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Congestion Control in Cognitive IoT-Based WSN Network for Smart Agriculture

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ABSTRACT Wireless sensor networking is being used extensively in agricultural activities to increase productivity and reduce losses in various ways. The greenhouse simplifies the concept of planting, which has several benefits in agriculture. In agricultural models, soil pH sensors and gas sensors are commonly used. These sensors are applicable in various Internet of Things (IoT) integrated agricultural activities. The paper discusses the hardware design and working of the proposed model. In addition, various agricultural models used for evapotranspiration are also explained. The key factors such as congestion control are evaluated using the Penman-Monteith equation. This paper focuses on implementing more than two references parameters like evapotranspiration and humidity under different conditions, which aids in splitting the relationship evenly by the number of sources. Furthermore, the paper shows the implementation done with MATLAB and values are adjusted using the code. The paper claims to achieve similar variations with the same source value, validating the proposed model's efficiency and fairness. In an optimal region, these schemes also demonstrate higher throughput and lower delay rates. The improved packet propagation through the IoT network is demonstrated using visualization tools, and the feedback is computed to determine the overall access amount (A1 + A2) obtained. The experimental results show that the propagation rate is 1.24, more significant than the link capacity value. The claims are verified by showing the improved congestion control as it outperforms different parameters, considering an additive increase condition by 0.3% and multiplicative decrease condition by 1.2 %.

INDEX TERMS Irrigation methods, agriculture, wireless sensor network, congestion control.

I. INTRODUCTION

The primary need for a human being to survive on the planet earth is food, so it is critical to work on various aspects of the country's agricultural needs. Agricultural activities necessitate the expansion of land available for cultivation and irrigation. So that the crop does not become overburdened, it must be cultivated in such a way that it recovers the bare necessities of the country's people. Agriculture accounts for 25% of the total Gross Domestic Product (GDP), 15% of total exports, and 65% of the country's total population's livelihood. With the advent of modern techniques, using traditional irrigation methods has many disadvantages. Air, water, sunlight, and soil are the four basic requirements for growing plants. Irrigation [1] of crops takes approximately eight to fifteen days using conventional irrigation methods and requires uniformity of water distribution for up to thirty percent only. It reduces irrigation efficiency because the total applied water does not reach the plants uniformly. It is assumed that only 40% of the total amount of water is effectively used in irrigation. Traditional irrigation methods are widely used in most developing countries. This paper focuses on the development of a model that deals with various parameter control measures related to agricultural activities, such as temperature control, humidity control, water level control, light control, and soil moisture control measures,

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in conjunction with the operation of the global system for mobile communication modelling. The hardware details the microcontroller's operation and the messages displayed in the LCD connected to the SIM installed in the GSM module. The paper discusses the analysis of the first and second stages and the effect of congestion control and other features.

Drop irrigation, ditch irrigation, sprinklers, and terraced systems are all widely accepted services. Water scarcity and poor farm performance are two consequences of traditional irrigation techniques. Automated wagering systems address these issues. This research focuses on irrigation systems that use sensors and modern technology. Farmers could obtain wireless sensor network information in real-time (soil and crop development) via SMS or some Android app in the existing agricultural system, but when data was overloaded, farmers could not address the problem. Farmers will be able to get information on their land and kindergarten, as well as an estimate when and how much water is needed for irrigation, by using the congestion control system. Farmers can use automatic irrigation systems or nursery irrigation systems to provide or deliver the right amount of water at the right time. This technology also enables agricultural management to keep the moisture level constant over time. According to some studies, using water at the right time and in the right amount can increase productivity.

This paper has developed a WSN based sensing system with Single-Chip-Microcomputer sensing nodes and analysis of congestion management protocols to provide a safe and reliable data transmission system in agriculture systems. We have also evaluated the traffic regulation of traffic rules, devices, and flow forms – distinguished by their many-to-one nature coordination. In this paper, we have optimized the transmission speeds of sources are at their maximum speed, which results in increased network life as energy is conserved across sensor network systems. Congestion controlled systems are proposed and evaluated in this model for various cases by cross-checking the algorithm with different values in the code. It leads to greater accuracy in agricultural data sent by farmers to the control room, which is beneficial.

The contributions of the paper are given as below:

- Research the exiting technology of agricultural methods, research gaps, and the operation of the complex components used in wireless sensor networks (WSN).
- We have proposed a model which considers various parameters to control related agricultural activities.
- Using a microcontroller, design a model hardware with automatic functionality combined with GSM.
- Conduct the first and second stages of analysis and the experiments for model verification and algorithm testing.
- To assess the model's efficiency by varying the effect of critical agricultural characteristics such as temperature control, humidity control, water level control, light control, and soil moisture in a greenhouse environment.

II. LITERATURE REVIEW

The section discusses the background details on irrigation methods, wireless sensor networks and presents the literature review.

A. CONVENTIONAL IRRIGATION METHOD

During the first three days of this procedure, soil pores are saturated with water under irrigation at eight-day intervals. Water replaces air in the soil at a disturbing capacity level. Excess water suffocates the root, causing water absorption to cease and crop growth to be hampered. Furthermore, soil moisture [2] will be reduced over the next three days. Following this, moisture, air, and nutrients reach optimum levels, while soil only reaches field capacity. The plant grows during this phase, and the moisture level falls below the root zone. The plant is stressed, which prevents it from quickly absorbing air and nutrients and limits its growth. Surface irrigation is one of the traditional methods used [3].

1) SURFACE IRRIGATION

The entire land is filled with water using this method. As a result, a large amount of water is wasted due to a lack of knowledge about the water used and the evaporation process. Surface conventional irrigation is further subdivided into several categories. These are as follows:

a) Level Basin– This technique is used when the irrigated plot is slight. Initially, the water is applied uniformly to the entire field. The extreme points are linked to small collective areas or ponds, where excess water drains. There is minor water loss due to runoff but no loss of fertilizers or organic manures. It may be more expensive if the field must be levelled first. This technique works well with rice, jute, and other fibers. It is simple to manage and performs well enough to achieve high application efficiency and improved salinity control. To design a level basin irrigation system, three different criteria must be met.

b) Furrow Basin– This method is mainly used for row crops like sugarcane, potatoes, cotton, vegetables, etc. The furrows are built along contours, and the water is filled only in the furrows rather than the entire field. It is appropriate for sloppy lands because it allows for easy water runoff along contours.

c) Border Strip Basin Irrigation– This is also known as Bay Strip Irrigation. To begin, the entire field is levelled, and two adjacent rows of beds are constructed in the field. Then a water channel is installed between the rows. The length of the bed varies from clay to loamy soils. The data only explains the usage of 20% to 40% of the water. The system necessitates a large amount of workforce and is best suited for high-value crops. It is adaptable to most soil textures, except for sandy soils, and uses less water in comparison.

These methods are only appropriate for uneven lands where the traditional form of levelling is prohibitively expensive.

The disadvantage of these is that they cannot be used in different types of soil. Micro-irrigation methods have taken the place of traditional irrigation methods to increase productivity while using a low volume of water sources [4].

2) MICRO IRRIGATION METHODS

The irrigation method which holds the application of low volume water at high frequency and low pressure is termed the micro-irrigation method. It leads to savings of 40 to 60 percent of water and is suitable for poor soil. 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 savings of labour cost, water up to seventy percent, and yield increased more than twice. The system successfully works over more than forty crops. Further, this method is categorized into two different types. These are as follows:

a) Drip Irrigation Method – It is also termed 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 the plant root zone using a network [5]. Main lines and sub-lines are black PVC lines. Water is distributed from the mainline to the subline, followed by the sub-line to the drip line. The localized application reduces fertilizer and nutrient loss. It is independent of soil type and doesn't require basin levelling. The method is advantageous over saving the amount of water from thirty-five to sixty-five percent. It is easier to install and have a low labour cost. The crop yield is increased, and plant growth is enhanced. It holds higher initial and maintenance costs [6]. The usable lives of supply tubes are decreased by the rays of Sun.

b) Sprinkler Irrigation Method– In this system, the water is distributed over by spreading into the air, followed by allowance to fall over the field area. It is like the process of natural rain. A pressurized pipe network is used to deliver water through a pipe to nozzles of sprinklers. The 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 an Impact Mechanism. In this, higher efficiency occurs under uniform water distribution. Limitations come over higher initial costing, the continuous energy requirement for operation and holding of poor application efficiency. This method is adaptable to nearly all types of soils. Evaporation losses are higher and require clean water [7] free from debris, sand slit and clay particles.

B. WIRELESS SENSOR NETWORK

WSN stands for Wireless Sensor Network. Sometimes, it is also called a wireless sensor and actor-network (WSAN).

