**A NODE OVERHAUL SCHEME FOR ENERGY EFFICIENT CLUSTERING IN WIRELESS SENSOR NETWORKS**

**CHAPTER -1**

**ABSTRACT**

Clustering of wireless sensor network nodes, a fundamental operation, is aimed at achieving load balancing and prolonged network lifetime. Low-energy adaptive clustering hierarchy protocol, the prominent standard, achieves these. An improved protocol, balance cluster formation, provides the additional advantage of equal size clusters, but at the cost of overlapping of clusters. This letter presents a node overhaul scheme that achieves load balancing and energy efficiency while also maintaining uniform size clusters without any overlapping. The proposed solution first forms initial clusters and later refurbishes the initial clusters based on a second best choice cluster head, wherever applicable. The results so obtained show a substantial improvement in network lifetime and node death rate as compared to other simulated methods.

Index Terms: Sensor networks, energy efficiency, load balancing, network lifetime, uniform size clusters (USCs).

**CHAPTER-2**

**INTRODUCTION**

With the popularity of laptops, cell phones, PDAs, GPS devices, RFID, and intelligent electronics in the post-PC era, computing devices have become cheaper, more mobile, more distributed, and more pervasive in daily life. It is now possible to construct, from commercial off-the-shelf (COTS) components, a wallet size embedded system with the equivalent capability of a 90’s PC. Such embedded systems can be supported with scaled down Windows or Linux operating systems. From this perspective, the emergence of wireless sensor networks (WSNs) is essentially the latest trend of Moore’s Law toward the miniaturization and ubiquity of computing devices. Typically, a wireless sensor node (or simply sensor node) consists of sensing, computing, communication, actuation, and power components. These components are integrated on a single or multiple boards, and packaged in a few cubic inches. With state-of-the-art, low-power circuit and networking technologies, a sensor node powered by 2 AA batteries can last for up to three years with a 1% low duty cycle working mode. A WSN usually consists of tens to thousands of such nodes that communicate through wireless channels for information sharing and cooperative processing. WSNs can be deployed on a global scale for environmental monitoring and habitat study, over a battle field for military surveillance and reconnaissance, in emergent environments for search and rescue, in factories for condition based maintenance, in buildings for infrastructure health monitoring, in homes to realize smart homes, or even in bodies for patient monitoring After the initial deployment (typically ad hoc), sensor nodes are responsible for self-organizing an appropriate network infrastructure, often with multi-hop connections between sensor nodes.

The on board sensors then start collecting acoustic, seismic, infrared or magnetic information about the environment, using either continuous or event driven working modes. Location and positioning information can also be obtained through the global positioning system (GPS) or local positioning algorithms. This information can be gathered from across the network and appropriately processed to construct a global view of the monitoring phenomena or objects. The basic philosophy behind WSNs is that, while the capability of each individual sensor node is limited, the aggregate power of the entire network is sufficient for the required mission. In a typical scenario, users can retrieve information of interest from a WSN by injecting queries and gathering results from the so-called base stations (or sink nodes), which behave as an interface between users and the network. In this way, WSNs can be considered as a distributed database .It is also envisioned that sensor networks will ultimately be connected to the Internet, through which global information sharing becomes feasible.

The era of WSNs is highly anticipated in the near future. In September 1999, WSNs were identified by Business Week as one of the most important and impactive technologies for the 21st century Also, in January 2003, the MIT’s Technology Review stated that WSNs are one of the top ten emerging technologies .It is also estimated that WSNs generated less than $150 million in sales in 2004, but would top $7 billion by 2010 .In December 2004, a WSN with more than 1000 nodes was launched in Florida by the ExScal team ,which is the largest deployed WSN to date.

The term wireless is normally used to refer to any type of electrical operation which is accomplished without the use of a "hard wired" connection. Wireless communication” is the transfer of information over a distance without the use of electrical conductors or "wires“ using some form of energy, e.g. radio frequency (RF), infrared light (IR), laser light, visible light, acoustic energy. A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument, e.g. thermocouple, strain gauge. In general, the term network can refer to any interconnected group or system. A network is any method of sharing information between two systems. Wireless sensor networks (WSNs) are a new class of wireless networks that are becoming very popular with a huge number of civilian and military applications. A wireless sensor network (WSN) is a wireless network that contains distributed independent sensor devices that are meant to monitor physical or environmental conditions. AWSN consists of a set of connected tiny sensor nodes, which communicate with each other and exchange information and data. These nodes obtain information on the environment such as temperature, pressure, humidity or pollutant, and send this information to a base station. The latter sends the info to a wired network or activates an alarm or an action, depending on the type and magnitude of data monitored [1–24]. Typical applications include weather and forest monitoring, battlefield surveillance, physical monitoring of environmental conditions such as pressure, temperature, vibration, pollutants, or tracing human and animal movement in forests and borders [1–23]. They use the same transmission medium (which is air) for wireless transmission as wireless local area networks (WLANs). For nodes in a local area network to communicate properly, standard access protocols like IEEE 802.11 are available. However, this and the other protocols cannot be directly applied to WSNs. The major difference is that, unlike devices participating in local area networks, sensors are equipped with a very small source of energy (usually a battery), which drains out very fast. Hence the need arises to design new protocols for MAC that are energy aware. Clearly there is some difference between a traditional WLAN and a WSN, as the latter has limited resources. The objective of this chapter is to provide an up-to-date treatment of the fundamental techniques, applications, taxonomy, and challenges of wireless sensor networks.

A wireless sensor network consists of hundreds, if not thousands, of small and inexpensive nodes, which could have a static location or be dynamically deployed to monitor the intended environment. Owing to their miniature size, they have a number of constraints. The function of a WSN is basically monitoring. There are three classes of monitoring that a WSN can observe: (a) entity monitoring, which means monitoring something such as civil structures like bridges, tunnels, highways, and buildings, or the human body, such as monitoring the organs of the body; (b) area monitoring, which includes monitoring the environmental area alarms; and (c) area-entity monitoring, which includes monitoring vehicles on the highway, and monitoring movement of an object [1–15, 23, 24]. The key positive feature of WSNs does not come from the strength of the individual sensor nodes; it comes from the entire array of interconnected sensor nodes. Hence, WSNs are expected to be large in scale from the point of view that they have a lot of nodes and they are apt to be self-configuring, in order to achieve reliability. Since a wireless sensor node is usually inexpensive, we would expect to have a huge number of nodes in a WSN. Typically, sensor nodes communicate with each other by means of a multi-hop scheme. The flow of information and data stops at particular nodes called base stations or sinks. A sink or base station usually connects the sensor network to a fixed network to distribute the data sensed for further processing. In general, base stations have enhanced capabilities over regular nodes as they should carry out compound processing. This substantiates the actuality that sinks have more advanced processors such as PCs/laptops with more RAM memory, secondary storage, battery and computational power as they are expected to perform more tasks than regular sensor nodes. It is worth noting here that one of the biggest drawbacks of sensor networks is power use, which is really influenced by the interaction between nodes. In order to work out this problem, aggregation points are set up to the network, which reduce the overall communication traffic between nodes and save energy. Typically, collection points are ordinary nodes that get data from nearby nodes, carry out some sort of processing, and then advance the filtered data to the subsequent hop. Sensor nodes are arranged into groups, each group having a “group/ cluster head” as the leader. Communication within a group should travel all the way through the cluster head. Then it is advanced to an adjacent group head until it arrives at its destination, which is the sink or base station. A different scheme for saving energy is to let the nodes go into sleep mode, if they are not needed, and to wake them up when they are needed. The progress of wireless sensor networks was initially provoked by military applications; however, wireless sensor networks are now employed in many civilian applications such as environment monitoring, industrial process monitoring, health care applications, road and highway traffic control, smart homes and cities, and office automation. In health care applications, wireless devices make patient monitoring less invasive, thus improving health care. For utilities applications, wireless sensors provide an inexpensive scheme for collecting system health data to minimize energy usage and enhance management of resources. As for remote monitoring, a wide range of applications are covered where wireless networks can go together with fixed networks and systems by minimizing wiring costs and permitting new sorts of testing and measurement applications. The main applications of remote monitoring are: (a) environmental monitoring of air, soil, and water, (b) building and structural monitoring of bridges, subways, and buildings, (c) process monitoring, (d) machine monitoring, (e) habitat monitoring, (f) intelligent transportation systems, (g) air traffic control, (h) traffic surveillance, (i) video surveillance, and (j) monitoring carbon transfer in rain forests, among others [1–24]. Each node in a wireless sensor network is usually equipped with a radio transceiver, a tiny microcontroller, and a power source(typically a battery). The cost of a sensor node ranges from hundreds of dollars to a quarter of a dollar, depending on the size of the network and the functionality and sophistication required of each node. The size and price restrictions on sensor nodes produce constraints on resources such as energy, memory, computational power, and throughput. In general, a sensor network forms a wireless ad-hoc computer network, which means that each sensor supports a multi-hop routing scheme. The major components of a wireless sensor network, which include sensors, signal convertors such as analog-to-digital (A/D) and digital-to-analog (D/A) convertors, processors, communication devices, and a power supply, are all becoming more and more inexpensive and smaller. Stringent power expenditure requirements are necessary because the sensor node needs to be reliable and able to run unattended for a long time, which can be years. Among the factors that should be considered in the design of power sources of a WSN are: (a) choice of power harvesting scheme or battery type, and (b) choice of small power electronic design schemes. Companies that produce these devices are now developing small sensor nodes and networks. Moreover, commercial off-the-shelf personal digital assistants (PDAs) or pocket computers contain impressive computing power in a small package. Such devices can easily be used as powerful sensor nodes. Wireless LANs like the popular IEEE 802.11 standards can now offer performance very close to those of wired networks. Moreover, we have now IEEE 802.15 standard that gives specifications for personal area networks (PANs), which can be employed for WSNs as well. Furthermore, advances in semiconductor technology allow us to have more chip capacity and more processor capabilities. This progress allows a reduction in the energy/bit requirements for both the computing and communication systems. It is expected that advances in micro-electro-mechanical-systems (MEMS) technology will produce more powerful and versatile sensors. MEMO technology integrates mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology, whereas the electronics are fabricated by using integrated circuit (IC) process sequences such as bipolar, CMOS transistors. The micromechanical elements are made up using well-suited micromachining techniques that purposely add new structural layers to create the mechanical and electromechanical devices [1–14].Latest technological advancement in the field of hardware has developed small size, low capacity sensors with limited embedded on board processing unit that is able to communicate wirelessly. However, a lot of sensor networks also obviously introduce an enormous amount of data in WSNs (wireless sensor networks), that can process receive and transmit signals/data When various sensor nodes that are independent to each other are employed inside the targeted area or in its vicinity, it is referred to as sensor network .A WSN is a self-organizing network which is designed using spatially distributed and is used sensors for monitoring physical environmental. Since WSN is usually dynamic in nature, its topology will change frequently. This will cause adding a new node into the network due to loss of connectivity. In past, there were many conventional centralized algorithms which require knowing whole knowledge of the overall network and also needing to update the information of entire network. In order to avoid serious protocol failure, it is required to have error free transmission or critical node free of failure .In order to avoid the failure caused by single node, clustering algorithms are used, as they execute locally within partial nodes.

