

Internet Data Bandwidth Optimization and Prediction in Higher Learning Institutions Using Lagrange's Interpolation: A Case of Lagos State University of Science and Technology

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Abstract
This research work studies the performance of the internet services of institution of higher learning in Nigeria. Data was collated from Lagos State University of Science and Technology (LASUSTECH) as case study of this research work. The problem of Internet Bandwidth optimization in the institution of higher learning in Nigeria was extensively addressed in this paper. The operation of the Link-Load balancer which provides an efficient cost-effective and easy-to-use solution to maximize utilization and availability of Internet access is discussed. In this research work, the Lagrange's method of interpolation was used to predict effective internet data bandwidth for significantly increasing number of internet users. The linear Lagrange's interpolation model (LILAGRINT model) was proposed for LASUSTECH. The predictions allow us to view the effective internet data bandwidth with respect to the corresponding acceptable number of internet users as the number of user's increases. The integrity of the model was examined, verified and validated at the ICT department of the institution. The LILAGRINT model was integrated into the management of ICT and tested. The result showed that the proposed LILAGRINT model proved to be highly effective and innovative in the area of internet data bandwidth predictability.
Keywords: Internet Data Bandwidth, Optimization, Link-load balancer, Lagrange's interpolation, Predictions, Management of ICT
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1.0 Introduction

Today, internet connectivity and reliability is the heart of every business operation. The campus environment is even of paramount importance than any other establishment. Establishments rely on it to run mission-critical business applications that drive productivity and profits. Campuses rely on it to promote academic knowledge and intellectualism. Actually, internet access is no longer a luxury, but a critical component of the overall network infrastructure that must be highly reliable and always available [1], [19], [20] & [17].

Link-load balancing provides an efficient cost-effective and easy-to-use solution to maximize utilization and availability of internet access while minimizing cost. To improve reliability of internet access, many enterprises lease two or three ISP links connecting the internal network to the internet. One of the links acts as a backup while the primary link is being utilized. This solution improves reliability by providing backup capacity for use during ISP link failure. This mode of internet connectivity is popularly known as multi-homing. However, it does not maximize utilization of all available capacity. Additionally, fail over to the backup link after primary link failure is disruptive to the traffic and affects application performance if it is not automated. This is illustrated in Fig. 1.1 below.

One alternative to keeping backup links idle is the use of Border Gateway Protocol (BGP) which supports the ability to utilize multiple ISP links simultaneously with multi-homing. But BGP is complex to manage and requires special expertise and active co-operation of the ISPs. In spite of the complexity and the challenges, BGP does not provide an efficient solution. There is no mechanism is BGP to optimize utilization on all the links and to effectively balance the load between in-bound traffic flows. Also, lack of client connection knowledge and slow convergence cause application-level disruptions during link failure for establishment like the University campuses that want to avoid the challenges of BGP routing without the wastefulness of idle backup ISP link. Link load balancing offers a powerful solution with quick return on investment. Link-load balancers balance in-bound and out-bound traffic efficiently among all available ISP links using intelligent traffic management. Links are selected using load-balancing methods based on critical performance metrics- such as bandwidth limit, link weight, bandwidth cost and ISP pricing model which have a direct positive impact on the business.

Institutions no longer have to rely on low-risk, high-cost ISP services to provide reliability. They can aggregate data bandwidth of multiple links from different ISPs which do not only reduce cost but also improves overall reliability and availability of access.

Because all the links are utilized simultaneously, failure risk associated with any one link is completely eliminated. Losing a link merely results in reduced bandwidth and not in the loss of access availability and performance. Applications are fully transparent to link failures and restoration, and continue operating, though with changed bandwidth capacity [1], [17], [18], [19], [20], [32], [33], [34].

