CHAPTER 1

INTRODUCTION

1.1 KEY ISSUES OF WIRELESS SENSOR NETWORKS

Wireless Sensor Network is an emerging field that is gaining much importance owing to its immense contribution to the varieties of target specific applications. Wireless Sensor Networks (WSN) have a great contribution to make in the fields of National Security, Habitat Monitoring, Environment Observation, Forecasting, Health Applications and Home and Office Applications. This has attracted numerous researchers making WSN an active area of application research. The use of small, inexpensive, low power, distributed devices which have the potential of local processing and wireless communication have been made a reality owing to the recent technological improvements. These nodes are known as Sensor nodes. The ability of each sensor node is restricted in terms of limited amount of processing. However, the sensor nodes have the capability to gauge a given physical environment in a great detail in cases where the sensor nodes are coordinated with the information from a large number of other nodes. Therefore, a collection of sensor nodes coordinating to perform some specific action is known as a sensor network.

Earlier, a sensor network comprising a few sensor nodes was wired to a central station. However, now, the focus is more on wireless, distributed, sensing nodes. The Distributed Sensing permits closer placement to the phenomenon than a particular sensor can permit whilst the accurate location
of a particular phenomenon is unfamiliar. Further, to conquer ecological impediments like obstructions, line of sight constraints and so on, multiple sensor nodes are essential in several cases. The environment to be observed does not possess an offered infrastructure in majority of the cases for either energy or communication. Staying alive on minute, the finite sources of energy and communicating through a Wireless Communication channel have become essential for sensor nodes. Minimizing energy consumption is the main goal in many wireless network environments especially, when the individual nodes of the network are battery powered. This requirement has become increasingly important for new generations of mobile computing devices as the energy density achievable in batteries has grown only at linear rate while processing power and storage capacity have both grown exponentially. As the consequence of these trends, many wireless enabled devices are now primarily energy constraints; while they possess the ability to run many sophisticated multimedia networked applications, their operational lifetime between recharges is often very small. Besides, the energy consumed in communication by the radio interfaces is often higher than or at least comparable to the computational energy consumed by the processor.

The availability of the low-power micro-sensors, actuators, embedded processors, and radios is enabling the application of distributed wireless sensing to a wide range of applications including environmental monitoring, smart spaces, medical applications, and precision agriculture. The most deployed sensor networks involve relatively small numbers of sensors wired to a central processing unit where all of the signal processing is performed. In contrast, the distributed, wireless, sensor networks in which the signal processing is distributed along with the sensing are also more important.
When the precise location of a signal of interest is unknown in a monitored region, the distributed sensing allows one to place the sensors closer to the phenomena being monitored than if only a single sensor were used. This yields higher SNR, and improved opportunities for the line of sight. While SNR can be addressed in many cases by deploying one very large sensitive sensor, the line of sight, and more generally obstructions, cannot be addressed by deploying one sensor regardless of its sensitivity. Thus, distributed sensing provides robustness to the environmental obstacles.

When wired networking of distributed sensors can easily be achieved, it is often the more advantageous approach. Moreover, when nodes can be wired to renewable (relatively infinite) energy sources, it greatly simplifies the system design and operation. However, in many envisioned applications, the environment being monitored does not have installed infrastructure for either of the communications or energy, and therefore untethered nodes must rely on local, finite, and relatively small energy sources, as well as wireless communication channels. Although sensors are distributed to be close to the phenomena, one might still consider an architecture in which sensor outputs can be communicated back to a central processing unit. However, in the context of untethered nodes, the finite energy budget is a primary design constraint. Communications is a key energy consumer as the radio signal power in sensor networks drops off owing to the ground reflections from short antenna heights. Therefore, one wants to process data as much as possible inside the network to reduce the number of bits transmitted, particularly over longer distances.

Distributed Processing capability is an additional necessity for sensor networks. As communication is the foremost consumer of energy, this is essential. The sensor may need to communicate over long distances in case of a centralized algorithm which may lead to further energy depletion. To
diminish the whole amount of information broadcast, it is beneficial to process as much information as achievable in the neighborhood.

