique is performed wherever every node estimates the local map otherwise it might be performed over powerful clusters gateway nodes when the sensor network employs central computing framework or at hierarchical framework when expected.

MDS-MAP is the other localization technique which produce local maps however global maps are built similarly. Three or higher general nodes are required in two dimensions to stitch rigidly through two maps by reflecting, rotating and/or translating one map with a view to adopt respective node as near to every other as probable. It can be either incremental or peer-to-peer, the order through that the local maps are combined (Kwon and Song, 2008). Two maps might be combined in peer-to-peer technique when they comprise adequate general nodes. Hence, there is node requirement for a global schedule as the stitching happens over the full network simultaneously. Single map is stated as core map in incremental stitching and others are stitched one for each time. Maximum Common Nodes First (MCF) stitching is a method that searches the map which comprises higher count of general nodes that is executed. To offer superior accuracy and to avoid flip errors, the researches project a technique which uses the entire distances among two maps that are available.

2.3 Localization Methods Proposed for Mobile WSNs

In MWSNs, The techniques that handle mobility are discussed in this section. These methods are segmented into three techniques for mobile anchor nodes that support in searching static node locations, these techniques that support both sensor and anchor nodes as mobile.

2.3.1 Algorithms for Mobile Anchor Nodes

With measurements among node pairs, mobile user is used to support in mobile-assisted localization (MAL). Until the distance conditions are met, measurements are done that is based on visible node counts in an applied area that produces a globally rigid framework which make sure a distinct localization. The needed conditions are decided through the minimal measurement count and it needs to be gathered and movement of nodes. "A robot or roving human roams over the region in this technique that gather distance data among the node and thyself" (Priyantha et al., 2004). For indoor environments, the MAL performance is examined by employing Cricket location system.

Through the GPS receiver usage, a localization method of distinct mobile anchor node is aware of the location in (Sichitiu and Ramadurai, 2004) is demonstrated. The proximity conditions that are inferred through the receiving sensor nodes data packets are employed to manage and to build position computation. Bayesian inference is employed in this technique. Mobile anchor nodes might be a plane, unmanned vehicle or human operator that the nodes are placed. This technique is radio frequency (RF) based that means that the attained signal strength indicator is employed for range metrics, through the other techniques of ranging measurement might be employed. The drawbacks of employing RSSI method are lower accuracy, interference, absorption and noise that impact mainly precision in indoor set up wherever the walls are main obstacles.

To reduce the location uncertainty, distributed online algorithm is projected through Galstyan et al. whereas geometrical conditions are used by nodes that are caused through sensing data and radio connectivity. Generally sensed data is offered by moving target in terms of sensing conditions wherever these conditions are tight when compared to the conditions of radio connectivity. Primarily, movement of anchor node is employed to self setting up the network dynamically by distributing the node coordinates that are in the sensing area as it roams over the network.

Each time, when the node senses anchor node, a novel quadratic condition is produced. To minimize the node locations uncertainty, this conditions is employed additionally. Through a rectangular bounding box, the sensing are is approximated, thereby replaces the quadratic condition through simpler linearized condition that make sure the node original position is in bounding box. With unknown coordinates, the moving target is used by researchers. When there are adequate nodes, the target might be localized which interprets the approximate locations. The received data out of the goal might be employed to inflict novel limitations over the node location, through enhancing the node's location accuracy.

For target localization, triangulation is the highly well-known technique however it need three sensors at least with 2D known locations that cannot be attained sometimes. Bounding rectangle is used through the researchers for the goal for this reason that makes sure that the original goal location is in bounding box always. In the below two manners, target data might be employed by nodes: (1) through target observation, the conditions are used over the node's location. (2) The node can employ the “negative” data to implicate the tight conditions over the own location, when the goal is not found through the node. The main disadvantage of this technique is the time it takes for the mobile anchor node towards node coordinates broadcasting in the sensing area that is based on network size, radio range of anchor node and deployment region. When node in the vicinity interprets the locations, other impact is time that might be needed for goal.

Mobile Anchor Point (MAP) is the other technique which employs mobile anchor nodes for node localization attainment (Ssu et al., 2005). Beacon messages are distributed anchors in the method with the location data as they move by the sensor domain. This technique gives communication range among the node and anchors that is encircled through a circle and at the circle centre, the node is positioned. To formulate the circle chord, the node employs moving anchor locations which are selected. Through estimating the two perpendicular bisectors intersection point of the cords, geometric corollary begin the chord perpendicular bisector which passes by the circle centre that is employed for node location determination. A visitor list saving the mobile anchors in which the messages had been attained through the linked lifetime and sensor node is managed through every sensor node. In the visitor list, the node validates whether anchor node have been inserted each time, out of a mobile anchor, it retrieves beacon message. Beacon message would be chosen as beacon point when the anchor node might not be inserted and the predefined anchor lifetime would be inserted in visitor list. In the node's visitor list, the mobile anchor node present and its lifetime is extended. The final beacon message of anchor node is recorded as beacon point; the respective visitor list entry is eliminated if the anchor node lifetime expires. The accuracy is based on the speed of mobile anchor nodes and count that available mobile anchor nodes.

2.3.2 Algorithms for Mobile Sensor Nodes

In mobile WSNs, the technique of Color-theory-based Dynamic Localization (CDL) (Shee et al., 2005) is localization technique that employs colour theory to node localization. In the centralized server, the algorithm function is to construct a location database to set map the rates of red-green-blue (RGB) towards the geographical location. This method work as below: RGB values are received by sensor node from anchor nodes, it estimates the RGB values. It transmits the rate of RGB towards the server, wherever the nearest probable location is questioned within database. In the CDL technique, distance measurements are depends on method of DV-hop in that the extracted shortest path is huge commonly when compared to the respective Euclidean distance that might cause inaccuracy in location computation. For mobile nodes localization, anchor-free and range-based technique is projected by (Yu and Yu, 2007) by employing rigidity theory.

- Every node comprise a arbitrary primary location and constant speed;
- Every node primary position is known, either through primary node placement otherwise through usage of stationary localization method.
- Every node transmission range, there exist two adjacent position at least.
- To search the distance among two sensor nodes, methods like ToA, AoA, RSSI, and TDoA might be employed.

By employing four expressions, through resolving for unknown node locations, the end node position is searched when there is a distinct solution. To follow the entire adjacent nodes and adjacent nodes neighbours, the drawback of the method is the sum of needed memory, and the entire predicted node positions should keep in memory till a last distinct solution is decided.

2.3.3 Algorithms for Mobile Sensor Nodes and Mobile Anchor Nodes

In the range-free localization context, mobile anchor nodes are the earlier work over mobile node localization is through Hu and Evans (Hu and Evans, 2004), who introduced series Monte Carlo Localization (MCL) technique for WSN that are mobile. The researchers demonstrated that a technique using mobility might minimize the localization costs and enhance the accuracy. In robotics, this technique depends on Monte Carlo Localization technique. The probable posterior distribution locations as valid solutions are demonstrated through weighted samples set.

No knowledge location is comprised by the nodes and therefore the N random locations set are selected as primary samples in deployment region. Two phases are contained through every step, which is known as filtering and prediction phase. A movement happens in prediction phase and increases the uncertainty, whereas the data updating is done in filtering phase depending on novel observations. The probable locations are estimated through the node in prediction phase depending on previous probable locations and the higher velocity. Location data is transmitted by anchor node and it depends on anchor node locations. Indirect and direct anchor observations are the two kinds of observations. The node should lie in a circle with r as radius when a node hears about the anchor. While a node may not even hear the anchor however any of the adjacent hears, indirect anchor observation is carried out which denotes that the node should lie in 2r and r of the anchors location. Until satisfactory nodes‟ location estimation is performed, this procedure is iterated.

Two modifications of technique of Monte Carlo Localization (MCL) is presented and analyzed which is known as Dual MCL that might be assumed as actual MCL algorithm logical inverse and Mixture MCL is an amalgamation of Dual MCL and actual MCL. Experimentations in which the count of nodes, node velocity, irregularity in radio pattern degree, seed count, samples that are modified are performed. The researchers suggest both Mixture MCL and Dual MCL are highly precise when compared to the actual MCL technique. The Mixture MCL succeeds the other technique by means of trade-off among computed location accuracy and computational time.

Filtering and prediction phases of actual MCL techniques are inverted rather in Dual MCL. From the deployment region, the instances are produced in Dual MCL prediction step and they are verified depending on anchor nodes that are heard through adjacent or the node itself. The predicted instances are filtered in phase of Dual MCL filtering, and the examined predicted instances are filtered depending on prior node location and higher node velocity might travel. The actual MCL and Dual MCL are merged by Mixture MCL through sample generation by employing both the techniques and combining the instances by employing mixing rate. The produced results by employing Mixture MCL is not precise when compared to Dual MCL, however by means of trade off among the computed location accuracy and computational time, Mixture MCL succeeds Dual MCL. The need of higher anchor node density is the main disadvantage of MCL technique.

The MAP algorithm extension is Extended Mobile Anchor Point (EMAP) (Ou, 2008) that is used for mobile sensor nodes. In static WSN, mobile anchors are used by MAP algorithm, where this technique is extended through EMAP to tackle the mobile sensor networks. As the anchor nodes move by the sensing are, anchor nodes transmit the location data. For the node location prediction, the perpendicular bisector corollary of a chord is employed.

By employing measuring devices like odometer and compass, EMAP considers that the moving direction and its distance are known by mobile nodes. A main disadvantage that the mobile node comprises moving direction and distance knowledge. This requires the extra hardware usage that enhances cost.

(Li et al., 2006) projected Enhanced Color-theory-based Dynamic Localization that depends on CDL method (Shee et al., 2005), in which accuracy of location is based on average hop distance derivation accuracy. Mobile anchor nodes are used by the researches in spite of static ones to improve the measurement accuracy and to minimize the sensor node isolation probability within multi-hop setup. Anchor nodes are adopted by four square field corners and shift the radio range (r) distance in each time period. For few nodes, this causes a minimization of hop count towards the anchors and causes enhancement for others.

The anchor nodes mobility is seem to problem solving of probable disconnections out of the network. Other enhancement of CDL technique is the presentation of two novel techniques for estimating the average hop distance metrics. The primary one estimates the desired rate of subsequent hop distance depending on subsequent hop that is location among r and 0.5r and average hop distance is adjusted by next projected technique depending on Euclidean distance ratio of shortest length of the path. E-CDL accuracy is based on RBG model granularity that is employed in this technique.

2.4 Routing protocols for MWSNs

The routing methodologies towards MWSNs might be distributed, hybrid or centralized. For MWSNs, A reliable and effective routing protocol model assumes sensor node mobility, network coverage, QoS, data aggregation, communication link heterogeneity, security, network topology, energy consumption, data transmission techniques, connectivity, sensor node and scalability. The previous routing protocols are combined depending on its routing frameworks like hierarchical, location and flat based routing protocols.

Hierarchical based routing might be divided extensively into optimized and classical hierarchical based routing. Towards the destination from source, path establishment explores that enables reactive, hybrid and proactive based routing (Mamun, 2012; Niculescu, 2005; Lai et al., 2013).

2.4.1 LEACH variants

For hierarchical routing depended sensor networks, LEACH is the well known dynamic clustering techniques, for the distributed environment that is modelled absolutely and there exist no global knowledge needed over the network. To choose the cluster head(CH), the sensor node employs attained threshold rates and signal strength that formulate a cluster. The interval is updated through topology or round is assumed for transmission of data that is segmented into time intervals that are fixed with equivalent length. Through choosing the arbitrary count among 0 and 1, every sensor node over network comprise the equivalent probability, and hence sensor nodes slowly die (Yu et al., 2014). The total network operations are assumed as round. Setup phase comprise every round and phase of steady state.

The data transmission LEACH protocol phase comprised of inter and intra cluster communications. The CH gathers cluster members data and combines instantly the data in intra-cluster communication. Inter-cluster communication is begin toward the data forwarding of CHs towards sink after the intra-cluster communication completion. Network lifetime enhances the dynamic clustering for MWSN in large scale, static LEACH is not appropriate. Hence, for dynamic networks, LEACH with mobility should be assumed.

For the mobile sensor networks (Gu et al., 2012; Mezghaniand Abdellaoui, 2014; Souid et al., 2014; Santhosh Kumar et al., 2008), mobile LEACH, LEACH-mobile-enhanced and T-LEACH are assumed as variants of LEACH.

2.4.1.1 T-LEACH

For dynamic, uneven and large scale distributed mobile WSNs, a hierarchical topology is offered by T-LEACH and LEACH protocol (Qi and Mini, 2014). To manage the full network energy utilization and to enhance the rate of packet delivery, it employs tree topology. Topology maintenance and construction are the two phases in which T-LEACH is executed. Primarily, the phase of topology construction gives a cluster structure, multi-hop transmission architecture and data aggregation tree. Multi-hop transmits method, cluster mobile reaction scheme and member nodes mobile reaction scheme is followed through the phase of topological maintenance. To offer a static network, the phase of topological maintenance follows the methods like member nodes mobile reaction, cluster mobile reaction and multi-hop transmits secondly. T-LEACH protocol might offer efficiency and manage the topological framework of uneven and dynamic distributed large-scale MWSNs from the experimental outcomes by means of average energy utilization and packet delivery ratio while comparing with cluster based routing (CBR) mobile LEACH and LEACH.

2.4.1.2 Mobile LEACH/LEACH mobile

For MWSN, mobility-centric protocol is modelled for Mobile LEACH (Gu et al., 2012). Towards the operations of static LEACH, operations of Mobile LEACH are highly same. However, in a setup stage, the mobile sensor nodes inclusion is allowed through mobile LEACH with non-CHs and rearranges the minimal energy utilization cluster. The CH allocates a time period after the formation of cluster for the entire sensor nodes within the cluster. To reduce the dissipation of energy of distinct sensors, radio is turned off by cluster members excluding the transmitting time. Through the data packet loss reduction, Mobile LEACH succeeds the LEACH which it is analysed from the simulation outcomes. However, Mobile LEACH comprise trade-off which enhances the unnecessary dissipations of energy when comparing with LEACH.

2.4.1.3 LEACH-mobile-enhanced (LEACH-ME)

For CH selection over every round, LEACH assumes residual energy level of sensor nodes, hence, for dynamic networks, LEACH is not appropriate. Depending on the energy level and mobility of sensor node, the CH is elected by LEACH-ME (Santhosh Kumar et al., 2008). Mobility factor, list of cluster members, node role and schedule of TDMA are few data that are maintained through LEACH-ME. Mobility factor is significant key for the CH election, even though sensor node manages entire four data. Depending on remoteness ideology and transition count, mobility factor is estimated. Every CH might be formed as cluster member group of minimal node mobility due to the pieces of data. When compared to the mobile LEACH, experimental outcomes demonstrates LEACH-ME does well by means of normalized performance, energy overhead, average successful communication, computational overhead in order to mobility factor.

2.4.2 Mobile sink-based routing protocol (MSRP)

To extend the cluster based WSN network life time, MSRP (Nazir and Hasbullah, 2010) is projected. While comparing with the farthest sensor nodes, node that are near towards the sink must pass a huge count of data packets commonly and it might reduce the residual energy quickly. The issue is known as problem of hotspot. The sensing area is the cluster portion and extends the network lifetime to prevent those problems.

Mobile sink is assumed in MSRP in spite of static sink and which visit every cluster to gather the data that is sensed over its CH. Residual energy data is gathered through mobile sink about the CH and move over the high energy CHs.

Setup and steady state phases are comprised by operation included in MSRP protocol. The entire network is partitioned into clusters in phase of setup and the mobile sink advertises the location towards the CHs through the beacon message broadcasting for process of registration. The steady state is introduced after the setup phase completion. Over the registered CH, the sink gathers the data in the steady state phase and from cluster members, the CH gathers the data. It might be segmented into three sub-stages like sink forwarding, sink movement and TDMA scheduling. Mobile sink visits frequently the entire CHs depending on the CH residual energy in a network and gathers the data between them. Over the mobile sensor nodes, experimental outcomes shows that the energy utilization is reduced by MSRP and it resolves the problem of hot spot because of one-hop adjacent node changing of mobile sink.

2.4.3 Mobility adaptive cross-layer routing (MACRO)

To satisfy the significant need of MWSNs, MACRO is build like minimal power utilization, packet delay and peer-to-peer reliability. Towards huge scale MWSNs, optimal solutions cannot be offered through development of single layer protocol. Cross-layer interaction MACRO protocol is build through researchers that merges Open System Interconnection (OSI), network, transport, physical layers and media access control (MAC) into one protocol. The model of MACRO protocol comprise data forwarding, route management techniques and route discovery that offers trustworthy quality links towards modification by frequent topology. Additionally, it minimizes the unnecessary control packets flooding, failure of node and severe MWSNs congestion.

2.4.4 Energy management algorithm in a WSN with multiple sinks (EMMS)

To enhance the data transmission quality and residual energy consumption, EMMS (Shi et al., 2016) is projected. For MWSN, for management of energy, the operation of EMMS protocol with numerous mobile sink is assumed into two phases: (i) Decide every mobile sink sojourn locations over the needed near tour, (ii) Search the nearest tour of every mobile sink. For the mobile sink, at every location and time is rooted through a routing tree.

Over every mobile sink, there exist two kinds of wireless transmission interfaces in EMMS: (1) lower power wireless interface- sensor node communication within sensor network, (2) higher bandwidth wireless interface— for remote data transfer purpose, third-party network communication. The operations of EMMS energy management are assumed to be in rounds like LEACH. At every sojourn location, every round comprise of construction of routing tree, sensing data transmission and data collection. Computation of sojourn time begins to estimate the constructed tree members and computes at every location the sojourn time over the every sink closed tour.

The sensed data is transmitted through the sensor nodes over the mobile sink in the data sensing and collection phase of data transmission through the built routing tree and broadcast the data that is sensed towards the remote monitoring centre. Residual energy data is collected by mobile sink at the data transmission end of the sensor nodes in the neighbour set and travels by the subsequent sojourn location. The usage of residual energy is enhanced by the experimental outcomes and the quality of MWSN data transmission significantly.

2.4.5 Artificial bee colony (ABC) based data collection for large-scale MWSNs

ABC algorithm is projected through (Zhang et al., 2013) that assume three groups of "bee" in the "colony". Every bee denotes a location in the searching space. To takes a honey form source, a bee waits usually over the “dance” region in onlooker, and finds scout and it returns the priory visited source of honey that is demonstrated as employed bee. The probable solution towards the problem of optimization is the honey sources position. Furthermore, the sum of honey source “nector” relative towards the correlated problem quality. The primary portion of the technique signifies the bees that are employed and the onlooker bees are employed by the next portion. The technique is segmented into four major phases such as selection of bee source, population elimination, initialization, updating of population.

2.4.6 Mobility-based clustering (MBC) protocol

To enhance the MWSNs performance, mobility-based clustering (MBC) Protocol is developed through (Deng et al., 2011). Over every round, the steady-state and setup phase are contained through the operations of MBC protocol like LEACH. To select the CH depending on the threshold rate, the entire sensor nodes comprise equivalent probability in setup phase. For the process of cluster formation, connection time is assumed through MBC that constructs highly trustworthy path depending on availability or stability of every link among the CH and cluster members.

