CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.1. Wireless Sensor Network Technology

Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors that monitor conditions in an environment such as sound, temperature, vibration, motion, pollutants and physical conditions and activities Originally developed for military usage, with advancement of technology and resources application of Wireless Sensor Network has now been extended to areas as diverse as industrial process monitoring, health monitoring, environment monitoring, traffic and home automation, to name a few.

Most sensor nodes, with few exceptions, consist of the following parts:

- Radio transceiver
- Microcontroller
- An energy source, usually a battery.

Size of a sensor node may be small or big depending upon the functioning 'motes' of its microscopic dimensions. Average cost of a sensor node, varying from a couple of hundred dollars to less than thousand dollars, is determined by the size of sensor network and the complexity involved in each component. Size and cost constraints restrict available energy, memory, computational speed and bandwidth etc of the network.

A Sensor Network normally consists of a Wireless Ad-hoc Network or a multi-hop algorithm, which is supported by each sensor where nodes take the data towards the base station (BS).

Regular international seminars, workshops and knowledge sharing programs concerning Wireless Sensor Network (WSN) have added yet another dimension in the ever-expanding knowledge base in the field of Computer Science and Telecommunication.

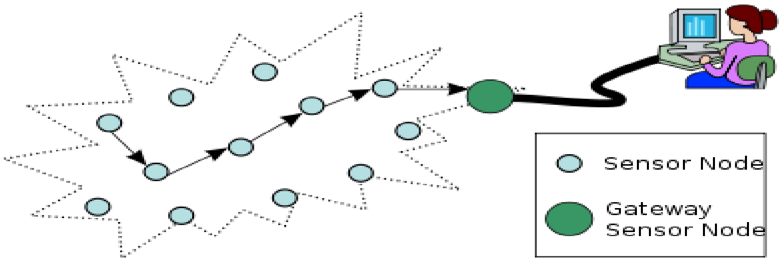


Fig 1.1: Typical Multihop Wireless Sensor Network Architecture [26]

A given environment changes and evolves every second. Natural as well as human environments have a number of attributes and utilities. Systematic monitoring of these utilities and the quick changes in them can provide immensely useful data concerning different environments such as industries, domestic environment, maritime, transportation and even completely natural environments with very little human activity. A WSN placed in any environment can collect data through its sensors, while simultaneously sifting the essential from trivial details without ignoring the latter and using it to further process the sensed data. The smart environments are extroverted as well as introverted since they not only consider the data from the surroundings but also from within the various nodes. WSNs located in different geographical locations provide information to the Main Station, which ranks relative quantities, observes and gathers data, estimates and analyzes information, gathers useful displays for users and makes the right and timely decisions and makes the alarm functions easy to begin placing pinpointed responsibility to concerned nodes in the WSN.

New developments have proven the significance of sensor networks like the DARPA SENSIT program [27] military programs, and NSF program [28] based on funded initiatives. The diagram below illustrates complications of wireless sensor networks made up of a network that acquires data and distributes the data, watched and regulated by a centre of management. Surplus of modern and new technologies makes the selection of parts complicated. There should be a conscientious, homogenous, boisterous system for all.

The study of wireless sensor network requires vast knowledge from a great variety of programs, making it quite interesting though a challenging field. Certain important topics will be covered in this chapter like communication networks, wireless sensor networks and smart sensors, physical transduction principles, commercially available wireless sensor systems, self-organization, signal processing, decision-making and also few topics of domestic automation.

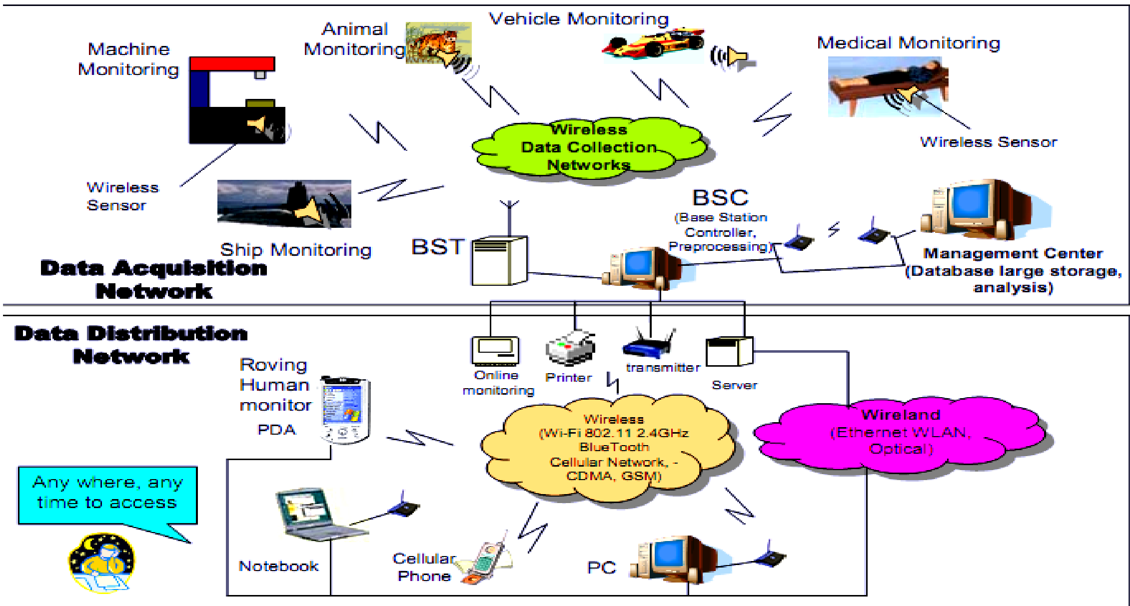


Fig 1.2: Working of WSN [29]

1.2. Application of Wireless Sensor Network

Uses of WSNs include typical applications like observing and monitoring, tracking and measuring [69]. Some specified applications include habitat observing, object tracking, fire detection, land slide detection, level and temperature sensors and traffic observation etc. Sensor nodes are used to collect data for WSN in a given setting, and for that purpose it is deployed in a region where it could gather the required data through its sensor nodes.

1.2.1. Area monitoring

Area monitoring/observing is a commonly used application of WSN. The Network is deployed in an area where monitoring has to occur. In a battle field, for example, in order to detect the adversary's interference or movement, large numbers of sensor nodes have to be deployed. After detecting or observing the parameters such as heat, pressure, sound, light, electro-magnetic field, vibration etc, the sensed data is then sent to a base station, and convenient actions are taken in order to tackle the situation accordingly e.g. spreading the message on internet or satellite. WSNs can also use a number of sensors in order to ascertain the presence of intermediaries like cars, motorbikes and trains.

1.2.2. Environmental Monitoring

Due to the forerunner nature of projects, different WSN are deployed for environmental scanning in which many proved to be short lived. The state of Permafrost in the Swiss Alps: The PermaSense Project [30], PermaSense Online Data Viewer [31], ASTEC Project [32] and glacier monitoring are some examples deployed sensors currently in use.

1.2.3. Greenhouse Monitoring

WSNs are installed in greenhouses where they scan the temperature and humidity and take the corrective measure when they reach a certain level. Greenhouse managers are alerted, through cyber visions, for the changes taking place while triggering the host system to take necessary corrective steps such as switching on the misting system, opening vents; turning on fans and other equipment in order to keep changes in the system under control. Some WSNs can be changed according to the needs of application as they are easy to install.

1.2.4. Landslide detection

A slight movement of soil is forecasted through WSNs before a land slide actually happens. With the help of WSNs gathered information makes it possible to forecast the event in real time with accuracy. Preventive, damage control or safety measures can then be taken effectively.

1.2.5. Machine Health Monitoring

Machinery Condition-Based Maintenance (CBM) [33] has been using WSNs, which have proved useful in terms of cost saving and low expenditures though wiring costs somehow limit the installation of sensors (cost $10-$1000 / ft). Wireless sensor is a new invention that is particularly useful in accessing otherwise inaccessible areas, rotating or moving machines, monitoring in dangerous or prohibited locations, and mobile assets etc. Standard techniques are still used by companies to check and gauge their equipments that incurs considerable costs on employing labor, maintenance of the equipment and that too with some risk of errors. US navy has therefore started employing WSNs instead to reduce the number of personnel on their ships as well as to reduce the errors and costs while boosting the basic monitoring (technical, security, emergency alarms) systems

1.2.6. Water/Wastewater Monitoring

Wireless sensors networks can be used in industrial units for water purification. Facilities that cannot be wired for power or data transmission can effectively function through use of wireless I/O devices and sensors using solar panels or batteries, for power. WSNs can be used to monitor the data from such underwater sensors that in turn are powered through solar energy. It is also used on ships for separating oil and water and thus minimizing water pollution.

1.2.7. Landfill Ground Well Level Monitoring and Pump Counter

Water levels in grounds and wells in the landfill site and the continuous addition and removal of waste in water are monitored through WSNs. A submersible pressure transmitter and a wireless machine monitor the waste level in water. There is a central data logging system which keeps the data of level provided by sensors, calculates it or informs the working men for a vehicle to provide appropriate services. The data is transferred from sensors to the central data logging system through a wireless device.

Leachate or waste removal pumps along with totalizing counter situated at the top of well are installed in order to monitor pump cycles and also the total amount of waste removed from the well. Although it is not common to use wireless devices to collect and transmit data from pumps to central control location (because usually the counter is read manually) yet wireless devices are used to save time and minimize chances of errors. Data transmitted to the control centre is used to check the operating pumps, extract waste volume from water and organize maintenance of the pumps.

1.2.8. Water Tower Level Monitoring

Small communities and neighborhoods are provided water with suitable pressure through water tower that store water and pressurize it in peak time of use in order to make sure that water is available to all users. Sensors designed to operate under water can monitor the level of water in these towers and transmit the data back to a control centre. They transmit data wirelessly as the maintenance of water level in these towers needs a significant check and control. Pumps are used for moving water from reservoirs to the towers when the level of water falls.

1.2.9. Agriculture

Use of Wireless Sensor Network (WSN) devices is getting popular in agriculture as a new advancement in this filed. Certain important issues like gravity fed water systems and control of pumps has now been made easy through use of pressure transmitters to monitor water tank levels and wireless I/O devices. Use of water can also be measured and transmitted wirelessly to a control location for billing. More efficient use of water and deduction of waste and leachate in water have been made possible through these new automated irrigation techniques.

1.2.10. Fleet monitoring

In a fleet where there are a large number of vehicles it is possible to put a mote with a GPS module on-board each vehicle. Motes detect position of various vehicles through GPS module to coordinate the whole operation effectively. In operations where the fleet is used to transport food, medicine or chemicals or explosives etc, safety of the cargo can be enhanced through this system where the motes are connected to temperature sensors to avoid any disturbance of cold or hot in severe conditions.

1.3. Implementation issues in operationalizing a Wireless Sensor Network

Conceptualizing and designing a WSN is a challenging area, however it is even more difficult to convert block diagram into a user end product with the help of trade-offs evaluated in different levels at the design stages. The cost and technical considerations involved in the implementation stage add further to this difficulty.

Block diagram of a Wireless Sensor Network is shown in the figure 1.3. The sensor node consists of an antenna - a protocol used for communication, radio frequency transceiver, random access memory, read only memory, an application processor and a transducer. Sensor node requires a long-duration battery for uninterrupted communicate to avert energy scavenging.

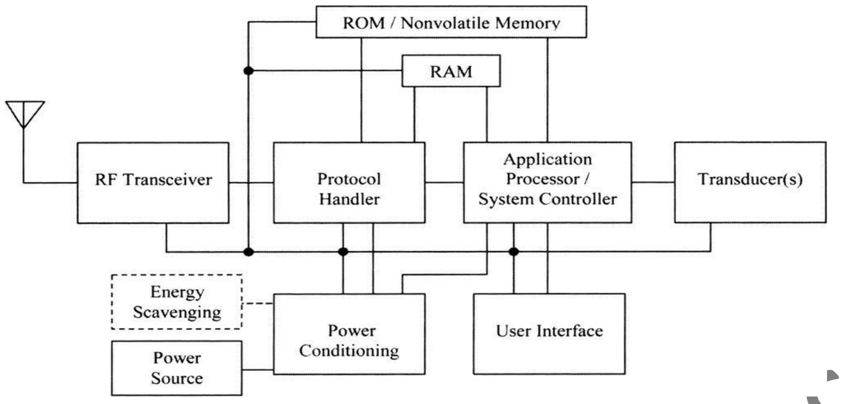


Fig 1.3: A Generic Wireless Sensor Network Node [34]

1.4. WSN Node Architecture:

A Wireless Sensor Node (WSN) is also called as “mote”; it is a node in a wireless sensor network used for processing of data. It senses any type of data and can communicate with different nodes in the wireless sensor network as well as with the outside world. Sensor nodes are deployed in a physical environment in order to gather data like sensing temperature, monitoring any routine (movement of animals) or unusual (e.g. terrorist) activity, weather forecasting and on railway tracks in order to signal an incoming train. The design of a wireless sensor network is shown 1.4.

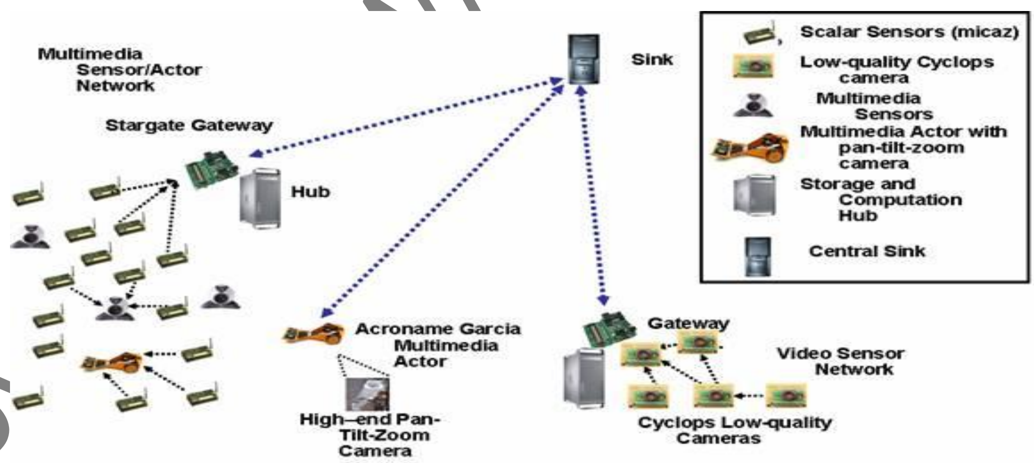


Fig 1.4: Design of typical WSN [35]

1.4.1. Components of a Sensor Node

Various components of a wireless sensor network shown in the diagram above include parts such as controller, transceiver, memory, battery and sensors etc [70].

1.4.1.1. Controller

Controllers, used in wireless sensor nodes, play an important role in data processing as well as data controlling inside the node. These controllers are mostly microcontrollers but there are few other controllers which in addition to the above functions are used as digital signal processor, desktop microprocessor, FPGAs and ASICs. The special type of controllers used in sensor nodes are the best option for majority of embedded systems due to their low cost, ease in deployment, easy connectivity with their neighboring sensor nodes, simple programming and last but not the least their low power consumption. Since microprocessors consume more power as compared to controllers it is always better to use microcontrollers rather than the microprocessors in sensor nodes. Application of digital signal processing is mainly for broadband wireless communication but as regards Wireless sensor Network, the wireless communication should be self-effacing i-e it should be simpler, should easily process different modulation techniques so that the signal that will go through processing stage will be less complicated.

If we compare Digital Signal Processing with traditional microcontrollers than it would be very difficult to use DSP in wireless sensor nodes. However, if we want to use FGPAs, first we have to reprogram it and then reconfigure it according to sensor node requirement. These factors will consume more time as well as energy as compared to the optimal level.

1.4.1.2. Transceiver

Better use of ISM band in wireless sensor network provides free radio as well spectrum allocation. Various options of transmission are available for wireless sensor network including Optical Communication (LASER) and Infrared. LASER can be used for wireless sensor network due to its low power consumption but it requires line-of-sight for better communication; secondly it is also very sensitive to the atmospheric conditions. In case infrared rays are used for wireless sensor network then there will be no need of antennas but the result will be limited broadcasting capacity. Wireless Sensor Network uses Radio Frequency (RF) which is more suitable for this purpose. WSN has free licensed frequencies which are 173MHz, 433 MHz, 868 MHz and 915 MHz up to 2.4GHz.

Transceiver can be defined as “transmitting and receiving of signals are done through one device i-e antenna”. These transceivers are used in wireless sensor nodes. Transceiver system has different identifiers i.e. they can transmit and receive signals in active as well as in sleep state. Transceivers which are based on new technology have built-in machines which perform majority of such operations automatically.

During most activities of the wireless sensor network, transceivers operate in idle mode and help in saving energy. Energy saved this way equals to the power consumed in the receiver mode. Hence it would be a better idea to turn-off the transceiver system in sensor node rather than operate it in idle mode. This process will work when there is no transmission and during receiving mode. In order to operate in such conditions, it will save considerable amount of power when sleep mode is switched to transmit mode in order to send data.

1.4.1.3. External Memory

External memory is a fundamental consideration in actual deployment of wireless sensor network. External memory can be on-chip memory as well as off-chip memory of microcontroller and flash memory. In majority of cases, flash memory is used for wireless sensor network.

Since memory requirements for wireless sensor networks are application dependent, researchers have introduced two broad categories of memory: a) User Memory for storing user (personal) data or different applications used by a sensor node, and b) Program Memory: The memory used for programming purpose.

1.4.1.4 Power Source

Power is the main resource for wireless sensor node. Sensor node consumes more power when it senses any external environment and sends that data to the neighboring node. However it consumes less energy while sensing external environment as well as processing sensed data. Research has proved that energy consumed by transmitting 1Kb of data within a distance of 100m is almost the same as energy consumed by processing 3 million instructions per second. Power required for such operation can be thus stored either in batteries or in the capacitors located in the sensor node.

The batteries used in wireless sensor nodes are of two types: a) Rechargeable. b) Non-Rechargeable. These batteries are also categorized with respect to the electrochemical material used by the electrodes i.e. (nickel-cadmium), NiZn (nickel-zinc), Nimh (nickel metal hydride) and Lithium-Ion.

Recent researches have led to the development of self recharging batteries that use solar energy, vibration or temperature. Researchers have categorized power saving into two broad policies i.e. Dynamic Power Management (DPM) and Dynamic Voltage Scaling (DVS). DPM are used to turn-off those parts which are not currently active or in use. DVS on the other hand is desgined to vary the power levels which depend upon un-deterministic workload in sensor nodes. This varying in voltage with the frequency results in quadratic lessening of power consumption in wireless sensor nodes.

1.4.1.5 Sensors

These are hardware devices used for monitoring conditions as diverse as temperature and pressure or a terrorist activity. Sensors are used to process physical data of that area in which they are deployed to monitor any change in the condition being monitored. According to general architecture of wireless sensor node, the sensor “senses” the external environment. The sensed data is in the analog form which is then digitized by a special modulation technique. This job can be performed by Analog-to-Digital Converter. Small size is an ideal characteristic of wireless sensor node so that it consumes less energy and can perform efficiently for long periods.

Typically, wireless sensor node has a very small electronic device that performs its task using very low power i.e. less than 0.5-2Ah and 1.2-3.7 V. Sensor nodes are categorized into following three categories:

- Omni-Directional Sensors: Used for sensing data instead of manipulating the physical environment through active inquiry. They have a self-powered nature which means that they will use energy in great volume whenever high amplification of analog signals is required. No concept of direction is involved in processing in these sensors.
- Narrow-Beam Sensors or Passive Sensors: These are passive sensors that have well defined concept of direction of processing e.g. ‘camera’

- Active Sensors: Used for sensing the external environment very closely e.g. radar sensors or seismic sensors which detect the alarm waves created by small explosions.