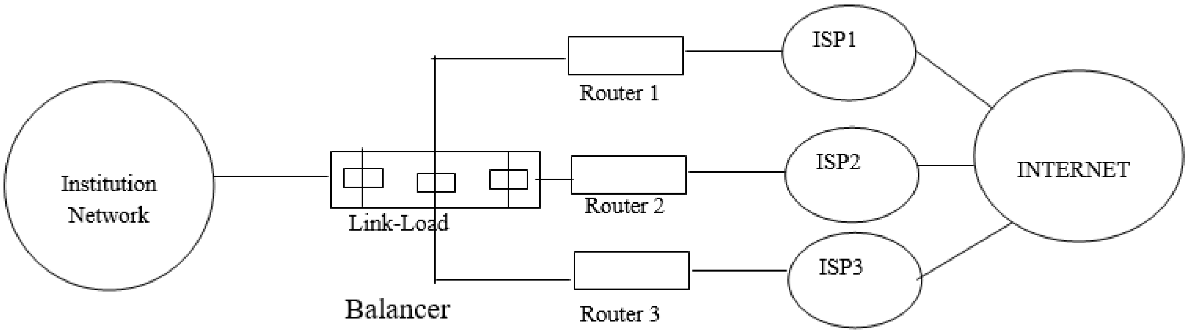

Fig. 1.1: An institution using a Link-load Balancer

Link load balancers use intelligent checks to monitor the health and performance of ISP links and dynamically switch traffic to healthier and better performing links. Some application products use the physical state of "next –hop" link to determine the health of ISP links. More advanced link-load balancers feature sophisticated health checks beyond the next hop link and use end-to-end proximity measures and service response time to determine the best link to service any given application transaction. In bandwidth optimization, network and application security is a critical enterprise need. Therefore, link-load balancers are ideally positioned at the intersection of the internal and external network to provide security. Using source Network Address Translation (NAT) forces return traffic to use the same ISP link as forward traffic for session persistence and consistent performance. Source NAT provides security by allowing internal network addresses to be private and completely invisible to external users. Additionally, some link load balancers use their layer 4-7 network and application intelligence to thwart Denial of service attacks by blocking traffic from malicious clients without adversely impacting performance for legitimate clients.

As institutions and Enterprises deploy link-load balancers to remove performance bottlenecks and weak "links" from their Internet access infrastructure, it is important to ensure that link load balancers do not become single points of failure. Products that support high-availability (HA) configuration deliver a fully fault- tolerant solution that is highly appropriate for an enterprise's mission-critical needs. In the HA mode, two link-load balancers operate as active and standby, with session synchronization and transparent sub-second failover. When one device fails, there is no impact to existing connections, because the other device becomes operational with full knowledge of all existing connections and continues servicing application traffic [1],[30],[31],[32],[33].

Historical Background of Lagrange's Interpolation

About Lagrange (1736-1813), Joseph Louis Lagrange was born in Turin, Italy, of French parents. At a very young age, he was made a professor at the Royal Artillery School in Turin. In 1766, he succeeded his friend and mentor Euler as the Director of the Mathematics section of the Berlin Academy. In 1787, he accepted a similar position at the Paris Academy of Sciences where he was active in establishing two very influential French Schools, the Ecole Polytechnique, and the Ecole Normale.

In his later years, he was granted a number of honours by the French Emperor, Napoleon Bomparte.

His results on interpolation were a major part of his work while in Berlin, but the interpolation formula ascribed to him here was not published until 1795 after he had moved to France. Ironically, Lagrange claims to have gotten the idea from some of Newton's work [67]. The literature reviews which comprise detailed related works, recent related works and classic literatures were full discussed in section 2.0. The research methodology on Internet Data Bandwidth prediction was sufficiently discussed in section 3.0. The results and calculation was equally addressed in section 4.0 and finally section 5.0 discussed the concluding report of this research work.

2.0Literature Review

2.1 Related Works

In order to provide quality of service (QoS) guarantees while achieving an acceptable level of internet bandwidth utilization, integrated networks, institutions often employ the concept of effective bandwidth in call admission control (CAC) and service scheduling [2],[3]. Significant research has been done on the notion of effective internet bandwidth prediction over wire line and wireless networks [2], [3], [4], [5], & [6].

Guerin et al. (2012) proposed an approximate expression for the effective bandwidth of both individual and multiplexed connections, arguing that this approximation is necessary for real-time internet network traffic control [3].

Mohammadi et al (2012) extended the concept of effective bandwidth predictability to wireless ATM networks [8].

Elwalid and Mitra (2011) studied the effective bandwidth for general Markovian traffic sources [2].

Elwalid et al (2012) proposed an approximation for the packet-loss rate (PLR) at a statistical multiplexer using a hybrid Chernoff-dominant eigenvalue (CDE) approach [7].

Carlos and Jaime (1998) proposed an admission control scheme based on adaptive bandwidth reservation to provide quality of service (QoS) guarantees for multimedia traffic carried in high-speed wireless cellular networks. The proposed scheme can provide high degree of QoS guarantees for multimedia traffic carried in microcellular high-speed wireless networks. The proposed scheme considers both local information (e.g. the amount of unused bandwidth in the cell where the user currently resides) and remote information (e.g. the amount of unused bandwidth in the neighbouring cells) to determine whether to accept or reject a connection. The proposed scheme distinguishes real-time traffic and non-real-time traffic and reduces the bandwidth in the cells to non-real-time connections to provide higher quality of service to real-time connections if necessary. The proposed scheme can also adjust the amount of reserved bandwidth based on the current network conditions [35].

