

## BANDWIDTH MODELING ON SMART CAMPUS BASED ON ENGINEERING METHOD – STATISTICS

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### Abstract

The importance of generating internet traffic as one of the basic considerations in bandwidth allocation policies between faculties is increasing due to the number of students who complain about connection services on campus. This study proposes internet traffic generation based on the statistical - engineering method. The population is calculated based on class capacity in each faculty, as the main alibi of student attendance on campus where traffic arrivals are generated based on the arrival model through information on possible scheduling variations. Although internet services have different characteristics, they are physically determined by the bitrate and idle mode in the traffic time series. The results show recommendations in three application bitrate categories, namely 200kbps, 400kbps, and 800kbps Traffic Shaping.

Keywords: Internet traffic generation, Traffic Shaping, Bandwidth allocation, statistical-engineering method

### Abstrak

Pentingnya membangkitkan trafik internet sebagai salah satu dasar pertimbangan dalam kebijakan alokasi Bandwidth antar fakultas semakin meningkat akibat banyaknya mahasiswa yang mengeluhkan layanan koneksi di kampus. Studi ini mengusulkan pembangkitan trafik internet berdasarkan metoda statistik - engineering. Populasi dihitung berdasarkan kapasitas kelas di masing-masing fakultas, sebagai alibi utama kehadiran mahasiswa di kampus dimana kedatangan traffic dibangkitkan berdasarkan model kedatangan melalui informasi kemungkinan variasi penjadwalan. Meskipun layanan internet memiliki karakteristik yang berbeda, namun secara fisik ditentukan oleh bitrate dan mode idle dalam rangkaian waktu lalu lintas. Hasilnya menunjukkan rekomendasi dalam tiga kategori bitrate aplikasi, yaitu 200kbps, 400kbps dan 800kbps Traffic Shaping.

Kata kunci: Internet traffic generation, Traffic Shaping, Bandwidth allocation, statistic-engineering method

### INTRODUCTION

A campus is a place where the infrastructure and operational facilities of a university are built. Most of the academic community spends their time on campus with various forms of activities, be it working, relaxing, or just socializing. Campus comfort is not only measured by environmental conditions but also must be supported by complete facilities for activities. So that the ideal campus will make the academic community feel at home without having to look for outside activities. (Anggrawan et al., 2018)

The smart campus model is one of the concepts for realizing the ideal campus. This concept is inseparable from the existence of the Internet of things (IoT), where the integrity and connectivity of sensor technology play an active role in managing information. (Wohn & Ahmadi, 2019) The definition of the term *Smart Campus* does not only mean the role of censorship. But also the availability of adequate connectivity in realizing accessibility, sociality, and empowerment of data information needed by the academic community. So that a *smart campus* can be realized if the sensor infrastructure and network connections owned by the campus are adequate. (Herianto & Vega, 2021)



The need for internet access is currently important to note. Advances in telecommunication equipment such as personal computers, *laptops*, and *smartphones* allow the exchange of information to take place quickly (Wohn & Ahmadi, 2019). Likewise, the development of *internet content* which includes data, text, sound, images, and videos, increasingly pampers users in communicating (Feng et al., 2019). The level of internet *bandwidth* used depends on the characteristics of its users. In a study in the campus environment, it was proven that the allocation of video *bandwidth usage* was more dominant, where the largest traffic sources came from the USA, Japan, and Korea (et al., 2020 ). The magnitude of the need for internet bandwidth is ultimately related to the population of the academic community who take shelter in the campus area.

In an environment where internet access is free or flat-rate, arbitrary resource use behavior tends to emerge (Yadav & Akhter, 2021). Priority-based quota restrictions have been proposed to overcome this condition (Mahmood et al., 2020). However, this policy can only be implemented in cases of limited bandwidth and service convenience is not a top priority (Herwin & Andesa, 2021). This will also have the potential to cause contradictions in the academic community when this policy is implemented. In addition, the interest in using the internet among students is very large for academic or other purposes (Adeyemi et al., 2018). Therefore, to meet all the needs of users on campus, we need a model that can predict the Internet Bandwidth requirement model on campus.

The bandwidth prediction model is generally dominated by statistical methods. Bandwidth needs exploration on the smart campus has been analyzed using regression and correlation techniques (Adeyemi et al., 2018). The use of high-order statistics in modeling Internet bandwidth has also been proposed to obtain better accuracy (Marnerides et al., 2018). Likewise, the dynamic statistical model uses long-term correlation (Markelov et al., 2017). Although these statistical methods produce high model accuracy for individual users, the relationship between types of internet content cannot be explained. So this weakness makes policy management on *resource use* difficult to implement.

