TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 5, October 2020, pp. 2304~2313
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i5.15774

TAMEx framework as an alternative for e-exam implementation in wireless network

Gede Sukadarmika[1], Rukmi Sari Hartati[2], Linawati[3], Nyoman Putra Sastra[4]
[1]Study Program of Doctoral Engineering Science, Faculty of Engineering, Universitas Udayana
[2,3,4]Department of Electrical Engineering, Faculty of Engineering, Universitas Udayana, Indonesia

Article Info

Article history:

Received Feb 8, 2020
Revised Apr 10, 2020
Accepted May 1, 2020

Keywords:

Availability
e-exam
RSSI
TAMEx
WLAN

ABSTRACT

One of significant change in learning process is exam implementation applying a computer-based test (e-exam) rather than paper-based test. Many institutions currently use wireless network with bring your own device (BYOD) policy for their e-exam implementation, due to limitation of space and user terminals. Moreover it is hard to maintain the availability of reliable signal quality in wireless network for all users during e-exam process. Therefore, this research proposes a development of time adaptive for mobile exam (TAMEx) framework to provide all users with good quality of service of e-exam in wireless network environment when dealing with signal quality variations. The received signal strength indication (RSSI) is the main indicator of the signal quality. The framework supports e-exam implementation in wireless local area network and the use of BYOD mechanism. The research shows that the framework successfully has provided time compensation for the users who experienced temporary connection loss due to bad signal quality. The result exhibits that tiny processing time has been needed for signal loss detection, user's request of compensation time, and server's execution. In conclusion, the TAMEx could guarantee good services for all users who doing e-exam in wireless network environment.

Corresponding Author:

Linawati,
Department of Electrical Engineering,
Udayana University, Bali, Indonesia.
Email: linawati@unud.ac.id

1. INTRODUCTION

Information and computer technology development has contributed significant changes in learning system. Electronic learning system (e-learning) with its advantages in term of efficiency and flexibility becoming more popular to be implemented in universities or others educational institutions. Learning material in e-learning system is able to be set to adaptive with the level of each student's knowledge [1]. As an example, e-learning system has been used to improve Indonesian human resources due to its characteristic that suitable for the field of art, science, engineering and technology [2]. The electronic examination (e-exam) system has been used as a model for evaluating learning systems. Some of the advantages of e-exam compared to the paper-based test system are the reduction in individual errors (human error), the distribution is done directly through the network, higher security levels, efficiency in time, space, cost and human resources. It also provides immediately test results with higher integrity [3].

As an effort to ensure the availability of e-exam services, educational institutions usually prepare special rooms such as computer labs that contain a number of computers connected to the network. However,

the limitations of adequate ICT infrastructure for conducting electronic exams for all students are a problem for most educational institutions. As a solution, the test is usually carried out consecutively. Research related to the application of the e-exam model with the bring your own device (BYOD) method has been conducted at several universities [4-6]. In conducting e-exam, institution does not need to provide the e-exam terminals but examinees bring and use their own laptop devices. The experience of using BYOD method, examinees feel more comfortable to conduct e-exams using tools they are familiar with [7].

In additions, with the support of infrastructure and improvement of students in the ability of using ICT devices for their daily activities, e-exam is being used widely in higher education to achieve the success of their students through their knowledge and skills in the modern world [8]. The examinees are possible to take the exam from any locations as long as they are connected to the Internet due to the e-exam is a service that delivered online in the form of web-based application. Even thought, e-exam offers various advantages there are still some challenges related to reliability, quality of service and high availability requirements in the implementation of e-exam. Furthermore, it also needs institutional attention to various parameters related to scalability, performance and security of e-exam implementation [9, 10].

Generally, e-exam is a software that is usually used in online education systems to assess student performance which is carried out using information and communication technology devices [11]. In recent years, the development of the use of e-exam has become more widespread, not only for evaluating student performance, but also for examinations in the context of employee selection, admission of new students or joint examinations participated by many examinees. In Indonesia for example, e-exam has been widely used in national exams for junior and senior high school students, examinations for new student enrolment in state universities and also for selection of admissions to prospective civil servants and various other similar exams [12]. In order to implement e-exam to support e-learning services and or other kind of examination purposes, the Educational institution needs to provide supporting infrastructure such as special room with good ICT infrastructure.

The implementation of e-exam is the most complicated in e-learning system. This relates to security, question distribution and also differences in the level of user's access that must be accommodated. These causes the requirement of various efforts to maintain the reliability of the implementation of e-exam. Several studies have been carried out related to securing e-exam, for example by applying cryptography techniques in the distribution of questions [10] and identifying fraud committed by examinees who committed it from a remote location [13], application of biometric systems to identify users and distributed firewalls to monitor user and control packets related to user authentication [14-16]. The study of e-exam security analysis comparing the security challenges of the modern exam with the traditional exam was also carried out in [17, 18].

