CHAPTER 1

INTRODUCTION

As we know, food being the primary need for a human being on the contrast to life, it is important to be attached with the agricultural aspect of the country. The agricultural activities in a country lead to the usage of more and more part of the land which can be used over for this. The crop must be cultivated on the basis to recover the minimum requirements of the people of the country so not to get demanded over on this issue.

Now, we come to our country India, being a developing country it has second highest agricultural land to be cultivated in a year. A majority of population totally depends over employment in agricultural sector. There are a number of issues to be controlled over in agriculture in our country. The biggest issue in agricultural sector is water management totally affecting the productivity of the crop. Indian irrigation system totally depends upon rain. It is highly affected by decrease in the amount of expected rain and water management. Therefore, we can't be dependent over rain in terms of irrigation. For this, there should be usage of technology in irrigation system to increase productivity and make it profitable.

The agricultural activities hold 25 % of the total Gross Domestic Product (GDP) while 15 % total export and 65 % of total population's livelihood of the country. On this stage yet we are still in practice of conventional methods of irrigation having lot of drawbacks. Global population growth and increasing urbanisation have resulted in increased competition for water resources among domestic, industrial and agriculture users. Commercial operations have been showing increased interest in the usage of wireless sensor networking technology which is designed to monitor and control irrigation events both.

In growth of a plant, some basic needs as air, water, sunlight, soil and others are required over for the development. It takes approximately eight to fifteen days in irrigation of crop in conventional method of irrigation with uniformity of water distribution is up to thirty percent only. It leads to reduction in irrigation efficiency as total applied water does not reach to the plant. Only up to forty percent of total amount of water is utilised over in the irrigation.

The methods of irrigation can be categorised into conventional and micro irrigation methods. In India, conventional methods of irrigation are mostly entertained over.

1.1 Conventional Irrigation Method

In the procedure, during first three days soil pores get saturated with water under irrigation with interval of eight days. The air is replaced by water in soil with disturbing capacity level. Root is suffocated by the excess water and water absorption is ceased and growth of crop is hampered.

Further, soil moisture is lowered due to evaporation loss, in the next three days. After this, moisture, air and nutrients come to an optimum level while soil comes to field capacity level only. During this phase, plant grows and the moisture level goes below the root zone. The plant undergoes stressed condition by which air and nutrients can't be taken easily and growth of plant is restricted. One of the conventional methods used is surface irrigation method.

1.1.1 Surface Irrigation

In this method, the complete land is filled up with water. As a result, a huge amount of water is wasted due to lack of knowledge of water to be used and the process of evaporation also. The surface conventional irrigation method is further classified into different categories. These are as follows:

(a)Level Basin – This technique is applied when the plot to be irrigated is small. Initially, the water is applied to the whole field in accordance. The extreme points are connected to small collective areas or ponds so that the extra water runs off to it.

There is little amount of water loss by runoff while no loss in terms of fertilisers and organic manures. It may be costlier if the field has to be levelled initially. This technique is suitably done over for rice, jute, etc.

It is easy in terms of managing and well enough to achieve high application efficiency and improved salinity control. There are three different criteria to design level basin irrigation system.

(b)Furrow Basin – This method is basically used over for row crops such as sugarcane, potatoes, cotton, vegetable, etc. In this the furrows are made up along contours and the water is filled only in the furrows rather of filling the whole field. It is suitable for sloppy lands so as that water runoff can be at ease along contours.

The length of furrow is determined by the soil permeability which varies from three to six meters. It is not expensive in order to maintain and easy in installation also. It holds with less usage of water but requires skilled labour in order to operation of machinery.

In terms of advantages, it goes with lower initial investment on the name of equipment and lower pumping costs per acre-inch of water pumped. While in terms of disadvantages, it holds lower application efficiency and greater labour costs.

(i)Border Strip Basin – It is also termed as Bay Strip Irrigation**.** Firstly, the whole field is levelled and two adjacent rows of beds are created up in the field. Then a water channel is provided between rows.

The bed length varies from clay to loamy soils. The data explains out the usage of twenty to forty percent of water only. The system requires a huge manpower and suitable for high value crops. It is adaptable to the most of the soil textures except sandy soils and uses less amount of water comparatively.

These methods under conventional form are suitable only for uneven lands where cost of levelling the field goes high. These lack their usage in different types of soil which is its disadvantage. In order to increase productivity under low volume usage of water sources, micro irrigation methods took place over conventional methods of irrigation.

1.1.2 Micro Irrigation Methods

The irrigation method which holds the application of low volume water at high frequency and low pressure is termed as micro irrigation method. It leads to savings of 40 to 60 percentage of water and suitable to be applied in poor soil also. By this, the productivity of crops is increased in this method. Initial and maintenance cost is high and requires high operating power. The system is advantageous over as savings of labour cost, water up to seventy percent and yield increased up to more than twice. The system successfully works over more than forty crops. Further, this method is categorised into two different types. These are as follows:

(a)Drip Irrigation Method – It is also termed as Trickle Irrigation**.** In this irrigation system, a network of mainline, sub-mains and lateral lines are used. The emission points in the system are spaced along with their lengths. The head part consists of a motor to lift water and then water is distributed to plant root zone by use of network.

Main lines and sub-lines are of black PVC lines. Water is distributed in the sequence from main line to sub-line followed by sub-line to drip line. Localised application reduces fertiliser and nutrient loss. It is independent over soil type and also doesn’t require basin levelling.

The method is advantageous over saving amount of water from thirty-five to sixty-five percent. It is easier to install and have low labour cost. The crop yield is increased and plant growth is enhanced. It holds higher initial and maintenance cost. The usable lives of supply tubes are decreased by the rays of Sun.

(i) Sprinkler Irrigation Method – In this system, the water is distributed over by spreading into air followed by allowance to fall over the field area. It is similar to the process of natural rain. A pressurised pipe network is used over to deliver water through pipe to nozzles of sprinklers. Water reaches at a higher pressure into sprinklers. The sprinklers move in a circle and are driven by a gear or ball drive and the mechanism taking place is termed as Impact Mechanism. In this higher efficiency occurs under uniform water distribution.

Limitations come over higher initial costing, continuous energy requirement for operation and holding of poor application efficiency. This method is adaptable to nearly all type of soils. Evaporation losses are higher and require clean water free from debris sand slit and clay particles.

1.2 Wireless Sensor Network (WSN)

WSN stands for Wireless Sensor Network. Sometimes, it is also called as a wireless sensor and actor network (WSAN). In the system of Wireless Sensor Network, a gateway is incorporated which provides unwired connectivity to the distributed form of nodes. The data obtained in this procedure is carried over to gateway node. The location of the sink node affects consumption of energy and lifetime of WSN also. In this technology, real-time can be accessed remotely and further analysis is done followed by a real-time reaction taken over it.

It enables completely newer capability to control and measure applications due to communication wirelessly. Long term monitoring applications have improved reliability by eliminating lead wires which also leads to savings in terms of cost.

1.2.1 Components

The various components under wireless sensor networks are as follows:

(a)SENSOR NODES – These are combination of some sensors and a mote unit.

Basically, sensor is defined as a device which is capable of sensing information. The obtained information is forwarded to the mote unit. Here, sensors based upon MEMS have better usage. A mote is a combination of memory, processor, battery, A/D converter in order to connection with a radio transceiver and a sensor and forms an Ad-hoc network. A sensor and a mote together form a sensor node. The unwired ad-hoc network of sensor nodes is a sensor network. Sensor nodes are used to forward data packets to any base station.

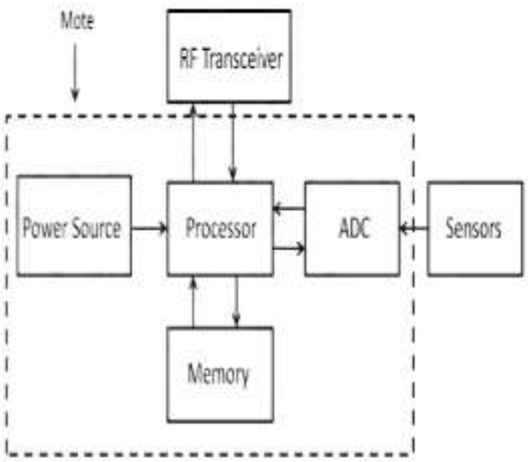

Fig 1.1: Sensor Node

(i)BASE STATION – Basically, it goes for the connection of sensor network to another network. It holds antenna, radio board, processor and a USB interface board. The data obtained is handed over for processing and decision making to the base station. Some issues as reliability, energy conservation and coverage are taken in accordance during deployment. Generally, these are static in nature.

1.2.2 Characteristics

The characteristics of wireless sensor network includes mobility, heterogeneity and power consumption constraints of nodes, ease of usage, resilience, scalability to large scale and many more. It also includes cross-layer design. The cross-layer design has been implanted in order to overcome the problems obtained from traditional layered approach. The cross-layer is used for improvement in transmission performances as Quality of Services, data rate, etc.

1.2.3 Benefits

The basic objectives of sensor network goes as accuracy, deployment ease, flexibility, reliability and much. Key benefits of wireless sensor networking are categorised as:

- **(i)** Minimal Human Interaction
- **(ii)** Area Coverage
- **(iii)** Connectivity
- **(iv)** Sensing Accuracy
- **(v)** Fault Tolerance
- **(vi)** Dynamic Sensor Scheduling

1.2.4 PERFORMANCE

The factors affecting performance of WSN are:

- **(i)** Application diversity
- **(ii)** Frequent topology change
- **(iii)** Dense deployment
- **(iv)** Lossy medium
- **(v)** Limited storage capacity and processing power

The transport protocol to be used over data transport control should be effective and should be considering following:

- **(i)** Energy efficiency
- **(ii)** Quality of Services
- **(iii)** Congestion control
- **(iv)** Reliable message delivery
- **(v)** High throughput and long network lifetime

WSN depends upon specific applications in relation to the delivery of upstream traffic. These are as follows:

- **(i)** Time-driven
- **(ii)** Query-driven
- **(iii)** Event-based
- **(iv)** Hybrid

1.2.5 Platform for WSN

In accordance to the hardware, WSN communicates with LAN or WAN through a gateway which acts as a bridge between WSN and another network. Whereas, in accordance to the software the scarcest source is energy by which the lifetime of WSN is determined. The operating systems for nodes are less complex. They resemble embedded systems so it’s possible to use embedded operating systems which are eCos or uC/OS for sensor networks. These are to be designed with real-time properties. Some of the operating systems are TinyOS, Contiki, RIOT, LiteOS, etc.

In terms of simulating a wireless sensor network agent-based modelling is used over which is based on social simulation. These are used with simulators like OPNET, OMNet++, NS2, etc.

1.2.6 Applications

The concept of wireless sensor networking can be applied over as follows:

- **(a) Process Management**
- **(b) Area Monitoring:** In this application, the WSN is deployed over a particular area or region where the monitoring of any parameter is to be done. It's a common application of Wireless Sensor Network. For e.g. detection of enemy intrusion by sensors, geo fencing of oil pipelines, etc.
- **(c) Health Care Monitoring:** The medical applications can be categorised into wearable and implantable types. The wearable devices are applied over body surface to get close proximity. The implantable medical devices are the ones which are inserted in the human body. For e.g. monitoring of ill patients, body position measurement, etc. Body area networks are implemented to get information about health, fitness and other of an individual.
- **(d) Environmental Sensing:** Some of the applications under environmental sensing are landslide detection, natural disaster prevention, forest fire detection, water quality monitoring, air pollution monitoring, etc.
- **(e) Industrial Monitoring:** In such type of application of WSN, structural health monitoring, data logging, machine health monitoring, water monitoring is also hold over.

1.2.7 APPLICATION IN AGRICULTURE

In this era, the conventional methods of irrigation are still used over in most part that lead to wastage of more than half of total water. There are a number of methods which can be used over for this. In contrast to WSN, the measurement of various environmental parameters likes humidity, temperature, pressure, etc. are measured. As same the data is collected and carried over to the node and then forwarded to the management station. These are widely used for increasing production and monitoring of crops.

WSN represents technology for measurement and control applications with low-power. Basically, it helps with the calculation of water requirements during crop growth. The field conditions can be monitored in real-time. This helps to overcome the problem instantly and get decision over various parameters. This can be illustrated to illiterate farmers by the usage of maps and graphs by the professionals or researchers. There is various simulation models available related to agriculture. Some of them are follows:

(a) DSSAT (Decision Support System for Agro Technology Transfer)
(b) APSIM (Agricultural Production Systems Simulator

These are considered as important tools for analysis of the whole farm systems with sequences and rotation of the crops. Wireless Sensor Networking is one of the enabling technologies going for the precision agriculture. On the concept of architecture, WSN follows the Open System Interconnection (OSI) model. OSI model is a reference model consisting of seven layers out of which only five of them are associated with Wireless Sensor Networking. These are Application layer, Transport layer, Network layer, Data link layer and Physical layer.