2.4.7 Cluster independent data collection tree protocol

For large-scale MWSNs, cluster independent data collection tree (CIDT) method is build, to offer trustworthy peer-to-peer communication (R.Velmani, 2014). For hybrid logical method, CIDT is distinct technique that employs data collection tree (DCT) communication and intra-cluster communication for tree and cluster topologies correspondingly. By means of energy utilization, PDR, network lifetime, data collection, delay and throughput, the protocol design aid to enhance the QoS attributes for large scale MWSNs. With superior connection time, every sensor node takes the CH in CIDT and the data packets are collected through CH in a allotted time slot. BS initiates the DCT after the election of CH to select one-hop adjacent DCN otherwise present DCN that picks up another CH and one-hop adjacent DCN with higher connection time, reduced network traffic and superior coverage distance.

Steady-state and set-up phase are contained by protocol operation. A sensor selects itself as CH over it depending on the threshold rate while in set-up phase. Cluster member merge with one-hop CH while forming the cluster additionally and depends on computed RSS, robustness and connection time in the connection. Through the BS, DCT communication is introduced to build a data collection tree that chooses for whole CH covering, data collection node (DCN). For certain round, DCN does not involve in sensing that gathers simply the sensed data and combines the data packets that depend on one-hop CH, which the data packet forwarding towards BS by DCT. To maintain the whole network life time, novel CHs and DCNs are selected for each round.

DCN maintains communication even though while sensor nodes are over higher mobility with CH and for certain round, CIDT does not require tree structure updating. Because of data forwarding with DCT, CIDT minimizes the link failure, CH traffic, energy consumption, peer-to-peer delay. To generate a tree structure, minor complexity is included that minimizes the CH energy utilization. For considerable sum of time, CIDT support to reduce the cluster formation frequently and manage a cluster.

Every cluster member transmits the collected data towards the CH in steady state phase within the allotted time slot and CH collects the data and passes it towards the BS through intermediate CHs through the technique of direct sequence spread spectrum (DSSS). While comparing with HEED, MBC and LEACH, experimental outcomes shows that the CIDT outperforms the method by means of throughput, total energy utilization, PDR and delay in mobile sensor ambiance.

2.4.8 Velocity energy-efficient and link-aware cluster-tree (VELCT)

Hybrid topology is VELCT that works depending on the method of energy efficient routing that had been modelled mainly to enhance the data collection, large scale mobile WSNs lifetime and network performance (R.Velmani, 2015). The CIDT technique enhancement is VELCT that reduces the previous problems efficiently in network topologies like coverage problem, RSS, connection time, fault tolerance, throughput, mobility, residual energy utilization, critical node occurrence, traffic, tree intensity, delay, PDR and network lifetime.

The data collection tree (DCT) is build through projected VELCT method. In a network, some sensor nodes had been allocated as data collection node (DCN) in DCT depending on CH position and it cannot be participated in sensing over the certain phase. The DCN consideration purpose is to gather CH data packets and delivers towards sink. In large scale MWSNs, VELCT protocol reduces the residual energy utilization and minimizes peer-to-peer delay and traffic because of the efficient DCT usage.

The major advantages of VELCT method are: building a simpler tree structure, reduction of residual energy utilization of CH, preventing the cluster formation frequently and manages the considerable amount of time.

The strength of VELCT protocol is, constructing a simple tree structure of cluster heads that maintain the cluster of a considerable amount of time, which reduces the energy consumption and control packet overhead, thereby avoid the bottleneck problem with the cluster head level and frequent clustering on mobility ambiance. Simulation results demonstrate that VELCT could yield better performance in terms of energy consumption, throughput, delay and PDR with reduced network traffic when compared to energy-efficient data collection protocol based on tree (EEDCP-TB), chain oriented sensor network (CREEC), cluster-tree data gathering algorithm (CTDGA), MBC and CIDT even in high mobility ambiance.

2.5 ENERGY EFFICIENT ROUTING PROTOCOLS

2.5.1 Termite Hill

Termite hill is developed to distribute the load in WSN to eliminate hot spot problem (Zungeru et al., 2012). It is based on the idea of using one mobile sink which capable of moving without any limits. The hot spot problem is avoided which is caused by the static nodes located need the sinks. Termite hill is a bio-inspired algorithm derived by the behaviour of termites. The method is employed in both static and mobile WSN and implemented in WSN hardware. From the result, it produces high throughput, reduced energy consumption compared to AODV (Perkins and Royer, 1999), in term of various speed. The network lifetime is improved than static sinks.

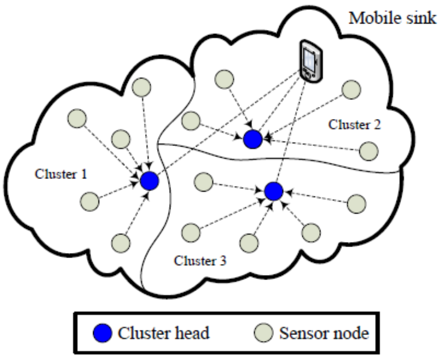


Fig. 2.1. Architecture of mobile WSN with clustering

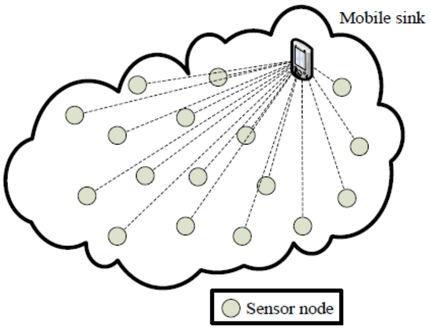


Fig. 2.2. Architecture of mobile WSN without cluster head

2.5.2 Mobicluster

Mobicluster is an effective clustering protocol for mobile sinks which moves in a predictable path (Konstantopoulos et al., 2012). It is used to cover isolated nodes which cannot move in the network. The CHs need to communicate with rendezvous nodes and takes turn in communicating data. There are 5 steps in mobicluster: clustering, rendezvous node selection, CH attachment to rendezvous node, data aggregation and forwarding to rendezvous nodes and communication between to rendezvous nodes and mobile sinks. An algorithm is also used to produce the cluster of various sizes. As a result, energy consumption in the network is well balanced. To select rendezvous nodes, a new algorithm is given which leads to reduce collision and increased throughput. For minimizing network lifetime, CHs can be rotated when their energy level is reduced.

2.5.3 Trace Announcing Routing Scheme (TARS)

Trace announcing routing scheme is developed to focus on various situations where the sink and targets need to be in mobility (Chi and Chang, 2012). As both targets and sinks are mobile, a virtual grid based routing called TARS is developed. It is an improved version of target assisted routing scheme for WSN. It is based on the process capturing the mobile objects movement path by flooding and trace-announcing packet instead of path reconstruction. TARS maintain two tables: routing and tracking information. Additionally, a simple shortcutting method is also developed to reduce energy consumption.

2.5.4 W-L

W-L is an effective distance aware routing protocol with various mobile sinks (Wang et al., 2014). To minimize the energy consumption, first order radio model is used to transmission power with respect to the distance. The reduction in transmission energy reduces the interference. The energy dissipation at the transmitter (ETX) and receiver (ERX) with distance d for transmitting an l-bit data packet. A relay node is chosen with higher energy and lesser distance to mobile sink. A parking position is used where the mobile sink can gather data. Here, the collection of data is not possible when the sink is in mobility.

2.5.5 Hierarchical and Adaptive Reliable Routing Protocol (HARP)

HARP is a heterogeneous network based protocol which divides the nodes in two ways: regular nodes and cluster nodes based on the residual energy (Atero et al., 2011). CH section is done based on the remaining energy of the node. It constructs a hierarchical tree with two divisions: intra cluster and inter cluster. A mechanism to recover nodes and mobility management is introduced to reconstruct tree when link failure occurs. HARP is more energy efficient, reliable and scalable when compared to LEACH.

2.5.6 Routing Algorithm for Heterogeneous Mobile Network (RAHMoN)

It splits the sensor nodes into static nodes and mobile nodes (Vilelaand Araujo, 2012). The energy of the static node is less and mobile node is of higher energy, it operates in 3 phases: network configuration, detection and selection of CH and data delivery to sink. It is assumed that every node can be selected as CH. The CH is selected based on residual energy, mobility level and distance to sink. It leads to effective routing in terms of less overhead and large number of data transmissions.

2.5.7 Heterogeneous Sensor Network (HSN)

HSN is clustering protocol with a mobile sink for heterogeneous WSN (Sudarmani and Kumar, 2013). It partitions the network in three ways based on the energy level: 1.H-nodes (higher energy level), 2.L-nodes (lower energy level), 3.sink (infinite energy level). H-nodes have longer data transmission range and high data rate compared to L-nodes. It produces better results than HARP and RAHMON, CH is stationary and 1-hop communication is provided. It uses PSO to adjust the movement of sink among CHs. It is useful for large scale WSN (Heinzelman et al., 2002). It provides better results compared to static sink.

2.5.8 Clue Based Data Collection Routing Protocol (CBDCR)

CBDCR uses a mobile sink which moves in random paths instead of fixed path and it broadcasts it location information to a limited distance and does not broadcast to the entire network. The sensor nodes which receive the location information are known as watchers which can send or receive data and assume the hop(s) from the sensor node to the mobile sink.

Then, the watcher node saves the information as clue to the location of mobile sink for data transmission. When the mobile sink moves, the number of watchers is increasing and the data sensed by the nodes can be easily transmitted to the mobile sink based on these clues.

Various simulations are done with mobile sinks in network to assess the performance of CBDCR and the results shows that CBDCR decreases the transmission of duplicate and balances the energy consumption of the network. The overview of CBDCR is shown in Fig. 2.3.

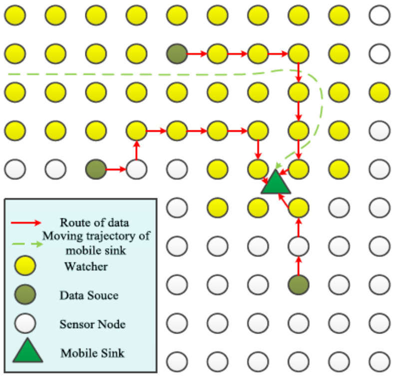


Fig. 2.3. Overview of CBDCR

2.5.9 Zone based Energy Efficient routing Protocol (ZEEP)

ZEEP is developed for both static and mobile nodes and needs no additional process for discovering path, maintaining routes or routing tables (Juhi et al., 2013). It employs the idea of dynamic forwarding and reduces the computation of the nodes. The simulations are done to verify that ZEEP achieves higher packet delivery ratio, reduced energy consumption by the network and results to maximum lifetime than well known protocol Adhoc On Demand Distance Vector routing (AODV) (Perkins and Royer, 1999). ZEEP provides better performance than AODV protocol in terms of energy consumption and packet delivery ratio of the network. ZEEP, the customized version of ZBR also decreases the number of control packets created in the network compared to AODV and there is no need of path discovery or route maintenance. ZEEP is scalable as ZBR ZEEP can be easily extended to integrate optimizations which are default in AODV. A major advantage of ZEEP is simplicity.

2.5.10 Location aware sensor routing (LASeR)

LASeR(Tom Hayes and Falah, 2016) protocol provides better solution to the issues of MWSNs. It concentrates on maximum reliability and minimum latency necessities of the emerging applications. It utilizes location information to retain a gradient field even in highly mobile environments, at the same time as minimizing the routing overhead. This leads to the usage of blind forwarding technique to circulate packets towards the sink. The protocol intrinsically uses multiple paths concurrently to generate route diversity and enhances its robustness. LASeR is proposed to employ in wide range of MWSN applications with independent land, sea or air vehicle. Logical expressions are derived and evaluated against the simulations. Extensive modelling and simulation of LASeR proves it is more flexible and robust. The results of LASeR is compared with advanced MWSN routing protocol includes the high performance mobility adaptive cross-layer routing protocol, as well as adhoc on-demand distance vector (AODV) and optimized link state routing. Protocols are analyzed based on the performance metrics such as packet delivery ratio, end-to-end delay, overhead, throughput and energy consumption. The performance of LASeR in several harsh environments shows that the proposed method is significantly better than the existing protocols.

Table 2.1 shows the comparative analysis of different energy efficient routing protocols with respect to Mobile element, Moving path, Node type, number of sinks and application. The node type can be classified into static and mobile nodes. In addition, the moving path can takes place through random, fixed and rectangle boundary.

Table 2.1. Comparison of various energy efficient routing protocols

Protocol	Mobile element	Moving path	Node type	Application
Termite-hill	Sink	Random	Static node	WSN with one mobile sink
TARS	Sink and targets	Random	Static node	Location aware WSN
Mobicluster	Sink	Fixed	Static node	fixed paths of mobile sinks in WSN
W-L	Sink	Rectangle boundary	Static node	Distance aware WSN
HARP	Sink	Random	CH and normal nodes	Reliable WSN
RAHMON	Cluster based sink	Random	Mobile and static node	Hydropower plant
HSN	Sink	Random	l-node, h-node, sink	Large scale WSN
CBCDR	Sink	Random	Mobile and static node	Large scale WSN
ZEEP	Sink	Random	Mobile and static node	Large scale WSN
LASeR	Sink	Random	Mobile	Large scale WSN

(Lee et al., 2010) presented a Density and Distance based Cluster Head Selection (DDCHS) technique which partitions the clustering region to different perpendicular diameters, and then chooses the CH using the density of member nodes and the distance from CH. (Elbhiri et al., 2010) introduced and validated a clustering method known as Developed Distributed Energy Efficient Clustering (DDEEC) scheme for heterogeneous WSN. This method depends upon the changing dynamically and with high efficiency in electing the CHs. The experimental results shows that it outperforms the Stable Election Protocol (SEP) by about 30%. (Abdellatief and Youness, 2017) introduced a distributed density-based clustering technique called Spatial Density-based Clustering (SDC). It will overcome the limitations of other related distributed approaches. It intends to attain balanced energy utilization all over the constructed clusters.

2.6. RESEARCH GAP

From the above literature, it is identified that most of the reviewed localization algorithms are developed based on the natural activity of biological systems and/or physical systems. It is noticed that every algorithm has its own advantages and disadvantages. Among the availability of diverse algorithms, BA is projected based on the echolocation activities of bats. BA has been introduced stimulated through the fantastic activities of echolocation of micro bats. BA to a great extent efficient compared to other approaches in terms of precision and efficiency. The BA suffers from low success rate due to the fact that bat is not capable to discover each and every way in the search space. Consequently, to conquer this issue, the existing BA is changed. Cluster based routing protocol is a commonly employed solution to achieve energy efficiency. Among the diverse solutions exist, cluster based routing protocol is a commonly employed solution. Though various clustering techniques for M-WSN have been developed, there is still a need to further improve the energy efficiency by considering the different perspectives. In addition, most of the existing models have concentrated only on node localization or energy efficiency. But, none of them has integrated both node localization and energy efficient techniques in MWSN. The research gap lies in this state where hybrid localization and clustering techniques is expected since MWSN applications are highly significant in the real world scenario. The absence of these type of hybrid techniques are motivated us to perform this research work.

2.7. SUMMARY

In this chapter, a detailed review of existing works on node localization techniques given in Sections 2.2 and 2.3. Next, a set of clustering techniques designed for MWSN is explained in detailed. Furthermore, a survey of energy efficient routing protocols designed for MWSN is presented in Section 2.4.

CHAPTER 3

SYSTEM DESIGN

3.1 OVERVIEW

In the previous chapters, a detailed explanation of the basic concepts, the existing works on node localization and energy efficient clustering algorithms are given. In this chapter, an explanatory perspective of research methodology has been provided. Next, this chapter explains the implementation setup to determine the effectiveness of the proposed research work. The experimentation part is successfully designed in a way that to demonstrate the effectiveness of the proposed model better than existing algorithms of the same group.

3.2 SYSTEM MODEL

3.2.1 Network model

A sensor network is designed with N number of sensor nodes which are randomly deployed in the field to be monitored and following assumptions are made.

- Nodes and BS are mobile.
- Every node has equal amount of energy at the time of deployment.
- Location unaware nodes.
- The distance between the nodes and BS can be computed by Received Signal Strength Indicator (RSSI).
- Node will die only when the energy level is completely exhausted.
- Nodes can change the transmission power by power control mechanism using the distance from receiver node.

3.2.2 Energy model

To minimize the energy consumption, first order radio model is used to very transmission power with respect to the distance. The reduction in transmission energy reduces the interference. The energy dissipation at the transmitter (ETX) and receiver (ERX) with distance d for transmitting an l-bit data packet is computed in Eqs (3.1) and (3.2):

$$E_{TX}(l,d) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^2 if d \leq d_0 \\ l \times E_{elec} + l \times \varepsilon_{mp} \times d^4 if d > d_0 \end{cases} \tag{3.1}$$

$$E_{RX}(l) = l \times E_{elec} \tag{3.2}$$

where Eelec is the dissipated energy in transmitter or receiver and it is based on various factors like digital coding, modulation, filtering, and spreading of the signal. The distance threshold is defined as $d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$. Based on the transmission distance d, the free space (εfs) or multipath fading channel (εmp) is used for the transmitter amplifier.

3.3 RESEARCH METHODOLOGY

3.3.1 Experimentation framework

The whole research work is framed into 3 distinct phases and experimental analysis takes place for every phase of the research work. The layered view of research methodology is depicted in Fig. 3.1. This framework holds different phases of the presented research work, experimentation analysis and evaluation parameters for every phase. The role of every layer is explained in the upcoming subsections.

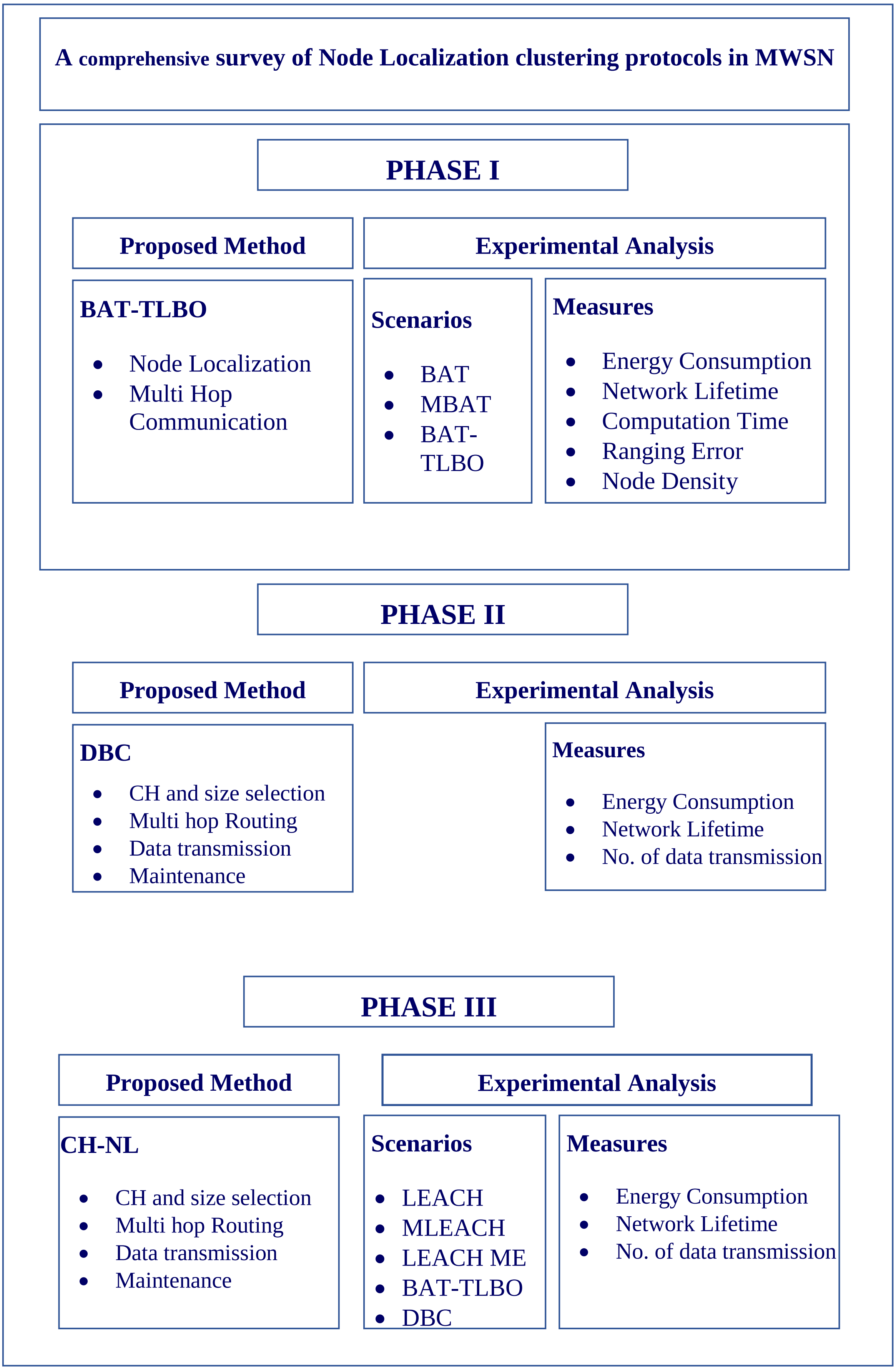


Fig 3.1 Framework experimental Phase

3.3.2 Phase I

The traditional BAT Algorithm is altered as TLBO algorithm. The new solutions are created by the equations inspired from the nature of knowledge exchange among teacher and students in the learning duration. This algorithm initiates with the group of agents (known as classes), where every agent (known as student) offers a significance solution to the problem. The TLBO has two stages: teaching stage and learning stage. In the former stage, the best agent of the class is chosen as the teacher and remaining agents (students) tries to enhance the knowledge level through learning from teacher. In the latter stage, the student tries to develop the knowledge level through interaction with each other. A single hop range based distributed approaches can be employed to localize the nodes in MWSN localization, to determine the coordinates of many sensor nodes by the use of anchor nodes.

