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Research Article

An Estimation of QoS for Classified Based Approach and Nonclassified Based Approach of Wireless Agriculture Monitoring Network Using a Network Model

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Wireless Sensor Network (WSN) can facilitate the process of monitoring the crops through agriculture monitoring network. However, it is challenging to implement the agriculture monitoring network in large scale and large distributed area. Typically, a large and dense network as a form of multihop network is used to establish communication between source and destination. This network continuously monitors the crops without sensitivity classification that can lead to message collision and packets drop. Retransmissions of drop messages can increase the energy consumption and delay. Therefore, to ensure a high quality of service (QoS), we propose an agriculture monitoring network that monitors the crops based on their sensitivity conditions wherein the crops with higher sensitivity are monitored constantly, while less sensitive crops are monitored occasionally. This approach selects a set of nodes rather than utilizing all the nodes in the network which reduces the power consumption in each node and network delay. The QoS of the proposed classified based approach is compared with the nonclassified approach in two scenarios; the backoff periods are changed in the first scenario while the numbers of nodes are changed in the second scenario. The simulation results demonstrate that the proposed approach outperforms the nonclassified approach on different test scenarios.

1. Introduction

Wireless Sensor Network (WSN) is a network consisting of sensing devices connected via wireless communication [1–3]. These devices are known as motes or sensor nodes that convert the raw signals into information through four modules: (1) *sensing unit* senses and detects events from targeted environment and then converts the physical measurement to digital signals; (2) *processing unit* controls all sensor functions and manages the communication between sensors by changing the sensors status from sleep mode to ideal mode or start mode; (3) *transceiver unit* sends the physical measurement from the sensor to the base station (sink node); (4) *energy unit (battery)* is power source of the sensors and allows the sensors to operate for years or months [3–7]. These make WSN suitable in many applications such as health care monitoring, wildlife monitoring, security monitoring, fire detection, and agriculture monitoring [8, 9].

In this work, we focus on wireless network for agriculture monitoring as depicted in Figure 1 [10]. Figure 1 shows the architecture of agriculture sensors connected with sink node. The aggregated data are sent to remote server to be processed, analyzed, and stored. This network is used to monitor and analyze crops health from the impact of unpredictable climate change or other conditions. The Wireless Agriculture Monitoring Network (WAMN) is widely considered as new generation of agriculture monitoring network to monitor different types of crops [11, 12]. WAMN mainly controlled greenhouse system via interconnected network that delivers data from greenhouse to control center. These data are acquired from multiple sensors such as temperature sensor and humidity sensor. However, it is challenging to implement the existing WAMN architecture [13–20] in large scale and large distributed area. This is because the sensors are susceptible to high delays and high energy consumption during sensing, processing, and transmitting data over the dense

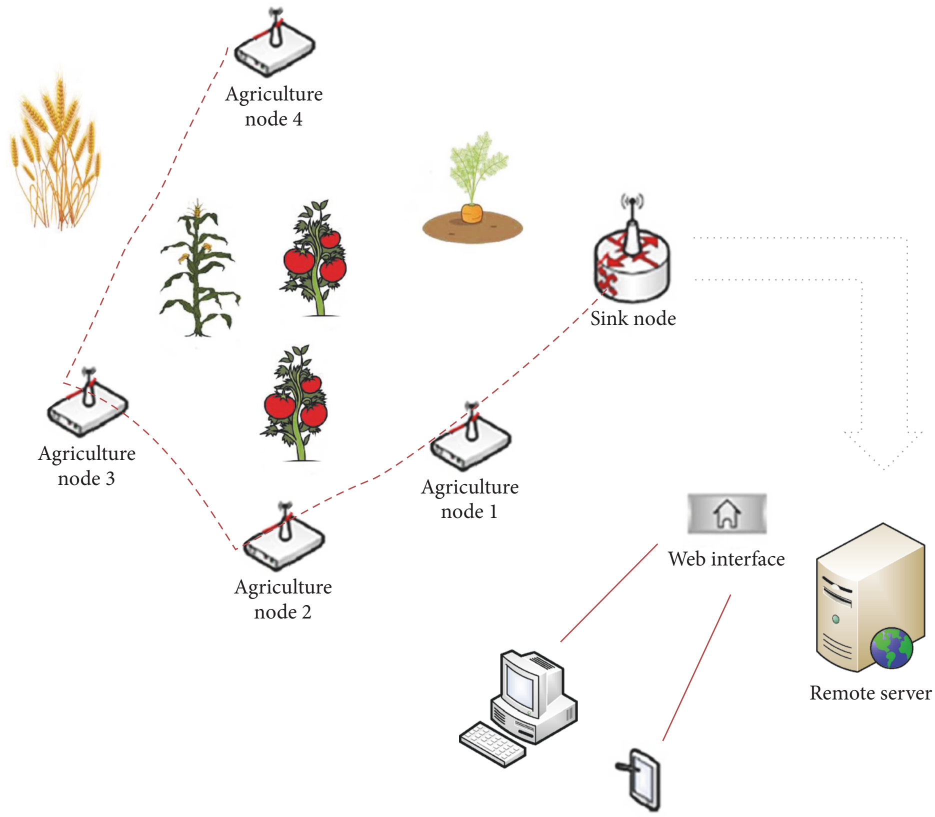

Figure 1: Agriculture monitoring network.

and Wide Area Network. Furthermore, the characteristic of a monitoring system also contributes to the aforementioned problem as large data from continuous monitoring induce message collision and packet drop. Retransmission of the drop messages increases the energy consumption and delay.

Implementing the existing WAMN architecture in large scale and large distributed area can be further challenging as the monitoring and data transmission are done continuously without sensitivity classification. Consequently, the unnecessary data transmission from all nodes in a network can lead to inefficient use of energy. Therefore, we propose a classified based approach to classify crops to a set of clusters based on their sensitivity of agricultural conditions. Sensitivity levels of 5°C and 10°C are introduced in this paper. The two levels of sensitivity are chosen based on the optimal temperature condition that will be discussed further in later section.

To evaluate the effectiveness of our proposed method, two tests are conducted. These tests investigate the effects of backoff period and number of nodes. Energy consumption, end-to-end delay, and jitter are then measured and compared with the nonclassified based approach.

This paper is organized as follows: Section 2 presents the challenges and related works of agriculture monitoring network. Section 3 shows a Smart Agriculture Monitoring Network (SAMN) architecture model. The classified based technique and the proposed methodology are presented in Section 4. Section 5 describes the details of the experiment and reports the results. Section 6 presents the discussion and we conclude the work in Section 7.

2. Literature Review

This section presents the challenges and related works of agriculture monitoring network. We organize this section as follows.

2.1. Challenges of Greenhouses Monitoring Network. The challenges of applying agriculture monitoring network in real life are summarized as follows:

(i) *Network scalability*, the nature of agriculture monitoring network based on the wide area of deployment: this makes the network very sensitive to failure and reduces the performance of network [12, 22, 23]. To diminish this challenge hierarchical architecture style would perform better than the simple style (flat single tier network architecture).