Wireless Sensor Networks (WSNs) can be defined as a self-configured and infrastructure-less wireless networks to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analysed. A sink or base station acts like an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals. A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components. The individual nodes in a wireless sensor network (WSN) are inherently resource constrained: they have limited processing speed, storage capacity, and communication bandwidth. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication with them. Then the onboard sensors start collecting information of interest. Wireless sensor devices also respond to queries sent from a “control site” to perform specific instructions or provide sensing samples. The working mode of the sensor nodes may be either continuous or event driven. Global Positioning System (GPS) and local positioning algorithms can be used to obtain location and positioning information. Wireless sensor devices can be equipped with actuators to “act” upon certain conditions.

Wireless sensor networks (WSNs) enable new applications and require non-conventional paradigms for protocol design due to several constraints. Owing to the requirement for low device complexity together with low energy consumption (i.e. long network lifetime), a proper balance between communication and signal/data processing capabilities must be found. This motivates a huge effort in research activities, standardization process, and industrial investments on this field since the last decade ([Chiara et. al. 2009](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network#B8)). At present time, most of the research on WSNs has concentrated on the design of energy- and computationally efficient algorithms and protocols, and the application domain has been restricted to simple data-oriented monitoring and reporting applications (Labrador et. al. 2009). The authors in ([Chen et al., 2011](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network#B36)) propose a Cable Mode Transition (CMT) algorithm, which determines the minimal number of active sensors to maintain K-coverage of a terrain as well as K-connectivity of the network. Specifically, it allocates periods of inactivity for cable sensors without affecting the coverage and connectivity requirements of the network based only on local information. In (Cheng et al., 2011), a delay-aware data collection network structure for wireless sensor networks is proposed. The objective of the proposed network structure is to minimize delays in the data collection processes of wireless sensor networks which extends the lifetime of the network. In ([Matin et al., 2011](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network" \l "B25)), the authors have considered relay nodes to mitigate the network geometric deficiencies and used Particle Swarm Optimization (PSO) based algorithms to locate the optimal sink location with respect to those relay nodes to overcome the lifetime challenge. Energy efficient communication has also been addressed in ([Paul et al., 2011](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network#B4); [Fabbri et al. 2009](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network" \l "B13)). In ([Paul et al., 2011](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network#B4)), the authors proposed a geometrical solution for locating the optimum sink placement for maximizing the network lifetime. Most of the time, the research on wireless sensor networks have considered homogeneous sensor nodes. But nowadays researchers have focused on heterogeneous sensor networks where the sensor nodes are unlike to each other in terms of their energy. In ([Han et al., 2010](https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/overview-of-wireless-sensor-network#B37)), the authors addresses the problem of deploying relay nodes to provide fault tolerance with higher network connectivity in heterogeneous wireless sensor networks, where sensor nodes possess different transmission radii. New network architectures with heterogeneous devices and the recent advancement in this technology eliminate the current limitations and expand the spectrum of possible applications for WSNs considerably and all these are changing very rapidly.

On comparing with centralized algorithms, clustering algorithms are more robust and scalable. To obtain prolong life of the network, energy efficient protocols are designed according to the characteristics of WSN, by efficiently organizing the sensor nodes in clusters.

A wireless sensor networks consist of tiny sensor nodes to monitor physical or environmental conditions such as temperature, pressure, sound, humidity etc. The network must possess self configuration capabilities as the positions of the individual sensor nodes are not predetermined. Routing strategies and security issues are a great research challenge now days in WSN but in this paper we will emphasize on the routing protocol. A number of routing protocols have been proposed for WSN but the most well known are hierarchical protocols like LEACH and PEGASIS .Hierarchical protocols are defined to reduce energy consumption by aggregating data and to reduce the transmissions to the Base Station. LEACH is considered as the most popular routing protocol that use cluster based routing in order to minimize energy consumption. In this paper firstly we analyze LEACH protocol and then in the third section we will discuss the phases of LEACH protocol. In the fourth section we define various possible attacks on it and in the fifth section there are the advantages and disadvantages of LEACH. In the last section we compare LEACH with other protocols.

CHARACTERISTICS OF WSN:

It was observed that there were many similarly between sensor network and ad hoc networks, both are dynamic and on demand. Some other similar characteristics are mobility, switching and the limit capability of the battery power. WSN also has some distinct properties as listed below

A. Power Efficiency Sensor nodes are often facing problem of void and dumped due to battery power run down of sensor node. In addition, as per many researches the energy consumes by the nodes in sending data over the communication is more than the energy of the nodes in computing. Therefore, maximize wireless sensor network’s lifetime is a problem is exists.

B. Fault Tolerance The wireless sensor nodes have ability of organizing itself in the network as nodes have deployed in random fashion remote location and unreceptive environment. For preventing from fault sensor nodes have worked in collaboration to reorganize itself and used distributed algorithm to form network automatically

C. Mobility of Nodes As it knows that wireless sensor network is collection sensor network in which some nodes are movable and some are static. We say that nature of WSN is dynamic. Due to limited resources nodes can failed for battery fatigue or some other conditions, communication channel may be disrupted. Topology is also affected by adding of node or failure of node. Thus, the WSN nodes have developed the function of self-governing and self-management

D. Heterogeneity of Nodes Heterogeneous means different nature of nodes, which are different from each other by the communication range, mobility, sensing parameters and work at different protocols etc. Heterogeneous WSN are collection of various different types of sensor nodes with have different features, follow different protocol, different computation capacity and different sensing and monitoring range. Deployment of heterogeneous sensor network more typical than homogeneous wireless sensor network

E. Scalability of Node In WSNs sensor nodes are able to collecting, processing, arranging, aggregating and sending data to sink node or base station. As number of nodes increases sensor network become very large. In the large network sensor nodes are able to communicate with faraway nodes but also produce traffic problem, difficult to manage and coordinate

F. Responsiveness WSN has ability to quickly adapt itself the changes in the topology. It has considered its responsiveness. To get highly responsiveness in the network. It needs to compromise with latency of network and as well as scalability

G. Communication Failures Wireless sensor networks work in free style fashion as ad hoc in nature. Sensor device has very low communication bandwidth and low communication distance range. And also it has some mobility degree of freedom. Sensor network will also be affected by the impact of natural disaster such as mountains slid, buildings damage and storms and cyclones, heavy rain falls and thunder lighting, the remote location obstacles, weather, and many more. That’s why; it is very difficult to manage and maintain WSN run smoothly. This is an important impact of research direction in the future

COMPONENTS OF WSN

A. Gateway: Gateways work as system network administrators to interface with node to Personal Computers (PCs) and Personal Digital Assistants (PDAs). Gateway may classify into various states:

1. Active

2. Passive

3. Hybrid Active gateway (sensor node) sends its message asynchronously to the server gateway. Passive gateway has worked in different way from active gateway. First it has sent a request packet to nodes and then has sent its own data. As the name suggest Hybrid gateway works as both active and passive gateway, which can operate in both of the states

B. Sensor/Actuator :

Without sensor we can image wireless sensor network. Sensors device collects data from their surrounding and convert environmental attribute/property just like sound, temperature, color, smoke, light, vibration and many more physical properties etc. into analog signals

C. Sensor Node:

Basically sensor nodes are three types

1. Temperature sensor node

2. Vibration sensor node

3. Moisture Sensor Node

But some other nodes can have more advantage that have taken capture pictures, motion detection, pressure monitor, intensity of light, etc

The sensor nodes are transceivers usually scattered in a sensor field where each of them has the capability to collect data and route data back to the sink/gateway and the end-users by a multi-hop infrastructure less architecture through the sink. They use their processing capabilities to locally carry out simple computations and transmit only the required and partially processed data. The sink may communicate with the task manager/end-user via the Internet or satellite or any type of wireless network (like WiFi, mesh networks, cellular systems, WiMAX, etc.), making Internet of Things possible. However, in many cases the sink can be directly connected to the end-users. Note that there may be multiple sinks/gateways and multiple end-users in the architecture, each sensor node is consisting of five main components; a microcontroller unit, a transceiver unit, a memory unit, a power unit and a sensor unit. Each one of these components is determinant in designing a WSN for deployment. The microcontroller unit is in charge of the different tasks, data processing and the control of the other components in the node. It is the main controller of the wireless sensor node, through which every other component is managed. The controller unit may consist of an on-board memory or may be associated with a small storage unit integrated into the embedded board. It manages the procedures that enable the sensor node to perform sensing operations, run associated algorithms, and collaborate with the other nodes through wireless communication. Through the transceiver unit a sensor node performs its communication with other nodes and other parts of the WSN. It is the most power consumption unit. The memory unit is for temporal storage of the sensed data and can be RAM, ROM and their other memory types (SDRAM, SRAM, EPROM, etc.), flash or even external storage devices such as USB. The power unit, which is one of the critical components, is for node energy supply. Power can be stored in batteries (most common) rechargeable or not or in capacitors. For extra power supply and recharge, there can be used natural sources such as solar power in forms of photovoltaic panels and cells, wind power with turbines, kinetic energy from water, etc. Last but not least is the sensor unit, which is the main component of a wireless sensor node that distinguishes it from any other embedded system with communication capabilities. It may generally include several sensor units, which provide information gathering capabilities from the physical world. Each sensor unit is responsible for gathering information of a certain type, such as temperature, humidity, or light, and is usually composed of two subunits: a sensor and an analog-to-digital converter (ADC). The analog signals produced by the sensor based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit. In WSNs, the sensor nodes have the dual functionality of being both data originators and data routers. Hence, communication is performed for two reasons: Source function: Each sensor node’s primary role is to gather data from the environment through the various sensors. The data generated from sensing the environment need to be processed and transmitted to nearby sensor nodes for multi-hop delivery to the sink. • Router function: In addition to originating data, each sensor node is responsible for relaying the information transmitted by its neighbours. The low-power communication techniques in WSNs limit the communication range of a node. In a large network, multi-hop communication is required so that nodes relay the information sent by their neighbours to the data collector, i.e., the sink. Accordingly, the sensor node is responsible for receiving the data sent by its neighbours and forwarding these data to one of its neighbours according to the routing decisions. Except for their transmit/receive operation state, transceivers can be put into an idle state (ready to receive, but not doing so) where some functions in hardware can be switched off, reducing energy consumption, a transceiver expends a similar amount of energy for transmitting and receiving, as well as when it is idle. Moreover, a significant amount of energy can be saved by turning off the transceiver to a sleep state whenever the sensor node does not need to transmit or receive any data. In this state, significant parts of the transceiver are switched off and the nodes are not able to immediately receive something. Thus, recovery time and start up energy to leave sleep state can be significant design parameters. When the transmission ranges of the radios of all sensor nodes are large enough and the sensors can transmit their data directly to the centralized base station, they can form a star topology. In this topology, each sensor node communicates directly with the base station using a single hop. However, sensor networks often cover large geographic areas and radio transmission power should be kept at a minimum in order to conserve energy; consequently, multi-hop communication is the more common case for sensor networks .In this mesh topology, sensor nodes must not only capture and disseminate their own data, but also serve as relays for other sensor nodes, that is, they must collaborate to propagate sensor data towards the base station. This routing problem, that is, the task of finding a multi-hop path from a sensor node to the base station, is one of the most important challenges and has received large attention from the research community. When a node serves as a relay for multiple routes, it often has the opportunity to analyze and pre-process sensor data in the network, which can lead to the elimination of redundant information or aggregation of data that may be smaller than the original data.

