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An Energy-Saving and Cost-Reduction Bandwidth Monitoring Model Using PRTG Monitoring Software

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Abstract:- A significant feature of bandwidth monitoring structure is the excellent delivery of internet facilities with larger data rates and bigger coverage. Existing research on bandwidth monitoring focused on pattern tracking, health monitoring, and the performance of numerous physical communication interfaces, amongst others. However, these researches were not Energy-saving and cost-reduction in reducing the overhead energy cost of bandwidth monitoring by which internet users achieve their goals to the background. This research was aimed at developing an Energy-saving and cost-reduction bandwidth monitoring model. These techniques had two stages which are network traffic observation and Bandwidth consumption analysis stages of bandwidth monitoring. Data collection for this research based on bandwidth monitoring using the Paessler Router Traffic Grapher (PRTG) network monitoring software was done at a network operating centre in South-Western Nigeria. The data collected comprised 8,673 records of bandwidth monitored metrics such as Date/Time of bandwidth monitoring, Network traffic volume (of end-to-end connectivity), Network traffic speed (from source to destination and vice-versa), Network downtime, and coverage. The model was formulated using bandwidth optimization (BO) techniques while the data collected were coupled with three algorithms: FUE-sub-channel matching algorithm (FSMA), Joint sub-channel and power allocations algorithm (JSPA), and integrated structure cabling system algorithm (ISCSA). The proposed algorithm was used to formulate the monitoring model using the PRTG monitoring tool. A new mathematical equation was formulated from the model for the integration of Anti-Meridian (AM) / Prime-Meridian (PM) Timer relays and the Normally-Open (NO)/Normally-closed (NC) switches for Energy-saving and cost-reduction to design the monitoring model. When the existing algorithms were compared to the proposed bandwidth monitoring model, the proposed model generated a higher success rate with a maximum of 50 wireless routers capacity.

***Keywords**:-* *Bandwidth Monitoring, Pattern Tracking, Bandwidth Tracking, Network Traffic, Bandwidth Optimization, Communication Interfaces.*

I. INTRODUCTION

Through the years, a multitude of large-scale information science and technology applications have generated vast volumes of data, now also referred to as 'big data,' borne by High-Performing Networks (HPNs) that have the capacity to deliver connectivity to accommodate multiple disconnected processes. Numerous HPN ventures are presently in development, including the Energy Sciences Network's (ESnet) On-demand Safe Circuit with Advanced Reservation Systems (OSCARS) and the Internet's Interoperable On-demand Network (ION) [8]. As bandwidth hassles on the operations network continue to rise, industries are placing a bigger emphasis on high-performance infrastructure elucidations to address performance in several levels of the network. In order to build a successful network in an energy-saving form, it is essential to choose the type of cable media that best suits the bandwidth monitoring and optimization model.

Like the way you care about your team, a good approach to thinking of high-performance networks is similar. If you were interviewing a potential hire, how can you through the recruitment process classify a high-performing candidate? Will you simply recruit the applicant who is able to operate at the lowest wage for you? Probably not. A competitive applicant who has an established track record of achieving the highest outcomes is likely to be more involved in you.

When describing a high-performance network, the same remains true of healthcare. Much too frequently, because they are configured exclusively dependent on the lowest expense, operator networks are called "high performance." That's like constructing a whole enterprise by finding the cheapest workers you can find. Sure, the overhead can be minimal, however, you end up spending more in the long run by losing efficiency.

Given that it is a top concern for many employers to control healthcare expenses, it is not shocking that high-performance networks are attracting a lot of interest. You should have a good view of what high-performance networks are and what they are not to make the best choice for your business.

A network that only involves providers that, like many limited networks, show lower rates is not a high-performance network. With treatment that is patient-centered, evidence-based, appropriate, and integrated, providers in a true high-performance network reliably deliver both lower rates and better efficiency. Robust data exchange and accurate assessment of efficiency often play a key role in finding services that deliver quality treatment at a reduced rate. Network quality criteria should be clearly established, comprehensive, and extracted from appropriate evidence to drive output that produces quality results and has a major effect on healthcare expenditure.