CHAPTER 2

LITERATURE REVIEW

Basically, Wireless sensor network is a group of dedicated sensors which can be used for monitoring of related physical conditions of the environment and further organisation of the obtained data to any central location. With the help of WSN, a number of parameters can be measured as sound, wind speed, vibration, pressure, wind direction, temperature, humidity, surface area, ground coverage, changes in health parameter of person and many more. The development was mainly motivated by military applications. Now, these have found applications in industries also. [1]

The base station of wireless sensor network holds antenna, radio board, processor and a USB interface board. The data obtained is handed over for processing and decision making to the base station. Some issues as reliability, energy conservation and coverage are taken in accordance during deployment. Generally, these are static in nature. [2]

The medical applications can be categorised into wearable and implantable types. The wearable devices are applied over body surface to get close proximity. The implantable medical devices are the ones which are inserted in the human body. For e.g. monitoring of ill patients, body position measurement, etc. Body area networks are implemented to get information about health, fitness and other of an individual. [3]

The WSN goes with water conservation by prediction of requirement of crop water followed up with different measures as bund building, rotation of crops, stripping etc. Now-a-days, there are many automated systems used. Sensor network technology is one of them to be used over in agriculture. This helps to obtain information over soil type, soil moisture, climatic changes, water requirement, etc. [4]

The sensor deployment can be done over in two different ways in wireless sensor networking. These are random deployment and deterministic deployment of sensors in wireless sensor network. The status can be best known by implementation of WSN. Sprinkler system and drip irrigation are monitored and controlled by wireless sensor networking. In WSN, sensor part can be mechanical, electronic or electrical as ZigBee (XBee) Module, Bluetooth, GSM module, etc. are used over for wireless communication purpose. [5]

The management systems uses over agricultural activities of three types in remote areas. It goes with irrigation management, green house management and also storage management. WSN is used over for all these management systems. [6]

Water irrigation control monitoring comprises of sensor nodes having capability with networking which can be deployed over ad hoc and monitoring purpose. It includes parameters which are to be controlled over in water reservation control. The control is measured by sensors in real time. Further, data is passed over to monitoring room so considered. [7]

One of important practice for water control agricultural activity is precision agriculture. The system allows maximization of productivity with managing water under consideration. Due to very high impact factor, it's difficult to get irrigation amount accurately. A method depending upon soil water potential and Evapotranspiration has been provided to overcome this issue. [8]

Now-a-days, issue has been with labour and water mostly. It has been key issue with importance in relation to irrigation. A solution with wireless networking for irrigation system having intelligent field control has been given which is based over ZigBee. It is with dedication to Jew's ear planting. [9]

Two types of storage management systems are used in order to control temperature and humidity. For this purpose, a wireless sensor network is developed. The variable information is processed after being gathered by humidity and temperature related sensors. ZigBee agreement is required to transfer packets under wireless transmission. A corresponding management is made over if number of parameter is greater than scope of set value. [10]

Implementation of WSN system can be done for grain depot in order to monitor humidity and temperature including storage, collection of data, transmission, etc. with stable performance. Nodes are installed conveniently and batteries are used to supply energy. Mostly such systems are used in small level and medium size granaries. [11]

Temperature and humidity parameters are to be controlled precisely by the usage of sensors in respective of it. These values vary from one place to another because of variable circumstances related to atmosphere. It is difficult to maintain uniformity but phone controlled system is proposed in order to provide facility over maintenance of its uniformity. It goes with combination of microcontroller and GSM feature in the irrigation system. GSM is used to inform about conditions of field to the user. [12]

Moisture content and fertility of soil are important factors in terms of agricultural activities. Seeds growth is decided over by these factors and also sufficiency in terms of contents to sow seeds. It has dependency over many factors. By traditional methods, a huge amount of water loss is seen. After being advancement in technologies, water loss has been reduced over by drip irrigation methods up to sixty percent. [13]

Evaporation and transpiration both occur simultaneously. No way to distinguish in between. Evaporation is determined by the fraction of solar radiation, at the time when the crop is growing, reaching the top surface of the soil. As the crop grows, the fraction decreases. When the crop is grown the transpiration process starts as after the development of crop the soil is completely covered. [14]

The evapotranspiration is a basic and crucial parameter for weather forecasts, weather modelling, hydrological surveys, climate studies, ecological monitoring and water resource management. Crop evapotranspiration rate is used over to identify the stress over crop, water deficiency, estimating the exact potential needs of crops in various areas of the agricultural sector for best yields. [15]

The land surface is cooled and soil moisture content is reduced over by the phenomenon. ET is estimated over these parameters. The changes in soil moisture content are studied by lysimeters. The patterns in land surface temperature are studied over with sensing remotely. By either of these evapotranspiration is estimated. There are many other physical properties and factors playing important role in being affected by the evapotranspiration. In order to achieve proper estimation a lot of variables are needed. These are held over field techniques and also for remote techniques. [16]

In both agricultural and non-agricultural environment, accuracy in terms of estimation of ET goes highly important. It leads to sustainable irrigation management. Pixel-scale and global-scale studies are taken in accordance as a great contribution of remote sensing technique. The increase in accessibility enables a broader spatial coverage, update of routine and others. Automated data collection is also provided in mixed vegetation conditions. [17]

Irrigation system is made efficient by usage of evapotranspiration and fuzzy logic for calculation over requirement of irrigation quantity. Irrigation is scheduled over as per the requirements of particular crop with avoidance of over and under watering. The algorithm provided helps in reducing of power switching which further leads to conservation of energy. Also, no water stress is observed in tool due to prohibition of depletion in moisture of soil. Algorithm so provided is suited over for both kinds of micro irrigation system. [18]

Being the key component ET is very difficult to identify, benefit of estimation has been over advancement in remote sensing. It still has complications because of heterogeneity of canopy covers and costly methods. Mostly require time investment, high skill level and simpler approach interface especially for mixed vegetation. Further, VI-based approach is used over both environs. Remote sensing method has been contributing in updating of routine, ability for measurements of physical properties and enabling of spatial coverage broadening. The selection must be at budget, spatial, accuracy, temporal resolution and ground data availability. [19]

Efforts have been focused over supply of spatial variables to study ET inversions or models for crops instead of applying data-based model. ET Watch is a model for calculation of ET and applied with irrigation applied model for simulation of spatial distribution. This has been proved as an effective approach. Sustainability of water resource has been serious problem which is due to declination in groundwater table and agricultural activities. Technologies for saving water can be used with geo specific assessments in order to get over this threat. [20]

Actual ET series obtained by using land surface and remote sensing both are combined over for monitoring of irrigation practices. It goes with estimation of blue water evapotranspiration. The observation has been marked over different areas and drought was obtained during analysis. Preliminary results prove that total blue ET allows distinguishing patterns. Presented application has potential for assessing of existence over irrigation, variability in time and especially for monitoring of irrigation in drought region. [21]

Six number of ET methods available on basis over estimation. These are compared over daily performances in respect to climate conditions. Penman-Monteith equation has been standardised by FAO as FAO-56 PM and taken in accordance over for comparison. All of these are varied according different parameters. Under consideration of reliability and availability of input data, all these methods can be applied if standard method FAO56-PM can't be used due to complexity. [22]

In terms of water management, requirement appraisal is crucial for regions where water consumption is higher in agricultural activities. For crop water requirement, empirical and simpler approaches are entertained. K_c-NDVI goes with correlation between crop coefficient and Normalised Difference Vegetation Index while other goes with Penman-Monteith under direct application. Crop water requirement were very much higher on basis of assessment done in respect of predefined surface water. The result obtained goes with closeness with Net requirements of irrigation water. [23]

Transfer control protocol is the main protocol for congestion and flow control on internet. It was developed over heuristic arguments. The purpose provided was prevention of network congestion. It has issues due to development of shifts in internet traffic. Various problem areas has been identified and reached over it. It came with a solution of using explicit notification and for enhancement in performance with control theory automatically. Feedback control with smith predictor in a simulation format has been compared with TCP with implementation in Stateflow and Simulink. There is observed improvement in performance by using feedback solution. It leads to avoiding packet loss with time delay reduction and stabilisation of traffic load. [24]

In order to lessen traditional techniques, wireless sensor networking has been introduced. Various sensors have been implanted in accordance of their value. Water management can be done in by sprinkler and also fertiliser amount management by pH sensor with use of GSM module. The information is provided to the farmer of pH so that production is handled over for next season. Also, provision has been concluded over for rice crop. It leads to rice crop production management. It is totally hold with use of WSN in agricultural activities. [25]

With the help of modern motes having multiple boards of sensor in WSN, heterogeneous applications are assimilated in it. Various kinds of generated data differ in terms of characteristics over transmission rate, packet loss, priority, etc. PHTCCP (Prioritized Heterogeneous Traffic Oriented Congestion Control) has been introduced in order to ensuring of rate control efficiently. Inter and Intra queue priorities are used over to ensure feasible transmission rates. All these goes for heterogeneous traffic under priority order. [26]

A single link in a network may be shared as two sources if it is of fixed capacity. The algorithm uses AIMD (Additive Increase Multiplicative Decrease) law. Various basic features of congestion control over internet have been clarified by the model. Adaptation of sending rate is done by two sources on the link from the network. It further leads to equilibrium point for operation over network. [27]

WSN is implemented over information and control in agriculture as applicative area. Implementation is hold over with using MATLAB software. Quicker response has been marked upon climatic conditions under this consideration. It leads to lowering of labour cost and increment in production. It requires lower data rate and power so suitable for precision agriculture perfectly. [28]

In respect of congestion, avoidance mechanisms provide operation over optimal region. It holds higher throughput and lower delay in order to prevent network. It is totally opposite of traditional control mechanisms. Avoidance and control both mechanisms are formulated over as system control issues. In avoidance, main component is the algorithm used to decrease or increase loads. Main point of metrics is fairness, convergence time and efficiency. [29]

In terms of networking theory, the process of deterioration of quality of services during excess of data carried over a node is termed as congestion. It leads to the delay, connection blocking or losses in packets. There are various control and avoidance techniques which are used over for this problem. Also priority schemes are implemented over in order to reduce it. It concerns handling traffic ingress in telecommunication network. [30]

CHAPTER 3

HARDWARE DESCRIPTION

On the contrast to the agriculture scenario in our country, there are very lesser number of techniques is employed over or we can say that in terms of technology in relation to the agriculture, it is not up to the mark. A large number of techniques are available to each and every point of issues in the agricultural. A lot of these have been used over worldwide under different scale. These are a lot helpful in terms of production on the annual ration and also in terms of efficiency. The various methods can be implemented over different kinds of agricultural practices and have great positivity in terms to relation.

Now, the issue comes to our country which we have already discussed that how much GDP and what percentage of population are totally dependent over agricultural activities. It is seen that mostly conventional methods of irrigation have been practiced in various parts. While in some parts the advancement in technologies has been taken in accordance. There are some of the states as Uttar Pradesh, Punjab, Bihar, West Bengal and some more where the agricultural practices are done over at large scale due to all the factors easily available. But being a large producer in the country these states have not been so much moved towards advancement in the name of technology. It leads to increase in productivity, efficiency, reduces labour cost and many other issues as advantages.

The technology goes with the analysis, calculation and implementation as per the accordance in relation to different parameters beneficiary in agricultural activities. The parameter goes as soil, water, air and more. These parameters have their different related parameters on the basis which agricultural activities are affected totally.

3.1 MODEL ANALYSIS

Here, a model is explained in order to overcome some of the difficulties and for being advantageous in agricultural practices in the country. It deals with different parameter control measures in relation to agricultural activities. The model goes with temperature control, humidity control, water level control, light control and soil moisture control measures in combination with Global System for Mobile communication modelling within the model.

In this model, the parameters taken in accordance related to agricultural activities in our country are soil moisture in the soil during cultivation time of the crop, temperature in the greenhouse, water level requirement in the field according to the method of irrigation and also the crop to be cultivated, light control in the greenhouse, humidity control as per the range for a particular crop. All these parameter controls are held over a single model small in size and comfortably usable with GSM connectivity in order to make it perform better and automatically. All these activities are to be displayed over a LCD on the microcontroller module to make it more convenient. By the addition of GSM the efficiency of the product goes better and also in terms of reliability.

This model is based upon an agricultural concept consisting of a number of control functions in it. It must be used in a greenhouse environment. The block diagram, circuit diagram and other necessary diagrams are explained out further. GSM concept for receiving information from greenhouse models for comparing their readings for better productivity is also done. The five different parameters such as soil moisture, temperature, light, water level and humidity are measured one after another and displayed over LCD. If an end user residing farther from the farm field wants to check the readings of different parameters he can just give a miss call to the SIM number installed in GSM. Water motor can also be controlled by GSM.