Adaramola et al (2015) studied the effective internet data bandwidth of an institution of higher learning with the increasing number of internet users and proposed a prediction model. The Linear Langrage's interpolation prediction model proposed predicts the acceptable internet bandwidth corresponding to the number of users. The effectiveness of the model was verified and validated at the ICT department of that same institution [20].

Ito et al (2016) tried to improve transmission links utilization in an ICT-based institution using a specialized algorithm [36].

Marquesone et al (2017) designed bandwidth consumption architecture in an organization but missed the specification of the IoT technology [37].

Liu et al (2017) presented a model to adapt the bandwidth in wireless sensor network (WSN) in an institution also considered that the WSN is the same for Internet of Things (IoT) [38].

Ma et al (2017) proposed two different methods to optimize the allocation of bandwidth for heterogeneous IoT traffics [39].

Zhao et al (2018) proposed an information flow model to minimize usage of bandwidth for IoT applications for an ICT-based institution and IoT environment [40].

Hsu et al (2018) proposed a model to utilize idle devices to maximize bandwidth and transmit critical data in an ICT-based organization and IoT environment [41]

Islam et al (2019) proposed a communication trial to enhance the bandwidth for IoT-based applications for an ICT-based organization and IoT environment. This trial was achieved only from a communication perspective [42].

Medeiros et al (2019) proposed a multi-objective approach to guide the routing process in mixed IoT traffics in IoT environment based on the use of Machine Learning (ML) and Deep Learning (DL). This approach was tested using only a data set of elderly health care scenario [43].

Wang et al (2019) analysed bottleneck performance in a cloud rendering system. This was conducted in an ICT-based institution [44].

Ghanbari et al (2019) investigated a survey about resource allocation algorithm and methods in IoT environments. It supports IoT devices and it was just a survey [45].

Fang et al 2019) introduced a learning methodology for software agent to control the sending rate of internet video calls in an ICT-based institution [46].

2.2 Recent Related Works

Wang et al (2020) introduced a scheme to achieve real-time routing traffic that is timely sensitive in an ICT-based environment. The proposed method was successful when optical networks were utilized [47].

Pappas et al (2020) predicted the data bandwidth in mobile broadband networks in the WAN of an organization using Machine Learning (ML) and Deep Learning (DL) [48].

Labonne et al (2020) presented a method for predicting data bandwidth on network links in an organization using Machine Learning (ML) and Deep Learning (DL) [49].

Yoo et al (2020) proposed a method to predict the bandwidth that was available for video streaming over HTTP using the machine learning (ML) and deep learning (DL) in a wide area network (WAN) environment [50].

Pratap et al (2020) maximized the number of tasks for the IoT-based 5G network environment. This was adequately examined in an ICT-based environment [51].

Orsini et al (2021) presented a mechanism to predict the data bandwidth and connectivity between mobile devices. It was able to address IoT devices using machine learning (ML) and deep learning (DL) in IoT environment. Observations showed that the implementation infrastructure comprised only mobile devices [52].

Nakhlestani et al (2021) designed a new voltage regulator called low drop-out (LDO). This regulator was used to enhance data bandwidth availability for IoT applications in IoT environment. The LDO regulator model used a special communication circuits in its implementation [53].

Chauhan et al (2021) proposed a bandwidth adjustment technique that considered the applications sensitivity using queuing system in the fog/cloud in an ICT-based organization [54]

De et al (2021) introduced an antenna design to enhance the data bandwidth and communication in numerous wireless body area networks (WBANs) in an ICT-based environment. The solution is proposed only for WBANs [55].

Mei et al (2021) proposed a data bandwidth prediction methodology to enhance the quality of experience (QoE) in 4G and 5G networks in a broadband network [56].

Lakshmanna et al (2022) surveyed and summarized the major efforts that were achieved in the field of deep learning (DL) for the IoT technology. The survey was carried out in the IoT environments using deep learning on the IoT devices [57].

Schellinas et al (2022) predicted the network performance in the IoT system by applying the long Short-term Memory (LSTM) algorithm in the IoT environment using machine learning (ML) and deep learning (DL) [58].

Bian et al (2022) demonstrated the result that highlighted the weakness and strengths in the machine learning (ML) and deep learning (DL) in the IoT environments [59]

Habeeb et al (2022) presented a novel quality of service (QoS) scheduling system to undertake the semiautomatic bandwidth slicing for processing of critical traffic in edge/cloud environment. This was carried out in the IoT environment and it was applied to the edge/cloud servers only [60].

Cibira et al (2022) presented a novel concept based on statistical detection and monitoring of sensing signals. This was successfully performed in an ICT-based environment [61].

Oktian et al (2022) introduced a bandwidth trading framework to utilize block-chain and software defined networking. This was carried out and tested in an ICT-based institution [62].

