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QOE Measurement model in wi-fi networks: analysis of socio-economics influences in Indonesia

***Abstract**. We measure the quality-of-service level of the existing Wi-Fi network on the office in Indonesia. Next, the user is asked to measure the level of network experience. We compare the results of our experience assessment survey with the system's quality of service. The method we use is to group volunteers into two socio-economic groups. The assessment results were carried out using an artificial neural network algorithm. Observation results show that the average quality of service in Socio 1 is 87,11%, while in Socio 2, 92.45%. The mean absolute percentage error measurement results we obtained statistically for Socio 1 were 3.54%, and for Socio 2, the value was 2.11%. The Mean absolute percentage error using artificial neural network backpropagation in Socio 1 is 4.02%, while in the Socio 2 group is 2.06%. The relationship between the two results shows a heavy correlation.*

***Streszczenie.** Mierzymy poziom jakości usług istniejącej sieci Wi-Fi w biurze w Indonezji. Następnie użytkownik proszony jest o zmierzenie poziomu doświadczenia sieciowego. Wyniki naszej ankiety oceny doświadczeń porównujemy z jakością obsługi systemu. Stosowana przez nas metoda polega na podzieleniu wolontariuszy na dwie grupy społeczno-ekonomiczne. Wyniki oceny przeprowadzono z wykorzystaniem algorytmu sztucznej sieci neuronowej. Wyniki obserwacji pokazują, że średnia jakość obsługi w Socio 1 wynosi 87,11%, zaś w Socio 2 92,45%. Średnie bezwzględne wyniki pomiaru błędu procentowego, które uzyskaliśmy statystycznie dla Socio 1, wyniosły 3,54%, a dla Socio 2, wartość ta wyniosła 2,11%. Średni bezwzględny błąd procentowy przy zastosowaniu propagacji wstecznej sztucznej sieci neuronowej w grupie Socio 1 wynosi 4,02%, podczas gdy w grupie Socio 2 wynosi 2,06%. Związek pomiędzy obydwoma wynikami wykazuje silną korelację. (**QOE Model pomiarowy w sieciach Wi-Fi: analiza wpływów społeczno-ekonomicznych w Indonezji**))*

Keywords: Wi-Fi Offloading, Artificial Neural Network, Quality of Experience, Quality of Service
Słowa kluczowe: Odciążanie Wi-Fi, sztuczna sieć neuronowa, jakość doświadczenia, jakość usług

Introduction

Measuring the reliability of telecommunication services in the past was only limited to the connection of a network circuit. Past communication service measurements were ancient when modern services provide users with experiences to assess a telecommunication application [6]–[9]. Assessment of experience based on the psychological condition of the user results are strongly influenced by the condition of the assessor [2], [10], [11], [11]–[14].

Ideally, the value of QoE has similarities with quality of service. However, various factors strongly influence the QoE value, for example, the level of education, economy, socio-culture, technology, and others from the appraiser users. Furthermore, this is a severe problem.

This study will investigate the socio-economic impact of the QoE assessment of an in-office Wi-Fi network [15], [16]. This research is significant to measure the level of closeness to the level of quality of experience of a user from different socio-economic conditions [5], [10], [17]. The method we use for assessment uses the Mean of Score [18]–[21]. We compared the assessment between QoE and quality of service with the Back Propagation neural network algorithm approach [5], [11], [22], [23]. The contribution made in this study is in the form of the closeness of quality of service to the assessment of the experience of the judges with different socio-economic levels.

Related Works

The behaviour of using Wi-Fi offloading measured based on socio-economic status has been measured in Malaysia [24]. Research conducted for 18 days showed that the duration of time connected to the Wi-Fi network was greater for socio-economic Group 1 than for Group 2. Group 1 included student groups, and Group 2 included lecturers and jobs in the campus environment.

According to [15], internet penetration in Indonesia in 2021-2022 has only reached 77.02%. In comparison, the use of Wi-Fi at work or school is only 0.61%. The applications most frequently accessed by internet users in Indonesia, 89.15%, are social media, online meetings are measured in Grade of Service [1], [2]. The era of a grade of service was replaced with a measurement of service quality in quality of service, which measures

overall system performance [3]–[6]. This era becomes only 4.05%, and online learning is only 2.81%. The duration of using the internet in one day at 6 to 10 hours reached 33.11% for male users and 30.75% for women.

MOS or Mean Opinion Score is the most widely used method for adjusting QoE values to QoS values. The parameters assessed by the user are adjusted to the QoS parameters. So QoE is an assessment of a system based on the point of view of its users [25]. The fairness index is among the most important in assessing QoE [26]. The fairness index value depends on the appraiser, user, or operator.

The QoE assessment approach model generally uses machine learning algorithms [20], [27]–[32]. The QoE approach model is also proposed by BP Neural Network [5], [9], [11], [20], NOVA [33], and others. All these models have advantages and disadvantages.

