ENERGY EFFICIENT CLUSTERING ALGORITHM FOR WIRELESS SENSOR NETWORK

Dissertation submitted in fulfilment of the requirements for the Degree of

MASTER OF TECHNOLOGY

in

INFORMATION TECHNOLOGY

By

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ABSTRACT

Wireless sensor network is a network formed by the sensor nodes that are deployed either in random or pre-planned way. Sensor nodes gather the data and route the data to the base station. Nodes can communicate to its nearby nodes only. Human administrators controlling the sensor network send orders and get reactions through the base station. In case any failure occurs within the network, the nodes are themselves responsible for the mishappening and require solving the issues by themselves using the protocols provided for the sensor network. Sensor nodes are small in size so the battery size is also small that can provide limited energy and power to the nodes. Sensor nodes utilize high amount of energy in sensing the environmental activities and communicating with other nodes in the network that effects the network lifetime. The lifetime of the network can be increased by using various protocols that provide numerous techniques for conserving the remaining energy of the sensor nodes. For this purpose clustering technique is considered to be as the most efficient out of other proposed techniques. Clustering divides the large network into small clusters where each cluster has its own cluster head. These cluster heads use TDMA method for providing time slots to each node to monitor the surroundings and remain inactive otherwise hence resulting in monitored energy utilization of nodes that helps the network to provide services for longer period of time.

DECLARATION STATEMENT

I hereby declare that the research work reported in the dissertation/dissertation proposal entitled "ENERGY EFFICIENT CLUSTERING ALGORITHM FOR WIRELESS SENSOR NETWORKS" in partial fulfilment of the requirement for the award of Degree for Master of Technology in Information Technology at Lovely Professional University, Phagwara, Punjab is an authentic work carried out under supervision of my research supervisor Mr. Arvind Kumar. I have not submitted this work elsewhere for any degree or diploma.

I understand that the work presented herewith is in direct compliance with Lovely Professional University's Policy on plagiarism, intellectual property rights, and highest standards of moral and ethical conduct. Therefore, to the best of my knowledge, the content of this dissertation represents authentic and honest research effort conducted, in its entirety, by me. I am fully responsible for the contents of my dissertation work.

Signature of Candidate

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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the M.Tech Dissertation/dissertation proposal entitled "**ENERGY EFFICIENT CLUSTERING ALGORITHM FOR WIRELESS SENSOR NETWORKS"**, submitted by **Puneet** at **Lovely Professional University, Phagwara, India** is a bonafide record of her original work carried out under my supervision. This work has not been submitted elsewhere for any other degree.

Signature of Supervisor

(Name of Supervisor)

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1) **Concerned HOD:**

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2) **Neutral Examiners:**

   External Examiner

   Signature: _____

   Name: _____

   Affiliation: _____

   Date: _____

   Internal Examiner

   Signature: _____

   Name: _____

   Date: _____

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Puneet

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CHAPTER 1

INTRODUCTION

1.1 Wireless Sensor Networks

Wireless Sensor Networks consists of nodes that have limited energy and memory and are helpful in monitoring the far located areas that are out of human reach. Network formed is distributed over a large area to monitor the surroundings for pressure, sound and temperature conditions and to cooperatively pass their data through the network to other locations. Moving back with time in 1970s' the time for first generation of sensor networks, a hierarchical structure is used to obtain a single signal and a point-to-point communication between the sensor nodes. The second generation of WSN has limited power sensor nodes operating independently then cooperating and transforming information to the network nodes for processing. Later in 1990s, the third generations of sensor networks used the bus connection method and sensor controller that collects variety of data resources. An advancement of self organizing capability and use of multiple hops for data transmission was achieved in the fourth generations of sensor networks [16]. Homogeneity of nodes, scalability of network, ability to withstand harsh environmental conditions and to cope with node failures are some of the characteristics that keeps the sensor network technology over all the other technologies. Sensor nodes communicate among themselves using radio signals, and are deployed to sense, monitor and understand the physical world. Once the nodes are deployed they provide services for longer period of time without the need of changing or recharging them. These nodes work in a collaborative manner to gather the information from the surroundings and transmit it to the base station on repetition basis until they die.

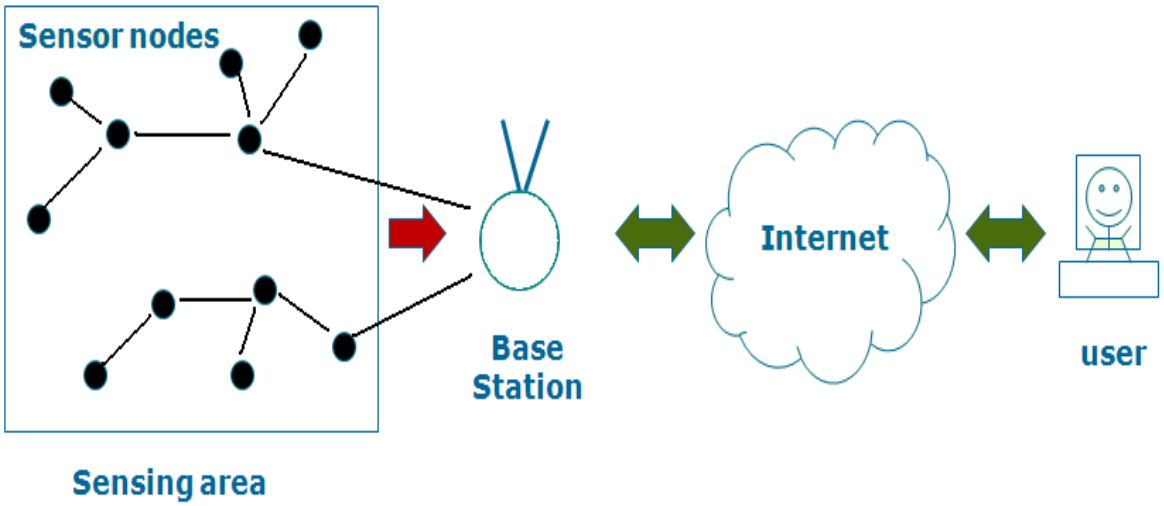

Fig 1. Sensor network general layout

As appeared in Fig1., a remote sensor network has been formed inside a geological range (called sensing area appeared as a rectangle outskirt), where there are some physical activities to be measured. Sensor nodes (appeared as dark spots) are disseminated inside the detecting range keeping in mind the end goal to accomplish the detecting successfully and precisely. At the point when sensor nodes get information from detecting their separate regions, they send the information consistently or intermittently to the base station (appeared as circle with antenna) straight forwardly or following a suitable directing way (appeared as solid lines). A base station, with respect to the next hand, is in charge of preparing, analyzing and extricating important data from the gathered information to give a whole perspective of the detecting region being distinguished. Sink nodes and Sensor nodes essentially two parts in the framework of a remote sensor network. Sink nodes are considered as base stations in the system that remotely gather information from all the sensor nodes in the system and give them to clients. From the base station clients can get the information, conceivably through web, for additionally preparing of the information and to separate helpful data [17].

1.2 Network Components

Sensor network components enable the wireless connectivity of the nodes within a network, connects an application platform from one end of network with the sensors in any part of the network. A wireless relay node can be added in between leaf node and gateway to extend the network range [18].

Gateway: An interface between the application platform and the network nodes. Information received from nodes is aggregated at gateway and forwarded to the application platform running on networked computer. In reverse, when application program issues a command for wireless node, the gateway relays that information to the sensor network. All gateways enable the sensor networks to work with non-standard network protocols by performing protocol conversion.

Relay Node: Intermediate nodes are the fully functional devices between sender node and the sink node that works as a router in the network are considered as relay nodes. These intermediate nodes are used for providing the backup routes in case of node failure or congestion conditions and also helpful in extending the network area. This node needs to remain active and listen to the nodes as it needs to route the data of its child nodes along with sensing of its own data and then forward it towards its parent.

