
IMPROVEMENT OF BANDWIDTH UTILIZATION FOR MOBILE NETWORK EDGE CARRIER ETHERNET USING MEASUREMENT-BASED ADMISSION CONTROL ALGORITHM

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ABSTRACT

The edge of mobile networks dominated with multiplexers which either use Synchronous Digital Hierarchy (SDH) or Wavelength Division Multiplexing (WDM) for transport experience packet loss due to underutilization of bandwidth during packet flow. To resolve this problem, a Measurement Based Admission Control (MBAC) algorithm was implemented on the multiplexer for edge carrier Ethernet network to improve the bandwidth utilization. The developed algorithm was implemented using C-sharp (C#) platform. Based on the simulation results, the bandwidth utilization of the WDM system was improved by 30.36% and that of the SDH system was also improved by 25.34% when compared to the results obtained from the measured data from the network before the implementation of the MBAC algorithm. From the t-test results obtained, the probability levels (P-values) of bandwidth utilization for both the edge systems were less than 0.05. This means that the developed algorithm has achieved better bandwidth utilization than that of the measured data from MTN Lagos network.

Keywords: Admission control, MBAC, SDH, WDM, MIB, Equivalent Capacity.

INTRODUCTION

Admission control is a set of actions, consecutively executed to decide whether a customer can be admitted into a network segment or not (Bohnert, 2011). It is a congestion avoidance mechanism. The primary role of admission control in a QoS enabled network is to control the amount of traffic injected into the network so that congestion is avoided (Gao et al, 2012). A well-defined IP- or Ethernet- based network which should satisfy the QoS requirements of IP services must exercise admission control at the edge and core of its network to control the amount of traffic injected into its network (Rathore et al, 2011). There are different types of admission control methods and their differences are mainly due to the different types of operations and methods of implementation. Some admission control methods are based on mathematical calculations and statistics

indicators, others on measured traffic (Chromy et al, 2013(a)). So many researchers have developed MBAC algorithm to solve QoS related issues, some of which are reviewed in this work.

Alwakeel and Alotaibi, (2011) proposed the EMBAC-L scheme for QoS in VOIP networks. They evaluated the performance of the scheme by using different distribution functions to find the admission scheme parameters that could provide the required acceptable QoS. They showed that the performance of EMBAC-L scheme provided an enhancement to the original EMBAC scheme. They did not make provision for decision to be taken by the scheme on packets that were rejected. (Ammar et al, 2011) submitted work on evaluation and comparison of MBAC solutions, where three MBAC solutions of measured sum, equivalent capacity, and aggregate traffic envelopes were evaluated and compared in terms of packet loss rate and packet

queuing delay. The researchers observed all investigated solutions were able to fulfil the target loss rate. On the other hand, only the aggregate traffic envelope was always able to meet the target queuing delay. The parameter set for packet loss rate in this work was not based on any known packet loss rate standard. (Chromy et al, 2013(b)) presented a work on admission control in IP Multimedia Subsystem (IMS) networks. They simulated admission control methods in MATLAB environment. Their simulation result showed that in case of higher traffic load, the selection of admission control algorithm was very important and from the effective bandwidth

utilization point of view, the Hoeffding bound method was most suitable. Best simulation result could be obtained if measured data was obtained, studied, and analysed before considering the nature of data to be used in the simulation.

1.0 Key Performance Indicator (KPI)

The most valuable KPIs in this paper which serve as tools in achieving the implementation of the MBAC algorithm at the edge of carrier Ethernet network to improve bandwidth utilization are itemized here under:

2.1 Equivalent Bandwidth allocation

The equivalent bandwidth, \hat{C} is defined by (Guerin and Naghshineh) as:

$$\hat{C} = \min\{m + \alpha' \sigma, \sum_{i=1}^N \hat{c}_i\} \tag{1}$$

where,

m is the mean aggregate bit rate:

$$m = \sum_{i=1}^N m_i \tag{2}$$

σ is the standard deviation of the aggregate bit rate:

$$\sigma^2 = \sum_{i=1}^N \sigma_i^2 \tag{3}$$

$$\alpha' = \sqrt{-2 \ln(\epsilon) - \ln(2\pi)} \tag{4}$$

2.2 Improved Percentage Bandwidth Utilization

The percentage improved bandwidth utilization is determined by (Okoh, et al, 2016):

$$\% \text{ improved Bandwidth} = \frac{N-M}{N} * 100 \tag{5}$$

where:

