Time Based Traffic Policing and Shaping Algorithms on Campus Network Internet Traffic

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***Abstract*—This paper presents the development of algorithm on Policing and Shaping Traffic for bandwidth management which serves as Quality of Services (QoS) in a Campus network. The Campus network is connected with a 16 Mbps Virtual Private Network line to the internet Wide Area Network. Both inbound and outbound real internet traffic were captured and analyzed. Goodness of Fit (GoF) test with Anderson-darling (AD) was fitted to real traffic to identify the best distribution. The Best-fitted Cumulative Distribution Function (CDF) model was used to analyze and characterized the data and the parameters. Based on the identified parameters, a new Time Based Policing and Shaping algorithm have been developed and simulated. The policing process drops the burst traffic, while the shaping process delays traffic to the next time transmissions. Mathematical model to formulate the controlled algorithm on burst traffic with selected time has been derived. Inbound traffic threshold control burst was policed at 1200 MByte (MB) while outbound traffic threshold was policed at 680 MB in the algorithms. The algorithms were varied in relation to the identified Weibull parameters to reduce the burst. The analysis shows that the higher shape parameter value that relates to the lower burst of network throughput can be controlled. This research presented a new method for time based bandwidth management and an enhanced network performance by identifying new traffic parameters for traffic modeling in Campus network.**

***Index Terms*—Policing; Shaping; Bandwidth Management; Internet Traffic; Quality of Service; Goodness of Fit; Anderson-Darling.**

I. INTRODUCTION

Nowadays, network traffic has grown tremendously due to the increasing usage of internet access. The significant growth of traffic is mainly driven by data applications, voice and video application. Network traffic is the main area to be controlled and managed in order to preserve network performance. Quality of service (QoS) requirements and efficient utilization of network bandwidth is an important service in network maintenance. Thus, bandwidth management is an approach that provides adaptability, feasibility and efficiency for real network [1]. Without bandwidth management, high rate over committed access rate is misused. A traffic algorithm to control bandwidth utilization is introduced and packet data can be saved in a study [2]. One of bandwidth management algorithms is called traffic policing and traffic shaping. It is a technique to prevent the traffic congestion in the network and improve the QoS performance. The policing process provides benefit to the bandwidth saving and avoids delay in transmission, but its drawback is that some of the data are dropped.

Understanding internet traffic characteristic and its model is important for QoS. Traffic model varies significantly depending on users and applications used in the network. Normal traffic model shows direct link to the presence or absence of extreme traffic burst, but it is suitable to model the traffic demand in large-scale network [3]. Lognormal distribution model presents slower decay [4], which is likely towards exponential distributions. Some links are not able to accommodate more traffic at short range and show some yields changes in their performance [5]. The variation of shape parameter of the Weibull distribution model can capture the transformation of internet traffic which consists of various sessions. Some traffic show heavy-tailed streams models and some are exponential [6]. The distribution model has its own characteristic and the selection of the traffic model does not only consider the type of traffic but also depends on the application.

This research presents a newly developed algorithms called Time based traffic policing and shaping (TBPS) with Weibull model (TBPSW) to control traffic burst over Committed Access Rate at two selected time which are at day and night in Campus network. Real internet traffic is collected and analyzed on inbound and outbound internet flow. Anderson-darling (AD) on Goodness of Fit (GoF) test was used to estimate the best parameter characterization and identify the best traffic model. Mathematical model on both new algorithms has been derived. The results present traffic performance in bandwidth management by controlling burst traffic with both TBPS and TBPSW algorithms. Traffic performance for both inbound and outbound on control burst was analyzed and presented. Thus, both algorithms have optimized bandwidth usage under certain policy threshold identified.