(ii) *Simplicity*: we should consider that the end users have limited knowledge of WSN. Thus, the designed solutions and platforms should be user-friendly and easy to use [24].

(iii) *Real-time monitoring*: most of previous works do not focus on the issue of real-time monitoring of the crops [24]. This factor has a strong relationship with network metrics that measure the quality of the network such as end-to-end delay [25]. For this reason, delay or network latency should be examined.

(iv) *Energy harvesting and energy management*: energy management is crucial in WSN as the power source of the sensor is limited. Thus, energy consumption should be considered in the designing of the system algorithms and components. Alternatively, the renewable energy resources [26] such as wind power [27] and solar power [28] can be used as unlimited power source for the sensor. For this reason, we propose a network model using nonconventional resources to power the network components.

2.2. State of the Art. This subsection presents the related works of WAMN in precision agriculture with various sensors deployments and data transmission scenarios over IEEE 802.15.4 communication technology. Most WAMN agricultural deployments [13–20, 29–31] transmit different types of information via devices that located up to several kilometres apart from control center. These existing works give the detailed description of the devices employed and describe the design on how the deployment of WAMN is performed. Though the method proposed is able to work accordingly, energy consumption or network life time of sensing devices remains a challenge in these works. Extending the network life time of sensing devices is important since agriculture cycle usually takes several weeks or months until the harvest time. Another important aspect that is not considered previously is number of nodes. Typically, the number of nodes set in the experiment is small (e.g., less than ten sensor nodes) and may not be suitable for implementation of dense WAMN.

WAMN are commonly implemented through short range communication technologies such as ZigBee and WiFi and long distance communications such as multihop network [32]. The costs to transmit the sensed data via these communication technologies are important in energy management strategy. Since many of the existing works will be actively sensing data almost all the time (keeping attention to the channel by listening and transmitting or receiving information), researchers devise various methods to reduce network complexity in order to simplify data transmission. For example, Ayday and Safak [33] proposed a network design that consists of gateways deployed between end sensors and control center which help to reduce the network complexity by centralizing and storing sensors' data in the gateways. Garcia-Sanchez et al. [34] look into further details evaluation by studying different test scenarios by changing the number of events and the parameter of Beacon Interval (BI) of synchronization scheme (the value of BO and SO). They also study the end-to-end delay of the network by changing the number of sensor nodes.

2.3. Nonclassified Based Approach. The WAMN implementation as discussed in the prior section shows many promising benefits for agriculture monitoring. However, all crops monitored are considered equally sensitive even if there is time where less (or close) monitoring is needed. In real agriculture implementation, monitoring frequency is flexible and can be based on the environment conditions. We call this common WAMN implementation as nonclassified based approach and the implementation is illustrated in Figure 2. Nonclassified based approach has limitation in managing energy usage. This is because monitoring is done continuously without considering other factors to adjust the sensitivity of the monitoring frequency.

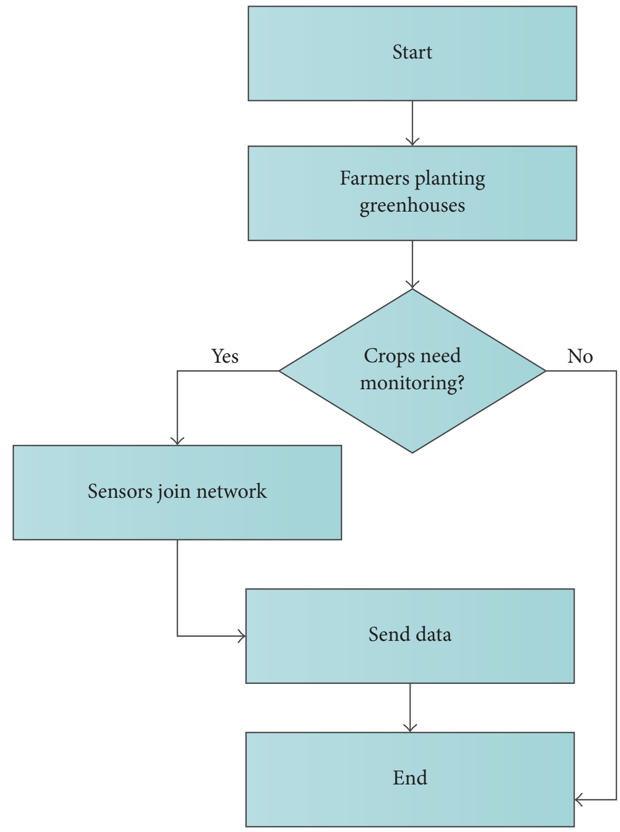

Figure 2: Nonclassified based technique.

3. A Smart Agriculture Monitoring Network (SAMN) Architecture Model

We propose the usage of a Smart Agriculture Monitoring Network (SAMN) instead of multihop network for large geographical greenhouses monitoring network. SAMN is a communications infrastructure model that consists of many parts (hierarchical architecture style). Furthermore, SAMN helps to prolong across the whole greenhouses to the neighborhood area and the wide area (monitoring center) which is used to provide many features that cannot be achieved with multihop network such as flexibility, stability, good quality of services, and maintainability. Figure 3(a) shows a greenhouse network model of multilayer structure. The previous features cannot be achieved by WAMN because it operates based on multihop network to reach the destination. This makes the network very sensitive to failure, as in case of any dead hop the whole network will crash. Moreover, WAMN has lower flexibility than SAMN, as the process of adding or deleting