In general, power sources are typically divided into primary and secondary sources. The primary sources cannot be recharged, where secondary sources have to be charged on a regular basis. The major factors of primary and secondary sources are: range, capacity, temperature, current depletion level, and self-discharge characteristics. Fuel cells are expected to come into use as power sources for the sensors of the WSNs [9–14]. Where secondary cells are employed, the charging source may be harvested from the cell’s operational environment. The famous example of this is the harvesting of solar energy in order to charge a battery. However, there are other harvesting energy methods that can be used such as wind power, thermal energy, and vibration. In mechanical driven settings, harvesting a battery may not be needed as the harvested movement is constant, for instance in a pipeline. One popular method is solar systems, which necessitate some degree of installation to guarantee the best direction, especially at soaring elevations. We can obtain only about 25% efficiency from the best available silicon solar cell systems.

Some reported accomplishments were found with vibration harvesting used in industrial applications as well as from oil pipelines [12–14]. \* Sensors. In general, sensors may be categorized into classes based on their operating principles: (a) physical sensors, (b) thermal sensors, (c) chemical sensors, (d) biological sensors, and (e) electromagnetic, optical, and acoustic sensors. Sensors are typically hardware devices that sense the data from the monitored environments and produce some response that is measurable in nature. An analog-to-digital (A/D) convertor is used for converting the analog collected data to the digital form to be processed further by the microcontroller. The sensors in wireless sensor nodes are typically very small sized microelectronic sensing devices which are equipped with a very limited supply of battery power. Examples of some commercial sensors include: BTnode, BEAN, COTS and DOT, MICA and KMote. Sensors can be placed in any kind of environment for days without any attention. The major challenge for a sensor is the life of the battery, which is limited. The battery has usually short life. Thus, schemes are needed to conserve as much energy as possible. If we envisage that such devices are deployed in the battle ground in enemy areas, we can clearly see that it is not possible to recharge or change the battery of these devices. It is true that we may be able to deploy these sensors in enemy territory by the use of aircraft/helicopter, but it may not be possible to invade the enemy territory just to replace the battery. The major source of energy consumption is the communication between the nodes. Moreover, nodes tend to coordinate with each other for some particular tasks [1–24].

Wireless sensor networks have been recognized as one of the most vital technologies of this century. Inexpensive, smart devices with many on-board sensors networked through wireless links and the Internet and deployed in huge numbers present unique prospects for instrumenting and controlling homes, cities, factories, and the environment. Moreover, networked sensors offer a new means for surveillance and other tactical applications. While sensor networks for various applications may be quite different, they share common characteristics. Primarily, sensors are electrical, electronic, or electromechanical devices, even though other kinds of sensors exist. In general, a sensor is a type of transducer that converts an input to another, usually electrical, form. Sensors can be direct or paired. An example of a direct sensor is a thermometer or an electrical meter which indicates directly. A paired sensor uses an analog-to-digital (A/D) converter in order to convert an analog signal to a digital signal. Sensors are often used in applications such as medicine, industry, environment, robotics, and military. With the advances in material technology, more and more sensors are being built with Micro-Electro-Mechanic-Systems (MEMS) technology. A good sensor/transducer should have the following main characteristics [16–24]. (1) It should be responsive to the considered property. (2) It should be insensible to any other property. (3) It is desirable that the output signal of the sensor is exactly proportional to the value of the measured characteristic. (4) It should have a reasonable lifetime. (5) It should not consume much power. A WSN is made up of hundreds or even thousands of nodes that use sensing devices (sensors) to observe different conditions and environments, such as motion, pressure, temperature, sound, vibration, pollution, levels of oxygen or carbon dioxide, traffic intensity and patterns, among many others, at different sites. In general, these devices are tiny and low-cost so they can be manufactured and deployed in large quantities. One major difference between traditional MANETs (Mobile Ad hoc NETworks) and WSNs is that WSNs often have strictly limited resources in terms of power, memory, computational power, and bandwidth. The sensor node is a self-contained unit equipped with a radio transceiver, a tiny microcontroller, and a power source that is usually a battery. The nodes dynamically self-organize their configuration based on different network circumstances. Owing to the limited life of batteries, nodes are built with power saving in mind and generally spend large amounts of time in the “sleep” mode or in handing out the sensor data. Hence, each sensor is equipped with wireless communication capability, and signal processing and networking abilities. The main functions of any WSN are sensing, communication, and computing [1–15]. One scheme to categorize wireless sensor networks is based on whether the nodes are separately addressable, and another is based on whether the data in the network are aggregated. For instance, the sensor node in a parking-lot network should be individually addressable, so that one can find out the spots of all free spaces. However, if a person wants to find out the temperature or pressure in a specific corner area of a room, then addressability may not be so important. The capability of the WSN to combine the gathered data can significantly decrease the number of messages needed to be sent through the network. In some situations, it is vital to send the signal by the sensor in a timely manner such as when it is needed to send a data alert signal to the police indicating that an intruder is trying to enter someone’s house or office. There are several challenges that face the progress of WSNs. Among these are [1–15] the following. (1) Scalability. Most nodes in intelligent sensor networks are stationary. Networks of huge numbers of nodes on the order of 10 000 or more are expected. This means that scalability is a crucial issue in designing or launching any new WSN because we like to see proportional improvement in performance as the size of the network is increased. The algorithms and protocols designed for WSNs should consider communication cost with respect to network size. (2) Power limitation. Since WSNs are often installed in remote areas such as deserts, forests, or military zones, their nodes are usually powered by batteries with limited life. Recharging such batteries may not be feasible. Given this constraint, the lifetime of any node is decided by the life of the battery powering it. As a result, the reduction of consumed power is vital. There are protocols and schemes that have been proposed to control power consumption by WSNs. These schemes are based on energy efficient MAC protocols, data aggregation, topology management, data compression, or intelligent use of batteries. Of course, using electronic devices and chips that consume less power is also a key design issue. (3) Self-organization. Given the fact that WSNs may be installed in hostile environments, it is essential that they are designed to be self-organized. Nodes may fail due to harsh environment or depletion of the batteries; therefore, the network must be able to periodically re-configure itself so that it can continue to function and new nodes can be added, if possible. Individual nodes may be disconnected from the network, but the major portion of the network must continue to function. (4) End objective. The ultimate objective of a WSN is not only communication; it has to detect and estimate certain events of interest. In order to enhance the detection and estimation capabilities, it is helpful to merge data from multiple sensors. Such a data fusion necessitates the transmission of data and control messages, which may put a limitation on the network design and structure. Furthermore, it is vital to distinguish between false data gathered and data reflecting a real emergency. For example, a high temperature in factory may indicate a real fire or may be due to sensing or processing errors. (5) Querying capability. In WSN environments, a user may need to make an inquiry of an individual node or a selected cluster of nodes, for information gathering in the area. Based on the degree of data fusion performed, it may not be practicable to send a huge volume of data over the network. As an alternative, different neighboring sink nodes can gather data from a given area and generate summary messages. An inquiry may be sent to the sink node closest to the preferred location. (6) Interoperability. With the impressive progress in sensing and communications technology, we start to see inexpensive, short-range radios, along with wireless networking devices and links. Of course, it is expected that WSNs will be widely deployed for all sorts of applications. Each node in the network may be equipped available at with different sensors including seismic, acoustic, video camera, and infrared light, among others. Nodes may be configured in groups and they can synchronize with each other in a way that makes locally transpiring events be identified by the majority, if not all, of the nodes of the cluster. Such nodes will collaborate in order to make local decisions based on the data gathered by each node in the cluster. In such an arrangement, one node may act as the master node and the rest may act as the slaves. (7) Cost. An important issue in the cost of wireless microcontrollers is the size of memory needed. Designers of wireless sensor networks will expect to have access to a range of chips or wireless microcontrollers with optimized memory size to meet the needs of a variety of applications. Likewise, the need for larger applications development such as gateway devices, and third party network layer development, show that there is a need for a much larger memory size, greater than 250 kB in some cases. (8) Transmission time. One issue that is sometimes neglected is the amount of time needed to send the packets. Transmission time affects performance, quality of service, power consumption, and interference. It is necessary to have reliable data transmission and extended battery life in wireless sensor networks. We can improve the reliability of data transmission by using a small practical packet size since this gives the highest probability of a packet being delivered to the destination in the presence of interference. Extended battery life is obtained by minimizing the on time of the radio device, where most power is consumed. In general, a small packet size and occasional transmission can help to reach this goal in saving power. (9) Compression of data. Compressing sensor data before transmission can offer a key decrease in transmission time. In sensor nodes like gas level, temperature, pressure, and light level sensors, the transmission of data on transition or exception, instead of normal planned transmissions, is an efficient way to minimize network traffic. Moreover, having the ability to perform digital filtering or data compression at the sensor node is a valuable approach to minimize the data size as well as the rate of recurrence of transmissions. (10) Interference and environment. In general, interference from other nearby wireless networks such as Bluetooth or wireless LANs, should be addressed. Usually, this only presents a transitory state of interference to the WSN. For example, the capability of an IEEE 802.15.4 or ZigBee-based network to carry out automatic repeat will probably overwhelm any effect of interference from Bluetooth. Similarly, for WSNs employing occasional transmissions and for Bluetooth with frequency hopping, the probability of a frame collision is small. By utilizing collision avoidance schemes, wireless LANs (WLANs) can listen for a clear radio-frequency (RF) channel before they send data. However, under heavy traffic conditions in WLANs, we may get limited availability of the RF channel to the WSN due to the continuous state of interference. In such a situation, it is recommended for the WSN to be set on a different channel. Surrounding building structures also affect the RF environment. Steel reinforced concrete floors, stone, available at walls and analogous construction resources bring in high levels of attenuation as well as multipath fading. Similarly, the movement of persons or equipment considerably affects the signal level at any specific position. In general, effects of complex building structures can be alleviated by using additional router nodes in a mesh network that are installed to get around such obstacles. (11) Security. Owing to the characteristics of the wireless communication medium, there are various security challenges that face WSNs including eavesdropping, man-in-the-middle attack, spoofing, and distributed denial of service (DDoS). The worry for security in WSNs can be even larger than that in a traditional adhoc wireless network as, in many cases, the computational and energyconsumption limitations create barriers in the implementation of powerful and effective security solutions in WSNs. Therefore, advances in the design of security mechanisms in WSNs for protecting the confidentiality, availability and integrity, are essential for the proper operation of such systems [3–15]. The acceptance of the Advanced Encryption Standard (AES) with a 128-bit key length guarantees data integrity and resistance to hacking. An AES security scheme can be implemented in software, while a dedicated hardware encryption processor offers a better solution since this reduces software overheads and permits faster encryption/decryption operation. Clearly, this is essential for sensor nodes, which must spend the least time possible awake, as staying awake consumes a lot of the power of the node’s battery. Furthermore making the AES encryption chip accessible to the application software facilitates a higher level of security [3].