Currently, a "high-performance" network is included in the insurance coverage of about 16% of bigger organizations. In the coming years, this amount is expected to increase as these networks expand and mature. However, considering that not all high-performance networks are made equal, it is critical that you question your health plan partner about how any high-performance network you choose with your company takes into account efficiency and cost measures.

Furthermore, the Internet was an integral component of connectivity to the outer world, the undertaking and writing of academic articles, and the procurement of funding. Digital networking is now readily available and has many benefits, but enterprises have found that this connectivity also results in certain unintentional side effects, such as unpleasant and unwanted Internet Protocol (IP) data flooding network overload interactions [5]. Effective Internet Connectivity requires a knowledge-sharing chain composed of four essential links: I constituent, (ii) connection, (iii) local resources, and (iv) bandwidth control. The constituent must be of a form that can be used by the user. The partnership is crucial to the constituent's access. In addition, the facilities are required to provide the end user with the constituent. This includes the local network, machines, the services needed, and the skills of the network administration staff. But bandwidth management is the key issue that attracts attention in order to have seamless transmission of information. Without diligent maintenance, the network capacity is filled with viruses and unnecessary traffic, and the connection is unreliable [7]. Network security is important throughout this situation [3]

Paessler Router Traffic Grapher (PRTG) software version 18.4.46.1754 is for bandwidth network monitoring. This software is used to analyze the bandwidth consumption and monitor the infrastructure. Decisions are now made on how to effectively utilize the bandwidth. This software is also used to adjust the individual bandwidth consumption of the network devices needed for this study which are Cisco **routers connected to a remote site, switches** connected to the router, and the server connected to the switch in the respective device’s settings.

The bandwidth clearly demonstrates the networking media's ability to transmit data from source to destination. The broader the route/path for data delivery, the more knowledge packets are sent to the Internet-enabled computers of the customer. Bandwidth is a gross statistic that takes the cumulative volume of data transmitted at a certain pace for a specified duration of time without taking into account the signal strength itself [4].

Bandwidth control is the act of evaluating and controlling traffic and packets within a specified network link, in order to reduce resource loading or overfilling of the connection, resulting in congestion of the network as well as degraded network performance. These measurements are in bits per second (bit/s) or bytes per second (B/s). This control framework works by arranging outbound organization traffic into unmistakable classes as indicated by administration and application classifications. The base and most extreme transfer speed arranged for each sort of traffic is then booked as needs be [1]. Bandwidth management requires three operations: (ii) monitoring and (iii) implementation of idealization. If all these activities are insufficient, the management of bandwidth is badly impaired. These practices inform and reinforce each other. High-performance networks are not just tiny networks (HPNs). HPNs deliver reduced prices and greater performance. Many smaller networks in the workplace or home and some larger networks are split into smaller bits as well. This smaller section is separated from the broader network by devices that is capable of filtering data and enabling more efficiency in the network.

II. HIGH-PERFORMANCE NETWORKS

High-performance networks (HPNs) are networks specialized in the usage of innovative network hardware and software technology for potential Internet infrastructure [6]. The Internet of Things (IoT), 5G cell networks, optical networks, Quantum Networking, Data Center and Cloud Storage, Software and Hardware-Based Networking, and AI Aided Networking are influenced by HPNs. In the field of technology, HPNs have documented progress and milestones over the years. This involves end-to-end network slicing, software-defined networking, QKD networking, virtualization of network functions, programmable network functions for hardware, end-to-end 5G network orchestration, integration of optical-wireless-IT networks, as well as field trials of new 5G uses and services in 5G smart city infrastructures.

