Chapter 3

Design Issues, Models and Simulation Platforms

This chapter discusses the different design issues of topology control and energy models for wireless sensor network application. Classification and methods for Topology Control algorithms are explained. Different types of simulators with their advantages and disadvantages are also discussed.

3.1 Introduction

Sensor nodes are usually deployed in a sensor field where they collect data and route it back to the sink. The collection of the sensor nodes and the wireless links created between them forms the wireless network. The sink nodes that receive the data may be one of the three types; they may be sensor nodes, gateways to a larger network such as the internet, or devices such as PDAs used to interact with the network. Direct communication between source nodes and sink nodes is not always possible in Sensor Networks, as they are supposed to operate in critical radio environments, where there is strong attenuation and required to cover much ground space. As a result, simple single-hop sensor network architecture is not always possible; instead, relay stations are used, allowing the data to take multiple hops from the source to the sink as shown in figure 3.1. A multi-hop architecture overcomes the problem of larger distances and obstacles; there are also suggestions that it can improve energy efficiency as less energy is used to relay a message over a short distance over a long distance, due the quadratic attenuation of signals in space with distance. The network may be optimized to cater for the different applications and scenarios that may occur. Figures of merit are used to perform this optimization. Some prominent figures of merit that are used are: For the Sensor Network feasibility, all

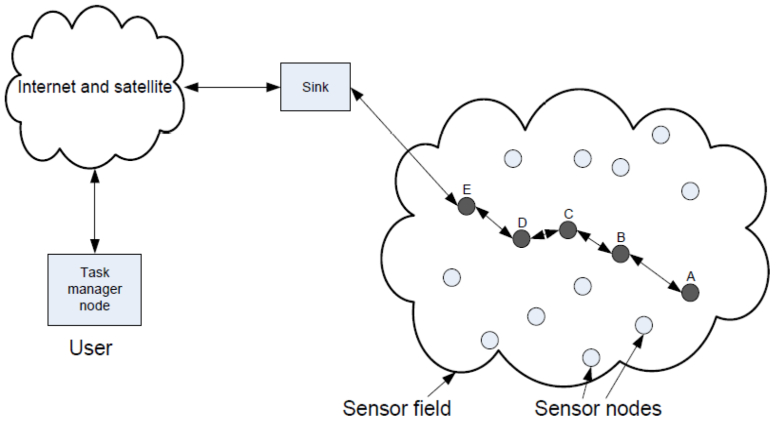

Figure 3.1: Multi-hop network architecture

the applications which are used in the network must be having lower cost; it must use network topology for network establishment. In a star topology, all the nodes communicate with a sink node in a single hop. However, this type of network has the drawback that when the sink node is a fail then the entire network will be down. Establishment of mesh topology is very feasible in such situation.

Energy efficiency: For wireless sensor networks, energy is a most valuable resource as it defines the network lifetime of the entire network. The consumed energy for communication among node m and n is nothing but a polynomial function of distance among node m and n. There are two basic notions for energy efficiency such as hop stretch factor and energy stretch factor.

- **Connectivity:** It refers to the number of nodes which are disconnected from sink node. After the activation of topology maintenance technique, it is a critical parameter representing the efficiency of topology maintenance Protocol Mathematical representation (if the mod of connectivity =0 then y protocol is excellent in working as the |X|>0 keeps on increasing this indicates that protocol is not efficient in providing the backbone and supporting the setup).

- **Coverage:** An important research issue in wireless sensor network is the coverage problem which reflects how efficiently the deployed sensor nodes can monitor the targets. Two types of sensor coverages are investigated: area coverage and target coverage. There are three types of coverage mentioned in the literature: partial coverage, single coverage, and multiple coverages.

- **Reliability:** Saving energy compromises reliability. We define the reliability of the WSN to be the probability that an end-to-end communication is successful (the sink receives i.e. The packet).

- **Maintainability and Simplicity:** Topology generated by using topology control method should be easy and straightforward for its maintenance. Additionally, it helps in the measurement of objectives easily which are easily used to analyze the individual goals. The topology control algorithm is having less overhead regarding performance metrics communication needs.

- **Hop and Energy Stretch Factor**: The stretch energy factor increases , as energy gets consumes in delivering the packet to source node and destination, with fewer energy routes between the topology controlled graph and original network graph. However, the hope stretch factor (HSF) is same as an energy stretch factor (ESF) except that it is focused on the length of the route selected for communication. Therefore, we can define these two elements as:

$$ESF = \max_{m, n \in n} E_T (m, n) \div E_G (m, n)$$

where $E_G (m, n)$ is the total energy consumed

$$HSF = \max_{m, n \in n} |(m, n)_T| \div |(m, n)_G|$$

Where $(m, n)_G$ is the shortest path in original network graph G and $|(m, n)_G|$ is its length.