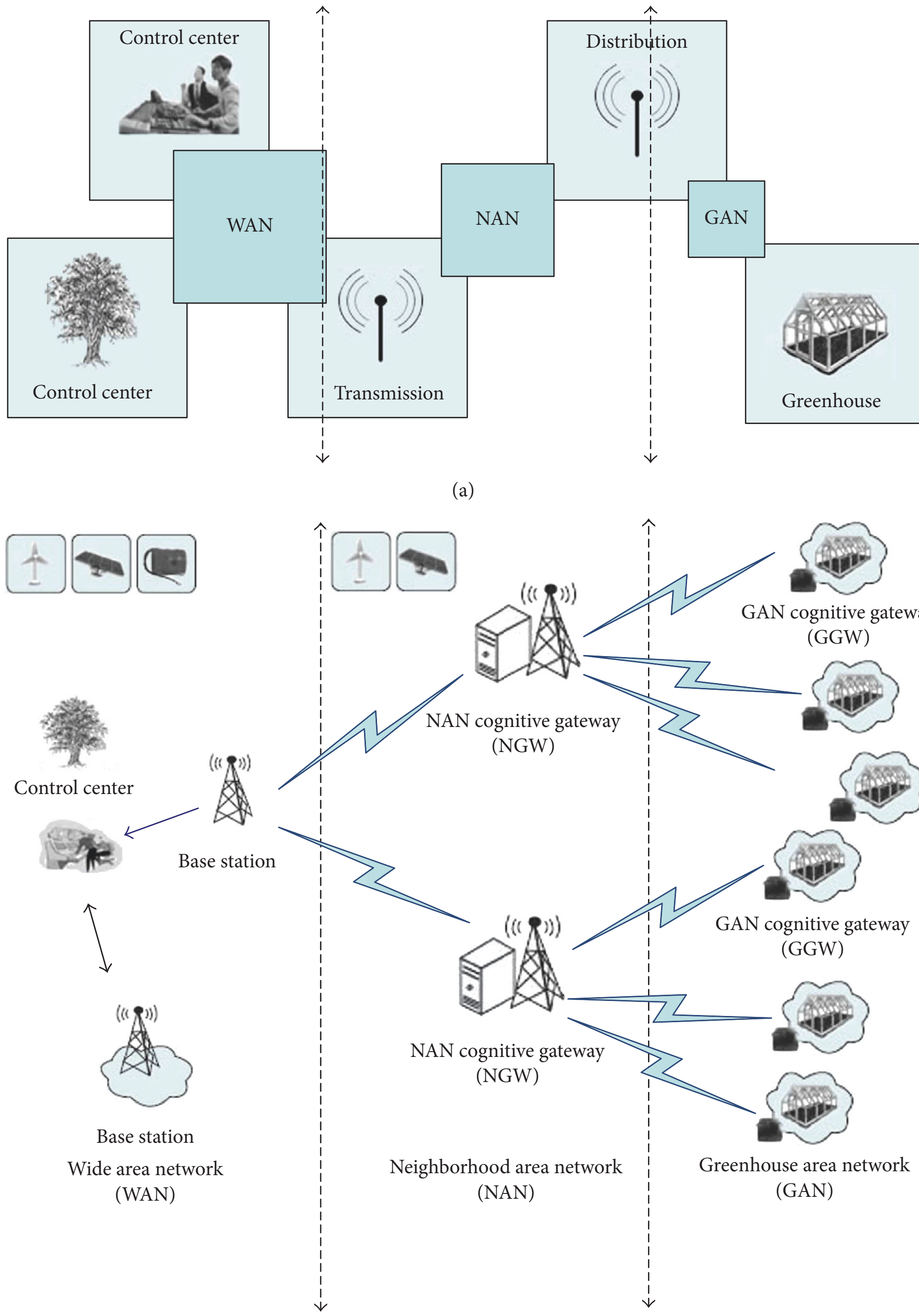

Figure 3: Hierarchical communications architecture in Smart Agriculture Monitoring Network.

node from the network in WAMN can be complicated. In addition, SAMN is easier to maintain than WAMN because SAMN deal with part of network rather than the whole network.

To support data transfer and management of agricultural equipment in SAMN, various wireless network architectures can be applied as shown in Figure 3(b). Three main networks used in SAMN are varied in locations and sizes are the greenhouse area network (GAN), neighborhood area network (NAN), and Wide Area Network (WAN). These networks are summarized as follows:

(i) *Greenhouse area network (GAN)*: GAN broadcasts on the local area wireless or short range transmission (e.g., ZigBee or WiFi) to support real-time data transformation, controlling different types of actuators like irrigation system and cooling and heating systems actuators. Wireless technologies are the popular choices for GANs due to their flexibility, low cost, and better control. For example, ZigBee is an appropriate technology for GANs in terms of interoperability. In a GAN, the greenhouse gateway or GAN gateway is used to transmit data to the external entity. A GAN gateway can be integrated into some greenhouse devices like programmable thermostat.

(ii) *Neighborhood area network (NAN)*: NAN relates multiple GANs together. As we can notice in Figure 3(b) GAN gateway transfers sensor data to Data Aggregation Unit (DAU) through NAN. The DAU communicates with the GAN gateway using short range network technologies such as ZigBee. Furthermore, DAU can act as the NAN gateway to transmit data to NAN servers. As we can notice in Figure 3(b), we propose the usage of renewable energy to support this part of the network such as using solar power or wind power to provide the transmission devices by power.

(iii) *Wide area network (WAN)*: WAN is used to relate remote systems (NAN servers) together. Furthermore, the WAN is used to collect and manage data transmission and, after that, to do different tasks like measurement and control purposes. WAN in this case should provide a backhaul connection which can adopt different technologies (e.g., broadband wireless access or cellular network) to transmit the data from DAU in a NAN to the control center. WAN gateway can broadcast over broadband connection (e.g., WiMAX, satellite, and 3G satellite) to collect the required data. Indeed, in this part of network as same as NAN part, we propose the usage of renewable energy to support this part of the network such as using solar power or wind power to provide the transmission devices with power. Figure 3(b) shows the WAN area network with the needed equipment.

4. Classified Based Technique and the Proposed Methodology

Various ideas are proposed to solve the challenges of agriculture monitoring network. Some of these ideas are based on topology type/size and sensors types to reduce the communication cost in WSN. Konstantinos et al. [32] proposed multihop network to solve the problem of a long distance communications, but the system failed in power management as the routers should be active almost all the time. On the other hand, some of researches used a smart gateway between sensors and control center to reduce the communication cost as the gateways are used to increase the network efficacy by storing a copy of sensors' data. Garcia-Sanchez et al. [34] controlled the power consumption in agriculture monitoring network by determining the optimal value of node events, BI of the network, and number of nodes in the network. These studies as same as many other studies such as in [13–20] used nonclassified based system (traditional agricultural monitoring system) to monitor the crops. Nonclassified based system treats all crops equally without classification. This reduces the network lifetime which leads to a rapid node death. For these reasons, we propose an approach for a traditional greenhouses monitoring system (nonclassified based system) that depends on the crops sensitivity profile. We classified crops into three clusters based on their sensitivity. Clusters include crops, which have sensitive agricultural conditions for transmission of their agricultural parameters continually, and crops that have less sensitive and nonsensitive agricultural conditions for transmission of agricultural parameters partially. This enables the lands to be monitored for a long time by selecting a set of nodes rather than utilizing all sensors in the network. Consequently, this reduces the power consumption in each node and increases the network efficiency by reducing network delay. Furthermore, this helps to manage communications between different types of agriculture sensors' and monitor center. The main idea of the selection process is by determining the optimal temperature for each crop and, after that, comparing it with environment temperature to determine the sensitivity of each crop. Figure 4 depicts the flow chart of classified based technique. Mainly, the greenhouse plantation is affected by the temperature which strongly related to humidity and CO_2. For example, the greenhouse with high temperature has a low relative humidity. Therefore, humidity and other influencing factors can be inferred from a known temperature [35]. For this reason, temperature sensor is integrated with humidity sensor in one microcontroller chip. The optimal temperature for crops is varied between types and sensitivity as there are crops that grow inside the soil (root crops) such as carrots and potatoes, and crops grow over the soil such as tomato and corn. The optimal temperatures for these crops are summarized in Table 1 [36–39].

