Chapter 2

Review of Literature

2.1 Introduction:

WSNs are quite different from general wireless networks due to various constraints and highly application specific nature of this network. Consequently, it creates different research challenges. In wireless communication system, the models for signal strength drop over a distance are well developed. Effects of signal reflection, scat- tiring and fading are well understood. In actual WSNs, cost and other application specific issues affect the communication properties of the system. For example, radio communication in WSN is of low power and short range compared to any other wireless communication network. Even though the same basic principles of wireless communication network are used in WSNs but the system performance characteristics vary considerably. The size, power, cost and their tradeoffs are fundamental constraints in WSNs. Considering the basic differences with the wireless communication systems, many issues have been identified and investigated. Major issues affecting the design and performance of WSNs are the following:

i. Deployment strategy

ii. Localization

iii. Clustering for hierarchal routing

iv. Coverage efficacy

v. Efficient medium access control

vi. Efficient database centric design

vii. Quality of service implementation

viii. Acceptable security

In this proposed work, we have restrained ourselves to the study of first three issues mainly, deployment strategy, localization and clustering for hierarchal routing.

Deployment Strategy:

The deployment strategy depends mainly on the type of sensors and the application. The following deployments strategies are generally used in WSNs.

Random deployment: Random deployment is the most practical way of placing the sensor nodes. For a dynamic sensor network, where there is no a-priori knowledge of optimal placement, random deployment is a natural option.

Incremental deployment: The incremental placement strategy is a centralized, one-at-a-time approach to place the sensors. The implementation makes use of information gathered through the previously deployed nodes to determine the ideal deployment location of the next sensor node. This can be calculated at base station.

The main goal of routing protocol in WSNs is to find a suitable way to improve the energy efficiency for reliable transmission of sent data to the base station. Almost all the routing protocols can be classified according to the network structure as flat, hierarchical and location-based.

The WSNs consists of sensor nodes and a base station. So researchers can solve two different problems of deployment.

Table 2.1: Different Deployment Technique:

Sensor node Deployment & Base Station Deployment	Xu et al. [46]	The impacts of random device deployment on connectivity and lifetime in a large-scale heterogeneous WSNs and also examine the BECR problem with the uniform random deployment in both single-hop and multi-hop WSNs. The deployment strategies shows that the new strategies have significant advantages to the connectivity-oriented deployment, which is the only random deployment strategy used in the literature. This paper provides a guideline for random deployment of typical large-scale heterogeneous WSNs.
	Tang et al. [47]	Present a monitor and rescue system utilizing *hybrid networks* which is a integration of stationary sensor networks and mobile sensor networks. Propose a pure distributed motion strategy for mobile sensors without reliance on Localization services such as GPS, focusing
	Yuan et al. [48]	Studied the energy-hole problem in WSNs by exploring node deployment. They first study mobile sink model, and conclude the best mobility strategy and then consider jointly sink mobility and node deployment, and propose a non-uniform node deployment strategy for periodical
	Dhillon et al. [49]	Probabilistic optimization of number of sensors.
	Tripathi et al. [25]	The objective is to minimise the overall energy consumption in a WSN. A heuristic algorithm has been proposed to find such a base station location.

Localization:

Localization of sensor nodes in WSNs is an important area of research for the last few decades. Localization is a method to determine the accurate physical position of sensor nodes. WSNs are used in the different environments to perform various monitoring tasks such as search, rescue, disaster relief, target tracking. In many such tasks, node localization is important to the application. Existing localization algorithms basically consists of two basic phases-

1. Distance (or angle) estimation and

2. Distance (or angle) combining

Table 2.2: Some of the Localization Techniques

Anchor Based Localization & Anchor Free Localization	Shekofteh et al. [50]	They have proposed and analyzed a new algorithm comprised of two phases for the localization of WSN using a short-term memory TS method and simulated annealing. From the performance analysis it is noted that in spite of its memory requirements, TS-based method has better convergence characteristics compared to simulated annealing based WSN localization proposed here.