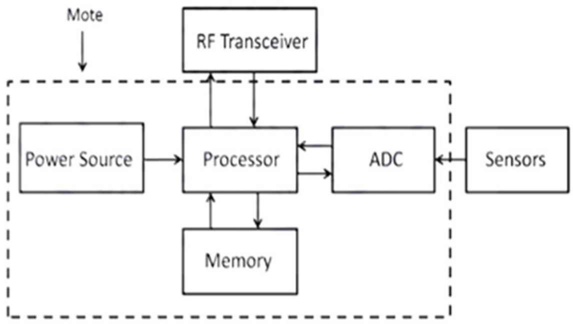

FIGURE 1. Sensor node.

In the system of Wireless Sensor Network, a gateway is incorporated, which provides unwired connectivity to the distributed form of nodes [8].

1) COMPONENT

The various components under wireless sensor networks are as follows:

1) Sensor Nodes – These are a combination of some sensors and a mote unit. A sensor is defined as a device that is capable of sensing information. The obtained information is forwarded to the mote unit. Here, sensors based upon MEMS have better usage. A mote combines memory, processor, battery, and A/D converter to connect with a radio transceiver and a sensor and form an ad-hoc network. A sensor and a mote together form a sensor node given in Figure 1. The unwired ad-hoc network of sensor nodes is a sensor network. Sensor nodes are used to forward data packets to any base station.
2) Base Station goes for the connection of the sensor network to another network. It holds an 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 with deployment. Generally, these are static.

2) CHARACTERISTICS

Mobility, heterogeneity, power consumption constraints of nodes, ease of use, resilience, and scalability to a large scale are all characteristics of wireless sensor networks. It also has a cross-layer design. To address the issues raised by the traditional layered approach, a cross-layer design was implemented. The cross-layer is used to improve transmission performance such as QoS, data rate, and so on.

Currently, traditional irrigation methods are still widely used, resulting in wastage of more than half of the total water. Several methods can be used for this. In contrast to WSN, various environmental parameters such as humidity, temperature, pressure, and so on are measured. Simultaneously, data is collected, transferred to the node, and forwarded to the management station. These are widely used for increasing crop production and crop monitoring.

Agriculture simulation models are available in a variety of formats. Here are few examples:

a) DSSAT is an abbreviation for Digital Satellite Services and Technology (Decision Support System for Agro Technology Transfer).
b) APSIM is an abbreviation for the Association for the Promotion of (Agricultural Production Systems Simulator).

These are regarded as essential tools for analyzing entire farm systems with crop sequences and rotation. WSN is one of the key enabler technologies for precision agriculture. In terms of architecture, WSN adheres to the Open System Interconnection (OSI) model. The OSI model is a reference model with seven layers, only five associated with Wireless Sensor Networking. There are five of them: the application layer, the transport layer, the network layer, the data link layer, and the physical layer

To explain the modern sensor-based irrigation systems and track environmental factors in agriculture, data must be transferred onto the WSN, including information collected via remote sensor collection, target controls, and a data management system. New scholars in this field will gain additional knowledge, stay up to date, and fill in the gaps due to this study.

C. RELATED WORK

WSN is a network of dedicated sensors that can monitor physical environmental conditions and organize the resulting data in any central location. WSN can detect various parameters such as sound, wind speed, vibration, pressure, wind direction, temperature, humidity, surface area, ground coverage, changes in a person's health parameters, and many more. Military applications were the primary driving force behind the development. These are now being used in industries as well [9]. The WSN promotes water conservation by forecasting crop water requirements and implementing various measures such as bund construction, crop rotation, stripping, etc. Many automated systems are now in use. Agriculture, for example, makes use of sensor network technology. This facilitates the collection of data such as soil type, soil moisture, climatic changes, water requirements, and so on [10].

There are two methods for deploying sensors in wireless sensor networking. In a wireless sensor network, these are random sensor deployment and deterministic sensor deployment. Implementing WSN is the best way to determine the status. Wireless sensor networking is used to monitor and control the sprinkler system and drip irrigation. WSN sensor components used for wireless communication can be mechanical, electronic, or electrical, such as ZigBee (XBee) modules, Bluetooth modules, GSM modules, and so on [11].

Temperature and humidity levels will be precisely controlled using sensors in each. These values differ from one location to the next due to differences in atmospheric conditions. It is difficult to maintain uniformity, but a phone-controlled system is proposed to control uniformity maintenance. In the irrigation system, a microcontroller and a GSM feature are used. GSM is used to send alerts to nodes about field conditions [12].

The phenomenon cools the land surface and reduces soil moisture content. ET is calculated using these parameters. A lysimeter is a device that detects changes in the moisture content of the soil. Remote sensing is used to investigate land surface temperature patterns. Evapotranspiration can be calculated using either of these methods. Evapotranspiration has an impact on a variety of other physical properties and factors. Many variables are required for accurate estimation. This is maintained for both on-the-ground and remote techniques [13].

Accurately estimating ET is critical in both agricultural and non-agricultural settings. The result is long-term irrigation management. Remote sensing techniques are thought to make significant contributions at both the pixel and global levels. Greater accessibility allows for more excellent spatial coverage, routine updates, and other benefits. In mixed vegetation conditions, automated data collection is also available [14]. The irrigation system is made more efficient by using evapotranspiration and fuzzy logic to calculate the amount of irrigation required. Irrigation is timed to meet the needs of a specific crop while avoiding overwatering and underwatering. The provided algorithm aids in the reduction of power switching, resulting in energy conservation.

Furthermore, no water stress is observed in the tool due to the prohibition on soil moisture depletion. The provided algorithm applies to both types of micro irrigation systems [15]. Because the critical component of ET is challenging to identify, the benefits of estimation have outweighed advances in remote sensing technology. It is still complicated due to the wide range of canopy covers available and the high cost of the methods. In general, time investment, a high skill level, and a more straightforward approach interface are required, particularly for mixed vegetation.

Furthermore, a VI-based approach is used in both environments. Remote sensing has aided in routine updates, measuring physical properties, and expanding spatial coverage. Budget, spatial accuracy, temporal resolution, and ground data availability must be considered [16]. Rather than using data-driven models, efforts have been made to increase the availability of spatial variables for the study of ET inversions or crop models. ET Watch is a model for calculating ET used in conjunction with an irrigation model to simulate spatial distribution. This has been proven to be an effective strategy. Water resource sustainability has become a significant concern because of groundwater table declination and agricultural activities. Water-saving technologies can be combined with geo-specific assessments to combat this threat [17]. Actual ET series obtained from the land surface and remote sensing are combined for irrigation practice monitoring. It has something to do with calculating blue water evapotranspiration. During the analysis, the observation was marked over various areas, and drought was obtained. Total blue ET, according to preliminary findings, is capable of distinguishing patterns. The application presented here can assess irrigation presence, time variability, and irrigation monitoring in drought-prone areas [18].

Six ET methods based on overestimation are available. These are compared to the weather daily. For comparison, the FAO-56 PM Penman-Monteith equation has been standardized. All of these are subject to change depending on a variety of factors. If the standard method FAO56-PM cannot be used due to complexity [19], all methods can be used while keeping input data reliability and availability in mind. Determining water requirements is critical in areas where agricultural activities consume the most water in water management. Empirical and more straightforward approaches are being considered for crop water requirements. For direct application, Penman-Monteith is used, whereas Kc-NDVI is based on a correlation between crop coefficient and Normalized Difference Vegetation Index. Crop water requirements were significantly higher based on an assessment of predefined surface water. The obtained result meets the Net irrigation water requirements [20].

The transfer control protocol (TCP) is the primary protocol used on the internet for congestion and flow control. It was created with the help of heuristic arguments. The stated goal was to prevent the network from becoming overcrowded. It is having issues because of changes in internet traffic. Several problems have been identified and resolved. It included a solution for using explicit notification and automatically improving performance using control theory. In a simulation format, feedback control with a Smith predictor was compared to TCP with implementations in State flow and Simulink. The implementation of a feedback solution improved performance. It reduces time delays and stabilizes traffic load while preventing packet loss [21].

Wireless sensor networking has been introduced to reduce the use of traditional techniques. Several sensors with varying sensitivity have been implanted. Sprinklers can manage water, and pH sensors can manage fertilizer amounts when combined with a GSM module. The pH information is given to the farmer so that the following season's production can be planned. There is also a provision for the rice crop. It leads to the management of rice crop production. It is entirely compatible with the use of WSN for agricultural purposes [22].

Modern motes with multiple sensor boards are used to integrate heterogeneous applications into WSN. Different types of generated data have different characteristics, such as transmission rate, packet loss, priority, etc. PHTCCP (Prioritized Heterogeneous Traffic Oriented Congestion Control) has been implemented to ensure efficient rate control. To ensure feasible transmission rates, inter and intra queue priorities are used. All of this is true for prioritized heterogeneous traffic [23].