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III. BANDWIDTH MONITORING: THE FOUNDATION FOR REGULATION OF BANDWIDTH

For bandwidth monitoring, the bandwidth of this sample will not be actively controlled by this study. Instead, this analysis would actually observe the quantity of bandwidth used by the computers and applications of the network. To get started, the PRTG bandwidth management tool is fine. This analysis can be used to track the IT infrastructure and assess the bandwidth usage of this study, and then determine how best to handle the bandwidth of this study. The amount of data that may be sent from one point in a network to another during a specific period of time is referred to as bandwidth. Bandwidth is usually represented as a bitrate and calculated in bits per second (bps). It relates to a connection's transmitting potential and is an important consideration when assessing a network's efficiency and speed.

Although tracking the bandwidth used to involve focusing only on internet traffic, monitoring bandwidth often requires a wider variety of components. For instance, bandwidth speed or capability may be monitored; network activity between devices or general web application traffic can be observed. However, it is important to consider the capacity that is being used, regardless of what traffic you control, so you can guarantee that consumers receive the best possible output from your network.

The truth remains that the most important role of any network administrator is managing network bandwidth utilization. With a network bandwidth controller, there are multiple ways to control bandwidth efficiently to preserve optimal network performance. Bandwidth is measured as the volume of data that can be transmitted over a given amount of time from one location to another within a network.

Bandwidth is usually represented as a bitrate and calculated in bits per second (bps).

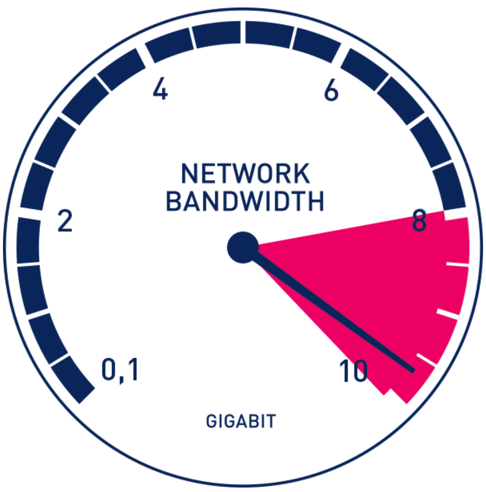

Fig 1. Network Bandwidth measurement

The word bandwidth applies to a link's processing potential and is an important consideration when assessing the efficiency and pace of a network or connection to the internet.

There are many common methods in which bandwidth can be calculated. To determine current data flow, some metrics are used, while others measure full flow, normal flow, or what is known to be reasonable flow.

In many other technical areas, bandwidth is indeed a central term. For example, in signal processing, the gap between the upper and lower frequencies in a communication, such as a radio signal, is represented and is generally calculated in hertz (Hz).

It's easy to equate bandwidth with water running via a drain. Bandwidth will be the rate at which water (data) under varying conditions flows through the pipe (connection). We could calculate gallons per minute instead of bits per second. The maximum bandwidth is the volume of water that will theoretically pass through the pipe, and the amount of water that actually passes through the pipe is the actual bandwidth.

In one term, to sum it up: info. As the sum of data transmitted in time is usually calculated in bits per second, bandwidth is quantified. Thirty years ago, data was transmitted via physical media such as the postal service; today, with the click of a button, there are countless ways to send and obtain vast quantities of data.

Since most businesses rely on the internet to execute business-critical tasks, internet speed will make all the difference in their efficiency. However what people don't realize is that there are currently two distinct bandwidth speed types: upload and download. The speed of upload is the speed at which information is transmitted to its destination, while the speed of transfer corresponds to the rate at which data is obtained. Today, to encourage the rise of data usage, those who have the funds should add Gigabit speed on their networks. In order to operate their company, businesses do need DSL and cable connections, but service providers have been able to devote more money to fund these lower-tier Telco alternatives.

