# ZONE BASED HYBRID APPROACH FOR CLUSTERING AND DATA COLLECTION IN WIRELESS SENSOR NETWORKS

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**Title**

ZONE BASED HYBRID APPROACH FOR CLUSTERING AND DATA COLLECTION IN WIRELESS SENSOR NETWORKS

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

**MASTER OF SCIENCE**

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## ABSTRACT

A wireless sensor network (WSN) is a collection of spatially distributed autonomous sensor nodes that can be used to monitor, among other things, environmental conditions. WSN nodes are constrained by their limited energy supply, communication range and local computational capabilities. Data routing is an area that can be optimized to allow nodes to conserve energy, improving the network's overall lifetime. Though many routing protocols can be used, using a clustering protocol can play an important role in conserving WSN energy.

A new hybrid algorithm is proposed which incorporates both distributed and centralized algorithms for selection of the cluster head (CH). In most networks, sensor nodes have limited energy, so a mobile data collector (MDC) is used to collect information, reducing energy requirements. The performance of proposed algorithm is evaluated using NS-2 simulations. The results show that proposed algorithm has better performance, throughput, network lifetime compared to existing routing protocols.

## ACKNOWLEDGEMENTS

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# 1. INTRODUCTION

A Wireless Sensor Network (WSN) is a group of typically small, lightweight, low-computational capacity sensor nodes[1]–[3]. WSNs can be deployed in support of a variety of applications such as monitoring environmental phenomena (e.g., the level of air contamination and climate change). The data gathered from the sensor nodes is forwarded to a base-station for further processing.

Energy conservation is important criteria for WSN design, as WSNs are typically deployed to remote locations or over large areas. In any case, replacing depleted batteries for large numbers of nodes or even a limited set of hard-to-access nodes is typically not a viable option.

## 1.1. Topology

The topology of the network is the arrangement of a network, including its nodes and the lines connecting nodes. The geometry of the topology can be defined in two ways: signal (or logical) and physical topology. The workstation layout generally uses the physical topology of a network. Several physical topologies are described below.

In a bus network, every computer or workstation is connected to a single network called bus. The computers will have direct access to other computers in the network. These are feasible for a small network. The major disadvantage is if the main cable goes off, the network fails. In a star network, other workstations are directly connected to a central server system. If any data is needed to be sent to another computer, the central server system takes the responsibility of transferring it. The ring topology uses closed loop configuration. Only the adjacent pair of workstations are connected directly, and other workstations are indirectly connected. The data is sent through intermediate nodes, which act as an interface. The mesh network topology has one of two schemes: partial mesh (or) full mesh. In full mesh the computers are connected directly to each other. While in partial mesh, some are connected to all of the other workstations and some are connected only to the workstations which exchange the data. A tree network is a bus network of star networks. Computers of star network are connected to a bus cable.

In many cases, the logical topology works the same as physical topology. But in some cases, it works different, for example some networks use the star network, but they operate logically as ring or bus networks.

**1.2. Multi-Hop Communications**

Since there are many sensor nodes densely deployed in the network, neighbor nodes are in close proximity to each other. With point-to-point communications, the nodes send the data directly to the base station as shown in Figure 1-1. However, multi-hop communications, as shown in Figure 1-2, use intermediate nodes for data transmission. This provides benefits for certain applications. For instance, when sensor nodes are far from the base station, single-hop communications use a lot of energy for transmitting the data to the base station, which in turn leads to nodes running out of power. If multi hop communication is used, the energy consumed for the data transmission is distributed so that the network lifetime increases. Because of this, multi-hop communications can be used instead of point-to-point communications to conserve energy[4]. Under this approach, node-to-node relay transmission takes place to send the data to its destination, requiring less energy and increasing the lifetime of the network.

As the WSN lifetime and power resources are limited, there is a need for energy efficient protocols to maximize the performance of this relay system. To this end, clusters [5] are formed which are used to coordinate data relay and reduce the consumption of energy. Various routing protocols have been previously designed, based on the use of clustering approaches [6]–[11].

Under the proposed approach, the WSN is divided into small clusters using a clustering scheme. Each node sends its data to the local cluster head. The cluster head is responsible for forwarding the data to the base station for further processing. The base station acts as a gateway to connect the WSN to the outside world.

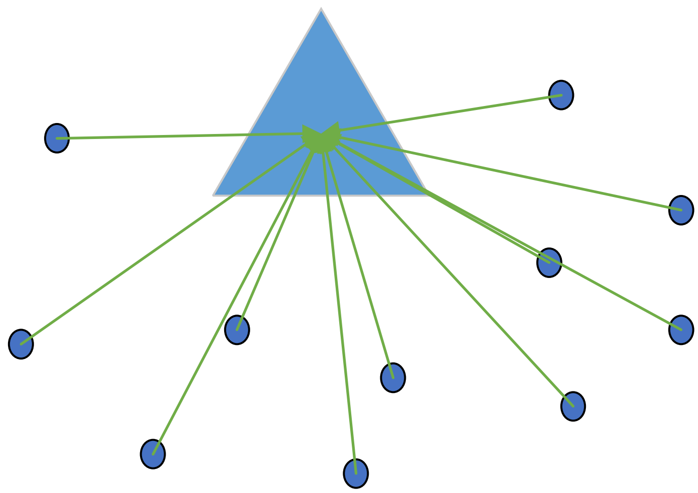

Figure 1-1. Point-to-point communication

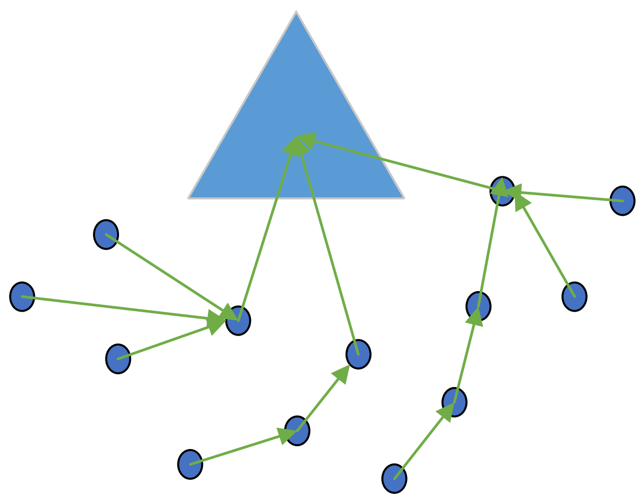

Figure 1-2. Multi-hop communication

### 1.3. Mobile Wireless Sensor Networks

The advent of Mobile Wireless Sensor Networks (MWSNs) is a result of the convergence between mobile wireless communication technologies and improved sensor technology [12]–

[15]. MWSN applications include, among other things, remote health monitoring, and field surveillance, weather monitoring, and land monitoring for farming. Mobile nodes are widely used for data aggregation [12], [16] in MWSNs.  These nodes can be configured to acquire and transmit data only when there is a change in surroundings. Mobile nodes can, thus, be configured to transmit data [17] to the base station only if they sense variation in the environmental phenomenon under observation. There are many types of mobile sensor nodes which can be grouped into three categories:

1. Portable nodes can be used for devices, which move with high velocities, such as motorcycles, cars, and others.
2. Mostly static nodes can be used for devices which move at low velocity, such as monitoring the building with moving robots.
3. Hybrid nodes are both portable and static nodes.

Problematically, mobility may cause rapid topology changes and frequent link failures [13], [14], [16], [18]–[20].  This presents a serious problem in routing for MWSNs. Rapidly changing networks may generate a sizable amount of duplicate data which wastes network resources and consumes node energy. This presents a distinct problem for those using MWSNs for managing and processing data. Therefore, the aggregation of data is also important in this context.

**1.4. Applications**

The applications of this protocol include animal monitoring (great duck island), environmental monitoring (volcanic monitoring), underwater sensor networks, smart spaces (car parking), animal networks (deer net), structural monitoring (bridge) and home automation.

## 1.5. Example

In a typical WSN application sensors are deployed to monitor a location or region. In some applications it is possible to select the sites where sensors can be placed while in hostile environments it is better to scatter or air drop expecting that it covers large area which is to be monitored. The best example for hostile environment is agriculture field where 200 acres of land needs to be examined in different aspects like temperature, humidity etc.

## 1.6. Proposed Approach

The subsequent chapters present and evaluate a prospective solution for a subset of these problems. A new hybrid algorithm is proposed that incorporates both distributed and centralized algorithms for selection of CH. The proposed approach is different from existing hybrid clustering schemes in that it will select CHs for the first and second rounds using centralized selection. For the first and second rounds CH selection will be based solely on node location. In subsequent rounds, remaining energy levels will be considered. Additionally, the network is divided into inner and outer zones. In the inner zone, data will be sent from the node to the CH to the BS; however, in the outer zone data is relayed via a Mobile Data Collector (MDC). The use of the MDC could increase the energy lifetime of the network.

# 2. LITERATURE REVIEW

Motivated by the challenges and the potential applications, academia and industry have studied routing and data collection methods for WSNs. WSN sensors are used to measure ambient conditions in the environment surrounding the sensor and to transform these measurements into signals, which when processed reveal characteristics of the phenomena located in the area around the sensors. A large number of sensors can be networked for applications that require unattended operations, hence producing a WSN. WSNs typically contain hundreds or thousands of sensor nodes and could communicate either among each other or directly to the base station (BS). A greater number of sensors allows for sensing over larger geographical regions and sensing with greater accuracy for a given area.

For their network architecture, WSNs typically use multi-hop routing approaches. Under these traditional approaches, the collection of data consumes power due to extensive path-traversal loss when data is relayed from node to node using radio transmission. A self-configuring network of small sensor nodes is deployed. These nodes communicate among themselves using radio signals. For science, they are deployed in an area to monitor phenomena of interest and aid the investigator’s understanding of biology, processes in the physical world, and similar. Numerous uses of sensornets beyond scientific purposes also exist, ranging from military to commercial to government and law enforcement uses.

## 2.1. Routing Protocols

WSN routing protocols can be divided into those that provide static and dynamic routing. Static routing is a process where the network statically configures a router to send traffic for specific destinations in preconfigured directions. A static routing table is maintained by the BS. Static routing provides a granular level of control over routing; however, it becomes impractical on large networks. Dynamic routing is useful for larger networks. For dynamic routing, a dynamic routing table is created, maintained, and updated by a routing protocol running on the router. Under this approach, data will use different routes at different time intervals. Routers share dynamic routing information with each other; therefore, if there are any failures in the network, data can be dynamically routed to the specified destination.

Multi-hop communications can be used for routing data. The use of these communication protocols is desirable, as they conserve the energy of the sensor nodes, as described in section 1. These protocols can be divided into several categories, which include location-based, flat, data-centric, mobility-based, quality-of-service-based, and hierarchal routing implementations [21]. This categorization is depicted in Figure 2-1. A number of clustering techniques [6], [22]–[28] have also been previously proposed for use in WSN routing.

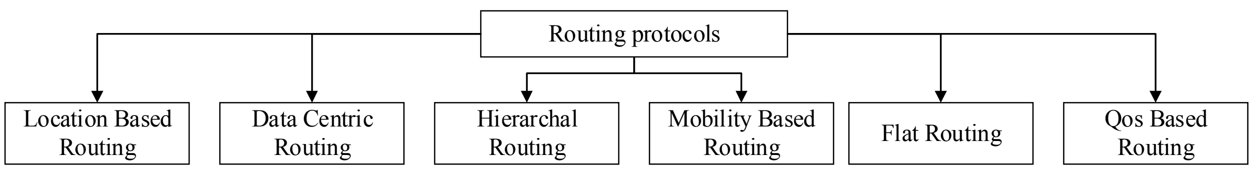


Figure 2-1. Routing protocols

### 2.1.1. Location-Based Routing

Location based routing [21] uses node location information to choose a path for the data to be routed via sensor nodes. To perform this technique, the network is divided into quadrants. Each node knows its position relative to a shared coordinate system. In flat routing, communication between nodes takes place in an ad-hoc fashion, using multi-hop routing. The data is sent to the centralized BS using an optimal path algorithm. In hierarchal routing, communication between most nodes does not take place directly. Instead, the network is divided into clusters. Each cluster is assigned a cluster head (CH). The CH is responsible for the data transmission between member nodes and the base station. As the CH can be far away from the

BS, it also uses multi-hop communications for transmitting data. Using these routing techniques, hierarchical clustering provides an efficient way to conserve energy.

### 2.1.2. Data-Centric Routing

Data-centric routing [21] differs from traditional routing in that, in traditional routing, sensor nodes send their data directly to the BS independent of other sensor nodes. However, data centric routing sends data to the BS using intermediate sensor nodes and data aggregation takes place, conserving the energy of sensor nodes.

### 2.1.3. Hierarchical Routing

Hierarchical routing is one solution to solve the scalability problem in Mobile adhoc networks. A typical way to build hierarchical routing is to group nodes into clusters, thus decreasing routing space and improving network performance [29]. A leader or a CH is selected for each group to coordinate the activities within the cluster and to communicate with nodes outside the cluster.

### 2.1.4. Mobility-Based Routing

Mobility-based routing can take one of two approaches. In the first, a mobile sink or BS collects data by moving among the network. Second, mobile sensor nodes may act as mobile sink nodes. These mobile nodes act as intermediate nodes, collecting data from the source and transmitting it to the destination. Using mobile nodes for a network has been shown to increase overall lifetime of the network [28].

### 2.1.5. Flat Routing

In flat routing, nodes are assigned equal roles or functionality. Information transmission is performed using a multi-hop flooding techniques [30]. Flat routing techniques are appropriate for use when node density is sparse.

### 2.1.6. Quality-of-Service Based Routing

Quality-of-service based routing considers the quality of service (i.e., meeting application needs, in terms of key metrics) that is provided, when making routing decisions. It can provide controlled levels of fault tolerance, security, reliability, delay, and speed,[31] in addition to managing performance against other metrics.

## 2.2. Discussion of Specific Techniques

There are many routing and data collection techniques available. Only the prospective routing techniques specific to this research are discussed. The first is the low energy adaptive clustering hierarchy (LEACH) approach, which was proposed by Zelman [22].The main idea of this clustering algorithm is to load balance the energy of the network. It uses a distributed algorithm for the selection of the CH. This means that the member nodes autonomously select the CH for each subsequent round, after the initial rounds. For data transmission, it uses the time division multiple access-based media access control protocol. To remove redundant data, the CH performs data fusion, a process of integrating multiple data sources and removing the redundant data reducing the amount of data that must be transmitted. The algorithm executes in two phases. The first is the setup phase.  During this phase, cluster formation takes place. The CH is elected by comparing a randomly generated number to a probability-based threshold value. If the node's value is greater than the threshold, then it is not elected as the CH and joins the nearest cluster. The first node with a value below the threshold becomes the CH.  The second phase is the steady phase. The data transmission takes place during this phase. Carrier-sense multiple access (CSMA) scheduling is used for the data transmission between member nodes and the CH and for transmissions from the CH to the BS. However, the CSMA protocol is problematic, as it does not consider the residual energy of nodes. For example, a node which has a low level of energy remaining could potentially be elected as the CH. Additionally, this approach is not suitable for large networks, as it only uses single-hop communication.  LEACH-C[32] is the centralized version of LEACH. It differs from the LEACH approach in the selection of the CHs.  It utilizes the BS for cluster formation (as discussed in [23]). The remaining functionality of LEACH-C is substantially similar to LEACH.

The power-efficient gathering in sensor information system (PEGASIS) approach was proposed by Lindsey, et al. [33]. It is a chain-based algorithm, which was derived from the LEACH protocol. The main idea of this protocol is that the farthest node is connected to a node that is nearer to the BS using a chain. Data is fused in each node reducing the amount of redundant data that is sent to the next node, which is responsible for transmitting the processed data to the BS. The performance is better than LEACH, as it eliminates the formation of dynamic clusters. But a problem still exists in this protocol. It is not feasible to use this approach in larger networks because it requires a priori topological knowledge of the network. The other issue is if one node dies in the network then there is a break in the chain and data from beyond this point cannot be transmitted.

The threshold sensitive energy efficient sensor network protocol (TEEN) was proposed by Manjeshwarand et al. [34] It is an event driven approach, which means that data is transmitted to the BS only when an event occurs. It uses two thresholds: a hard threshold and a soft threshold. When a member node achieves the hard threshold, it acts as a transmitter and sends its data to the CH. But, when a member node achieves the soft threshold the data is not sent to the CH. This protocol is good to use when there is a time concern; however, it is not feasible for use when the data has to be sent periodically. The other flaw with this protocol is it is not known when a node dies as data is only sent when the hard threshold is achieved, so the CH could be waiting for the data indefinitely.

The adaptive threshold sensitive energy efficient sensor network (APTEEN) protocol was proposed by Manjeshwarand et al. [35]. APTEEN is an improvement over LEACH and TEEN. This algorithm uses the event driven approach of the TEEN protocol and the periodic approach of the LEACH protocol. The CH is elected by the BS using a centralized algorithm. The CH broadcasts four parameters in a packet to the member nodes: attributes, schedules, thresholds, and count time. Based on the packet information nodes sense the environment and send data only if it satisfies the hard threshold. Nodes that have a soft threshold do not transmit the data for a specific time. The CH will force the node to send the data after a specific time period. This algorithm is flexible as it is possible to adjust the parameters. The problem with this protocol is it increases the complexity of the algorithm, which is problematic on computationally limited sensor nodes.