From various studies that have been conducted, almost all of them emphasize the security mechanism of the implementation of e-exam that aim to anticipate the occurrence of fraudulent conducted by various parties in implementation of e-exam. The security mechanism is carried out at some stages. It is start form the stage of providing electronic questions, in the stage of the distribution of questions through the network and the stage of e-exam implementation to make sure that examinees who take e-exam are authenticated examinees and unable to do any fraudulent. No research has been found that addresses security related to access that focus on the reliability of e-exam services, especially in institutions that have limited infrastructure such as most educational institutions in developing countries. Besides securing e-exam from various possible frauds committed by various parties, it is also required to pay attention to security regarding access to e-exam services so that examinees do not lose their time and work if there is a network interruption occurred.

Time allocation is one of the most sensitive factors in conducting e-exam. The e-exam organizer needs to work on a mechanism to anticipate the loss of time allocation for the examinees which is caused by a connection loss during the e-exam implementation due to gradation of the network quality of services. In case of wireless network, signal strength is one of the factors that determine the quality of service. As well known that the amount of signal strength is affected by many factor including the number users [19, 20], the use of spectrum [21] and environment impact such as indoor air problems [22] that possible to contribute attenuation, interferences and fading [23]. This signal strength is also the main concern in [24], which build a model to describe a relationship between the propagation of a radio signal with random waveform. The signal strength could be estimated using numerical modeling [25] which shows that the numerical model has an acceptable relative error in terms of the hydrodynamic parameters which could be equivalent with the waveform. On the other hand, an LNA circuit can be used in wireless system to improve gain of signal with low power consumption is a good promising to be other solution in this e-exam model [26].

The objective of this research is to develop an e-exam framework namely TAMEx Framework that suitable to be implemented in wireless network especially in wireless local area network. This framework could be an alternative solution for institution that facing limitation in ICT infrastructure and e-exam terminals. In the TAMEx development, we mainly focus to investigate of availability and reliability of good signal quality of wireless local area network. The received signal strength indication (RSSI) of the e-exam

terminal is applied as the main indicator of the availability and reliability of the signal. None of previous researches have observed the relationship between the RSSI and the e-exam process. When the RSSI is low then user can experience bad or lost connection during the e-exam process. Then with the TAMEx framework, it has an ability to provide time compensation automatically to the examinees when the examinees got lost connection during examination stage. The time extent corresponds to the duration of the connection loss experienced by the examinee. Thus, the connection disruption that occurs will not cause a loss of time allocation for examinees to work on the e-exam. This research is a continuation of previous research to convey a more structured mechanism in the TAMEx model [27]. Contribution of this research is to provide framework which is adaptable with the signal quality of wireless networks, i.e. the RSSI and makes implementation of e-exam in wireless environment more reliable and accountable. The research method will be presented in the section 2 that is started by introducing the schema of the TAMEx Model. Then the TAMEx Framework is explained briefly. The results and discussion are presented in section 3. Finally, section 4 comes out with the conclusion and future works of the study.

2. RESEARCH METHOD

2.1. TAMEx model mechanishm

The time adaptive for mobile e-exam (TAMEx) Model is developed to support e-exam services on wireless networks environment. Figure 1 shows the e-exam mechanism in the TAMEx model. It can be seen in the picture that there are several components involved in the e-exam process, namely examinees, e-exam terminals, access points and e-exam servers.

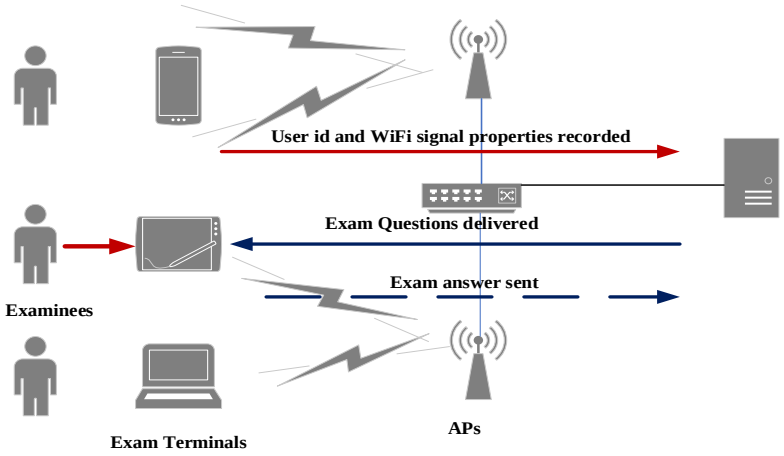

Figure 1. TAMEx model for e-exam mechanism

Examinees access e-exam services through its own mobile device (BYOD). An examinee must install the TAMEx adapter application in his or her mobile device. This application works to generate properties of data and received signal strength indicator (RSSI) of the device. The next mechanism can be done if the examinees and their terminals have been authenticated in the e-exam system. The availability of e-exam services is an important factor of concern in this study. In the exam mechanism, all examinees should get the same quality of service and access to the system to maintain the fairness of e-exam services. Related to the use of wireless networks, various factors can affect the quality of wireless local area network (WLAN) services, for example the distance of e-exam terminals with access points, the presence of attenuation, noise interference or fading, that all can affect the performance of WLAN services [28]. Although the number of access points to cover all the exam area, can be provided based on analyzes of the data rate and RSSI [29, 30], unpredictable connection problems still occurred at the terminals. The TAMEx model uses the RSSI level as an indicator of the quality of e-exam services. When the RSSI is low which means that a user has a connection problem, then a user is given an extended time in accordance with the duration of the interruption experienced.