The capability of bandwidth is also a significant factor. The ability for bandwidth indicates the highest data rate a channel will transmit. Bandwidth capacity is a significant thing to remember when you need to be sure you can afford the bandwidth you need as you customize your networks. For example, the mobile phone plan's coverage model is dependent on how much data you use on the network of the provider. If you can do some monitoring of the use of bandwidth, you can help decide the package is right for your setting. Consider an area of hundreds of users, as another illustration. How do you assess what bandwidth to enforce? It is important to have appropriate measurements and resources that will inform you how much bandwidth you would need to conduct your day-to-day activities. For business users, without network insight, predicting existing and potential bandwidth demand will become quite challenging. Management of the output of the network is the primary feature of network monitoring systems.

This will definitely involve multiple forms of bandwidth use that can and should be recorded, such as the usage of a wide area network (WAN) or a local area network (LAN). The next stage includes active control of bandwidth, which involves the allocation of bandwidth to the computers in the network of this research.

A range of tools for bandwidth control is available to help handle bandwidth in this report. The individual bandwidth usage of devices (routers, switches) in the respective system configurations may also be modified through this analysis. Depending on the maker, these settings may differ (Cisco, Jupiter, etc.). Initially, bandwidth was measured in bits per second and denoted by the abbreviation bps. Today's networks, though, usually provide much greater capacity than can be conveyed easily by utilizing those limited units. Higher numbers denoted by metric prefixes, such as Mbps (megabits per second), Gbps (gigabits per second), or Tbps, are now widely used (terabits per second).

K = kilo = 1,000 bits
1,000 kilos equals one million bits, or M.
G = giga = 1,000 mega = 1 billion bits.
T stands for tera, which is equal to 1,000 gigabits.

There are Petabit, Exabit, Zettabit, and Yottabit after Terabit, each reflecting an additional power of 10. It is also necessary to express the bandwidth as bytes per second. With a capital B, this is usually denoted. 10 megabytes per second, for instance, will be represented as 10 MB/s or 10 MBps. Eight bits is one digit.
Thus, 10 MB/s = 80 Mb/s.

The same metric prefixes can be used with bytes as with bits. Thus, 1 TB/s is one

IV. PRTG ROUTER MONITORING SOFTWARE

Paessler AG's PRTG Network Monitor (Paessler Router Traffic Grapher up to version 7) is an agentless network management program. It will monitor and categorize machine conditions such as bandwidth utilization or uptime, and gather data such as switches, routers, servers, and other devices and applications from different hosts. On 29 May 2003, the first edition of PRTG was published by the German business Paessler GmbH (now Paessler AG), established in 2001 by Dirk Paessler [2].

PRTG Network Monitor has an auto-discovery mode that searches an enterprise network's predefined areas and produces a list of devices from this input. Further details on the detected devices may be obtained using different communication protocols in the next stage. Typical protocols are Ping, Simple Network Management Protocol (SNMP), Windows Management Instrumentation (WMI), NetFlow, jFlow, and sFlow, but contact is also possible through DICOM or the RESTful API [2]. The method is used on Windows systems only [2].

Furthermore, Paessler AG provides the "PRTG hosted by Paessler" cloud-based management solution [2]. The application is focused on sensors that are designed for a particular function. For starters, for switches, routers, and servers, there are HTTP, SMTP/POP3 (e-mail) application sensors, and hardware-specific sensors [2]. There are over 200 separate predefined sensors in the PRTG Network Monitor that retrieve information from tracked cases, such as reaction times, CPU, memory, storage details, temperature, or device status. You will run the app entirely using an AJAX-based web interface. The web interface is ideal for both real-time troubleshooting and data sharing by maps (dashboards) and user-defined reports with non-technical workers [2]. An additional management interface is accessible in the form of Windows and macOS desktop software [2]. Notification is also supported by push notification on smartphones utilizing an iOS or Android app, in addition to regular contact platforms such as email and SMS [2]. Customizable reports are also accessible at PRTG (Andres & Rockland, 2004). Notification is also supported by push notification on smartphones utilizing an iOS or Android app, in addition to regular contact platforms such as email and SMS [2]. Customizable reports are also offered by PRTG.