N = computed equivalent bandwidth (computed ifHcOutUcastPkts)

M = system recorded bandwidth (ifHcOutUcastPkts)

DEVELOPED MBAC ALGORITHM IMPLEMENTATION

The MBAC algorithm developed is to improve bandwidth utilization at the edge of carrier Ethernet network. The implementation of the algorithm was achieved by applying the steps of flow chart represented in Figure 1. Simulation results obtained from the developed algorithm were validated against raw data results from MTN mobile network, Lagos using Welch's T-Test.

The MBAC algorithm was implemented using C# (C-sharp) programming environment. Lenovo laptop computer system with its properties as: processor of Intel(R) core(TM) i3 2.40GHZ, RAM of 4.00Gb of 64 bits Windows 8 was used. The simulation of the developed MBAC algorithm was carried out for an average of twenty-four hours.

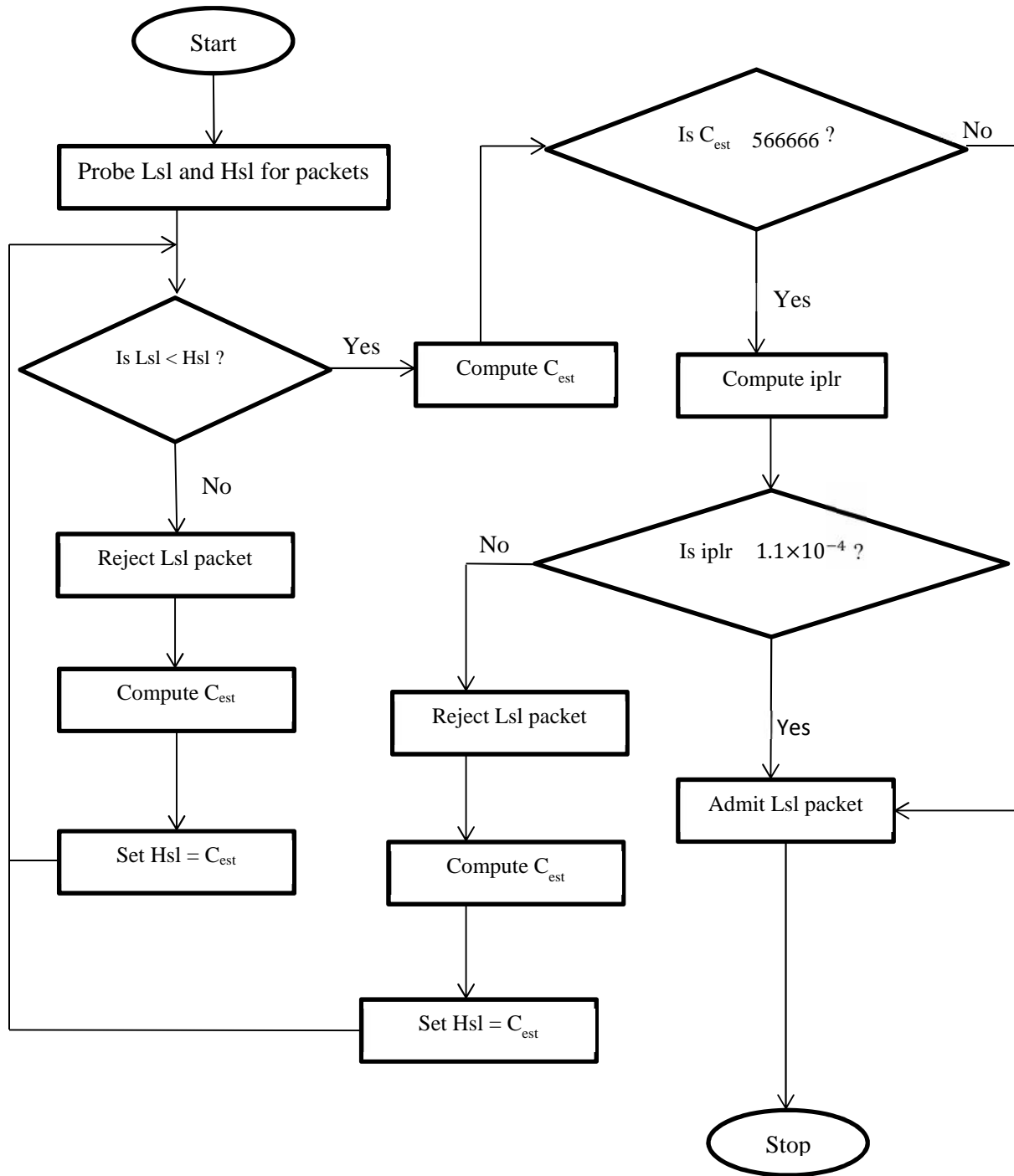


Figure 1: Flow Chart of MBAC Algorithm (Okoh et al, 2016)

RESULTS AND DISCUSSIONS

Here, discussions are centred on simulation and raw data results obtained from MTN, which were evaluated to establish the authenticity and improvement made by the developed algorithm. The results of the two systems (SDH and WDM) were analysed and tabulated to

show improvement of the developed model. The significance and uniqueness of the findings of this paper were centred on resolving three issues not addressed by Alwakeel and Alotaibi, (2011), Ammar et al., (2011), and Chromy et al., (2013b), in order to achieve the quality of the results obtained and the improvement of bandwidth

utilization crucial in communication. These three key issues were the ability to decide what to do with rejected packets in the channel, having packet loss rate that was based on standard, and using measured data to get better simulation results, which were not respectively addressed by these researchers. In this paper, however, the developed MBAC algorithm was able to address these limitations adequately, particularly the rejected packets issue, which resulted in the significant improvement of the bandwidth.

4.1 Simulation and Measured Data Results