In another study, it was stated that engineering methods have been successful in predicting random models by explaining the relationship between their constituent elements (Shiraki et al., 2016). Although this study analyzes the electricity demand in a household, the random characteristics of electricity consumption can be

analogized to *bandwidth consumption* on internet use (Tampubolon et al., 2022).

The constituent elements of Bandwidth usage modeled as the types of *internet content* generated by each user. By using the *engineering* method, the relationship between the population of the academic community and the built Internet *bandwidth profile* can also be explained.

Based on this research (Singichetti et al., 2021), we propose a new method for modeling internet bandwidth requirements on campus, namely by combining engineering and statistical methods. The research case study was conducted at the Sultan Syarif Kasim State Islamic University (UIN Suska) Riau, by mapping the contribution of each content accessed by the campus academic community. Here, engineering techniques will break down and distribute traffic occurrences based on content categories (Sihotang, 2019).

Simple statistical techniques will then be used to generate internet traffic in a given population quantity. In this way, it is hoped that changes in the population of the academic community will have a clear relationship to the internet bandwidth model on the smart campus.

## RESEARCH METHODS

### Student Arrival Model

The existence of students on campus is generally caused by the process of learning and teaching activities that have been scheduled, taking into account the availability of physical classes. From the results of the survey that has been carried out, it is proven that the reason for student attendance at the Panam campus - UIN SUSKA Riau 93% is caused by arrivals caused by the lecture schedule that must be carried out, while the other 7% is caused by the need for guidance or academic activities outside of lectures, administration, socialization ( look at picture 1). While the distribution of classrooms for each faculty is given in table 1.

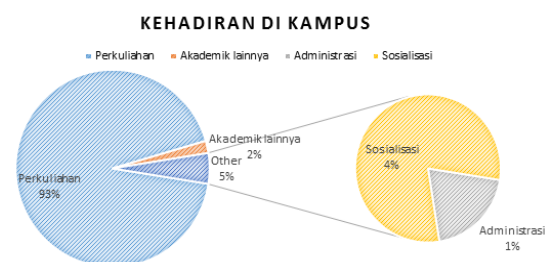
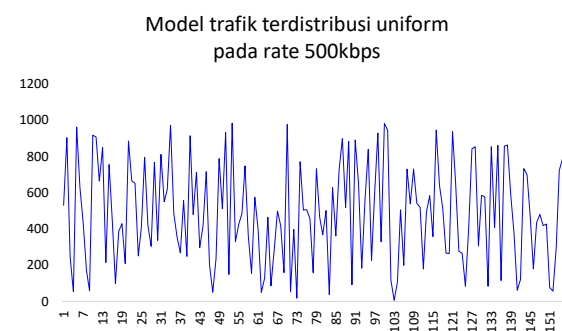


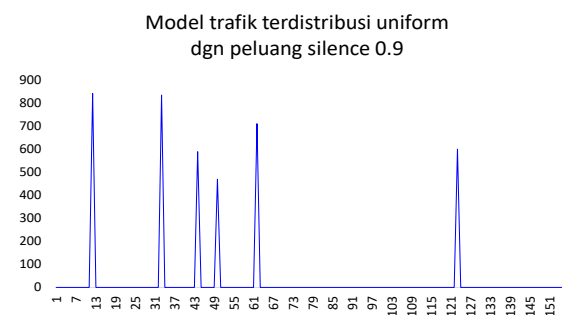
Figure 1. Reasons for student attendance at UIN SUSKA Riau Campus

Table 1. Classroom capacity at UIN SUSKA Riau campus (2018 Survey Results).

