CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO SENSOR NETWORKS

The advancement and application of Wireless Sensor Networks (WSNs) become an invincible trend into the various industrial, environmental, and commercial fields. A typical sensor network may consist of a number of sensor nodes acting upon together to monitor a region and fetch data about the surroundings (Alamri et al 2013). The wireless sensor network (WSN) is a dynamic network that has properties of large-scale, self-organization, and strong concealment ability.

It is widely used in many applications, such as temperature acquisition (Souissi and Ammar 2014), volcanic earthquake detection (Tan et al 2010), environmental monitoring (Ke et al 2008), and military applications (Hussain et al 2009). WSNs are composed of sensor nodes and sinks. Sensor nodes have the capability of self-healing and self-organizing. They are decentralized and distributed in nature where communication takes place via multi-hop intermediate nodes. The main objective of a sensor node is to collect information from its surrounding environment and transmit it to the sink.

WSNs have many applications and are used in scenarios such as detecting climate changed, monitoring environments and habitats, and various other surveillance and military applications. Mostly sensor nodes are used in such areas where wired networks are impossible to be deployed. WSNs are deployed in physical harsh and hostile environments where nodes are always exposed to physical security risks damages. Furthermore, self-organizing nature, low battery power supply, limited bandwidth support, distributed operations using open wireless medium, multi-hop traffic forwarding, and dependency on other nodes are such characteristics of sensor networks that expose it to many security attacks at all layers of the OSI model (Alrajeh et al 2013).

According to WSN is a network that consists of small nodes with sensing, computation and communication capabilities. Defines WSN as a network consisting of large number of nodes that are deployed in such a way that they can sense the phenomena. Similarly according to WSN is a special class of ad hoc wireless network that are used to provide a wireless communication infrastructure that allows us to instrument, observe and respond to the phenomena in the natural environment and in our physical and cyber infrastructure.

1.1.1 Wireless Sensor Networks (WSN) Architecture

A WSN is a collection of sensor nodes which are deployed in a sensor fields which collect and route data back to the Base Station. A sensor node can be divided into four basic parts, viz. the sensing unit, a processing unit, a transceiver unit, and a power unit. Localization is the heart of the routing principle in WSN. The position finding system helps the sensor node to discover its position in the environment. The power unit gives the constant power supply to the sensor nodes which is the prime target area of the intruders (Panigrahi et al).

Wireless sensor networks follows most common architecture OSI model. Basically, there are five layers in sensor network. These are application layer, transport layer, network layer, data link layer and physical layer. There are three cross layers planes added to those above five layers of OSI model i.e. power management plane, connection management plane, task management plane. These layers are used to manage the network connectivity and allows the nodes to work together to increase the overall efficiency of the network.

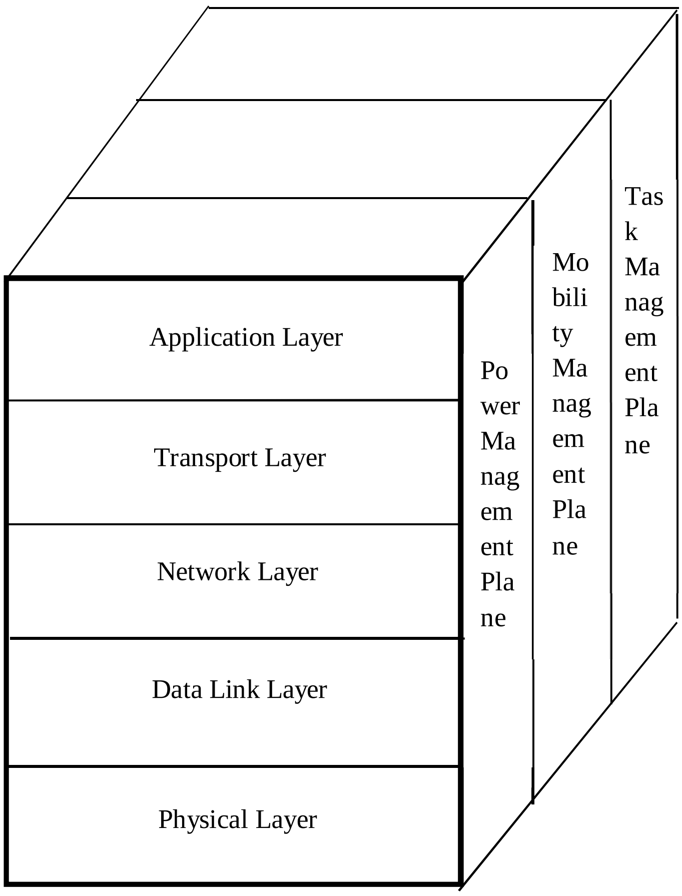

Figure 1.1 WSN Architecture

Transport Layer

The function of this layer is to provide congestion avoidance and reliability and there are a lot of protocols designed to provide this function are either applied on downstream and upstream. This layer is particularly needed when a system is organized to access other network. The basic function of this layer is to accept data from above layers and split it up into smaller units then pass these to the network layer and ensure the delivery of all pieces at the other end. It contains a variety of protocols like TCP, UDP, SCTP, DCCP, SPX (Kaur et al 2014).