ARCHITECTURE OF SENSOR NODE :

This section discusses major components and other dependants components of wireless sensor network.

A. Main Components 1) Sensing Unit All sensor devices are equipped with sensing units. It is usually are divided into two sub units: sensors part and analog-to-digital. In sensor part which contains cameras, video, sound, and/or scalar sensors and analog-to-digital converters. Analog signals generated by sensor nodes and converted into digital signals with help of software and send to processing unit 2) Power Unit Power unit provides power to sensor node and sensor uses energy for many areas as sensing environment, data processing which come from sensor nodes and communicated to other sensor nodes. From many researches it is found that more energy is consume than any other processes. Basic source of power of sensor node is electrochemical material such as NiMH, NiZn, and lithium ion cells 3) Communication Unit . A communication unit is subsystem, stabilize interface between the device and the network and a make possible transmission and receiver with the help of communication software 4) Processing Unit After getting information or data from sensor nodes/devices then processing unit starts its execution in the system software as coordinating sensing. It is interacted with storage unit and communication tasks.

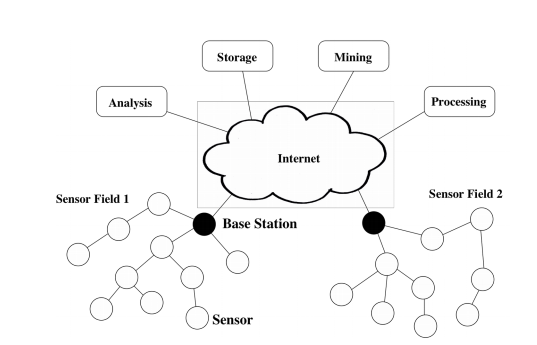


Figure: General System Model of a WSN

WSN Network Topologies:

For radio communication networks, the structure of a WSN includes various topologies like the ones given below:

#### Star Topologies:

Star topology is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to several remote nodes. In instar topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station).

Due to its dependency on a single node to manage the network, the gateway must be within the radio transmission range of all the individual nodes. The advantage includes the ability to keep the remote nodes’ power consumption to a minimum and simply under control. The size of the network depends on the number of connections made to the hub.

#### Tree Topologies:

Tree topology is also called as a cascaded star topology. In tree topologies, each node connects to a node that is placed higher in the tree, and then to the gateway. The main advantage of the tree topology is that the expansion of a network can be easily possible, and also error detection becomes easy. The disadvantage with this network is that it relies heavily on the bus cable; if it breaks, all the network will collapse.

#### Mesh Topologies:

## The Mesh topologies allow transmission of data from one node to another, which is within its radio transmission range. If a node wants to send a message to another node, which is out of the radio communication range, it needs an intermediate node to [forward the message](https://www.elprocus.com/wireless-pc-communication-system-using-transceiver/) to the desired node. The advantage of this mesh topology includes easy isolation and detection of faults in the network. The disadvantage is that the network is large and requires huge investment.

## Types of Wireless Sensor Networks

Depending on the environment, the [types of networks](https://www.elprocus.com/important-of-network-in-embedded-systems-for-beginners/) are decided so that those can be deployed underwater, underground, on land, and so on. Different types of WSNs include:

1. Terrestrial WSNs
2. Underground WSNs
3. Underwater WSNs
4. Multimedia WSNs
5. Mobile WSNs

#### Terrestrial WSNs

Terrestrial WSNs are capable of communicating base stations efficiently, and consist of hundreds to thousands of wireless sensor nodes deployed either in an unstructured (ad hoc) or structured (Pre-planned) manner. In an unstructured mode, the sensor nodes are randomly distributed within the target area that is dropped from a fixed plane. The pre-planned or structured mode considers optimal placement, grid placement, and 2D, 3D placement models.

In this WSN, the [battery power](https://www.elprocus.com/battery-charger-timer-tips/)is limited; however, the battery is equipped with solar cells as a secondary power source. The Energy conservation of these WSNs is achieved by using low duty cycle operations, minimizing delays, and optimal routing, and so on.

#### Underground WSNs:

The underground wireless sensor networks are more expensive than the terrestrial WSNs in terms of deployment, maintenance, and equipment cost considerations and careful planning. The WSNs networks consist of several sensor nodes that are hidden in the ground to monitor underground conditions. To relay information from the sensor nodes to the base station, additional sink nodes are located above the ground. The underground wireless sensor networks deployed into the ground are difficult to recharge. The sensor battery nodes equipped with limited battery power are difficult to recharge. In addition to this, the underground environment makes wireless communication a challenge due to the high level of attenuation and signal loss.

More than 70% of the earth is occupied with water. These networks consist of several sensor nodes and vehicles deployed underwater. Autonomous underwater vehicles are used for gathering data from these sensor nodes. A challenge of underwater communication is a long propagation delay, and bandwidth and sensor failures .Underwater, WSNs are equipped with a limited battery that cannot be recharged or replaced. The issue of energy conservation for underwater WSNs involves the development of underwater communication and networking techniques. Multimedia wireless sensor networks have been proposed to enable tracking and monitoring of events in the form of multimedia, such as imaging, video, and audio. These networks consist of low-cost sensor nodes equipped with microphones and cameras. These nodes are interconnected with each other over a wireless connection for data compression, data retrieval, and correlation. The challenges with the multimedia WSN include high energy consumption, high bandwidth requirements, data processing, and compressing techniques. In addition to this, multimedia contents require high bandwidth for the content to be delivered properly and easily. These networks consist of a collection of sensor nodes that can be moved on their own and can be interacted with the physical environment. The mobile nodes can compute sense and communicate. Mobile wireless sensor networks are much more versatile than static sensor networks. The advantages of MWSN over static wireless sensor networks include better and improved coverage, better energy efficiency, superior channel capacity, and so on. Wireless Sensor Network (WSN) consists of a large number of very small sensors deployed in a specific area depending on the desired application .Each sensor contains sensing, data processing, and communication components. These sensors form WSN nodes that transfer the sensing data to the Base Station (BS) or sink. In the BS, the data is processed and computed to give understandable results. The communication between BS and wireless nodes is arranged by different protocols. One of the energy-efficient protocols is the LEACH

routing protocol. In this protocol, the network is divided into different clusters and each cluster has elected Cluster Head (CH) which connected with cluster member nodes and the BS, collecting data from the nodes and then sending the aggregated data to the BS. As a cluster head has more functions than the other nodes, so it consumes its energy faster than the other nodes which leads it to die earlier. In this paper, we propose a new algorithm called Secondary Cluster Head (SCH) which becomes a cluster head simultaneously with the death of the previous CH. So, all WSN cluster keep transmitting data even if some nodes dead which increase the network lifetime and performance. LEACH protocol uses TDMA or CDMA .

First, LEACH processes start with the setup phase then the steady-state phase. The cluster formation and then Head has been chosen are in the setup phase. We propose in this project to select the CH besides of Distance-Based Cluster Head (DBCH) algorithm that improvements combination with SCH approach would maximize the network lifetime, save energy, reduce delay time and increase the data transmission rate.

**CHAPTER-3**

**LITERATURE REVIEW**

**[1] F. Karray, M. W. Jmal, A. Garcia-Ortiz, M. Abid, and A. M. Obeid:** [Wireless sensor nodes](https://www.sciencedirect.com/topics/engineering/wireless-sensor-node) are the main components in [wireless sensor networks](https://www.sciencedirect.com/topics/engineering/wireless-sensor-network). Such devices affect the performance and the accuracy of the network. Countless commercial and research nodes exist and their comparison is critical. Literature surveys do not provide a comprehensive overview about all the existing nodes’ technologies.

The main goal of this paper is to provide a deep overview of the current state of the art with enough background, to allow to design evolutionary nodes and to analyse thoroughly the node design components and application trends. This survey is helpful not only for researchers but also for industry. Therefore, a work that gives an inclusive overview is required. With the [exponential growth](https://www.sciencedirect.com/topics/engineering/exponential-growth) of technologies and electronics, it is essential to know the latest trends, the innovative future directions and to eliminate redundancies.

This paper allows a global overview about existing nodes in industrial and research works to get decisions about the future of node fabrication.

**Summary:** Studied about acquiring information from physical word in automatic, systematic and intelligent way using a large number of WSND.

**[2] A. Shahraki, A. Taherkordi, Ø. Haugen, and F. Eliassen:** Wireless Sensor Networks (WSNs) typically include thousands of resource-constrained sensors to monitor their surroundings, collect data, and transfer it to remote servers for further processing. Although WSNs are considered highly flexible ad-hoc networks, network management has been a fundamental challenge in these types of networks given the deployment size and the associated quality concerns such as resource management, scalability, and reliability. Topology management is considered a viable technique to address these concerns. Clustering is the most well-known topology management method in WSNs, grouping nodes to manage them and/or executing various tasks in a distributed manner, such as resource management. Although clustering techniques are mainly known to improve energy consumption, there are various quality-driven objectives that can be realized through clustering. In this paper, we review comprehensively existing WSN clustering techniques, their objectives and the network properties supported by those techniques. After refining more than 500 clustering techniques, we extract about 215 of them as the most important ones, which we further review, categorize and classify based on clustering objectives and also the network properties such as mobility and heterogeneity. In addition, statistics are provided based on the chosen metrics, providing highly useful insights into the design of clustering techniques in WSNs.

