IMPROVED DIVIDE AND RULE SCHEME TO INCREASE LIFETIME OF WIRELESS SENSOR NETWORKS

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By

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CERTIFICATE

I declare that the dissertation entitled "IMPROVED DIVIDE AND RULE SCHEME TO INCREASE LIFETIME OF WIRELESS SENSOR NETWORKS" has been prepared by me under the guidance of Er. Surinder Singh Khurana, Assistant Professor, Centre for Computer Science & Technology, School of Engineering & Technology, Central University of Punjab.

No part of this dissertation has formed the basis for the award of any degree or fellowship previously.

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I certify that SWATI SAINI has prepared her dissertation entitled "IMPROVED DIVIDE AND RULE SCHEME TO INCREASE LIFETIME OF WIRELESS SENSOR NETWORKS", for the award of M.Tech. degree of the Central University of Punjab, under my guidance. She has carried out this work at the Centre for Computer Science & Technology, School of Engineering & Technology, Central University of Punjab.

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ABSTRACT

IMPROVED DIVIDE AND RULE SCHEME TO INCREASE LIFETIME OF WIRELESS SENSOR NETWORKS

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Key words (Five minimum): Wireless Sensor Networks, Divide and Rule, Cluster Head, Sink

Wireless sensor network (WSN) is a network of small light weight wireless nodes which are highly distributed and deployed in large numbers. The sensor nodes scan the environment and provide useful information to the user through sink node. One of the major issues in wireless sensor networks is developing an energy-efficient routing technique which has a significant impact on the overall lifetime of the sensor network. Our dissertation work focuses on increasing lifetime of wireless sensor networks. This is done by improving the existing Divide and Rule Scheme which is based on dividing network area into logical divisions to reduce distance for intra cluster and inter cluster communications. Improvement of Divide and Rule Scheme is done by developing a new scheme called Segregated Receive and Relay Scheme in which addition of relay nodes is done in inner and middle regions. The Proposed Scheme results in around 50% increase in lifetime of inner region nodes and leading to overall increase in lifetime of the network. Other parameters such as Delay, Throughput and Packet loss also shows better results in new Scheme.

Swati Saini | Er. Surinder Singh Khurana

DEDICATED TO

MY LOVING PARENTS

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Swati Saini

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LIST OF ABBREVIATIONS

Sr. No.	Full Form	Abbreviation
1.	Ad hoc On-Demand Distance Vector	AODV
2.	Adaptive demand-Driven Multicast Routing	ADMR
3.	Analog to digital Convertor	ADC
4.	Ant Colony Optimization	ACO
5.	Base Station	BS
6.	Cluster Head	CH
7.	Constant Bit Rate	CBR
8.	Corner Regions	CR
9.	Distance Function	DFi
10.	Distributed Divide and Rule Scheme	DDR
11.	Divide and Rule Scheme	D & R
12.	Global Cooperative Caching for Sensor Networks	GCCS
13.	Global Positioning System	GPS
14.	Hybrid Energy Efficient Distributed	HEED
15.	Inner Square	Is
16.	Liquid Crystal Display	LCD
17.	Low Energy Adaptive Clustering Hierarchy	LEACH
18.	Low Energy Adaptive Clustering Hierarchy-Centralized	LEACH-C
19.	Media Access Control	MAC
20.	Micro Electro-Mechanical Systems	MEMS
21.	Microcontroller Unit	MCU
22.	Middle Square	Ms
23.	Network Animator	NAM
24.	Network Simulator	NS

Sr. No.	Full Form	Abbreviation
25.	New Active Caching	NAC
26.	Non-Corner Regions	NCR
27.	Object-oriented Tool Command Language	OTCL
28.	Open shortest path first	OSPF
29.	Optimized Link State Routing Protocol	OLSR
30.	Outer Square	Os
31.	Power-Efficient Gathering in Sensor Information Systems	PEGASIS
32.	Relay Nodes	RN
33.	Security Protocol for Sensor Networks	SPIN
34.	Segregated Receive and Relay Scheme	SRR
35.	Sensor Node	SN
36.	Stable Election Protocol	SEP
37.	Storage and Display card	SD card
38.	Threshold Sensitive Energy Efficient sensor Network protocol	TEEN
39.	Tool Command Language	TCL
40.	Transmission Control Protocol	TCP
41.	User Datagram Protocol	UDP
42.	Very Large Scale Integration	VLSI
43.	Wireless Sensor Networks	WSN

CHAPTER 1

INTRODUCTION

A Wireless Sensor Network (WSN) is a set of self-powered sensor nodes. These nodes are deployed in infrastructure less mode to collect the useful information from the environment and transmit it to sink node. Monitoring of environmental conditions such as rainfall, humidity, temperature, head of an active volcano etc. and monitoring of friendly forces, opposing forces and various attacks etc. in military are some of the activities of sensor nodes (Maraiya et.al., 2011) (Enami et. al., 2010).Sensor networks allow the nodes to communicate wirelessly, hence avoiding the expensive wired system. The wireless medium may include radio frequencies, infrared, optical medium. Sensor nodes consist of radios that can transmit, receive and can stay in idle and sleep modes. The radio should not be kept in idle mode completely in order to prevent power consumption. They should get shutdown completely when they are idle (Jangra et. al., 2010). Sensor Networks provide the ability to operate devices such as actuators, motors and switches that control conditions and provide efficient and reliable communications.

Wireless Sensor Network provides fault-tolerant wireless connections between sensors, controllers and actuators (Poonkodi et. al., 2014).WSN is a self healing and self organizing network. Self-healing networks reconfigure their link associations and find other pathways around powered-down nodes or failed nodes. Self organizing allows a network automatically join new node without the need for manual interference (Stankovic, 2006).Sensor nodes are devices which are capable of gathering, storing, sensing and transmitting information. The magnitude of sensor node is higher than ad-hoc network nodes. The topology of a sensor network changes very frequently. Different types of wireless sensor networks applications require different types of MAC Protocols (Kumar, et.al, 2012).

1.1. Energy Consumption in Wireless Sensor Networks

Sensor nodes carry out three main functions i.e. acquisition, communication and data processing. Out of these three functions communication consumes more energy as much energy is wasted during transmitting and receiving of information. Data processing also consumes energy because of calculation operations but it is comparatively low. Acquisition consumes almost negligible energy (Kumar, et.al, 2012).

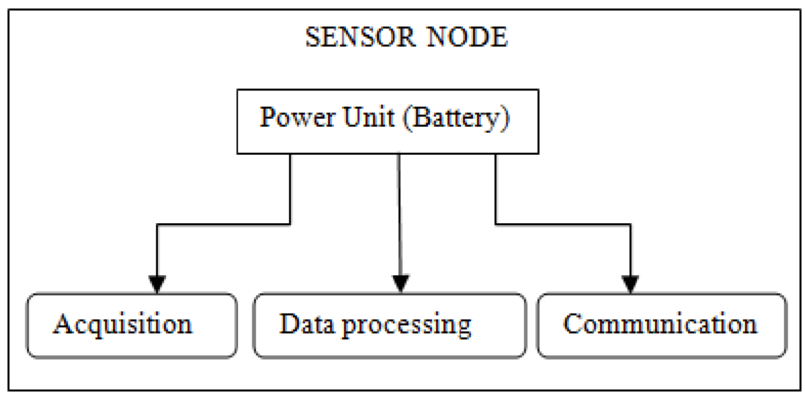


Fig 1.1 Functions of Sensor Node

The main source-sink communication is based upon multi-hop message rely. If the sensor is closest to the sink the battery will exhaust very quickly and nodes which are far away have still more than 90% of their initial energy. The reason for above phenomenon is simple: compared with sensors from a sink, nearby sensors are shared by more sensor-to-sink paths, have heavier message relay load, and therefore consume more energy. Researchers have built many energy models to give proper explanation. The depletion of energy causes energy holes which leads to degraded network performance.

We can make energy efficient Wireless Sensor Networks only when the load is equally distributed to all the nodes that consumes power equally and network become operationally as possible. To make energy efficient wireless Sensor networks following efforts can be applied:

- To gain proper utilization of the benefits of deploying grid in the network.
- To reduce number of hops during transmission by utilizing dual radio based sensor nodes.

- A novel caching technique is used to increase the efficiency and to reduce the obsolete network which enhances the network performance.
- To optimally utilize the limited cache memory, a cache invalidation scheme is developed which removes the obsolete entries from it.
- To utilize all the above effort in multiple sink environments, providing continuous information to mobile sinks.

To broadcast information to all over the network consume more nodes and more network resources. It also consumes more energy and bandwidth (Chand, 2012). Sensor nodes carry limited power resources that are irreplaceable therefore; there is a need to design an energy efficient technique to increase the life of wireless sensor networks. An inbuilt trade-off mechanism should be made so that the end-user should opt for prolonging network lifetime at the cost of lower throughput or higher transmission delay (Kumar, et.al, 2012).

Sensors nodes are based upon a battery with limited lifetime. Due to physical constraints such as harsh environment battery replacement is not possible. Moreover the architecture and protocol of sensor networks must be able to scale up any number of sensor nodes. Since the battery lifetime can be extended if we manage to reduce the amount of communication, caching the useful data for each sensor either in its local store or in the neighborhood nodes can prolong the network lifetime.

Caching is a technique which provides faster data access in any computing system. With the discovery of cache data accessibility has been increased as it stores data to be needed in future and can be retrieved rapidly. Caching has made its impact in the Wireless sensor networks also (Akyildiz, 2002).The traffic in Wireless Sensor Network depends on number of queries generated per Mean time. As stated before the sink injects the query into the Wireless Sensor Network and sensor nodes responds to the query accordingly. They further floods the query to the downstream nodes either responds as a query reply. Ultimately the sensor node having the result of the injected query will reply to the sink node through some routing protocol. A sensor node also aggregates the replies to a single response which saves the number of packets to send back to the sink node.

To increase the lifetime of battery various energy-aware techniques, processing density control techniques multi-hop communication etc should be followed while designing Wireless Sensor Networks. But these approaches still need to be improved. Energy depletion or physical destruction of nodes may lead to failures in wireless sensor networks. Developing a protocol to deploy sensor nodes in an organized and collaborative way is the most important challenge (Kharazian, et.al. 2012), (Lv, 2010).

The optimization of energy can be done with the awareness of energy as design aspects. Different types of algorithms and protocols were developed to minimize the energy consumption of the network sensor. The lifetime of a sensor network can be increased by designing the operating system, application layer and network protocols as an energy aware. These protocols and algorithms have the special features of microprocessor and transceivers to minimize the sensor node energy consumption.

1.2 Divide and Rule Scheme

(Latif et. al., 2013), have proposed a Divide and Rule Scheme to reduce energy consumption during communication. To reduce communication distance for intra cluster and inter cluster transmission, they divide the complete network area into small logically divisions referred as outer, middle and inner regions. Middle and inner regions have been further divided into corner and non-corner regions. Each non-corner region has one cluster head (CH) while corner regions and inner region has no cluster head. By using multi-hop routing each present in non-corner region sends the sensed data to cluster head of the same region. Cluster head after data aggregation forwards it to the cluster head of the middle region. Cluster head of middle region further forwards received data to the base station through the nearby sensor nodes of inner region. As the base station is placed in center of network area, the sensor nodes placed in inner region are close to base station and send data directly to the base station.