The simulation was carried out on C# platform and it depicts the network from which the measured data was taken. Unlike the real network, the simulation incorporated the MBAC algorithm. The simulation was carried out for an average of twenty-four hours. Like the measured data, weekly average was taken for thirteen weeks. The results obtained from WDM and SDH systems simulations using the developed MBAC algorithm are summarized as presented in Table 1 and Table 2.

Table 1: Simulation Results from WDM System

Week	ifHclnUcastPkts (Pkt/s)	Bandwidth utilization (Pkt/s)
1	390,660	0
2	390,869	526,073
3	390,956	526,103
4	390,750	525,927
5	390,695	525,844
6	391,365	526,545
7	391,017	526,175
8	390,804	525,968
9	390,441	525,611
10	390,757	525,890
11	390,574	525,706
12	391,014	526,132
13	390,487	525,677

Table 2: Simulation Results from SDH System

Week	ifHclnUcastPkts (Pkt/s)	Bandwidth utilization (Pkt/s)
1	390,779	0
2	390,396	525,541
3	389,141	524,271
4	389,932	525,047
5	390,578	525,711
6	389,318	524,454
7	390,529	525,671
8	391,023	526,166
9	390,099	525,189
10	388,968	524,114
11	390,551	525,705
12	390,614	525,829
13	388,861	523,974

The measured data was collected from MTN network Lagos, Nigeria for period of three months, from January to March, 2016. There were two sets of data collected as follows:

1. **Data from 1 Gb Ethernet interface of an ETEXIOS card.** ETEXIOS is a packet capability module on Tellabs 6300 multiplexer that supports Ethernet over SDH services. The data collected from the ETEXIOS was studied, analysed, and used for the development of MBAC algorithm for the SDH system on a carrier Ethernet network.
2. **Data from 1 Gb Ethernet interface (line card) of Tellabs 8660 multiplexer.** Also,

the same analysis was done on the data collected and used for the development of MBAC algorithm when the Tellabs 8660 support Ethernet over WDM on a carrier Ethernet network service was implemented.

These multiplexers were accessed through the Tellabs Intelligent Network Management (INM) and the data were pulled out using performance management tool. The measured data results are shown in Table 3 and Table 4. These data were used for analysis to aid the development of the MBAC algorithm and to validate the developed MBAC algorithm using statistical Welch's T-Test.

