ENERGY EFFICIENT ROUTING IN WIRELESS SENSOR NETWORKS USING MOBILE SINK STRATEGY

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Under the esteemed guidance of
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DECLARATION

We hereby declare that the thesis work entitled "**Energy efficient routing in Wireless Sensor Networks using Mobile Sink Strategy**" which is being submitted to Delhi Technological University, in partial fulfilment of requirements for the award of degree of Master of Technology (Software Engineering) is a bonafide report of thesis carried out by me. The material contained in the report has not been submitted to any university or institution for the award of any degree.

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CERTIFICATE

This is to certify that Sugandha (2K16/SWE/18) has completed the thesis titled "**Energy efficient routing in Wireless Sensor Networks using Mobile Sink Strategy**" under my supervision in partial fulfilment of the MASTER OF TECHNOLOGY degree in Software Engineering at DELHI TECHNOLOGICAL UNIVERSITY.

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ABSTRACT

Wireless Sensor Networks (WSN) facilitates to observe and acquire environmental information by using sensor devices with wireless communication capability. WSNs are significantly expected to apply to various applications such as monitoring of temperature, humidity in agriculture, tracking of animals. Sensor nodes have limited resource of energy like batteries and nodes are usually remain stationary after deployment. After losing their energy, it will no longer provide sensing and data processing. This can lead to a huge loss in the network due to the routing path re-allocation and failure of sensing and reporting events in the environment. Hence, energy conservation has been receiving increased attention in WSN research works. In this dissertation, the main focus is on using mobile sinks, which move around a WSN to collect data from wireless sensor nodes. By using the concept of mobile sink or base station, energy of sensor nodes can be saved for improving lifetime of network and assure better connectivity of sensing data to sink nodes. In this dissertation, we proposed a framework which uses mobile sink concept with 4 sojourn locations path patterns in addition with one centralized static sink to improve the network lifetime by diverting the load of sensor nodes to nearby static or mobile sink. Furthermore, the performance of proposed framework is compared with hierarchical network protocols named as TEEN. Simulation results demonstrated that proposed framework of sink mobility is more energy efficient and improve the network lifetime as compared to TEEN.

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CHAPTER – 1
INTRODUCTION

1.1 WIRELESS SENSOR NETWORKS

The scattered nature & active topology of wireless sensor networks (WSN) have some particular necessities that are as follows – the reduced energy utilization of the network, and maximizing the system lifetime. These requirements should be met in routing protocols of wireless sensor network. Wireless sensor network consists of tiny nodes called sensor nodes. These nodes are battery powered and have limited energy for use. Also over an area these nodes are randomly deployed to monitor the happenings in the environment such as humidity, seismic events, temperature, pollution, fire detection etc. [1]. These nodes are mobile or static depending on the physical phenomenon monitored. There are two types of WSN- unstructured and structured WSN [2]. Unstructured WSN – it is the one containing a large collection of small sensor nodes. The sensor nodes are placed randomly in the network area. Whereas in structured WSN, all the nodes are deployed in a pre-planned manner. Network maintenance (managing connectivity and detecting failures) is quite difficult in unstructured WSN than structured WSN. Also, in structured WSN, the sensor nodes are placed at specific positions which help in providing full coverage, whereas there are uncovered areas in unstructured WSN.

Collection of data and sending it to the base station are the primary function of a sensor node. A sensor node contains three basic components [3]:

a. Sensing Subsystem: - It is utilized for procurement of information from the physical condition where hubs are sent.
b. Processing Subsystem: - It is utilized for putting away the information and nearby information handling is done.
c. Wireless Communication Subsystem: - It is used for data transmission.

The energy needed to perform the programmed task is supplied by a power source of non-rechargeable batteries. Nodes when once deployed are unreachable to users. So, it is inconvenient to recharge the batteries. To prolong the lifetime of network different techniques are applied.

1.2 WSN ARCHITECTURE

The model illustrated in Figure 1.1 is the broadly adopted network and node level architecture of wireless sensor networks. It consists of large number of sensor nodes randomly deployed over an area with one base station. The data is transmitted from source to the base station using multi-hop communication paradigm [2].

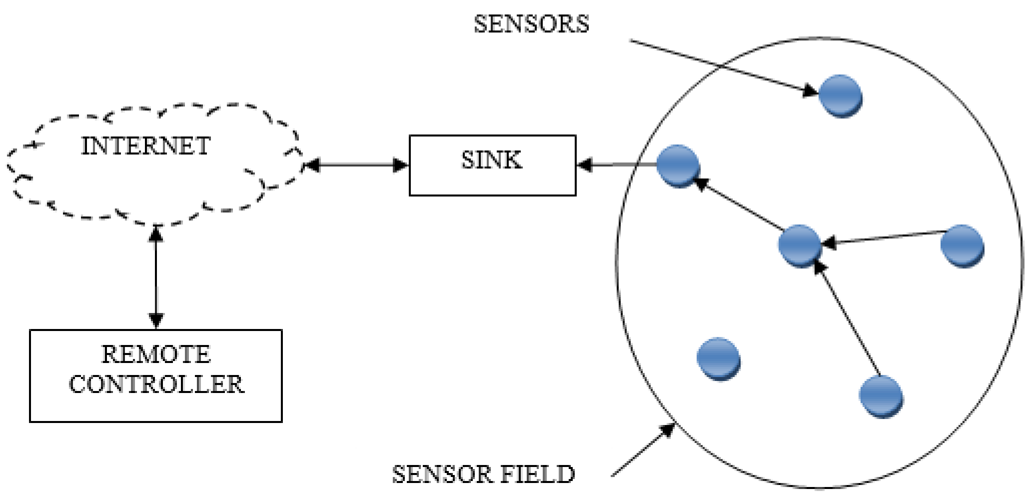

Figure 1.1: WSN Architecture (redrawn from [2]).

On the other side figure 1.2 depicts the design of a wireless sensor node. It consists of 4 main elements

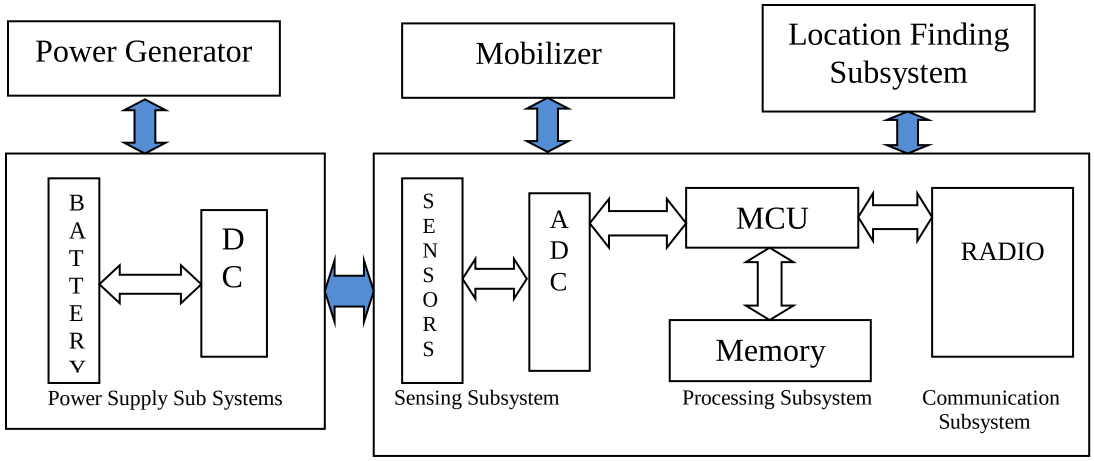

Figure 1.2: Wireless Sensor Node Architecture (redrawn from [4]).

1.2.1 CONTROLLER: - It is used to perform task, process data and to control the functionality of other components. The most common controllers are microcontrollers.

1.2.2 TRANSCEIVERS: - When the functionality of transmitter and receiver are combined they form transceivers. It is used to both transmit and receive data. Its operational states are transmit, receive, idle and sleep.

1.2.3 SENSORS: - They are devices that react to a sudden change in the physical condition of the environment. The analog signal that is produced by sensors is digitized by ADC and the data is sent to controller for further processing.

1.2.4 POWER SUPPLY: - When sensors are deployed they are unreachable to users, thus changing batteries regularly can be inconvenient. At the time of deployment of sensor nodes, it should be ensured that adequate energy is available to provide power to the system. Thus batteries and capacitors are used.

1.2.5 EXTERNAL MEMORY: - The breakdown of power is dependent on some specific node. Power characteristic of mote class node is totally different from star-gate node [4].

On the basis of above design and break down of power, different techniques have been suggested to decrease the consumption of power in WSN. The three main approaches are duty cycling, mobility and data-driven approaches [4].

1.2.5.1 Duty Cycling: - In a very simple manner, to reduce the energy consumption when the communication is not required we can put the sensor nodes into the sleep mode i.e. the sensor node should be turned off when there is no more data to send/receive, and should be turned on when the data packets are ready to transmit.

1.2.5.2 Mobility: - It can also be used as a means for reducing the total energy consumption. When sensor nodes are static the packets being transmitted from the sensor nodes to the sink follows a multi-hop routing. Thus resulting in more traffic at certain paths, the nodes that are closer to the sink will subject to impulsive energy depletion Therefore if a portion of the sensor hubs are versatile, the activity stream can be adjusted if cell phones are in charge of information gathering straightforwardly from static hubs. Common hubs sit tight for the section of the cell phone and course messages towards it, so correspondence happens in promptness. As a result, normal hubs can spare vitality since way length, dispute and sending overheads are lessened too.

1.2.5.3 Data-Driven Approach: - The energy efficiency can be improved by this technique even more. In fact, data sensing can impact the energy consumption of sensor node in following two ways:

i *Un-needed samples:* - There is no compelling reason to convey the excess data to the sink on the grounds that inspected information for the most part have solid spatial or worldly connections.

ii *Power consumption of sensing subsystem:* - When the sensor itself is power hungry then reducing communication is not enough.

1.3 ROUTING PROTOCOLS IN WSN

Routing is more challenging in wireless sensor networks these days due to following reasons. First, Sensor node requires careful management of resources. Second, wireless sensor networks are quite functioning specific. Third, position of sensor nodes should be known at the time of data collection. Fourth, Data collected at the base station has higher possibility of redundancy [1]. Due to such disparities, various routing algorithms have been developed. The routing protocols can be divided into four main categories: Network Structure Scheme, Communication Model Scheme, Topology Based Scheme and Reliable Routing Scheme [1], as shown in Figure 1.3.

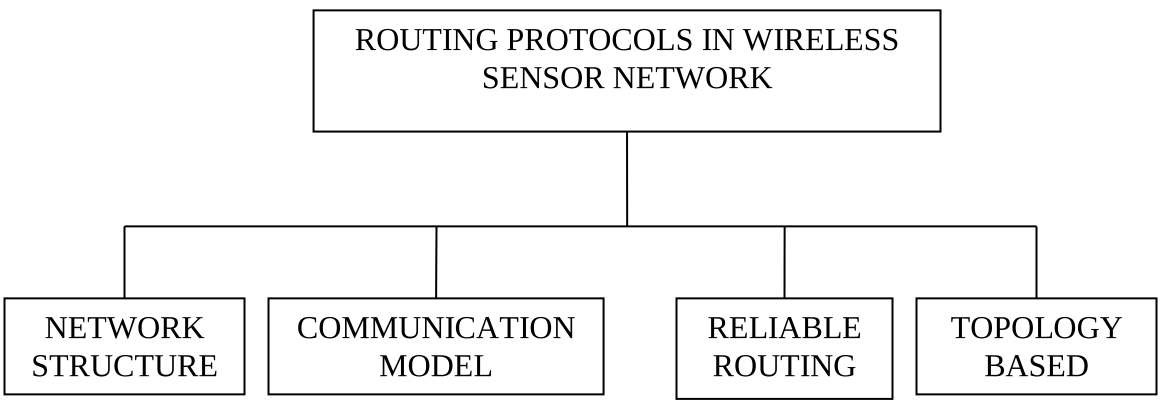

Figure 1.3: Routing Protocols in WSN (redrawn from [1])

1.3.1 NETWORK STRUCTURE: - The protocols based on network structure can be classified on the basis of node uniformity. The nodes when are deployed uniformly over an area to form a network. Some networks consider that all the nodes are same as each other, while some other systems make difference between other nodes of the network [5]. This class includes flat and hierarchical protocols.

1.3.1.1 Flat Protocols: - Every one of the nodes in the system assume the comparative part [5]. Level system design displays a few points of interest, including least overhead to safeguard the framework between conveying nodes. It is categorized as Re-active and Pro-active protocols.

i *Pro-active Protocols:* - Also called table-driven protocols. These protocols are similar to wired network. The nodes periodically exchange data between themselves and generate a routing table that is utilized to search the path to destination. These tables respond to the changes in the system by sending updates all through the network [1].

For example, *Wireless Routing Protocol (WRP)* is a routing protocol which is table based, which takes all of its properties from Bellman Ford algorithm. It keeps a modern view of system by utilizing a set of tables. These tables are distance table, routing table, link cost table, and message re-transmission list [1].