- **Energy overhead:** It is termed as the fraction of network energy which is used in topology construction. We can express this mathematically as; let the total network energy be X and Sf represent a particular fraction of the energy, which will be utilized in topology construction. So, Sf =1/X (this quantity will vary according to for different protocols). In specialized cases such as topology maintenance, this metric calculates the overhead, which is generated during the reconstruction of topology under specific conditions.

- **Residual energy:** It is defined as the ratio of energy in active node sets to the total energy of a network, at the end of the experiment. Let total energy in active node set/total energy of network=Ro. Ro measures life expectancy of the network. As the value of Ro falls below threshold value represented by Tv, it leads to network partitioning represented by Np.

- **Message overhead**: This term is used to define the total number of packets sent or received, which are generated in the whole network during the experiment. Mathematically we can formulate this as; let us represent message overhead as M and energy consumption as E M α E (we can state this as, more the message overhead maximum is the power consumption). The effort are taken to design a WSN to minimize M .

3.2 Sensor Network Topologies

The network topology is used to create the virtual shape and the structure of the network. In the network, multiple computers are connected to each other, using some hardware devices. Every networked computer performs a role as a client or a server . For data transmission, we use a device called as communication media. To establish network communication, we use copper cables, fibre optic or wireless communication. In Sensor Network, wireless network communication is established.

3.2.1 Star Network (Single point-to-multipoint)

The star topology contains one base station. The base station sends data received by the network node. In this type of network topology, it has one base station for data, which sends, and receives the network nodes. This base station is centrally located in the network. In the star topology, all the nodes are connected to the base station for data transportation. This is shown in following figure 3.2

In star topology, if any network is ready to send data to another network node, it is sent by using the base station. No node in the topology can send or receive data directly from another node. Remote nodes can send and receive messages from the only the single base station. It is a very useful network for the wireless sensor network because it can keep minimum power consumption by sensor nodes. Sensor and the base station take the very limited communication time in this type of network. The disadvantage of this network is, the base station must be within the range of the radio transmission of all nodes. The Star topology network is not as robust as the other network topologies. In this type of network when base station will fail then, the entire network will fail, this is the major disadvantage of this type of network

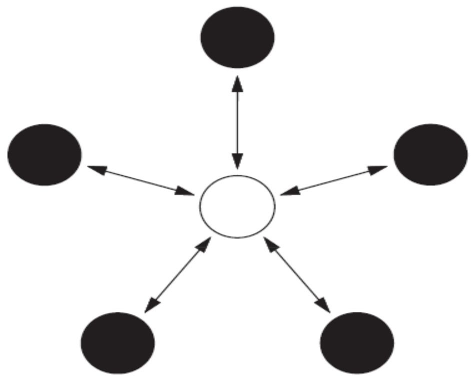

Figure 3.2: Star Network Topology

3.2.2 Mesh Network Topology

In this kind of network, all the nodes are connected to each other. Any node can send data to any node directly. In this network, if any node disconnected from the range of the sensor network, other nodes do not get the problem of data transportation. This type of network allows multihop communications, that means if any node tries to send data to another node, and at that time this node is not available in radio communication range, then it takes another intermediate node to send data to this particular node. Redundancy and scalability are the advantages of this network. In this type of network which does not have a range of nodes it means network size, we should be allowed to increase our network size.

The power consumption of the sensor node shows the disadvantage of this system because it supports to multihop communication system. Sensor nodes have limited battery power, that's why in multihop communications it will lose fast as compared to the standard node to node communication. It also increases message delivery time, when the number of communication hops is increased at the destination. An example of such type of topology is shown in figure 3.3.

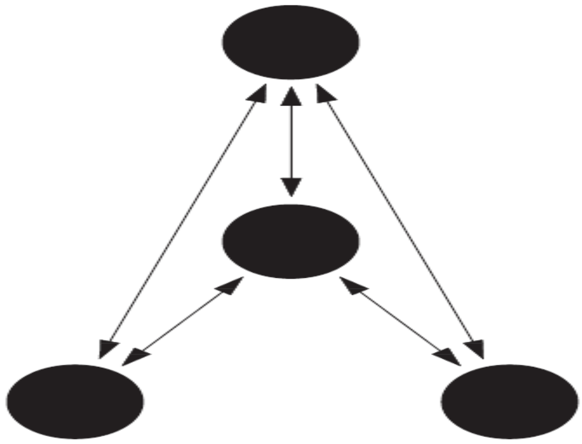

Figure 3.3: Mesh Network Topology

3.2.3 Hybrid Star-Mesh Network Topology

The hybrid star-mesh network provides robust and multipurpose communication network. This kind of network can consume minimum sensor nodes power. In this type of network when any sensor node has less battery power, then it will not be able to send the messages to the other nodes. In the networks, other nodes have the ability to multihop communication and they can be able to send messages to those sensor nodes, which have low power. Multihop communication nodes have high power, and if possible we can also plug this into electrical switches. The latest Zigbee implements this topology. The example of hybrid topology is shown in figure 3.4.

