Intelligent Traffic Routing Algorithm for Wireless Sensor Networks in Agricultural Environment

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***Abstract*—Wireless Sensor Networks (WSNs) is an area that has attracted a lot of attention currently worldwide. WSNs are implemented to monitor temperature, humidity, and pressure, among others within the agricultural environment. This paper addresses the traffic congestion that occurs within WSNs in the agricultural environment during packet transmission that is normally caused by head-of-line blocking. As a result, packet loss, packet delay, and network performance impairment occurred during packet distribution in the network. This paper proposed an Intelligence Traffic Routing (ITR) algorithm to manage packet flow to avoid traffic congestion in WSNs within the agricultural environment while improving Quality of Service (QoS). The LBRM (Load Balancing Routing Management) and MLCC (Machine Learning Congestion Control) algorithms were integrated to develop the proposed ITR algorithm. Network Simulator 2 (NS-2) was used to test the effectiveness of the proposed ITR algorithm. The simulation results showed that the proposed ITR algorithm reduced packet loss by 27.3%, packet delay by 43.4%, and improved network throughput by 98.4% when compared with LBRM and MLCC algorithms.**

***Keywords*—Quality of Service (QoS), traffic congestion, network simulator 2, ITR algorithm, packet delay, packet loss, and network throughput**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are self-configured wireless networks that use dedicated Sensor Nodes (SNs) to monitor and record the conditions of the environments [1, 2]. The SNs are mostly battery-operated and highly constrained regarding energy resources, which are difficult to be recharged once depleted [3]. Furthermore, SNs have the capabilities of sensing, processing, and communicating over the wireless channel in a harsh environment. SNs transmit data packets through wireless channels from a source to the destination node [4, 5]. These nodes are inexpensive compared to traditional wired sensors predominantly used for structural health monitoring. Moreover, the data is sensed, measured, and gathered by these SNs to significantly improve the consistency and efficiency of the system infrastructure.

WSNs may be randomly deployed in any place such as healthcare, military, home, and irrigation environment [6]. The SNs have the potential to move around within the network environment to allow sensing and monitoring processes in WSNs. Furthermore, network users in these networks can access information stored in a network as long as there is network coverage [7]. WSNs are observed as a revolutionary data gathering method, used in the system infrastructure to improve consistency and efficiency [8]. Moreover, the data is sensed, measured, and gathered by these SNs.

This paper implemented WSNs in the agricultural environment to monitor environmental conditions such as soil moisture, humidity, and soil temperature. Therefore, if the temperature is high or low the appropriate environmental parameters required for high yield of crop production will be implemented. Hence, the remote user and mobile devices will be used for communication, to notify the agriculturalists about the temperature conditions, as they will be accessing information through the internet. This paper will help the agriculturalists to manage the temperature condition in agriculture using different technologies such as SNs and drones, which will manage and provide signals, based on the crops' needs, such as soil temperature, sufficient light, warmth, and moisture. Furthermore, several input parameters are used in WSNs within the agricultural environment for packet routing such as network load, throughput, bandwidth, humidity, radiation, and latency during packet transmission [9].

Therefore, this paper delineated the traffic congestion that occurs in an agricultural environment which is caused by head-of-line blocking, and as a result, this led to packet delay, throughput impairment, and packet loss. Then, this paper will develop a routing algorithm that will manage traffic packets and avoid congestion to give a proper decision-marking within the agricultural environment.

Therefore, to archive, this method, an Intelligence Traffic Routing (ITR) algorithm is proposed to manage the packet flow to avoid congestion while improving the Quality of Service (QoS) in WSNs within the agricultural environment. The proposed ITR algorithm is designed by

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integrating two algorithms, namely: Machine Learning Congestion Control (MLCC) algorithm, and the Load Balancing Routing Management (LBRM) algorithm to manage packet flow and avoid congestion in WSNs, which will lessen the packet delay, packet loss during packet transmission and improve network throughput. The routing traffic path is one of the techniques used in the proposed ITR algorithm. The following multiple input parameters: network load, throughput, bandwidth, latency, radiation, humidity, intermediate hops, delays, and packet loss was used when designing the proposed ITR algorithm.

The remainder of the paper is organized as follows: this paper in Section II presented a Related Work. Section III presented WSNs overview. Congestion in WSNs is presented in Section IV. Section V presented the proposed system architecture. In Section VI, the design of ITR is presented. Section VII presented the proposed ITR algorithm. Section VIII presented the implementation of the proposed ITR algorithm. Section IX discussed the Simulation results, and lastly, Section X is the conclusion.