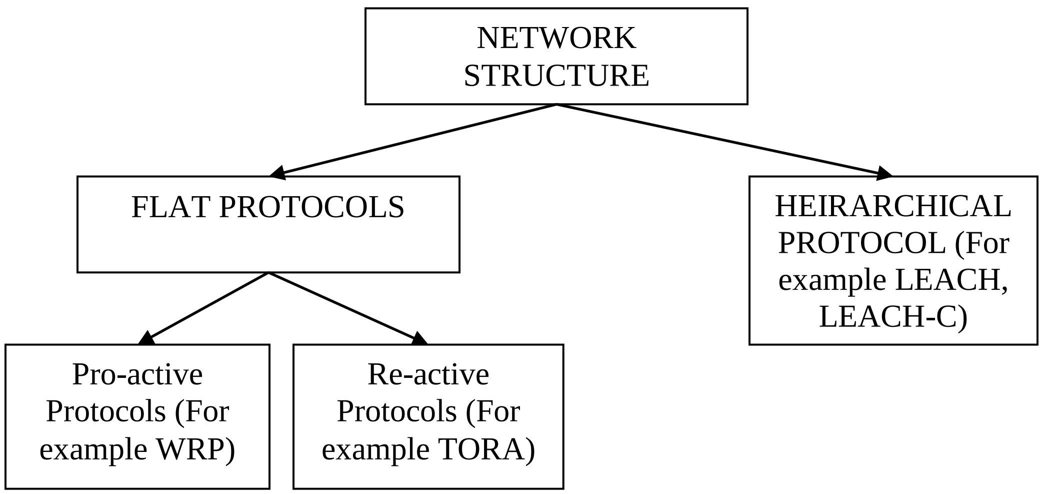

Figure 1.4: Classification of Network Structure Scheme

ii *Re-active Protocols:* - It is also called source-initiated routing. The conventions in this class begin course disclosure method when required. At the point when a course from source to goal is required a worldwide pursuit system begins, this procedure causes delay as the courses are not accessible and must be found [1]. Sometimes routes are found in caches maintained by the sensor nodes.

1.3.1.2 Hierarchical Protocols: - It is also called Cluster Based Routing. The network nodes are organized into clusters and based on some criteria a cluster head for each cluster is selected [1] i.e. higher energy nodes are used to route the data, and lower energy nodes are used to sense the area. Figure 1.5 illustrates the clustering based scheme of the wireless sensor network. The cluster heads are then responsible for organizing the activities within the cluster. Here, in hierarchical routing the no. of messages which are transferred to base station are decreased due to fusion and data aggregation thus it lowers the energy consumption and hence helps to improve the lifetime of the network [5]. In such protocols the energy of the nodes which are around the base station and cluster head will exhaust faster than all the other nodes.

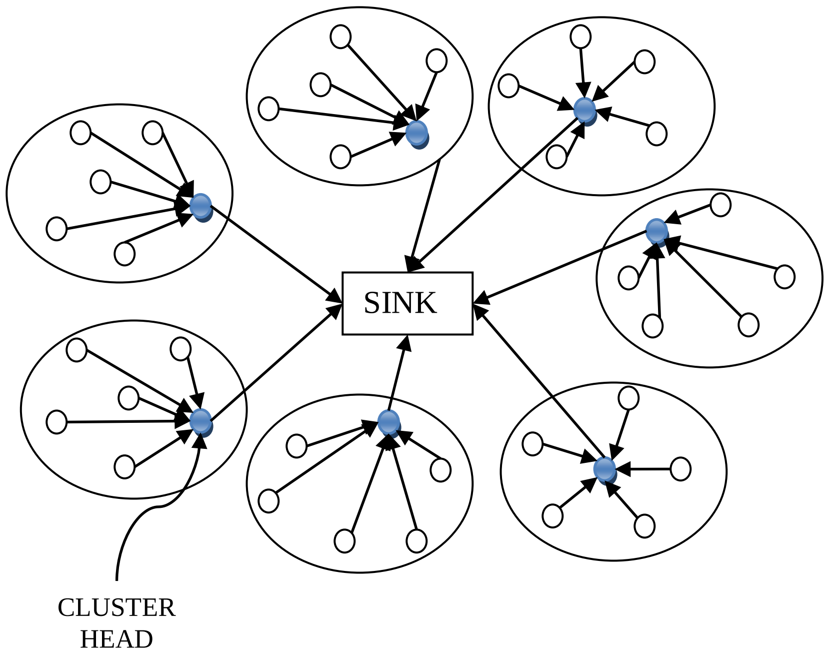

Figure 1.5: Clustering Schema for Wireless Sensor Network (redrawn from [6]).

Some of the well-known protocols under this section are: -

i. *Low Energy Adaptive Clustering Hierarchy (LEACH):* - LEACH is a clustering based algorithm. Key features of LEACH are [7]: - First, to reduce the global communication it uses local compression. Second, it uses randomized rotation for making clusters. Third, for cluster setup and other operations localized coordination and control is required. Unlike, the conventional clustering algorithm, LEACH is self-organizing, adaptive clustering algorithm [8]. To distribute the energy load amongst the sensor it uses a process of randomization.

The purpose of using randomized rotation for selecting cluster heads is –as in conventional clustering algorithm number of clusters are fixed, and the unlucky sensor nodes chosen as cluster head will die or deplete their energy quickly. These sensor nodes broadcast messages to other nodes of the network. The non-cluster head nodes have to decide to which cluster it wants to belongs by choosing the cluster heads which require less energy for communication. Also, the nodes that have become the cluster head drain their battery a little fast. So, to spread the energy usage the cluster head is changed in every round.

The operation of LEACH protocols is divided into rounds and every round is broken into two phases the setup phase where the clusters are organized and steady state phase when actually the data is transferred to the base station [9].

Setup phase – At this phase, adaptive clusters are created. Now of time all the sensor hubs choose whether to wind up a group set out toward this specific round in light of the two things. In the first place - likelihood factor that is pre-decided; and Second – how frequently the hub has moved toward becoming group head up until now. The sensor hub n needs to pick an arbitrary number in the vicinity of 0 and 1. In view of the limit condition introduced in eqn. (1.1) the hub can progress toward becoming bunch set out toward the current round [7].

$$T(n) = \begin{cases} \frac{p}{1-p*\left(r \bmod \frac{1}{p}\right)} & for\ n\ \in G \\ 0 & otherwise \end{cases} \qquad (1.1)$$

Where p is the percentage of cluster head (default value = 0.5),

G is the set of nodes that have not become cluster head for the last 1/p rounds.

i.e. the node will become cluster head when the arbitrary number selected by the node is lesser than or equals to T (n) and n ϵ G. All the nodes are permitted to become cluster head at the very first round, and the nodes that have become cluster head for the first round are not chosen cluster head for next $\frac{1}{p}$ rounds, it means other nodes have increased probability of becoming cluster heads. Each node that has been elected as cluster head for the present round a message is broadcasted to the rest of the nodes. The advertisement heard with the largest signal strength is the one to whom the minimum amount of transmitted energy is required for communication [7]. Next is all the nodes have to respond to the corresponding cluster heads that node will become a member of the cluster. CSMA-MAC protocol is again used by these non-cluster head nodes to send this information back.

Steady State Phase – When the TDMA schedule is fixed the data transmission begins. It is expected that the nodes dependably have information to send, they send it in the transmission time assigned to them. The ratio of non-cluster head nodes can be killed until the point that the node's apportioned transmission time [7]. This helps in minimizing the energy dissipation of the network, hence improving the lifetime of the network. When the data from all the nodes is received by the cluster heads, it performs signal processing functions to compress the data into single signal. This composite signal is then sent to the base station.

ii. *Low Energy Adaptive Clustering Hierarchy Centralized (Leach-C):* - Since LEACH has a problem of determining the no. of group heads in every round. For the formation of the clusters, LEACH-C uses the base-station [1]. LEACH- C is an enhancement over LEACH by the accompanying focuses: First, to create clusters that needs less vitality for transfer Base-Station uses it worldwide learning of the system, Second, not at all like LEACH where the quantity of cluster head shifts from round to round because of absence of worldwide coordination among nodes, in LEACH-C the quantity of cluster heads in each round equivalents a foreordained ideal esteem. [1].

iii. *PEGASIS:* S. Lindsey and others have invented a protocol, i.e. Power Efficient Gathering in Sensor Information Systems (PEGASIS), which was an enhancement over the LEACH protocol. This convention is a close ideal chain-based convention. PEGASIS exceeds LEACH'S execution by (1) cleansing the overhead of dynamic bunch development, (2) diminishing the separation non pioneer hubs must transfer, (3) decreasing the quantity of transmissions among all hubs, and (4) utilizing just a single transmission to the base station per round. Essential objectives in the activity PEGASIS are (a) enlarge the lifetime of every sensor hub by utilizing synergistic strategies (b) decreasing the transmission capacity of correspondence by permitting nearby coordination among nearby sensor nodes. The execution assessment in [8] demonstrates that PEGASIS can upgrade the sensor arrange lifetime twice as much as the system actualizing LEACH convention.

iv. *Reactive Network Protocol: TEEN:* In this division, a new network protocol called TEEN (Threshold sensitive Energy Efficient Sensor Network protocol) is presented. It is focused at receptive systems and is the principal convention created for responsive systems. In this plan, at each bunch change time, notwithstanding the characteristics, the groups make a beeline for its members.

Table 1.1 shows the comparison of various hierarchical routing protocols in WSNs.

LEACH, LEACH-C, TEEN, SEP and DEEC is compared based on various performance criteria such as architecture, cluster stability, cluster head selection criteria, heterogeneity level, number of hops and network global knowledge. TEEN shows very high cluster stability as compared to other protocol and it does not require any global knowledge.

Table 1.1: Comparison of various Routing Protocols

Performance Criteria	**LEACH**	**LEACH-C**	**TEEN**	**SEP**	**DEEC**
Architecture	Distributed	Centralized	Distributed	Distributed	Distributed
Cluster Stability	Lower	Higher than LEACH	Very High	Moderate	High
CH Selection Criterion	Probabilistic Approach	Nodes Energy and Distance	Randomly	Based on Initial and Residual Energy	Initial, Residual and Average Energy
Heterogeneity Level	Not present	Not present	Not present	Two-level	Multilevel
Number of Hops	Single Hop	Single Hop	Multi-Hop	Multi-Hop	Multi-Hop
Network Global Knowledge	Not Required	Required	Not Required	Not Required	Not Required

1.3.2 COMMUNICATION MODEL: - The Communication Model adjusted in a directing protocol, depends in transit the information is steered towards the base station as bundles. For a measure of energy, the protocols of this class can convey more information [10]. The issue with the class of protocols is that their conveyance proportion is low, and they don't ensure the conveyance of information. This class incorporates query based, negotiation based, and coherent and non-coherent based protocols.

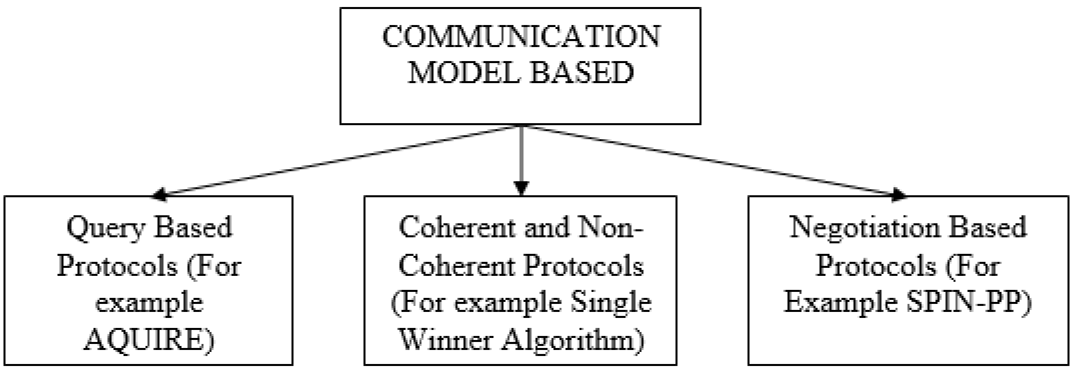

Figure 1.6 Classification of Communication Model Based Scheme.

1.3.2.1 Query-Based Protocols: - As the name propose, in these protocols the goal hub communicate an inquiry for a few information from a node (present in the network) called intermediate node, all through the system. Then again in the wake of accepting the communicate message the node containing the information (that coordinates the query) sends the information to the intermediate hub to pass it to the destination node.

For example, *Active Query Forwarding in Sensor Network (AQUIRE)* sees a network as the scattered database. The sensor nodes receive the query from the Base-Station.

1.3.2.2 Coherent and Non-Coherent-Based Protocols: - The protocols that belong to this class have a bit different functioning. In coherent routing, the data is forwarded to the aggregators after some minimum processing, this minimum processing includes task like time stamping and duplicate suppression. However, in non-coherent routing nodes handle the raw data privately and then it is transmitted to different nodes for additional processing [12].

For instance, *Single Winner Algorithm (SWE)* chooses a solitary aggregator for tough processing. The nodes that have effectively received them will begin contrasting themselves with the applicants proposed and react. The message that speaks to a superior competitor is enlisted and can be sent to all nodes. A minimum hop spanning tree will cover the network by the end of this SWE process.

1.3.2.3 Negotiation-Based Protocols: - To decrease the discharged transmissions in the system meta-data negotiations are used by these protocols.

For example, *Sensor Protocols for Information via Negotiation – Point to Point Communication (SPIN- PP)*, two nodes in the network can communicate with one another without any intervention. The protocol is a 3-way handshake protocol without any energy consideration. When the node has few new data; it uses ADV message for advertising to its neighbours. The nodes receiving the ADV message checks the meta-data to verify if the data is present. If not, the node sends a REQ message. Thus originating node sends the data through DATA messages containing the requested data [12].