3.3.3 Experimental Phase I

The proposed method BAT-TLBO is simulated in MATLAB. To simulate the BAT-TLBO algorithm, the unknown and anchor sensor nodes are arbitrarily placed in a C-shape topology in the sensing region. The communication range of every sensor node is found to be identical. For comparison purposes, the BA with MBA algorithm is used. The BAT-TLBO has been tested with different scenarios with varying anchor node density. To authenticate the highlights of the BAT-TLBO algorithm, a comparison is made with the state of art methods by executing the objective function for P × I times where P represents the population size and I indicate the maximum number of iterations (optimum or P x I time reached, whichever is earlier). Here, P and I are kept as 20 and 100 respectively for all the applied algorithms. For these algorithms, the extra control parameters f_{min} and f_{max} are kept as 0.01 and 0.05 kHz respectively. The starting values of the variables r and A are set to 0.5ms and 0.2 ms, respectively. The parameter initialization of the MWSN scenario is tabulated in Table 3.1.

Table 3.1 Parameter initialization

Parameter	**Value**
Node count (n)	200
Anchor nodes (m)	30
Sensing field	200*200m^2
Ranging error	5%
Transmission range	30m
population size (P)	20
number of iterations (I)	100
f_{min} and f_{max}	0.01 kHz and 0.05 kHz
Pulse rate (r)	0.5ms
Loudness (A)	0.2ms

3.3.4 Phase II

This phase introduces a Density Based Clustering (DBC) technique to select CHs it perform energy dissipation and extend the network lifetime. The proposed method operates in three phases: cluster construction, data transmission and cluster maintenance. There are two levels in cluster construction phase namely: CH selection and cluster formation. In cluster construction phase, BS runs density based cluster to produce balanced clusters. For CH selection, Density Based with three input variables namely residual energy, distance to BS, and node centrality are used. The output parameters are Probability of becoming CHs and cluster size. The inclusion of these three input parameters is highly important to select CHs and cluster size efficiently. Nodes with the higher probability of becoming CH will be final CHs and the neighbouring nodes with the communication radius of the CH join the cluster.

The CH accumulates the data from its cluster members and then transmits it to BS. The DBC algorithm follows multi-hop transmission for inter-cluster communication. The CHs will transmit the aggregated data to BS via intermediate CHs and then it reaches the

SCH. Similar to CH, the SCH receive the data, accumulates it and transfer it to the BS directly. Since the SCH involves higher power compared to normal CHs, it helps to reduce the communication distance of the CHs to BS and thereby reduces the energy utilization significantly. In the proposed DBC algorithm, aim to cluster the sensor nodes which have high energy, less distance and high centrality. Finally, cluster maintenance phase uses cross-level data transmission to enhance the network lifetime significantly.

3.3.5 Experimental Phase II

For validation, the energy model explained in previous section is used and the parameter settings are given in Table 3.2 with the following parameters E_{elec}=50nJ/bit, E_{fs}=10pJ/bit/m^2, and E_{DA}=5nJ/bit/signal. The d^2 energy loss because of channel transmission is employed. It is assumed that the communication channel is symmetric in nature so that the energy needed for data transmission from node i to node j is equal to the energy needed for data transmission from node j to node i. A MWSN of 200 nodes is deployed in the area of 100x100m^2 and the BS is located at the point of (150, 50).

Table 3.2 Parameter settings

Parameters	**Unit**	**Values**
Area	Meter^2	100mx100m
Node count	Integer	200
BS Position	(x,y)	(150,50)
E_{elec}	nJ/bit	50
E_{fs}	ρJ/bit/m^2	100
E_{DA}	nJ/bit	5
Packet size	Byte	500
Header size	Byte	25
Initial Residual energy	Joule	5

3.3.6 Phase III

Propose a CH-NL protocol for WSN to eliminate clustering and node localization problem and extend the network lifetime and energy efficiency. This protocol comprises two phases: Node localization using hybrid BAT-TLBO and Clustering using Density base cluster head (DBC) selection. Initially, the sensor nodes undergo random deployment in the target field. Then, the sensor node gathers information about its neighbouring node. Next, the clustering process will be executed to generate the clusters and effective selection of CHs. Once the nodes are clustered, the cluster members begin to send the data to the CH. Due to the nature of mobile nodes in MWSN, the CHs tends to move in the sensing field. Then, the node localization algorithm gets executed to determine the location of the sensor nodes. Once the location of the sensor nodes is determined, this information is utilized. By the use of localized nodes, the data transmission will takes place from cluster members to CHs and then to SCHs. Finally, it reaches the BS.

3.3.7 Experimental Phase III

For validation, the energy model explained in previous section is used and the parameter settings are given in Table 3.3 with the following parameters E_{elec}=50nJ/bit, E_{fs}=10pJ/bit/m^2, and E_{DA}=5nJ/bit/signal. The d^2 energy loss because of channel transmission is employed. It is assumed that the communication channel is symmetric in nature so that the energy needed for data transmission from node i to node j is equal to the energy needed for data transmission from node j to node i. A MWMSN of 200 nodes is deployed in the area of 100x100m^2 and the BS is located at the point of (150, 50).The objective function for $P \times I$ times where P represents the population size and I indicate the maximum number of iterations (optimum or PxI time reached, whichever is earlier). Here, P and I are kept as 20 and 100 respectively for all the applied algorithms. For these algorithms, the extra control parameters f_{min} and f_{max} are kept as 0.01 and 0.05 kHz respectively.

Table 3.3 Parameter settings

Parameters	**Unit**	**Values**
Area	$Meter^2$	100mx100m
Node count	Integer	200
BS Position	(x,y)	(150,50)
E_{elec}	nJ/bit	50
E_{fs}	$\rho J/bit/m^2$	100
E_{DA}	nJ/bit	5
Packet size	Byte	500
Header size	Byte	25
Initial Residual energy	Joule	5
Ranging error	Integer	5%
Transmission range	Meter	30m
population size (P)	Integer	20
number of iterations (I)	Integer	100
f_{min} and f_{max}	KHz	0.01 kHz and 0.05 kHz
Pulse rate (r)	ms	0.5ms
Loudness (A)	ms	.2ms

3.4 SUMMARY

In this chapter, we have discussed the research methodology which is carried out to resolve the node localization and clustering problem in MWSN. In this chapter, the overall system framework was designed and described with different layers. The system model including the network model and energy model are also discussed. In the upcoming chapters, a detailed explanation of proposed techniques will be given.

CHAPTER 4

BAT WITH TEACHING AND LEARNING BASED OPTIMIZATION ALGORITHM FOR NODE LOCALIZATION

4.1 OVERVIEW

Mobile sensor nodes have the nature of changing their location often in the provided sensing region. The process of node localization in MWSN is a challenging task which intends to determine the location coordinates to every device with unknown positions in the target region. Presently, different meta-heuristic based optimization algorithms for node localization have been devised. This paper introduces a BAT-TLBO algorithm by altering the characteristics of traditional bat algorithm (BA) with the teaching and learning based optimization (TLBO) algorithm for determining the proper node localization in the network. Furthermore, the BAT-TLBO algorithm has been tested with different scenarios with varying anchor node density.

4.2 BASIC CONCEPTS OF BAT ALGORITHM

Bats are interesting animals and its inherent characteristic of echolocation has drawn interest from more number of researches in various domains. The principle of echolocation follows the nature of sonar bats, particularly micro-bats, produce a loud and short pulse of sound which strikes to an object and then an echo will be returned back to their ears (D. R. Griffin, 1960). By this way, the bats determine the actual distance of the object (W. Metzner et al, 1991). Additionally, this remarkable orientation method helps the bats to differentiate between obstacle and prey, allows it for hunting the prey without any light (H.-U. Schnitzler et al,2001). Inspired from the nature of the bats, (X-S Yang, 2011) has proposed a meta-heuristic optimization algorithm as BA. This algorithm has been proposed to act as a group of bats for identifying the prey/foods by the use of echolocation property. To formulate the bat algorithm, the following rules should be followed: Every bat utilizes the echolocation principle for sensing distance and they can distinguish between the food/prey and obstacles in a supernatural manner;

A bat b_i flies in a random manner with a velocity v_i at position x_i with a predefined frequency $f_{\min}$, differing wavelength (λ) and loudness (A_0) for searching the prey. It can routinely modify the λ of the emitted pulses and vary the rate of pulse emission is $r \in [0, 1]$, based on the nearness of their target.

Though the A_0 can fluctuate in different forms, assumed that the A_0 lies in the range of large (positive) A_0 to a minimum constant value A_{min} .

At the beginning, initialization takes place for every bat in terms of starting position x_k, velocity v_k and frequency f_k are initialized for every bat b_k. For every time step t, T is the maximum number of iterations, the motion of bats is calculated by the updation of v_k and position by the use of Eqs. (1)-(3).

$$f_k = f_{min} + (f_{max} - f_{min})\beta \tag{4.1}$$

$$v_k^t = v_k^{t-1} + (x_k^t - x^*)f_k \tag{4.2}$$

$$x_k^t = x_k^{t-1} + v_k^t \tag{4.3}$$

Where β indicates a randomly generated number lies in the range of [0,1] , x_k^t indicates the value of the decision variable l for a bat l at the time step t. The result of f_k can be employed an used to manage the pace and range of the movement of the bats. The variable x^* indicates the present global best location (solution) for decision variable$l$, which is attained when compared to all the solutions given by m bats.

4.3 PROPOSED NODE LOCALIZATION ALGORITHM IN MWSN

4.3.1 BAT-TLBO ALGORITHM

The traditional bat algorithm is altered by the TLBO algorithm. The pseudo code of the BAT-TLBO algorithm is illustrated in Algorithm 4.1. The new solutions are created by the equations inspired from the nature of knowledge exchange among teacher and students in the learning duration. This algorithm initiates with the group of agents (known as classes) where every agent (known as student) is a significance solution to the problem.

The TLBO has two stages: teaching stage and learning stage. In the former stage, the best agent of the class is chosen as the teacher and remaining agents (students) tries to enhance the knowledge level through learning from teacher. In the latter stage, the student tries to develop the knowledge level through interaction with each other

. This nature is used in the node localization problem, the present current node namely δ_k arbitrarily selects other node δ_l, where $k \neq l$, and when the selected node has better objective value, the present node move towards it, or else, the δ_k moves away from δ_l, which can be defined by,

$$\delta_i^{update\_location} = \begin{cases} \delta_k + r.(\delta_k - \delta_l) iff(\delta_k) < f(\delta_l) \\ \delta_k + r.(\delta_l - \delta_k) iff(\delta_k) \geq f(\delta_l) \end{cases} \tag{4.4}$$

where r is a random number lies in the range of 0 and 1. When δ_k gives a better objective value, it is substituted with the present agent, else δ_k will remain.

Algorithm 4.1: Pseudo code for BAT-TLBO algorithm

Objective function $f(x), x = (x_1, \dots \dots \dots x_d)^T$
 	
Initialize the bat population $x_k (i = 1,2,3 \dots \dots n)$ and v_k
 	
Define Pulse frequency f_k at x_k
 	
Initialize pulse ratesr_k and the loudness A_k
 	
While (t< Max number of iterations)
 	
Generate new solutions by adjusting frequency and updating velocities and locations /solutions according to equation (1), (2) and (3).
 	
Evaluate objective function. If solution is away from the optimal value of objective function then move to step 8 else jump to step 9.
 	
Generate new solutions by following TLBOalgorithm given in Eq.(4)
 	
If $(rand > r_k)$
 	
Select a solution among the best solutions
 	
Generate a local solution around the selected best solution
 	
End if
 	
Generate a new solution by flying randomly
 	
If $(rand < A_k \& f(x_k < fx^*))$
 	
Accept the new solutions
 	
Increase r_k and reduce A_k
 	
End if
 	
Rank the bats and find the current best x^*
 	
End while
 	
Post process results and visualization

The mapping of TLBO algorithm for the node localization problem takes place as follows. Here, the group of students in a class is considered as total population, i.e. number of sensor nodes in MWSN. Then, different subjects are allocated to the students in the class are assumed as different design variables, i.e. sensor node parameters namely energy, distance, and so on. Next, the results scores obtained by the students are defined by the fitness values of the problem which is applied to determine the location of the anchor nodes. Finally, the best solutions generated by the algorithm are considered as teachers, i.e. localized nodes whose location is determined by the use of the applied algorithm and anchor nodes. The mapping process of BAT-TLBO algorithm is shown in Table 4.1

Table 4.1.Mapping process of BAT-TLBO algorithm

Variables in BAT	**Variables in TLBO**	**Variables in MWSN**
Number of bats	Number of students	Node count (N)
Different Design Variables	Different Subjects	Node parameters (Energy E, distance d)
Fitness Value of the problem	Result Scores	Determination of anchor node location
Best Solution	Teacher	Localized nodes

4.3.2 PROPOSED NODE LOCALIZATION ALGORITHM IN MWSN

A single hop range based distributed approaches can be employed to localize the nodes in MWSN localization, to determine the coordinates of many sensor nodes by the use of anchor nodes. For determining the location of Nsensor nodes, the following process will takes place. At the beginning, N sensor nodes undergo random deployment in the sensing felid in the C-shaped topology. In a network of N node, M anchor nodes are present, which know their coordinates earlier, undergo deployment in C-shape topology. $(N - M)$ are the unknown nodes, whose coordinates needs to be determined. Every node has a transmission range of R. An unknown node can easily determine its own location coordination if and only if it has more than two non-coplanar anchor nodes as neighbors, i.e. the node is known to be a localizable node. Every localizable node computes its distance from every one of the nearby anchor nodes. The distance measurement gets distorted with Gaussian noise n_i because of environmental considerations.

$$\widehat{d_L} = [d_k + n_k] \tag{4.5}$$

where d_i is the distance from the localizable node to anchor node which is determined by

$$d_k = \sqrt{(x - x_k)^2 + (y - y_k)^2} \tag{4.6}$$

Where (x, y) is the location coordinates of the unknown node and (x_k, y_k) is the location coordinates of the ith anchor node in the nearby area. The location determination of a given unknown node can be formulated as an optimization problem, involving the minimization of an objective function indicating the localization accuracy. So, every unknown node needs to determine the location coordinates and execute the stochastic algorithms in an independent manner for the localization by identifying the coordinates(x, y).

The objective function for localization problem is defined as:

$$f(x, y, z) = \frac{1}{M}\sum_{k=1}^{M}(d_k - \widehat{d_L}) \tag{4.7}$$

Where $M \geq 3,$ (2D position of a node requires atleast three anchor nodes) in communication range, R, of the unknown node. The process of localization is a repetitive task. The unknown nodes with a minimum of 3 nearby anchor nodes are localized and then it is also considered as the anchor nodes to help the localization process of the remaining unknown nodes. This procedure is iterated till all the unknown nodes are correctly localized.

Every algorithm provides the optima coordinates of the unknown nodes, i.e. (x, y) by minimizing the error function. The localization error can be termed as the distance between the actual and calculated coordinates of an unknown node which is determined as the mean of square root of distance of computed node coordinates $(x_i, y_i)$and the real node coordinates (X_i, Y_i), for i =1, 2,…N_L (where N_L is the number of localized nodes) as equated in Eq. (4.8).

$$E = \frac{\sum_{i=M+1}^{N} \sqrt{(x_i - X_i)^2 + (y_i - Y_i)^2}}{(N_L)} \tag{4.8}$$

Localization error is defined in-terms of mean localization error (MLE) in a transmission range R to verify the performance of the application results, which can be computed as:

$$E = \frac{\sum_{i=M+1}^{N} \sqrt{(x_i - X_i)^2 + (y_i - Y_i)^2}}{(N_L)R} \tag{4.9}$$

4.4 PERFORMANCE EVALUATION

For validating the performance of the proposed BAT-TLBO algorithm, it is simulated in MATLAB R2014a on a PC of 8GB RAM. To simulate the BAT-TLBO algorithm, the unknown and anchor sensor nodes are arbitrarily place in a C-shape topology in the sensing region. The communication range of every sensor node is found to be identical. For comparison purposes, the BA with MBA algorithm is used. The BAT-TLBO has been tested with different scenarios with varying anchor node density.

4.4.1 Parameters Setup

To authenticate the highlights of the BAT-TLBO algorithm, a comparison is made with state of art methods by executing the objective function for $P \times I$ times where P represents the population size and I indicate the maximum number of iterations (optimum or $P \times I$ time reached, whichever is earlier). Here, P and I are kept as 20 and 100 respectively for all the applied algorithms.For these algorithms, the extra control parameters f_{min} and f_{max} are kept as 0.01and 0.05kHz respectively. The starting values of the variables r and A are set to 0.5ms and 0.2 ms, respectively. The parameter initialization of the MWSN scenario is tabulated in Table 4.2.

Table 4.2 Parameter initialization

Parameter	**Value**
Node count (n)	200
Anchor nodes (m)	30
Sensing field	200*200m^2
Ranging error	5%
Transmission range	30m
Population size (P)	20
Number of iterations (I)	100
f_{min} and f_{max}	0.01 kHz and 0.05 kHz
Pulse rate (r)	0.5ms
Loudness (A)	0.2ms

4.4.2 Results and Discussion

Figs. 4.1-4.3 show the node localization results of the BA, MBA and the proposed BAT-TLBO algorithm. Here, blue color indicates the localized sensor nodes, red color represents the anchor nodes and the black circle indicates the unknown nodes.