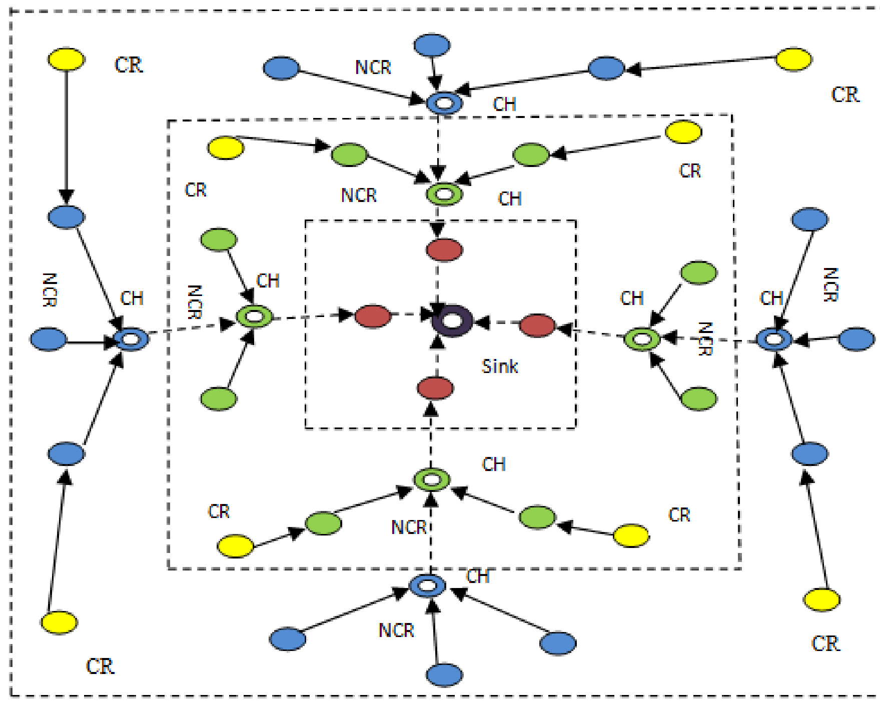


Fig 1.2 Divide and Rule regions formation

1.3 Problem Statement

- The communication between sensor nodes to sink is based upon multi-hop message relay. The batteries of the sensor nodes placed near the sink will exhaust faster as compared to those that are placed far away. This is because nearby sensors are shared by more sensor-to-sink paths, heavier message relay load and therefore consume more energy. If sensors placed around the sink all run out of energy, the sink will be isolated from the network; if all sink are isolated, then entire network fails. Since replacement/recharge of sensor batteries manually is not feasible due to operational factors. There is a need to minimize and balance energy usage among sensors (Niculescu, et.al., 2001).
- Energy depletion causes energy holes which degrade the network performance. Researchers have develop many energy models (Mamalis, et.al., 2007), (Tyagi, 2013), (Heinzelman, et. al., 2002) to give proper explanation but these models still need to be improved. Clustering technique in routing protocols plays a key role to prolong the stability period and lifetime of the

network. One of the energy efficient routing protocols for wireless sensor network is Divide and Rule scheme.

- In Divide and Rule scheme (Latif, et.al., 2013),Cluster Head in Outer Square (Os) regions send data to Cluster Head of exactly one level above adjacent region's Cluster Head. These Cluster Heads are also known as secondary level Cluster Heads, secondary level Cluster Heads aggregate their own cluster nodes data and, data of the primary level Cluster Head then, transmit data to Base Station this will lead to more energy consumption of Cluster Head nodes present in the Middle Square (Ms) and nodes present in the Inner Square (Is) regions which may lead to energy hole and may cause data routing problems. So there is need to improve this scheme to increase the life of nodes in Middle Square (Ms) and Inner Square (Is) regions.

1.4. Objectives of the Dissertation

The objective of this research is to increase the lifetime of inner square and middle square nodes in Divide and Rule Scheme.

Table 1.1 List of Simulations and their Objectives

List of Simulations	Objectives
1. Simulation of the existing Divide and Rule routing scheme.	For analysis of existing scheme.
2. Inserting relay nodes in each inner and middle square.	To increase the life time of Wireless Sensor Networks.

CHAPTER 2

REVIEW OF LITERATURE

(Tyagi, & Kumar, 2002), have presented the most popular protocol for clustering in WSNs that is Low Energy Adaptive Clustering Hierarchy (LEACH) which is based on adaptive clustering technique. This paper provides the taxonomy of various clustering and routing techniques in WSNs based upon metrics such as power management, energy management, network lifetime, optimal cluster head selection, multi-hop data transmission etc. LEACH forms clusters on the basis of received signal strength. The Cluster Head nodes perform data processing tasks such as data fusion and data aggregation and also act as routers to the base-station. Clusters are formed by LEACH by using a distributed algorithm. In distributed algorithm nodes make decisions without any centralized control. Initially a node decides to be a Cluster Head with a probability p and broadcasts its decision. A node becomes a Cluster Head for the current rotation if the number is less than the pre-defined threshold. The limitation of this approach is that since the decision to change the Cluster Head is probabilistic, therefore it can be possible that a node with very low energy gets selected as a Cluster Head. When this node dies, the whole cell doesn't function properly. Cluster Head is considered to have long communication range; therefore data can be forwarded to base station directly. Since Cluster Heads are regular sensors, therefore this assumption is not realistic. Due to signal propagation problems such as presence of obstacles etc., base-station may not be directly reachable to all nodes. Hence, it is not applicable to network deployed in large regions.

(Heinzelman, et.al., 2002), have proposed central control algorithm to form the clusters that may produce better clusters by dispersing the cluster head nodes throughout the network. This is the basis for LEACH-centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using a GPS receiver) and energy level to the Base Station. In addition to determining good clusters, the Base Station needs to ensure that the energy load is evenly distributed among all the nodes. To do this, the Base Station computes the average node energy, and nodes with energy less than this average cannot be selected as cluster heads for the current round. Using the remaining nodes as possible cluster heads, the Base Station finds clusters using the simulated annealing algorithm to solve the NP-hard problem of finding optimal clusters. This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster head, by minimizing the total sum of squared distances between all the non-cluster head nodes and the closest cluster head. But LEACH-C is fully dependent on the location of the sink. LEACH-C doesn't provide good performance if the energy consumption while communication with sink is higher than the energy consumption of sensor nodes during cluster formation. As the location of the sink can be far from the network location, hence depending on the sink location is a major disadvantage of LEACH-C.

(Lindsey & Raghavendra, 2002) proposed PEGASIS (Power-Efficient Gathering in Sensor Information Systems) in which each node communicates only with a neighbor node close to it and takes rounds to transmit data to the base station, thus reducing the amount of energy spent per round. PEGASIS is a greedy chain protocol that is optimal for data-gathering problem in sensor networks. PEGASIS eliminates the overhead of dynamic cluster formation, minimizes the distance non-leader nodes, limits the number of transmissions and receive among all nodes and uses only one transmission to the BS per round. Nodes take rounds to transmit the aggregated data to the BS so as to balance the energy depletion in the network and preserve robustness of the sensors as nodes die at random locations. PEGASIS is a chain based protocol which avoids cluster formation and uses only one node in a chain to transmit to the BS instead of using multiple nodes.

(Ye et.al, 2003), presents a new MAC Protocol, S-MAC for energy conservation in Wireless Sensor Networks. S-MAC uses three techniques to reduce consumption of energy and support self-configuration such as energy consumed while idle channel listening can be reduced by allowing nodes to sleep periodically. Neighboring nodes form clusters to synchronize automatically on sleep schedules. S-MAC has good energy conserving properties and according to traffic conditions it has the ability to make trade-offs between energy and latency. There is a need to analyze it on larger test-beds.

(Duboris-Ferries & Estrin, 2004) proposed an algorithm based on Voronoi clusters to handle multiple sink nodes. This Voronoi algorithm designates a sink for each cluster to perform data acquisition from sensors in cluster. Each node keeps a record of its closest sink and of the network distance to that sink. When a message arrives from a sink, the recipient checks whether the distance traversed by the packet is less than the current estimate of closet sink distance. If so, the node updates its closest sink and parent entries and resends the message. A node also re-forwards the message if the distance traversed is equal to closest distance and the message came from the closet sink. A drawback of this algorithm is that it does not consider residual energy sensor node.

(Younis & Fahmy, 2004), have presented, HEED (Hybrid Energy Efficient Distributed) protocol is the clustering protocol. It is based on usage of residual energy and network topology features such as node degree, distance to neighbors etc. as a metric for cluster selection to achieve load balancing. But this paper assumes that sensor nodes taken have same initial energy that is all nodes are assumed to be homogenous and not heterogeneous.

(Smaragdakis et.al., 2004), proposed SEP (Stable Election Protocol) which is a heterogeneous-aware protocol that prolongs the time interval before the death of the first node. SEP elects cluster Head on the bases of weighted election probabilities of each node according to the remaining energy of each node to increase energy conserving power. In this approach Cluster Head election is selected randomly and is distributed on the bases of the fraction of energy of each node assuring a uniform use of the nodes energy. SEP only works for two types of nodes (two tier in-clustering) and two level hierarchies were considered.

(Mamalis, et. al., 2007), describe the concept of Clustering and described various design challenges of clustering in Wireless Sensor networks. The paper also describes various clustering Protocols including Probabilistic Clustering Approaches and Non-Probabilistic Clustering Approaches. The algorithms discussed in these protocols consider periodically re-election of Cluster Heads (rotation of Cluster Head role) among all nodes. The main drawback of these algorithms is that the time complexity of these algorithms is difficult to be kept low as the size of the Wireless sensor Networks becomes larger and larger, the extension in multi-hop communication patterns is unavoidable which increases the routing path.

(Okdem & Karaboga, 2009), presented a new protocol for WSN routing operations. In this protocol an ACO (Ant Colony Optimization) algorithm is used which optimizes routing paths and provides an data transmission method which is multi-path to achieve reliable communications in case of node faults hence, leading to maintain maximum network lifetime. But this paper works only for single sink and not included multiple sinks.

(Aderohunmu & Deng, 2009), proposed an Enhanced Stable Election Protocol (SEP) for Clustered Heterogeneous WSN in a three-tier node scenario to prolong network lifetime. Using heterogeneous three-tier node setting in a clustering algorithmic approach, nodes elect themselves as cluster heads based on their energy levels, retaining more uniformly distributed energy among sensor nodes. Enhanced SEP is more robust with respect to network lifetime and resource sharing. But, as Enhanced SEP uses Clustering in heterogeneous scenario therefore; the traffic pattern is constant bit rate (CBR). There is a need to explore variable bit rate traffic pattern for application specific system such as dealing with compressed video streams.

(Pant et.al, 2010), have presented Effective Cache based Policies in Wireless Sensor Networks which is a data caching techniques in wireless networks. To make the faster access data caching techniques are utilized. Caching schemes are used to improve performance in wireless sensor networks. Energy can be making efficient if the load on all the nodes in the networks are distributed equally so that all nodes consume power equally hence, network become operational as longer as possible.

(Kumar, et. al., 2010), performed the selection of Cluster Head using neural network with adaptive learning. This paper discusses multipath data transmission in which paths are chosen by means of a probability that depends on how low the energy consumption of each path is. But limitation of this approach is that as all work is on probabilistic bases so it can be possible that low energy nodes may become as a router during data transmission which can lead to energy hole hence disturbing the data transmission.