In terms of congestion, avoidance mechanisms operate over an optimal region. To avoid network congestion, it maintains higher throughput and lower latency. Traditional control mechanisms diametrically oppose it. The mechanisms for avoidance and control are both expressed as system control issues. The main component of avoidance is the algorithm used to reduce or increase loads. The primary goals of metrics are fairness, convergence time, and efficiency [24].

To address the WSN (Wireless Sensor Networks) congestion problem with fairness, congestion, and power, the author proposed a Multiway Routing Protocol (MR-CACM) congestion avoidance and control method [25]. The network may avoid congestion due to the proposed work by redirecting traffic to alternate routes. It aids in the identification of congestion by allocating traffic based on transmitting capacity values and decreasing congestion when congestion is present. The results evaluate the Multiway Routing Protocol's ability to avoid and relieve congestion, as well as its tolerable dependability, low energy consumption, and overall high levels of congestion. The limitation of this work is that they transmit data in exclusive mode, which reduces the channel's transmitting capacity.

Congestion control has received increased attention in the developing field of wireless sensor networks (WSN). In this work author [26] present a new wireless sensor network concept and congestion management approach based on feedback control (FBCC). The technique was developed using linear, discrete temporal control theory—a feedback control mechanism established between the kindergarten and the parent node. The FBCC determines the start of the congestion based on the length of the wait. The new proposed active system will then select the appropriate incoming traffic to be implemented by an active flow control system. A Lyapunov-based approach demonstrates the recommended closing loop stability hop-by-hop congestion control. The system raises the theoretical level of WSN congestion management. The FBCC reduces congestion and improves congestion detection and prevention performance (CODA) based on simulation findings. The simulation results demonstrate the FBCC's ability to avoid and reduce congestion and reasonable reliability, low energy consumption, and high overall effects.

Author [27] proposed the Wireless Sensor Network (WSN) AQM algorithm to reduce congestion in wireless networks of active queue management due to high efficiencies (AQM). The simulation work is performed in NS2, and the performance of three WSN AQM algorithms: RED, REM, and PI, is compared. The simulation results show that the WSN, RED, and REM have longitudinal and performance drawbacks; the PI performance is rather good, but the wireless connection function still shakes the queue.

III. HARDWARE DESCRIPTION

In contrast to the agriculture scenario in most developing countries, very few techniques are used, or agriculture technology is out of date. There are numerous agricultural techniques available to address all issues. Many of these have been used on different scales. These are highly advantageous in terms of both annual ration production and efficiency. The methods can be applied to various agricultural practices

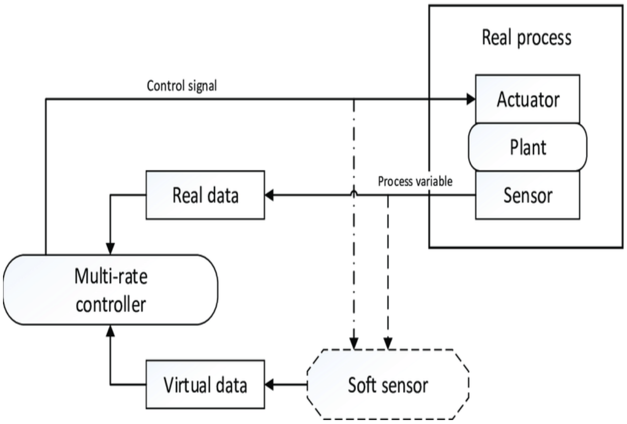

FIGURE 2. Block diagram of controller with sensors.

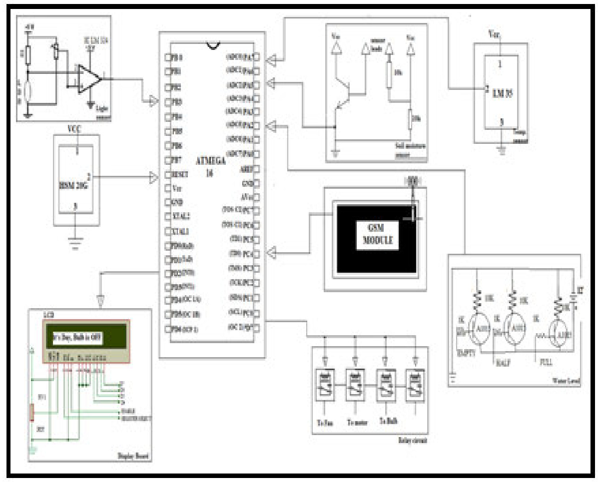

FIGURE 3. Circuit diagram for congestion control in WSN.

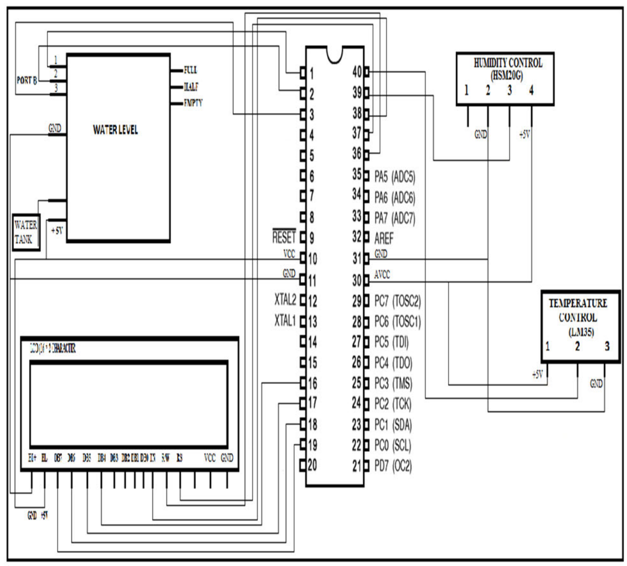

FIGURE 4. Model architecture and pin configuration details for proposed model.

and have a significant positive impact on the relationship. Now we return to the issue of our country, which we have already discussed: how much GDP and what percentage of the population is entirely dependent on agricultural activities. Traditional irrigation methods were primarily used in various parts. At the same time, technological progress has been made in some areas in accordance. Because of the abundance of available resources, agricultural practices are carried out on a large scale in some states such as Uttar Pradesh, Punjab, Bihar, West Bengal, and others. Despite being the country's largest producer, these states have made little progress in technological advancement. It leads to higher productivity, efficiency, lower labour costs, and other advantages [28]. The technology entails analyzing, calculating, and implementing various parameters that benefit agricultural activities. Soil, water, and air are among the parameters. These parameters are linked to several other parameters, all of which significantly impact agricultural activities.

A. MODEL DESCRIPTION

This section describes the overall model for overcoming agricultural challenges, which will be helpful in most developing countries' agricultural practices. In conjunction with Global System for Mobile communication modelling, it addresses various parameter control measures related to agricultural activities within the model, such as temperature control, humidity control, water level control, light control, and soil moisture control measures. This model's parameters are chosen to correspond with agricultural activities, and soil moisture is measured during crop cultivation. Other measures include greenhouse temperature control, field water level requirements based on irrigation method and crop to be cultivated, greenhouse light control, and humidity control within a specific crop's range. These parameter controls are housed in a single model that is small and easily usable with GSM connectivity to make it perform better and automatically. For your convenience, all these activities will be displayed on the microcontroller module's LCD. The addition of GSM improves the product's efficiency and dependability. This model is based on an agricultural concept and includes several control functions. It must be used in a greenhouse setting. Figures 2, 3, and 4 go into greater detail about the block diagram, circuit diagram, and architecture. The GSM concept is also used to receive data from greenhouse models and compare their readings for increased productivity. Soil moisture, temperature, light, water level, and humidity are measured and displayed on an LCD screen in sequence. If a user who lives a long distance away from the farm field wants to check the readings of various parameters, he can simply dial the SIM number installed in GSM [29]. GSM can also be used to control a water motor.

With agricultural activities in mind, this model was created. It is primarily used in greenhouses because the parameters used are following and placed under greenhouse conditions. It is used to describe a specific crop that will be planted in a greenhouse. In the greenhouse, all the crop-related data is gathered. The model contains several sections. To begin, the model's division into sections is explained as follows:

1) AGRICULTURAL PARAMETERS

This section includes some parameters related to the country's agricultural practices. These are reviewed and explained in accordance with their behalf below. The parameters considered are soil moisture, temperature, light, water level, and humidity. All these parameters must be controlled in a greenhouse. The model was developed by considering all the greenhouse's conditions. As explained further in the model, wireless sensor networking can control many parameters related to agricultural activities. The greenhouse model can control all the parameters considered in the model.