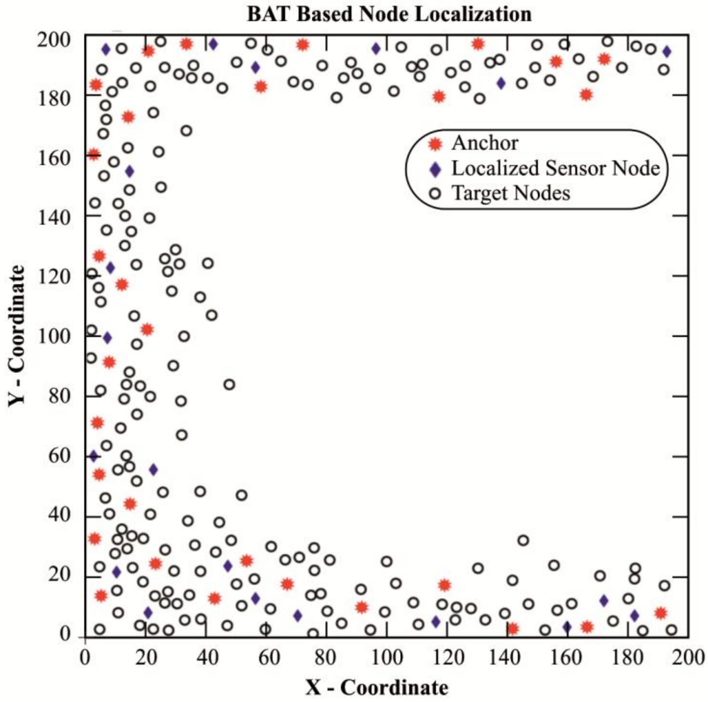


Fig. 4.1. Node localization using BA

From these figures, it is observed that only less number of nodes is localized using BA compared to MBA and Bat-TLBO algorithms. At the same time, the number of localized nodes (NL) of MBA is high compared to BA. But, the maximum NL is obtained by the BAT-TLBO algorithm than the compared ones. Moreover, the proposed BAT-TLBO algorithm achieved the highest success rate due to the fact that the number of nodes which are localized is higher compared to BA and MBA.

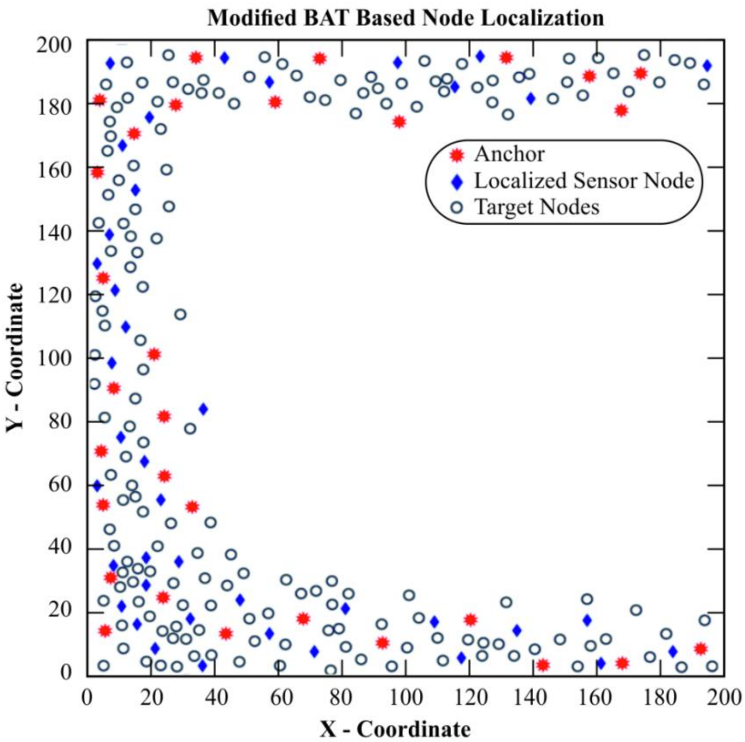


Fig. 4.2. Node localization using MBA

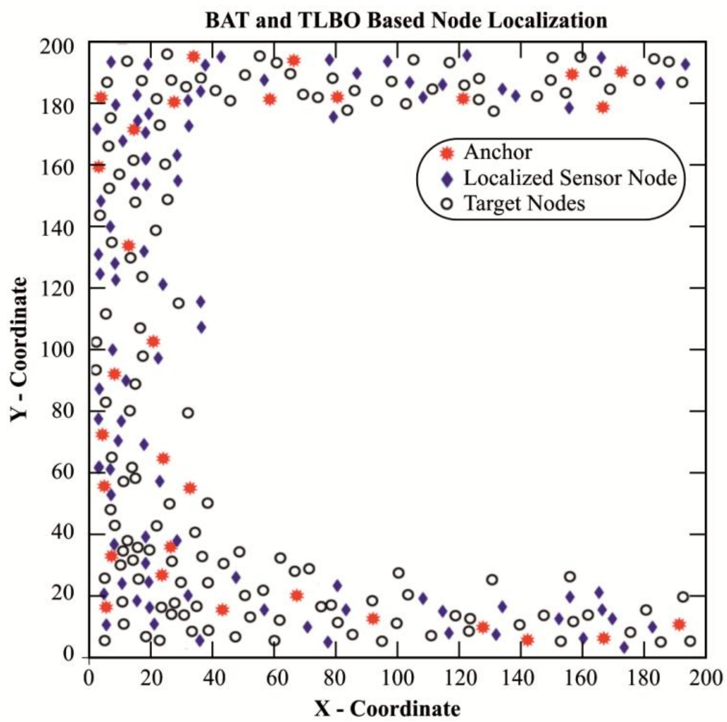


Fig. 4.3. Node localization using BAT-TLBO

4.4.2.1 Impact on Varying Anchor Node Density

The performance of the output parameters of MWSN node localization is determined for varying anchor node density. Here, 200 nodes are deployed in the sensing field with varying anchor node density from 10 to 100. The high anchor node density will be beneficial due to the fact that many references will be available for the unknown nodes. The number of nodes which can be localized is mainly based on the count of anchor nodes in the network. To study the impact of anchor nodes on MWSN node localization performance, an experiment is carried out using different anchor node density. The measures employed to validate the performance are MLE, computation time and NL. The comparison results of these measures are given in Table 4.3. To depicts the comparative analysis of three localization algorithms namely BA, MBA and BAT-TLBO in terms of MLE, computation time and NL respectively shown Figs. 4.4 - 4.7.

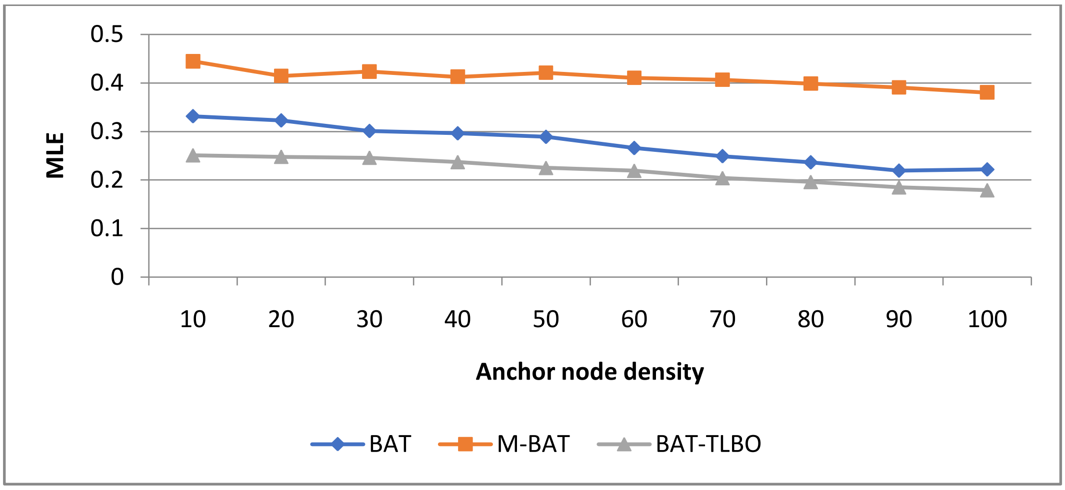


Fig. 4.4. Impact of varying anchor node density interms of MLE

Fig. 4.4 shows the results of different versions of bat algorithms interms of MLE with respect to different number of anchor node density. From the graph, it is observed that the MLE starts to decrease with increasing anchor node density. From this figure, MBA achieved worst performance with a maximum MLE of 0.38. On average, the MLE of BA, MBA and BAT-

TLBO are 0.259, 0.541 and 0.219 respectively. The proposed BAT-TLBO algorithm obtained the superior performance with the lowest MLE of 0.179. At the same time, the BA showed better performance than the MBA with a minimum MLE of 0.2216. But, the BAT-TLBO outperforms the compared methods in a significant way. The incorporation of TLBO in the localization process of the BAT-TLBO leads to the higher level of precise localization performance.

Table 4.3 Impact of varying anchor node density

Anchor	**BAT**			**M-BAT**			**Proposed**		
	MLE	**Time (s)**	**NL**	**MLE**	**Time (s)**	**NL**	**MLE**	**Time (s)**	**NL**
10	0.3314	6.14	56	0.4445	2.188	172	0.251	0.71	180
20	0.3227	6.92	65	0.4144	2.90	177	0.248	0.73	185
30	0.3009	7.98	73	0.4232	2.86	179	0.246	0.76	187
40	0.2961	8.50	82	0.4126	2.98	180	0.237	0.78	188
50	0.2888	3.30	89	0.4209	2.82	182	0.225	0.81	192
60	0.2658	9.40	93	0.4104	2.98	188	0.219	0.82	194
70	0.249	9.76	94	0.4064	2.79	188	0.204	0.85	196
80	0.2363	9.55	103	0.3984	2.87	193	0.196	0.87	197
90	0.2191	9.98	114	0.3904	2.86	194	0.185	0.93	199
100	0.2216	9.29	120	0.3801	2.96	195	0.179	0.97	201

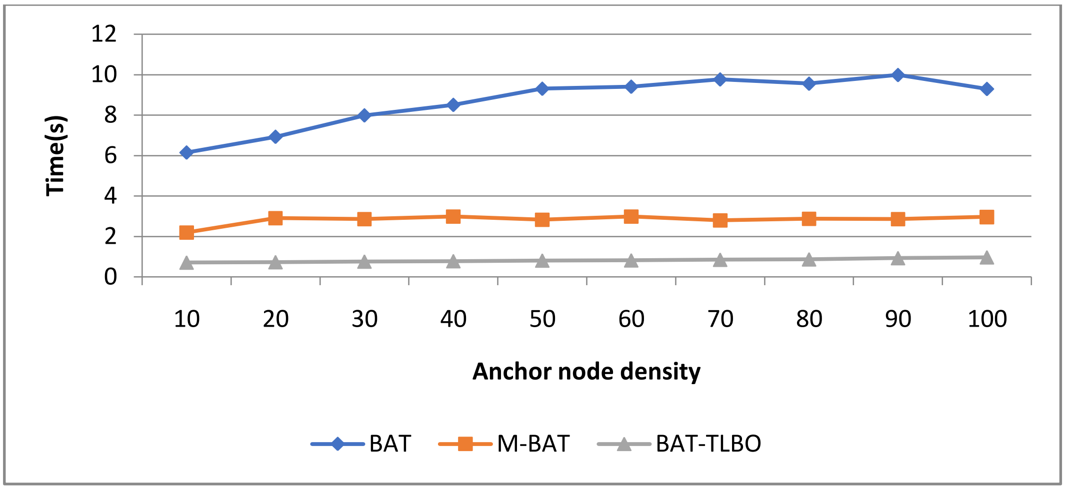


Fig. 4.5. Impact of varying anchor node density in terms of computation time

Fig. 4.5 provides an investigation of the impact of the varying anchor nodes in terms of computation time. From the figure, it is evident that the computation time is too high for the BA compared to MBA and proposed algorithm. However, the MBA consumes less time for the localization process than BA. At the same time, proposed BAT-TLBO consumes slightly lesser time than the MBA. It is also noted that the computation time starts to increase slightly with the increasing anchor node density. At the 100th anchor node, the BAT-TLBO requires a computation time of 0.97s whereas the BA and MBA needs a computation time of 9.29s and 2.96s respectively.

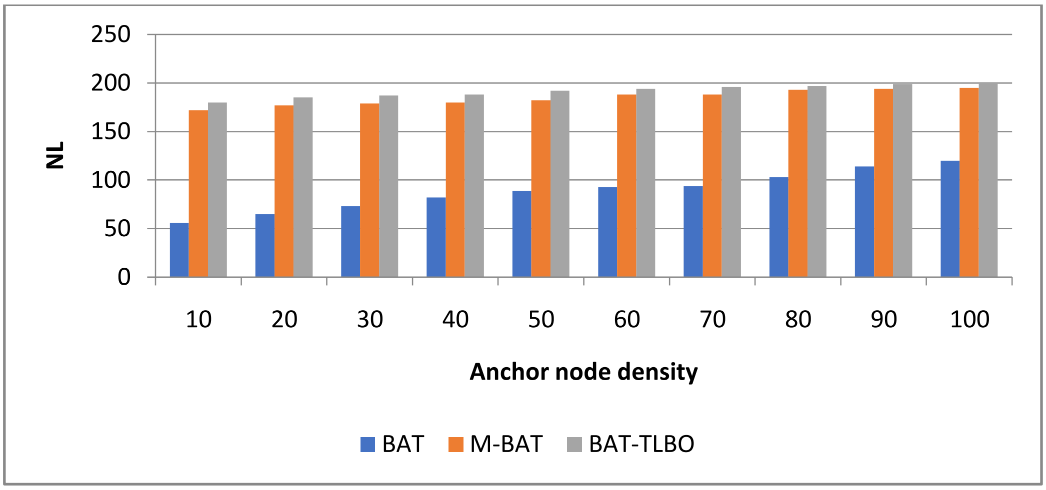


Fig. 4.6. Impact of varying anchor node density interms of NL

Table 4.4 MLE for 30 iterations

Trails	BA	MBA	Proposed
1	0.2397	0.5364	0.2165
2	0.2922	0.548	0.2154
3	0.1948	0.5385	0.2132
4	0.167	0.5373	0.2097
5	0.2447	0.4753	0.2078
6	0.1935	0.6188	0.1912
7	0.1964	0.5515	0.1931
8	0.2414	0.5766	0.1912
9	0.1632	0.5391	0.1908
10	0.4429	0.5297	0.2467
11	0.1455	0.5476	0.1378
12	0.2282	0.575	0.2134
13	0.2315	0.5529	0.2098
14	0.1845	0.5727	0.1793
15	0.2244	0.537	0.2132
16	0.1736	0.527	0.1654
17	0.2844	0.5753	0.2486
18	0.1611	0.591	0.1543
19	0.1215	0.561	0.1098
20	0.1649	0.499	0.1542
21	0.3415	0.5685	0.2789
22	0.2516	0.526	0.2278
23	0.1845	0.5426	0.1643
24	0.2244	0.5503	0.2087
25	0.1736	0.5476	0.1487
26	0.2844	0.575	0.2367
27	0.2282	0.5297	0.2086
28	0.1935	0.5475	0.1865
29	0.2315	0.5753	0.2076
30	0.2397	0.5364	0.2165

The comparison results of the localization performance on the impact of varying anchor node density interms of the NL are shown in Fig. 4.6. As seen in figure, for 10 anchor nodes, the BAT-TLBO properly localizes 180 nodes whereas the BA localizes only a minimum of 56 nodes. Though MBA attains a NL of 172 which is higher than the results obtained by the BA, it fails to show superior performance over the BAT-TLBO algorithm. Similarly, for the 100 anchor nodes, the BAT-TLBO effectively localizes 201 which are much higher than the NL of other algorithms. The order of increased number of NL of different algorithms is BAT-TLBO, MBA and BA. For better understanding, the Table 4.4 reported the MLE of the different algorithms on the 30 iterations.

4.4.2.2 Impact On Ranging Error

Table 4.5 tabulates the performance of the node localization algorithms on the different ranging error. In this simulation, the ranging error is set in the range of 5 to 50 with an interval of 5%. The ranging error is a crucial parameter, the quantity of Gaussian noise linked with the distance measurements which greatly influences the precision of localization. The dependency of MLE on ranging error is analyzed for 30 iterations for every value of error ranges between 5% to 50%. Figs. 5.7-5.9 depicts the comparative analysis of three localization algorithms namely BA, MBA and BAT-TLBO algorithms in-terms of MLE, computation time and NL respectively on ranging error.

Firstly, Fig. 4.7 shows the performance analysis of different localization approaches interms of MLE. From the figure, it is clearly shown that the MLE starts to increase with an increase in error rate. For the 5% error, the MLE of the BA, MBA and BAT-TLBO are 0.1260, 0.3191 and 0.0910 respectively. From these values, it is apparent that the BAT-TLBO achieves lowest MLE than the other methods. In addition, for the 50% error, the MLE BA, MBA and BAT-TLBO are 0.303, 0.6024 and 0.2467 respectively. These values imply that the MLE is increased from 5% to 50% and the addition of noise worsen the localization performance. Here, the MBA showed poor performance compared to BA and proposed algorithm. Compared to all the algorithms, the BAT-TLBO achieved lowest MLE on all the applied error rates.

Table 4.5 Impact of ranging error

Ranging error (%)	BA			MBA			Proposed		
	MLE	Time (s)	NL	MLE	Time (s)	NL	MLE	Time (s)	NL
5	0.1260	4.22	46	0.3191	2.89	197	0.0910	0.85	199
10	0.1411	5.67	40	0.3319	2.85	190	0.0919	0.83	196
15	0.1672	5.74	38	0.3346	2.98	190	0.1012	0.82	195
20	0.1750	5.75	36	0.3368	2.92	189	0.1156	0.82	192
25	0.1788	5.76	30	0.4484	2.90	187	0.1389	0.79	189
30	0.1932	6.68	28	0.4499	2.87	187	0.1596	0.78	189
35	0.2056	6.88	26	0.5006	2.93	186	0.1865	0.76	188
40	0.2806	6.88	26	0.5122	2.88	183	0.1954	0.73	186
45	0.2813	6.93	24	0.5223	2.98	180	0.2289	0.72	185
50	0.3030	6.25	22	0.6024	2.81	171	0.2467	0.71	179

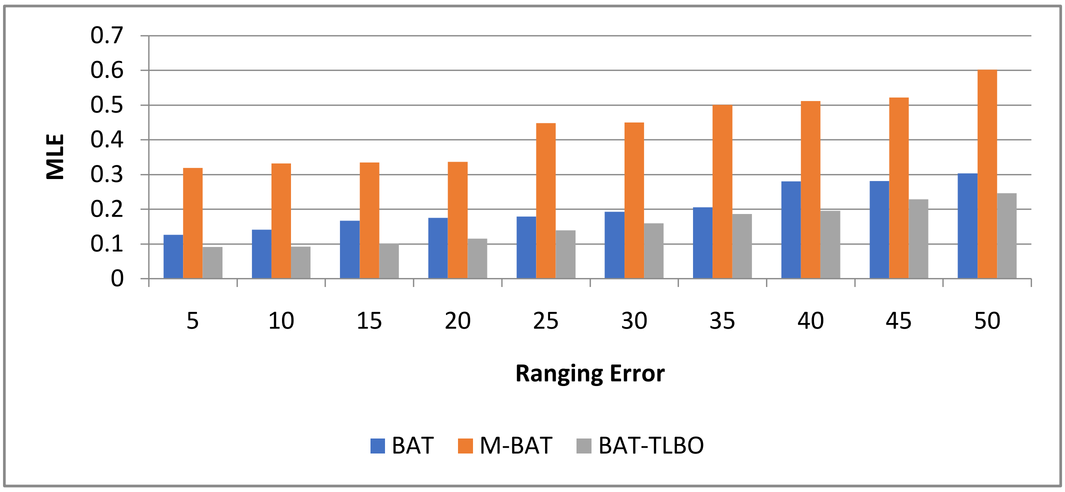


Fig. 4.7. Impact of ranging error in-terms of MLE

Fig. 4.8 illustrate the results of the localization algorithms on the influence of ranging error between 5 to 50% in-terms of computation time. The values shown in figure ensure that the computation time is very high for the BA. Then, the BAT-TLBO consumes only less time compared to other algorithm on all the applied ranging error. The MBA shows competitive performance over BAT-TLBO algorithm. However, the BAT-TLBO outperforms the MBA. For instance, for the ranging error 5%, the computation time of the BA, MBA and BAT-TLBO are 4.22s, 2.89s and 0.85s respectively.