	zarei et al. [51]	Proposed a more intelligent routing algorithm than other existed algorithms. Routing is accommodated in a multi-hop way; however each CH takes part in the algorithm only if has an amount of energy more than the considered threshold; consequently it has been avoided that sensors die too early. Furthermore, if a CH has any neighbour closer than itself to destination, it will use the right hand rule to select the next hop. Every CH from its own RT detects whether it is in the obstacle boundaries or not. CHs are being in the obstacle boundaries and not having any neighbour closer than themselves to destination send a critical message to neighbouring head.
Waldmeyer et al. [52]		They proposed a multi-stage AUV-aided localization technique for underwater WSNs (UWSN)s. The proposed method combines the flexibility and localization accuracy of an AUV-aided localization, the energy efficiency of "Silent Localization" and improved localization coverage with k-stage localization based on sensor nodes.

Routing:

Routing in the WSNs is challenging due to the inherent characteristics that distinguish these networks from the other wireless networks like *ad-hoc* networks or cellular networks. It is not possible to use a global addressing scheme for the deployment of a relatively large number of sensor nodes. Thus, traditional IP-based protocols may not be applicable to WSNs. Sensor nodes are tightly constrained in terms of energy, processing and storage capacities. Thus, they require more cautious resource management. In most of the application scenarios, nodes in WSNs are generally stationary after deployment except for a few mobile nodes.

Nodes in other traditional wireless networks are free to move about, which results in random and frequent topological changes. Routing protocols in the WSNs mainly depend on the application and the network architecture of the sensor networks.

Routing in the WSNs can be classified into two broad categories:

1. Network structure based routing and

2. Protocol operation based routing.

Table 2.3: Different Routing Techniques:

Algorithm	**Clustering Rule**
LEACH	Random probabilistic clustering.
LEACH-C	Centralized clustering algorithm to produce better clusters.
LEACH-F	Clustering with fixed number of clusters.
TEEN	Total numbers of transmissions are reduced by allowing the nodes to transmit only when the sensed value less than a threshold value.
APTEEN	New TDMA schedule is introduced to avoid collisions of close-by nodes which fall in the same cluster. As these nodes sense similar data and try to send their data simultaneously.
PEGASIS	Each node communicates only with a close neighbor and takes turns in transmitting to the base station, thus reducing the amount of energy spent per round.
HEED	Cluster heads are selected periodically according to a hybrid of the node residual energy and node proximity to its neighbors or node degree.

EECS	Clustering based on residual energy through local radio communication while achieving better cluster head distribution.
Hansen et al.	Clustering for large sensor networks using a minimum separation distance.
TB-LEACH	Nodes which have the shortest time intervals from randomly selected time interval by nodes will win the competition and become cluster heads to ensure that the partition of cluster is balanced and uniform.
EEHC	Cluster head selection based on weighted election probabilities according to the residual energy in each node. Heterogeneous topology is assumed.
EECED	Nodes with more residual energy have more chances to be selected as cluster head.
IB-LEACH	Clustering using characteristic parameters of heterogeneity.
MMCR	Multi-interface multi-channel routing for enhancing capacity of WSN.

2.2 Literature Review of Some Existing Protocols:

2.2.1 Related Work for LEACH:

Several researchers have evaluated and presented comparative analysis of WSN Routing protocols. Several conclusions have been drawn by evaluating the performance of routing protocols. Braman et al. [53] provided a brief introduction of routing challenges and some design issues in WSNs. The authors also reported the comparative analysis of various routing protocols along with the most energy efficient protocol (LEACH) and some of the improved versions of it. Gnanambigai et al. [54] surveyed the different hierarchical routing protocols derived from LEACH. This paper highlighted issues and drawbacks of LEACH and discussed a comparative study of features and performance issues of all hierarchical protocols.

