CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The main challenge in implementing Wireless Sensor Networks is the design of routing protocols to provide general and flexible platforms that can be used for many applications (Willig 2008). There are different approaches to achieve optimal performance of the network. A detailed review is made on clustering schemes, routing protocols, duty cycling schemes and data driven approaches. The energy management has been studied extensively and recent literatures are reviewed on data centric routing and cluster based routing to frame energy efficient model.

2.2 DATA CENTRIC ROUTING

Routing in sensor networks is different from Ad-hoc networks. In sensor networks the energy dissipation, in transmission of data directly depends on the routing algorithm (Bansal et al 2006). Based on the architecture and power breakdown, several approaches are considered simultaneously to reduce power consumption in Wireless Sensor Networks. Hence, resource constraint sensor networks require an optimum algorithm for routing.

The techniques followed for traditional routing protocols for sensor networks are Directed Diffusion, Flooding and Gossiping. Rumor Routing,
Gradient Based Routing (GBR) protocol, Low Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS), Threshold sensitive Energy Efficient sensor Network protocol, Geographic Adaptive Fidelity (GAF), SPEED, Sensor Protocols for Information via Negotiation (SPIN), are some of the commonly used protocols. The traditional routing protocols have its own, architectural framework classification, attributes for application requirements and constraints in meeting the QoS.

Flooding is easy to implement, but it suffers from duplicated messages to same node, overlap of packets and resource unawareness (Heinzelman et al 1999). Directed diffusion is a time dependent protocol that requires extra overhead at the sensors. It is not suitable for continuous data delivery model, as it is based on query-driven data delivery model (Intanagonwiwat et al 2000). SPIN suffers from sequential overhead in processing of data and overhead in energy consumption and storage. Rumor routing is advantageous in energy saving, but the tuning overhead problem exists, while adjusting the parameters for any application (Brakinsky and Estrin 2002). Hence researchers apply hybrid model using a combination of data delivery models or techniques or communication mechanism; to alleviate the deficiencies of one technique with another as per the application. Such routing protocol is highly influenced with regard to the minimization of energy consumption and route stability.

The main drawback confronted by data centric protocols is lack of simultaneously meeting the constraints like scalability, energy awareness, guarantee of data delivery, and multihop communication. The constraints of data centric routing, directs other modes of routing like hierarchical, QoS centric and location-based protocols.
2.3 CLUSTER BASED ROUTING

It is inferred that the traditional routing protocols has its advantages and constraints. The analysis paved path to develop next level of routing protocols. Clustering is an unsupervised learning method that assigns a set of observations into clusters so that observations in the same cluster are similar in some sense (Shen et al 2010). Every Sensor node is grouped under various clusters based on its energy level, distance from node to the base station and distance between adjacent nodes.

Clustering prolongs the network lifetime by supporting localized decision-making and communication of locally aggregated data within the clusters by conserving energy (Venkatraman et al 2008). Cluster based routing protocols have the advantages of reduced control messages, bandwidth reusability, enhanced resource allocation, larger scalability and improved power control (Slama et al 2007).

A survey on energy efficient clustering algorithms is detailed by Wei (2007). Comparative Study of Wireless Sensor Networks Energy-Efficient Topologies and Power Save Protocols are explained by Niewiadomska-Szynkiewicz et al (2009). Based on the comparative study the authors have developed a new clustering based approach that utilizes the periodical coordination of nodes to reduce the overall energy usage by the network. Low Energy Adaptive Clustering Hierarchy (LEACH) is a distributed single-hop clustering algorithm developed by Heinzelman et al (2002) for energy utilization problem in Sensor Networks. The cluster head is periodically rotated among the sensor nodes to balance energy consumption. The cluster head rotation requires that all the nodes should be capable of performing data aggregation, cluster management and routing decisions. This results in extra hardware complexity in all the nodes. Hybrid Energy Efficient
Distributed clustering (HEED) is one of the effective data-gathering protocols for Sensor Networks (Younis and Fahmy 2004). The cluster head is selected based on the node’s residual energy and a subordinate parameter, as proximity to its neighbors. LEACH and HEED both are applicable for mobile and static data collection. Based on traditional approaches, chain-based protocol PEGASIS, Base-Station Controlled Dynamic Clustering Protocol (BCDCP), and Cluster Head Election Protocol (CHEP) are developed (Wei 2007).