Method

Wi-Fi offloading is switching data access from a cellular network to a Wi-Fi network. We studied 100 volunteers working in an office building who access Wi-Fi while in the office. We group volunteers into different socioeconomic groups. Socio 1 Group consists of users who have regional minimum salary income. Group 2 has an income above the regional minimum salary. The research was conducted for 20 days. We measure the Quality of Service of users recorded on the server. Meanwhile, users are asked to assess the perceived experience in accessing the Wi-Fi.

We used parameter assessment based on signal strength, distance, data speed, and obstacles from the user's perception. Furthermore, the assessment uses MOS. Figure 1 describes the data collection process in this study. Table 1 is an assessment that the user must carry out. The method we use to determine service quality is by limiting the bandwidth for each user. We create user settings with the same bandwidth and with the same priority. On the router, we give the command to provide bandwidth according to the service class, data, voice, and video. When the number of users is large, the system will share the bandwidth proportionally for the same class of service.

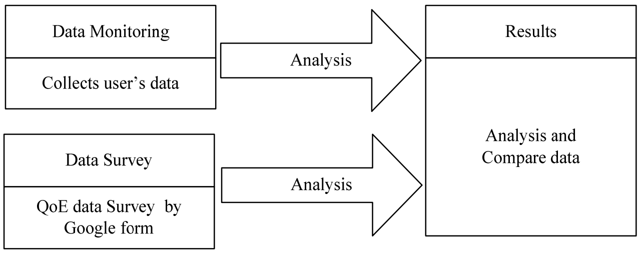

Fig.1. Method of Data Collection

Table 1. The QoE Measurement Parameter

Metric	Star	MOS
Data Rate	5	Excellent
	4	Good
	3	Fair
	2	Poor
	1	Bad
Distance	5	<10 m
	4	11-20 m
	3	21-30 m
	2	30-40 m
	1	> 40 m
Obstacle	5	LOS
	4	1 layer
	3	2 layers
	2	3 layers
	1	> 3 layers
Signal Strength	5	4 Bars
	4	3 Bars
	3	2 Bars
	2	1 Bar
	1	No Signal

Our survey results match the quality of service value measured in the system. To obtain a quality of service value close to the quality of service value, we approach it with an artificial neural network algorithm—the tool used with Matlab software. In Matlab, ANN processing is available. The details of the research methodology are given in Figure 2.

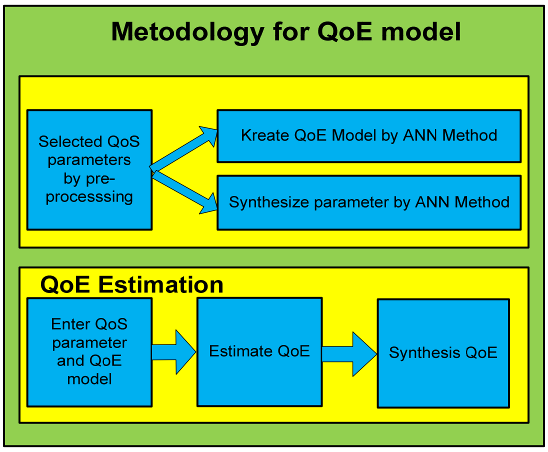

Fig. 2. The method of determining QoE with the ANN method

Experimental Results

We display the quality of service of every user we observe. Our data is presented based on the average daily QOS recorded on the control server. The QoS value of each user in real-time is recorded in the Wi-Fi Controller. The data will be recorded and stored on the server. The magnitude of the QoS value significantly changes when the user performs mobility. Socio-1 groups generally have high mobility. Socio 1his is because they work for building services. The QoS measurement results for Socio 1 groups as given in Figure 3. The average quality of service in the Socio 1 group is 87.11%.

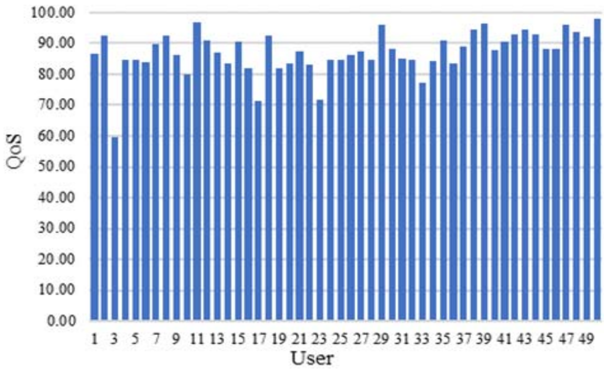

Fig. 3. Measurement graph of the average quality of service users in the Socio 1 group.