Negi et al (2022) presented an optional control system that minimized the closed-loop of the physical system and reduced the data bandwidth cost in the ICT-based environment [63].

Subramani et al (2022) proposed a technique to reduce the energy consumption for IoT nodes and increased the efficiency in addition to route adjustment scheme. The IoT devices were used in the IoT environment in course of testing the proposed method [64]

Hui et al (2022) proposed a dynamic algorithm for data bandwidth allocation. In addition, the neural network was used to predict and improve the polling mechanism. This was carried out using machine learning (ML) and deep learning (DL) in the IoT-based environment [65].

Bzai et al (2022) discussed and classified the literature on machine learning (ML)-enabled IoT upon three perspective applications, data and industry [66].

The research on effective internet bandwidth has generally been addressed in the context of high-speed (wired) asynchronous transfer mode (ATM) and wireless networks. Recently, it has tremendously project the Internet of Things (IoT), Edge and Cloud data bandwidth management of various institutions [11], [12], [13], [15], [16], [17], [19], [68], [69], [70], [71], [72], [73], [74] & [75].

2.3 Classic Literature Reviews

2.3.1 Internet Data Bandwidth Scheme

The adaptive Bandwidth Reservation Scheme for high-speed Networks was also studied from its grassroots in [3]. This paper proposed an admission control scheme based on adaptive bandwidth reservation to provide QoS guarantees as they are expected to support multimedia applications. This paper proposed an admission control scheme based on adaptive bandwidth reservation to provide QoS guarantees for multimedia traffic carried in high-speed wireless cellular networks. The proposed scheme allocates bandwidth to a connection in the cell where the connection request originates and reserves bandwidth in all neighbouring cells. When a user moves to a new cell and a handoff occurs, bandwidth is allocated in the new cell, bandwidth is reserved in the new cell's neighbouring cells, and reserved bandwidth in more distant cells is released.

2.3.2 Data Transmission on the Internet Networks

The performance analysis of Data Packet discarding in ATM Networks was also studied in [4]. Data performance in Asynchronous Transfer Mode (ATM) networks should be measured on the packet level instead of the cell level, since one or more cell losses within each packet are equivalent to the loss of the packet itself. Two packet-level control schemes, packet tail discarding and early packet discarding, were proposed to improve data performance. In this paper, a new stochastic modelling technique is developed for performance evaluation of two existing packet-discarding schemes at a single bottleneck node. It was assumed that the data arrival process is independent of the nodal congestion, which may represent the unspecified bit-rate traffic class in ATM networks, where no end-to-end feedback control mechanism is implemented. Through numerical study, the effects of buffer capacity, control, threshold, packet size, source access rate, underlying high-priority real-time traffic, and loading factor on data performance were sufficiently explored. The study shows that a network system can be entirely shut down in an overload period if no packet-discarding control scheme is implemented under the assumption that there are no higher layer congestion avoidance schemes.

2.3.3 A Bandwidth Control Scheme for reducing the negative impact of bottlenecks in IoT environments

In [16], the paper proposed verifiable solutions to the control data bandwidth in IoT environments. The Internet of Things (IoT) environment comprises heterogeneous transmission channels. The statuses of these channels may change rapidly due to dynamic variations in things, data, topologies, etc. Thus, many bottlenecks may suddenly occur and dynamically change. Therefore, the quality of services (QoS) may be affected due to the lack of the bandwidth. Hence, this paper proposes a bandwidth control scheme to face the challenge of bottlenecks in the IoT environment. In this scheme, a bottleneck detection methodology, bandwidth prediction approach, reduction of bandwidth usage mechanism, and bandwidth management model are proposed. This bandwidth management model comprises reassigned and reallocated bandwidth plans. To test the proposed bandwidth control scheme, a large-scale simulation environment was constructed using NS-3. The performance of the proposed scheme was measured using the effect of reassigned and reallocated bandwidth plans in the cases of normal and prioritized data. In addition, packet loss, energy consumption, delay and bandwidth prediction accuracy were measured. Moreover, to make sure that the proposed scheme was positively effectiveness, its simulation results were compared to those of the famous machine learning and deep learning techniques: long short-term memory (LSTM), gated recurrent unit (GRU), autoregressive integrated moving average (ARIMA), multi- layer preceptor (MLP), and deep reinforcement learning (DRL). Finally, the simulation results proved that the proposed bandwidth control scheme notably outperformed the IoT environment's efficiency and limited the negative impact of the bottlenecks

3.0 Research Methodology

3.1 Research Considerations on Internet Data Bandwidth Prediction Methodology

The research method for Internet data bandwidth prediction is one of the metric for evaluating effective internet data bandwidth management in higher institution of learning.