The earlier researchers have not focused much on the problem of integrating two algorithms in different categories. Several cluster based approaches that have been suggested in the literature estimates the energy consumption required to achieve conservative approximations, resulting in communication and processing overheads with under utilization of network resources. The Adhoc On-demand Energy efficient routing protocol is developed in this research to maintain competence in energy and find the active nodes in the network. The threshold attribute of TEEN protocol is one of the main features to tradeoff energy efficiency and accuracy. The threshold constraints of TEEN are incorporated in Ad hoc On-demand Distance Vector to maintain route while transmitting the data. The overhead of the network and energy consumption of the nodes are significantly reduced and the overall performance is enhanced.

The study of literature infers that, the traditional approaches lack in meeting the real time requirements, limitation in sequential processing, insufficient naming schemes, dynamic topology change, mobility, and computation time. The contemporary approach of repeated cluster based routing have been extensively exploited, introduces the problem of premature node/cluster death, imbalance data delivery to sink, nonequivalence cluster lifetime, communication and processing overheads (Shu and Krunz 2010).
Hence an energy efficient cluster based routing protocol should encompass robustness, scalability, minimum overhead or delay, reduction in data redundancy, multihop communication and shortest path routing.

2.4 NEED FOR COMPUTATIONAL INTELLIGENCE TECHNIQUES

The objective in this research is to search for an optimal solution. The taxonomy of optimization algorithms are broadly classified as deterministic and probabilistic algorithms. Most of the biologically inspired optimization algorithms fall under the category of Monte Carlo algorithms. An important class of probabilistic Monte Carlo metaheuristics is Evolutionary Computation. It encompasses all algorithms that are based on a set of multiple solution candidates called population which is iteratively refined. This field of optimization is also a class of Soft Computing and a part of artificial intelligence area (Weise 2009).

Parallel solutions and multiobjective methods are more desirable for fast Computation and to overcome deficiencies in traditional algorithms. This led to the development of computational intelligent techniques in the design of sensor networks. Sensor networks as well as biological systems need to adapt to the varying environmental circumstances including the ability to self-organize, scale efficiently and to provide robust and resilient operation for the long-term survival of the system. These characteristics constitute the base for the development of different approaches and algorithms at different network layer for efficient, robust and resilient communication and information networks (Jacobsen et al 2011). The computational intelligent techniques inspired from nature, like Evolutionary Algorithms (EA), Simulated Annealing, Tabu Search, Particle Swarm Optimization, Monkey
Search Algorithm, Cuckoo Search Optimization, Ant Colony Optimization, Fire Fly and Bee Optimization, Fuzzy Logic and Neural Networks are utilized in dynamic optimization problems for data aggregation and fusion, energy aware routing, task scheduling, security, optimal deployment and localization in Wireless Sensor Networks (Celik et al 2010, Kulkarni et al 2011).

Celik et al (2010) have briefly discussed the Swarm intelligence based routing protocols for Wireless Sensor Networks. The routing algorithms are compared in terms of energy efficiency, scalability, data gathering, and network lifetime, ratio of packet delivery, latency, success rates, fault tolerance, and simulator characteristics. Masazade et al (2010) discussed the distributed detection problem to evaluate the sensor thresholds by formulating and solving a multiobjective optimization problem, where the objectives are to minimize the probability of error and the total energy consumption of the network. Genetic Algorithms with Immigrants and Memory Schemes for Dynamic Shortest Path Routing Problems in Mobile Ad Hoc Networks are developed by Yang, Cheng and Wang (2010). Dynamic shortest path routing is balanced well by the memory schemes and immigrants. Enami et al (2010) have stated that the dimensionality reduction and prediction of sensor data obtained from the outputs of the Neural-Networks (NN) algorithms could lead to lower communication costs and energy conservation. The NN approach results in simple parallel distributed computation, distributed storage, data robustness, auto-classification of sensor nodes. The analogy and compatibility between WSNs and NN are explained with respect to the characteristics chosen for analysis. Pongchairerks and Kachitvichyanukul (2009) have proposed a variant of Particle Swarm Optimization algorithm which enhances the social learning structure of the standard PSO by incorporating multiple social best positions.
Among the different approaches based on “Heuristics from Nature”, Genetic Algorithm, Particle Swarm Optimization, Ant Colony Optimization algorithms are performing better for handling the optimization problems. The research problem is solved by developing and implementing different optimization techniques for sensor networks, by considering the following aspects.

