Chapter 1

Introduction

The goal of this chapter is to explain motivation, and challenges for Topology Control for Wireless Sensor Networks. Problem statement formulated and the scope of the research is presented. Aims and objectives of research are elucidated. Scientific contributions of this thesis are explained and finally, the outline of the thesis is provided to give an overview of the individual chapters.

1.1 Research background

The sensor networks are nothing but a group of nodes, with tasks of sensing, data collection and processing as well as transmitting data over a wireless medium, which are deployed densely within the sight or very near to it. Every sensor node in the Sensor Network is collecting information and sending back this collected information to the sink node in the network. Sensor Network must have the capability of self-organization, as the location of sensor nodes is not fixed and predefined. Therefore, the efficient positioning of sensor nodes yields the efficient Sensor Network performance. This kind of network heavily depends on the cooperation between sensor nodes, to disseminate the collected information to the intended recipient in the network. The current technologies and methods for MEMS (Micro Electro Mechanical Systems), digital electronics as well as wireless communications enable researchers to design the less power, less cost and multifunctional sensor devices, which are freely communicated in limited distances and have a small size. Such small sensor nodes compose of processes such as sensing, communicating, information processing, data aggregation, data dissemination. The current sensor networks are drastically improved once as compared to earlier sensor networks. The previous sensors are deployed based on below listed approaches:

- Sensors are located at a very far distance from the actual site. In this method, many sensors utilize the complex methods, which are required to differentiate the real targets from the network noise.

- Deployment of the sensors is done in the network, which only performs the task of sensing.
- It is required to design communication topology. The positioning of the sensors is to be done very carefully, which is time consuming and manual task.

All these problems of earlier sensor networks are overcome by recent Sensor Network designs, which are self-organized in all aspects. It does not require any physical infrastructure.

Overall, the main aim of Sensor Network is to perform the task of collection of data from the environment in which it is deployed and forward it to the intended recipient to which data reporting is to be done. Data can be processed, analyzed and stored for different purposes. The devices of the sensor network are additionally responding to the queries which are executed from the remote site, and are processing the necessary instructions to get samples of on demand sensing. Such wireless sensor devices are further designed with actuators to (or "intending to") process a particular event based on actions in the network. Therefore, such networks are also known as wireless sensor and actuator networks. There are wide ranges of applications on Sensor Networks nowadays which are used for controlling, monitoring and tracking.

Figure 1.1 depicts the design of Sensor Network with all components involve.

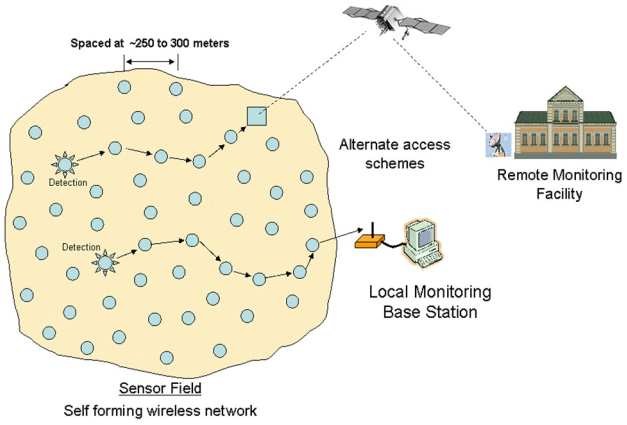

Figure 1.1: Sensor Networks Design And Application

In the figure, it is shown that, in the sensor field, if any event is detected by sensor nodes, then its information passes through sensor nodes to the remote monitoring facility. Initially, such Sensor Networks were designed for military application to monitor the battlefield. However, now it has multiple day-to-day applications such as in commercial and industrial sector to monitor the health care systems, environmental conditions, traffic monitoring, etc. Based on the requests and demands, there are various types of Sensor Networks, but all the Sensor Networks are designed by using the wireless communication devices, radio transceiver or energy source.

However, these sensor nodes are small and have less power. Power consumption is a major concern and is a deciding factor about overall network lifetime. Data collection, processing, sending, receiving and forwarding processes consumes more sensor node energy. In Sensor Network, there are many factors based on which the energy efficiency is determined. Like the architecture of Sensor Network, topology design, routing protocol, MAC (Medium Access Control) protocol, data aggregation schemes etc.