Leaf Node: Endpoint of the network consists of the devices or nodes with reduced functioning or the limited tasks to perform are the leaf nodes of the network. Opposite to intermediate node a leaf node can remain active only to sense the surroundings periodically and then move to sleep state after sending the data gathered towards the parent node.

Sensor/Actuator: Sensor device or actuator is the main part of a network that interacts with the physical world and collects the information required by the user for monitoring or analyzing the surroundings. Sensors are of various types that can monitor temperature, pressure, humidity, sound etc and provide various applications in different fields. A sensor node in itself is an autonomous system with main components as microcontroller, transceiver, external memory, power source. Each of them is discussed below [10].

1.3 Sensor Node Components

A sensor node, otherwise called a mote, is equipped for preparing, gathering tactile data and speaking with other associated nodes in the system. A bit is a hub however a hub isn't generally a bit [11]. A sensor hub is comprised of four fundamental segments as appeared in Fig. 2: a sensing unit, a processing unit, a transceiver, and a power unit. The sensing unit additionally has two segments: at least one sensor and an analog-to-digital converter (ADC) [12]. The processor/processing unit generally comprises of a microcontroller or chip with memory which gives clever control to the sensor node. The resultant information from a processing unit is stored into the nearby memory and then comes the turn for a sensor node to transmit it. A transceiver unit interfaces the node to network. The power unit comprises of a battery for providing energy to drive every single other part in the framework. Moreover, a sensor node can likewise be furnished with some different units, contingent upon particular applications. For instance, a global positioning system (GPS) might be required in a few applications that require location data for network operation. An engine might be expected to move sensor nodes in some detecting tasks. All units ought to be incorporated with a little module with low power utilization and low creation cost which, thus, is additionally prepared by a processing unit.

Controller: The task of the controller is to process the data and have a control over node components. While the most widely recognized controller is a microcontroller, different choices that can be utilized as a controller seem to be: a general purpose desktop microprocessor, digital signal processors, Field-Programmable Gate Array (FPGA) and (ASIC) Application Specific Integrated Circuit. A microcontroller has priority over the other indicated controllers due to its attributes like minimal effort, adaptability, simplicity of programming and less power utilization contrasted with the others. Microprocessor consumes more power than microcontroller hence making it less suitable for sensor nodes. Time and energy consumption in FPGAs is also high than microcontroller in performing the configuration and programming related tasks. DSPs features are of less importance to sensor networks as the data sensing task is less complicated.

ADC: Subsequent to detecting the physical phenomenon, the raw information produced by a sensing unit is in analogous form which isn't human readable; in this way, an analog-to-digital convertor (ADC) is regularly required to change the simple information into computerized form.

The ADCs change over the analog signals into digital format, which are then passed to the processing unit.

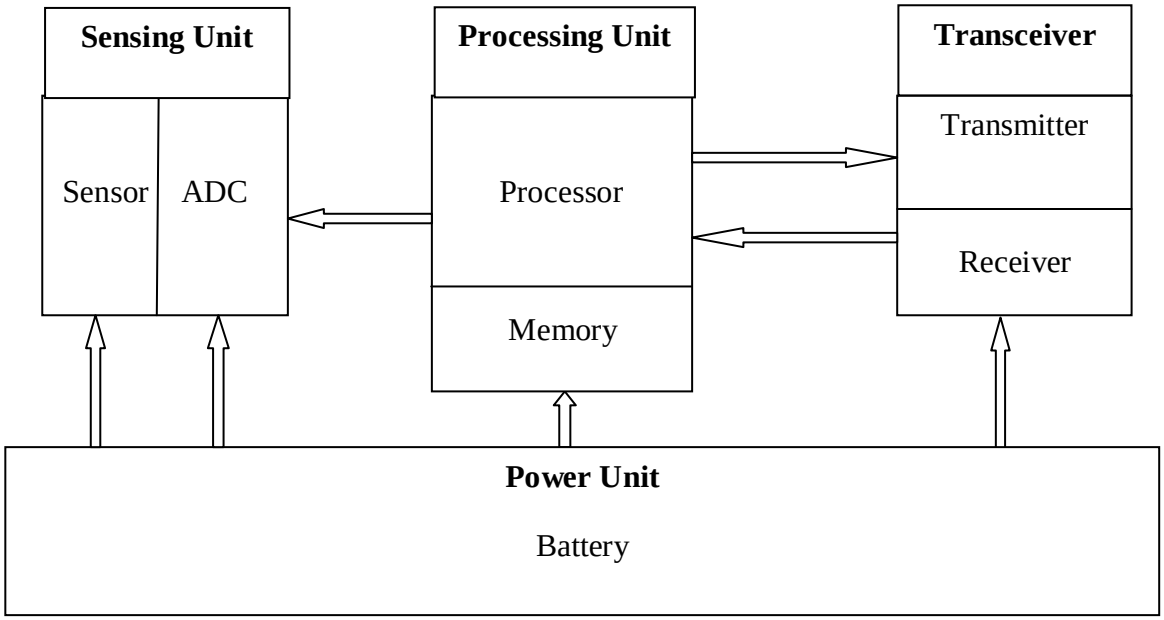

Fig 2. Components of a Sensor Node

Transceiver: Transceiver is a combination of both transmitters and a receiver. An electronic switch prevents transmitter output from damaging the receiver and connects the transmitter and receiver to the antenna. Some transceivers work in full duplex mode while the others work in half duplex means while transmitting the signal cannot be received that is possible in full duplex because of the use of different frequencies for sending and receiving the signal. Instead of the radio frequencies the optical communication like laser as well as the infrared transmission medium can also be used but both have some limitations like lasers require line-of-sight and infrared has limited broadcasting capacity making the radio frequencies to be optimal to be used as a transceiver. Transceivers have in-built state machines with states categorized as active, transmit, receive, idle and sleep state. These transceivers help the nodes to build the system lifetime by bringing down the energy utilization by the nodes by switching idle nodes to slwwp state.

External memory: Magnetic disks, tapes or flash memory are mainly used as a secondary memory. For sensor nodes flash memories are mainly used because of their low cost and high storage capacity. The data collected by the sensors is used for analysis purpose but the nodes sometimes contain user specific data also. So based on these two types of data the memory unit can have user memory that stores application related and user related data and programming memory is used for the programming purpose and contains identification data

Power source: Wireless Sensor Network is located in the areas that are out of human reach and it is not easy for human to visit the network nodes and check for the remaining energy of each node and manually replace the energy deficient nodes with power source. For continuous working of sensor nodes there should be sufficient energy available with the nodes. Nodes perform the task of sensing communicating and data processing results in continuous energy usage. Rechargeable or non-rechargeable power sources like batteries or capacitors are used for power supply. Sensors can use the temperature differences, solar sources or pressure and vibration for recharging the batteries. Switching between the states in transceivers from active to sleep state helps the sensor node to save the energy and use it later in active state only. Sensor nodes, because of their small size are equipped with limited power only that is less than 0.5-2.0 amp-h and 1.2-3.7 V.

Sensors: Sensors, main part of the sensing unit that are deployed randomly in some distant area for sensing the environment and gathering information from the surroundings. Sensor nodes generate the information that can easily be understood by human and any of the change can easily be analyzed using the data gathered by the sensor nodes from various locations. Small sized sensor nodes consume less energy even operating in high volumetric densities. Sensors can be categorized as active and passive sensors. Passive sensors can further be categorized as narrow beam and omni directional sensors with one have a notion of direction and the other without the notion of direction.

1.4 Wireless Sensor Network Models

Sensor networks, as per their inner architecture, can be ordered into two classes: flat sensor networks and hierarchical sensor networks [20].