On the basis of the simplified Wireless Sensor Network model, there exist three operating options with different schemes for local processing and data transmission, known as Centralized options, the Distributed options and the Quantized options. To be specific, the Centralized option transmits all the information contained in the observed data to the control centre which results in a simple binary hypothesis testing problem. For the Distributed option, each sensor node makes its own decision by local decision rule. One bit decisions are transmitted to the control centre, where a final decision is made. The Quantized option does some local processing at sensor nodes and transmits the resultant data to the control centre which contains the partial information of the original observed data.

The following are the challenges:

1. Untethered for energy and communication requiring maximal focus on energy efficiency.

2. Ad hoc deployment, requiring that the system identifies and copes with the resulting distribution and connectivity of nodes.

3. Dynamic environmental conditions requiring the system to adapt over time to changing connectivity and system stimuli.

4. Unattended operation requiring configuration and reconfiguration to be automatic (self-configuration).
The Strategies to address these challenging environments are as follows:

1. Collaborative signal processing among nodes that have experienced a common stimulus will greatly enhance the efficiency (information per bit transmitted) of these systems. To develop both coherent signal processing on small clusters by a centralized entity within the cluster, and noncoherent processing with much less stringent synchronization requirements, applicable across larger numbers of more loosely coupled elements.

2. Exploiting redundancy of hardware elements to compensate for ad hoc deployment of systems. If elements cannot be carefully positioned relative to each other and the environment, then an alternate strategy to achieve “coverage” is to deploy so great a density of elements that one can make use of some subset that have the desired absolute and relative position. In certain contexts, even if elements can be uniformly placed in 3-space, the environmental conditions may be such that the coverage is not uniform owing to obstacles and other sources of noise. Another application of redundancy is when the incremental cost of a node during initial deployment is much smaller than the incremental cost of deploying new nodes or renewing node resources (e.g., energy). In this case, one can exploit redundancy to extend the lifetime of the system by adjusting duty cycle based on local density and local demand.

3. Adaptive fidelity signal processing is another strategy that can be exploited in sensor networks to make trade-offs among
energy, accuracy, and rapidity of results. Recognizing that one is trying to detect non-deterministic phenomena in the presence of communication noise and sensor diversity, the fidelity and timeliness of the signal processing at individual sensor nodes can be adapted to energy resources and latency requirements.

4. A hierarchical, tiered architecture can greatly contribute to overall system lifetime and capability. Whenever possible, the higher capacity system elements can be used to offload drain on small form factor elements, while the latter can be exploited to obtain the desired physical proximity to stimuli. Moreover, even among elements with homogenous capabilities, creating clusters and assigning special combining functions to cluster heads can contribute to overall system scalability. However, to avoid compromising robustness, such clusters/hierarchy must be self-configuring and reconfiguring in the face of environmental or network changes.

1.1.1 Performance Issues

Though certain types of energy harvesting are conceivable, energy efficiency will be a deciding factor in the success of WSNs in the foreseeable future. This requirement pervades all aspects of the system's design, and drives most of the other requirements. The key design challenges in the domain of wireless sensor networks are defined as follows:

1. Large number of sensors: Given the large number of sensor nodes deployed, scalability is a major issue. Nodes may fail and new nodes may join the network.
In the light of target tracking, the coordination function should scale with the size of the network for the number of targets to be tracked.

2. Low energy use: Since in many applications the sensor nodes are deployed in a remote area, the service of a node may not be available. In this case, the lifetime of a node may be determined by the battery life, thereby requiring the minimization of energy consumption.

3. Network self-organization: Since the network can be randomly deployed in inaccessible regions, the sensor nodes should be capable of organizing themselves into a network and achieving the desired objective in the absence of any human intervention.

4. Collaborative signal processing: The ultimate goal is the detection/estimation of some events of interest, and not just communications. It is often quite useful to fuse data from multiple sensors to improve the detection/estimation performance.