(Maraiya, et. al. 2011), have presented an overview of wireless sensor network, how wireless sensor networks works and various applications of wireless sensor networks. In this paper it has been described that characteristics of wireless sensor network are dynamic network topology, lower power, node failure and mobility of nodes, short-range broadcast communication and multi-hop routing and large scale of deployment. But low power of sensor nodes is one of the limitation of wireless sensor network as in harsh environments it is difficult to replace sensor nodes so low power may cause energy hole in wireless sensor networks. Also multi-hop routing may cause more nodes deplete their energy while routing as compared to single hop routing.

(Maraiya, et. al., 2011), has studied various cluster head selection algorithm for aggregation of data in wireless sensor networks. This paper proposed the algorithm for efficient cluster head selection in which there is no need to select cluster head periodically, so lots of energy is saved in the wireless sensor network. The limitation of this algorithm is that in this algorithm the base station decides the location of sensor node i.e to which cluster it belongs by first receiving information from sensor node about its current location but if the base station is located far away from the sensor node then energy is wasted in deciding to which cluster the sensor node will be located.

(Kharazian et.al, 2012), presented a paper on adaptive clustering in Wireless Sensor Network that discusses about how to increase network life time with low energy nodes. In this paper, only low energy nodes decide which node will become cluster-head. The selection of the cluster-head is based on the weight of the neighboring nodes. These weights were calculated on the bases of the residual energy of the sensor nodes and distance between the sensor nodes. This paper shows the simulation of 100 nodes resulting in better performance than LEACH and LEACH-C. The proposed algorithm in the paper have shown good performance than LEACH and it has result almost like LEACH-C. LEACH-C (Low Energy Adaptive Clustering Hierarchy- Centralized) is a centralized algorithm while the proposed algorithm in the paper has no global information and is the distributed algorithm. In this paper if the energy of all nodes gets low then it becomes difficult to know that which all nodes will decide and who will become Cluster Head.

(Chauhan et.al, 2012), have presented Cluster Based Efficient Caching Technique for Wireless Sensor Networks. This technique uses Global Cooperative Caching for Sensor Networks (GCCS) to improve Wireless Sensor Network performance. GCCS exploits cooperation among SNs and decision regarding data items are depends upon the value of distance function DFi. The proliferation of sensor applications where huge amount of data is generated at active nodes and sink issues queries randomly to fetch these data items, the present work targets at caching maximum data items in the network. Grid based approach is used to utilize energy consumption throughout the network by periodically checking the nodes energies of dissemination nodes. Then this technique is further enhancing to improve network performance. The proposed work is working well in real world situations. Caching technique only works for the availability of data and not pay much attention on the energy conservation due to caching.

(Chand, 2012), has presented cooperative caching scheme ZCS to improve performance the performance of wireless sensor networks. In this scheme, in a zone nodes share their data which shows limited nodes problems and limited query latency at a node to prolong lifetime of wireless sensor networks. a cache discovery Process, distance based admission control, consistency check and utility based cache replacement policy is include by ZCS scheme. To improve hit ratio replacement policy is also used. Disadvantage of this model is that there are overheads to maintain & rotate the token.

(Jerusha et.al, 2012), has presented new cluster technique Location aware Cluster based Routing in WSN by modified K-mean clustering. This scheme is used to improve lifetime performance and avoid network traffic. Clustering is an important issue in Wireless Sensor Network. Information gathering in sensors is easily achieved by enabling GPS. The sensor nodes are aware of its own position also. Sensor Nodes can be clustered on the bases of energy by knowing the position information of sensor nodes and on the bases of shortest path distance. Clustering of nodes by using modified k means clustering algorithm can minimize the residual energy and maximize the performance. Hence, improving the network lifetime and reducing network traffic. But as WSN are widely used in many applications such as location monitoring, military surveillance etc. Therefore, there is a need to transmit information between the nodes securely which can be done only on the generation of secure keys between sensor nodes in sensor networks.

(Shiri et.al, 2012), In this paper they proposes a new active caching method to guarantee desired communication reliability in Wireless Sensor Networks which is a method for recovering lost packets by caching data in some of network nodes. These nodes are the combination of Extended NACK and Active Caching methods known as New Active Caching (NAC).The proposed approach used in this paper is the combination of Active Caching and Extended NACK approaches. In order to increase the reliability in Extended NACK approach some of the nodes are considered as caching nodes. Consider a network with eight nodes. In this network, nodes are taken as caching nodes. Packets were sent by source node will reach the sink based on multicasting method. The transmitted packet by source node has successfully reached node 1. Node E will transmit the packet so it can reach the sink through node F. If node E does not receive the transmitted packet again in a certain time, it will infer as node F has not received the packet and packet loss has occurred and it will send a NACK message to node D consequently and node D will send the same NACK message to caching node C. After receiving the NACK message by caching node C, this node will re-transmit the packet. As a result this seems to be optimized in factors such as delay in packet transmission, number of transferred packets and energy consumption. The common methods used to recover information in case of packet loss in WSN being E2E and HBH methods. The results indicate that AC method shows a better performance in comparison to previous methods, hence a new approach which tries to reduce the number of NACK message and increases the lifetime of the network. This approach is called NAC was compared with AC method. Results of the simulations indicate that the proposed approach in parameters such as transfer delay of packets, number of transmitted packets and energy consumption demonstrates better performance. But this paper doesn’t discuss about the number of nodes used for caching and the order of placing them.

(Latif, et. al., 2013), have presented routing technique called Divide-and-Rule which is based on static clustering and minimum distance based Cluster Head selection. Network area is logically divided into small regions (clusters). Old fashioned routing techniques such as LEACH, LEACH-C are not as energy efficient as present day clustering techniques such as Divide-and-Rule scheme. The benefit of Divide-and-Rule scheme is that when it is compared with LEACH and LEACH-C this scheme provides better results in terms of stability period, network life time, area coverage and throughput. But the limitation of this scheme is that during routing each node in

Os region sends its data to Primary level Cluster Heads which then forwards the aggregated data to the secondary level Cluster Head present in the Ms, Secondary level Cluster Heads then, aggregate all collected data and forward it to Base Station which will lead to more energy consumption of CH nodes present in the Middle Square and Inner Square regions which may lead to energy hole and may cause data routing problems.

(Ahmad et. al., 2013), DDR is based on static clustering and optimum number of CH selection in each round. In DDR we divided the network field into logical segments. The segmentation process helps to reduce communication distance between node and CH and between CH and BS. Multi-hop communication in inter-cluster further reduces communication distance. In DDR we have tried to overcome the problem of coverage hole and energy hole through density controlled uniform distribution of nodes in different segments of network. Optimum number of CHs in each round helps to achieve balanced load distributed which enhances stable period and network lifetime.

CHAPTER 3

WIRELESS SENSOR NETWORKS

3.1. Routing in Sensor Networks

The monitoring of physical phenomena such as environmental and habitat applications is done by sensor networks. A distributed algorithm is executed by sensor nodes to produce a routing table. The choice of routing algorithm is important to minimize resource utilization in an environment. As sensor nodes can encounter communication failures which can be resolved by various routing protocols such as AODV (Ad hoc On-Demand Distance Vector) etc. hence, minimizing failure duration that is from time a node detects a failure until the active paths coverage to stable state. As sensor nodes have wireless links therefore they can suffer from transient periods of disconnection. Such failures can occur frequently due to system errors or due to some external stimuli. Careless behavior while dealing with faults can cause network instability. Therefore, only best chosen protocol should be used to deal with these faults.

There can be reactive or proactive maintenance of routes by sensor nodes. In reactive routing protocols the path is established only on the bases of request imposed. Sensor nodes forward the routing request and then in response the sink replies back in reverse communication path. That is sensor nodes remain idle until the response of the sink. While in proactive routing protocols monitors the peer connectivity periodically to ensure the ready availability of communication path amongst the nodes. In this sensor nodes advertise their routing state within the whole network. Reactive routing protocols have been the choice in mobile ad-hoc networks due to frequent node mobility.

Sensor routing protocols basically refers to resource awareness. A hop count reduces the number of transmissions but the increase in communication distance between sensor nodes or the presence of noise etc. may result in decrease in probability of data delivery. Energy or bandwidth efficiency, the increased signal strength or packet delivery ratio &packet load metrics can prolong system lifetime, avoidance of lossy radio links &distribution of application traffic for congestion control.

Various distance vector routing protocol and link-state based protocols have been developed to choose the best path till destination. Distance vector routing protocol, notify their neighbors of inter mediate results until routing table stabilize according to best routing path. While in case of link-state protocols each sensor node contributes to establish distributed database of network topology running a shortest path algorithm (e.g. Dijkastra's algorithm) over this topology (Koliousis & Sventek, 2007).

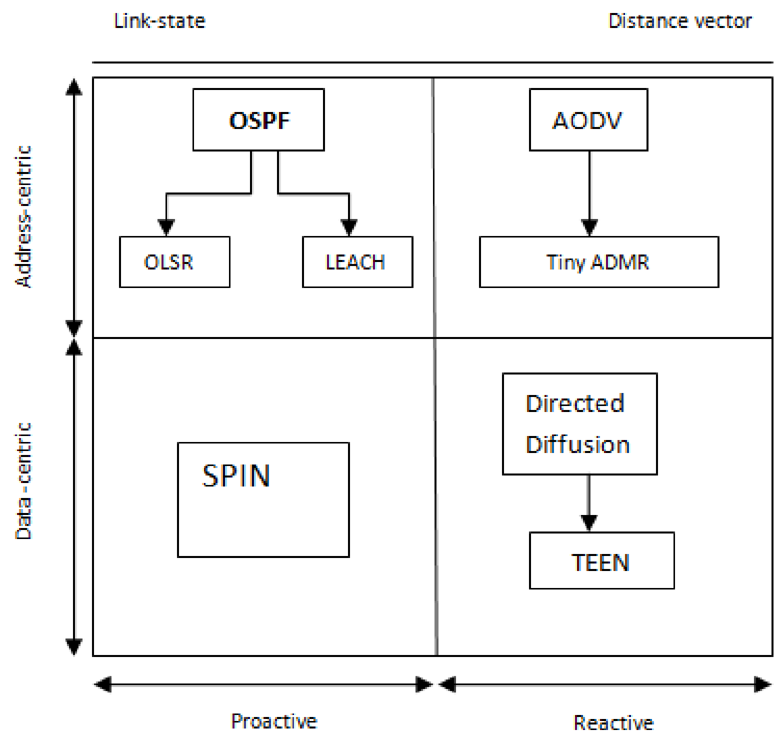


Fig 3.1 Exemplar routing protocols for Wireless Sensor Networks.

OSPF: Open shortest path first

AODV: Ad-hoc On Demand Vector Routing

SPIN: Security Protocol for Sensor Networks

TEEN: Threshold Sensitive Energy Efficient sensor Network protocol

LEACH: Low energy adaptive clustering Hierarchy

OLSR: Optimized Link State Routing Protocol

ADMR: Adaptive demand-Driven Multicast Routing

3.2. Communication in Sensor Networks

Sensor nodes in WSN work cooperatively to serve the user requests. WSNs are decentralized systems in which peer to peer communication takes place between deployed nodes. As deployment of sensor networks are infrastructure less, so sensor nodes can be easily added or removed from the network if required to do so. By doing this, there can be changes in network topology, network tree and many kinds of changes such that updating of routing path may occur. The sink may be connected to the outside world through Internet from which the information can be recruited within time constraints (Pant et. al., 2010).