1.4.1 Flat Sensor Network

In a flat sensor network in fig. 3, only two types of nodes are used, a sink node and multiple sensor nodes. All nodes are given a same task of sensing the surroundings and transmit the data towards the sink node using the relaying technique. No special relaying nodes are inserted in the network for performing the routing of data towards sink node. Each node acts as both a sensing node and a relaying node.

1.4.2 Hierarchical Sensor Network

A hierarchical sensor network consists of various types of nodes each are assigned with different tasks. HSN consists of a Sink node and sensor nodes that performs sensing and routing tasks separately. Network forms two-tier models where sensor nodes performing the sensing task lie in the lower tier. These nodes grouped together to form clusters and out of these clusters a cluster

head is assigned. Each sensor node can become a part of a single cluster only and lie range of a single cluster head. Cluster head communicates to the nodes in its cluster with a single hop only.

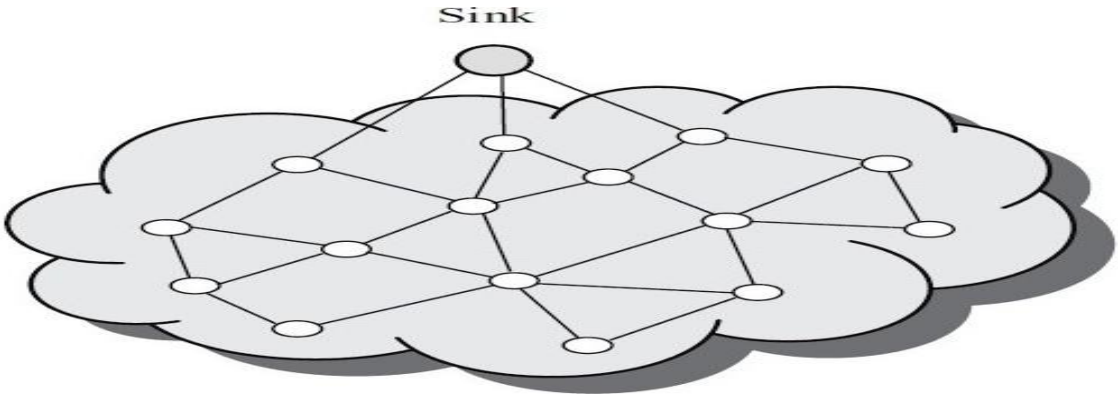

Fig 3. Flat Network Architecture

Cluster heads, the part of the upper tier of network collects the data from the nodes in their clusters and sends towards the base station by forming the network with other cluster heads. Energy conservation, load balancing, data aggregation and intercommunication are the advantages of using HSNs instead of FSNs.

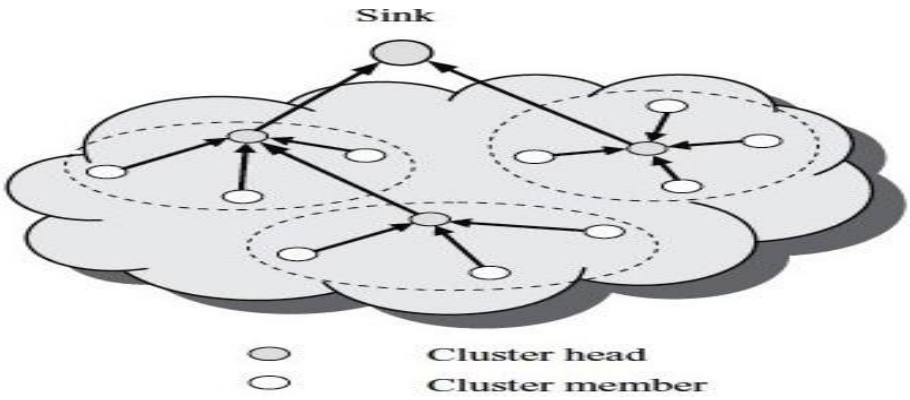

Fig 4. Single - hop Clustering Architecture

1.5 Design Objectives

The attributes of sensor network and prerequisites of various applications decisively affect the network design objectives as far as network capacities and network execution. The primary objectives for sensor systems incorporate the following several aspects [21]:

• **Scalability:** Scalability refers to as the ability of any network to change the size as per the requirements. Sensor network should be scalable so that any number of nodes can be added or removed from the network whenever required. The network protocol design should be adaptive to these topological changes.

• **Reliability:** Reliability is the ability of network to consistently perform the task given to each node in the network without any failure. Wireless sensor network should be providing reliable services even in the opposite conditions. For this the protocols must provide error control and correction mechanism and ensure the reliable delivery of data

• **Low Power Consumption:** Wireless sensor network is an autonomous system that performs its task without being connected to any external power source. So the sensor nodes must ensure less power consumption for the sensing and communication tasks. The network lifetime is dependent on the lifetime of the nodes. If nodes remain alive for longer period of time only then the network can provide services else it will be of no use. So the protocols should be able to provide increased network lifetime.

• **Security:** Sensor networks provide applications in various areas where the data collected by the sensor nodes is of high value to the particular individual or organization. For example in military grounds or various health regarding applications, the sensed data is confidential for a specific authority and cannot be shared. So the sensor network should introduce effective security mechanisms to provide high security to the data.

• **Self – Configurability:** Sensor networks are deployed in an unattended environment where human reach turns out to be costly. So in case if any node failure occurs or any node get disconnected from the network because of its power, in such cases it is not possible for human to check the network and change the damaged nodes. So nodes should be able to configure themselves without knowing about the topology change in advance [25].

• **QoS Support:** For various applications that wireless sensor networks provide, different levels of quality of service is a demand. QoS can vary because of the limited energy and memory availability in the sensor nodes. So the network routing protocols are expected to provide better quality of services as per the applications they are being used for because some applications demand fast delivery but quality is not a concern and others can incur delay but reliable delivery of data .

• **Low Node Cost:** Sensor network is made of small independent nodes deployed randomly or in a preplanned manner in a large number so that huge area can be covered. Individual node cost decides the cost of the complete network. The nodes should be of low cost so that they can be deployed over a huge area with minimum network cost.

1.6 WSN TYPES

Depending on the location and environment the wireless sensor network types are as follows that gives an idea of where the network is established and what type of applications it can provide.

- Terrestrial WSNs
- Underwater WSNs
- Underground WSNs
- Mobile WSNs
- Multimedia WSNs

Terrestrial WSNs: Designed to operate on the land. In a region either on plains, desserts or mountains where human reach results out to be costly a network is deployed to collect data about the changes happening in the surroundings. These sensor nodes can be deployed either randomly or in a systematic manner. The energy issues the nodes charge themselves by the temperature differences, solar sources or pressure and earth vibrations. Structured network formation is done using the grid or the 2D and 3D placement models. Application areas of terrestrial WSNs include environment sensing and monitoring, industrial monitoring and surface explorations.

Underground WSNs: Costs more than the terrestrial WSNs in terms of equipment cost, under water deployment and maintenance. As in terrestrial network the nodes can be deployed randomly in a specific area but in underground network the nodes location is preplanned. Main focus is on the locations from where nodes can provide services for longer period of time regarding various underground activities. Instead of the nodes that are deployed underground some relay nodes also deployed over the ground that act as relay nodes and transfer the data gathered from the network nodes to the user for analyzing purpose. In the underground networks, because of the weak signal strength at locations where as no signal at others, data loss is a major challenge.