5. Distributed processing: While a centralized architecture is theoretically optimal and conceptually simple, it is not suitable in a large scale area because of the limited communication bandwidth of the wireless sensors. Moreover, failure of the fixed superior node may imply failure of the whole system.

6. Tracking accuracy: To be effective, the tracking system should be accurate and the likelihood of missing a target should be low.
7. Computation and communication costs: While developing protocol for sensor networks one should keep in mind the costs associated with computations and communication. With the current technology, the cost of computation locally is lower than that of communication in a power constrained scenario. As a consequence, emphasis should be put on minimizing the communication requirements.

8. Uncertainty: The exact positions of the nodes cannot be known, so any position estimate of the target being tracked will be affected.

9. Multi-modality sensor network: A multi-modal network can obtain more complete descriptions of the monitored environment by combining the data from various sensors with different capabilities and strengths.

10. Time synchronization: Time synchronization is a critical piece of infrastructure for any distributed system.

1.2 OBJECTIVE OF THE RESEARCH

The research addresses the following challenges: energy efficiency, adaptation to changing connectivity and reconfiguration. These challenges are addressed with the help of the proposed energy efficient distributed coverage algorithm for WSN as discussed in the forthcoming chapter 2 and the algorithm for dynamic coverage maintenance as discussed in chapter 3. The performance issues like minimum number of sensors, low energy use, self organization, distributed processing and tracking delay are verified by the algorithms proposed for energy efficient target tracking in chapter 4 and energy efficient distributed coverage algorithm for target tracking in chapter 5 with simulation results.
Due to communication, processing and energy constraints, tracking in sensor networks creates different challenges. Since the existing algorithms utilize the information from all the sensors for tracking, it results in a higher consumption of energy and reduced lifetime for the network.

An energy efficient distributed algorithm has been developed for the connected sensor cover design to reduce the energy consumption with a lower communication overhead. Rather than treating coverage and connectivity as two separate sub problems, the proposed algorithm attempts to merge them in a single algorithm. Every sensor has a priority assigned to it in the proposed distributed algorithm. The priorities are assigned based on their remaining energy and battery capacity. Naturally the nodes with high residual energy and battery capacity are assigned to be higher priorities. To reduce the chance for selecting the least priority nodes, the connected sensor covers are chosen with high priority nodes. To reduce the energy, the low priority nodes that are not needed in the coverage can go to a sleep mode. The distributed algorithm is evaluated using simulations which have shown that this approach results in significant reduction of energy with strong connectivity and coverage.

A set of algorithms has been proposed that aids in the tracking of changes in network topology thereby addressing the issues related to the dynamic coverage and loss recovery. These algorithms can assist in the adaptive maintenance of the coverage either by migrating sensor node or by updating the radii accordingly. The distributed algorithm and dynamic coverage algorithm were evaluated using simulations and shown that this approach results in a significant reduction of energy with strong connectivity and coverage.

An energy efficient tracking algorithm has been proposed to accomplish reduced coverage in wireless sensor networks. Tracking issue is
first addressed through the determination of a reduced cover for the region of interest. To have reduced coverage, distributed connected coverage algorithm is applied. The algorithms make use of a minimal subset of sensor nodes in order to track a target which minimizes the overall energy consumption and therefore the lifetime of the network. Tracking algorithms are developed using a reduced set of sensor nodes. The simulation results have shown that the substantial savings can be obtained by using a reduced number of nodes at each instant for tracking the target. Based on the reduced cover, tracking algorithms use only a fewer nodes and so they are efficient from an energy point of view. The energy consumption of the network can also be reduced by activating only those nodes in the surrounding area of the target which is being tracked. This can be achieved by activating the sensor nodes in the surrounding area of the sensor nodes which detect the target.

The following steps are involved in the energy efficient tracking of a target.

1. Determining a reduced sensor coverage for the given targeted region.
2. Determining the boundary sensor nodes of the given targeted region.
3. Detecting the target entry or movement.
4. Broadcasting the coordinates of the boundary sensor node.