Most theoretical works concerning wireless sensor network are described by Passive or Omni-directional sensor. As every wireless sensor node has its own coverage area, within that specified area it senses the data, processes that data and if needed sends it to the neighboring node in an accurate manner. Also there might be various power consumption sources in wireless sensor node which are: conversion of physical signals to electrical signals, condition of signals, analog to digital and digital to analog conversion.

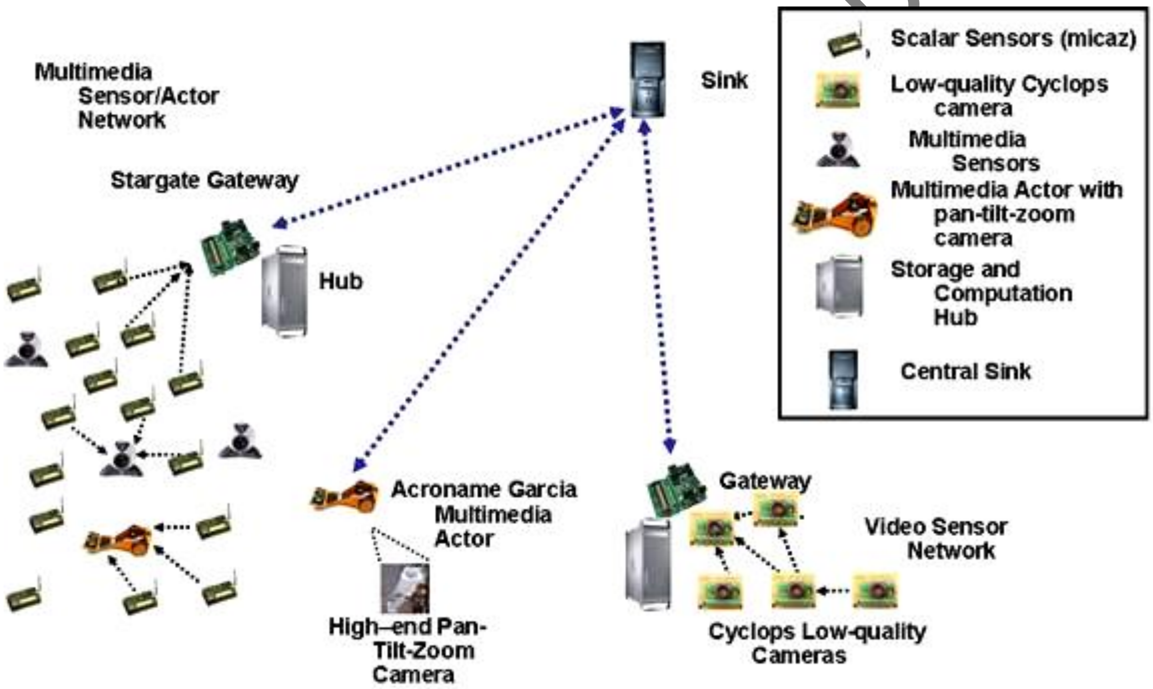


Fig 1.5: Architecture of Wireless Sensor Network [71]

CHAPTER 2

LAYER-2 DATA LINK LAYER

CHAPTER - 2

LAYER-2 DATA LINK LAYER

2.1. Data Link Layer

OSI model is composed of seven layers, in which data link layer is the second layer of OSI model. Mainly, the research work is on Layer-2 Data Link Layer. This chapter is a detailed overview of Data Link Layer and sublayer of Data Link Layer i.e. MAC sublayer as shown in fig 2.1.

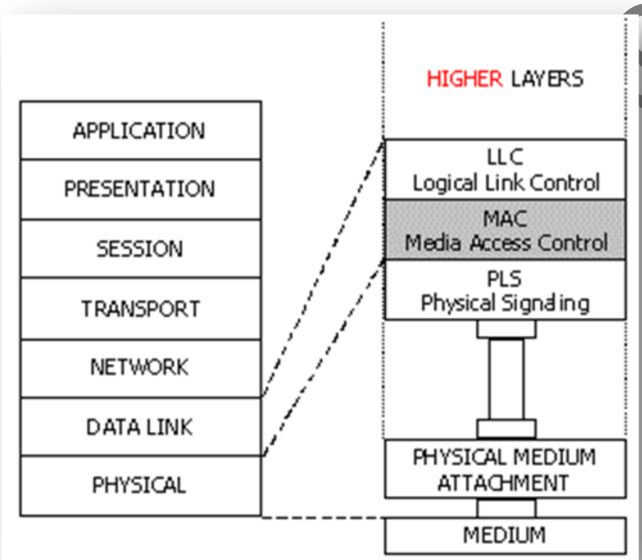


Fig 2.1: OSI Model [68]

Layer-2 Data Link Layer is responsible for delivering data to different nodes in the network in Local Area Network or wide Area Network. Also it is responsible for sending data in correct form due to protocol used in Layer-2 i-e error detection and error correction. Few examples of Layer-2 are: Point-to-Point Protocol (PPP), ADCCP, and HDLC.

The main role of the Layer-2 (Data Link Layer) is to deliver packets/frames between different nodes in the same Local Area Network or in the same Wide Area Network. In this layer data is combined with the control information to form Protocol Data Unit (PDU) that is not supposed to cross boundaries of the same network i.e. LAN/WAN.

In most cases where two nodes want to send data at the same time to the central node called 'sink', there are chances of collision at the sink node. This results in dropping or loss of data packets thereby compelling the transmitter to send the data again. This obviously leads to use of extra energy, data loss in the network resulting in an inefficient system. So the Layer-2 is responsible to fix this issue through its special protocols i-e CSMA/CD or CSMA/CA. These protocols work to minimize the ratio of data collision in the network.

Improper or misuse of hardware can cause damage to data packets/frames as they reach their destination points. The packet/frame header carries data about the source address and destination address informing the network about the origin and final delivery point of the data packet. In Network layer, just like hierarchical and routing protocol, Data Link Layer also uses flat addressing technique which means that there will be no part address that can be used to rectify the physical or logical group to which address they belong.

The Data Link Layer (Layer-2) is responsible for delivering of data across Physical link. This delivery can be *Reliable* or *Unreliable*. Majority of protocols in Data Link Layer are unable to provide *acknowledgement* for packet/frame acceptance; secondly many protocols are also unable to provide *checksum* in order to check data transmission errors. Therefore, in these cases, protocols which belong to higher level in the OSI model perform acknowledgement and retransmission of data as well as checksum job for Data Link Layer.

2.2. Models of communication

Mainly, communication model in Data Link layer is divided into two broad categories:

- Connection-oriented communication.
- Connectionless communication.

2.2.1. Connection-oriented communication

In Telecommunication, in the 'Connection-Oriented' model (CO mode) nodes use a protocol to establish end-to-end physical or logical connectivity for data transmission that are located at the end points of the network. CO-mode communication is however not always as reliable for the networks which may provide successful acknowledge after successful delivery of data and also a repeat function which should be generated automatically in those cases where the data is missed or faced some kind of error.

Few examples of CO-mode are Public Switched Telephone Network (PSTN), Integrated Service Digital Network (ISDN), Synchronous Optical Networking (SONET), Synchronous Digital Hierarchy (SDH) and Optical Mesh Networks (OMN). If we compare Circuit Mode with Packet Mode, the circuit mode provides best guarantee of data delivery within the constant amount of bandwidth and delay. However Packet Mode, also called Virtual Circuit Mode, suffers from variation in bit rate as well as delay due to fluctuations in traffic load as well as length of packet queue in the network.

TCP (Transport Layer Protocol) is connection-oriented transport layer protocol which may be based on connectionless oriented protocol i.e. IP achieving delivering of data in byte-stream in the form of segmented allotment of numbers on the receiving edge and re-arrangement of their order at the source edge. The typical working of TCP is shown in figure 2.2.

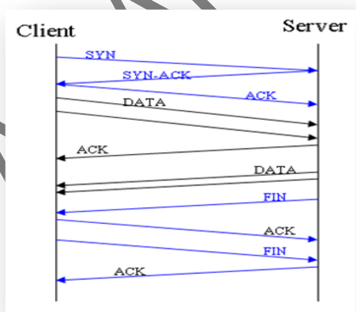


Fig 2.2: The diagram shows the typical TCP connection. [64]

Packet Switching uses connection oriented technique in which entire data is sent through the same network path (LAN/WAN) in one session. The protocol used by packet switching technique does not guarantee the routing information i.e. source and destination address in the packet, but it has only channel stream number usually called Virtual Circuit Identifier (VCI) [65].

Various examples of connection-oriented communications are:

- TCP based on Datagram Protocol (IP Protocol)
- X.25
- Frame Relay
- GPRS
- ATM
- MPLS

2.2.2. Connectionless Communication

In Connectionless Communication, method of data transmission technique contains all the information in the header of the data packet including receiver address to allow the self-governing delivery of the data packet to its destination through the network. A Data packet sent via network in a connectionless communication model is often called *Datagram*. As compared to the Connectionless mode, the CO-mode first sets up a physical or logical data channel (connection) in order to exchange the data in the network as shown as in fig 2.3.

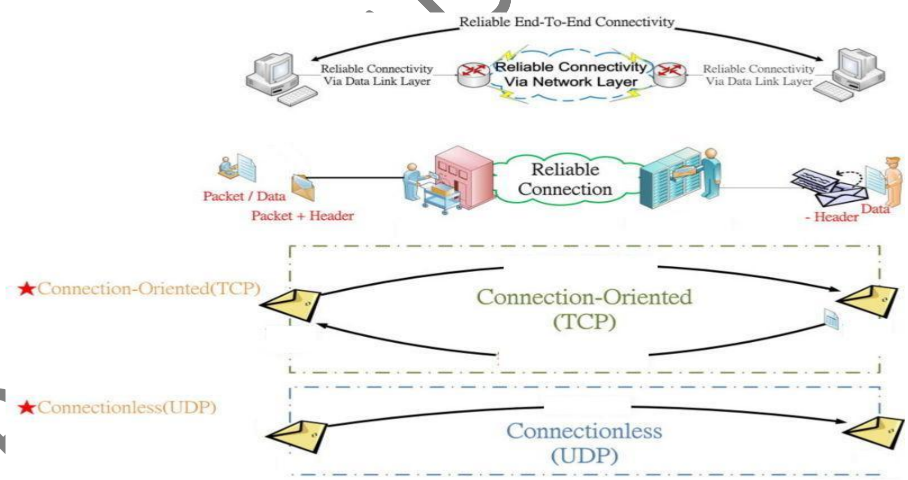


Fig 2.3: Connectionless Communication vs. CO-mode [66]

The main advantage of the connectionless communication model over the CO-mode is the low *overhead* in the network. The communication model is based on multicast as well as broadcast modes. This technique also reserves the network resources when the node sends the same amount of data to maximum number of its users. It uses Point-to-Point (Unicast) connection.

On the other hand, the main drawback of the Connectionless Communication is that when it transmits the packet, the service provider often gives no guarantee about loss of data in the network, error correction, data duplication, delivery failure and unordered sequence of data packets.

There is also a problem of cache or re-computation of routing information of the network when data has been sent through the network and the node re-computes its routing information on every hop. This technique unnecessarily wastes capacity of the network.

The dissimilarities between CO-mode and Connectionless Communication occur on several OSI Layers, which are:

- Transport Layer: UDP is connectionless and TCP is CO-mode.
- Network Layer
- Data Link Layer:

2.3. Sublayers of Data Link Layer

Data Link layer is further divided into two broad categories:

- Logical Link Control (LLC)
- Medium Access Control (MAC)

2.3.1. Logical Link Control (LLC)

The top layer of the Data Link Layer is the Logical Link Layer (LLC). Main functions of the LLC are to provide efficient flow control, acknowledgement of data packets as well as error announcements. Addressing as well Control functions are provided by LLC. It also tells the network about the mode of addressing as well control mechanism to be used in the exchange of data between two devices.

Functions:

Following functions are performed by the Data Link Layer:

- **Logical Link Control:** In order to establish the logical links connection between two devices in the network. Majority of LANs use LLC Protocol for IEEE 802.2.

- **Medium Access Control (MAC):** This technique is used to provide access to the network medium before any data is sent. Most networks use a shared medium in which MAC plays an important role in providing such rules to access the medium without any loss or congestion on the network. Some important protocols used by MAC are CSMA/CD and CSMA/CA.
- **Framing:** DLL uses encapsulation technique for higher level messaging which are converted into frames so that they may be sent to their required destinations.
- **Addressing:** DLL is responsible for address. It tells the network about the addressing mechanism so that the data packet follows the rules of address and reaches its final end.
- **Error Handling and Error Detection:** DLL is responsible for data integrity that usually resides in the lower layers of the OSI reference model.

2.3.2. Medium Access Control

The second sublayer of the DLL is the Medium Access Control Layer (MAC Layer). MAC Layer provides access to the network through CSMA/CD or CSMA/CA. In each data packet, there is a header of the MAC address.

Generally, we classify the MAC Layer into two categories i.e. Distributed MAC Layer and Centralized MAC layer. The mentioned categories are used for communication between two devices (nodes). MAC layers works as follows

"Suppose we have a group of people, and they started conversation. First of all, they will search for clues to start there communication in order to find who will start communication first. If two people start their communication at the same time, then one of the person in the group will back off and will give the permission to another so that all the persons in the network understand what he/she is saying. If they do not follow that rule, then there will be miscommunication among the group and no one will clearly benefit from the conversation"

MAC layer is also responsible for data starting and when that communication finishes. It also informs others when to start communication.

Media Access Control (MAC) is the sublayer of DLL known as Medium Access Control (Layer-2). The protocol is used in the network composed of several nodes that want to communicate with each other in a multipoint network model i-e LAN, WAN and MAN. MAC Layer uses a hardware known as **Medium Access Controller.**

MAC Layer provides an interface between the Physical Layer and the Logical Link Control (LLC). It uses full-duplex transmission mode in the communication model which may provide unicast, multicast and broadcast modes of communication.

2.4. MAC Layer - Addressing Mechanism

MAC Layer uses the Physical Address or MAC Address. MAC Layer uses a distinctive serial number. When that distinctive serial number has been allotted to a meticulous network at the time of network assembly the device will be indentified with the distinctive serial number which has been allotted at the beginning. Every device in the network will use different MAC address. This will enable the network to deliver data packets with accuracy and without errors.

It is not necessary for the MAC Layer to use full duplex PPP communication.

2.5. Channel Access Control Mechanism

The technique for channel access control is provided by Media Access Control Layer which is also called Multiple Access Protocol. This protocol helps the network in identifying as to which different stations share the physical medium. A typical example of Multiple Access Protocol is Bus Topology, Ring Topology, Hub Topology and also half-duplex wireless networks which use PPP links. The main advantage of Multiple Access Protocol is to detect as well as avoid any type of data collision which occurs in the network.

An important protocol used by Multiple Access Protocol is Carrier Sense Multiple Access with Collusion Detection (CSMA/CD). This protocol is awakened in the network when collision occurs in Ethernet Hub or Bus Topology.

2.6. Different Multiple Access Protocols

Few examples of Multiple Access Protocols in wired networks are:

- CSMA/CD

- Bus Topology
- Ring Topology

Few examples of Multiple Access Protocols in wireless networks are [67]:

- Dynamic TDMA
- PFDMA
- CDMA
- Slotted ALOHA
- CSMA/CA

2.7. Different Protocol Examples:

Different protocols used by MAC Layers are as follows:

- ATM
- ARCNET
- CDP
- CAN
- Econet
- Ethernet
- EAPS
- FDDI
- Frame Relay
- HDLC
- LocalTalk
- SLIP
- Starlan
- PPP
- MPLS
- Token Ring
- UDLD

Different protocols used in Wireless Sensor Network:

- Sensor MAC (S-MAC)
- Wise MAC (W-MAC)
- Traffic-Adaptive MAC Protocol (TRAMA)
- SIFT
- DMAC
- SMAC
- Timeout-MAC
- (T-MAC)/DS-MAC:

CHAPTER 3

LITERATURE SURVEY

CHAPTER - 3

LITERATURE SURVEY

Existing protocol to control wastage of energy and congestion in mobile wireless sensor network are not really effective in addressing this problem. Congestion of cluster head creates overhead which entails considerable amount of energy, packet loss and delay in the network. A network that is free from these ills must be able to assign time slots to different mobile nodes in the zone, and in each time slot a particular node should be active for communication and performing the assigned task.

There are various protocols to avoid congestion in wireless networks like CSMA/CA in IEEE 802.15.4 protocol for CR-WPAN which is used to cover beacon enable mode in [1]. In random way point Mobility model (RWP) and Ad-Hoc On Demand (AODV) routing protocol is being used in [1]. The protocol beacon enabled mode has been used for regulating the active period of a node. Cross layers terminology has been used in order to share information in between different protocol layers which helps in increasing interlayer interactions. In this scenario one major issue has been found i.e. interaction of MAC and transport layer operation results in collision as well as congestion are the major problems in the source packet loss in wireless sensor network. In this research paper, the Radosveta Sokullo and Cagdas Donertas investigate the relationship between the local contention resolution and end to end congestion, which is based on RWP. These protocols are used to evaluate the node density, transmission buffer size and operation mode on the network performance in different mobile scenarios. In this scenario, different mobile nodes take the roll of sink node on sequence routing basis. This process is used for equal distribution of energy consumption and enhances the network life time.

3.1. IEEE 802.15.4 WPAN

Low power consumption, network flexibility, low cost and low data rate are some of the important tasks in ad hoc. IEEE 802.15.4 is specially designed for addressing the LR-WPAN, which is used to provide self organizing functionality among fixed and moving nodes which generates throughput requirements, which is unable to handle the power consumption of heavy protocol stacks. It is used to cover the PHY as well as MAC LAYER of LR-WPAN. PHY is used to activate and de- activate the radio transceiver, energy detection (ED), Link quality indication (LQI), Channel selection, clear channel assessment (CCA) as well as transmitting and receiving packets across the physical medium.

Synchronization of different attached devices is done by beacon in order to identify the personnel area network and to describe the structure of super frame. Super frame consists of two periods i.e. active and inactive period. In this scenario the sensor node will be active during the entire duration of the superframe; however, the second node will be active for only half of the super frame direction. During inactive period, nodes will not interest with pan and can consume low power energy.

3.2. Mobility in WSN

Mobility in wireless sensor network is an important feature which is based on requirements of different applications. Mobility aspect can be characterized by the movement of various components i.e. movement nature, its speed, direction and rate of charge can affect the entire operation of different nodes. Mobility model describes the speed as well as location of different mobile nodes. Communication capacity can also be increased due to mobility environment, which enhances coverage area in the network. Different examples of mobility environment are fire fighter scenario, logistics scenarios, and medical scenarios.

3.3. Random Way Point Model

(RWP) uses synthetic model for mobility purposes for example in Ad-Hoc Networks. It is the basic element which is used for movement of different nodes. In RWP, each node moves in a zigzag pattern in a given area where the way-points are uniformly distributed.

In RWP the mobile nodes move in a given area without any restriction. To be specific, the destination, speed and direction and all such attributes are randomly chosen. RWP was first proposed by Johnson and Maltz and soon it became “bench mark” mobility model [1].