The Two-Level LEACH (TL-LEACH) protocol [36] is an extension of LEACH protocol. The main idea of this algorithm is that it uses primary and secondary CHs for transmitting data to the BS. It uses a distributed algorithm for selection of CHs. In every round, two CHs are selected. Data is transmitted from member nodes to the secondary CH and sequentially from the secondary to primary CH. Then the primary CH sends the data to the BS for further processing. Data fusion can take place in both of the CHs (primary & secondary). CH selection is the same as in the LEACH protocol. The advantage of using this algorithm is that it reduces the number of nodes participating in data transmission to the BS, in turn reducing network traffic. This approach is not feasible if the CH is far away from the BS.

The Base-Station Controlled Dynamic Clustering Protocol (BCDCP) was proposed by S. Muruganathan, et al. [37]. In this algorithm, the CH forms a minimal spanning tree for routing the data to the BS. It uses an iterative cluster splitting algorithm for CH selection. The network is equally clustered, which means that every cluster has the same number of nodes. It utilizes multi-hop communications for transmitting the data. This protocol shows better performance when compared with LEACH and LEACH-C. However, it is not suitable for larger networks due to network topology constraints. The iterative cluster splitting algorithm conserves energy while forming clusters for a network.

The Energy Efficient Hierarchical Clustering (EEHC) [38] protocol, implements a randomized and clustering algorithm. It is divided into two phases: initial and extended. In the initial phase, each sensor node announces itself as a potential CH with probability p to neighboring nodes within its communication range. All the other nodes within the communication range of the CH receives this advertisement by direct or forwarded communication. When a node receives an advertisement, it joins the closest cluster. If a node does not receive an advertisement within a specific interval of time then it becomes a forced CH (as it knows that it is not within k hops of a volunteer CH). This first stage is called a single level clustering scheme. The extended stage, called a multi-level clustering scheme, is used to build h levels of hierarchy. This type of algorithm guarantees h-hop connectivity between the BS and CHs. The consumption of energy is reduced when the CH is far away from the BS because CHs don't have to transmit directly to the BS. But CHs close to the BS must act as a relay to other CHs, which is a disadvantage.

The Cluster Head Election using Fuzzy logic (CHEF) protocol was proposed by Kim et al. [39] and provides an improvement over the LEACH protocol. In this algorithm, a CH is elected based on two parameters: the residual energy and its distance, using fuzzy logic. In each round, a random number is generated within the probability range of 0 to 1. If the random number is less than the nodes energy, the chance of the node becoming a CH is calculated by fuzzy logic rules and an advertisement of candidacy message takes place. This message means that the node may act as a candidate to become a CH with the given chance value. The node broadcasts its candidate message to other nodes and compares its own chance value with the other node's chance value. If its chance value is greater than the other nodes, it becomes a CH and sends notice to the other nodes. This protocol ensures that there is only one CH elected within a radius R.

In Sector-chain based clustering routing protocol for energy efficiency in heterogeneous wireless sensor network (SCBC) [40], the network is divided into sectors. This reduces the consumption of energy by constructing a data transmission chain for each cluster with the CH or secondary cluster head (SCH) as the chain leader. A SCH is used when it has a high level of energy remaining and provides the shortest distance path between transmitting nodes and the BS. SCBC performance is enhanced due to the consideration of the lengths of rounds and a protocol that ensures that CHs and SCHs will still have sufficient power to operate in the next round. The use of SCBC enhances energy efficiency to prolong the WSN's lifetime.

### 2.3. Mobile Element Sensornets

Several WSN architectures based on mobile elements (MEs) have been proposed [12]–[15]. The main elements of WSN-MEs are [41]:

1. Sensor nodes are the source of information.
2. BSs (also called sinks) are the destination for the information.
3. Intermediate nodes act as data collectors or mobile gateways.

M-LEACH is a modified version of LEACH that incorporates a MDC. The MDC itself is an autonomous robotic sensor network node. The MDC physically moves around the CHs to collect data and forward the collected information to the BS. This, thus, is a three-tier architecture incorporating a multi-hop, store, and forward communications approach [12].

Another similar approach has been introduced. Under this approach, one or more mobile base stations move throughout the network of senor nodes and collect data from the sensor nodes using short range wireless communications. Current research [12]–[15] in this area has been focused on how to route the data to the BS using mobility-enhanced network members, so that cost, latency, and energy consumption are reduced.

**2.4. Mobile Element Path Generation**

One method for path generation is to predetermine the optimal method for data collection; however, this requires that all service requests and locations are known a priori. The label covering problem, based on the well-known travelling salesman problem, has been presented [42]. In this problem, the tour is completed only when all sensor nodes have been visited. Another algorithm was proposed [43] which uses a spanning tree approach for the network and a Hamiltonian circuit is generated to control the physical movement of a mobile base station (MBS). A routing tree [44] is created at each sojourn (temporary stop) location where the MBS waits for periods of time. When the MBS moves to other locations, the tree has to be reconstructed for the new position. This results in energy depletion of nodes in the network. In order to make this viable, the MBS must be able to be used at a location for at least T time units, where acceptable values of T can be determined as a function of the cost of tree reconstruction. Using multiple mobile elements presents even more complication. This has been investigated and work on this topic has been presented [45], [46].

The other method for determining the path of the mobile element is online scheduling. Under this approach, new requests are sent to the mobile element while it is operating. A variety of approaches can be used to determine what order to service queued requests. Use of the first come first serve (FCFS) approach has been studied [44]. Alternately, a nearest-job-next strategy and an extended version of the nearest-job-next strategy in combination with service requests have been considered [47].

Cluster-based designs have also been identified as an energy efficient way of performing data aggregation [12], [16], [48]. Energy consumption is reduced for mobile sensor nodes by using a distributed clustering algorithm. There are two main steps in this clustering algorithm, the first step is CH election. The second step is cluster formation. When using a mobile element, the technique used to select a CH must be mobility aware. An algorithm is proposed [16][49] that is responsive to this. It is based on the following principles:

1. Every cluster should have one CH.
2. The CHs operate in the same manner across all the clusters.
3. Cluster size of the generated clusters should be the same.

It has been discovered that incorporation of mobile nodes into a WSN enhances the network lifetime and makes it suitable for large scale applications [50].

**2.5. Voronoi Diagrams**

In literature, there are numerous space segment strategies [51]. Voronoi diagram is one kind of partition method, which divides the space into various sub-regions. Now-a-days Voronoi diagrams are used in various applications, for example, GIS, meteorology, and data framework. Many researchers use Voronoi diagram to study coverage issue in WSN.

WSN algorithms and protocols must possess self-organizing abilities because sensor node lifetime depends on lifetime of the battery. Coverage is interpreted as how a sensor network will monitor a field of interest. There are numerous coverage problems including k-coverage, area coverage, and m-connected k-coverage problems [49]. An area coverage problem is to find a minimum number of sensor nodes to work in a given physical point and make sure that the area is monitored by at least an active (working) sensor. If a given point is monitored by at least k sensor nodes, then it is called as k-coverage problem where k is coverage degree. Voronoi diagram solves these coverage problems allowing to distribute the task by portioning the network into sub-regions.

# 3. SYSTEM DESCRIPTION

This section discusses the functional capacity of the sensor networks and factors influencing the design of the WSN. The factors include: fault tolerance, scalability, and cost. The basic hardware components required for a sensor are presented. As discussed in section 1, power consumption is considered as an important factor for a sensor network. Henceforth, power consumption for a sensor node is discussed in detail. The data transmission takes place in the form of packets between member nodes and the BS. Thus, packet formation of the sector table and the control packet format are explained. The N-tier hierarchy of the network topology is discussed below in detail.

## 3.1. Functional Capacity of Wireless Sensor Networks

The sensor network sends data to the BS periodically. Thus, the BS must periodically evaluate the received sensor data. The rate at which this evaluation can be completed is dependent upon how frequently the data from each of the nodes is collected. An example collection scheme is the round robin approach, in which each sensor reports data directly to the BS one after the other. In this example, the BS receives and can process data for one node per n rounds, which achieves a rate of 1/n.

## 3.2. Factors Influencing the Design of Wireless Sensor Networks

A WSN design is influenced by many factors like scalability, fault tolerance, the network topology applicable to the WSN's application, hardware constraints, power, and cost [31]. These factors provide guidelines to design an algorithm or protocol. Each is now considered.

### 3.2.1. Fault Tolerance

Due to physical damage, loss of power or environmental interference, sensors nodes may be available temporarily or permanently. Node failure, thus, should not affect the whole network.

Fault tolerance is the capacity to maintain sensor network functionalities with limited or no impact due to the failure of a sensor node [52]–[54]. A reliability model for a sensor node is proposed [52] using the Poisson distribution for not having a failure within a given interval (0,t).

$$R_k(t) = \exp(-\lambda_k t) \tag{1}$$

here $R_k$ is the reliability and $\lambda_k$ and t are the sensor node failure rate and period of time, respectively.

For example, if sensor nodes are deployed in battlefield surveillance the fault tolerance has to be high because nodes are prone to failure or could be destroyed by the enemy. In contrast, sensors used for home automation are not as easily damaged, necessitating a lower level of fault tolerance. Thus, the importance of fault tolerance depends on the type of WSN application.

**3.2.2. Scalability**

Depending on the application, the density of the sensor nodes deployed can range from a few sensor nodes to a few thousand sensor nodes in a location, which can be less than 10m in diameter [55]. Protocols should be able to work with the density of nodes deployed in a region. Density can be formulated as [56]:

$$\mu(R) = (N\pi R2)/A \tag{2}$$

here N is the number of deployed nodes in region A, R is the range of radio transmission, and $\mu(R)$ is the nodes deployed within the transmission range

For example, a vehicular tracking application requires 10 sensor nodes per region, which can be as high as 20 sensor nodes/m3 [57]. An office may contain 30 appliances with sensor nodes [58], but this number may grow over time. For monitoring humans, 25 to 100 nodes per region may be required [59].

### 3.2.3. Cost

A WSN consists of a number of sensor nodes, therefore it is important to consider each node and thus the aggregate cost of the network. For example, Bluetooth sensors are available starting at $10 USD [60] , while Pico Node is less than $1 [61]. Thus, it is feasible for the cost of a sensor node to be only $1. Bluetooth radio is a low-cost device, which is 10 times more than a basic sensor node. As a result, the cost of a sensor node with the desired functionalities is a challenging process.

### 3.2.4. Sensor Network Topology

A challenging task for the sensor network is topology maintenance, as sensor nodes are prone to frequent failure. For some applications, hundreds of nodes will be deployed within 10 feet of each other [62] in a random fashion. Therefore, it is necessary to handle the topology of the network.

## 3.3. Hardware Constraints

A sensor node is comprised of four components [31] shown in Figure 3-1. These are:

### 3.3.1. Sensing Unit

The sensing unit is subdivided into two units. Sensors and analog to digital converters (ADCs). The sensors sense the environment, which produces analog or digital signals. Analog signals are converted into digital signals using the ADC. The data is then sent to the processor.

### 3.3.2. Processor

The processor consists of a processing unit and a storage unit. This subsystem takes care of preparing the sensor node’s data for transmission to other nodes or to the BS.

### 3.3.3. Transceiver

Many sensor nodes utilize the ISM band, which gives free radio and spectrum access globally. However, other choices for wireless transmission exist, including optical communications (laser), infrared communications, and radio frequency (RF) communications. The transceiver connects a node to other nodes.

### 3.3.4. Power Unit

The power unit is a critical component of sensor nodes. Power units may have a built in power generation capability such as solar cells.

In addition to these hardware components, nodes may also have GPS, a power generator, external memory and a mobilizer. Each is now briefly discussed.

### 3.3.5. GPS

Global Positioning System Units provide accurate location coordinates. Most routing algorithms regulate the exact location of the node to be known with a high accuracy.

### 3.3.6. Power Generator

The power unit can also have a power generation capability to drive the sensor nodes and recharge their batteries.

### 3.3.7. Mobility

The ability to move is required when a sensor node needs to carry out data collection tasks in multiple locations.

### 3.3.8. External Memory

If there is a lot of data to keep in the memory it is possible, with some nodes, to connect an external memory unit to the processor.

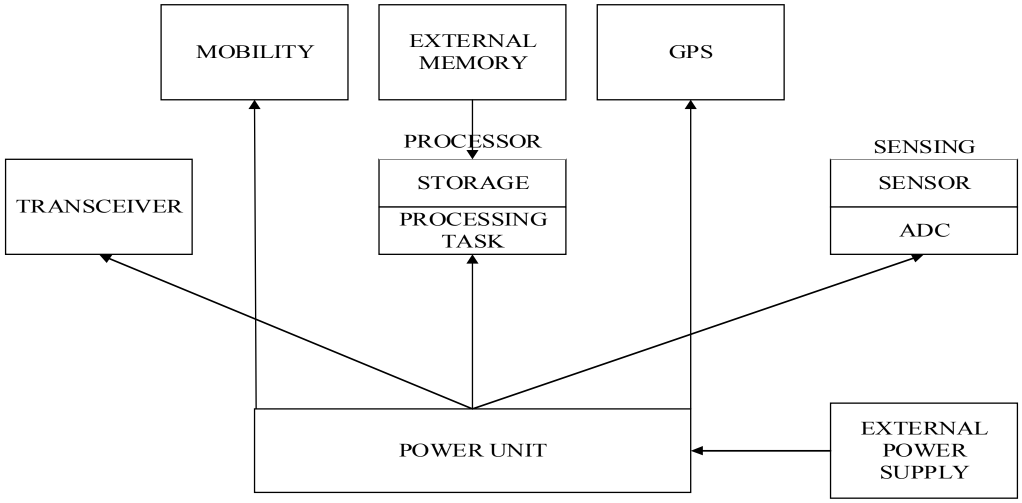


Figure 3-1. Components of a sensor node

Despite what must be included, sensor nodes must typically be small. In some cases, these components need to fit into a match box sized module [62]. The size could be reduced to less than a cubic centimeter [63] when the node needs to be suspended in air. Other constraints include [64]:

1. Power consumption should be low.
2. The node should be able to work in a high volumetric density area.
3. The cost should be low, and the node should be disposable.
4. The node should be independent and able to function while unattended.
5. Be versatile and able to function across all produced environmental conditions.

Sensor network lifetime depends on the node's power resources. Due to size constraints, it is typically not possible to integrate much power storage capacity into a sensor node. For example, the energy stored in a smart dust mote unit is 1 J [63]. For wireless integrated network sensors the current supply average can be less than 30 μA to still operate efficiently [65]. With wireless integrated network sensors, it is possible to extend the sensor network lifetime with energy generation [60] augmentation or replacing the lithium ion battery with solar cells.

Despite the energy limitations, higher levels of computational power are being made accessible in sensor nodes. For example, the processing and storage capability of a smart dust mote is 512 byte RAM, 512 byte EEPROM, and a 4 MHertz Atmel AVR 8535-micro controller with 8KB flash memory [66]. The Tiny OS occupies 3500 bytes of space and leaves 4500 bytes of space for use.

For some applications sensor nodes are deployed in a random fashion and it is required to know the exact position of the sensor node in the field. For some approaches to make routing decisions, GPS is included. The assumption is that the GPS unit has at least 5m of accuracy [67]. It is agreed that sensor nodes with GPS are not feasible for wireless sensor networks [68].

### 3.4. Environment

Sensor nodes will be deployed in numerous areas, including some which are easily accessible and others which are remote. Some of the applications of WSNs include:

1. battle field surveillance;
2. underwater data collection;
3. measurements on the surface of a volcano when on eruption takes place;
4. home automation;
5. attached to animals to collect data about the animal habits;
6. data collection or monitoring inside a machinery.

The above list gives an overall idea of how sensor networks can be used in the real world. They must work under high pressure, extreme noise, extreme heat, and other adverse environmental conditions.

### 3.5. Power Consumption

In many cases a WSN has a very limited power source, solutions less than 0.5 Ah, at 1.2 Volt. There are some applications where it is impossible to replace the battery of a sensor node. So, the lifetime of a sensor node depends on the initial power resources and generation capabilities, if applicable, of a sensor node. Therefore, it is crucial to conserve and manage the power of each sensor node.

In ad hoc and mobile networks the consumption of power is not commonly a primary consideration, but it is considered as an important factor in designing environment sensing and other WSNs. The sensor node senses the environment and transmits the data to the BS for further processing. Hence the consumption of power in a sensor node takes place in three areas.

#### 3.5.1. Environment Sensing

As explained above the sensing power is application dependent. Constant monitoring of the sensing field consumes more energy than sporadic sensing.