A target zone detection algorithm has been proposed to estimate the locations of the targets from the sensors within the target zone. The locations of the sensors are estimated by the localization algorithm. This is performed with the unknown location information by utilizing the knowledge of the positions of the sensors and inter-sensor measurements. The simulation results
have shown that the proposed algorithm achieves a reduced energy consumption and coverage along with a minimum delay.

1.3 LITERATURE REVIEW

O’Rourke (1987) discussed Art Gallery Problem (AGP) in computational Geometry which seeks to determine the minimum number of cameras that can be placed in a polygonal environment so that every point in the environment is monitored.

Historically, three types of coverage have been defined by Gage (1992) as Blanket Coverage to achieve a static arrangement of sensor nodes that maximizes the detection rate of targets appearing in the sensing field, Barrier Coverage to achieve a static arrangement of sensor nodes that minimizes the probability of undetected penetration through the barrier and Sweep Coverage to move the number of sensor nodes across the sensing field so that it addresses a specified balance between maximizing the detection rate and minimizing the number of missed detection per unit area.

The sensor placement problem can be modeled as a special case of the alarm placement problem described by Rao (1993) and it has been shown that the minimal placement of alarms for arbitrary graphs is NP-complete problem.

Chakrabarty et al (2002) studied the sensor placement issues for target tracking analytically and provided a modified problem model for target localization, based on a grid manner discretization of space.

Chakrabarty et al (2002) modeled the optimization problem of coverage with Integer Linear Programming (ILP) and represented the sensor
field as a two or three dimensional grid using methods for placement with desired coverage.

Zhao et al (2002) proposed an information driven dynamic sensor collaboration technique where the participants for collaboration were determined by dynamically optimizing the information utility of data for given cost of computation and communication.

Meesookho et al (2002) presented an improved moving vehicle target classification performance using the data obtained from the sensor networks with collaboration both across nodes and within a node in terms of multimodal fusion. Their results show that a 50% relative improvement in classification error can be obtained using collaboration both in the case of single vehicle target and those involving multi-vehicle convoys.

Dan Li et al (2002) outlined a framework for collaborative signal processing in distributed sensor networks. Their ideas are presented in the context of tracking multiple moving objects in a sensor field. The key steps involved in the tracking procedure include event detection, target classification, and estimation and prediction of target location. Algorithms for various tasks are discussed with an emphasis on classification. The results based on experiments with real data which provide useful insights into the essential nature of the problems are reported.

Ye et al (2002) described a distributed localized algorithm for density control based on probing mechanism where each node can be in one of the three states: Sleeping, Wakeup or Working. A working node is responsible for sensing and data communication, while nodes in wake up state prepare themselves for replacing a dying node owing to energy depletion or other kinds of failures.
Howard et al (2002) proposed a potential field based deployment approach using mobile autonomous robots to maximize area coverage. Poduri and Sukhatme (2004) augment the scheme in such a way that each node has atleast k neighbors. The potential field technique using mobile robots was first introduced by Khatib (1986).

Howard et al (2002) presented an incremental and greedy self deployment algorithm for mobile sensor networks in which nodes are deployed one at a time into an unknown environment where each node makes use of the information gathered by the previously deployed nodes to determine its optimal deployment location.

Wang et al (2003) presented the design and analysis of the novel protocols that can dynamically configure a network to achieve guaranteed degrees of coverage and connectivity. The Coverage Configuration Protocol (CCP) can provide different degrees of coverage requested by applications. This flexibility allows the network to self-configure for a wide range of applications and (possibly dynamic) environments. They have also integrated CCP with the SPAN to provide both coverage and connectivity guarantees when the sensing range is higher than half of the communication range. The simulation results demonstrate that CCP and CCP+SPAN+2Hop can effectively configure the network to achieve both the requested coverage degrees and satisfactory communication capacity under different ratios of sensing/communication ranges as predicted by their geometric analysis relationship between coverage and connectivity but unable to handle more sophisticated coverage models and connectivity configurations for energy efficient distributed detection and tracking. The research addresses the above problem by proposing an energy efficient distributed coverage for target tracking in WSN for adaptive coverage reconfiguration distributed detection and tracking techniques.
Dhillon et al (2003) proposed a grid coverage algorithm that ensures that every gridpoint is covered with minimum confidence level and considered a minimalistic view of a sensor network by deploying a minimum number of sensors on a grid that would transmit a minimum amount of data.