Network Layer

The major function of this layer is routing. This layer has a lot of challenges depending on the application but apparently, the major challenges are in the power saving, limited memory and buffers, and sensor does not have a global ID and have to be self-organized. This is unlike computer networks with IP address and central device for controlling. The basic idea of the routing protocol is to define a reliable path and redundant paths according to a certain scale called metric, which differs from protocol to protocol.

There is a lot of routing protocols available for this layer, they can be divide into; flat routing (for example, direct diffusion) and hierarchal routing (for example, LEACH) or can be divided into time driven, query driven and event driven. In continuous time driven protocol, the data is sent periodically and time driven for applications that need a periodic monitoring. In event driven and query driven protocols, the sensor responds according to action or user query.

Data link layer

Responsible for multiplexing data streams, data frame detection, MAC, and error control, ensure reliability of point–point or point– multipoint. Errors or unreliability comes from:

- Co-channel interference at the MAC layer and this problem is solved by MAC protocols.

- Multipath fading and shadowing at the physical layer and this problem is solved by forward error correction (FEC) and automatic repeat request (ARQ).

ARQ: not popular in WSN because of additional re-transmission cost and overhead. ARQ is not efficient to frame error detection so all the frame has to retransmit if there is a single bit error.

FEC: decreases the number of retransmission by adding redundant data on each message so the receiver can detect and correct errors. By that can avoid re-transmission and wait for ACK.

MAC layer: Responsible for Channel access policies, scheduling, buffer management and error control. In WSN need a MAC protocol to consider energy efficiency, reliability, low access delay and high throughput as some major priorities (Alkhatib and Baicher 2012).

Physical layer

Physical layer can provide an interface to transmit a stream of bits over physical medium. Responsible for generating carrier frequencies, frequency selection, signal detection, signals modulation and data encryption.

Application layer

Responsible for traffic management and provide software for different applications that translate the data in an understandable form or send queries to obtain information. Sensor networks deployed in different applications in various fields, for example; medical, military, environment, agriculture fields. It contains a variety of protocols like NNTP, SIP, SSI,

DNS, FTP, GOPHER, NFS, NTP, SMTP, SMPP, ANMP and TELNET. The three cross planes or layers are:

- Power management plane: It is responsible for managing the power level of sensor nodes for processing, sensing and communication.
- Connection management plane: It is responsible for configuration or reconfiguration of sensor nodes in attempt to establish or maintain network connectivity.
- Task management plane: It is responsible for distribution of tasks among sensor nodes to prolong network lifetime and improve energy efficiency.

1.2 OVERVIEW OF WSN APPLICATIONS

The applications are categorized according to its current state. Two main categories are (Sheta2013, Martincic&Schwiebert 2005):

- Deployed: the Deployed category contains the actual applications that are implemented in real-world.
- Potential: the second category contains the applications that are not yet mature, and are viewed as vital and promising.

a. Military Applications: It was the first motivation for development of WSN. In 1980, the Defense Advanced Research Projects Agency (DARPA) adopted the Sensor Information Technology (SENSIT) and National Science Foundation (NSF) Programs explored WSN for more tracking capabilities (Chong and Kumar 2003). Other applications included battle field surveillance, and intrusion detection. The sensors were programmed to collect measurements, communicate with each other, and send notification in case of object movement detection. More recent military projects were the detection of nuclear, chemical and biological toxins as well as calculation of their concentration levels.

b. Environmental Applications As sensors are deployed in a natural hostile area, long term environmental data were gathered either for future research, monitoring, or disaster detection (as fire, flood or earthquake forecast, etc.) (Steere et al 2000). In 1970s, the earliest real world project founded was the Automated Local Evaluation in Real Time, (ALERT). It was designed to detect the existence of flood using sensors that take measurements as: temperature, humidity, rain, and water level. The data was transmitted to a station using Laser technology. In 2002, Intel Research Laboratory and University of California founded the Great Duck Island, North Atlanta, project to monitor the behavior of Petrel bird. There are about hundred well equipped sensors; some of them have cameras for video monitoring. It was not only beneficiary to monitoring, but it also reported the network operation and functionality problems that needed more research.

c. Home and Office Buildings Started in late 1980s, Smart buildings are those equipped with systems that do some intelligent actions, as door opening. Wireless sensors are used to study the effect of wind, monitor the employees and students (Srivastava 2010).In1990s, research has been adopted to use smart buildings to disabled people. WSN is recently incorporated in smart building for more quality of life. Smart Kindergarten deploys wireless sensors for childhood education and monitoring (Srivastava et al 2001).

d. Agriculture Applications Precision agriculture means applying the right amount of input (water, fertilizer, etc.) at the right location and at the right time to enhance production and improve quality, while protecting the environment (Shingha et al 2010). It is accomplished with WSN that monitors parameters as: soil moisture and air temperature, then calculates the amount of water and fertilizers needed. Also, irrigation management, adopted by WSNs, helps farmers to prevent damages to their crops and increasing crop production. WSN is also used to control the green house temperature and humidity levels starting from messaging to using controller (Park et al 2011).