II. Related Work

Over the past decades, a lot of research work has been conducted on traffic routing within WSNs. A lot of researchers have contributed to the field and provided solutions as discussed below:

An artificial intelligence-based semantic Internet of Things (AI-SIoT) algorithm was proposed by [16] to integrate heterogeneous IoT devices to support and manage intelligent services within the agricultural fields. This algorithm provides the flow function of each packet with the high-priority traffic which is based on the moves through the network environment in a series of hops with various parameters within the agricultural environment. According to the authors, their proposed algorithm is aided by semantic and AI technologies, which allow for flexible connections among diverse devices in agricultural fields for high-priority traffic packets. The algorithm proposed by the authors used the following input parameters namely: bandwidth, latency, mobile speed, and throughput to lessen packet delay in a network. They implemented their AI-SIoT algorithm in MATLAB, and simulation findings confirmed that their algorithm reduces packet delay caused by high-priority packets in a network. The high-priority packets are regarded as unusual packets which are gathered by the SNs, and those packets are higher than a given traffic threshold within the agricultural environment. However, the algorithm proposed by [16] does not consider the packet delay with low priority in a network which remains a problem for network performance. This is because their algorithm focuses more on packets with high priority. This research study proposed the use of the AI-SIoT algorithm to prioritize the packets with high-priority and low priority in the agricultural environment during packet transmission. In this research study, the packets with high priority are regarded as a packet that is gathered by sensor nodes within the agricultural environment carrying critical information that needs to be transmitted immediately, and packets with low priority are regarded as packets that do not have any critical information which needs to be transmitted immediately. Moreover, this research study regarded low priority packets, as a packet that are marked according to the threshold and can cope with the utilization of channels in the agricultural environment.

Congestion-aware Clustering and Routing (CCR) algorithm was proposed by [17] to lessen packet congestion issues in agricultural yields as it affects the bandwidth usage and QoS downgrade in farming. The authors indicated that the proposed algorithm achieved this issue by decreasing the end-to-end delay, by choosing the appropriate Primary Cluster Head (PCH) and the Secondary Cluster Head (SCH) within the environment. Furthermore, the authors illustrated that when sensor nodes want to send the packet to the destination node within the agricultural environment, it first checks the availability of PCH before SCH, then if PCH is available to receive packets, the sensor node will forward the packets and if not available, sensor node will forward a packet to SCH. To demonstrate the efficiency of the proposed CCR algorithm, the authors used NS-2.35 as their experimental method. When compared to state-of-the-art farming methods, their experimental findings showed that the proposed CCR algorithm reduced packet overflow and bandwidth utilization.

The new Neuro-Fuzzy Rule Based Cluster Formation and Routing Protocol method was proposed by [18] to minimize delay, in an attempt to further enhance the QoS in the network. The authors explained that the minimization of packet delay is a primary factor for communication in WSNs because it prevents a considerable high level of packet drops and unreasonable reduction in packet transmission. In addition, the proposed method improves overall network performance by using intelligent machine learning algorithms to make appropriate routing decisions. To evaluate the efficiency of the proposed method, they utilized the GloMoSim as their simulation tool. In terms of the metrics used, such as energy usage, packet delivery ratio, network lifespan, and latency, their simulation findings demonstrated that their proposed method delivers improved network performance. However, the proposed method does not consider the amount of available bandwidth which is located in the network when distributing the packets across the nodes.

The ambient crop field routing (ACFR) algorithm was proposed and implemented by [19], to decrease the number of packet drops and manage the hop count based on every packet forwarded from the sensor node to the destination node in agricultural fields. The authors indicated that the proposed algorithm achieved its goal by integrating two operations namely: Multiple Path Identification and Congestion Mitigated routing. The Multiple Path Identification was used for unknown coordinates of sensors within the agricultural fields, this assisted in forming more packet transmission paths within the existing paths. While the Congestion Mitigated routing is used for routing packets from the source to the destination node by considering the forwarded packets per second and bandwidth size. The authors used MATLAB to evaluate their proposed algorithm. Their simulation results showed that the proposed ACFR algorithm decreases the packet drops by 4.7% and hop count-based also improved by 2.1% when compared with the congestion-aware routing (CAR) mechanism and Agri-based routing algorithm (ARA). However, the algorithms presented [19] did not consider the buffer overflow, this happens when the amount of packet generated by a node exceeds its transmission throughput. This is because their algorithm failed to minimize packet delay when more packets are transmitted at the same time. As a result, their algorithm experienced poor network throughput within the agricultural fields. This paper implemented the proposed ITR algorithm alongside AI-SIoT in order to lessen the packet delay and improve network throughput process by establishing the traffic source which will identify traffic routes within the agricultural environment.

A Congestion Control Predictor (CCP) algorithm was proposed by [20] based on the agricultural environment which managed the packet flows during the packet transportation within a network. During the development of CCP, the authors consider some parameters such as network energy consumption, packet delay, and percentage of the delivered high and medium priority packets to the destination. The authors outlined that their proposed algorithm consists of congestion prevention, congestion control, and energy control plans using the shortest path selection algorithm. In the congestion prevention plan, congestion is prevented by investigating the length of the queues. In the congestion control plan, the congestion is controlled by reducing the transmission rate. Lastly, energy control is used to balance the energy nodes which avoids network failures due to energy outages on the node within the agricultural environment. They used NS-2 to implement their proposed CCP algorithm. The simulation results indicated that their proposed CCP algorithm has a higher efficiency regarding the parameters.

The Priority-based Congestion Control (PCC) algorithm was proposed by [21]. This algorithm consists of three mechanisms, which are as follows: Intelligent Congestion Detection (ICD), Implicit Congestion Notification (ICN), and Priority-based Rate Adjustment (PRA). The authors indicated that the proposed algorithm implemented in agricultural fields is based on crops and soils, and mitigating flood risks through farming practices. The objective of the proposed algorithm was to identify congestion, the ICD employs the ratio of packet inter-arrival time (time spent receiving packets at the node) to packet service time (time spent processing packets at the node). This ratio is also known as congestion degree. Congestion notification in ICN is accomplished by setting a bit in the data packet header. Then, depending on their purpose or location, each SN may have a varied priority.