Table 3: Measured Data Results from WDM System

Week	ifHclnUcastPkts (Pkt/s)	Bandwidth utilization (Pkt/s)
1	390,660	374,409
2	390,869	374,815
3	390,956	366,353
4	390,750	373,883
5	390,695	372,248
6	391,365	368,593
7	391,017	368,781
8	390,804	369,602
9	390,441	374,551
10	390,757	370,469
11	390,574	366,869
12	391,014	375,421
13	390,487	371,159

Table 4: Measured Data Results from SDH System

Week	ifHclnUcastPkts (Pkt/s)	Bandwidth utilization (Pkt/s)
1	390,779	394,639
2	390,396	393,532
3	389,141	394,674
4	389,932	394,131
5	390,578	394,268
6	389,318	393,797

Week	ifHclnUcastPkts (Pkt/s)	Bandwidth utilization (Pkt/s)
7	390,529	392,869
8	391,023	392,797
9	390,099	393,831
10	388,968	392,975
11	390,551	393,131
12	390,614	393,517
13	388,861	393,700

The simulation and measured data results were used to compute improved percentage bandwidth utilization in Table 5 and Table 6.

Table 5: Percentage Improved Bandwidth for WDM System

week	Bandwidth utilization_meas (Pkts/s)	Bandwidth utilization_sim (Pkts/s)	percentage improved bandwidth (%)
1	374409	0	0
2	374815	526073	28.75228343
3	366353	526103	30.36477648
4	373883	525927	28.90971561
5	372248	525844	29.20942333
6	368593	526545	29.99781595
7	368781	526175	29.91286169
8	369602	525968	29.72918505
9	374551	525611	28.73988558
10	370469	525890	29.5538991
11	366869	525706	30.21403598
12	375421	526132	28.64509287
13	371159	525677	29.39409561

Table 6: Percentage Improved Bandwidth for SDH System

Week	Bandwidth utilization_meas (Pkts/s)	Bandwidth utilization_sim (Pkts/s)	percentage improved bandwidth (%)
1	394,639	0	0
2	393,532	525,541	25.11868722
3	394,674	524,271	24.7194676
4	394,131	525,047	24.93414875
5	394,268	525,711	25.00290083
6	393,797	524,454	24.91295709
7	392,869	525,671	25.26333011
8	392,797	526,166	25.34732385

Week	Bandwidth utilization_meas (Pkts/s)	Bandwidth utilization_sim (Pkts/s)	percentage improved bandwidth (%)
9	393,831	525,189	25.01156726
10	392,975	524,114	25.0210832
11	393,131	525,705	25.21832587
12	393,517	525,829	25.16255285
13	393,700	523,974	24.86268403

Superimposed graph of bandwidth utilization versus load and improved percentage of bandwidth utilization are plotted using data of Table 5 and Table 6 to

show improvement when the developed MBAC algorithm was applied. These graphs are illustrated in Figure 2 to Figure 5 respectively.

