QoS-aware Channel Allocation in Directional Wireless Sensor Networks

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Declaration

We, hereby, declare that the work presented in this thesis is the outcome of the investigation performed by us under the supervision of Dr. Maheen Islam, Assistant Professors, Department of Computer Science and Engineering, East West University. We also declare that no part of this thesis has been or is being submitted elsewhere for the award of any degree or diploma.

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Abstract

In WSNs, majority of the channel allocation mechanisms considered energy efficiency as the many objective and assumed data traffic with similar priority. However, the introduction of image and video sensors demands certain QoS from the channel allocation mechanism and the underlying network. Managing real-time data requires both energy efficacy and QoS assurance. In this paper, we first present a novel QoS aware channel allocation algorithm, QDCA (QoS-aware Channel Allocation in Directional Wireless Sensor Networks), that supports high data rate for real-time traffic. By exploiting node clustering and directional communication, the channel is allocated dynamically by mapping the data priority requirements of the transmitting to the appropriate channel. The proposed mechanism works in distributed manner to ensure bandwidth and end-to-end delay requirements of real-time data. At the same time, the throughput of non-real-time data is also maximized. We have also proposed an improved QDCA mechanism, IQDCA, that enhances data throughput by inducing little computational and communication overhead. Results evaluated in simulation shows that QDCA and IQDCA mechanisms exhibit enhanced performance in terms of average delay, throughput and fairness.

Acknowledgments

As it is true for everyone, we have also arrived at this point of achieving a goal in our life through various interactions and help from other people. However, written words are often elusive and harbor diverse interpretations even in one's mother language. Therefore, we would not like to make efforts to find best words to express our thankfulness other than simply listing those people who have contributed to this thesis in an essential way. This work was carried out in the Department of Computer Science and Engineering at East West University, Bangladesh. First of all, we would like to express our deepest gratitude to Almighty Allah for his blessing on us. Next, our special thanks goes to our supervisor "Dr. Maheen Islam" who gave us this opportunity and initiated us into the field of "QoS-aware Channel Allocation in Directional Wireless Sensor Networks" and without whom this work would not have been possible. Her encouragements, visionaries, thoughtful comments, suggestions and unforgettable support at every stage of our BSc study were simply appreciating and essential. Her ability to muddle us enough to finally answer our own question correctly is something valuable what we have learned and we would try to emulate, if we get the opportunity ever.

There are numerous other people too who have shown us their constant support and friendship in various ways, directly or indirectly related to our academic life. We will remember them in our hearts and hope to find a more appropriate place to acknowledge them in the future.

Table of Content

Chapter 1

Introduction

1.1 Computer Network

Networking means sharing. A computer networking is a process of connecting two or more computers to share information. A system is a gathering of PCs, servers, centralized servers, organize gadgets, peripherals, or different gadgets associated with each other to permit the sharing of information [1]. The figure of a computer network is given in Fig 1.1.

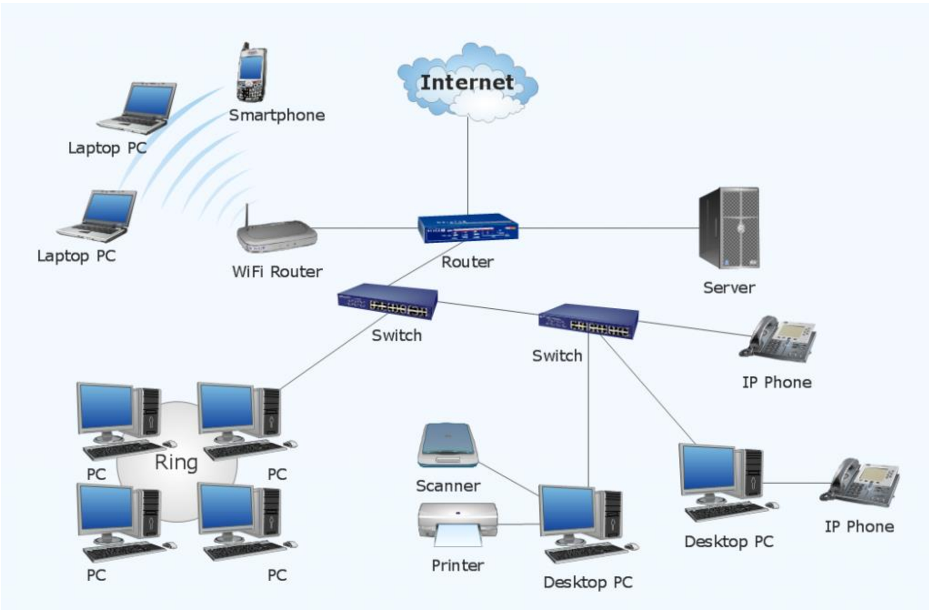

Fig 1.1 Computer Network

1.2 Wireless Network

A wireless network is a computer network that uses wireless data connections between network nodes. Wireless networking is a method by which homes, telecommunications networks avoid the costly process of introducing cables into a building or as a connection between various equipment locations. Wireless telecommunication networks are generally implemented and administrated using radio communication [2].The figure of a wireless network is given in Fig 1.2.

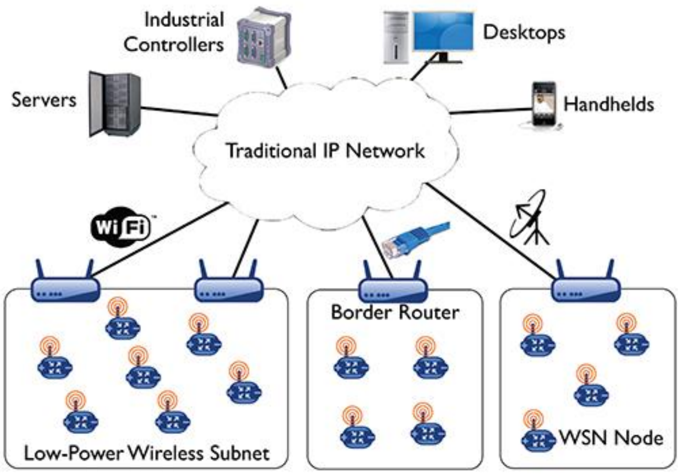

Fig1.2 Wireless Network

1.2.1 The Benefits of Wireless Network

Advantage of a wireless network over a wired one is that users can move around freely within the area of the network with their laptops, handheld devices etc. and get an internet connection. Users are also able to share files and other resources with other devices that are connected to the network without having to be cabled to a port. Not having to lay lots of cables and put those through walls etc. can be a considerable advantage in terms of time and expense. It also makes it easier to add extra devices to the network, as no new cabling is needed. If you are a business such as a cafe, having a wireless network that is accessible to customers can bring you extra business. Customers generally love wireless networks because they are convenient. Private companies can encounter many advantages from a remote system, including [3]:

- Comfort. Access your system assets from any area inside your remote system's scope region or from any WiFi hotspot.
- Versatility. You're never again attached to your work area, as you were with a wired association. You and your workers can go online in gathering room gatherings, for instance.

- Efficiency. Remote access to the Web and to your organization's key applications and assets enables your staff to take care of business and supports joint effort.
- Simple setup. You don't need to string links, so establishment can be brisk and practical.
- Expandable. You can without much of a stretch extends remote systems with existing hardware, while a wired system may require extra wiring.
- Security. Advances in remote systems give vigorous security insurances.
- Cost. Since remote systems dispense with or decrease wiring costs, they can cost less to work than wired systems [3].

1.2.2 Types of Wireless Network

There are four types of Wireless Network. The all types are described in the below.

- Wireless personal area network (WPAN): A wireless personal area network (WPAN) is a personal, short distance area wireless network for interconnecting devices centered on an individual person's workspace. WPANs address wireless networking and mobile computing devices such as PCs, PDAs, peripherals, cell phones, pagers and consumer electronics.
- Wireless local area network (LAN): A wireless local area network (WLAN) is a wireless computer network that links two or more devices using wireless communication within a limited area such as a home, school, computer laboratory, or office building.
- Wireless metropolitan area network (WMAN): The wireless metropolitan area network (WMAN) is a wireless computer network that interconnects users wirelessly with computer resources in a geographic area or region larger than that covered by even a large local area network (LAN) but smaller than the area covered by a wide area network(WAN). The term MAN is applied to the interconnection of networks in a city into a single larger network which may then also offer efficient connection to a wide area network. It is also used to mean the interconnection of several local area networks in a metropolitan area through the use of point-to-point connections between them.
- Wireless wide area network (WWAN): A wireless wide area network (WWAN), is a form of wireless network. The larger size of a wide area network compared to a local area network requires differences in technology. Wireless networks of different sizes deliver data in the form of telephone calls, web pages, and streaming video [4].