Topology control design methods are one of the key areas, which are utilized in achieving the energy efficiency in the Sensor Networks. Figure 1.2 shows the placement of topology control algorithm in the protocol stack. Before going to further discussion on energy efficiency, below are our formal understandings about energy efficiency, network lifetime and other parameters, which are used to claim the effectiveness of the particular approach in Sensor Network. Below we discuss about the energy efficiency and network Lifetime parameters.

- ***Energy Efficiency****:* The Processing of Sensor Network should be extended as much as possible. In the normal topology control protocol, every sensor consumes a similar amount of energy for each network round or second. However, the topology control protocol is energy efficient if it can extend the overall network lifetime of Sensor Networks. For every sensor node, power consumption should be minimized if we consider the fact that all sensor nodes have similar importance.
- ***Network lifetime****:* The term network lifetime is nothing but some data collection rounds, or overall lifetime in minutes, until the first sensor node

in Sensor Network dies. For example, in some Sensor Network applications, it is required that operation of all sensor nodes should be done together, and then in such case lifetime is nothing but the total number of rounds of network till the first sensor node dies.

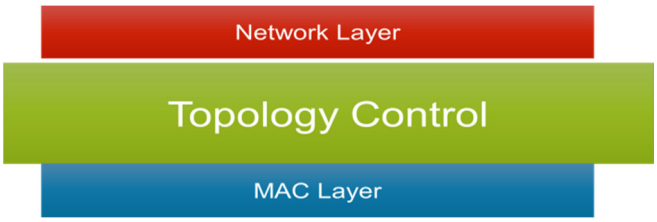

Figure 1.2: Placement Of Topology Control Algorithm In Protocol Stacks

Therefore, for Sensor Networks, at present, energy consumption is most important research problem considered while using topology control protocol. The importance of energy efficiency is explained as 1) the single small radio sensor device has a low power battery, which is expected to operate many months after its deployment. 2) If designing and deployment of Sensor Network is done over the inaccessible region, then it is required, that all the wireless sensor devices in such network utilize their batteries efficiently so that network lifetime is extended. Hence, many researchers are focusing their interests on designing energy efficient approach.

Topology control is the key approach, which applied for reducing the Sensor Networks power consumption. There are different techniques, which introduces for topology control protocols. There are two main types of topology controls used for Sensor Networks design, such as user control and random deployment of topology. For these approaches, unnecessary energy wastage, less scalability, and general condition issues arise. To overcome these problems, recently different methods over topology control and design are proposed with the goal of improving the energy efficiency of Sensor Networks. Thesis presented the extensive analysis of different topology control methods with their pros and cons, and then suggesting a new energy efficient topology control approach based on various parameters.

1.2 Motivation

Sensor Networks are the special type of mobile ad hoc network (MANET), in which wireless devices are treated as tiny sensors. Some of the problems related to ad hoc/sensor networking are still unsolved. Many application challenges are still unsolved before they get deployed on a large scale. The main challenge related to Sensor Network implementation is Topology control. In Sensor Networks, communication (receiving as well as transmitting) consumes a significant amount of energy. Since routing involves several nodes, its energy cost outweighs the cost of data processing. The exact number of nodes that participate in a routing task is not fixed. The detail classification is shown in figure 1.4.

Table 1.1: Reference for Motivation Graph

Parameters	Identified reference papers	Total
Network Lifetime	[1], [2],[3], [7], [8], [10], [11] ,[12],[13], [14], [15], [19], [20], [21], [22],[23], [25], [26], [30], [31], [55], [50],[51],[53],[55],[61], [62], [63],[66], [67],,[68],[70],[71],[76]	34
Connectivity	[1], [5], [6] ,[7], [8], [11],[13] ,[14], [15], [18] ,[19], [26], [28], [30], [33], [55], [59],[47],[48], [49],[50], [55], [61], [64], [66], [67],[68],[69],[70],[71]	30
Coverage	[3], [5] ,[6], [14], [19] ,[29], [45],[50],[53],[54],[55], [56],[58],[59],[61],[66],[72]	17
Reliability	[2], [6], [72],[76], [62],[63],[64],[65],[66], [67],[69] [70],[71]	13