II. LITERATURE REVIEW

A. Bandwidth Management Algorithms

Recent bandwidth management has been developed as high utilization of internet access application. Scheduling algorithm is one of the control algorithms on network traffic related to bandwidth management which improves the performance on bandwidth [7]. It optimizes ordered throughput using an autonomic cloud bursting schedulers. Shaping traffic is another bandwidth management that uses multiple correlated token bucket to buffer packet flow, which holds high bandwidth rates [8]. Others, like traffic policing or filtering dropped packets also control high packet rates but they use leaky buckets [9, 10]. The drawback of traffic policing and traffic shaping is that they can only decrease the data rates, but have less impact on aggregate burst traffic behavior. The additional aggregation will maintain the burst within burst phenomena in real time traffic and make reduction of data transfer rate [11]. Therefore, the next generation of network traffic must deploy new aggregation models as data rates move toward bigger network bandwidth at higher transmission speed. New aggregation methods must rearrange burst to minimize heavy tail and self-similarity without degradation of performance in the QoS. As high throughput in the network grows, it may increase the transmission burst with huge overflows at intermediate router queues. Implementation of packet layer policing in network is an example of bandwidth policing [12]. The introduction of inter-packet delays to spread packets in time helps to reduce burst in the network.

B. Distribution Theory and Fitted Test

In order to keep the performance in constant, evaluation on traffic models and parameters should be defined to quantify the model at its optimum utilization. The best parameter of the models should come from an actual performance measures especially real data collection. Some algorithms are developed based on random data simulation. Important parameters, such as the Mean, μ and standard deviation, σ are the parameters that show the characteristic of normal distribution. Lognormal distribution is used to model continuous random data when the normal distribution is a skewed curve [13]. Weibull model involved with scale, β and shape α are also recognized as parameters. The advantages of Weibull distribution model used to model traffic are its constant failure rate, decreasing failure rate or increasing failure rate. Exponential distribution is related to Poisson distribution and it is widely used to model waiting time[14].

There is a formal statistical technique for assessing the principal distribution of traffic data called the GoF test. The GoF test is applied to measure the compatibility of the real data with theoretical probability distribution function or empirical distribution of data population. GoF tests is considered as one of the best tested technique [15]. Probably it is depended on the specific distributions. Anderson-Darling (AD) statistical parameter is important to determine the fitted model as well as probability level (p-value) in the GoF test [16]. GoF test is essentially based on either of the two distributions, which are the CDF and the probability density function (PDF).

III. METHODOLOGY

The method comprises statistical analysis on real data and algorithms development called TBPS and TBPSW.

A. Statistical Test with AD and GOF

Figure 1 shows the flowchart to characterize the real internet traffic. It involved data collection on campus network, Gof test with AD. AD test presented the P-value. Traffic characterization and parameters are presented.

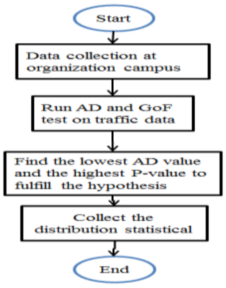

Figure 1: Methodology Flow

Empirical CDF is used to approximate the parameters. AD test as in Equation 1 is used where it is the sample size and the standard normal cdf [(x-μ)/σ]. The Weibull distribution is as presented in Equation (2).

$$A^2 = -n - \left(\frac{1}{n}\right)\sum_{i=1}^{n}(2i-1)\left[\ln(w_i) + \ln(1 - w_{n-i+1})\right] \qquad (1)$$

$$w_i = 1 - e^{-\left(\frac{xi}{\beta}\right)^{\alpha}} \qquad (2)$$

The AD and GoF test use specific distribution in calculating critical values. This has become an advantage of GoF where more sensitive test is allowed, although it has the disadvantage, in which the calculation of the critical values for each distribution must be performed. The parameters of each data population were compared and the most suitable distribution was chosen. The distribution model with lower of AD value and higher probability value (p-value) was selected.

B. Token Bucket Mechanism

Token bucket mechanism was used as buffer to control the congestion traffic.

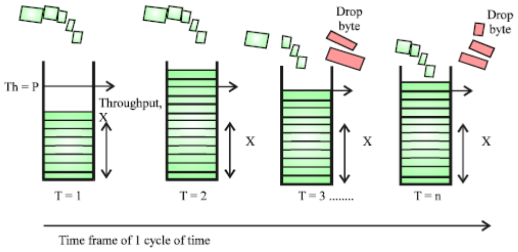

Figure 2: The Token Bucket Concept

Figure 2 presents the Token Bucket transitions of throughput, X on policy and threshold, Th [17]. Threshold is the maximum possible transmission rate in bytes/second or identified as Policy, P. The maximum burst time is the time where the rate of throughput, X is fully utilized. Bytes as token are discarded from the bucket if it is beyond the threshold, th or policy, P and per Bucket size, B_k. The incoming throughput is put in bucket according to the identified policy condition P.