2.2. Time adaptive for mobile e-exam (TAMEx) framework

The e-Exam mechanism is generally similar to the mechanism of electronic transactions through computer networks. This mechanism requires an effort to secure transactions whose level depends on the level

of confidentiality of the transactions made. In the e-exam system, availability is also a very important security factor to consider besides the user authentication factor and the integrity of the questions and answers. Thus the TAMEx framework is able to secure the availability of e-exam service to all examinees. The TAMEx framework discussed in this section is further developed from the initial model [27]. The improvement is on the mechanism of determining extended time duration and of ending the e-exam session which is shown in Figure 2. The framework compensates for lost connection of an examinee by giving additional time automatically. The additional time is given in accordance to the duration of the lost connection. Here is used the received signal strength indication (RSSI) of the e-exam terminal to identified the connection status whether it is connected or not. The TAMEx model e-exam framework is divided into five stages, namely preparation stage, registration stage, e-exam process stage, ending of e-exam stages and notification stage.

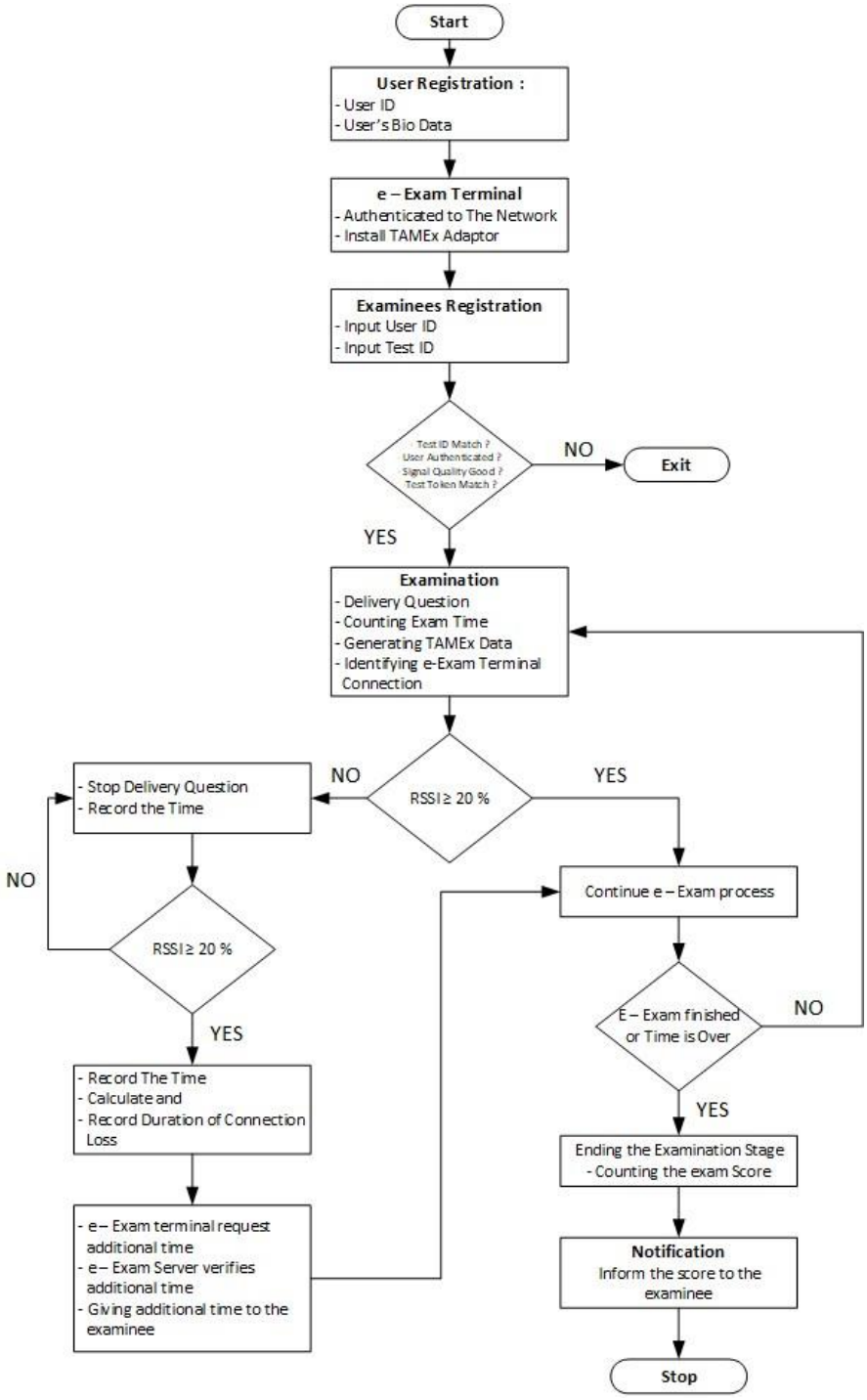

Figure 2. The TAMEx framework

2.2.1. The preparation stage

The framework applies the BYOD mechanism for the implementation of e-exam. At this stage the examinee authenticates their device connections on the WLAN network. Then, at the device of e-exam terminal is installed the TAMEx adapter application. This application performs authentication check using user Id and password. When the examination is authenticated, the TAMEx adapter also identifies the user_id, terminal_id (MAC address and IP address) and the received signal quality (RSSI and data rate).

