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Secure and Efficient Bandwidth Allocation Algorithm for Intelligent Home Networks

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Abstract: It has been observed that the “Internet of Things” is causing a significant shift in the environments of “information technology” (IT). As a result, its significance has also been recognised, and it has played an essential part in the development of “intelligent home networks” (IHNs). The Internet of Things (IoT) is responsible for establishing a link between things and the Internet. This connection is established via the utilisation of various sensing devices to implement intelligence that is responsible for the identification and administration of connected objects. In order to carry out their day-to-day activities, IHNs make use of intelligent systems. In the meanwhile, these networks provide users and devices with comfort, safety, healthcare, automation, energy saving, and remote management capabilities. In addition to that, these networks provide support in self-healing procedures for a variety of issues, including reconfigurations, power outages, and defects. Nevertheless, we have come to the realisation that these networks continue to see the introduction and use of an increasing number of sophisticated devices and services. Consequently, this has resulted in rivalry for the limited resources, services, and bandwidth that are accessible on the network. Consequently, in this research, we describe “the design and implementation of a Novel Dynamic Bandwidth Allocation (NoDBA) method in order to address the performance bottleneck that is associated with IHNs. The method that has been presented addresses the management of bandwidth as well as the allocation of bandwidth. This research incorporates two algorithms, namely the Offline Cooperative method (OCA) and the Particle Swarm Optimisation (PSO), into the suggested method in order to enhance the Quality of Service (QoS). In the network, PSO is responsible for defining the priority limits for both subnets and nodes. While this is going on, OCA makes it easier to dynamically allocate bandwidth inside the network. For the purpose of simulating and evaluating the NoDBA, the Network Simulator-2 (NS-2) was used, and the results that it produced were superior to those that were achieved by the conventional bandwidth allocation methods.” When compared to “Dynamic QoS-aware Bandwidth Allocation” (DQBA) and “Data-Driven Allocation” (DDA), the findings that were obtained demonstrate an average throughput of 92%, an average latency of 0.8 seconds, and a reduction in energy usage of 95%.

Keywords: *Internet of Things (IoT), Intelligent Home Networks (IHNs), Dynamic Bandwidth Allocation (NoDBA), Quality of Service (QoS), Bandwidth Management.*

1. Introduction

Internet of Things (IoT) has been the driving force behind a huge revolution that has taken place inside the Information Technology (IT) industry over the most recent period of time. IoT, which stands for the Internet of Things, is the technology that is responsible for establishing a connection between physical objects and the internet. “The establishment of this link is accomplished by the utilization of a variety of sensing devices in order to integrate intelligence that is accountable for the identification and management of connecting objects. Radio Frequency Identification Devices (RFID), infrared sensors, the Global Positioning System (GPS), laser scanning devices, and many others are examples of the many different types of information sensing devices that are available. Each of these devices is connected to the Internet in order to ensure that they are able to achieve remote perception and control. Because of this, the growth of computer networks has taken place, and as a result of this, there has been a continual requirement to have these sensing devices in any environment whatsoever. The communication between the various devices is further facilitated as a result of this, which enables them to share the resources and services that are present on the network. Networks that are known as Intelligent Home Networks (IHNs) have been formed as a result of the requirement for communication between these devices throughout the course of the past few years. This need has led to the joining of home gadgets, which has resulted in the construction of networks. Comfort, safety, healthcare, automation, energy saving, and remote management are all supplied to the devices and users that are included within an IHN, and it is guaranteed that they will have access to these features.

The use of intelligent systems is something that IHNs do in order to carry out their day-to-day operations. There are a multitude of other benefits that come along with the utilization of intelligent systems in IHNs, in addition to the fact that they assist in the process of self-healing for flaws, power outages, reconfigurations, and other problems. These networks may also be accessed and controlled either locally or remotely, which makes it possible to monitor, schedule, and control a wide variety of users and equipment. In addition, these networks can be accessed and managed over the internet. Integrated Home Networks (IHNs) are composed of sub-networks, which are also referred to as subnets, in their most fundamental form. WLAN (Wireless Fidelity), ZigBee, Smart Grid, Bluetooth, Body Area, Ultra Wide Band (UWB), and other types of networks are all examples of subnets. According to the workflow protocols that each subnet adheres to, this inquiry has attributed differing degrees of significance to the numerous subnets that are included in its scope. The devices that are a part of each subnet are connected to Sub Network Gateways, which are also referred to as SNGs. This is done in order to make it easier for devices to communicate with one another over long distances. For the purpose of connecting to the internet, SNGs, on the other hand, are connected to Home Network Gateways (HNGs). HNGs are the ones who are responsible for facilitating this connection, and it is their responsibility to integrate IHNs with other networks, such as the Internet and other networks.

However, it has been brought to the attention of a certain individual that these environments continue to witness the development and utilization of more advanced devices and services. Internet of Things networks (IHNs) are also being significantly impacted by the ongoing shift from Internet Protocol version 4 (IPv4) to IPv6 standards. This change is taking place across the globe. As a result of this, there has been an increase in the number of congestion issues that have developed as a consequence of this. In addition to this, the introduction of increasingly complex devices and network resources into these networks has also played a role in doing so. When additional devices are added to the network, competition arises for the limited resources and services that are available on the network, as well as for the bandwidth that is available. This is a negative aspect of the situation. These networks, on the other hand, continue to endure and suffer from poor Quality of Service (QoS) while carrying out activities both domestically and worldwide. The bandwidth that is available to users of these networks is not only inconsistent and wasteful by design, but it is also unavailable because of the low quality of service that is provided." The results of the research that was carried out in indicate that effective algorithms for resource allocation are necessary for the management of bandwidth. Both the quality of service (QoS) and the requirements of each individual customer are taken into consideration when this action is taken.