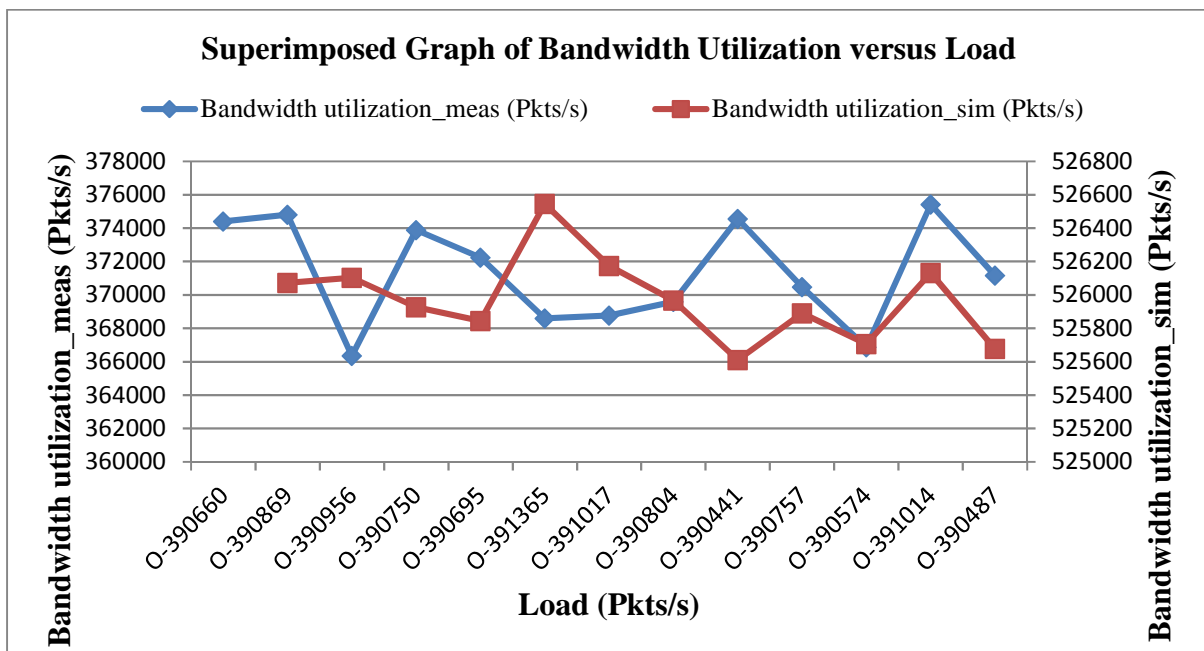


Fig. 2: Superimposed Graph of Bandwidth Utilization versus Load for WDM System

The graph covers the 13 weeks of measured data obtained from the network. There was no bandwidth utilization when the algorithm was applied in week 1. MBAC algorithm is based on a preceding measured value. In the first week, there was no preceding measured value. This is the reason for absence of Bandwidth utilization_sim in week 1. The real test for the algorithm was observed from the 2nd week. The bandwidth utilization of the measured

value was observed to be less than the load throughout the 13 weeks. This was one characteristics observed with the WDM system and this contributed to the large value of packet loss. The bandwidth increased more than the load when the algorithm was applied for the period of the simulation. The maximum bandwidth (526545 pkts/s) when the algorithm was applied was achieved in week 6.

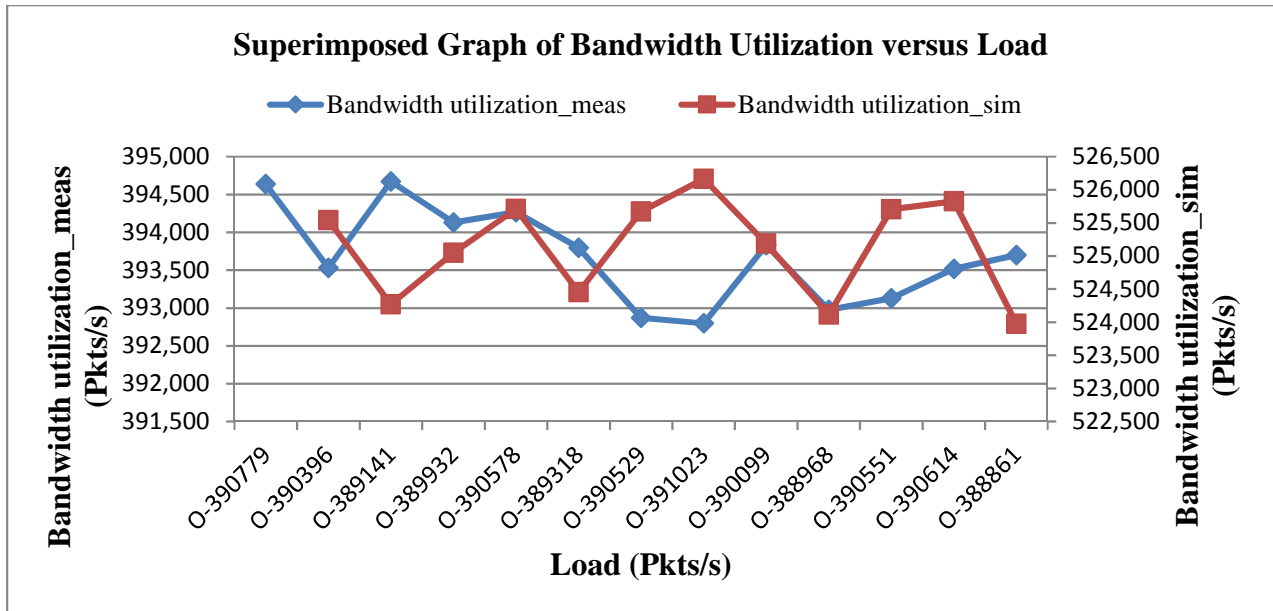


Fig.3: Superimposed Graph of Bandwidth Utilization versus Load for SDH System

The graph covers the 13 weeks of measured data obtained from the network. Unlike the WDM system, the bandwidth utilization of the SDH system was greater than its load for the period of the measurement. The bandwidth

utilization was optimized when the algorithm was applied. The maximum bandwidth (526166 pkts/s) when the algorithm was applied was achieved in week 8.