V. DESIGN OF ESCRBM MODEL

The proposed model is presented in two (2) stages namely: (A) Network traffic observation and (B) bandwidth consumption analysis as shown in Figure 2. The result of each stage was taken as input for the next stage to finally achieve the aim of developing an Energy-saving and cost-reduction bandwidth monitoring model.

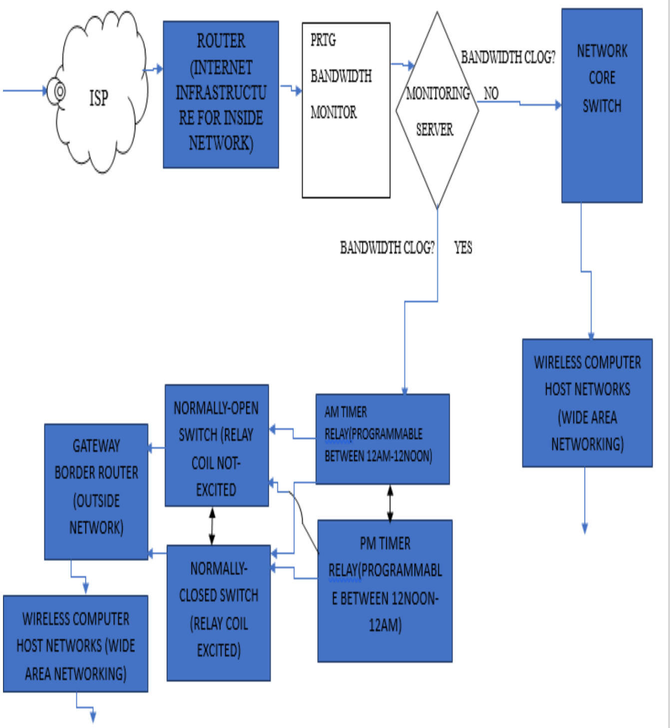

Fig 2. Energy-Saving and Cost Reduction Bandwidth Monitoring (ESCRBM) Model (Researcher's Model, 2023)

A. Network traffic observation stage

This stage is composed of a number of two sub-stages, namely: prtg bandwidth monitoring and prtg network traffic review sub-stages. Each stage is presented in the following section.

- *PRTG BANDWIDTH MONITORING*

The PRTG monitoring software was first installed on the monitoring network server in line with the following monitoring metrics: Date/Time of bandwidth monitoring, network traffic volume, network traffic speed, network downtime, and network coverage.

- *PRTG NETWORK TRAFFIC REVIEW*

The result of the network traffic data from the bandwidth monitoring tool was now compared with Existing literature which was reviewed to identify bandwidth monitoring methods. Results from the existing literature review were used to review the analyzed internet traffic. Additionally, PRTG enabled the monitoring of the network's total bandwidth usage, measured network throughput, and tracked internet traffic by IP address to assess the bandwidth consumption rate for energy-reduction and cost-reduction objectives.

Table 1 shows the Screenshot of Data collected showing the Date/Time, Traffic volume, and Traffic Speed transmitted from PRTG NETWORK MONITOR

Table 1 Screenshot of Data collected showing Date/Time, Traffic volume and Traffic Speed transmitted from PRTG PRTG NETWORK MONITOR 19.4.54.1506 (NOC, 2020)