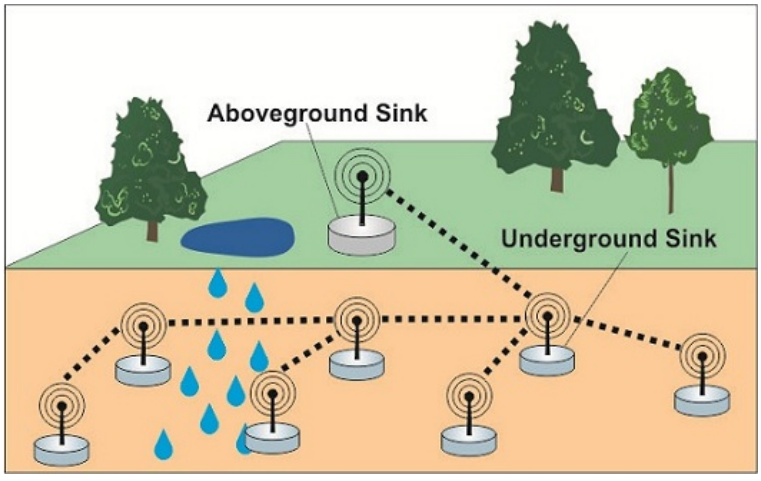

Fig 5. Underground deployment of sensor network

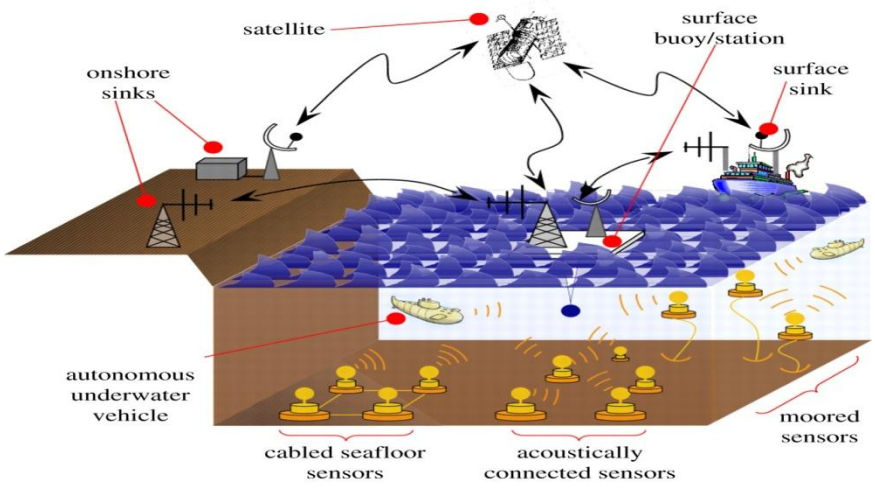

Fig 6. Underwater sensor network deployment

Underwater WSNs: Earth comprises of 70% of water and just 30% of land. Applications of underwater sensing include prediction of normal unsettling influences, inquiry and survey missions and marine life examine. From the sensor nodes the autonomous vehicles accumulates the information. Cabled sea observatories are based on submarine links to convey a broad fiber-optic system of sensors (cameras, wave sensors and seismometers) covering miles of sea depths. Underwater communication systems use acoustics technology results in communication channel of low quality and high inertness [27].

Multimedia WSNs: Network of remotely interconnected sensor nodes outfitted with media devices fit for recovering sound, video, pictures and etc. The primary parts are correlative metal-oxide semiconductors (CMOS) cameras and microphones. Real application areas are the military grounds. MSNs have capability of improving the level of data gathered, extending the area of scope and empowering the multi-determination views [29].

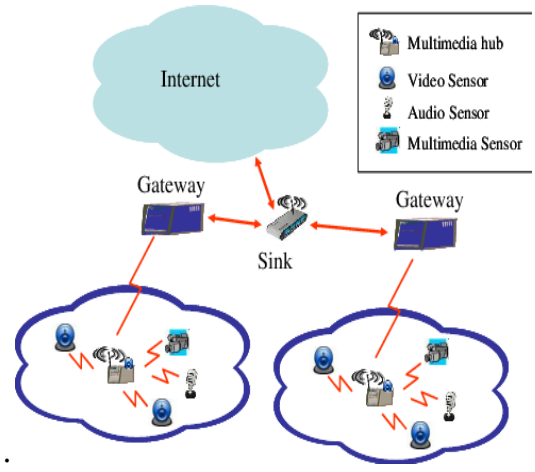

Fig 7. Multimedia wireless sensor network

Mobile WSNs: Instead of the sensor networks deployed either under or over the earth surface or under water networks, mobile WSNs have the nodes that can move by their own. Mobility can enhance the flexibility and capacity of a static network. Mobile sensor networks are substantially more flexible than the static sensor networks. Node movement is directed by the external forces over which they are deployed. Mobile nodes are allowed to move only within the sensing region that results in maximum network area coverage. In normal sensor networks the nodes near the sink lose their energy fast as compared to the nodes located at distance from sink node or the leaf nodes but when the nodes are mobile they are capable to change their location and move away from the gateway if their energy falls [28].

Wireless sensor networks instead of classification on the basis of location where the sensor networks to be deployed can also be differentiated on the basis of physical measurement devices into temperature sensors, pressure sensors, current sensors, humidity sensors, light sensors and chemical sensors [30].

Temperature sensors: temperature measurement and control units are most common devices found commonly in home heating systems, refrigerators, air conditioners and ovens. Most common temperature sensors are resistance-temperature detectors (RTDs), thermistors and thermo couples out of these thermocouples are the sensors of most common type because of their wide temperature range (up to 760^{o}C), less cost and robustness. They use two wires made of different metals joined at the point of measurement. Because of the different metals the voltages generated will be different that represents the temperature. On the other hand RTDs have, as compared to the thermocouples, less temperature range but provide better accuracy than thermocouples. Application areas of RTDs are regulated industries such as food processing industries, with less temperature ranges but require most accuracy. For the areas where highest resolution is required but with least temperature range, thermistors are used such as in medical devices and home thermostats.

Pressure sensors: Modern and assembling frameworks depend intensely on the pressure sensors. These are for the most part used to gauge air, gas or liquid weight and are planned utilizing piezoelectric or quartz sensors. Pressure sensor usually acts as a transducer that converts energy from one form to another. A pressure switch is an example of pressure sensor, with an application in water pump, which turns on and off at specific pressure. Pressure sensors have various types such as: absolute pressure sensor, vacuum pressure sensor, sealed pressure sensor and differential pressure sensor. Leak testing, flow sensing, length/depth sensing, altitude sensing are some of the application areas where pressure sensors are used.

Current sensors: A device that detects the electric current in a wire and generates a signal proportional to the current. In its most basic forms a current sensor is basically a resistor. Sensors are placed in a circuit and the voltages are measured across the resistors for the calculation of current. Current sensors designed on a principle which states that from a circuit when current is passed, the voltage across that path decreases and a magnetic field is generated near the

conductor. Current sensing devices follow direct and indirect way of sensing the current where the former one uses ohm's law and the latter follow ampere and faraday's law for sensing.

Humidity sensor: Humidity is the amount of water vapor in the given substance thus the sensors provide an indication of the moisture levels in the surroundings. It can be measured as absolute, relative and dew or frost point humidity. For measuring the water vapors in environment hygrometer is used. Bulb hygrometer, dew point and electronic hygrometer are the humidity sensors that are mostly used. Capacitive, resistive and thermal are the three basic types of humidity sensors. Capacitive sensors use metal oxide strip and electrodes and measure relative humidity. Resistive sensors use salt ions and with the change in humidity the electrodes resistance also changes. In thermal humidity sensors the difference between the readings of two sensors gives a measure to the humidity. Out of the two sensors one is placed in dry nitrogen and the other is in near surroundings.

Light sensor: light sensors are used by the robots to detect the light level in the near surroundings. Different types of light sensors are photoresistors, photodiodes and phototransistors. Phototransistor uses light levels to determine the amount of current that can pass through the circuit. Dark light allows small amount whereas bright light allows larger amount of current to pass through the circuit. Photoresistor is similar to phototransistor but the former changes its resistance according to the amount of light that falls upon it. Photodiode generates electric current when light falls on it.