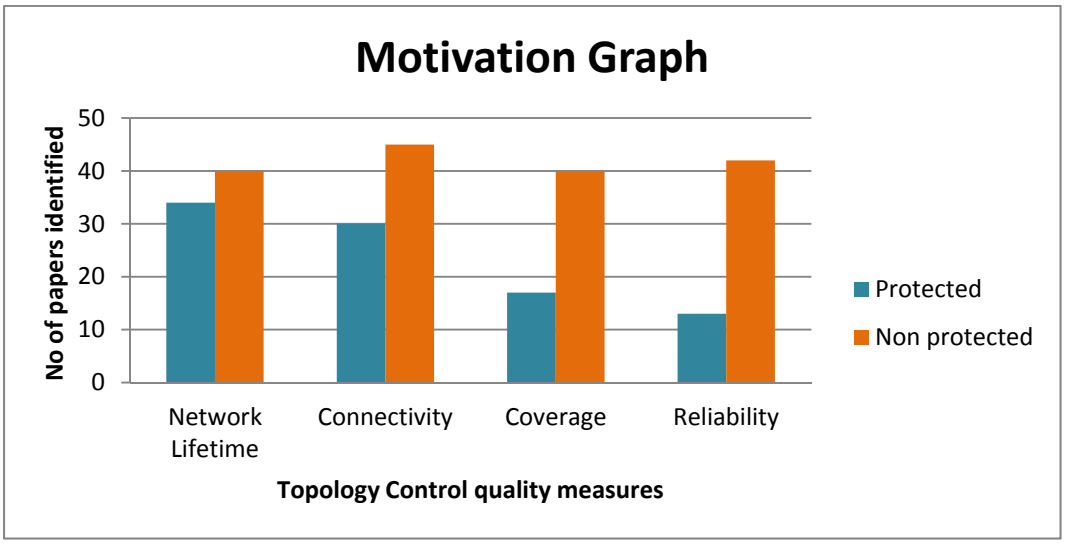

Figure 1.3: Motivation Graph

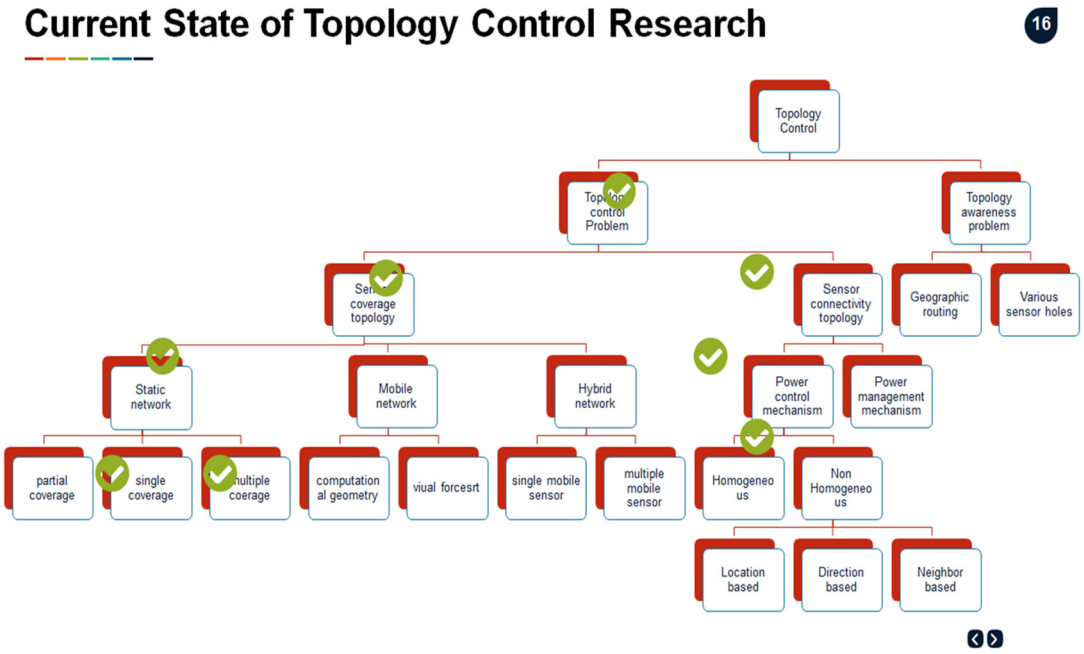

Figure 1.4: Taxonomy of Topology Control Algorithm

1.3 Problem Definition

The last two decades, several technique proposes for minimizing the overall Sensor Network power consumption, such as underlying routing protocol, MAC protocol, topology design and other components of Sensor Networks. Topology control plays a significant role in improving the energy efficiency of sensor networks. The energy efficient topology control protocol results in less power consumption and hence more network lifetime. There are many methods for topology control introduced by various researchers recently. Each of these methods have their own advantages and disadvantages. As the Sensor Networks designing and deployment is particularly based on applications, maintenance and design of completely connected topology are research challenges. This process needs a proper method for topology control. The performance of the topology control method is measured in terms of network lifetime and energy consumption. The main motive of using topology control method is to minimize the power consumption in the network and to extend the network lifetime. Some of the existing methods achieve the energy efficiency but suffers from the collision in the network if network traffic and size increases. Therefore, topology method should be supported for collision avoidance in Sensor Networks. In addition

to this, existing methods also suffer from the different problems such as data redundancy and delays. Data transmission done by sensor nodes to the next node with full power, which results in excessive energy consumption in Sensor Networks. This can lead to more energy consumptions and wastage. Based on literature review, we have listed below the main research problems in topology control in Sensor Networks:

- **Network Lifetime Definition**: The definition of network lifetime builds on the requirement of particular application in use. However, with existing topology control methods, the application requirements not taken into consideration while defining the network lifetime in topology control. The existing topology control method's definition for network lifetime is inefficient and not accurate.
- **Energy Model**: There are different energy models used by existing topology control methods to compute the energy consumption of sensor nodes in Sensor Networks. However, the problem with these models is that they are not considering the use of energy at the receiver's side, but considering only transmitter's side. Therefore, use proper real energy model with topology control methods.
- **Energy Conservation:** The main motivation behind topology construction phase is to build reduced topology that will save energy. It preserves network connectivity and coverage. Energy saving can be achieved by turning off nodes not part of the active topology.