Faculty	Number of classes	Capacity
FTK	49	1470
FLUENT	30	900
FUSH	15	450
FDK	32	960
FST	31	930
FPSI	6	180
FEIS	29	870
FPP	32	960
<b>Amount</b>	<b>224</b>	<b>6720</b>



(a) Streaming mode



(b) On-off model

Figure 2. Internet traffic generation model

## RESEARCH RESULTS AND DISCUSSION

### Validation Model

Based on the information in table 1, the pattern of student arrivals to campus for lecture reasons can be predicted based on an exponential distribution, where there is a deadline of a few minutes or hours for them to arrive before the set schedule. By analogy with the possible scheduling model, the allocation of student arrivals can be modeled as shown in Figure 3 below :

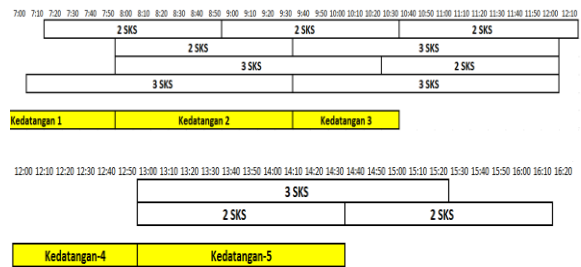


Figure 3. Lecture scheduling model with a weight of 2-3 lecture credits

The analogy given in Figure 3 above generally gives three sessions of student arrivals on campus, namely at 07:00 – 08:00, 08:00-09:40, and 09:40 -10:30. If the probability of the emergence of each schedule model is assumed to be the same, then the student portion is given by 100% of class capacity on arrival-1, 75% on arrival-2 and 50% on arrival-3. With the same technique, daytime scheduling can be illustrated as shown in Figure 3. The classroom use model based on the given time can only provide 2 variations of the model so that the arrival also has less variation than the arrival model in the morning session. Based on the same method, the 4th and 5th arrivals must fulfill the quota of 100% and 50% of the total class capacity given. The results of modeling the arrival of this lecture session are shown in Table 2. Distribution of student arrivals.

Table 2. Distribution of student arrivals

Faculty	Sessio n-1 (60m)	Sessio n-2 (100 m)	Sessio n-3 (50m)	Sessio n-4 (110m )	Sessio n-5 (100m )
FTK	1470	1103	735	1470	735
FLUENT	900	675	450	900	450
FUSH	450	338	225	450	225
FDK	960	720	480	960	480
FST	930	698	465	930	465
FPSI	180	135	90	180	90
FEIS	870	653	435	870	435
FPP	960	720	480	960	480
<b>Amount</b>	<b>6720</b>	<b>5040</b>	<b>3360</b>	<b>6720</b>	<b>3360</b>

Arrival given in table 2 assumes that the lecture participants for each session are different students. This data may differ from the actual population because there is a possibility that the same student will undergo 2 lecture sessions on the same day. The following are the results of the simulation of student arrivals as shown in table 2 (see Figure 3).

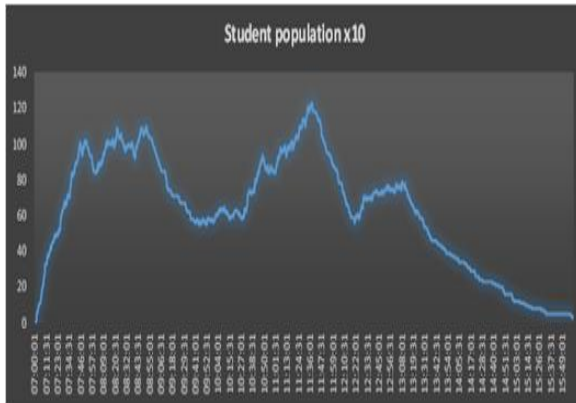


Figure 3. The student population in a timeline for FTK

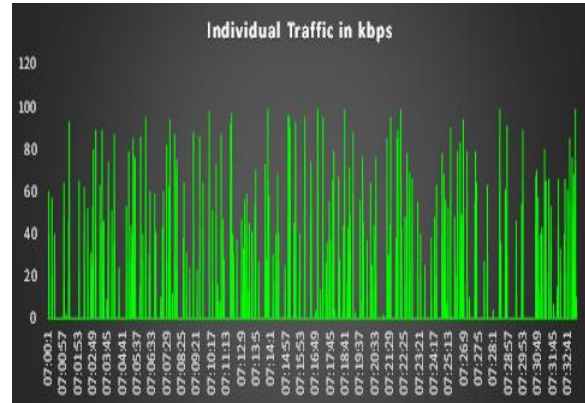


Figure 4. Individual traffic for 100kbps rate and 90% silence.

In Figure 3, there are three significant population peaks, namely at 07:46-09:06 with a population of around 1150 people and at 11:47 with a population of almost 1200 people. This figure means that the peak population only reaches 82% of the total population of 1470 people. The small number given to the population is due to the duration of each student staying on campus limited by an average value of 1 hour, as the average time the student connects online. In other words, the population profile given in Figure 3 is the population of internet traffic connection requests.