Kyoungseokoh, Seok Woo et.al discussed packet collision due to many to one traffic pattern under heavy traffic loads in [2]. Due to packet collision, extra energy is consumed which results in loss of energy in the network. In the mentioned research paper, they have proposed energy efficient MAC protocol. In this protocol, there will be full sleep cycle at different leaf nodes which helps in minimizing the load on leaf nodes in heavy traffic. In such environment, the leaf node goes in to full sleep state for one complete cycle, this leads to reduction of packet collision as well as reduce the consumption of energy which saves energy at low depth nodes.

However, DMAC protocol that has been used in this paper in order to improve the efficiency as well as consumes energy and latency while gathering data in tree structure.

Many to one scenario in tree structure which may lead towards packet collision as well as congestion at low depth nodes under heavy traffic environment. However, sink has the capability to handle low amount of input data. In this scenario, the input data degrades the network performance which results in packet collision and loss of energy.

The researchers have introduced full sleep cycle at leaf node [2]. In this scenario, if the traffic increases, the leaf nodes turn their transceiver into sleep state for one cycle. In such scenario, if a receiver node receives large amount of data flag, that node increases its duty cycling. This can be done by taking extra additional active periods. For example when the duty cycle is 10% sink can have a maximum of 4 receiving states for 1 cycle due to the duty cycle adaptation algorithm of DMAC protocol. In order to reduce the unnecessary energy consumption and to achieve extra energy savings, the nodes which are located at leaf of the network turn into sleep state of the frame structure for one cycle entirely as shown as in figure 3.1.

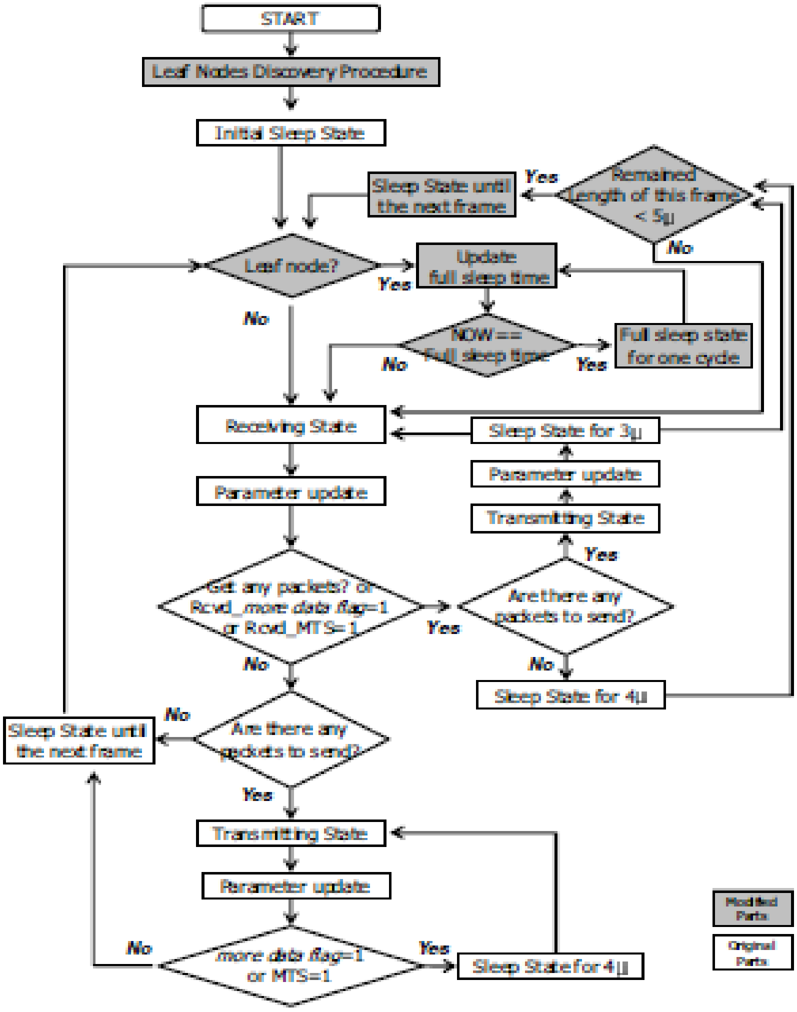


Fig 3.1: Flow chart of proposed protocol [2]

Yunlu Liu et.al have proposed Robust Routing Algorithm with Fair Congestion Control (RRA-FCC) algorithm in [3]. This algorithm has been used in order to reduce the congestion on the sink node. Sink is a node to which two or more devices send data at a time, the challenge is the congestion. RRA-FCC is an algorithm which is used to control congestion and thereby reserve energy for the network.

A typical wireless sensor network consists of one or two sink nodes, but new research techniques now enable to deploy tens to thousands of sink nodes in a region. If we compare this with Ad- Hoc Network, the following characteristics have been noticed.

- **Limited resources**: limited resources include energy processing capacity as well as memory to store sensed Data.
- **Low mobility**: the general scenario of WSN includes static nodes however; there can be very few nodes which can move in the environment.
- **Data centric**: data sensing is an important feature of WSN. The data has been sensed without knowing the IDs of which the nodes set the data [3].

In such conditions the scenario can be time driven or event driven. In both cases, congestion on sink node can occur. In such situations, size of the environment has been kept fixed where nodes will be deployed according to data centric phenomena of WSN. In this paper, they have divided the sensing area in to several regions which result the enhancement of packet transmission and reduce the cost. In this scenario, there will be no storage of routing table. The only thing which will be known is the subarea in which that data has been sensed by a particular area. Also there will be no sending of HELLO packets which is used for establishing the path which may help in preserving the node's energy.

3.4 NETWORK MODEL

In this model the WSN is composed of different sensor nodes, which are deployed in a two dimensional region that is divided into sub regions with each sensor node belonging to a sub region. There are sink nodes m>=1 which are used to sense data. The sensing region is divided into many sub regions which are based on geographical deployment of the nodes and the attributes of collected information. The last one is to setup the vector for each region which is based on distance between it and the sink node as shown in figure 3.2. The simulation of this research paper is done by OMNET++.

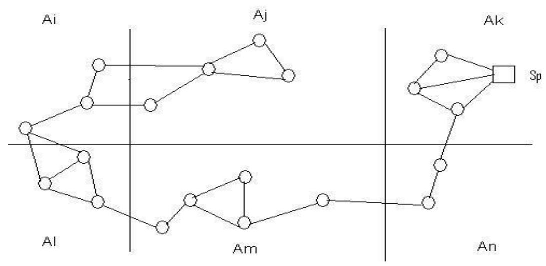


Fig 3.2: A Special examples of vector setting [3]

Mac Protocol for Wireless Senor Networks: A survey by Ilker Demirkol Cem Erosoy et.al has proposed several MAC protocols for wireless sensor network [4]. It is used to find the strength and weakness of MAC protocol used by wireless sensor network.

It has been noticed that by sensing and sending data from one node to another node or from one node to the cluster head consumes considerable energy as compared to the computation of data by sensor nodes or cluster head.

3.5. MAC Layer in WSN

MAC protocol should be designed in a manner that the designed network survives for long duration. However MAC protocol is not that efficient because of which the desired topology in the network fails and hence the network fails to survive for long duration.

3.5.1. Reasons for wastage of energy:

Controlling energy wastage is a big issue while working on MAC layer. Lot of energy is lost when one node receives more than one packet from different resources at a time. These results in dropping of second packet so the sender will again send that packet and will consume that much energy as it used in sending it for the first time. It means there transmission of packet consumes a lot of energy.

Another important reason of wastage of energy is "over hearing". Overhearing is a process when one receives extra packets that are not required. It means that the data has been broadcast over the network for one specific node but other nodes also receive the same data as 'unwanted' or extra packet.

The third reason of wastage of energy is the result of central pack overhead [4]. This can be minimized by using the minimum number of control packets for data transmission.

Another important reason for wastage of energy is the "idle listening". It is the process when the node is listening to a channel when idle that results in increase of traffic in the network. The last reason is "over meting". This can be done by sending packet to that node which is not ready for intake of the information. The result will be drop of the packet and extra energy will be required for re transmission of that packet

3.5.2. Definition of MAC Protocol Properties:

In order to design the MAC protocol well, following attributes need to be organized so that the network does not face congestion, energy wastage or drop of packets.

- Energy efficiency
- Scalability
- Adaptability

In order to prolong the life time of a network energy efficiency protocol need to be defined which helps the network overcome energy deficiency.

On the other hand network size and density of nodes for the network should be handled rapidly. In some networks there is limited node lifetime. Newly arrived nodes and changes in the interference act on the scalability as well as adaptability. However, other attributes such as latency, throughput and bandwidth should not be misunderstood while designing wireless sensor network.

3.6. MAC Layer Protocols

In this section various MAC LAYER protocol has been discussed in [4] which are as follow:

3.6.1. Sensor MAC (S-MAC):

Synchronization and periodic sleep/awake listening schedules depend upon these synchronizations. Various nodes from different cluster must follow the sleep schedule. This is the core idea behind SMAC. Another important concept of SMAC is the division of long message in to small frames and then to send them in the form of burst mode. This technique reduces energy consumption.

3.6.2. Wise MAC (W-MAC)

In this protocol all sensor nodes define two channels for communication where one is the data channel and the other is the control channel. The data channel is controlled by

TDMA technique whereas the control channel is controlled by CSMA technique [4]. These techniques require signal channel. WISEMAC uses Non-Persistent CSMA (NP-CSMA) [4] which is used for decreasing idle listening in the network as shown as in Figure 3.3.

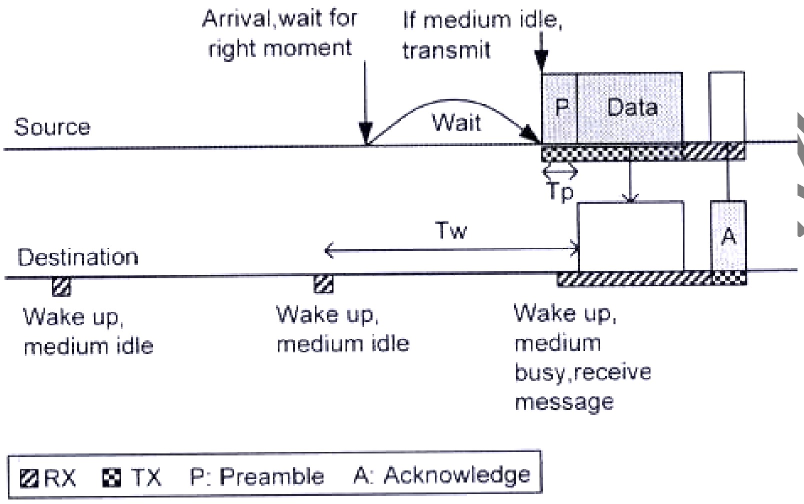


Fig 3.3: WiseMAC concept [4]

3.6.3. Traffic-Adaptive MAC Protocol (TRAMA):

It is a TDMA based protocol which increases the use of TDMA in the context of energy efficiency. This protocol follows random allotment of time to different nodes. It uses high ratio of sleep time due to which less collisions take place in the network vis-à-vis the CSMA protocol.

3.6.4. SIFT:

SIFT protocol is used for event driven sensor network and is used in the network when an event has been sensed in the environment. The crucial part of this protocol is the R and N reports based on low latency. If we compare 802.11 MAC protocol with SIFT, the latter clearly stands out in effectively decreasing latency in the network.

3.6.5. DMAC:

DMAC protocol achieves very low latency in the network. Secondly it is an energy efficient protocol. Low latency is achieved due to assignment of different time slots to different nodes at leaf which helps in successive data transmission is shown as in figure 3.4.

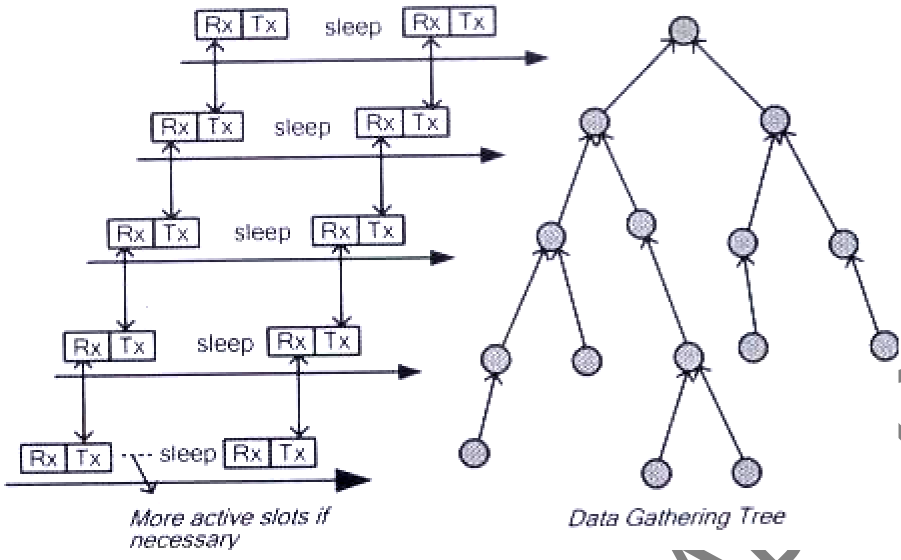


Fig 3.4: Data gathering tree and its DMAC implementation [4]

3.6.6. Timeout-MAC (T-MAC)/DS-MAC

From the above discussion it is clear that SMAC gives high latency and low throughput. This problem has been solved by introducing Time-Out MAC (T-MAC) protocol which is used to increase the poor results of SMAC under variable traffic. Further, when there is no occurrence of an event, it will stop its listening period immediately up-to a specific threshold "TA". However DMAC protocol adds some of its features of dynamic duty cycling to enhance the short coming of SMAC protocol with a view to decrease the latency as shown as in figure 3.5.

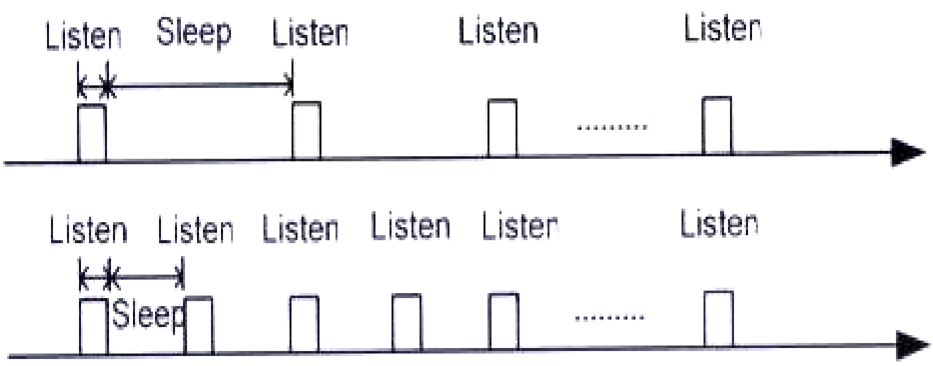


Fig 3.5: DSMAC duty cycle doubling [4]

Table 1: Comparison of MAC Protocol:

	Time Synch. Needed	*Comm. Pattern Support*	*Type*	*Adaptivity to Changes*
S-MAC / T-MAC / DSMAC	No	All	CSMA	Good
WiseMAC	No	All	np-CSMA	Good
TRAMA	Yes	All	TDMA / CSMA	Good
SIFT	No	All	CSMA/CA	Good
DMAC	Yes	Convergecast	TDMA / Slotted Aloha	Weak

Fig 3.6: Comparison of MAC Protocol [4]

The work of Celal Coken [5] introduces "An energy efficient and delay sensitive centralized MAC protocol for wireless sensor network" in which he proposed a new TDMA based MAC protocol that results in energy awareness and reduced delay in a network. In the proposed MAC protocol wireless sensor nodes conserve energy and also minimize the duty cycling technique and idle listening. In this protocol, when queue size exceeds highest threshold value, the cluster head will assign extra time slots.

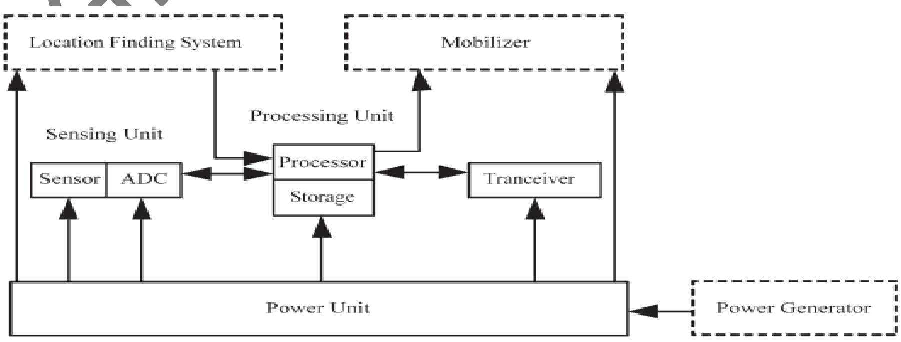


Fig 3.7: General architecture of WSN [5]

In traditional wireless sensor networks, energy consumption is based on communication cost and not only on processing. The functions of sensor nodes are receiving, idle-mode and transmission. The determining factor in energy consumption is the distance between neighboring nodes; greater the distance between nodes higher the energy consumed. Following are some important reasons for higher energy consumption by the nodes:

- ***Idle listening***: Sensor nodes sensing the medium for data throughout the session.
- ***Collision***: Collision occurs in the network when two nodes send data to one node. i.e. to sink node at the same time.
- ***Over hearing***: When sensor node receives data which is destined for other nodes.
- ***Central packet overhead***: Central packets should be small in size so that it requires less energy for transmitting it.
- ***Overmitting***: When the receiving node is not ready to accept the data.