Flooding is a method in which the nodes send data to all the nodes except the one from which the data is received. Hence, sink request can be send through this method to each node (Bhat, 2011), (Okdem, 2009). To broadcast information to all over the network consume more nodes and more networks resources. Sensor nodes are deployed randomly to make the ad-hoc network communicate among themselves. If the nodes are not able to communicate with other through direct link, i.e. these nodes are out of coverage area of each other; the data can be sent to the other node by using the nodes in between them. This is called multi-hop routing.

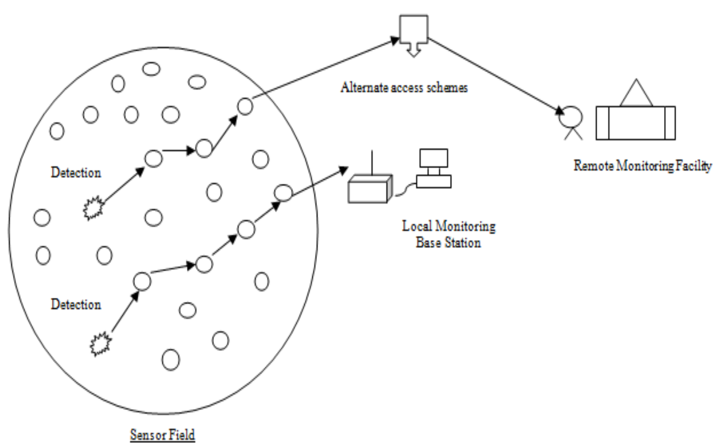


Fig. 3.2 Wireless Sensor Network (Pintaya, 2010).

In the Fig. 3.2 the sensor nodes are deployed randomly in the sensor field. The sensor node after gathering the required information forwards the data to the Remote monitoring facility through other access methods such as Internet and to local

Monitoring Base Station directly. The sensor nodes use multi-hop routing to forward data to both the base stations (Remote and Local Base Stations). Since large number of sensor nodes is deployed densely, neighbor nodes are very close to each other. Hence it is expected that multi-hop sensor communication networks has to consume less power than single hop communication. The low level of transmission power can be kept which is highly desired in covert operations. Multi-hop communication can also effectively overcome some of the signal propagation effects experienced in long-distance wireless communication (Akyildiz, 2002). The data which is generated by sensors is called sources. The data is transferred to one or more sinks for processing and analysis. Without any changes measurement is come to the sink. Data transmission can be takes place either in push mode or pull mode. In push mode, Sources send to sink actively. In pull mode data is sending only on sink request (Isaac, et.al., 2012).

3.3. Sensor Node

The sensor node (Sahu, 2010) may also contain some optional components that provide more specialized functions. A sensor node can act both as a data collector and as a data router. A sensor node can have different types of sensors that can measure pressure, humidity, light, acoustic, temperature, and various other parameters. A sensor node includes some basic components that are organized as shown in the block diagram of Figure 3.3:

- *Processor* is responsible for managing and coordinating various activities of the sensor node and for processing data. The *sensors* measure some properties of the physical environment.
- The *Analog-to-Digital Converter (ADC*) converts the analog data measured by the sensors to digital format so that it can be stored and processed.
- *Transceiver* is a radio device that can receive and transmit information. If the node is part of a network, data can be transmitted from the source to the destination using single hop or multiple hops communication.

- *Power source* supplies power to the sensors and to the other components of the sensor node. The power source may be supported by power scavenging units such as solar cells.
- *Memory* stores the collected data until it is forwarded to the next node.

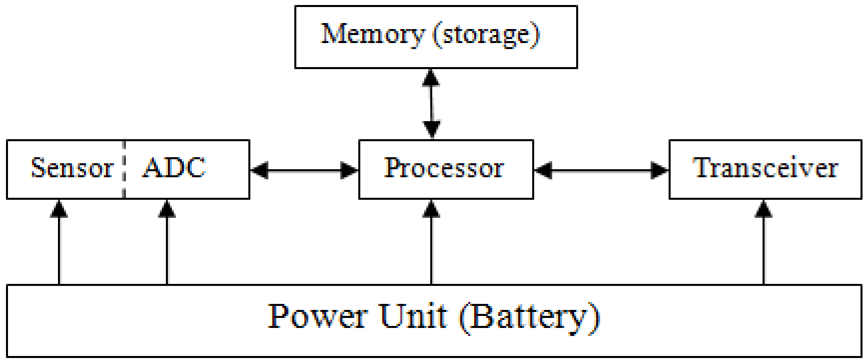


Fig 3.3 Block diagram of a sensor node (Sahu, 2010)

Figure 3.3 shows the Power Source supplying power to the Sensor, ADC, Processor, Memory, and Transceiver.

3.4. The Structure of Sink Node

Sink node as a connecting link between the preceding and the following plays an important role in Wireless Sensor Network, which can manage the sensor nodes and communicate with the data terminal. It is mainly responsible for sending the commands from the data terminal (such as data query, distribution of ID address, etc.), receiving the data from sensor nodes. To sum up, sink node must be with capacity of high speed processing, large storage, long-distance transmission, low-power consumption, and low cost. The overall structure of the sink node for the design is shown in Fig. 3.4. It is divided into four parts, the MCU, the Power module, the Communication module, the Storage and Display module (Lv, et.al. 2010).

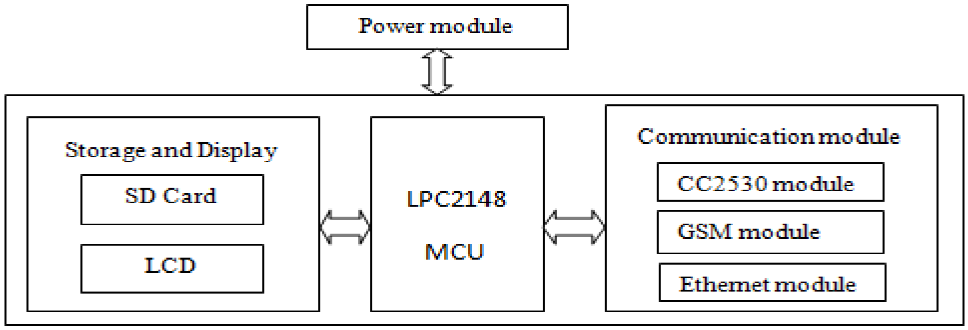


Fig 3.4 Structure of Sink Node (Lv, et.al. 2010)

3.5. Multiple Sink Concepts

For large-scale WSNs, a single-sink model is not scalable since message transfer delay as well as energy consumption of the sensor nodes become prohibitive, due to the fact that most of the nodes would be far away from the sink and thus many hops must be traversed before the sink is reached. As a result, response times become excessive and the lifetime of the WSN becomes very short. Therefore, it is sensible to deploy multiple sinks so that messages reach their destination with less hops and consequently response times are decreased and energy is saved (Poe, et.al., 2008).

WSN also serve for multiple applications, each running on distinct devices. Therefore, a need of multiple sinks is required here that may be mobile or static (Ciciriello, et.al., 2007).The multiple sink could be present at any place in the sensor field and thus request can be generated from anywhere in the sensor network (Chauhan, 2012). If any system has more than one sink, then it can generate the same query to the sensor nodes in Sensor Networks. For such a system each sink will have its own path developed to the source node which is somehow not required or there can be a way which avoids this. For handling such issues caching comes into picture. To realize the helpfulness of the using caching consider a tree of multiple levels and think of their leaf nodes are communicating to a common child internal node rather than the root node. Means the results can be cached in some intermediate nodes such that each sink will not have to communicate directly to the source node which saves time and avoids obsolete data traffic in the network. Caching could reduce a lot of data traffic and saving response time and energy consumption. Wireless Sensor Networks are prone to node failure due to power loss. In order to provide reliable service through the network, the network should be self adjusting and must have adaptable properties as required from time to time. A bottleneck node may encounter failure due to limited battery life. In such case the network protocol should be intelligent enough to handle such failures and keeps the network operational (Chauhan, 2012), (Pant, et. al., 2010).

3.6. Traffic in Wireless Sensor Networks

The traffic in Wireless Sensor Network depends on number of queries generated per Mean time. As stated before the sink injects the query into the Wireless Sensor Network and sensor nodes responds to the query accordingly. They further floods the query to the downstream nodes either responds as a query reply. Ultimately the sensor node having the result of the injected query will reply to the sink node through some routing protocol. A sensor node also aggregates the replies to a single response which saves the number of packets to send back to the sink node (Kumar, et.al, 2012).

3.7. Design issues and challenges of a Wireless Sensor Network

The sensor networks have a many technical challenges due to some factors as given:

- **Ad-hoc deployment and discovery**: Sensor nodes are deployed by tossing them from an aero plane & are deployed in an infrastructure-less manner. Hence, it is the responsibility of nodes only to identify other sensor nodes for connectivity and distribution (Akyildiz, 2002).

  For sensor nodes to operate properly having knowledge of the network is compulsory such as knowledge about the identity and location of its neighbors to support processing and collaboration. For ad hoc networks, network topology should be constructed in real time and updated periodically due to failure or addition of sensor nodes. In case of mobile ad-hoc networks different mechanism is provided for fixed and mobile sensors for their location discovery. Each sensor node should know about its own location as well as the location of the neighboring nodes (Chong, et.al., 2003). In Wireless Sensor

Networks, geographic routing plays a key role in sending the source message to the geographic location of the destination than to the network address. This routing uses geographic and topological information of the network to achieve optimal routing schemes with high routing efficiency and low power consumption (Bhat, 2011).

- **Battery depletion and lifetime**: In the Wireless Sensor Network, there is no any external energy source for the sensor nodes. Sensor Nodes have only finite source of energy provided by battery. Most of the energy is consumed during packet transmission through sensing, signal processing and hardware operation in standby mode. Many proposed protocols tend to minimize energy consumption on forwarding paths, but if some nodes happen to be located on most forwarding paths (e.g., close to the base station), their lifetime will be reduced (Raghunandan, et. al. 2011), (Okdem, et.al. 2009).

- **Data Reporting Model:** Data sensing and reporting in wireless sensor networks depends on the application and the time criticality. Data reporting can be categorized as either time driven (continuous), event-driven, query-driven, and hybrid. The routing protocol is influenced by the data reporting model with regard to energy consumption and route stability (Raghunandan, et. al. 2011).

- **Fault Tolerance and Dynamic changes:** Sensor network is dynamic in nature. The sensor nodes are configurable itself. Sensor nodes are adaptable to the changes in the network such as addition and failure of any node. Some nodes may get blocked or fail due to either physical damage or lack of power or due to some environmental interference. If many nodes fail then new links and routes to the sink can be formed through MAC and routing protocols. The regular adjustment of transmitting powers and signaling rates on the links is done to reduce energy consumption or rerouting packets through those nodes of the network which has more energy available. Hence, multiple levels of redundancy may be needed in fault-tolerant sensor networks (Raghunandan, et. al. 2011).