Although the population of internet traffic demand can be simulated as shown in Figure 3, there is a fact that not all students who attend will access the internet instantly. In this study, the ratio of every student who attends accessing the internet cannot be implemented due to the online lecture policy due to the COVID-19 pandemic. Therefore, in the next analysis, 3 scenarios of the ratio of internet traffic demand to the student population on campus will be given at each time unit, namely 1:10, 1:15, and 1:20.

### Individual Traffic Model

Individual traffic is influenced by 3 characteristics, namely the average value, maximum throughput, and opportunity silence mode. The traffic generation model in this study uses a simple method as shown in Figure 4 which is normally distributed. As a result, setting traffic with an average bitrate of 100kbps will give an average value of 50kbps theoretically, but the maximum given traffic will reach 100kbps. However, accumulatively, the average bitrate per unit time will decrease due to the effect of silent mode. To increase *bandwidth efficiency*, we need a method called traffic shaping.

*Traffic Shaping* is a bandwidth management technique on a computer network by provides delays on the arrival of long data packets, namely by cutting them into several *packets*. The goal is to take advantage of the free space of time on the receiver by limiting excessive bandwidth usage in a short period. This policy is also very useful in dealing with user behavior in using their online applications. Regardless of the QoS characteristics of each internet service, in the end, what is visually visible is the average bitrate, *silence mode*, and maximum *throughput* as described previously. Logically, dividing the throughput into 2 sending *frames* will have the effect of reducing the duration of the silent mode on traffic, and this allows for variations in frame delay or what is called Jitter.

Table 3. Simulation results – Relationship of throughput and silence mode to bitrate achievement

Throughput	Silence mode	bitrate
100 kbps	0.001	50 kbps
200 kbps	0.001	101 kbps
300 kbps	0.001	150 kbps
400 kbps	0.001	200 kbps
500 kbps	0.001	258 kbps
500 kbps	0.01	250 kbps
500 kbps	0.1	227 kbps

From the results of 6 experiments, it can be seen that the relationship between throughput and bitrate generated in table 3.2 in the first five rows tends to be *linear*, where the ratio is 1:2 in silence mode 0.001. In this mode, the resulting delay variation (jitter) is 1:1000 from the actual *throughput*. For example, in the case without Traffic Shaping the delay is 1 ms, then with 0.001 modes, it will vary up to 1000 ms.

The impact of this jitter will make the *video streaming application* stutter if the required delay frame is less than 1000ms. But if the *jitter* is reduced to 10 times, the *bitrate* that can be achieved at 500kbs *throughput* is 227 kbps. While at 100 times the *jitter* still produces a *bitrate* of 250 kbps, the same is the case when the *delay* is enlarged up to 1000 times.

### Faculty Accumulation Traffic Model

Based on the needs of video applications with a minimum standard of 360 pixels with a resolution of 640x360 ( *YouTube support* ), the required *bitrate* is 400-1000kpbs. This means that smooth video will only be possible if *traffic shaping* or *throughput* restrictions from each user are maximum up to 800 kpbs. However, the minimum required *audio streaming* smoothness is 64 kpbs whereas on *google meet communication* without using video. So that *traffic shaping* is enough to do only at 200 kpbs. The following are the simulation results for the scenarios given in table 4 below:

Table 4. Scenarios of total traffic on FTK

Faculty	Maximum population	Traffic shaping
FTK	10% of arrival	200 kbps
FTK	10% of arrival	400 kbps
FTK	10% of arrival	800 kbps

In this experiment, the FTK unit was chosen as the largest population among faculty units in UIN SUSKA Riau. If it is assumed that out of 10 students being observed, 1 person is accessing internet services, then the configuration of *Traffic Shaping* 200kpbs, 400 kpbs, and 800 kpbs is given in Figure 5-7.