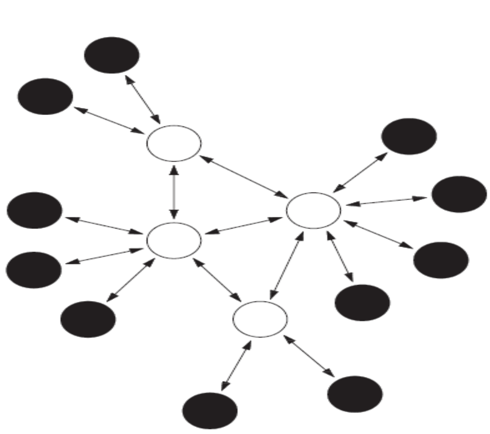

Figure 3.4: Hybrid Star Mesh Network Topology

3.3 Topology Control Design Guidelines

The first design guideline is validation of the appropriate networking model followed by the system design and analysis. Networking models consist of the sensing model, the interference model, the node distribution model, the topology model, and so on. With the rapid growth in WSN techniques, the acquired system performances from real systems are mostly complicated and do not match the descriptions offered simple networking models. The simple models cannot analyze the core performance of the network. They are a big failure in capturing it. They fail to capture the essence of real behaviors of the system. Therefore, the conclusion drawn from the simplified models may be very inaccurate and misleading. The main challenges for the theoretical analysis and protocol design are to produce a realistic and a proper networking model. However it helps in contributing and performing research work in a real scenario. The first design guideline can be very beneficial for the real time and critical event monitoring applications, such as volcanic earthquake monitoring, building fire control, bridge health monitoring, and so on. Figure 3.5, 3.6, 3.7 and 3.8 describes the taxonomy structure for power control, construction and maintenance, connectivity and coverage respectively.

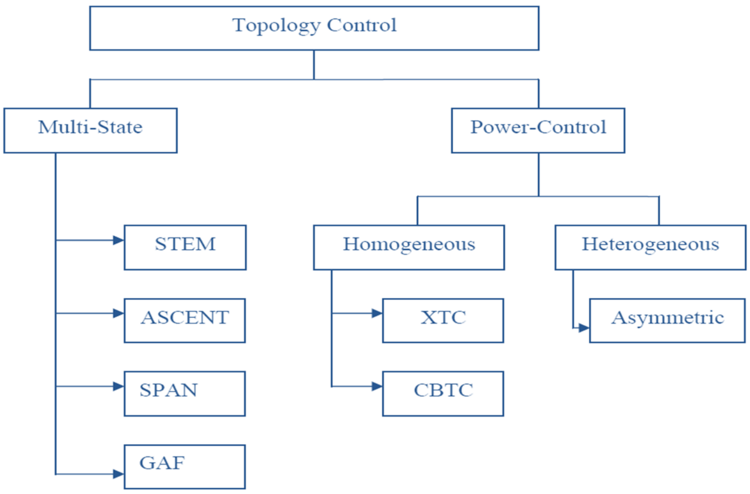

Figure 3.5: Multistate and Power control topology

The desired performance is not achieved in these requests by the simple networking models, because of the mentioned sophisticated physical features. Coverage and connectivity The primary motivation behind putting the guidelines is to help the people who design the topology protocols between network performance and network lifetime. Figure 3.4 shows that topology control algorithm should consider the multi-state and power control approach. Deployment of WSN attracts lots of attention as it shows the quality of services provided by the network as one of the main focus areas in the proposed work. It is to provide plenty of protocols that help in better performance in topology control, at the minimal cost Network coverage focuses more on the system performance whereas connectivity network concerns more on the network lifetime so we say that their priority areas are quite conflicting. However, many topology control protocols cannot treat both aspects with balanced performance consideration. With the proposed protocols, for the network coverage, excellent performance of the system can be acquired, but the system may fail inconsistently working over an extended period.

This guideline ensures the balanced coverage and connectivity performance by providing several rules which guide the design of sensor network topology control protocols. The second design guidance greatly benefits the monitoring systems deployed in remote or harsh places, such as forest monitoring, underground environmental monitoring, and so on. Such applications bar the network operators from repeatedly replacing the battery for each sensor mote. Therefore, by balancing network coverage and pairwise connectivity, the tradeoff between network performance and network lifetime can be performed. Unified Framework for different service demands developing combined protocols which support more network services simultaneously, is the central focus area of the third design guideline in topology. In the practical system, a set of different services is provided by sensor networks for the various application. Additionally, some extra information such as the system diagnosis information might be required for the system operator. All those cooperation's and information are closely coupled with various network services. Most existing topology control protocols are designed for network services to achieve an excellent performance of the system.