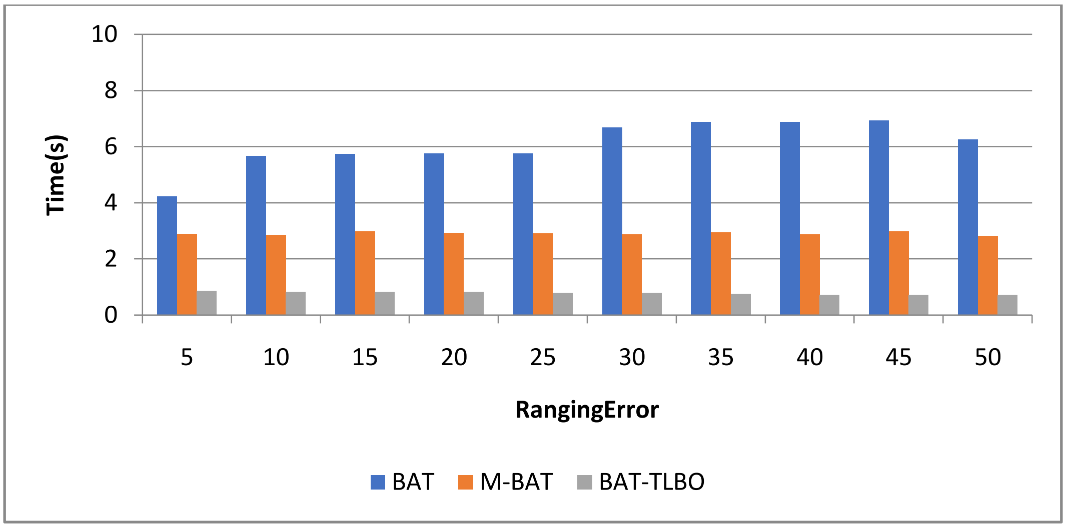


Fig. 4.8. Impact of ranging error in terms of computation time

From these values, it is apparent that the BAT-TLBO achieves lowest MLE than the other methods. From the values, it is revealed that the computation time also increase with increasing error rate. This can be proved by comparing the computation time needed by the localization algorithm at the error rate of 5% and 50%. For the 50% error, the computation time of BA, MBA and BAT-TLBO are 6.25s, 2.81s and 0.71s respectively.

Finally, the effectiveness of the localization algorithms are analyzed on the varying error rate in terms of the NL is shown in Fig. 4.9. As seen in figure, for 5% error rate, the BAT-TLBO properly localizes 199 nodes whereas the BA localizes only a minimum of 46 nodes. Though MBA attains a NL of 197 which is higher than the results obtained by the BA, it fails to show superior performance over the BAT-TLBO algorithm. Likewise, for the error rate of 50%, the localization performance is degraded and the NL starts to decrease with an increase in error rate. The order of increased number of NL of different algorithms is BAT-TLBO, MBA and BA. For the 50% error, the NL of the proposed BAT-TLBO algorithm is 179 whereas the NL of the BA and MBA are only 22 and 171 nodes respectively.

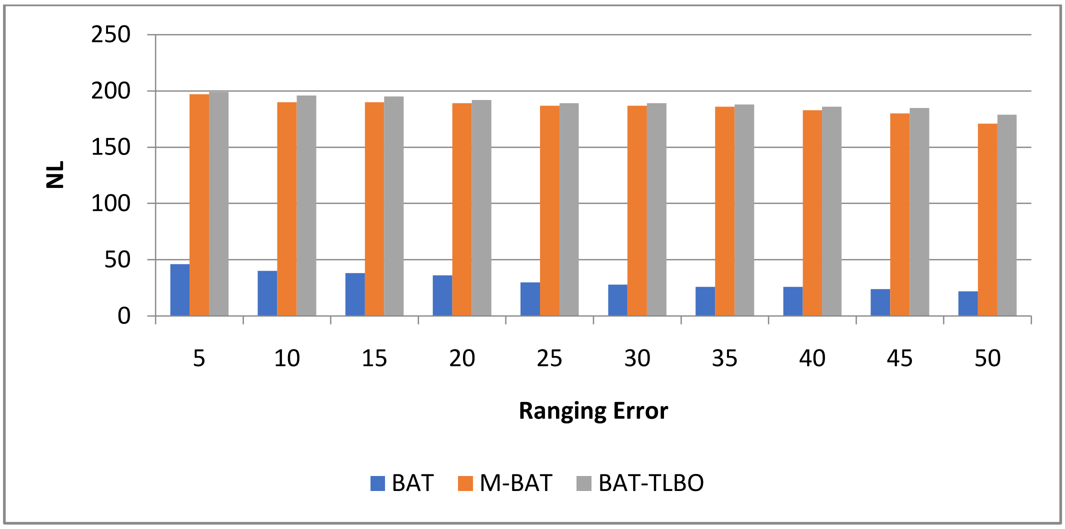


Fig.4.9. Impact of ranging error in terms of NL

Table 4.6 Mean and Standard deviation

Algorithm	Min.	Max.	Av.	SD.
BA	0.1215	0.4429	0.28220	0.063889
MBA	0.4753	0.6188	0.54705	0.027401
Proposed	0.1098	0.2789	0.19435	0.035598

Table 4.6 provides the mean and standard deviation values of the proposed BAT-TLBO algorithm compared to BA and MBA. From these values, it is depicted that the proposed algorithm attains a minimum MLE of 0.1098 whereas the existing BA and MBA are 0.4753 and 0.1098 respectively. Meanwhile, the proposed BAT-TLBO algorithm achieves a maximum of only 0.2789 whereas the MBA obtains a value of 0.6188.This implies that the proposed algorithm is found to be efficient than the compared algorithms.

4.5 SUMMARY

This chapter has presented a new node localization algorithm for MWSN by integrating the bat algorithm with the TLBO algorithm. The proposed BAT-TLBO algorithm employs the nature of bat's echolocation and the characteristics of TLBO algorithm. An extensive set of experiments takes place to validate the results of the BAT-TLBO algorithm to resolve the node localization issue. To verify the consistency in the performance, the proposed and compared BA and MBA algorithms are tested with varying anchor node density and ranging error. From the experimental values, it is ensured that the BAT-TLBO algorithm effectively localizes more number of nodes with less computation time and MLE than the state of art methods. In future, the BAT-TLBO can be improved to reduce the computation time taken to complete the localization process in MWSN.

CHAPTER 5

DENSITY BASED CLUSTERING TECHNIQUE FOR MWSN

5.1 OVERVIEW

This chapter aims to introduce a new cluster based routing protocol where the Cluster Heads (CHs) are selected and clusters are formed using density based clustering technique. The Density Based Clustering (DBC) technique mainly depends on three input variables such as remaining energy level, distance and node centrality. In addition, two static data collector points called Super CH (SCH) are placed to collect the data from CHs and it forwards it to the BS directly. The use of SCH supports multi-hop communication which helps to balance the available energy effectively. The proposed DBC technique improves the network lifetime to a maximum of 16500 rounds. The proposed method is experimented in MATLAB and the results are verified in terms of network lifetime, energy efficiency and throughput.

5.2 PROPOSED DENSITY BASED CLUSTERING (DBC) TECHNIQUE

A MWSN is generated using N number of mobile sensor nodes which are randomly placed in the sensing region with the following considerations:

- Sensor nodes are mobile whereas the BS and SCH are stationary
- Heterogeneous nodes
- Sensor nodes are not aware of their location
- Death of node occurs due to an energy depletion
- Nodes can adjust the transmission power

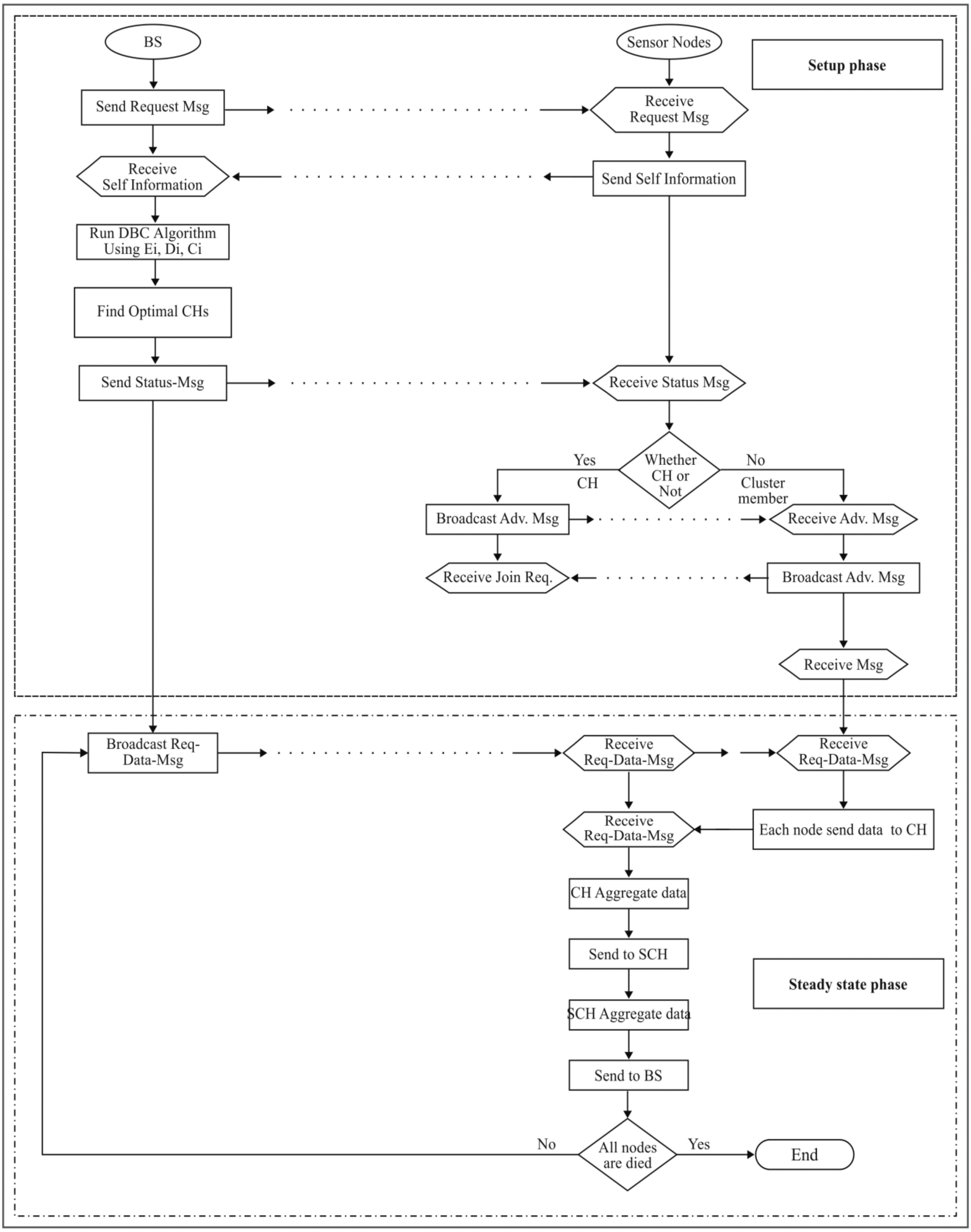


Fig. 5.1. Overall operation of the DBC algorithm.

A simplified first order radio energy model is utilized here. The total amount of energy consumption for transmitting l-bit packet over a distance 'd' can be equated as:

$$E_{TX}(l,d) = E_{TX-ELEC}(l) + E_{TX-AMP}(l,d) \tag{5.1}$$

The energy spent for free space propagation $E_{TX-FS}(l,d)$ is computed as:

$$E_{TX-FS}(l,d)=l \times E_{elec} + \times \varepsilon_{fs} \times d^2 \tag{5.2}$$

The energy spent for multipath propagation $E_{TX-MP}(l,d)$ is computed as:

$$E_{TX-MP}(l,d)=l \times E_{elec} + l \times \varepsilon_{fs} \times d^4 \tag{5.3}$$

where E_{elec} is the energy dissipation per bit in the source or destination side, ε_{fs} and ε_{mp} indicates the energy dissipated per bit in the RF amplifier, d_0 is the threshold distance computed by:

$$d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \tag{5.4}$$

The total amount of energy consumption for receiving *l*-bit can be equated as:

$$E_{RX}(l) \quad = \quad l \times E_{elec} \tag{5.5}$$

This model is used for the estimation of the total amount of energy needed for the transmitting and receiving data between two mobile nodes. For the distance computation, the nearby nodes can be identified for each node and is equated as:

$$\mathrm{D_i} = [|\mathrm{N_i}|] = \left[\frac{\mathrm{n_i}}{\mathrm{dist\ (i,j)}} < \mathrm{T_r}\right] \tag{5.6}$$

where $i \neq j$, T_r is the transmission range of node, and $\mathrm{dist(i,j)}$ is the distance between nodes i and j. The distance $\mathrm{dist(i,j)}$ is calculated as Euclidian distance which is given below:

$$\mathrm{dist(i,j)} = \sqrt{(S(i).xd - s(j)xd)^2 - (S(i).yd - s(j)yd)^2} \tag{5.7}$$

The basic idea of DBC method is to group the sensor nodes based on similar properties, i.e. dense regions, for instance, the nodes with similar amount of residual energy will be dense together and forms a cluster. In the proposed DBC algorithm, we aim to cluster the sensor nodes which have high energy, less distance and high centrality.

In algorithm 5.1, the CHs are selected based on the three parameters namely residual energy, distance and node centrality. The node which has optimal values under these parameters is selected as CHs and the elected CHs construct the cluster. In algorithm 5.2, the computation of residual energy is carried out. When the energy of the present node is lesser than the energy level of the neighbouring node, it will be elected as CM and does not compete for CH selection. Else, it will determine the other parameters. In algorithm 5.3, the nodes execute this algorithm to determine the centrality value. The centrality value is determined based on the computation of distance between the neighbouring nodes. When the cluster potential exceeds the threshold value, it is determined that the node is located at the centre of the cluster. Else, it is rejected and is considered that it is located not at the cluster centre. When the node located at the centre is chosen as CH, it leads to effective intra-cluster communication by reducing the communication distance and thereby achieves energy efficiency. In algorithm 5.4, distance metric will be computed. The distance between the sensor nodes and the BS is determined by the use of Cartesian coordinates.

The node which has maximum of residual energy, node centrality and minimum distance is chosen as CH.

Algorithm 5.1: CH Selection

```
Initialization: Receiving messages from Base station to all nodes S
If(CHs_exist = = True)
      CH←Current_NodeID
      Clustered←Form a group using CH
Else
Select feasible CH using computation of Residual Energy, Distance, Node centrality
Ri← Residual Energy (Node_ID)
Di ←Distance (Node_ID)
Ci← Node Centrality (Node_ID)
       CH ← Best (Ri, Di, Ci)
       Clustered ← Form a group using CH
End if
```

In algorithm 5.1, the CHs are selected based on the three parameters namely residual energy,

Algorithm 5.2: Residual Energy Computation

```
fori =1 to n do
      Status xi ← Member
forj =1 to no. of neighbor do
          If Energy (i) < Neighboring Node Energy(j)
                    Status.xi ← Elected_Member
          Else if Energy(i) = Neighboring Node Energy(j)
                    Status.xi ← Elected_Member
          End if
Return Status.xi
End for
```

Algorithm 5.3: Node centrality Computation

$for\ i$ =1 to n do x_i
    If (cluster potential) > Threshold
Assign
        x_i ← Cluster center
    Else if
        Reject x_i
  End if
        Return x_i
End for

The DBC algorithm operates on two phases: setup phase and steady state phase as shown in Fig. 5.1. In the setup phase, the DBC algorithm forms the clusters and CHs are selected for each cluster. In the latter phase, the DBC algorithm enables the cluster members to send the data to CH whereas the CHs transmit the data to the BS or data collector (SCH) whichever is closer. The SCH will receive the data, aggregates it and transmits to the BS. The detailed working of the proposed DBC method is given in Algorithms 5.1 to 5.4.

5.2.1 Setup stage

Initially, the deployed region is divided into two equaled space regions called grid in a horizontal way. For instance, in a network area of 100x100m^2, the region is divided into two grids, each of 50x50m^2. Once the grids are formed after node deployment, every node shares it information to its nearby nodes.

MMSN is data fusion is recommended in which the every round of the gather process will leads in a predefined number of K sensor nodes as the CHs. At the initial rounds, each sensor node creates a random number between 0 and 1 and a comparison is made with the arbitrary value with a probability value $P_i(t)$.

When the arbitrary value is lesser than $P_i(t)$, the sensor node will occasionally transmits an advertisement message to its nearby nodes to intimate that it will be the CH and the $P_i(t)$ can be equated as:

$$P_i(t) = \begin{cases} \frac{K}{N-K*(r \bmod (N/K))} & C_i(t) = 1 \\ 0 & C_i(t) = 0 \end{cases} \tag{5.8}$$

where $P_i(t)$ is the possibility that node act as the CH at time t. Let N and K indicates the nodes and CHs at every round, r indicates the present working round. Since the DCH is a distributed clustering technique, the nodes exchange its own information directly.

Using the information communication process, each node updates its neighbor details in the form of triplet $\{E_i, D_i, C_i\}$, where E_i, d_i and C_i represents the energy level, distance and centrality. The energy E_i will be computed using the Eqs. (5.3) and (5.5). Next, the distance D_i will be determined using the Eqs. (5.6) and (5.7).

Node centrality value indicates how centrally the node is present among the neighbors and is determined by taking a total of the squared distance of sensor nodes from a fixed sensor node. The nodes with almost identical values in the triplet will be grouped together and forms a cluster. At the beginning, every node considers itself as a candidate for CH selection. When a node finds a neighboring node with higher energy, it becomes a cluster member automatically. This process continues till a CH is selected.