1.3 Wireless Sensor Networks (WSNs)

A Wireless Sensor Networks (WSN) is a set of thousands of micro sensor nodes that are capable of sensing and establishing wireless communication. A wireless sensor network consists of distributed sensors to monitor physical and environmental conditions which are of autonomous type. These of sensors are used to measure temperature pressure etc [5]. The figure of a wireless sensor networks is given in Fig 1.3.

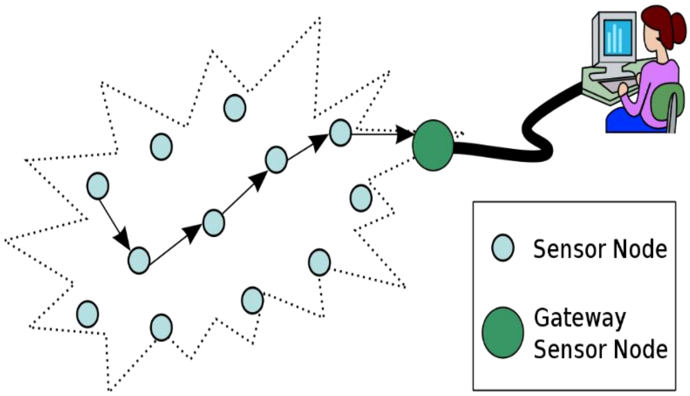

Fig1.3Wireless Sensor Networks

The wireless sensors were initially used in military applications but now a day it is used in many industrial and consumer applications for monitoring and controlling. It performs the computational and processing operations between two nodes. Wireless sensor networks generally provide us unique benefits in order to reduce the power consumed and in reducing the cost. The nodes in WSN are battery operated with sensing devices where energy resources are limited. When designing a power-efficient protocols the main issue that is wholly considered is to prolong the life time or to make the system energy efficient [6].

1.3.1.1 Wireless Sensor Networks Architecture

The sensor nodes are usually scattered in a sensor field. Each of these scattered sensor nodes has the capability to collect data and route data back to the sink/gateway and the end-users. Data are routed back to the end-user by a multi-hop infrastructure less architecture through the sink as shown in Figure 1.4. The sink may communicate with the task manager/end-user via the Internet or satellite or any type of wireless network (like WiFi, mesh networks, cellular systems, WiMAX, etc.), or without any of these networks where the sink can be directly connected to the end-users. There may be multiple sinks/gateways and multiple end-users in the architecture. In WSNs, the sensor nodes have the dual functionality of being both data originators and data routers. Hence, communication is performed for two reasons:

- Source function: Source nodes with event information perform communication functionalities in order to transmit their packets to the sink.

Router function: Sensor nodes also participate in forwarding the packets received from other nodes to the next destination in the multi-hop path to the sink [7]. The figure of a sensor network architecture is given in Fig 1.4.

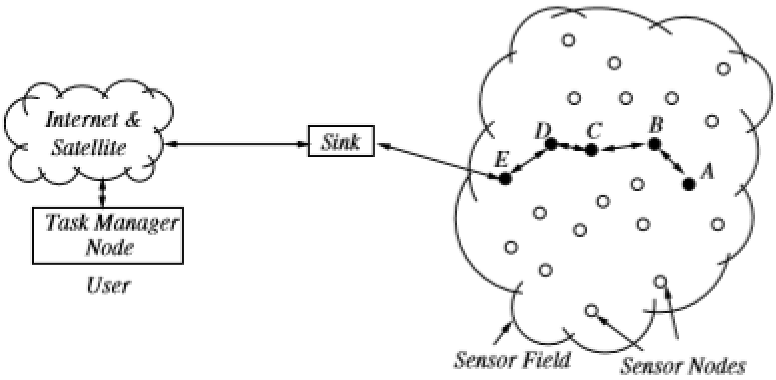

Fig 1.4 Sensor Network Architecture

1.3.1.2 WSN Deployment Challenges

- Sensor systems may comprise of various sort's sensors, for example, seismic, visual, infrared, RADAR, warm, attractive and so on to screen extensive variety of parameters continuously. Sending of hubs in a remote sensor hub application will be in an irregular style or this can likewise be planted physically. Remote sensor organizes smooth the advancement of observing and controlling of physical condition from remote region with absolute best precision. Progressions have been accomplished in remote sensor systems which prompted parcel of new conventions which is uniquely intended for sensor systems. Many directing conventions have been outlined where vitality mindfulness is an imperative thought. WSN isn't yet executed progressively because of its different disadvantages, for example, low power transmitter poor battery reinforcement, substantial vitality utilization and absence of security highlights and so forth. Different issues in arrangement of WSN include: [8]
- When sensor hubs are conveyed there is a shot for both of the two will be responsible for hub passing either the vitality consumption is caused by typical battery release or because of short out. To limit information misfortune issues influencing sink hubs ought to be identified.
- Deployment of sensor systems prompts arrange blockage because of numerous simultaneous transmission endeavors made of a considerable amount of sensor hubs.
- Another issue is the physical length of a connection. Two hubs might be close-by still they will be unable to convey because of physical meddling in reality while hubs which are far away m ay speak with each other.
- The organize conveys deficient measure of data which is likewise called as low information yield is a typical issue [8].

1.3.1.3 Wireless Sensor Network: Constraints and Challenges

Martin Haenggi (2004) specifies precisely the basic characteristics that the WSN have, including the following:

- Self-organizing capabilities.
- Short-range broadcast communication and multi-hop routing.
- Dense deployment and cooperative effort of sensor nodes.
- Frequently changing topology due to fading and node failures.
- Limitations in energy, transmitted power, memory and computing power.
- They also highlight that the WSN differ from the wireless and-hoc mesh networks in the latter three characteristics.

Before some of the above concerns are analyzed further, we will discuss in the following section the important WSN applications that set the requirements and drove a WSN development [9].

1.4 Directional Wireless Sensor Networks

An omnidirectional reception apparatus is a remote transmitting or getting recieving wire that emanates or catches radio-recurrence (RF) electromagnetic fields similarly well in every single even bearing in a level, two-dimensional (2D) geometric plane. Omnidirectional receiving wires are utilized in most customer RF remote gadgets, including cell phone sets and remote routers [10]. WSNs work in omnidirectional way. In any case, in omnidirectional system number of conspiracy is high. To stay away from the intrigue sectoring is done is WSNs. A directional remote sensor system (DWSN) is an arrangement of thousands of smaller scale sensor hubs that are fit for detecting and setting up remote correspondence in a specific bearing. A directional remote sensor arrange comprises of appropriated sensors to screen physical and ecological conditions which are of self-sufficient compose and they speak with the sink toward a path through directional reception apparatus. These kinds of sensors are utilized in savvy matrix framework, horticulture field and so on. [11].

1.4.1 Directional Wireless Sensor Network Architecture

The scattered sensor hubs have the ability to gather information and course information back to the sink and the end-clients however as a rule toward a path. A system is made toward a path. The sink or entryway speaks with the sensor hubs through directional receiving wire. The sensor hubs don't detect data from the outside scope of course. In directional remote sensor arrange, the sensor hubs have the double usefulness of being the two information originators and information switches [12]. The figure of a directional sensor network is given in Fig 1.5.