Chemical sensor: Detect the presence or concentration of particular chemical elements usually contains chemically sensitive film and a transducer. Chemical sensors transforms chemical information originates from chemical reaction into signals. Basic functional units are receptor and transducer part. In former part the chemical information is transformed into energy form where in latter part an analytical signal is generated from that information. Examples of the chemical sensors that are in use include their applications as carbon monoxide detector, glucose detector and pregnancy tests. Sensors are classified according to the method they use for measuring the effect [31].

1.7 Applications of Wireless Sensor Network

As the deployed network is out of human reach the nodes are themselves responsible for the amount of energy they use in sensing and delivering the information to the base station. Network formed with these sensors have an awesome potential for long term applications and furthermore can change human lives in different viewpoints. These small, limited energy motes provide applications in industry, science, civil infrastructure, and security such as Environment monitoring, military applications, Health related and Home network applications, biomedical, event detection, forest fire, vehicular telemetric, highway monitoring and smart parking etc. There are numerous applications of Wireless sensor networks which have increased considerable

fame because of their flexibility in taking care of issues in different application areas [12] Such as:-

Military Applications: Since most of the basic learning of sensor systems is major on the security application toward the beginning, particularly two essential activities the DSN and the Sensor Information Technology (SenIT) structure the Defense Advanced Research Project Agency (DARPA), sensor systems are adequately related in the military detecting. Today remote sensor organize are more basic for military order, observation, control, perception, correspondences, enrolling, understanding and concentrating on systems. WSN is also a bit of military applications. In the battle zone setting, quick sending, self-affiliation, adaptation to internal failure security of the system should be required. The sensor gadgets or nodes should give taking after administrations [26]:

- Monitoring well disposed powers, gear and ammo.
- Battlefield reconnaissance.
- Reconnaissance of restricting powers.
- Targeting.
- Battle damage evaluation.
- Nuclear, natural and substance assault identification observation.

Health applications: These days sensor networks are moreover used as a part of medicinal services area. In specialist's office sensor networks are used to screen quiet physiological information, to control the medication organization track and monitor patients and specialists and inside a healing office. In spring 2004 some specialist's office in Taiwan even use RFID basic of above named applications to get the circumstance at direct. Long-term nursing home: this application is focus on nursing of old people. In the town ranch cameras, pressure sensors, introduction sensors and sensors for recognition of muscle development build an intricate network. Sensors reinforce fall detection, unconsciousness, urgent sign checking and dietary/exercise observing. These applications lessen personnel cost and quick the response of rise circumstance.

Home Application: Today with creating business utilization of sensor network, it is not much difficult to picture that home application will advance into our typical life later on. When you are back at home, door sensors detects your presence, the door will automatically open and later on closes automatically after you enter inside your home. The tube light, air conditioner, fan, switches will automatically be turned on of the room in which you are sitting. When you sit on sofa, under the cushion sensors detect your weight and on the table light and turned on TV. One sensor has checked that you are sitting before it. As the temperature of the room increases the sensors detect your body temperature and lowers down the temperature of air conditioner. The sensors in the room can gauge the room temperature. Nevertheless, it can just get the temperature at the edge of the machine not the genuine temperature in the room. So the sensors in the room will perceive the earth. The cool will swing to rest mode until the point when each one of the

sensors get the correct temperature. The light on the lobby, in the washing man of the hour and overhang are altogether presented with sensor and they can be turned on or turn out naturally. In fact, even the matrons are moreover annexed with vibratory sensors associated with police to against cheat. You get to be medical attendant and bodyguard at the same time.

Environmental Applications: Sensor nodes are deployed either in the environment or in the near surroundings of the area that is to be monitored [23]. Sometimes the areas are out of human reach therefore, they usually work unattended in remote geographic areas. Today a sensor networks are additionally connected in environmental applications like natural surroundings monitoring, agriculture research, fire detection and traffic control. By utilizing sensor network as a part of environmental area, there is no interruption to the environment sensor networks is not strict as in front line. Sensors are working in busy intersections such as:

- In the inside of extensive apparatus,
- At the base of a sea,
- On the surface of a sea amid a tornado,
- In a home or an extensive building,
- In a vast distribution center,
- Attached to creatures or quick moving vehicles,
- An a deplete or waterway moving with momentum,
- In a naturally or artificially sullied field,
- In a combat zone past the foe lines

These points give us a thought regarding under which conditions sensor nodes are relied upon to work. They work under high weight in the base of a sea, in harsh situations, for example, debris or a war zone, under outrageous warmth and cold, for example, in the spout of an aircraft machine motor or in ice locales, and in extreme loud condition, for example, under purposeful sticking. A distributed wireless sensor network system can be installed to control the air flow and temperature in different parts of the room.

Other miscellaneous applications

Interactive museums: In future, kids will have the capacity to associate with objects in museums to take in more about them. These items will have the capacity to react to their touch and discourse. Likewise, youngsters can take part in real time cause-and-effect tests, which can show them about science and condition. Furthermore, the wireless sensor networks can give paging and localization inside the historical center [24].

Detecting and monitoring thefts: With the advancements in the use of sensor technology the thefts can easily be detected and it becomes easy to report the theft with the help of internet. An example for this is can be a highly used fuel theft sensors that generates an alert if fuel is taken out of the cars and it gives the exact reading of the quantity of fuel that is taken out.

Managing inventory control: Small sized sensor chips can be attached to the items placed in an inventory so that it becomes easy to manage the inventory and to track the number of items left in the inventory. End clients can track and find where the inventories are consistently. On inserting new items the chip needs to be attached that can be removed when the item moves out of the inventory.

Vehicle tracking and detection*:* Sensors are used to review, analyze and manage the traffic for any situation that affects the transportation. On the roads small sensors are deployed that interacts with the receiving sensor chips in the vehicles moving over the highways and give information if any road blockage or accident occurred.

1.8 Challenges in Wireless Sensor Network

Although WSN is featured with various advantageous characteristics, still it is shrouded with various issues that dampen the spirit of researchers [9]. Wireless sensor networks have various challenges that include:

Network lifetime: Network lifetime is the main challenge of the wireless sensor networks. Lifetime of sensor network depends upon the lifetime of individual nodes. If the nodes in the small portion of the network died it will affect the whole network. Lifetime of the node on which the network lifetime depends, further depends on the battery power. If a node remains active for a longer period of time its power will decrease very frequently thus lowering the node lifetime. Many protocols have been defined that allows the nodes to transmit and sense the data for a particular time period and then moves to sleep state in order to prevent unnecessary power consumption in data forwarding.

Limited battery supplies: Initially all the sensor nodes are deployed with equal amount of energy. Sensors utilize the battery power for sensing and data relaying tasks. Nodes that are deployed far away from the sink node or near the outside corners of the network area perform the sensing task only where as the nodes located near the sink face high power utilization because they act as relay nodes also so their energy depletes at a high rate.

Performance: Sensor nodes describe the performance of the network. In a few situations, sensor network frameworks are required to be profoundly delicate to the adjustment in some encompassing conditions (for instance, the temperature of the reactor in an atomic power plant) and require fast reaction to the occasions or wonder within the environment. Along these lines the affirmation of effective information conveyance and briskness of information handling and information transmission has a urgent impact in giving solid detecting administrations. Generally scientists take the transmission delay as an estimation to survey the execution and nature of administration of a sensor organize framework and consequently, to limit the transmission delay

and amplify the yield in vitality effective way is additionally an essential worry in the examination works [19].

Energy consumption: Sensor nodes which are located in particular region to perform any application of wireless sensor network must consume energy at same rate. In chance that the energy utilization rate ends up plainly unique, then any one of node depletes at quick rate and that particular node ends up and network will dead. To avoid this, energy consumption rate must be equivalent.