Table 1: Optimal temperatures for crops [36–39].

Type of crops	Optimal temperature [°C]
Potato	15–20
Corn	22–25
Soybean	25–28
Wheat	20–25
Tomato	21–24
Cucumber	24–27
Carrots	15–18

Sensitivity defined in (1) is the difference between optimal temperature of the crops and actual temperature (environment temperature). Hatfield and Prueger [40] found that the productions of crops were reduced when the actual temperature changes over 5°C above the optimal temperature of the crops. Therefore, we choose 5°C as the first threshold value in this procedure [40]. Additionally, the production of photosynthetic pigments is affected when the temperature is 10°C above the optimal growth temperature of the crops. This can limit the photosynthesis and leads to crops damage. Therefore, 10°C is set as the second threshold value in this procedure [41].

$$\text{Sensitivity} = \left|\text{optimal temperature} - \text{environment temperature}\right|. \quad (1)$$

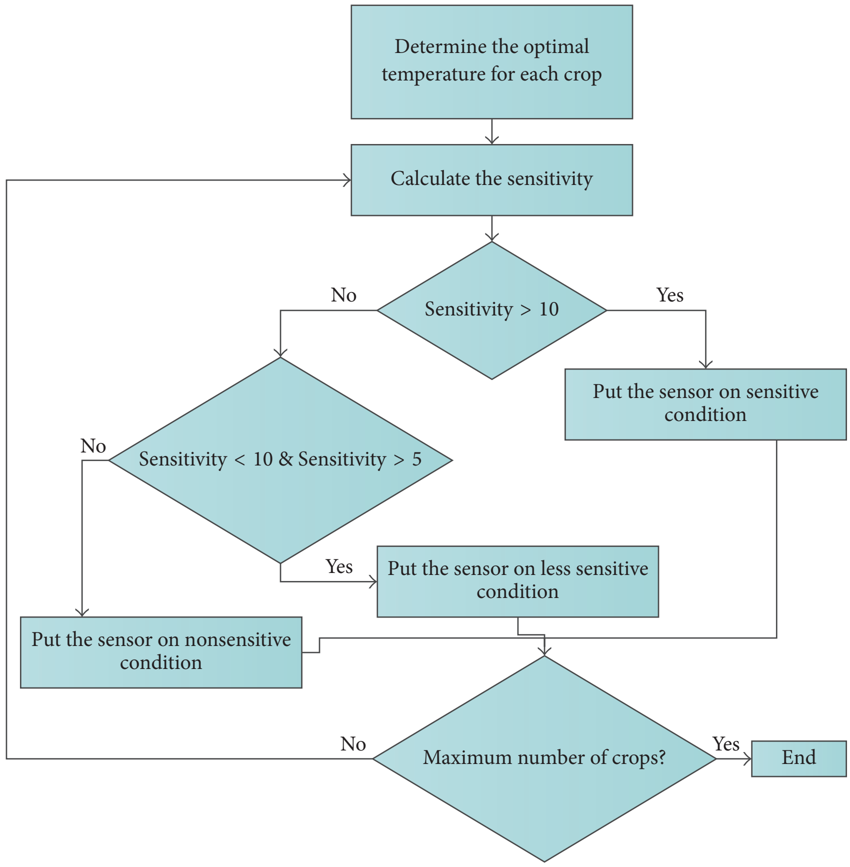

Figure 4: Flow chart of classified based technique.

5. Experimentation and Results

In this experiment, the proposed method is implemented in Ns2 and simulated on two scenarios. First, the size of network topology is fixed and other network parameters such as amount of transmission rate and size of data packets are constant. We distribute 20 sensors of type S05-TH in 20 greenhouses where each greenhouse has one sensor. In addition, we use cluster tree topology to connect GAN with NAN area networks. Each sensor such as Reduced Functional Device (RFD) senses and transmits environment data to a router. Then, the router transmits the data to a Greenhouses Area Network Gateway (GGW) of Full Functional Devices (FFD) type to perform all network management tasks. The cognitive gateway is responsible for delivering the gathered data to NAN server for broadcasting these data over WAN. Moreover, it is used to store a copy of these data to make the network more reliable. In the second scenario, network sizes are varied from 7, through 14, to 21 sensors. These sensors are formed using tree topology which send the data to a set of routers. After that, the routers resend the data to GGW. Figure 5 shows the components of greenhouses area network. The topology size was 100×105. Agricultural parameters in simulations are set according to standard values and in [20] as listed in Table 2. We determine the transmission time for each cluster and these intervals are summarized in Table 2.

5.1. Network Metrics. We focus on a set of important network metrics that are used to determine the quality of services (QoS) of any network. We organized them as follows.

5.1.1. Energy Consumption. This parameter is important for determining the quality of network. The energy consumption is calculated in each node at four modes (receive mode, transmit mode, sleep mode, and idle mode). Energy consumption is summarized in the following equation [42]:

$$\text{Energy}\ (\mu\text{J}) = \text{Current} \cdot \text{Voltage} \cdot \text{Time}, \quad (2)$$

where

(i) current consumption is in Amperes;

(ii) voltage is in Volts;

(iii) time is in seconds.

5.1.2. End-to-End Delay. This parameter measures the time taken to successfully deliver a data packet from sensor node to coordinator node including transmission time of packet, turnaround time of transceiver's (T_{TA}), backoff time (T_{bo}), interframe space time (T_{IFS}), and acknowledgment transmission time (T_{ACK}). End-to-end delay can be expressed in the following equation [43]:

$$T_l = T_{\text{packet}} + T_{\text{bo}} + T_{\text{TA}} + T_{\text{IFS}} + T_{\text{ACK}}. \quad (3)$$