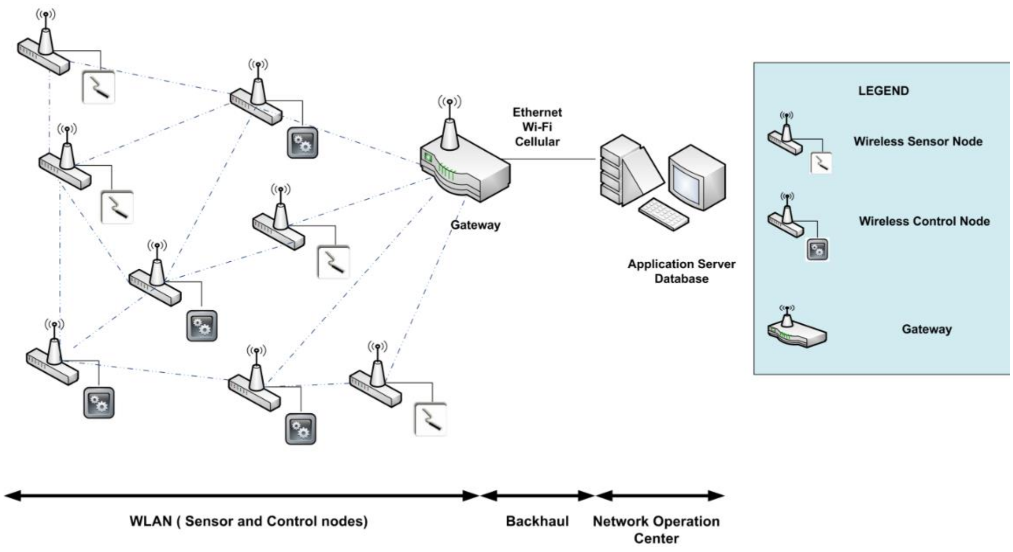

Fig1.5 Directional Wireless Sensor Network

1.4.1.1 Directional Antenna for Wireless Networks

A directional antenna or beam antenna is an antenna which radiates or receives greater power in specific directions allowing increased performance and reduced interference from unwanted sources. Directional antennas provide increased performance over dipole antennas – or omnidirectional antennas in general – when greater concentration of radiation in a certain direction is desired.

A high-gain antenna (HGA) is a directional antenna with a focused, narrow radio wave beam width. This narrow beam width allows more precise targeting of the radio signals. Most commonly referred to during space missions, these antennas are also in use all over Earth, most successfully in flat, open areas where no mountains lie to disrupt radio waves. By contrast, a low-gain antenna (LGA) is an omnidirectional antenna with a broad radio wave beam width that allows the signal to propagate reasonably well even in mountainous regions and is thus more reliable regardless of terrain. Low-gain antennas are often used in spacecraft as a backup to the high-gain antenna, which transmits a much narrower beam and is therefore susceptible to loss of signal [13].

1.4.2 Advantages of Directional Wireless Sensor Networks

There are many advantages of directional wireless sensor networks than the omnidirectional wireless sensor networks. Directional wireless sensor networks are comparatively cheaper than the omnidirectional networks. Directional networks are energy saving. Directional wireless sensor networks have more efficiency of neighbor discovery process because it has more communication range than the omnidirectional antenna when the same transmission power is used. Using directional network unnecessary data sensing can be avoided [14].

1.4.3 Applications of Directional Wireless Sensor Networks

In wireless sensor networks field directional antenna is highly used. To maintain a smart grid system directional wireless sensor networks is used. Through the WSNs the condition of the equipment is monitored and necessary step is taken collecting the information form the sink node. In agriculture field to monitor the condition of temperature, moisturizer, fertility of the land WSNs can be set up. In smart home system to monitor the room temperature WSNs is used. If the temperature reach in a certain level the room heater will be turned off automatically and if the temperature decreases the heater will be turned on again. In factory, medical sector, detecting smart dust, detecting forest fire directional wireless sensor networks is used. Military also use directional antenna for detecting the movement of enemy and also for military tank detection. They apply WSNs for border patrolling [15].

1.4.4 Challenges in Directional Wireless Sensor Network:

In directional wireless sensor network all the sector do not remain under the antenna coverage at a time. The sector that is not under the antenna coverage have to face the deafness. The nodes cannot communication with sink when the antenna is in another direction. For this reason, data waiting time increases and sometime the RT data has to wait to pass data to the sink node. This effect on the total performance of the network model [16].

1.5 Directional Channel Allocation Protocol

OSI model has seven layers' structure for computing networks. The second layer of OSI model is data link layer. The main function of data link layer is to transfer the data to neighbor network nodes. The data link layer is concerned with delivery of frames between devices on the same network. The sub layer of data link layer is MAC. The MAC layer provide mechanism that address and control channel access. Directional MAC protocol make it possible to communicate within a shared medium like wireless sensor network in a direction. The hardware that implements the directional MAC is referred to as a media access controller in a direction. Directional MAC layer is responsible for Generating and managing beacons, manages network coordinators, Channel access, Guaranteed Time Slot management, Frame validation and Acknowledged frame delivery in a directional network. The directional MAC protocols are broadly classified as scheduled based protocols and contention based protocols [17].

1.5.1 Channel Allocation Challenges in Directional Wireless Sensor Network

In directional wireless sensor network the communicating antenna cannot cover the area at a time. The antenna work in different sector by changing its direction. When the antenna work in one direction, the sensor nodes of other direction goes on deafness. So they cannot communicate with the sink node. In direction wireless sensor network waiting time and delay of data increases because of deafness. These effect on the throughput of the network.

1.6 Outline of Thesis

In this literacy, in Chapter 1, we have written the background study of our work. In Chapter 2, we have written the summary of the others work that are related with our work. In Chapter 3, we have proposed our protocol, written our network model, clustering the network and described the working procedure for channel allocation. In Chapter 4, we have analyzed the performance of our work. In Chapter 5, we have given the conclusion of our thesis. And at the last of our report we have added the references from where we have taken information to complete our thesis.

Chapter 2

Related Work

2.1 Related Work

WNS technology communicate on the multiple channels and this channel increases network capacity parallel transmission and robustness. Based on the benefits and the challenges in the multichannel communications, principally frequency of channel assignment, channel selection policy and channel assignment method.

Multiple techniques are given and contributed many multiple ways. Final mentioned class is discussed which deals with MCC in WMSNs. WMSNs are not appropriate for MC solution ad-hoc-networks. At a time, a sensor node has a single radio transceiver can use only one channel. Lower energy and bandwidth limitation creates constraint to apply present MC protocols. There are two major steps in multichannel protocols: one is multichannel MAC and another is channel assignment protocols.

Some benefits and problem for the adaptation on multichannel WSN have been identified first. Classifying three classes channel assignment is used: static, dynamic and semi dynamic method and give some ideas to implement and real use cases. A table is generated for classification and analyses of existing multichannel assignment protocols. This table is surveyed protocols [18].

The main topic of this paper, Free Space Optical(FSO) communication within the wireless sensor network using medium access control (MAC) protocol. Two photodiode for receiving data instead of one photodiode and used a stop transmission request (STR) signal is proposed here.

A FSO is the communication system where air is used as a medium to transmit light wave signals to another location. The main advantage of optical communication is that optical signals do not leak through walls nor interfere with delicate wireless equipment. Thus, providing security from intruders Sensor networks have consistently relied on Radio Frequency (RF) to provide connectivity between various sensor nodes and Cluster Head (CH). Sensor nodes sense the present situation of all channels. The requirements for Medium Access Control (MAC) protocol in directional sensor networks are different than traditional sensor networks. The protocol must be fast in providing access to the node and energy consumption must be least [19].

The MAC protocols are broadly classified as scheduled based protocols and contention based protocols. The scheduled MAC protocols are based on Time Division Multiple Access (TDMA) which is one-time slot is assign to each node, Code Division Multiple Access (CDMA) and Frequency Division Multiple Access (FDMA). CH is responsible for channel time division and timing synchronization of the nodes. The approach of Contention based MAC protocols are Carrier Sense Multiple Access (CSMA) and Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA). The problem of contend among all the nodes to get wireless channel for sending data is resolved by MAC protocol. The performance of any network increases if the chances of collision decrease. If the channel is free we can send data on the channel but if channel is not free it will wait for random amount of time. The collision can be avoided by CSMA/CA using three strategies: the interface space, the contention window and Acknowledgement (ACK). CSMA have low latency and higher throughput.

If multiple nodes transmit information to the same cluster head at same time, it will lead to collision of data packets. The collision of data packets requires retransmission of data packet which results in wastage of energy and Random Access (RA) time will increases. RA time should be minimum for MAC protocol to be effective. The challenge in implementing MAC protocol in FSO sensor networks is that most of the nodes are unknown to the transmission of other nodes because of their narrow directional link. Sensor node uses one transmitter with narrow FOV and one receiver only. In this paper author have proposed two photodiodes for receiving data instead of one photodiode. One photodiode is dedicated only for communicating with an urgent node while other will receive transmission from nodes in RA algorithm. If increasing the number of photodiodes, then the number of independent receiver channels would increase it's also reduce the random-access time. This method is called as receiver diversity. In this paper author have also proposed to use a stop transmission request (STR) signal. SRT signal is broadcasted to all the sensor nodes. The purpose of this signal is to temporarily halt the network traffic to build the D-TDMA queue. The total amount of energy consumption used in network is calculated by considering the energy used to transmit a packet, energy wasted in collisions and timeouts [19].