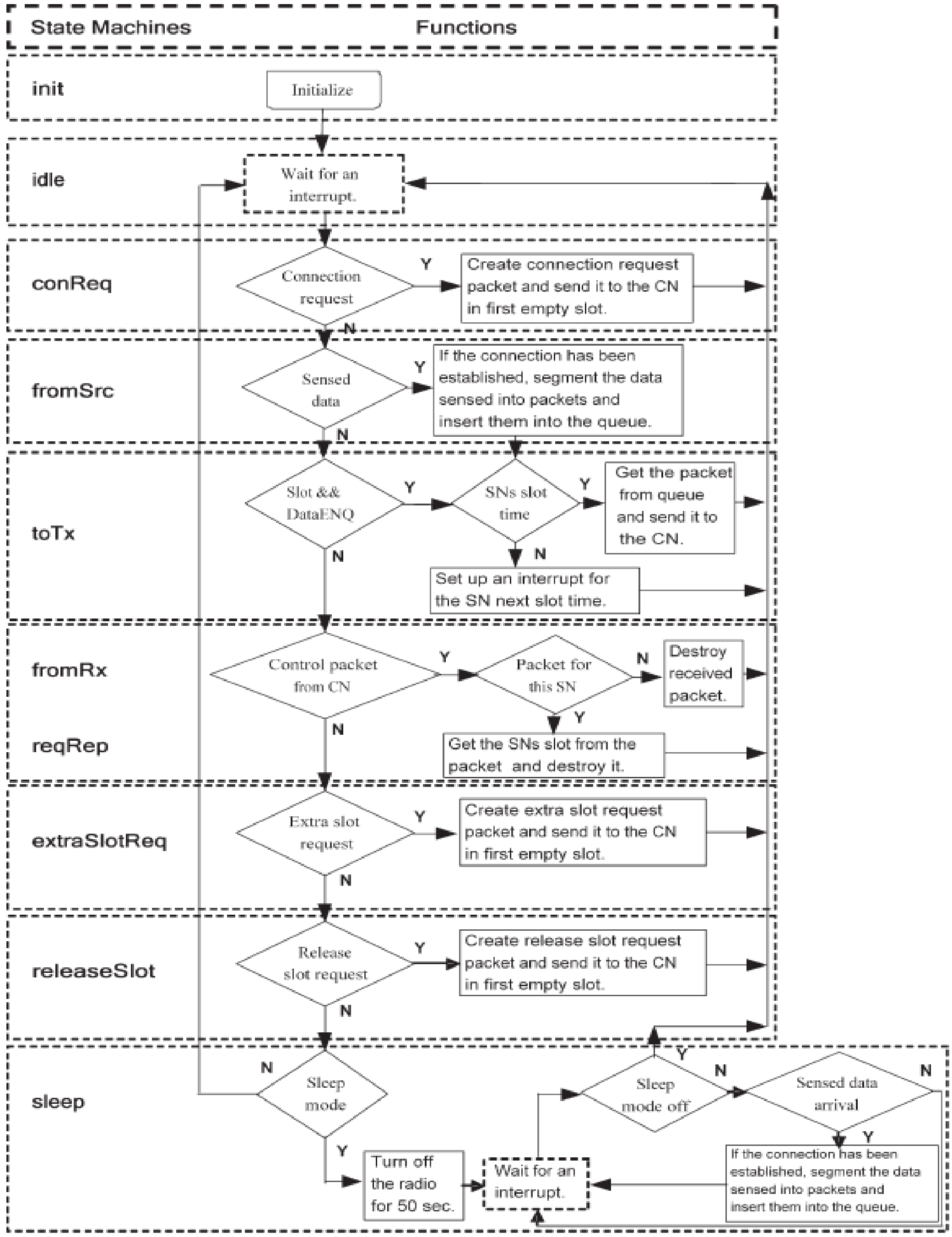


Fig 3.8: The SN MAC layer process Model Algorithm [5]

"Energy conservation in wireless sensor Network: A Survey" by Giuseppe Anastasi et.all has described various protocols and algorithms regarding delay and congestion in the wireless sensor network in [6]. It identifies limited battery power as the main issue in wireless sensor network functioning.

A wireless sensor node is a device which includes following components [6].

- The sensing subsystem
- The processing subsystem
- The memory

As already discussed, wireless nodes have limited battery power. If deployed in an environment where recharging of these batteries is difficult or impossible, the WSN could fail as shown as in figure 3.9.

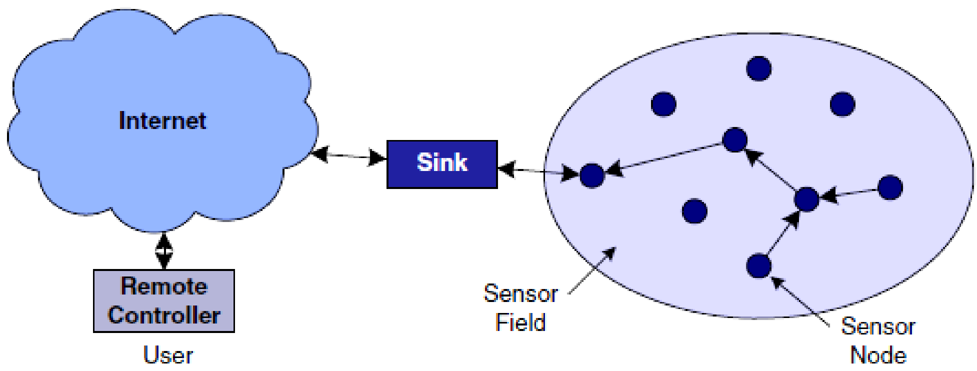


Fig 3.9: Sensor Network Architecture [6]

In this survey paper there is a network consisting of sink node i.e. cluster head and the rest are the large number of sensor nodes, as shown as in figure 3.9. Communication with the sink node is through multi-hop sequence that will avoid congestion and memory overloading. It has also been noticed that transmitting a single bit uses the same amount of energy as required for processing thousands of bits of information [6].

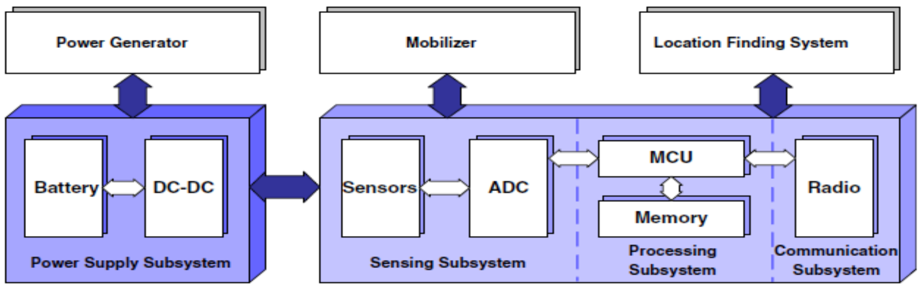


Fig 3.10: Sensor Node Architecture [6]

The figure 3.10 shows the general architecture of typical wireless sensor nodes. Mainly it is made of four basic components.

- Sensing subsystem
- Processing subsystem
- Radio subsystem
- Power supply unit

There are three important techniques which are mentioned in [6]. These are: *duty cycling, data driven approach* and *mobility*. Duty cycling technique is used when there is no sensing, the radio transceiver is turned off in order to save energy. On the other hand data driven approach is used when we want to minimize the amount of sampled data while keeping the sensing process more accurate. However, mobility plays an important role while minimizing the battery usage due to rapid changing in location as shown as in figure 3.11.

Fig 3.11: Taxonomy of approaches to energy saving in sensor network [6]

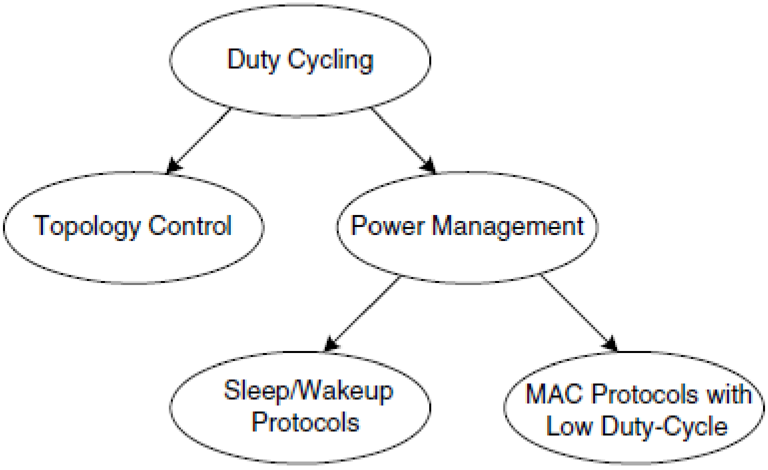


Fig 3.12: Taxonomy of Duty Cycling Technique [6]

Another approach for minimizing use of battery as well as memory overflow is the data compression. This technique is used when user wants high ratio of delivery. In this technique data has been compressed. This compressed data is sent to the sink node to reduce energy consumption as compared to that used in sending large number of data packets as shown as in figure 3.13.

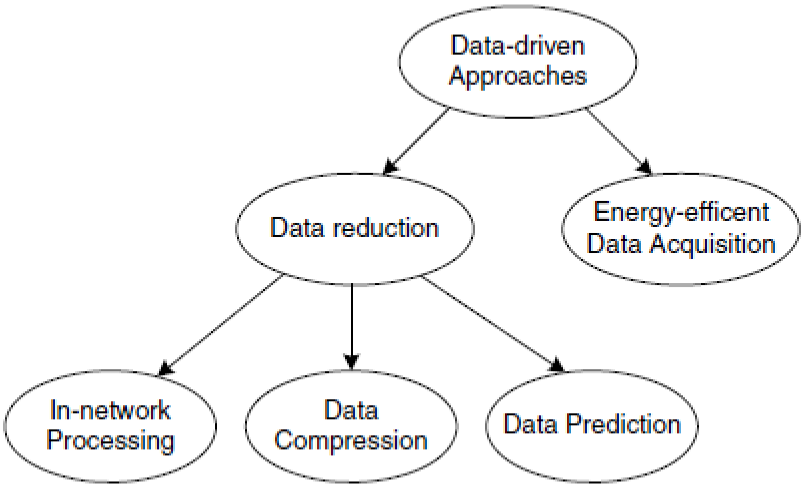


Fig 3.13: Taxonomy of data-driven technique to energy conservation [6]

'Connectivity-Driven' is another technique a periodic awake/sleep schedule exists of the sensor nodes. However Scheduled Rendezvous Schemes require high level of synchronization between different sensor nodes. In this scenario when one node is awake it means all the neighboring nodes are awake at the same time.

3.7. TDMA Based MAC Protocol

In this technique time slots have been arranged in sequence and assigned to each frame. This is the most important protocol which increases efficiency in TRAMA [15]. TRMA is the TDMA based approach which splits the time into two parts i.e. random access protocols and scheduled access period.

While deploying wireless sensor nodes in any physical environment, the assignment of cluster head is an important task. There are different techniques discussed while selecting cluster head in a given network [16] [17] [18].

Different models for assigning of cluster head have been proposed; some important techniques need to be observed in these models:

- WSN composed of large number of sensor notes and lesser count of master nodes.
- In WSN environment, all the sensor nodes are deployed to sense external data and send it to the master node with or without any processing.
- The master node which has high battery power as well as memory will collect data from different sensor nodes and process that data and analyze it for further usage.

There are different advantages of cluster head including convergence rate, cluster stability, awareness of the location, clusters overlapping, different nodes mobility and most importantly a long network lifetime [7]. In this research paper a modified WSN model called COSMOS (Cluster Base Heterogeneous Model for Sensor Network). Young mi back et.all proposed self adjustable rate control in wireless Body Area Network in [8]. This model has been used to reduce the rate of congestion as well as evaluation functions.

The algorithm used in this research paper is “reinforcement learning algorithm” [19] and “vector space model” [20]. Also Node level congestion [21] which increase the queuing delay as well as buffer overflow, which lead to packet loss in the network. The packet lost requires extra energy for retransmitting the packet again. However

Link level congestion [22] results in interference as well as collision. LLC occurs due to poor management of MAC protocol.

In [9] a simple active congestion control in wireless sensor network by Ying Oiyang, Fergyran et.al uses the active network (AN) technology, which is utilized for congestion control. The design of Back Pressure (BP) is used to allocate bandwidth proportional to the size of trace (ABPS) [9]. This protocol tells the node as how to respond to congestion and while also stabilizing itself after congestion occurs, as shown as in fig 3.14(a) (b) below.

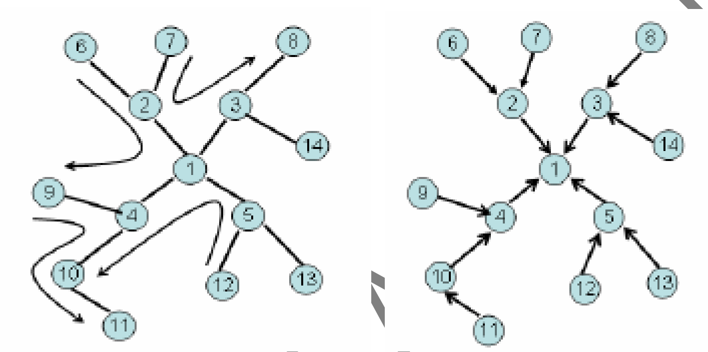


Fig 3.14 (a): Disordered traffic in traditional network [9] (b): Many to one traffic pattern in WSN [9]

In order to minimize battery usage there must be a stabilized algorithm which could give a clear response to increasing congestion as how to avoid it? When receiver gets more packets from different resources at the same time, collision between packets and memory overflow are unavoidable that result in dropping the packets. This problem is solved by ABPS [9].

In [10] Liu Yong Min and Nian Xiao Hong proposed a new solution to enhance network throughput as well as minimize delay in transmitted data. In order to measure the performance criteria of a wireless sensor network it basically uses the life expectancy of the network and the average flow of node with highest load [10]. Life expectancy shows the total time interval of that node which starts its basic functioning. On the other hand average flow of the biggest-load nodes is used to calculate congestion in the network.

3.8. CCP

It is an algorithm used in WSN. The working of CCP [23] algorithm is as described. It puts a large number of nodes to sleep state while ensuring the K coverage and K connectivity; so CCP algorithm basically deals with connectivity of the network. Location of the nodes is of critical importance in the algorithm.

3.9. SPAN

It is an algorithm used in WSN. This algorithm ensures the existing network connectivity but fails to deal with a network that is pre-configured upto a certain connectivity level [24].

3.10. HEED

It is an algorithm used in WSN. This algorithm deals with the battery life time as well as communication cost of the specific node [25].

An effective algorithm has been proposed which deals with congestion in the network in [11]. The algorithm mentioned in this research paper describes the congestion arising on the cluster head. Cluster head calculates its total weight and then that weight is sent to neighboring nodes. Neighboring node then change their data rate as shown in fig 3.15(a) and 3.15(b).

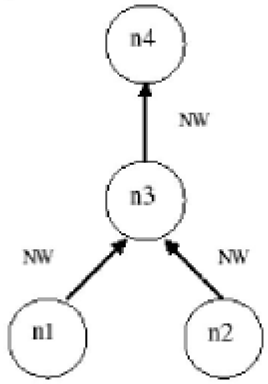
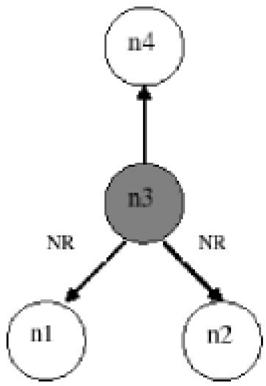


Fig 3.15(a): Node weight propagation [11]



3.15(b): New rate propagation [11]

3.11. ECODA

ECODA Enhanced congestion detection and avoidance for multiple class of traffic in sensor networks [12] deals with the energy-efficient congestion. ECODA works on MAC layer. It has following operations:

- ECODA has cross-layer optimization. This cross layer technique is used to avoid and detect congestion
- This algorithm uses hop-by-hop implicit back pressure.
- There will be dynamic selection of the queue so that the packet can be sensed out with priority as shown figures below:

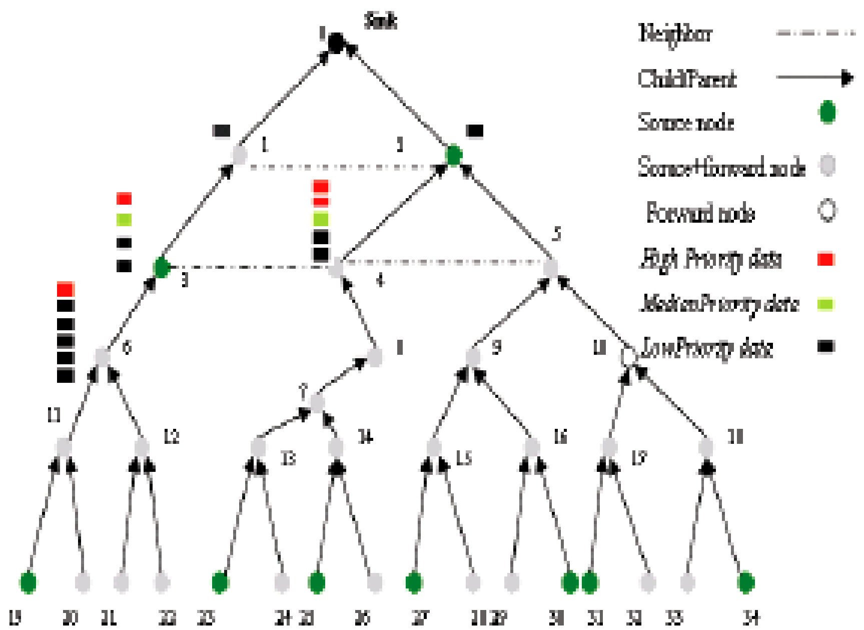


Fig 3.16: A network topology for discussion [12]

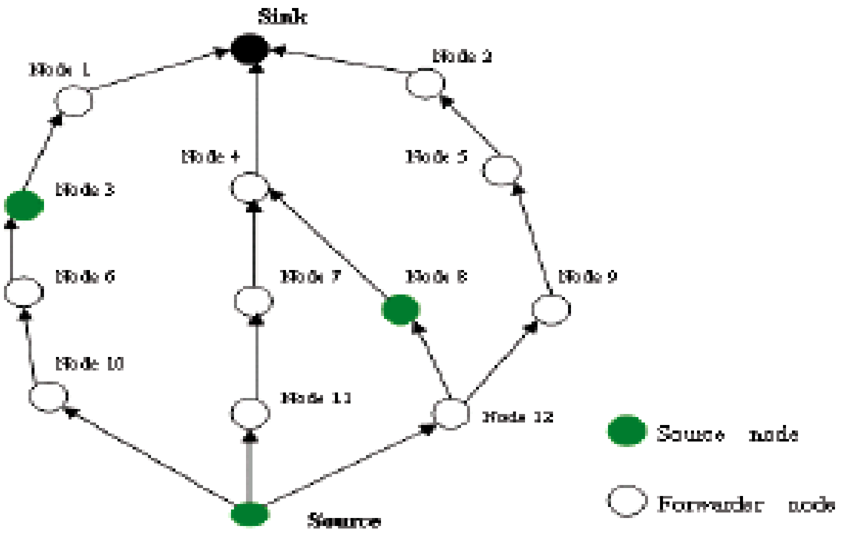


Fig 3.17: Bottleneck node based source data sending rate control [12]

Fasik Assegei gives an explicit approach about the decentralization of the Fames Synchronization of TDMA based WSN in [13]. In this paper, nodes are mobile and due to this mobility factor nodes frequency drift due to oscillation factor. If there is no provision taking place then synchronization of nodes will be switched off.

Median algorithm and set back:

The median algorithm [13] is describes as follows.

- Packets are broad casted by the node.
- Each receiver has a timer. The receiver records the receiving packet time.
- Every receiver 'i' evaluate the phase error. To any node 'j' in the neighbor.

$$\Delta t_{ij}^{(n)} = t_i^{(n)} - t_j^{(n)},$$

ti = wake up time of node i & j

- Receiver node evaluates the offsets, ξi, which is the median of the phase error

$$\xi_i^{(n)} = median(\Delta t_{ij}^{(n)}), \forall j$$

- Receivers adjust their wake-up time by the computed offsets value

$$t_i^{(n+1)} = t_i^{(n)} + T_i^{(n)} - G\xi_i^{(n)},$$

Where *G* is the gain factor

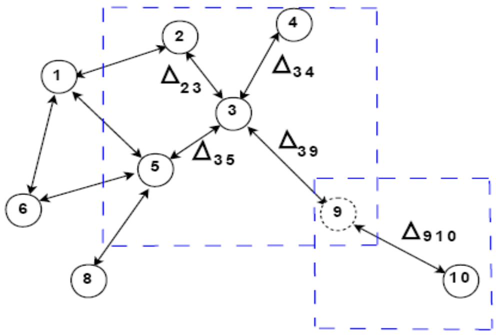


Fig 3.18: WSN Scenario [13]

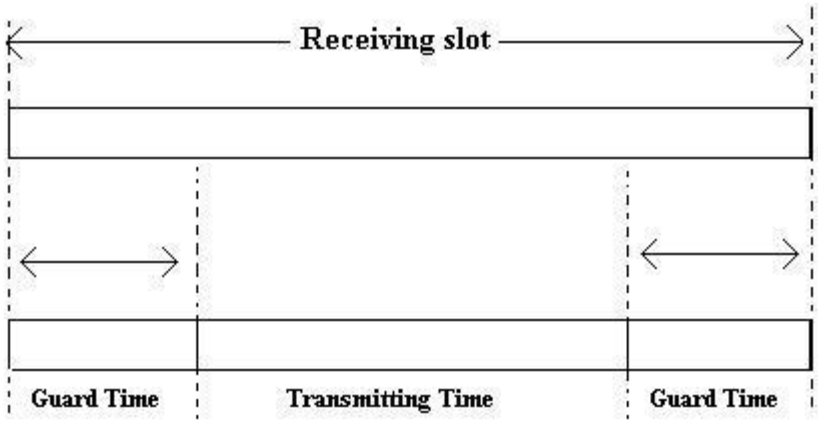


Fig 3.19: Guard time of the nodes [13]

Ataul Bari et.al proposed two fine algorithms for the assignment of sensor nodes to the cluster in two-tiered network in [48]. The first algorithm deals with the sending of data direct to base station, while second algorithm uses multi-hop scheme for sending of data to base station. The investigation of cluster protocol called EECS-M [49], in which few nodes plays voluntarily plays a role of cluster head. The node with maximum energy as well as near to base station will be the cluster head in the designed network. This will increase the network efficiency as well as reserve sensor energy [51], [25] and [53].