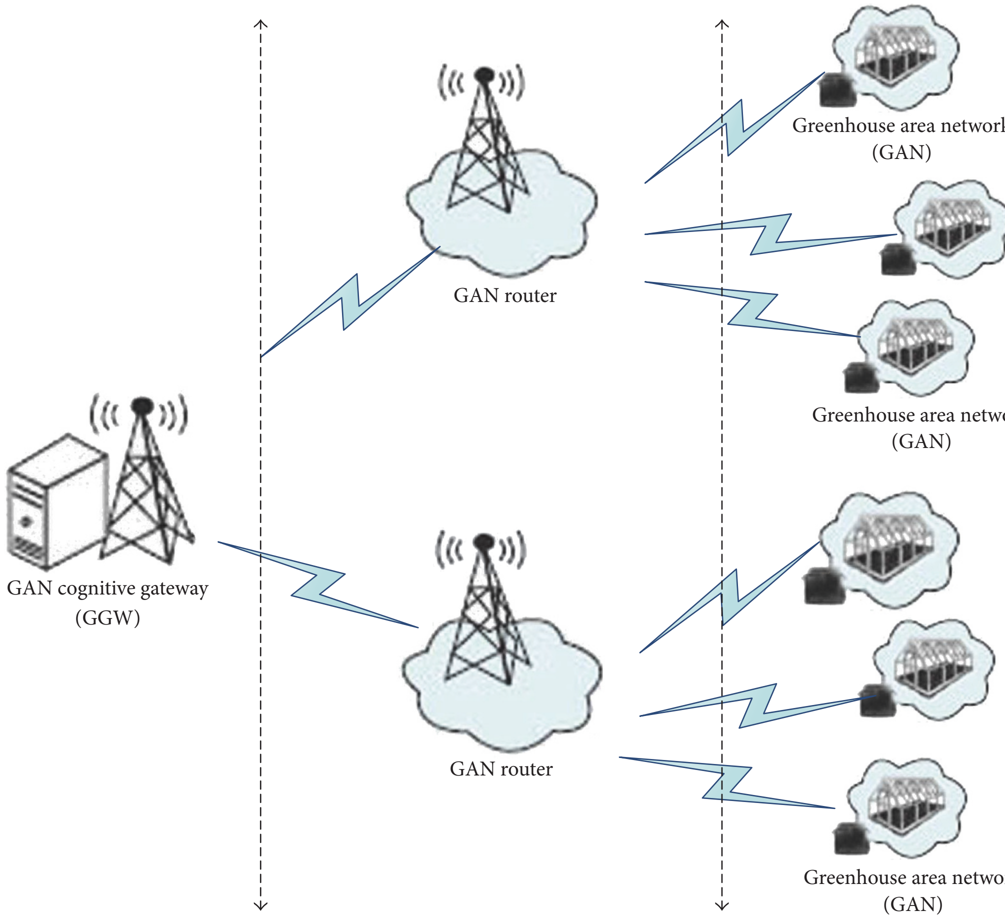

FIGURE 5: Components of greenhouses area network (GAN).

T_{packet} is a transmission time of any data packet. It can be expressed as follows:

$$T_{\text{packet}} = \frac{L_{\text{PHY}} + L_{\text{MHR}} + \text{payload} + L_{\text{MFR}}}{R_{\text{data}}}, \quad (4)$$

where

(i) LPHY is size of physical header (byte);

(ii) LMHR is size of MAC header (byte);

(iii) payload is size of data in the packet (byte);

(iv) LMFR is size of MAC footer (byte).

Now we should take into consideration the equation that is used to measure the backoff periods for each node in the network. This model can be determined by calculating the device probability (P_s) of accessing the medium in successful way. P_s can be measured by the following equation:

$$P_s = \sum_{a=1}^{a=b} P_c \left(1 - P_c\right)^{(a-1)}, \quad (5)$$

where b is the number of maximum backoff periods and P_c is the node probability to assess the idle channel at the end of backoff period.

$$P_c = \left(1 - q\right)^{n-1}, \quad (6)$$

where q is the node probability to transmit at any time and n is the number of nodes that operate on the network.

The average of backoff period (R) is given as

$$R = \left(1 - P_s\right) b + \sum_{a=1}^{a=b} a P_c \left(1 - P_c\right)^{(a-1)}. \quad (7)$$

Thus, the total of backoff time (T_{bo}) can be measured as

$$T_{\text{bo}} = \text{FractionalPart}\,[R]\, T_{\text{bop}} \left(\text{IntegerPart}\,[R] + 1\right) + \sum_{a=1}^{a=\text{IntegerPart}[R]} T_{\text{bop}}(a), \quad (8)$$

where T_{bop} is the average backoff period; it is given as

$$T_{\text{bop}}(a) = \frac{2^{\text{macMinBe}+a-1} - 1}{R_{\text{data}}} T_{\text{boslot}}, \quad (9)$$

where

(i) macMinBE is initial value of backoff;

(ii) T_{boslot} is backoff time at one slot duration equal to duration of 20 symbols in IEEE 802.15.4\ZigBee.

Table 2: Simulation parameters.

Parameter	Values
Simulator	Ns2
Sensing area	105 m × 100 m
Number of greenhouses (nodes) in first scenario	20
Number of routers in first scenarios	4
Number of greenhouses (nodes) in second scenario	7, 14, 21
Number of routers in second scenario	1, 2, 3
Number of gateways in both scenarios	1
Simulation time	1000 sec
Radio type	IEEE 802.15.4
Frequency band	2.4 GHz
The distances between sensors, router, and gateway	10 meters
Antenna model	Omni Antenna
Energy model	MicaZ
Topology type	Cluster tree
Item to send	0
Item size	16 bytes
Channel access mechanism	CSMA enabled
Traffic	Constant Bit Rate (CBR)
(BO, SO)	Shown in Table 3
Start time	15 sec
End time	1000 sec
Transmission time for sensitive cluster	1000 sec
Transmission time for less sensitive cluster	(2/3) · Simulation time
Transmission time for nonsensitive cluster	(1/3) · Simulation time

5.1.3. Average Jitter or Packet Delay Variation (PDV). PDV measures the variance of end-to-end delay value of packets flow in single flow direction. PDV can be expressed by measuring the difference in delay values for successfully received packets summarized in the equation [44]

$$J_i = \left|(R_{i+1} - R_i) - (S_{i+1} - S_i)\right| \tag{10}$$

or by using

$$J_i = \left|(R_{i+1} - S_{i+1}) - (R_i - S_i)\right|, \tag{11}$$

where

S_i is time when packet i is sent from sender;

R_i is time when packet i is received from receiver.

Through the simulation, N packets are sent from sender to receiver; for that, we use the above definition to calculate jitter and then get the average.

5.2. Backoff Period and Superframe Structure in IEEE 802.15.4. Backoff period is a chosen period that checks for channel clearance before packet transmission. In WSN, coordinator is responsible for determining the tasks for each node which allows the nodes to accomplish their tasks simultaneously. Full Functional Devices (FFDs) such as coordinator are authorized to send beacon frame. Beacon frame from ZigBee is a new technique to let coordinator identify and synchronize sensor of type Reduced Functional Devices (RFDs). Beacon Interval (BI) consists of two parts as summarized in Figure 6:

(i) Active period is divided into 16 time slots and determined by Superframe Duration (SD). SD is composed of Contention Access Period (CAP) and Contention Free Period (CFP). In CAP, all RFDs try to access the channel simultaneously in ideal mode, while in CFP all the packets owned by a specific node are guaranteed to transmit on the channel: this way is called Guaranteed Time Slot (GTS) [3, 4].

(ii) Inactive period: all nodes and their coordinator are in sleep mode [3, 4].

Coordinator is responsible for choosing BI period wherein Beacon Order (BO) determines the Beacon Interval while Superframe Duration is expressed in terms of Superframe Order (SO). The duty cycle of each node in active mode can be identified by the values of (BO, SO). Both CFP and CAP are referred to as the Active Period which is the time when the active nodes use the channel and is referred to as Super Frame Duration (SD). We measure the BI value by using BO value and SD value can be measured by using SO value [45–48].

$$\begin{aligned} \text{BI} &= \text{aBaseSuperframeDuration} \cdot 2^{\text{BO}}, \\ \text{SD} &= \text{aBaseSuperframeDuration} \cdot 2^{\text{SO}}, \end{aligned} \tag{12}$$

where $0 \leq \text{SO} \leq \text{BO} \leq 14$.