Gao et al (2003) proved that at least three and at most five one hop neighbors are needed to cover the whole sensing area of node $S_i$. The algorithm described by Tian and Georganas (2002) consists of two phases: self scheduling phase and sensing phase. Each sensor broadcasts its position and node id, and listens to advertisement messages from its neighbors and checks whether the union of their sponsored sectors can cover its own sensing area. If so, it decides to turn itself off. Moreover, the authors have addressed only the coverage problem without investigating the connectivity problem. The coverage and connectivity problems are addressed in this research.

Heo and Varshney (2003) proposed a distributed self deployment algorithm for mobile sensor networks that maximizes coverage and maintains uniformity of node distribution. They defined coverage as the ratio of union of uncovered areas of each node to the complete area of the sensing field and uniformity as the average of local standard deviations of intermodal distances.

Wang et al (2003) described a protocol called the bidding protocol for mixed sensor networks to reduce the problem to NP hard set covering problem and provides heuristics to solve it near optimally.

West (2003) proved that if a graph is k-node connected, it is also k-edge connected but the reverse is not necessarily true and is applied to node degree and connectivity in Geometric Random Graph (GRG) to study the connectivity in adhoc wireless networks.
Shakkottai et al (2003) considered an unreliable wireless sensor grid network with \( n \) nodes placed over a unit area and indicated that when \( n \) is large, each node can be highly unreliable and the transmission power can be small but can still maintain connectivity with coverage.

Huang (2003) showed that how each node check if the local area in its sensing range satisfies the \( k \)-coverage condition. Further, the placement of sensor nodes also affect the way how the target localization is conducted.

Aslam et al (2003) initially investigated Target tracking using a sensor network. With advances in the fabrication of technologies that integrate the sensing and wireless communication technologies, the sensor motes can be densely deployed in the desired field to form a large scale wireless network.

Zhou et al (2003) proposed a sensor deployment algorithm based on virtual forces to increase coverage after an initial random deployment. Since, a random placement does not guarantee effective coverage, an approach that modifies the sensor locations after the random placement is useful.

Zhou and Chakrabarty (2004) presented two algorithms for efficient placement of sensors when exact locations are not known where the sensor locations are modeled as random variables following Gaussian distribution.

Wang et al (2004) described three distributed self deployment algorithms (VEC, VOR and min-max) for mobile sensors using Voronoi diagrams which locates coverage holes and calculates new positions that would increase coverage by moving sensors from densely populated regions to sparsely ones.
Funke et al (2004) proposed an approach for energy conservation scheduling sleep intervals for some sensors, while the remaining sensors stay active providing continuous service. In this, they have considered the problem of selecting a set of active sensors of minimum cardinality so that sensing coverage and network connectivity are maintained. They have shown that the greedy algorithm provides complete coverage. There is a trade-off between the ease of implementation and the accuracy of the proposed algorithms, which allows one to select the proper algorithm for the specific needs. An open problem is whether it is possible to obtain a distributed constant approximation algorithm that can provide full coverage.

Gui and Mohapatra (2004) discussed the sleep-aware pattern of each node during the tracking stage to obtain the power efficiency.

Romit Roy Choudhury and Robin Kravets (2004) discussed the great problem of coverage in wireless sensor networks, and identified the large dependence on infrastructure (e.g., GPS, directional antennas, etc.) in the existing solutions. To eliminate the reliance on infrastructure, they proposed an energy efficient distributed protocol that aims at preserving coverage by exploiting local neighborhood information. Turning off redundant nodes can conserve energy, increasing sensing lifetime of the entire system – a crucial goal of most sensor networks. Through geometric analysis, they have shown that their protocol can efficiently preserve coverage (when feasible), but the energy efficiency for target tracking was not addressed in the above and so this research focuses on the distributed coverage along with target tracking in an efficient manner.