The explanation of these parameters goes as follows:

a: TEMPERATURE

It is the physical property of any system that underpins the typical whimsy of coldness and hotness. Its relationship varies depending on how the accordance is approached. A thermometer is a device that is commonly used to measure temperature. It is accomplished using particle velocity, heat radiation detection, or kinetic energy. It can be determined using a variety of scales. Celsius (denoted by 0C and unitized as centigrade), Kelvin (denoted by K), and Fahrenheit are the various scales (denoted by ^{0}F). This parameter is critical in many scientific fields and almost every aspect of life. Temperature, in contrast to agricultural activities, now plays a significant role. Using LM35 in the model is a practical approach to resolving agricultural activity issues.

b: LIGHT CONTROL

An LDR and a 555 timer were combined to create the light sensor. A light sensor detects the presence of light, which is necessary for crop growth. When light strikes the LDR (photocell) in this combined light sensor circuit, the 555 timers are activated. To turn off the 555 Timer, the voltage on Pin 4 must be held below 0.7V; voltages above 0.7V will activate the circuit. Setting the voltage level necessitates the use of adjustable sensitivity control. An LDR must detect a large amount of light. As the LDR's resistance decreases, so does the voltage across the 555, and the circuit is activated. The sensor detects the presence or absence of light in the field when the circuit is turned on. It can determine whether it is day or night. If enough light falls on the LDR, the LCD will display the day, and the bulb will remain off. However, if there is insufficient light, the LCD will display night, and the bulb will turn on. The output of the combined circuit sensor is connected to the microcontroller. The absence or presence of light will be displayed on the LCD screen.

c: HUMIDITY CONTROL

As we measure the parameters for crops, humidity is one of the main concerns for growing crops in various conditions throughout the year. It varies from day to day depending on the environmental conditions. As a result, we must proceed with caution when measuring it. For this purpose, the HSM 20G sensor is used to measure humidity. It will supply digital data. The HSM 20G's operation is entirely dependent on programming. This programming can be tailored to the crop that requires specific humidity conditions to grow. This should be a straight line.

d: pH AND AMBIENT TEMPERATURE

The hydrogen ion's pH is a negative measure that has a significant impact on the nature of the soil. Calculations for an acidity balancing test or the alkaline content of hydrogen ions in water are critical and essential in crop production. Natural water has a pH of about 7, with a pH range of 6.5 to 9.5, considered safe for consumption. The pH source for acidic solutions is low (0), while the pH source for alkaline solutions is high (14). The concentration of hydrogen ions drops tenfold with each increase in pH level, and water becomes less acidic. A pH sensor has a measurement electrode as well as a reference electrode. The hydrogen ion is electrochemically sensitive, with a potential proportional to the concentration of hydrogen ions in the solution. The temperature sensor must also rectify the voltage shift because the electrical differential tension varies with temperature. The DS18B20 temperature sensor has a temperature range of −55 to +125 °C. Because it is digital, this temperature sensor provides precise data. The pH sensor data processing algorithm is configured with the required parameters. The temperature value will be initially set to zero in the flow, and the analog values of ten samples will be examined. Later, the average of all ten samples will be computed. The pH vol and pH Value will be calculated. The identical values are then sent to the controller and displayed on the Serial monitor.

e: WATER LEVEL CONTROL

Three wires are used in this system to indicate the level of water in the soil. One wire is buried deep in the ground. Another wire is inserted in the soil's mid-level. The final wire is almost at the top of the soil. These three wires will indicate the various levels of water in the soil. As the water level drops, the water motor can be activated via the GSM module.

B. WORKING OF MODEL

Before proceeding with the procedure, the circuit is initially connected according to the circuit diagram, and all connections are checked. The GSM module is connected to the power supply with a SIM initially inserted in the module. The SIM looks for a network as soon as the power is turned on. The module's mid-LED will continue to glow indefinitely until the network is discovered. While the module is connected to the network, the LED will glow once every 3 seconds. Because the module is network-connected, it can send and receive signals.

Furthermore, the process begins when the microcontroller's Tx, Rx, and GND pins are connected. The module starts working as expected. It receives data from the microcontroller and sends it as signals to the destination via SIM.

The data procedure is repeated as the password is sent to the SIM placed in the module from the SIM saved according to the programming done with the contact number, followed by data being sent to the SIM containing the saved contact number. If another contact number sends the same password code or any other message, the LCD will display an error, and no message will be sent to that number with an error message of an attempt to the main number saved in the program. All of this is displayed as a message received, message sent, or attempted by any other contact number on the microcontroller-connected LCD. These data are transmitted to that contact number via the GSM module's transmit pin. The message is sent using the SIM card contact number installed in the GSM module.

GSM Module: SIM cards used in GSM modules should not contain any information other than the programmed phone number of the user. The SIM card must be programmed with the Indian pin code +91 followed by the ten-digit mobile number. The name saved in SIM should not be longer than 12 characters. When you insert a SIM card into a GSM phone, the LED light starts blinking. If it blinks incessantly, it means that no network was discovered. It means that the network has been discovered if it blinks once every three seconds. The module is now ready to communicate with the rest of the world. We must now call our registered phone number to report a missed call. When it receives the message, it will respond with the parameters' readings to the same number. However, if someone else makes a missed call to the SIM number inserted in the GSM module, the SIM will send a warning message to the registered number informing them that the information was attempted to be collected by someone else. GSM operates in this manner while also placing a premium on security. Individual parameter controls are discussed in more detail. Temperature control, soil control, humidity control, water level control, and light control can all be implemented in a greenhouse. The parameters and the components are listed in Table 1.

TABLE 1. Parameters & components.

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 pins)	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.	Moisture Sensor	ECH2O EC-5	5
		IC connector (14 pin)	5
		Resistors (10 k Ω)	5
		Resistor (1 k Ω)	3
		Variable resistor (1 k Ω)	3
5..	Others	Adaptor (12 V AC TO DC)	2
		ATMEGA 16 module	1
		LCD16x2 Character	1
		Connecting wires	40
		GSM Module	1

IV. EXPERIMENTAL ANALYSIS

We have discussed the hardware based on ideas formed over time concerning agricultural issues in our country. Going through all the parameters, many factors rely on them and can be analyzed or controlled to improve efficiency. Several of them are related to temperature, pressure, and other commonly considered parameters in hardware. In contrast, it has been considered and worked on further. In terms of stages, the work has progressed. In this first stage of the work, we will discuss evapotranspiration.

A. STAGE-I

Based on agricultural activity related parameters, evapotranspiration has been taken as per this work. To estimate it, there have been various estimation methods. These are analyzed over here and connected with the model to make it better. All aspects of evapotranspiration have been discussed below and analyzed in terms of estimation methods related to hardware proposed for agricultural activities.

1) INTRODUCTION

ET is the product of two atmospheric processes: evaporation and transpiration. It is a necessary part of the water cycle. A component that contributes to it, such as trees, is known as an evapotranspirator. In Hydrology, evapotranspiration refers to both evaporation and transpiration (which involves evaporation within plant stomata).

The excess of environmental demand over evapotranspiration is referred to as "Reference Evapotranspiration." Figure 5 depicts the evapotranspiration rate of grass that completely shades the ground, has uniform height and is well-watered. It is the amount of available energy for evaporation. Actual evapotranspiration equals reference evapotranspiration if there is plenty of water [30].

2) EVAPORATION

Evaporation is the movement of water from various sources to the atmosphere, such as the soil, water bodies, etc. It is

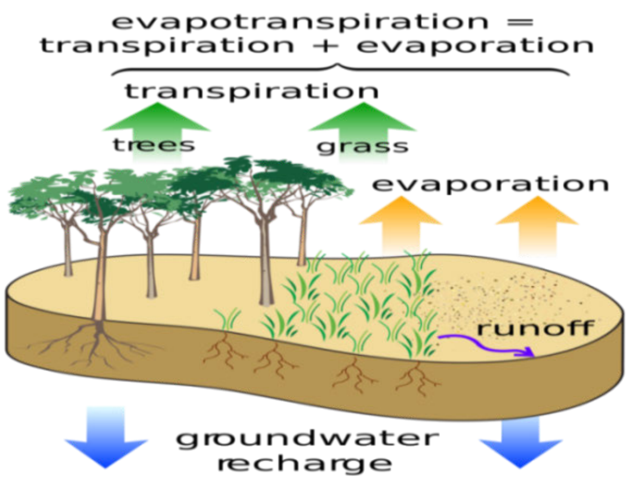

FIGURE 5. Evapotranspiration.

simply the vaporization of a liquid from its surface into a gaseous phase that is unsaturated to the substance. It occurs directly from the solid phase to the melting point, as seen with ice at or near the freezing point, and the process is known as sublimation. The process is an integral part of the water cycle. Solar energy is used to restart the process. It happens when the surface of a liquid is exposed, allowing molecules to escape and resulting in the formation of water vapours. It continues to rise, resulting in the formation of clouds.