e. Health Applications Health care is considered a potential application of WSN whose research is dominant (Yick et al 2008). Deployed applications are tele-monitoring physiological data, tracking patient locations and patient drug management (Maraiya et al 2011). WSN will allow the patient to be under constant supervision without hospital admission. Two promising applications are being investigated: glucose level and artificial retina (Schwiebert et al 2001). The diabetic patient can be implanted with glucose meter that monitors the sugar level and alerts the patient in case of serious condition detection. The second project considers implanting a chip of micro-sensors in the human eye to enhance vision. Important functional requirements as reliability, communication, and safety are challenging issues.

f. Smart Energy Energy production and consumption is an extremely critical problem worldwide. Research on producing smart building has gained great interest. The energy improvement solution incorporated the use of wireless sensors for improving home utilities, such as lighting, water and gas (Fernandez-Montes et al 2009 and Huynh et al 2011). Studies are in-process to design the network to monitor the energy consumption parameters, analyze them and finally regulate consumption. Recent studies are working on controlling the devices automatically. WSN is expected to be the next generation for smart home by improving energy distribution and consumption. In the United States, it is expected that WSN will be able to save about 50 billion dollars yearly and reduce 35 million metric tons of carbon emissions (Akyildiz et al 2002).

Sensor is a tiny device which detects and measures amount of physical parameters, or an event occurrence, or an object existence; then, it converts that value to electrical signal; finally, if necessary, it actuates a special operation by using electrical actuators. Major features of WSNs are:

- Infrastructure-less and no public address, often (data-centric network);
- Consisting of many (hundreds or even thousands) tiny sensor nodes;
- High-density of nodes distribution (in operational environment);
- Insecure radio links;
- Application-oriented networks;
- Different communication models, including: hierarchical/distributed WSNs; or homogenous/heterogeneous WSNs;
- Limited resources of sensor nodes;
- Having decision making capability to react to the events;

Main application domains of WSNs are: monitoring and tracking; therefore, some of the most common applications of these networks are: military, medical, environmental monitoring, industrial, infrastructure protection, agriculture, intelligent buildings and transportation.

The taken approach in the WSN is a combinational model; i.e. hierarchical, distributed and heterogeneous; since, sensor nodes, cluster-heads and the central server are different than each other and each one of them have special and different capabilities, hardware and software specifications than others. In continue of this section, it will be presented an outline of different aspects of WSNs, such as characteristics, architecture, vulnerabilities, different security dimensions and routing (Jadidoleslamy 2011).

1.3 ROUTING IN WSN

Routing algorithms (Kaur and Dhanda 2013) determine the specific choice of route. . A routing protocol shares this information first among immediate neighbours, and then throughout the network. This way, routers gain knowledge of the topology of the network. The term routing protocol may refer specifically to one operating at three layers of OSI model. There are various routing protocols that for routing data in wireless sensor networks.

The mechanisms of routing consider the architecture and applications along with the characteristics of sensor nodes. There are few routing protocols that are based on quality of service awareness or network flow whereas all other routing protocols can be classified as hierarchical or location based and data centric. There are two types of routing protocols which are reactive and proactive. In reactive routing protocols the routes are created only when source wants to send data to destination whereas proactive routing protocols are table driven.

AODV Routing Protocol

Ad-hoc on Demand Distance Vector (AODV) is a reactive protocol (Rakesh 2010). The reactive routing protocols do not periodically update the routing table like table driven proactive protocols. It is the modification of DSDV (Destination Sequence Distance Vector). It provides uncast, multicast broadcast. It works on, on demand algorithm. It searches for route between nodes only as decide by source nodes. These routes are maintained as long as they are needed by source.

AODV builds route using route request and route reply query cycle. It is the loop free, self-starting scale to large number of nodes. AODV is a well-known distance vector routing protocol (Taleb et al 2007) and it works as follows. Whenever a node wants to communicate with another node, it looks for an available path to the destination node, in its local routing table.

If there is no path exists, then it broadcasts a route request (RREQ) message to its neighbourhood nodes. Any node that receives this message for route discovery looks for a path leading to the respective destination node. The important feature of AODV is the maintenance of time based states. This means that routing entry which is not used recently is expired. The intermediate nodes store the route information in the form of route table. Control messages used for the discovery and breakage of route are as follows:

- Route Request Message (RREQ)
- Route Reply Message (RREP)
- Route Error Message (RERR)

Dynamic Source Routing (DSR) Routing Protocol

Dynamic Source Routing (DSR) protocol is specifically designed for multi-hop ad hoc networks. DSR allows the network to be completely self-organizing and self-configuring without the need for any other existing network. It is the reactive protocol. It has two major parts:

- Route Discovery
- Route Maintenance

In route discovery route reply would only be generated if message is reached to intended node. To return from route reply destination node must have a route to source node. The route may be destination node route cache. In route maintenance is initiated where by route error packets are generated at the node. The initiator (source) and target (destination) of the route discovery is identified by each route request packet.