Consequently, during the course of this investigation, we provide an enhanced method for the administration and distribution of bandwidth for IHNs. The Novel Dynamic Bandwidth Allocation (NoDBA) algorithm is the name given to this system of computation. Due to the fact that none of the earlier research has taken into account the prospect of developing bandwidth management and allocation algorithms for IHNs, this is the primary reason why this is the case. We also came to the conclusion that the algorithms that are currently being utilized for the distribution of bandwidth were initially developed for wireless networks, such as Wireless Mesh Networks (WMNs) and other sorts of networks. This was a realization that we came to. In order to determine how much bandwidth is available, the method that has been developed takes into account the workflow procedures that are specific to each subnet that is part of the IHN. There is a workflow that the algorithm is accountable for, and it ensures that the bandwidth that is allocated to each subnet is decided by that workflow. Subnets that have workflow operations that are more extensive than those of other subnets are given a higher priority and are provided with more bandwidth than the other subnets. This is because of the fact that. Particle Swarm Optimisation (PSO) and Offline Cooperative strategy (OCA) are two optimisation approaches that are incorporated into the suggested strategy. As a result, the suggested approach integrates both of these techniques. At the core of OCA's solution to any bandwidth allocation dilemma is the game-theoretical framework, which serves as the basis. Taking this into consideration, the solution that has been proposed is one that is capable of performing the dynamic distribution of bandwidth along the network. PSO is the one that is accountable for defining the priority limits for each and every subnet and node in the network. This is in contrast to the previous statement.

With the assistance of" Network Simulator-2 (NS-2), simulation, testing, and assessment of the process that was suggested were carried out. During the experimental evaluation of the proposed technique, two algorithms were utilized. These algorithms were Dynamic QoS-aware Bandwidth Allocation (DQBA), which was proposed and developed in, and Data-Driven Allocation (DDA), which was created in. Both of these algorithms were utilized. An instrument for the modeling of discrete-event networks that was meant to replicate network behavior was developed by the Virtual Inter-Network Testbed (VINT) research group at the University of California. This instrument is known as NS-2. According to the findings of the simulation, the NoDBA algorithm appeared to reduce the amount of congestions. Additionally, it appeared to make better use of the bandwidth that was available. In light of this, it appeared that NoDBA was able to increase throughput while concurrently lowering energy consumption and delay, in contrast to DQBA and DDA."

Taking into consideration the other components of this work, they are structured in the following manner. An in-depth analysis of the works that are connected will be presented in the second half of this work. You can find Section 3, which provides an overview of the PSO and OCA algorithms, by clicking on this link. The system design and architecture of the IHNs that could be implemented are discussed in Section 4, which is the fourth section of the report. Finally, in Section 5, we take a look at how the proposed model was put into action and evaluate the results that were obtained. In addition, we present the results of the actions that were taken. This research is brought to a close in the final section, when we conduct an investigation into the possibilities of future enhancements.

2. Related Work

Over the course of "the past several years, a substantial amount of research has been published on the subject of dynamic bandwidth allocation. As a consequence of this, a variety of approaches have been presented and developed as a result of this research. On the other hand, the vast majority of these algorithms have been developed for wireless networks, which includes Wireless Mesh Networks (WMNs) as well as other kinds of networks. In the meantime, traditional algorithms that have been developed in recent times have been made available for Mobile Ad hoc Networks (MANETs). The utilization of energy and the transmission of the message through dissemination have been given a greater amount of importance, in addition to the aforementioned." The majority of classical algorithms employ flooding methods during the entire process of message transmission, which is the primary reason why this is the case. Dedicated servers are not available on MANETs, which is the reason for this. In the majority of cases, flooding tactics are responsible for the accumulation of network overhead, as was stated in the previous sentence. On the other hand, flooding strategies require a substantial amount of bandwidth, processing resources, and battery resources in order to successfully operate the system.

Within the following section, we will investigate the numerous bandwidth allocation mechanisms that are already being utilized for Internet of Things networks. Subsequent to this, we will proceed to discuss the various flaws that are inherent in these algorithms.

Dynamic Load Balancing, often known as DLB, is the name of the algorithm that was developed to improve quality of service (QoS) while concurrently providing mobility management to the home networks of the future generation. This technique appeared to have a good responsiveness to changes in the network, regardless of whether the changes were brought about by connection failures or by the mobility of nodes in home networks when they happened. This method, which incorporated the Langrangian Relaxation algorithm, the Dijkstra algorithm, and Column Generation, was utilized in order to accomplish the goal of achieving a steady load balancing. Using these algorithms allowed for the establishment of the Inter MAC layer as well as its utilization, which was made possible by the integration of them. "For the purpose of determining the shortest path for signals that needed to travel between their origins and their destinations, the Dijkstra algorithm was utilized. In addition to ensuring that the amount of bandwidth that was consumed was kept to a minimum, this also helped to reduce the amount of latency that was experienced. It should be noted, on the other hand, that the sessions that were aggregated and utilized by the system were those that shared the same source, destination, and level of service quality. While this was going on, Column Generation was utilized in order to address the challenges associated with linear programming variables, which led to situations of recurrence. This algorithm was able to enable efficient utilization of the network by way of the utilization of link capacity, the mobility of users, and a reduction in latency. However, in contrast to the methods that were previously utilized, NoDBA made use of the VLAN protocol in order to classify subnets, prioritize, and schedule the services that were offered by the network. This was done in order to enhance the efficiency of the network.