To ensure all demanding services, one practical system needs to assimilate multiple protocols. However, real system implementation, which is not limited to WSNs, shows that complicated integrated systems are more prone to losing the attributes of scalability and efficiency. The principle of a simplified design is practically applicable. If one follows the guidelines properly then, WSN can work with the minimum number of protocols and also achieve the scalability and efficiency at the same time. The third design direction benefits the large-scale monitoring systems, for e.g. city-wise urban CO2 monitoring. Such systems have a huge number of sensor motes (e.g., more than 1000 nodes). This guideline also helps in minimizing the number of protocols and the total amount of messages that are exchanged. It also ensures the overall utilization of the network resources and improvement of the system robustness. The collaborative signal processing algorithm is developed for wireless sensor network. Many raw data are collected by the sensor nodes in an environment but only small amount of data are useful for the processing. Hence, data must be filtered , and only useful data should get back to the end user.

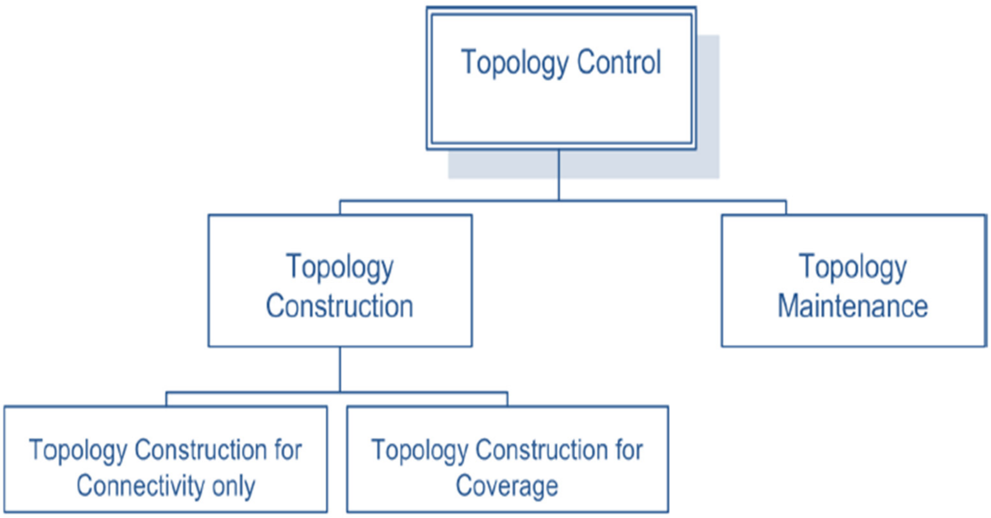

Figure 3.6 : Taxonomy topology control construction

This computation is more energy efficient than wireless communication; this helps to save energy which is required to send large amount of raw data. Information fusion is most important for collaborative signal processing. It collects data from multiple sensors and it also checks noise between sensor nodes; it filters collected data and provides accurate and useful information generated by a large number of sensor nodes. For data collaboration, a comprehensive set of techniques is used which generates important information.

The sensor has limited energy power and size and cost constraints. Each sensor has a limited power supply and every sensor node has batteries. These batteries are rechargeable or can be self-powered. The power is critical for monitoring environmental changes in the wireless sensor network, some of the sensors are active continuously, and some sensor nodes are in sleep mode. During the sleep mode sensor node, consumes low power . The Sensor node performs the task by two ways that are : a) It perform a task by applying high voltage and return sensor node to sleep mode. b) It performs tasks slowly by consuming very low power and completing the task. In the wireless sensor network rechargeable and non-rechargeable batteries are used. If the environment is not possible to recharge the batteries, then non-rechargeable batteries are preferred.