The source node also provides a unique request identification number in its route request packet. However, if no suitable route is found, target will execute its own route discovery mechanism in order to reach toward the initiator (Johnson et al 2003). DSR is designed to restrict the bandwidth which is consumed by control packets in wireless adhoc networks by eliminating periodic table update message requires in table driven approach.

ZRP (Zone Routing Protocol): ZRP is an amalgam variety of routing protocol (Bhat et al 2011). This is the first routing protocol with reactive and proactive. The Zone Routing Protocol (ZRP) (Raju &Mungara 2010) aims to address the problems by combining the best properties of both the proactive and reactive approaches.it was to reduce the control overheads of proactive routing protocol which means that time is wasted on update the routing table and decrease the latency which is caused by route discovery in reactive protocol.

The ZRP aims to address the problems by combining the best properties of both the proactive and reactive approaches. (Kumar 2012). The proactive routing protocol is Intra-Zone Routing Protocol (IARP) is used inside routing zones. Reactive outing protocol is Inter-Zone Routing Protocol (IERP) is used between routing zones. In proactive a route of source to destination within local zone can be created from sources.

If source to destination packet are of same zone then packet can delivered immediately. In reactive the source node sends route request to nodes of the border which contain its own address the destination address and unique sequential no. Each border node check its local zone for destination. If destination is not a member of this local zone, then border node add its own address to route request packet and forward packet. If destination is member of local zone then it sends route reply on reverse path back to the source.

1.4 CLUSTERING IN WSN

Organization of large multi-hop wireless networks into clusters is essential for achieving basic network performance. In WSN, the clustering is primarily characterized by data aggregation by each cluster head, which significantly reduces the traffic cost. The hierarchical model requires two main methods:

- periodic selection of cluster heads (CHs); and
- Assignment of each node to one or multiple clusters.

Optimal clusters selection is equivalent to the minimum dominating set problem which is an NP-complete problem. An energy-efficiency algorithm may select a few CHs for energy-saving, but if these CHs do not have good connectivity or if they are not stable, the retransmission and the dropped packets may significantly degrade the network performance and the total energy wasted may end up to be higher. Therefore, taking reliable communication into account is essential for any clustering algorithm which aims to reduce the energy consumption in a network (Anker et al 2008).

Naturally, grouping sensor nodes into clusters has been widely adopted by the research community to satisfy the above scalability objective and generally achieve high energy efficiency and prolong network lifetime in large-scale WSN environments. The corresponding hierarchical routing and data gathering protocols imply cluster-based organization of the sensor nodes in order that data fusion and aggregation are possible, thus leading to significant energy savings.

In the hierarchical network structure each cluster has a leader, which is also called the CH and usually performs the special tasks referred above (fusion and aggregation), and several common sensor nodes (SN) as members. Such overload might cause latency in communication and inadequate tracking of events. In addition, the single-tier architecture is not scalable for a larger set of sensors covering a wider area of interest because the sensors are typically not capable of long-haul communication. Hierarchical clustering is particularly useful for applications that require scalability to hundreds or thousands of nodes.

Scalability in this context implies the need for load balancing and efficient resource utilization. Applications requiring efficient data aggregation (e.g., computing the maximum detected radiation around a large area) are also natural candidates for clustering. Routing protocols can also employ clustering. In, clustering was also as a useful tool for efficiently pinpointing object locations. In addition to supporting network scalability and decreasing energy consumption through data aggregation, clustering has numerous other secondary advantages and corresponding objectives (Mamalis et al 2009).

Clustering schemes offer reduced communication overheads, and efficient resource allocations thus decreasing the overall energy consumption and reducing the interferences among sensor nodes. A large number of clusters will contest the area with small size clusters and a very small number of clusters will exhaust the cluster head with large amount of messages transmitted from cluster members. LEACH protocol is hierarchical routing based on clustering and find the optimal number of clusters in WSNs in order to save energy and enhance network lifetime (Kumar et al., 2011).

1.4.1 Clustering Based Routing

From a routing perspective, clustering allows to split data transmission into intra-cluster (within a cluster) and inter-cluster (between cluster heads and every cluster head and the sink) communication. This separation leads to significant energy saving since the radio unit is the major energy consumer in a sensor node. In fact, member nodes are only allowed to communicate with their respective cluster head, which is responsible for relaying the data to the sink with possible aggregation and fusion operations. Moreover, this separation allows to reduce routing tables at both member nodes and cluster heads in addition to possible spatial reuse of communication bandwidth.

Intra-cluster communications

Most of the earlier work on clustering assume direct (one-hop) communication between member nodes and their respective cluster heads. All the member nodes are at most two hops away from each other. One-hop clusters makes selection and propagation of cluster heads easy, however, multi-hop intra-cluster connectivity is sometimes required, in particular for limited radio ranges and large networks with limited cluster head count. More recent WSN clustering algorithms allow multi-hop intra-cluster routing.