**Summary:** Studied about that most of existing clustering techniques are unable to support heterogeneous and mobile network infrastructures. Given that many applications require supporting such network characteristics, more effort is needed on addressing heterogeneity and mobility through clustering. In addition, the results show that although clustering techniques focus on reducing energy consumption and improving load balancing, they are able to solve more divers challenges. This will encourage the scientists to leverage clustering to solve other networking challenges..

**[3] Hein zelman, Wendi Rabiner, Anantha Chandrakasan, and Hari Balakrishnan:**

Networking together hundreds or thousands of cheap microsensor nodes allows users to accurately monitor a remote environment by intelligently combining the data from the individual nodes. These networks require robust wireless communication protocols that are energy efficient and provide low latency. We develop and analyze low-energy adaptive clustering hierarchy (LEACH), a protocol architecture for microsensor networks that combines the ideas of energy-efficient cluster-based routing and media access together with application-specific data aggregation to achieve good performance in terms of system lifetime, latency, and application-perceived quality. LEACH includes a new, distributed cluster formation technique that enables self-organization of large numbers of nodes, algorithms for adapting clusters and rotating cluster head positions to evenly distribute the energy load among all the nodes, and techniques to enable distributed signal processing to save communication resources. Our results show that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multihop approaches

**Summary:** Studied about LEACH outperforms static clustering algorithms by requiring nodes to volunteer to be high-energy cluster-heads and adapting the corresponding clusters based on the nodes that choose to be cluster-heads at a given time. At different times, each node has the burden of acquiring data from the nodes in the cluster, fusing the data to obtain an aggregate signal, and transmitting this aggregate signal to the base station.

**[4] I. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci:** This paper describes the concept of sensor networks which has been made viable by the convergence of micro-electro-mechanical systems technology, wireless communications and digital electronics. First, the sensing tasks and the potential sensor networks applications are explored, and a review of factors influencing the design of sensor networks is provided. Then, the communication architecture for sensor networks is outlined, and the algorithms and protocols developed for each layer in the literature are explored. Open research issues for the realization of sensor networks are also discussed.

**Summary:** Studied about architecture for sensor networks is outlined, and the algorithms and protocols.

**[5] H. Shin, S. Moh, I. Chung, and M. Kang:** This study examines the problem that sensors are irregularly deployed in a wireless sensor network (WSN). Such irregularity makes clustering protocols less efficient. This paper proposes a new clustering algorithm, called balanced clustering algorithm (BCA), for irregularly deployed WSNs. In BCA, each node determines the probability that the node itself becomes the cluster head (CH) by considering the sensing population, which is defined as the number of nodes within the sensing range of a node. As a result, the coverage area of each cluster is distributed almost equally and unused redundant nodes are turned into sleep mode. Therefore, the large deviation of the coverage areas of clusters in a network can be decreased and the unnecessary duplication of sensing and transmission can also be decreased. In addition, the inefficient energy consumption is reduced significantly because the sleeping nodes do not send duplicated information over high populated areas. According to the simulation, the proposed BCA reduces energy consumption, increases the network lifetime and distributes the detection area of each cluster evenly, compared to the conventional schemes.

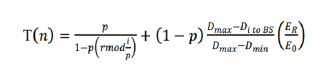
**Summary:** Studied about balanced clustering algorithm (BCA).

**CHAPTER-4**

**EXISTING METHOD**

Wireless sensor technology is growing rapidly, especially with many new Internet of Things (IoT) applications. In another side, researches are coming out with diversities of approaches to enhance and improve this technology trying to cover the needs in this era. The drawback of sensor Technologies is the low battery and short lifetime. So, most of the following researches considering to sophisticate these weaknesses and suggest different algorithms and approaches overcome these issues. Sharma proposed novel LEACH protocol in the heterogeneous network and compared the simulation results with LEACH Homogeneous system; They chose 100 \* 100 meters area to simulate the protocol. Sharma found that 10 nodes have more energy than the rest of 90 nodes which improves the system lifetime and enhanced wireless sensor network performance.

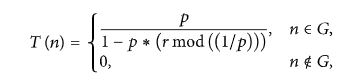
Naveen explored fifteen different types of clustering wireless sensor protocols which considered more in energyefficient and lifetime of the network system.. Prasad simulated LEACH using TDMA routing protocol. Also, they surveyed the previous approaches for selecting CH and improving the WSN performance such as Euclidian Distance from a node to BS, remaining energy and number of nodes in the same cluster. Increasing the number of dead nodes in the cluster would be the reason for shortening the WSN lifetime. Nandi [10] implemented a new protocol for choosing an optimal place for the BS, which overcomes the issues of delivering data and they compared the simulation result with the basic LEACH protocol with TDMA technique. Commonly when the BS located far away from the node, then transmitting data from a node to BS will cost more energy in the node, which leads to reduce the node lifetime and therefore reduce the network lifetime [10]. Moreover, packet delivery time would be reduced when the sink positioned in the center near the nodes [10]. The authors proposed an algorithm called Distance Based Cluster Head (DBCH) which the threshold value measured by the following equation :



where ER is the residual energy of the node for the current round and E0 is the initial energy. This algorithm proposes to select the closest node to the BS as a cluster head. This enhancement considered on two-parameter energy and distance. In addition, it considers the distance from the node to cluster head base station and compared the distance from node cluster head and BS. This study simulated the suggestions on a homogenous network, where all nodes have the same amount of energy. LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol is a basic clustering-based routing protocol for WSNs.

LEACH routing protocol is a WSN routing algorithm designed by Heinzehnan et al. from MIT in the United States, which is the earliest typical hierarchical routing protocol [9]. LEACH protocol adopts the method of distributed CH election, in which some nodes are randomly selected from the network as CHs, and other nodes become cluster member nodes [10]. The CH broadcasts the message that it becomes a CH, and other nodes select the CH with the strongest received signal to join to form a cluster [9]. The cluster member node collects data and transmits it to the CH, which receives data and transmits it to the BS through single-hop communication. The CHs undertake the heavy tasks, including managing the member nodes of the cluster, collecting the data transmitted by the member nodes, data fusion, and intercluster forwarding. Therefore, to balance the energy consumption of nodes, CHs rotate, and the cluster structure is updated periodically. LEACH is a self-adaptive cluster formation protocol. The basic idea of the LEACH protocol is to divide the network into clusters of equal size. The CH rotates periodically, and each cycle is called a “round.” Each round is divided into two stages: the establishment stage of the cluster and the stable transmission stage [10].

In the establishment stage of the cluster, each node generates a random number from 0 to 1, and the threshold T(n) is calculated according to equation ([1](https://www.hindawi.com/journals/jece/2020/8059353/#EEq1)). Then, the random number generated by each node is compared with T(n). If the value is less than T(n), the node is selected as the CH:



where  p is the percentage of CH in all nodes, r is the number of current election rounds,

(r mod(1/p)) is the number of nodes that have been selected in this round, and G is the set of nodes without CHs selected in this round. After the end of each CH selection round, each selected CH broadcasts its message of becoming a CH to other nodes. After receiving the broadcast message, other nodes choose to join a cluster according to the received signal strength and send their joining message to the selected CH [11]. Each CH creates and assigns a TDMA schedule between each member node after its member nodes are joined. Then, end the cluster establishment stage and start the data transmission stage. Node becomes cluster head for the current round if the number is less than threshold T (n). Once node is elected as a cluster head then it cannot become cluster head again until all the nodes of the cluster have become cluster head once. This is useful for balancing the energy consumption. In the second step, non-cluster head nodes receive the cluster head advertisement and then send join request to the cluster head informing that they are members of the cluster under that cluster head. All non-cluster head nodes save a lot of energy by turning off their transmitter all the time and turn it on only when they have something to transmit to the cluster head [2]. In third step, each of the chosen cluster head creates a transmission schedule for the member nodes of their cluster. TDMA schedule is created according to the number of nodes in the cluster. Each node then transmits its data in the allocated time schedule [3].

In the data transmission stage, each member node sends data to the CH within its allocated period, and the CH transmits data to the BS after data fusion. Therefore, CHs consume more energy than member nodes. LEACH ensures that all nodes are equally likely to act as CHs employing cycle circulation so that the nodes consume energy in a relatively balanced manner. However, factors such as residual energy of nodes and distance from the BS are still not considered. The randomness of the CH election may lead to the death of the CH far away from the BS due to the rapid exhaustion of energy, which affects the survival time of the whole network.



Figure :Hierarchical or cluster based routing

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is a TDMA based MAC protocol. The principal aim of this protocol is to improve the lifespan of wireless sensor networks by lowering the energy consumption required to create and maintain Cluster Heads.

LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station (sink). Each node uses a [stochastic](https://en.wikipedia.org/wiki/Stochastic) algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy.

Nodes that have been cluster heads cannot become cluster heads again for P rounds, where P is the desired percentage of cluster heads. Thereafter, each node has a 1/P probability of becoming a cluster head again. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data.

All nodes that are not cluster heads only communicate with the cluster head in a TDMA fashion, according to the schedule created by the cluster head. They do so using the minimum energy needed to reach the cluster head, and only need to keep their radios on during their time slot.

LEACH also uses [CDMA](https://en.wikipedia.org/wiki/Code_division_multiple_access) so that each cluster uses a different set of CDMA codes, to minimize interference between cluster. The operation of LEACH protocol consists of several rounds with two phases in each [3] [4]: Set-up Phase and Steady Phase.