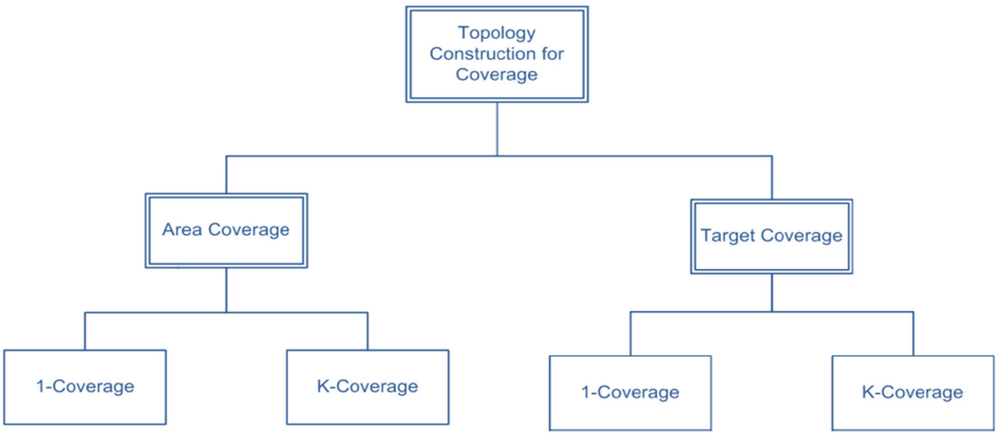

Figure 3.7 : Taxonomy for coverage

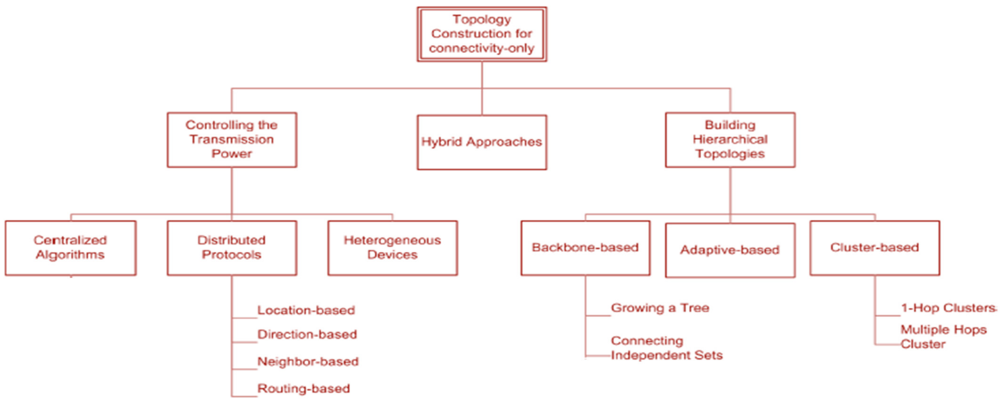

Figure 3.8 : Taxonomy for connectivity

3.4 Network Models

3.4.1 Homogeneous Model

Suppose n nodes are placed in R =$[0,l]^d$ for d= 1,2,3, a question arises as ,"what are the minimum values of the transmitting range r such that the homogeneous range assignment produces a connected network?" This minimum value r is known as the critical transmitting range C_{TR} for connectivity. It is important to study the critical transmitting TR range as in a number of cases it is not feasible to dynamically change the transmitting range. Some expensive radio transmitters may not allow the transmitting range to be adjusted. In such situations, it is reasonable to set the same transmission range for all nodes and the C_{TR} is the only choice for reducing power consumption and increasing network capacity.

Finding the value of C_{TR} depends on the information that is available about TR node deployment. In cases where the position of nodes is known in advance, C_{TR} is the length of the longest edge of the euclidean distance Minimum Spanning Tree (MST). Many WSNs, however, are deployed in an ad hoc manner, and node placements are not known in advance. When node placement is not known the minimum value of *r* that ensures connectivity in all possible cases is the one that considers the fact that nodes may be concentrated at opposite ends of the deployment region.

The scenario, of nodes being deployed such that they are concentrated at opposite ends of the deployment region, is unlikely, As a result, C_{TR} has been studied with the assumption that TR nodes are distributed according to some probability distribution in *R*. The goal in such a case is to characterize the minimum value of *r,* which provides connectivity with a high probability. A common power throughout the network ensures bi-directionality of links which in turn ensures that the MAC protocol works efficiently. Figure 3.9 shows the sparser topology after reducing transmission power.

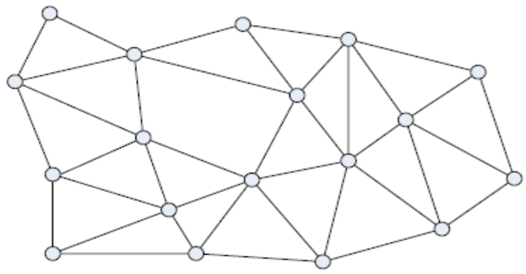

Figure 3.9 : Sparser topology after reducing transmission power

3.4.2 Wireless Propagation Model

In wireless sensor communication, the wireless signal is transmitted from source to destination, via a wireless radio channel. Such signals which are forwarded at specific power from the transmitter suffer from the problem of signal attenuation over a radio channel. At destination for senders transmission, if the received signal with a level of power is more than its transceiver sensitivity, then communication has attenuation. Signal attenuation is nothing but the channel path loss which is directly based on distance between the source and destination, other related facts and frequency of operation.