C. Mathematical Model on Algorithm

Table 1 presents the analyzed parameter gathered from the GoF test in the previous research. The traffic model used these parameters to develop the new algorithms.

Table 1
Variable Parameter

Parameter	Symbol Values	Values
Time based traffic	X	0.00 am to 11.50 pm
No. of Day	D	7
Network Speed	S	16Mbps
Inter Arrival Time	Ta	10 minutes
Min time Frame	Tmin	0.00 am
Max Time Frame	Tmax	11.50 pm
Arrival Traffic	x	1>x>1108
Weibull Shape	α	2.33 , 1.9909
Weibull Scale	β	1058.523, 379.8954
Min data	i	1
Max data	n	1108
Policing Inbound threshold	PThi	1200 MByte (MB) 1050 MB
Policing Outbound Threshold	PTho	680 MB 434 MB
Number of Time	t	(1,2)
Day time Policing	DP=1	8.00 am to 11.59 pm
Night Time Policing	NP=2	12.00 am to 7.59 am
Traffic Cycle	C	1008

Four main algorithms have been developed based on the enhancement on the mathematical model in [18, 19]. Equation 3 presents the enhanced parameter for time based on Policing and Shaping (TBPS) algorithm. The enhancement has been done on Policing traffic at a time based where Th_{it} is enhanced from Th_i, where:

$$t = \{1,2\} \tag{3}$$

Time based was the added parameters to the algorithms as in equation Equation 4 with B_p is the bucket for policing.

$$B_p = \left\{ \begin{array}{l} \sum_{i=1,t=\{1,2\}}^{n,m} x_i - (x_i - Th_{it}), x_i > Th_{it} \\ \sum_{i=1,t=\{1,2\}}^{n,m} x_i \text{ , } x_i < Th_{it} \end{array} \right\} \tag{4}$$

In the shaping process, the traffic was shaped according to selected T_h or allocation of bandwidth at identified time. The purpose of shaping is to optimize the traffic and increase the utilization of internet bandwidth. The shaping algorithms was derived based on Equation 5 with B_s as the bucket shaping.

$$\sum_{i=1,j=1,t=\{1,2\}}^{n,m} B_S = \sum_{i=1}^{n,m} \left\{ \begin{array}{l} (x_1 - (x_1 - Th_{j_t})), 0 < x_i \le C \text{ and } x_1 > Th_{j_t} \\ (x_{i+1} + (x_i - Th_{j_t})), 0 < x_i \le C \text{ and } x_i > Th_{j_t} \\ x_i, 0 < x_i \le c \text{ and } x_i < Th_{j_t} \end{array} \right\} \tag{5}$$

where $C \in \{1,2\}$ and $j \in \{1,2,3\}$

The second algorithms called Time Based Policing and Shaping with Weibull model (TBPSW) was developed. Weibull parameter was used with the conditions β>=0, 1<α<3 in the algorithms. The mathematical model for Weibull policing and shaping was based on the previous study but the real traffic, x was transformed to Weibull fitted traffic as in Equation 6. Simulation in Matlab programming was conducted. The algorithms flow method was derived as shown in Figure 3. Real inter-arrival time is equal to x_i.

$$x_i = 1 - e^{-\left(\frac{x_{i_t}}{\alpha_j}\right)^{\beta_k}}, t = \{1,2\} \tag{6}$$

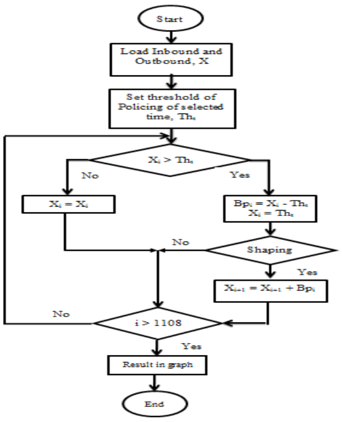

Figure 3: Method Flow of Policing and Shaping Algorithm

IV. ANALYSIS AND RESULT

A. Analysis on Real Traffic

Figure 4 shows the real inbound and outbound campus traffic throughputs over time in 7 days. The trend of inbound data increases over time, while slightly stable for outbound data. The inbound data above 1000 MB shows that there exists burst traffic in the traffic. It is identified as bottleneck of the real network. Thus, optimization of throughput was needed by performing policing and shaping technique for traffic QoS. Traffic for daily time policing and shaping was set to DP and NP which was set at 1050 MB based on 95 percent throughput of original internet traffic population. Token bucket mechanism was used for both policing and shaping algorithms.