- **Collision Avoidance:** The topology construction reduces packet collision, the number of retransmission and communication cost.
- **Reliability:** The nodes in Sensor Networks are small and tiny devices with more risk of its failures. In most applications, such devices are required to be thrown over the area of interest for long distance using a helicopter. Hence, this can result in the failure of such devices, affecting the normal functionality of devices. Therefore, reliability is a main motivation for designing the efficient topology control protocol.
- **Scalability**: As we know that wireless sensor networks are nothing but a collection of many numbers of sensor nodes, starting from small to large networks deployed over the geographical area. Hence, another motivation for

designing topology control protocols is to support the scalability with any number of sensor nodes.

As a conclusion, the main challenge in this area is to discover a new topology control technique, which will apply them into the framework, without sacrificing basic metric. It judges the aspects of topology control such as connectivity, stretch factor, graph metric, throughput, and robustness to mobility, coverage, scalability, algorithm overhead, etc.

1.4 Aims and Objectives

The main goal of this thesis is to discuss the energy efficiency, dynamics and distributed approach for topology control in Sensor Networks with the aim of improving the network lifetime by overcoming the existing problems of topology control methods. Figure 1.4 describes the detail workflow diagram to achieve the parameters such as energy efficiency, reliability, connectivity, and coverage. The main objectives of this research study listed:

- To study related work in topology control algorithms for wireless sensor networks
- To design energy efficient topology control algorithms for specific application
- To design analytical formulation of the problem defined
- To decide the performance metrics for evaluation of topology control algorithms for energy optimization of topologies.
- To design and validate the proposed algorithm on simulation platform.
- Testing of the proposed algorithm in agriculture field

1.5 Scope of Thesis

The new Energy efficient topology control method designed for homogeneous sensor networks, and this is the main scope of this thesis. This research study considers the practical approach for evaluating the efficiency of the proposed topology control method over various topology controls. The concepts of graph theory, link efficiency, dominating sets and neighbourhood schemes are used to design sensor networks and evaluate its performance via simulation studies. The scope of this

research is to design of proposed algorithm as well as heuristics, which are necessary for generating the energy efficient wireless sensor network topology.