Figure 4 is the result of measuring the average quality of service from the Socio 2 group. The average value of quality of service in the Socio 1 group is only 87.11 %, while in Socio 2 group reaches 92.45 %. The mobility of Group 1 is very high. Meanwhile, the Socio 2 workers have a fixed and non-moving workplace. With this, Socio 2 has a higher average QoS. The smallest QoS was recorded up to 59.44 on Socio 1.

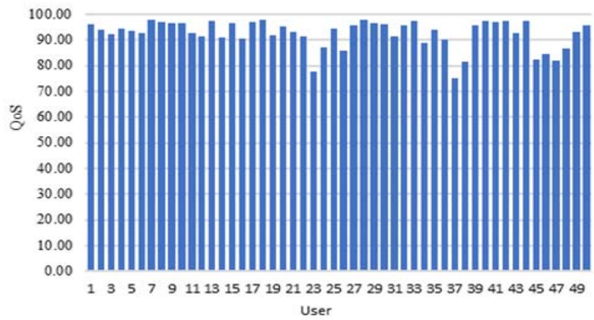

Fig. 4. The average QoS users in the Socio 2 group

The quality of experiences is a qualitative assessment [5], [8], [25], [34]. However, we take an assessment approach. We use a manual survey using google forms. Volunteers were asked to fill in daily to assess the quality of the Wi-Fi used daily in the office [35]. Figure 5 shows the Cumulative Distribution Function (CDF) from the quality of service and experience.

In the Socio 1 group, the QoS measurement value is higher than the QoE measurement. This value means that users still feel that the speed they get has yet to meet their expectations. The graph in Figure 5 is the result of measurements on Socio-1. The chart shows the QoE value using the ANN method, which offers a better deal. This result can be seen by the exponential regression value R^2 reaching 0.95.

Meanwhile, the exponential regression value on the manually calculated QoE value is $R^2 = 0.88$. The approach chosen in the trendline is exponential. This trendline is the most suitable for the resulting data distribution compared to other trendline models.

In Socio 2, the survey results have higher QoE values than QoS measurements. In Socio 2, the survey results have higher QoE values than the quality-of-service measurements. The results are given in Figure 6.

Compared to the QoE value with manual calculations and an Artificial Neural Network, the quality-of-service value has a higher regression value. This value shows that the level of satisfaction with the existing Wi-Fi network is relatively high on Socio 2.

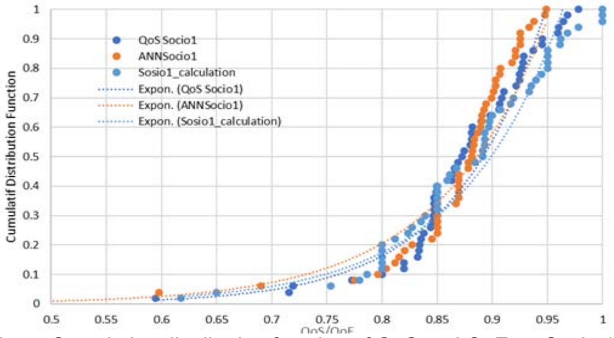

Fig. 5. Cumulative distribution function of QoS and QoE on Socio 1

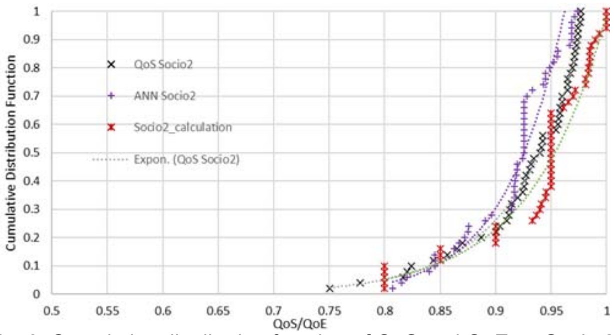

Fig. 6. Cumulative distribution function of QoS and QoE on Socio 2

The magnitude of the QoS regression value on Socio 2 is $R^2 = 0.9893$. The regression value on the artificial neural network is $R^2 = 0.9163$, and the regression with the manual calculation method is $R^2 = 9468$. These results identify that the Socio 2 group feels better Wi-Fi speed.

To compare the QoS results measured by the system with the QoE value from the survey results, we measured the Mean Absolute Percentage Error (MAPE). MAPE is calculated by finding the absolute error in each period divided by the actual observation value, and an average of the absolute percentage error is made. Statistically, the relationship between quality of service and QoE is given in Table 2.