Node cost: Sensor network is formed by deploying numerous sensor nodes. It follows that the total network cost directly depends upon the cost of individual node that collectively forms a network. If the sensor node is of high cost it will increase the cost of the network and indirectly affect the size of the network. With high node cost sensors the network formed will be of small size hence covers less area and generate less amount of data that will not be helpful in generating useful outcomes. So the node cost should be kept at minimum so that more nodes can be deployed and huge network can be formed.

1.9 Routing types and Protocols

1.9.1 Routing Strategies

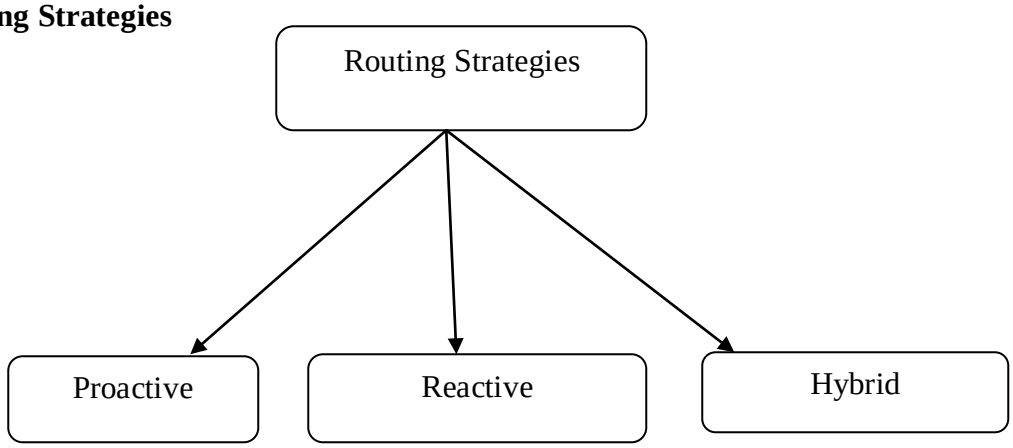

Fig 8. Routing strategies

Proactive: Periodic dissemination of information across sensor nodes. Routing paths and states are fixed before they are demanded by the routing traffic and are maintained even in no traffic conditions. This strategy does not require maintenance of costly routing information in sensor nodes.

Reactive: On demand routing path setup when the queries are initiated. Routing actions are performed only when there is availability of data that needs to be sent.

Hybrid: Both the proactive and reactive routing strategies are followed. For routing within a cluster hybrid strategy is used and the proactive technique is used for the data dissipation among the cluster heads.

1.9.2 Routing Protocols

In a sensor network sensor nodes deployed on the far away locations at some distance from each other, in a randomly distributed manner. Nodes sense the surroundings and generate the data that is routed towards the base station or the sink node so that it can be forwarded further for analysis purpose. For the routing of data from different nodes towards the sink node various routing models have been proposed. These models can be classified further depending on the network structure and protocol operation. Further the routing protocols can be divided into seven classes as shown:

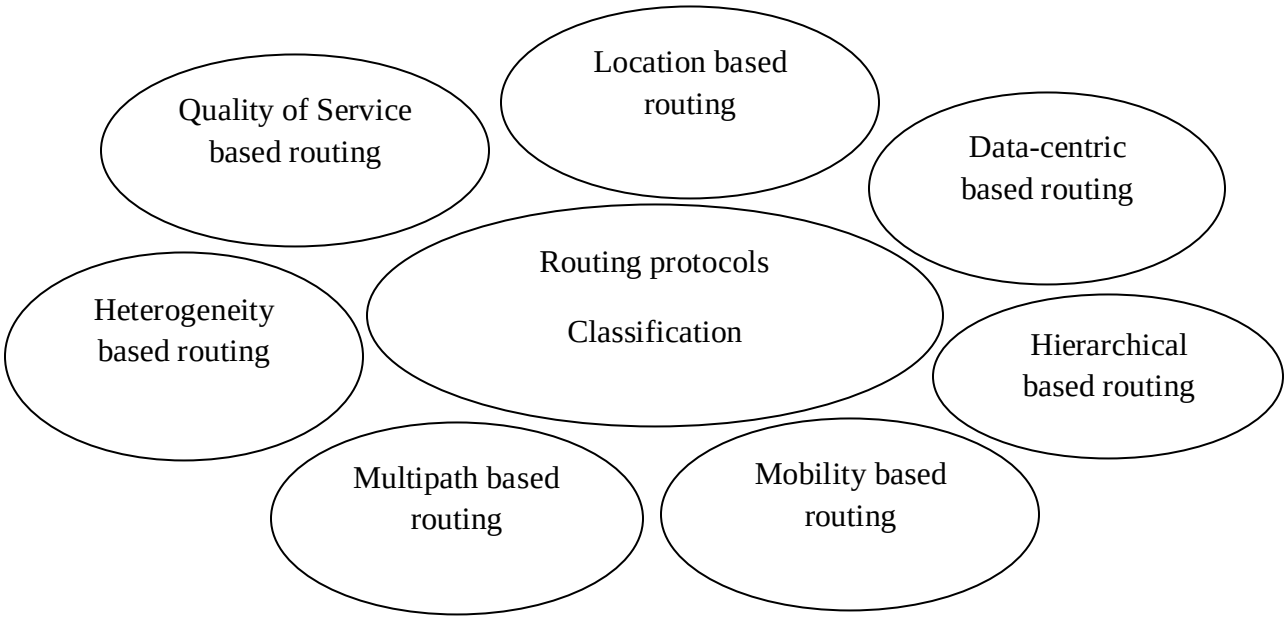

Fig 9. Routing protocols classification

Data and information from the distributed sensor nodes is aggregated at the base station or the sink node. For this purpose various routing protocols have been proposed in general [13]. SPIN (Sensor Protocols for Information via Negotiation), HEED (hybrid energy efficient distributed clustering), DD (directed diffusion), RR (rumor routing), GBR (gradient based routing), CADR (Constrained Anisotropic Diffusion Routing.), SAR (sequential assignment routing), LEACH [25,26] (low energy adaptive clustering hierarchy), PEGASIS [23] (power efficient gathering in sensor information system), GEAR (geographical and energy aware routing) are the names of some routing protocols [12] that varies in the techniques they follows and the services they provide. These protocols can be classified as node-centric or data-centric, whether reactive or proactive and source-initiated or destination-initiated. Out of all these protocols LEACH, HEED and PEGASIS are highly efficient protocols but because of the limitations of HEED and

PEGASIS LEACH is mainly considered as an effective protocol for sensor network as it works on the basis of cluster formation. LEACH is the first cluster based routing protocol that distributes the energy load evenly over the network in a randomized manner [10, 12, 13].