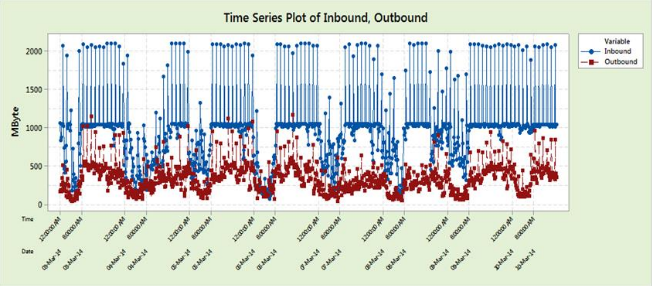

Figure 4: Time series plot of Inbound and Outbound

Figure 5 shows that TBPS on traffic inbound have reached 60 percent of throughput time at the maximum allowable bandwidth 1200 MB, while throughput for policing was at 90 percent total time to reach 1200 MB. The analysis presented that shaping process is essential for data efficiency and QoS improvement. The burst of inbound traffic after policing shows the bandwidth used up to 1000 MB of whole usage of internet traffic. However, the burst of traffic data was kept for shaping process in the next arrival time. Identified total burst existing in inbound traffic was 77799 MB. Shaping was done with no traffic drops. Figure 6 shows TBPS for outbound traffic. The threshold of policing outbound was set at 680 MB at DP and 434 MB at NP. The threshold was set based on 95 percent throughput of total outbound traffic. The analysis shows that shaping has high throughput of 94.5 percent to reach 680 MB while policing throughput was slightly less with 97.2 percent cumulative traffic to reach 680 MB. TBPS algorithms enhanced the performance by fully utilizing the allocated bandwidth and improved the QoS.

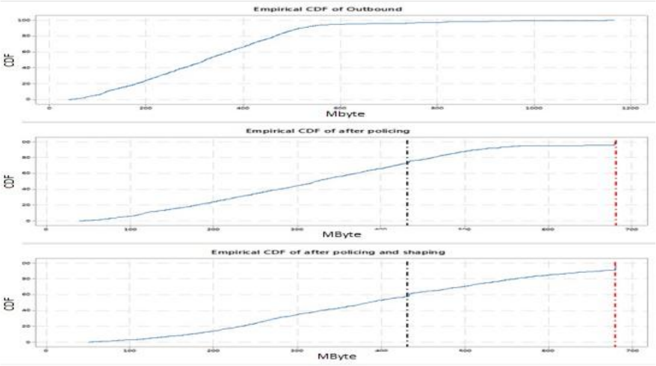

Figure 5: TBPS on Inbound Traffic

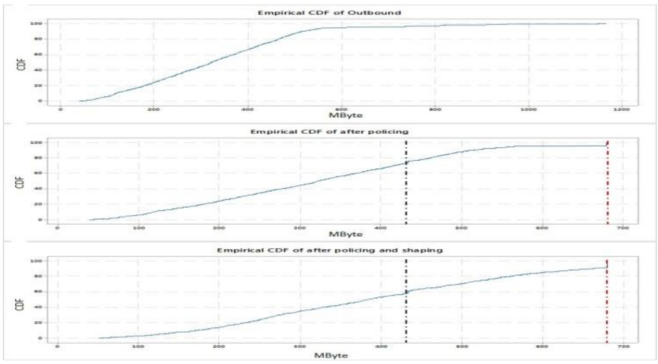

Figure 6: TBPS on Outbound Traffic

Figure 7 and 8 show inbound and outbound traffic burst on and after policing. The burst traffic used the bandwidth up to 500 MB in one time. This burst can be kept in bucket by doing shaping. Total burst for outbound traffic was 10285 MB as shown in Figure 9.