The development of an algorithm for prioritising schedules took place within the framework of real-time application systems. On the other hand, the algorithm was in charge of scheduling procedures and assigning a priority level to each individual operation. This resulted in processes with a lower priority having a longer waiting and reaction time within the algorithm. As a consequence of this, the processes with a higher priority that were coming frequently disrupted the processes with a lower priority. Processes that have a higher priority experience the least amount of waiting time and packet loss in contrast to activities that have a lower priority." This is because of the fact that higher priority processes are more efficient. Taking into account the classification and prioritization of processes, which are services and resources that are supplied by the network, this technique acts in a manner that is comparable to that of NoDBA. This is because it also takes into consideration the classification of processes. In contrast, NoDBA makes use of DSCP in order to handle the categorization, prioritization, and scheduling of subnets throughout the whole network. This is accomplished through the usage of

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these protocols. The delay period of packet transmission between nodes in the network was decreased as a result of this action, which alleviated hunger and ensured that the performance of intelligent home networks was optimized. This was the case regardless of the increase in the number of devices and services that were included into the network.

During the implementation of a quality of service harmonization mechanism, it was employed in a home network. For the purpose of this method, a communication protocol that was constructed on classes was utilized. The algorithm was developed with the intention of assisting in the differentiation of priorities in the third and second layers. This was the original purpose of the algorithm. DSCP was utilized in a manner that was analogous to the previous method in order to adjust the signal statuses, priority levels, and protocol Identification (ID) of classified and marked packets in layer three. This methodology was able to go from standardization to harmonisation. It was with the goal of recovering DSCP values from the mapping table, which was situated in the second layer, that the IDs were generated. Because of this, the bandwidth allocation of the network was optimized to a larger extent than it had been before. OCA, on the other hand, was utilized by NoDBA in order to deal with the installation of dynamic bandwidth allocation. The fact that there has been an increase in the number of devices and services does not prevent us from being able to obtain a quality of service (QoS) that is optimized in home networks.

In contrast, we have come to the conclusion that the field of computer networks has been the topic of a number of distinct routing protocols that have been established. These protocols have been developed across different time periods. Notwithstanding this, the vast majority of the protocols that are currently in use were, in reality, constructed and developed for certain computer networks in terms of the scale of those networks. These routing protocols have a number of objectives, one of the most essential of which is to find the shortest distances that are possible between the nodes that constitute the source and the nodes that constitute the destination.

The researchers conducted a number of experimental evaluations of "the performance of a variety of routing protocols, such as Link State Routing (LSR), Dynamic Source Routing (DSR), Ad hoc On-demand Distance Vector (AODV), and the various swarm intelligence routing protocols. These evaluations were included in the report. In accordance with the objective, which was to evaluate the effectiveness of a number of different routing protocols in Vehicular Ad hoc Networks (VANETs), this objective was realized through the utilization of extensive simulation testing. For the purpose of carrying out an efficient investigation into these protocols, the most significant aspects that were taken into consideration were performance metrics such as throughput, latency, delivery ratio, and delivery cost." When all was said and done, these researchers arrived at the conclusion that the performance of swarm intelligence routing protocols is significantly superior to that of traditional protocols such as LSR, AOD, and DSR. Furthermore, the researchers have demonstrated that swarm intelligence routing protocols frequently exhibit superior performance in comparison to traditional MANET routing protocols.

3.Cooperative Algorithms for Offline Use and Particle Swarm Optimization

PSO and OCA algorithms that are combined are the topic of discussion in this portion of the research. The standard quality of service (QoS) and dynamical bandwidth allocation techniques for IHNs were combined with these two algorithms in order to eliminate the different gaps that were present in those algorithms. Additionally, we give views on the advantages and disadvantages of the two combined algorithms that we have developed.

3.1. Particle Swarm Optimization

According to the findings of the study that has been conducted on optimisation algorithms, the PSO approach is the one that is acknowledged as having the best level of reliability. According to the findings of the research that were carried out, PSO was discovered to be the most up-to-date and significant approach for dealing with optimization in networking environments. This method was initially presented with the intention of resolving optimization problems in continuous nonlinear functions, and it was subsequently altered to get the desired results. Using this approach, which is a stochastic process by its very nature, one may model the navigation and formation of a school of fish or a flock of birds. When utilizing this approach, each and every solution to a particular problem is handled as a particle within the framework of the procedure. This programme was designed with the intention of simulating three distinct behaviors that flocks display when they are in a swarm. (i) Cohesion, which takes place when birds remain in close proximity to one another. (ii) Separation, which occurs when birds do not engage in close vicinity to one another and do not approach one another. (iii) Alignment, which is a phenomenon in which every single flock that makes up a swarm moves in the same general direction as the flock that is leading it. "This algorithm, on the other hand, is stated to simulate the process of searching randomly across the design space in order to obtain the maximum potential value of the goal, according to the research that was carried out in. An additional remark that was made by the study revealed that it was implemented on two separate paradigms, specifically one that was globally oriented (GBEST) and one that was locally focused

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(LBEST). The fact that PSO has been implemented in a wide range of fields, including those in the scientific and industrial sectors, is the most significant benefit that it possesses." We utilized this strategy in order to deal with the categorization of relay and child nodes on the network, as well as to assign varied degrees of priority to each of these categories. This inquiry was carried out for the aim of determining the nature of the network.