1.3.3 TOPOLOGY BASED PROTOCOLS: - The protocols belonging to this class uses a principle that every node present in the network has to maintain the topology information of the network, also the main course of action of the protocol is based on the topology of the network. This class further includes the following protocols: -

1.3.3.1 Location-Based Protocols: - These protocols have an advantage over the others, the nodes here have position information. The protocol here finds the path between source and destination and helps in minimizing the total energy consumption of the sensor nodes of the network.

For example, *Geographic and Energy Aware Routing (GEAR)* uses energy aware and geologically informed neighbour’s choice to route the packets [13]. It has two characteristics –

i. When all the nodes are far from the destination it is a hole and GEAR picks the route that minimizes the cost.

ii. When a closer neighbour to the destination exists than GEAR picks that node as a next hop to destination.

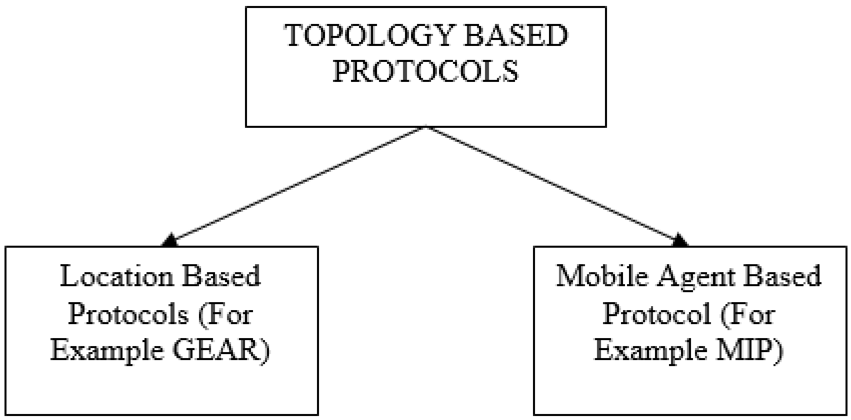

Figure 1.7: Classification of Topology Based Scheme

1.3.3.2 Mobile Agent-Based Protocols: - These sorts of protocols in WSN are utilized to course the information from the detected zone to the destination. The primary segment of these portable specialist frameworks are the versatile operators that make a float among the nodes of the network to play out the assignment autonomously, whimsically and shrewdly, in light of the ecological conditions [14].

1.3.4 RELIABLE ROUTING: - The protocols are very flexible of this class to route the failures by either attaining load balancing routes or by satisfying QoS metrics, as bandwidth, delay and energy. This routing scheme includes multipath based and quality of service based protocols.

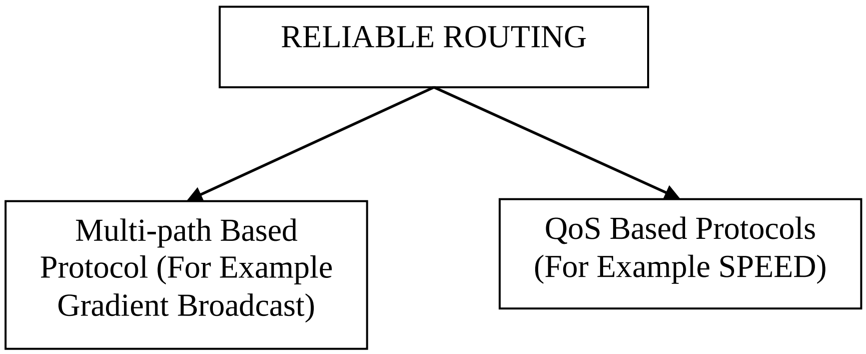

Figure 1.8: Classification of Reliable Routing Scheme

1.3.4.1 Multipath-Based Protocols: - At the time of increased data traffic these kind of protocols are used to achieve Load balancing so that the network does not suffer route failures.

For example, *Gradient Broadcast (GRAB)* is intended for enthusiastic data conveyance and to manage temperamental nodes and flawed remote connections. The receiver node receives the packet and cost is calculated by adding its cost of link to the sender advertisement cost. It compares the new and the previous cost and set the new cost (smaller of the two). As the cost obtained is smaller it broadcast an ADV message to other nodes containing the new cost.

1.3.4.2 QoS-Based Protocols: - These types of protocols are used in WSN to maintain the data quality. In this way the protocols here need to keep up the harmony between energy utilization and data quality [5].

For example, *SPEED Protocol* provides avoidance of the congestion when the network is very congested. Under heavy traffic load the energy consumption of SPEED is higher. But it delivers higher number of packets than other protocols at the time of overcrowding.

1.4 APPLICATIONS OF WIRELESS SENSOR NETWORKS

Wireless sensor networks are utilized as a part of assortment of regular daily existence exercises or administrations. The most widely recognized utilization of WSN is for checking where we randomly send a few nodes to screen some phenomenon. We classify the uses of WSN in military, health home, environment and other commercial areas [15-16].

i. *Military Applications:* - Wireless sensor networks could be an essential piece of military Command, Intelligence, Control, Computing, Communication, Surveillance, Targeting and Reconnaissance. The quick sending, self-association and adaptation to internal failure attributes of sensor networks make them an extremely encouraging detecting procedure for military. The military uses of sensor networks are biological and chemical attack detection, monitoring friendly forces, battle damage assessment, targeting and so on.

ii. *Environmental Applications:* - The environmental applications of WSN are tracking the movement of flying creatures, monitoring the environmental conditions that effect crops and livestock's, precision agriculture, pollution study, forest fire detection, meteorological or geophysical research, bio-complexity mapping of the environment.

iii. *Health Applications:* - This area of WSN provide interfaces for the disabled, integrated patient monitoring, tracking and monitoring doctors and patients inside the hospital, it additionally offers noteworthy cost sparing and empower new functionalities that will help individuals with unending sickness on every day exercises etc. [15].

iv. *Home Applications:* -Home applications include automation and smart environment. In home automation the sensors are buried in the domestic devices that will help them to interact with each other and with the external environment via internet. And it will allow user to coordinate these devices locally and remotely [16].

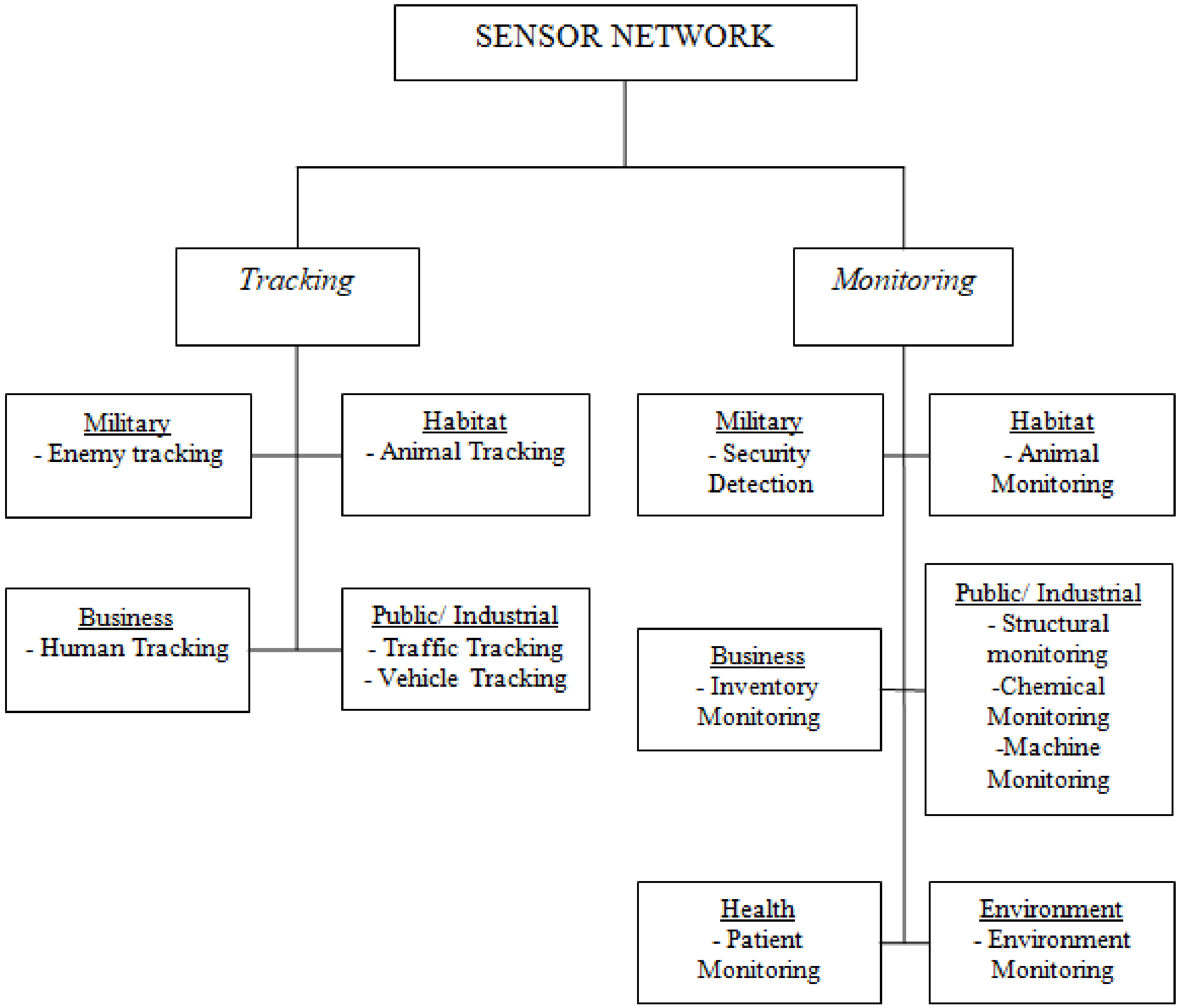

Figure 1.9: Overview of Sensor Network Applications (redrawn from [16]).

1.5 CRITICAL ISSUES OF WIRELESS SENSOR NETWORKS

The primary outline objective of WSN is to not just transmit the data amongst source and destination but at the same time is to build the network lifetime; which can have accomplished by applying energy effective protocols. The task of the protocol is not only to choose a path having lower energy consumption between sources to destination (BS), but also to search an efficient technique to prolong the system lifetime.

Performance of the routing protocol is calculated based on some terms which includes [17-20]: -

i. Energy per Packet
ii. Low Energy Consumption
iii. Total Number of Nodes Alive
iv. Average Packet Delay
v. Energy Spent Per Round
vi. Packet Size

CHAPTER - 2

LITERATURE REVIEW

Pantazis et.al [1], The paper clarifies energy effective routing protocols have been proposed for WSNs which depend on four fundamental plans: Network Structure, Topology Based, Communication Model and Reliable Routing. The paper further discusses various protocols and their mechanism based on the above schemes. These protocols are proactive protocols, reactive protocols, wireless routing protocols, TORA, LEACH, PEGASIS, TEEN, APTEEN, TT-DD, DD, ACQUIRE, SWE, MWE, SPIN-PP, SPIN-RL, GEAR, GDSTR, IGF, GEM, MGR, DGR, GRAB etc.

The authors in [2] have focused on the key issues of wireless sensor networks, types of sensor networks, its applications, internal sensor system, network services, and the communication protocols used. The authors also discussed the application of WSN in brief which basically includes tracking and monitoring of event in various areas like military, health, habitat, industrial, and business etc.

In [3] the authors describe the concept of sensor network, as the recent advancements in the wireless communication systems have facilitated the development of those multifunctional sensor nodes which are of small size and communicate in short distance. The paper then illustrates the differences in ad-hoc networks and wireless sensor network. Then, the authors have discussed the communication architecture for sensor networks. It includes application layer, transport layer, network layer, data link layer, physical layer. It also includes power management plane, mobility management plane, and task management plane.

Anastasi et.al [4], the paper discusses the sensor network and sensor node architecture. At that point, the paper portrays a methodical and far reaching scientific classification of the energy protection plans like obligation cycling which incorporates topology based protocols and rest and wakeup protocols, versatility which incorporates versatile sink based methodologies and versatile transfer based methodologies, and data driven methodologies which incorporates data expectation and energy proficient data securing approaches.

The author in [5] discusses the node and the network level architecture of the wireless sensor network. They also discuss the design of a typical sensor node. The paper also discusses the routing challenges in wireless sensor networks which include scalability, node deployment, link heterogeneity, network dynamics, fault tolerance, etc. the paper also describes various routing protocols divided on the basis of network structure and protocol operation. Network structure includes Flat based, Location based and Hierarchical based protocols.

In [6] the authors provide a brief introduction of clustering based algorithms like LEACH, LEACH-C, and PEGASIS. According the authors LEACH-C is one of the powerful (essential) parameters in network life time in light of energy expending esteem convention. Accordingly, the paper talks about another way to deal with bunching wireless sensor networks and deciding cluster heads. The calculation that is proposed by the creators depends on unified clustering. Clusters are made in light of every node's energy. Development of the creator's technique is in appropriate portrayal of chromosomes and furthermore in deciding legitimate wellness work as per issue highlights in light of energy measure.

In [7], On the basis of finding of author and some certain factors it has been concluded that all the conventional protocols of direct transmission, minimum transmission energy, multi-hop routing and static clustering are not optimal, which in turn lead to large amount of energy dissipation and decreased network lifetime. In addition, the authors provide the energy analysis of these routing protocols. So they have proposed a new algorithm called LEACH (Low Energy Adaptive Clustering Hierarchy) which is a clustering based protocol and utilized randomized rotation of local cluster heads so that the energy load is evenly distributed amongst the network. LEACH algorithm is also self-organized adaptive clustering algorithm. Based on these factors leach provides less energy consumption and longevity of the network.