- **Connectivity:** Sensor networks being densely deployed are difficult to be isolated from each other. Therefore, sensor nodes are expected to be highly connected. This, however, may not prevent the network topology from being variable and the network size from being shrinking due to sensor node failures. In addition, connectivity depends on the, possibly random distribution of nodes (Raghunandan, et. al. 2011).

- **Time Constraint:** In some applications, data should be delivered very soon within a certain period of time from the period it is sensed; otherwise the data will be useless. Therefore, for time constrained applications latency is bounded for data delivery. As the energy gets depleted in case the data doesn't reach in suitable time therefore; the quality of the results must be reduced by the network in order to reduce the energy dissipation in the nodes which leads to increase in the total network lifetime. Hence, energy aware routing protocols are required to solve this requirement (Raghunandan, et. al. 2011).

- **Operating Environment and Production Costs:** We can set up sensor network in the interior of large machinery, at the bottom of an ocean, in a biologically or chemically contaminated field, in a battle field beyond the enemy lines, in a home or a large building, in a large warehouse, attached to animals, attached to fast moving vehicles, in forest area for habitat monitoring etc. Since the sensor networks consist of a large number of sensor nodes, the cost of a single node is very important to justify the overall cost of the networks and hence the cost of each sensor node has to be kept low.

- **Sensor Holes:** Sensor hole is a region in a sensor network where either nodes are not available or the available nodes cannot participate in the routing of the data due to various reasons (Muthukarpagam, et.al. 2010).There is a need to identify holes in wireless sensor network since breakdown of sensor nodes in larger area may indicate fire outbreak, earthquakes destruction etc. The task of identifying holes is difficult since wireless sensor networks consist of less weight and low capacity nodes which are not aware of their geographic location.

- **Coverage Topology:** Coverage problem reflects how well an area is monitored or tracked by sensors. The coverage and connectivity problems in sensor networks have received considerable attention in the research community in recent years. This problem can be considered as a decision problem which determines whether every point in the area of the sensor networks is covered by at least k sensors, where k is a given parameter (Muthukarpagam, et.al. 2010).

- **Transmission Media:** In a multi-hop sensor network, nodes are communicated through wireless medium. The problems associated with a wireless channel such as fading and high error rate affect the operation of the sensor network (Muthukarpagam, et.al. 2010).

3.8. Clustering

3.8.1. Cluster Head Selection

Wireless Sensor networks include two kinds of nodes which are sensor nodes and sink or base station. Sensor nodes have limited energy but sink or base station has no energy restriction and generally located far away from the area of sensor nodes. They use the direct transmission or multi-hop transmission to communicate with the base station. Sensor nodes sense environment at a fixed rate and sends data to the base station. Sensor nodes can revise the transmission power of wireless transmitter according to the distance. Cluster head performs data aggregation and BS receives compressed data. The lifespan of WSN is the total amount of time before the first sensor node runs out of power (Chen, et. al., 2003).

Weak nodes choose cluster head based on the following two measures:

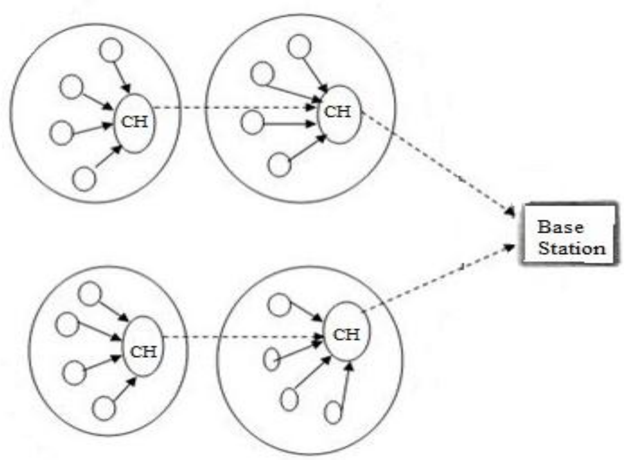
- The head cluster nodes has more residual energy than other neighbors.
- The distance between them is lower than other (Jangra, et.al., 2010).

Grouping of sensor nodes into clusters is adopted to satisfy scalability objective and achieve high energy efficiency and prolong network lifetime in large-scale WSN environments. Each cluster has the leader cluster-head which performs data fusion and aggregation and several common sensor nodes as members (Ramesh & Somasundaram, 2011).

3.8.2. Clustering Formation Process

- This Process leads to 2 level hierarchy:
    - Cluster Head nodes form the higher level.
    - Cluster- member nodes form the lower-level.
- Sensor nodes transmit data to corresponding Cluster Head nodes.
- Cluster Head nodes aggregate the data and transmit them to the base station either directly or through intermediate communication with other Cluster Head nodes.
- Because the Cluster Head nodes send all the data to higher distances than the common (member), they naturally spend energy at higher rates.
- A common solution in order to balance the energy consumption among all the network nodes is to periodically re-elect new Cluster Heads (thus rotating the Cluster Head role among all the nodes over time) in each cluster.
- BS processes data for the data received from sensor nodes, and where the data is being accessed by the end user.
- BS is generally considered fixed and at a far distance from sensor nodes.
- Cluster Head nodes act as a gateways between sensor nodes and the BS.
- The structure formed between the sensor nodes, Cluster head and the base station can be repeated as many times as it is needed, creating multi-level cluster hierarchy.
- Hierarchical routing is an efficient way to lower energy consumption within a cluster, performing data aggregation and fusion so as to decrease the number of transmitted messages to the BS.

- Single-tier network allow the gateway to overload with the increase in sensor density.



→ Intra-cluster Communication

- - - - - -→ Inter-cluster Communication

Fig. 3.5 Data Communication in Clustered Network

3.8.3. Benefits of Clustering

- Useful tool for efficiently pinpointing object locations.
- Support network scalability and decreasing energy consumption through data aggregation.
- It localizes the route setup within the cluster and thus reduces the size of the routing table stored at the individual node.
- It conserves communication bandwidth because it limits the scope of inter-cluster interactions to Cluster Head s and avoids redundant exchange of messages among sensor nodes.
- It can stabilize the network topology at the level of sensors (Mamalis, et. al., 2007).

3.9. Location aware Cluster based Routing

When self-location by GPS is too expensive or not feasible then other means of self-location, such as relative positioning algorithms, have to be provided (Chong & Kumar, 2003).

It uses three phases in wireless sensor networks:

- In the first phase, the location information of each sensor node is computed by using the localization algorithm such as Trilateration, Triangulation etc.
- In the second phase, clusters are formed to minimize the residual energy and maximize the network performance and the Cluster head is elected based on the minimum distance between the cluster node's and the centroid.
- In the third phase, routing takes place between the cluster head and the cluster members and also between the cluster head and the base station (Jerusha, et.al., 2012).

3.9.1. Location of Sensor Node

The location information of each sensor node should be known to form a cluster in the wireless sensor network. The nodes which are deployed in the sensor network, knows their location information. The coordinates (xi, yi) of each sensor node are used to estimate the distance between two sensor nodes. Based on minimum distance and highest residual energy, the sensor nodes are clustered by using Modified K means clustering algorithm. When a node has information about distances or angles and positions, it can compute its own position using any one of the localization method. Several methods can be used to compute the position of a node such as trilateration (Santos, et.al., 2008), multitrilateration (Santos, et.al., 2008), triangulation (Bhat, 2011) etc. Trilateration is a geometric principle which is used to find a location, if their distances from other nodes are known. It computes a node's position via the intersection of three circles. To calculate the unknown node's location, trilateration method uses the known locations of two or more reference points, and then measured distance between the unknown node and each reference point. To accurately determine the relative location of a node using trilateration, generally at least three reference points are needed. These three reference nodes are assumed like a GPS enabled node (Niculescu & Nath, 2001).

CHAPTER 4

PROPOSED MODEL

4.1. Segregated Received and Relay Scheme

To increase the life time of WSNs, a new scheme called Segregated Receive and Relay (SRR) has been proposed for communication in WSNs. In our proposed scheme, the network area is divided into various regions as in Divide and Rule scheme (Latif et.al., 2013). To reduce the energy consumption of inner and middle region nodes, relay nodes have been introduced. These relay nodes have been placed in middle and inner region of the WSN. The relay node will receive the data from cluster head of region surrounding the region of relay node. Further it will forward the same to relay node placed in interior region. Based upon this concept the communication between outer region node X and the sink took place as:

- Node X will sense the data and forward it to the cluster head of outer region
- Cluster head will aggregate the data received from node X and other nodes of outer region.
- Cluster head will forward the aggregated data to the relay node of middle region.
- Relay node of middle region will send the received data to sink node through relay node placed in the inner region.

In this way, nodes of interior regions will not be included in path of communication between outer region nodes and the sink node. Henceforth the overall energy requirements of these nodes will be decreased.

In the proposed work, we have inserted 8 relay nodes in the network scenario comprising of nearly 4 relay nodes in each Inner and middle region to communication path between outer & middle region nodes and sink node. Fig. 1 shows proposed work (Segregated Receive and Relay Scheme).

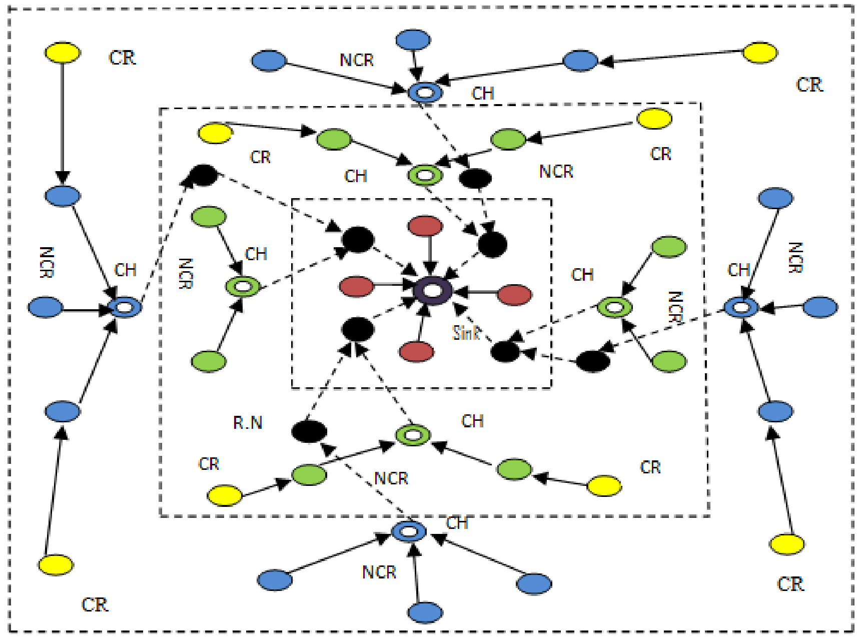


Fig 4.1 Segregated receive and relay scheme

CR= Corner Region, NCR= Non-Corner Region, CH= Cluster Head,

RN= Relay Node

←- - - - - Communication through Relay Nodes

←——— Communication between Sensor Nodes & Cluster Head

4.1.1. Routing using Relay Nodes:

- Outer Square region does not contain any relay node, sensor nodes of Os region forwards data to their CH which aggregates data and forward it to relay node of Region Ms which then further forward data to relay nodes of Is region which then further forward data to the Base Station.
- Sensor nodes of Ms Region will forward data to their CH which then will forward data to relay node of Is region which then further forward data to base station.
- Inner Square region relay nodes will receive data from the relay nodes present in middle square region and also from Cluster Head present in the middle square region and then forward it to sink.
- Therefore, the communication between Cluster Head and Relay node and between relay nodes and relay nodes takes place.