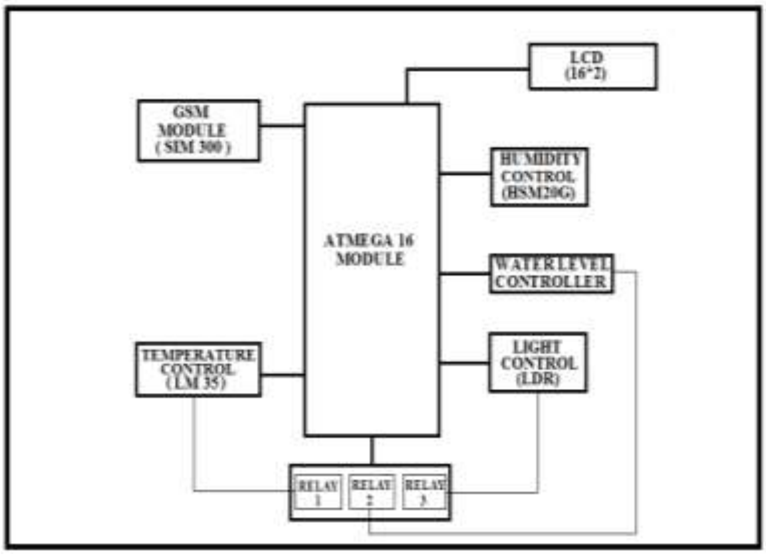

Fig3.1: BLOCK DIAGRAM

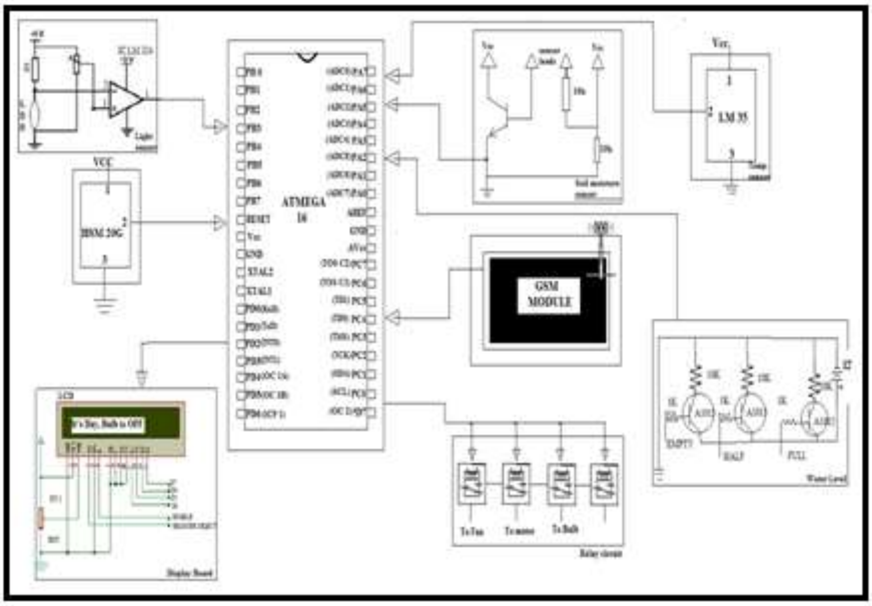

Fig3.2: CIRCUIT DIAGRAM

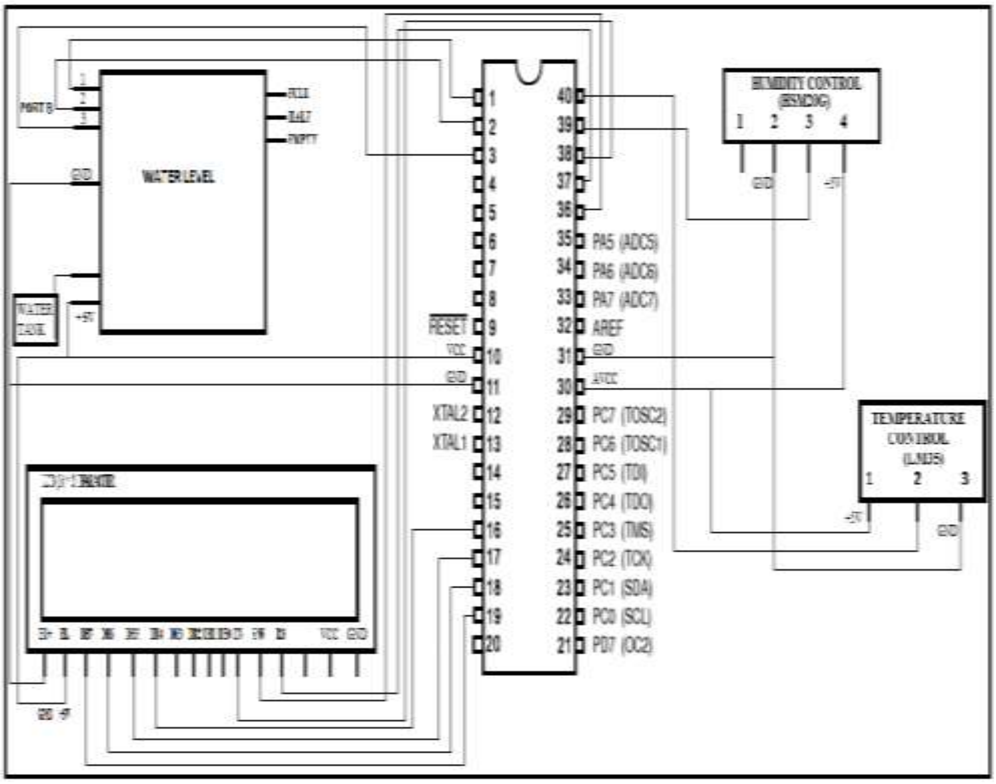

Fig3.3: Model Architecture

As we know, the model is made under putting the concept of agricultural activities in mind. Basically, it is used over in greenhouse because the parameters taken in accordance are put over under the circumstances of a greenhouse. It is used over the particular crop to be planted in a greenhouse. All of the required data are collected over in relation to the crop in the greenhouse. The model goes with a number of sections included in it. We will come to it one by one. Initially, the categorization over various sections in the model is explained as follows:

- **(a)** Agricultural Parameters
  - **(i)** Temperature
  - **(ii)** Light Control
  - **(iii)** Water level
  - **(iv)** Humidity
- **(b)** Microcontroller (ATMEGA 16 Module)
- **(c)** LCD **(**Liquid Crystal Display**)**
- **(d)** GSM Module
- **(e)** Circuit Analysis Software Proteus

3.1.1 Agricultural Parameters

This section holds various parameters related to the agricultural practices in the country. On the behalf, these are considered over and explained below as per the accordance. The parameters taken in accordance are soil moisture, temperature, light, water level and humidity. All of these parameters are to be controlled over in a greenhouse. The model has been made on the virtue of all the conditions related to the greenhouse. Even more number of parameters related to agricultural activities can be controlled over through use of wireless sensor networking which will be explained further out of the model. All of the parameters taken in accordance in the model can be controlled over through the model used in a greenhouse. The individual explanation of these parameters goes as follows:

3.1.1.1 Temperature: The physical property of any system which forms base for common whimsy of coldness and hotness is termed as temperature. Its relation varies over different approaches on the accordance. Generally, temperature is measured with a device called thermometer. It is done over through particle velocity, detection of heat radiation or kinetic energy. There are various types of scales on which it can be determined. The various scales are Celsius which is denoted by ^{0}C and unitised as centigrade, Kelvin which is denoted by K and Fahrenheit which is denoted by ^{0}F. This parameter has its own importance in various fields related to science and almost all aspects of life. Now, in contrast to agricultural activities, the temperature has a very important role. A paragmatic approach to solve the issues related to agricultural activity is by using LM35 in the model. We can measure temperature more accurately than using a thermistor. The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

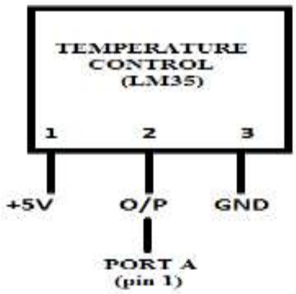

Fig3.4: Pin Description

As the scale factor of LM35 is 0.1v/^{o}C. The characteristic of LM35 is that it draws only 60 microamperes from its supply a low self-heating capability. The first pin is of +5v which gives the power supply to the sensor and the second pin is for output which is connected to the port A of ATMEGA 16 on 40th pin. The third pin is for ground to complete the circuit. As the circuit is completed the temperature sensor senses the temperature and shows it on LCD. As per programming, the threshold is set on the values of temperature i.e. 20–30 ^{o}C. As whenever the temperature increases from threshold the fans connected through relay starts and it automatically decreases the temperature which is very helpful in the growth of crops.

3.1.1.2 Light Control: Light sensor has been designed by using LDR and 555 Timer. Light sensor is used to measure the presence of light necessary for growth of crops. This combined light sensor circuit detects light falling on the LDR (photocell) to turn on the 555 timer. Pin 4 of 555 Timer must be held below 0.7V to turn the 555 off, voltage above 0.7V will activate the circuit. The adjustable sensitivity control is needed to set the level of voltage. An LDR must be able to detect large amount of light. As the resistance of the LDR decreases, the voltage across the 555 will increase and circuit gets activated. When the circuit gets activated, sensor senses the presence or absence of light in the field. It actually detects whether it is day or night. If the light intensity falling on LDR is sufficient it will indicate day on LCD and the bulb will remain off. But if the light intensity is not sufficient it will indicate night on LCD and bulb will be ON. The output of this combined circuit sensor is connected to the microcontroller. Absence or presence of light will be displayed on the LCD screen.

3.1.1.3 Humidity control: As we are measuring the parameters for agricultural crops, Humidity is one of the main concerns for growing crops in different conditions all over the year. It fluctuates every day depending on the environment conditions. So we need to be very careful while measuring it. For this purpose HSM 20G sensor is used for measuring Humidity. It will give data in digital form. The working of HSM 20G is totally dependent on the programming. This programming can be designed as per the required crop to grow under certain humidity conditions. The graph for this should be linear.

HSM 20G, the humidity sensor is used for measuring humidity as well as temperature. But, we are using it to measure only humidity. The sensor is composed of 4 pins which are named as 1, 2, 3 & 4. The first pin is for temperature measuring. This pin is not taken in use and so it is left as it is. The second pin is grounded. The third pin is for measuring humidity. This pin is connected to ATMEGA 16 at second pin of port A. The fourth pin is connected to the 5V power supply.

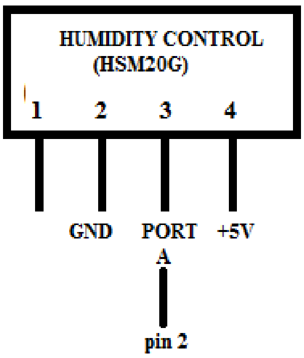

Fig3.5: Pin connection

The second pin senses the humidity level present in the environment and converts it to percentage form readable and understandable by the user. The sensor is programmed internally to function as per required in the agricultural farms. The range for this sensor is set between 20 to 49 %. The reading between these ranges is considered normal. But if the reading extends the set range then the display will read critical. This means that the range is not suitable for growing crops and suitable steps should be taken to reduce or increase humidity level as per required.

3.1.1.4 Water level Control: For this system three wires are used to indicate the level of water in soil. One wire is inserted deep in the soil. Another wire is inserted in mid level of soil. The last wire is placed almost on the topmost part of soil. These three wires will indicate different levels of water present in soil. As the level of water decreases, water motor can be started via GSM module.

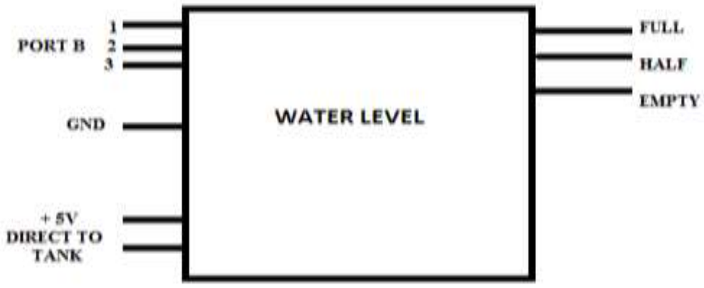

Fig: Pin Connection of Water Level Control

3.1.2 Microcontroller ATMEGA 16

3.1.3 LCD

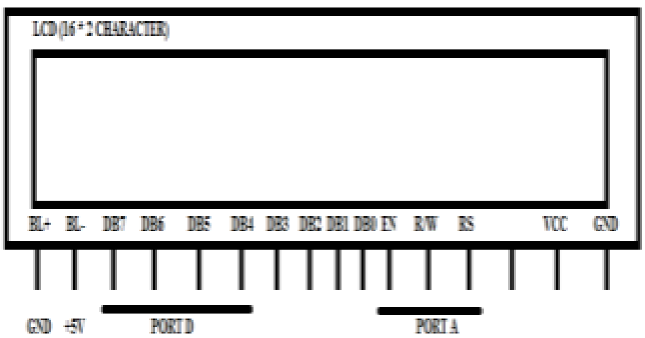

Fig3.6: Liquid Crystal Display

3.2 Working of model

Initially, the circuit is connected as per the circuit diagram and all the connections are checked up on the basis and then the procedure is further preceded. The GSM module is connected to the power supply with a SIM initially inserted in the module. As, the power supply is ON the SIM searches for the network. In the module the mid LED glows continuously until the network is found. Then, as the module is in network the LED starts glowing once in 3 seconds. As the module is in network it is capable of transmitting and receiving the signals. Furthermore, the process starts as the T_x, R_x and GND is connected to the microcontroller. The module starts functioning as per the need. It receives data from the microcontroller, transmits the data in form of signals by using SIM to the destination. The data procedure is done over by as the password is send to the SIM put in the module from the SIM saved as per in the programming done with the contact number followed by sending of the data to the saved contact number containing SIM. If the same password code or any other message is sent over by other contact number it will show an error on the LCD display and no message will be sent to that number with an error message of attempt to the main number saved in the program. All these things are displayed up in the LCD connected to the microcontroller as either message received, message sending or attempt by any other contact number. These data are sent over through the transmit pin on the GSM module to that particular contact number. The message is sent on by the contact number of the SIM put up in the GSM module.

3.2.1 GSM module: SIM used in the GSM module should not contain any details other than the number of that person which is set in the programming. The number needs to be saved in the SIM with Indian pin code as +91 followed by the 10 digit mobile number. Name of the person saved in SIM should not be more than 12 letters. As the SIM is inserted in GSM the LED light starts blinking. If it blinks continuously it means that there is no network found. If it blinks once in three seconds it means that network has been found. Now the module is ready for communication.

Now through registered number we need to give a miss call. It will receive the message and response back with the details of the parameter readings to the same number. But if someone else gives a miss call to the SIM number inserted in GSM module, the SIM will return a warning message to the registered number informing that someone else has tried to collect the information. In this way GSM works and at same time gives security a priority.

The parameter controls are individually explained up further. These parameters which can be implemented in a green house are Temperature control, Soil control, Humidity control, Water level control & Light Control.

3.3 Components used

S. No.	**Parameter**	**Component used**	**Quantity**
1.	Temperature	Thermistor (LM35)	1
		3-pin plug	1
		one to one connecting wire	3
2.	Water Level Control	Transistor (547B)	3
		Resistor (10 k Ω)	3
		Resistor (1 k Ω)	3
		Three pin connector	1
		One to one connecting wires	2
		Burgstrip	5
3.	LDR	IC (LM324)	1
		IC connector (14 pin)	1
		Resistors (10 k Ω)	3
		Resistor (1 k Ω)	1
		Variable resistor (1 k Ω)	1
		Three pin connector	1
		Burgstrip	2
		One to one connector	5
4.	Others	Adaptor (12 V AC TO DC)	2
		ATMEGA 16 module	1
		LCD16x2 Character	1
		Connecting wires	40
		GSM Module	1

CHAPTER 4

FIRST STAGE ANALYSIS

Till now we have covered up the hardware which is based upon ideas formed over in relation with agricultural issues in our country. Going through all of the parameters there may be many of the factors which depend upon them and can be analysed or controlled using it to increase efficiency. Several of them are related to temperature, pressure, etc. which is most common parameter considered in hardware. Contrary to this, it has been further taken in accordance and worked over. The work has been moved further in terms of stages. Here, we are going to discuss evapotranspiration in first stage of the work.

4.1 STAGE I:

On the basis of agricultural activity related parameters, evapotranspiration has been taken in accordance in this work. In order to estimate it, there have been various estimation methods. These are analysed over here and connected with the model to make it better. Now, all aspects of evapotranspiration have been discussed over below and analysed in terms of estimation methods with getting related to hardware proposed for agricultural activities.

4.1.1 Introduction

Evapotranspiration (ET) is basically the addition of processes evaporation and transpiration related to atmosphere. It is an important part of the water cycle. Element like trees which are contributing to it are termed as an Evapotranspirator. In Hydrology, evaporation and transpiration (which involves evaporation within plant stomata) are collectively termed evapotranspiration.