However, the algorithm proposed by [20] did not prevent packets that are dropped during packet distribution caused by signal degradation over the transmission channel due to multi-path fading. This is because their algorithms focus more on packet flows, delays, and notifications for each packet, which is distributed in WSNs. This research study uses multiple links in the agricultural environment for packet transportation to avoid any packet drop. Furthermore. this research study used the TPFC algorithm to manage the packet flows during packet transportation within the agricultural environment.

The Automata-Based Congestion Avoidance (ACA) algorithm was proposed by [22] to prevent traffic congestion in WSNs which results in packet loss and bandwidth reduction. The authors further illustrated that the proposed ACA algorithm was instigated in the agricultural field to monitor the soil temperature and moisture for crop production. The proposed algorithm uses packet inter-arrival time to check the distributions for each packet sent to the destination node from the source node and further imposes the hop-by-hop count for bandwidth usage within the agricultural fields. The authors simulated their proposed algorithm using the MATLAB simulator. The proposed algorithm was able to decrease packet loss and stabilize bandwidth utilization in the agricultural area, according to their simulation results. However, the delays remain a problem within the environment in the proposed algorithm. As a result, their proposed algorithm during packet transmission produced poor network throughput within the agricultural field in WSNs.

In this paper, gaps and proposed methods based on WSNs challenges has been outlined that presented by different authors [16-22] such as delay of packets, high-priority traffic, network throughput, packet congestion and many others. The proposed solution provides different results as mentioned above in the related work.

III. Wireless Sensor Networks Overview

A WSN is a collection of devices known as SNs (wireless sensors) that work together to establish a wireless network connection [1], [2]. Moreover, these SNs transfer information from the SN (node that gathers information from the agricultural environment) to the sink node (node that receives information from SN) using the transmission channel provided (see Fig. 1).

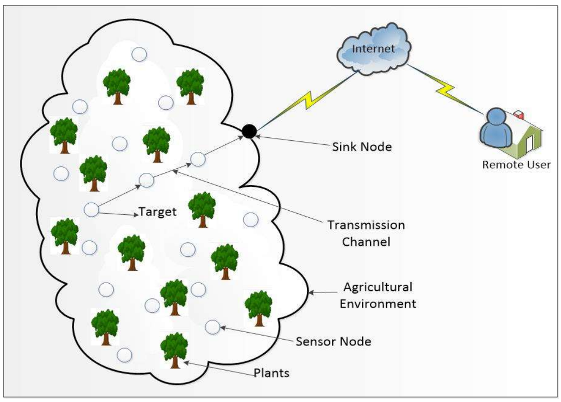

Figure 1. Wireless sensor network structure.

SNs can be mobile or static as presented in Fig. 1. These SNs have the capability of sensing and transmitting information. Further, all SNs share a single communication channel (transmission channel) through multiple access protocols, for example, random access protocols (the protocol used for transmitting node, to transmit at the full rate of the channel always) and media access control protocol (the protocol used for coordinating the access from active nodes).

IV. Congestion in WSNs

WSNs are formed by a group of devices known as SNs connected to share information across the wireless network [1, 3]. These nodes communicate with each other through wireless networks while collecting environmental data from the monitored zone to the sink node using hops.

However, due to the resource constraints of WSNs, there is a high number of deployed nodes that are event-driven nature within WSNs. As a result, there is many-to-one communication and high SNs traffic, which WSNs encounter substantial issues in some applications, such as event-driven applications, due to a large volume of transmitted data from the nodes in the event location. This large volume of transmitted data might cause traffic congestion.

Additionally, this can decrease network performance and energy efficiency, as well as packet loss, delays, and network throughput. Loss packets must be retransmitted, which costs more energy within WSNs and reduce the QoS.

There are different types of WSN congestion, which are categorized into two categories constructed on the environmental [6, 7].

First category: It is based on the two forms of packet loss: node-level congestion (buffer overflow) and link-level congestion (see Fig. 2).

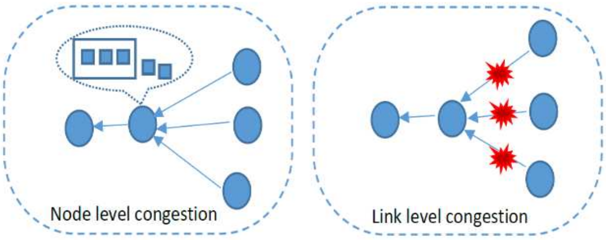

Figure 2. Common congestion in WSNs [10].

(1) Node-level congestion - occurs when packets requiring transmission exceed the buffer of a specific node, resulting in node-level congestion [11]. As a result, when the packet arrival rate exceeds the packet service time, a network overflow occurs, which ends up causing congestion within WSNs.
(2) Link-level congestion - this type of congestion happened when there are multiple active SNs use the same transmission medium to send the packets. Therefore, a collision may occur [12]. This type of packet collision increases the packet service time it takes for packets to be delivered and reduces link utilization.