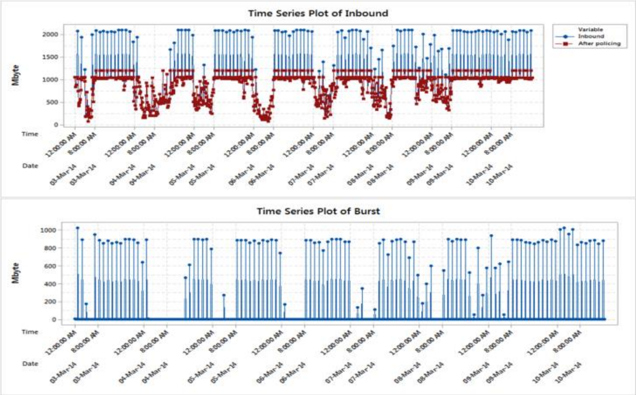

Figure 7: Burst of Inbound after Policing

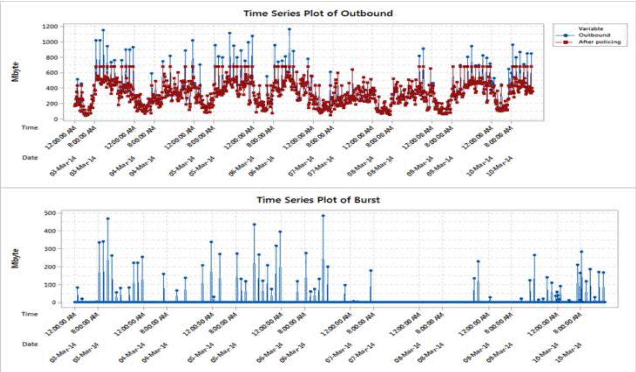

Figure 8: Burst of Outbound after Policing

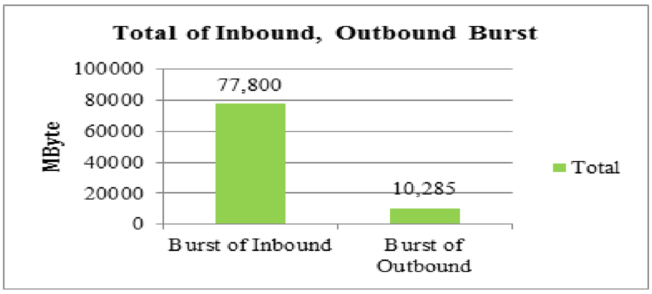

Figure 9: Total burst of Inbound and Outbound

B. Analysis on Fitted Weibull

TBPSW algorithm has been developed based on Weibull parameter in Table 1. Two important Weibull parameters which are shape, α and scale parameter β were used in the algorithms. The Weibull data then were policed at 1200 MB for DP and 1050 MB at NP. The burst after policing was utilized up to 1600 MB bandwidth. Figure 10 shows the time TBPSW for inbound traffic. Traffic in the network was shaping 65 percent usage to reach full utilization 1200 MB while policing was at 82 percent usage to reach full utilization. It shows that shaping process has reach maximum utilization of bandwidth without compromising missing data. For outbound, Weibull distribution was generated with random data based on shape parameter (α=1.9909) and scale parameter (β=379.8954). The random Weibull data policed at 680 MB and 434 MB.

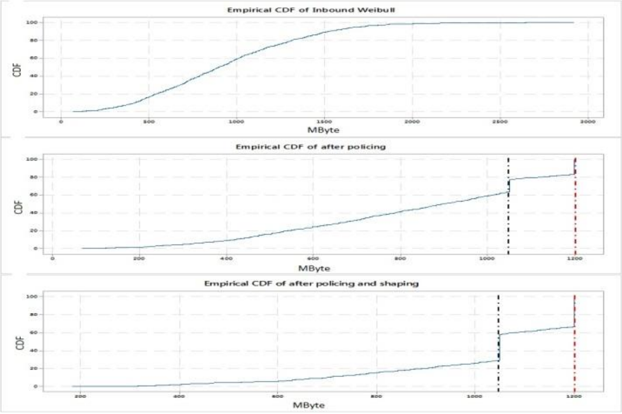

Figure 10: TBPSW for Inbound Traffic

TBPSW for outbound presented burst was up to 460MB bandwidth per time as in Figure 11. The burst of Weibull outbound data was occupied in the next cycle in order to maximize the bandwidth utilization. The cumulative traffic data increased over time by comparing outbound traffic, traffic after policing and traffic after shaping and policing. The Shaping after policing process provides improvement on the utilization of bandwidth and performance of QoS.