Reference evapotranspiration represents environmental demand over evapotranspiration. It shows the evapotranspiration rate of grass which completely shades the ground, having uniform height and present with adequate water. It equals to energy present for evaporation. In case if there is presence of ample water, actual evapotranspiration is equal of reference evapotranspiration.

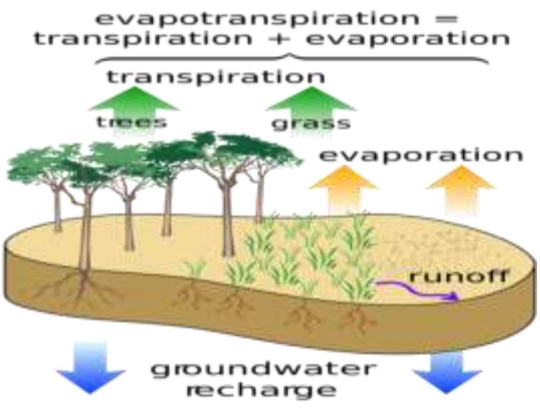

Fig 4.1: Evapotranspiration

4.1.2 Evaporation

Evaporation is movement of water from various sources such as the soil, water bodies, etc. to the atmosphere. It is just vaporisation of a liquid which takes place from surface of liquid into gaseous phase which is unsaturated in relation with the substance. It occurs from solid phase down the melting point directly, which is observed with ice commonly at or down the freezing point and process is termed as sublimation. The process is an essential part of water cycle. The process is done over by solar energy. It takes place when surface of liquid is exposed which allows molecules to escape and then water vapour is formed. Further, it rises up and formation of clouds takes place.

4.1.2.1 Factors Influencing Evaporation: Evaporation is influenced by following factors:

(a) Pressure

(b) Temperature

(c) Surface area

(d) Inter-molecular forces

(e) Flow rate of air

4.1.3 Transpiration

Transpiration process goes with movement of water in plant and loss of water in form of vapour from leaves. It is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapour and is released to the atmosphere. Transpiration is basically evaporation of water from plant leaves. Transpiration also includes a process called guttation, which is the loss of water in liquid form from the uninjured leaf or stem of the plant, principally through water stomata.

4.1.3.1 Factors Affecting Transpiration: Transpiration gets affected by followings:

- **(a)** Temperature
- **(b)** Relative humidity
- **(c)** Wind and air movement
- **(d)** Soil-moisture availability
- **(e)** Type of plant

4.1.4 Factors affecting Evapotranspiration

The phenomenon of evapotranspiration goes with some factors which totally have influence over it. These factors are as follows:

- **(A) Weather parameters:** In this category, there are four factors under consideration as:
  - **(a)** Radiation
  - **(b)** Air temperature
  - **(c)** Humidity

(d) Wind speed

(B) **Crop factors:** This factor goes with crop dependent parameters as:

(a) Crop type

(b) Crop variety

(c) Development stage

The evapotranspiration levels due to crop factors differ in various crops under identical environmental conditions are given by:

(a) resistance to transpiration

(b) crop height

(c) crop roughness

(d) reflection

(e) ground cover

(f) crop rooting characteristics

(C) **Management and environmental conditions:** Such conditions depend upon:

(a) soil salinity

(b) poor land fertility

(c) limited application of fertilizers

4.1.5 Reference crop evapotranspiration (ET_o)

The rate of evapotranspiration under a reference surface (hypothetical grass reference crop having specific characteristics). Atmosphere's evaporation power is expressed by ET_o at a specific location and time of the year and does not consider the crop characteristics and soil factors. It shows evapotranspiration through a vegetated surface in standardised manner. It is also termed as potential ET. It is affected by climatic parameters. It can be computed by weather data as it depends upon climatic parameters.

Crop evapotranspiration under standard conditions (ETc) – It is the evapotranspiration from disease-free, well fertilized crops, grown in large fields, under optimum soil water conditions and achieving full production under climatic conditions provided. Here, crop water requirement is the amount of water required to compensate the evapotranspiration loss from the cropped field. It refers to the amount of water that needs to be supplied. Crop evapotranspiration is total amount of water which is lost in the process. Both of them are identical.

4.1.6 Concept of Energy Balance: The energy arriving must be equal to the energy leaving the surface for same time period with all fluxes under consideration. Equation for an evaporating surface goes as: $\mathbf{R_n - \{G + H + \lambda\, ET\} = 0}$ **(1)**

Where R_n is the net radiation, G the soil heat flux, H the sensible heat and λ ET (**Evapotranspiration fraction**) the latent heat flux, R_n & G can be estimated by climatic parameters, while H is hard to obtain but can be done by measuring temperature gradients.

Evapotranspiration fraction **λ ET** can be obtained by **Penman-Monteith** form of the combination equation which requires aerodynamic and bulk resistances, vapour pressure deficit, density and specific heat of air.

4.1.6.1 Reference Surface – it resembles an extensive surface with green grass which is actively growing, having uniform height completely shading the ground and with adequate water. The requirements for grass surface to be extensive and uniform result from the assumption that all fluxes are one-dimensional upwards.

4.1.6.2 Wind Profile: The speed of wind differs upon measuring at different levels above the surface of the soil. It increases with height and is slowest at the surface as friction tends it to slow down. In relation to evapotranspiration, wind speed is measured at the height 2 meters above the surface and the data obtained at other levels are controlled by setup of wind speed profile.

4.1.7 Estimation Methods

Various methods for estimation of evapotranspiration are as follows:

- **(a)** **Semi-empirical methods** – these are used in order to estimate from various climatic variables.
- **(b)** Methods using meteorological parameters which include air temperature, wind speed and humidity.

4.1.7.1 Remote Sensing Technique: It diminishes farm irrigation cost up to 25 percent by which net profit is stepped up. It is done over with auxiliary ground truth data which includes Leaf Area Index-LAI and crop height to approach better results. Energy balance algorithms are used up with remote sensing data for estimation of energy budget components. These techniques require detailed experimental validations and approximations are required to characterize.

The technique offers a huge amount of information in lesser time in comparison to other methods. It also reduces the cost required for acquisition of data mostly when the area under consideration has been broadened. Models used are 'SEBAL' and **'**Penman-Monteith' with satellite data widely to estimate evapotranspiration. Further by modifying and applying these with semi-empirical models for accuracy. These values can be used over to determine the requirement of water.

4.1.7.2 Resources in experiments: Various resources required in experiment are as follows:

- **(a)** Spectroradiometer (light weighted, single beam and high performance) – it is portable and covers visible and ultraviolet wavelengths with near infrared also. It rapidly scans and acquires spectral data in least amount of time. It supports stand-alone operation and operations assisted with computer systems by using its serial ports. The storage of data is done in ASCII format in order to transfer over to other software.
- **(b)** Sunscan canopy analyser system – Indirect method given by Delta-T devices Ltd. UK. Leaf Area Index (LAI) monitors the growth of the crop. The system measures LAI by

ratio of transmitted to incident radiation. Another method is on the basis of the transmittance of radiation. Crop canopy factors are LAI (Leaf Area Index) and CH (Crop Height). These factors are very much responsible in estimation of Evapotranspiration. These are statistically described through the VI (Vegetation Indices). Indices are obtained initially from spectro radiometer and then filtered by RSR (Relative Spectral Response) filters.

4.1.7.3 Steps for experiment:

- **(a)** Spectro radiometer measurements
- **(b)** LAI and CH
- **(c)** VI
- **(d)** Modelling of VI to LAI and CH
- **(e)** Preprocessing of satellite images
- **(f)** Mapping of indices
- **(g)** Model verification
- **(h)** Algorithm testing

4.1.8 Evapotranspiration Model

Globally, we have no validated evapotranspiration product yet. Generally, the products of other components are found over. It leads to requirement of specific skills in order to remote estimation. The basic drawback is that one can’t measure it directly. As it affects energy balances and water so these are observed in relation to evapotranspiration.

The requirement over quantification of evapotranspiration is of both interest and concern. Three sources mainly lead to water loss by evaporation as atmosphere, soil and vegetation surface. ET is the main consumptive of precipitation and irrigation. It occurs also from flowers, stem and roots. It is also hold as the main component of hydrological cycle. In return soil water chemistry, aesthetics, vegetation healthiness and more is affected over. It covers more than ninety percent of annual rainfalls. As a result measuring ET’s importance can’t be denied. Various numerical models have been introduced yet in respect to measurement of the ET. Limitation occurs in respect to specific areas as per data needed. Estimation has been improved over highly developed instrument and infrastructures with advanced technologies**.** Satellite imagery is the most economic technology employed over broad range efficiently. For simplification coupling was done with empirical methods. Later, microwave imagery was introduced for minimisation of atmospheric effects over optical data. It leads with measurement of surface temperature and moisture.

In spite of all this, ET estimation remains characterised insufficiently. Diversity in requirement of water leads to complexity. Point measurement holds estimation under hydrological or direct methods. Also, extrapolation over a large area from a point leads to decrease in the accuracy. The practical method goes with airborne images used over with remote sensing techniques. It goes as ideal technique for mixed landscape vegetation due to highly distributive nature. Various algorithms and R-S based models are evaluated over scales for different types of vegetation. Mostly, these are compared in the pixel-scale. In urban areas, consideration of biophysical components is done. In 1995, VIS (Vegetation-Impervious-Soil surfaces) model was introduced for consideration of major urban features. Then it was matched with image processing methodology. Further, combination of satellite and field based measurements were recommended for obtaining daily, monthly and annual estimation of ET rates.

4.1.9 Remote sensing methods

- **(a)** Empirical direct methods
- **(b)** Residual methods
- **(c)** Inference methods
- **(d)** Deterministic methods

4.1.10Advantages and Disadvantages of experiment

(a) Advantages – satellite image and group based technique combination enhances the accuracy of climatic data which in result enhances ET measurements. It involves rapid analyses for a bigger area. Here, only mid level skilled technician are required.

(b) Disadvantages – it is hold with time period between satellite captures. High resolution images are costlier to obtain. It leads to uncertainty in estimation of aerodynamic components. There are errors obtained in measurement of narrow vegetation areas. Also, SEBAL **(**Surface Energy Balance Algorithm for Land**)** can't be used in cloudy days due to regression model which is not suitable for all locations. The energy balance technique consumes more time and requires extensive skills. The Allen's viewpoint was mostly agreeable by others in respect to RS-based estimation and least complications by use of vegetation indices.

4.1.11 Comparison of Remote Sensing methods

S.No.	**Model**	**Advantages**	**Disadvantages**
1.	**Empirical direct**	Operation from local to regional scales	Spatial variation of coefficients
2.	**Interference model**	Operational if combined with ground measurements methods	Requires calibration for each crop type and K_c varies according to water stress
3.	**Residual (SEBAL, S-SEBI)**	Low cost and needs no additional climatic data	Requires detection of wet and dry pixels

4.	**Deterministic**	Permits estimation of intermediate variables such as LAI and has possible links with climate and/or hydrological models	Requires more parameters and accurate remote sensing data

Table 4.1: Remote Sensing Approaches

4.1.12 Evapotranspiration Methods:

[1] **Penman-Monteith Equation** – FAO56 by FAO (Food and Agriculture Organisation) – The formula for estimating the evapotranspiration under FAO56 PM is as follows:

$$ET_o = [\ 0.408\ \Delta(R_n - G) + \gamma\ \{900/\ (T+273)\}\ u_2\ (e_s - e_a)\ ]\ /\ \Delta + \gamma\ (1+0.3u_2)$$

Where, ET_o – Reference evapotranspiration

R_n – net Radiation

G – Soil heat flux density

T – mean daily air temperature @ 2m

μ_2 – wind speed @ 2m

e_s - saturation vapour pressure

e_a - actual vapour pressure

$(e_s - e_a)$- saturation vapour pressure deficit

Δ - slope vapour pressure curve

γ - psychrometric constant

It is calculated over 24-h time steps

G = 0

$e_s = [e^0\ (T_{max}) + e^0\ (T_{min})]\ /\ 2$

1. Standardised by FAO
2. Standard method for estimation of evapotranspiration.

3. Used as index for R_s and R_n based equations.
4. Drawback – it requires air temperature, relative humidity, wind speed, and solar radiation.
5. Uses unit conversions and lengthy calculation is followed up.

[2] **Thornthwaite method**

It gives underestimate in arid area and overestimate in humid area. The advantage of this method is that the temp information is needed only besides the reference evapotranspiration,

$$ET_0 = 16 \times (10T_i / I)^a (N / 12) (1 / 30)$$

where,

$$I = \sum (Ti / 5)^{1.51}$$

$$a = (492390 + 17920\, I - 771\, I^2 + 0.675\, I^3) \times 10^{-6}$$

T_i – mean monthly temperature

N – mean monthly sunshine hour

1. Uses temperature as input variable.
2. Highly correlated with the FAO56-PM method.
3. Provides inconsistent values in winter season.
4. Popular method
5. Requires monthly average temperature only.
6. Developed for temperature under potential conditions.
7. Represents potential evaporation if no stress in soil moisture.
8. Applying air surface temperature tends to overestimate potential evaporation in arid areas.

[3] **Hargreaves method**

In this method, only air temperature is to be measured as R_a is obtained by information on site location and mean air temp by average of T_{max} and T_{min}. The reference evapotranspiration is given by,

$$ET_o = 0.0023\, (T_m + 17.8)\, (T_{max} - T_{min})^{1/2}\, R_a$$

Where, T_m – daily mean air temperature

T_{max} – daily max air temp

T_{min} - daily min air temp

R_a – extraterrestrial radiation

1. Uses solar radiation as input variable.
2. Proximity shows that solar radiation is important as input variable.
3. Simpler method
4. Requires two climate parameters: temperature and incident radiation.
5. Tested using some lysimeter data and broad range in climatic conditions.
6. Results obtained nearly accurate to PM method.
7. Recommended where reliable data are lacking.

[4] **Hamon method**

$$ET_0 = 2.1 \times H_t^{\,2}\, e_s / (T_{mean} + 273.2)$$

Where, H_t - avg daylight hours per day

1. Simplest method to estimate evapotranspiration.
2. Monthly and annual values estimated.
3. easily applicable.
4. requires saturated vapor pressure and average no. of daylight hours a day.