Jan et al. [55] presented a brief survey of Cluster-Based Hierarchical routing protocols, which shows how protocols organize nodes into clusters. A comparison among clustering protocols taking features such as their transmission mode and selection algorithms for

CHs has been carried out. Usha et al. [55] provided the comparative analysis of LEACH and its descendants based on metrics like mobility, reliability and hop count. Vinay Kumar et al. [56] presented taxonomy of energy efficient clustering algorithms in WSNs and also presented the timeline and description of LEACH and its descendants. Manimala et al. [57] surveyed different hierarchical protocols developed from LEACH along with their pros and cons.

2.2.2 Related Work for BSP:

In the literature so far, many heuristic algorithms have been proposed to find sub-optimal solutions [58, 59] of optimum base station positioning in two tiered WSN. Although these heuristics are shown to be effective, their algorithms depend on the topology and are based on structural metrics. Akkaya et al. [60] reported a different method for finding the optimal position of a base station. Pan et al. [61] considered only free space loss and found that minimum enclosing circle gives the maximum lifetime for a sensor network.

The optimal location of a base station can be analyzed with respect to minimum energy expenditure or maximum lifetime of a sensor network. Even though both seems to have the same objectives but this is not true. Pan proved in his paper that the center of a minimum enclosing circle, is the optimal location for the *n-of-n* lifetime. *n-of-n* lifetime means the time after which the first node dies or time upto when n out of n nodes remain alive. The minimum enclosing circle is equivalent to minimizing the maximum distance between the base station and any sensor node in the network, i.e.

$$\left(x_{0,}y_{0}\right)=\underset{(x,y)}{\arg\min}\left(\max_{\forall i\in N}\sqrt{\left(x-x_{i}\right)^{2}+\left(y-y_{i}\right)^{2}}\right) \tag{2.1}$$

Here (x_0; y_0) is the center of the minimum enclosing circle. This approach is also known as the minmax algorithm for the optimum base station location [19], which provides maximum lifetime for a static single base station in a two tiered WSN. Recently Paul et al. [62] proposed an optimal location of base station by combining multi-hop inter-cluster routing with single-hop intra-cluster routing where the death of the first sensor node indicates the end of network lifetime. Paul used the center of minimum enclosing circle as the optimal location of the base station.

They proved that the overall energy consumption is minimized at the centroid of the nodes when path loss exponent α is *2*. In this method, average energy expenditure is minimized but first nodes may die earlier compared to min-max approach, as energy consumption in the sensor nodes, is rather uneven. For example, it may happen that most of the nodes are close to the base station, while a few nodes are far from it. Therefore, these far off sensors use more energy than nearer ones and hence deplete their energy at a faster rate and die sooner. This approach in known as minimum average or minavg [63].

Vass et al. [63] has also reported that maximum relative energy is a better approach as compared to minimum average or minmax approach. This approach uses current status of the sensor nodes, thus being more effective for a short period of time. But in the long run, minavg approach is considered to be a better choice. Lin et al. [64] minimized the total distance from sensor nodes to the base station to reduce the number of data relays, and placed the base station in an area with a high density of sensor nodes. This is the point where $\sum_{i=1}^{n} w_i d_i$ is minimized. Here, d_i is the distance between sensor *i* and base station and w_i is sensor's density in the vicinity of sensor *i*.

Son et al. [65] proposed that Fermat point is the best point for positioning the base station. They used hexagonal topology for showing lifetime optimization. Power aware base station positioning was proposed in [65]. It has been proved that the choice of position of base station depends on the data rate or equivalently, the power efficiency of the network.

They have used a weighted centroid method for finding the optimal base station location. This method has also been recently used for localization algorithms in the WSNs [59, 62, 64, 66-68].