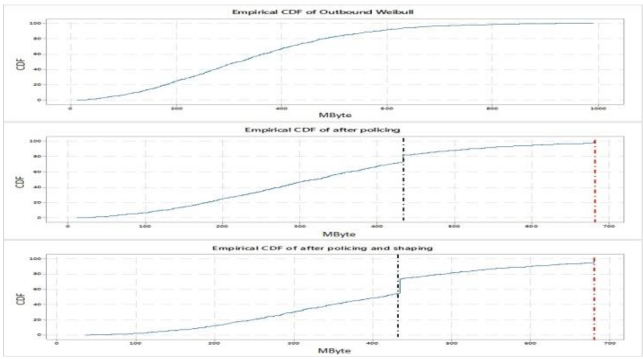

Figure 11: TBPSW for Outbound Traffic

Figure 12 and Figure 13 show the Weibull traffic burst for Inbound and Outbound traffic after policing. The total burst of inbound and outbound data was calculated according to variation of shape parameter. An increase number of shape parameter reduces the total burst and higher throughput as shown in Figure 14. The variation of shape Weibull parameter shows a control for burst in the network traffic.

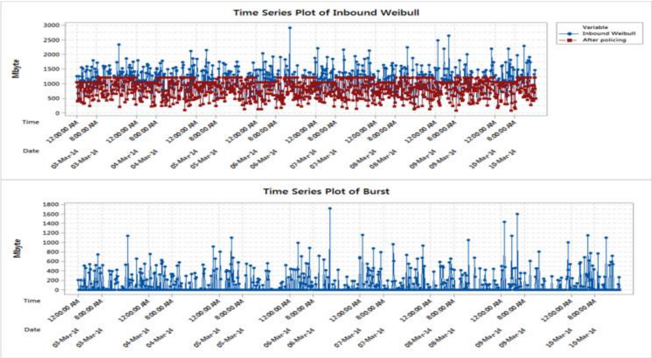

Figure 12: Burst of Outbound after Policing on Weibull

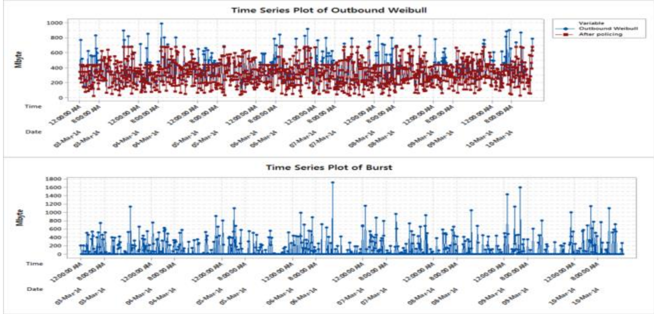

Figure 13: Burst of Outbound after Policing on Weibull

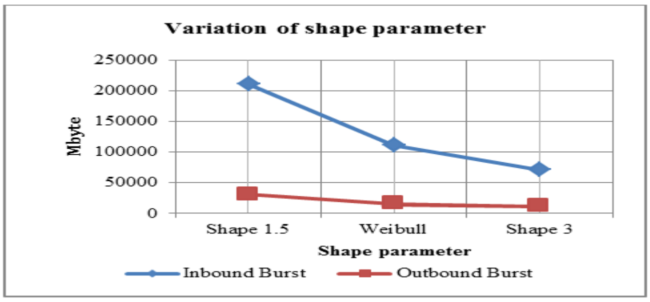

Figure 14: Total Inbound and Outbound Burst on Shape variation

V. CONCLUSIONS

This study has successfully presented a development of two algorithms to control burst traffic for bandwidth management in an IP campus network. Time based Policing and Shaping (TBPS) and Time based Policing and Shaping with Weibull Model (TBPSW) have been presented. The results of the simulation show the network performance in bandwidth management where real network was controlled based on the characteristics of the identified parameters and fitted Weibull parameters. Both algorithms have optimized bandwidth usage under certain policy threshold. Weibull parameters also presented control on burst traffic in which higher value of the shape parameter results in lower burst of network throughput. This will help to increase the quality of service (QoS) in bandwidth utilization, speed and network performance.

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