i) Energy efficient clustering of nodes and
ii) Communication Phase from cluster-head to base station.

Four different techniques are proposed incorporating Particle swarm Optimization, Cuckoo Search, Ant Colony Optimization, Tabu Search and Generalized particle approach algorithm.

2.4.1 Hybrid Swarm Optimization

The Particle Swarm Optimization and Ant Colony Optimization are high performance global optimization tools that ensures the minimization of the objective function with simple mathematical model. The application of these algorithms to the problem of network routing is sporadic at times, but the exploration of search space by repeated iterations results in high quality optimal solution. Yourui et al (2009) developed quantum particle swarm optimization algorithm to reduce energy consumption and ensure the Quality of Service in WSN. Hong and Shiu (2009) discussed the maximization of the K-of- N network lifetime in Wireless Sensor Networks. The algorithm based on PSO has high execution time with the increase in the number of application nodes and particles. Particle-based Routing with Overlapping Swarms for energy-efficiency in sensor networks is developed by Haberman and Sheppard (2012). The algorithm is meant for static environment with limitation in swarm size and objective functions.
Lee et al (2011) developed three pheromones Ant Colony Optimization to solve Efficient-Energy Coverage (EEC) problem in sensor networks. The authors have introduced the heterogeneous WSN, which is created by the random selection of the parameters of the probabilistic sensor detection model. Depending on the applications, reinforcement component that implicitly lead to better solutions, constriction and acceleration factors, inertia weight, and velocity factors are chosen by the researchers. The focus of their approach is either restricted to update the functions or incorporation of multiobjective metrics. It leads to locally optimal performance but does not increase the global performance of the network, within finite amount of time and do not address energy efficiency. In this research, Timeline cluster formation algorithm incorporating a hybrid swarm optimization is developed for Wireless Sensor Networks. The hybrid swarm optimization encompassing Particle Swarm Optimization and Ant Colony Optimization is used to perform energy efficient routing with minimal number of clusters.

2.4.2 Tabu Swarm Optimization

Particle Swarm Optimization loses its efficiency, when it requires pinpointing the exact minimum in a refined local search (Clerc 1999). Tomassetti (2010), states that, in spite of having demonstrated to be an effective algorithm, with PSO it is quite difficult to identify a global minimum even when the problem strictly requires a global exploration and the detection of a global extreme. Many research papers have confirmed the improvements in performance obtained by hybridizing PSO algorithms implementing other evolutionary algorithms and swarm intelligence algorithms. Hybrid methods combining PSO and Tabu Search have been proposed for various engineering problems. Padmavathi et al (2008) have modeled Directed Acyclic Graph scheduling using hybrid swarm optimization. The authors have analyzed the clustering of work stations using list scheduling algorithm using PSO based on Tabu Search.
Nakano et al (2007) designed a new PSO based on the concept of Tabu Search. The tabu states and the activity of the swarms are considered to maintain constant value through the search. The limitation of this algorithm is, it is modeled for unconstrained problems. Tabu Search (TS) algorithm for cluster building is proposed by Rhazi and Pierre (2009). The main drawback of this scheme is the usage of additional cost for communication. Li et al (2010) have developed a hybrid PSO and TS algorithm for flexible job-shop scheduling problem. PSO was used to produce a swarm of high quality candidate solutions, while TS was used to obtain a near optimal solution around the given good solution. Based on the studies of hybridization of PSO with TS for various applications in engineering disciplines, a metaheuristic approach is developed in this research for sensor networks. Tabu Swarm Optimization incorporating the optimal search capability of PSO and cognitive ability of TS is proposed for energy efficient routing in sensor networks.