#### 3.5.2. Communication

Communication requires the most energy of any task of the sensor node. This involves reception and transmission of data. It is important that the startup of the sensor node is taken into consideration. However, in many cases startup time is almost negligible, it is only a few micro seconds. A formulation for the radio power consumption (Pc) is presented [57] as:

$$P_c = N_T [ P_T (T_{on} + T_{St}) + P_{out} ( T_{on} ) ] + N_R [ P_R ( R_{on} + R_{St} ) ] \quad (3)$$

Where $P_{out}$ is transmitter output, $R_{on}$ is the on time of the receiver, $T_{on}$ is the on time of the transmitter, $P_T$ is the consumed power by the transmitter, $P_R$ is the consumed power by the receiver, $T_{St}$ is the startup time of the transmitter, $R_{St}$ is the startup time of the receiver, $N_T$ is the number of transmitter switches on per unit time, and $N_R$ is the number of receiver switches on per unit time. Modern radio transceiver $P_T/R$ values are around 20 dbm and transmitter output will be close to 0 dbm.

### 3.5.3. Data Processing

The cost of data processing is less than the cost of the data communication. The disparity is effectively explained [63]. In a multi hop sensor network the data processing should be done in the local node which minimizes power consumption. The consumption of power in data processing is given as:

$$P = ACV^2f + VI_{leak} \quad (4)$$

Where V is the swing of the voltage, f is the switching frequency, A is the fraction of gates switching actively, and C is switching capacitance. The second term in the above equation demonstrates leakage currents due to loss of power [69].

## 3.6. Topology of Network

To enhance the overall network lifetime and throughput an n-tier hierarchy of nodes is proposed. This is shown in Figure 3-2. The hierarchy of nodes depends on the network coverage area. First, the network is divided into inner and outer zones. The inner zone includes two levels and the outer zone includes three levels. In the proposed protocol nodes can be categorized into different roles. The description is as follows.

### 3.6.1. Base Station

The top-level hierarchy of nodes is the base station. This is the central manager node. It is responsible for processing data and initiating requests.

### 3.6.2. Mobile Node (MN)

Mobile nodes act as intermediate nodes for data transmission between CH and the BS. It is the second level hierarchy of nodes in the proposed protocol. Each sector is assigned a MN.

Thus, the MN is the sector manager. It manages the operations taking place in the sector, like data aggregation, and initiates sector requests.

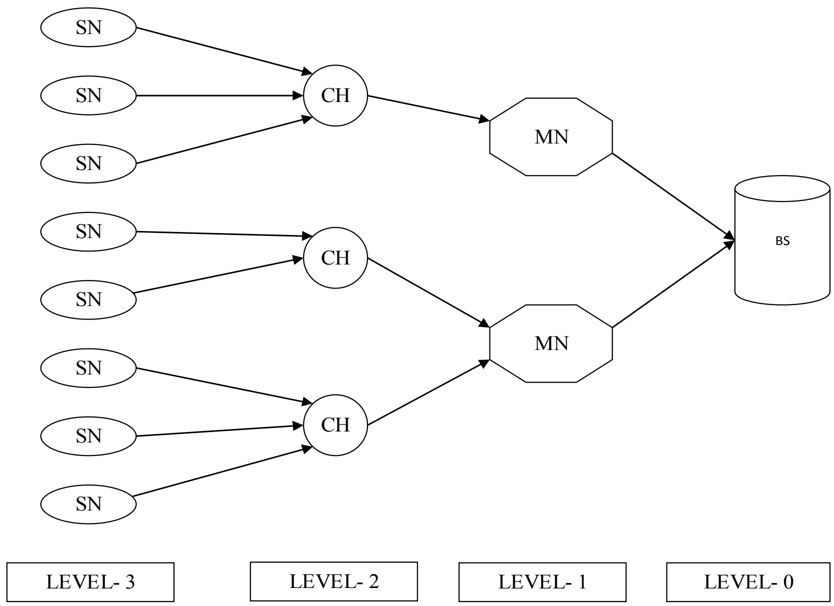


Figure 3-2. N-tier hierarchy of network

### 3.6.3. Cluster Head

Cluster heads act as local leaders of the sensor network. They reside at the third level of the hierarchy of the proposed protocol. Each CH has a group of sensor nodes and acts as an aggregator to transmit data between the sensor nodes and the mobile nodes. The CHs are responsible for communicating and aggregating data.

### 3.6.4. Sensor Node (SN)

The sensor nodes are independent of each other. Their main role is to sense the environment and send the associated data to the CH. The sensor nodes are the lowest level of the hierarchy.

## 3.7. Packet Formation

To understand the packet forwarding process consider the sector table shown in Figure 3-3. The Sector_ID field is the primary key value in this table. The outer zone has many sectors and each sector has x and y coordinates. Each sector has a mobile node, which has an ID called a Mobile ID. This ID is used to identify the packet to the BS and calculate where to send data.

| Sector_ID | Sector X location | Sector Y location | Mobile node ID |
|---|---|---|---|

Figure 3-3. Sector table

The data packet, presented in Figure 3-4, consists of 32 bits. The SRC ID denotes where the data originated from in the network, and the DEST ID field stores the address of the intended recipient. The packet type field indicates the data format/content of the packet. The packet ID differentiates it from similar packets. The Mobile ID field denotes which mobile node the data is being transmitted through/from. The remaining bits are filled with padding for security. A Sector_ID value is also included, which comes from the sector table.

| 8 | 16 | | 8 |
|---|---|---|---|
| Packet Type | Packet ID | | Sector_ID |
| SRC ID | Mobile ID | Padding | DEST ID |

Figure 3-4. Control packet format

# 4. NETWORK MODEL AND PROPOSED ALGORITHM(ZHCD)

## 4.1. Network Model

This section describes the network model that is used for the ZHCD technique. This network model is shown in Figure 4-1. It consists of member nodes, CHs, a BS, and an MDC. The network is partitioned into two zones. Each zone consists of clusters having one CH (yellow color) that collects the data from multiple member nodes (blue color). Each sector is assigned an MDC (red color) for data collection from CHs. The inner zone sends the data directly from the CH to the BS. In the outer zone, data is sent from the CH to the BS via an intermediate node.

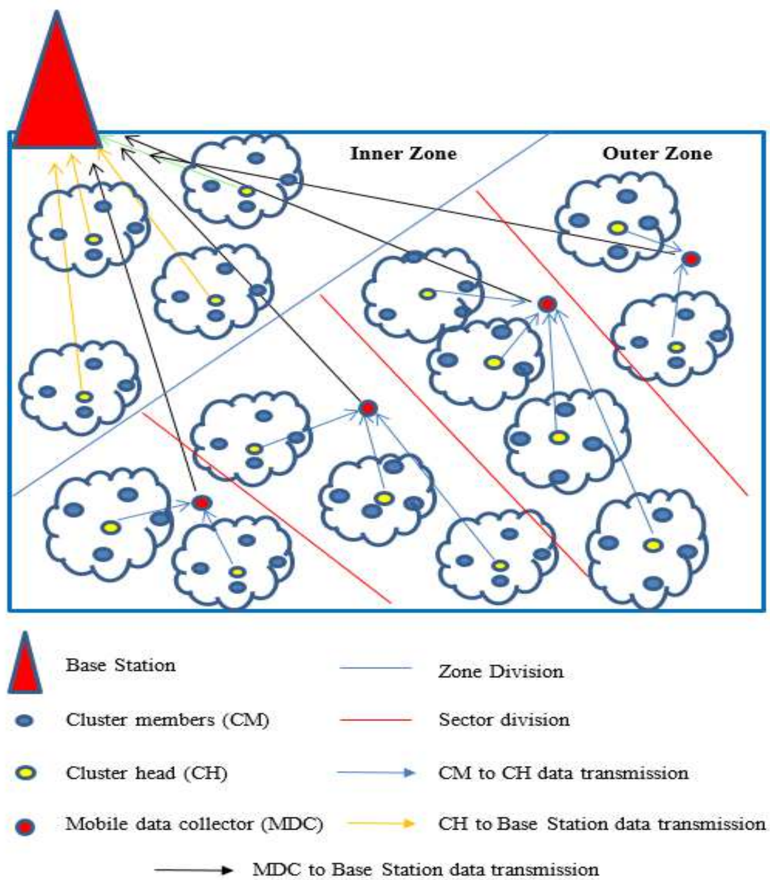


Figure 4-1. Network model [1]

### 4.2. Assumptions of Network

Several assumptions are relied upon in the presentation and analysis of the proposed technique, herein. Many of these are configuration parameters that can be arrived at heuristically or optimized using multiple optimization techniques.

First, when n sensor nodes (SNs) are deployed in a particular area, they are divided into inner and outer zones. The inner zone is comprised of 10% of the area and the remaining 90% of the area is the outer zone. The outer zone is further divided into sectors. Each sector contains 25% of the CHs present in the outer zone. The total number of CHs is 20% of n.

The CHs in the inner zone are nearby the BS and directly send data to it without help from intermediate nodes. While, the clusters in the outer zone are divided into sectors. Each sector is assigned an MDC node for facilitating data transmission to the BS.

### 4.3. Example of Network Assumptions

An example of 200 sensor nodes deployed in an area of 100 units x 100 units is now considered. As per the foregoing, the inner zone is comprised of 10% of the area (or 1000 units) and the remaining 90% (9000 units) is classified as outer zone area. Among the 40 CHs (20% of the SNs), it is assumed that 10 are in the inner zone. The remaining 30 CHs in the outer zone are divided into 8 sectors. Each sector is assigned an MDC.

### 4.4. Overview of Algorithm

This section represents the pseudocode of the ZHCD algorithm. First, area of the network in which nodes are to be deployed is divided into inner and outer zones. The initial energy for all the nodes is equal. The outer zone is further divided into sectors based on the clusters. The nodes (n) send their location to the BS. The BS divides the nodes into clusters. It selects 2 CHs and broadcasts (BC) to the network. The nodes n (pz) checks with the BC ID to become a CH. If its true then that CH_n(pz) is fixed for one complete round. The advertisement (ADV) is BC to member nodes. The member nodes send association request and join the cluster. In outer zone each sector is assigned a mobile data collector (MDC). From third round the nodes compute the energy efficiency (Eeff(nz)) and it compares with other nodes and checks to become a CH or member node. . It its true then that CH_n(nz) is fixed for one complete round. The advertisement (ADV) is BC to member nodes. The member nodes send association request and join the cluster. In outer zone each sector is assigned a mobile data collector (MDC). The inner and outer zone is called for the data transmission from member nodes to base station.The function inner zone is if the node is given a time slot then if it is having the sensed data it sends to cluster head and to the BS respectively else no data is sent. If that node is not given the time slot it does not have any communication involved in it. In function outer zone is if the node is given a time slot then if it is having the sensed data it sends to cluster head and to the BS via MDC respectively else no data is sent. If that node is not given the time slot it does not have any communication involved in it.

$E_{init}$ – initial energy of the node

$E_0$- Default energy of each node

$E_{eff}$–energy efficiency of nodes

**4.4.1. Setup of Network**

1. Specify the area of network (a)
2. Depending on the area it is divided into inner zone and outer zone
3. Specify the nodes in the network area (n); //n=100
4. For (p=1 to n)
5. $E_{init}$(p) = E0
6. End For
7. Outer zone is further divided into sectors

**4.4.2. Network Initialization Phase**

1. Do (for first and second rounds)
2. Each node broadcast its location and E0 to base station

```
3. Base station selects 2 cluster heads and broadcast to
    network
4. For p=1…n
5. If (node_p = Broadcasted ID) then
6. node_p is a cluster head
7. Else
8. node_p is a member node
9. End If
10.  If (node_p is a cluster head) then
11.    node_p = fixed for one complete round broadcast
       advertisement message for member nodes member nodes send
       association request
12.    Join associated cluster
13.  End If
14.  End for
15.  Each outer zone sector has a mobile data collector
     assigned to it
16.  Perform inner zone ()
17.  Perform outer zone ()
18.End Do
19.Do (for third round onwards)
20.    compute E_eff of the node
21.    Each node broadcast its energy to other nodes and
       compares with it.
22.     For p=1…n
23.     If (node_p = Broadcasted ID) then
24.         node_p is a cluster head
25.     Else
26.         node_p is a member node
27.     End If
28.     If (node_p is a cluster head) then
29.         node_p = fixed for one round broadcast advertisement
            message for member nodes
30.         member nodes send association request
31.         Join associated cluster
32.     End If
33.     End for
34.    Each outer zone sector has a mobile data collector
       assigned to it
35.    Perform inner zone ()
36.    Perform outer zone ()
37.END DO
```

#### 4.4.3. Data Transmission Phase

##### 4.4.3.1. Inner Zone

```
1. For p=1..n
2. If(node_p= time slot)
3. If ( node_p having sensed value) then
4. Receive Data packet from member nodes
5. Aggregate data packet in cluster head
6. Transmission from cluster head to base station
7. Else
8. No data is sent
9. End If
10.Else
11.  No communication mode
12.End If
13.End for
```

##### 4.4.3.2. Outer Zone

```
1. For p=1..n
2. If (node_p = time slot)
3. If (node_p having sensed value) then
4. Receive Data packet from member nodes
5. Aggregate data packet in cluster head
6. Transmission from cluster head to mobile data collector
7. Aggregate data packet in mobile data collector
8. Transmission from mobile data collector to base station
9. Else
10.    No data is sent
11.  End if
12.Else
13.  No communication mode
14.End if
15.End for
```

### 4.5. Proposed Algorithm

The proposed ZHCD algorithm incorporates two phases: the setup phase and the steady phase.

#### 4.5.1. Setup Phase

The operation of the algorithm is now described in more detail.  It is comprised of 10 steps. The setup phase is presented in Figure 4-2.

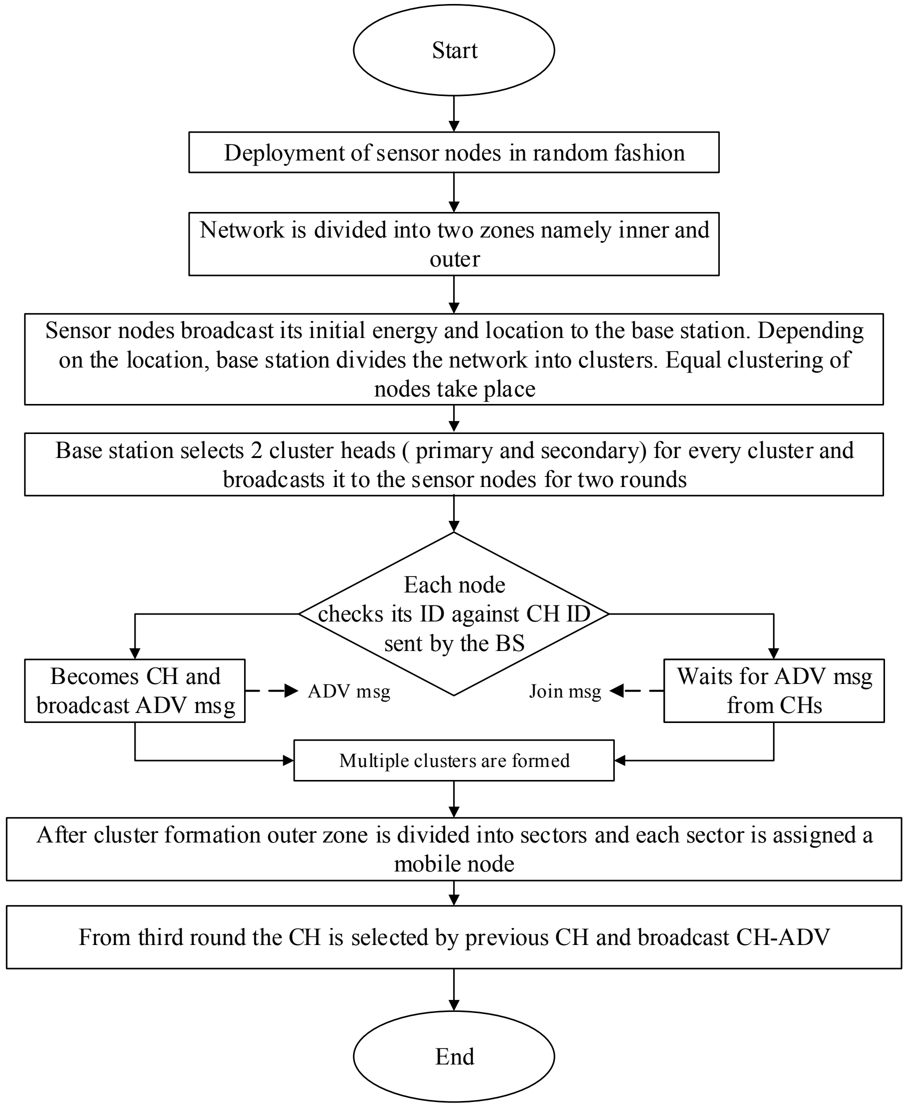


Figure 4-2. Cluster formation of sensor nodes [1]

Step 1: First, the sensor nodes are deployed in a random fashion.

Step 2: The BS divides the network area into the inner zone and the outer zone [70].

Step 3: The BS decides the number of cluster groups and divides the outer zone into sectors. Each sector is assigned an MDC.