Table 2. Comparison between QoS and QoE

	QoS		QoE Calculation		QoE ANN	
	Socio1	Socio2	Socio1	Socio2	Socio1	Socio2
Min	59.44	75.06	61.76	80.00	49.46	80.73
Max	97.82	97.67	100.00	100.00	94.86	97.36
Mean	87.11	92.45	87.53	93.62	86.19	91.36
Med	87.36	94.07	89.12	95.00	88.15	92.54
Std	7.01	5.48	8.08	5.85	8.13	4.34

From Table 2, the standard deviation of Socio 1's QoS is 7.01% with a minimum value of 59,44% and a maximum of 97,82 %. Socio 2 has a minor standard deviation and a larger mean at 94,64 %. The quality-of-service value on Socio 2 has a better average of 92.45%, with a standard deviation of 5.48%. QoE measurements with artificial neural networks provide a better standard deviation of 4.34% on Socio 2, while manual calculations have a standard deviation of 5.58%. On the other hand, in the Socio 1 group, manual calculations gave a better standard deviation value than using an artificial neural network, each with a value of 8.08% and 8.13%.

Based on the calculations obtained in the Socio 1 group, the mean square error QoE based on manual calculations is 3.54%, while with artificial neural networks, it has a value of 4.02%. Meanwhile, the Soscio 2 group has the opposite number. The calculated QoE value is 2.11%, while with an artificial neural network, it is 2.06%.

We did a comparative analysis of the QoS and QoE values that we got. *Correlation analysis* is an analysis used to determine the close relationship between the two variables. This correlation test closely relates to the regression test which shows whether each variable influences each other. We apply the Pearson correlation coefficient to compare QoE and QoS [36], [37].

The results of the correlation between the quality of experience and quality of service are given in Table 3 below. From these data, the correlation result in the Socio1 group is 0.65. This value shows a strong correlation according to Table 2. The Socio 2 group produced a correlation value of 0.91, this shows a very strong correlation between quality of service and quality of experience. These two groups produce different correlation values where the level of correlation between the Socio 2 group is better than Group-1. The combined correlation value gives a correlation value of 0.79.

This condition could occur because, while filling out the questionnaire, the quality of experience assessment from Socio 1 was less accurate. This inaccuracy is due to the high mobility of this group. So that the correlation level between QoS and QoE is only 0.65, and this value is close to the moderate correlation. When this group of users moves away from the access point, the Wi-Fi signal will drop for a while. However, the assessment will give low marks for that day.

In the Socio 2 group, filling out the quality of experience questionnaire was more repeated daily because the Socio 2 group does not have high mobility during work. As a result, the correlation between the quality of service recorded on the Wi-Fi Controller has a very strong correlation to the measurement of quality of experience. The correlation value reaches 0.91, as given in Table 3. Using an Artificial Neural Network compared to statistical calculations has a lower correlation level. However, the ANN method has a better mean square error rate.

Table 3. The QoS and QoE Correlation value based on Pearson Correlation Algorithm

Group	QoE Calculation		QoE ANN	
	Value	Correlation	Value	Correlation
Socio1	0.729952	Strong	0.597079	Moderate
Socio2	0.911833	Very Strong	0.86518	Very Strong

Using Pearson's correlation, in the Socio 1 group, the statistical correlation has a value of 0.729952 ("strong"), while with ANN, it has a value of 0.597079 (moderate). The Socio 2 group has a statistical correlation of 0.911833, while the artificial neural network method gives a value of 0.86518, both of which have a "very strong" correlation. From these results, in the Socio 1 group, filling in the MOS value is less accurate for the experience of using a Wi-Fi network while working.

The artificial neural network method has a weakness—the resulting value from the training that is carried out changes every time. Processing time can be a very long exercise for vast amounts of data. Meanwhile, ANN needs to learn so that it can process more extensive data so that it can get a more optimal value. The advantage of ANN is that the output pattern issued by ANN can resemble its target pattern even though the input pattern is very random.

Conclusion

Observation results show that the average QoS in Socio 1 is 87,11%, while in Socio 2, 92.45%. In Socio 1, the value of QoS is smaller than Socio 2. Our analysis is because, in Socio 1, the work location is constantly changing as a support worker with high work mobility. They access Wi-Fi from different locations with different environments. Unlike in Socio 2, this group has a fixed and non-moving workplace. The smallest QoS was recorded up to 59.44 in Socio 1. The mean absolute percentage error measurement results we obtained statistically for Socio 1 were 3.54%, and for Socio 2, the value was 2.11%. The Mean absolute percentage error using artificial neural network backpropagation in Socio 1 is 4.02%, while in the Socio 2 group is 2.06%. The relationship between the two results shows a heavy correlation. Even in Socio 2 group, the results show a Very Heavy Correlation between QoS and QoE with a value of 0.91. The correlation in the Socio 2 group on the statistical calculation method has a value of 0.911833, and using an artificial neural network has a value of 0.86518. These two values show a "very strong" correlation. In contrast to the Socio 1 group, which has a strong correlation with statistical calculations with a value of 0.729952, while using the ANN method, the value is 0.597079 with a moderate correlation. This moderate correlation means that in the Socio 1 group, the MOS survey assessment needed to be more accurate.

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