Date Time	Traffic Total (volume)	Traffic Total (speed)	Traffic In (volume)	Traffic In (speed)	Traffic Out (volume)	Traffic Out (speed)	Downtime	Coverage
2/1/2020 12:00:00 AM - 1:00:00 AM	1,901,165 KByte	4,327 kbit/s	125,352 Kbyte	285 kbit/s	1,775,813 KByte	4,042 kbit/s	0%	100%
2/1/2020 1:00:00 AM - 2:00:00 AM	2,039,892 KByte	4,643 kbit/s	95,414 Kbyte	217 kbit/s	1,944,478 KByte	4,426 kbit/s	0%	100%
2/1/2020 2:00:00 AM - 3:00:00 AM	2,141,250 KByte	4,873 kbit/s	178,546 Kbyte	406 kbit/s	1,962,705 KByte	4,467 kbit/s	0%	100%
2/1/2020 3:00:00 AM - 4:00:00 AM	764,278 KByte	1,739 kbit/s	76,887 Kbyte	175 kbit/s	687,391 KByte	1,564 kbit/s	0%	100%
2/1/2020 4:00:00 AM - 5:00:00 AM	827,958 KByte	1,884 kbit/s	165,293 Kbyte	376 kbit/s	662,665 KByte	1,508 kbit/s	0%	100%
2/1/2020 5:00:00 AM - 6:00:00 AM	3,137,146 KByte	7,140 kbit/s	147,611 Kbyte	336 kbit/s	2,989,535 KByte	6,804 kbit/s	0%	100%
2/1/2020 6:00:00	2,410,431	5,486	167,679	382	2,242,752	5,104	0%	100%

B. Bandwidth consumption analysis Stage

Following the prtg bandwidth monitoring and prtg network traffic review of the network's total bandwidth usage, there was a need to move to the bandwidth consumption analysis stage. From the isp, internet service is supplied to the monitoring server via the modem and the router (Internet infrastructure for inside network). Next, if after the prtg bandwidth monitor has indicated in its results based on the performance metrics that there is a bandwidth clog on the network, then the monitoring server will be redirected to the am/pm timer relay (programmable between 12 am till 12 noon and vice-versa as the case may be). The am/pm timer relay will in turn trigger the no/nc switch which then automatically shuts down the active gateway border router (the outside network where there was a bandwidth clog recorded) while turning on the previously passive gateway border router (the outside network where there was no bandwidth clog recorded). These active border gateway routers immediately send network signals to the wireless computer host networks (wide area networking) to ensure energy-saving and cost-reduction bandwidth monitoring internet service. On the other hand, if after the prtg bandwidth monitor has indicated in its results based on the performance metrics that there is no bandwidth clog on the network yet, then the monitoring server triggers the network core switch to automatically connect the wireless computer host networks (wide area networking) to ensure a seamless energy-saving and cost-reduction bandwidth monitoring internet service. In addition to this stage, the total bandwidth was subjected to bandwidth consumption analysis by applying a number of bandwidth monitoring algorithms. The algorithms were applied one after the other on the total bandwidth usage following which the performance of the algorithms Fue-subchannel matching algorithm (FSMA), Joint sub-channel power allocation algorithm (JSPA), and Flow-based predictive algorithm (FBPA) were evaluated based on a number of performance evaluation (Bandwidth monitoring) metrics which are **network bandwidth dropping, network bandwidth blocking, bandwidth utilization, and bandwidth consumption**. The bandwidth monitoring model is used to automatically perform a short-term switching of the normally-open, and normally-closed switches to regulate the active and passive border gateway routers during bandwidth distribution.

The bandwidth monitoring model was implemented to solve the mathematical equation involving the integration of the am/pm timer relay that triggers the no/nc switches in both on-peak and off-peak modes (12 midnight till 12 noon and also from 12 noon till 12 midnight the following day) from PRTG data collected for this study.

The various algorithms developed for bandwidth monitoring varied in accuracy when applied to other bandwidth monitoring models from the bandwidth usage [4]. Therefore, three (3) bandwidth monitoring algorithms namely: the FUE-sub-channel matching algorithm (FSMA), Joint sub-channel and power allocations algorithm (JSPA), and integrated structure cabling system (ISCS) algorithms were applied in comparison with the proposed Energy-saving and cost reduction bandwidth monitoring algorithm

(ESCRBM) on the total bandwidth usage considered in this study following which their performance was compared based on the performance evaluation metrics.