   In 2003, FAO56-PM method was simplified by using multi-linear regression function having use of less parameters and computations. It uses R_s (solar radiation, R_n (net radiation) and T_m(mean daily temperature) as input for estimation of ET_o.

[5] ***R*** **R_s-based – Solar Radiation method**

The reference evapotranspiration is given as:

$$ET_0 = -\,0.611 + 0.149\, R_s + 0.079\, T_{mean}$$

Where, R_s – solar shortwave radiation

1. Simplified version of FAO56-PM.
2. Proximity shows that solar radiation is important as input variable.
3. Uses solar radiation as input variable.

[6] **R_n-based radiation methods – Net Radiation method**

The reference evapotranspiration is given as:

$$ET_0 = 0.489 + 0.289\, R_n + 0.023\, T_{mean}$$

Where, R_n – net radiation

1. Simplified version of FAO56-PM.
2. Uses net radiation as input parameter.

4.1.13 Comparison Table of ET estimation methods:

Method	**FAO56-PM**	**Thornthwaite**	**Hargreaves**	**Hamon**	**R_s-based radiation**	**R_n-based radiation**
Wind speed	compulsory	-	-	-	-	-
Radiation	compulsory	-	compulsory	-	compulsory	compulsory
Humidity	compulsory	-	-	-	compulsory	compulsory
no. of daylight hours	-	compulsory	-	compulsory	compulsory	compulsory
Saturated vapour pressure	compulsory	-	-	-	-	-
Temperature	compulsory	compulsory	compulsory	compulsory	compulsory	compulsory

Table 4.2: Method comparison relative to parameters required

The major drawback is that the "real" Reference Evapotranspiration (ET_o) is unknown. Various tests have been performed, the FAO56-PM method have shown to be the best method for estimation. At the time of sowing of a crop, total percentage of evapotranspiration comes from the phenomenon of evaporation while at the stage of grown crop when_there is full crop cover then more than 90 percentage of evapotranspiration obtained from the phenomenon of transpiration. ET Rate here shows the lost amount of water from cropped surface under units of depth. Its unit goes as millimetres per unit time

CHAPTER 5

SECOND STAGE ANALYSIS

Moving from evapotranspiration and mulching thesis work goes to second stage. In this stage, most common issue related to WSN as congestion control has been taken in accordance. Here, various issues related to congestion and its problem is discussed with various protocols related to them. The problem comes during transfer of data from transmission point to the reception point. If there are a lot of users, problem goes on a large scale. So it must be tackled up with issues related to transfer of data in agricultural activities to the control room.

Further, the work has been continued with an algorithm and coding over MATLAB in SIMULINK toolbox for problems in congestion control under wireless sensor networking. It has been discussed and graph for various users has been obtained for analyses.

5.1 Introduction

In terms of networking theory, the process of deterioration of quality of services during excess of data carried over a node is termed as congestion. It leads to the delay, connection blocking or losses in packets. There are various control and avoidance techniques which are used over for this problem. Also priority schemes are implemented over in order to reduce it. It concerns handling traffic ingress in telecommunication network.

In order to avoid congestive collapse, oversubscription of any process of nodes which are intermediate and networks is avoided like reduction of rate of sending of packets of data. The application of convex optimisation and microeconomic theory described the concept of congestion control.

There are classified many types of algorithms to be applied over. These are classified by the fairness criterion, amount & type of the feedback received, incremental deploy ability, etc. There are mechanisms which are to prevent network congestion. These are as follows:

- **(i)** Congestion notification
- **(ii)** Network scheduler
- **(iii)** Congestion avoidance algorithm

Basically, congestion being a complex problem in networking, raised due to access of same resource, must be handled over properly. This problem leads to degradation of the performance of the network. Congestion control basically means the controlling of the phenomenon of the congestion in a network. It is a critical issue and should be on priority due to size, demand, speed, etc. Basic concepts to be used over the congestion control mechanisms must be under consideration. The three parameters should be under control as available bandwidth, rate of change and TCP response.

5.2 Congestion Control

The type of flow has higher importance than that of application in terms of guidance to real congestion control. It includes single, fewer and many packets format which are to be needed with control on their level. The flows cross when many nodes transmit information, at the intermediate nodes. A large number of sources increase congestion while on the other hand helps over in improvement of reliability. The area across the point of intersection goes to be a hotspot which leads to buffer overflow and links interference. Because of this, an algorithm over congestion control must be there for data packet transmission.

The process of congestion goes with categorisation as:

- **(a) Contention-based congestion:** Interference takes place when some nodes attempt to transmit being in range of one another. It leads to losses and also packet loss goes engendered. Further, it leads to reduction in throughput of all the nodes. The contention takes place especially in networks with high density between different packets of same flow and different flows in the same area.
- **(b) Buffer-based congestion:** There are buffer used for the packets which are waiting to be sent over by each node. Congestion and packet losses are caused by the overflow of the buffer. All this goes by high reporting rate having variation in time. When large buffer size is used, it leads to increase in network load which further harms reliability. It can be improved by reducing buffer size to some extent. When low buffer size is used, packet losses occur due to buffer overflows while results in lower channel contention.

The congestion control functionality goes with three steps as follows:

- **(A) Congestion Detection Strategies:** There are a lot of congestion detection mechanisms which are used over and tested. The mostly used ones are as follows:
  - **(a) Packet loss:** It is measured at the sender where ACKs are used up while also at the receiver with the use of sequence number. CTS (Clear to Send) packet loss is used over as congestion indication.
    Not overhearing is used for packet loss indication. If reliability is ensured then time to repair losses are used as congestion indication. Loss ratio is also considered in some protocols.
  - **(b) Queue length:** Having a buffer by each node, its length can give proper indication of congestion. It is based over threshold level. A fixed threshold level is set and as the buffer exceeds this level, congestion is signalled. The difference of traffic rate and remaining buffer is used as congestion indication.
    The number of non-empty queues also indicates congestion level. The number goes more than zero if congestion takes place and increases with network load.
  - **(c) Queue length and channel load:** As packet collision increases and having unsuccessful MAC retransmissions, packets are removed over. Under such condition for accuracy, there must be use of hybrid approach with combination of queue length and channel load for congestion indication**.** Node delay and

buffer length are used as an indication for congestion depending upon used rate and channel load. Throughput is used with channel load for problems with effect of nodes in multi-hop environment. Throughput is used for quantifying the number of successful transmission.

(d) Packet service time: It is just another measure of queue length and channel load. It is the interval between packet arrival at MAC layer and successful transmission. It holds collision resolution, packet waiting and packet transmission time. It changes according queue length and channel load. Its drawback is when incoming traffic is less or equal than outgoing traffic through overloaded channel.

(e) Ratio of packet service time and packet inter-arrival time: Here, a scheduler is used up between network and MAC layer for packets. The scheduling time (inter- arrival time) quantifies number of packets scheduled per unit time. It indicates both link level and node level congestion.
Buffer length is also used for detection of congestion.

(f) Delay: The use may be misleading in terms of usage for congestion. Sleep latency by use of duty-cycling leads to heavier delay at MAC layer.

(B) Congestion notification: On the detection of congestion, propagation of information must be allowed for appropriate decision over this. The information sent must be as small as one bit. It can be transmitted over in data packets header as implicit notification or as separate control message as explicit notification.

(C) Congestion control: The throughput can't be ameliorated for some type of application by applying similar congestion controlling at all of the nodes. The rate has to be regulated at which the intermediate nodes forward event packets after happening of bottleneck, to the sink. Further rate will be controlled at intermediate nodes. Phase shifting is useful in the cases where event is reported and congestion control extends to rate control. Decoupling can't be done over of the congestion control from the MAC protocol.

The events have different priorities and reported at other rates in WSN monitoring and control. It is totally subjected to the weighted fairness. There are many ways for this. In token bucket scheme, every node transmits only if it consists of a token while for equal and weighted division, the exact rate partitioning is used up. The case comes for addition to rate partitioning with the application of scheduling. Also, different metrics are used up for defining priority having dependency over application needs.

The congestion detection in end-to-end congestion control protocol goes with responsibility over end sink. The control is applied for each source through an exact rate adjustment. It can hold both control and detection of congestion. One RTT (Round Trip Time) is required at least for congestion detection due to long latency of end-to-end control.

Some of the algorithms for controlling congestion are designed across MAC and transport layers for better efficiency. The cross layer design helps in minimizing end-to-end delay. On dependency over control policy transport protocols are divided into:

(A) Resource control: These techniques are used where rate control methods are unable to meet application's requirements as it may be violated by reduction of source traffic during a critical situation. Higher resulted traffic can be faced over by increasing the capacity through turning on extra resources. During congestion, the data around congested area are sent over through routing methods having alternative routes. Preventive load balancing with an interference avoiding based scheduling is used between congested and uncongested routes for load balancing the traffic upon congestion reaction.

Multiple radios and clustering concept can be used for assurance of resource control. In this, there are two radios equipped. First one is to exchange packets with nodes at short distance while other one to communicate with cluster heads and the sink at long distance. While in some protocols, transmission power is adapted in order to ensure sending over long distance. Some protocols also assure resource control by adapting of duty cycling related parameters in order to maintain balance between traffic fidelity and energy efficiency. There are cases where some protocols take in accordance neither of these both. Such protocols go with aggregation strategies. Here, the congested nodes can be provided with a prioritized channel access by permission to drain of buffer with the use of prioritized MAC schemes.

The comparison between both control techniques can be done over basis under parameters as network lifetime, source data rate, average node-energy consumption and number of packets drops. The alternative path creation algorithms give assurance of a high network lifetime by making data rate stable. The data rate reduction algorithms give low power consumption and packet drops minimally. The contention increases in spreading off the traffic by various paths with reducing congestion because of crossing of multiple routes towards same sink.

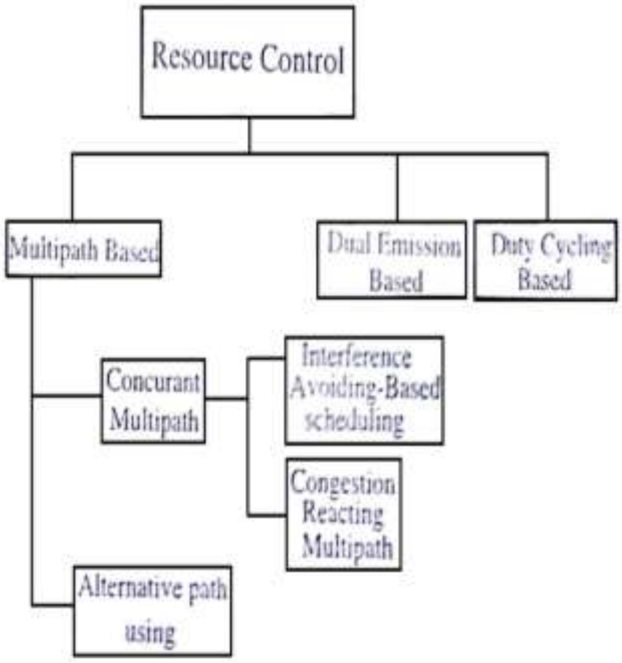

Fig 5.1: Resource Control Techniques

(B) Traffic control: It is applied over by throttling the node rates. The change in rate of packets may be assured in different ways which are sent after congestion notification (CN). When there is usage of a single CN bit, AIMD (Additive Increase Multiplicative Decrease) scheme is usually applied over. The availability of detailed congestion information leads to the implementation of exact and accurate rate adjustment. In order to adjust reporting rates in-network or sink based solutions are taken. Also, packets are dropped out not to propagation of congestion. If no CN is used up, the sources do not achieve their final destination and waste resources by continuous submission of traffic. The traffic control is performed in two manners. The first one is avoiding manner and other is reacting manner. Both of these can be dependent of buffer overflow or interference control. Avoiding interference is through partitioning of rate in order to prevent the capacity from exceeding of interfering nodes and also to avoid collisions through scheduling. There are schemes which are based upon limiting the sending avoid butter overflowing.

Both buffer overflow and interference are mitigated with traffic control which is reacting based. The mitigation is on the basis of individual control or organised hierarchic rate control, for which only the adjustment of rate of concerned node is done. The hierarchic based organised rate control is applied over by weighted or equal rate partitioning without any schedule or scheduling based upon rate. When individual traffic control is applied over then assurance is with coarse grained or exact rate control.

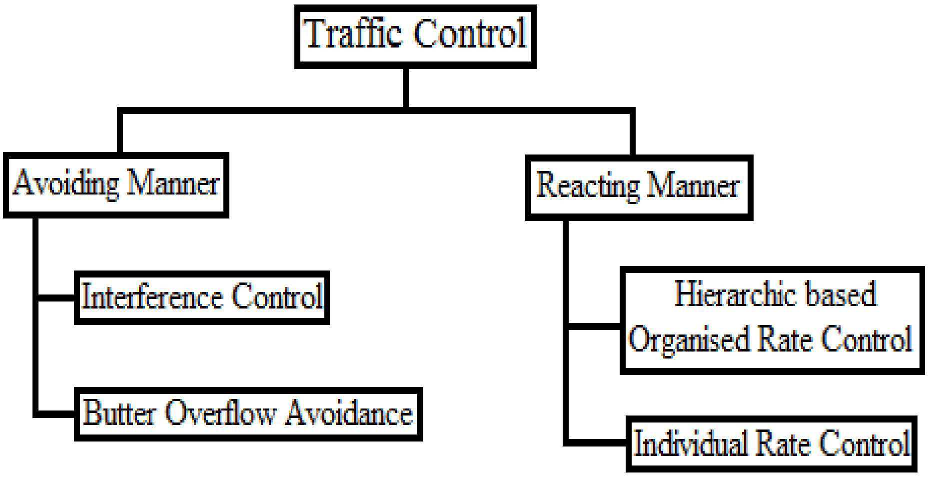

Fig 5.2: Traffic Control Classes

5.3 Evaluation

In concept of congestion control, there must be format for evaluation of it. It must be done in order to show efficiency in the purpose with in having overload traffic. It goes with metrics which are used in some protocols to achieve evaluation. The most common among them are as follows:

(a) Network fairness: The desired condition goes with allocating bandwidth fairly from each node to base station. Variation degree in transmitting rate is quantified over and for fairness guarantee node throughput is taken in accordance.