3) REFERENCE CROP EVAPOTRANSPIRATION (ETO)

Evapotranspiration rate under a reference surface (hypothetical grass reference crop having specific characteristics). ETo expresses the evaporation power of the atmosphere at a specific location and time of year and does not take crop characteristics or soil factors into account. It depicts standardized evapotranspiration through a vegetated surface. It's also known as potential ET. Climatic factors influence it. It can be calculated using weather data because it is dependent on climatic parameters.

4) REFERENCE CONCEPT OF ENERGY BALANCE

The energy arriving must equal the energy leaving the surface for the same period with all fluxes under consideration. The equation for an evaporating surface goes as:

$$Rn - \{G + H + \lambda ET\} = 0(1) \tag{1}$$

where Rn is the net radiation, G is the soil heat flux, H is the sensible heat and λ ET (Evapotranspiration fraction) the latent heat flux, Rn& 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 air heat.

5) REFERENCE SURFACE

It resembles a large expanse of green grass actively growing, has a uniform height that completely shades the ground, and is well-watered. The assumption that all fluxes are one-dimensional upwards requires a large and uniform grass surface.

6) WIND PROFILE

Wind speed varies depending on where it is measured above the soil's surface. It accelerates with height and slows down at the surface due to friction. Wind speed is measured at the height of 2 meters above the surface concerning evapotranspiration, and the wind speed profile setup controls data obtained at other levels.

7) ESTIMATION METHODS

Various methods for estimation of evapotranspiration are as follows:

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

a: REMOTE SENSING TECHNIQUE

It reduces farm irrigation costs by up to 25%, increasing net profit. It is repeated with auxiliary ground truth data such as Leaf Area Index-LAI and crop height to achieve better results. Energy balance algorithms are combined with remote sensing data to estimate the components of the energy budget. To characterize these techniques, detailed experimental validations and approximations are required.

Compared to other methods, the technique provides a large amount of information in a shorter time. It also lowers the cost of data acquisition significantly when the scope of the study is expanded. To estimate evapotranspiration, models such as 'SEBAL' and 'Penman-Monteith' are used in conjunction with satellite data. Furthermore, these can be improved by modifying and applying semi-empirical models for accuracy. These values can be used to calculate the amount of water needed.

b: RESOURCES IN EXPERIMENTS

Various resources required in the experiment are as follows:

a) Spectroradiometer (Light-weighted, single beam and high performance) is portable and covers visible and ultraviolet wavelengths with near-infrared. It rapidly scans and acquires spectral data in the 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 to transfer over to other software.
b) Sunscan Canopy Analyzer System – Indirect method is given by Delta-T devices Ltd. UK. Leaf Area Index LAI) monitors the growth of the crop. The system measures LAI by a ratio of transmitted to incident

radiation. Another method is based on the transmittance of radiation. Crop canopy factors are LAI (Leaf Area Index) and CH (Crop Height). These factors are very much responsible for the estimation of evapotranspiration. These are statistically described through the VI (Vegetation Indices). Indices are obtained initially from a spectroradiometer and filtered by RSR (Relative Spectral Response) filters.

The steps for experimenting are given as measurements done using spectroradiometer, then LAI and CH have been taken, Modelling of VI is performed to LAI and CH. The pre-processing of satellite images is done for the mapping of indices. Last, the model is verified, and the algorithm is tested.

8) EVAPOTRANSPIRATION MODEL

There is currently no validated evapotranspiration product in the market. Byproducts of other components can be found. It is necessary to acquire specific skills to perform remote estimation. The main disadvantage is that it cannot be directly measured. It is observed about evapotranspiration because it affects energy and water balances. The requirement for the quantification of evapotranspiration is both intriguing and concerning. Evaporation is primarily caused by three sources: the atmosphere, the soil, and the vegetation surface. ET is the primary consumer of rainfall and irrigation. It's also found in plants' flowers, stems, and roots. It is also considered to be an essential component of the hydrological cycle. Soil water chemistry, aesthetics, vegetation healthiness, and other factors are all influenced as a result. It is responsible for more than 90% of the annual rainfall.

As a result, determining the significance of ET is unavoidable. Various numerical models for calculating the ET have yet to be developed. Based on data requirements, limitations occur in specific areas. The estimation has been improved by utilizing highly developed instruments and infrastructures outfitted with cutting-edge technologies. Satellite imagery is the most cost-effective technology with a wide range of applications [31]. To make coupling easier, empirical methods were used. Later, microwave imagery was introduced to reduce the effects of the atmosphere on optical data. It all starts with surface temperature and moisture readings. Despite this, ET estimation is still poorly described. The variety of water requirements adds to the complexity. Point measurement holds estimation in hydrological or direct methods.

Furthermore, extrapolation from a point over a large area reduces accuracy. The practical method combines airborne images with remote sensing techniques. It is an ideal technique for mixed landscape vegetation because of its highly distributive nature. At various scales, various algorithms and R-S-based models are evaluated for various types of vegetation. Typically, these are compared pixel by pixel. In urban areas, biophysical components are considered. In 1995, the VIS (Vegetation-Impervious-Soil Surfaces) model was introduced to account for major urban features. It was then combined with image processing techniques. Furthermore, a combination of satellite and field measurements was recommended to estimate ET rates daily, monthly, and annually.

TABLE 2. Remote sensing approaches.

S. No.	Model	Advantages	Disadvantages
1.	Interference Model (IM)	Operational if combined with ground measurements methods	It requires calibration for each crop type, and K_c varies according to water stress
2.	Empirical Direct (ED)	Operation from local to regional scales	Spatial variation of coefficients
3.	Deterministic	It Permits estimation of intermediate variables such as LAI and has possible links with climate and hydrological models	It requires more parameters and accurate remote sensing data
4.	Residual (SEBAL, S-SEBI)	It is Low cost and needs no additional climatic data	It requires detection of wet and dry pixels

9) REMOTE SENSING METHODS

The different remote sensing methods are taken, and their comparison is shown in Table 2.

10) REFERENCE EVAPOTRANSPIRATION METHODS

Centibars (cb) or kilopascals (kPa) of soil water concentration is used to measure the state of soil water. The amount of energy that a plant's root system expends to take water from its surroundings. With each reading from your sensor that you examine and interpret, you will obtain a clearer picture of what is going on with the soil moisture in the roots of your crop.

- 0-10 cb (kPa) = Saturated soil
- 10-30 cb (kPa) = The soil is sufficiently moist (except coarse sands, which are beginning to lose water)
- 30-60 cb (kPa) = Usual range for irrigation (most soils)
- 60-100 cb (kPa) = Typical irrigation range in heavy clay
- 100-200 cb (kPa)* = Caution: the soil becomes dangerously dry for maximum production. Proceed with caution.

The difference between current soil moisture levels and soil moisture levels three to five days earlier is one of the most important variations in current soil moisture levels. The earth looks to be drying out slowly but steadily. One the less, a significant rise indicates that the soil is rapidly losing water. This indicates that the crop is working harder to extract water from the soil and is becoming stressed. You can use the readings to predict when the field needs to be irrigated if they are trends.

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

$$ETo = [0.408\Delta(Rn - G) + \gamma\{900/(T + 273)\} \times u2(es{-}ea)]/\Delta + \gamma(1 + 0.3u2) \quad (2)$$

were,

ETo – Reference evapotranspiration,
Rn – Net Radiation
G – Soil heat flux density
T – Mean daily air temperature @ 2m
$\mu 2$ – Wind speed @ 2m
es – Saturation vapour pressure
ea – Actual vapour pressure
(es-ea) – Saturation vapour pressure deficit
Δ – Slope vapour pressure curve
γ – Psychrometric constant
It is calculated over 24-h time steps

$$G = 0$$
$$es = [e0\,(Tmax) + e0\,(Tmin)]/2 \quad (3)$$

It is Standardized by FAO and a Standard method for estimation of evapotranspiration. It is used as an index for Rs and Rn based equations.