Inter-cluster Routing

Earlier cluster-based routing protocols such as LEACH assume that the cluster heads have long communication ranges allowing direct connection between every cluster head and the sink (Maimour et al 2010). Although simple, this approach is not only inefficient in terms of energy consumption, it is based on irrealistic assumption. The sink is usually located far away from the sensing area and is often not directly reachable to all nodes due to signal propagation problems.

Wireless sensor networks are containing of the thousands or more sensors that are widely distributed in the environment. Distribution of the sensors in the environment can be done manually or randomly. These networks have many applications such as environmental monitoring, healthcare, military operations, target tracking and etc. Due to the power constraint, energy balancing and maximizing network lifetime have been important challenge in wireless sensor networks. For this reason, use of data aggregation which limits redundant transmission between sensors is essential.

One of the techniques that use the data aggregation to reduce energy consumption in WSNs is called clustering based routing algorithm. In there are protocols that use the clustering technique in the network. LEACH is one of the most famous clustering based routing protocols in WSN. Cluster head selection among sensor nodes is done randomly and also data transmitting between cluster heads and base station is done directly in the LEACH. Although this specification of LEACH avoids energy hole problem but causes the energy of cluster heads that are far from the base station be discharge faster than others (Azizi et al 2012).

These surveys mainly aim at outlining some characters of clustering and summarizing some popular clustering routing algorithms with comparison based on different attributes and performances. A comprehensive survey of different clustering routing protocols in recent years. Differs from other surveys of WSN clustering routing algorithms as follows:

(1) As far as know, this survey is the first attempt to comprehensively review and critically the most prominent clustering routing methods developed for WSNs;

(2) It presents a novel taxonomy of clustering methods for WSNs, which is, to the best of our knowledge, the most comprehensive and fine-grained taxonomy of WSN clustering approaches at present;

(3) This is the first time that the popular clustering routing protocols are surveyed based on the classification of different algorithm stages;

(4) It summarizes the surveys of WSN clustering routing protocols. As far as know, work is the first attempt to outline these contributions made by other researchers (Liu 2012).

1.4.2 Energy Efficient Clustering

Clusters can be organized hierarchically when the network size increases. It is a clustering-based protocol which is designed to minimize the energy dissipation in wireless sensor networks. This new algorithm has the capability of combining the load balancing, topology and energy information. Moreover, on contrary to the traditional energy-efficient clustering approaches, it can generate fewer clusters and a longer network lifetime. There are not any assumptions about sensor location and network topology in this protocol, and it is fully distributed and energy efficient (Lotf et al., 2008).

Many studies have focused on saving energy in different ways such as reducing the power spent on the modulation circuits, or managing the power usage on the MAC layer of sensor nodes. However, these schemes focused of the individual device, and that approach is too narrow when working with wireless sensor networks. Since sensor nodes have limited transmitting ranges, only a few nodes can communicate directly with the sink node. In most cases, the sensor nodes gather sensing data which must then be forwarded by the other node to the sink node.

However, these cumbersome relaying operations consume too much energy, thus causing the relay nodes to rapidly expend much of their power. Therefore, developing a load-balanced routing algorithm to maximize the network's lifetime has become an important research topic. A large number of routing protocols for wireless sensor networks, but most are flawed in one way or another. In the fixed path schemes, sensor nodes arrayed in a fixed path will consume much energy and get exhausted rapidly because they continually provide relaying service. The flooding scheme consumes too much energy for relaying duplicate packets.

Source routing schemes solved some of the drawbacks of the flooding approach; however, they cannot operate well when the number of hops between the source and sink is large. Energy-aware, multi-path routing schemes have the advantage of sharing the energy among all the sensors in the wireless networks. Nevertheless, the chief disadvantage of multi-path routing schemes is that the sensor nodes only keep a local view of energy usage and the nodes in the network cannot have an even traffic dispatch. In addition, many studies have focused on cluster-based energy-efficient routing protocol for wireless sensor networks (Chang 2010).

A WSN consists of spatially distributed sensor nodes, which are interconnected without the use of any wires. In a WSN, sensor nodes sense the environment and use their communication components in order to transmit the sensed data over wireless channels to other nodes and to a designated sink point, referred to as the Base Station (BS). BS collects the data transmitted to it in order to act either as a supervisory control processor or as an access point for a human interface or even as a gateway to other networks.

Through the collaborative use of a large number of sensor nodes, a WSN is able to perform concurrent data acquisition of existing conditions at various points of interest located over wide areas. Nowadays, WSNs, due to the numerous benefits that their utilization offers, support an ever growing variety of applications, including agriculture, traffic control, environment and habitat monitoring, object tracking, fire detection, surveillance and reconnaissance, home automation, biomedical applications, inventory control, machine failure diagnosis and energy management.

However, despite the advantages that the utilization of a WSN offers, their use is severely limited by the energy constraints posed by the sensors. The energy expenditure of the sensor nodes occurs during the wireless communication, the environment sensing and the data processing. Therefore, most of the routing protocols in WSNs aim mainly at the attainment of power conservation. Since most of the routing protocols developed for wired networks pursue the attainment of high Quality of

Service (QoS), they are practically improper for application in WSNs (Nikolidakis et al 2013).