Step 4: All sensor nodes, which have the same initial energy, send their location coordinates to the BS. The BS divides the network into clusters with equal numbers of nodes [71].

Step 5: The BS selects and broadcasts two cluster heads (primary & secondary) for each cluster group. It describes these units to the members using the coordinate points of the sensor node. The CH selection is made such that it is projected to optimize (minimize) the energy required to communicate among the cluster members.

Step 6: Each SN checks the position information broadcasted by the BS to determine if it is a CH. If the node is a CH it broadcasts an advertisement message (ADVmsg) to other nodes. The collision sense multiple access with collision detection (CSMA-CD) MAC [72] protocol is used for forming clusters. Each CH forms a cluster group with the (equal) BS-determined number of nodes. The nodes, may receive an ADVmsg from multiple cluster heads. Each node decides which one of the cluster groups to join based on:

1. If a node receives an ADVmsg from multiple CHs, it will join the CH with the highest signal strength.
2. If a node has joined a CH and receives an ADVmsg from another CH with a higher signal strength level, then it will drop the existing connection and join the new CH with the higher signal strength.
3. If a node receives an ADVmsg from multiple CHs with the same signal strength, then it will join the cluster group with the lowest number of nodes.

Step 7: The first two rounds will have the primary and secondary CHs assigned by the BS. The BS deploys the MDC to each sector [12], to the known coordinate point for each CH. The MDC then calculates the midpoint of the coordinate points and positions itself there for receiving data from CHs.

Step 8: From the third round onwards, the round's CHs are selected by the previous CH and broadcast to all of the other nodes in the cluster.

Step 9: Upon receiving the new CH message, each node checks its identity (ID) and compares it to the received CH ID to determine if it is the new CH.

Step 10: If the node determines that it is the new CH, it then broadcasts an ADVmsg to the nearby sensor nodes and the mobile nodes. The criteria described in step 6 determines what nodes (or whether nodes) join the cluster.

### 4.5.2. Steady Phase

Once the clusters are formed for each round, the system moves into the steady phase. Each cluster head creates a Time Division Multiple Access (TDMA) schedule for the member nodes for their data transmission. The flowchart for data transmission is shown in Figure 4-3. In the proposed algorithm data transmission includes three different types of transmission:

1. Member nodes to the CH
2. CHs to the BS
3. CHs to the BS via the mobile (intermediate) node

The cluster members sends data to the CH using the TDMA schedule. The total available transmission time is divided into slots. Each member node is given a time slot for data transmission. The main advantage of TDMA is that the sensor node will be in sleep mode most of the time. It only needs to be active when it is required to perform sensing and transmission / receiving tasks.

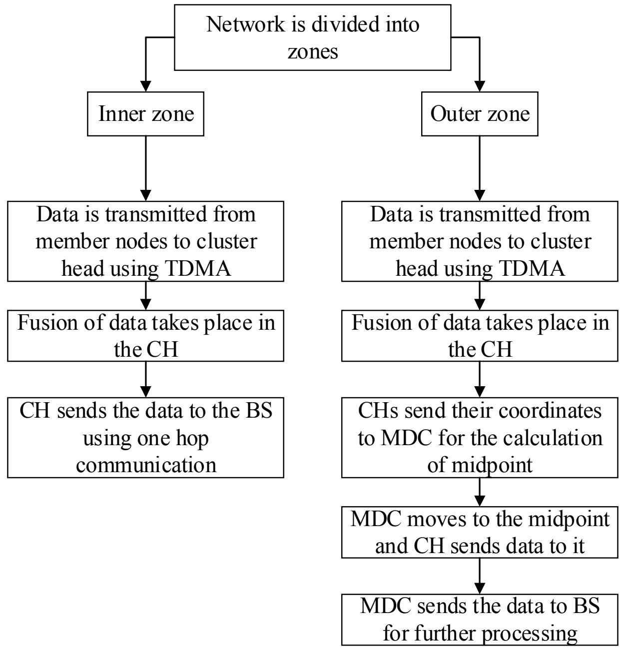


Figure 4-3. Data transmission from sensor nodes to base station [1]

Once data has been collected by the CH from all of the cluster members, it compares the data to eliminate any redundant data. This process conserves energy resources and minimizes the bandwidth required to transmit data. This increases the lifetime of the nodes and network. In some data-rich application, it may also result in more relevant information being transmitted (if insufficient time to transmit all data is not available) via the removal of the duplicate data.

As previously discussed, the network is divided into inner and outer zones. Each operates slightly differently.

In the inner zone, data is sent directly to the BS from the CHs without an intermediate node because of the close proximity. Direct transmission to the BS reduces the data delay time making the system more responsive. Only two hops of data communication occur: data is sent from the sensor to the CH to BS for processing.

In the outer zone, data is transmitted to the BS via the MDC, as the CHs are farther from base station. MDCs present at the midpoint of coordinates collect data from the CHs and send it to BS for further processing.

### 4.6. Estimation Metrics of Selection of CH

The CH for each cluster is selected by calculating the score of each (prospective CH) sensor node. In the first round of operations, sensor nodes broadcast their scores to the base station. From third round onwards, the scores are sent to previous CH. The relevant scores include residual energy and energy density values, link connection time and signal strength

#### 4.6.1. Residual Energy

The remaining energy after transmission of packet is called residual energy. After each transmission the residual energy decreases drastically, a critical issue in WSN.

The degree of residual energy (DRE) is calculated:

$$DRE = 1 - \left(\frac{residual\ energy}{initial\ energy}\right) \tag{5}$$

#### 4.6.2. Energy Density

It is the amount of energy stored in the sensor nodes. The degree of energy density (DED) is calculated [73]:

$$DED = 1 - \left(\frac{number\ of\ nodes\ in\ the\ cluster}{energy\ density\ of\ nodes}\right) \tag{6}$$

The energy density of the nodes (U) can be calculated:

$$U = \frac{1}{2}\varepsilon_0 E^2 \tag{7}$$

where ε0 is a constant (ε0 = 8.8541 x 10-12F/m) and E is energy in Joules.

#### 4.6.3. Link Connection Time

The time taken by the sensor node to communicate with other sensor nodes (i.e., the signal latency).

#### 4.6.4. Signal Strength

The signal strength is measured in terms of hardware specific parameters.

### 4.7. Calculation of Midpoint between MN and CH

The coordinates of all sector CHs are sent to the MDC. The CH values are provided as X and Y coordinates, as shown in Figure 4-4. Generally, the MDC is positioned in the middle of all of the CHs to collect data. The MDC calculates the midpoint using this formula:

$$MP_x = \frac{\sum_{a=1..n} x_a}{n} \quad (8)$$

$$MP_y = \frac{\sum_{a=1..n} y_a}{n} \quad (9)$$

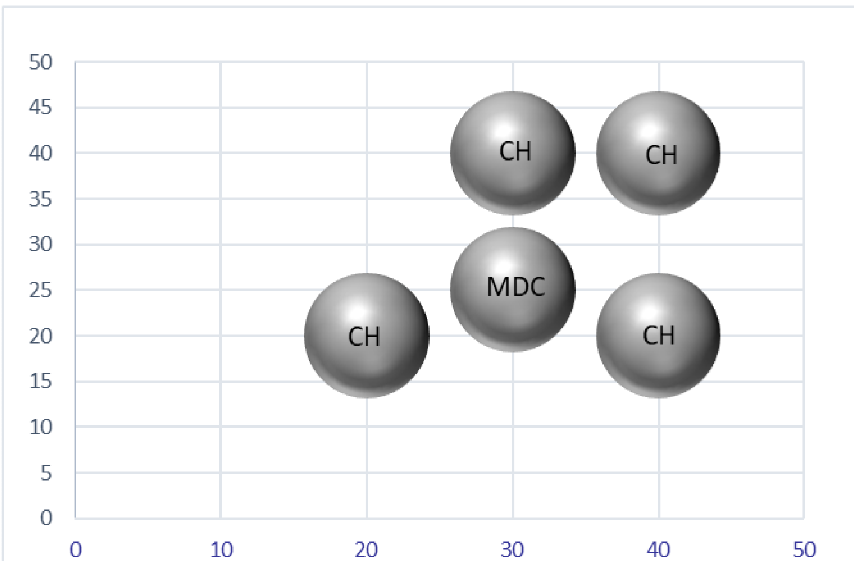


Figure 4-4. Coordinate calculation [1]

# 5. PERFORMANCE EVALUATION

## 5.1. NS-2 Simulator

Simulations have been performed using the NS2-Simulator. The architecture of the NS-2 simulation is shown in Figure 5-1. It uses two languages C++ and Object-oriented Tool Command Language (OTcl). OTcl is used to setup simulation of objects by configuring and assembling them. In addition, it also schedules discrete events. While C++ allows the creation and simulation of the internal mechanisms of objects. TclCL is used as an interlink to create functionality between the two languages. OTcl domain variables are referred to as handles and does not have any inherent functionality. Their functionality is defined by mapping a C++ object. The OTcl domain variables and procedures are said to be instant variables and instant procedures. The input is given to set up a simulation using a Tcl Simulation script. NS2 outputs can be either animation or text-based results. To view the results graphically, NAM and XGraph tools can be used.

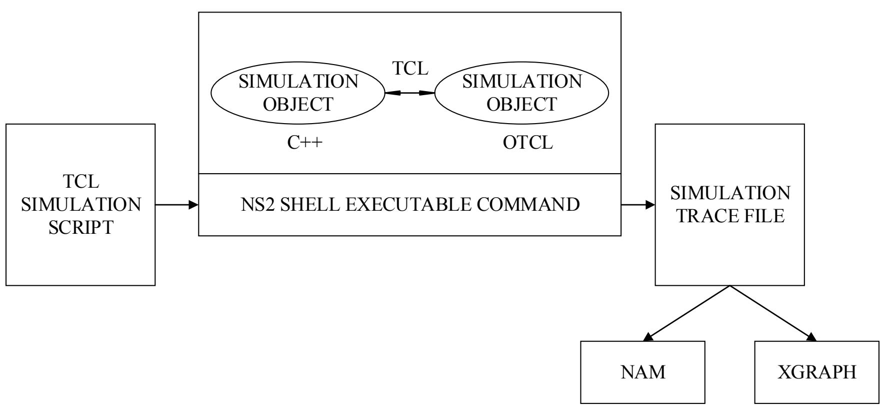


Figure 5-1. Architecture of NS-2

## 5.2. Comparison Parameters

### 5.2.1. Energy Consumption

Energy consumption can be defined as the total amount of energy consumed throughout the network. This is evaluated on the basis of the cost of sending, controlling, and delivering packets to the BS. Energy is also consumed during zone creation, cluster head selection, and routing data.

### 5.2.2. Packet Delivery Ratio

The packet delivery ratio is calculated as number of packets received by the destination divided by the number of packets sent by the source. This ratio represents the probability of end-to-end delivery.

### 5.2.3. Delay

Total time taken by the data to reach from source to destination is delay time. It can be measured as the time required to sense the data, to reach the destination, and for the data to be processed successfully. This metric inherently considers the traffic across the data links sent by the other nodes.

## 5.3. Division of Zone Scenarios

The ZHCD protocol is divided into inner and outer zones. We have analyzed different ratios of inner and outer zones through NS 2-simulation. There are 9 scenarios taken into account. First, the zone scenario starts with 10 percent inner and 90 percent outer zone. Each scenario is incremented with +5 percent in the inner zone and decremented with -5 percent in the outer zone. In these scenarios energy consumption, throughput delay, and packet delivery ratio are taken into account to decide which scenario is suitable in the real world application as shown in Figures 5-2, 5-3, 5-4. The simulation parameters are shown in table 5-1.

Table 5-1. Simulation parameters and values for zone scenarios

| Parameter | Value |
|---|---|
| Number of nodes | 100 |
| Channel type | Wireless channel |
| Radio-propagation model | Propagation/TwoRayGround |
| Network interface type | Phy/WirelessPhy |
| MAC protocol | 802.11 |
| Packet Size | 780 bytes |
| Antenna Model | Antenna/OmniAntenna |
| Energy | 1001 Joules |
| Speed | 1.0 m/ms |
| Transmitter Electronics | 50 nJ/bit |
| Transmit amplifier | 100 pJ/bit/m2 |
| Network Field | 300x200 m2 |
| Interface Queue Type | Queue/DropTail/PriQueue |
| Data Interval | 0.3 s |

Ten simulation runs of data sample for energy consumption, packet delivery ratio and end to end delay have been taken into consideration in Table 5-2, 5-3, 5-4. The average of these samples is used to create a bar graph as shown in Figure 5-2,5-3 and 5-4.

Table 5-2. Simulation runs of energy consumption for different zone scenarios

| simulation runs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 82.4895 | 82.6797 | 83.0321 | 83.3971 | 83.5881 | 83.7647 | 81.5704 | 81.9482 | 82.1267 | 82.304 | 82.690 |
| Scenario 2 | 82.2618 | 82.472 | 82.8487 | 83.2375 | 83.4203 | 83.5943 | 81.3084 | 81.7017 | 81.8811 | 82.0851 | 82.517 |
| Scenario 3 | 82.2618 | 82.472 | 82.8487 | 83.2375 | 83.4203 | 83.5943 | 81.3084 | 81.7017 | 81.8811 | 82.0851 | 82.517 |
| Scenario 4 | 82.2618 | 82.472 | 82.8487 | 83.2375 | 83.4203 | 83.5943 | 81.3084 | 81.7017 | 81.8811 | 82.0851 | 82.517 |
| Scenario 5 | 82.2618 | 82.472 | 82.8487 | 83.2375 | 83.4203 | 83.5943 | 81.3084 | 81.7017 | 81.8811 | 82.0851 | 82.517 |
| Scenario 6 | 82.2646 | 82.4486 | 82.8567 | 83.22 | 83.4003 | 83.6314 | 81.3084 | 81.6937 | 81.8961 | 82.0811 | 82.480 |
| Scenario 7 | 82.3172 | 82.4994 | 82.9015 | 83.2817 | 83.4743 | 83.7084 | 81.3085 | 81.7086 | 81.884 | 82.1313 | 82.521 |
| Scenario 8 | 82.2618 | 82.472 | 82.8487 | 83.2375 | 83.4203 | 83.5943 | 81.3084 | 81.7017 | 81.8811 | 82.0851 | 82.48 |
| Scenario 9 | 82.2428 | 82.4395 | 82.7979 | 83.1593 | 83.3316 | 83.6073 | 81.3084 | 81.6916 | 81.8855 | 82.0753 | 82.453 |

Table 5-3. Simulation runs of PDR for different zone scenarios

| simulation runs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 0.91 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.97 | 0.92 | 0.92 | 0.92 | 0.924 |
| Scenario 2 | 0.83 | 0.82 | 0.80 | 0.79 | 0.78 | 0.77 | 0.95 | 0.9 | 0.87 | 0.84 | 0.835 |
| Scenario 3 | 0.83 | 0.82 | 0.80 | 0.79 | 0.78 | 0.77 | 0.95 | 0.9 | 0.87 | 0.84 | 0.835 |
| Scenario 4 | 0.83 | 0.82 | 0.80 | 0.79 | 0.78 | 0.77 | 0.95 | 0.9 | 0.87 | 0.84 | 0.835 |
| Scenario 5 | 0.83 | 0.82 | 0.80 | 0.79 | 0.78 | 0.77 | 0.95 | 0.9 | 0.87 | 0.84 | 0.835 |
| Scenario 6 | 0.85 | 0.84 | 0.81 | 0.79 | 0.78 | 0.77 | 0.95 | 0.9 | 0.88 | 0.87 | 0.844 |
| Scenario 7 | 0.78 | 0.79 | 0.74 | 0.7 | 0.69 | 0.67 | 0.91 | 0.86 | 0.84 | 0.82 | 0.78 |
| Scenario 8 | 0.83 | 0.82 | 0.78 | 0.79 | 0.78 | 0.77 | 0.95 | 0.89 | 0.87 | 0.84 | 0.832 |
| Scenario 9 | 0.82 | 0.79 | 0.78 | 0.75 | 0.76 | 0.75 | 0.95 | 0.9 | 0.88 | 0.85 | 0.823 |