There are certain unique and classic assumptions that were made in the process of collation of data in Lagos State University of Science and Technology.

1. Categorization of Internet Users are as follows:
   a. Staff that stays Online (SSO1)
   b. Staff that lives Online (SLO1)
   c. Students that stays Online (SSO2)
   d. Students that lives Online (SLO2)
2. Internet data bandwidth allocation for each category of users are:
   a. 0.25GB/day (i.e. 4 Hours Daily) for Staff that stays Online (SSO1)
   b. 1.0GB/day (i.e. 12 Hours Daily) for Staff that lives Online (SLO1)
   c. 0.25GB/day (i.e.4 Hours Daily) for Students that stays Online (SSO2)
   d. 1.0GB/day (i.e. 12 Hours Daily) for Students that lives Online (SLO2)
3. The calculations assumed a total of 30 days for a month. This was reflected in the overall monthly or annually internet data bandwidth subscription of the institution. The total number of internet users includes the sum of SSO1, SLO1, SSO2 and SLO2.

There are sensitive unique assumptions that were made in the process of collation of data. They are as follows:

1. The total numbers of internet users were NOT taken to be exact and precise. There was a little bit of plus or minus tolerance applied on the data sheets that were available on the post-data presentation report.
2. The total time allocated on the internet scheduler for staff that stays On-line (SSO1) was the average. It implies that a percentage of this category may stay longer than the time allocated, whilst some may stay lesser.
3. It was presumed that the staff that stays On-line (SSO1) may either increase or decrease with a very small margin (5%) on monthly basis.
4. The total time allocated on the internet scheduler for staff that lives On-line (SLO1) was predominantly on the average. It was also assumed that these set of staff may either increase or decrease with a very small margin (5%) on monthly basis.
5. The students that live On-line (SLO2) were NOT allocated 20 hours per day because there were NO hostel accommodations installed with Internet Hotspot services for them. It was presumed that a sum of 12 hours per day would be enough to make internet data bandwidth available to them.
6. It was also assumed that the students that lives On-line (SLO2) may either increase or decrease with a small margin (5%) on monthly basis. The candidates that come to write mock UTME and main UTME examinations at the ICT building are categorised as Students that Stay Online (SSO2). The 100 Level students that come to write CBT examinations at the ICT centre are also grouped with the SSO2.
7. In order to ensure the integrity and validity of the data collation process, all data were collated from the office of the Director of ICT Department using the daily Record Chart on Internet Data Bandwidth Usage.
8. It was discovered that there are few number of internet users that are neither staff nor student. They do have access to the institution internet data bandwidth without any difficulty. They are categorized as

visitors in the data bandwidth tables below.

The information provided through step 1 to 8 above, were used to give the total annual internet data bandwidth of Lagos State University of Science and Technology (LASUSTECH). This methodology was employed using the mathematical analysis of the linear Lagrange's interpolation for predicting the acceptable number of internet users to effective internet data bandwidth. The basic interpolation can be posed in one of the two ways hereunder.

1. Given a set of nodes (x_i, $0 \le i \le n$) and corresponding data values for y_i, ($0 \le i \le n$), find the polynomial P_n (x_i) of degree less than or equal to n, such that $P_n(x_i) = y_i$, $0 \le i \le n$ [67].
2. Given a set of nodes (x_i, $0 \le i \le n$) and a continuous function, f (x_i), find the polynomial P_n (x_i) of degree less than or equal to n, such that $P_n(x_i) = f(x_i)$, $0 \le i \le n$. Note that in the first case, we are trying to fit a polynomial to the data and in the second case, we are trying to approximate a given function with the interpolating polynomial [67]. The process is as follows:
   A. Development of a workable model of Internet data bandwidth optimization and prediction for scalable and reliable ICT-based organisations
   B. Testing of the Linear Lagrange's Interpolation (LILAGRINT) data bandwidth prediction model was carried out and found successful.
   C. Model modification and improvement will be necessary in the future if the students are provided with state-of-art hostel accommodation.
   D. Re-validation of the model would arise if the students are provided with state-of-art hostel accommodation.

3.1.4 Internet Data Bandwidth Calculations

The Lagos State University of Science and Technology (LASUSTECH) Ikorodu, Lagos (formerly known as Lagos State Polytechnic) as a case study of this paper has the following data shown in tables below. This is the most recent numerical data of the total number of Internet Users of the campus.