Bhattacharya et.al [8], the paper describes that a wireless sensor networks is the collection of tiny sensor nodes and energy consumption still is the key concern in the field. As per authors expanding the lifetime of wireless sensor networks is a noteworthy test in light of the fact that the nodes are furnished with low power battery. For expanding the lifetime of the sensor nodes energy proficient routing is one arrangement which limits upkeep cost and boosts the general execution of the nodes. Productive battery use strategies and release qualities are then portrayed in the paper, which as indicated by the authors upgrades the operational battery lifetime.

W. Wang *et al.* [10] presented a survey on methods used for reducing energy holes' problem in wireless sensor networks(WSN). It has been concluded that among all techniques non-uniform distribution strategy has been most effective technique. However, any of the technique is not capable to completely removing the holes from the network. Non-uniform distribution energy has improved network lifespan and data delivery ratio but it is costly. Clustering techniques provides fair load balancing but some region may remain uncovered. By using different probability distributions for nodes deployment network lifetime can be maximized. An energy holes removing method must consider spatial-temporal aspects for nodes deployment.

S. K. D. Xiaobing Wu *et al.* [11], have explored the theoretical aspects of the non-uniform node distribution strategy that addresses the energy hole problem in WSNs. Simulations showed that with the proposed non uniform node distribution strategy, the network can achieve very high energy efficiency.

Rohini Sharma *et al.* [12] demonstrated that the lifetime of the network can be expanded essentially if the versatile sink moves around the fringe of the WSN. Along these lines, they proposed an advancement issue for picking a portability technique that limits the most extreme movement heap of the nodes. Be that as it may, they accepted the briefest way routing, which, as a rule, does not create the best lifetime.

Padmalaya Nayak *et al.* [13] introduced profundity examination around two grouping routing protocols or WSN as this two protocols give fundamental building squares to bunching calculations. In this way, there is a necessity to dissect the methods that expand the network lifetime by adjusting the heap at every node. Clustering based routing convention is one such illustration. LEACH is considered as one of the main circulated bunch arrangement convention.

This convention does not give any assurance about the positions of CHs and number of CHs. As the bunch arrangements are versatile, and poor set up stage in a given round does not incredibly impact the general execution of the network.

S. R. Gandham *et al.* [16] have proposed an energy proficient use of different, portable base stations to build the lifetime of wireless sensor networks. The proposed approach utilized a number straight program to decide the areas of the base stations and a stream based routing convention. They reasoned that utilizing a thorough way to deal with improve energy usage prompts a critical increment in network lifetime. In addition, the tradeoff between arrangement quality and figuring time enables us to process close ideal arrangements inside a sensible time for the network sizes considered.

K. Akkaya *et al.* [17] introduced a repositioning approach for a portal keeping in mind the end goal to refine the general execution of a wireless sensor network(WSN) as far as mainstream metrics, for example, energy, postponement and throughput. The displayed approach considers migration of the portal by checking the movement thickness of the nodes that are one-bounce far from the door and their separation from the entryway. Recreation comes about have demonstrated that such repositioning of the passage builds the normal lifetime of the nodes by diminishing the normal energy expended per packet. In addition, the normal deferral per packet is diminished fundamentally.

Young Sang Yun *et al.* [18] proposed a new framework for enhancing the lifetime of the network by exploiting delay tolerance and sink mobility. It is expected to be useful in those areas that can bear some amount of delay in data delivery.

Can Tunca [19] have displayed a complete survey of the current appropriated versatile sink routing protocols. The one of a kind difficulties related with versatile sinks and the plan necessities of a portable sink routing convention are examined in detail to give a knowledge into the inspirations and the inborn components. An exact arrangement of the protocols is given and the points of interest and downsides of the protocols are independently decided as for the execution necessities.

CHAPTER - 3

PROBLEM FORMULATION AND MOTIVATION

3.1 PROBLEM FORMULATION

Computational power and bigger energy support are the typical characteristics of the sink nodes. So, research works of the energy conservation are for the most part directed to limit the power utilization amongst the sensor and/or relay nodes [8]. Power consumption can be partitioned into three areas as per the elements of sensor nodes: detecting, communication, and data preparing. Maximum energy is expended in data communication by a sensor node out of the three areas. That prompts the research inclination in the networking zone to principally center around limiting the costs of communication in data transfer so that the ideal power efficiency can be achieved. Intermediate sensor nodes send the sensor data from the place of event occurrence into the sink. As per the data transmission model which is multi-hop, different sensors send data packages to the sink hub. Also the sensors which are nearer to the sink have to receive and forward the data from other far away sensors from the sink. The data forwarding of the sensor nodes is directly proportional to the closeness to the sink. Subsequently a considerable measure of computational and correspondence assets is required to process the information transferring work for those sensors which are near the sink, particularly those sensors that are just a single bounce far from sink, it implies that those sensors can transmit information particularly to sink node. This issue is recognized and tended as “Hotspot” issue in previous research [12], and an instance of the situation is depicted in Figure 3.1.

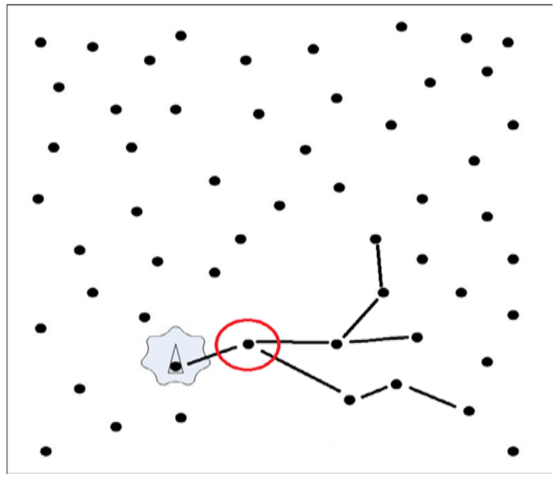

Figure 3.1: Illustration of “Hotspot Problem”

In Figure 3.1, it can be seen that the circle showing sensor node A is seen as highly stacked node. As marked by data transfer ways, that is depicted by the lines shown in the figure. The sensor A can forward the data to and from different sensors & in this manner energy spread is concentrated on the specific sensor.

3.2 MOTIVATION

Various ongoing methodologies, for decreasing energy utilization, center around moving the weight from the sensors to the sink node [12]. Rather than a great framework shows where sink node stays fixed at some place in system network & inactively get information to & from the sensors, the sink node can be enabled to be portable. The sink nodes can travel in the network region to effectively search for sensors that send the data & draw nearer to those sensors. In this way the lifetime of network can also be expanded In this manner, the energy utilization has a tendency to be all the more uniformly divided in the network and the "Hotspot" issue is lightened with the goal that the execution of network can be enhanced as far as nature & lifetime of the service [12].Problems of maximum lifetime of the network having an approach of sink mobility incorporate how the movement of sink can be controlled to accomplish more proficient data collecting both for ensuring the service quality & to lessen energy utilization.

CHAPTER - 4
METHODOLOGY

Conventional clustered routing protocols like TEEN have been using single centralized static sink as which leads to energy hole problem. To beat this issue in our system, a controlled versatile sink is utilized that guided in light of limiting the disseminated energy of all sensor nodes. Apart from mobile sink, we also include one centralized sink for data collection so that if any one of sink fails, sensor node still can send data to the other sink. For energy preservation purpose, fewer hops for data transmission is preferable so network field is partitioned into R identical regions. Furthermore, partitioning the network into small regions provide better connectivity between CHs and BS.

1. Set-up phase

In which the cluster heads (CHs) formation and its member assignment are performed. Here, before sending the aggregated data to the sink node first CH calculates two distance parameters:

a) Centralized distance (CD) is distance between the CH and the network's centralized sink.
b) Region distance (RD) is distance of CH to current region mobile sink in which the CH present. After this, CHs compare these distances and choose the minimum distance sink for data transmission.

2. Steady State Phase

Where the member node transferred data to CHs and aggregate the data; then transferred these aggregated data to the sink. In proposed framework after formation of CHs the mobile sink goes to its predefined temporary location. When mobile sink enters into a region then the sensor nodes in that region wake up, where as in remaining regions(R) node are still sleep. The sensors begin collecting the information; TDMA schedule is created by CHs for its member nodes to send the sensed data. Then, sensed data is transmitted by every node to its CHs or the sink (centralized static sink/ mobile sink) whoever is near to the sink than the CH. When all sensor nodes send their data to their respective CHs, CHs perform data aggregation operation after that CHs sends their aggregated data to the minimum distance sink node. After a predefined time called sojourn time, mobile sink moves to the next region sojourn location for collection of data in this region. Until all the R regions are visited this process is repeated. After completion of all regions, first round of the mobile sink completed then to begin the new round the mobile sink again starts with the first region. Here, firstly sensor network divided into 4 equal regions to perform the routing as shown in Figure 4.1.

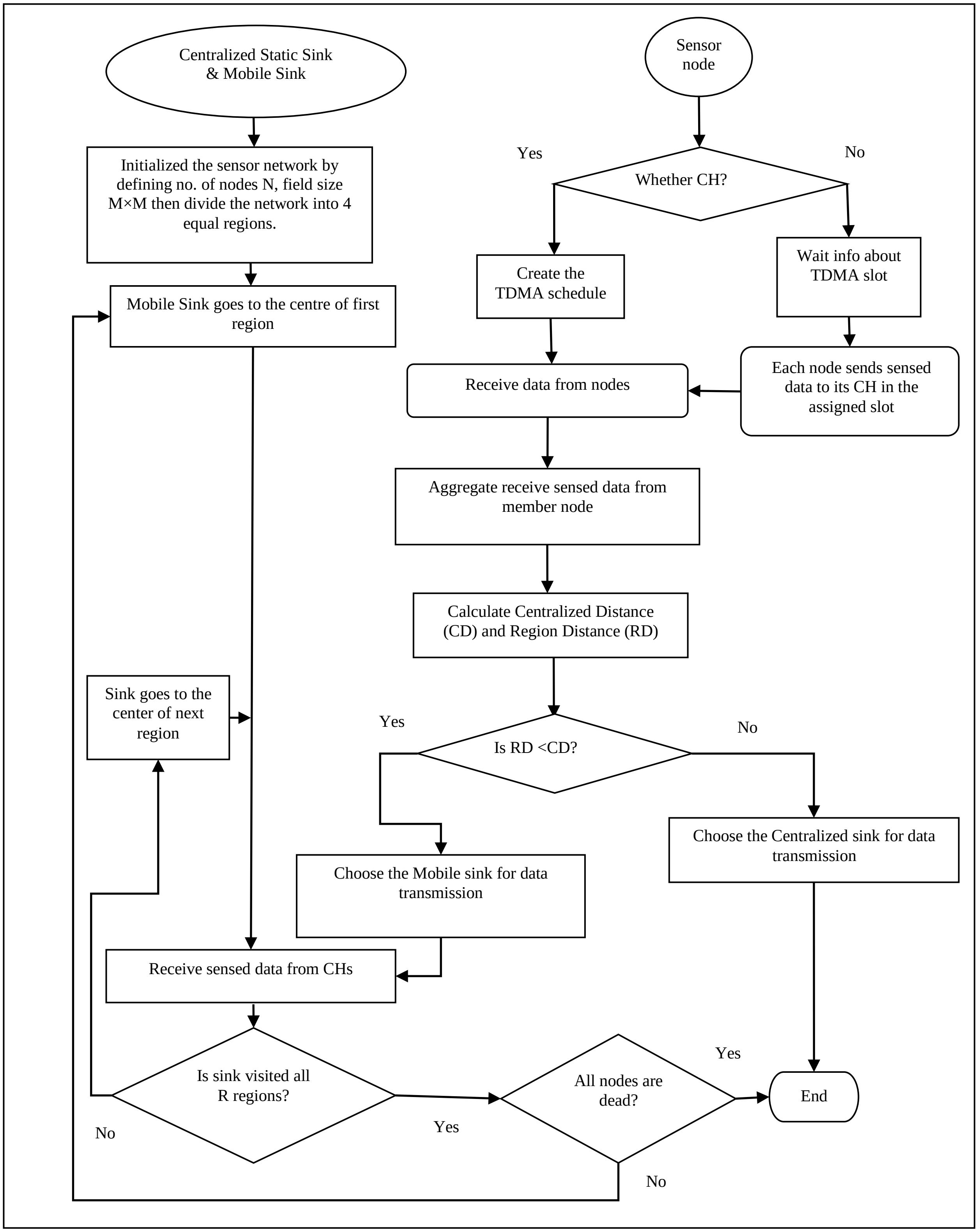

Figure 4.1 Framework of proposed sink mobility (four different positions)

CHAPTER 5
RESULTS ANALYSIS

Performance analysis of TEEN protocols with mobile sink is performed using MATLAB R2017a. The simulation has been experimented on a sensor network of different sizes i.e. 150m×150m, 250m×250m and 350m×350m with randomly deployed 200,300 and 400 sensor nodes. Here, we considered two cases for sink position -

1) Stationary sink placed at middle of the network field (Centralized static network sink).
2) 4 sojourn positions movable sink with 1 centralized stationary sink.

In the first case, all the cluster head directly sends the aggregated data from their members to the centralized stationary sink. In the second case, cluster head firstly compares the distance to the network's centralized sink with the distance to the region's centralized sink in which the cluster head is present. After the selection of sink with minimum distance, CHs send aggregated data to the selected sink. The radio parameters which are used in the simulations are listed in Table 5.1.

The simulation parameters for 150m×150m area are given in table 5.1. Total number of nodes taken for simulation are 200 with initial energy 1 joule. Size of data packet is taken as 4000 bits and probability to become cluster head is taken as 0.1.