While talking about cluster head, it plays in efficient and effective role in conservation of energy as well as congestion in the network [50]. One of the major drawbacks of assigning cluster head in the wireless sensor network is the security. As the network become more vulnerable to the attacker. To cope with this issue, better network coverage in high resolution [54], [55] as efficient mechanism is required to select cluster head in a network. Guanhua Ye Tarek et.al [56] discussed reliability and high throughput of the network. To achieve these two attributes, a Standard Stream Control Transmission Protocol (SCTP) using multi-paths has been proposed for load sharing and load balancing as well as congestion control in the network. SCTP and TCP uses same scheme for congestion control [57]. Both are using SACK extensions of TCP [58]. SCTP is a message oriented TP which uses TSN (Transmission Sequence Number). It shows the sequence of packets chunks while parting the Transport Layer. It helps in keeping track of the transmission packet chunks.

Jian Xiao and Fengqi Yu present a Transmission Power Control (TPC) in [59]. TPC is based on Request To Send and Clear To send (RTS/CTS) algorithm in S-MAC. This algorithm deals with low power RTS, CTS, Data as well as ACK frames and avoiding collision and overhearing in the network by sensor nodes. The mechanism of RTS/CTS is explained in [60]. However in the implementation of efficient RTS/CTS is as fallows.

- MAC layer notifies the discrete power level of the transmitted frame by the physical layer.
- Measurement of RSSI of the received frame is done by physical layer.
- It uses bidirectional link for communication.

Due to extra measurements by the sensor node, it will consume extra time for processing and the leads towards the delay in the network. However, energy will be reserved. One of important limitation in the Wireless Sensor Network is sending the alerts message to base station at the same time. This will leads to collision of packets in the network which will consume extra energy. The resultant will be the expiration of network time before its due time. This problem is solved by H-C. Le, H. Guyennet in [61]. The proposed solution states the dynamical adjustment of access mechanism of channel. This mechanism will minimize collision as well as number of contention times in the network.

Redundancy of data is another important factor in Wireless Sensor Network. While discussing event driven technique in detail, the sensor node while sensing an external environment, all the sensor nodes will send same data at the same time. So the receiving node will receive redundant data. However, the send nodes will consume extra amount of data while sending same data again and again. On the other hand, the sensor node which broadcast data in the network, all the nodes will receives same data. Thus, it causes the problem of *overhearing*. So minimizing redundant data as well overhearing by sensor nodes, Hung-Cuong Le, Hervé Guyennet et.al proposed an algorithm for energy efficient MAC protocol for event driven technique [61]. When the node wants to access the channel, it uses CSMA/CA. In which a node pick a time slot randomly. If that channel is free, a node will transmit message. If channel is busy, the node will turn its state to silence mode and will wait for a time until the channel became free and node sends its data. In [62], there are different energy wastages reasons are mentioned, which are: due to *collision*, *over-hearing*, *over-mitting*, *out of range* and *idle listening.*

Sensor node has basically four operating modes, they are: Transmission, Reception, idle and sleep. MICA [63] is a basic example whose energy consumption is listed in below table:

State	**Energy Consumption (mW)**
Transmission	80
Reception/idle	30
Sleep	0.003

Fig 3.20: MICA Sensor Specification [63]

3.12. Limitations of Existing Relevant Literature

Congestion Control, energy conservation and allocation of Time slots constraints are not satisfactorily implemented by any protocol and hence there are still deficiencies in the said protocols and algorithms, as evident from the above literature survey. CR-WPAN [1], mentions full sleep cycle at different leaf nodes and DMAC [2] considered congestion on the sink node, which results in consuming extra energy. RRA-FCC and time driven or event driven models try to diminish the congestion problem as well as improve energy conservation in the network in [3]. A new TDMA based MAC protocol results in energy awareness and less delay in a network. In this proposed MAC protocol, the wireless sensor nodes conserve energy and also minimize the duty cycling technique and idle listening. In this protocol when node requires extra time slots from the cluster head, it is done when the queue size exceeds the highest threshold value [5]. Distance plays an important role in energy conservation; greater the distance more energy will be consumed and vice-versa. Important reasons of wastage of energy are *idle listening, collision, over hearing, central packet overhead and overmitting* [5]. Duty Cycling and data-driven technique [6] step ahead to cover the aforementioned three features but improvement is still required in allocation of time slots to avoid congestion in the network. CCP [23], SPAN [24], HEED [25], ECODA [12] are the protocols used to avoid congestion, but their use does not avoid delay in the network. Hence a new hybrid protocol "TS-TDMA" has been used to effectively circumvent all these limitations.

3.13. Objectives in Proposed Solution:

Energy efficiency and congestion control in mobile WSN is really a fascinating area with great potential of research. Comprehensive literature survey reveals that the mentioned protocols help in conserving energy as well as in avoiding congestion in the Mobile WSN. As wireless sensor nodes are powered by batteries they should be used in a manner with optimal utilization of the available power and high quality results. Therefore ensuring energy conservation by every node in the network is the important constraint factor in the designing of MAC protocol. Hence incorporation of Energy Efficiency with Congestion Control is the prime consideration and distinguished objective of our proposed algorithm.

CHAPTER 4

PROPOSED SOLUTION

CHAPTER - 4

PROPOSED SOLUTION

4.1. Tradeoff Management

The exchange of commodities among different factors in Wireless Sensor Network has its own worth. The scenario of WSN becomes more crucial when there is close relation between different entities. The entities may include energy efficiency, congestion control and delay in the network. These entities must be the foremost consideration in designing any protocol or network of wireless sensor nodes. Energy Efficient Congestion Control in WSN cannot be ignored while discussing energy as well as delay. When congestion arises in a network, it causes delay as well as requires extra energy in order to re-transmit the same amount of data in the network.

For this purpose, we have proposed a protocol ST-TDMA (Shared Time-Time Division Multiple Access Protocol) to achieve both energy conservation as well as congestion avoidance in the network. It follows the customized time sharing technique among different mobile nodes. The simulation results of ST-TDMA illustrate its efficiency as well as achievement of a non-congested network with minimal delay.

4.2. Proposed Solution

4.2.1. Overview

First, all mobile nodes will organize themselves against their cluster head. Assignment of time slots to different mobile nodes in the cluster is the next step especially for data sensing and sending it to neighboring nodes as well as cluster head. To cope with this issue, our proposed algorithm consists of the following modules.

- Organizing the mobile nodes.
- Assignment of time slots to different mobile nodes.
- Sharing of assigned time slots among neighboring nodes.

- Sensing and transmission of sensed data within given time slots to avoid congestion on cluster head.

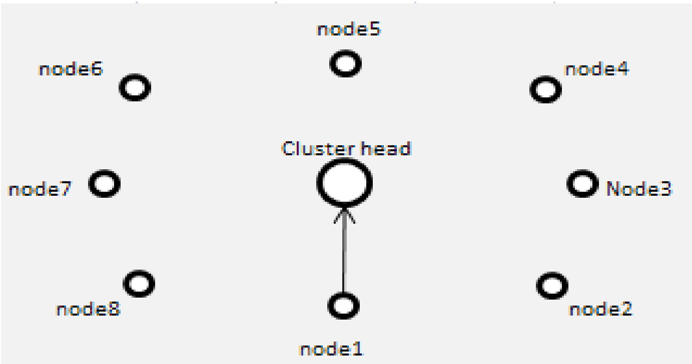


Fig 4.1: A Zone: Cluster Head surrounded by Nodes

Reference *Fig 4.1* above. Consider a centralized network; assume a particular node (node 1) is assigned 3 time slots to send information. Nodes in a zone either have information to send or they have no data to share with the cluster head. In case it has no information to send at all, it will generate an alert for the cluster head accordingly. In case node 1 on time t_i *(i=0, 1, 2… n)* broadcasts an alert about lack of information to share, the succeeding mobile nodes will shift back their time slots to rest of the nodes by a factor of two. Hence these two slots will move in the zone unless some other node uses them.

Let T represent time slot then

If (a node has no data)

Then

t_i ***→ alert to cluster head***

Cluster head → shiftback T of other nodes by a factor of t_{i+1}, t_{i+2}

$node_i$ ***→ (T of*** $node_i$***) –*** $(t_{i+1} + t_{i+2})$

Two main strategies are available under the umbrella of SEEC to cope with the delay introduced due to freeing up of allocated Timeslots called Time Allocation Leister (TAL) strategy and Load Based Allocation (LBA) strategy.

LBA is purely based on ST-TDMA method of time slot allocation. The three-fold nature of TAL strategy manipulates the effects arising out of mobile nodes joining and leaving the zone. The three prongs of TAL are: Extricated Time Allocation (ETA), Shift Back Time Allocation (SBTA) and eScaped Time Allocation (STA).

Time freeing up by the sensor node due to the absence of sensing in a scenario, where a mobile entering the zone and there is no mobile entering the zone is handled by ETA. SBTA conduces the time released due to the node leaving the zone in the same scenario as of ETA. STA presents the solution of allocation of free time slots in a scenario where one node is leaving the zone and other node has no data to sense as shown as in figure.

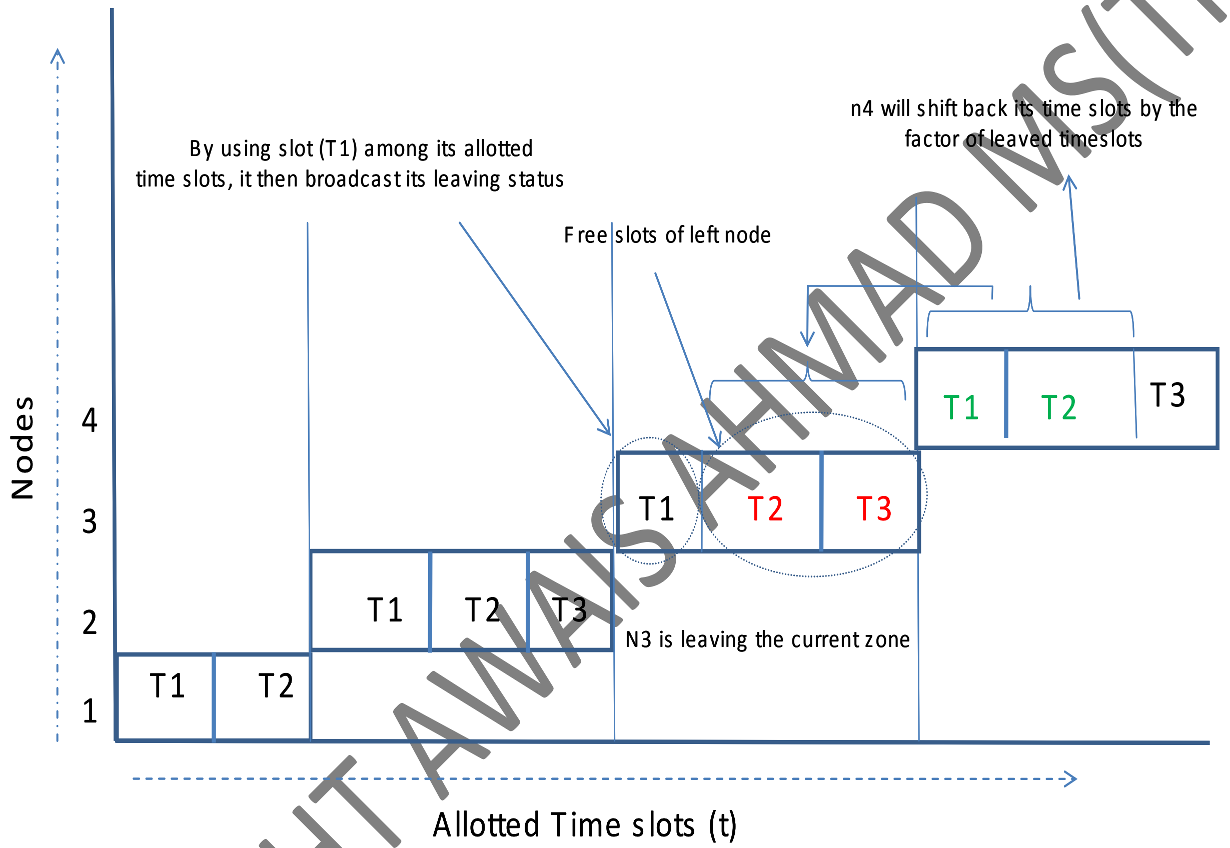


Fig 4.2: A typical SBTA working

In our scenario, we have two zones i-e Zone1 and Zone2 surrounded by mobile nodes. Each mobile node will communicate with its cluster head. A mobile node, when leaving its current zone due to its mobility factor will first acknowledge its cluster head and will broadcast its time slots in the entire cluster head. On the other hand, a newly arrived node while entering its neighboring cluster will first broadcast its arrival and will wait for some time so that the cluster head may give time slots with the help of ST-TDMA newly designed protocol as shown in figure 4.3.

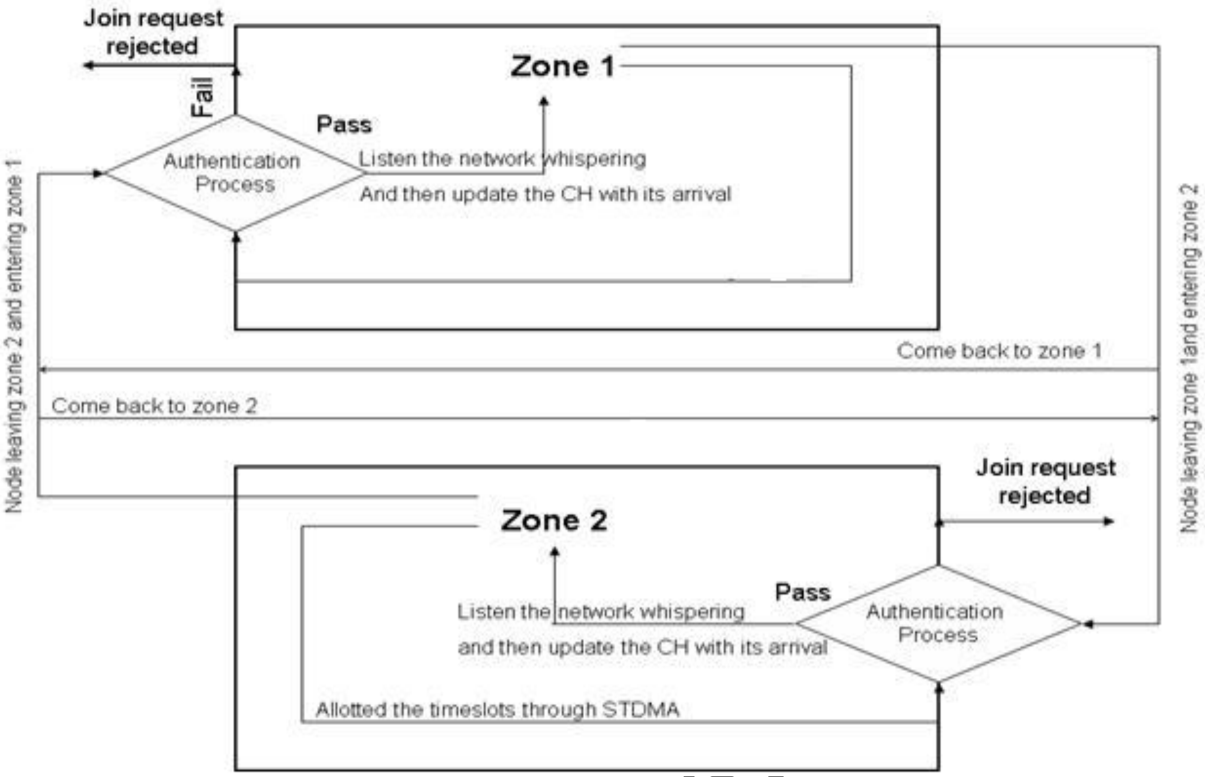


Fig 4.3: A typical working of Allocation of Time Slots Based on STDMA

The innovative technique of 'ST-TDMA hybrid-protocol' is a useful remedy for controlling both these traffic congestions, as follows:

- The STDMA uses a technique of statistical measurement of the data load and energy requirements on each mobile node, thereby helping the mobile nodes send data to the receiver without NLC. The mobile nodes share information about their respective unique ID, packet load, energy level and location with the static Cluster Head;
- Using the feedback from the nodes and the TDMA technique, the Cluster Head assigns time slot to different mobile nodes;
- ST-TDMA (Shared Time-TDMA) is our new innovative technique that helps the mobile nodes share their allotted time-slots among themselves depending on whether a mobile node has sensed any data or not. Cluster Head remains the coordinator as shown as in figure.

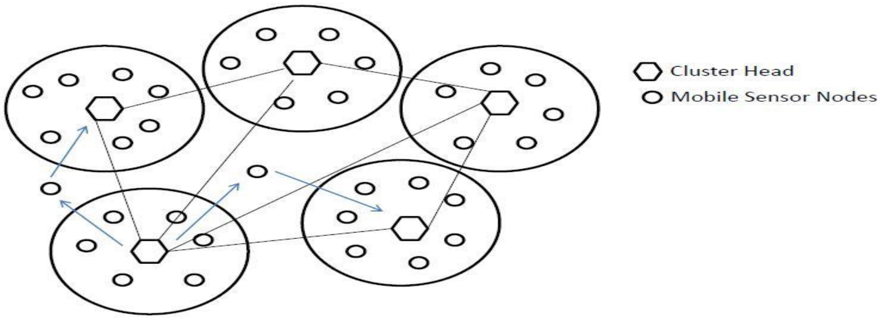


Fig 4.4: Assignment of Cluster Head along with mobile sensor nodes

In addition to these, our proposed algorithm also deals with energy reservation due to sharing of time slots among neighboring mobile nodes. The assignment of time slots due to their location and battery life lead to conservation of energy as well as provides efficient network which has the following attributes.

- Time Manager (TM).
- Nodes Location Manager (NLM).
- Power Manager (PM).
- Efficiency (E).