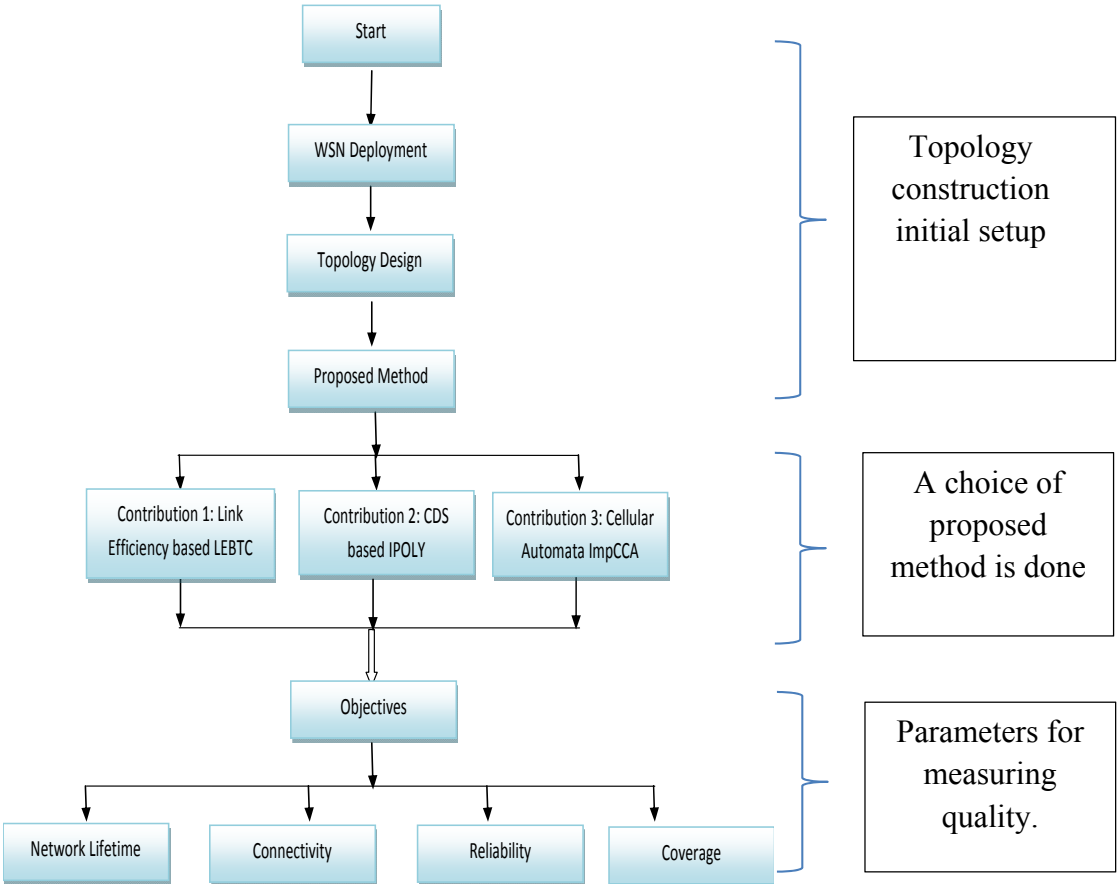

Figure 1.5: Workflow Diagram

1.6 Summary of Contributions

The research work focuses on six novel methods proposed to overcome the research challenges of existing topology control methods. The experimentation is carried out on a personal computer with Intel (R), Core i3, 2.10 GHz, 4GB RAM and 32-bit Windows. The method for generating topology can be distributed, localised or centralized. The structure of the generating network can be flat, hierarchical or clustered.