2.2.2. The registration stage

If the user is authenticated and the quality of the received signal is adequate for communication, the next step is the registration stage in the system exam. In order for examinees to take e-exams in accordance to their topic, they need to get a code or token of the taken exam. A token is a combination of numbers that generated by the e-exam system as a code for a certain subject. This exam token is delivered by the proctor to the examinee when the e-exam is ready to be started. If the token entered into the system matches and authenticated means that the examinee is registered in the exam topic. Then, the examination is ready to be started. The exam server starts to deliver first question to each terminal used by the examinee. At the same time the TAMEx adapter application generates data of the User_Id, Terminal_Id, RSSI, Data rate, connection status and e-exam time to be periodically delivered and recorded to the e-exam server. Therefore, the e-exam server will receive two kinds of data, i.e. answer of e-exam question and the data which generates by the TAMEx Adaptor here is called TAMEx Data.

2.2.3. The examination stage

The examination stage is the most critical stage in the exam process. In this stage, the e-exam system must be able to anticipate fraudulent, provides the stability and sustainability of e-exam information services. As can be seen in Figure 2, when the e-exam starts to deliver the first question, it starts to count the exam time. On the other side, the e-exam terminal receives the delivered question, and it starts to generate the TAMEx Data. The TAMEx adapter records the RSSI to identify the connection status of the e-exam terminal. If those are higher than the saturation level, the examination process is continued as usual, but if it is lower than the level, the e-exam server will stop the delivery of question to the terminal. The saturation level is for the RSSI of 20% [31].

In case of loss connection experienced by a terminal, the e-exam terminal is stop to receive the new question. The TAMEx adapter continuously generates the TAMEx Data. It is set in every 1 second. Identification of connection status is continuously based on the value of RSSI. If the e-exam terminal has received a signal that meets the level, the e-exam terminal is automatically connected to the e-exam server and the examination process continues automatically as well. Then the TAMEx adapter calculates the duration of the connection loss and sends it to the e-exam server to adjust the exam time for examinees that experience the connection interruption. So the lost connection duration is calculated at the terminal. The terminal will request extended time. Then the e-exam server verifies the time request and adjusts the e-exam time.

Therefore, there are two mechanisms for calculating the loss connection duration, namely the calculation at the e-exam terminal and the calculation at the e-exam server. At the e-exam terminal, connection loss duration is calculated based on the duration of the RSSI data recorded which are lower than 20%. On the other side, at the e-exam server, it is calculated based on the duration of arrival time between TAMEx data. The calculation mechanism in the e-exam terminal is shown in the following pseudocode.

```
TAMEx Addaptor Application
show login
login <- get login data
send to server
if login == true
   show dashboard application
   while (1)
   read data wlan network interfaces from netsh
   get data from netsh
   signal <- convert to int (get signal)
   while signal < 20
        send notification
        count loss duration
   if signal > 20
        send data to server
   test <- get data test
   if test == 'over'
        exit application
else
   exit application
```