4.3. Statement of Goals

Development of innovative applications and sensor environment services owe much to the advancement in the technology today. Optimal energy utilization in WSN, TS-TDMA/STDMA protocol becomes one of the best alternatives with the following objectives:

- The collecting of load and energy information through STDMA is an efficient and low cost job.
- The Hybrid Protocol "ST-TDMA" when combines together for allocation of timeslots to different mobile nodes in the zone as per there need and geographical location. Also the sharing of timeslots amongst different mobile nodes in the same zone is used to prevent data loss and also saves energy.

CHAPTER 5

SIMULATION REQUIREMENTS

CHAPTER - 5

SIMULATION REQUIREMENTS

5.1. Introduction

NS (Network Simulator) is simulator which is used for designing any network as well as for research aspect in network (wire and wireless). NS provides support for simulation of TCP, Routing and Multicast Protocols.

This user manual provides different steps for installation of NS-2.31 [72]. NS-2.31 runs best on LUNIX platform, but can also be installed on windows XP using cygwim.

5.2. Version

This documentation is based on the following versions:

- *pre-release2 of the wimax model developed by NIST*

-ns-2.29/ns-2.30/ns-2.31

5.3. Installation of NS-2.31 of Ubunto 9.04

5.3.1 Download and Install

First, we download the ns-2 all-in-one file [54.4 MB].

$ wget http://nchc.dl.sourceforge.net/sourceforge/nsnam/ns-allinone-2.31.tar.gz

Now you need to install and upgrade your system in order to install NS. Follow the following steps. Open the terminal and type the following line.

$ sudo apt-get install build-essential autoconf automake libxmu-dev

The prompt will ask you to install dependant files and upgrade your system. Do whatever you are asking to do. It will take some time depending upon your interest speed. Remember! You have to restart after upgrading your system
Then write in terminal,

$ tar -xzvf ns-allinone-2.31.tar.gz

$cd ns-allinone-2.31

Then before installation of NS2.34, if you want to use NAM then you will also need to fix a bug. Failure to do so, will give the following error when NAM is run.

[code omitted because of length]
: no event type or button # or keysym
while executing
"bind Listbox {
*%W yview scroll [expr {- (%D / 120) * 4}] units*
}"
invoked from within
"if {[tk windowingsystem] eq "classic" || [tk windowingsystem] eq "aqua"} {
bind Listbox {
%W yview scroll [expr {- (%D)}] units
}
bind Li..."

There are two patches to solve this problem from
http://bugs.gentoo.org/show_bug.cgi?id=225999
Make the correction to both files as

First in file ***tk8.4.18/ generic/tk.h***

NOTE:"-"sign indicates the line to be deleted, and "+" sign indicates the lines to be added. The rest of the lines are to remain untouched.

-#define VirtualEvent (LASTEvent)

-#define ActivateNotify (LASTEvent + 1)

-#define DeactivateNotify (LASTEvent + 2)

-#define MouseWheelEvent (LASTEvent + 3)

```
-#define TK_LASTEVENT     (LASTEvent + 4)

+#define VirtualEvent     (MappingNotify + 1)

+#define ActivateNotify     (MappingNotify + 2)

+#define DeactivateNotify    (MappingNotify + 3)

+#define MouseWheelEvent     (MappingNotify + 4)

+#define TK_LASTEVENT     (MappingNotify + 5)

 #define MouseWheelMask     (1L << 28)

 #define ActivateMask     (1L << 29)

 #define VirtualEventMask    (1L << 30)

-#define TK_LASTEVENT     (LASTEvent + 4)
```

Secondly, in file *tk8.4.18/generic/tkBind.c*

```
/* ColormapNotify */  COLORMAP,

/* ClientMessage */  0,

/* MappingNotify */  0,

+#ifdef GenericEvent

+/* GenericEvent */  0,

+#endif

/* VirtualEvent */  VIRTUAL,

/* Activate */  ACTIVATE,

/* Deactivate */  ACTIVATE,
```

At this stage, you will be ready to install NS-2.34

$cd ns-allinone-2.31

$./install

Now update Environmental Variables

$ gedit ~/.bashrc

add the following code to the end of the file. Remember replace “/your/path” by the folder where you have to store the extracted files of ns-2.34.

```
# LD_LIBRARY_PATH
OTCL_LIB=/home/adeel/ns-allinone-2.31/otcl-1.13
NS2_LIB=/home/adeel/ns-allinone-2.31/lib
X11_LIB=/usr/X11R6/lib
USR_LOCAL_LIB=/usr/local/lib
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$OTCL_LIB:$NS2_LIB:$X11_
LIB:$USR_LOCAL_LIB
# TCL_LIBRARY
TCL_LIB=/home/adeel/ns-allinone-2.31/tcl8.4.14/library
USR_LIB=/usr/lib
export TCL_LIBRARY=$TCL_LIB:$USR_LIB
# PATH
XGRAPH=/home/adeel/ns-allinone-2.31/bin:/home/adeel/
ns-allinone-2.31/tcl8.4.14/unix:/home/adeel/ns-allinone-2.31/tk8.4.14/unix
NS=/home/adeel/ns-allinone-2.31/ns-2.31/
NAM=/home/adeel/ns-allinone-2.31/nam-1.13/
PATH=$PATH:$XGRAPH:$NS:$NAM
```

Now since you have changed the environmental variables, they are not active yet. Thus, you need to either restart your computer or run the following command

$ source ~/.bashrc

If it gives some error for unknown or invalid paths, you will need to recheck the paths given for each library.

Note: The previous step is important; else you cannot successfully run ns-2.

(Alternatively, you may have to restart your X-windows, i-e logout, and then login, or restart your computer.)

Now, the installation has been completed. Try:

$ ns

The "%" symbol appears on the screen. Type "**exit**" to quit.

5.3.2. Validation

To run the ns validation suite:

$ cd ns-2.31

$ ./validate

CHAPTER 6

RESULTS AND DISCUSSION

CHAPTER - 6

RESULTS AND DISCUSSION

6.1 Results and Discussion

For performance evaluation of our proposed algorithm, SEEC, Network Simulator (NS-2.27) is used. In our previous chapter (chapter 4), Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 demonstrating the basic working of our proposed SEEC algorithm. In our simulation, we have considered energy consumption per node, per cluster, per Cluster Head, Message Interval Time (MIT) in Low Traffic Load (LTR) and High Traffic Load (HTR), Latency in LTR and HTR, Delay in LTR and HTR and a Hybrid Protocol of MAC and 802.11n, which influence overall network efficiency.

The following table shows the basic configuration of our simulation.

Type	**Subtypes**
Channel Type	Wireless
Radio Propagation	TwoRayGround
MAC Type	802.11 and 802.11n
Interface Queue Type	PriQueue
Link Layer Type	LL
Antenna Type	Omni Antenna
Max Packet in ifq	100
No. of Mobile Nodes	50
Routing Protocol	AODV
X,Y Dimension of Topography	1000*1000
Energy Value	15 Joules

Table 6.1: Simulation Parameters

For manipulation of research parameters, we have used GNUPLOT function for trace file. Various snap shots of our research simulations are given below:

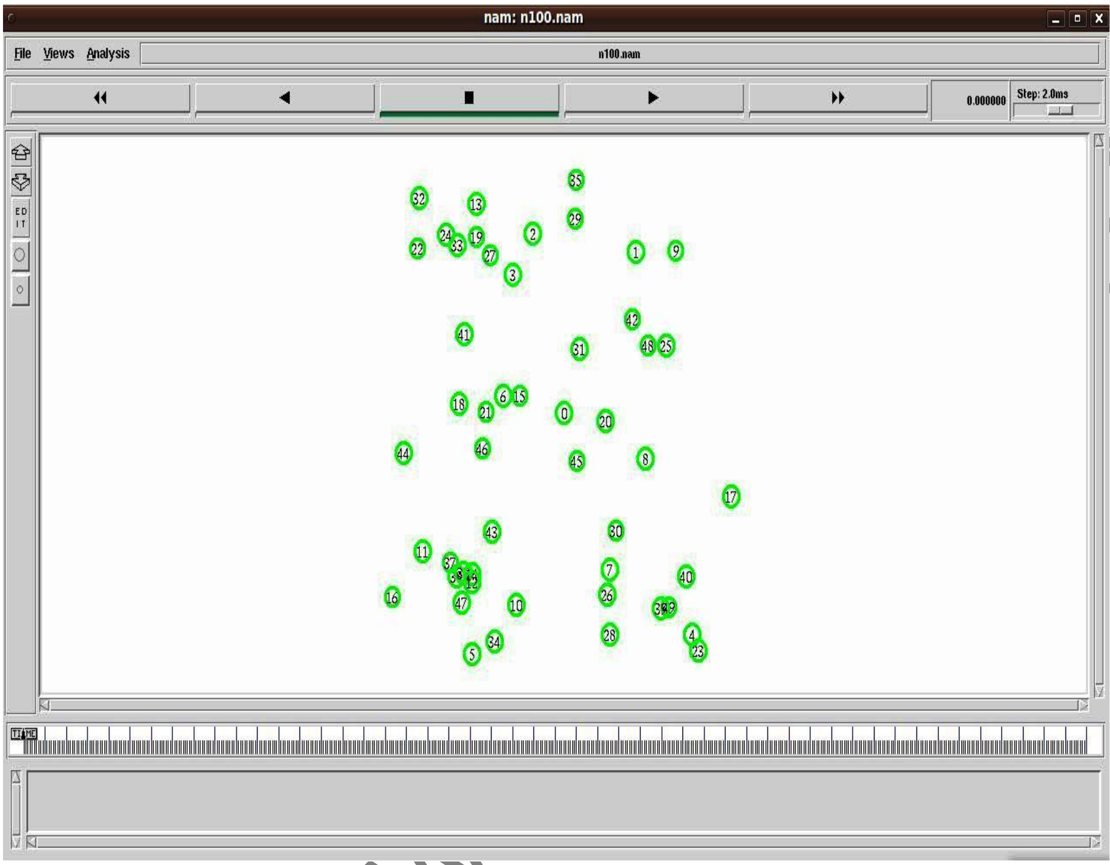


Fig 6.2: Deployment of Mobile Sensor Nodes

As shown in Fig 6.2, this simulation was carried out in NS-2.27, in which 50 mobile sensor nodes were deployed in *x* and *y* coordinates. In this all the mobile sensor nodes will sense data and send it either to the neighboring mobile nodes (if any) or to their Cluster Head.

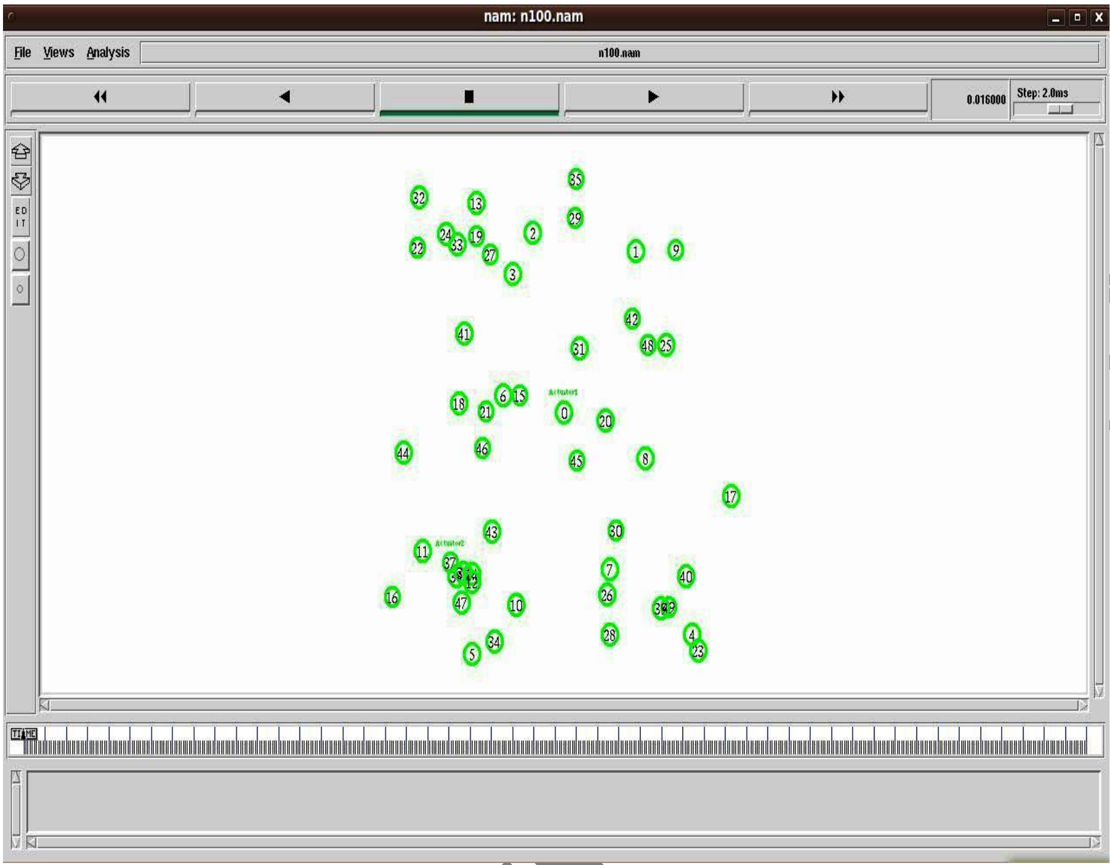


Fig 6.3: Arrangement of Mobile nodes in Cluster (Cluster Formation)

In the above figure, all the mobile sensor nodes arranged themselves into a cluster. Before sensing any data, the nodes send their location information, battery life time to cluster head to form appropriate cluster for requirement of time slots with the help of STDMA. In this figure there are 2 clusters, each with 25 mobile sensor nodes.

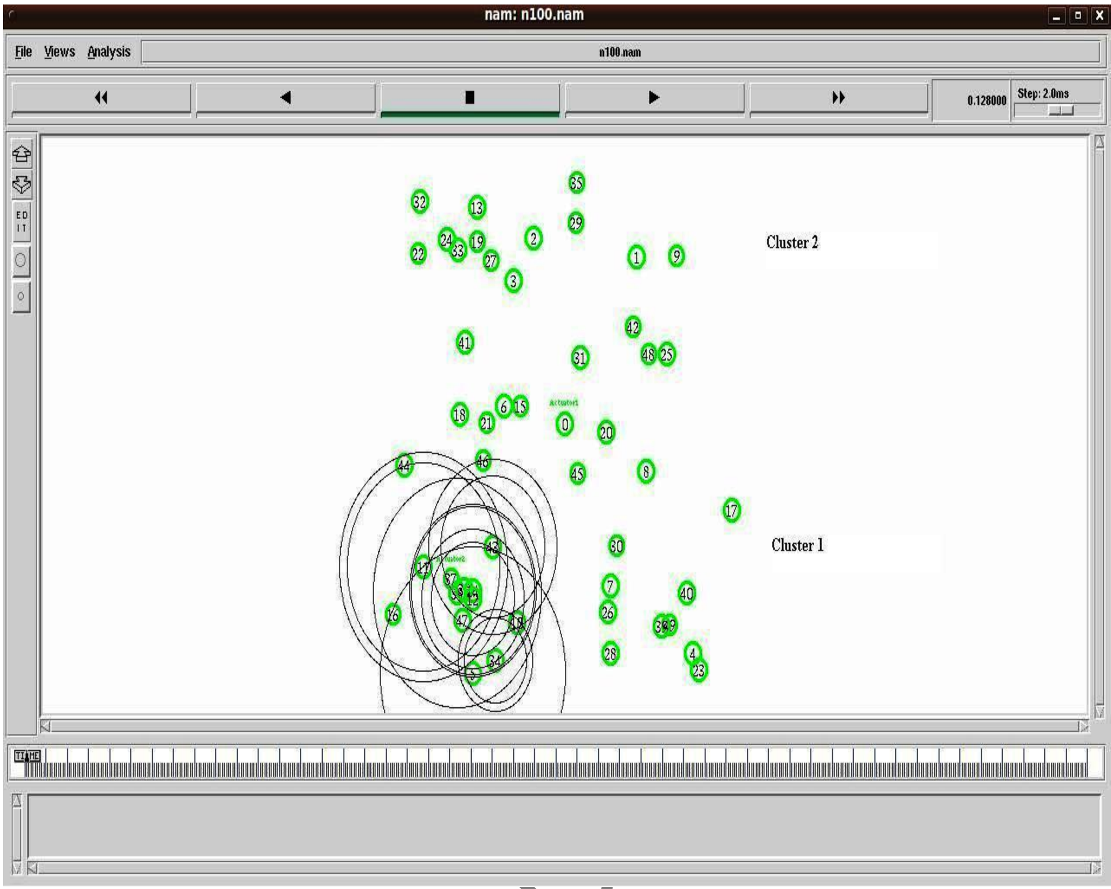


Fig 6.4: Sensing of data in Cluster 1

Figure 6.4 shows all the mobile sensor nodes busy in sensing data. Here TDMA technique will be applied with the help of cluster head. The mobile sensor nodes first sense data and then forward it to cluster head. The mobile sensor nodes will use ST-TDMA technique to share the time slots assigned by the cluster head. Time Allocation Leister (TAL) strategy and Load Based Allocation (LBA) strategy are the main mechanisms under SEEC to cope with the delay introduced due to freeing up of allocated timeslots.