Low energy adaptive clustering hierarchical (LEACH)

LEACH is a clustering based protocol. In which the network is divided into clusters. Each cluster has some number of nodes where each cluster has a cluster head. CH is chosen from the nodes in the network based on their receiving signal strength. After each round the cluster head is changes which collects the data from other nodes in the cluster and send the data to the sink. 5 percentage of total number of nodes are chosen as cluster head.

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left(r \bmod \dfrac{1}{p}\right)} & if \ \mathrm{n} \in \mathrm{G} \\ 0 \end{cases}$$

The aggregation is performed in each cluster. Each node selects a random value 0 and 1. The nodes whose random value is less than the threshold those nodes are chosen as cluster head for current round only where P=desired percentage of cluster heads, r=current round and G is the set of nodes that have not been cluster heads in the last 1/P rounds. The nodes that are cluster head in round 0 cannot be cluster head for the next 1/P rounds. Various modifications have been made to the LEACH protocol such as TL-LEACH, E-LEACH, M-LEACH, LEACH-C, V-LEACH, LEACH-FL, W-LEACH, T-LEACH.

Threshold-sensitive energy-efficient sensor network protocol (TEEN)

TEEN protocol is used for precipitous changes in the sensed attributes in the network. It uses a data centric mechanism and makes clusters in a hierarchical fashion. Two threshold values are broadcast to the nodes: hard threshold and soft threshold etc. The hard threshold is the minimum possible value of an attribute. Sensor nodes send data to the cluster head only if they found the sensed value is greater than the hard threshold.

If sensor nodes found that the sensed value is less than the attribute value of threshold than they do not send the data to the cluster head. By this way only relative data is send by the sensor nodes. Next time when sensor node again sense value greater than the hard threshold value than they check the difference between current and earlier value with soft threshold. If the difference is again greater than the soft threshold than the sensor nodes will send recent sensed data to the cluster head. This process will remove burden from the cluster head.

Adaptive TEEN

This protocol is used to capture the data periodically. Three types of data query are made: historical, one time, persistent etc. In historical, the previous recorded values are analyzed and further decisions are also being taken based on their value (previous value). In one time, the snapshot of current network is taken and also envisioned (visualized). In persistent, when an event takes place than it monitors the network (Sharma & Nayyar 2014).

1.4.3 Clustering Based Routing Schemes

The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. However, wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control. WSN is formed with wireless sensor modules called nodes. The key components of a node are a micro-sensor to detect the desired event, a microprocessor, and memory to store information, a battery, and a transceiver to communicate with the rest of network.

Because the power supply, transmission bandwidth and processing capability are limited, efficient routing becomes very important. Based on the literature review on network structure based routing, WSNs routing schemes can be divided into three types; flat routing, hierarchical routing and location based routing. Flat routing algorithms are relatively effective in small scale networks. However, they are relatively undesirable in large scale networks because resources are limited and more data processing power and bandwidth is required.

In hierarchical routing, nodes execute different tasks and are typically grouped into clusters on the basis of specific requirements. A cluster has cluster head and member nodes. Cluster heads can be grouped according to the hierarchical levels. Higher energy nodes work as CHs and perform data processing and information dissemination jobs, while nodes with lower energy acts as member node and carry out the information sensing job. Cluster based routing algorithms are suitable part of routing technology for WSNs on the description of a various advantages such as greater scalability, less load, less energy consumption and more robustness (Singh and Sharma).

Clustering based routing schemes can be further classified into block cluster- based routing (LEACH, HEED etc.), chain cluster based routing (PEGASIS, CCS etc.) and grid cluster based routing(GAF, PANEL etc.). Based on the cluster head selection process many clustering protocols were designed like LEACH, HEED, SEP, WEP, SDEEC, DCHE, MNCP, TBC, HSR, FEED, LBS etc. (Nayyar and Gupta 2014).

Clustering is a technique employed in wireless sensor networks to provide balance in the network. In clustering, clusters are formed among the nodes and three different types of nodes- ordinary node, cluster head and gateway. Ordinary nodes simply perform the sensing task and transmit their data to the cluster head. Cluster heads act as relays between the ordinary sensor nodes and base station. Cluster head also perform the task of data aggregation. Gateway nodes are those which are responsible for inter cluster communication. Major advantages of clustering are

- It reduces the distance which data has to travel sent by the ordinary node. Thus saves the lot of energy of ordinary nodes.
- It limits the amount of redundant data in the network as data aggregation is performed at the cluster heads. It also saves energy and utilizes the bandwidth effectively.

WSN routing schemes can be divided into two types according to network structure: flat routing and hierarchical routing. In a flat topology, all nodes carry out the same tasks and have the same functionality in the network. Information dissemination is performed hop by hop, in general, using the flooding technique. Flat routing algorithms are relatively effective in small-scale networks. However, they are relatively undesirable in large-scale networks because resources are limited and more data processing power and bandwidth are needed. In a hierarchical topology, nodes execute different tasks and are typically grouped into clusters on the basis of specific requirements.