Table 5-4. Simulation runs of delay for different zone scenarios

| simulation runs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 26.4031 | 31.7608 | 39.2345 | 10.3323 | 14.6467 | 19.4916 | 15.6252 | 17.9467 | 21.0827 | 23.1978 | 21.972 |
| Scenario 2 | 31.5438 | 34.1465 | 47.832 | 56.2547 | 56.1852 | 56.1756 | 19.5674 | 21.626 | 23.9136 | 25.5319 | 37.278 |
| Scenario 3 | 31.5438 | 34.1465 | 47.832 | 56.2547 | 56.1852 | 56.1756 | 19.5674 | 21.626 | 23.9136 | 25.5319 | 37.278 |
| Scenario 4 | 31.5438 | 34.1465 | 47.832 | 56.2547 | 56.1852 | 56.1756 | 19.5674 | 21.626 | 23.9136 | 25.5319 | 37.278 |
| Scenario 5 | 31.5438 | 34.1465 | 47.832 | 56.2547 | 56.1852 | 56.1756 | 19.5674 | 21.626 | 23.9136 | 25.5319 | 37.278 |
| Scenario 6 | 27.9094 | 25.5515 | 31.9376 | 37.1336 | 37.7218 | 40.7847 | 19.5674 | 22.2259 | 22.9845 | 26.6805 | 29.25 |
| Scenario 7 | 22.3568 | 27.3583 | 29.7752 | 32.2131 | 35.5964 | 35.865 | 19.2466 | 20.3647 | 20.8666 | 22.7228 | 26.637 |
| Scenario 8 | 31.5438 | 34.1465 | 47.832 | 56.2549 | 56.1852 | 56.1756 | 19.5674 | 21.626 | 23.9136 | 25.5319 | 37.278 |
| Scenario 9 | 26.5842 | 29.1994 | 36.5914 | 45.8966 | 49.7973 | 48.6256 | 19.5674 | 22.8755 | 23.3222 | 23.6778 | 32.614 |

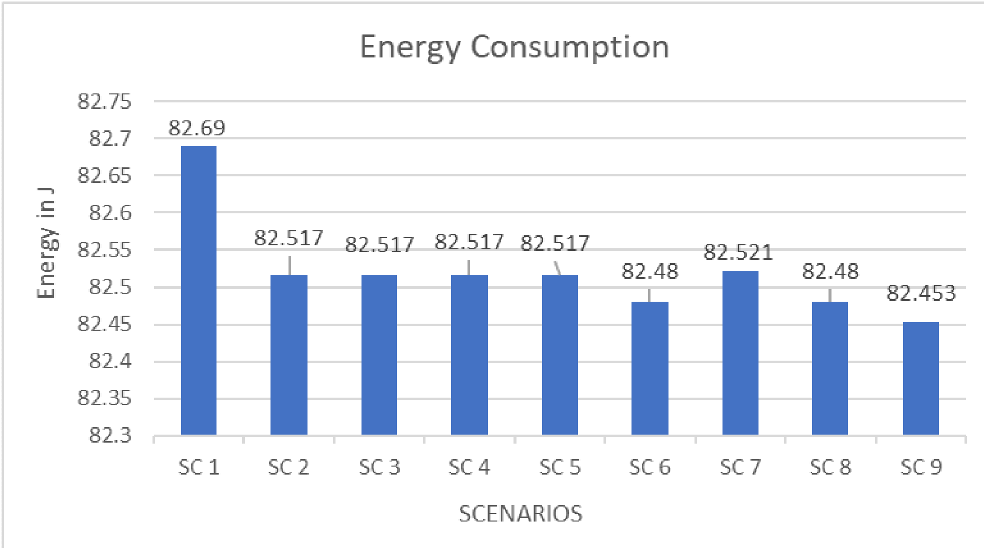


Figure 5-2. Energy consumption of different scenarios

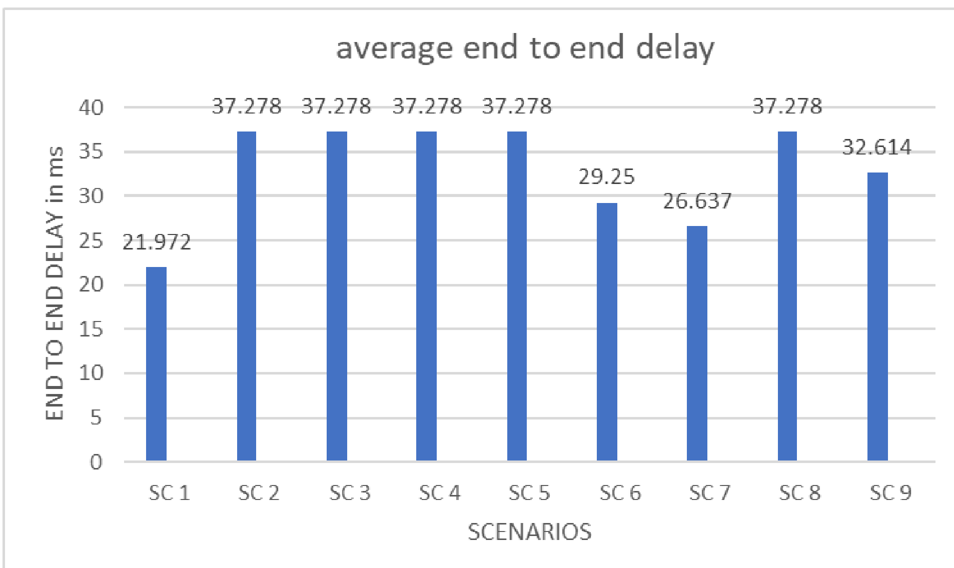


Figure 5-3. Average end to end delay of different scenarios

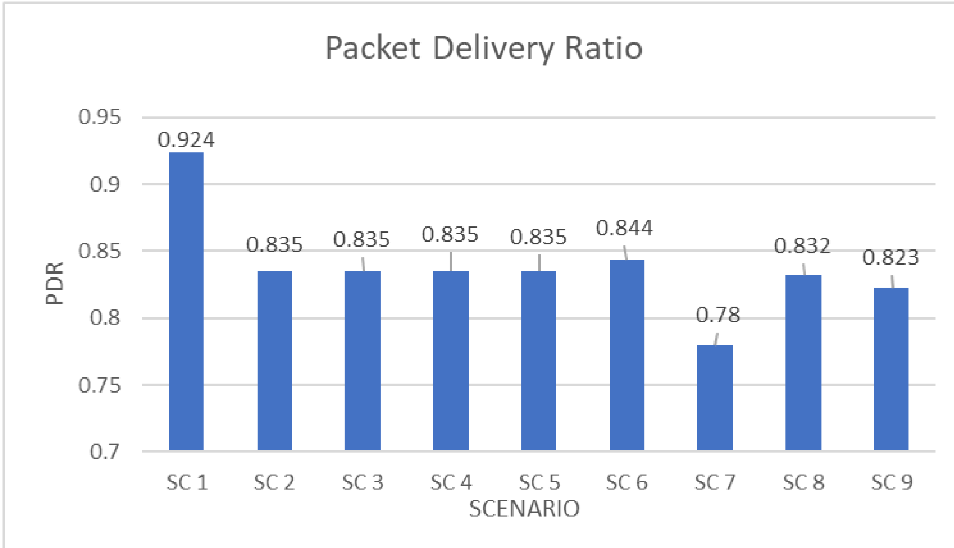


Figure 5-4. Packet delivery ratio of different scenarios

In Figure 5-2, the energy consumption of scenario 9(82.453) seems to be low compared to other scenarios. In Figure 5-3, the average end to end delay is low in scenario 1(21.972) compared to different scenarios. In Figure 5-4, the packet delivery ratio is high in scenario 1(0.924). By considering energy consumption, packet delivery ratio, and delay scenario 1 is taken for experimenting with other comparison protocols.

### 5.4. Comparison Protocols

The proposed ZHCD algorithm is compared to two protocols: These include the Hybrid Advanced Distributed and Centralized Clustering (HADCC) path planning algorithm for WSNs and The Energy Efficient Odd-Even Round Number (EEOERN) based data collection using mules (Mules) for WSNs.

#### 5.4.1. HADCC Algorithm

In HADCC algorithm the network comprises of homogenous and heterogenous nodes. However, to compare it with ZHCD algorithm I assumed the network to be homogenous. The cluster formation of HADCC and ZHCD algorithm uses centralized and distributed clustering schemes. In HADCC, the data is transmitted from sensor nodes to CH and CH to base station. In ZHCD algorithm, the data is transmitted from sensor nodes to cluster head in the inner zone and sensor nodes to CH, CH to MDC and MDC to base station in the outer zone. Initial energy and all other parameters are kept similar for HADCC and ZHCD protocols to obtain realistic results.

### 5.4.2. Mules Algorithm

In Mules and ZHCD algorithm the nodes are of same energy in the network. The cluster formation in Mules is centralized and ZHCD has distributed and centralized clustering schemes. In Mules algorithm, data is transmitted from sensor nodes to CH, CH to mobile nodes and mobile nodes to base station. Depending on the even and odd round numbers, two mobile nodes are deployed to collect the data from CH. However, to compare Mules with ZHCD algorithm I assumed the Mules network with multiple mobile nodes equal to the mobile nodes deployed in ZHCD network to obtain realistic results. In ZHCD algorithm, the data is transmitted from sensor nodes to cluster head in the inner zone and sensor nodes to CH, CH to MDC and MDC to base station in the outer zone. Initial energy and all other parameters are kept similar for Mules and ZHCD protocols.

### 5.4.3. Overview of the Results

We simulated the ZHCD algorithm, HADCC path planning algorithm for WSNs, and the EEOERN based data collection using mules approach in WSNs using the simulation parameters defined in Table 5-1.

The results show that the proposed protocol outperforms the other two protocols because it reduces energy consumption and delay reduction. The results also show that the proposed approach provides a higher packet delivery ratio than the other protocols.

#### 5.4.3.1. Energy Consumption

Table 5-5. Simulation runs of energy consumption for different comparison protocols

| simulation runs | ZHCD | HADCC | MULES |
|---|---|---|---|
| 1 | 82.4895 | 105.227 | 105.939 |
| 2 | 82.6797 | 105.411 | 106.113 |
| 3 | 83.0321 | 105.764 | 106.487 |
| 4 | 83.3971 | 106.117 | 107.43 |
| 5 | 83.5881 | 106.297 | 107.698 |
| 6 | 83.7647 | 106.477 | 107.878 |
| 7 | 81.5704 | 104.322 | 105.024 |
| 8 | 81.9482 | 104.867 | 105.387 |
| 9 | 82.1267 | 104.681 | 105.566 |
| 10 | 82.304 | 105.053 | 105.762 |
| Average | 82.690 | 105.422 | 106.328 |

Ten simulation runs of data sample for energy consumption of ZHCD, HADCC and MULES protocols is considered in Table 5-5. The average of these samples is used to create a bar graph as shown in Figure 5-5. The results from the simulation, with a twenty-five second duration, are shown in Figure 5-6. The total energy consumption of the proposed protocol is 82.690 J. While the HADCC protocol and mules protocol require 105.422 J and 106.328 J, respectively.

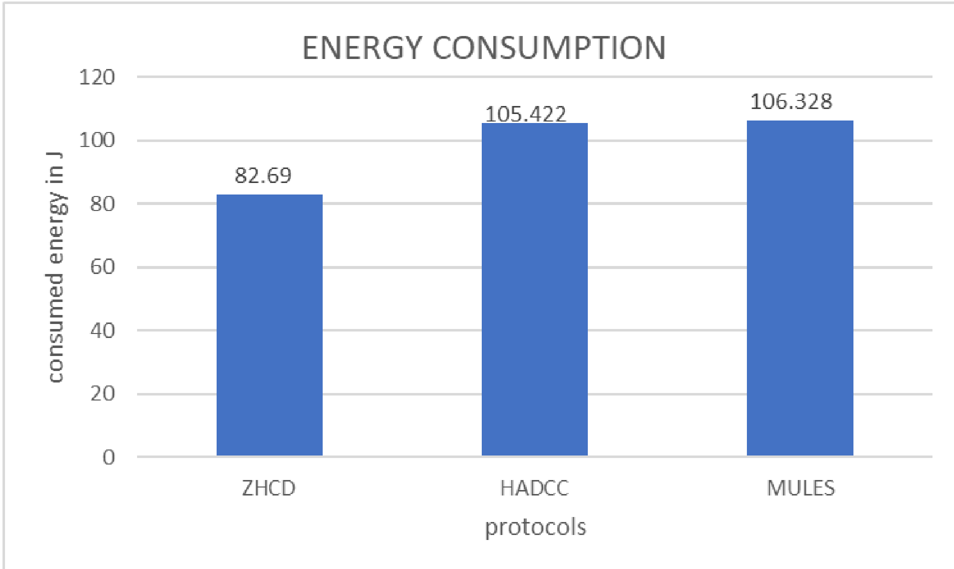


Figure 5-5. Energy consumption of protocols in 25 seconds

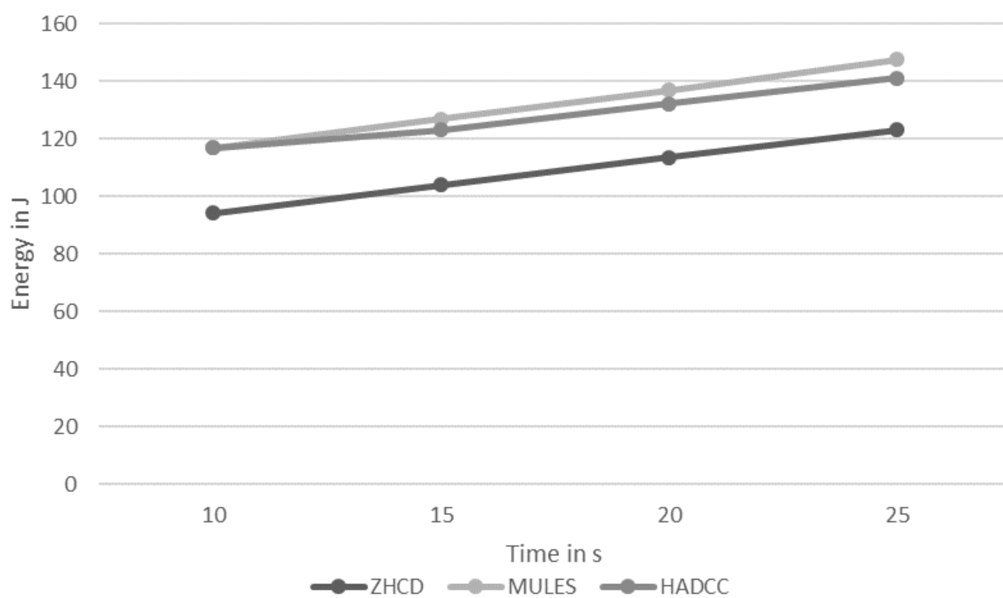


Figure 5-6. Simulation time Vs consumed energy

#### 5.4.3.2. Packet Delivery Ratio

Ten simulation runs of data sample for PDR of ZHCD, HADCC and MULES protocols is considered in Table 5-6. The average of these samples is used to create a bar graph as shown in Figure 5-7, the proposed protocol has high end-to-end delivery, compared to the other two protocols discussed. For the 25 seconds simulation time, the packet delivery ratio of the ZHCD, HADCC and MULES protocol is shown in Figure 5-8.

Table 5-6. Simulation runs of PDR for different comparison protocols

| simulation runs | ZHCD | HADCC | MULES |
|---|---|---|---|
| 1 | 0.91 | 0.81 | 0.79 |
| 2 | 0.92 | 0.81 | 0.80 |
| 3 | 0.92 | 0.80 | 0.79 |
| 4 | 0.92 | 0.80 | 0.79 |
| 5 | 0.92 | 0.80 | 0.78 |
| 6 | 0.92 | 0.80 | 0.77 |
| 7 | 0.97 | 0.81 | 0.77 |
| 8 | 0.92 | 0.81 | 0.79 |
| 9 | 0.92 | 0.81 | 0.78 |
| 10 | 0.92 | 0.81 | 0.78 |
| Average | 0.924 | 0.806 | 0.784 |

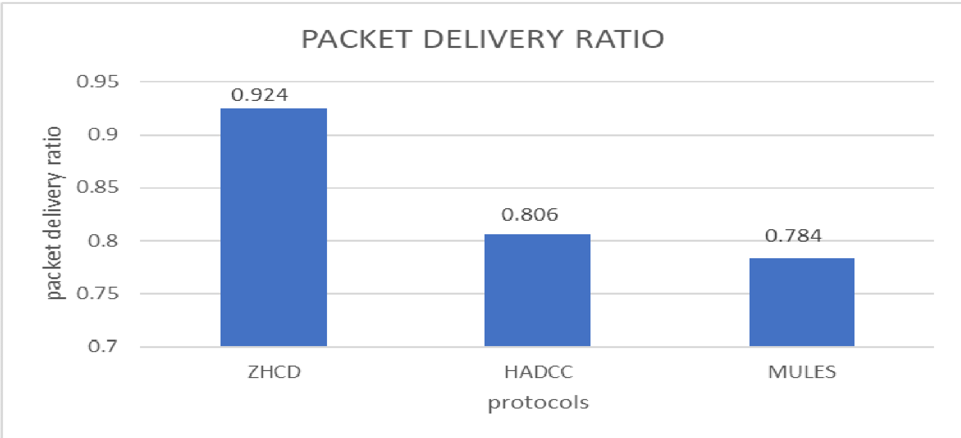


Figure 5-7. PDR of protocols in 25 seconds

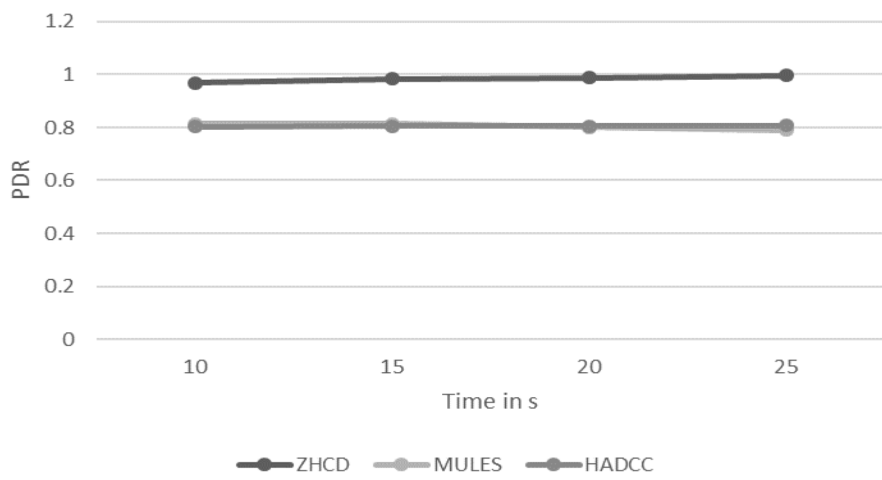


Figure 5-8. Simulation time Vs PDR

#### 5.4.3.3 Average End to End Delay

Table 5-7. Simulation runs of delay for different comparison protocols

| simulation runs | ZHCD | HADCC | MULES |
|---|---|---|---|
| 1 | 26.4031 | 372.161 | 189.278 |
| 2 | 31.7608 | 382.363 | 191.853 |
| 3 | 39.2345 | 384.17 | 200.656 |
| 4 | 10.3323 | 393.709 | 191.069 |
| 5 | 14.6467 | 403.098 | 185.986 |
| 6 | 19.4916 | 401.967 | 189.25 |
| 7 | 15.6252 | 340.452 | 167.73 |
| 8 | 17.9467 | 360.043 | 176.782 |
| 9 | 21.0827 | 366.402 | 183.48 |
| 10 | 23.1978 | 369.66 | 189.656 |
| Average | 21.972 | 377.402 | 186.574 |

Ten simulation runs of data sample for end to end delay of ZHCD, HADCC and MULES protocols is considered in Table 5-7. The average of these samples is used to create a bar graph as shown in Figure 5-9, the proposed protocol has low end-to-end delivery, compared to the other two protocols discussed. For the 25 seconds simulation time, the end to end delay of the ZHCD, HADCC and MULES protocol is shown in Figure 5-10.