(b) Energy efficiency: Total energy spent over in listening channel and transmission & forwarding of packets in whole network. The measurement unit is Joule (J) and also calculated as per unit of successful received packets.

(c) Sink received throughput: this is the total no. of received packets successfully during time unit. Also, it is weighted in relative of data priorities.

(d) Network Efficiency: Undelivered packets transmission wasted energy is calculated. Variation in dropping cost of packets depends over distance from sink.

(e) Packet latency: It is also termed as end to end delay. Packet latency is time taken to reach base station by packet from its generation time. Also, per hop and weighted delays are used somewhere.

5.4 Table for sources and solution

S. No.	Sources	Solution
1.	Channel contention and interference	1. ART-Asymmetric and reliable transport mechanism 2. XLM
2.	Packet collisions	1. FUSION (hop-by-by flow control, source limiting scheme, prioritized MAC) 2. CODA-Congestion detection and avoidance
3.	Reporting Rate	1. ESRT-event to sink reliable transport 2. HTAP-hierarchical tree alternative path algorithm
4.	No. Of event sources	1. RCRT-Rate controlled reliable transport 2. Congestion Avoidance Based on Lightweight Buffer Management 3. ARC-Adaptive rate control
5.	Priority based congestion	1. ECODA-Enhanced Congestion detection and avoidance 2. PCCP-priority based congestion control protocol

Table 5.1: Sources and their solution

5.5 Congestion Control Algorithm

As we have seen all the perspective of congestion over wireless sensor networking in introduction of second stage of the model. The procedure goes with notification, detection and at last with controlling of the problem so generated. It goes under traffic control and resource control classes. On their behalf several protocols are there in order to deal with the issue. Various metrics are taken in accordance to get the proper evaluation of congestion. Congestion control is done over as per circumstances by the related methodology.

Here, an algorithm has been proposed in order to get fair and efficient congestion control. This algorithm is for a simple network which consists of a single link. Further, it goes with AIMD law and also with fixed capacity over the network. The algorithm clarifies many of basic features. It holds concept of equilibrium point at a stage in the process.

Initially, congestion control problem is abstracted by presentation of a network having single link with fixed capacity to be shared by two sources. In this, Additive increase Multiplicative decrease law is used so as to adapt the transmission rate to feedback from network in order to check either the link is congested or not, of two sources leads to equilibrium. Congestion will occur when the link access rate goes more than link capacity. It’s common as when accessing goes more than capacity of link, it would create congestion automatically. The algorithm is operated over by steering of network towards an operation point corresponding to stable equilibrium.

5.5.1 Assumptions

Let us suppose condition for two sources on a single link. It is with capacity C (packets/sec). Suppose A_i be rate of packet transmission into network for i=1, 2. Feedback is provided to sources in order to indicate either total excess rate ($A_1 + A_2$) exceeds capacity of link C or not. Congestion occurs as the situation arrives when accessing rate of link crosses link capacity. Feedback signal is represented by $I(A_1 + A_2 > C)$ where, $(A_1 + A_2 > C)$ is indicator function of event. The value is taken as 1 when event is true otherwise 0 when it is false.

The purpose is of sharing link by sources must be fair. It should be fully utilised in respect to convergence of transmitting rates of sources at an operation point which is stable. This is used in realization of unique equilibrium for network. Transmission rates are adjusted in accordance with a particular differential equation with concept as if total receiving rate at link is less than capacity C, then transmitting rate is additive increased by a source and if it is more than Capacity C, then it goes under multiplicative decrease. The concept is also known as additive increase and multiplicative decrease law. Both of events are said to be complimentary as only one can occur at a time. Here, resources are dynamically allocated which is fundamental in derivation of packet switching in terms of benefits. An algorithm should support fairness in allocation of rates to several users with providing a rate region as large as possible. Each of sources uses a single bit feedback over network and they doesn't need to communicate each other.

5.5.2 Analysis

The experiment requires equilibrium convergence behaviour for differential equation. It is done by using MATLAB. Initially, discretization of differential equation has been done over to get difference equation which is further implemented as a computer program.

The basic differential equation:

$$A_i = \alpha\, I\,(A_1 + A_2 \leq C) - \beta\, A_i\, I\,(A_1 + A_2 > C) \text{ for } i \in \{1, 2\}$$

Further, continuous derivative is replaced over by discrete counterpart. Then values are replaced over and some values as constant are considered as: $C = 1$, $\alpha = 1$, $\beta = 0.5$, $\delta = 0.05$

The difference equation so obtained to be implemented over is:

$$A\,(k + 1) = A\,(k) + \alpha\,\delta\, I\,(A_1 + A_2 \leq C) - \beta\,\delta\, A_i\, I\,(A_1 + A_2 > C)$$

Equation so obtained is implemented over in MATLAB and equilibrium convergence behaviour is achieved as result in plot. It is confirmed totally that link is totally utilised at equilibrium and equal sharing takes place. [31]

5.6 MATLAB Simulation

5.6.1 Rate Evolution for two sources A_1 and A_2 with C=1

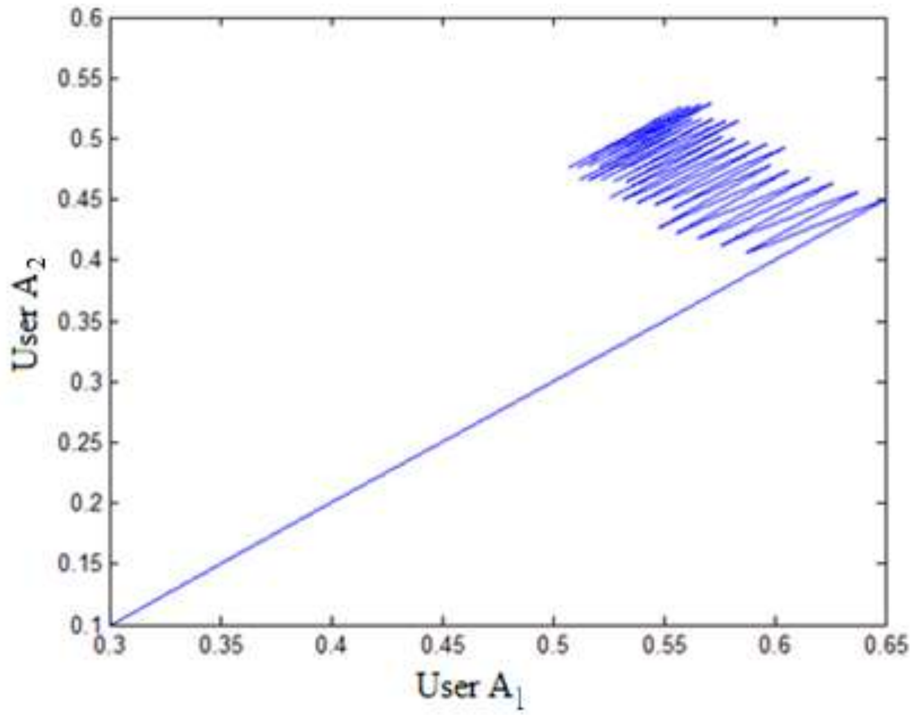

Fig 5.3: Rate evolution of two sources

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.3000	0.6500
7	A2	<101x1 double>	0.1000	0.5284

Table 5.2: Min and Max values of both sources

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.3;
A2=zeros(size,1);
A2(1)=0.1;

C=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure;
set(gcf,'Color','white');
plot(A1,A2);

xlabel('User A₁');
ylabel('User A₂');
```

5.6.2 Time vs Users share (A_1 and A_2)

Initially fixed values are C=1, $\alpha = 1$, $\beta = 0.5$, $\delta = 0.05$. Further, we will go for both of the conditions as additive increase and multiplicative decrease.

5.6.2.1 Additive Increase Condition

Now, let $A_1 = 0.2$ and $A_2 = 0.1$

Then, $A_1 + A_2 = 0.2 + 0.1 = 0.3 < C$

So, $A_1 + A_2 \leq C$ and the condition is followed up and the equilibrium point is obtained at $A_1 = 0.5$ and $A_2 = 0.5$ as shown in the graph plot. So, (0.5, 0.5) may be considered as the equilibrium for the condition where both of the sources are sharing the link equally which is having capacity C = 1. This is both fair and efficient for congestion control issue.

This is the condition where $A_1 + A_2 \leq C$, so as per AIMD law there must take place additive increase which can be seen in the plot obtained.

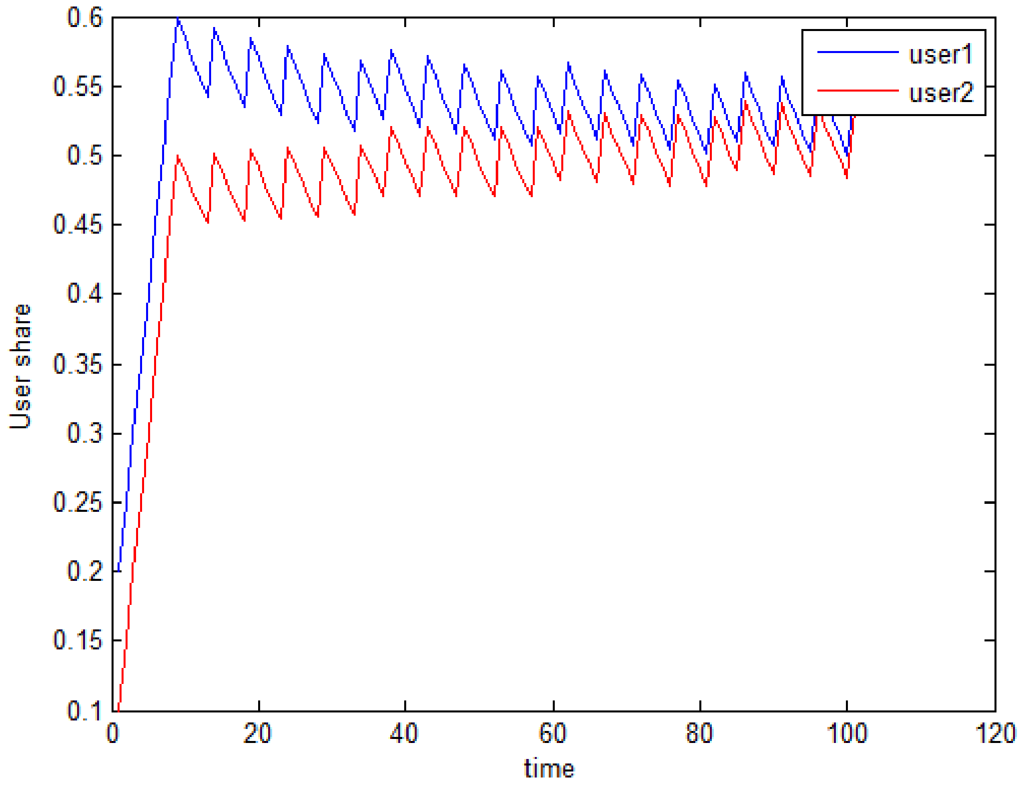

Fig 5.4: Additive Increase plot for 0.2 & 0.1

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.2000	0.6000
7	A2	<101x1 double>	0.1000	0.5391

Table 5.3: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.2;
A2=zeros(size,1);
A2(1)=0.1;

C=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
xlabel('time');
ylabel('User share')
legend('user A1','user A2')
```

Further, we will go for some other values of both sources.

So, let $A_1 = 0.4$ and $A_2 = 0.3$

Then, $A_1 + A_2 = 0.4 + 0.3 = 0.7 < C$

This is the condition where $A_1 + A_2 \leq C$, Again as per AIMD law there must take place additive increase which can be seen in the plot obtained.

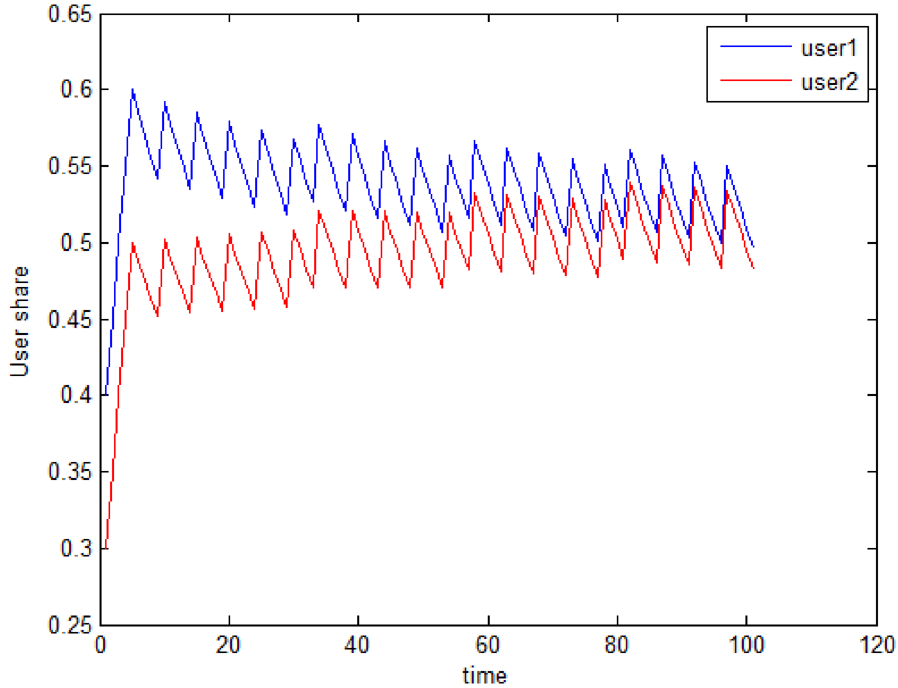

Fig 5.5: Additive increase plot for 0.4 & 0.3

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.4000	0.6000
7	A2	<101x1 double>	0.3000	0.5391

Table 5.4: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.4;
```

```
A2=zeros(size,1);
A2(1)=0.3;