Table 5.1: Network Parameters for 150m x 150m Area

PARAMETERS	Values
Area	150m ×150m
No of Nodes	200
Initial Energy Per Node	1 J
Total Energy	200 J
Transmission energy, E_{TX}	50nJ/bit
Receiving Energy, E_{RX}	50nJ/bit
Data Aggregation Energy, E_{DA}	5 n J/b/message
Probability of Becoming Cluster Head Per Round	0.1
Size of Data Packets	4000 bits
Threshold distance, d_0	87.7m
Transmit Amplifier Energy	
Energy for Free Space Loss, E_{FS}	0.0013 p J/b/m^4
Energy for Multi-path Loss, E_{MP}	10pJ/b/m^2

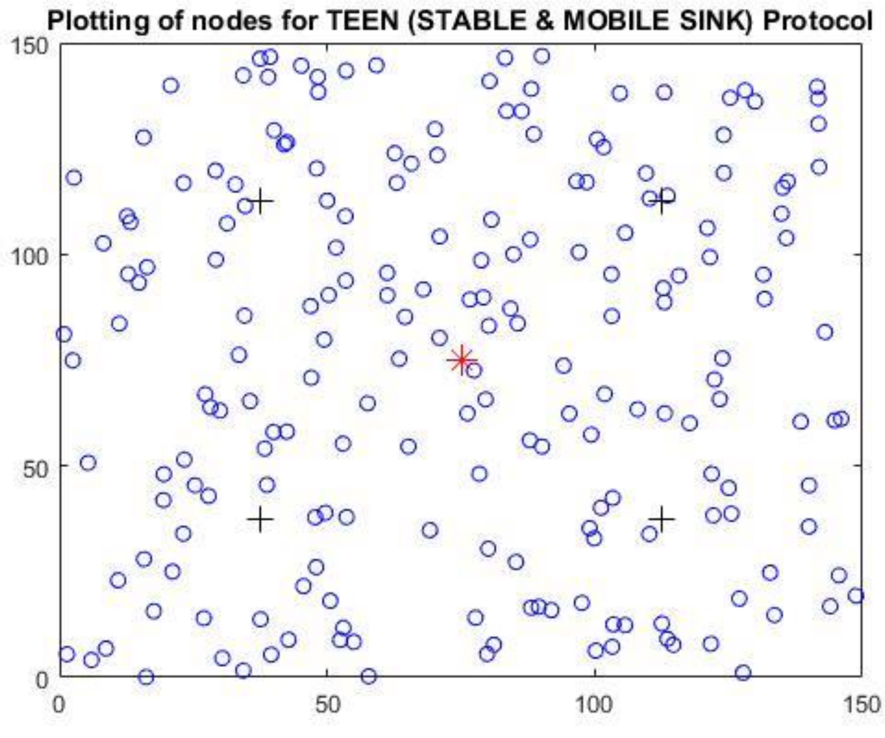

Figure 5.1: Random deployment of nodes and Positions of Mobile Sink and Stable Sink for TEEN protocol in an area of 150m×150m

Figure 5.1 demonstrates the deployment of nodes and base station in a specific area. The region we have taken for simulation is 150m×150m. The 'o' symbol denotes the nodes and '*' symbol denotes the position of static base station (sink) and '+' symbol denotes the various positions of mobile sink.

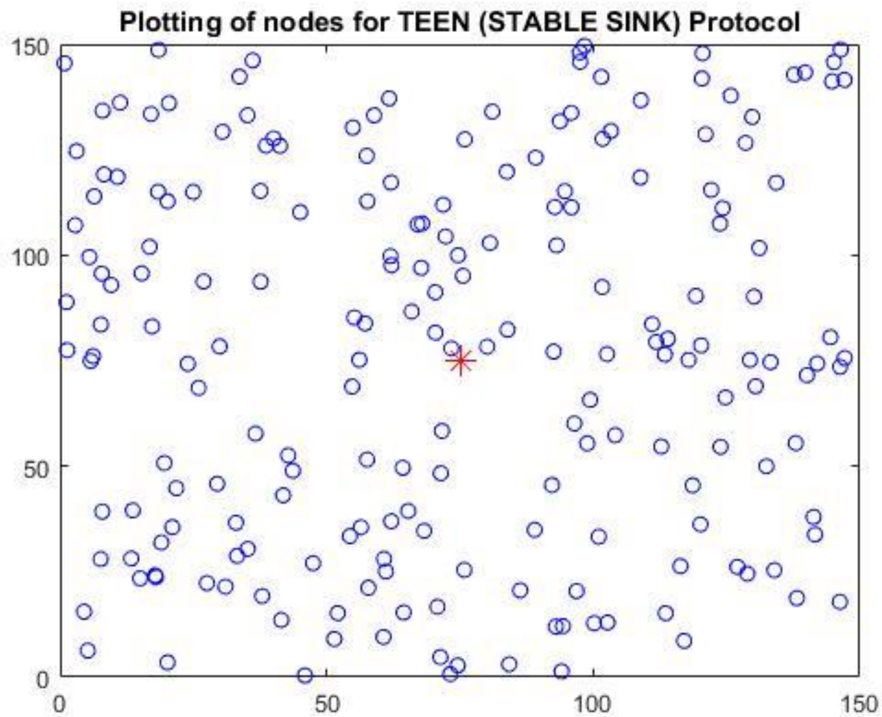

Figure 5.2: Random deployment of nodes and position of Stable Sink for TEEN protocol in an area of 150m×150m

Figure 5.2 demonstrates the deployment of nodes and base station in a specific area. The region we have taken for simulation is 150m×150m. The 'o' symbol denotes the nodes and '*' symbol denotes the position of static base station (sink).

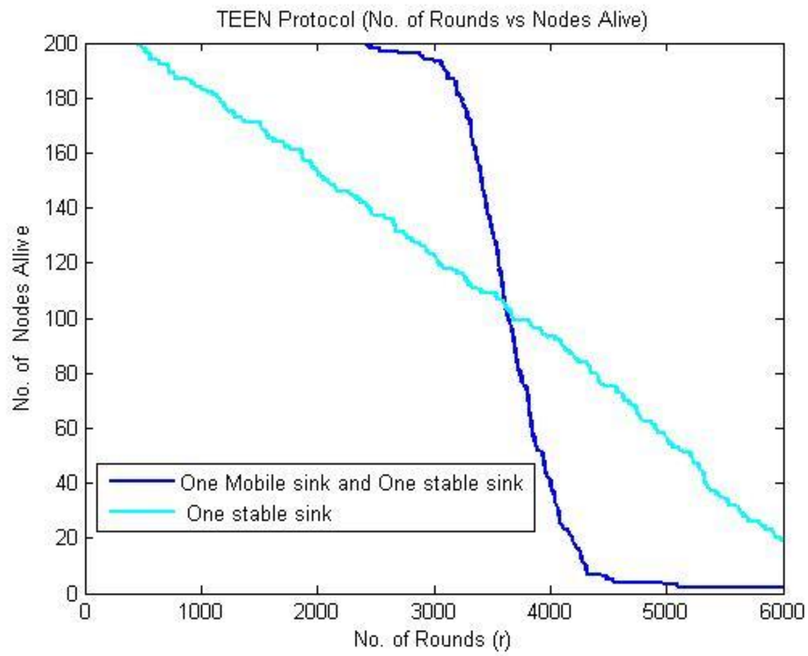

Figure 5.3: Number of Nodes Alive per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 150m×150m

Figure 5.3 shows the network lifetime, from the figure 5.3 it’s clear that the number of alive nodes are higher when mobile sink and stable sink are used in combination as compared to one stable sink.

Figure 5.4 shows the network lifetime. from the figure 5.4 it’s clear that the first node dies very earlier when one stable sink is used as compared to mobile sink and stable sink when used in combination

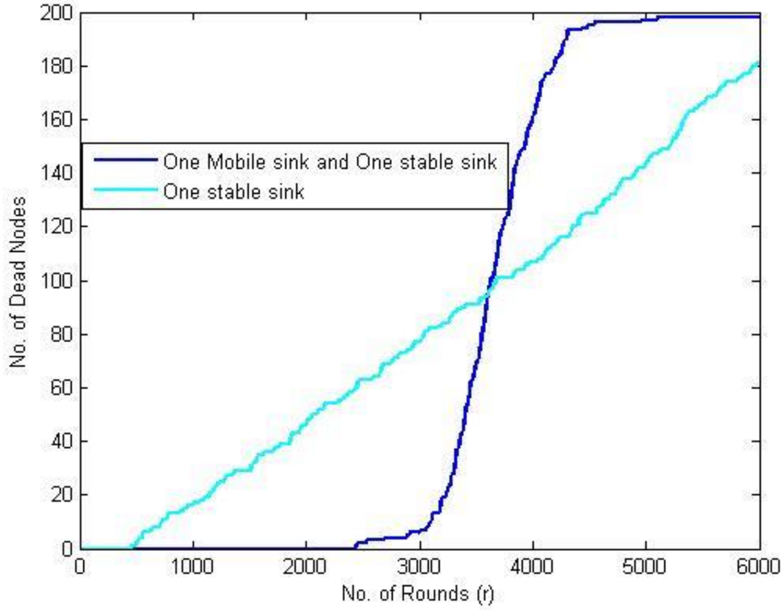

Figure 5.4: Number of Dead Nodes per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 150m×150m

Figure 5.5 shows energy consumption per round by the network. Energy consumption ratio per round is stable in both the cases. However, after 2500 rounds, energy consumption is higher in case of mobile sink strategy.

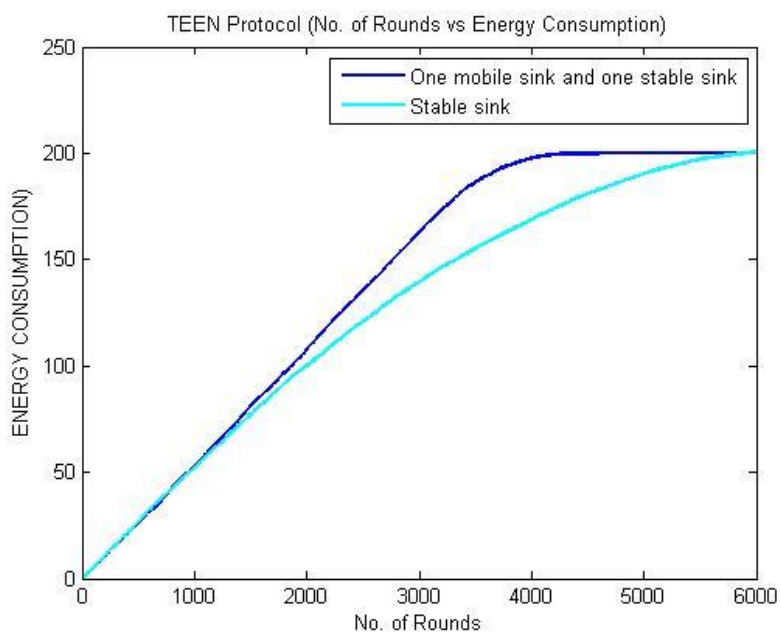

Figure 5.5: Energy consumption per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 150m×150m

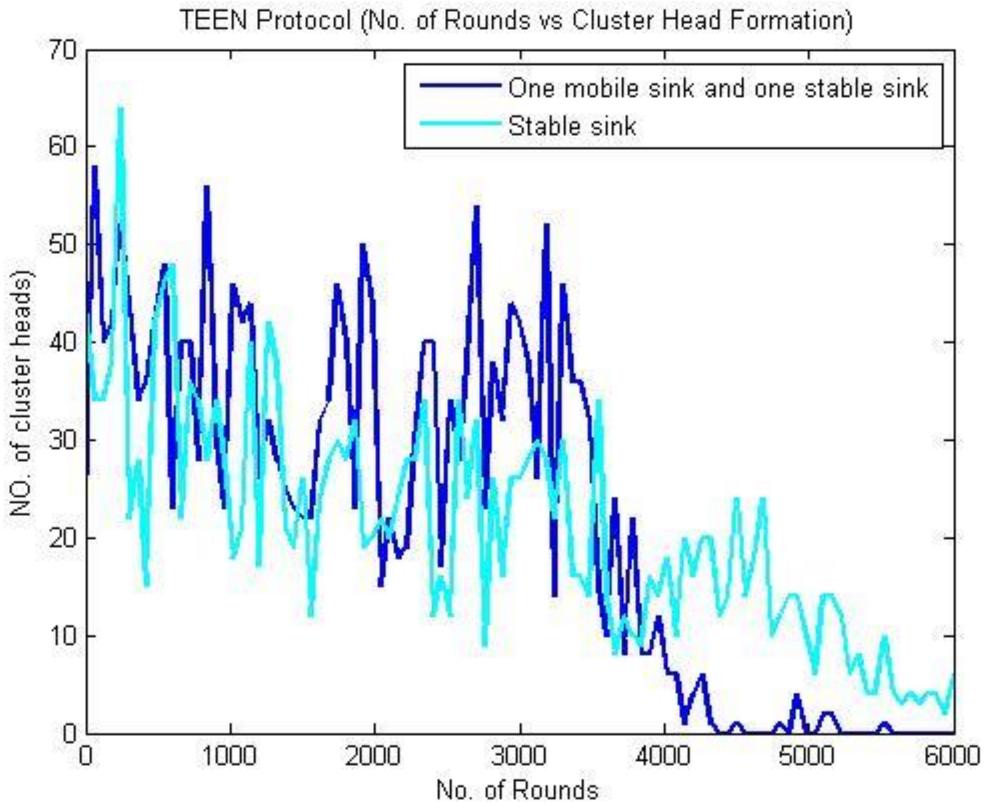

Figure 5.6: Cluster head formation per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 150m×150m

Figure 5.6 shows Cluster head formation per round for Stable Sink and Mobile Sink for TEEN protocol in an area 150m×150m. Cluster head formation is quite similar in both the techniques, but after 3800 rounds the cluster head formation is higher in TEEN protocol with stable sink as compared to stable and mobile sink strategy.