In each cluster, a CH will be selected and the status will be broadcasted to every cluster member. The cluster member may get two CH status messages in case of overlapping communication range of two nodes. In such cases, the node joins to the nearest CH. Sometimes, in exceptional cases, the nodes fail to join to any other CH and it chooses itself as a CH. This is called as isolated nodes which transmit the data to the nearby CH. When a CH or cluster member moves out of the cluster, the CH selection process will be repeated and the relative mobility needs to be computed. Relative mobility (Rm) of nodes indicates the relative mobility among sensor nodes and CH, not the total vector of velocities as it indicates stable clusters. It is needed to choose the nodes with less mobility as CHs. And, the relative mobility can be computed as:

$$R_m = \max_{k=1..k}\left\{\sum_{\forall n_i \in c_k}\sqrt{v_{ni}^2 + v_{ck}^2 - 2v_{ni}^2 v_{nk}^2 cos\left(\frac{\theta_{ni} - \theta_{ck}}{2}\right)}\right\} \tag{5.9}$$

where v_{ck} is the velocity of the CH, v_{ni} is the moving velocity of member sensor nodes, θ_{ni} is the movement angle of sensor nodes, and θ_{ck} is the movement angle of the CH. A data vector Vect-MSG (e_i, d_i, c_i) is sent by each sensor node in the earlier stage towards the neighbors set N_i and derives a data vector provided through every neighbor j. The vector of data comprises data relative to energy e_i, distance d_i and centrality c_i. The sensor i estimates the mark M_{ij} and transmits Mark-MSG M_{ij} for every neighbor j. The mark Mi,j is computed as

$$M_{ij} = e_j / \sum_{k \in N_i} e_k + d_j / \sum_{k \in N_i} d_k + c_j / \sum_{k \in N_i} c_k \tag{5.10}$$

The sensor i estimates the eligibility weight W_i and transmits it to the neighbors set while mark is relative to neighbors sets are derived and expressed as

$$W_i = \sum_{k \in N_i} M_{k,i} \tag{5.11}$$

For illustration, three sample scenarios are taken and shown in Figs. 5.2-5.4. In a network of 30 mobile sensor nodes, four clusters are formed with 4 CHs and 2 static SCHs. In scenario 1, Fig.5.2, the mobile sensor nodes are formed into four clusters and CH is selected from each cluster. From each cluster, the selected CHs are N8, N21, N13 and N30 for clusters 1-4 respectively. For instance, in the cluster 1, the selected CH is N8 and the respective cluster members are N2, N3, N4 and N5. Similarly, in cluster 2, the selected CH is

N32 and the corresponding cluster members are N15, N16, N17, N18 and N19. In the cluster 3, the chosen CH is N13 with three cluster members N9, N10 and N14 respectively. In the cluster 4, the selected CH is N30 and the cluster members are N22, N23, N24 and N25. It is also shown that two SCHs are placed in the region to receive the data from CHs and forwards it to BS.

After some rounds of operation, the sensor nodes move into other cluster and a new network scenario is formed as shown in Fig. 5.2. Similar to Scenario 1, the nodes in scenario 2 is also clustered into 4 groups and a CH is selected from each cluster. It can be seen that some of the cluster members move out of the cluster and become the normal mobile node.

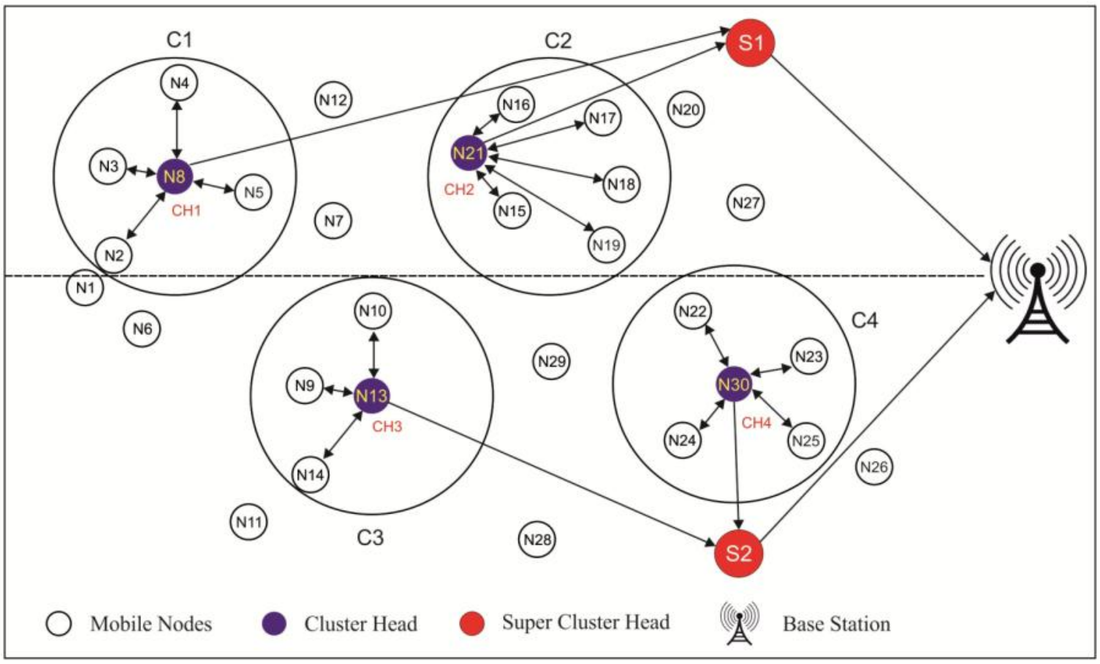


Fig. 5.2. Scenario 1: Cluster construction by DBC algorithm

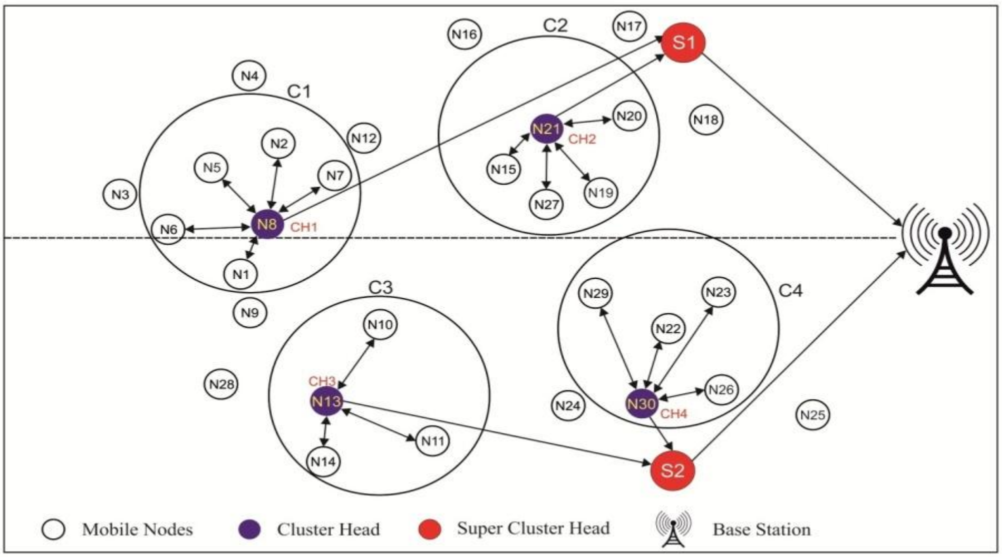


Fig. 5.3. Scenario 2: Cluster construction by DBC algorithm

For instance, in cluster 1, the node N4 moves out of the cluster and node 2 joins into the cluster 1 due to the cause of mobility. As shown in Fig. 5.4, in scenario 3, it is noted that the CH is also changed from N30 to N26 where the N30 moves out of the cluster. In all the above three scenarios, the present CHs will transfer the data to the SCH and it will transfer the data to BS. The process of updating CHs in mobility by the proposed method significantly enhances the energy efficiency and network lifetime.

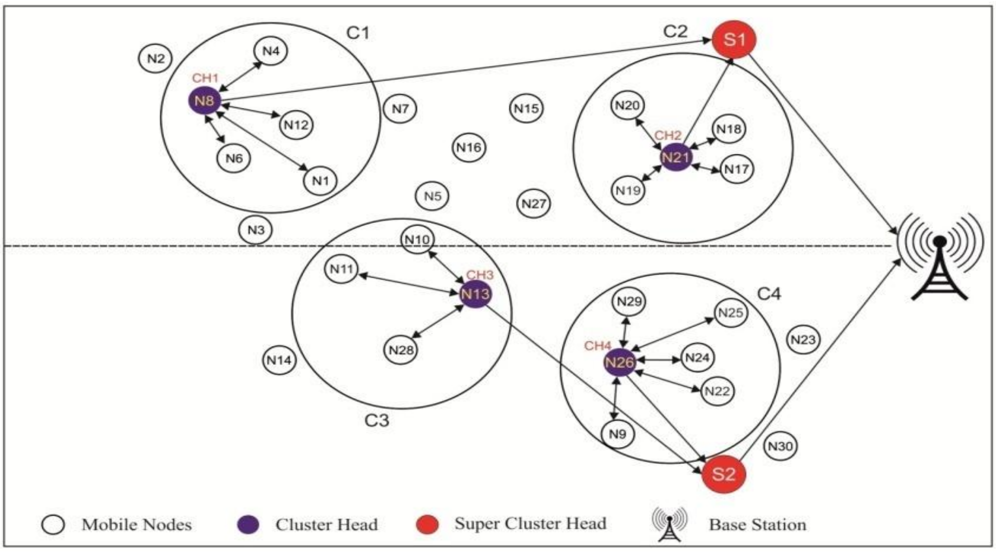


Fig. 5.4. Scenario 3: Cluster construction by DBC algorithm

5.2.2 Steady state phase

The DBC technique divides the network into two grids and two SCHs are placed nearer to BS. After the process of cluster formation and CH selection, each CH generates a TDMA slot and is transmitted to the cluster members. To avoid data collision and interference, the cluster members will transmit the data to CH in their respective slot. The CHs receives the data and aggregates it. The data aggregation process involves the deletion of redundant and unwanted data.

The proposed work introduces a concept of SCH, which acts as a data collector point. The SCH is a static sensor node with superior power compared to other nodes in terms of computation power, energy level and it is located nearer to BS. The SCH will receive the data from the CHs and it simply forwards the data to BS. The usage of SCH will significantly reduce the energy consumption of the CHs and it minimizes the distance of data transmission between CHs and BS.

In other words, it can be stated that the SCH will relay the data from CHs to BS via multi-hop communication. The CH accumulates the data from its cluster members and then transmits it to BS. The DBC algorithm follows multi-hop transmission for inter-cluster communication. The CHs will transmit the aggregated data to BS via intermediate CHs and then it reaches the SCH.

Similar to CH, the SCH receive the data, accumulates it and transfer it to the BS directly. Since the SCH involves higher power compared to normal CHs, it helps to reduce the communication distance of the CHs to BS and thereby reduces the energy utilization significantly.

5.3 PERFORMANCE VALIDATION

5.3.1 Experimental setup

For validation, the energy model explained in previous section is used and the parameter settings are given in Table 5.1 with the following parameters E_{elec}=50nJ/bit, E_{fs}=10pJ/bit/m^2, E_{mp}=0.001310pJ/bit/m^4 and E_{DA}=5nJ/bit/signal. The d^2 energy loss because of channel transmission is employed. It is assumed that the communication channel is symmetric in nature so that the energy needed for data transmission from node i to node j is equal to the energy needed for data transmission from node j to node i. A M-WMSN of 200 nodes is deployed in the area of 100x100m^2 and the BS is located at the point of (150, 50).

To ensure the highlights of the DBC protocol, a comparison is made with the following clustering techniques:

- LEACH: A traditional clustering techniques widely used for comparison purposes. It is a probability based clustering technique which elects CHs in a random manner.
- TEEN: A reactive approach, transmits data on the occurrence of events. When the sensed data exceeds the threshold value, then the sensed data will be transmitted. In case, when the sensed data does not exceeds the threshold value, the data will not be transmitted. This reduces the number of data transmissions and thereby energy efficiency can be achieved.
- M-LEACH: Mobility based clustering protocol which is a famous mobility based clustering technique which follows the CH selection process identical to LEACH.

Table 5.1 Parameter settings

Parameters	**Unit**	**Values**
Area	$Meter^2$	100mx100m
Node count	Integer	200
BS Position	(x,y)	(150,50)
E_{elec}	nJ/bit	50
E_{fs}	$\rho J/bit/m^2$	100
E_{DA}	nJ/bit	5
Packet size	Byte	500
Header size	Byte	25
Initial Residual energy	Joule	5

5.3.2 Measures

The proposed DBC algorithm is validated based on three important measures namely network lifetime, packets delivered at the BS and energy utilization.

- **Network lifetime:** The network lifetime can be defined in various forms such as number of alive nodes, number of dead nodes over several rounds, etc. In this work, the network lifetime is measured in terms of number of alive nodes and it indicates the node count which does not exhaust its energy.
- **Packets delivered at BS:** It indicates the total number of packets successfully delivered at the BS.

- **Energy consumption:** Energy consumption analysis is an important metric to assess the results of the clustering technique. It indicates the amount of energy, on average, required by all the nodes in M-WMSN. The lower value of energy consumption indicates better results.

5.3.3 Result analysis

A detailed experimental analysis is made to ensure the benefits of the DBC method. Fig. 5.5 and Table 5.2 shows the comparative results of different clustering approaches interms of network lifetime, number of alive nodes. From this figure, it is clear that the LEACH shows poor performance where the number of alive nodes is drastically reduced over several rounds. At the earlier rounds of 1100, the nodes start to exhaust its energy completely.

Table 5.2 Network lifetime analysis

	No. of rounds								
	1000	**3000**	**5000**	**7000**	**9000**	**11000**	**13000**	**15000**	**17000**
LEACH	200	137	89	43	13	3	0	0	0
TEEN	200	150	103	66	27	10	1	0	0
MLEACH	200	160	118	79	39	19	8	0	0
PROPOSED	200	175	135	100	65	43	24	7	0

At the round number of 4634, the 50% of nodes die in the network, i.e. only 100 nodes are alive and the other 100 nodes are dead. In the round number of 6459, only 25% of nodes are alive indicating that 175 nodes are dead. In line with, the last node in the network dies at the round number of 11241. Next, the TEEN attained increased network lifetime compared to LEACH but not greater than M-LEACH and proposed DBC technique. Similarly, the M-LEACH manages to show good results compared to LEACH and TEEN. But, it does not outperform the DBC technique.

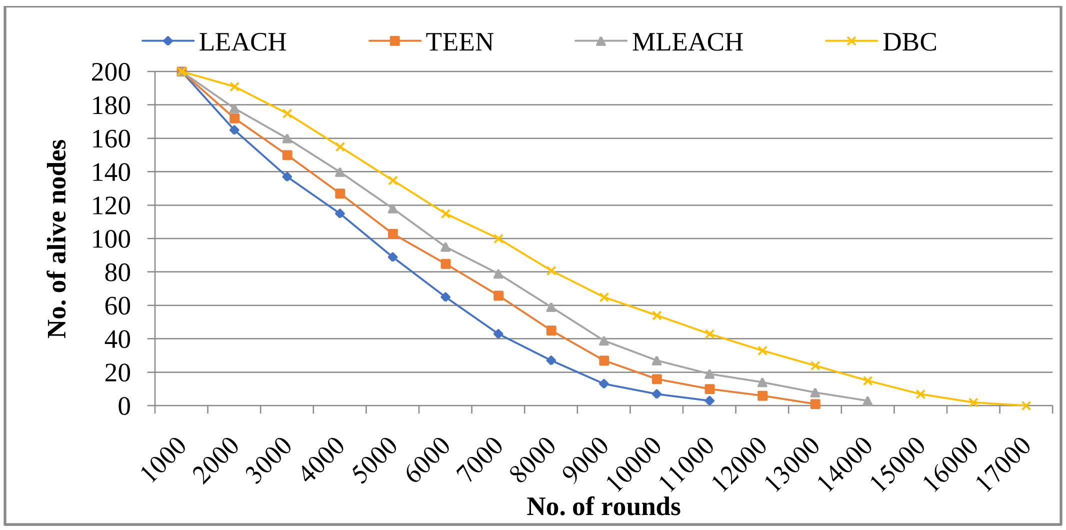


Fig. 5.5. Network lifetime analysis

The efficiency of the clustering technique can also be investigated using the number of packets successfully delivered at the BS over several rounds. The results are based on the number of packets delivered rather than sent packets in the MWSN. Fig. 5.6 shows the comparison of different clustering techniques in terms of number of packets received at the BS. The figure clearly indicated that the number of packets delivered at the BS in the time interval of 1000 rounds. At the round number of 1000, it is shown that least number of packets is delivered using the LEACH whereas the value is slightly increased by TEEN. At the same time, the M-LEACH tries to perform well and shows better performance than LEACH and TEEN. But, the proposed DBC algorithm outperforms the compared methods significantly.

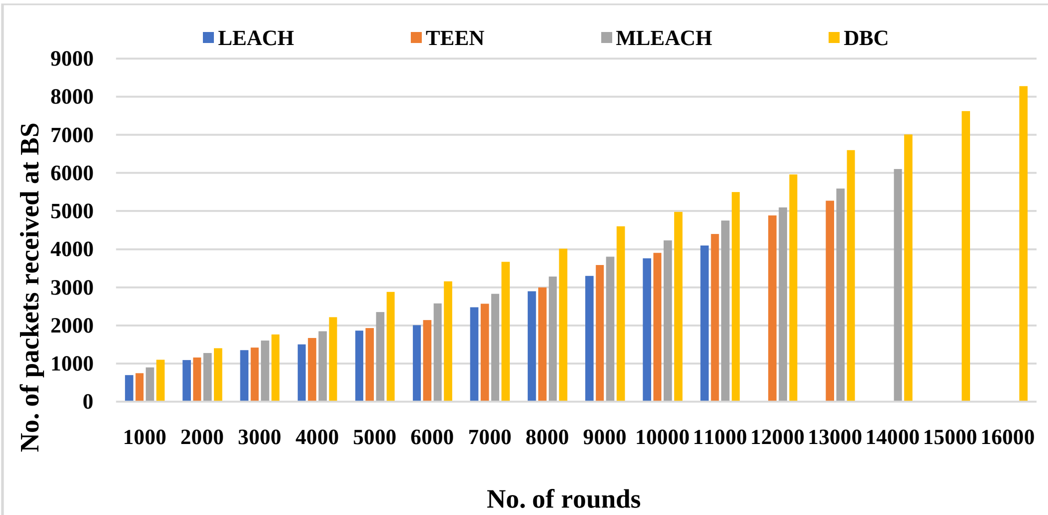


Fig. 5.6. Packets delivered at the BS

From the figure, it also shown that no packets are received by LEACH, TEEN and M-LEACH after the round number of 11000, 13000 and 14000 respectively. This is because of the fact that none of the nodes are alive and the network becomes inoperative at the particular rounds. Interestingly, the DBC method allows the data transmission till 16000 rounds. This increased data transmission is due to enhanced lifetime of the M-WMSN nodes. The worst result of the LEACH is due to the uncontrolled CH selection and it results to reduced data transmission from each sensor node to BS.

Additionally, the reactive nature of TEEN resulted to reduced data transmission and also it is inefficient to observe the overall picture of the M-WMSN. The M-LEACH also selects the CHs arbitrarily; it also fails to achieve better data transmission successfully to the BS.