2.4.3 Cuckoo Search

The computational drawbacks of conventional numerical methods lead to the development of metaheuristics and learning algorithms for solving complex combinatorial problems. Over the last decades, many meta-heuristic algorithms have been successfully applied to various engineering optimization problems. Cuckoo Search is a recently developed metaheuristic technique, which is inspired by the brood parasitism of cuckoo species. Yang and Deb (2009), discovered that the performance of the CS can be improved by using Levy Flights instead of simple random walk. A random walk is a random process which consists of taking a series of consecutive random steps. The random walk can be fixed or varied depending upon the application. Yang and Deb, improved the random walk with Levy distribution, using simple power law and obtained fast linear relationships in flight patterns. The
Cuckoo Search controls the boundary conditions in each computation steps. When the value of an attribute overflows the allowed search space limits, then the value of the related attribute is updated with the value of the closer limit value to the related attribute. At the start of the iterative search process, the Cuckoo Search detects the most successful position as X best position.

The authors have determined the mean optimal values for various test functions and impart results closer to PSO. Similar to PSO, the Cuckoo Search recursively develop pattern matrix components, to realize better solution in the search space. Cuckoo Search for unconstrained optimization problems is discussed by Tuba et al (2011). The step size is modified using random functions and fitness function is calculated. Improved cuckoo search algorithm for feed forward neural network training is proposed by Valian et al (2011). The authors have modified the probability to find the worse nets ‘P_a’, by multiplying with a scaling factor related to number of iterations and current iteration. Based on the studies inferred, Cuckoo Search is modified and applied for clustering of nodes in Wireless Sensor networks. The proposed Cuckoo Search is targeted to achieve energy efficiency and extend lifetime of the sensor network.

Researchers also try to implement the Hybridization of Cuckoo Search with other evolutionary algorithms. Tein and Ramli (2010) have implemented nurse scheduling model with hybrid evolutionary algorithm. The model is implemented by incorporating cuckoo s selection into the crossover parameter. Noghrehabadi et al (2011) implemented a hybrid power series cuckoo search to estimate electrostatic deflection of micro fixed-to-fixed actuators. The cuckoo search via levy flights optimization algorithm is applied to find adjustable parameters of trial solution. In this research, Cuckoo Based Particle approach is developed to achieve energy efficient sensor network by considering the multiobjective optimization of network
entities. Energy constraints are incorporated into Generalized Particle Approach Algorithm to yield optimized route.

2.4.4 Applications of bioinspired Networking

In context of networking, the applications of bioinspired principles and methods are addressed for routing in computer networks, optimal node deployment, node localization, network clustering, robust and distributed clock synchronization, monitoring and tracking of system behaviour, misbehaviour detection, intrusion detection systems, node and rate selection, coordination and control in distributed systems, protection in terms of security and privacy (Jacobsen et al 2011). Among the challenges encountered, robustness of the system has to be maintained by appropriate utilization of network services.

Network services like localization, tracking, data aggregation and energy-efficient multihop routing are used for monitoring the resources with appropriate control mechanism. Considering the above characteristics and prominent features of monitoring, a mesh model is developed to monitor the effective functioning of Liquefied Petroleum Gas (LPG) Plant. The nodes in the plant are clustered by cuckoo search algorithm and the sensed information is transmitted to the base station by wireless HART protocol. The developed mesh network model aims to implement an energy efficient plant in leakage detection and monitoring of events.

2.5 CONCLUSION

This chapter summarized a detailed review on energy efficient techniques for Wireless Sensor Networks under three categories namely Data Centric Routing, Cluster Based Routing and Bio inspired Networking. The need for development of Adhoc on-Demand energy efficient protocol,
Timeline Cluster Formation algorithm with hybrid optimization, Tabu Swarm Optimization, Modified cuckoo Search, Cuckoo Based Particle approach, and Cuckoo based Hart Protocol are explicated. The implementations of the proposed techniques are presented in the following chapters.