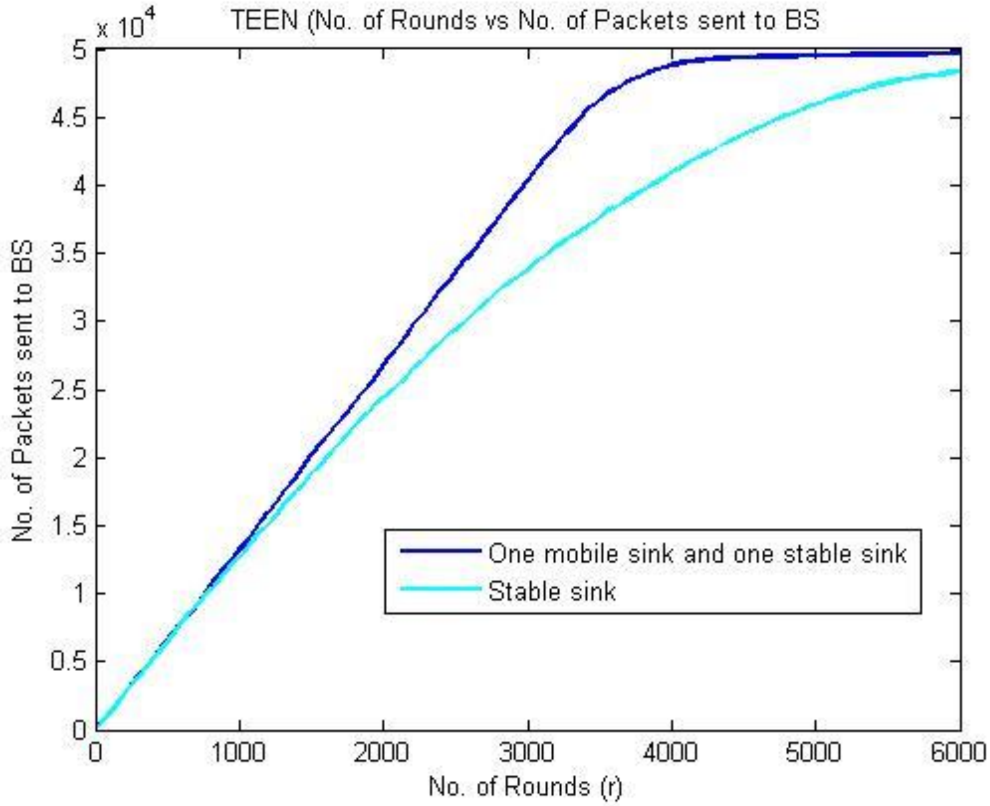

Figure 5.7: No. of the packets which are sent to the base station for Stable Sink & Mobile Sink for TEEN protocol in an area of 150m×150m

Figure 5.7 shows No. of the packets which are sent to the base station for Stable Sink & Mobile Sink for TEEN protocol in an area 150m×150m. No. of packets sent to the base station is higher in case of mobile & stable sink strategy because mobile sink tries to collect as much data by the nearest cluster heads so that data would not get lost. The mobile sink strategy will make the protocol more reliable.

The simulation parameters for 250m×250m area are given in table 5.2. Total number of nodes taken for simulation are 300 with initial energy 1 joule. Size of data packet is taken as 4000 bits and probability to become cluster head is taken as 0.1.

Table 5.2: Network Parameter for 250m×250m Area

PARAMETERS	Values
Area	250m ×250m
No of Nodes	300
Initial Energy Per Node	1 J
Total Energy	300 J
Transmission energy, E_{TX}	50nJ/bit
Receiving Energy, E_{RX}	50nJ/bit
Data Aggregation Energy, E_{DA}	5 n J/b/message
Probability of Becoming Cluster Head Per Round	0.1
Size of Data Packets	4000 bits
Threshold distance, d_0	87.7m
Transmit Amplifier Energy	
Energy for Free Space Loss, E_{FS}	0.0013 p J/b/m^4
Energy for Multi-path Loss, E_{MP}	10pJ/b/m^2

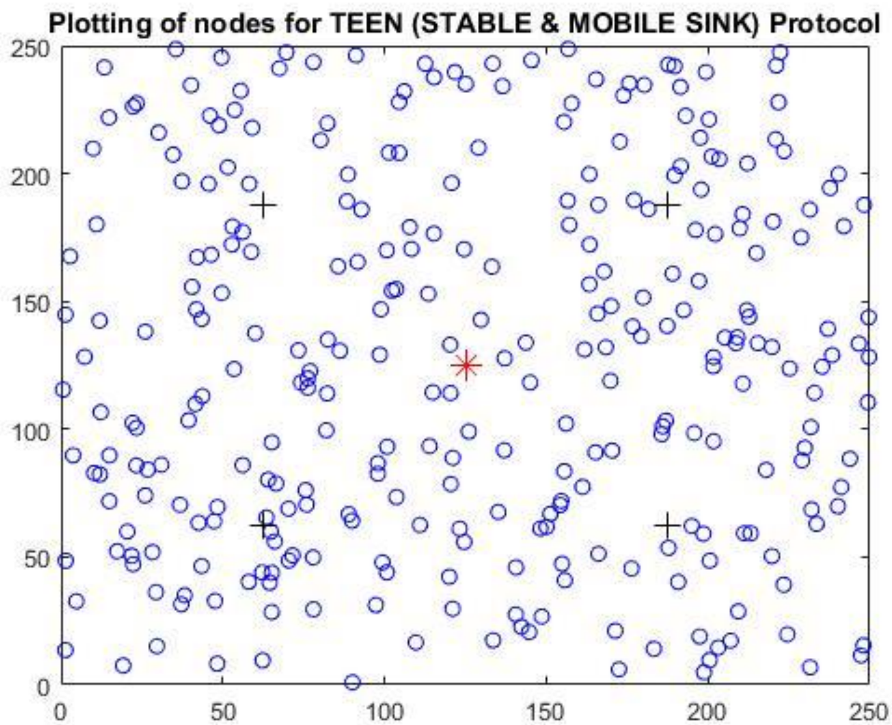

Figure 5.8: Random deployment of nodes and Positions of Mobile Sink and Stable Sink for TEEN protocol in an area of 250m×250m

Figure 5.8 demonstrates the deployment of nodes and base station in a specific area. The region we have taken for simulation is 250m×250m. The ‘o’ symbol denotes the nodes and ‘*’ symbol denotes the position of static base station (sink) and '+' symbol denotes the various positions of mobile sink.

Figure 5.9 demonstrates the deployment of nodes and base station in a specific area. The region we have taken for simulation is 250m×250m. The ‘o’ symbol denotes the nodes and ‘*’ symbol denotes the position of static base station (sink).

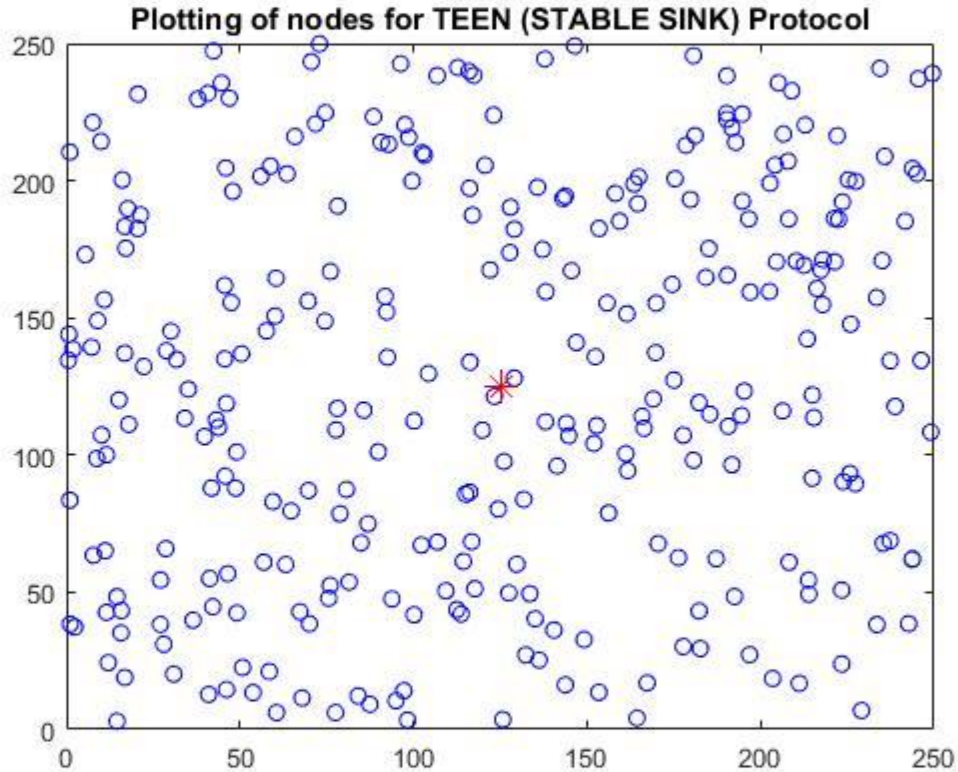

Figure 5.9: Random deployment of nodes and position of Stable Sink for TEEN protocol in an area of 250m×250m

Figure 5.10 shows the network lifetime. From the figure 5.10, it’s clear that the number of alive nodes are higher when mobile sink and stable sink are used in combination as compared to one stable sink. Number of Nodes Alive per round for Stable Sink and Mobile Sink for TEEN protocol in an area 250m×250m.

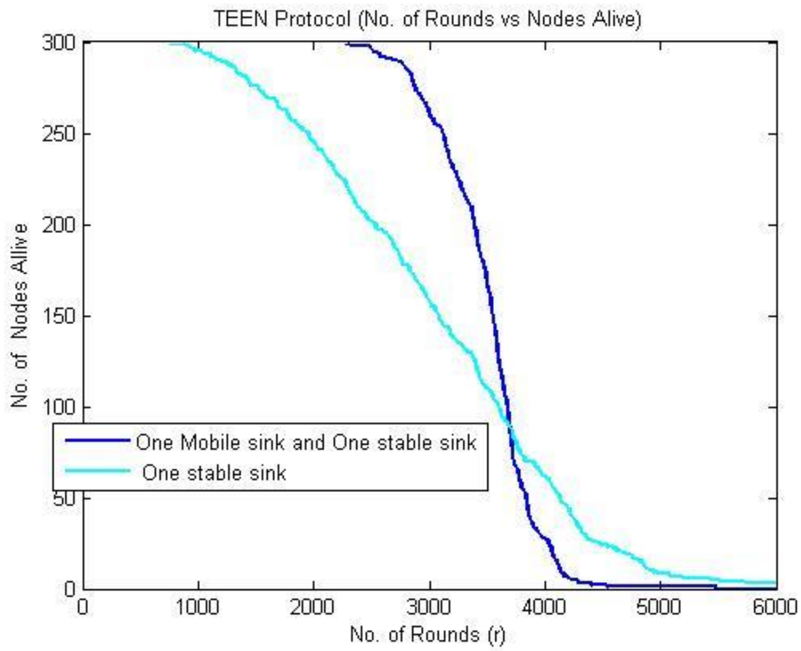

Figure 5.10: Number of Nodes Alive per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 250m×250m

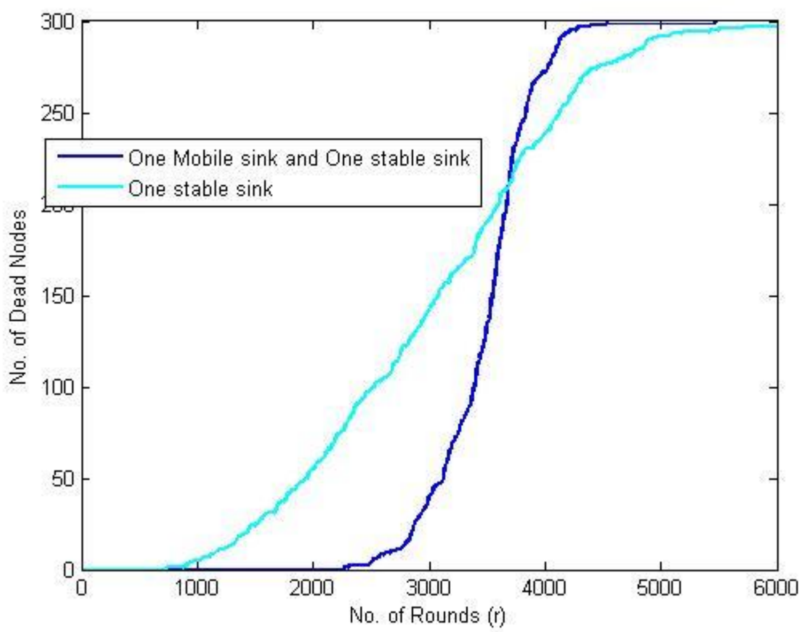

Figure 5.11: Number of Dead Nodes per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 250m×250m

Figure 5.11 shows the network lifetime. From the figure 5.11, it's clear that first node dies very earlier when one stable sink is used as compared to mobile sink and stable sink when used in combination.