Santi (2005) proposed an efficient topology control for deploying nodes in large sensing fields where nodes can either be placed manually at predetermined locations or dropped from an aircraft.
Zhang et al (2005) addressed the issues of maintaining sensing coverage and connectivity by keeping a minimum number of sensor nodes in the active mode in wireless sensor networks. They derived, under the ideal case in which node density is sufficiently high, a set of optimality conditions under which a subset of working sensor nodes can be chosen for complete coverage. Based on the optimality conditions, they devised a decentralized and localized density control algorithm, OGDC. OGDC was fully localized and could maintain coverage as well as connectivity, regardless of the relationship between the radio range and the sensing range.

Mechitov et al (2006) proposed a distributed approach to target tracking using binary sensors which determine whether the object is within their detection range and then collaborate with neighbor node data and perform statistical approximation techniques to predict the trajectory of the object.

Choi and Das (2006) presented a two phase clustering scheme for energy saving and delay adaptive data gathering in order to extend the network’s life time for efficient resource management.

Xiaole Bai et al (2006) proposed an optimal deployment pattern to achieve both full coverage and 2-connectivity, and demonstrated its optimality for all values of \( rc/rs \); where \( rc \) is the communication radius, and \( rs \) is the sensing radius. They have put forth a strip-based deployment pattern to achieve coverage and 2-connectivity, and proved its optimality. They have also shown the optimality of a previously proposed strip-based deployment pattern to achieve coverage and 1-connectivity. Finally, they have established the efficiency of popular regular patterns of deployment, thus enabling a deployer make a more informed decision.
Guoliang Xing et al (2006) proposed an analysis and simulation, showing that simple greedy geographic routing algorithms such as GF and BVGF. It may be highly efficient in sensing-covered networks with deterministic or probabilistic communication links. Second, their results indicate that the redundant nodes can be turned off without significant increase in network length as long as the remaining active nodes maintain sensing coverage. In that dilation bounds enable a source node to efficiently compute an upper-bound on the network length or expected number of transmissions of its routing path based on the location of the destination. This capability can be useful to real-time communication protocols that require such bounds to achieve predictable end-to-end communication delays.

Christopher Taylor et al (2006) introduced the Simultaneous Localization and Tracking, called SLAT, the problem of tracking a target in a sensor network while simultaneously localizing and calibrating the nodes of the network. Their proposed solution provides on-line probabilistic estimates of sensor locations and target tracks which do not require globally accessible beacon signals or accurate ranging between the nodes.

Himanshu Gupta et al (2006) proposed an approach to reduce the communication cost of a query and to self-organize the network, in response to a query, into a topology that involves only a small subset of the sensors sufficient to process the query. The query is then executed using only the sensors in the constructed topology that develops the notion of a connected sensor cover and designs a centralized approximation algorithm that constructs a topology involving a near-optimal connected sensor cover. They proved that the size of the constructed topology is within the optimal size. They also developed a distributed self-organization version of the approximation algorithm and proposed several optimizations to reduce the communication overhead of the algorithm, but did not provide any guarantee
on the size of the connected sensor cover constructed. However, the distributed algorithm is heuristic based and does not guarantee the optimal size of the network. Finally, they evaluated the distributed algorithms using simulations and showed that the approaches result in significant communication cost reductions.

A novel approach explored by Yuan et al (2007) described the use of hierarchical architecture for the heterogeneous broadband sensor network to facilitate interaction between sensor nodes and improve energy efficiency.

Zijian Wang et al (2008) studied the target tracking with wireless binary sensor networks in which each sensor can return only 1-bit information regarding target’s presence or absence in its sending range. They have proposed a novel, real-time and distributed target tracking algorithm for an imperfect binary sensing model. They have observed that their algorithm yields good performance in terms of accuracy and estimates the target location, velocity and trajectory.