Second category: It is determined by the congestion point on the network (hotspot). There are two common hotspot circumstances, which are illustrated below [13].

(1) Source hotspot: this type of hotspot comes as a result of occurred event when packets are transferred from source nodes to sink node whose sensing range cover the event spot (see Fig. 3).

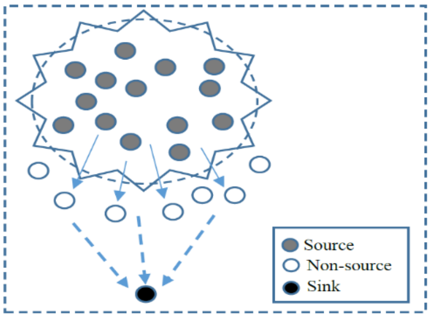

Figure 3. Source hotspot event [14].

As indicated in Fig. 3, the different nodes are transmitting the control information from overloaded nodes to source nodes, which is effective in controlling the traffic rates and altering the sending path. The traffic rates depend on the packet speed transferred from one node to another which includes the priority packet, packet delivery ratio and many others.

(2) Intersection hotspot: A traffic intersection might occur in the network due to a large number of sinks, (see Fig. 4) [15]. Intersection nodes can therefore become congested hotspots as a result of cumulative traffic load overflows.

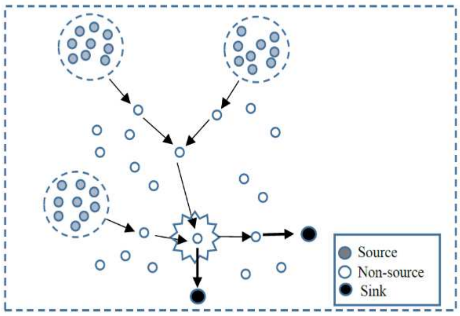

Figure 4. Intersection hotspot with numerous sinks [14].

Fig. 3 and Fig. 4 demonstrated several kinds of network congestion that have a detrimental impact on the network, which include reducing the network throughput, increased delay, and increased energy usage. As a result, there is a need to improve network performance and effectively manage traffic using appropriate algorithms to control the arisen congestion such as packet delay and packet loss. Hence, the ITR algorithm is developed to manage packet traffic and avoid congestion in a network.

V. Proposed System Architecture

WSN users are unrestricted in terms of movements when connecting to the network as long as there is network coverage in that particular area. Processes of different nodes communicating together by sending in an agricultural environment are termed packet transmission as this research study illustrated in Fig. 5.

Furthermore, all SNs collect the information from the agricultural environment separated by different zones (zone 1 to zone 6) to send the information to the Access Point (AP). An ITR algorithm must perform the traffic routing management to avoid head-of-line blocking which occurs when the first packet holds up a line of packets during packet transmission within an agricultural environment. The goals of managing packet congestion may include less packet loss, minimizing delays, and improving network throughput during packet transmission in WSNs.

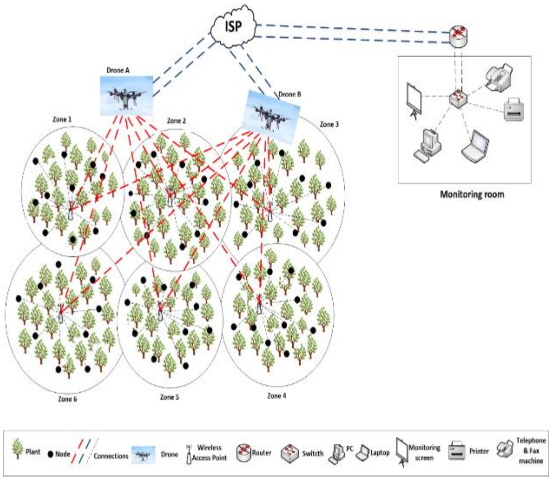

Figure 5. WSNs system architecture.

As indicated in Fig. 5 of the presented WSNs system architecture, before the Access Points (APs) send packets to the next drone, SNs will first collect all the relevant information from the ground in the zones, thereafter, SNs send the collected information to the AP. The AP will transmit packets to the drones (drones A and B) which are moving around from zone1 to zone 6. Thereafter, the drones transmit the received packets from APs to the cloud where the network users who are monitoring the zones will be able to access all the information. Furthermore, if the first drone (drone A) reaches the maximum number of packets that need to be collected from APs, then the other packets will be re-directed to the second drone (drone B), for packets to be transmitted to the Internet Service Provider (ISP). This process lessens traffic congestion in the agricultural environment because the load balance is introduced. All information will be saved on the servers and the printer will be used to print out the reports for all the events that took place with the entire system architecture.

VI. Design of Intelligent Traffic Routing Algorithm

This paper assimilated the existing solutions algorithms such as Machine Learning Congestion Control (MLCC), and Load Balancing Routing Management (LBRM) when designing the proposed ITR algorithm to minimalize the packet loss, and delays, and improve network throughput during packet transmission in WSN within an agricultural environment.

A. Machine Learning Congestion Control

The proposed ITR algorithm integrates the MLCC method with LBRM to overcome packet congestion caused by head-of-line blocking within an agricultural environment. The proposed ITR algorithm used MLCC for predicting possible packet congestion and offers some decision-making mechanisms based on packet transmission within the network in the agricultural environment from different zones using links that connect AP with drones and ISP. The MLCC provides high flexibility in packet transmission which is implemented by the decision tree algorithm when distributing packets within the network environment.