3.4.3 Model of Free Space Propagation

If there is a line of sight in the network, then adaptation of model calls for the free space propagation. The computation of received power over the distance d among source and destination sensor nodes is done by:

$$Prx\ (d)= Ptx*Gtx*Grx*\ \lambda^2\ /\ (4\lambda)^2 *d^2 *L$$

$$= Cf*\ Ptx/^{d2}$$

3.4.4 Model of Long Distance Path

The long distance path model is given by

$$Prx(d)\ \alpha\ \ Ptx/D^{\alpha}$$

This states that path loss is a directly proportional to Ptx (transmission power), over the distance d.

3.4.5 Hop Model

In this section, we will discuss on defining and designing the hop model. For any sensor node in the network, lets say p, the adjacent node position is represented by its deviation from the position of optimal relaying. The optimal relaying position is nothing but the direct link between base station and node p. This is d_{char}, the characteristic distance function. Here, node p is a coordinate system origin, u and v are represented as coordinates of node p denoting d as $d_{char} \cdot a$ and $d_{char} \cdot b$ simultaneously, where a, b ∈ A.

The total distance from node m to n is then computed as $d(m, n) = d_{char} \cdot c$, where $c^2 = a^2 + b^2$. Addressing the multi-hop link in the network is dependent only on local information. The required optimized number of hopes can be estimated as

$K = D/\bar{a} \cdot d_{char} = K_{opt} / \bar{a}$ where $\bar{a}$ is the average value of all a.

For topology control, different methods generate different outcomes. Let V be set of nodes on graph G . There is a link from sensor node m to sensor node n, If node m is able to reach node n directly. Resultant topology should be measured and compared with other methods of topology control. For comparative analysis of topology control methods, a list of performance metrics is used such as energy efficiency, connectivity, robustness, throughput, mobility etc.

3.4.6 Energy Model

To assess the lifetime of a given topology, it is important to include a model to drain the nodes' energy whenever node performs any action. The energy model is used to model the energy consumption of the nodes. It is based on the following Equations

$$E_{Tx} = E_{elec} + E_{amp} * R^2_{comm} * \pi$$

$$E_{Rx} = E_{elec}$$

Where, E_{Tx} is the energy spent to transmit 1 bit, E_{Rx} is the energy to receive 1 bit, E_{elec} is the energy used by the electronic components of the radio, and E_{amp} is the energy used by the radio amplifier. The second term is proportional to the square of the transmission range that is achieved by the radio signal. Despite the simplicity of this energy model, it is still commonly used in the literature of wireless sensor networks.

Initial energy source = 1 Joule

Eelec = 50nJ/bit

Eamp = 10pJ/bit/m^2

Energy consumption is negligible.

3.5 Methodologies and techniques used

Research methodology consists of the following

1. **A literature study:**
    a. Relevant literature on wireless sensor networks is identified.
    b. Relevant literature on topology control is identified.
    c. A detailed study of different topology control algorithms for wireless sensor network is undertaken.
2. **Design :** The design of topology control techniques that use local information to enhance energy efficiency.
3. **Implementation:**
    a. This is the visualization of the network, created by the new topologies.
    b. Simulation of WSNs uses designed techniques to evaluate fairness regarding performance.
    c. Identification and collection of data, that gives statistically significant result that could be assessed and compared to results from past studies.
4. **Assessment :**
    a. The new topology control algorithm is compared to other existing topology control algorithms.

b. The result of the developed algorithm is analyzed and discussed.

Developed algorithm should have the following characteristics:

1. It must be simple and efficient so that it is suitable for small sensor nodes.
2. If the original topology changes due to node failures or mobility, it must be possible to reconstruct a connected sub graph without global coordination.
3. It does not make many assumptions about link layer, radio propagation model and the hardware of each node.
4. It is fully distributed and should work in the homogeneous environment.
5. It increases the network lifetime.

3.6 Simulation Platform

3.6.1 Introduction to MATLAB

It is the fourth generation programming language which is process oriented. MATLAB allows matrix manipulations, plotting of graphs, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, and FORTRAN. The world MATLAB is borrowed from two words matrix Laboratory. It is the language of technical computing. It is a commercial product. MATLAB was developed in late 1970 by Cleve Molar. He was the computer science department chairman, New Mexico. MATLAB is rewritten in C and founded Math Works in 1984 to continue its development. These rewritten libraries were known as JACKPAC. In 2000, MATLAB was rewritten to use the newer set of libraries for matrix manipulation. It was originally designed, for solving linear algebra type problems. It is easy to use. It can handle huge size array. It has a sensitive numeric algorithm. A large number of numeric/image library functions and Platform independent. Easy to create GUI like buttons, menus. Object-oriented programming makes life simple.