- The choice to which relay node the CH of Os or the relay node of Ms or the CH of Ms node sends data depends upon the shortest communication distance.

CHAPTER 5

SIMULATION SETUP

The performance of the proposed approach has been evaluated by simulating it in NS-2. We have also simulated Divide and Rule scheme and compare the performance with the proposed approach. This chapter discusses about the simulation parameters.

5.1. Network Simulator (NS2)

Network Simulator (Version 2), also called NS2, is a simulation tool which is an event driven and is very helpful in studying dynamic nature of communication networks. NS2 is useful in performing simulations of wired as well as wireless networks as well as protocols such as routing algorithms, TCP and UDP. Therefore, NS2 help users in simulating the behaviors of network protocols.

Figure 5.1 shows the basic architecture of NS2. An executable command in ns in NS2 takes an input argument, the name of Tcl simulation scripting file. In most of the cases, graph plotting and animation creating is done by a simulation trace file.

In NS2 two key languages are used mainly i.e C++ and Object-oriented Tool Command Language (OTcl). As C++ defines the internal mechanism i.e backend of the simulation objects while the OTcl provides simulation setup by assembling and configuring the objects as well as scheduling of discrete events i.e front end. TclCl links together both C++ and OTcl.

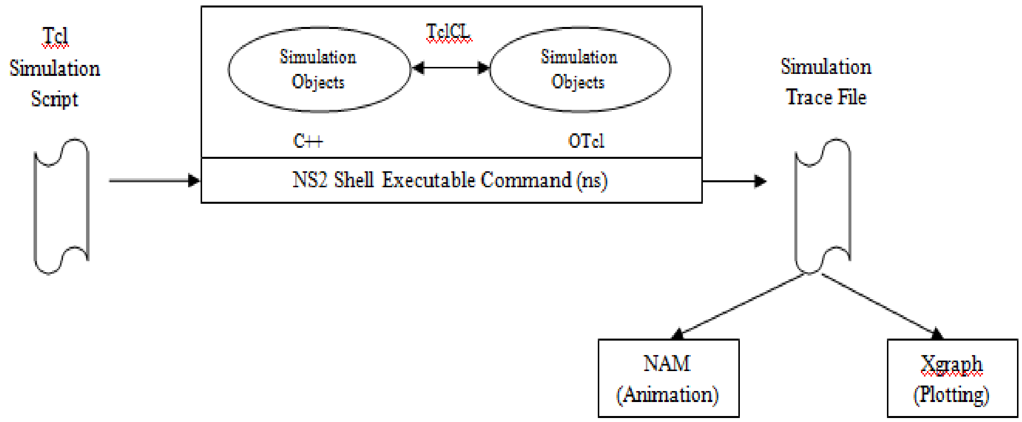


Fig. 5.1 Basic architecture of ns2

5.1.1. Tcl Script

Tcl (Tool Command Language) is easy to learn dynamic programming language. Tcl is used in many applications such as web and desktop applications, networking, administration, testing etc. It is open-source and user friendly language (Active State, 2000).

Tk is a graphical user interface toolkit which takes developing of desktop applications to higher level than conventional approaches. Tk is a standard GUI for Tcl as well as for many other dynamic languages which can produce rich and native applications that run across operating systems such as Windows, Mac OS X, Linux and more.

Tcl script is saved using .tcl. The script is allowed to compile using ns hello.tcl if the script name is hello.tcl.

5.1.2. X-Graph

The X-graph draws a graph on X display. In X-graphs data are read from data files or from standard inputs if no files are specified. X-graphs use different colors and/or line styles for displaying 64 independent data sets. X-graph has the ability to annotate the graph with a title, axis labels, grid lines or tick marks, grid labels and a legend. There are many options to control appearance of many graphical components.

Data set consists of ordered list of points of the form directive XY. For “draw” directive a line must be drawn between the previous and the current point. “Move” directive tells x-graph not to draw lines between the points. Window manager manages the size and location of the window currently in use. All the data sets will be displayed graphically in the upper right corner of the screen, once the window has been opened (X-Graph Utility of NS-2, 2014).

5.2. Simulation Parameters

The proposed approach and existing approaches have been simulated in Ns2 (Network Simulator) with simulation parameters as mentioned in table 5.1.

Table 5.1 Simulation Parameters for both Existing & Proposed Work

Parameter	D & R Scheme	SRR Scheme
Sink	1	1
Total No. of Sensor Nodes	40	40
Total No. of Relay Nodes	NIL	08
Channel Type	Wireless Channel	Wireless Channel
Radio-propagation Model	Two Ray Ground	Two Ray Ground
Antenna Type	Omni Antenna	Omni Antenna
Max. Packet in Queue	50	50
Network Interface type	Phy/Wireless Phy	Phy/Wireless Phy
Mac Type	802_11	802_11
Topographical Area	800*800 sq. m.	800*800 sq. m.
Agent Type	TCP	TCP
Traffic Type	Constant Bit Rate	Constant Bit Rate

5.3. Methodology

- We have simulated the Existing Work that is Divide and Rule Scheme and the graphical analysis of the results is done.

- The problem in existing work is analyzed thoroughly and the new method to solve this problem is proposed.
- The proposed work Segregated Received and Relay scheme is developed by adding optimum no. of relay nodes
- The 4 relay nodes are added in each inner region and middle region of the network
- There is one relay node in each non-corner region of middle square region and 4 relay nodes in inner region.
- Hence, routing through relay nodes is done in both middle and inner region to the sink.

5.4. Performance Metrics

Following performance metrics have been observed:

- **Delay:** It refers to the time taken by a packet to transmit across a network from source to destination.

  End to end delay D = packet received time – packet send time
- **Packet loss:** Number of packets lost during transfer of packets from source to destination
- **Throughput:** It is the rate of sending and receiving of data by a network which is proportional to a good channel capacity of network connections. It is rated in terms bits per second (bits/s) (Jain & Shrivastava, 2013).

  Network Throughput = (Sum of Throughput of Nodes Involved in Data Trans.) / (Number of Nodes)
- **Energy consumption:** This is the total energy consumed by the nodes located in different regions of the network.

  Average Energy Consumed= Sum of Percent Energy Consumed by all Nodes / Number of Nodes (Marandin, D., 2004).

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1. Results of the Existing Work

Graph shown in fig-6.1, represents the total energy consumed by nodes of Inner region, Middle region and Outer region during routing. This graph clearly indicates that the nodes in Inner region consume more energy as compared to nodes placed in middle and outer regions.

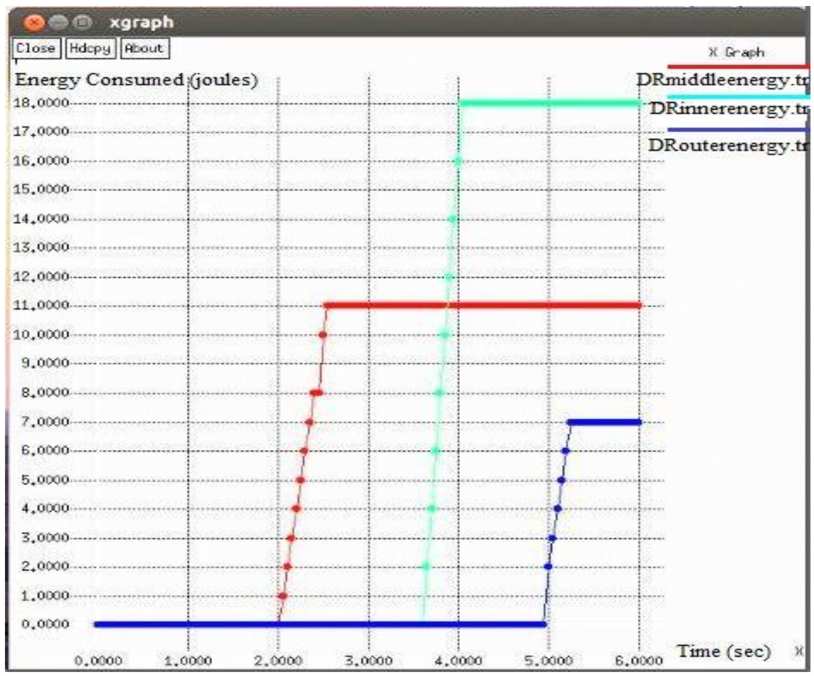


Fig. 6.1 Graph- Energy Consumed by Divide & Rule Scheme v/s Time

The graphs given in fig-6.2 to fig-6.4 represent delay, packet loss and throughput respectively. These graphs shows that delay, packet loss and throughput increase with respect to time.

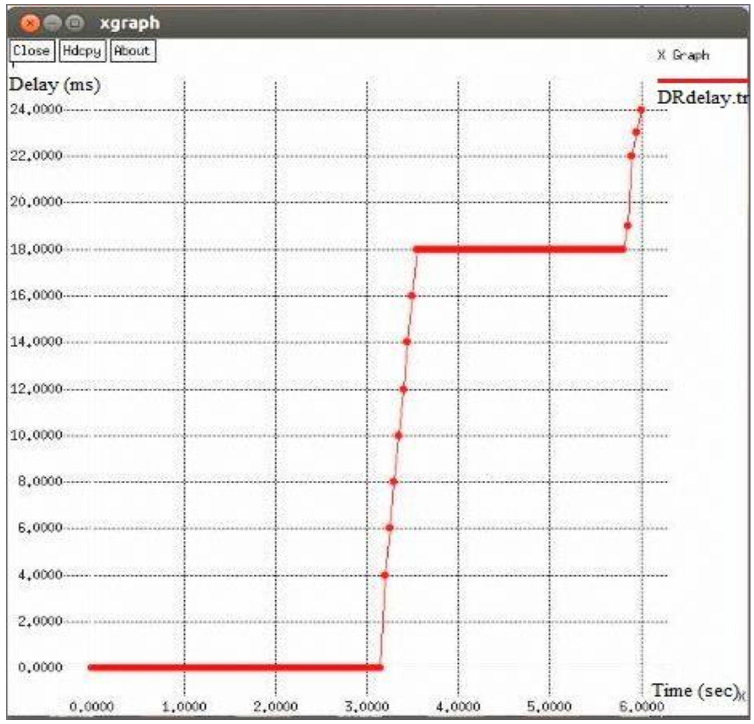


Fig. 6.2 Graph- Delay v/s Time (Divide & Rule Scheme)