QoS-Aware MAC protocols utilizing sectored antenna for wireless sensor networks-based smart grid applications presents two new priority-based QOS-aware Directional Channel Allocation Protocols that coordinate the medium access based on the traffic class with efficient service differentiation mechanism to support QoS for smart grid applications. Authors first proposed a QoS-aware omnidirectional antenna-based medium access control (QODA-MAC). Then in order to investigate the impact of using sectored antennas on meeting QoS requirements, authors also proposed another QoS-aware four-sectored antenna-based MAC protocol (QFSA-MAC). The aim of the proposed approaches is to increase channel utilization with efficient service differentiation considering traffic flows with different requirements as well as providing reliable and fast delivery of data. Authors measure the performance of QODA-MAC and QFSA-MAC by making extensive simulations and compare them with each other. In the first scheme, named QODA-MAC protocol, in this protocol sensor nodes are equipped with omnidirectional antennas and also assigns the time slots and by considering the interference and channel conditions. And the second approach, named QFSA-MAC protocol, uses sectored antennas and dynamically assigns the time slots as opposed to the QODA-MAC protocol. Both QODA-MAC and QFSA-MAC protocols have two types of mode in terms of prioritized and not prioritized. The results show that QFSA-MAC outperforms the QODA-MAC protocol and satisfies QoS requirements of smart grid applications by achieving significant improvement in terms of latency, energy consumption and data delivery [20].

The authors have developed a target coverage aware using the clustering algorithm for directional sensor network. A Directional Sensor Network (DSN) consisting of large number of stationary directional sensor nodes in a 2-D Euclidean plane is considered. TRACE system is proposed to design a clustering algorithm. This TRACE algorithm works in three phases 1. Formation of clusters 2. Selection of gateways 3. Renewing of clusters heads and gateways [21].

Formation of clusters: Toward the start of bunch arrangement every sensor hub I ϵ N finds an arrangement of plausible bearings among every one of its headings segments that can suitably contend to participate in the grouping procedure [21].

Gateway Selection: To impart between two adjacent CHs, we have to choose portal hubs. The possibility for the entryway hubs are those that can impart between the two CHs in their working correspondence parts [21].

Renewing of Cluster heads and gateways: The CHs and the doors are dependable to convey all information parcels created by the detecting hubs toward the sink. This extra movement would debilitate the vitality of CHs and portals speedier than different hubs, bringing about lopsidedness vitality stack appropriation in the system and decreased system lifetime. Keeping in mind the end goal to accomplish adjusted vitality stack circulation among the hubs and to drag out the system lifetime, the obligations of CHs and passages are given over to different hubs through the span of time.

This Follow calculation demonstrated the viability of thinking about abused number of targets and neighbors in the region, separate from the sink and lingering vitality of the hubs to choose CHs and passages. The Follow framework adequately can diminish the quantity of dynamic sensors hubs and increment the system lifetime contrast with TCDC framework [21].

Chapter 3

Proposed Channel Allocation Mechanism

We have considered a sensor network on agricultural field which will sense data from the field and pass to the sink node. From the sink node the needed data can be collected and reading the data one can easily know about the environmental condition of the field. Based on the data, necessary step can be taken to improve the condition of the agricultural field and also the decision can be taken cultivating which crop is more beneficial for the field. When sensor nodes require transmitting data to the sink, a channel is required to be allocated. We opt to allocate good quality channel to higher priority data in order to ensure timely delivery of data. The Real Time (RE) data will have the higher priority to allocate with the channel. The Non Real Time (NE) will have the second highest priority and the Best Effort (BE) data will have the last priority to get the channel. We have used directional antenna for communication among the sensor nodes and with the sink node. In this thesis work, we have proposed two channel allocation mechanisms, namely QoS-aware Channel Allocation for Directional Sensor Networks (QDCA) and Improved QDCA (IQDCA) for achieving high throughput and low latency data delivery for real-time and Non Real-Time data. Our proposed mechanism allocates channel to transmitting nodes to reduce communication overhead and latency.

3.1 System Model and Assumption

We have considered a wireless sensor networks over2600m^2 area approximately. There is a sink node in the center of the field. The coverage area of the sink node will be distributed in four sectors. There are two cluster heads in every sector and the cluster heads which are connected with the sensor node of the sector will communicate with the sink node through directional antenna. If we divide 2600m^2 in four sectors, then the area of each sector will be around $650m^2$ and there may be more than one cluster head in each of the sector which will cover the sectored area. There are n number of sensor nodes under a cluster head. If any sensor node is in one hop distance from the sink node, then it will directly pass the data to the sink node. The cluster heads will communicate through a gateway with each other.

3.1.1 Network Model Structure

In our QDCA network there is sink which has the central control. All the data collected by the sensor nodes are passed to the sink. To reduce the pressure on the sink nodes we have clustered the network. We have divided our network in four sectors. There is sensor nodes (SN), Gateways, Cluster heads (CH) in every sector. The sensor node which has the highest energy will work as the cluster head. The network is based on directional antenna but the antenna cannot cover the all four sector at a time. It can only cover the sector which is in the direction of this antenna. The diagram of our proposed network model is given in Fig 3.1.

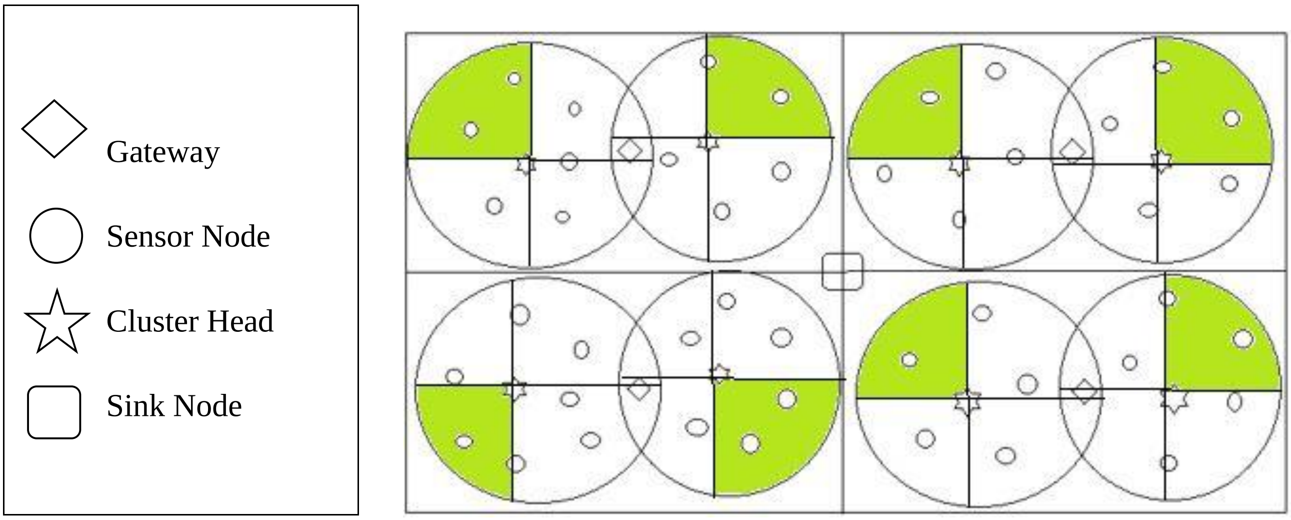

Fig 3.1 Network Structure

For the improvement of the throughput and reducing the delay we have applied the method IQDCA and in this network model we have considered four cluster heads in every sector and every cluster head will have two directional antennas to collect data and communicate with the sink node. The diagram of our improved network model is given in Fig 3.2.