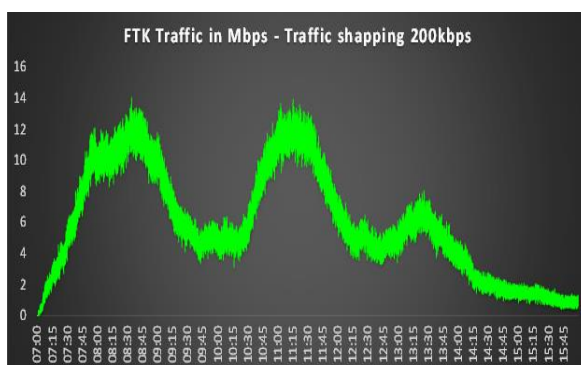


Figure 5. Simulation of FTK traffic at 200kpbs Traffic Shaping, average bandwidth 5.92Mbps

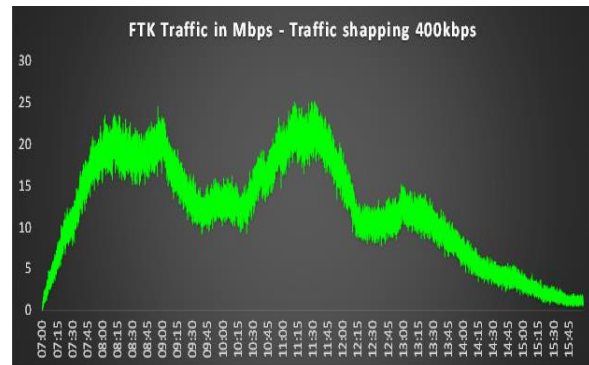


Figure 6. Simulation of FTK traffic at 200kpbs Traffic Shaping, average Bandwidth 12 Mbps

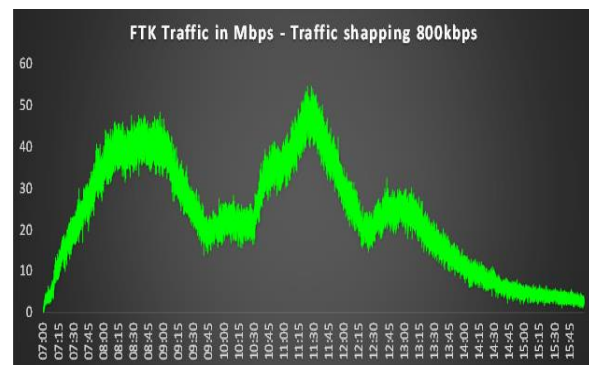


Figure 7. Simulation of FTK traffic at 200kpbs Traffic Shaping, Average Bandwidth 22.88 Mbps

The results given in Figure 3.4 are internet traffic with 200 kpbs *Traffic Shaping*. Maximum traffic occurs at 08:00 – 09:00 and 11:00 – 12:00, with a maximum *bandwidth* of 13Mbps. The decline in traffic between the two peaks was in the 4-6Mbps range. Meanwhile, afternoon traffic tends to decrease gradually. If *bandwidth* allocation is given to this faculty at peak conditions, then *bandwidth* is wasted in 7 hours of this traffic observation time. So that the optimum decision in *bandwidth* allocation should use the average traffic value over the given observation time, which is 5.9Mbps. In the same way, for *traffic* shaping, 400kpbs and 800kpbs result in an average *Bandwidth* allocation of 12Mbps and 22.88 Mbps.

### Bandwidth Allocation per Unit

The decision in dividing the *bandwidth* requirements for each faculty must be in the context of fairness. The meaning of fair is not necessarily an equal distribution between faculties, but the policy must pay attention to the possible number of users that must be served. This number of users can be modeled as the arrival time and opportunities for each student to access the internet.

Although the internet service content has a lot of variations, physically and in *traffic* shaping

techniques, the traffic characteristics can only be seen from the distribution model used, the bitrate, and the *silent mode* that occurs between frame arrivals. With the validation of the models that have been discussed previously, the traffic for each faculty is generated as shown in Figure 8. While the results of the rounding of *Bandwidth allocation* for each faculty are given in table 5.

Table 5. Simulation results in 8 faculties at UIN SUSKA Riau

Faculty	200 kbps	400 kbps	800 kbps
FTK	6	12	25
FLUENT	4	8	14
FUSH	2	4	8
FDK	4	8	16
FST	4	8	15
FPSI	1	2	3
FEIS	4	7	14
FPP	4	8	16
<b>Total</b>	<b>29</b>	<b>56</b>	<b>111</b>