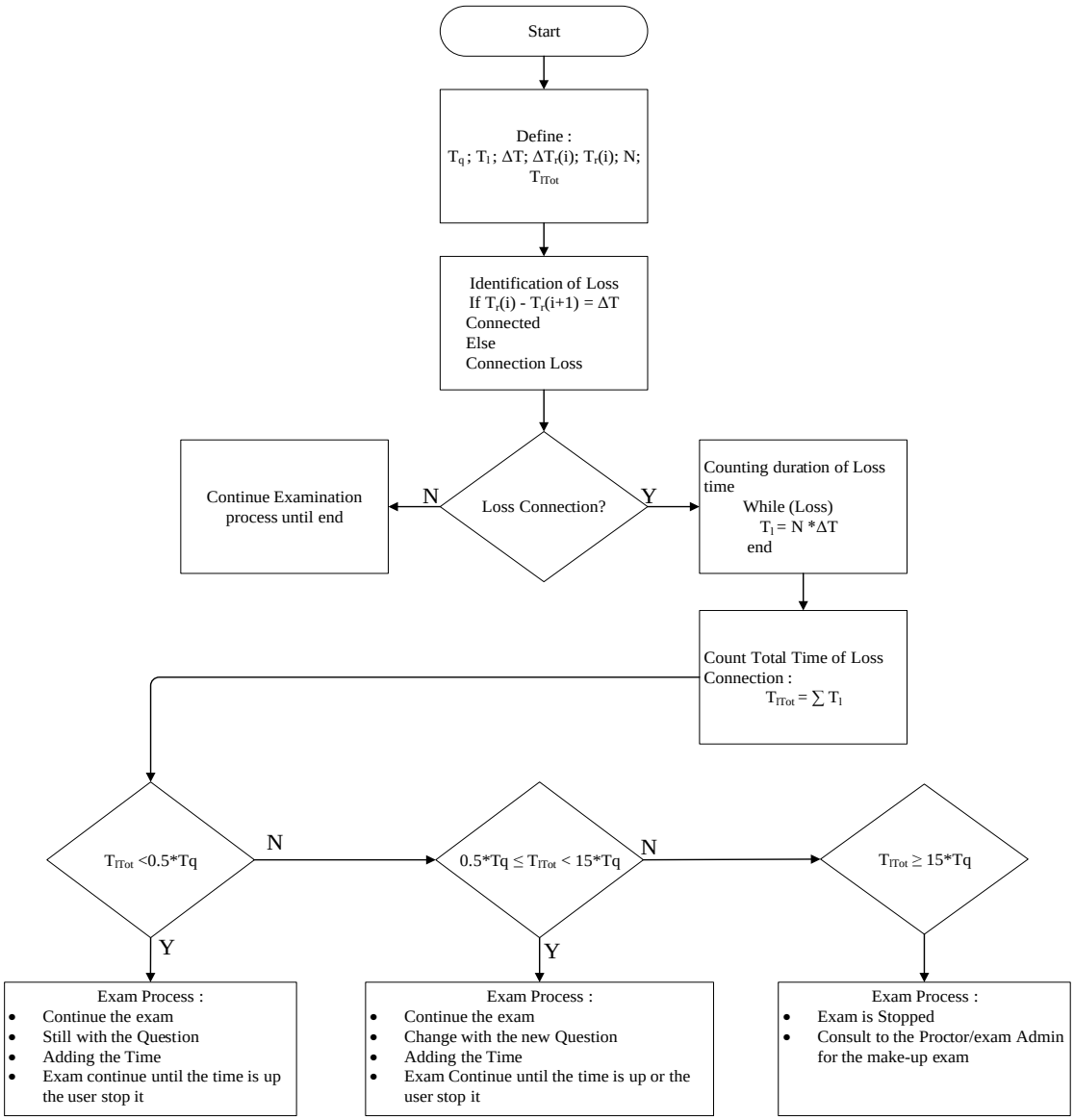

Figure 3. Three scenarios when the lost connection occurred

On the other side, mechanism for calculating the duration of a connection loss is shown in Figure 3. Definition of variable for calculating the time of loss connection can be seen in Table 1. From the Figure 3 can be seen that the calculation of Time Loss (T_l) is based on the TAMEx data which is generated and sent by the e-exam terminal to the e-exam server periodically with the period of ΔT. If the time duration between T_r (i) and T_r (i + 1) is ΔT, this condition is identified as a normal condition or there is no connection loss. Connection loss is identified if the duration is greater than ΔT.

Table 1. Definition used in calculation of lost connection time

No.	Notation	Definition
1	T_q	Question Time is the Average of expected time for user to answer one question in the exam. T_q = Allocation time for the exam divided by the number of questions
2	T_l	Time Loss ($T_l = \Delta T_r * \Delta T$)
3	ΔT	Periodic Time for generating and sending TAMEx data by e-exam terminal
4	$\Delta T_r(i)$	Time deviation of received TAMEx data by Server ($\Delta T_r = T_r(i+1) - T_r(i)$
5	$T_r(i)$	Time when server receive the i^{th} of TAMEx data
6	N	Number of expected rows of data between Tr(i) and Tr(i+1)
7	T_{lTot}	Total duration of loss

Furthermore, the duration of an even of lost connection is calculated as follows. In the condition of connection loss, the ΔT_r is higher than ΔT. At the time of ΔT_r the e-exam server expected to receive a certain amount of N rows of data. Due to the connection loss, the expected rows of data are never been received. So, the time duration of connection loss is obtained by multiplying N with ΔT. Hence, $T_l = N^* \Delta T$. For example, if ΔT is one second and the numbers of expected requests are 10 rows, then the duration of connection loss is counted for 10 seconds. Hence the exam server calculates the total duration of time loss by summing all of the time loss. So, the $T_{lTot} = \sum T_l$.

2.2.5. The notification stage

At the notification stage, the e-exam system provides notification to the examinees. There are two kinds of notification delivered, i.e a notification during the examination stage and a notification after the end of e-exam stage. The TAMEx model provides notifications for each examinee about their remaining time for doing their exam. The model continuously updates the remaining time and informs it to each examinee. This model also provides exam score notification after the end of e-exam stage. When an examinee submitted and finished their exam, the e-exam system sends the score achievement to the examinee.