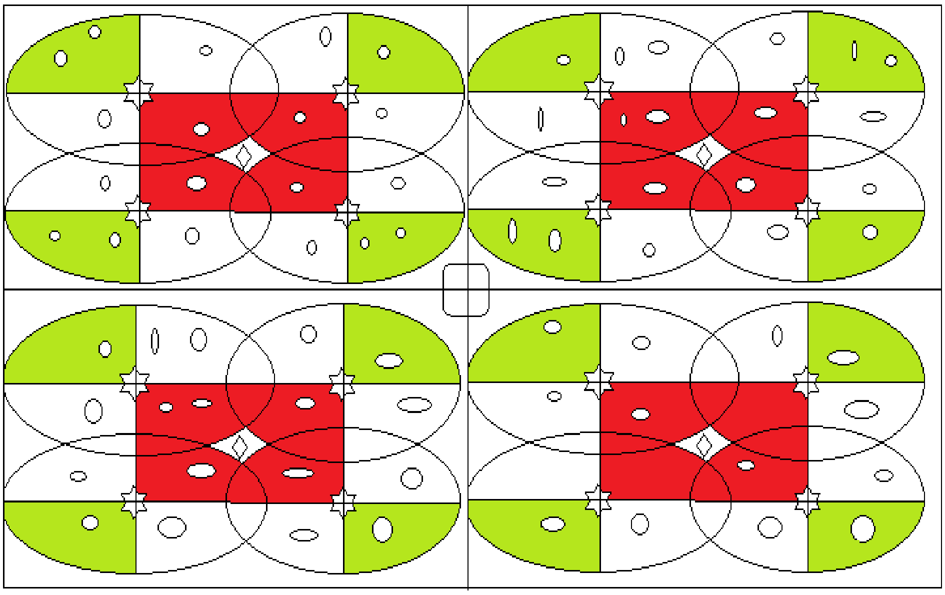

Fig 3.2 Improved Network Structure

Notation Used for Network Elements:

The notations have used in our equation is given in Table 3.1.

Symbol	Definition
Ɲ	Sink
A	Network Area
N	Set of Sensor Node
n_i	i-th sensor node
H	Set of Cluster Head
CH_i	i-th cluster head
G	Set of Gateways
$g_{i,j}$	Gateway between $Ch_i$and Ch_j
S	Set of Sector
S	Sector number
$n_{i,s}$	i-th node is active on sector s $n_{i,s}$= {1, sector s is active 0, sector s is inactive}
|C|	Set of channel
C_i	i-th channel

E_o	Initial energy of node n_i
E_t	Total energy of node n_i
E_r	Residual energy of node n_i
P	Data priority
T	Waiting time
τ_r	Response time
τ_a	Arrival time
M	Channel success rate
Ƙ	Channel capacity
B	Available channel Bandwidth
Λ	Load
H	Channel occupancy
d(n_i, Ɲ)	Distance between node to sink
d(CH_i, Ɲ)	Distance between cluster head to sink
$d(n_i, CH_i)$	Distance between node to cluster head
$d(CH_i, g_{i,j)}$	Distance between cluster head to gateway
$d(CH_i, CH_j)$	Distance between cluster head to cluster head
Ω_c	Set of communication sector
Ω_s	Set of sensing sector

Table 3.1 Notation

3.1.1.1 Network Model (QDCA)

In our proposed network model, we have considered a $2600m^2$network area. A sink will cover the whole area. The sink coverage area will be distributed in 4 sector and area of every sector is $2600m^2$. There will be 2 cluster head in every sector. Distance between 2 cluster head is around 95m and the cluster heads of the sector will be connected through a gateway.

- Ɲ → 1
- $A \rightarrow 2600m^2$
- $s \in S$
- $A/S \rightarrow 650m^2$
- $CH_i/s \rightarrow 2$
- $CH_i \in H$
- $g_{i,j}/s \rightarrow 1$
- $n_{i,s} \rightarrow 100m^2$
- $d(CH_i, CH_j) \rightarrow 95m$

3.1.1.2 Network Model (IQDCA)

In our IQDCA model all most all the elements and structure are same as the QDCA method. But in our IQDCA method there are four cluster heads in every sector. Then the distance between the cluster heads has reduced.

- $CH_i/s \rightarrow 4$

3.2 Clustering

We have clustered our network to improve the total performance. The formation of this clustering has three part. All the parts have been described below.

1. Formation of cluster
2. Selection of gateways
3. Renewing of Cluster head(CH) and gateways

3.2.1 Cluster Formation for QDCA

In a cluster formation each sensor node I ϵ N finds a set of feasible directions among all its directions sectors that can viably compete to take part in the clustering process.

0Each node i calculate a matric $Q_{i,\omega}$ for itself

$$Q_{i,s} = w1 \times \left\{1 - \left(\frac{d(i,N)}{d^i_{max}}\right)\right\} + w2 \times \left(\frac{E_0}{E_i}\right) \;\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where w1, w2 are weight factors and $w1 + w2 = 1$

The values N^i_{max},d^i_{max} are determined by using

$$N^i_{max} = max_{\forall s \Omega c}\{max_{j.j \epsilon ni,s}\{max_{s \in \Omega c}(|n_{j,s}|)\}, |n_{j,s}|\} \;\ldots\ldots\ldots\ldots\ldots..(2)$$

$$d^i_{max} = max_{\forall \omega \epsilon \Omega c}\{max_{j.j \epsilon ni,s}\{max_{s \epsilon \Omega c}(d(j,N))\}, d(i,N)\} \;\ldots\ldots\ldots..(3)$$

Each sensor node iϵN checks the following condition:

$$max_{\forall s \epsilon \Omega c}(Q_{i,s}) >= max_{\forall s \epsilon \Omega c}\left\{max_{j.j \epsilon ni,s}\{max_{s \epsilon \Omega c}(Q_{i,s})\}\right\}\ldots\ldots\ldots(4)$$

Based on the outcome of the inequality checking (i) the following actions are taken

- If the eq.(i) returns true value for a node iϵN, it declares itself as a cluster head(CH). Fixes its working communication sector to s, sends messages to its neighbor nodes. The message contains theID of CH.
- When a node $j \epsilon n_{i,s}$ receives a CH formation message from its neighbor i , it checks whether it is in the working sector of CH i. If yes, then it selects its working communication sector toward i and sends a cluster membership message to all its single hop neighbor. Otherwise, the node j updates its $Q_{j,s}$.
- When a sensor node receive a cluster member message, it updates its $Q_{i,s}$ for itself and its neighbor [21].

3.2.1.1 Selection of Gateways

To establish the communication between two nearby CH, we need to select a gateway to connect them. The candidates for the gateway nodes are those that can communicate between two CHs in their working communication sectors.

The CH calculate the gateway selection priority for the nodes i

$$`Q_{i,s} = w1 \times \left(\frac{|n_{j,s}|}{N^i_{max}}\right) + w2 \times \left(1 - \frac{d(i,N)}{d^i_{max}}\right) + w3 \times \left(\frac{E_i}{E_0}\right) \;\ldots\ldots\ldots\ldots (5)$$

The cluster head greedily selects a node as gateway that has the highest $g_{i,s}$ value [21].

3.2.1.2 Renewing of Cluster Head(CH) and Gateways

The CHs and the gateway nodes are responsible to carry all data packets generated by the sensing nodes toward the sink. This additional activity would exhaust the energy of CHs and gateway faster than other nodes, resulting in imbalance energy load distribution in the network and reduced network lifetime.

In order to achieve balanced energy-load distribution among the nodes of CHs and gateway are handed over to other nodes over the course of time.

The renewal process of cluster formation is started whenever the residual energy $E_k$of a CH is reduced to below a certain E_{th} (E_k<=E_{th}). A CH send message to its member nodes M_k about the relation of CHs and the member nodes renew the clustering process using eq.(i). The value of the energy threshold E_{th} is not fixed rather its set dynamically that actually allows more nodes to participate in the clustering process.

Similarly, the gateway nodes are also renewed by the CH when their energy value is less than a certain threshold value. This dynamic update of the threshold to achieve better network lifetime [21].

3.2.2 Cluster Formation (IQDCA)

For Clustering the IQDCA method we have used the equation 1,2,3,4 as we have used in the QDCA method. But in IQDCA method there are 4 cluster in every sector.

3.3.1 QoS Aware Channel Allocation (QDCA)

In our work the sensor nodes will sense 3 types of data (RT, NRT, BE) and the data type is based on their priority. We will allocate the best channel to the node to pass the higher priority data to sink.