Table 1.2: Research Contributions

Approach	Contributions	Details of Proposed Scheme
Energy Optimization using Link Efficiency	Tech1-LEBTC	Link Efficiency based Topology Control Algorithm for Wireless Sensor Network. In this, we have designed the new algorithm with the goal of redundant edge removal process without affecting the connectivity as well as reducing the interferences.
Energy optimization using CDS	Tech2-IPOLY	IPOLY: Improved Reliable and Energy Efficient Topology Control Protocol for Wireless Sensor Network
	Tech3-IPOLY	Improved Reliable and Energy Efficient Topology Control Protocol for Wireless Sensor Network using static and dynamic maintenance
Energy Optimization using Cellular Automata	Tech4-ImpTCA1	ImpTCA1: Extending Lifetime Of Wireless Sensor Network Using Cellular Automata moor neighbourhood
	Tech5-ImpTCA1	ImpTCA1: Extending Lifetime Of Wireless Sensor Network Using Cellular Automata weighted Margoles neighborhood
	Tech6-ImpTCA2	ImpTCA2: Extending Lifetime Of Wireless Sensor Network Using Cellular Automata Moor neighborhood
	Tech7-ImpTCA2	ImpTCA2: Extending Lifetime Of Wireless Sensor Network Using Cellular Automata Margolos neighborhood
	Tech8-ImpCCA	Extending Lifetime Of Wireless Sensor Network Using Cyclic Cellular Automata.

1.7 Organization of Thesis

Chapter 1: Introduction

This chapter describes a research overview, motivation, challenges, problem definition, aims and objectives of the research. The scientific contributions of this thesis are explained and finally, the outline of the thesis is provided to give an overview of the individual chapters.

Chapter 2: Literature Survey

In this chapter, the introduction of topology control, different methods, research problems, etc. presented. First, introduction and basics of wireless sensor networks presented, as it is the main domain of this thesis. Then, a survey on topology control protocols and its taxonomy discussed. The third section focuses on a review of different topology control protocols proposed by various researchers with different aims and goals, as the topology control protocol is the main topic of this thesis. Finally, the comparative study of all recent topology control methods varying various parameters and strategies.

Chapter 3: Design Issues, Models and Simulation Platform

This chapter discusses the different design issues of topology control and energy models for wireless sensor network application. Classification of topology control algorithms explained in this chapter. Different types of simulators with their advantages and disadvantages have discussed.

Chapter 4: Link Efficiency based Topology Control Algorithm for Wireless Sensor Network

In this chapter, the discussion over the results for contribution is carried out with extensive simulation results and comparative analysis. This chapter presents the

details of link efficiency based topology control algorithm for wireless sensor network. This chapter is based on received signal strength indicator and distance between neighboring nodes. The second section describes the algorithm and energy model. The chapter ends with a result and discussion where the result of the proposed approach is compared with GG, RNG, and other algorithms. Chapter presents the shortest path and energy-efficient topology control algorithm. The algorithm tries to realm the shortest path linking itself to nearby nodes and the minimum energy paths.

Chapter 5: Improved Reliable and Energy Efficient Topology Control Algorithm for Wireless Sensor Network

In this chapter, the discussion over the results of contribution carried out with extensive simulation results and comparative analysis. Computed the reliability for CDS based POLY protocol and contrasted it with the static and dynamic deployment of nodes. By considering EH as a backup node, the lifetime of wireless sensor network field can boost the time allotment of sensor fields with clustering and base station arrangement.

Chapter 6: Cellular automata based topology control algorithm for Wireless Sensor Network

In this chapter, the discussion over the results for contributions related to cellular automata is carried out with extensive simulation results and comparative analysis. A Cellular Automaton versus Self-reproduction System is an appropriated processing established model. It is additionally called as a self-regenerative framework in literature and in lattine cell called as cella. Utilizing local data, it offers a superb stage for performing complex counts. The impact of various square choice plans examined and looked at the execution of all calculations. The outcome demonstrates that cyclic self-reproduction is efficient. The performance of CCA is more than the well-demonstrated Self-reproduction system.

Chapter 7: Conclusion and Future Work

This chapter concludes the thesis and proposes the future work, which can be researched and build based on the ideas proposed. In this chapter, we are discussing the achieved results and percentage of improvement as compared to existing methods. There are still many aspects of Topology Control for sensor networks that were not considered in this thesis due to the fact that some of them were out of scope or due to limitations of time and resources. There are plenty of rooms that can be explored and added on top of our proposed algorithms. Beyond the issues that have been evaluated in the focus of this thesis, there are still numerous aspects for further research.