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,

$$EET0 = 16 \times (10Ti/I)a(N/12)(1/30) \quad (4)$$

were,

I = $\sum$ (Ti/5)1.51
a = (492390 + 17920 I – 771 I2 + 0.675 I3) × 10-6
Ti – Mean monthly temperature
N – Mean monthly sunshine hour

It uses temperature as an input variable and is highly correlated with the FAO56-PM method. It provides inconsistent values in the winter season and requires monthly average temperature only. It is developed for temperature under potential conditions. It represents potential evaporation if no stress in soil moisture. By applying air surface temperature, tends to overestimate potential evaporation in arid areas.

a: HARGREAVES METHOD

In this method, only air temperature is measured as Ra is obtained by information on on-site location and mean air temp by an average of Tmax and Tmin. The reference evapotranspiration is given by,

$$ETo = 0.0023(Tm + 17.8)(Tmax - Tmin)1/2Ra \quad (5)$$

were,

Tm – Daily Mean air temperature,
Tmax – Daily Max air temp
Tmin – Daily Min air temp,
Ra – Extraterrestrial Radiation

It uses solar radiation as an input variable, and Proximity shows that solar radiation is important as an input Variable. It requires two climate parameters: temperature and incident radiation. It is tested using some lysimeter data and a broad range in climatic conditions. The results obtained are nearly accurate to the PM method and is recommended where reliable data are lacking.

b: HAMON METHOD

It is the simplest method to estimate evapotranspiration. Monthly and annual values estimated. It is easily applicable and requires saturated vapour pressure and an average no. of daylight hours a day.

$$ET0 = 2.1 \times Ht\,2\,es\,(Tmean + 273.2) \quad (6)$$

were,

Ht - avg daylight hours per day

FAO56-PM method was simplified by using multi-linear regression function having use of fewer parameters and computations. It uses Rs (Solar Radiation, Rn (Net Radiation) and Tm (Mean Daily Temperature) as input for estimation of ETo.

Rs-based – Solar Radiation Method

The reference evapotranspiration is given as:

$$ET0 = -0.611 + 0.149\,Rs + 0.079\,Tmean \quad (7)$$

were,

Rs – Solar Shortwave Radiation

Rn-based Radiation Methods – Net Radiation Method

The reference evapotranspiration is given as:

$$ET0 = 0.489 + 0.289\,Rn + 0.023\,Tmean \quad (8)$$

were,

Rn – Net Radiation

It is a simplified version of FAO56-PM and uses net radiation as an input parameter.

The Comparison of ET Estimation Methods is given in Table 3.

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

B. STAGE-2 ANALYSIS

Moving on from evapotranspiration and mulching, the work progresses to the second stage. At this point, the most

TABLE 3. Method comparison relative to parameters required.

Method	FAO56-PM	Thornthwaite	Hargreaves	Hamon	Rs-based radiation	Rn-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

common WSN issue, congestion control, has been addressed in accordance. Various issues related to congestion and its problems are discussed here and various protocols related to them. The issue arises during the data transfer from the transmission point to the reception point. When there are many users, the problem becomes widespread. As a result, issues concerning data transfer in agricultural activities to the control room must be addressed.

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

V. SIMULATION AND RESULT

There are classified many types of algorithms to be applied over. These are classified by the fairness criterion, amount & type of feedback received and incremental deployability. Some mechanisms are to prevent network congestion, such as Congestion notification, Network scheduler, and Congestion avoidance algorithm

Congestion, a complex problem in networking raised due to access to the same resource, must be appropriately handled. In this experimental setup, we have used 7 nodes to perform the simulations. This problem leads to the degradation of the performance of the network. Congestion control means the controlling of the phenomenon of 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 [32].

The process of congestion goes with categorization as:

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

The congestion control functionality goes with three steps as follows:

Congestion Detection Strategies: Many congestion detection mechanisms are used over and tested. The most used ones are as follows:

a) Packet loss is measured at the sender where ACKs are used up and the receiver using the 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 a proper indication of congestion. It is based on a threshold level. A fixed threshold level is set, and as the buffer exceeds this level, congestion is signalled. The difference of traffic rate and the 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: Packets are removed when packet collision increases and have unsuccessful MAC retransmissions. Under such conditions for accuracy, there must be a hybrid approach with a combination of queue length and channel load for congestion indication. Node delay and buffer length are used to indicate congestion depending upon the used rate and channel load. Throughput is used with channel load for problems with the effect of nodes in a multi-hop environment. Throughput is used for quantifying the number of successful transmissions.
d) Delay: The use may be misleading in terms of usage for congestion. Sleep latency by use of duty-cycling leads to heavier delay at the MAC layer [33].

Congestion notification: On detecting 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 an explicit notification.

Congestion control: Some applications cannot benefit from increased throughput by implementing similar congestion control at all nodes. After a bottleneck occurs, the rate at which intermediate nodes forward event packets to the sink must be regulated. The rate will be further controlled at intermediate nodes. Phase shifting is proper when an event is reported, and congestion control extends to rate control. The MAC protocol's congestion control cannot be separated.

WSN monitoring and control events have varying priorities and are reported at varying rates. It is utterly vulnerable to weighted fairness. There are several approaches to this. Each node transmits only if it has a token in the token bucket scheme, whereas exact rate partitioning is used for equal and weighted division. In this scenario, scheduling is used in conjunction with rate partitioning.

Furthermore, a variety of indicators are used to prioritize tasks based on application requirements. In an end-to-end congestion control protocol, end sink responsibility is linked to congestion detection. To apply the control to each source individually, an accurate rate adjustment is used. It is capable of both controlling and detecting congestion. Due to the long latency of end-to-end control, congestion detection necessitates at least one RTT (Round Trip Time). Some congestion-control algorithms are designed to work across MAC and transport levels for maximum efficiency. The cross-layer design helps to reduce end-to-end latency.

On dependency over control policy, transport protocols are divided into:

Resource control: When rate control approaches cannot meet the application's needs, these strategies are utilized, as they may be broken by reducing source traffic during a crucial moment. The increased traffic can be handled by expanding capacity and activating additional resources. During congestion, data from the congested area is routed using various routing mechanisms. Preventive load balancing with an interference avoiding based scheduling is employed between crowded and uncongested routes for traffic load balancing in reaction to congestion. Multiple radios and the clustering idea can be employed to ensure resource control. This vehicle is equipped with two radios. The first exchanges packets with nearby nodes, while the second communicates with cluster heads and the sink across a great distance. At the same time, transmission power is adjusted in various protocols to ensure long-distance transmission. Some protocols also assure resource control by modifying duty cycling settings to balance traffic fidelity and energy efficiency. Some protocols function contrary to both. These techniques work in tandem with aggregation strategies. Allowing permission to drain the buffer utilizing prioritized MAC techniques allows congested nodes to access the priority channel. Parameters such as network longevity, source data rate, average node-energy consumption, and the number of packet drops can be used to compare both control strategies. The alternate path construction algorithms assure a long network lifetime by keeping the data rate steady. Data rate reduction algorithms employ little power and result in few packet losses. Because numerous routes to the same sink cross, the contention increases in dispersing the flow through diverse paths while lowering congestion.

Traffic control: It is used repeatedly by throttling the node rates. A change in packet rate can be assured in various ways that are sent following the congestion notification (CN). The AIMD (Additive Increase Multiplicative Decrease) scheme is typically used when a single CN bit is used. Because detailed congestion data is available, precise and accurate rate adjustments can be implemented. To adjust reporting rates, in-network or sink-based solutions are used.

Additionally, packets are dropped because of congestion propagation. If no CN is used, the sources fail to reach their destination and waste resources by submitting traffic indefinitely. There are two ways to control traffic. The first is the avoidance mode, and the second is the reaction mode. Buffer overflow and interference control can both have an impact on both. Interference is avoided by using rate partitioning to keep the capacity of interfering nodes from being exceeded and scheduling to avoid collisions. There are schemes based on limiting the amount of butter sent to prevent it from overflowing. Reactive traffic control reduces buffer overflow as well as interference. Individual control or organized hierarchic rate control are used for mitigation, with only the rate of the affected node adjusted. Instead of weighted or equal rate partitioning with no schedule or rate-based scheduling, hierarchic-based organized rate control is used. When using individual traffic control, coarse-grained or exact rate control provides assurance.

A. EVALUATION

Congestion management definition must provide structure for measuring it. It must be done to demonstrate efficiency with overload traffic in the intent. It goes hand in hand with metrics used in some protocols to achieve assessment.

The most common among them are as follows:

a) Network fairness: The desired condition goes with allocating bandwidth fairly from each node to the 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 the whole network. The measurement unit is Joule (J) and is also calculated as per unit of successfully received packets.
c) Sink received throughput: this is the total no. of received packets successfully during the time unit. Also, it is a weighted relative of data priorities.
d) Network Efficiency: Undelivered packets transmission wasted energy is calculated. Variation in dropping cost of packets depends on the distance from the sink.

TABLE 4. Sources and their 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)PCCPpriority-based congestion control protocol

e) Packet latency: It is also termed an end-to-end delay. Packet latency is the time taken to reach the base station by a packet from its generation time. Also, per-hop and weighted delays are used somewhere. Table 4 presents the sources and their solutions.