ρ: RT=3, NRT=2, BE=1

We have calculated the channel c selection based on some parameters. We have calculated channel success rate (μ_c) and for this calculation we have considered some outcome (o) of previous transmission. If the transmission is successful then we have set the outcome value to 1, if the transmission is not successful then we have set the outcome value to 0. Then we have multiplied the outcome value with the i-th interval and summated the ‘m’ no of intervals multiplication value and then divided with the summation value of the intervals. The μ is given below.

$$\mu_c = \frac{\sum_i^m (i \times o_i)}{\sum_i^m i} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

We have considered the load (λ) of the channel. To calculate load of the channel we have divided the channel occupancy (η) by the channel capacity (Ķ).

$$\lambda_c = \frac{\eta_c}{\text{Ķ}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Available channel bandwidth (β) is also in our consideration for channel allocation. We have subtracted channel occupancy from channel capacity to calculate available channel bandwidth.

$$\beta_c = \text{Ķ} - \eta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

To calculate the waiting time (τ) of data we have subtracted the arrival time (τ_a) from the response time (τ_r).

$$\tau = \tau_r - \tau_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

To calculate the total channel performance (q_c) we have multiplied the channel success rate with 100 and divided the available channel bandwidth by the channel capacity then multiplied with 100 and then done the summation and then subtracted the 100 times of load. The channel has the highest q_c is the best channel and we allocated the channel for the RT data. If there is same priority data, then we have considered the waiting time. The data waited form more time, we allocated with the available better channel to the data.

$$q_c = \mu_c \times 100 + \frac{\beta_c}{\text{Ķ}} \times 100 - \lambda_c \times 100 \quad \ldots\ldots\ldots\ldots\ldots..(10)$$

Channel Allocation:

input – data
output – channel for data passing

1. initialization of variable
2. assign C_T
3. λ_c ← load of channel
4. μ_c ← success rate of channel
5. β_c ← available bandwidth
6. τ ← waiting time of data
7. ρ ← data priority
8. if β_c = 0
9.   channel busy
10. else if β_c> 0
11.   for i← 1, C_T do
12. w_i← weight of i-th interval
13. μ_c ←success rate of channel
14. q_c← total channel performance
15. tdt← total channel performance

```
for i ← 1, tdt do
ρ ← assign data priority
  if ρ = 3
      RT++
  else if ρ =2
      NRT++
  else if = 1
      BE++
for j ← 1, tdt do
   if CT> 0
         if RT > 0
allocate channel to RT
 if sv =1
data passed successfully
else  if sv=0
data droped
RT - -
CT - -
if NRT > 0
              check τ
                allocate channel to NRT
if sv =1
data passed successfully
                else  if sv=0
data droped
NRT - -
                CT - -
if BE > 0
 check τ
                allocate channel to BE
                if sv =1
                       data passed successfully
                else  if sv=0
                        data droped
                RT - -
                CT - -
        else
              data is in waiting queue
```

Example:

No. of Channel = 3

Ҁ= 5

For Channel_1:

η= 2

$$\beta_c = \frac{5-2}{5} \times 100 = 60$$

$$\lambda_c = \frac{2}{5} \times 100 = 40$$

Channel Success Table:

1	2	3	4	5
×	×	√	√	×

$$\mu_c = \frac{7}{15} \times 100 = 46.66$$

q_c =60+46−40 = 66.66

For Channel_2:

η= 1

$$\beta_c = \frac{5-1}{5} \times 100 = 80$$

$$\lambda_c = \frac{1}{5} \times 100 = 20$$

Channel Success Table:

1	2	3	4	5
×	×	×	√	√

$$\mu_c = \frac{9}{15} \times 100 = 60$$

q_c =80+60−20 = 120

For Channel_3:

η= 5

$$\beta_c = \frac{5-5}{5} \times 100 = 100$$

$$\lambda_c = \frac{5}{5} \times 100 = 100$$

Channel Success Table:

1	2	3	4	5
√	√	√	√	√

$$\mu_c = \frac{15}{15} \times 100 = 100$$

q_c = 0+100−100 = 0

Total Channel Request = 10

Data Priority: RT=3, NRT=3, BE=4

Channel Allocation:

For RT:

1. Channel_2 (i)
2. Channel_2 (ii)
3. Channel_2 (iii)

For NRT: (Based on τ)

1. Channel_2 (iv)
2. Channel_2 (v)
3. Channel_1 (i)

For BE: (Based on τ)

1. Channel_1 (ii)
2. Channel_1 (iii)
3. Channel_1 (iv)
3. Channel_1 (v)

3.3.2 QoS Aware Channel Allocation (IQDCA)

We have used the same algorithm for channel allocation for IQDCA method as we have used for QDCA method. But in IQDCA method we have allocated two parallel channel for each cluster head for receiving data from sensor nodes and transmitting data to the sink node at a time.

Chapter 4

Performance Analysis

4.1 Experiment Setup

We have established a directional wireless sensor network and divided the network in four sectors. There are two clusters in each sector. We have used a gateway to establish communication with cluster to cluster. The data that the sensor nodes collect reach to sink through cluster head. The sensor nodes pass the data to its cluster head and the cluster head send to the sink. For this communication we have used directional antenna. In our network we have multiple channels for transmitting data and we have measured the channel performance based on some parameters. We have prioritized the data that are collected by the sensor nodes based on their importance. The best performing channel is allocated for the most important data. In our work, we used the channel in frequency domain. The work is related with us, they also tried to allocate the better performing channel for the higher priority data. They allocated their channel in time division but they did not cluster their network and they had no cluster head also. In their model sink node controlled the network. We have implemented our work using the method QDCA and IQDCA and compared with the QFSA-MAC [20].

4.2 Performance Metric

We have measured the performance of our work based on four matrics. We have measured the throughput, delay, fairness, reliability of our network.

Throughput: The data in bits are successfully reached from sensor node to the sink in a second is throughput. [22]

Delay: We have considered the delay of data as a performance matric. To calculate the delay, we have counted the arrival time and received time of the data packet. We have added the waiting time with the subtraction of arrival time from received time. [23]

Fairness: We have three types of data based on their priority. RT data has the higher priority, NET data has the second higher priority and the BE data has the less priority than the other two types data. As the fairness of our network we have ensured that RT data gets the best performing channel and RT data has no need to wait for getting the channel. The delay of the RE data is comparatively less. NRT and BE data get the channel if there is no RT data in the queue. NRT data allocate with the second better performing channel and BE data get the channel at the last. [24]

Reliability: Reliability of the network is the ration of successfully delivered data and the transmitted data. The network will have the highest reliability=1if the all data transmitted from the sensor nodes reaches to the sink node successfully. [25]

4.3 Scenario

In our simulation part, we have tested our algorithm changing the traffic load and increasing the channel. We see that if we increase the traffic load the throughput increases at the starting but at after a point throughput decrease. We also see that delay increases if the load of the network increase and the reliability of the network decrease if the load increases. From our output we see that, if we increase the channel of the network the reliability and throughput increase but delay decreases. Comparing with others work that is related to our work we see that if we increase the traffic load and channel at both case our output is better.But we can say that, the fairness of both of us is around more than 90%, even if the traffic load and channel both are being increased.

4.3.1 Increasing Traffic Load

We have increased the traffic load of our network to see the output of our network in respect of throughput, delay, reliability and fairness.

We see that, increasing the traffic load of our network and improved network the throughput start increasing. It stops increasing at a level and after that it starts decreasing. The output graph of throughput in respect of the increasing traffic load is given Fig 4.1.