3.2 Offline Cooperative Algorithm

The OCA was conceived of and designed by Guo et al. (2016), who did so on the basis of the game-theoretical framework that they had developed. Specifically, "the technique that has been described is an attempt to solve the problem of bandwidth allocation within the framework of datacenter networking infrastructures. It was two intriguing outcomes that were explored in regard to the bargaining game technique that led to the development of the concept that drives this algorithm. The following is a list of these outcomes: There are two types of variables: (i) dual variables, in which each server is able to be updated independently with local information; and (ii) iteration of each rate, which requires the bandwidth information of the hosting servers. The inquiry's findings also indicated that the two techniques served as the impetus for the development of Falloc, which was meant to attain the optimal rate by utilizing a distributed cooperative approach. This realization was made possible by the findings of the investigation. The game-theoretical framework is the foundation upon which this algorithm is built in order to handle any bandwidth allocation problem." In order to deal with the dynamic allocation of bandwidth in the IHNs, we have utilized this method for the purpose of this study where we are carrying out the investigation.

4. Revolutionary Dynamic Bandwidth Method

In this section, we will offer a short discussion on the suggested system architectures, and we will also describe how the combination of PSO and OCA was helpful in the design of the proposed NoDBA. On the other hand, we talk about the different components of the system that were utilised to develop it, as well as the configurations that were done while creating the suggested network. We also explain the setup of each device and its connection to the network, which was done in order to optimise the network by taking into consideration the dynamic distribution of internet bandwidth.

4.1. System Architecture

Over the course of the last several years, it has come to light that the proliferation of home devices results in an increase in the amount of traffic, competition, and the exhaustion of the limited resources available on the network. The quality of service on IHNs suffers as a consequence of this. Consequently, we suggested that we make use of the system architecture that was developed through.

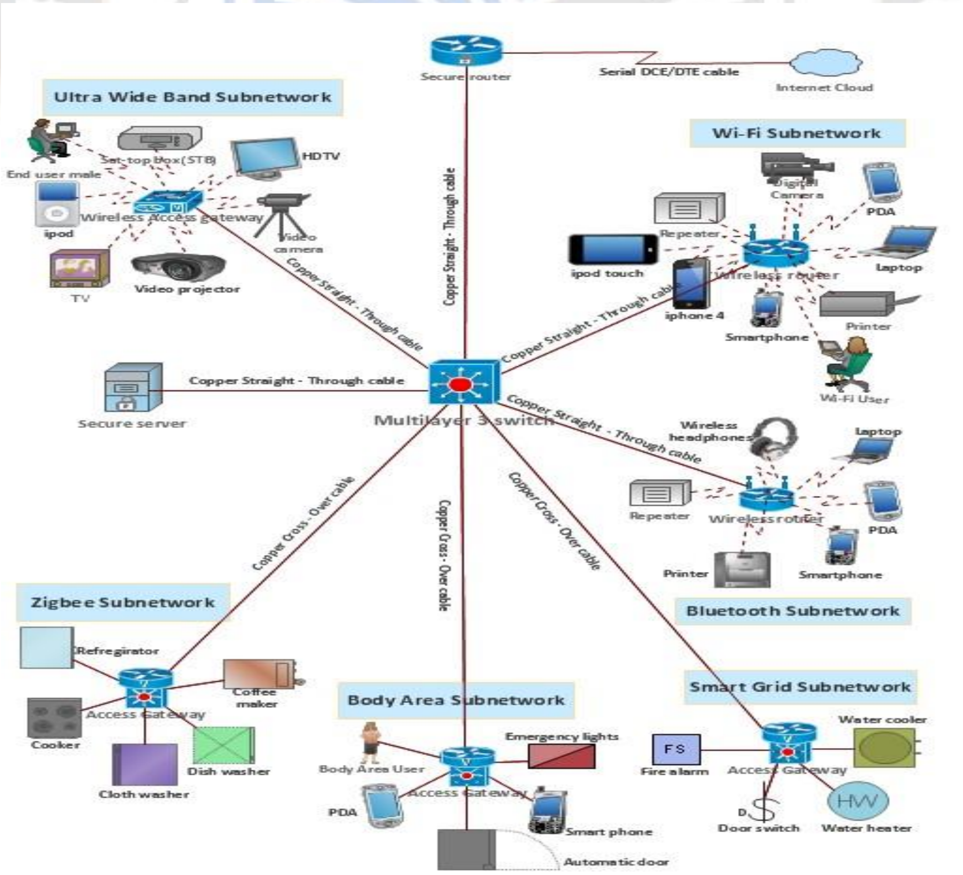

Figure 1.A standard design for an IHN system was suggested in

It is advised that the architecture be designed in the form of a star topology, as depicted in Figure 1, in order to guarantee that administration and configurations are centralized. Specifically, the suggested architecture is comprised of six subnets that are divided. In addition to the Smart Grid subnetworks on the list, these subnetworks consist of UWB, Wi-Fi, ZigBee, Body Area, and Bluetooth. The segmentation of these subnets encourages prioritization, which in turn guarantees that the limited resources and services that are available are allocated in an appropriate manner. This is accomplished through the utilization of the subnets.