Protocols	**Classification**	**Power**	**Overhead**	**Scalability**	**Model for delivery of data**	**Qos**
SPIN	Flat/ query based/ source initiated/ data centric	Medium	Low	Medium	Event driven	No
HEED	Hierarchical	Medium	Low	High	Weight based	No
DD	Flat/ query based/destination initiated/ data centric	Medium	Low	Medium	Demand driven	No
RR	Flat/ query based	Low	Low	High	Demand driven	No
GBR	Flat/ query based	Low	Low	Medium	Hybrid	No
CADR	Flat/ query based	Medium	Low	Medium	Continuous	No
SAR	Data centric/ query based	High	High	Medium	Continuous	Yes
GEAR	Location based	Medium	Medium	Medium	Demand driven	No
LEACH	Hierarchical/ destination initiated/ node centric	High	High	High	Cluster head	No
PEGASIS	Hierarchical	High	Low	High	Chain based	No

Table 1. Routing protocols comparison

1.10 Low Energy Adaptive Cluster Hierarchy (LEACH)

LEACH [14] a CDMA and TDMA based routing MAC protocol for micro sensor networks which achieves energy efficient, scalable routing and fair media access for sensor nodes. Main aim is to improve the network lifespan by lowering the energy consumption of the sensor nodes. Leach protocol functions in two phases: Setup phase and Steady phase. In the setup phase the main task is cluster formation and head selection within the cluster. The head selection is based on various parameters such as remaining energy, mobility and the distance from base station. This phase further has three steps: advertisement, setup and election of cluster head. Leach works on rotational basis so the cluster head election is carried out in each round. In the three steps different messages are advertised by the nodes that shares the information of the sender node to the other nodes in the network. Each node selects a number between 0 and 1 which then compared with the threshold value T(n) eq.(1) [15].

$$T(n) = \frac{p}{1 - p\left(r \bmod \left(\frac{1}{p}\right)\right)} \quad if\ n \in G$$

- Where p: cluster head probability
- r: random number
- n: total number of nodes in the network
- T(n): threshold value
- G: set of nodes involved in CH election

If number selected is less compared to the T(n) the node becomes CH for that round. Once a node selected as a CH cannot become CH until all nodes in network got selected once. The selected CH advertises a message as a join request to neighboring nodes to become a part of its cluster. Then the CH creates a schedule for the nodes under its cluster on TDMA basis so that nodes remain in active state as per the scheduled time and remain in sleep state otherwise. Second phase of leach protocol is steady phase. In this phase the nodes senses and gather data from the surroundings and by a single hop transmit the data to the cluster head. The data is aggregated at the cluster heads and the nodes moves to sleep state. The gathered data is transmitted to the base station using inter or intra-cluster communication, if required else use the single hop to send the data to base station.

CHAPTER 2

REVIEW OF LITERATURE

Jianpo Li et al (2017) proposed the fuzzy power optimized clustering routing algorithm (FPCRA) [1]. FPCRA categorize the nodes according to node degree by optimizing the iteration radius before electing the cluster head to avoid the delay caused by excessive iteration. As a hierarchical routing process it works on round basis where each round has four stages: broadcast, cluster head election, cluster formation and data dissemination. For dynamically adjusting the power of cluster nodes, fuzzy control has been used during each stage of routing process. The proposed scheme is divided into four sub tasks i.e optimizing the broadcast power and iteration radius, cluster head election, check for uneven clusters formation and the applying the power optimal method. On comparison with predefined algorithms such as LEACH, LEACH-E and UCRA, FCA prolongs the network lifetime by 42.2% with 40.1% increase in amount of data packets. The total energy consumption rate is less in FPCRA by approx 7%.

Karthika Sundaran et al (2017) proposed the algorithm named as Energy Conserved Unequal Clusters with Fuzzy logic (ECUCF) [2] as an enhancement of fuzzy based unequal clustering. ECUFC first divides the network and then select the cluster head using probability function. For energy consumption model free-space and multi-path fading channel models are used. The sensing field is divided into three sectors namely closest, middle and outside sector. Nodes carry the neighbor information table that helps in recognizing the nodes with less remaining energy and the CH on comparison with threshold value puts those nodes to sleep state that have less remaining energy value than threshold value. The performances obtained are compared with the performances of other clustering schemes like LEACH and FBUC that based on respectively the equal and unequal clustering. On comparison with the unequal and equal clustering based algorithms the proposed algorithm ECUFC provides the improved performance by maximizing the number of clusters, increasing the number of live nodes and extending the nodes lifetime on each round of operation.

Dr. V. Natarajan et al (2016) proposed Fuzzy Based Dynamic Clustering (FDC) algorithm [3]. Two major problems are discussed and new algorithm is proposed to solve these problems by using particle swarm optimization (PSO) algorithm and FIS. to overcome the problems mainly faced by the WSN in a non-distributed clustering. FDC uses three parameters: node density, position and remaining energy of nodes for determining cluster heads. Cluster formation task has to come across three stages: election stage, radius optimizing stage and cluster formation stage. FDC ensures that no node over exploits its energy or uses it continuously. Nodes on the basis of three parameters give a fitness value from which the first node is selected as cluster head after arranging in descending order. Cluster radius is directly proportional to the distance to the cluster head and residual energy but in inverse proportion with cluster head density. Results shows that

the starting point of node depletion starts after all other algorithms with which FDC is compared that ensures enhanced network lifetime. Advantage of FDC algorithm is that it can eliminate the hotspot problem by using the fuzzy logic.

Mohd Nasir Taib et al (2015) proposed Energy Source Saving Approach Using Multi-Tier Network Design Technique [5]. Author's aim is to minimize the energy usage of sensor nodes resulting in extended network lifetime. Protocol works as Initialization phase, Node distribution phase, Primary node selection phase, Cluster head selection phase, Cluster formation phase, Data transmission phase. At early stage of data transmission nodes are used evenly until they start to deplete. For efficient data transmission two-tier network design is followed. Each tier has its own cluster head for data transmission control between node and sink. The cluster head will collect data from cluster member nodes and pass to primary nodes before it reaches sink. From the proposed work author concluded that the implementation of Fuzzy Logic uses all nodes evenly and the nodes died sequentially as the data was increased causes nodes to use the energy efficiently and prolonging network lifetime.

Kishor kolhe et al (2015) proposed a Fuzzy manage based General Self-Organized Tree-Based Energy-Balance directing convention (FGSTEB) [6] which depends on the GSTEB, in this work creator manufactures a steering tree for information transmission by choosing the fitting steering way and hand-off hub utilizing fluffy standards. The principle objective of the work is to enhance the execution of GSTEB convention by adjusting vitality utilization which delaying the lifetime of WSN. Work is isolating into four stages i.e. Starting Phase, Tree Construction Phase, Self-Organized Data Collection and Transmitting Phase, and Information Exchange Phase. Nodes keep up table about neighbor of neighbors. Root ID and root directions to all sensor nodes is conveyed by the base station. Using TDMA and FHSS techniques data is collected and sent towards base station. Nodes before going to sleep state inform its neighbor node to update their table and continue with the routing process. Results are compared using different parameters like throughput, end to end delay, energy, Routing load, PDR and network lifetime. FGSTEB is capable of finding the optimal route to BS with minimum energy used with 10-15% less energy consumption compared with other method under the same network scenario like HEED and GSTEB.

Md. Mustafa Kamal et al (2014) proposed TSFL-LEACH (Two Stage Fuzzy Logic based Low Energy Adaptive Clustering Hierarchy) [8] with two separate cluster levels. To enhance network life-length fuzzy asymmetrical clustering is used. Formed clusters then divided into two stages depending upon their threshold value. Both the stages differs in the cluster radius where the stage 1 clusters have radius less than or equal to half of the threshold value and more in other case. For calculation two input variables have been selected i.e. distance from base station to cluster head and cluster head energy. For result analysis TSFL-LEACH is compared with three different algorithms LEACH, LEACH-C and EEUC and experimental results show that the proposed algorithm performs better than the other algorithms. TSFL-LEACH sensor nodes start to die later

than other algorithms. Moreover, total remaining energy level of TSFL-LEACH at a certain round is higher than all the other algorithms.

Prasenjit Chanak et al (2013) Author proposed a technique based on distributed and load balancing scheme in which nodes decide multi-hop data transmission path according to their efficiency distributing the routing load throughout the network. The scheme Fuzzy-based Dynamic Load Management Policy for wireless sensor network (FDLMP) [7] reduces cluster head as well as cluster members' load to elongate network lifetime and improved network performance. FDLMP frequently reduces the energy holes within the network formed due to unbalanced traffic in multi-hop data transmission. Policy is to divide the task in three phases wiz: Nodes classification through fuzzy logic inference system, cluster formation and traffic node selection, and the Data routing phase. BS classified the nodes as strong, moderate and weak nodes with strong ones being the cluster head. Membership functions Triangle and Trapezoid shape are used to reduce the complexity of computing. Results show that with FDLMP, network life span is better when compared to LEACH, CHEF and HEED protocols by 51.21%, 46.34% and 56.09% respectively due to minimum global energy dissipation.