3. RESULTS AND ANALYSIS

3.1. Evaluation result

The TAMEx has been tested by a number of 12 clients. All clients simultaneously access e-exam system through WLAN using the same WiFi access point. The TAMEx adapter was set with the period to generate and send the TAMEx data to the server (ΔT) in 1 second. Table 2 is part of the data from one of the clients during the testing process. Table 2 shows the process to calculate additional time when lost connection was occurred. As can be seen from the Table 2, column 1 is the time when the server receives TAMEx data which was sent by the e-exam terminal. Furthermore, in order to calculate duration between the received data and the next received data, the recorded time which shows in column 2 is firstly converted into units of seconds. The results of the conversion are shown in column 3.

Then, time duration between the received data is calculated by comparing the time of received data with the time of the next received data. The deviation of the time of received data is duration of received data. The deviation of time between the time of received data and the time of the next received data is shown in column 4. The compensation of additional time is calculated based on the duration of each received data. Calculation is done by subtracting the value of duration of received data with the previous one. If the value is less than 1 the value of Time loss is 0. It means that there was no loss connection or the client is connected. Else, the duration of loss connection is recorded and the e-exam system provide the additional time in accordance to the duration of loss. The result of additional time given is shown in column 5.

Table 2. Mechanism of counting time loss in TAMEx model

No.	Recorded Time of Received data	Recorded Time of Received data ($T_r(i)$) (Seconds)	Duration of Received data ($\Delta T_r(i)$) (Seconds)	Time Loss (T_l) (Seconds)
1	2	3	4	5
1	11:46:25:921454	42385.92145	1.737351	0
2	11:46:27:580016	42387.58002	1.658562	0
3	11:46:29:418096	42389.4181	1.838080	0
4	11:46:31:042749	42391.04275	1.624653	0
5	11:46:32:759157	42392.75916	1.716408	0
6	11:46:35:336260	42395.33626	2.577103	1
7	11:46:39:819265	42399.81927	4.483005	2
8	11:46:43:515375	42403.51538	3.696110	0
9	11:46:46:676943	42406.67694	3.161568	0
10	11:47:08:297067	42428.29707	21.620124	18
11	11:47:44:435290	42464.43529	36.138223	15
12	11:47:47:853118	42467.85312	3.417828	0
13	11:47:50:866084	42470.86608	3.012966	0
14	11:47:52:772953	42472.77295	1.906869	0
15	11:47:55:695134	42475.69513	2.922181	1
16	11:47:57:742656	42477.74266	2.047522	0
17	11:48:00:351674	42480.35167	2.609018	1
18	11:48:04:502568	42484.50257	4.150894	2
19	11:50:06:672988	42606.67299	122.170420	118
20	11:50:08:229838	42608.22984	1.556850	0

Table 3 shows the difference between the addition of time requested by the e-exam terminal and the addition of time validated by the server. There is a tendency that the additional time configured by the server is higher than the additional time requested by the e-exam terminal. This tends to be caused by the computation and delay process that occurs in the process of sending data from the e-exam terminal to the e-exam server.

Table 3. Additional time requested by terminal and verified by server

No	User	Additional time requested by terminal (Seconds)	Additional time verified by Server (Seconds)	Deviation (Seconds)
1	Examinee 1	101	127	26
2	Examinee 2	111	132	21
3	Examinee 3	238	259	21
4	Examinee 4	343	354	11
5	Examinee 5	132	134	1
6	Examinee 6	186	200	14
7	Examinee 7	220	228	8
8	Examinee 8	238	257	19
9	Examinee 9	168	178	9
10	Examinee 10	16	22	6
11	Examinee 11	129	144	14
12	Examinee 12	260	264	5

3.2. Discussion

TAMEx Framework has been able to strive to secure the implementation of e-exam through wireless networks. By providing additional time automatically as compensation for the occurrence of connection disruptions that may be experienced by each examinee is a contribution of this research. The additional time for implementing e-exam for each e-exam examinee tends not to be the same, because this mechanism is adjusted to the duration of the disturbance experienced by each examinee.

The method using the e-exam service condition identification via RSSI on a laptop used as an e-exam terminal is sufficient to obtain the information of the e-exam terminal connection status. The TAMEx Adapter application which is installed on the e-exam terminal identifies the device connection status by periodically generating the RSSI data. Based on the period of generating and sending data to the server, the duration of the connection loss can be calculated. This method is work effectively. The deviation in the verification data by the server is inevitable due to the computational mechanism and the delay of data transmission from the e-exam terminal to the e-exam server. However, the deviation is acceptable.

Based on the total additional time, the TAMEx framework provides 3 alternative conditions as indicated in section 3. TAMEx provides e-exam terminal to connect automatically to the authenticated Access Point when it receives RSSI ≥ 20%. Providing those three conditions is in order to anticipate the fraud if examinee try to increase the examination time by deliberately switching off their WiFi connection. Research in term of the determination of the duration of time for those three conditions above has not been found. This study uses the basis on the standard availability system [32]. As an example, here was used the National exam for Senior High School in Indonesia in 2019 with the subject exam was English. The number of questions was 50 questions and allocation time for doing the exam was 2 hours (from 07.30 to 09.30). At the first condition ($T_{ltot} > 0.5*T_q$), system availability was 99.99% while for the second condition ($0.5T_q \leq T_{ltot} < 15*T_q$) the system availability was 99.7%. Then, for the third condition ($T_{ltot} \geq 15*T_q$) the system availability was lower than 99%.