5.3. Results. We make two scenarios to measure the previous metrics as follows.

5.3.1. By Changing the Backoff Period. In this scenario, we test the network by changing the backoff period for each test. The values of (BO, SO) are changed from (1, 1) to (5, 5). These values are used by coordinator to synchronize between sensors which is a chosen period that checks channel clearance before packet transmission.

By examining this period, we determine the value of this parameter that gives the best synchronization between nodes to reduce delay and power consumption. The test is repeated 10 times to ensure the quality of results. Table 3 summarizes the comparison between classified based approach and nonclassified based approach in terms of energy consumption, average end-to-end delay, and average jitter, including various (BO, SO) values. The simulation results show that classified based approach outperforms nonclassified based approach. Specifically, the energy consumption is reduced by 29.4%, end-to-end delay is improved by 41.6%, and average jitter is improved by 39.9%.

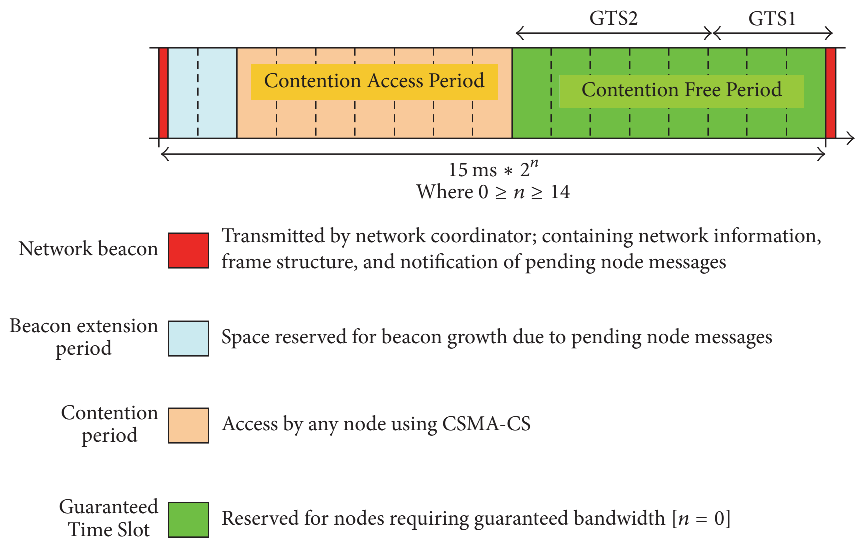

Figure 6: Superframe structure of IEEE 802.15.4 MAC [21].

Table 3: Comparison between classified based approach and nonclassified based approach.

(BO, SO)	Energy consumption		Average delay (S)		Average jitter (S)	
	Nonclassified based approach	Classified based approach	Nonclassified based approach	Classified based approach	Nonclassified based approach	Classified based approach
(1, 1)	5.430595	3.82021	0.080376	0.011147	0.016831	0.010891
(2, 1)	3.86659	2.970488	0.507429	0.05402	0.496642	0.048795
(2, 2)	4.414995	3.05634	0.007193	0.006783	0.00714	0.006717
(3, 1)	3.425723	2.57706	0.012856	0.012528	0.012565	0.012169
(3, 2)	3.41323	2.58846	0.353966	0.010849	0.340354	0.010489
(3, 3)	3.817103	2.72464	0.00779	0.006512	0.007687	0.006485
(4, 1)	3.299546	2.423932	0.126403	0.072692	0.125846	0.071958
(4, 2)	3.372698	2.506478	0.043967	0.019212	0.043512	0.018852
(4, 3)	3.362108	2.63793	0.019911	0.012546	0.013207	0.011956
(4, 4)	3.513385	2.446568	0.019227	0.01082	0.018857	0.010439
(5, 1)	3.423613	2.47945	3.631231	3.086479	3.630403	3.065488
(5, 2)	3.112943	2.325575	0.374811	0.119828	0.369399	0.11773
(5, 3)	3.045893	2.39331	0.3783	0.130883	0.374485	0.127778
(5, 4)	2.98724	2.355568	0.27799	0.13272	0.273567	0.129005
(5, 5)	3.479038	2.371425	1.311405	0.173336	1.311013	0.169969

The energy consumed for both classified and nonclassified based approaches, including various BO and SO values, is shown Figure 7. The classified based approach outperforms nonclassified based approach, as (1, 1) has the largest amount of energy consumption between (BO, SO) values, while (5, 4) has consumed the lowest amount of energy between (BO, SO) values. The rest of (BO, SO) values have the medium energy consumption values.

Figure 8 shows information about the average end-to-end delay for both classified and nonclassified based approaches, including various BO and SO values. We can notice that classified based approach outperforms nonclassified based approach, as (5, 1) has the largest amount of delay between (BO, SO) values, while (2, 2) has had the lowest amount of delay between (BO, SO) values. The rest of (BO, SO) values have the medium delay values.

Figure 9 shows information about the average jitter for both classified and nonclassified based approaches, including various BO and SO values. We can notice that classified based approach outperforms nonclassified based approach, as (5, 1) has the largest amount of jitter between (BO, SO) values, while (2, 2) has had the lowest amount of jitter between (BO, SO) values. The rest of (BO, SO) values have the medium jitter values.

5.3.2. By Changing the Number of Nodes. In this scenario, the number of nodes in each test is changed to examine the

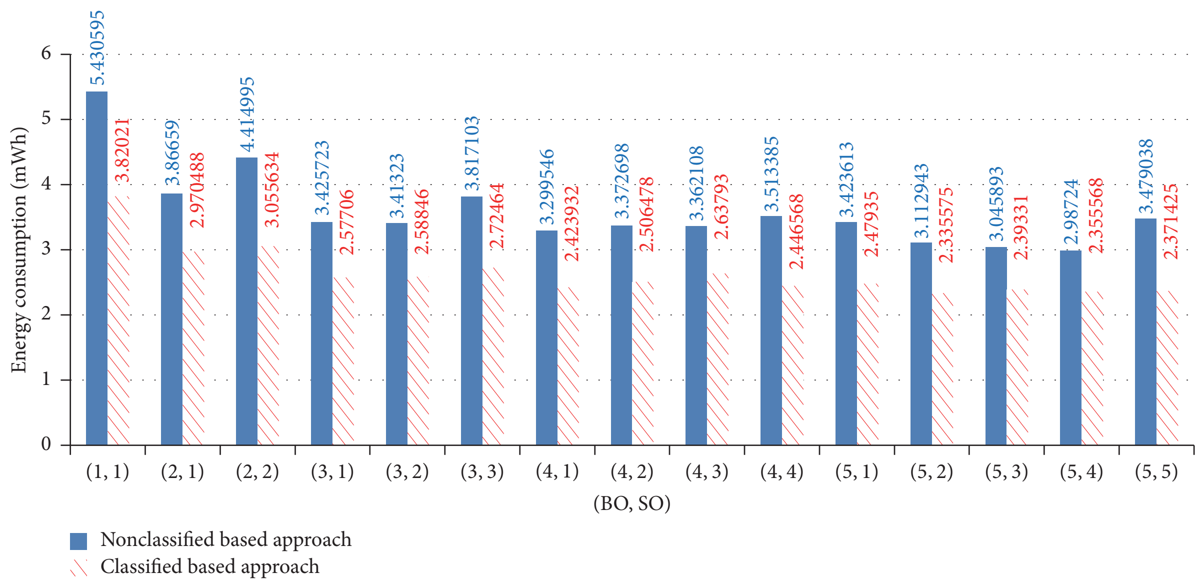

Figure 7: Classified based approach versus nonclassified based approach in terms of energy consumption for first scenario.