1) CONGESTION CONTROL ALGORITHM

We have seen all the perspectives of congestion over wireless sensor networking in introducing the 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 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 [34].

a: ASSUMPTIONS

Let us presume that two references on a single relation are conditional. It is C (packets/sec) with power. Assume that Ai is the propagation rate of the packet through the network for i = 1, 2. Sources generate feedback to determine whether the overall excess amount (A1 + A2) approaches or does not exceed the capability of Source C. The condition happens where the connection speed exceeds the connection potential. Congestion occurs. Feedback signal (A1 + A2 > C), where the feature of an event predictor is (A1 + A2 > C). If the case is true 0, if it is false, the value is 1. The goal must be to create a link between the sources. It is fully capable of integrating source transmission speeds at a stable operating stage. This is done to keep a specific network harmony. In relation, the complete reception rate is less than capability C. A specific differential equation of definition changes the transmission rate, and then the transmission rate is increased by source, and if it is greater than capability C, this rate is multiplied. The phrase "additive increases and multiplicative decreases" is frequently used. Both incidents are considered gratuitous because only one occurs at a time. In this section, we assign complex resources required to derive benefits from packet switching. An algorithm should encourage equity in assigning rates to different consumers, offering the widest rate zone possible.

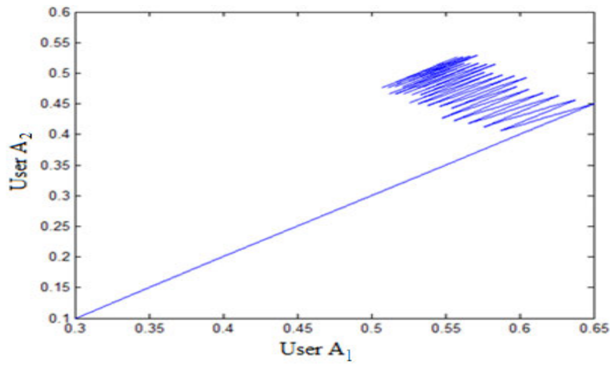

FIGURE 6. Rate evolution of two sources.

b: ANALYSIS

For the experiment, it is essential to have a controlled convergence action. The procedure is implemented with MATLAB. At first, the differential equation was discretized to obtain the differential equation and is later applied as a computer application.

The basic differential equation:

$$Ai = \alpha I(A1 + A2 \leq C) - \beta\, Ai\, I(A1 + A2 > C) \quad for\ i \in \{1, 2\} \qquad (9)$$

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:

$$A(k+1) = A(k) + \alpha\delta\, I\, (A1 + A2 \leq C) - \beta\, \delta\, Ai\, I\, (A1 + A2 > C) \qquad (10)$$

The equation obtained is plot applied by MATLAB and balance integration behaviour. The maximum use of ties in harmony and fair distribution is thoroughly verified [34].

2) MATLAB SIMULATION

a: RATE EVOLUTION

Rate Evolution for two sources A1 and A2, with C = 1, is shown in Figure 6, and the values are displayed in Table 5.

TABLE 5. Min and Max values of both 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

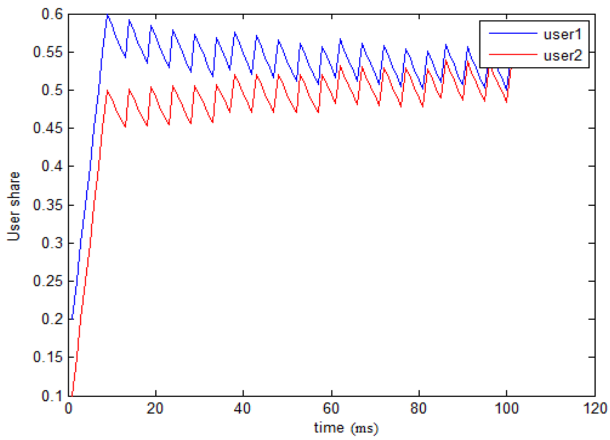

FIGURE 7. Additive increase plot for 0.2 & 0.1.

b: TIME V/S NODES SHARE (A1 AND A2)

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

c: ADDITIVE INCREASE CONDITION

Now, let A1 = 0.2 and A2 = 0.1.

Then, $A1 + A2 = 0.2 + 0.1 = 0.3 < C$.

So, A1 + A2 $\leq$ C and the condition is followed up, and the equilibrium point is obtained at A1 = 0.5 and A2 = 0.5, as shown in the graph plot. So, (0.5, 0.5) may be considered the equilibrium for the condition where both sources share the link equally, with a capacity of C = 1. This is both fair and efficient for congestion control issues. This is the condition where A1 + A2 $\leq$ C, so as per AIMD law, an additive increase must occur, as shown in the plot obtained in Figure 7, and the variables' values are demonstrated in Table 6.

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

So, let A1 = 0.4 and A2 = 0.3.

Then, A1 + A2 = 0.4 + 0.3 = 0.7 < C.

This is the condition where A1 + A2 $\leq$ C. Again, as per AIMD law, an additive increase must occur, as seen in the plot obtained in Figure 8 and the values listed in Table 7.

d: MULTIPLICATIVE DECREASE CONDITION

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

TABLE 6. Min and Max values of variables in the plot.

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

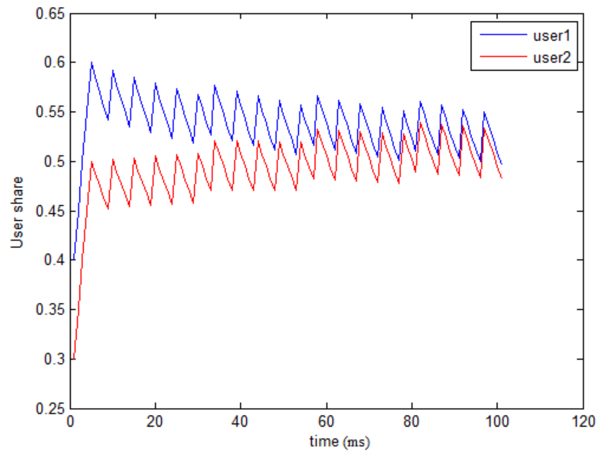

FIGURE 8. Additive increase plot for 0.4 & 0.3.

TABLE 7. Min and Max values of variables in the plot.

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

Let, A1 = 0.7 and A2 = 0.5.

Then, $1 + A2 = 0.7 + 0.5 = 1.2 > C$.

The condition is fulfilled as a sum of all the sources exceed the link capacity, C. This leads to a multiplicative decrease in the plot to obtain equilibrium which is a requirement for the algorithm. Further, in Figure 9 and Table 8, the plot can be checked out for the conditions and the equilibrium point at which all sources share the link equally. This is the condition for the congestion avoidance mechanism.

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

So, let A1 = 0.6 and A2 = 0.9.

Then, A1 + A2 = 0.6 + 0.9 = 1.5 > C.

Again, the condition of A1 + A2 > C is followed up, and there must be a multiplicative decrease in the plot of time v/s nodes share. It can be seen in the plot shown below in Figure 10 and Table 9, the change in the values is shown.

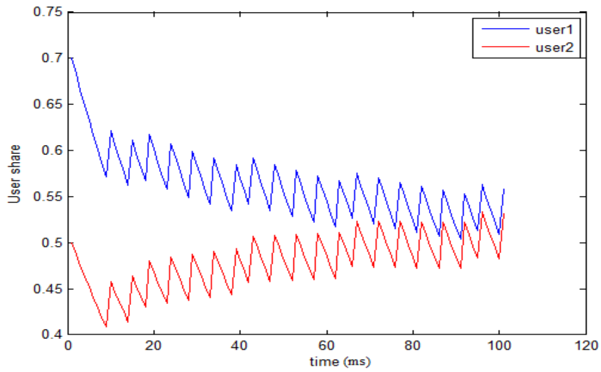

FIGURE 9. Multiplicative decrease plot for 0.7 & 0.5.

TABLE 8. Min and Max values of variables in the plot.

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

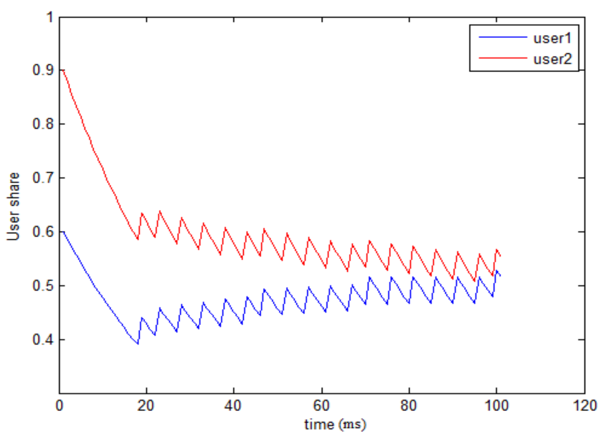

FIGURE 10. Multiplicative decrease plot for user (node) share 0.6 & 0.9 of network utilization.

e: TIME V/S NODE SHARE (7 NODES)

We have seen the cases for different values over additive increase and multiplicative decrease for two sources. In this, conditions have been checked out for either additive increase or multiplicative decrease as per the AIMD law under consideration. This can be seen in the plot, which is obtained by changing the values of both sources A1 and A2. 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.

f: ADDITIVE INCREASE CONDITION

This is the case for seven sources to be taken according to the same link, which has a capacity one. Here, the sources taken

TABLE 9. Min and Max values of variables in the plot.