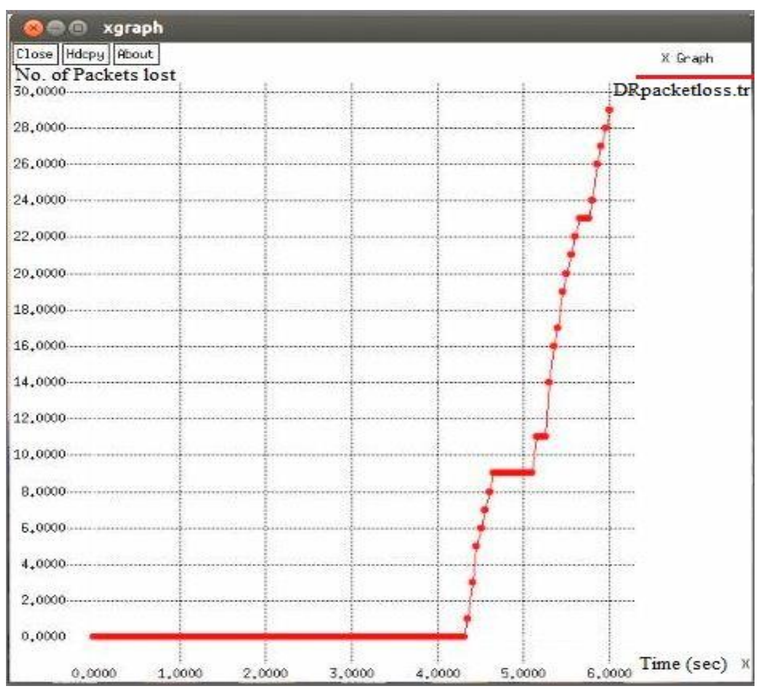


Fig. 6.3 Graph- Packet loss v/s Time (Divide & Rule Scheme)

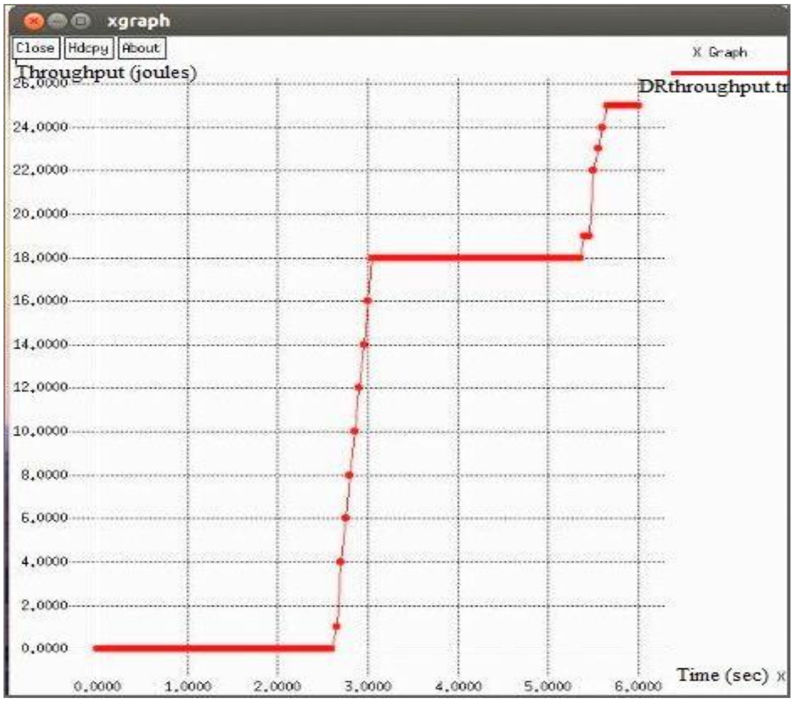


Fig. 6.4 Graph- Throughput v/s Time (Divide & Rule Scheme)

6.2. SRR Scheme v/s D&R Scheme

Energy Consumption: The graph in fig-6.5 represents energy v/s time graph showing total energy consumed by inner, middle and outer region in both existing as well as proposed work. This graph shows that the inner, middle and outer region nodes energy is consumed less in proposed work as compared to inner, middle and outer region nodes energy of existing work. This happens due to addition of relay nodes in the proposed scenario. Relay nodes forwards the communicated data to the sink either directly or through other region relay nodes, hence decreasing the stress of message relay load on sensor networks. This leads to increase in lifetime of Sensor Networks.

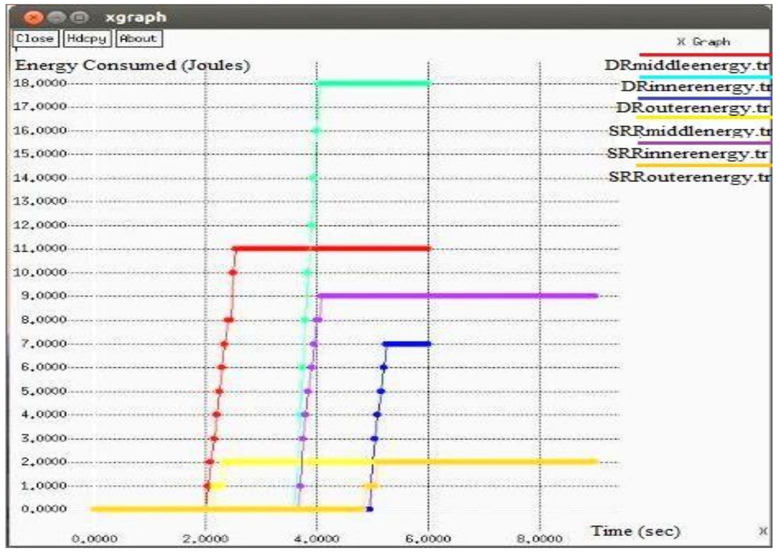


Fig 6.5 Graph showing energy consumption by D&R scheme and proposed scheme

The graph in fig-6.6 & fig-6.7 represents comparison of energy consumed by inner and middle region with Divide & Rule scheme and proposed scheme:

- **Inner Region Energy Consumption:** The graph in fig-6.6 shows that the energy consumption of inner square region of SRR Scheme decreases with respect to time as compared to the energy consumption of inner square region of Divide and Rule Scheme. Hence, showing approximately 50% decrease in energy consumption by inner region nodes in proposed Scheme.

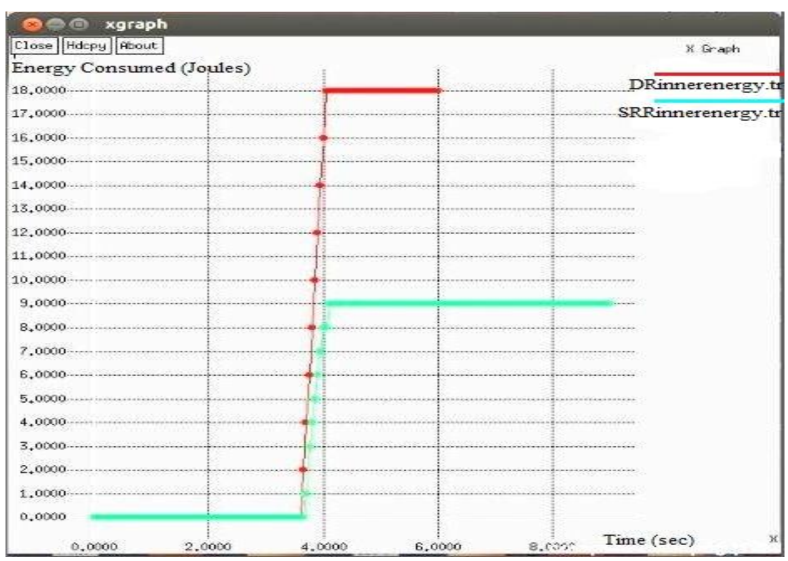


Fig. 6.6 Graph- Comparative graph of inner region showing Energy Consumed v/s Time graph of Existing and Proposed Work

- **Middle Region Energy Consumption:** The graph in fig-6.7 shows that the energy consumption of middle square region of SRR Scheme decreases with respect to time as compared to the energy consumption of middle square region of Divide and Rule Scheme. Hence, showing 80% decrease in energy consumption by middle region nodes in proposed Scheme.

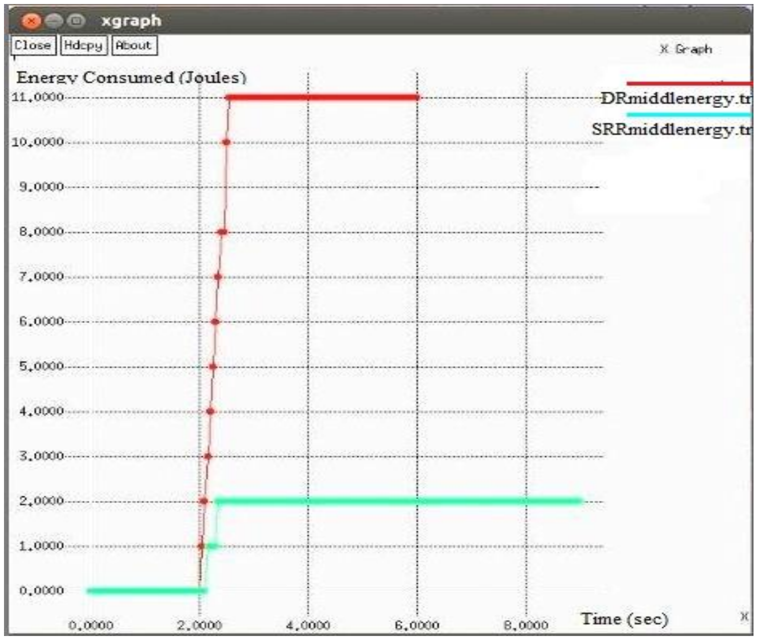


Fig. 6.7 Graph- Comparative graph of middle region showing Energy Consumed v/s Time graph of Existing and Proposed Work

Energy consumed by sensor nodes in proposed work in both inner and middle region is shown in figure 6.8 to 6.9.

- **Sensor nodes inner and middle region Energy Graph:** The graphs in fig-6.8 and fig-6.9 shows that energy consumed by inner region sensor nodes is less due to addition of relay nodes in inner and middle region. As the routing of data from cluster head of middle region to sink is done through relay nodes of inner region and not through inner region nodes, therefore the sensor nodes present in inner region only senses the information and transmit it to the base station without any multi-hop relay. Hence the energy consumed earlier due to multi-hop message relay through inner region nodes is decreased. Thereby, increasing the lifetime of inner region sensor nodes.