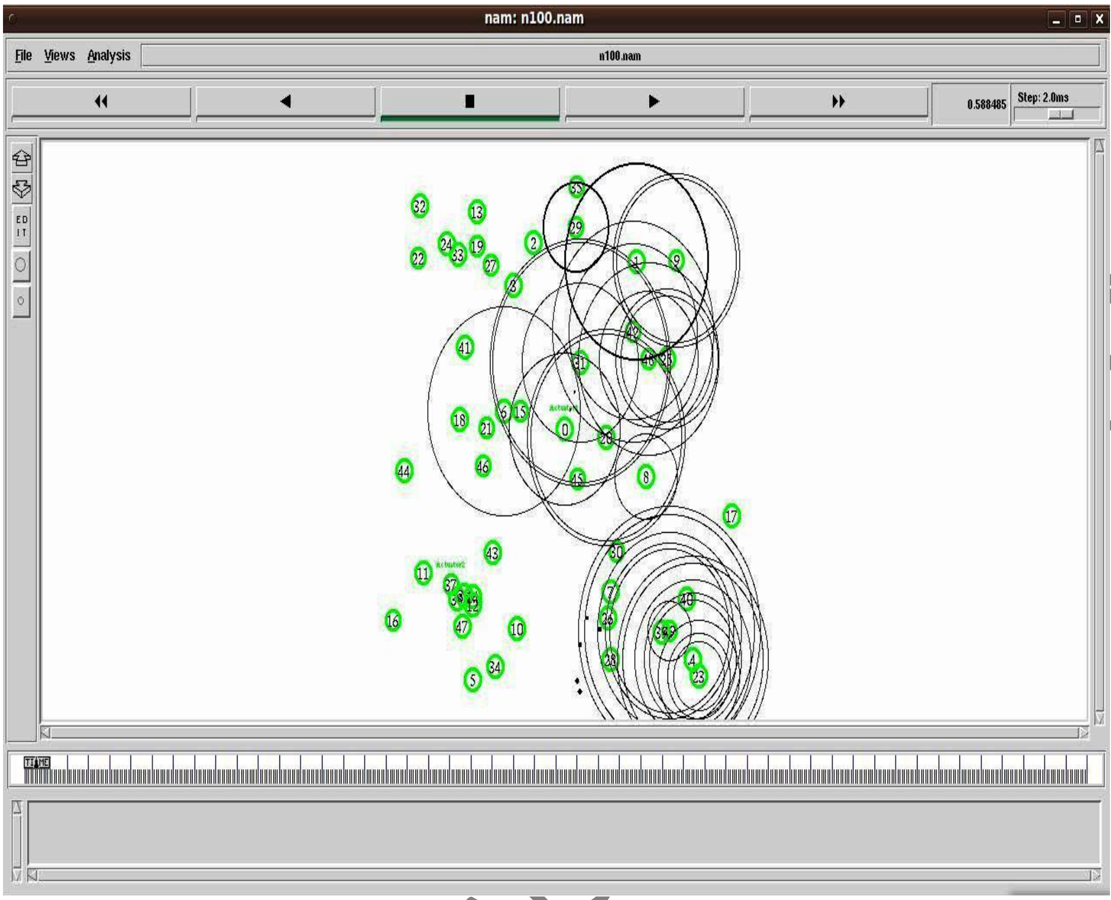


Fig 6.5: Sensing and transmission of sensed data

In the above figure, the data is being sensed by mobile sensor nodes in Cluster 2 and then it is received by the cluster head. If a node in Cluster 1 wants to send data to the Cluster Head 2, the latter will drop the data packets since they are coming from another cluster. Similarly, if a node from Cluster 1 physically moves to Cluster 2, the data sent by it will still be dropped until the newly entered node has been assigned time-slot by the Cluster Head 2. The three prongs of TAL are: Extricated Time Allocation (ETA), Shift Back Time Allocation (SBTA) and eScaped Time Allocation (STA)

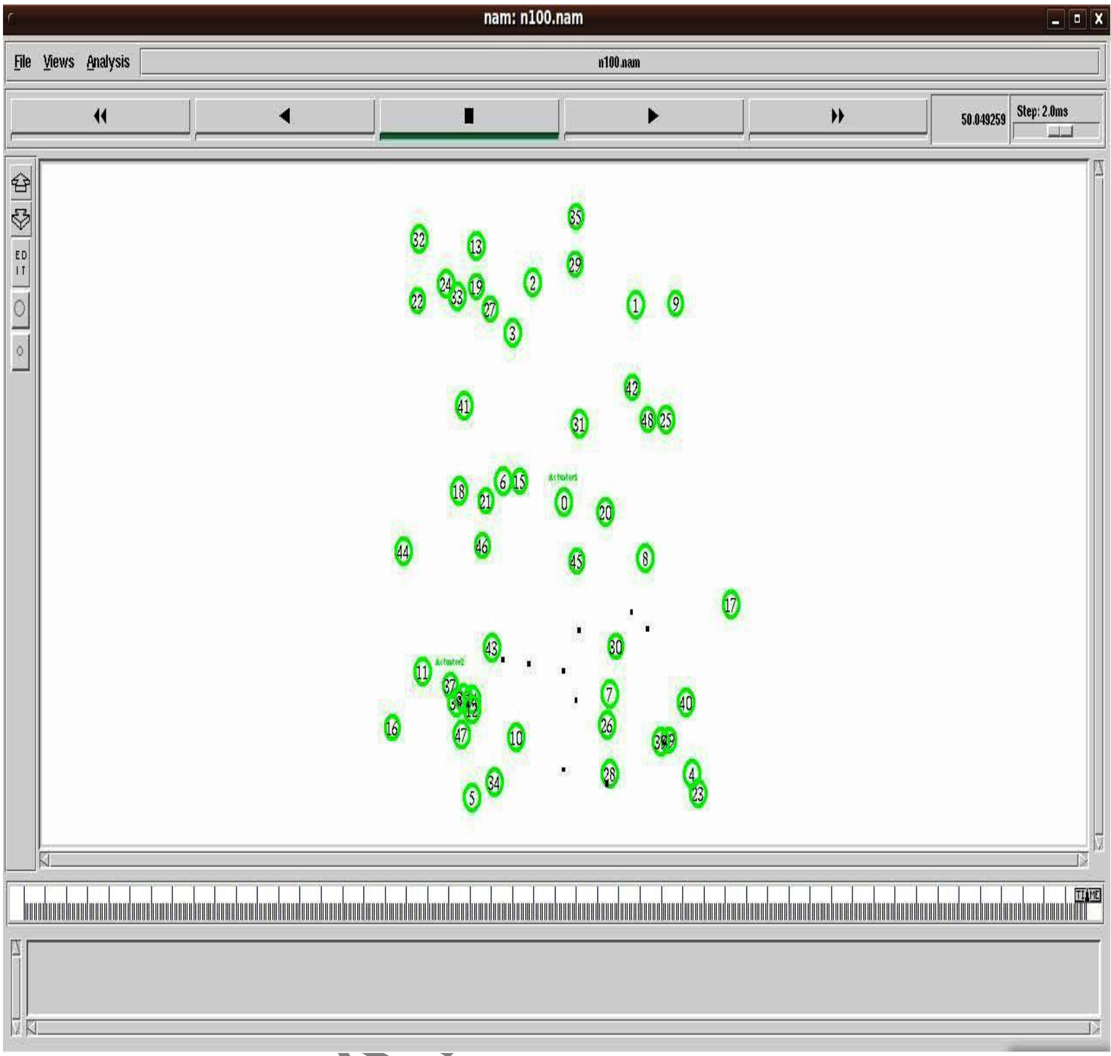


Figure 6.6: End of the simulation

Fig 6.6 shows end of the simulation.

The following comparison graphs have been obtained by using GNUPLOT in NS-2.27.

6.1.1 Message Interval Time (MIT):

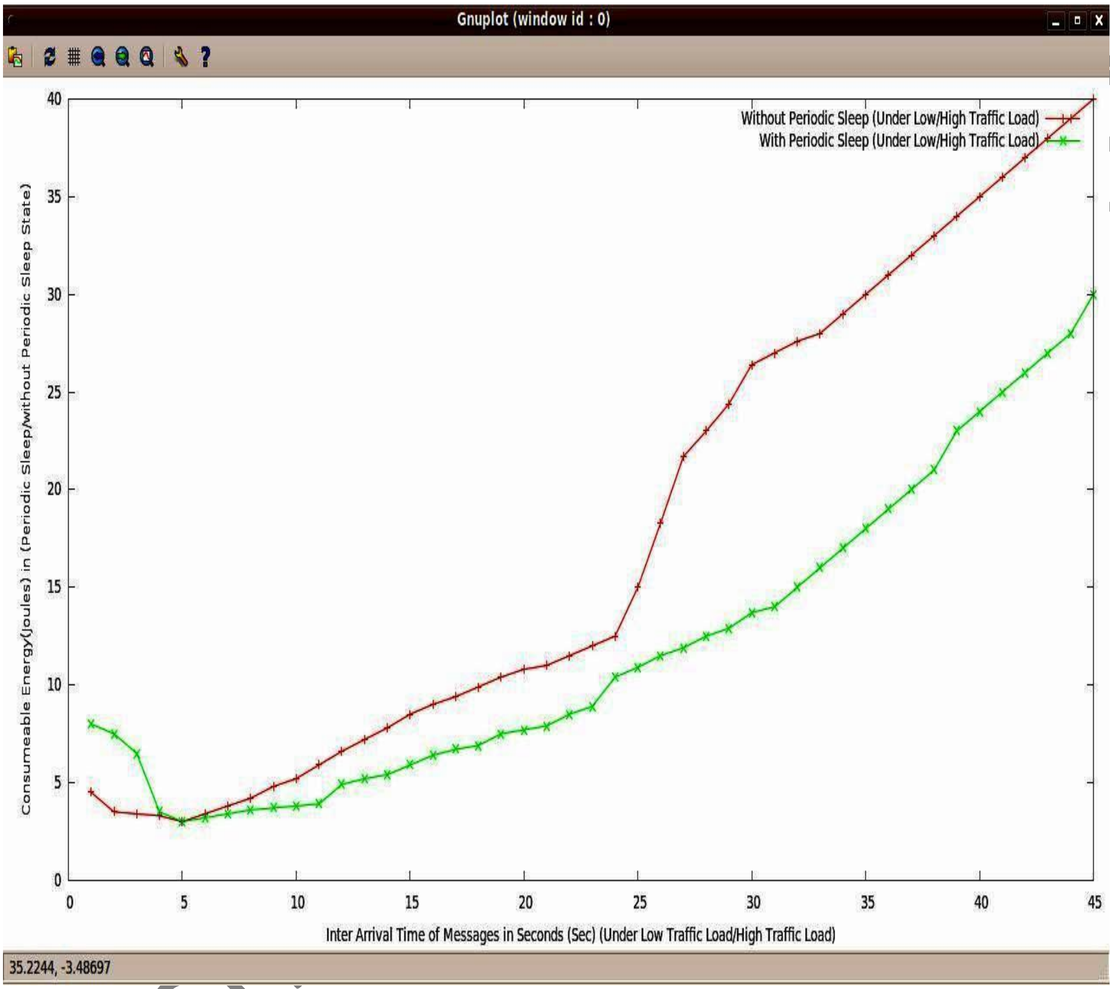


Fig 6.7: Calculating Message Interval Time (MIT)

The graph depicts energy levels obtained both with-periodic-sleep-state as well as without- periodic-sleep-state. We have considered low traffic load in this scenario. It can be noticed that the nodes which are in without-periodic-sleep-state consume much more energy as compared to those which follow the sequence of periodic-sleep-state, in low traffic load. It can be concluded that while deploying mobile sensor nodes in any environment to calculate MIT in low traffic load situations, the best technique is to employ nodes that follow periodic-sleep-state with ST-TDMA.

6.1.2 Energy Level of Mobile Sensor Nodes

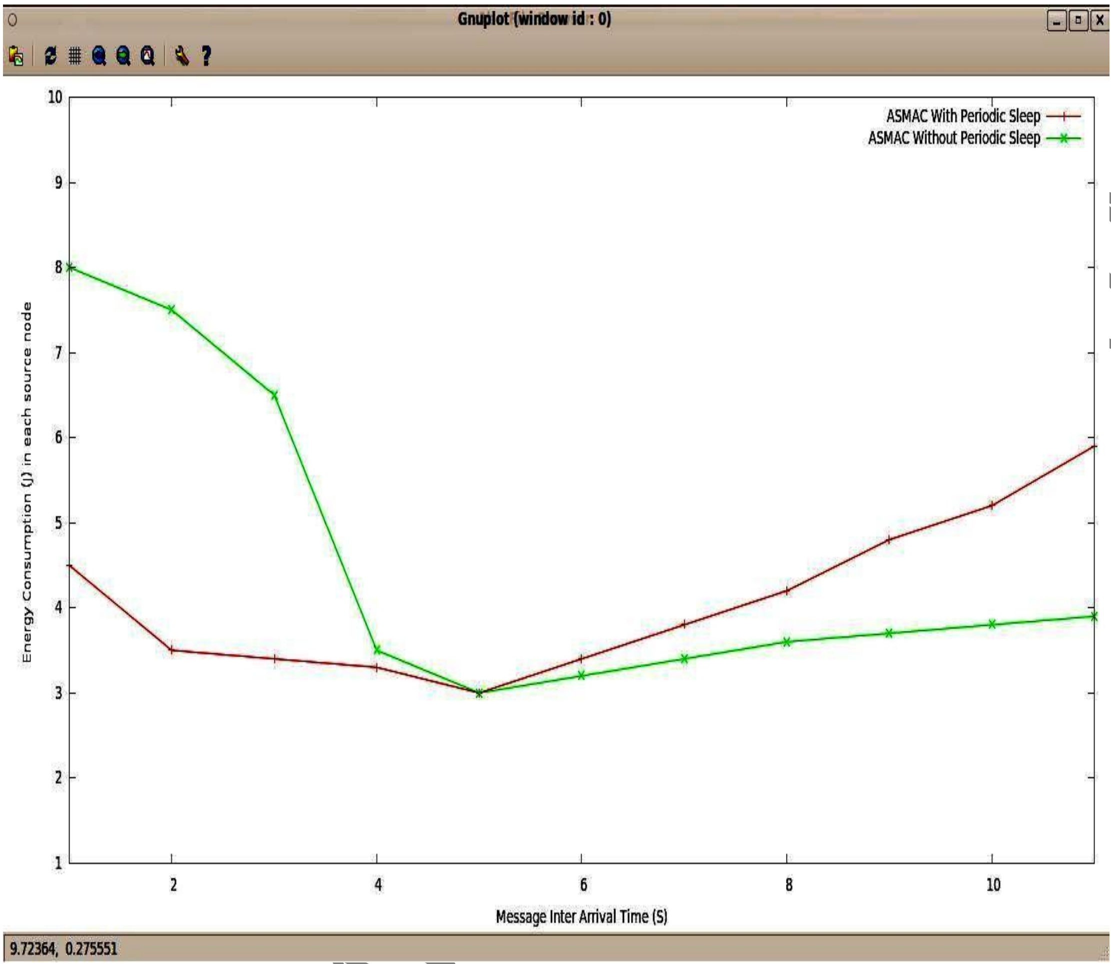


Fig 6.8: Calculating energy level at every mobile sensor node.

The graph in figure 6.8 illustrates that with simultaneous employment of periodic-sleep-state and ST-TDMA techniques (as against the traditional TDMA technique) individual nodes consume much less energy. A node with-periodic-sleep-state (red line) preserves it energy much longer (starting with 4.5 Joules) within its own time slot. If the mobile node has no data to sense, it will broadcast this message for its neighboring nodes to shift back their time slot and start further communication with the cluster head. This helps the idle mobile node to preserve its energy during free time and consume its total energy over a longer period of time. This technique, therefore, considerably enhances the overall Efficiency of the network. On the other hand, nodes in without-periodic-sleep-state suffer from sudden and abrupt changes of energy level (green line) leading to quick exhaustion of their energy stores.

6.1.3 Latency under Low Traffic Load (LTR)

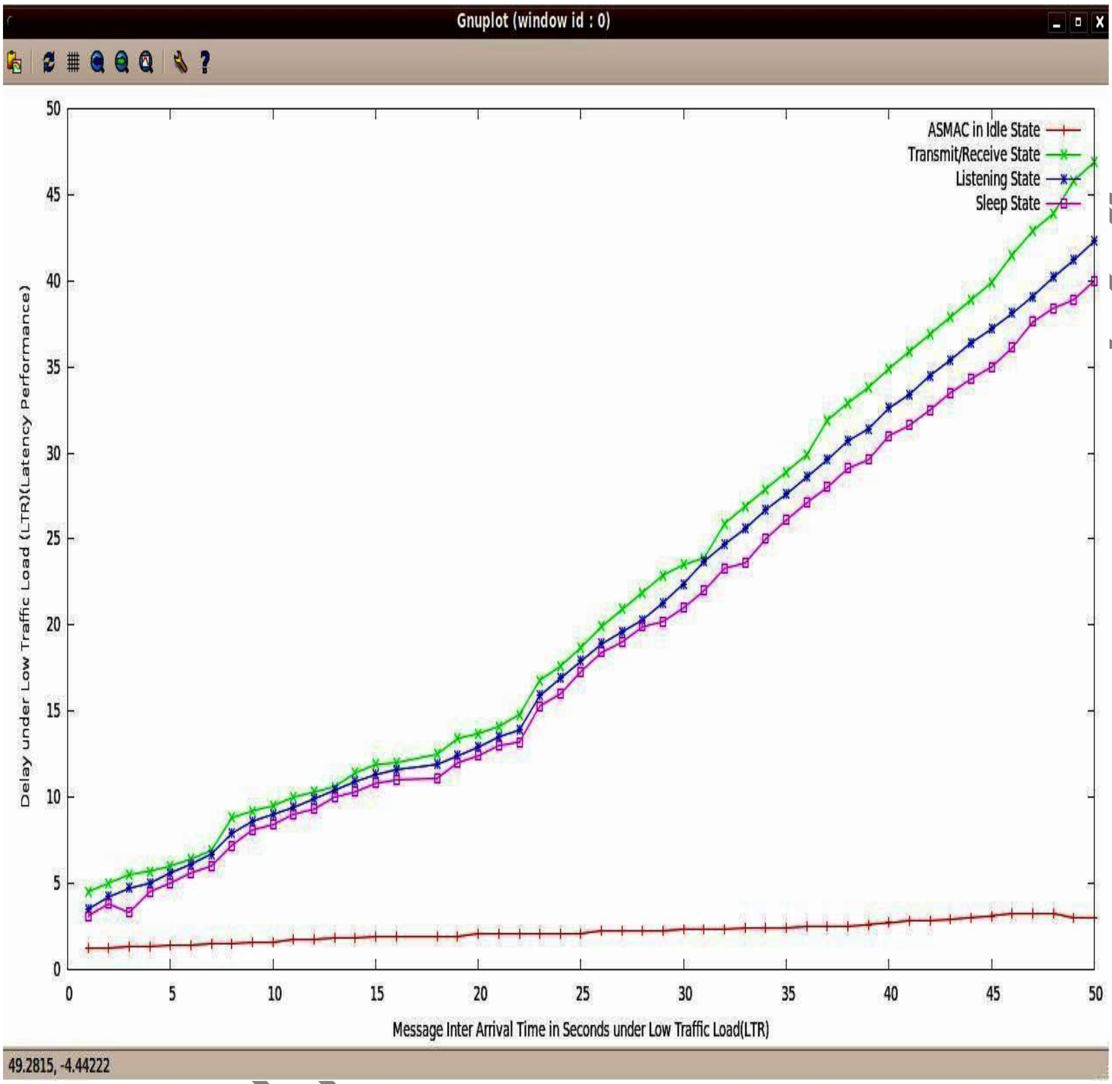


Fig 6.9: Calculated Latency under Low Traffic Load (LTR)

In the above graph, we have calculated latency under LTR. In our main scenario there is no node in idle state. The nodes which constantly send and receive data start with high latency because of delay factor. On the other hand the nodes which are in sleep state have low latency because they do not receive or transmit data. The resultant latency calculated under periodic sleep state is the average of latency values of active and idle nodes, and will be represent the overall Network Latency.