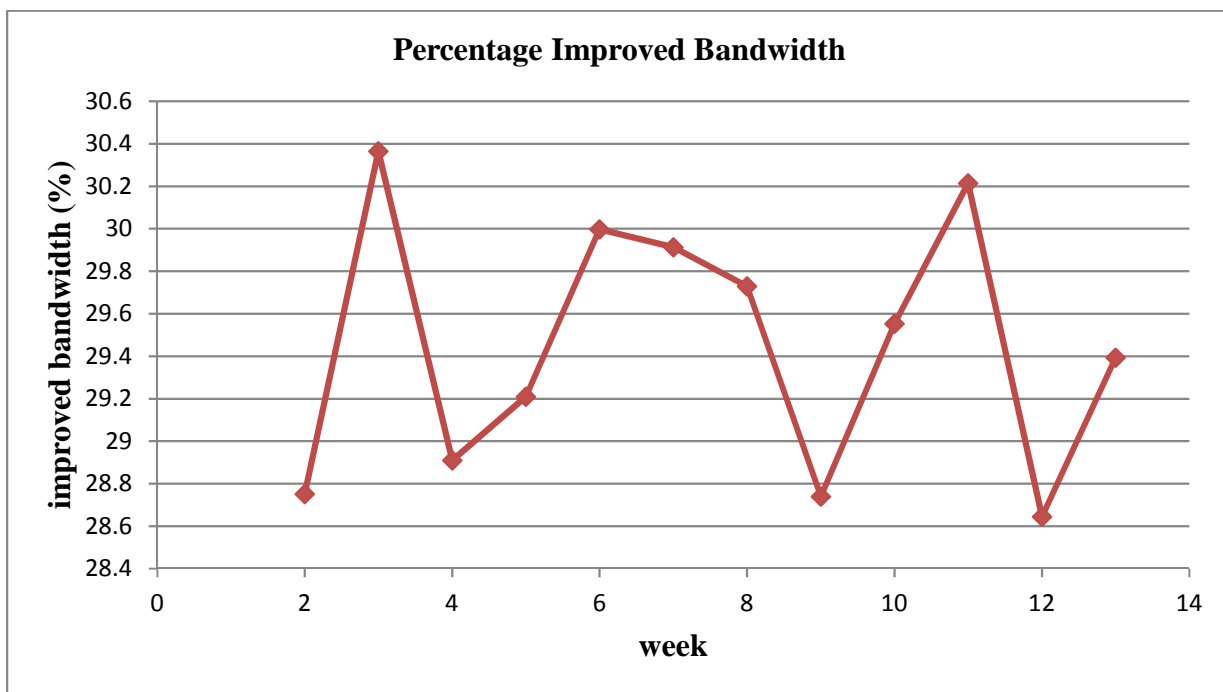


Fig. 4: Percentage Improved Bandwidth for WDM System

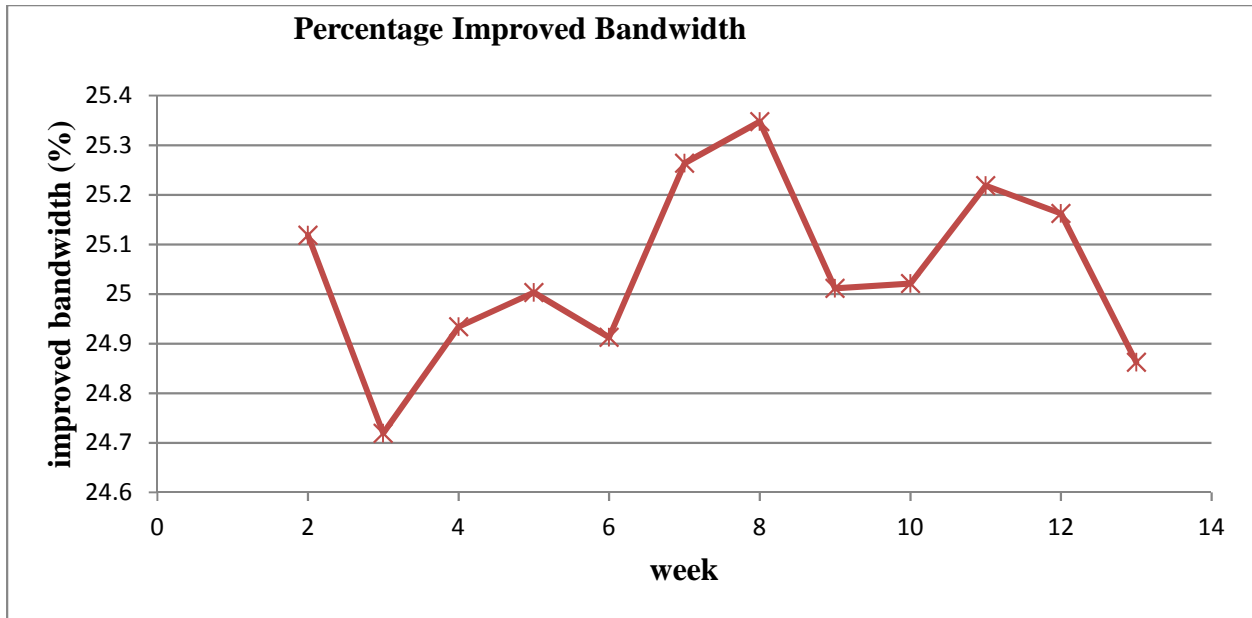


Fig. 5: The highest percentage improved bandwidth utilization for WDM system within the 13 weeks was 30.36% while that of SDH system was 25.34%.

4.2 Validation of Results

Validation was carried out by comparing the simulation results of the developed MBAC algorithm with the measured data from MTN Lagos network using Welch's t-test of unequal variances. The results of the Measured Data (MD) and Simulated Data (SD) performance metrics of bandwidth utilization were inserted and run using IBM SPSS statistics 24 software tool. The t-test results of the

bandwidth utilization obtained were extracted as shown in Table 9 and Table 10, respectively.

4.2.1 IPLR T-Test Results

The results of the independent-sample t-test for bandwidth utilization between MD and SD for the WDM and SDH systems are shown in Table 9 and Table 10.

Table 9: Results of T-Test on Bandwidth Utilization for WDM System

Bandwidth utilization	N	Mean	SD	t-value	P
MD	12	371062.00	3135.88	-170.54	0.00
SD	12	525970.92	258.62		

From the results of Table 9, t-value is -170.54, P is 0.00. Since P (0.00) is less than α (0.005), which implies rejection of the null hypothesis and therefore means that, there is significant difference between the

developed algorithm and existing one. This indicates that the developed algorithm has better results when compared with results of the measured data of MTN Lagos network.

Table 10: Results of T-Test on Bandwidth Utilization for SDH System

Bandwidth utilization	N	Mean	SD	t-value	P
MD	12	393601.83	585.60	-476.72	0.00
SD	12	525139.33	754.65		

Similarly, from the result of Table 10, t-value is -476.72, P is 0.00. Since P (0.00) is also less than α (0.005), null hypothesis is rejected, which means that there is significant difference between the developed algorithm and existing one. This indicates that the developed algorithm achieved improved performance and better in comparison with the measured data results of present MTN Lagos network.

CONCLUSION AND FURTHER WORK

The MBAC algorithm was developed and implemented on a C# platform. Based on the simulation results, WDM system bandwidth utilization was improved by 30.36% and SDH system bandwidth utilization was improved by 25.34% as compared to the baseline result before implementation of the MBAC algorithm. From the t-test results obtained, the probability level (P-value) of bandwidth utilization for both edge systems was less than 0.05. This implies that P-value of the metrics reject the null hypothesis which means that the developed algorithm has better performance in comparison with the measured data from MTN Lagos network without the algorithm. This work can further be improved by developing an end-to-end model for packet loss management in an IP network.

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