In the bandwidth monitoring stage, the aim is to develop an Energy-saving and cost-reduction bandwidth monitoring model (ESCRBM) also known as the bandwidth control model that accurately describes the consumption as contained in the bandwidth usage. The bandwidth monitoring model was presented with a modified mathematical equation [5] that solves the integral problem of merging the am/pm timer relay with the process involved to ensure Energy-saving and cost reduction. The new mathematical formulae alongside MILP for this study were chosen for the following main reasons:
(i) Two discrete time series serve as the input data for the bandwidth monitoring: Anti-meridian (AM) and Prime-Meridian (PM)
(ii) The total number of active and passive routers attached to each monitoring area (iii) The total number of active routers traffic passing from monitoring area 1 to 2 in the interval (T, 0) in both time series of bandwidth consumption

The resulting bandwidth monitoring model was used to reduce both the bandwidth and energy consumption rates of the devices and applications integrated with it and also to maximize Energy-saving and cost reduction by reducing the overhead cost of bandwidth management considered in this study

VI. IMPLEMENTATION OF ESCRBM MODEL

The proposed model was implemented with PRTG network bandwidth monitoring software version 19.4.54.1506 and OMNET++ 5.6.2 network simulation tool. Hence, this research work implemented an Energy-saving and cost-reduction bandwidth monitoring model in wireless wide area networks to formulate a modified mathematical equation [5], involving the integration of the AM/PM timer relay that triggers the NO/NC switches both on-peak and off-peak modes (12 midnight till 12 noon and also from 12 noon till 12 midnight the following day) from PRTG data collected for this study. Moreover, the study applied a total number of active and passive routers attached to each monitoring area with the aim of integrating the total number of active routers traffic passing from monitoring areas 1 to 2 in the interval (T, 0) in both time series of bandwidth consumption.

The various algorithms developed for the bandwidth monitoring technique vary in accuracy when applied to other bandwidth monitoring models from the bandwidth usage [26]. Therefore, three (3) bandwidth monitoring algorithms namely: the FUE-sub-channel matching algorithm (FSMA), Joint sub-channel and power allocations algorithm (JSPA), and integrated structure cabling system (ISCS) algorithms were applied in comparison with the implemented Energy-saving and cost reduction bandwidth monitoring (ESCRBM) algorithm on the total bandwidth usage considered in this study following which their performance was compared based on the performance evaluation metrics.

In the bandwidth monitoring stage, the aim is to develop an Energy-saving and cost-reduction bandwidth monitoring model (ESCRBM) also known as the bandwidth control model that accurately describes the consumption as contained in the bandwidth usage. The bandwidth model was presented with a modified mathematical equation [5] that solves the integral problem of merging the am/pm timer relay with the process involved to ensure Energy-saving and cost reduction. The new mathematical formulae alongside MILP for this study were chosen for the following main reasons:
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The resulting bandwidth model was used to reduce both the bandwidth and energy consumption rates of the devices and applications integrated with it and also to maximize Energy-saving and cost reduction by reducing the overhead cost of bandwidth management considered in this study.

- *Network traffic observation Stage*

The bandwidth model proposed in this study for developing an Energy-saving and cost-reduction bandwidth monitoring model was implemented by a combination of a number of technologies. These technologies were modified for each stage of development of the bandwidth model. They are presented as follows: The stage of network traffic observation and bandwidth consumption analysis was performed by using the Paessler Router Traffic Grapher (PRTG) software version 19.4.54.1506 for bandwidth network bandwidth monitoring. The data collection was done at a network operating centre in South-Western Nigeria. The data collection was used to formulate the total bandwidth consumption using the PRTG monitoring tool of about 8,673 records.