As can be seen in Figure 1, quite a few distinct components were brought together in the course of the process of putting together the suggested design for the IHN. "There is a Multi-Layer 3 switch that is configured as HNG in the design that has been provided to the viewers. Some of the most recent varieties of Multi-Layer 3 switches that are available are the SG500-28P, the NETGEAR M4100, the Cisco SG300 series, the Cisco 3650, 4500, and 6500, and the Cisco 3650. Some of the advantages of this switch include the following: it is able to manage a substantial volume of traffic, it allows for the routing and prioritisation of virtual local area networks (VLANs), it enables hardware-based packet switching, and it prioritises packets by six bits in IP DSCP communications. It is responsible for the implementation of the Quality of Service DiffServe service, on the other hand. This particular type of switch is also capable of performing the duties of a server for the VLAN Trunking Protocol (VTP), which is an acronym for virtual local area network. This has led to its utilization in the process of defining the bandwidth capacity of ports and in the administration of the allocation of interfaces to various SNGs from the HNG. As a consequence of this, it has been utilized. Additionally, it has been configured to make use of seven virtual local area networks (VLANs) at the HNG through the usage of this configuration. Based on the priorities that were established in the past, the Virtual Local Area Networks (VLANs) 60, 50, 40, 30, 20, and 10 have been assigned to their respective subnets. VLAN 100 has been assigned to it for the purpose of administering the network while this is going on. Due to the fact that we have Layer 2 switches that are configured to function as VTP clients, we have delegated the job of managing these switches to the SNGs. Layer 2 switches that have recently become available on the market include the DES – 3200 series, the S3100 series, the S3610 series, and other series. These are some of the most recent releases. Single Network Gateways (SNGs) have been verified to possess VLAN numbers and names, which considerably simplifies the process of identification. Conversely, we have utilized the Dynamic Host Control Protocol (DHCP) pool in order to dynamically allocate IP addresses to devices that are a member of subnets." This has allowed us to accomplish this. This results in an even greater reduction in the amount of direct participation that users have in the process of assigning IP numbers. In the meantime, we have enabled Linksys wireless routers to function as SNGs by establishing wireless subnets. With the purpose of contributing to the authentication and authorization of users who are intended to use Linksys routers, the routers are branded with the names of subnetworks and are provided with passwords. This can be seen in Figure 1. One of the benefits of this is that it helps to increase network security while also reducing the amount of bandwidth that is wasted on the network. In order to simplify connectivity to the rest of the network as well as to distant locations, individual Internet Protocol (IP) addresses have been assigned to the internet interfaces of the Linksys wireless routers. This move was made in order to facilitate connectivity.

For the purpose of enabling wireless subnets to support static IP addresses, we have enabled Dynamic Host Configuration Protocol (DHCP) within the network and established static IP addresses. More devices can be added to the subnets as a result of this, which makes it possible to do so. Databases, emails, configurations, management, and security are only some of the resources that can be stored on the secure server, which is designed to host a wide range of resources. The provision of IHN services, resources, and operations in a timely way and with availability is made feasible as a result of this being the case. There is no difference between the Web server's Internet Protocol (IP) address and its Domain Name System (DNS) address. Devices take advantage of it in order to provide themselves with access to the resources of the server. We were able to establish a connection from a distance by utilizing both a Secure Router and a Virtual Private Network (VPN). Moreover, the secure router is able to establish connections to remote sites by utilizing Internet Service Providers (ISP) or Digital Subscriber Lines (DSL). This facilitates the establishment of connections. The VLAN database of the secure router is established using the names and numbers of the VLANs that have been formally assigned. This is done in order to identify and prioritise incoming signals from faraway locations. The secure router is equipped with a single gateway that makes it possible to manage traffic coming from and/or going to virtual local area networks (VLANs).

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4.2. System Modelling

The service discovery model that we have described, which contains both PSO and OCA algorithms, will be the topic of discussion in this section. In order to avoid the numerous gaps that are found in the dynamic bandwidth allocation strategies that are currently being utilized for IHNs, these two algorithms that are inspired by behavioral patterns are utilized.

In order to put the proposed model into action, the researcher has utilized a directed graph, which is a tree with the equation T = (V,E) as its representation. This graph has been employed to describe the network. In this paradigm, the set of nodes in the network is denoted by the letter V, while the set of connections contained within the network is denoted by the letter E. Because of this, the value of V is equal to (v1,v2,...,vn), while the value of E is equal to (e1,e2,...em,). However, let n V function as wired and wireless nodes, respectively, on the other side of the equation. Let's say that the number of wired or wireless connections for each link is equal to one, which is equal to (s,n,t). In addition, the method makes it possible to differentiate between three various types of nodes that are contained within the network and gives each of these nodes a particular collection of responsibilities. i) the root node, ii) the relay node, and iii) the child node are the three categories that are utilized in the process of determining the nodes. A one-of-a-kind node known as the root node is the node that is accountable for the coordination of the network as a whole through its role as the root node. It is responsible for performing the duties of gateway nodes within the network. The relay node, on the other hand, is the one that is accountable for accepting requests from the outside world and then sending them on to the child nodes. In addition, each relay node communicates with the root node that it is connected to in order to transmit a request to join a corresponding node. The assignment of dynamic slots is the responsibility of these nodes, and it is carried out once they have received the traffic requests from their child nodes. Every single child node is connected to exactly one other connection that is always located next to it. Kid nodes are the endpoints of the network, and they are accountable for carrying out the functions of receiving control packets, producing node join requests, and supplying bandwidth needs to their parent nodes. It is also their responsibility to ensure that the network is functioning properly. Based on the findings shown in Figure 1, we arrived at the conclusion that the proposed IHN ought to be logically partitioned into clusters that consist of a single hop. Consequently, the clusters exhibit a parent-child link and behave in the same manner as a result of this. Consequently, as a consequence of this, we have put into action the process of optimizing relay nodes in order to alleviate the bottleneck that is present in relation to the allocation of bandwidth. In addition, we introduced the Offline Cooperative Algorithm (OCA) in order to alleviate the bottleneck that was happening in the network's bandwidth distribution. This was done in order to ease the bottleneck.