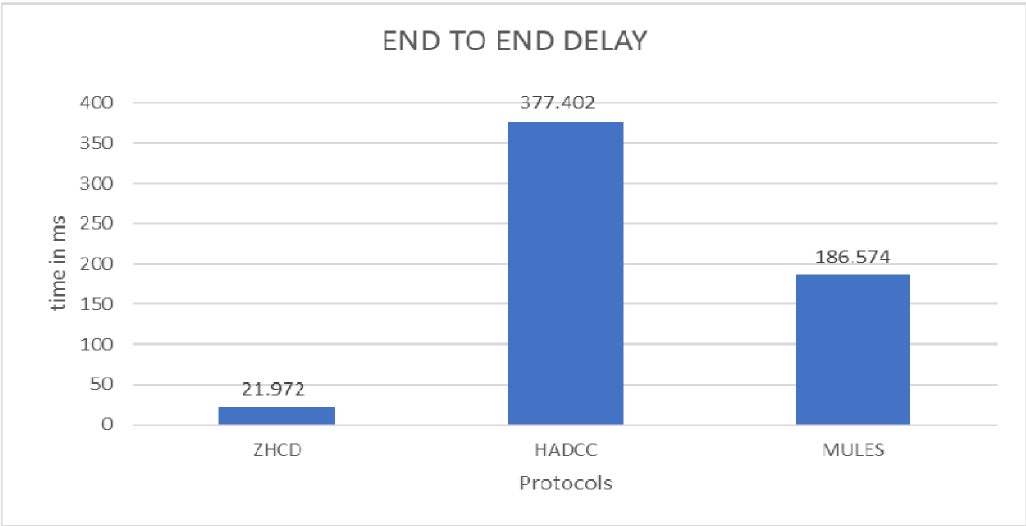


Figure 5-9. End to end delay of protocols in 25 seconds

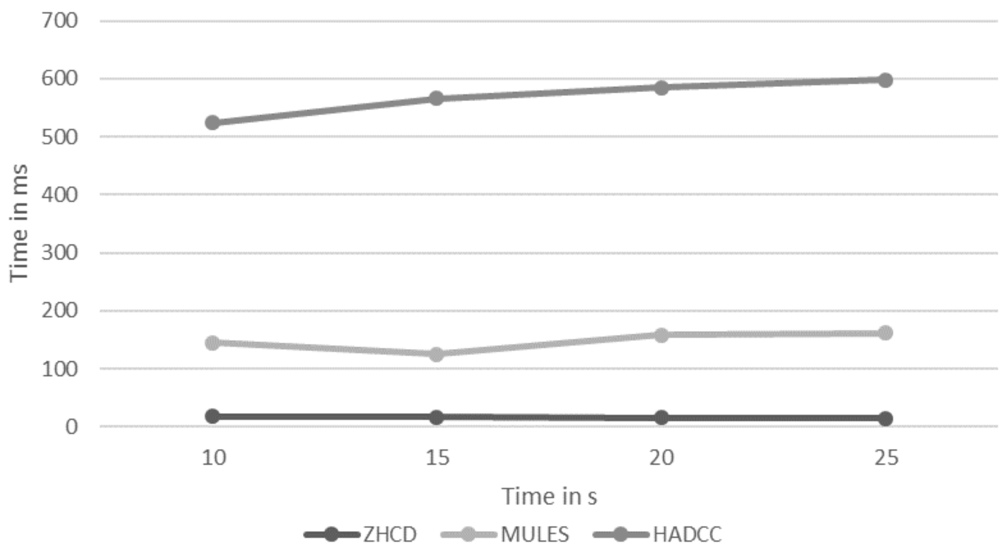


Figure 5-10. Simulation time Vs delay time in ms

## 5.5. Positioning of Base Station

The base station can be positioned in different scenarios in the network as shown in Figure 5-11,5-12,5-13. Depending on the application the base station is placed. The application like monitoring of the agricultural field requires the base station to be kept in the middle of the farm, so that it covers large area and the communication cost can be reduced. Even the network lifetime can be increased and delay of transmitting the data can be reduced.

The application like military surveillance or monitoring battle field, the base station cannot be placed in the middle. As it is known that base station is hidden, and it cannot be kept open in middle of the field. Therefore, it is feasible to keep the base station in the corner of network.

In applications like structural monitoring, the base station should be kept in such a way that it covers large density of nodes. For instance, if 10 bridges are taken into consideration and 5 bridges are close in proximity. The remaining are far away from each other. Then it is feasible to place base station near to the dense nodes comparing it to place in other positions. As discussed above, the base station can be placed in three scenarios:

- Positioning of base station in middle of the network
- Positioning of base station in the corner of the network
- Positioning of base station where nodes are dense in the network

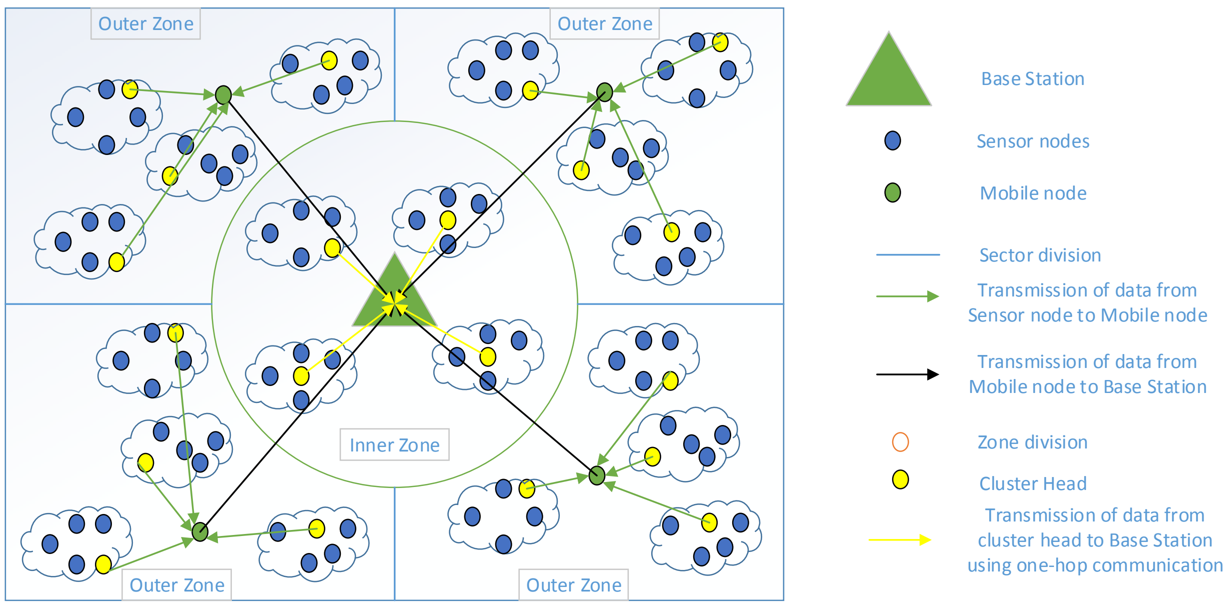


Figure 5-11. Positioning of base station in the center of network

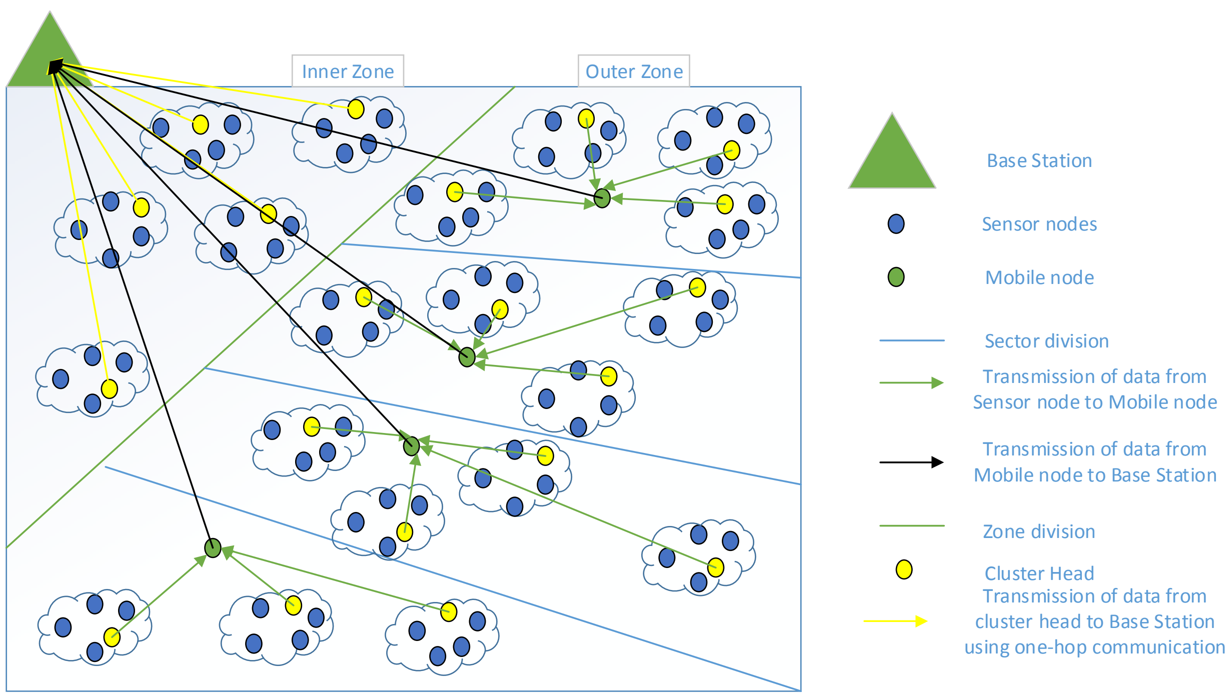


Figure 5-12. Positioning of base station in the corner of network

The simulation parameters for three scenarios is shown in Table 5-8.

Table 5-8. Simulation parameters and values for base station

| Parameter | Value |
|---|---|
| Number of nodes | 200 |
| Channel type | Wireless channel |
| Radio-propagation model | Propagation/TwoRayGround |
| Network interface type | Phy/WirelessPhy |
| MAC protocol | 802.11 |
| Packet Size | 780 bytes |
| Antenna Model | Antenna/OmniAntenna |
| Energy | 1001 Joules |
| Speed | 1.0 m/ms |
| Transmitter Electronics | 50 nJ/bit |
| Transmit amplifier | 100 pJ/bit/m2 |
| Network Field | 300x200 m2 |
| Interface Queue Type | Queue/DropTail/PriQueue |
| Data Interval | 0.4 s |

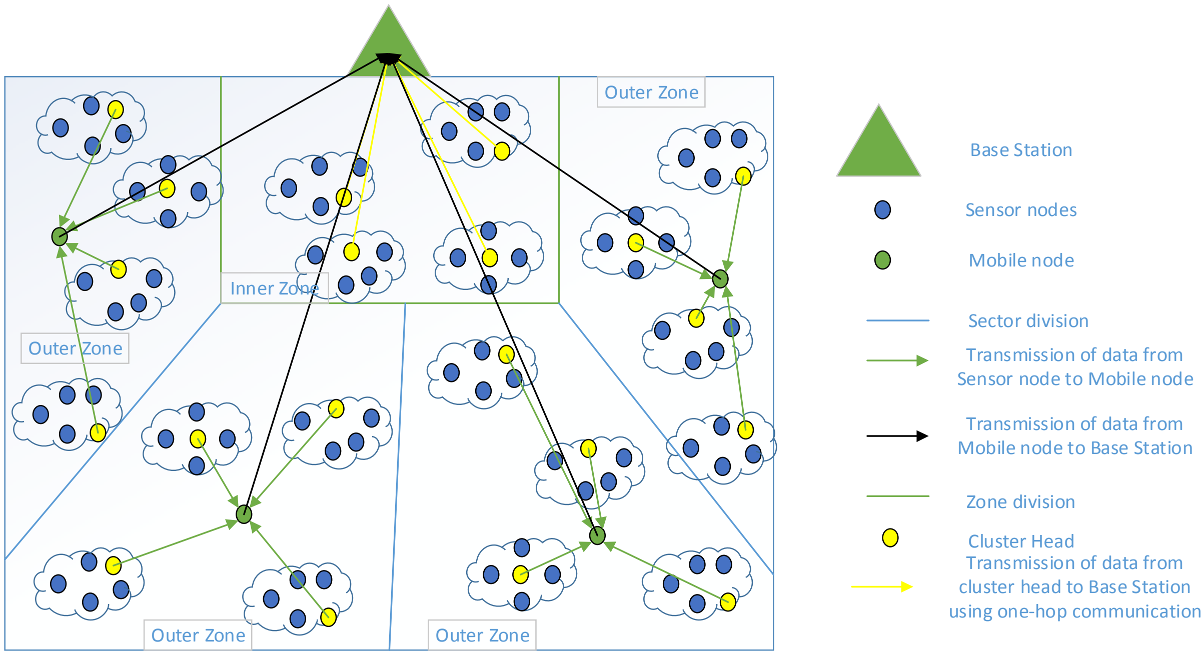


Figure 5-13. Positioning of base station where nodes are dense in the network

### 5.5.1. Energy Consumption

Ten simulation runs of data sample for energy consumption have been taken into consideration in Table 5-9. The average of these samples is used to create a bar graph as shown in Figure 5-14, base station placed near the dense nodes consumes less energy compared to other two scenarios. The results from the simulation, with a twenty-five second duration, are shown in Figure 5-15.