A cluster has a leader, called the cluster head, and member nodes. Cluster heads can be grouped into further hierarchical levels. Nodes with higher energy act as cluster heads and perform the task of data processing and information dissemination, while nodes with lower energy act as member nodes and perform the task of information sensing. Cluster-based routing algorithms are becoming an active part of routing technology in WSNs on account of a variety of advantages, such as greater scalability, less load, less energy consumption and more robustness (Sikander et al 2013).

1.5 CHALLENGES FOR WSN

1) Power Each protocol considers this limitation. Since power consumption is important factor for setting up the infrastructure of wireless sensor network. as distance increases the power consumption will also increase. When there more obstacles are in between the nodes then multi hope routing consumes more energy than directing routing (Chen and Varshney 2004).

2) Bandwidth Lack of bandwidth presents more difficulties in achieving the good performance in wireless sensor network. Using data compression and utilizing different bandwidth capabilities based on nature of stream are two proposal to overcome the scare of bandwidth.

3) Memory Size Since sensor node do not have much storing capability so memory size is one more important factor for considering wireless sensor network performance. As the limitation of memory size is affecting most proposals to enhance wireless sensor network networking capabilities.

4) Standardization There are no standards are fixed for functions of wireless sensor network .though Zigbee is considered as first standard for wireless sensor network.

5) Lifetime Life of wireless sensor network lies on nodes. Each node in wireless sensor network has its own power source like battery. If battery low then no node will sense any event. In future wind power or solar power can be thought as option for recharging battery in future.

6) Density Since each node in wireless sensor network broadcast the packet to the entire node so each node have multiple copy of data. This causes the redundancy of data. Even this provides the reliability but needs the aggregation of these multiple copies which consumes more power.

The challenges and properties of WSN deployment can be summarized as follows:

- Wireless Ad-hoc Network: A fixed communication infrastructure does not exist the share wireless medium places additional restriction on the communication between the node and the problem like unreliable and asymmetric link are raised. But it gives broadcast advantage: a packet transmitted by a node to another is received by all neighbor of the transmitting node.

- Mobility and Topology Changes: WSN always work in dynamic scenario new node may join the network and the existing node may either changing position throughout the lifetime of network. The nodes may cease to function, and surviving nodes may go out of transmission radii of other nodes. WSN application must satisfy robustness against dynamic topology and node failure.

- Energy Limitation: Limited energy of a node is one of a major constraint. The basic scenario includes a topology of sensor nodes and limited number of more powerful base station. Once the nodes are deployed recharging and maintenance of the batteries on the sensor node is not possible. Communication task consume maximum power available to sensor node, and in order to ensure the task completion node must have sufficient energy, which is used frugally.

- Physical Distribution: In WSN each unit is a autonomous computation unit that communicate with its neighbor via messages. The data is distributed throughout the nodes in the network and can be gathered at central station only with high communication cost. Subsequently, the algorithm that operate on global information from the entire network become very expensive. Hence, distributed algorithms are highly desirable (Pradnya et al 2013).

1.6 OPTIMIZATION GOALS FOR WSN

Wireless sensor networks are developing rapidly because large number of scientists from fields of electrical engineering, computer science, telecommunications, medicine, biology and other, are researching implementation and optimization of wireless sensor networks. This versatility rises from the fact that wireless sensor networks can be used for various purposes and in different environments because sensor nodes are small, cheap, and intelligent and have low power consumption. They are mostly used in areas of environment observation, vehicle traffic monitoring, and habitat monitoring, industrial automation and health applications.

Scientists are using various energy efficient strategies for energy preservation. The classic way it to optimize routing protocols in layered protocol architecture. This could be accomplished by minimizing energy consumption and/or by maximizing network life time. In these classic strategies are put in four categories: energy efficient routing, scheduling the node sleeping rate, topology control by tuning node transmission power and reducing the volume of transferred information (Martinović et al 2009).

Routing and cross-layer optimization protocols for wireless sensor networks are optimizing only communication but the big challenge is how to optimize data sensing which will decrease computing and the number of communications, as well. Towards the various literatures, cross-layer approach is the best solution for energy-efficient communication in wireless sensor networks but there is no universal systematic methodology for performance evaluation of various optimization methods for wireless sensor networks. There is a need for universal performance evaluation method and standardized performance metrics so various optimization methods could be evaluated and compared.

QUALITY OF SERVICE

Objective of quality of service is to provide much better network services over existing. Quality of service of wireless sensor network defines three features: delay, loss, jitter.

- Delay it is the total time being spent in a network for transmitting a data packet from source to destination.
- Jitter it is variation of time for delivering the data packet from the last one delivered.

- Loss Total data received over total data send by network. Maximum loss degrades the quality of network.