In order to classify and rank the relay nodes in order of importance, the Particle Swarm Optimisation (PSO) technique is utilized, as demonstrated in Figure 1. Those nodes that are relayed are represented by the letter s in the network. To get started with the model, we will first specify priority limits for each relay node, as indicated in (1). This will allow us to get started with the model.

$$X_s^L \le X_s \le \ldots \le X_s^H \forall_s \quad s = 1,2,3,..6 \; X_s \in R \tag{1}$$

In which X is a representation of the priority that is assigned to each relay node according to the workflow protocols. L denotes the relay node with the lowest priority for the relay. A relay node with the highest priority is denoted by the letter H. The value of R indicates that the priority assigned to each subnet is accurate.

The priority of relay nodes is thus predetermined by us, as seen in the following:

If $\min s \in \{1,2,\ldots 6\} = 1$

Relay node 1 becomes least prioritized.

Else if $\max s \in \{1,2,\ldots 6\} = 6$

Relay node 6 becomes the highest prioritized.

Since every relay node, denoted by the letter s, has child nodes contained inside it. In accordance with equation (1), we rank and schedule each child node, denoted by the letter *d*, that is part of the subnets by making use of the weighted factor numbers given in (2):

$$X_d^L \le X_s \le \ldots \le X_d^H \forall_d \quad d = 1,2,3,\ldots\infty X_d \in R \tag{2}$$

In this sentence, *X* stands for the priority that is assigned to each child node. Within a relay node, the letter *L* denotes the child node that has the lowest priority. The child node in a relay that has the greatest priority is denoted by the letter *s*. The value of *R* indicates that the priority that is assigned to each child node in the relay node is accurate. In light of this, we use the following method to predetermine the precedence of child nodes:

If $\min d \in \{1.2.3\ldots\infty\} = 1$

Child node 1becomes the highest prioritized.

$$\text{If } \max d \in \{1.2.3...\infty\} = \infty$$

Child node ∞ becomes least prioritized.

The equation (1) was used in order to correctly calculate the total bandwidth, b, that was utilised in the network. In addition, the bandwidth for relay nodes was summed up as shown in (3):

$$b_6 + b_5 + b_4 + b_3 + b_2 + b_1 = \sum_{i=1}^{n} b_i$$

It has been brought to everyone's attention that not every packet will be able to be successfully broadcast across the network. As a result, we calculate the packet loss using the formula provided in (4).

$$packetloss = \left\{ \frac{\sum_{t_1}^{t_n} dropped\, packet}{\sum_{t_1}^{t_n} sent\, packet} \right\} * 100$$

The time t1 represents the initial dispatch time of the first packet in each child node, and the time tn represents the time at which the final packet in each child node is also dispatched. Both of these times are reflected in the variable that is being discussed. To properly execute the suggested NoDBA algorithm in IHNs, as was described in section 1, we utilized OCA to dynamically enforce rate allocation depending on the necessary traffic demand of each node. This was done in order to ensure that the algorithm was successfully implemented. Our ability to successfully develop these methods was made possible by this. Specifically, the architecture of this method is comprised of two components: the algorithm for distributing bandwidth on each server, and the communication protocols between servers, as demonstrated in the algorithm that is described below:

Algorithm: **Offline Cooperative Algorithm (OCA)**

Input:
The step-size: ξ
Server bandwidth capacity: $C_m, \forall m \in M$
Bandwidth demand matrix: $[D_{i,j}] N \times N, \forall_m \in M, \forall_i \in N$
VM placement: $[W_{m,i}] M \times N, \forall_m \in M, \forall_i \in N$
The total number of iteration rounds: S
The gap between two consecutive iterations: Δ
Output:
1: **while** $s < S$ or $r_{i,j}^{(s)} - r_{i,j}^{s-1} > \Delta$ **do**
2: Update allocated bandwidth
$r_{pm}^{E} = \sum_i W_{m,i} r_i^E, r_{pm}^{I} = \sum_i W_{m,i} r_i^I$
3: Update dual variables as (3)
$\lambda_m^E = \max(0, \lambda_m^E - \xi(C_m - r_{P_m}^E))$
$\lambda_m^I = \max(0, \lambda_m^I - \xi(C_m - r_{P_m}^I))$
4: **for all** $r_{i,j}, i \in V_m$ **do**
5: Update $\lambda^E = \lambda_m^E$
6: Obtain $\lambda^I = \lambda_l^I$ from server $I, j \in V_l$
7: **if** $\frac{K_{i,j}}{\lambda^E + \lambda^I} > U_{i,j} - L_{i,j}$ **then**
8: $r_{i,j}^{(s)} + U_{i,j}$
9: **else**
10: $r_{i,j}^{(s)} = L_{i,j} + \frac{K_{i,j}}{\lambda^E + \lambda^I}$
11: **end if**
12: **end for**
13: Update step-size: ξ
14: Update iteration round: $s + s = 1$
15: **end while**

5. Dynamic Bandwidth Allocation Method Deployment

In this section, we will discuss the execution of the anticipated NoDBA and the manner in which it would be carried out. This stage of the procedure encompasses not just the simulation environment but also the process of developing the topology that has been suggested. In addition, we discuss and analyze the results of the simulation that we ran. A number of performance characteristics were investigated throughout the duration of the simulation. These indicators included service discovery throughput, service availability, service selection, and service discovery latency. In the process of service discovery in WMNs, the metrics that were discussed above were chosen because they are significant characteristics that have an impact on the quality of service throughout the process.

5.1. Simulation Environment

Within the scope of this investigation, we used NS-2 Version 2.35 (NS-2.35) to carry out the simulations. One advantage of NS-2 is that it includes models such as IEEE 802_11b/g, in addition to other models. This tool, on the other hand, is a free source simulation environment, and as a result, it is freely accessible on the internet. This is the reason why we decided to use it. Aside from that, it offers compatibility with a variety of operating systems. Users are able to assist one another with a variety of networking initiatives via the usage of an online user group chat that is integrated into the platform. Figure 2 depicts the simulation topology that we designed as part of our proposed simulation.