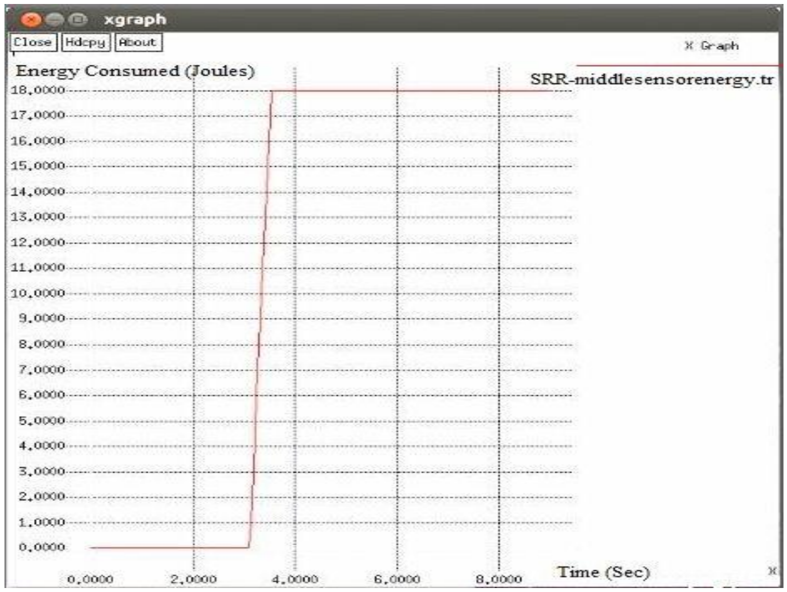


Fig 6.8 Graph- Energy v/s Time of middle-region Sensor nodes

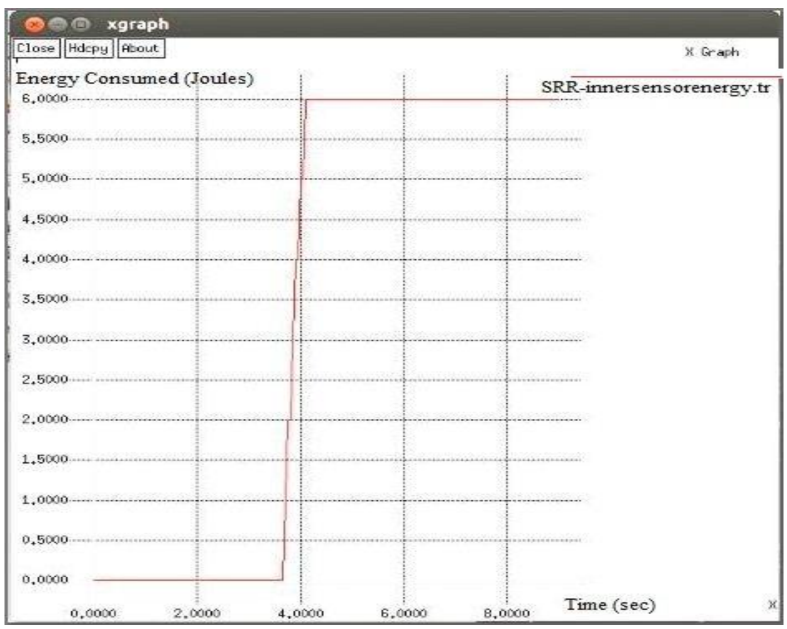


Fig 6.9 Graph- Energy v/s Time of inner-region Sensor nodes

Energy consumed by relay nodes in proposed work in both inner and middle region is shown in figure 6.10 to 6.11.

- **Relay nodes inner and middle region Energy Graph:** The graph in fig-6.10 and fig-6.11 shows the energy consumed by inner region relay nodes and middle region relay nodes. It is depicted from the graph that the energy consumed by middle region relay nodes is 1% higher as compared to the energy consumed by inner region relay nodes.

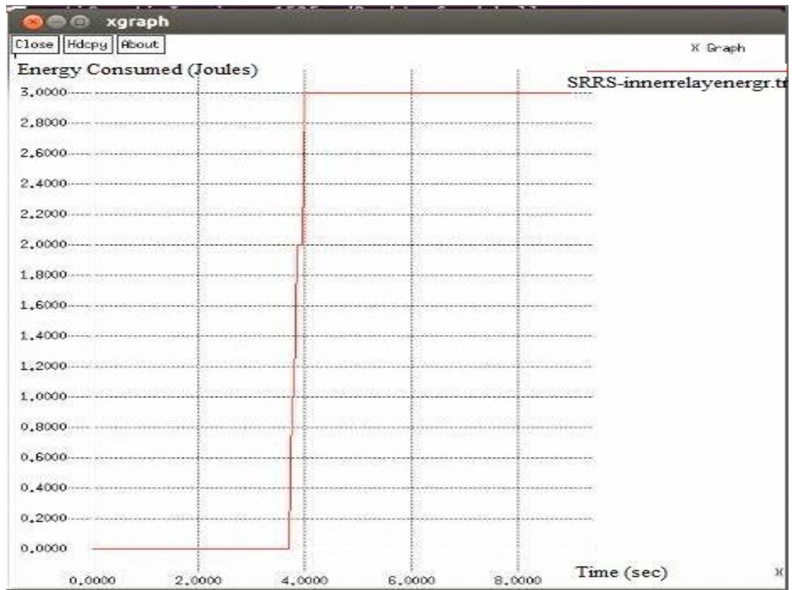


Fig 6.10 Graph- Energy v/s Time of inner region relay nodes

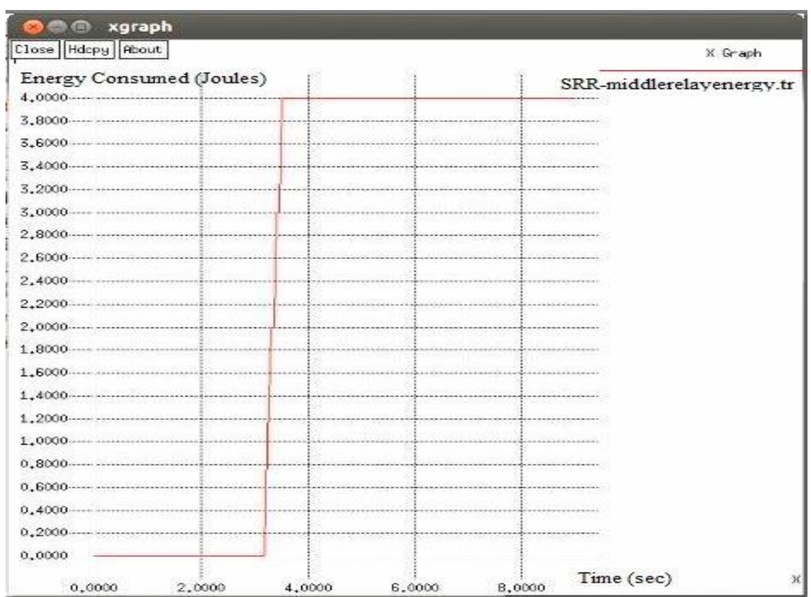


Fig 6.11 Graph- Energy v/s Time of middle region relay nodes

The graphs given in figure 6.12 to figure 6.14 represent the comparative graph SRRS v/s D & R Scheme for delay, packet loss and throughput respectively.

- **Delay Graph:** This graph in fig-6.12 shows that the delay in the network with respect to time decreases nearly 3 times in case of SRR Scheme as compared to in D&R Scheme.

Fig. 6.12 Comparative graph of Delay v/s Time in D&R and SRR Scheme

- **Throughput Graph:** The graph in fig-6.13 shows nearly 40% increase in throughput of SRR scheme as compared to D&R scheme.

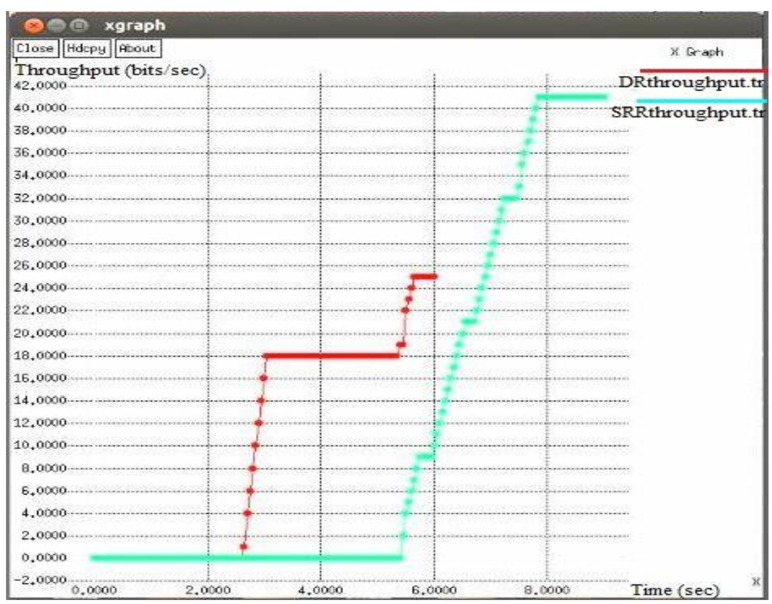


Fig. 6.13 Graph- Comparative graph of Throughput v/s Time in existing and proposed work

➢ **Packet loss Graph:** The graph in fig-6.14 shows that there is nearly 45% decrease in packets loss in SRRS approch as compared to that of D&R Scheme.

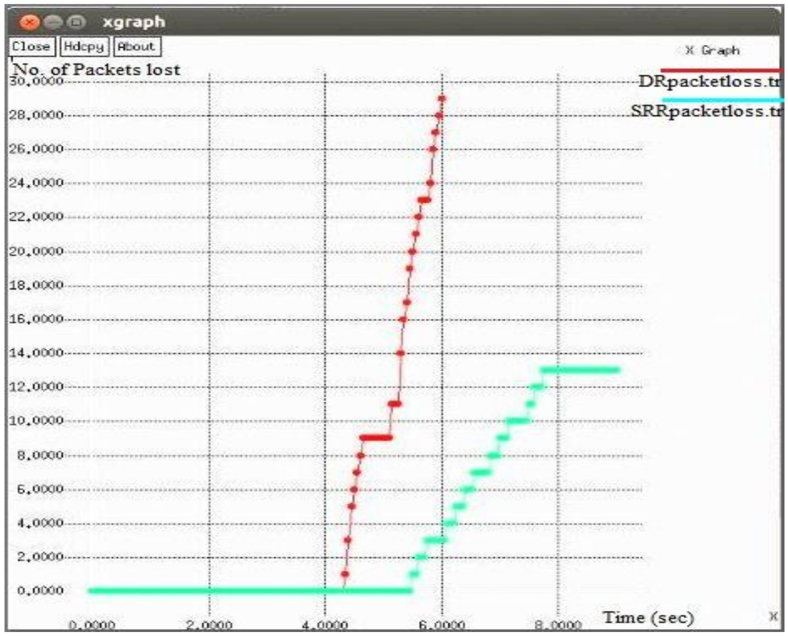


Fig. 6.14 Graph- Comparative graph of Packets lost v/s Time in existing and proposed work

CONCLUSION AND FUTURE WORK

The Dissertation is based on increasing the lifetime of sensor networks. In our Dissertation work we have simulated Divide and Rule scheme and developed a new scheme i.e Segregated Receive and Relay Scheme.

In Divide and Rule Scheme, the network area is divided into 3 square regions, inner, middle and outer regions and these regions are further divided into corner and non-corner regions. The simulation results of this existing work show that the energy consumption of the inner region nodes is more as compared to nodes present in middle and outer regions due to heavier message relay load. Hence, leading to decrease in lifetime of overall network.

To solve the problem faced by existing work we have added relay nodes in middle and inner region of the network area. The routing is performed through these relay nodes. The results shows that there is approximately 50% increase in lifetime of inner region nodes which leads to overall increase in lifetime of the network. Other parameters such as Delay, Throughput and Packet loss are also measured for both existing and proposed work. Delay and Packet loss decreases and throughput increases in our new scheme. Thereby, increasing the overall network performance.

In the future, we can further divide the outer region because the size of outer region is larger as compared to interior regions which may lead to routing overhead. This problem can be more in case there are large no. of sensor nodes. Each division of outer region shall contain their own cluster head hence performing routing through cluster head nodes. As the area of various regions is reduced, the communication between Sensor Nodes and Cluster Head of the same region will lead to less energy consumption.

Further we have found that as the sensor nodes in corner regions has forward data to the nodes present in non-corner regions that lie in shortest communication distance of the corner region nodes hence leading to more stress on sensor nodes present in non-corner regions leading to more packet loss. This problem can be more serious if there are large no. of sensor nodes present in corner regions. Therefore, to remove this stress we can deploy CH in each corner region so as to perform CH to CH routing between corner and non-corner regions.

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