The examinee can do cheating by deliberately switching off their WiFi access, so they can work on e-exams with a longer duration. This case can be resolved based on the frequent and duration of lost connection. The examinee will be stop doing the exam according to the end of exam stage at the TAMEx Framework. Therefore, if the total extended time is more than 15 times for answering one question, then the system will be closed automatically. Thus the examinee must consult to the proctor or exam manager to retake the exam.

4. CONCLUSION AND FUTURE WORKS

4.1. Conclusion

An improvement of the TAMEx Framework has been accomplished as an alternative to implement adaptable, reliable and accountable e-exam in wireless environment with BYOD mechanism. This is a promising solution for educational institutions to resolve limitations of ICT infrastructure, a special room for e-exam and the terminals. By applying the TAMEx framework, the TAMEx adapter application was developed to capture and process TAMEx data. One of TAMEx data is the RSSI level. When the RSSI level is below than 20%, then user terminal is identified not connected. The user is then successfully having an extended time to continue the exam process. The extended time is varies which depends on the received

signal quality or the RSSI level at the e-exam terminal. Thus, the RSSI level as the main indicator of the connection status of the e-exam terminal is effective. As a result, the TAMEx framework can guarantee availability and reliability of e-exam process.

4.2. Future Works

Futher investigations are considered for next project to improve the TAMEx framework and e-exam process. Firstly is to capture more data of the RSSI level for the long period to set the best RSSI saturation level. Moreover, the model of relationship between various level of the RSSI with TAMEx response will be investigated as in [23]. Thirdly, it is necessary to study the usage of TAMEx framework for various types of questions of exam. Finally the quality of experience of the examinees using the Main Opinion Score method can be further explored in term of question type variation, number of questions and number of examinees.

ACKNOWLEDGEMENTS

This research was supported by the Udayana University Research and Community Service Institute (LPPM) under Research Grants of Unggulan Udayana. Big thank to our colleagues at Study Program of Doctoral Engineering Science, Faculty of Engineering, Universitas Udayana for their great assistance during this research period.

REFERENCES

[1] C. Andharini Dwi, et al, "Design an adaptive e-learning application architecture based on IEEE LTSA reference model," *Telkomnika (Telecommunication Comput. Electron. Control*, vol. 13, no. 1, pp. 284-289, January 2015.
[2] R. J. Widodo, "E-Learning for improvement quality of the Indonesian human resources," *TELKOMNIKA Telecommunication Computing, Electronics and Control*, vol. 5, no. 2, pp. 121-126, August 2007.
[3] M. Al-Fayoumi and S. J. Aboud, "An efficient e-exam scheme," *Int. J. Emerg. Technol. Learn.*, vol. 12, no. 4, pp. 153-162, April 2017.
[4] B. Küppers and U. Schroeder, "Bring your own device for e-Assessment - a Review," *EDULEARN16 Proc.*, vol. 1, no. January 2017, pp. 8770-8776, July 2016.
[5] M. Hillier, "e-Exams with student owned devices : Student voices," *Proc. Int. Mob. Learn. Festiv. 2015 Mob. Learn. MOOCs 21st Century Learn. May 22-23, 2014, Hong Kong SAR China*, May 2015.
[6] R. Ferdiana and O. Hoseanto, "The implementation of computer based test on BYOD and cloud computing environment," *Int. J. Adv. Comput. Sci. Appl*, vol. 9, no. 8, pp. 121-124, January 2018.
[7] T. K. Seow, S. Kit, and A. Soong, "Students ' perceptions of BYOD open-book examinations in a large class : a pilot study," no. 1995, 2013.
[8] M. Hillier and A. Fluck, "Arguing again for e-exams in high stakes examinations," *30th Annu. Conf. Aust. Soc. Comput. Learn. Tert. Educ. ASCILITE 2013*, pp. 385-396, 2013.
[9] J. Castellà-Roca, *et al.*, "A secure e-exam management system," *Proc. - First Int. Conf. Availability, Reliab. Secur. ARES 2006*, vol. 2006, pp. 864-871, May 2006.
[10] A. Huszti and A. Petho, "A secure electronic exam system," *Publ. Math*, vol. 4, no. 77, pp. 299–312, January 2010.
[11] R. Giustolisi, et al., "What security for electronic exams?," *2013 Int. Conf. Risks Secur. Internet Syst. Cris. 2013*, April 2013.
[12] B. S. N. Pendidikan, "Penyelenggaraan Ujian Nasional Badan Standar Nasional Pendidikan", 2018.
[13] N. Chiranji, et al., "A novel approach to enhance security for online exams," *Int. J. Comput. Sci. Technology*, vol. 2, no. 3, pp. 84-89, September 2011.
[14] M. Onyesolu, et al., "Enhancing security in a distributed examination using biometrics and distributed firewall system," *Int. J. Emerg. Technol. Adv. Eng*, vol. 3, no. 9, September 2013.
[15] Y. Levy and M. M. Ramim, "A theoretical approach for biometrics authentication of e-Exams," *Chais Conf. Instr. Technol. Res.*, vol. 2005, pp. 93-101, January 2007.
[16] Y. Sabbah, et al., "Synchronous authentication with bimodal biometrics for e-assessment: A theoretical model," *2012 6th Int. Conf. Sci. Electron. Technol. Inf. Telecommun. SETIT 2012*, pp. 139-145, March 2012.
[17] J. W. Gathuri and S. Kamundi, "Impersonation challenges associated with e-assessment of university students", *J. Inf. Eng. Appl.*, vol. 4, no. 7, pp. 60-69, 2014.
[18] J. Dreier, et al., "Formal security analysis of traditional and electronic exams," *Commun. Comput. Inf. Sci*, vol. 554, pp. 294-318, December 2015.
[19] G. Hayardisi, et al., "Analysing signal strength and connection speed in cloud networks for enterprise business intelligence," *TELKOMNIKA Telecommunication Computing, Electronics and Control*, vol. 16, no. 4, pp. 1779-1784, August 2018.
[20] Ç. Kurnaz, et al., "Investigating the effect of number of users on signal strength level and throughput for wi-fi system," *2017 International Artificial Intelligence and Data Processing Symposium (IDAP)*, September 2017.
[21] A. A. Astaneh and S. Gheisari, "Review and comparison of routing metrics in cognitive radio networks," *Emerging Science Journal*, vol. 2, no. 4, pp. 191-201, August 2018.
[22] D. Mulenga and S. Siziya, "Indoor air pollution related respiratory Ill health, a sequel of biomass use," *SciMedicine Journal*, vol. 1, no. 1, pp. 1-8, 2019.
[23] A. Sohail, et al., "Analysis and measurement of Wi-Fi signals in indoor environment," *Int. J. Adv. Eng. Technol*, vol. 6, no. 2, pp. 678-687, May 2013.