MLCC is used for estimating the congestion in a dynamic network environment by predicting the traffic flow or traffic pattern using parameters including traffic speed and delay. It ensures that the transmission of each packet in the network is transmitted appropriately from one node to another node without delays or congestion. Therefore, this research study applied this Machine Learning (ML) technique to predict the possibilities of packet congestion and make a decision in terms of the packet flow to avoid packet congestion which may occur during packet transmission and result in head-of-line blocking within WSNs in an agricultural environment. The prediction of packet congestion is calculated using Eqs. (1), (2), and (3).

$$P_s = \frac{1}{n}\sum_{i=1}^{n}(|V_i - \overline{v_i}\,|) \tag{1}$$

where P_s represents the packet set initialized from the network, n represents the total number of nodes, V_i represent the traffic packet flow, meanwhile $\overline{v_i}$ represents the possible predicted traffic packet congestion during packet transmission within the network.

$$T_s = \frac{1}{\mathrm{n}}\sum_{i=1}^{n}\left(\frac{|\overline{v}_i - v|}{|\overline{v_i}|+|v|/2}\right) * 100 \tag{2}$$

where T_s represents the traffic speed based on the bandwidth in a network during packet transmission from various nodes within the agricultural environment.

$$C_i = \sqrt{\frac{\sum_{i=1}^{n}(\overline{v_i} - v_i)^2}{n}} \tag{3}$$

where C_i represents the congestion index experienced during the prediction of traffic flow in the network. Furthermore, the decision-making as to how the packets will be distributed or re-routed during packet transmission in the network is calculated using Eq. (4).

$$D_m = \frac{C_i}{T_s + P_s} \tag{4}$$

where D_m represents the decision-making process that controls the flow of how the packets are to be routed from APs to drones and from drones to ISP to avoid packet congestion in the network.

B. Load Balancing Routing Management

This research study integrated the LBRM and MLCC into the proposed ITR algorithm to manage the packet flow by providing the available link which needs to be utilized by MLCC during packet transmission from APs to drones and from drones to ISP in the network. Furthermore, when packets in the network are well managed, this resulted in a reduced delay, packet loss, packet congestion, and further reduced head-of-line blocking in the network. Hence, this research study used LBRM to perform load balancing by managing the traffic flow in the network.

The MLCC predicts possible packet congestion and makes a decision based on the traffic flow within the network. To determine the link availability, it is more important to consider the stability of the link. Therefore, to determine Link Stability (LS), the concept of Link Expiry Time (LET) plays a vital role in a network. This is used to determine how long (time) a connection between two linked nodes may be maintained without interruption. The LET between the two nodes, x, and y, is calculated using the equation proposed by [23] and defined in Eq. (5).

$$LET = \frac{-(\mathrm{ab}+\mathrm{cd}) + \sqrt{(a^2+c^2)r^2 - (ad-bc)^2}}{a^2+c^2}$$

With

$$\begin{aligned} \mathrm{a} &= \mathrm{vx}\ \cos\theta\mathrm{x} - \mathrm{vy}\ \cos\theta\mathrm{y} \\ \mathrm{b} &= \mathrm{wx} - \mathrm{wy} \\ \mathrm{c} &= \mathrm{vx}\ \sin\theta\mathrm{x} - \mathrm{vy}\ \sin\theta\mathrm{y} \\ \mathrm{d} &= \mathrm{zx} - \mathrm{zy} \end{aligned} \tag{5}$$

where in, vx, and vy are the speeds and θx θy are the moving directions of nodes x and y, respectively. On the other hand, (wx, zx) and (wy, zy) are the coordinates of nodes x and y, respectively.

Furthermore, when two linked nodes are traveling at the same speed and in the same direction, the LET for both nodes is infinite. Consequently, the LET value is proportional to the LS between two nodes. The form of LS can, therefore, be calculated using Eq. (6).

$$LS = 1 - e\frac{-LET}{\alpha} \tag{6}$$

where by α is a constant and its' value should be improved to enhance LS and be able to predict any future network link failure.

Normally, not all packets are successfully transmitted in the network. Therefore, it is important to compute packet loss as shown in Eq. (7).

$$pkt_{loss} = \left\{\frac{\sum_{\mathrm{t_1}}^{\mathrm{tn}} \mathrm{pkt}_{dropped}}{\sum_{\mathrm{t_1}}^{\mathrm{tn}} \mathrm{pkt_{sent}}}\right\} * 100 \tag{7}$$

where by t_1 represents the time in which the first packet was sent from the source node and t_n represents the time in which the last packet was sent from the source node.

Furthermore, this research study uses LBRM to perform the load balancing, then, by doing so, this will assist in reducing packet congestion caused by head-of-line blocking which results in delays, packet loss, and packet congestion. This research study also used the MLCC to provide the prediction of possible packet congestion and offers a decision-making mechanism based on packet transmission within the network. This integration of these two algorithms improved the consistency of packet transmission within WSNs in an agricultural environment.