Table 3.1: Total Number of Internet Users -2020

Category of Internet User	Internet User	Number of Internet Users
Users that Stays Online (SSO)	Academic Staff Non-Academic Staff Student	150 50 400
Users that Lives Online (SLO)	Academic Staff Non -Academic Staff Student	300 70 900
	Visitors	130
Total Number of Internet Users		**2,000**

Table 3.2: Total Number of Internet Users -2021

Category of Internet User	Internet User	Number of Internet Users
Users that Stays Online (SSO)	Academic Staff Non-Academic Staff Student	100 100 500
Users that Lives Online (SLO)	Academic Staff Non -Academic Staff Student	300 70 1100
	Visitors	130
Total Number of Internet Users		**2,300**

Table 3.3: Total Number of Internet Users -2022

Category of Internet User	Internet User	Number of Internet Users
Users that Stays Online (SSO)	Academic Staff Non-Academic Staff Student	100 100 600
Users that Lives Online (SLO)	Academic Staff Non -Academic Staff Student	300 70 1300
	Visitors	130
Total Number of Internet Users		**2,600**

The data table below was obtained from the Network Administrator's Users Record attached to the office of the Director of ICT at which the overall ISPs Internet Data Bandwidth is approximated to 36.12 in the year 2020. Measurement at peak periods (i.e. 1:00pm to 2:00pm) from the SNMP and Solaris Bandwidth Manager Program installed on the Internet Servers also showed that LASUSTECH campus has the following measured Internet data bandwidth analysis in the table below.

Table 3.4: Effective Internet Data Bandwidth with Acceptable Number of Internet Users

Year	Acceptable number of internet users	Effective Internet Data Bandwidth (Terabyte)
2020	2,000	36.12
2021	2,300	42.12
2022	2,600	48.12

In the last three years, we have three measured and estimated data points which can be interpolated so as to predict the effective internet data bandwidth and the acceptable number of internet users for the Internet access in the entire campus community. For better analysis: Let use the following representations described hereunder:

x_i: Represents the Acceptable number of Internet users ('000)

$F(x_i)$:Represents the Effective Annual Internet Data Bandwidth (Terabyte).

The measured and estimated data points are tabulated in table 3.5 below:

Table 3.5: Effective Internet Data Bandwidth with Acceptable Number of Internet Users

x_i('000)	$F(x_i)$ (Terabyte)
2.00	36.12
2.30	42.12
2.60	48.12

Using the first three data points, we can apply the Lagrange's interpolation for the prediction. The Linear Lagrange's interpolation (LILAGRINT) model is a Polynomial which was described in [4] and [12]. The LILAGRINT model is a mathematical modelling generated from the three data points measured and estimated from the tables above. The LILAGRINT model polynomial is as follows:

$$P_n(x) = L_o(x_o)f(x_0) + L_1(x_1)f(x_1) + L_2(x_2)f(x_2)$$

Where:

$$L_o(x_o) = \frac{(x - x_i)(x - x_2)}{(x_O - x_i)(x_O - x_2)} ,$$

$$L_1(x_1) = \frac{(x - x_0)(x - x_2)}{(x_1 - x_O)(x_1 - x_2)} \text{, and}$$

$$L_2(x_2) = \frac{(x - x_0)(x - x_1)}{(x_2 - x_O)(x_2 - x_1)}$$

From the available data points,

$$L_0(x_0) = \frac{(x - 2.30)(x - 2.60)}{(2.00 - 2.30(2.00 - 2.60)} , \quad L_1(x_1) = \frac{(x - 2.00)(x - 2.60)}{(2.30 - 2.00)(2.30 - 2.60)} \text{ and}$$

$$L_2(x_2) = \frac{(x - 2.00)(x - 2.30)}{(2.60 - 2.00)(2.60 - 2.30)}$$

At this junction, we can now obtain values for the expected number of internet users and the corresponding effective internet data bandwidth. For 2,750 internet users, the corresponding effective data bandwidth will be calculated as follows:

$$P_n(2.75) = L_o(x_o)f(x_o) + L_1(x_1)f(x_1) + L_2(x_2)f(x_2)$$

$$= \frac{(2.75 - 2.30)(2.75 - 2.60)\ (36.12)}{(2.00 - 2.30)(2.00 - 2.60)} + \frac{(2.75 - 2.00)(2.75 - 2.60)\ (42.12)}{(2.30 - 2.00)(2.30 - 2.60)} +$$

$$\frac{(2.75 - 2.00)(2.75 - 2.30)\ (48.12)}{(2.60 - 2.00)(2.60 - 2.30)}$$

$$= \frac{(0.45)(0.15)\ (36.12)}{(-0.3)(-0.6)} + \frac{(0.75)(0.15)\ (42.12)}{(0.3)(-0.3)} + \frac{(0.75)(0.45)\ (48.12)}{(0.6)(0.3)}$$