Figure 5.12 shows consumption of energy per round by the network. Ratio of consumption of energy per round is stable in both the cases. However, after 3000 rounds, energy consumption is higher in case of mobile sink strategy.

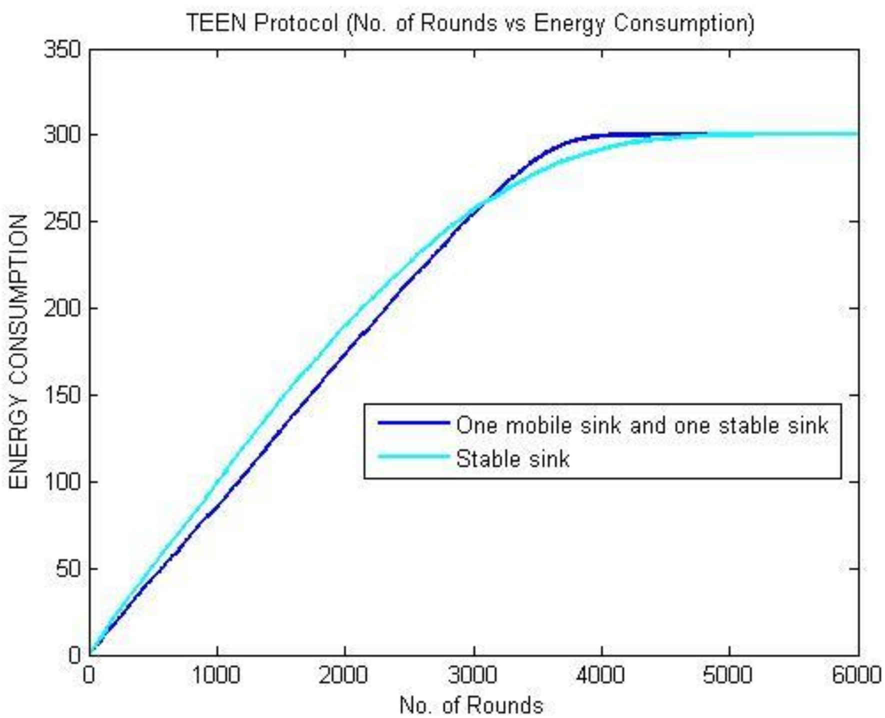

Figure 5.12: Energy consumption per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 250m×250m

Figure 5.13 shows Cluster head formation per round for Stable Sink and Mobile Sink for TEEN protocol in an area 250m×250m. Cluster head formation is quite similar in both the techniques, but TEEN protocol with mobile sink strategy is showing more number of spikes i.e. cluster head election is more. After 2000 rounds the cluster head formation is higher in TEEN protocol with stable sink as compared to stable and mobile sink strategy.

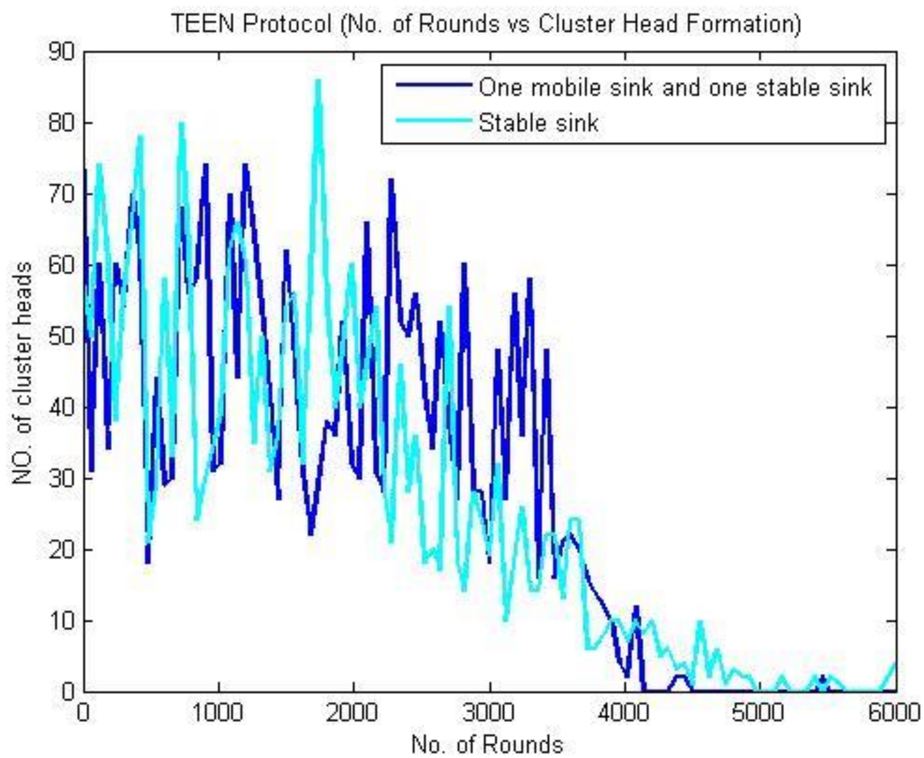

Figure 5.13: Cluster head formation per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 250m×250m

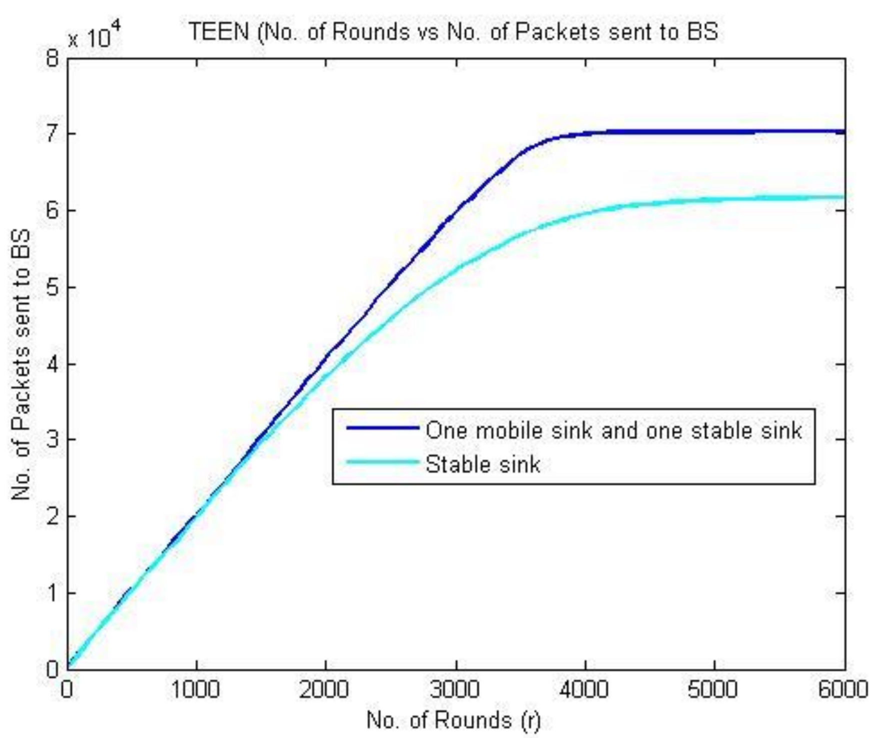

Figure 5.14: No. of packets which are sent to the base station for Stable Sink & Mobile Sink for TEEN protocol in an area of 250m×250m

Figure 5.14 shows No. of packets which are sent to the base station for Stable Sink & Mobile Sink for TEEN protocol in an area 250m×250m. No. of packets sent to the base station is higher in case of mobile & stable sink strategy because mobile sink tries to collect as much data by the nearest cluster heads so that data would not get lost. The mobile sink strategy will make the protocol more reliable.

The simulation parameters for 350m×350m area are given in table 5.3. Total number of nodes taken for simulation are 400 with initial energy 1 joule. Size of data packet is taken as 4000 bits and probability to become cluster head is taken as 0.1.

Table 5.3: Network Parameter for 350m×350m Area

PARAMETERS	**Values**
Area	350m ×350m
No of Nodes	400
Initial Energy Per Node	1 J
Total Energy	400 J
Transmission energy, E_{TX}	50nJ/bit
Receiving Energy, E_{RX}	50nJ/bit
Data Aggregation Energy, E_{DA}	5 n J/b/message
Probability of Becoming Cluster Head Per Round	0.1
Size of Data Packets	4000 bits
Threshold distance, d_0	87.7m
Transmit Amplifier Energy	
Energy for Free Space Loss, E_{FS}	0.0013 p J/b/m^4
Energy for Multi-path Loss, E_{MP}	10pJ/b/m^2

Figure 5.15 demonstrates the deployment of nodes and base station in a specific area. The region we have taken for simulation is 350m×350m. The ‘o’ symbol denotes the nodes and ‘*’ symbol denotes the position of static base station (sink) and '+' symbol denotes the various positions of mobile sink.

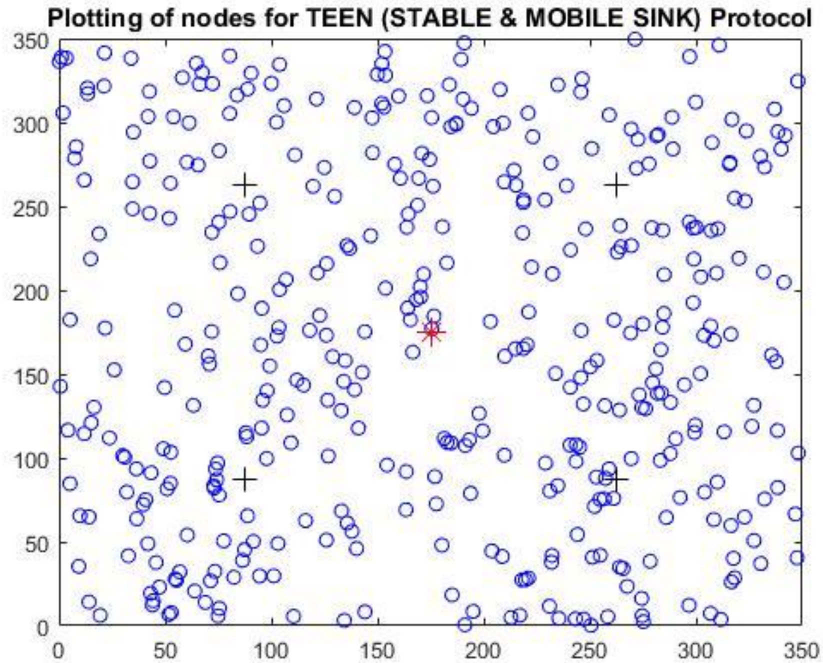

Figure 5.15: Random deployment of nodes and Positions of Mobile Sink and Stable Sink for TEEN protocol in an area of 350m×350m

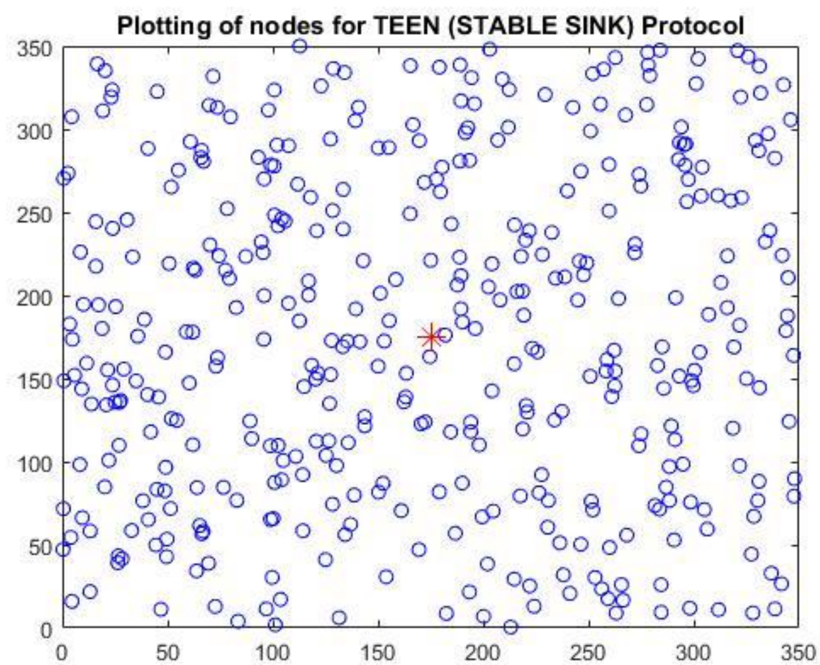

Figure 5.16: Random deployment of nodes and position of Stable Sink for TEEN protocol in an area of 350m×350m

Figure 5.16 demonstrates the deployment of nodes and base station in a specific area. The region we have taken for simulation is 350m×350m. The ‘o’ symbol denotes the nodes and ‘*’ symbol denotes the position of static base station (sink).

Figure 5.17 shows the lifetime of the network. From figure 5.17, it is clear that the number of alive nodes are higher when mobile sink and stable sink are used in combination as compared to one stable sink. Number of Nodes Alive per round for Stable Sink and Mobile Sink for TEEN protocol in an area 350m×350m.