Zhang Baihai et al (2011) [4] proposed an algorithm considering a factor of region density that is not mainly used by the existing algorithms. Cluster head selection is on the basis of inter and intra-communication distances and the residual energy. The transmission model consists of energy consumption of the transceiver circuitry and the power amplification circuit consumption that depends on the distance between the transmitting and receiving nodes. The energy needed by the cluster head normally consists of three components: reception energy, transmission energy and aggregation energy. For balanced clusters and proper cluster head selection, three parameters have been considered: region density, residual energy and required energy to play the role of cluster head. Evaluation of network lifetime is based on time in which all the nodes die, packets sent to BS and stability period, the time before the first node die. Proposed technique can achieve an increment in network lifetime and total packets delivered to BS by 40% and 90% as compared with normal LEACH-C.

CHAPTER 3

PRESENT WORK

3.1 Problem Formulation

In wireless sensor networks sensor nodes sense the environmental conditions and generate information in form of analog signals. These signals before moving to the base station pass through an ADC that converts them into digital form. The sensor nodes have a small sized battery that provides power and energy to the nodes in limited amount. In the recent times various techniques have been proposed to reduce the energy consumption of the sensor networks. Out of those proposed techniques, clustering technique is the most efficient, used by various sensor network protocols to increase network lifetime. In LEACH, an energy efficient protocol, the network is divided into fixed sized clusters using location based clustering. In each cluster, a cluster head is selected on the basis of remaining energy and distance between a node and the base station. In Multi-objective fuzzy clustering algorithm for wireless sensor network [32] (MOFCA), the technique of fuzzy logic has been applied for the selection of most efficient cluster heads in the network. In this research, improvement in the fuzzy logic based leach protocol will be proposed to reduce packet overhead in the network.

3.2 Objective of the study

Main objectives of the study are:

1. To study and analyze various energy efficient techniques of wireless sensor networks.
2. To propose an improvement in fuzzy logic based cluster head selection technique to reduce packet overhead in the network.
3. To implement proposed technique and compare with existing technique in terms of various parameters.

3.3 Expected outcomes

The performance of the proposed technique can be analyzed in terms of various parameters like energy consumption, packets transmitted to base station. Along with the existing parameters mainly used in making the energy efficient algorithms three parameters remaining energy, distance to base station and mobility of the nodes are considered. By

adding an extra parameter i.e. density the result will vary if compared to the existing algorithms. We will have a new scheme that will:

- Reduced energy consumption
- Decrease in number of packets transmitted to the base station
- Reduced routing overhead with the use of fuzzy parameters

CHAPTER 4

RESEARCH METHODOLOGY

In order to create a wireless sensor network that is distribution independent along with its property of being energy efficient a novel technique has been evolved. Clustering, an efficient method which gathers data by dividing the network in forms of clusters results in an energy efficient technique for wireless sensor network. The gathered data is transmitted to a cluster head to which the node belongs within the clustered networks. Once the data is gathered by the cluster-head amongst all the member nodes, the gathered data is forwarded to the base station. The transmitted data can be in a compressed or uncompressed form. Through the cluster heads, the data is transmitted within the multi-hop network scenario. Due to the huge inter-cluster dependency, the cluster-heads that are near to the sink deplete at much faster rate within such networks. This complete issue is named as hotspots problem. There are numerous unequal clustering methods being proposed for solving this issue. There are small sized clusters formed due to unequal clustering. This helps in reducing the intra-cluster dependency within the network. Due to the modification in the area of node deployment, the energy-hole problem also arises here. There are no studies proposed on solving both of the issues within the uniform and non-uniform distributed networks. Here, a multi-objective fuzzy clustering algorithm (MOFCA) in both static and mobile networks which solves both of the discussed issues. With the help of some common clustering algorithms a proper analysis on the performance is performed and the results are achieved. It is seen here that as compared to the already existing algorithms, the MOFCA technique provides better results within the same scenario. There are various efficiency metrics that provide estimation for the lifetime of WSN as well as the efficiency of the protocols.

For generating a system model, various assumptions are made that are listed below:

- All the nodes present within the network are identical.
- There is a manual deployment of the nodes which further generates a non-uniform distribution manually or in a random manner.
- Within the area-of-interest (AOI) the base station can be located anywhere. There is no need of locating the base station far from the sensing region.
- Once the deployment phase is completed, movement can occur within the sensor nodes. The initial position of the base station is not necessarily changed due to the mobility of nodes. Due to the terrestrial movements there are various changes occurring within the network such as erosion or displacement which is mainly due to external objects. The networks being evolved are also targeted through this assumption.
- There are various external sources to be created due to the assumptions of mobility. The energy consumption by the nodes is not caused here.
- When the nodes are developed, there is similar amount of energy in all the sensor nodes. There is one Joule of battery-power at the first point.

- For the purpose of adjusting transmission power the nodes provide it as per the distance of the receiving nodes.

Distance to the Base Station	**Remaining Energy**	**Calculated Density**	**Node Mobility**	**Competition Radius**
Close	Low	Dense	Dense	12XS
Close	Low	Normal	Normal	11XS
Close	Low	Sparse	Sparse	10XS
Close	Medium	Dense	Dense	9XS
Close	Medium	Normal	Normal	8XS
Close	Medium	Sparse	Sparse	7XS
Close	High	Dense	Dense	6XS
Close	High	Normal	Normal	5XS
Close	High	Sparse	Sparse	4XS
Medium	Low	Dense	Dense	3XS
Medium	Low	Normal	Normal	2XS
Medium	Low	Sparse	Sparse	XS (Extra small)
Medium	Medium	Sparse	Sparse	S (Small)
Medium	Medium	Normal	Normal	M (Medium)
Medium	Medium	Dense	Dense	L (Large)
Medium	High	Sparse	Sparse	XL (Extra Large)
Medium	High	Normal	Normal	2XL
Medium	High	Dense	Dense	3XL
Far	Low	Sparse	Sparse	4XL

Distance to the Base Station	**Remaining Energy**	**Calculated Density**	**Node Mobility**	**Competition Radius**
Far	Low	Normal	Normal	5XL
Far	Low	Dense	Dense	6XL
Far	Medium	Sparse	Sparse	7XL
Far	Medium	Normal	Normal	8XL
Far	Medium	Dense	Dense	9XL
Far	High	Sparse	Sparse	10XL
Far	High	Normal	Normal	11XL
Far	High	Dense	Dense	12XL

Table 2. Fuzzy rule base

CHAPTER 5

CONCLUSION AND SUMMARY

In wireless sensor network the sensor nodes have small sized battery that can provide limited amount of energy and power to the nodes. Nodes if continuously keep on sensing the environment dies in very faster rate hence reducing the network lifetime. For wireless sensor network, to increase the network lifetime numerous protocols have been proposed. These protocols provide the techniques that can enhance the network lifetime. For enhancing network lifetime, clustering technique is considered to be as highly efficient. In this technique the large network is divided into small clusters with each cluster elects its cluster head for the purpose of data transmission to the base station. Cluster head selection is based on the three parameters that are remaining energy of nodes, distance between node and base station and the node mobility. In the proposed work an additional density parameter is also considered when selecting the cluster head for a particular cluster. With the addition of density parameter the proposed algorithm, along with other three parameters remaining energy, mobility and distance between sink and sensor nodes, the routing overhead as compared to other routing protocols, will be decreased and provides enhancement in network lifetime.

CHAPTER 6

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