In the Set-up phase the main goal is to make cluster and select the cluster head for each of the cluster by choosing the sensor node with maximum energy. Leach protocol is a typically representation of hierarchical routing protocol. It is self-adaptive and self-organized [2]. Leach protocol uses round as unit, each round is made up of cluster set-up stage and steady state storage for the purpose of reducing unnecessary energy costs. Phases of leach protocol are as follows: A. Set-up phase In the set-up phase, the main goal is to make cluster and select the cluster head for each of the cluster by choosing the sensor node with maximum energy [3]. Set-up phase has three fundamental steps: 1. Cluster head advertisement 2. Cluster set up 3. Creation of transmission schedule During the first step cluster head sends the advertisement packet to inform the cluster nodes that they have become a cluster head on the basis of the following formula:

Steady Phase which is comparatively longer in duration than the set-up deals mainly with the aggregation of data at the cluster heads and transmission of aggregated data to the Base station. In steady phase, cluster nodes send their data to the cluster head. The member sensors in each cluster can communicate only with the cluster head via a single hop transmission. Cluster head aggregates all the collected data and forwards data to the base station either directly or via other cluster head along with the static route defined in the source code. After predefined time, the network again goes back to the set-up phase. The LEACH protocol adopts the concept of clustering and periodic data collection, which can reduce the data transmission between the nodes and the BS. Therefore, this protocol can not only reduce the energy loss, but also can extend the network lifetime. In addition, the CH uses the method of data aggregation, which can reduce correlated data locally. This method can also optimize the amount of data in the network and reduce energy consumption. Moreover, the time division multiple access (TDMA) schedule used by LEACH allows the member nodes to go into sleep mode, and this mechanism holds back the collision between clusters and extends the sensors’ battery life



Figure:Leach phases

A cluster head in the LEACH protocol is not stabilized; LEACH is established over the round concept and each round includes two stages: a setup stage and a steady-state stage. The setup stage is separated into advertisement aspect and cluster setup aspect, while the steady stage includes the creation of schedule and transferring of data .The LEACH protocol suits WSNs under the following suppositions: & Every sensor node is static, exactly alike, and charged with the identical quantity of initial energy. & Every node consumes energy at the same degree and is capable to identify its remaining energy and controls power transferring and distance. & All nodes can directly connect to every other node, as well as the sink node. & The sink node is determined and in a distance from the wireless network. Thus, the energy consumed by the sink node is ignored. & All nodes have transferred data in each period. The data transmitted by sobering nodes are connected and can be combined.

However, the density of nodes is not considered in the traditional LEACH protocol when selecting the CH. The placement of nodes and the expected number of CHs per round are considered when assigning CHs. Therefore, this protocol cannot ensure the uniform distribution of the CHs Additionally; the LEACH protocol does not consider the residual energy of nodes and the average energy of all nodes when selecting the CH. This will lead to a node with a lower energy being chosen as the CH. Thus, this protocol leads to the quick exhaustion of the node energy. Finally, the CH communicates directly with the BS by adopting a single hop communication mode.

LEACH protocol is threatened by the following types of attacks which degrade the performance of LEACH by dropping, altering, spoofing or replying the packets. A. Sybil Attack Most of the peer to peer networks face security threats due to Sybil attack [8], [9]. This attack is the most difficult attack to detect. In this attack, malicious node uses the identity of many other legitimate nodes to gain the data exchanged between the legitimate nodes. It affects the network by dropping vital packets, increasing traffic, lowering network lifetime etc. Encryption and authentication techniques can be used to prevent wireless sensor network from the Sybil attack. B. Selective Forwarding LEACH protocol is also susceptible to selective forwarding attack. In this kind of attack a malicious node places itself in the path where data is exchanged between the two legitimate nodes. It collects the data and instead of forwarding this node drops all the data. It is the case where the malicious node can easily be detected. The worst scenario of this attack is that when malicious node does not discard the entire data, but selectively forwards some of the non vital information. In this case it is very difficult detect the malicious node. C. HELLO Flooding Attack In many protocols sometimes it is required for node to transmit HELLO packets to advertise itself to its neighboring nodes. The nodes receiving these packets assume that it is within the range of the sender. But in case of malicious node, it continuously keeps on sending the HELLO packets and thus increases the network traffic and causes collisions. It also consumes the energy of the sensor nodes when these nodes receive large amount of HELLO packets continuously and thus lowering the lifetime of the wireless sensor networks. This type of attack is known as HELLO Flood attack .

To develop the LEACH protocol we consider the scenario consisting of the following network model and energy model as proposed by the author:

Network Architecture

The network model for development of the algorithm for clustering and routing consist of the following:

1) In our model we have 100 nodes with equal initial energy The base station is under human observation therefore

has unlimited power and the transmit power can be adjusted in an available range.

2) The nodes are considered to be immobile and their locations have been known with the help of either GPS or

node self-localization algorithms.

3) We have single sink node which can be moved. The distance between node in the network and the sink node is

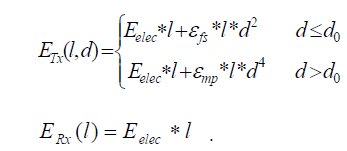
known by exchanging information. We can change the positions of sink node for analyzing the best position so that

minimum distance and low energy communication will take place.

4) CHs can use a single hop to the sink node and need more energy in transmitting the data to the base station and Cluster Member (CM) nodes use single-hop communication with CH as they are closer to the CHs.

5) Sensors periodically sense the environment and send the data to the Base Station

Radio Signal Propagation Model: The first order radio frequency energy consumption model to describe energy feather of the communication channel. The first order radio model can be divided into free-space model and multi-path fading model according to the distance between the sending node and receiving node. The protocol assumes that the communication channel is symmetrical, the energy consumption of l bits message between two nodes with a distance of d can be shown as below equations :



Where E (l,d) Tx is the energy consumption in transmitting l bits data to a node with a distance of d , E (l) Rx is the energy consumption in receiving l bits data. E elec equals the per bit energy consumption for transmitter and receiver circuit . E mp and E fs are the amplifier parameters of transmission corresponding to the multi-path fading model and the free-space model respectively. d0 is the threshold distance between multi-path fading model and the free-space model, If d0 < d , the channel approximates free-space model, the energy dissipation in transmitter amplifier is in direct ratio to d^2 . If d0 > d , the multi-path fading model will be employed and the energy dissipation is in direct ratio to d^4 .

Where, Eelec is the electronics energy; εfs and εmp are the amplifier energy of the free space model and the multipath model. As discussed in the previous section the operation of leach takes place in two phases. Initially all the nodes have equal probability to become the cluster head. Depending upon the random number selected the nodes themselves decide whether to become the cluster head or not. The nodes eligible to become cluster heads then broadcast its decision with larger signal strength so as to reach all the member nodes. ɛmp is the amplification power needed to

transmit the signal. The energy dissipated in setup phase can be calculated as follows.If k numbers of nodes are the CHs then to transmit the l bit message over a distance d each node needs



To receive this message from each CH the member nodes will need



When the nodes hear the cluster head message from the CHs they check for the signal with highest signal strength. The signal from the CH which is closest will have highest signal strength. So the node will join the corresponding head. For joining as member the nodes will send a request to the CH. To transmit the join request the energy dissipated is as follows:

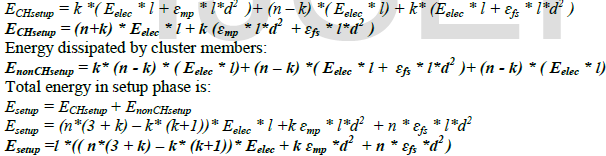


The schedule sent by CHs will be received by all the member nodes consuming the energy as follows:



Thus the total energy needed by the network in setup phase can be calculated as follows:

Energy dissipated by Cluster Head:



**DISADVANTAGES:**

* 1. It does not guarantee the formation of equal size clusters.
* 2. LEACH disregards the BS and cluster head geographical positions, energy consumption, which reduces network lifetime **.**
* 3. We have noticed that the cluster head missions are more than the ordinary nodes, so the cluster head consumes more energy than the others

**CHAPTER-5**

**PROPOSED METHOD**

The proposed LEACH-USC approach has the following three objectives: 1) to generate clusters of uniform size (as in [7]); 2) to achieve clusters with crisp boundaries (as in [3]); 3) longevity of the network lifetime (as in [3] and [7]).

In the proposed solution, all the nodes are assigned with a cluster head as it happens in case of LEACH protocol, but there will be a few unclustered nodes because of threshold Thcluster. The idea of the cluster refurbish phase of the proposed solution is to allow extra nodes (MNs—Thcluster) of large clusters to join other clusters according to the second best choice of cluster heads. the proposed solution has uniform size clusters (USCs); thus, the approach is named as LEACH-USC), along with reduced intracluster communication.

The operation of the proposed strategy has been depicted in Fig. Cluster head selection depends on the probabilistic approach as also performed by LEACH. In the initial cluster formation operation, all the nodes join the nearest cluster head. As a consequence of probabilistic cluster head selection and assigning the nodes to the nearest clusters head, clusters of different sizes exist after the completion of initial cluster formation operation like the LEACH approach, but there will be no node without a cluster head, unlike the BCF approach. In the cluster refurbish operation of the proposed approach, clusters will be reorganized to obtain USCs with the goal of sending the nodes from the a large clusters to the other clusters according to the second best cluster head. First, the largest cluster among all clusters has been identified, and then, the distance between the MNs of the cluster and the rest of the cluster heads are calculated. This is done in order to find second best choice of cluster heads. The k-nodes [MN—Thcluster], which have least communication distance to other cluster heads, will be assigned to respective second best cluster heads. Consequently, nodes near the cluster boundary will be assigned to other cluster heads. Algorithm 1 explains the working of the cluster refurbish process. The inputs provided in the algorithm includes: number of cluster heads (X ), number of nodes in each cluster (CLUSTER[]), Thcluster. First, the largest cluster is identified. Then, the second best distance of the MNs of the largest cluster is found so that they can join the second best cluster head. These distances are then arranged in ascending order and this step is necessary to ensure that nodes, which are closer to the clusters other than their respective clusters will join them and not the one which are farther away from them. Finally, the first k nodes (k = CLUSTER[largest] − Thcluster) from SecondBestCH[] will be sent from the largest cluster to their new clusters according to the second best distance. This process will continue until we have all the clusters of uniform size. There may be 02 cases. In the first case, the number of nodes is divided completely by the number of cluster heads, i.e., remainder is zero then each cluster will have equal number of MNs, in the proposed LEACH-USC protocol. In the second case, the number of nodes is not completely divided by the number of cluster heads, i.e., remainder is not zero then (X-1) cluster heads will have equal sizes, and only one cluster will have a different number of MNs than the others. That is the reason why the name of the protocol is USCs. After the cluster refurbish process, the TDMA schedule is created by each cluster head in the network according to the number of nodes in each cluster. In the data transmission phase, nodes will send data to their respective cluster heads, and cluster heads will aggregate the data and transmit the aggregated data to the base station. Eventually, reclustering is done to rotate the role of the cluster heads for the next round.

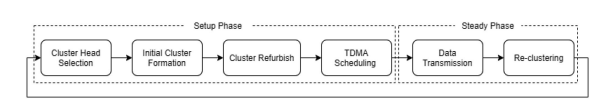


Fig. Sequence of operations in the proposed LEACH-USC.