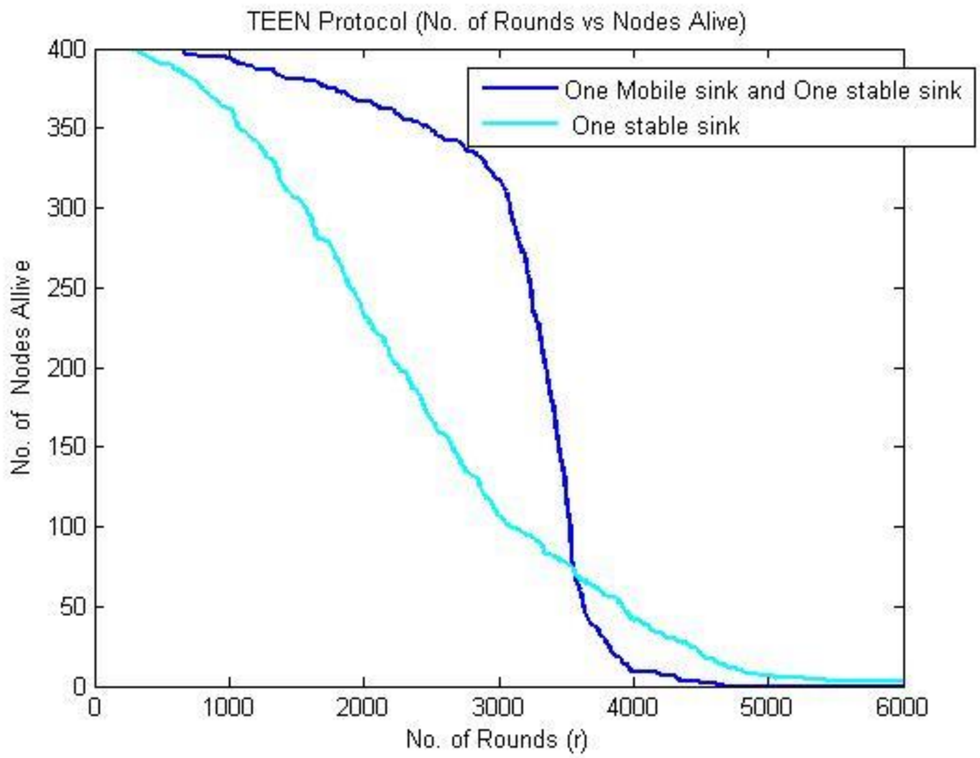

Figure 5.17: Number of Nodes Alive per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 350m×350m

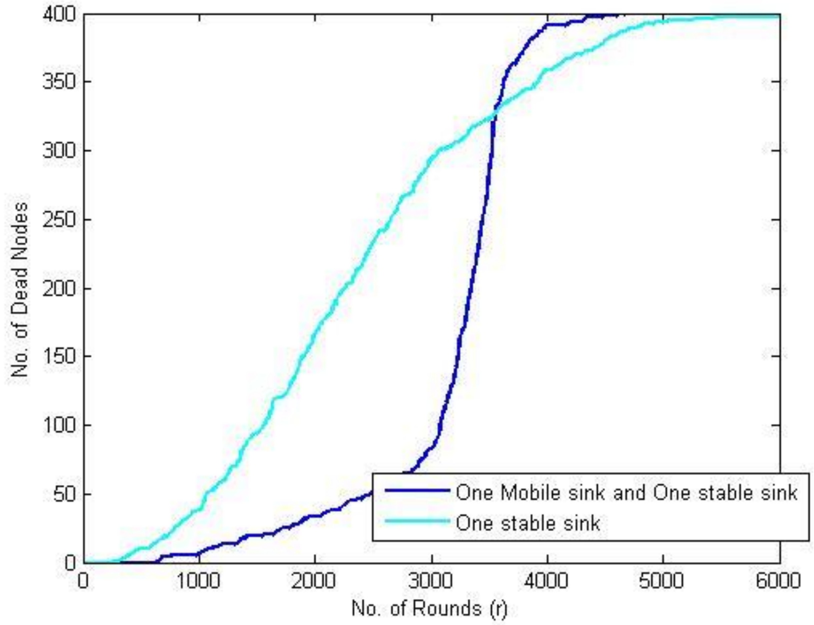

Figure 5.18: Number of Dead Nodes per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 350m×350m

Figure 5.18 shows the network lifetime. From the figure 5.18, it's clear that the first node dies very earlier when one stable sink is used as compared to mobile sink and stable sink.

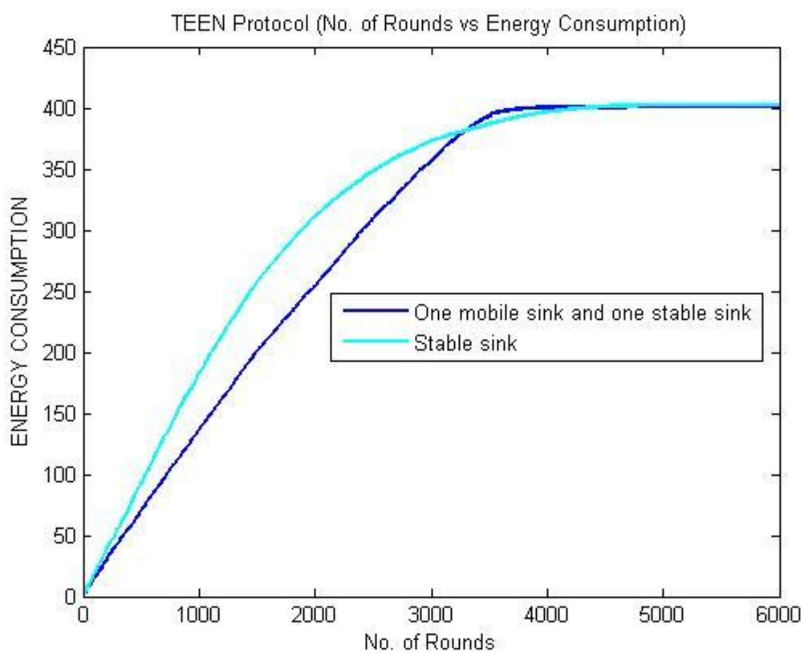

Figure 5.19: Energy consumption per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 350m×350m

Figure 5.19 shows energy consumption per round by the network. Energy consumption ratio per round is stable in both the cases. However, after 3000 rounds, energy consumption is higher in case of mobile sink strategy. TEEN protocol with stable sink has higher energy consumption than TEEN protocol with mobile sink, but after 3500 rounds energy consumption is bit higher in TEEN protocol with mobile sink strategy.

Figure 5.20 shows Cluster head formation per round for Stable Sink and Mobile Sink for TEEN protocol in an area 350m×350m. Cluster head formation is quite similar in both the techniques, but TEEN protocol with mobile sink strategy is showing more number of spikes i.e. cluster head election is more. After 1000 rounds the cluster head formation is higher in TEEN protocol with stable sink as compared to stable and mobile sink strategy.

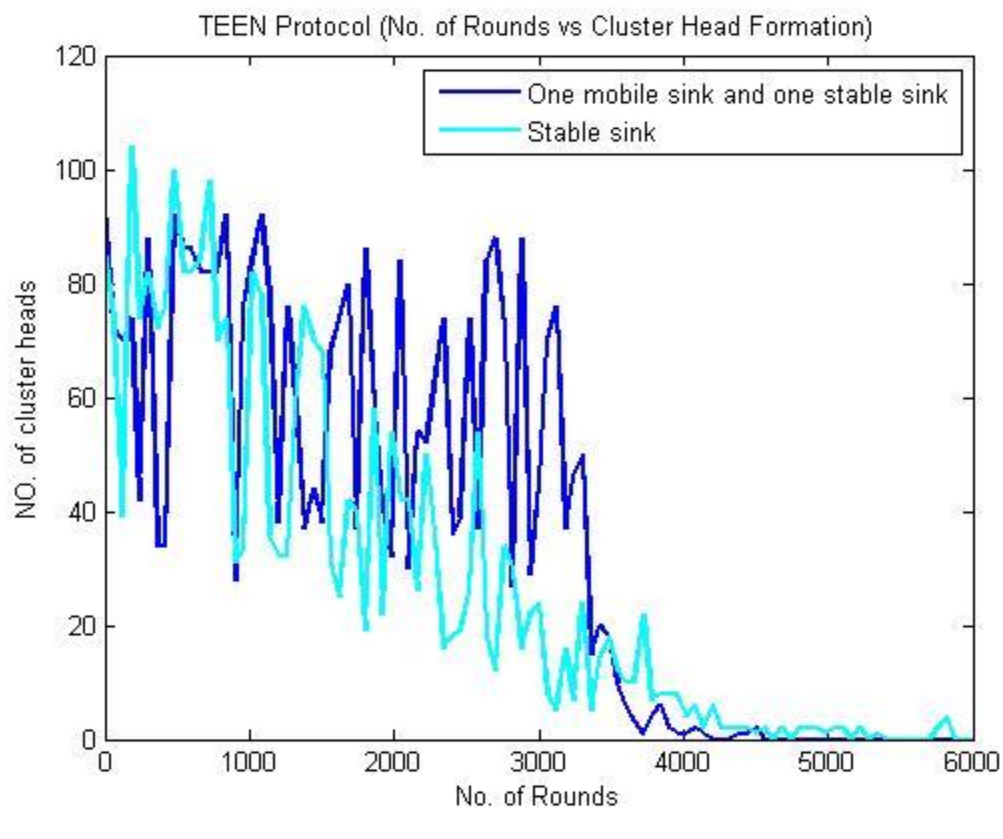

Figure 5.20: Cluster head formation per round for Stable Sink and Mobile Sink for TEEN protocol in an area of 350m×350m

Figure 5.21 shows No. of packets which are sent to the base station for Stable Sink & Mobile Sink for TEEN protocol in an area 350m×350m. No. of packets sent to the base station is higher in case of mobile & stable sink strategy because mobile sink tries to collect as much data by the nearest cluster heads so that data would not get lost. The mobile sink strategy will make the protocol more reliable.

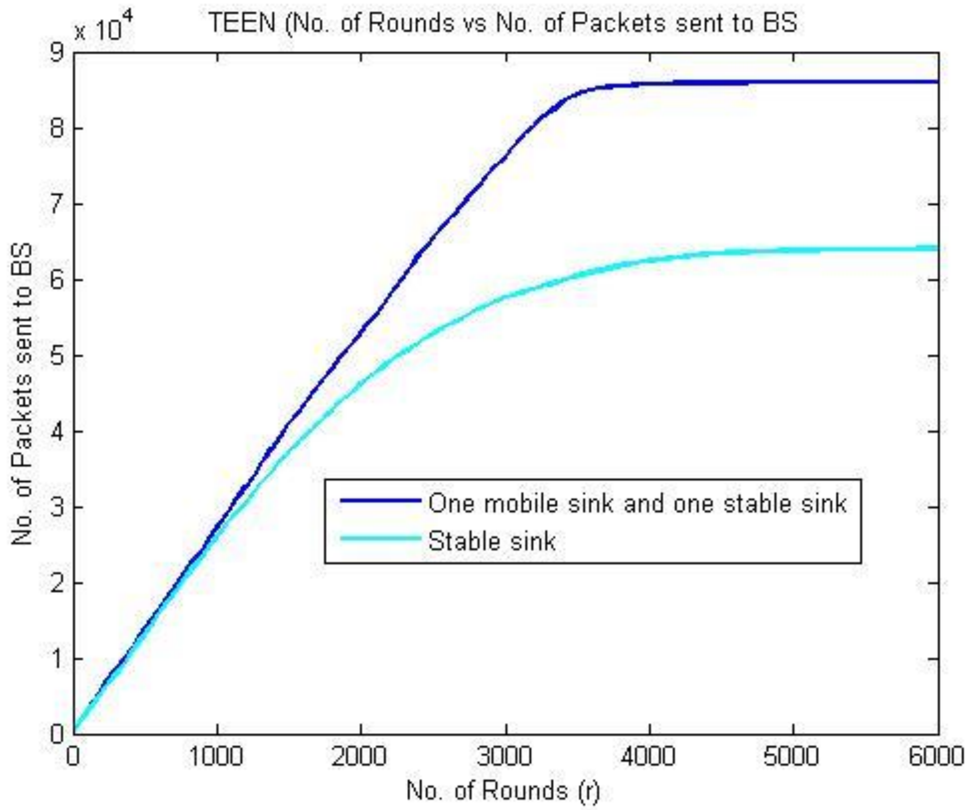

Figure 5.21: No. of packets which are sent to the base station for Stable Sink & Mobile Sink for TEEN protocol in an area of 350m×350m

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

Cluster formation based routing is the best way to archive energy efficiency goal in hierarchical routing protocols for large area. The performances of these protocols are judged by the simulation result under the various performance metrics. Hence, this thesis concluded that TEEN is more energy efficient, while DEEC is more reliable because it is sending maximum data packets to base station as compared to other routing protocols. This dissertation, have also briefly explained problems with clustering routing protocols using static sink. As sensor nodes near the sink quickly died which creates energy hole in network. Furthermore, advantage of mobile sinks over static one and its applications are also explained. We used mobile sink sojourn path patterns with centralized sink to collect the data from CHs and from sensor node by comparing their distance to CHs. The proposed framework is applied to homogeneous network routing protocol (TEEN). The comparison of TEEN protocol with one mobile sink and one static sink is done with one static sink strategy. Simulation results showed that by using mobile sink in the network the energy depletion reduced which enhances lifetime of the network as well as it improves throughput of the network.

6.2 FUTURE WORK

In WSN, thousands or hundreds of the sensor nodes are arbitrarily dispersed in the sensor field. These nodes used to sense the information and send this detected information to cluster head (in case of hierarchical routing) or straightforwardly to base station as indicated by the TDMA (time division multiplexing access) given by the cluster head or the base station respectively. Be that as it may, there is no authentication & security while conveying. So this can be another exploration region where security can be considered. So in future, security can be connected to the proposed routing method.

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