- *Bandwidth Consumption Analysis Stage*

The process of bandwidth and bandwidth management required in this study was done by measuring, checking, and limiting the network traffic to avoid clogging and poor internet speed. The data collected from the PRTG network bandwidth monitoring tool was analyzed using bandwidth monitored metrics such as Date/Time of bandwidth monitoring, network Traffic volume (of end-to-end connectivity), network traffic speed (from source to destination and vice-versa), network downtime, and coverage.

VII. CONCLUSION

The ESCRBM was developed using bandwidth monitoring techniques. Data collection for this research based on bandwidth monitoring using the Paessler Router Traffic Grapher (PRTG) network bandwidth monitoring software was done at a network operating centre in South-Western Nigeria. The data collected comprised 8,673 records of bandwidth monitored metrics such as Date/Time of bandwidth monitoring, network Traffic volume (of end-to-end connectivity), network traffic speed (from source to destination and vice-versa), network downtime, and coverage. The model was formulated using bandwidth monitoring techniques while the data collected were coupled with three algorithms: FUE-sub-channel matching algorithm (FSMA), Joint sub-channel and power allocations algorithm (JSPA), and integrated structure cabling system (ISCS) algorithm. The performance of the algorithms was evaluated based on four BO metrics: network bandwidth dropping, network bandwidth blocking, bandwidth utilization, and bandwidth consumption. The optimal algorithm was used to formulate the model using the PRTG monitoring tool. A modified mathematical equation [5] was formulated from the model for the integration of Anti-Meridian (AM)/ Prime-Meridian (PM) Timer relays and the Normally-Open (NO)/Normally-closed (NC) switches for Energy-saving and cost reduction to design the ESCRBM. The ESCRBM was implemented by solving a problem using the mixed-integer programming technique. The ESCRBM was tested and evaluated using the OMNET++ simulation software. (OSS).

REFERENCES

[1]. A. Bahnasse, F. Louhab, H. Oulahyane, M.. Talea, & A. Bakali, "Smart bandwidth allocation for next generation networks adopting software-defined network approach", in *Data In Brief*, ch. *20*, pp. 840-845. 2018 https://doi.org/ 10.1016/j.dib.2018.08.091

[2]. AG. Paessler, "Welcome to Paessler" in Paessler, the Monitoring Experts, PRTG Network Monitor, Nuremberg, Germany, 2022 [online]. Available: www.paessler.com

[3]. B. Sharma, C. Reddick, R. Enriquez and R. Harris, "Determinants of broadband access and affordability: An analysis of a community survey on the digital divide", *2020* doi: https://doi.org./10.1016/j.cities.2020.102904

[4]. Gale, "Bandwidth Management", in Encyclopedia.com, March 2021, from Available: [Online]: https://www.encyclopedia.com/economics/encyclopedias-almanacs-transcripts-and-maps/bandwidth-management

[5]. K. Bilal, et al., "A survey on Green communications using Adaptive Link Rate", in *Cluster Computing*, *16*(3), 575-589, 2012 https://doi.org/ 10.1007/s10586-012-0225-8

[6]. R. Nejabati, "High-Performance Networks Group", in Faculty of Engineering, School of Computer Science, Electrical and Electronic Engineering and Engineering Maths. , 2019. Available: [Online]: http://www.bristol.ac.uk/engineering/research/hpn/

[7]. S. Gorinsky,& N. Rao, "Dedicated Channels as an Optimal Network Support for Effective Transfer of Massive Data". *Proceedings IEEE INFOCOM 2006. 25TH IEEE International Conference On Computer Communications*, 2006. https://doi.org/ 10.1109/infocom.2006.20

[8]. Y. Lin, & L. Wu, "Exploring the role of dynamic capabilities in firm performance under the resource-based view framework", in *Journal of Business Research, 67(3) pp. 407-413.* 2014. *https://doi.org/10.116/j.jbusres.2012.12.019*