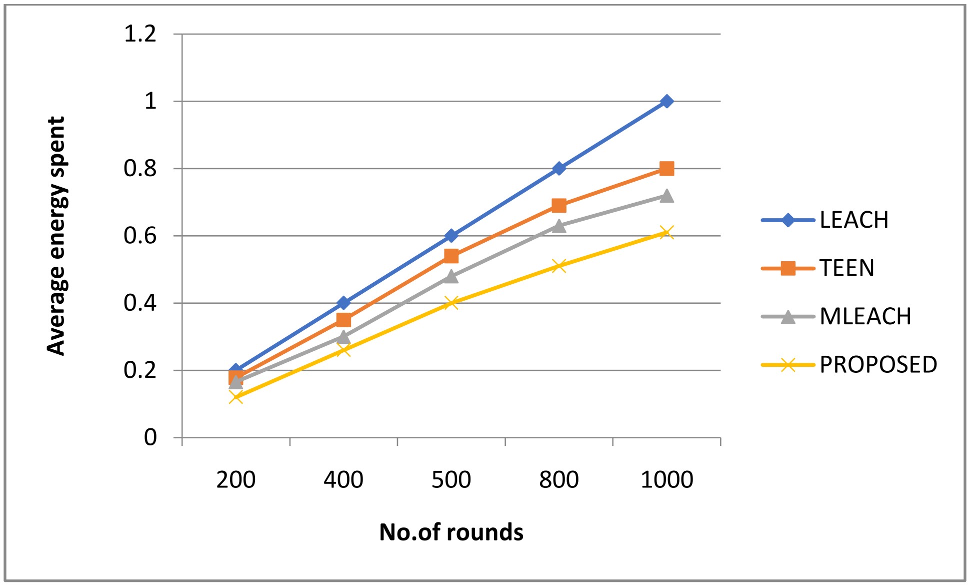


Fig. 5.7. Energy consumption analysis for 1000 rounds

To validate the consistent results of the presented DBC method, the energy consumption is analyzed for 1000, 2000 and 3000 rounds and the results are depicted in Figs. 5.7-5.9 respectively.

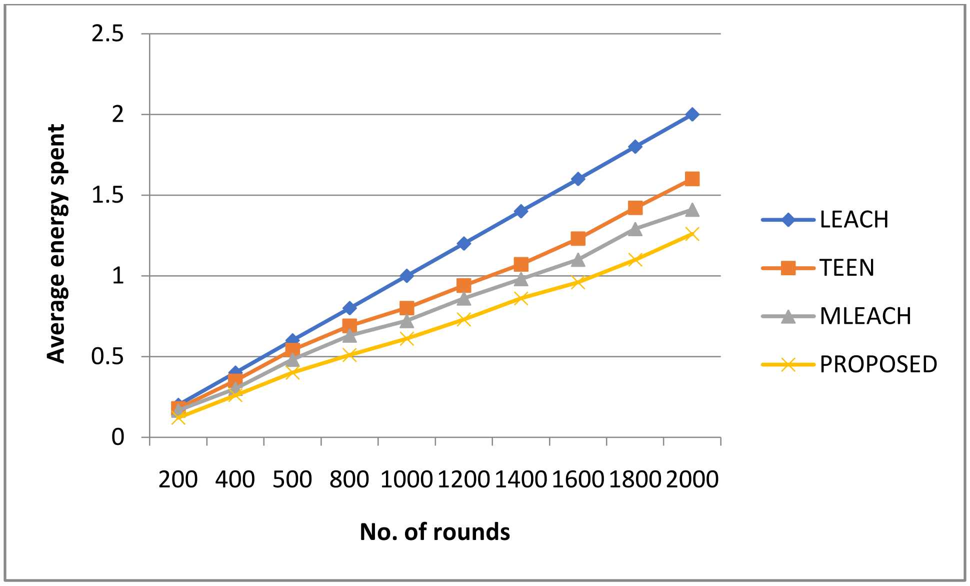


Fig. 5.8. Energy consumption analysis over 2000 rounds

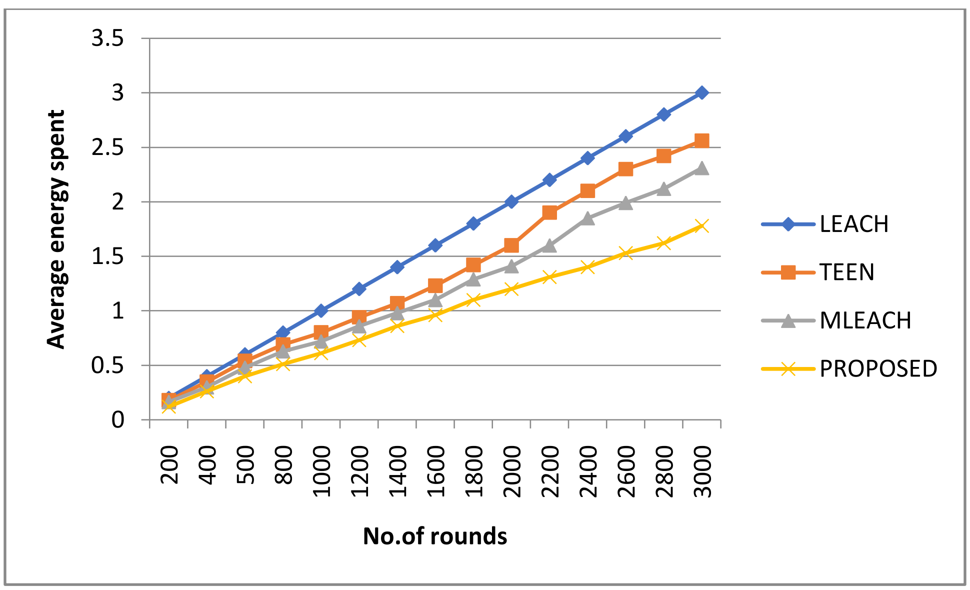


Fig. 5.9. Energy consumption analysis over 3000 rounds

From these figures, it is noted that the proposed DBC required less amount of energy than the other methods. The randomized CH selection and single hop communication of the LEACH protocol have strong impact on energy consumption. Since TEEN transmits data on the occurrence of event, the energy consumption is automatically reduced and leads to higher energy efficient compared to LEACH. However, the probability based CH selection TEEN makes it inefficient over the M-LEACH and DBC technique. Though M-LEACH offers some benefits over the LEACH and TEEN, it is found to be inefficient than DBC technique. The proposed DBC method is found to be superior to the other methods. The reduced energy utilization is due to the characteristics of DBC algorithm. The DBC algorithm utilizes the SCH to forward the data from the CHs. This in turn, significantly reduces the energy needs for data transmission among clusters to BS. The effective process of CH selection is also paves a way for reduced energy utilization. In addition, the process of multi-hop communication also leads to reduced energy utilization.

5.3.4. Comparison with recently proposed method

To further analyze the effective performance of the proposed DBC technique, a detailed comparative analysis is carried out with the state of art methods namely DDEEC, DDCHS and SDC techniques interms of average energy spent. Fig. 5.10 shows the comparison results of various methods in terms of average energy consumed. The figure clearly states that the DDEEC technique offers least performance by attaining the maximum energy utilization. At the same time, the DDCHS technique achieved better energy consumption over DDEEC, but, it fails to show better results compared to SDC and DBC technique. Besides, it is also noted that the SDC method offered manageable results over other methods. However, the proposed DBC technique achieved maximum energy efficient by achieving least energy utilization over the compared methods.

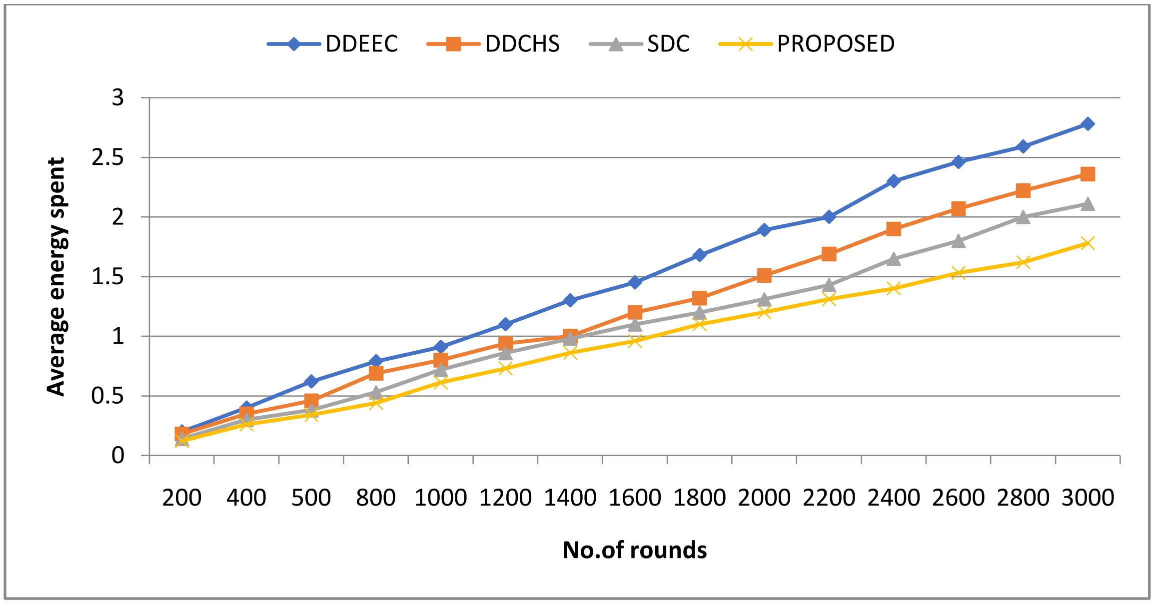


Fig. 5.10. comparison result of proposed method in term of energy

5.4 SUMMARY

This chapter has proposed a novel clustering technique called DBC algorithm to select CHs using three input variables like energy level, distance and node centrality. In addition, two static data collector points called SCH are placed to collect the data from CHs and forwards to the BS directly. The use of SCH supports multi-hop communication which helps to balance the available energy effectively. The proposed method is experimented and the results are verified in terms of network lifetime, energy efficiency and throughput. The DBC method is found to be energy efficient with maximum lifetime compared to LEACH, TEEN and M-LEACH. The DBC method enables data transmission till 16000 rounds whereas no packets are received by LEACH, TEEN and M-LEACH after the round number of 11000, 13000 and 14000 respectively. These values clearly indicate the superiority of the proposed method in terms of network lifetime.

CHAPTER 6

CLUSTER BASED NODE LOCALIZATION (CH-NL) TECHNIQUE FOR MWSN

6.1 OVERVIEW

In this chapter introduced a new CH-NL protocol for MWSN to eliminate clustering and node localization problem and extend the network lifetime and energy efficiency. This protocol comprises of two phases: Node localization using hybrid BAT-TLBO and Clustering using Density based cluster head (DBC) selection. A detailed experimental analysis is made to ensure the benefits of the CH-NL protocol. A comparative results of different clustering approaches include LEACH, M-LEACH and LEACH-ME are made in terms of network lifetime, energy consumption.

6.2 THE PROPOSED CH-NL ALGORITHM

This protocol comprises of two phases: Node localization using hybrid BAT-TLBO and Clustering using Density based cluster head (DBC) selection. Initially, the sensor nodes undergo random deployment in the target field. Then, the sensor node gathers information about its neighbouring node. Next, the clustering process will be executed to generate the clusters and effective selection of CHs. Once the nodes are clustered, the cluster members begin to send the data to the CH. Due to the nature of mobile nodes in MWSN, the CHs tends to move in the sensing field. Then, the node localization algorithm gets executed to determine the location of the sensor nodes. Once the location of the sensor nodes is

determined, this information is utilized. By the use of localized nodes, the data transmission will takes place from cluster members to CHs and then to SCHs. Finally, it reaches to the BS.

For MWSN, we propose a CH-NL protocol depending on node localization and clustering problem and prolong the energy efficiency and network lifetime.

- It contains two phases:
    - By employing hybrid BAT-TLBO, Node localization.
    - With the help of Density Based Cluster head (DBC) selection.

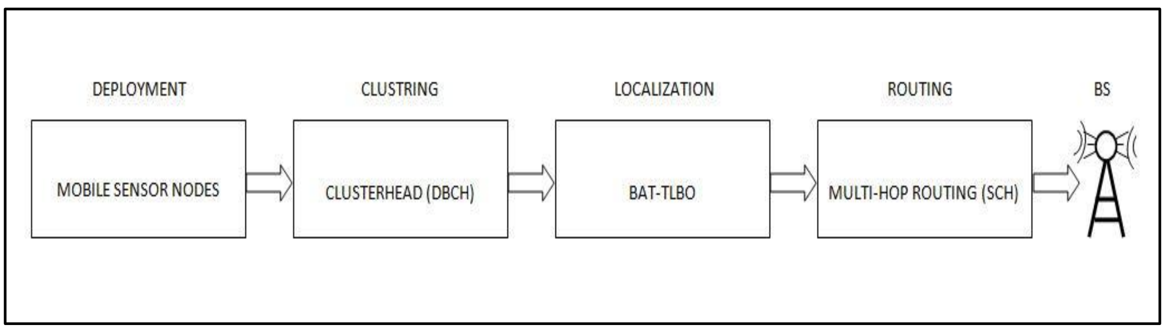


Fig. 6.1. The Overall Structure of CH-NL algorithm

DBC technique mainly depends on three input variables such as remaining energy level, distance and node centrality. In addition, two static data collector points called SCHs are placed to collect the data from CHs and it forwards it to the BS directly. The use of SCH supports multi-hop communication which helps to balance the available energy effectively. The proposed DBC technique improves the network lifetime to a maximum of 16500 rounds. The proposed method is experimented in MATLAB and the results are verified interms of network lifetime, energy efficiency and throughput. A MWSN is generated using N number of mobile sensor nodes which are randomly placed in the sensing region with the following considerations:

- Sensor nodes are mobile whereas the BS and SCH are stationary
- Heterogeneous nodes
- Sensor nodes are not aware of their location
- Death of node occurs, due to an energy depletion
- Nodes can adjust the transmission power

Clustering process is carried out by:

- Initially, the sensor nodes undergo random deployment in the target field.
- Then, the sensor node gathers information about its neighboring node.
- Next, the clustering process will be executed to generate the clusters and effective selection of CHs.
- Once the nodes are clustered, the cluster members begin to send the data to the CH.
- Due to the nature of mobile nodes in MWSN, the CHs tend to move in the sensing field.
- Then, the node localization algorithm gets executed to determine the location of the sensor nodes.
- Once the location of the sensor nodes is determined, this information is utilized.
- By the use of localized nodes, the data transmission will takes place from cluster members to CHs and then to SCHs. Finally, it reaches to the BS.

6.2.1 Node localization using hybrid BAT-TLBO

A single hop range based distributed approaches can be employed to localize the nodes in MWSN localization, to determine the coordinates of many sensor nodes by the use of anchor nodes. For determining the location of Nsensor nodes, the following process will takes place. At the beginning, N sensor nodes undergo random deployment in the sensing filed in the C-shaped topology. In a network of N node, M anchor nodes are present, which know their coordinates earlier, undergo deployment in C-shape topology. $(N - M)$ are the unknown nodes, whose coordinates needs to be determined. Every node has a transmission range of R. An unknown node can easily determine its own location coordination if and only if it has more than two non-coplanar anchor nodes as neighbours, i.e. the node is known to be a localizable node. Every localizable node computes its distance from every one of the nearby anchor nodes. The distance measurement gets distorted with Gaussian noise n_i because of environmental considerations.

$$\widehat{d_L} = [d_k + n_k] \tag{6.1}$$

where d_i is the distance from the localizable node to anchor node which is determined by:

$$d_k = \sqrt{(x - x_k)^2 + (y - y_k)^2} \tag{6.2}$$

Where (x, y) is the location coordinates of the unknown node and (x_k, y_k) is the location coordinates of the ith anchor node in the nearby area. The location determination of a given unknown node can be formulated as an optimization problem, involving the minimization of an objective function indicating the localization accuracy.

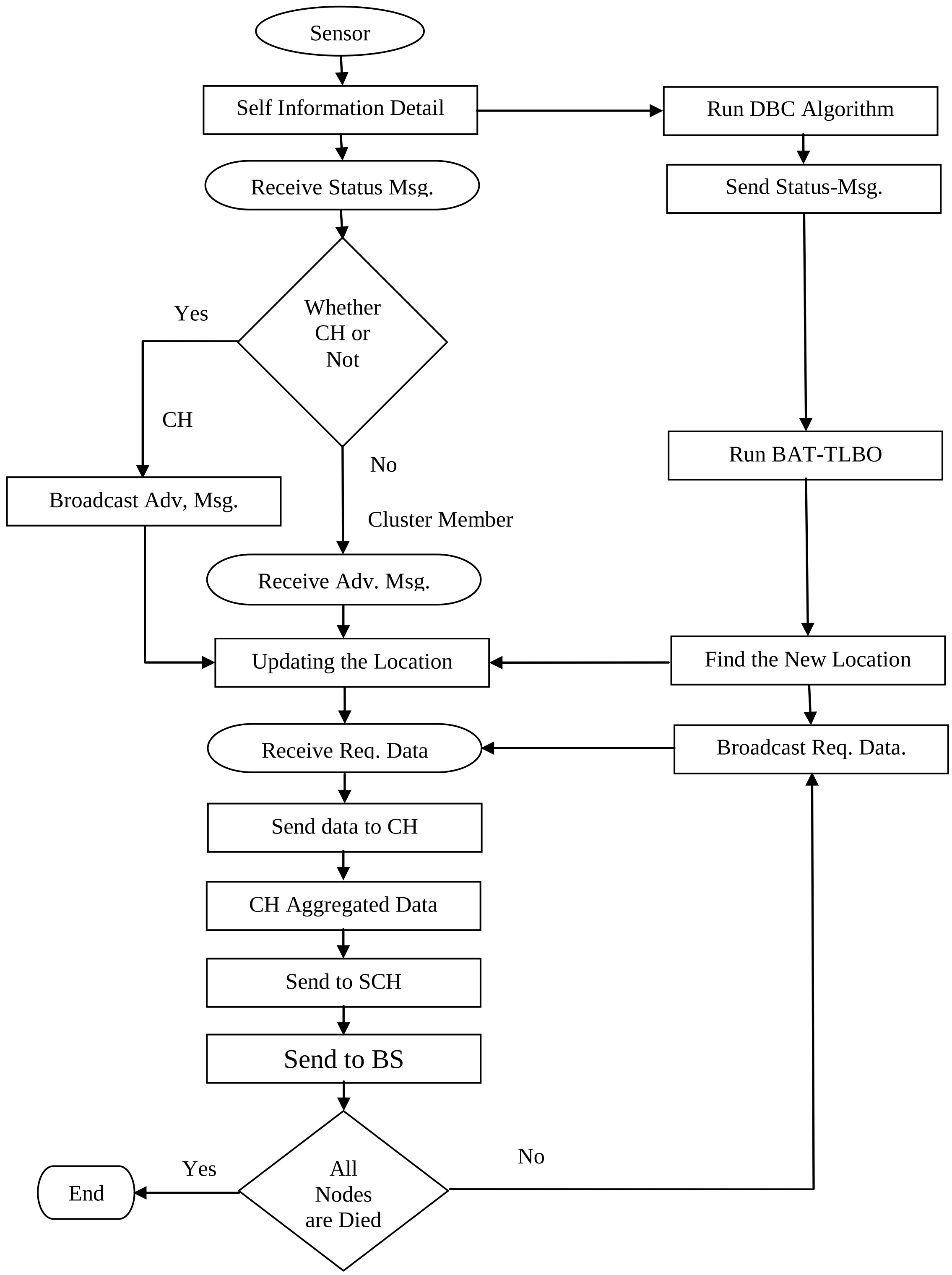


Fig.6.2 The CH-NL FLOW CHART

6.3 PERFORMANCE EVALUATION

6.3.1 Experimental setup

For validation, the energy model explained in previous section is used and the parameter settings are given in Table 6.1 with the following parameters E_{elec}=50nJ/bit, E_{fs}=10pJ/bit/m^2, E_{mp}=0.001310pJ/bit/m^4 and E_{DA}=5nJ/bit/signal. The d^2 energy loss because of channel transmission is employed. It is assumed that the communication channel is symmetric in nature so that the energy needed for data transmission from node i to node j is equal to the energy needed for data transmission from node j to node i. A M-WMSN of 200 nodes is deployed in the area of 100x100m^2 and the BS is located at the point of (150, 50).