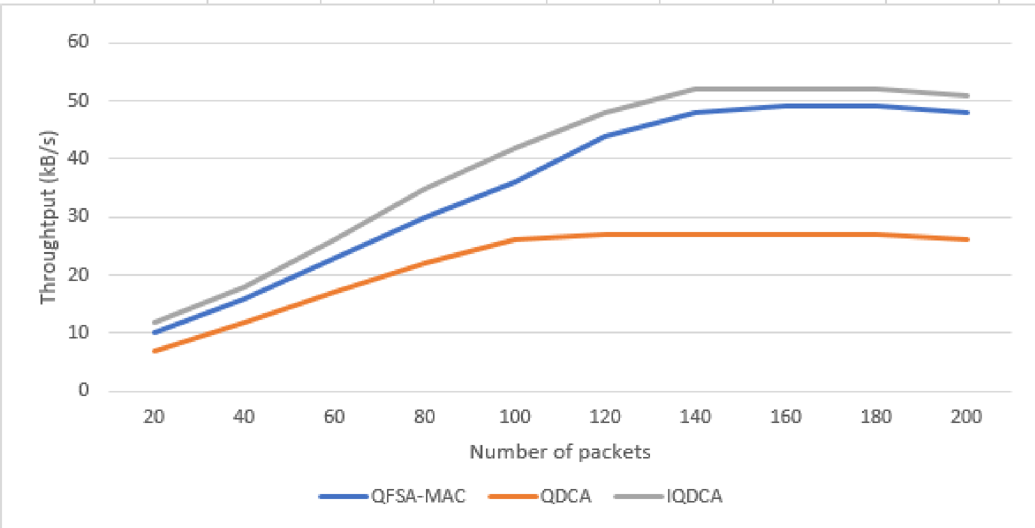

Fig 4.1 Number of Packets(KB) vs. Throughput(KB/s)

From the graph we can see that, the throughput of our work and improved work is increasing when we are increasing the traffic load of the network till the point 140 in the x-axis. But after the point 140 the increasing rate of throughput became too slow and if we increase the load more than the graph line will start decreasing. We also see that from the graph that our improved throughput is better than our first throughput line and the both of our throughput lines are better than the others.
Increasing the traffic load, we can see that the delay of our network and improved network is also increased. The graph of the changes of delay with respect to traffic load is given Fig 4.2.

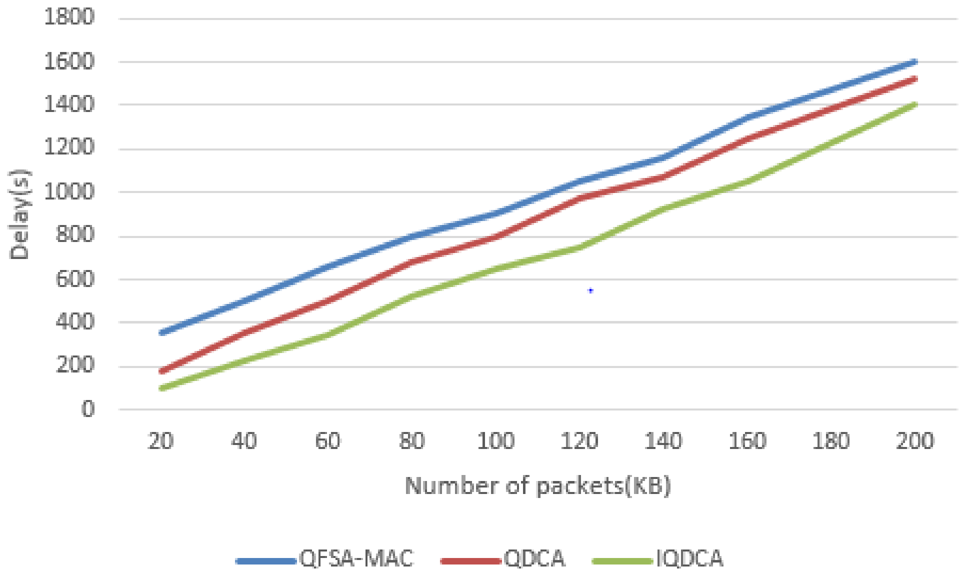

Fig 4.2 Number of Packets(KB) vs. Delay(s)

From the graph we see that, if the traffic load increases then the delay of our both network increases but the delay of our improved network is less than our previous network and our both performance is better than the others work.
Increasing the traffic load, we see that the reliability of our first network and improved network decreases continuously. The reliability can be maximum 1 in the case of successfully delivering of all transmitted packet to the sink. But it is a rare case. The graph between the traffic load and the reliability is given Fig 4.3.

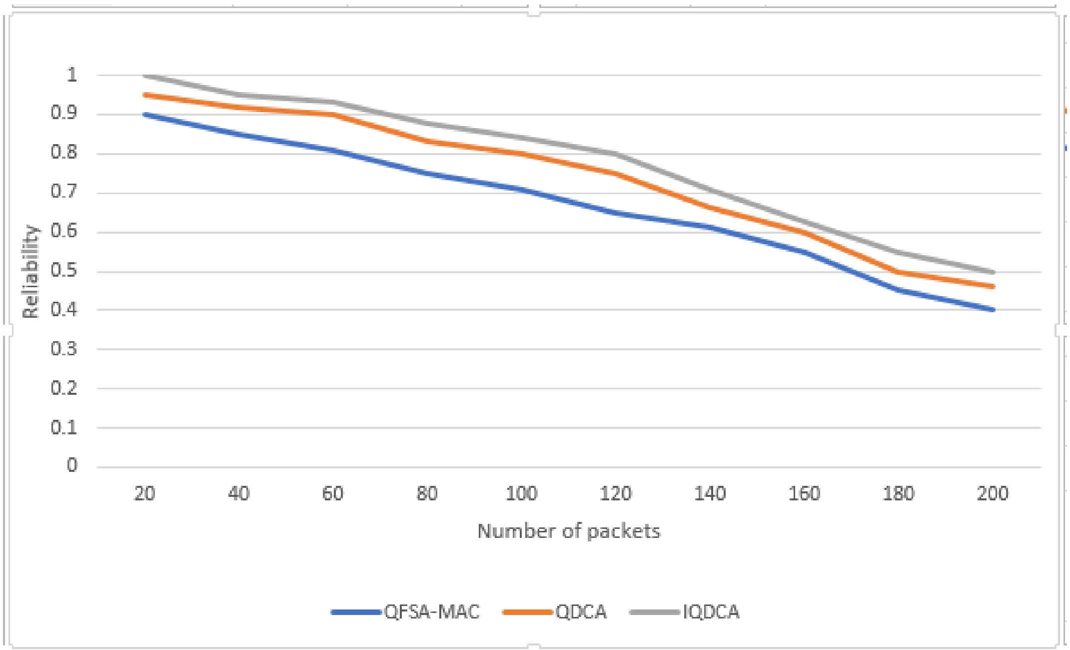

Fig 4.3 Number of Packets vs. Reliability

From the above graph we see that the reliability of our improved network is better than our previous network and in both case the reliability of our algorithm is always better than others. We have the highest reliability when the load of the network is less.

In our work we have highly considered to ensure the fairness of the network. In our network with respect to traffic load the RT data has a minimum of delay. If load is increased the delay of RT data increases at a low rate but the delay of NRT and BE data is increased with the increasing traffic load. The graph of fairness of our work and improved work is given Fig 4.4 and Fig 4.5.

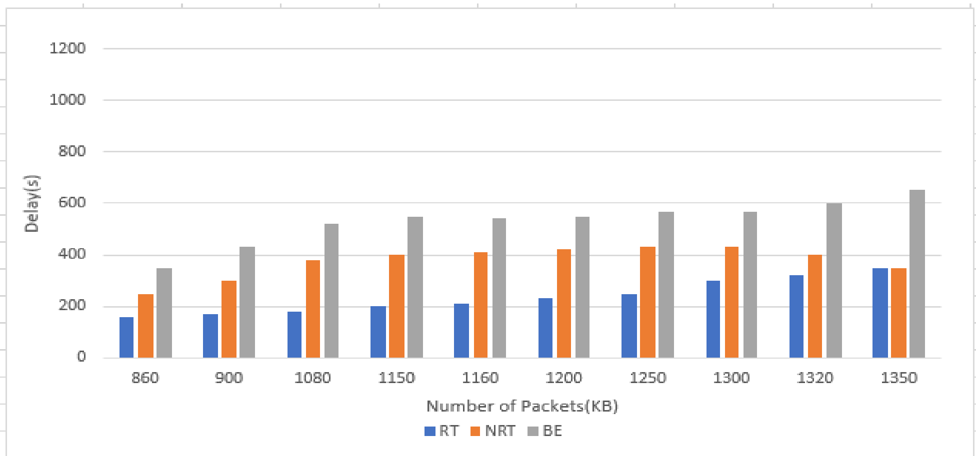

Fig 4.4 Fairness (QDCA)