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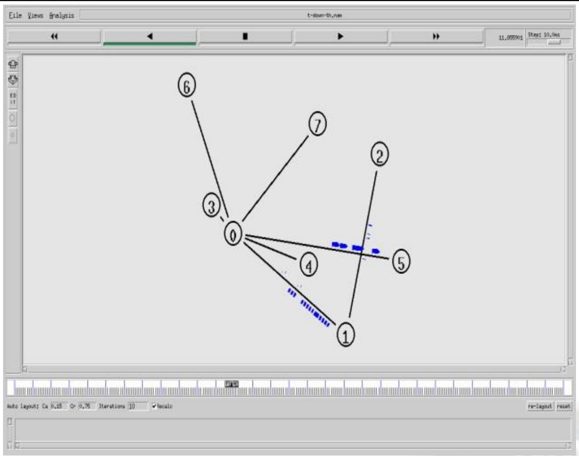

Figure 2. Typical WMN of 43 nodes

"The simulation topology that we built is made up of eight computer nodes that are completely stationary. Each of these nodes is assigned a number between 0 and 7 and is put on a network in a random order, with the exception of the server. We found the transmission and receiving of data via multicasting to be fascinating. In order to process and send messages between nodes, we made use of the simplex-link layer, often known as SLL. In addition, we used LTEQueue/ULAirQueue and LTEQueue/DLAirQueue in order to set distinct priority limitations to each and every relay node. It is the workflow operations that serve as the basis for the set priority limitations. This was accomplished by the use of the PSO algorithm. Through the use of OCA, the bandwidth was dynamically assigned. In the network, the suggested model is implemented on the distribution layer, which is also known as the server layer." During the assessments, we made the decision to run each simulation for a total of one hundred seconds. Over the course of multiple iterations, the assessments were carried out in order to get encouraging outcomes. Due to the fact that NS-2 is not scalable, it is necessary to run many simulations. As a consequence, the results of the simulations may not always be dependable enough.

To keep a record of the findings that were acquired, NS-2 produced trace files. We used those data in order to compute the average throughput and latency, in addition to the amount of energy that was consumed. R, on the other hand, was the programming language that was used in order to analyse and show the findings that were produced in the shape of graphs. In addition to that, we created AWK programmes in order to compute the average throughput and delay, in addition to the amount of energy that was used. Throughout the course of the simulation, we documented a number of packet losses. In comparison to DQBA and DDA, the suggested NoDBA was put through its paces and assessed.

During the simulations, the parameters and values that were utilised for the simulations are shown in the table below.

Table 1. Simulation parameters

Experimental Parameters	
Routing Protocol	OLSR
MAC Protocol	IEEE 802.11b/g
Number of nodes	43
Mobility Mode	Random waypoint
Propagation Model	TwoRayGround
Queue Type	Queue/DropTail/PriQueue
Message Size	64 bytes
Simulation area	1800m X 840m

During the course of the experimental evaluations of the proposed model, the Network Animator (NAM) that was built was displayed in Figure 2. This NAM interface provides an illustration of the recommended topology that was utilized in the simulations that were carried out. This particular interface was utilized in order to carry out a number of simulations of the suggested model in comparison to DQBA and DDA.

5.2. Analysis and Results of the Simulation

To analyze the recommended algorithm in comparison to other algorithms, we were needed to build a framework that tackles challenges that have an influence on the quality of service in IHNs. This was done so that we could evaluate the suggested algorithm. In a previous statement, it was mentioned that in order to achieve the objectives of our research, we documented the results of our performance. "In light of the fact that the DQBA and DDA algorithms both describe traffic conditions that are equivalent to one another, they were chosen. Furthermore, the objectives of these algorithms were to improve the throughput and latency of the network, in addition to lowering the amount of energy that was consumed by the network. The following features, which include both similarities and differences, served as the source of inspiration in addition to the aforementioned criteria. The OLSR protocol, which depended on bandwidth and energy consumption characteristics, was utilized by both DQBA and DDA in order to determine which paths on the network were the most effective in terms of efficiency.

But these algorithms did not take into consideration the potential of assigning different priority limits to relay nodes in order to guarantee a particular level of performance while the data is being sent over the network. This would have been necessary in order to guarantee a certain level of performance. In light of this, we incorporated the PSO and OCA algorithms into the model that we proposed in order to alleviate the bottleneck that had been encountered. To

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evaluate the performance of the proposed NoDBA algorithm in comparison to DQBA and DDA, the performance metrics that are described below were taken into consideration. This evaluation was done for the goal of assessing the performance of the NoDBA algorithm."

- When referring to the assessment of the number of transmissions that may be carried out between two nodes in a network at a particular instant in time, the word "average throughput" is the term that pertains to the evaluation.
- It is recommended that the measurement of the length of time it takes for packets to be transmitted between network nodes be delayed, on average.
- Energy consumption is the measurement of the amount of energy that is spent by nodes in a network at a certain instant in time during the transmission of data. This measurement is done in order to determine how much energy is being used. The average network throughput that we saw in the NoDBA approach that we showed was quite encouraging when they were compared to the DQBA and DDA algorithms that we had previously shown. As can be seen in Figure 3, this is something that is easily comprehendible. Not only does NoDBA impose priority constraints for all relay nodes, but according to these priority limits, each relay node is allocated a particular degree of priority depending on the workflow pattern that it follows. This is the reason why this is the case. The NoDBA protocol, on the other hand, grants access to the resources and services offered by the network to a maximum number of clients, and it does so in the order of priority. Consequently, this leads to enhancements in the level of service that the network is able to provide.