2.2.3 Related Work for BEC:

WSN is widely used as an effective medium to integrate physical world and information world of IA [69-72]. In the sensor networks, each sensor node is both a sensor and a router, and its computing ability, storage capacity, communication ability, and power supply are limited. Therefore, the design of network topology, routing algorithm, and protocol is the most fundamental and key work in the study of the large-scale WSN communication system [73-78]. In recent years, in order to balance the energy consumption and maintain coverage and connectivity, multiple mechanisms are applied to WSN topology control and routing designing [79, 80].

Most of the real networks of IA, independent of their age, function, and scope, converge to similar architectures [81, 82] therefore researchers tried to build a unified model for complex networks in the last decades. In [83], Erdös and Rényi propose ER random graph model based on classic graph theory and statistical physics. In [84], the small-world property of complex network is found by Watts and Strogatz, who establish the WS small-world network model. In [85], Barabási and Albert build the BA model, which reveals the scale-free characteristic of complex networks. In [86], the BBV weighted network model is created by Barrat, Barthélemy, and Vespignani; this model not only defines the strength of connections, but also takes the change of connection strength into consideration, which makes the model closer to real network of IA.

Nowadays, BBV model is widely used to analyze the real complex networks such as scientist collaboration network (SCN) and worldwide airport network (WWAN) [87- 89]. Similar to SCN and WWAN, there are numerous nodes and community structures (clusters) in WSN, important nodes (cluster heads) have more connections than common nodes. Many researches on “energy hole” shows that the data flow on each connection varies considerably in WSN because of these different distances to the sink node. Thus, it is not suitable to represent a connection as connected (“1”) or connectionless (“0”). Furthermore, global information is limited in WSN of IA sensors exchange information in their “local-world”. Overall, weighted network and local-world theory is appropriate to model WSN of IA.

2.2.4 Related Work for Proposed Protocol:

Babaie et al., have proposed a [90] new clustering method for increasing of network lifetime. Several sensors are distributed with a high-energy for managing the cluster head and to decrease their responsibilities in the network. The performance of the proposed algorithm via computer simulation was evaluated and compared with other clustering algorithms like LEACH (Low energy Adaptive Clustering Hierarchy) and SEP (Stable Election Protocol). The simulation results show the high performance of the proposed clustering algorithm. However in their paper they have considered the sensor nodes and gateways to be fixed and motionless.

Peng et al. have proposed a novel cluster-head selection algorithm [91] is presented and analyzed which uses the minimum mean distance between sensor nodes as a selection parameter. The proposed algorithm has clear advantages and takes 1.2 times longer to reach the point where 50% sensor nodes remain alive than the Low Energy Adaptive Clustering Hierarchy algorithm (LEACH) while maintaining information throughput at a high level. This minimizes the energy consumption.

Niculescu et al. have proposed an Ad-Hoc Positioning System (APS) Using AOA. In APS [93] a reduced number of beacon nodes (e.g. three or more) are deployed with the unknown nodes. Then each node estimates its distance to the beacon nodes in a multihop way. Once these distances are estimated, the nodes can compute their positions using trilateration. Three methods of hop-by-hop distance propagation are proposed: Dv-Hop, Dv- Distance, and Euclidean. In Dv-Hop APS the beacon nodes start the propagation of their position information. Working as an extension of the distance vector algorithm, all nodes receive the position information of all beacon nodes as well as the number of hops to these beacons. An advantage of the APS is that its localization algorithm requires a low number of beacon nodes in order to work. However, the way distances are propagated, especially in Dv-Hop and Dv-Distance, as well as the way these distances are converted from hops to meters in Dv-Hop, result in erroneous position computation, which increases the final localization error of the system.

Dhillon et al. have proposed Kernel k-means, [93] Spectral Clustering and Normalized Cuts. Kernel k-means and spectral clustering have both been used to identify clusters that are non-linearly separable in input space. Weighted kernel k mean’s spectral clustering algorithm with normalized cuts are used to group the sensor node. Nodes are clustered by using positive definite matrices. It is also applicable for non-linear environment. It is not suitable for indefinite matrices. It’s only suitable for positive definite matrices.