3.6.2 The MATLAB System

There are five main components of MATLAB subsystems which are discussed in the following points:

- Development Environment: It is the framework consisting of tools and functionalities that help us to use the functions and files in MATLB. Most of the tools of MATLAB are GUI supported. It considers the command window, MATLAB desktop, command history, debugger, editor, workspace, search path, files, browsers etc.
- Library of Mathematical Function: As the name indicates, this library is a collection of a large number of mathematical functions and algorithms such as elementary operations (cosine, size, sum, complex arithmetic etc.), sophisticated operations (fast Fourier transforms, matrix inverse, Bessel functions, matrix eigenvalues etc.).
- LAB Language: LAB language is high-level language of the matrix with the inclusion of functions, control flow statements, input-output, data structures, features of object oriented coding etc. This enables both operations such as programming in the small as well as programming in the large to support both quick and complex application programs respectively.
- Graphics: MATLAB supports the graphics extensively in order to display matrixes and vectors as graphs with proper labeling and annotation. It consists of high-level operations for 2D and 3D visualization of data, animation, image processing as well as presentation graphics. This considers the low-level operations, which enable you to completely customize the appearance of graphics and design entire GUIs on the applications.
- The MATLAB API: The API of MATLAB enables us to write the library in FORTRAN and C programs which interact with MATLAB tool. This includes the functionality for calling the routines from the MATLAB through the dynamic linking. MATLAB is called as a computational engine for reading and writing the MAT files.

3.6.3 Comparative Study of Simulators

Table 3.1 shows the comparative study among the various simulators used for research studies.

Table 3.1: Comparative Study of Simulators

Name of Simulator	Information	Platform	Developer/ Licensing
Atarraya	This is Java based simulation framework which is used to teach and perform research on topology control methods in WSNs. It is discrete event network simulation framework presented for evaluating and implementing the topology control methods. This tool supports different algorithms and has GUI, which supports the designing of topology construction as well as maintenance.	Java	The developers is MA Labrador and PM Wightman
Avrora	This is a framework for simulation and evaluation purpose for AVR microcontroller. It supports simulation of large WSNs. It is built using Java API. It provides the proper GUI for end user interaction.	Java	Group of UCLA Compilers
Castalia	This simulation tool is presented for BAN, LPED and WSN simulations. It is capable of simulating a large number of platforms. It supports different radio models and advanced channel. It has some MAC protocols support. It is highly parametric	OMNeT++	Develo ped by NICTA Acade mic. IEEE Lic
GloMoSim / QualNet	It is open source simulation framework for wireless networks. It supports some options for radio propagation. It is good for mobile IP networks simulation. It evaluates the WSNs.	Parsec, the variant of C.	GloMoSi m (Free) and QualNet (Commer cial)

Name of Simulator	Information	Platform	Developer/ Licensing
J-Sim	J-Sim is nothing but the simulation framework for the quantitative numeric models. It has GUI for editing or compiling the different models. It is based on input from either video or other real events representation. It supports an advanced configuration and expounded data analysis. It supports sensor.	Java	Open source. Designed and developed by National Simulation Resource, University of Washington
MATLAB	It is adamant and multipurpose simulation tool. It is industry standard simulation framework. For sensor network simulation, it provided the separate library for doing simulation and analysis.	Windows	Student-Academic-Commercial License
NetTopo	This supports the various network topology of routing paths, based on simulation parameters change. It supports the multi-source data collection with dead sensor nodes. It supports 3D visualization	Java	GPL-Digital Enterprise Research Institute
NS-2 and NS-3	Both are known as discrete event network simulator which supports the extensive simulation of MANET, WSN, Zigbee, VANET, etc. Based on C/C++ and OTcl. GUI is not supported, but performances are evaluated through AWK scripts.	Windows, Red Hat Linux, Ubuntu OS	-Open Source and Free
OMNeT++	This is another discrete event simulation framework. It is modular, component based, extensible framework. It is based on C++ library. It is mainly used for building the network simulators. It contains large number of other components such as a compiler, utilities, CLI, etc.	Windows, Linux, Unix, MAC.	Free for academic András Varga (OMNeT++ Community)

Name of Simulator	Information	Platform	Developer/ Licensing
OPNET	This simulation framework is used for networks management, application management, network planning, network operations and research, performance management, etc. This supports the functionalities like VoIP, MPLS, IPv4, IPv6, OSPFv3, MANET, WSN, etc.	Mainly for Windows OS	Commercial-OPNET Technologies
Prowler & JProwler	It is one of the probabilistic simulators for WSN. It includes the different radio models. It is targeted at Berkeley MICA Mote hardware on TinyOS. It provides single MAC protocol to use.	Prowler-MATLAB JProwler-Java	
Ptolemy II	It is Java based, supporting the complex model, design, and simulation. It is addresses the improved heterogeneity, modularity, GUI, mutable systems, etc. It acts as a baseline for designing other emulators and simulators.	Java	Baldwin-UC Berkeley
SENS	It is special kind of WSN simulator tool. It supports few models from the wireless medium from simple perfect to probabilistic message loss model .It is not simulating the MAC protocol . It supports the actuators, sensors,	C++	Sundresh
SENSE	This another simulation framework for WSNs designed in 2004. It supports the use of energy model while designing the WSNs. It does not support the sensors, environmental effects, actuators, etc. It is running based on COST (component-based discrete event simulator)	C++	Chen