C=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
xlabel('time');
ylabel('User share')
legend('user A1','user A2')
```

5.6.2.2 Multiplicative Decrease condition

Now, let's go to the other condition over where $A_1 + A_2 > C$ must be followed as per the values of the sources. Initially fixed values will be the same and values of sources will be changed.

Let, $A_1 = 0.7$ and $A_2 = 0.5$

Then, $A_1 + A_2 = 0.7 + 0.5 = 1.2 > C$

So, the condition of $A_1 + A_2 > C$ is followed up and there must be multiplicative decrease in the plot of time vs users share. It can be seen in the plot shown below.

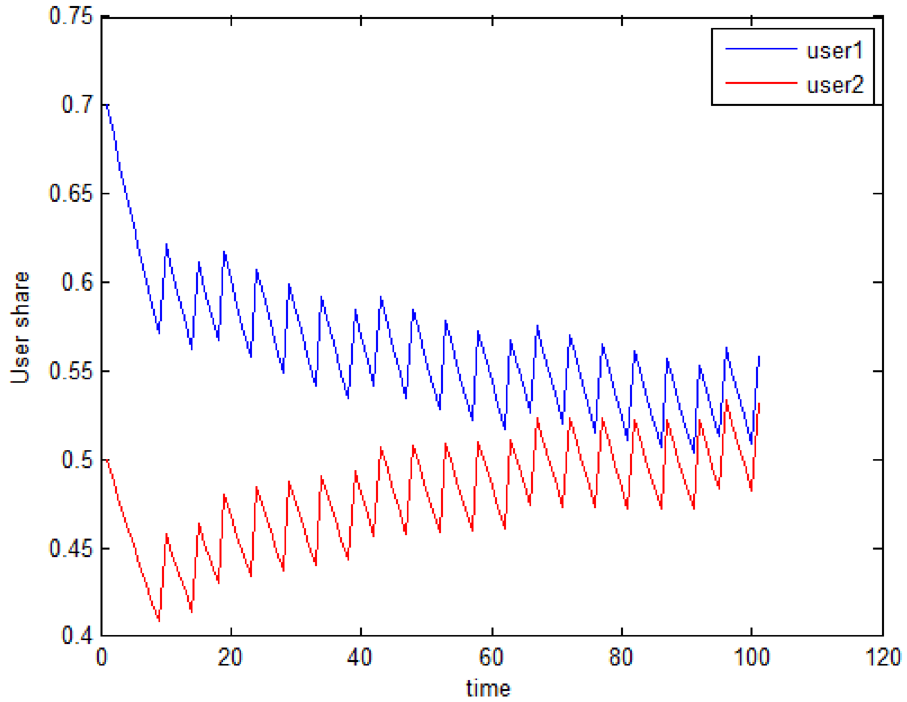

Fig 5.6: Multiplicative decrease plot for 0.7 & 0.5

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.5034	0.7000
7	A2	<101x1 double>	0.4083	0.5337

Table 5.5: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.7;
```

```
A2=zeros(size,1);
A2(1)=0.5;

C=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
xlabel('time');
ylabel('User share')
legend('user A₁','user A₂')
```

Further, we will go for some other values of both sources.

So, let $A_1 = 0.6$ and $A_2 = 0.9$

Then, $A_1 + A_2 = 0.6 + 0.9 = 1.5 > C$

Again, the condition of $A_1 + A_2 > C$ is followed up and there must be multiplicative decrease in the plot of time vs users share. It can be seen in the plot shown below.

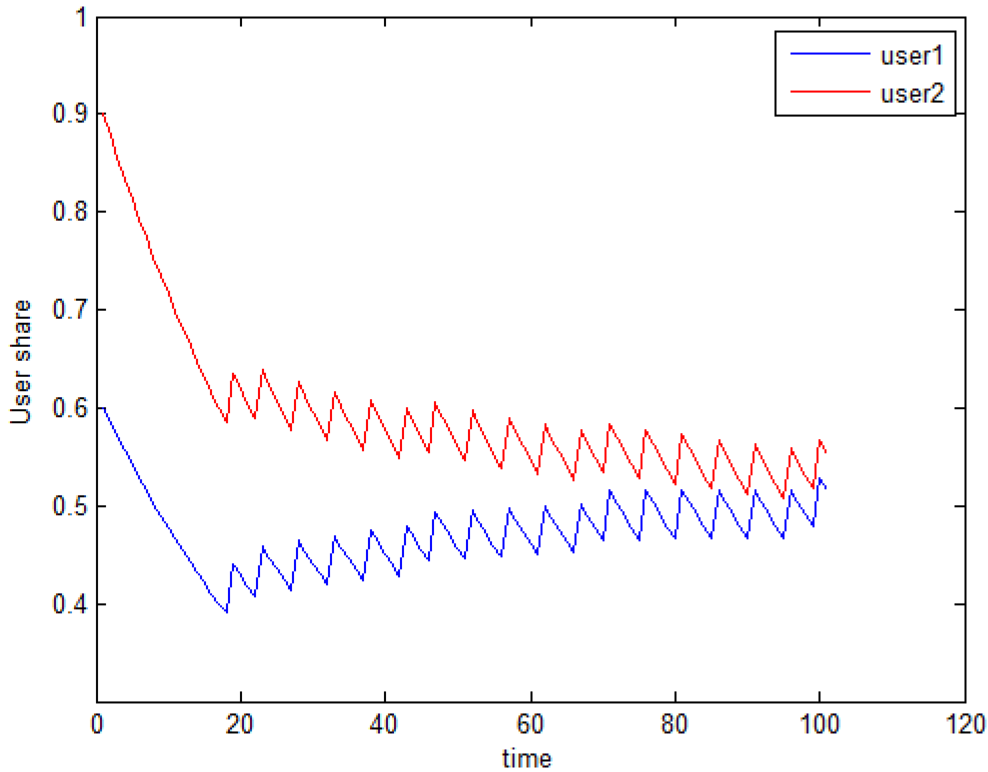

Fig 5.7: Multiplicative decrease plot for 0.6 & 0.9

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.3901	0.7000
7	A2	<101x1 double>	0.5084	0.5337

Table 5.6: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
```

```
A1(1)=0.6;
A2=zeros(size,1);
A2(1)=0.9;

C=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
xlabel('time');
ylabel('User share')
legend('user A1','user A2')
```

5.6.3 Time vs User Share (7 users)

Till now, we have seen the cases for different values over additive increase and multiplicative decrease in order for two sources. In this, conditions have been checked out for both either additive increase or multiplicative decrease as per AIMD law under consideration. This can be seen in plot which is obtained by changing values of both sources A_1 and A_2. Further, we are going to check this for more than two sources. Then, the conditions will be checked out as per the law over MATLAB.

5.6.3.1 Additive Increase condition

This is the case for seven numbers of sources to be taken in accordance on the same link which is having capacity one. Here, the sources taken are A_1, A_2, A_3, A_4, A_5, A_6 and A_7. There values are put over and the conditions are checked over as in the obtained plot. Initial values will be same as in the previous cases.

Let, $A_1 = 0.07$, $A_2 = 0.17$, $A_3 = 0.16$, $A_4 = 0.09$, $A_5 = 0.08$, $A_6 = 0.21$ and $A_7 = 0.14$

Then, $A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 = 0.07 + 0.17 + 0.16 + 0.09 + 0.08 + 0.21 + 0.14$

$$= 0.92 < C$$

The condition followed here is when sum of the sources is less than or equal to the Capacity of the link which is one here. Plot is obtained by putting values in the code of MATLAB and plot is obtained in which the condition is checked out. As seen in the plot below additive increase condition is followed up and the equilibrium point is obtained by the division of the capacity in seven numbers equally due to seven sources. Here, all of the sources are allotted the link equally at the equilibrium point which can be seen in the plot so obtained.

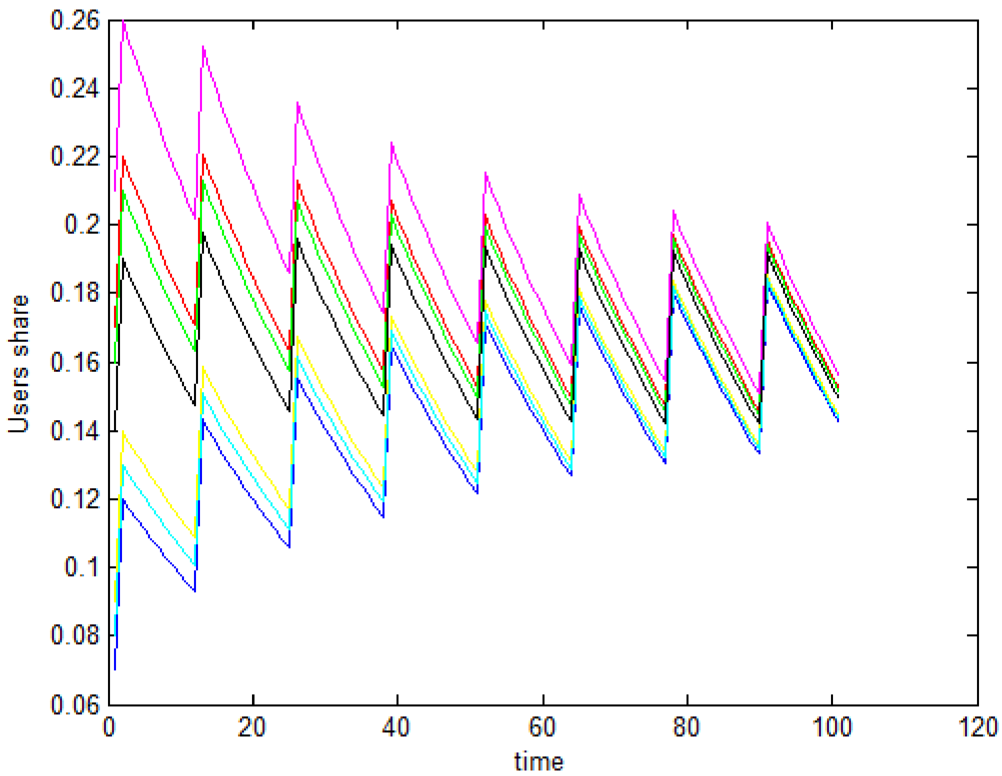

Fig 5.8: Additive Increase plot for 7 sources

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.0700	0.1831
7	A2	<101x1 double>	0.1457	0.2208
8	A3	<101x1 double>	0.1444	0.2130

9	A4	<101x1 double>	0.0900	0.1856
10	A5	<101x1 double>	0.0800	0.1844
11	A6	<101x1 double>	0.1507	0.2600
12	A7	<101x1 double>	0.1400	0.1975

Table 5.7: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.07;
A2=zeros(size,1);
A2(1)=0.17;
A3=zeros(size,1);
A3(1)=0.16;
A4=zeros(size,1);
A4(1)=0.09;
A5=zeros(size,1);
A5(1)=0.08;
A6=zeros(size,1);
A6(1)=0.21;
A7=zeros(size,1);
A7(1)=0.14;

c=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+A2(i)+A3(i)+A4(i)+A5(i)+A6(i)+A7(i)) <=C
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
A3(i+1)=A3(i)+delta;
A4(i+1)=A4(i)+delta;
A5(i+1)=A5(i)+delta;
A6(i+1)=A6(i)+delta;
A7(i+1)=A7(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
```

```
A2(i+1)=A2(i)-delta* beta * A2(i);
A3(i+1)=A3(i)-delta* beta * A3(i);
A4(i+1)=A4(i)-delta* beta * A4(i);
A5(i+1)=A5(i)-delta* beta * A5(i);
A6(i+1)=A6(i)-delta* beta * A6(i);
A7(i+1)=A7(i)-delta* beta * A7(i);
end
end
 figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
hold on
plot(A3,'g')
hold on
plot(A4,'y')
hold on
plot(A5,'c')
hold on
plot(A6,'b');
hold on
plot(A7,'r')
hold on
xlabel('time');
ylabel('Users share')
```

5.6.3.2 Multiplicative Decrease condition

Initial values will be same as in the previous cases as for C, α, β and δ. Further, we change values of all sources in accordance to obtain multiplicative decrease condition.

Let, $A_1 = 0.27$, $A_2 = 0.15$, $A_3 = 0.12$, $A_4 = 0.24$, $A_5 = 0.04$, $A_6 = 0.13$ and $A_7 = 0.29$

Then, $A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 = 0.27 + 0.15 + 0.12 + 0.24 + 0.04 + 0.13 + 0.29$

$$= 1.24 > C$$

The condition is fulfilled as sum of all the sources exceed the link capacity, C. This leads to multiplicative decrease in the plot to obtain equilibrium which is requirement for the algorithm. Further, plot can be checked out for the conditions and the equilibrium point at which all of the sources will share the link equally. This is the condition for congestion avoidance mechanism.