Pan et al. have proposed a [94] distributed clustering algorithms for WSNs by taking into account of the lossy nature of wireless links. First formulate the one-hop clustering problem that maintains reliability as well as saves energy into an integer program and prove its NP hardness. Then propose a metric based distributed clustering algorithm to solve the problem and adopt a metric called selection weight for each sensor node that can indicate both link qualities around the node and its capability of being a cluster head. Further extend the algorithm to multi-hop clustering to achieve better scalability.

Veena et al. have proposed a method for clustering and their analysis to study the cluster formation, their behavior with respect to the system parameters and applications requirement. The most important challenge in WSN is to improve the operational efficiency in highly resource constrained environment based on dynamic and unpredictable behavior of network parameters and applications requirement. The technique involves the adoption of computational intelligence to form clustering. Nero-Fuzzy technique [95] is used to obtain dynamic clustering. The simulations are carried out to evaluate the performance of the proposed method with respect to different parameters of sensor node and applications requirement.

The large-scale deployment of WSNs and the need for data aggregation necessitate efficient organization of the network topology for the purpose of balancing the load and prolonging the network lifetime. Clustering has proven to be an effective approach for organizing the network into a connected hierarchy. Younis et al. [96] have discussed about the challenges in clustering a WSNs, the design rationale of the different clustering approaches and classify the proposed approaches based on their objectives and design principles and several key issues that affect the practical deployment of clustering techniques in sensor network applications.

Geographic routing has been proven to be efficient to provide scalable unicast routing in resource-constrained sensor networks. However, its applications in multicast routing remain largely unexplored. Recently GMR (Geographic Multicast Routing) and DCGM (Destination Clustering Geographic Multicast) have been proposed by Zhao et al. [97] which preserve the distributed computation of geographic routing while delivering data packets to multiple destinations with efficient routes. To further reduce the number of transmissions, a clustering strategy is applied to GMR and DCGM. This strategy improves the performance of GMR and DCGM by dividing the destinations into many clusters and sending the packet first to the closest destination in each cluster, which then sends the packet to other nodes in the cluster. Simulation results show that the strategy can reduce the number of transmissions up to 35% percent.

Bandyopadhyay et al. have proposed a distributed, randomized clustering algorithm [98] to organize the sensors in a WSN into clusters. A wireless network consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. The data collected by each sensor is communicated through the network to a single processing center that uses all reported data to determine characteristics of the environment or detect an event. The communication or message passing process must be designed to conserve the limited energy resources of the sensors. Clustering sensors into groups, so that sensors communicate information only to cluster heads and then the cluster heads communicate the aggregated information to the processing center, may save energy. This algorithm is extended to generate a hierarchy of cluster heads and observe that the energy savings increase with the number of levels in the hierarchy. Results in stochastic geometry are used to derive solutions for the values of parameters of our algorithm that minimize the total energy spent in the network when all sensors report data through the cluster heads to the processing center.

Kim et al. have proposed [99] an Energy Efficient Intersection Routing Protocol in Mobile Sensor Networks. Typically, sensor networks consist of fixed sensor nodes. Sometimes, creating such a fixed sensor networks could be a daunting task. Sensor nodes assume deploying a stationary sensor network over a dangerous area such as a battlefield. Even if an advanced method to make the deployment safer is used, diverse element will cause a coverage holes. Even though perfect coverage can be achieved initially, various factors such as malicious attacks will certainly degrade network coverage as time goes on. However, mobile sensor networks can solve some of the problems. Each node of mobile sensor network is mounted on various unmanned vehicles as a result the sensor nodes have mobility. Mobility reinforces fault-tolerance and the scalability of the network. But conventional sensor routing protocols find it hard to deal with the mobile sensor networks. Therefore, this study suggests an energy efficient routing scheme by using the location information of a global positioning system (GPS) and the energy levels of sensor nodes.