$= 13.545 - 52.650 + 90.225$

P_n (2.75) = 51.12 Terabytes

For 2,900 internet users, the corresponding effective data bandwidth will be calculated as follows:

$$P_n(2.90) = L_o(x_o)f(x_o) + L_1(x_1)f(x_1) + L_2(x_2)f(x_2)$$

$$= \frac{(2.90-2.30)(2.90-2.60)\ (36.12)}{(2.00-2.30)(2.00-2.60)} + \frac{(2.90-2.00)(2.90-2.60)\ (42.12)}{(2.30-2.00)(2.30-2.60)} + \frac{(2.90-2.00)(2.90-2.30)\ (48.12)}{(2.60-2.00)(2.60-2.30)}$$

$$= \frac{(0.6)(0.3)\ (36.12)}{(-0.3)(-0.6)} + \frac{(0.90)(0.30)\ (42.12)}{(0.3)(-0.3)} + \frac{(0.75)(0.45)\ (48.12)}{(0.6)(0.3)}$$

= 36.12 – 126.36 + 144.36

P_n (2.90) = 54.12 Terabytes

For 3,050 internet users, the corresponding effective data bandwidth will be calculated as follows:

$$P_n(3.05) = L_o(x_o)f(x_o) + L_1(x_1)f(x_1) + L_2(x_2)f(x_2)$$

$$= \frac{(3.05-2.30)(3.05-2.60)\ (36.12)}{(2.00-2.30)(2.00-2.60)} + \frac{(3.05-2.00)(3.05-2.60)\ (42.12)}{(2.30-2.00)(2.30-2.60)} + \frac{(3.05-2.00)(3.05-2.30)\ (48.12)}{(2.60-2.00)(2.60-2.30)}$$

$$= \frac{(0.75)(0.45)\ (36.12)}{(-0.3)(-0.6)} + \frac{(1.05)(0.45)\ (42.12)}{(0.3)(-0.3)} + \frac{(1.05)(0.75)\ (48.12)}{(0.6)(0.3)}$$

= 67.725 – 221.130 + 210.525

P_n (3.05) = 57.12 Terabytes

For 3,200 internet users, the corresponding effective data bandwidth will be calculated as follows:

$$P_n(3.20) = L_o(x_o)f(x_o) + L_1(x_1)f(x_1) + L_2(x_2)f(x_2)$$

$$= \frac{(3.20-2.30)(3.20-2.60)\ (36.12)}{(2.00-2.30)(2.00-2.60)} + \frac{(3.20-2.00)(3.20-2.60)\ (42.12)}{(2.30-2.00)(2.30-2.60)} + \frac{(3.20-2.00)(3.20-2.30)\ (48.12)}{(2.60-2.00)(2.60-2.30)}$$

$$= \frac{(0.9)(0.6)\ (36.12)}{(-0.3)(-0.6)} + \frac{(1.6)(0.6)\ (42.12)}{(0.3)(-0.3)} + \frac{(1.2)(0.9)\ (48.12)}{(0.6)(0.3)}$$

= 108.36 – 336.96 + 288.72

P_n (3.20) = 60.12 Terabytes

4.0: Empirical Analysis of Results

The post data results obtained from the analysis is workable and reliable. Internet data bandwidth predictor was examined and modelled. The corresponding results from the empirical data analysis of the Linear Lagrange's Interpolation (LILAGRINT) model predictor is shown in the table below.

Table 4.1: Interpolated Internet Data Bandwidth with Acceptable Number of Internet Users

x_i (‘000)	F (x_i) (Terabyte)
2.0000	36.1200
2.3000	42.1200
2.6000	48.1200
2.7500	51.1200
2.8250	52.6200
2.9000	54.1200
2.9750	55.6200
3.0500	57.1200
3.1250	58.6200
3.2000	60.1200
3.2750	61.6200
3.3500	63.1200
3.4250	64.6200
3.5000	66.1200
3.5750	67.6200
3.6500	69.1200
3.7250	70.6200
3.8000	72.1200
3.8750	73.6200
3.9500	75.1200
4.0250	76.6200
4.1000	78.1200
4.1750	79.6200
4.2500	81.1200
4.3250	82.6200
4.4000	84.1200
4.4750	85.6200
4.5500	87.1200
4.6250	88.6200
4.7000	90.1200
4.7750	91.6200

There are several points of discussion in the graph of the Linear Lagrange’s Interpolation (LILAGRINT) model predictor that emanated as learned outcomes in this research work. These were presented in the post-data presentation report hereunder and there is no competing interest in this area of work.