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

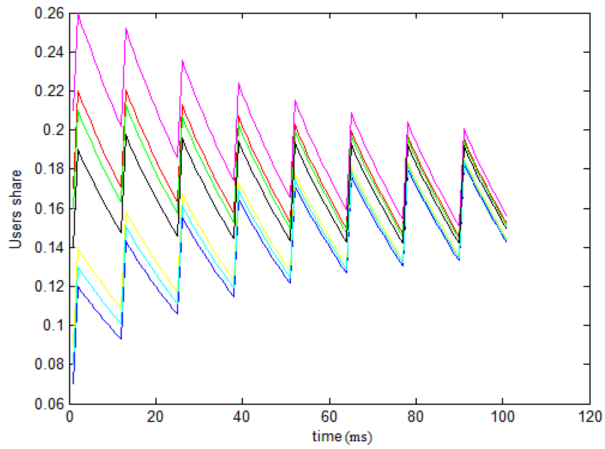

FIGURE 11. Additive increase plot for 7 nodes.

are A1, A2, A3, A4, A5, A6 and A7. Their values are put over, and the conditions are checked over as in the obtained plot. Initial values will be the same as in the previous cases.

Let, A1 = 0.07, A2 = 0.17, A3 = 0.16, A4 = 0.09, A5 = 0.08, A6 = 0.21 and A7 = 0.14.

Then, $A1 + A2 + A3 + A4 + A5 + A6 + A7 = 0.07 + 0.17 + 0.16 + 0.09 + 0.08 + 0.21 + 0.14 = 0.92 < C$.

When the sum of the sources value is less than or equal to the Capacity of the link, then Additive Increase Condition is followed. Plot is obtained by entering values into the MATLAB code [35] and obtaining a plot in which the condition is checked out. As shown in the plot below, the additive increase condition is followed, and the equilibrium point is obtained by dividing the capacity in seven numbers that are equally distributed due to seven sources. At the equilibrium point, which can be seen in the plot in Figure 11, all the sources are allotted the link equally, and Table 10 shows the variations obtained.

g: MULTIPLICATIVE DECREASE CONDITION

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

Let, A1 = 0.27, A2 = 0.15, A3 = 0.12, A4 = 0.24, A5 = 0.04, A6 = 0.13 and A7 = 0.29.

Then, $A1 + A2 + A3 + A4 + A5 + A6 + A7 = 0.27 + 0.15 + 0.12 + 0.24 + 0.04 + 0.13 + 0.29 = 1.24 > C$.

TABLE 10. Min and Max values of variables in the plot.

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

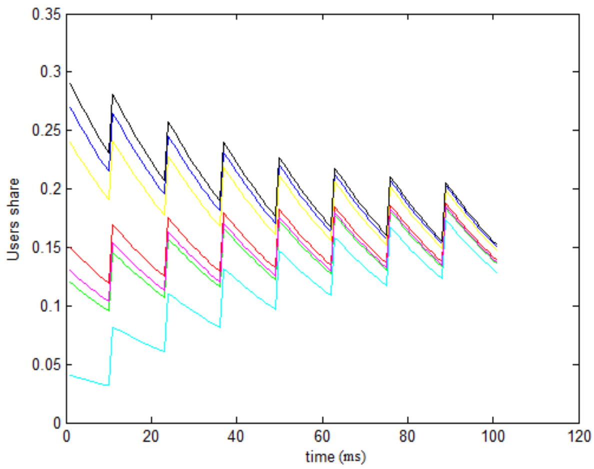

FIGURE 12. Multiplicative decrease plot for 7 nodes.

The condition is fulfilled as a sum of all the sources exceed the link capacity, C. This leads to a multiplicative decrease in the plot to obtain equilibrium which is a requirement for the algorithm. Further, the plot in Figure 12 and the variations in values, as shown in Table 11, can be checked out for the conditions and the equilibrium point at which all sources share the link equally. This is the condition for the congestion avoidance mechanism.

Furthermore, these conditions can be double-checked by changing the values of the sources as needed to follow either of the conditions. All of these have demonstrated that the algorithm can be used for efficiency and fairness. These schemes enable operation in an optimal region with higher throughput and lower latency. The achievement is accomplished by monitoring the load level and increasing or decreasing it as needed. Because feedback is limited to one bit, it informs about the current load, which is either lower or higher than the goal.

TABLE 11. Min and Max values of variables in the plot.

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

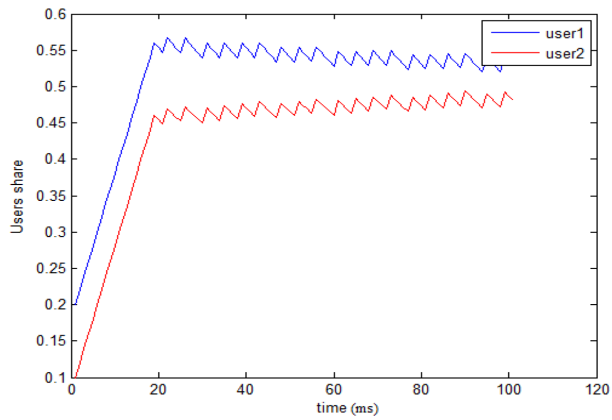

FIGURE 13. Additive increase plot for different values of β & δ.

h: TIME V/S NODES SHARE

Until now, the plot has been produced using fixed values of C and, followed by changing the initial values of the rates. This was done for two sources under both conditions at different values, and the plot was observed after it was obtained. Furthermore, the same procedure was followed for seven different sources with the same values for both conditions, and the plot was observed under the conditions. The plot will now be observed by changing the values of and, because the values of Capacity C and cannot be changed in the difference equation. This section will change the MATLAB program's values without affecting the remaining values [36], [37]. As in previous cases, the plot would show the initial values of the sources.

i: ADDITIVE INCREASE CONDITION

In this condition, the values will be as $C = 1$, $\alpha = 1$, $A1 = 0.2$ and $A2 = 0.1$. Here, the values of β and δ will be changed.

Let, $\beta = 0.6$ and $\delta = 0.02$.

TABLE 12. Min and Max values of variables in the plot.

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

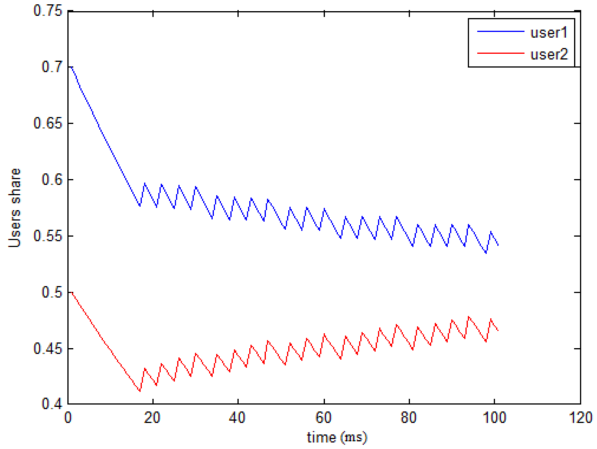

FIGURE 14. Multiplicative decrease plot for different values of β and δ.

TABLE 13. Min and Max values of variables in the plot.

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

Then, $A1 + A2 = 0.2 + 0.1 = 0.3 < C$.

The condition A1 + A2 $\leq$ C for an 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. The change in the plot in Figure 13 and variations as min and max values in Table 12 from the previous case can be easily identified.

j: MULTIPLICATIVE DECREASE CONDITION

In this condition, the values will be as C = 1, α = 1, A1 = 0.7 and A2 = 0.5. Here, change the values of β and δ. Let, $\beta = 0.6$ and $\delta = 0.02$.

Then, $A1 + A2 = 0.7 + 0.5 = 1.2 > C$.

The condition A1 + A2 > 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 in Figure 14 and Table 13 from the previous case can be easily identified.

VI. CONCLUSION

WSNs are subjected to adverse conditions such as confinement and fragmentation, which affects the device's overall efficiency. After investigating congestion management protocols, it was discovered that traffic regulation and the control of traffic rules, devices, and flow forms – which are defined by their many-to-one nature coordination – are distinct from one another. Since energy is saved across sensor network systems, the transmission speeds of sources are at their maximum, increasing network life. Using a cross-checking algorithm with different values in the code, this model can control congestion in various situations. It improves accuracy in agricultural data transferred from farmers to the control room, which is a positive development.

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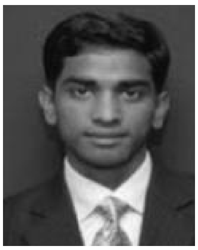

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