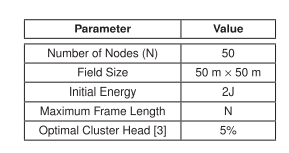
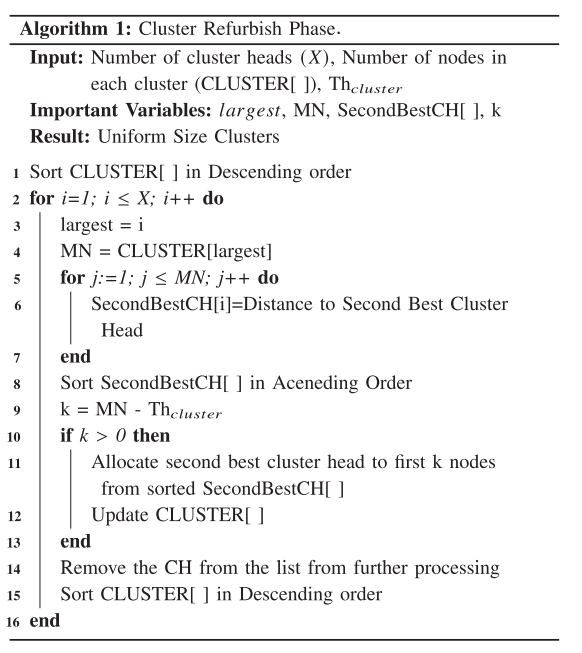


Table : Network Parameters.



**CHAPTER-6**

**ADVANTAGES AND APPLICATIONS**

**Advantages:**

1) Longevity of the network lifetime

2) To generate clusters of uniform size

3) To achieve clusters with crisp boundaries

**Applications:**

1.industrial control

2.environmental monitoring,

3. military surveillance,

4.intelligent transportation systems and medical field.

5.Furthermore, it can function independently in harsh or high-risk places where human presence is not possible

6.Disaster relief operations.

7.Biodiversity mapping

8.monitoring of temperature, pressure, and humidity.

**CHAPTER-7**

**MATLAB**

**7.1 INTRODUCTION TO MATLAB**

**What Is MATLAB?**

MATLAB is an elite dialect for specialized registering. It incorporates calculation, representation, and programming in an easy to-utilize condition wherein issues and preparations are communicated in herbal numerical documentation. Run of the mill utilizes comprise

• Math and calculation

• Algorithm advancement

• Data obtaining

• Modeling, re-enactment, and prototyping

• Data examination, investigation, and representation

• Scientific and designing illustrations

• Application advancement, including graphical UI building

MATLAB is an intuitive framework whose important statistics aspect is an show off that does not require dimensioning. This allows you to tackle several specialized processing issues, particularly those with framework and vector info, in a small quantity of the time it'd take to compose a program in a scalar non intuitive dialect, as an instance, C or FORTRAN.

The call MATLAB stays for grid studies facility. MATLAB changed into first of all composed to present easy access to framework programming created by way of the LINPACK and EISPACK ventures. Today, MATLAB motors fuse the LAPACK and BLAS libraries, inserting the cutting side in programming for network calculation.

MATLAB has advanced over a time of years with contribution from several customers. In university situations, it's far the usual academic apparatus for early on and propelled guides in mathematics, designing, and science. In enterprise, MATLAB is the tool of choice for excessive-profitability studies, advancement, and exam.

MATLAB highlights a collection of more utility-specific arrangements known as tool booths. Important to most clients of MATLAB, device kits permit you to learnandapply particular innovation. Tool compartments are exhaustive accumulations of MATLAB capacities (M-records) that reach out the MATLAB condition to take care of precise training of problems. Territories in which tool stash are reachable include flag coping with, manipulate frameworks, neural structures, fluffy reason, wavelets, pastime, and severa others.

**The MATLAB System:**

The MATLAB system consists of five main parts.

**Development Environment:**

 This is the set of tools and centres that help you operate MATLAB features and files. Many of that gear are graphical person interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing assist, the workspace, files, and the hunt direction.

**The MATLAB Mathematical Function:**

This is a great collection of computational algorithms ranging from standard capabilities like sum, sine, cosine, and complex arithmetic, to extra sophisticated features like matrix inverse, matrix eigen values, Bessel functions, and speedy Fourier transforms.

**The MATLAB Language:**

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

**Graphics:**

MATLAB has considerable centres for displaying vectors and matrices as graphs, as well as annotating and printing those graphs. It consists of high-stage functions for 2-dimensional and 3-dimensional records visualization, photograph processing, animation, and presentation graphics. It also consists of low-stage capabilities that will let you absolutely customise the appearance of graphics as well as to construct complete graphical person interfaces for your MATLAB programs.

**The MATLAB Application Program Interface (API):**

This is a library that allows you to put in writing C and Fortran applications that have interaction with MATLAB. It consists of facilities for calling workouts from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for studying and writing MAT-documents.

**7.2 MATLAB WORKING ENVIRONMENT:**

## MATLAB DESKTOP:

Matlab Desktop is the principle Matlab application window. The desktop consists of five sub windows, the summon window, the workspace program, the existing catalog window, the order records window, and at the least one figure home windows, which can be proven simply while the consumer suggests a sensible.

The order window is the area the customer sorts MATLAB orders and expressions at the initiate (>>) and wherein the yield of these fees is shown. MATLAB characterizes the workspace because the association of factors that the customer makes in a work session. The workspace software demonstrates these elements and some statistics approximately them. Double tapping on a variable within the workspace application dispatches the Array Editor, which may be applied to get data and salary instances modify sure homes of the variable.

The present Directory tab over the workspace tab demonstrates the substance of the existing registry, whose way is seemed within the present index window. 1For case, within the windows running framework the manner may be as consistent with the subsequent: C:MATLABWork, demonstrating that registry "paintings" is a subdirectory of the primary catalog "MATLAB", which is delivered in pressure C. Tapping on the bolt inside the present index window demonstrates a rundown of as of past due utilized approaches. Tapping at the seize to one aspect of the window enables the client to exchange the existing catalog.

MATLAB utilizes an inquiry way to discover M-data and different MATLAB related documents, which might be sort out in catalogs within the PC file framework. Any file keep strolling in MATLAB must dwell inside the ebb and go with the flow registry or in an index that is on are trying to find manner. Of direction, the statistics supplied with MATLAB and math works device kits are included into the inquiry way. The least stressful method to look which indexes are at the inquiry manner. The handiest method to peer which catalogs are soon the quest way, or to encompass or regulate an inquiry manner, is to pick set manner from the File menu the computer, and after that utilization the set way exchange container. It is exquisite exercise to add any typically utilized catalogs to the pursuit way to hold a strategic distance from again and again having the exchange the existing index.

The Command History Window contains a record of the orders a client has entered in the charge window, including both present and past MATLAB sessions. Already entered MATLAB orders can be chosen and re-executed from the charge history window by right

tapping on a summon or arrangement of orders. This activity dispatches a menu from which to choose different choices notwithstanding executing the orders. This is helpful to choose different choices notwithstanding executing the summons. This is a valuable component while trying different things with different orders in a work session

**Using the MATLAB Editor to create M-Files:**

The MATLAB manager is both a word processor unique for making M-statistics and a graphical MATLAB debugger. The proofreader can display up in a window without everybody else, or it could be a sub window in the laptop. M-facts are intended by means of the expansion .M, as in pixelup.M. The MATLAB editorial manager window has various draw down menus for errands, for instance, sparing, seeing, and troubleshooting documents. Since it plays out a few basic checks and furthermore utilizes shading to separate between exclusive additives of code, this content device is suggested as the equipment of selection for composing and changing M-capacities. To open the proofreader, sort regulate at the incite opens the M-report filename.M in a supervisor window, organized for altering. As referred to before, the record has to be inside the momentum catalog, or in an index within the pursuit manner.

**Getting Help:**

The important technique to get help on line is to utilize the MATLAB assist application, opened as a exclusive window both via tapping at the query mark image at the computing device toolbar, or by using writing help program on the provoke within the order window. The help Browser is an internet application coordinated into the MATLAB computing device that shows a Hypertext Markup Language (HTML) statistics. The Help Browser contains of two sheets, the assistance pilot sheet, used to find out data, and the show sheet, used to look the statistics. Clear as crystal tabs aside from pilot sheet are applied to play out a pursuit. Second, within the motion pictures taken via transferring camera setup, the state of affairs becomes extra complex because the heritage may additionally exchange by using shifting shot, we cannot tune item motion exactly inside the sum of distinction map. Therefore, in this situation, the purpose is executed through reusing the previous seam and applying it to the cutting-edge body. In order to discover the seams, we use the preceding seam from previous body to look the modern-day seam in contemporary frame. our method is using a seam computed in frame1 (in crimson) to go looking a comparable seam in frame2. For the pixels close by the area of previous seam, we decide how a lot the selected pixel might vary from the pixel of preceding seam. We use difference of the 2 pixels as the degree of temporal coherence. If the distinction value of first seam pixel is over the threshold, we can keep to go looking the next seam pixel on three feasible pixels (in yellow, blue and brown) in subsequent row, until we discover 5 consecutive pixels that also exceed the threshold.

When we can't search the matching seam, we recalculate the energy for a new seam. We assume a seam 𝑆l-1 has been calculated inside the previous body, and a seam must be calculated for the contemporary frame. For preserving the temporal coherence, we want to make a new seam close to the previous seam with the identical index. We use the distinction among preceding seam and all pixels at the current body as the measure

Thus we upload temporal coherence price Tc(i,j) to the strength map earlier than calculating a seam 𝑆L. The price Tc is zero while the body pixels have the equal fee as previous seam pixels. Using our temporal coherence price, we will calculate the seam which has least electricity and is more close to the preceding seam in previous frame. Consequently, we will decrease the jittery artifacts inside the films.

**COMMUNICATION:**

Communications System Toolbox™ offers algorithms and gear for the layout, simulation, and analysis of communications systems. These capabilities are furnished as MATLAB ® features, MATLAB System gadgets™, and Simulink ® blocks. The machine toolbox includes algorithms for source coding, channel coding, interleaving, modulation, equalization, synchronization, and channel modeling. Tools are supplied for bit blunders charge evaluation, producing eye and constellation diagrams, and visualizing channel characteristics. The machine toolbox additionally provides adaptive algorithms that allow you to version dynamic communications structures that use OFDM, OFDMA, and MIMO techniques. Algorithms support fixed-point facts arithmetic and C or HDL code era.