Table 5-9. Simulation runs of energy consumptions for BS in different positions

| simulation runs | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| 1 | 7022.36 | 7022.78 | 7021.39 |
| 2 | 6982.05 | 7122.13 | 7121.29 |
| 3 | 7142.05 | 6982.44 | 6962.12 |
| 4 | 7102.68 | 6942.05 | 6981.37 |
| 5 | 7062.02 | 7062.16 | 7061.78 |
| 6 | 7122.85 | 7102.76 | 7101.77 |
| 7 | 6902.58 | 7142.39 | 7141.74 |
| 8 | 6942.84 | 6902.06 | 7001.38 |
| 9 | 6962.87 | 6962.16 | 6902.17 |
| 10 | 7002.19 | 7002.76 | 6942.09 |
| Average | 7024.449 | 7024.369 | 7023.71 |

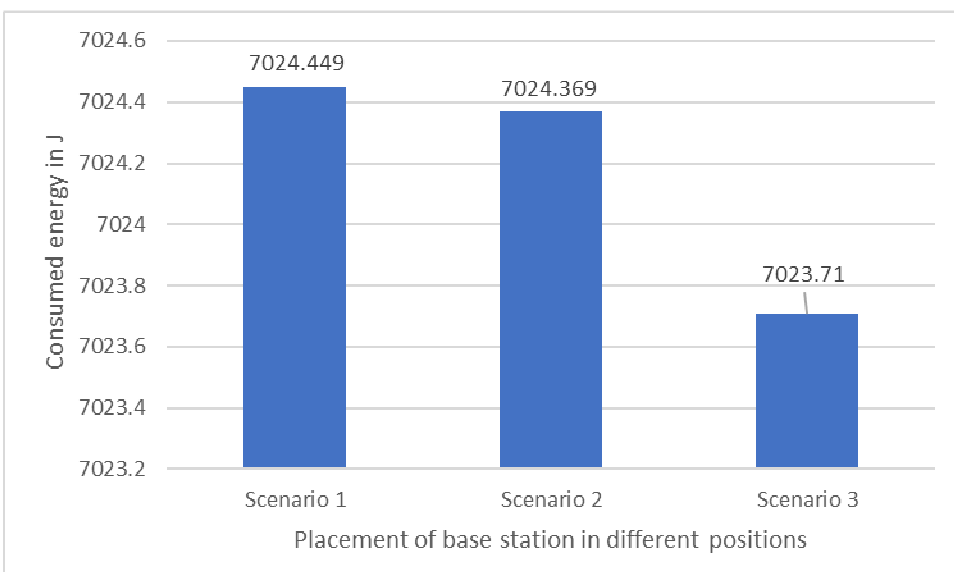


Figure 5-14. Energy consumption of three scenarios

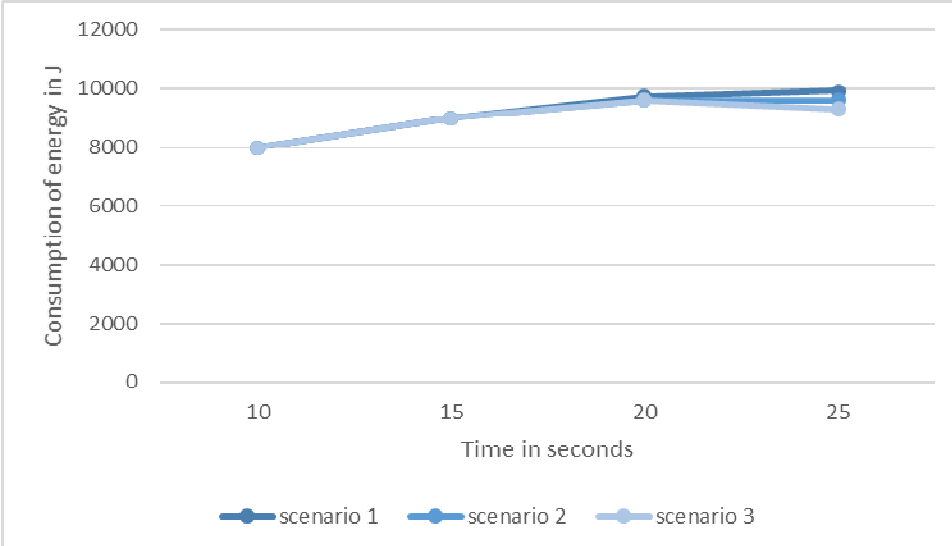


Figure 5-15. Simulation time Vs energy consumption

### 5.5.2. Packet Delivery Ratio

Ten simulation runs of data sample for packet delivery ratio have been taken into consideration in Table 5-10. The average of these samples is used to create a bar graph as shown in Figure 5-16. From the graph, we can infer that the scenario 3 and scenario 2 has same high end-to-end delivery, compared to the scenario 1 discussed. For the 25 seconds simulation time, shown in Figure 5-17 the packet delivery ratio of the scenario 2 seems to be higher with a value of 0.869 compared to other two scenarios discussed.

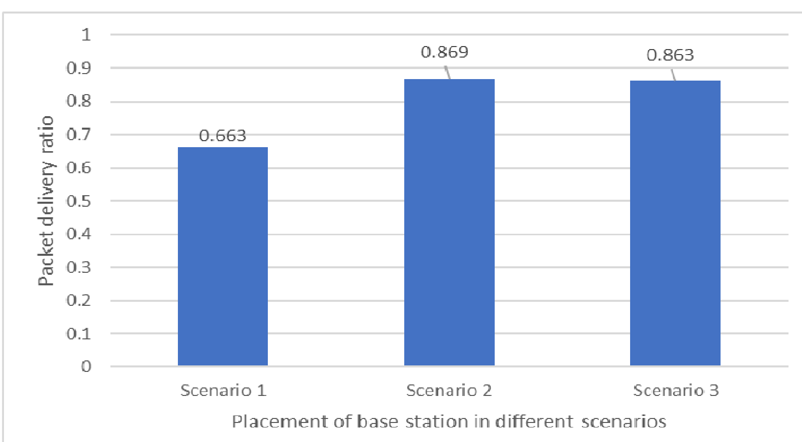


Figure 5-16. Packet delivery ratio of three scenario

Table 5-10. Simulation runs of PDR for BS in different positions

| simulation runs | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| 1 | 0.66 | 0.87 | 0.86 |
| 2 | 0.66 | 0.88 | 0.87 |
| 3 | 0.69 | 0.86 | 0.86 |
| 4 | 0.68 | 0.86 | 0.87 |
| 5 | 0.67 | 0.87 | 0.87 |
| 6 | 0.68 | 0.88 | 0.87 |
| 7 | 0.64 | 0.88 | 0.87 |
| 8 | 0.64 | 0.86 | 0.86 |
| 9 | 0.65 | 0.86 | 0.85 |
| 10 | 0.66 | 0.87 | 0.85 |
| Average | 0.66 | 0.869 | 0.863 |

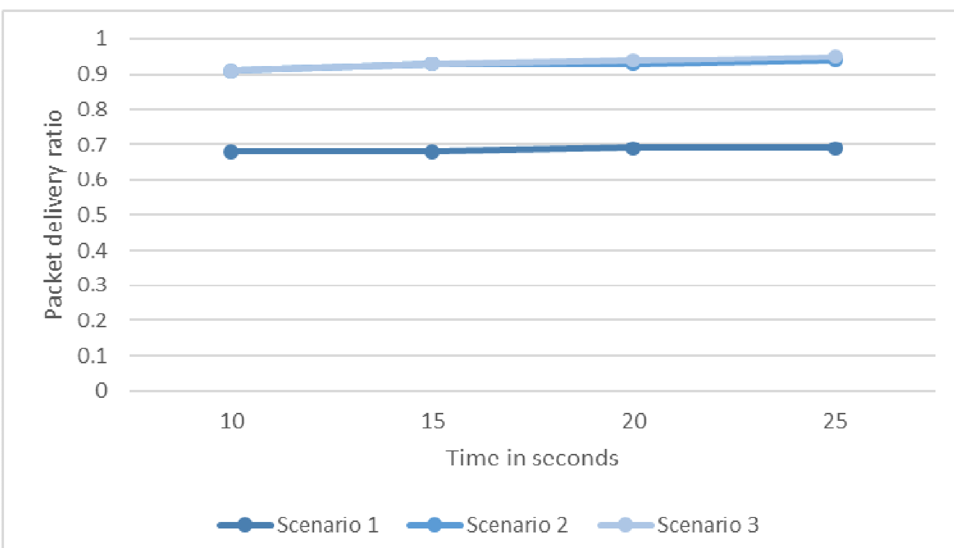


Figure 5-17. Simulation time Vs PDR

### 5.5.3. Average End to End Delay

Ten simulation runs of data sample for packet delivery ratio have been taken into consideration in Table 5-11. The average of these samples is used to create a bar graph as shown in Figure 5-18, scenario 1 has low delay values compared to scenario 1 and scenario 2. For the 25 seconds simulation time, the average end to end delay time is shown in Figure 5-19.

Table 5-11. Simulation runs of delay for BS in different positions

| simulation runs | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| 1 | 91.0679 | 181.086 | 284.16 |
| 2 | 86.9557 | 206.855 | 293.966 |
| 3 | 100.622 | 166.591 | 293.047 |
| 4 | 98.8605 | 139.846 | 280.765 |
| 5 | 93.2274 | 194.627 | 289.727 |
| 6 | 100.254 | 198.738 | 293.047 |
| 7 | 61.4556 | 212.872 | 295.367 |
| 8 | 81.9538 | 127.189 | 280.648 |
| 9 | 83.875 | 149.737 | 263.165 |
| 10 | 89.5747 | 176.046 | 271.876 |
| Average | 88.785 | 175.359 | 284.577 |

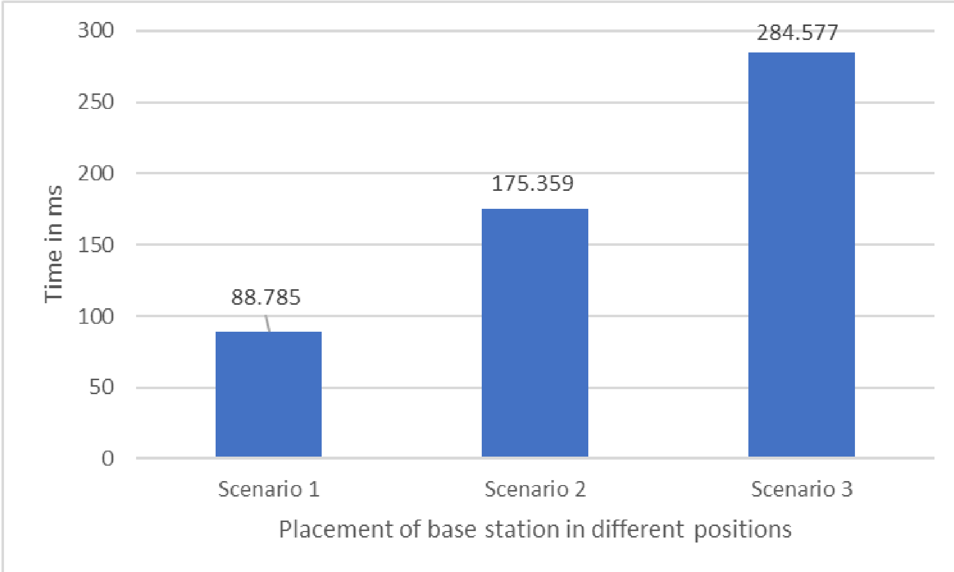


Figure 5-18. End to end delay of three scenarios

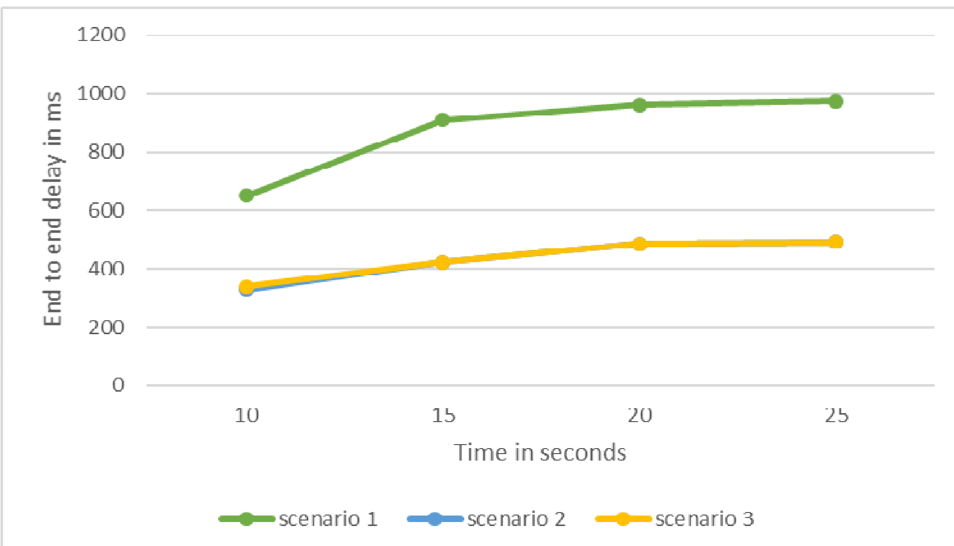


Figure 5-19. Simulation time Vs end to end delay

### 5.6. Cluster Group Division

As it is known fact that WSN is application dependent. There are some applications where you need to manually install the nodes and configure the clusters. There are four scenarios taken into consideration.

- Scenario 1: Three-member nodes are made into a cluster group.

- Scenario 2: Four-member nodes are made into a cluster group
- Scenario 3: Five-member nodes are made into a cluster group
- Scenario 4: Six-member nodes are made into a cluster group

These four scenarios are examined through energy consumption, packet delivery ratio, and end to end delay to prove which scenario tends to be a good fit in the application. The four scenarios are simulated through the parameters specified in Table 5-12.

Table 5-12. Simulation parameters for cluster group division

| Parameter | Value |
|---|---|
| Number of nodes | 200 |
| Channel type | Wireless channel |
| Radio-propagation model | Propagation/TwoRayGround |
| Network interface type | Phy/WirelessPhy |
| MAC protocol | 802.11 |
| Packet Size | 780 bytes |
| Antenna Model | Antenna/OmniAntenna |
| Energy | 1001 Joules |
| Speed | 1.0 m/ms |
| Transmitter Electronics | 50 nJ/bit |
| Transmit amplifier | 100 pJ/bit/m2 |
| Network Field | 300x200 m2 |
| Interface Queue Type | Queue/DropTail/PriQueue |
| Data Interval | 0.4 s |

### 5.6.1. Energy Consumption

Ten simulation runs of data sample for packet delivery ratio have been taken into consideration in Table 5-13. The average of these samples is used to create a bar graph as shown in Figure 5-20, 4-member nodes in a cluster group consumes less energy compared to other cluster groups. The results from the simulation, with a twenty-five second duration, are shown in Figure 5-21.

Table 5-13. Simulation runs of energy consumption for cluster group division

| simulation runs | 3 MN | 4 MN | 5 MN | 6 MN |
|---|---|---|---|---|
| 1 | 7021.79 | 7001.31 | 7021.51 | 7121.11 |
| 2 | 7062.39 | 7062.39 | 7031.27 | 7061.11 |
| 3 | 6901.7 | 7021.79 | 6961.23 | 6901.08 |
| 4 | 7101.71 | 7122.59 | 7101.48 | 6961.32 |
| 5 | 6941.89 | 7101.71 | 7001.45 | 7021.05 |
| 6 | 7122.59 | 6982.75 | 6981.23 | 6981.07 |
| 7 | 6981.75 | 6962.84 | 7141.44 | 7001.09 |
| 8 | 6961.84 | 6941.89 | 7121.41 | 7101.06 |
| 9 | 7001.31 | 6905.26 | 6942.04 | 6941.77 |
| 10 | 7142.51 | 7100.01 | 6901.54 | 7141.1 |
| Average | 7023.95 | 7020.25 | 7020.46 | 7023.17 |

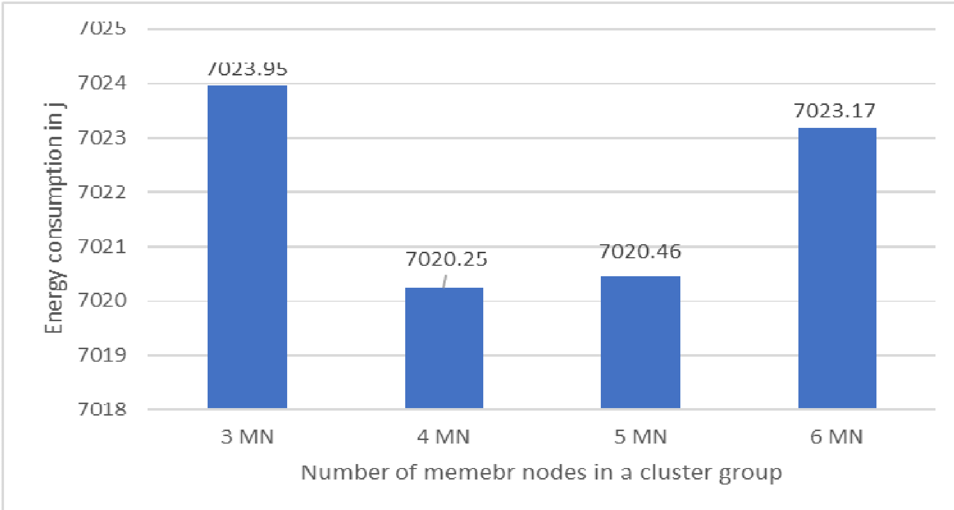


Figure 5-20. Energy consumption of different member nodes in a cluster group

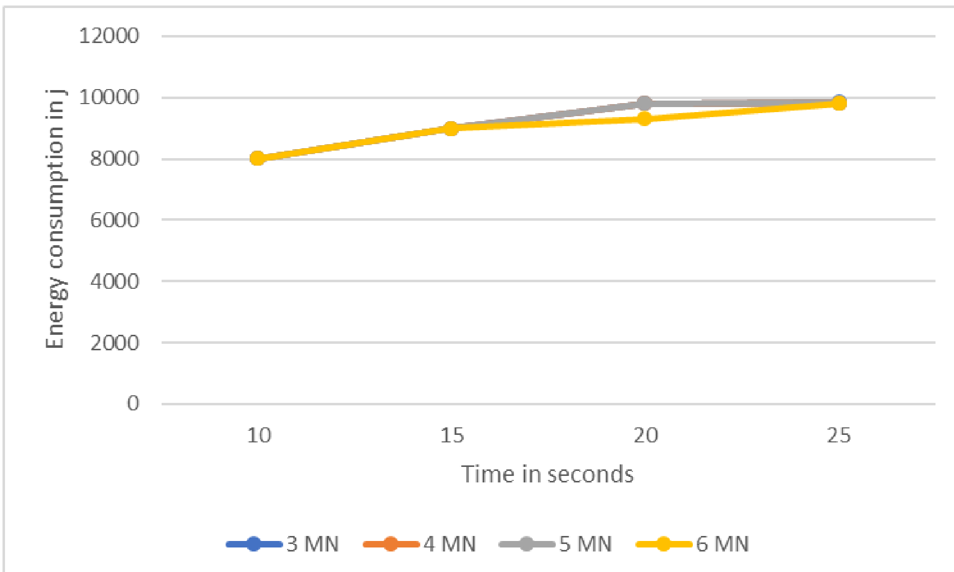


Figure 5-21. Simulation time Vs energy consumption

### 5.6.2. Packet Delivery Ratio

Ten simulation runs of data sample for packet delivery ratio have been taken into consideration in Table 5-14. The average of these samples is used to create a bar graph as shown in Figure 5-22, 6 MN has high end-to-end delivery, compared to the other cluster groups discussed. For the 25 seconds simulation time, shown in Figure 5-23 the packet delivery ratio of the 5 MN cluster group shows higher packet delivery ratio compared to other member nodes cluster group.