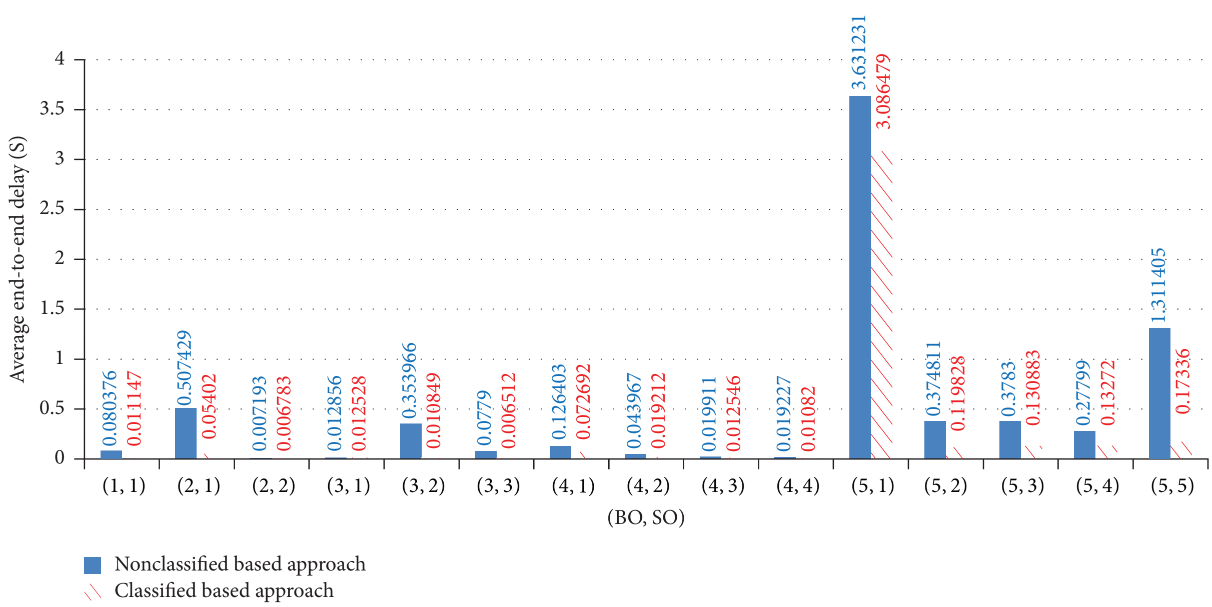

Figure 8: Classified based approach versus nonclassified based approach in terms of end-to-end delay for first scenario.

stability of the network and this is repeated 10 times to ensure the quality of results.

(1) GAN contains seven nodes which are used to send the data to single router; after that, router resends the data to one gateway.

(2) GAN contains 14 nodes to send the data to two routers; after that, routers resend the data to one gateway.

(3) GAN contains 21 nodes to send the data to three routers; after that, routers resend the data to one gateway.

Figure 10 shows information about the energy consumed for both classified and nonclassified based approaches under the condition of changing the number of nodes (from 7 nodes, through 14 nodes, to 21 nodes). We can notice that the classified based approach consumed less power than nonclassified based approach in the different conditions.

Figure 11 shows information about the average end-to-end delay for both classified and nonclassified based approaches under the condition of changing the number of nodes (from 7 nodes, through 14 nodes, to 21 nodes). We can notice that the classified based approach has less delay than nonclassified based approach in the different conditions.

Figure 12 shows information about the average jitter for both classified and nonclassified based approaches under

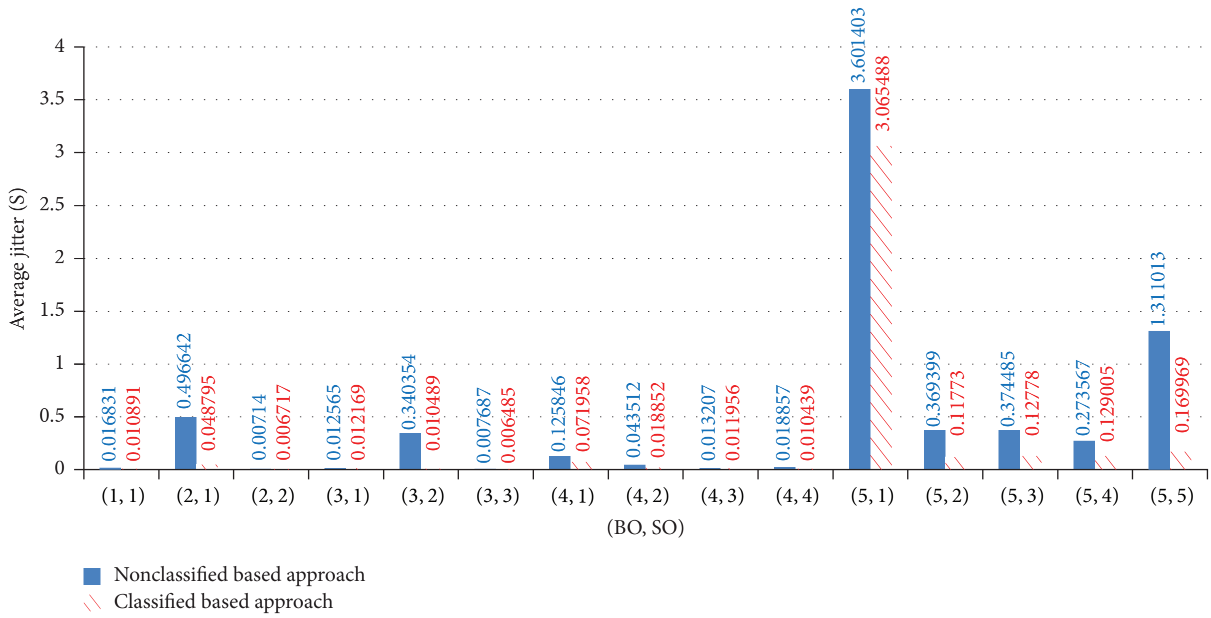

FIGURE 9: Classified based approach versus nonclassified based approach in terms of average jitter for first scenario.