Xiaole Bai et al (2008) studied the issue of optimal deployment to achieve four connectivity and full coverage for WSN under different ratios of sensors communication range (denoted by \( r_c \)) to their sensing range (denoted by \( r_s \)). They have worked on the “Diamond” pattern that can be viewed as a series of different evolving patterns. When \( r_c/r_s \geq \sqrt{3} \), the Diamond pattern coincides with the well-known triangle lattice pattern; when \( r_c/r_s \leq \sqrt{2} \), it degenerates to a “Square” pattern. They have proved the Diamond pattern to be asymptotically optimal when \( r_c/r_s > \sqrt{2} \).

Pinar Oguz-Ekim et al (2009) solved the problem of Euclidean Distance Matrix (EDM) completion to obtain initial sensor/target positions.
The likelihood function is then iteratively optimized through either a Majorization-Minimization (MM) or Newton method. To reduce the computational load, they have proposed an incremental scheme whereby each new target position is estimated from range measurements, providing additional initialization for ML without the need for solving an expanded EDM completion problem.

Liu et al (2009) addressed the sensor selection problem which is an important issue where many sensors are available to track a target. They selected an appropriate group of sensors each time to perform tracking in a WSN. As the theoretical tracking performance is bound by posterior Cramer-Rao lower bound (PCRLB), it is used as a criterion to select sensors. Based on the PCRLB, sensor selection algorithms with and without the sensing range constraint are developed. The effectiveness of their proposed methods is validated by simulation results.

Kuei-Ping Shih et al (2009) considered the connected target coverage (CTC) problem in wireless heterogeneous sensor networks (WHSNs) with multiple sensing units, termed MU-CTC problem. MU-CTC problem can be reduced to a connected set cover problem and further formulated as an integer linear programming (ILP) problem. However, the ILP problem is an NP-complete problem. Therefore, two distributed heuristic schemes, REFS (remaining energy first scheme) and EEFS (energy efficiency first scheme) were proposed. Without good coordination among sensing units or sensors, $m$-SU-CTC turn on many redundant sensing units or sensors, and thus, result in higher energy consumption. The research compares the EEFS method and the proposed energy efficient distributed tracking method because REFS is not efficient compared to EEFS. The simulation results of the proposed method show that the average energy consumed by the nodes is 25% less than the EEFS.
1.4 ORGANIZATION OF THE THESIS

The Thesis is organized as follows:

Chapter 1 emphasizes the need for Energy Efficient Distributed Coverage and Target Tracking along with several methods suggested by various authors taken from well-known literature. The importance of selecting this method is highlighted and the objective of the thesis is also elucidated.

Chapter 2 presents an Energy Efficient Distributed Algorithm for the Connected Sensor Cover Design to reduce the energy consumption with a lower communication overhead. The distributed algorithm is evaluated using simulations and proved that this approach results in significant reduction of energy with strong connectivity and coverage.

Chapter 3 discusses the Distributed Algorithm for Connected Sensor Cover with Dynamic Coverage Maintenance in Sensor Networks that aid in the tracking of changes in network topology thereby addressing the issues related to dynamic coverage and loss recovery. The distributed algorithm and the dynamic coverage algorithm were evaluated using simulations showing that this approach results in significant a reduction of energy with strong connectivity and coverage.

Chapter 4 illustrates an Energy Efficient Tracking Algorithm for Reduced Coverage in Wireless Sensor Networks where Tracking includes identifying an object by its particular sensor signature and determining its path over a period of time. Tracking algorithms are developed using a reduced set of sensor nodes. The simulation results showed that the substantial savings can be obtained by using a reduced number of nodes at each instant for tracking the target.
Chapter 5 describes the importance of Distributed Coverage and Target Tracking Algorithm for Wireless Sensor Networks to estimate the locations of the targets from the sensors within the target zone. The locations of the sensors are estimated by the localization algorithm. The simulation results have shown that the proposed algorithm achieves a reduced energy consumption and coverage with a minimum delay.

Chapter 6 summarizes the conclusions and explains the scope for future work of the research findings.