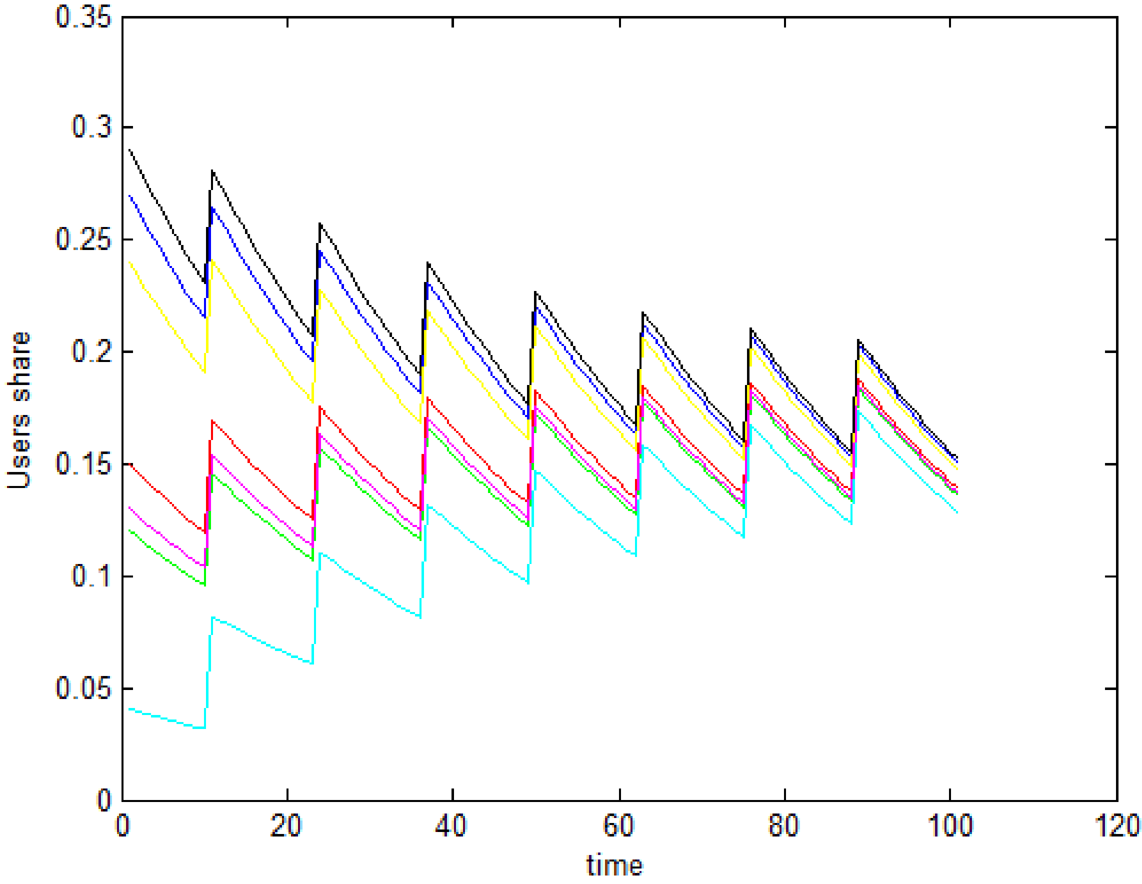

Fig 5.9: Multiplicative Decrease plot for 7 users

S. No.	Name	Value	Min	Max
1	beta	0.5000	0.5000	0.5000
2	C	1	1	1
3	delta	0.0500	0.0500	0.0500
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.1497	0.2700
7	A2	<101x1 double>	0.1194	0.1874
8	A3	<101x1 double>	0.0955	0.1835
9	A4	<101x1 double>	0.1468	0.2411

10	A5	<101x1 double>	0.0318	0.1732
11	A6	<101x1 double>	0.1035	0.1848
12	A7	<101x1 double>	0.1516	0.2900

Table 5.8: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.27;
A2=zeros(size,1);
A2(1)=0.15;
A3=zeros(size,1);
A3(1)=0.12;
A4=zeros(size,1);
A4(1)=0.24;
A5=zeros(size,1);
A5(1)=0.04;
A6=zeros(size,1);
A6(1)=0.13;
A7=zeros(size,1);
A7(1)=0.29;

c=1;
delta=0.05;
beta=0.5;

for i=1:1:size
if (A1(i)+A2(i)+A3(i)+A4(i)+A5(i)+A6(i)+A7(i)) <=C
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
A3(i+1)=A3(i)+delta;
A4(i+1)=A4(i)+delta;
A5(i+1)=A5(i)+delta;
A6(i+1)=A6(i)+delta;
A7(i+1)=A7(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
```

```
A2(i+1)=A2(i)-delta* beta * A2(i);
A3(i+1)=A3(i)-delta* beta * A3(i);
A4(i+1)=A4(i)-delta* beta * A4(i);
A5(i+1)=A5(i)-delta* beta * A5(i);
A6(i+1)=A6(i)-delta* beta * A6(i);
A7(i+1)=A7(i)-delta* beta * A7(i);
end
end
 figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
hold on
plot(A3,'g')
hold on
plot(A4,'y')
hold on
plot(A5,'c')
hold on
plot(A6,'b');
hold on
plot(A7,'r')
hold on
xlabel('time');
ylabel('Users share')
```

Further, these conditions can be checked over by changing the values of sources as required for following either of the conditions. All of these have shown that the algorithm can be undertaken for efficiency and fairness.

These schemes allow to be operated in optimal region with higher throughput and lower delay. Achievement is done over by monitoring of load level and increasing or decreasing it as per requirement. Since feedback is limited to one bit, it tells about current load which is either below or above the goal.

5.6.4 Time vs Users Share

Till now, the plot has been resulted over the fixed values of C, α, β and δ followed by changing of initial values of rates. This has been done for two sources over both conditions on different values and the plot has been observed after obtaining it. Further, the same procedure has been done for seven numbers of sources with same values for both of the conditions and the plot has been observed as per the conditions.

Now, the plot will be observed by changing the values of β and δ as the value of Capacity C and α can’t be changed in the difference equation. Here, we will change the values of β and δ in the MATLAB program without any change in the remaining values. The initial values of sources would be seen in the plot for same as in previous cases.

5.6.4.1 Additive Increase Condition

In this condition, the values will be as C = 1, $\alpha = 1$, $A_1 = 0.2$ and $A_2 = 0.1$. Here, the values of β and δ will be changed. Let, $\beta = 0.6$ and $\delta = 0.02$

Then, $A_1 + A_2 = 0.2 + 0.1 = 0.3 < C$

The condition $A_1 + A_2 \leq C$ for additive increase has been followed up in the case. The values have been put over in the MATLAB program and the plot has been observed. Now, the change in the plot from previous case can be easily identified.

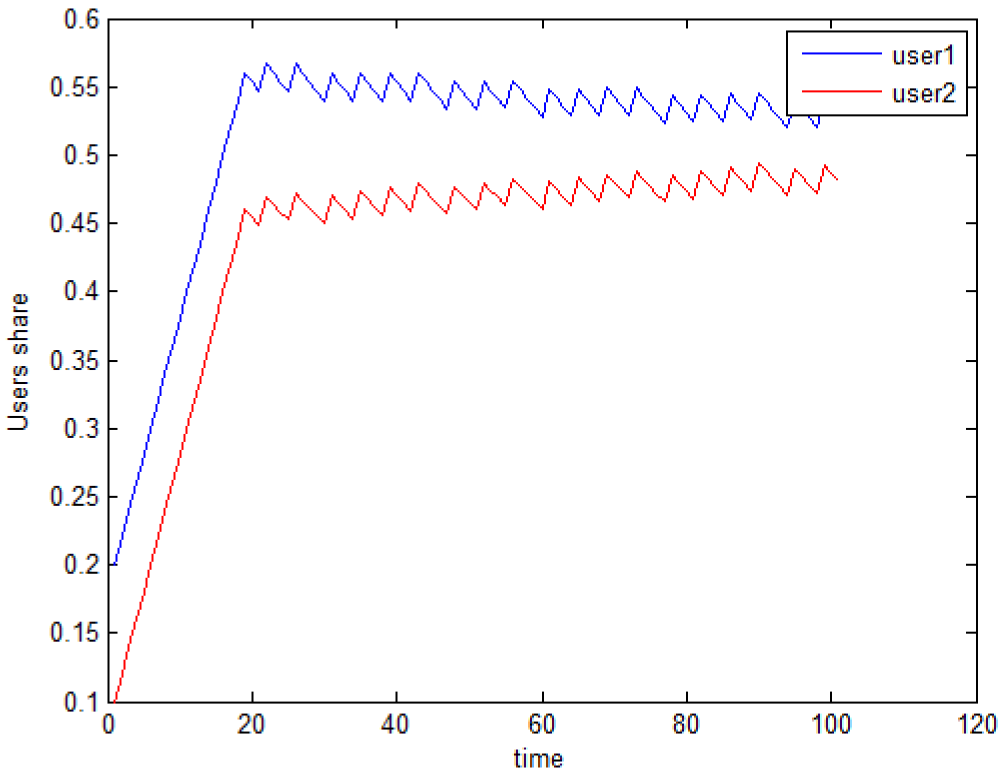

Fig 5.10: Additive Increase plot for different values of β and δ

S. No.	Name	Value	Min	Max
1	beta	0.6000	0.6000	0.6000
2	C	1	1	1
3	delta	0.0200	0.0200	0.0200
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.2000	0.5666
7	A2	<101x1 double>	0.1000	0.4935

Table 5.9: Min and Max values of variables in plot

Program:

```
clc;
clear all;
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.2;
A2=zeros(size,1);
A2(1)=0.1;

C=1;
delta=0.02;
beta=0.6;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
xlabel('time');
ylabel('User share')
legend('user A1','user A2')
```

5.6.4.2 Multiplicative Decrease Condition

In this condition, the values will be as $C = 1$, $\alpha = 1$, $A_1 = 0.7$ and $A_2 = 0.5$. Here, change the values of β and δ. Let, $\beta = 0.6$ and $\delta = 0.02$

Then, $A_1 + A_2 = 0.7 + 0.5 = 1.2 > C$

The condition $A_1 + A_2 > C$ for multiplicative decrease has been followed up in the case. The values have been put over in the MATLAB program and the plot has been observed. Now, the change in the plot from previous case can be easily identified.

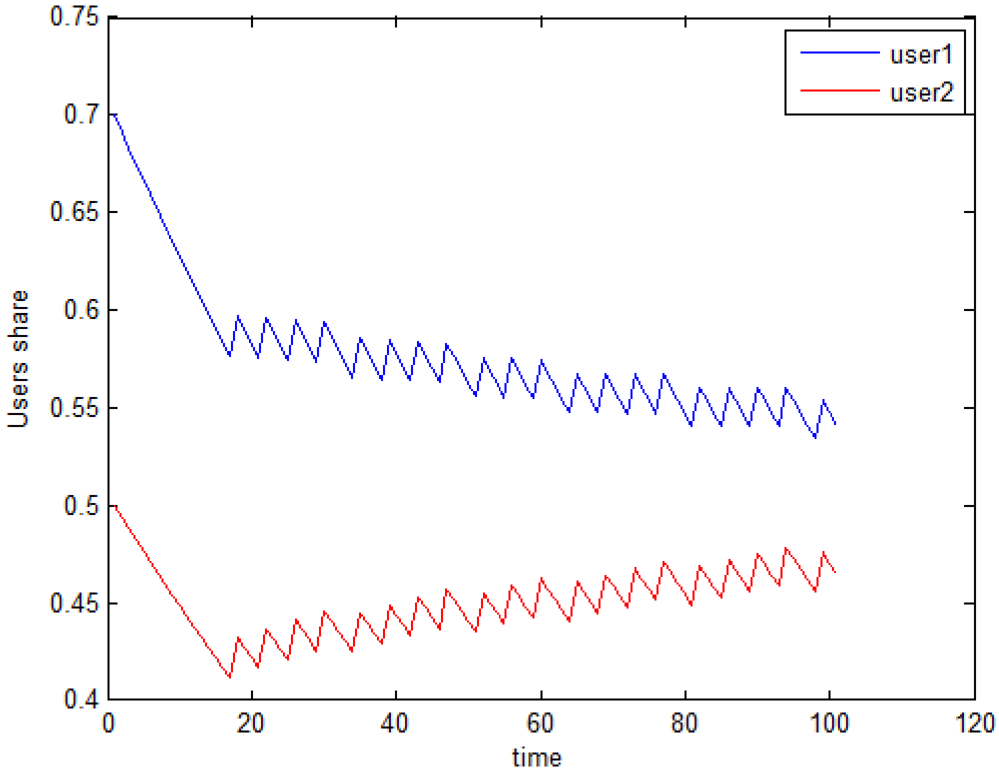

Fig 5.11: Multiplicative Decrease plot for different values of β and δ

S. No.	Name	Value	Min	Max
1	beta	0.6000	0.6000	0.6000
2	C	1	1	1
3	delta	0.0200	0.0200	0.0200
4	i	100	100	100
5	size	100	100	100
6	A1	<101x1 double>	0.5341	0.7000
7	A2	<101x1 double>	0.4122	0.5000

Table 5.10: Min and Max values of variables in plot

Program:

```
clc;
clear all;
```

```
close all;

size=100;
A1=zeros(size,1);
A1(1)=0.7;
A2=zeros(size,1);
A2(1)=0.5;

C=1;
delta=0.02;
beta=0.6;

for i=1:1:size
if (A1(i)+ A2(i))<=c
A1(i+1)=A1(i)+delta;
A2(i+1)=A2(i)+delta;
else
A1(i+1)=A1(i)-delta* beta * A1(i);
A2(i+1)=A2(i)-delta* beta * A2(i);
end
end

figure
set(gcf,'Color','white');
plot(A1,'b');
hold on
plot(A2,'r')
xlabel('time');
ylabel('User share')
legend('user A1','user A2')
```

CHAPTER 6
CONCLUSION AND FUTURE SCOPE

6.1 Recommendations

As we have seen, wireless sensor networking has been employed over in agricultural activities on a large scale in order for increment in various aspects and reduction in losses to be made during procedure.

In respect of agro model, the recommendation goes as there can be implementation of soil pH sensor for measurement of pH of soil which is to be used in agricultural activity. Also, soil moisture sensor can be implemented over for moisture in soil under consideration. Various gas sensors mainly for carbon dioxide, carbon monoxide, ammonium chloride, etc. in the series of MQ3 to MQ7 can be used. Further, internet connectivity with GSM module over to control room can also be added.

In respect of evapotranspiration, various models can be used over for connection with agro model in terms of evaluation. Any of the remote sensing methods can be employed over. Being one of the important parameter, evapotranspiration must be evaluated correctly. Make use of Penman-Monteith equation which is basic equation if any other method is not applicable.

In respect of Congestion control, it is recommended that there must be implementation for both of conditions over more than two numbers of sources. In that condition, also there is equal sharing of the link in division basis on the number of sources. Further, also there can be implementation in MATLAB by changing the values of β and δ in the code. In such cases, there is observed different patterns for the same values of sources in both conditions. It can be visually observed in plot.

At last, overall model can be handled over in greenhouse under agricultural activities.

6.2 Conclusion and Future Scope

The wireless nature of WSNs expose their utilisation to harsh environment conditions like contention (links interference) and congestion (buffer overflows) which impact the overall system performance. Transport protocols play a pivotal role in improving the network reliability and throughput. Our study on congestion control protocols has shown that the application and flow types – characterised by the many-to-one nature communication – influence and guide control applied to traffic.

Being energy constrained over sensor networks, sending rates of sources are upper bounded resulting in network lifetime. It is important for application fidelity. Reliability is mostly dealt with at transport layer and effectiveness and dependency must be assured over essentially.

The future scope goes with following of recommendations as per introduced above. In this model congestion issue can be controlled over for various cases by cross checking of algorithm under variation of values in the code. It leads to higher accuracy in terms of agricultural data to be sent by farmers to the control room which is very much necessary.