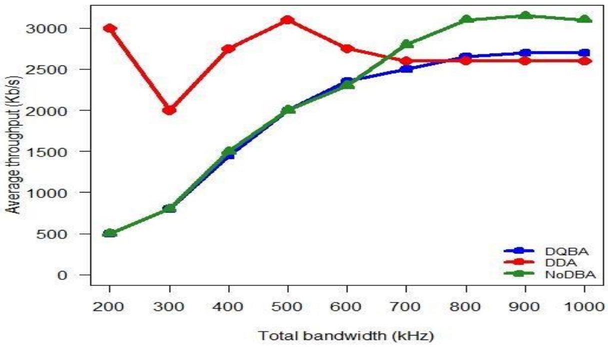

Figure 3.Average Throughput

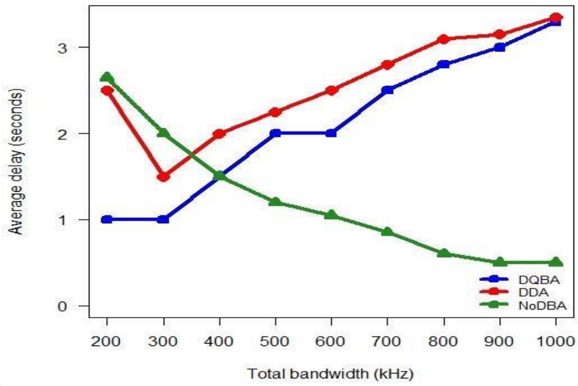

Figure 4. Average Delay

The purpose of this article is to demonstrate and analyse the average network latency that was acquired by NoDBA via several comprehensive simulations in comparison to the DQBA and DDA methodologies. When compared to other methods, the NoDBA algorithm resulted in a reduction in the average network latency. The PSO method was used in order to create priority limits for each and every node in the network, which allowed for this to be accomplished. Additionally, the latency was decreased by minimising congestion, which was accomplished by allowing a maximum number of nodes to access the network in priority order. This allowed for the delay to be considerably reduced. This reduces the amount of bandwidth that is used.

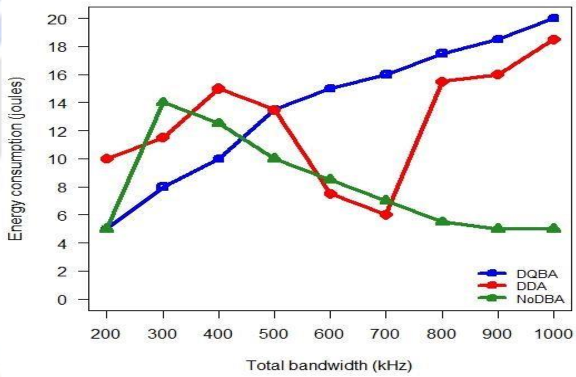

Figure 5.Energy Consumption

As can be seen in Figure 5, the NoDBA algorithm has significantly reduced the amount of energy that it consumes in comparison to the DQBA and DDA algorithms. PSO and OCA, which give a promising and minimised bandwidth utilisation in comparison to other current bandwidth allocation algorithms, were combined into the NoDBA algorithm, which is the reason why this excellent improvement occurred. Furthermore, the suggested NoDBA algorithm minimises congestions by using the PSO algorithm, which, on the other hand, also plays an important part in reducing the amount of energy that is used.

6. Conclusion and Future Work

In this study, we examined and proposed potential solutions to a number of problems that have an effect on the performance of IHNs as a result of bandwidth distribution in these networks. These problems have an influence on the overall performance of these networks. We delivered a presentation that included an overview of IHNs, which included a discussion of the benefits and drawbacks associated with these networks. With that out of the way, we discussed the common algorithms that are developed and utilized in artificial neural networks. On the other hand, we provided a comprehensive analysis of a number of shortcomings that were found in the dynamic bandwidth allocation strategies that are currently being utilized. In addition to that, we presented experimental evaluations, as well as findings and discussions on the NoDBA that was made available. For the purpose of conducting an analysis and developing a graphical representation of the results, the statistical programming language R was utilized.

“The performance bottleneck that was placed on IHNs as a result of bandwidth allocation limits was eliminated by including two well-known algorithms in the field of networking into the framework of the technique that was provided.” The PSO method was utilized in order to perform the task of defining the priority limits for each and every subnet and node that was present in the network. When it comes to the process of data transmission on IHNs, this will guarantee that a particular level of performance is maintained through the process. We made use of OCA in order to dynamically distribute bandwidth to the various nodes that were participating in the network while this was taking place.

The NS-2 tool was utilized in order to achieve simulation, testing, and evaluation of the proposed NoDBA. The DQBA and DDA software were used as a point of reference for this. Furthermore, the results of the simulation reveal that the recommended approach for bandwidth distribution has the potential to considerably boost the throughput of users and minimize the latency of the content that is received. When compared to the other algorithms that were utilized, NoDBA was able to accomplish a reduction in energy consumption, an average throughput of 92%, and an average latency of 0.8 seconds. These results were achieved as a consequence of this.

As an additional point of interest, the more sophisticated research that is being carried out for “the purpose of this investigation can focus on the implementation of the improved PSO, which is known as Accelerated Particle Swarm Optimisation (APSO). On the other hand, we are interested in doing research into the security issues that have surfaced for IHNs as a result of the advent of modern technologies such as the Internet of Things (IoT) and other similar technologies.”

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