Table 5-14. Simulation runs of PDR for cluster group division

| simulation runs | 3 MN | 4 MN | 5 MN | 6 MN |
|---|---|---|---|---|
| 1 | 0.79 | 0.79 | 0.82 | 0.97 |
| 2 | 0.797 | 0.8 | 0.81 | 0.97 |
| 3 | 0.8 | 0.8 | 0.81 | 0.97 |
| 4 | 0.8 | 0.8 | 0.81 | 0.97 |
| 5 | 0.8 | 0.8 | 0.81 | 0.97 |
| 6 | 0.79 | 0.8 | 0.81 | 0.96 |
| 7 | 0.79 | 0.79 | 0.82 | 0.96 |
| 8 | 0.79 | 0.79 | 0.81 | 0.96 |
| 9 | 0.795 | 0.8 | 0.82 | 0.97 |
| 10 | 0.794 | 0.79 | 0.82 | 0.97 |
| Average | 0.795 | 0.796 | 0.814 | 0.967 |

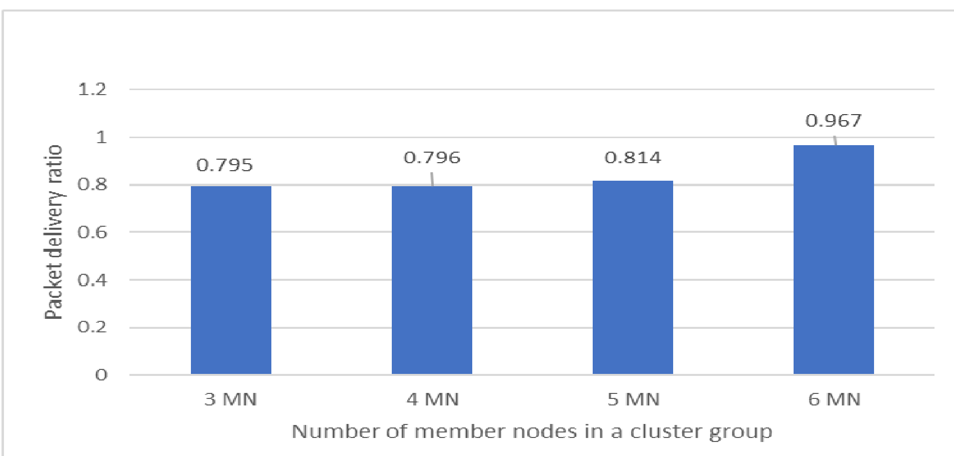


Figure 5-22. Packet delivery ratio of different member nodes in a cluster group

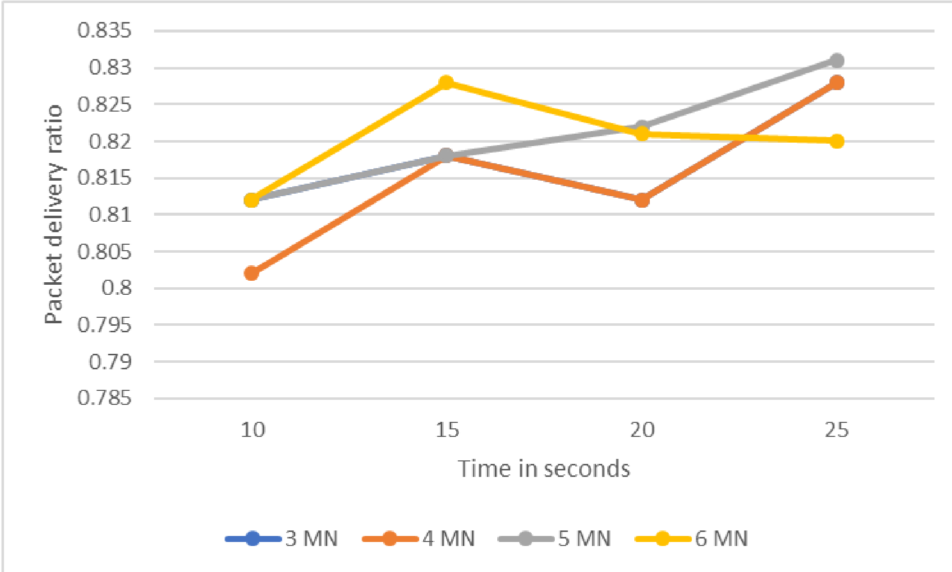


Figure 5-23. Simulation time Vs PDR

### 5.6.3. Average End to End Delay

Ten simulation runs of data sample for packet delivery ratio have been taken into consideration in Table 5-15. The average of these samples is used to create a bar graph as shown in Figure 5-24, 6-member nodes in a cluster group has low end to end delay compare to other member nodes. For the 25 seconds simulation time, the average end to end delay time of 6-member nodes seems to be low compare to other member nodes shown in Figure 5-25.

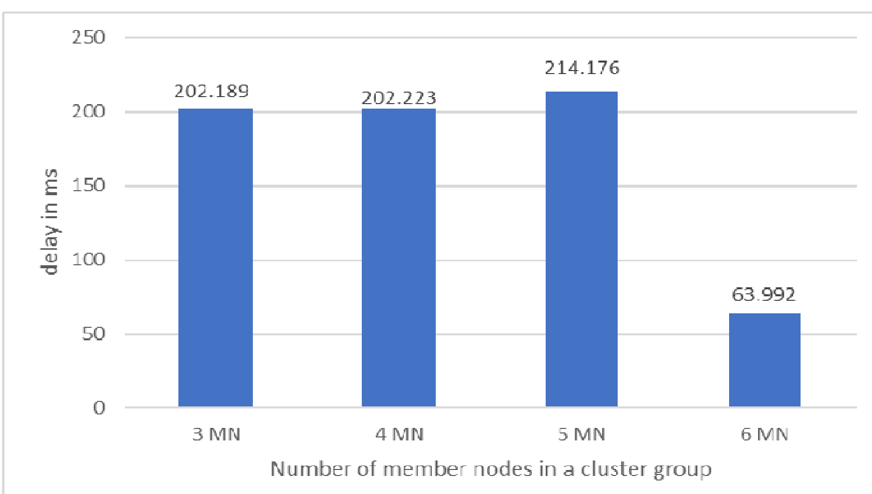


Figure 5-24. End to end delay of different member nodes in a cluster group

Table 5-15. Simulation runs of delay for cluster group division

| simulation runs | 3 MN | 4 MN | 5 MN | 6 MN |
|---|---|---|---|---|
| 1 | 204.065 | 204.065 | 223.821 | 63.6728 |
| 2 | 240.014 | 222.334 | 254.786 | 61.2642 |
| 3 | 156.682 | 246.226 | 262.002 | 59.0721 |
| 4 | 222.333 | 233.480 | 238.792 | 58.0546 |
| 5 | 246.226 | 240.014 | 273.578 | 57.0714 |
| 6 | 167.869 | 156.72 | 170.177 | 72.5067 |
| 7 | 233.474 | 167.869 | 138.464 | 69.2175 |
| 8 | 175.785 | 175.785 | 194.045 | 67.7625 |
| 9 | 183.876 | 183.876 | 177.642 | 66.3295 |
| 10 | 191.865 | 191.865 | 208.457 | 64.9686 |
| Average | 202.189 | 202.223 | 214.176 | 63.992 |

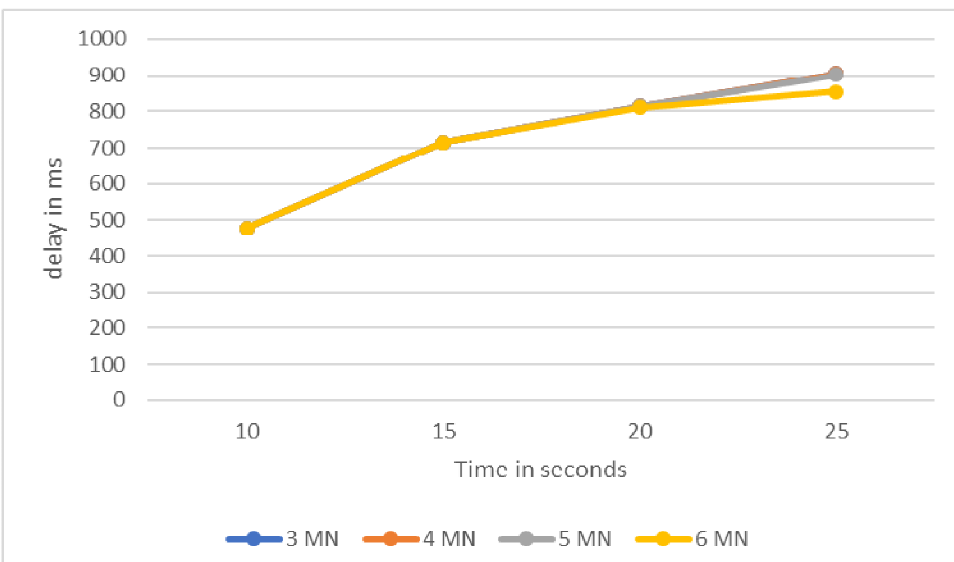


Figure 5-25. Simulation time Vs delay

# 6. ANALYTICAL ANALYSIS

## 6.1. Energy Consumption

HADCC protocol uses distributed and centralized clustering path to route the data. In this the nodes have different energy levels and the network is divided into two which are homogenous and heterogeneous. The senor nodes form clusters and send data to the base station. The nodes which are near to the BS uses centralized clustering and far away uses distributed clustering. The data is sent to CH and CH to base station where the nodes deplete their energy in transmitting the data in turn increasing the consumption of energy. But in the case of odd and even mules all the nodes have same energy and nodes form cluster group. It sends the data from CH to mules and mules to BS. Here mules have no memory and power constraints. Even then the consumption of power is more as the nodes have same energy and multi routing of data takes place as the mule will be moving in the path where CH waste lot of energy in transferring data to the mules.

The proposed protocol energy consumption is less compared to HADCC and odd and even mules protocol. As the network is divided into zones and the sensor nodes form cluster. The inner zone has one hop communication which consumes energy to route data directly to base station. The outer zone as it is far away from the BS MDC is used to collect the data from CH and send the data to the BS. Here the MDC moves near to CH to collect data. It saves lot of energy in doing this.

## 6.2. Packet Delivery Ratio

In HADCC protocol it sends data to multiple CH to route data to BS. There is higher risk when transmission takes place between several nodes. However, in the case of mules also it has multi path routing and data is sent to different CH to route data to mule. There is a higher risk of losing the data packet.

In the proposed protocol the inner zone uses one hop communication so that data is sent directly to BS. In outer zone data is collected with MDC where it moves near to the CH to collect data. Therefore, there is a guarantee that data packet is delivered successfully.

### 6.3. Average End to End Delay

HADCC protocol has higher delay because as it has two levels of hierarchy so that data can be delayed in sending to the BS. If two cluster heads wanted to send data then there is possibility of delay in delivering data to the BS. In mules there is only one mule set up for each round. If there is any immediate required data want by the BS then there is a delay in sending data to the BS. Because the mules goes in particular route and slot. The CH needs to wait till mule reaches them.

In proposed protocol inner zone has one hop communication to send data so there is no delay in relaying data. However, in outer zone it is divided into sectors and each sector is assigned a mobile node so that the CH in the sector sends that data to assigned mobile node. So there is a low delay.

# 7. PROS AND CONS OF PROPOSED PROTOCOL

This section considers the performance of the proposed method qualitatively. Specifically, this section is designed to aid those considering the use of this approach ascertain whether it may be appropriate to their application through consideration of the identified benefits and drawbacks of the approach [1].

## 7.1. Benefits

WSNs using this approach are comprised of self-organized nodes. This allows network setup to occur in a short period time. It also allows a person to set up a WSN by deploying nodes and simply turning them on. The rest of the organization and configuration will be performed automatically.

Using this adaptive approach, a WSN can easily overcome CH node failures by finding other paths for routing data. This dynamic network topology also means that when a sensor node fails, other nodes can join the failed node's cluster, re-balancing the network.

The proposed approach can also be applied to large-scale networks in numerous fields. It is suitable for battlefield use because of its low setup cost and lack of infrastructure requirements.

WSNs using this approach can also be left unattended, after initial deployment. The WSN largely does the required sensing work on its own. New devices may need to be manually deployed. If a SN fails, a human operator can easily deploy a new unit to replace it which will integrate itself into the applicable cluster and identify its path of communication to the BS.

The approach of dividing the network into clusters conserves the energy stored by the member nodes. Clustering also reduces the number of nodes taking part in long-distance data transmission, reducing the potential for nodes to interfere with sister nodes. Under the proposed approach, each CH uses a TDMA schedule, so that nodes need to be operating only when they are sensing or transmitting / receiving data.

From third round onwards, the selection of the CH is performed by the previous CH . This saves energy for all of the member nodes, as it allows this decision making to be performed locally without requiring all of the nodes to communicate (over longer distances) with the BS.

The step of partitioning the network into zones provides the advantage of allowing these two areas to be dealt with differently (and more appropriately to their location). In the inner zone, where the CHs are (comparatively) closer to the BS, data is sent directly to the BS, preventing the delay that would be induced by the store-and-forward process of an intermediate node (as well as the additional power spent on a second local transmission). In the outer zone, the CHs are farther from the BS so MDCs have been used that have greater energy reserves than the CHs (and can be replaced more easily than having to replace numerous nodes).

The CHs also eliminate duplicate data from their area. This reduces overall data transmission needs for the system.

**7.2. Drawbacks**

Perhaps the largest problem for WSNs, in general, are the low data rates supported. The rate of transmission of data depends on the frequency used for transmission by the sensor nodes, the type of antenna incorporated and the level of power used. The mobile nature of some components of this approach limits the use of directional antennas which would support higher gain levels and faster transmission (for a given power level and frequency).

The adaptive nature of the proposed network could facilitate the inclusion of an intruder node. Security will need to be considered more fully in future work in this area.

WSNs have higher error rates as compared to wired systems. In some applications, a wired network may be desirable. This approach does not support a fully wired network; however, it may have some application to networks where clusters are locally wired, and long-distance transmission is performed by the (selected) CH wirelessly.

The use of a MDC makes the network costlier to build and operate. It also introduces an element of movement into the network which could introduce safety considerations and make the approach unsuitable for many applications.

# 8. CONCLUSION

Prolonging network lifetime is very important to maximizing the value that users can obtain from WSNs. An algorithm that tries to maximize cluster longevity through managing the power consumption of individual nodes and controlling where power is depleted from (facilitating power use on nodes with greater power stores or which are more readily replaceable or rechargeable) has been presented. This algorithm uses a hybrid approach for data transmission and cluster formation. By using a MDC, CH energy consumption is reduced prolonging the lifetime of the network. The advantages of clustering and the use of zones where data transmission to the BS is handled differently have been discussed. Different scenarios are proposed for the positioning of the base station depending on the application. When sensor nodes need to be installed manually, four scenarios have been presented and the assumptions are simulated through NS-2. Simulation results have been discussed saying that the proposed protocol outperforms the other existing protocols. It reduces the energy consumption and delay. It also increases end to end packet delivery ratio. Simulation results have been discussed for the different scenarios how the ratio must be decided between the inner zone and outer zone of the network.

Future work will include Network security also remains an area for additional consideration, in moving from a research system to a system that is suitable for use in the real world.

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