VII. Proposed ITR Algorithm

This paper integrated MLCC and LBRM to design the proposed ITR algorithm. The aim is to minimalize the packet loss, packet congestion, and delays caused by head-of-line blocking to improve network throughput during packet transmission in WSNs within the agriculture environment as given by Algorithm 1.

Algorithm 1: Intelligent Traffic Routing (ITR)

//Initialization: set of nodes
//Initialization: set of links or link utilizations
//Event: routing packets from different nodes in the zones to ISP using links
Initialize the population of nodes on zones
Node gathers information from different zones
Initialize the set of links in the environment to transmit the packets
Check the availability of links to send packets from APs to ISP
Do while when packets are ready to be transmitted from sensor nodes to APs
If $P_s = \frac{1}{n}\sum_{i=1}^{n}(|V_i - \overline{v_i}\ |)$ **Then**
  Initialized the packet set to be transmitted from the network
Else
  Use Eqs. (1) and (2)
End if
Checking the possibilities of packets congestion during transmission
If $C_i = \sqrt{\frac{\sum_{i=1}^{n}(\overline{v_i} - v_i)^2}{n}}$ **Then**
  Patterned the possibilities of packet congestion from APs to ISP
Else if there are possibilities of packets congestion **Then**
  Utilize Eqs. (4) and (5)
End
Keep transmitting packets from APs to ISP using the initiated links
Calculate the number of packets transmitted successfully using Eq. (7)
Monitor the agricultural environment using the collected data
Loop

VIII. Implementation of the Proposed Algorithm

This paper implemented the proposed ITR algorithm using the IEEE 802.11ac model developed using Network Simulator 2 (NS-2) version 35. The ITR algorithm is evaluated to check its performance based on WSNs traffic congestion caused by head-of-line blocking which occurs in the agricultural environment. Therefore, this paper illustrates the NAM simulation scenario based on the topology which is created for simulations using Fig. 6. This paper implemented two nodes which are demonstrated as node 6 (drone 1) and node 7 (drone 2) which acted as the moving drones within the NS-2 simulator to gather information from all six (6) zones within the agricultural environment.

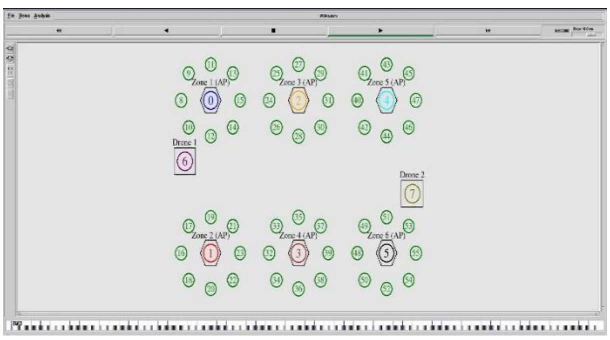

Figure 6. WSNs simulation scenario 1.

The topology illustrated in Fig. 6, represents WSNs architecture, which was used to carry out the simulations. In the simulations, this paper had a network topology of 900m×900m with 6 fixed located access points (APs) in the zones which are labelled (AP-0, AP-1, AP-2, AP-3, AP-4, and AP-5), and 8 randomly located nodes for each zone (labelled node 8-55) which was used to compare the three algorithms as exemplified using Fig. 6 and Fig. 7.

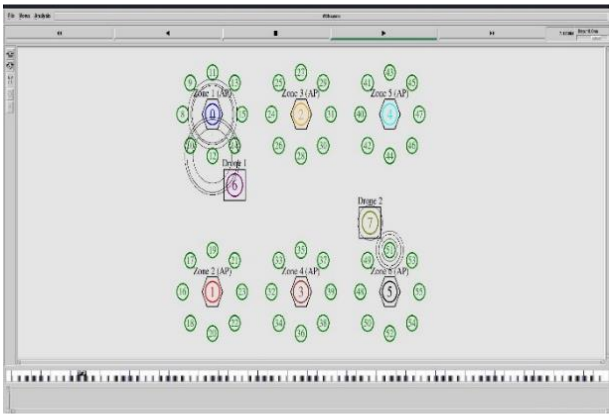

Figure 7. WSNs simulation scenario 2.

The above Fig. 7, illustrated that, when drone 1 and drone 2 start moving around the zones within the agricultural environment, they start by collecting information from the zone which is near to the drone through its APs. All APs collect packets from SNs within the zones which are implemented in the agricultural environment. Therefore, when drone 1 starts moving, it collects the packet from zone 1 using AP-0, while drone 2 starts collecting information from zone 5 using AP-6 when it starts moving around the agricultural environment. This process happened because, during the configuration of the simulation in this research study, zone 1 was configured as the first zone to send its packets to drone 1 using AP-0, while zone 6 was configured as the first zone to send its packets to drone 2 using AP-5. When the drones are done collecting packets from zone 1 and 6, then they will move to the next zones which is zone 3 and 4, as they are close to zone 1 and 6, and start collecting the packets in zone 3 and 4 using the AP-2 on zone 3 and AP-3 on zone 4 as illustrated in Fig. 8.