Traditional wired network uses end to end communication model, for sending data one node to another node hence the loss, delay, jitter can be considered in wired network. While in wireless sensor network, each node broadcast the data to all nodes so quality of service parameter is fully acceptable. in wireless sensor network ,even the end to end communication model is not required but the factor of energy consumption is considered since each node must be capable of broadcasting data, so wireless sensor network quality of service parameter are coverage area ,exposure, energy cost and network life time (Reena et al 2013).

ENERGY EFFICIENCY

The energy consumption of sensor nodes is mainly for sensing data of physical phenomena, processing the information, and communicating with other nodes. In fact, more energy is required for the data communication than any other process. The energy cost for transmitting 1Kb a distance of 100 meters (330ft) is approximately the same as that used for the execution of 3 million instructions by a 100 million instructions per second/W processor (Kleinrock 2003 & Zhang et al 2015).

Therefore, the prime goal is to minimize the energy consumption of the communication so as to prolong the lifetime of the entire network. The communication protocol is based on clustering and is a kind of energy-efficient routing protocol. The cluster heads are responsible for the information exchange between clusters and the sink node, thus effectively reducing the communication cost of cluster members. However, the communication protocol based on clustering, to a certain extent, accelerates energy consumption by the cluster heads.

Selection of Cluster Heads. Since the LEACH algorithm is simple and efficient, but also suitable for our application scenario, choose the LEACH protocol to use for selecting cluster heads. The cluster head selection algorithm in LEACH is described as follows.

Each sensor node randomly generates a number between 0 and 1. If the random number of a sensor node is less than a threshold (n), then the node will be selected as a cluster head in the current round.

SCALABILITY

The major concern of sensor network is network performance and scalability. Network performance is achieved by increasing network lifetime/optimizing energy. Scalability is measured such that network performance should be constant with increasing network nodes. Hence wireless sensor network works as one in association as a network towards achieves a frequent goal of sensing a physical parameter over a huge geographic region with energy optimization. This algorithm has following design goals: Increase energy optimization, and provide scalability to network.

To prolong the lifetime of wireless sensor network is to maintain QoS parameters and improve the lifetime and scalability of network.

A. Parameters of Sensor are:

- Energy Efficiency: Energy is scarce resource of sensor network. So Energy consumption is one of the most challenging factor in designing the wireless sensor network. Energy consumption should be low for sensor network.

- Scalability: Wireless sensor network increases in size as the number of nodes increase. So performance should not degrade with the increase in number of nodes.
- Security: Wireless sensor network should introduce effective security mechanism for secure data transmission and avoidance of malicious attack.
- End to end delivery: The sink must be able to receive any notification or data within short time period. So that any action can be taken by sink. Wireless sensor network should have stricter delay constraint.
- Packet Loss: Whole packets should be delivered at the destination without losing a single packet.
- Small node size: Sensor node size should be small so that can easily deploy in harsh environment and reduce power consumption and cost.
- Reliability: Network protocol designed for sensor network should provide error control and correction mechanism for reliable delivery of data packet (Kumrawat and Dhawan).

Clustering sensor networks, is an effective technique to increase the scalability and survivability nodes, the main goal of clustering is to divide network to a set of individual and limited nodes that can be easy controlled. By apply clustering can routing table size, repeats end messages reiteration and energy consumption is reduced and enhance the network lifetime, until the nodes their data transfer to the shortest distance of associated cluster heads (Rostami and Mottar 2014).

“The ability to maintain performance characteristics irrespective of the size of the network is referred to as scalability.” Given various applications are being applied and large number of sensor nodes deployed into WSN; the system should be deployed in a uniform and standard way so that it is easy to extend for more and different applications. Whereas scalability may also bring some negative effects, so systems should apply appropriate and suitable scalability instead of trying to be as scalable as possible.

ROBUSTNESS

In order to achieve the goals such as QoS expectations, scalability, the WSN should maintain its operations in a robust way even though some environment disturbances happen. For instance, minority of nodes failure will not cause a destructive damage or changes in conditions will not bring vital influences to the system. But the specific robustness standard is application independent (Dai 2012).

Wireless sensor networks should not fail just because a limited number of nodes run out of energy, or because their environment changes and severs existing radio links between two nodes. They should exhibit an appropriate robustness and these failures must be solved by finding other route. A precise evaluation of robustness is difficult in practice and depends mostly on failure models for both nodes and communication links (Norouzi and Sertbas 2011).

WSNs consist of hundreds or thousands of low-power nodes that form dynamic ad-hoc multi-hop networks. The desired behavior of WSNs have to be achieved by local algorithms running on each sensor node with very limited knowledge about the whole sensor network. A central theme of past and current research is the improvement of the robustness and resource utilization of such algorithms. Both robustness and efficiency are important and often conflicting optimization goals under the dynamic behavior and resource constraints WSNs (Steffan et al 2005).

1.7 OBJECTIVES OF THE RESEARCH

The objectives of this work can be broadly classified into

- Evaluate the performance of LEACH protocols
- Propose an exponential cuckoo search strategy for energy efficient clustering in WSN with novel objective function and
- Propose an improved cuckoo search for energy efficient clustering in WSN.