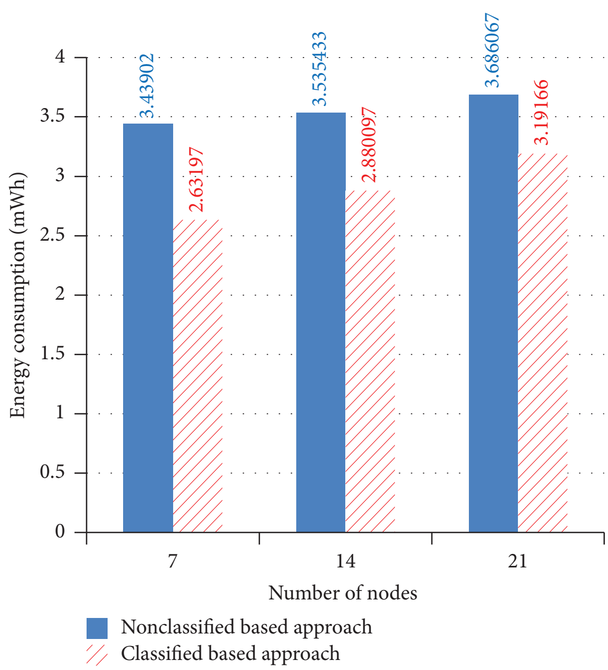

FIGURE 10: Classified based approach versus nonclassified based approach in terms of energy consumption for second scenario.

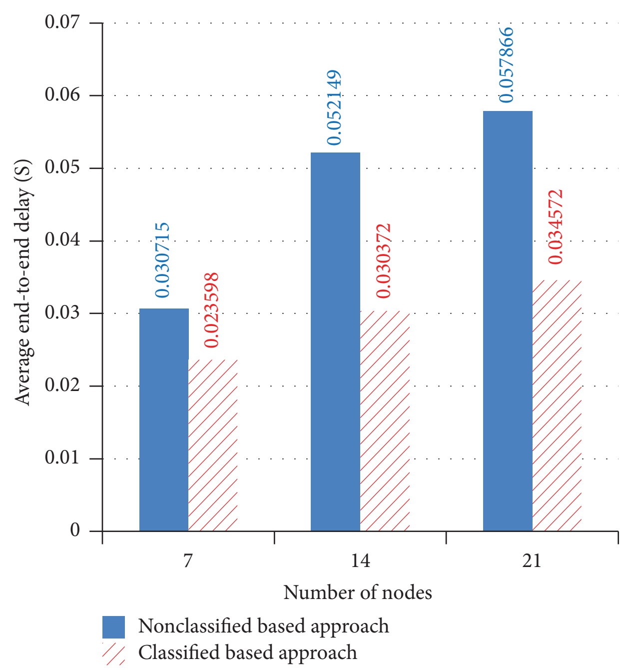

FIGURE 11: Classified based approach versus nonclassified based approach in terms of end-to-end delay for second scenario.

the condition of changing the number of nodes (from 7 nodes, through 14 nodes, to 21 nodes). We can notice that the classified based approach has less average jitter than nonclassified based approach in the different conditions.

6. Discussion

The nature of cultivation in agriculture areas is based on wide area of crop deployments. The traditional agriculture monitoring network operates on dense network by forming multihop network to cover a large area and connect the greenhouses with control center. However, WAMN suffers from energy consumption and packet collision as all the nodes continuously monitor the crops. In case of dropped messages, retransmission can cause more energy consumption and higher delays. Therefore, we proposed a classified based approach to reduce energy consumption and network

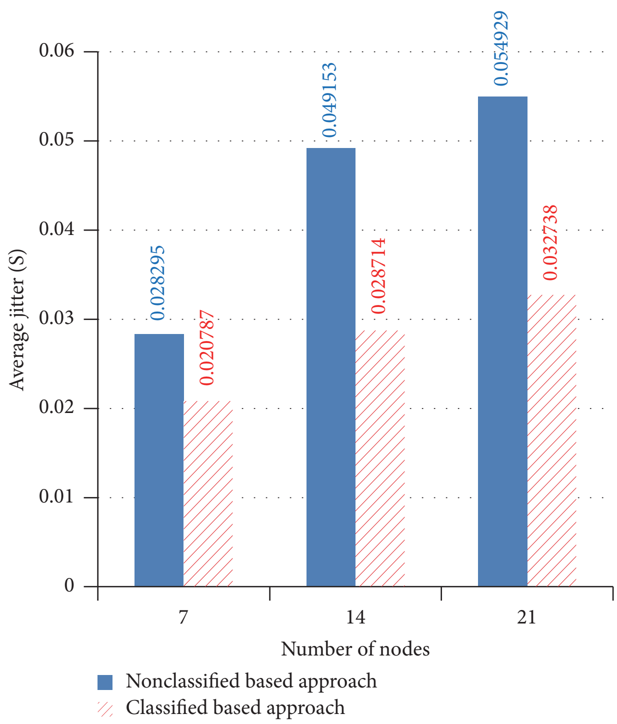

Figure 12: Classified based approach versus nonclassified based approach in terms of average jitter for second scenario.

delay in WAMN. Our approach selects a set of sensors in the network according to the sensitivity of the crops. The sensitivity is calculated by measuring the difference between optimal temperature of the crops and actual temperature (environment temperature). Additionally, we proposed a multilayer architecture network model that enables the lands to be controlled and monitored remotely. The proposed approach is compared with nonclassified based approach in two scenarios by changing the backoff periods and the number of nodes in first and second scenarios, respectively. The simulation results indicate that the proposed classified based approach outperforms nonclassified based approach by reducing energy consumption by 29.4%, improving end-to-end delay by 41.6% and average jitter by 39.9%.

7. Conclusion

From literature review, most researchers focus on building agricultural monitoring network, but the quality of services and stability of the network are ignored. Furthermore, the prior works monitor all crops equally without classifying. This consumes more battery power and reduces the life time of the network. Additionally, the prior works are untested in large scale agriculture monitoring network.

In this paper, we proposed a classified based approach for large scale agriculture monitoring network. We examine the factors affecting the QoS of the proposed approach such as energy consumption and end-to-end delay. Our findings demonstrate that utilizing a set of sensors rather than all the sensors in the network reduced the power consumption and delay. This provides a high quality of services for the agriculture monitoring network. Furthermore, the proposed approach improves the traditional approach by 29.4% for average energy consumption, 41.6% for an average end-to-end delay, and 39.9% for average jitter.

In future, we will apply the proposed approach in real-life agricultural monitoring network through integration with cloud computing to facilitate monitoring, accessibility, and the process of storing the data.

Disclosure

The work was deduced from Hisham's Ph.D. thesis as Dr. Ismail Ahmedy and Dr. Mohd Yamani Idna Idris supervised him along his study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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