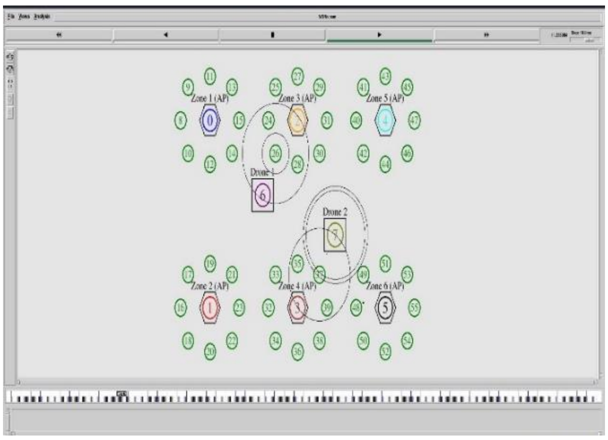

Figure 8. WSNs simulation scenario 3.

IX. Simulation Results

This paper discusses the performance of the proposed ITR algorithm based on the findings analyzed during simulations in terms of the three performance metrics: packet loss, packet delay, and throughput. The number of SNs used during the simulation process was 55 nodes. The highest traffic load implemented was 90 packets per second. The proposed ITR algorithm is compared with MLCC and LBRM algorithms as shown in Fig. 9, Fig. 10, and Fig. 11.

The following metrics performance is analyzed during simulations:

(1) Packet Loss: this happened during packet transmission when one or more packets fail to reach their intended destination. Packet loss affects users by causing network interruption, and slowing down the network performance.

(2) Packet delay: occurs when one or more packets took time to reach their destination from the source node as per allocated time within the network environment. This outlined that the packet transmitted gets delayed reaching its destination, as a result, this process slower the network performance.

(3) Network throughput: the amount of data successfully transmitted from one location to another in a specific period, usually measured in bits per second (bps), megabits per second (Mbps), or gigabits per second (Gbps).

The proposed ITR algorithm is compared with MLCC and LBRM algorithms. MLCC algorithm becomes one of the nominated algorithms because is used for estimating the congestion in a dynamic network environment by predicting the traffic flow using parameters including traffic speed and delay control as discussed in section VI (A). While LBRM algorithm was chosen to perform the load balancing by managing the traffic flow within the network as discussed in section VI (B).

The packets that are collected from the zones by SNs are distributed to the APs, thereafter, packets are sent to the drones by the APs. This method performs better compared to other mechanisms used by other researchers.

A. Packet Loss

Packet loss was evaluated and analyzed based on one or more packets failing to reach their intended destination, during packet transmission within the network environment. Fig. 9 presented the proposed ITR algorithm compared with MLCC and LBRM algorithms to see the effectiveness of the proposed algorithm. Therefore, the time/seconds used to calculate the average packet loss start at 10s. Simulation results indicated that the three algorithms showed a similar average number of packet losses. The traffic load began from 10 to 90 packets per second.

The proposed ITR algorithm demonstrated in Fig. 9, shows that when the packet traffic increases ITR algorithm produced a lower average percentage of the packet loss. While the LBRM and MLCC algorithms produce a high average percentage of the packet drop during packet transmission. The proposed ITR algorithm produced better QoS because the number of packets lost within the WSN in the agricultural environment was reduced by 27.3%. The proposed ITR algorithm achieved this process because it utilizes the load balancing mechanism during packet distribution within WSNs.

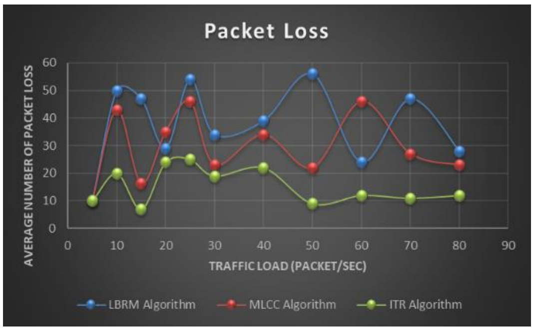

Figure 9. Number of packet loss.

B. Packet Delay

Packet delay in this paper was analyzed based on the transmission of one or more packets that took time to reach their destination from the source node as per allocated time within the network environment. Fig. 10 shows the performance of the proposed ITR algorithm. The proposed ITR algorithm is compared with LBRM and MLCC algorithms. The simulation results illustrated in Fig. 10, show that three algorithms have a similar average number of packet losses starting at 10s on the simulation. The traffic load began from 10 to 90 packets per second.

During the evaluation performance demonstrated in Fig. 10, shows that the proposed ITR algorithm produces better results on the packet delay within the network environment. When packet traffic increases, the ITR algorithm produces a lower average percentage of packet delay, but the LBRM and MLCC algorithms provide a high average percentage of packet delay during packet transmission. The proposed ITR algorithm produced better transportation of packets because the number of delayed packets was dropped by 43.4% within WSNs in an agricultural environment. The proposed ITR algorithm achieved this process by implementing load balancing and machine learning algorithms during packet transmission in WSN within the agricultural environment.

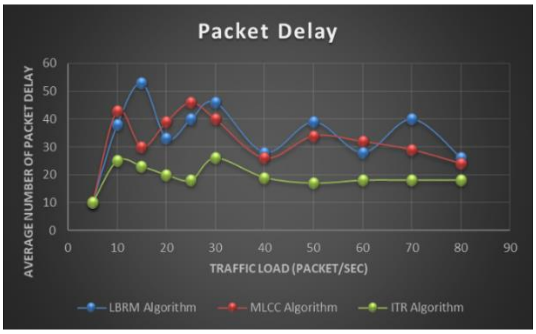

Figure 10. Number of packets delay.