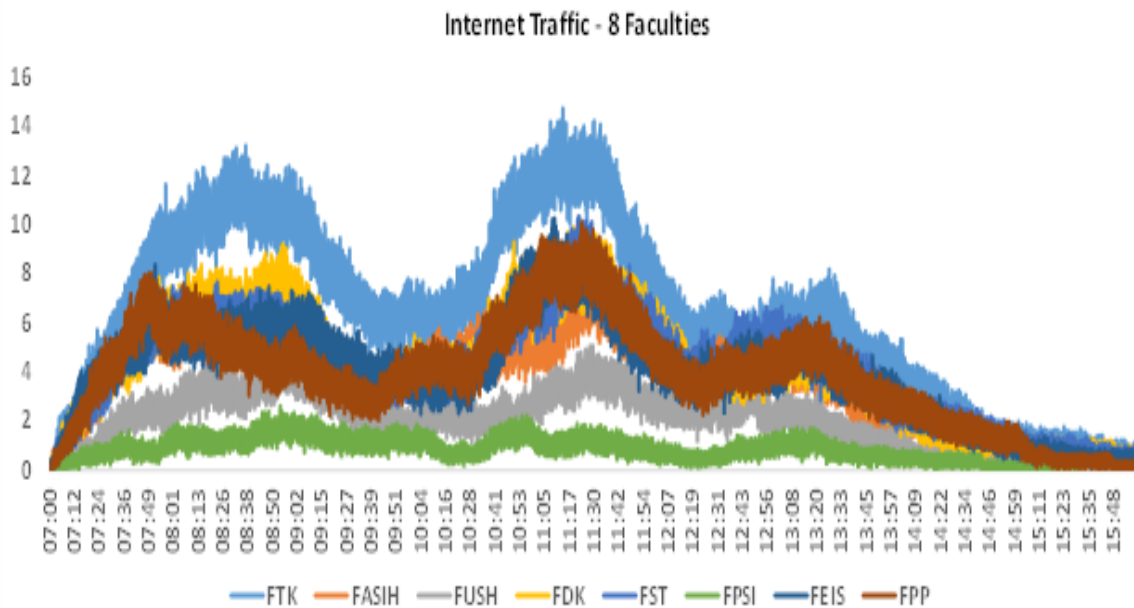
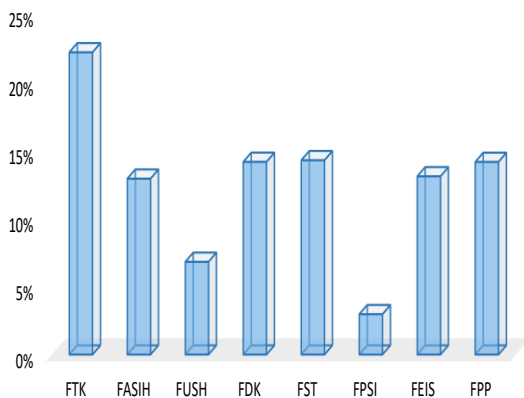


Figure 8. Simulation of FTK traffic at 200kbps traffic shaping, average bandwidth of 22.88 Mbps

### Bandwidth share portion



Bandwidth portion allocation among 8 faculties of UIN SUSKA Riau

The results of the calculations in table 5 are based on the average bitrate generated from each faculty within 9 hours of observation, which is presented here in integer form. Although in this study only three *Traffic Shaping scenarios* were carried out, namely 200kbps, 400kbps, and 800 kbps with bitrate variations in the application of 100kbps, 200kbps, and 400kbps, the allocation of *bandwidth requirements* for each faculty can also be presented in the form of a portion of the total bandwidth provided by the university. . Thus, regardless of the *bandwidth that has been provided*, the *bandwidth allocation* can be reduced based on this portion, as shown in Figure 9. So that the meaning of fairness between faculties can be derived based on the population of each faculty.



## CONCLUSIONS AND SUGGESTIONS

Internet traffic generation based on engineering - statistical methods for Bandwidth sharing needs at UIN SUSKA Riau has been modeled in this study. The engineering-statistical method is used to predict user arrivals based on variations in lecture scheduling patterns. Individual traffic is validated by the shipping technique method to limit the user's free behavior in generating traffic. The effectiveness and efficiency of traffic for the faculty can be calculated by calculating the average value of Bandwidth usage in the given scheduling time duration. Then the research scenario provides the optimal sharing portion in three service options, namely the allocation of 200kbps, 400kbps, and 800 kbps for each student. The results show that the total traffic for eight faculties at UIN SUSKA Riau requires a bandwidth of 29 Mbps, 56 Mbps, and 111 Mbps.

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