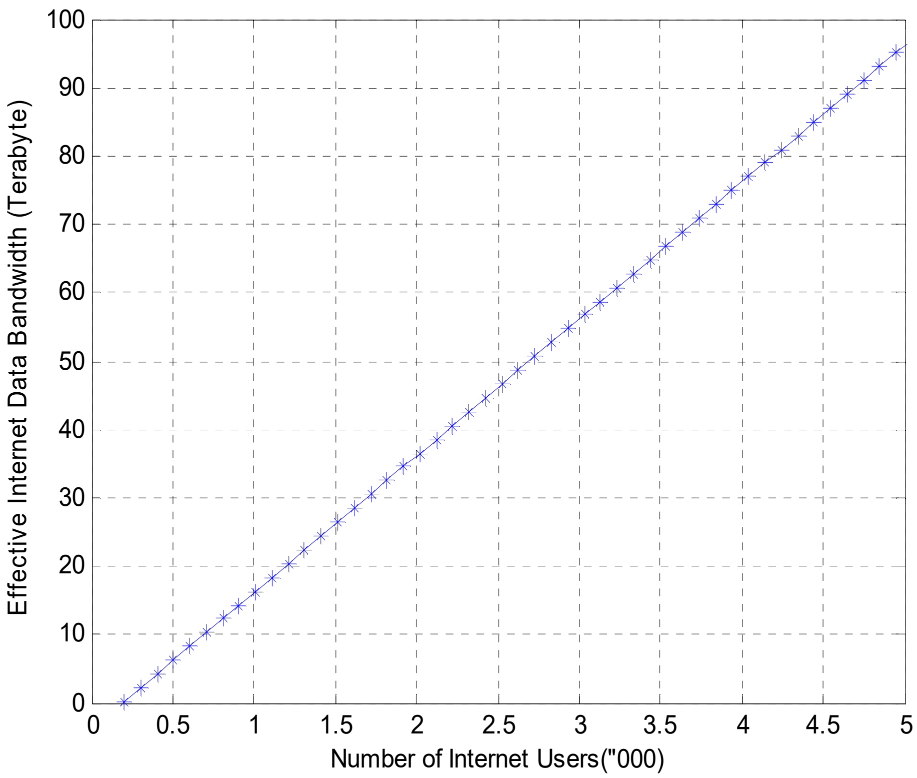

Fig.4.1: Effective Internet Data Bandwidth versus Number of Internet Users

4.1 Graph of Linear Lagrange's Interpolation (LILAGRINT) Model

The result of the MATLAB program in Appendix A is represented in the graph above. We represent Effective Internet Data Bandwidth (Terabyte) as B and the Number of Acceptable Internet Users ('000) as U. Mathematically; we have the relation governing the two parameters as shown below:

$$B = mU + C_0$$

Where, m = Gradient of the straight line and

C_0= Constant of the linear equation.

Also, $m = \Delta B/\Delta U = (78.12 - 36.12)/ (4.100 - 2.000) = 42.00/2.100 = 20$.

Therefore, m=20

$$B = 20U + C_0$$

From the graph, when B= 0. U=0.25

$0 = 20(0.25) + C_0$

$C_0 = -5$

The final relation could be written as

$$B = 20U - 5 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The equation (1) above governs the relationship between the Effective Internet Data Bandwidth (B) and Number of Acceptable Internet Users (U) in the Lagos State University of Science and Technology as the case study of this research [67]

5.0 Conclusion

In this research paper, the method of Internet Data Bandwidth optimization known as Link-Load Balancing technique proved to be an effective way of maximization of utilization and availability of internet access. The LILAGRINT model is a mathematical modelling generated from the three data points measured and estimated from the tables above. The Linear Lagrange's Interpolation (LILAGRINT) model was proposed, tested and validated at the ICT department of LASUSTECH. The Lagrange's method of interpolation stands out to be one of the best means of predicting Internet Data Bandwidth and the acceptable number of Internet Users in a campus-based environment [10]. The graphical representation allows us to view and evaluate the effective internet data bandwidth and the corresponding acceptable number of internet users as the population of user's increases.

6.0 Recommendation

Model modification and improvement will be necessary in the future if the students are provided with state-of-art hostel accommodation installed with internet services.

AUTHOR DECLARATIONS

Competing Interests

Authors have declared that no competing interests exist

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Appendix A
MATLAB PROGRAM OF LINEAR LANGRAGE'S INTERPOLATION (LILAGRINT) MODEL FOR LASUSTECH

```
clc
clear
x=linspace(0,10.00,100);
A=36.12.*(x-2.30).*(x-2.60)./(0.18);
B=42.12.*(x-2.00).*(x-2.60)./(-0.09);
C=48.12.*(x-2.00).*(x-2.30)./(0.18);
P=A+B+C;
figure, plot(x,P,'*-'),axis([0,5.0,0,100]);
xlabel('Number of Internet Users("000)');
ylabel('Effective Internet Data Bandwidth (Terabyte)');
grid on
```