C. Network Throughput

This paper evaluated and analyzed the effectiveness of network throughput performance based on three algorithms such as ITR, LBRM, and MLCC algorithms. The proposed ITR algorithm was compared with LBRM and MLCC algorithms during the simulation process. The proposed ITR algorithm produced better network throughput as illustrated in Fig. 11 when compared with LBRM and MLCC algorithms. The simulation process for network throughput began with an average of 10s and a traffic load ranging from 10 to 90 packets per second.

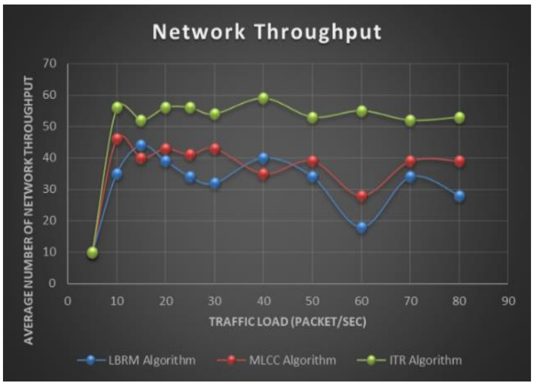

Figure 11. The network throughput.

The proposed ITR algorithm shows that it outperforms both LBRM and MLCC algorithms when the traffic load increase as demonstrated in Fig. 11. average network throughput of 98.4%, compared to 63.2 % for the LBRM algorithm and 73.4% for the MLC algorithm. The proposed ITR algorithm achieves this process by implementing load balancing and machine learning algorithms when transmitting packets from the source to the destination node in WSNs within the agricultural environment.

X. Conclusion

The implementation of WSNs within the agricultural environment has increased so fast. This is because WSNs are observed as a revolutionary information gathering method, which forms information and communication systems within different infrastructures such as agricultural environment and healthcare, irrigation environment, and others. This paper implemented WSNs in the agricultural environment to monitor environmental conditions such as soil moisture, humidity, and soil temperature. Therefore, the methods provided in this paper is very useful which needs to be taken to consideration when implementing WSNs within the agricultural environment. Moreover, this paper shows that the network users in different environments always require good network performance, which allows them to monitoring their agricultural environments. As a result, this paper developed an algorithm that manages packet transmission in WSNs within the agricultural environment. The proposed ITR algorithm shows the improvement in network throughput, minimization of packet delay, and packet loss during the simulation results while compared with LBRM and MLCC algorithms. This research paper did not consider the issue of security and energy consumption on sensor nodes when packet transmission occurs in WSNs.

APPENDIX TLC SCRIPTS

Simulation Parameter Setup

```
set val(chan)   Channel/WirelessChannel      ;# Channel type
set val(prop)   Propagation/TwoRayGround ;# Radio-propagation model
set val(netif)  Phy/WirelessPhy              ;# Network interface type
set val(mac)    Mac/802_11                   ;# MAC type
set val(ifq)    Queue/DropTail/PriQueue      ;# Interface queue type
set val(ll)     LL                           ;# Link layer type
set val(ant)    Antenna/OmniAntenna          ;# Antenna model
set val(ifqlen) 50                           ;# Max packet in ifq
set val(nn)     56                           ;# Number of nodes
set val(rp)     AODV                         ;# Routing protocol
set val(x)      1800                         ;# X dimension of topography
set val(y)      840                          ;# Y dimension of topography
set val(stop)   60.0                         ;# Time of simulation end

#===================================
#                Initialization
#===================================
#Setting the simulator objects
set ns_ [new Simulator]

#Define different colors for data flows (for NAM)
$ns_ color 1 Blue
$ns_ color 2 Red

#create the nam and trace file:
set tracefd [open WSNs.tr w]
$ns_ trace-all $tracefd

set namtrace [open WSNs.nam w]
$ns_ namtrace-all-wireless $namtrace  $val(x) $val(y)

set topo [new Topography]
$topo load_flatgrid $val(x) $val(y)

# general operational descriptor- storing the hop details in the network
create-god $val(nn)

#Defining node configuration
$ns_ node-config \
        -adhocRouting $val(rp) \
        -addressingType flat \
        -llType $val(ll) \
        -macType $val(mac) \
        -ifqType $val(ifq) \
        -ifqLen $val(ifqlen) \
        -antType $val(ant) \
        -propType $val(prop) \
        -phyType $val(netif) \
        -topoInstance $topo \
        -agentTrace ON \
```

CONFLICT OF INTEREST

The authors state that there are no conflicts of interest in the publication of this research.

Author CONTRIBUTIONS

Tshimangadzo M. Tshilongamulenzhe carried out the research, wrote the paper, design of the algorithm, simulated, and evaluated the results. Topside E. Mathonsi have been involved in revising the manuscript for important intellectual content. Deon P. Duplessis have contributed to the manuscript's creation and critical revision for key intellectual substance. Maredi I. Mphahlele have contributed to proofreading and language editing. All authors approved the final version.

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