6.1.4 Latency under High Traffic Load (HTR)

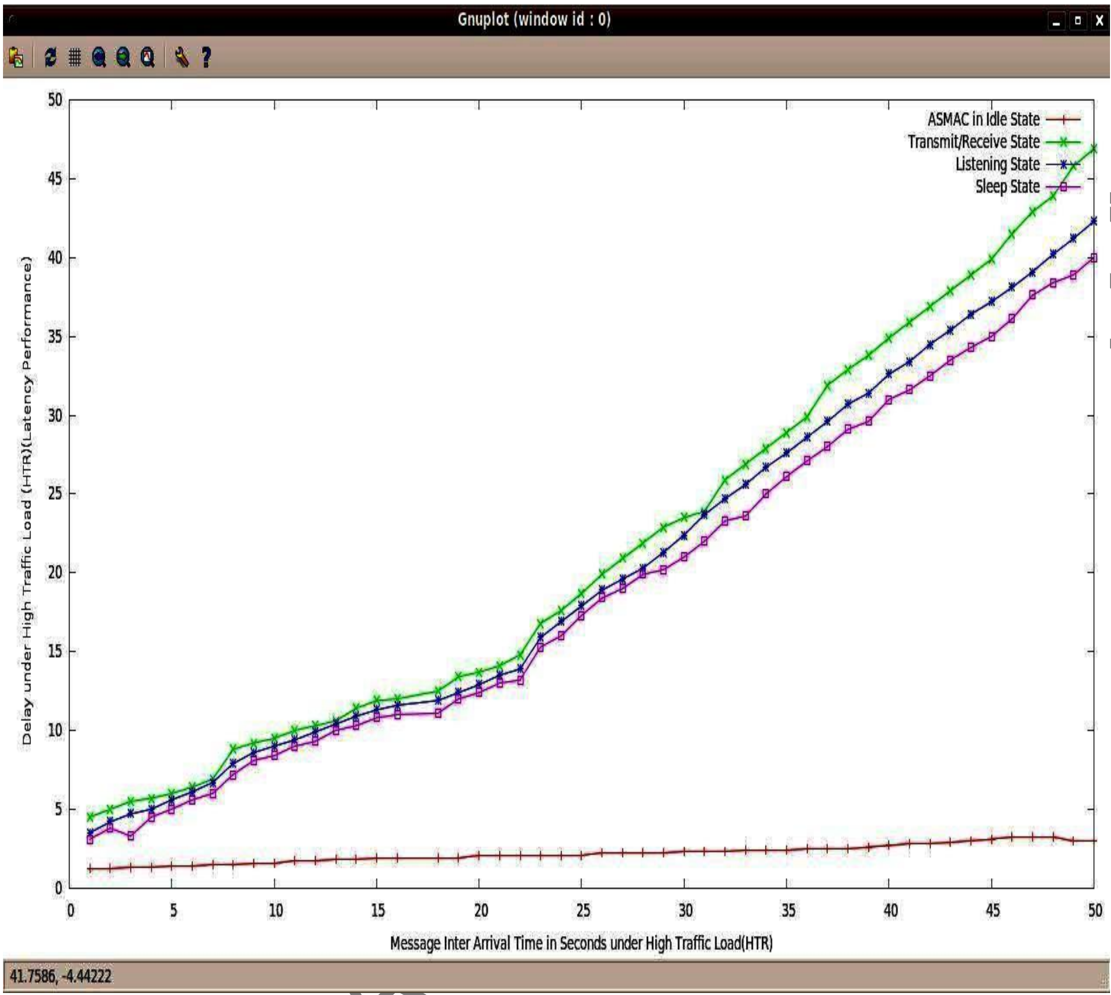


Fig 6.10: Calculated Latency under High Traffic Load (HTR)

In figure 6.10, we have calculated latency under HTR. In our main scenario the nodes in idle state consumes no energy. The nodes which constantly send and receive data start with high latency because of delay factor. On the other hand the nodes which are in sleep state have low latency because they do not receive or transmit data. The resultant latency calculated under periodic sleep state is the average of latency values of active and idle nodes, and will be represent the overall Network Latency.

6.1.5 Comparison of Delay under LTR and HTR:

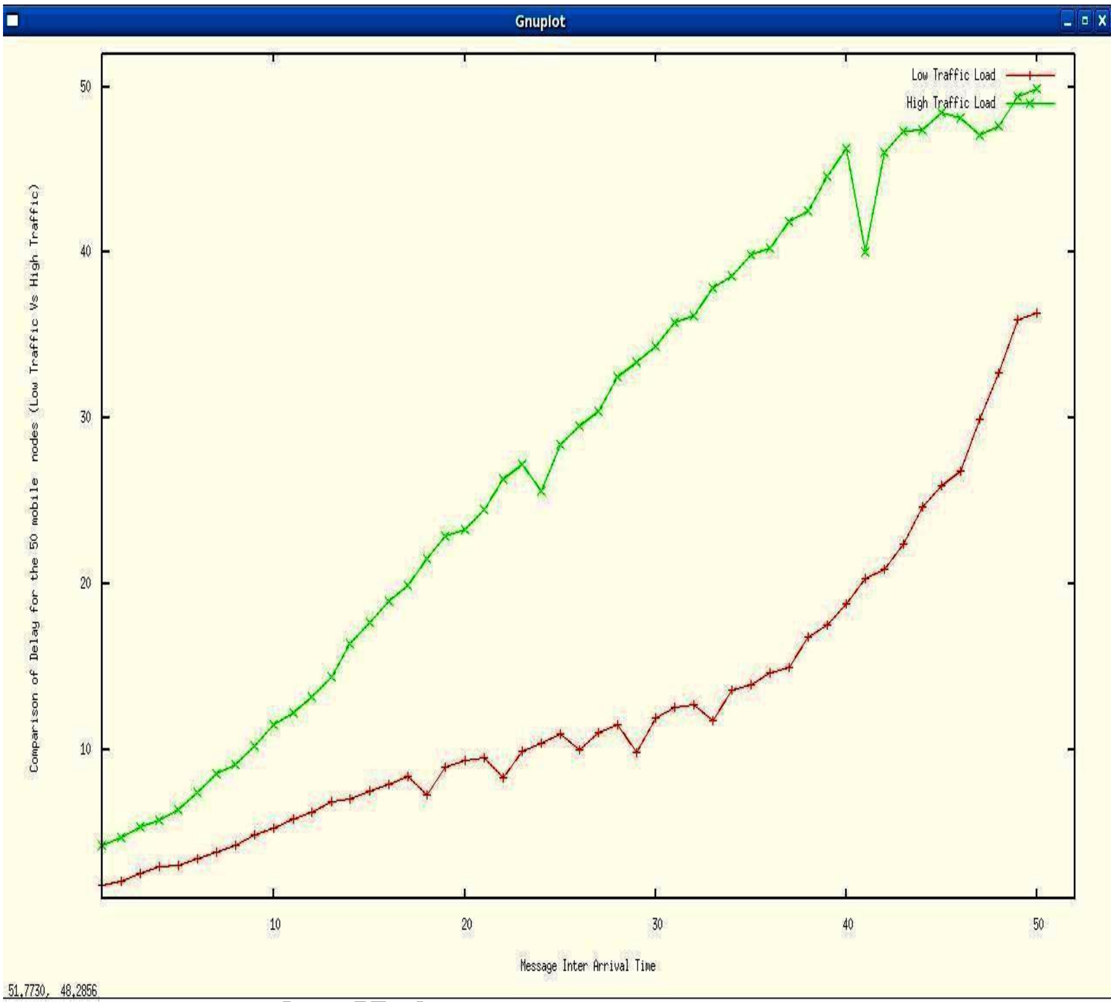


Fig 6.11: Delay comparison among 50 mobile sensor nodes under LTR and HTR.

In the above figure, we have calculated delay in all 50 nodes using GNUPLOT function. The results have been fetched from trace file of our main scenario. While calculating the delay, our newly proposed protocol i.e. ST-TDMA less delay resides under LTR as compared to HTR; meaning that the ST-TDMA protocol works better under LTR than the HTR.

6.1.6 802.11n energy level:

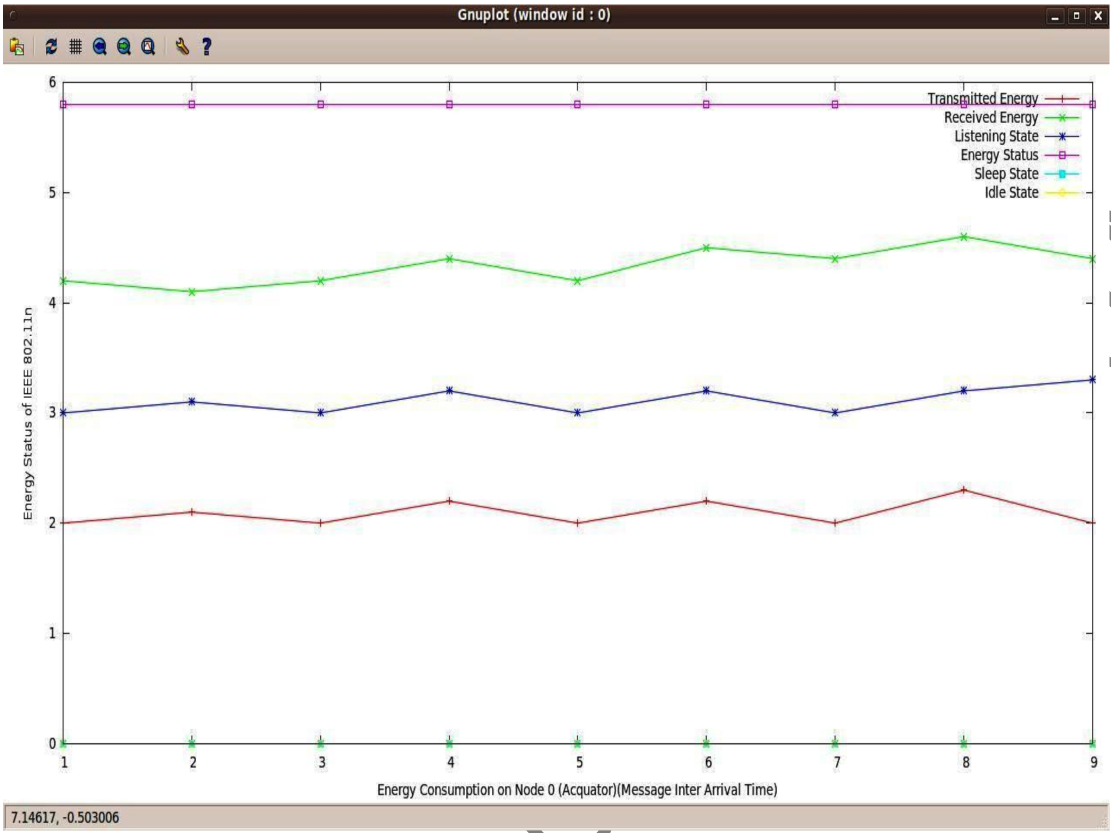


Fig 6.12: Calculating energy of 802.11n (Back End)

We have implemented 802.11n at back end i.e. on cluster head in order to calculate its energy level. All the nodes have 15 Joule energy; within that energy they have to communicate throughout the entire session. From the above graph it is apparent that the CH while receiving data consumes 4.1 Joules of energy and in the listening mode consumes 3 Joules of energy. Transmitting of data consumes 2 Joule of energy under protocol of ST-TDMA. The total energy consumed throughout the session can be calculated as follows:

Consumed energy = Total Energy - Sum of energy in all states

$C_e = T_E - T_S$

$C_e = 15J - 9.2J$

$C_e = 5.8J$

C_e is the level of energy consumption of our entire scenario.

6.1.7 Message Inter Arrival Time (MIAT):

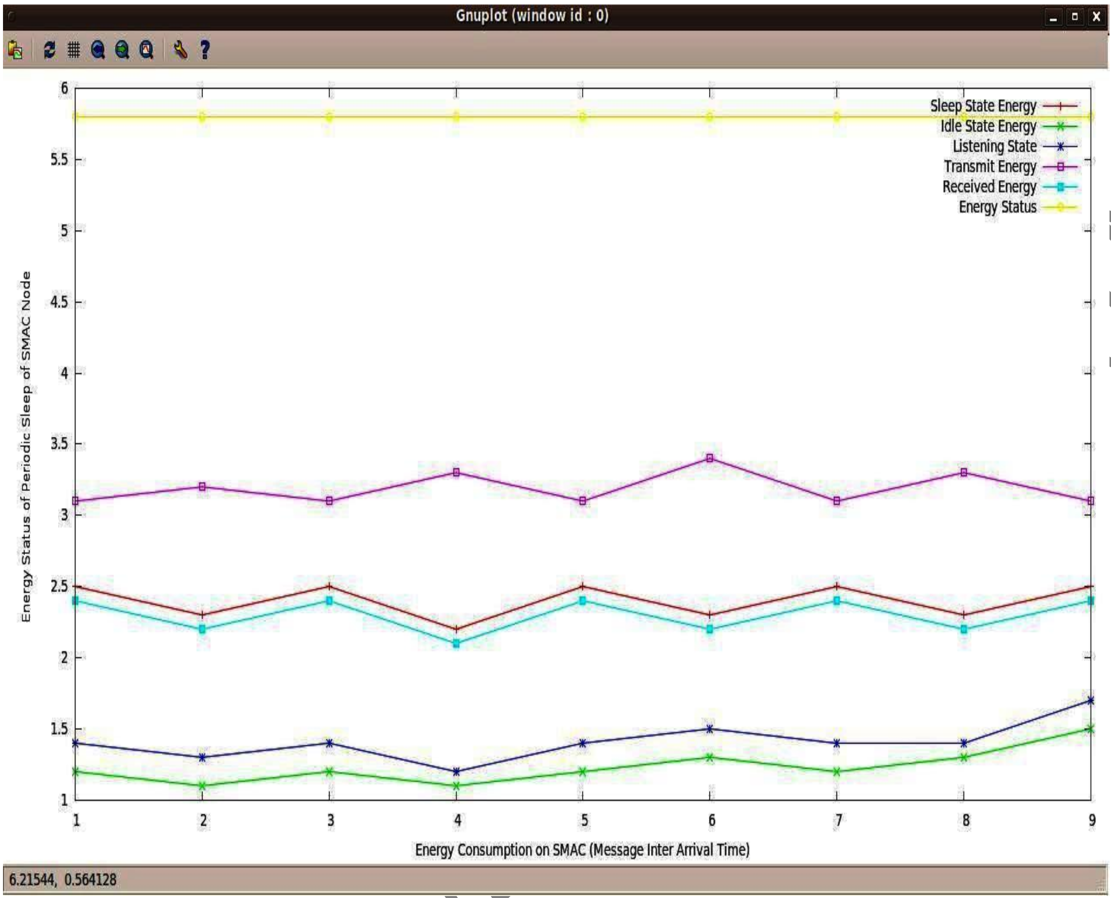


Fig 6.13: Energy Consumption on SMAC (MIAT)

Figure 6.13 shows the energy consumption of SMAC and MIAT. The nodes in sleep state consume 2.5 Joules of energy. Nodes which are in idle state consume 1.3 Joules of energy. Nodes in listening state consume 1.3 Joules of energy. The nodes which transmit data consume 3.1 Joules of energy. The nodes which receive data consume 2.4 Joules of energy. The resultant energy of SMAC and MIAT throughout the session can be calculated as follows:

$T_{EC} = E_{SS} + E_{LS} + E_{TE} + E_{RE}$

$T_{EC} = 2.5J + 1.3J + 3.1J + 2.4J$

$T_{EC} = 9.3J$

So total energy consumed throughout the session will be:

$C_E = T_E - T_{EC}$

$C_E = 15J – 9.3J$

$C_E = 5.7$ Joule

6.1.8 Calculated Delay in our Hybrid Network:

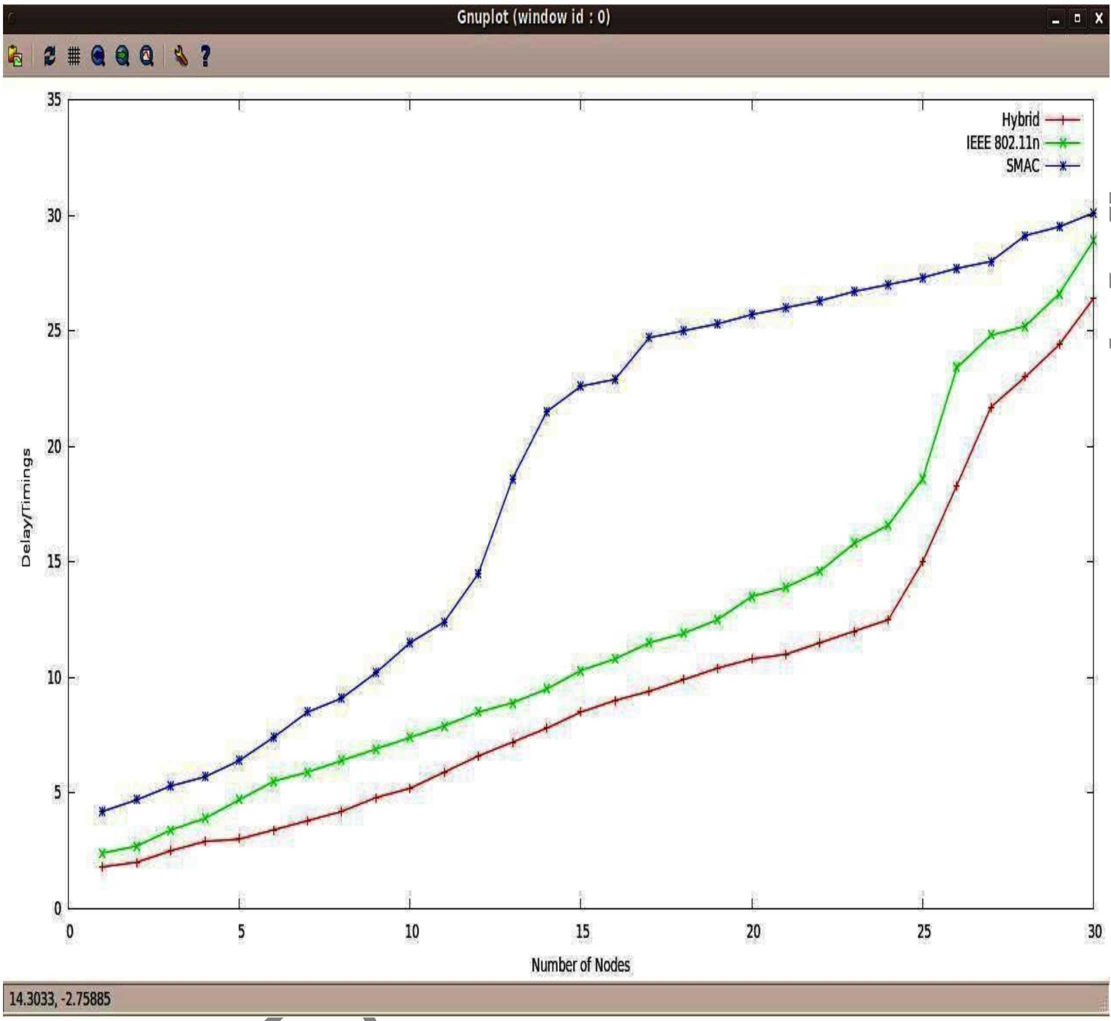


Fig 6.14: Delay/Timings in Hybrid Network

This graph shows the delay in 802.11n and SMAC. In SMAC protocol and IEEE 802.11n, considerable amount of delay has been found; combining these two protocols in our network significantly reduces this delay. Hence packets will be received with much shorter delay as compared to the said protocols individually. Hence we can prove from the above graph that Hybrid Network along with ST-TDMA consumes less Energy, has average Latency and high Efficiency, which helps in the prolonging the network life time without delay and congestion.

Chapter 7

Conclusion

CHAPTER - 7

CONCLUSION

7.1 Conclusion:

In our research work we have discussed various available techniques regarding congestion control, latency, delay and energy wastage in WSN. We have also implemented the innovative technique of ST-TDMA hybrid-protocol to avoid congestion, reduce both delay and the resultant energy deficiency. Secondly, allocation of time slots and sharing of time slots amongst different mobile nodes and load balancing technique helps in minimizing memory as well as extra energy wastage. The synergistic mating of ST-TDMA strategies comes up with reduced energy consumption, effective and efficient time allocation, lessening communication delay between node and the cluster head, sagacious congestion control. We have implemented our work on mobile sensor nodes in different sub-areas with static cluster head. We have seen its results after implementation on NS-2.27 and for deriving graphs GNUPLOT function has been made use of. ST-TDMA algorithm has been found to be the most suited solution to deal with major bottlenecks in WSN communication i.e. congestion, latency, energy wastage, delay on mobile nodes and cluster heads and overall efficiency of the network.

7.2 Future Work:

Our future work includes the energy wastage due to memory overloading in decentralized network in mobile sensor network. More-over, Node Level Security (NLS) combined with Load Balancing Algorithm to form a Hybrid Protocol.

"PDyLBA: Predictive and Dynamic Load Balancing Algorithm in Secure Mobile Wireless Sensor Network"

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