**Key Features**

▪ Algorithms for designing the physical layer of communications systems, which includes supply coding, channel coding, interleaving, modulation, channel fashions, MIMO, equalization, and synchronization

▪ GPU-enabled System objects for computationally intensive algorithms together with Turbo, LDPC, and Viterbi decoders

▪ Interactive visualization equipment, consisting of eye diagrams, constellations, and channel scattering capabilities

▪ Graphical tool for evaluating the simulated bit mistakes rate of a machine with analytical outcomes

▪ Channel models, consisting of AWGN, Multipath Rayleigh Fading, Rician Fading, MIMO Multipath Fading, and

LTE MIMO Multipath Fading

▪ Basic RF impairments, along with nonlinearity, section noise, thermal noise, and section and frequency offsets

▪ Algorithms available as MATLAB features, MATLAB System objects, and Simulink blocks

▪ Support for fixed-point modeling and C and HDL code technology

**System Design, Characterization, and Visualization:**

The layout and simulation of a communications gadget requires analyzing its reaction to the noise and interference inherent in real-world environments, reading its behavior the usage of graphical and quantitative manner, and determining whether the resulting overall performance meets requirements of acceptability. Communications System Toolbox implements a selection of obligations for communications machine layout and simulation. Many of the functions, System objects™, and blocks inside the device toolbox perform computations associated with a specific thing of a communications gadget, consisting of a demodulator or equalizer. Other talents are designed for visualization or evaluation.

**System Characterization**

The system toolbox offers several standard methods for quantitatively characterizing system performance:

▪ Bit error rate (BER) computations

▪ Adjacent channel power ratio (ACPR) measurements

▪ Error vector magnitude (EVM) measurements

▪ Modulation error ratio (MER) measurements

Because BER computations are fundamental to the characterization of any communications system, the system toolbox provides the following tools and capabilities for configuring BER test scenarios and accelerating BER simulations:

**BER tool**— A graphical user interface that enables you to analyze BER performance of communications systems. You can analyze performance via a simulation-based, semi analytic, or theoretical approach.

**Error Rate Test Console** — A MATLAB object that runs simulations for communications systems to measure error rate performance. It supports user-specified test points and generation of parametric performance plots and surfaces. Accelerated performance can be realized when running on a multi core computing platform.

**Multi core and GPU acceleration** — A capability provided by Parallel Computing Toolbox™ that enables you to accelerate simulation performance using multi core and GPU hardware within your computer.

**Distributed computing and cloud computing support** — Capabilities provided by Parallel Computing Toolbox and MATLAB Distributed Computing Server™ that enable you to leverage the computing power of your server farms and the Amazon EC2 Web service. Performance Visualization. The system toolbox provides the following capabilities for visualizing system performance:

**Channel visualization tool** — For visualizing the characteristics of a fading channel

**Eye diagrams and signal constellation scatter plots** — for a qualitative, visual understanding of system behavior that enables you to make initial design decisions

**Signal trajectory plots** — for a continuous picture of the signal’s trajectory between decision points

**BER plots** — for visualizing quantitative BER performance of a design candidate, parameterized by metrics such as SNR and fixed-point word size

**Analog and Digital Modulation**

Analog and digital modulation strategies encode the facts circulation into a sign this is appropriate for transmission. Communications System Toolbox presents some of modulation and corresponding demodulation abilities. These talents are available as MATLAB features and gadgets, MATLAB System Modulation sorts provided by the toolbox are:

**Source and Channel Coding**

Communications System Toolbox affords source and channel coding talents that can help you develop and compare communications architectures fast, enabling you to discover what-if eventualities and avoid the need to create coding competencies from scratch.

**Source Coding**

Source coding, also referred to as quantization or signal formatting, is a manner of processing facts a good way to lessen redundancy or prepare it for later processing. The system toolbox offers a diffusion of styles of algorithms for imposing source coding and interpreting, inclusive of:

▪ Quantizing

▪ Companding (*µ*-law and A-law)

▪ Differential pulse code modulation (DPCM)

▪ Huffman coding

▪ Arithmetic coding

**Channel Coding**

▪ orthogonal area-time block code (OSTBC) (encoder and decoder for MIMO channels)

▪ Turbo encoder and decoder examples

The gadget toolbox offers application functions for developing your personal channel coding. You can create generator polynomials and coefficients and syndrome deciphering tables, in addition to product parity-take a look at and generator matrices.

The system toolbox additionally presents block and convolutional interleaving and deinters leaving functions to reduce facts errors as a result of burst mistakes in a conversation machine:

**Block,** including General block interleaver, algebraic interleaver, helical scan interleaver, matrix interleaver, and random interleaver.

**Convolutional,** including General multiplexed interleaver, convolutional interleaver, and helical interleaver

**Channel Modeling and RF Impairments**

Channel Modeling

Communications System Toolbox provides algorithms and tools for modeling noise, fading, interference, and different distortions which might be commonly found in communications channels. The system toolbox supports the subsequent styles of channels:

▪ Additive white Gaussian noise (AWGN)

▪ Multiple-enter multiple-output (MIMO) fading

▪ Single-enter single-output (SISO), Rayleigh, and Rician fading

▪ Binary symmetric

A MATLAB channel object provides a concise, configurable implementation of channel models, enabling you to

specify parameters such as:

▪ Path delays

▪ Average path gains

▪ Maximum Doppler shifts

▪ K-Factor for Rician fading channels

▪ Doppler spectrum parameters

For MIMO systems, the MATLAB MIMO channel object expands these parameters to also include:

▪ Number of transmit antennas (up to 8)

▪ Number of receive antennas (up to 8)

▪ Transmit correlation matrix

▪ Receive correlation matrix

To combat the effects noise and channel corruption, the system toolbox provides block and convolutional coding and decoding techniques to implement error detection and correction. For simple error detection with no inherent correction, a cyclic redundancy check capability is also available. Channel coding capabilities provided by the system toolbox include:

▪ BCH encoder and decoder

▪ Reed-Solomon encoder and decoder

▪ LDPC encoder and decoder

▪ Convolutional encoder and Viterbi decoder

****

**RF Impairments**

To model the effects of a non-ideal RF front end, you can introduce the following impairments into your communications system, enabling you to explore and characterize performance with real-world effects:

▪ Memory less nonlinearity

▪ Phase and frequency offset

▪ Phase noise

▪ Thermal noise

You can include more complex RF impairments and RF circuit models in your design using SimRF™.

****

**Equalization and Synchronization**

Communications System Toolbox lets you discover equalization and synchronization strategies. These techniques are usually adaptive in nature and tough to design and symbolize. The machine toolbox affords algorithms and tools that will let you swiftly select the proper approach on your communications machine. Equalization To compare one-of-a-kind techniques to equalization, the device toolbox offers you with adaptive algorithms which include:

▪ LMS

▪ Normalized LMS

▪ Variable step LMS

▪ Signed LMS

▪ MLSE (Viterbi)

▪ RLS

▪ CMA

These adaptive equalizers are available as nonlinear decision feedback equalizer (DFE) implementations and as

Linear (symbol or fractionally spaced) equalizer implementations.

**Synchronization**

The device toolbox provides algorithms for each service segment synchronization and timing phase synchronization. For timing section synchronization, the machine toolbox presents a MATLAB Timing Phase Synchronizer object that offers the following implementation techniques:

▪ Early-late gate timing method

▪ Gardner’s method

▪ Fourth-order nonlinearity method

**Stream Processing in MATLAB and Simulink**

Most verbal exchange structures cope with streaming and frame-primarily based statistics using a aggregate of temporal processing and simultaneous multi frequency and multichannel processing. This form of streaming multidimensional processing can be visible in superior communication architectures consisting of OFDM and MIMO. Communications System Toolbox enables the simulation of advanced communications structures via helping move processing and frame-based simulation in MATLAB and Simulink. In MATLAB, circulate processing is enabled by way of System items™, which use MATLAB objects to symbolize time-based and facts-driven algorithms, sources, and sinks. System objects implicitly manipulate many information of flow processing, including information indexing, buffering, and management of set of rules state. You can mix System gadgets with fashionable MATLAB functions and operators. Most System items have a corresponding Simulink block with the identical abilities. Simulink handles circulation processing implicitly with the aid of coping with the float of information thru the blocks that make up a Simulink model. Simulink is an interactive graphical environment for modeling and simulating dynamic systems that uses hierarchical diagrams to symbolize a machine version. It includes a library of widespread-reason, predefined blocks to represent algorithms, resources, sinks, and device hierarchy.

**Implementing a Communications System**

Fixed-Point Modeling Many communications systems use hardware that requires a fixed-point representation of your design.

Communications System Toolbox supports fixed-point modeling in all relevant blocks and System objects™ with tools that help you configure fixed-point attributes.

Fixed-point support in the system toolbox includes:

▪ Word sizes from 1 to 128 bits

▪ Arbitrary binary-point placement

▪ Overflow handling methods (wrap or saturation)

▪ Rounding methods: ceiling, convergent, floor, nearest, round, simplest, and zero

Fixed-Point Tool in Simulink Fixed Point™ facilitates the conversion of floating-point data types to fixed point. For configuration of fixed-point properties, the tool tracks overflows and maxima and minima.

**Code Generation**

Once you've got advanced your set of rules or communications device, you can robotically generate C code from it for verification, rapid prototyping, and implementation. Most System gadgets, functions, and blocks in Communications System Toolbox can generate ANSI/ISO C code the use of MATLAB Coder™, Simulink Coder™, or Embedded Coder™. A subset of System gadgets and Simulink blocks also can generate HDL code. To leverage present highbrow belongings, you can choose optimizations for specific processor architectures and integrate legacy C code with the generated code.

You can also generate C code for both floating-point and fixed-point data types.

DSP Proto typing DSPs are used in communication system implementation for verification, rapid prototyping, or final hardware implementation. Using the processor-in-the-loop (PIL) simulation capability found in Embedded Coder, you can verify generated source code and compiled code by running your algorithm’s implementation code on a target processor. FPGA Prototyping

FPGAs are used in communication systems for implementing high-speed signal processing algorithms. Using the FPGA-in-the-loop (FIL) capability found in HDL Verifier™, you can test RTL code in real hardware for any existing HDL code, either manually written or automatically generated HDL code.

**CHAPTER -8**

**HARDWARE & SOFTWARE REQUIREMENTS:**

**Software:**

• Matlab R2018a.

**Hardware:**

**Operating Systems:**

• Windows 10

• Windows 7 Service Pack 1

• Windows Server 2019

• Windows Server 2016

**Processors:**

Minimum: Any Intel or AMD x86-64 processor

Recommended: Any Intel or AMD x86-64 processor with four logical cores and AVX2 instruction set support

**Disk:**

Minimum: 2.9 GB of HDD space for MATLAB only, 5-8 GB for a typical installation

Recommended: An SSD is recommended a full installation of all Math Works products may take up to 29 GB of disk space

**RAM:**

Minimum: 4 GB

Recommended: 8

**CHAPTER-10**

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