Name of Simulator	Information	Platform	Developer/ Licensing
TinyOS	TinyOS is nothing but the component dependent OS supporting the designing of WSNs. For Eclipse platform, IDEs are available. It is the base for designing and developing many other simulators and emulators.		Open source and Free
TOSSIM	For the simulation structure, It compiles under the TinyOS. It is scalable for all applications of TinyOS. It supports the GUI using TinyViz and tool of interaction intensive. High fidelity simulation of a complete TinyOS sensor network	TinyOS	Phil Levis (CS Berkeley)
Visual Sense	It is also simulation and modeling tool for WSNs. It provides the extensible and accurate radio model. This tool is useful for representation of energy propagation. However it is not used for localization.	Ptolemy II	UC Berkeley

3.7 Simulation Assumptions and Constraints

3.7.1 Assumptions

- All nodes had an entire communication coverage disk and located in a two-dimensional space.
- All nodes have equal communication ranges, and all links are bidirectional.
- Multihop communication is preferred over single hop communication
- All nodes have a single sensor and have an entire sensing coverage disk.
- Nodes in the network do not have information about their position, orientation, or neighbors.

- The initial graph is formed right after the deployment using the maximum communication range.
- Distances between nodes can be calculated as a metric perfectly proportional to the Received Signal Strength Indicator (RSSI).
- Packet loss is not considered in data link layer.
- There is a mechanism by which a node can be awakened when its radio is off.
- The network duty cycle is 100% – The network is always active.
- The time units of the simulation clock are approximately 1 second.
- Lambda is the Poisson process density, and it is related to the density of the network.
- Two widely used propagation models are used a) Free Space model ($\Upsilon = 2$) and b) Two-Ray Ground propagation model ($\Upsilon = 4$).

3.7.2 Constraints

- The algorithms and protocols run in a distributed manner so that they can be implemented in the large networks.
- Topology control algorithm has a profound message andcomputational complexity.
- Algorithm must run in a computationally weak device.
- It is desirable that the algorithms can move without the help of additional hardware like GPS devices or localization mechanisms, so low cost is maintained, and no additional energy is spent.
- Topology construction algorithm must produce connected networks, that will cover an area of interest with a minimum number of nodes.
- Topology maintenance algorithms must guarantee, that the resources of the network are used effectively to keep the network active for the longest possible time.

Many WSN applications share some common characteristics that define a particular type of implementation. In the majority of cases, a clear distinction is made between source nodes that sense data and sink nodes that receive data. Sinks is a part of the network or in some cases, they can be part of systems outside of the network, such as gateways, to fix networks or handheld PDA's communicating with the network. In many cases, their identity is of secondary concern with the data itself of greatest importance. Patterns of interaction between sources and sinks illustrate some typical patterns. Some patterns that are useful in classifying different applications are as follows.

- **Event detection** : Sensor nodes report data on a specified event to sinks once it has occurred and is detected.
- **Periodic measurements:** Sensor nodes report data on measured values of the environment to sinks at regular intervals.
- **Function approximation:** Sensor nodes find an approximation of function representing the distribution of a measured phenomenon with the location and report it to sink nodes.
- **Edge detection:** Sensor nodes find isoclines, that connect points in space which have equal values of the phenomenon being measured and report them to sink nodes.
- **Tracking:** Sensor nodes report updates on the position of a specified event to sink nodes where the source of the event is mobile. The interaction patterns highlighted above can have temporal and spatial restrictions placed on them, allowing events to be reported over certain time intervals or in certain areas. Each application includes a certain set of options that need to be considered beforehand. These include deployment options, maintenance options, and energy supply options.
- **Deployment Options:** These include planned fixed deployment and random deployment. Once deployed the sensors may remain static in the same position or may become mobile, either by their accord or as a result of being attached to a mobile object.
- **Maintenance options:** These include if the sensor nodes unattended for extended periods of time and whether maintenance is out of the question, due to the reasons such as short time interval .

- **Energy supply options:** These include whether or not energy supply should be replenished externally, or if sensor nodes should do it themselves through energy harvesting. This also includes whether wired power from an external source or self-sustained power is used. Price, size, and capacity must be considered.

3.8 Conclusion

This chapter describes the different models used for topology control, various types of topology with their pros, cons and network models. Methodology opted for topology control is described. At the end comparative analysis of topology control algorithms and simulation softwares including MATLAB is described.