Table 6.1 Parameter initialization

Parameters	**Unit**	**Values**
Area	$Meter^2$	100mx100m
Node count	Integer	200
BS Position	(x,y)	(150,50)
E_{elec}	nJ/bit	50
E_{fs}	ρJ/bit/m^2	100
E_{DA}	nJ/bit	5
Packet size	Byte	500
Header size	Byte	25
Initial Residual energy	Joule	5

To ensure the highlights of the DBC protocol, a comparison is made with the following clustering techniques:

- LEACH
- M-LEACH
- LEACH-ME
- BAT-TLBO
- DBC

6.3.2 Result analysis

A detailed experimental analysis is made to ensure the benefits of the CH-NL protocol. To authenticate the highlights of the CH-NL protocol, a comparison is with state of art methods like LEACH, MLEACH, LEACH-ME, BAT-TLBO and DBC in terms of network lifetime, energy consumption rate, Packet Delivery Ratio and Ranging error. Fig. 6.3 and Table 6.2 shows the comparative results of different clustering approaches in terms of network lifetime, energy consumption. From this figure, it is clear that the LEACH, M-LEACH and LEACH-ME shows poor performance where the number of alive nodes is drastically reduced over several rounds. At the earlier rounds of 1100, 1200 and 1300 respectively, nodes start to exhaust its energy completely. At the round number of 4000 to 6000, 50% of nodes die in the network, i.e. only 100 nodes are alive and the other 100 nodes are dead. In the round number of 6459, only 25% of nodes are alive indicating that 175 nodes are dead. In line with, the last node in the network dies at the round number of 11241. Next, the BAT-TLBO attained increased network lifetime compared to LEACH, M-LEACH and LEACH-ME but not greater than DBC and proposed CH-NL technique. Similarly, the DBC manages to show good results compared to LEACH, M-LEACH and LEACH-ME . But, it does not outperform the CH-NL technique.

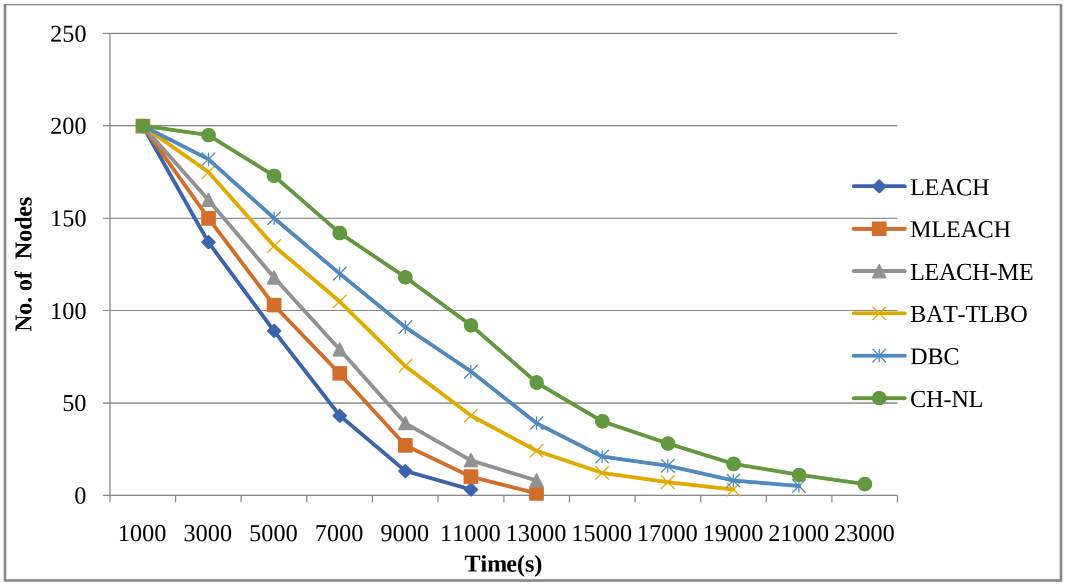


Fig. 6.3. Comparison results of proposed method in terms of network lifetime under varying no. of nodes.

Table 6.2 Comparison results of proposed method in terms of network lifetime.

ALGORITHM	1000	3000	5000	7000	9000	11000	13000	15000	17000	19000	21000
LEACH	200	137	89	43	13	3					
MLEACH	200	150	103	66	27	10	1				
LEACH-ME	200	160	118	79	39	19	8				
BAT-TLBO	200	175	135	105	70	43	24	12	7	3	
DBC	200	182	150	120	91	67	39	21	16	8	5
CH-NL	200	195	173	142	118	92	61	40	28	17	11

Fig. 6.4 and Table 6.3 shows the comparative outcomes of projected technique and existing methods by means of PDR. With the varying time, LEACH shows the poor results, by attained PDR of 1090, whereas the other methods like MLEACH and LEACH-ME attains 1160 and 1280 as PDR rate. The proposed method attains 1640 as PDR rate. In 10000, LEACH shows the poor results, LEACH attains 3760, whereas the other methods like MLEACH and LEACH-ME attains 3900 and 4230 as PDR rate. The proposed method attains 5538 as PDR rate. In 16000, LEACH shows the poor results, LEACH attains 6400, whereas the other methods like MLEACH and LEACH-ME attains 6560 and 7006 as PDR rate. The proposed method attains 5538 as PDR rate. The other methods do not exhibit considerable performances. Therefore, the proposed method attains enhanced performance when compared to all in terms of PDR.

Table 6.3 Comparison results of proposed method in terms of PDR.

ALGORITHM	**No. of rounds**							
	2000	**4000**	**6000**	**8000**	**10000**	**12000**	**14000**	**16000**
LEACH	1090	1500	2010	2900	3760	4576	5370	6400
MLEACH	1160	1669	2140	3000	3900	4890	5640	6560
LEACH-ME	1280	1846	2575	3280	4230	5100	6100	7006
BAT-TLBO	1405	2220	3158	4010	4980	5960	7010	8278
DBC	1450	2280	3290	4100	5075	6200	7190	8540
CH-NL	1640	2652	3580	4610	5538	6759	7695	9120

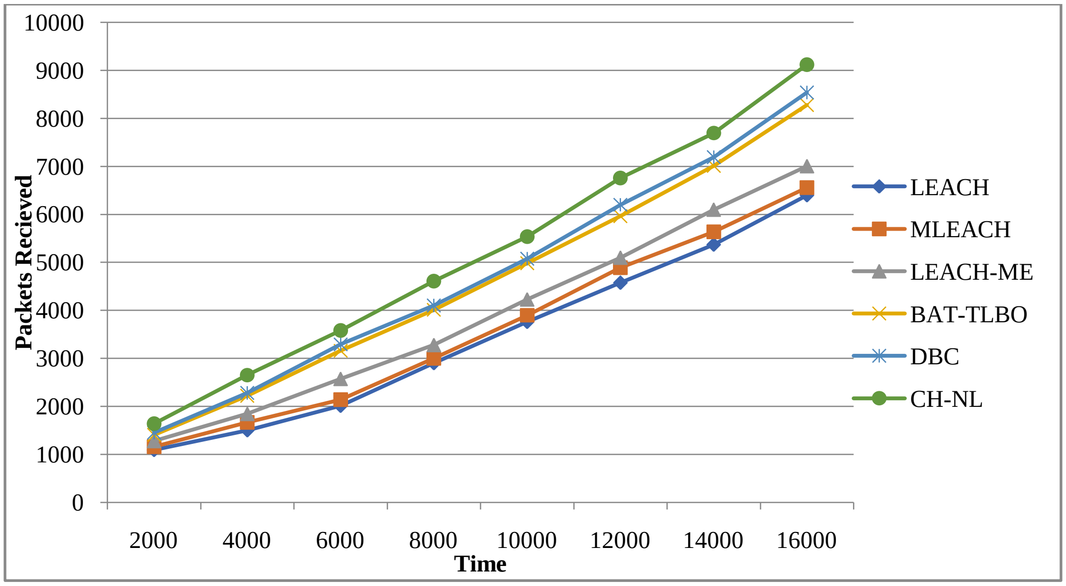


Fig. 6.4. Comparison results of proposed method in terms of PDR

To validate the consistent results of the presented proposed method, the energy consumption is analyzed for 3000 rounds and the results are depicted in Fig. 6.5 and Table 6.4 respectively. From these figure, it is noted that the proposed method required less amount of energy than the other methods. The randomized CH selection and single hop communication of the LEACH protocol have strong impact on energy consumption. Since M-LEACH and LEACH-ME transmits data on the occurrence of event, the energy consumption is automatically reduced and leads to higher energy efficiency compared to LEACH.

Table 6.4. Comparison results of proposed method in terms of Energy Consumption

ALGORITHM	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000
LEACH	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3
MLEACH	0.178	0.35	0.54	0.69	0.8	0.94	1.07	1.23	1.42	1.6	1.9	2.1	2.3	2.42	2.56
LEACH-ME	0.165	0.3	0.48	0.63	0.72	0.86	0.98	1.1	1.29	1.41	1.6	1.85	1.99	2.12	2.31
BAT-TLBO	0.12	0.26	0.4	0.51	0.61	0.73	0.86	0.96	1.1	1.2	1.3	1.4	1.53	1.62	1.78
DBC	0.1	0.22	0.35	0.46	0.49	0.61	0.72	0.86	0.95	1.02	1.11	1.23	1.32	1.39	1.45
CH-NL	0.09	0.2	0.27	0.31	0.36	0.41	0.51	0.6	0.69	0.8	0.92	0.99	1.06	1.16	1.22

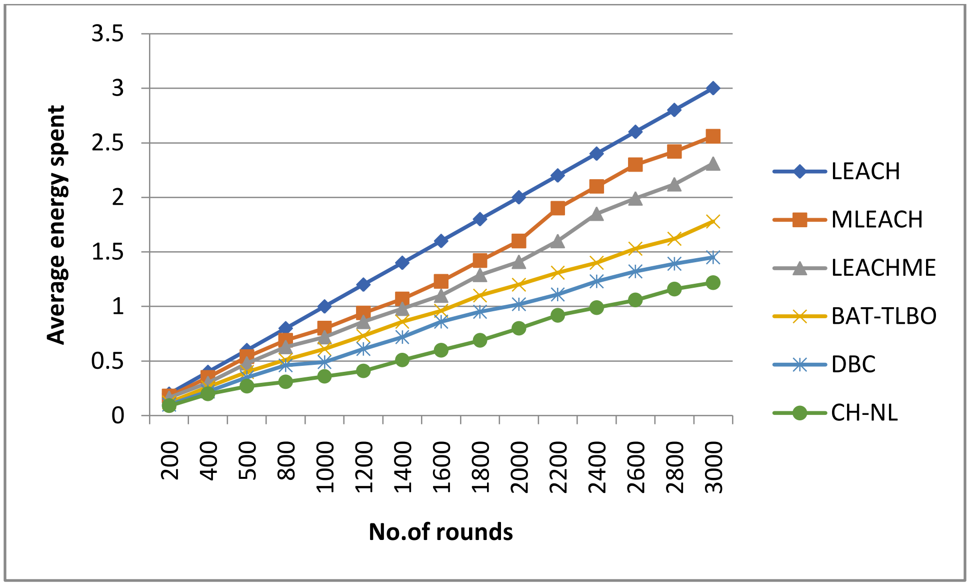


Fig. 6.5. Comparison results of proposed method in terms of energy consumption varying number of nodes

However, the mobility based CH selection M-LEACH and LEACH-ME makes it inefficient over the BAT-TLBO, DBC and CH-NL technique. Though BAT-TLBO and DBC offers some benefits over the LEACH, M-LEACH and LEACH-ME, it is found to be inefficient than CH-NL technique.

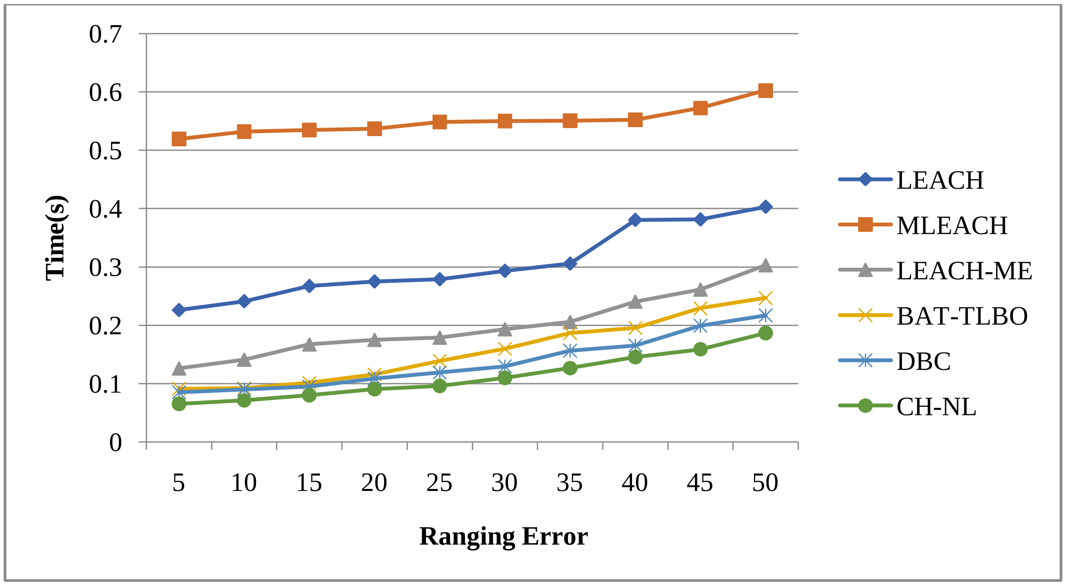


Fig. 6.6 Comparison results of proposed method in terms of ranging error

Table 6.5 Comparison results of proposed method in terms of Ranging error

ERROR RANGE	Algorithms					
	LEACH	**MLEACH**	**LEACH-ME**	**BAT-TLBO**	**DBC**	**CH-NL**
5	0.226	0.5191	0.126	0.091	0.0851	0.0651
10	0.1411	0.5319	0.1411	0.0919	0.0899	0.0899
15	0.2672	0.5346	0.1672	0.1012	0.9512	0.09012
20	0.275	0.5368	0.175	0.1156	0.1086	0.0948
25	0.2788	0.5484	0.1788	0.1389	0.1189	0.0960
30	0.2932	0.5499	0.1932	0.1596	0.1296	0.1096
35	0.3056	0.5506	0.2056	0.1865	0.1565	0.1265
40	0.3806	0.5522	0.2806	0.1954	0.1654	0.1454
45	0.3813	0.5723	0.2813	0.2289	0.1989	0.1589
50	0.403	0.6424	0.303	0.2467	0.2167	0.1867

Fig. 6.6 and Table 6.5 shows the comparative analysis of various methods in terms of ranging error. Here, for varying time, the error range is computed. From the results, the poor performance is attained through MLEACH which attains highest error range of 0.226 for the error range of 5, whereas the proposed method attains 0.0651 as error range. For the error range of 15, the poor performance is attained through MLEACH as 0.5346 and better performance is achieved by the presented CH-NL method as 0.09012.

6.4 SUMMARY

In this chapter, a new CH-NL algorithm has been proposed depending on node localization and clustering problem to prolong the energy efficiency and network lifetime. Initially, the sensor nodes undergo random deployment in the target field. Next, the clustering process will be executed to generate the clusters and effective selection of CHs. Then, the node localization algorithm gets executed to determine the location of the sensor nodes. By the use of localized nodes, the data transmission will takes place from cluster members to CHs and then to SCHs. Finally, it reaches to the BS. A detailed experimental analysis is made to ensure the benefits of the CH-NL protocol. To authenticate the highlights of the CH-NL protocol, a comparison is with state of art methods like LEACH, MLEACH, LEACH-ME, BAT-TLBO and DBC in terms of network lifetime, energy consumption rate, PDR and Ranging error. The experimental outcome verified the superior nature of the presented algorithm.

CHAPTER 7

CONCLUSION AND FUTURE ENHANCEMENTS

7.1 CONCLUSION

MWSNs act as a major part in practical scenarios in that the sensor nodes are movable and not stagnant in nature. The major hardware restrictions are inbuilt battery source, compact size and installation cost. In addition, the nodes in MWSN should achieve high energy efficiency for the longer network lifetime. At the same time, the complexity level of the algorithms derived for various tasks like localization, clustering, routing, and so on. The main intention of this research work is to maximize the network lifetime by using BAT and TLBO based node localization techniques and density based Clustering and multi-hop data transmission protocol. Hybrid energy efficient techniques are also introduced to maximum network lifetime by minimizing the energy consumption in MWSN. So, in principle, the goals of the proposed research are three folded as mentioned below.

GOAL I: To design and combine BAT and TLBO (BAT-TLBO) based algorithm to resolve node localization problem and attains maximum lifetime

GOAL II: To develop a density based Clustering (DBC) and multi-hop data transmission protocol to achieve energy efficiency and maximum lifetime.

GOAL III: To device a cluster based node localization (CH-NL) and network life time maximization MWSN.

In this research work, all the above mentioned three goals are successfully implemented and attained outstanding performance over the existing methods. Firstly, the design of node localization algorithms based on BAT-TLBO algorithm is implemented. The proposed BAT-TLBO algorithm employs the nature of bat's echolocation and the characteristics of TLBO algorithm. An extensive set of experiments takes place to validate the results of the BAT-TLBO algorithm to resolve the node localization issue. To verify the consistency in the performance, the proposed method and compared algorithms are tested with varying anchor node density and ranging error. From the experimental values, it is ensured that the BAT-TLBO algorithm effectively localizes more number of nodes with less computation time and MLE than the state of art methods.

Secondly, the clustering algorithms based on DBC are also developed called as DBC algorithm to select CHs using three input variables like energy level, distance and node centrality. In addition, two static data collector points called SCH are placed to collect the data from CHs and it forwards to the BS directly. The use of SCH supports multi-hop communication which helps to balance the available energy effectively. The proposed method is experimented and the results are verified in-terms of network lifetime, energy efficiency and throughput. The DBC technique is found to be energy efficient with maximum lifetime compared to LEACH, TEEN and M-LEACH. The DBC method allows the data transmission till 16000 rounds whereas no packets are received by LEACH, TEEN and M-LEACH after the round numbers of 11000, 13000 and 14000 respectively. These values clearly indicate the superiority of the proposed method in-terms of network lifetime.

Finally, a hybrid cluster based node localization algorithm is also developed to attain maximum energy efficiency. A detailed experimental analysis is made to ensure the benefits of the CH-NL protocol. The experimental outcomes show the comparative results of different clustering approaches in terms of network lifetime, energy consumption. A well-defined layered experimentation framework is designed for the research narrated in this thesis. The proposed method shows its significance in the aspects such as energy efficiency, network lifetime, and power saving. This research can further be extended to any real time application with increased performance and for reducing computational time.

7.2 FUTURE ENHANCEMENTS

In future, the BAT-TLBO can be improved to reduce the computation time taken to complete the localization process in MWSN. In addition, the proposed DBC algorithm can be implemented in real time applications. At the same time, the performance of the proposed research work can be further enhanced by the hybridization of the bio-inspired algorithms.

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