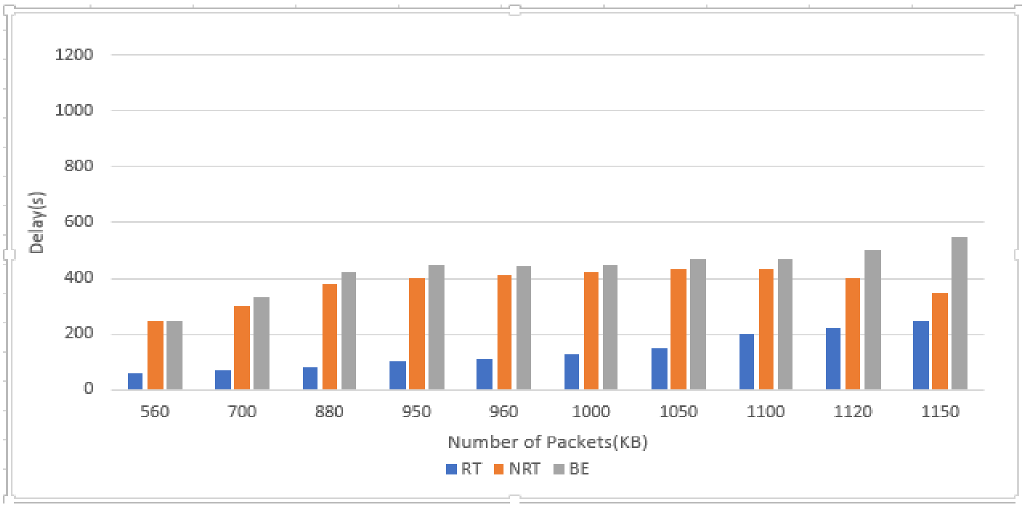

Fig 4.5 Fairness (IQDCA).

From the both graph we see that, the RT data has a very low delay, and with the increasing load the delay of RT data changes at a low rate and the NRT data always has a less delay the BE data. We also see that, the delay of RT, NRT and BE data of our improved work is less than our first work.

4.3.2 Increasing Channel

We have increased the channel of our network to see the output of our network in respect of throughput, delay, reliability.

We see that, increasing the channel of the network the throughput and reliability of our first work and improved work start increasing. The increasing graph will be slow after a point for both case. The graph of throughput with respect to increasing channel is given Fig 4.6.

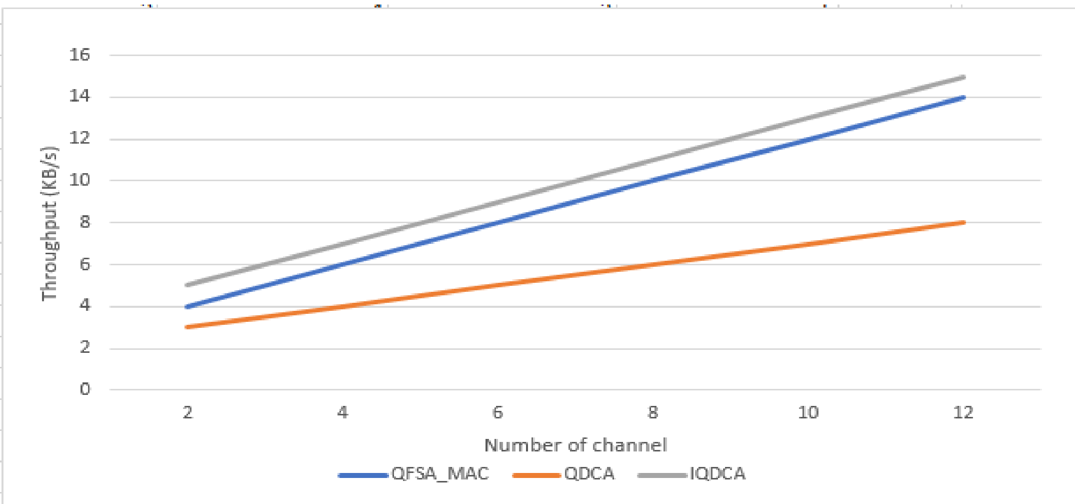

Fig 4.6 Number of Channel vs. Throughput(KB/s)

From the graph we see that when we increased the number of channel from 2 to 4 the throughput line went up for our both work and after the point (x) in x-axis the increasing became slower. We have better throughput for our improved work then our previous work and our both throughput line is above then the comparing line.
Increasing the channel, we see that the reliability of our both network is also increased continuously. The graph between the traffic load and the reliability is Fig 4.7.

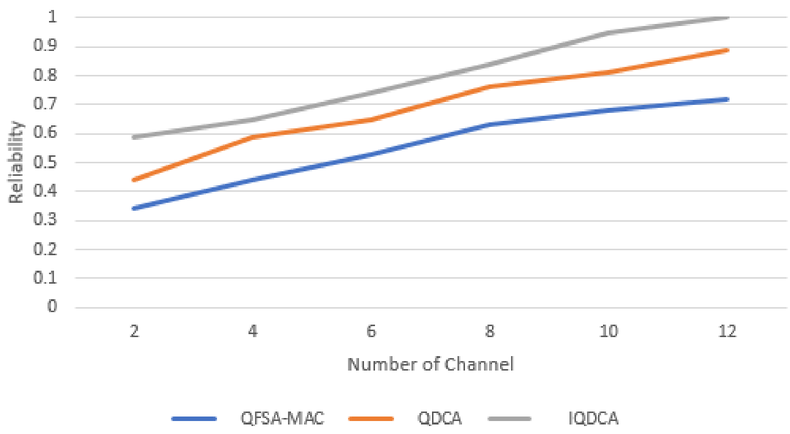

Fig 4.7 Number of Channel vs. Reliability

From the graph we see that, the reliability graph is increasing with the increasing number of channel and our both graph line is above then the other graph line and the improved line is better than the other two lines.
Increasing the channel, we can also see that the delay of our network is decreased. The graph of the changes of delay with respect to the increasing number of channel is given Fig 4.8.

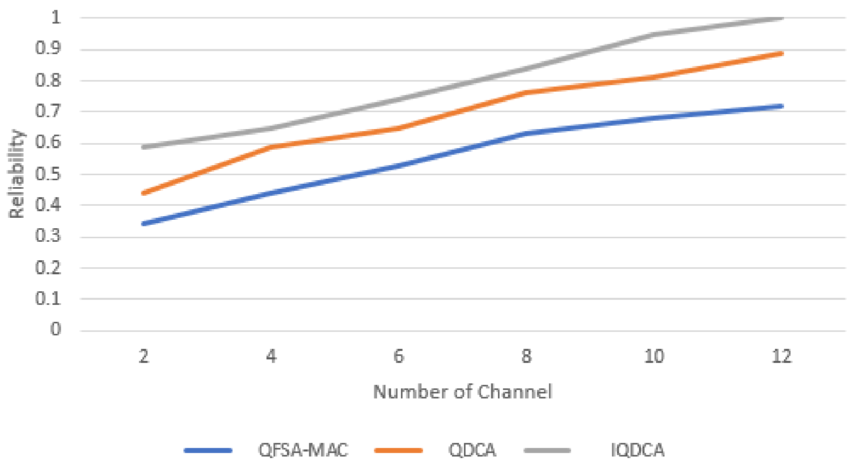

Fig 4.8 Number of Chanel vs. Delay(s)

From the graph we see that, the delay of our both work is decreasing when number of channel is increasing and the improved work has less delay than our first work. We also see that, in both case we have less delay in our algorithm.

Chapter 5

Conclusion and Future Work

5.1 Conclusion:

Our work gives architecture to find answer for necessary plan. Here, a wireless sensor networks on an agriculture field collect data and send to the sink node. Our works helps to sector a network. We have calculated the channel performance of the network based on six parameters and the parameters are channel success rate, load, available channel bandwidth. We have also prioritized the data based on their importance. In our algorithm we have allocated the best channel to the most important data. Allocating the data, we have considered the waiting time of NRT and BE data. We have simulated our architecture, shown the fairness and we have compared our graph with the others works and have shown our performance.

5.2 Future Works:

Though the initial motivation of this approach is to be able to provide QoS aware multichannel MAC for directional wireless sensor network that can select channel based on data priority; there are also many steps for further implementation. The further steps of this procedure that we want to work in future are:

a. Simulating through NS3 network simulator.
b. Solving the deafness of sectors which are not in the direction of the antenna

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