[24] K. D. Kalistatov, "Wireless video monitoring of the megacities transport infrastructure," *Civil. Engineering. Journal*, vol. 5, no. 5, pp. 1033-1040, May 2019.
[25] O. Aminoroayaie Yamini, *et al*., "Numerical modeling of sediment scouring phenomenon around the offshore wind turbine pile in marine environment," *Environmental. Earth Science.*, vol. 77, no. 23, p. 12665, November 2018.
[26] A. Omidi, et al., "Design of the low noise amplifier circuit in band l for improve the gain and circuit stability," *Emerg. Science. Journal*, vol. 1, no. 4, pp. 192-200, January 2018.
[27] G. Sukadarmika, et al., "Introducing TAMEx model for availability of e-exam in wireless environment," *2018 Int. Conf. Inf. Commun. Technol. ICOIACT 2018*, pp. 163-167, January 2018.
[28] E. C. Lo, "An investigation of the impact of signal strength on wi-fi link throughput through propagation measurement," 2007.
[29] A. F. Group and W. Paper, "The Invisible Threat: Interference and Wireless LANs," May, 2010.
[30] AirMagnet Inc; Whitepaper, "802.11n Primer", 2008. Available: http://wiki-files.aircrack-ng.org/doc/others/WP-802.11nPrimer.pdf.
[31] J. Bardwell, "Converting signal strength percentage to dBm values", *WildPackets, Inc*, , pp. 1-12, November 2002.
[32] Sandesh et al., "Availability metrics: under controlled environments for web services", *Int. Journal on Web Service Computing*, vol. 2, no. 3, pp. 1-9, September 2011.

BIOGRAPHIES OF AUTHORS

Gede Sukadarmika received MSc in Networked Information Engineering at Sheffield Hallam University, Sheffield, UK in 2000. He was a head of the Unit of Computer Center in Udayana University 2019-2014. He is a lecturer in Department of Electrical Engineering in Udayana University, Bali, Indonesia 1995-now. Currently, he study in in Study Program of Doctoral in Engineering Science in Udayana University. Research Interest: Learning Technology, Telecommunication Network and Wireless Network. He is IEEE Member.

Rukmi Sari Hartati is a lacturer in Department of Electrical Engineering, Udayana University, Bali Indonesia. She received her PhD in Dalhousie University Canada in 2002. She was a head of Electrical Engineering Depertment 1984 - 1989. She is a member of IEEE. Her research interest ise in the field of Power System Engineering.

Linawati hold PhD majoring telecommunications engineering from the University of New South Wales, Sydney, Australia in 2004. She was an Executive Director of Global Development Learning Network (GDLN) 2006 - 2014, and Head of ICT of Udayana University in 2007 - 2014. She is head of electrical engineering postgraduate study program, Udayana University from 2017 – now and IEEE member.

Nyoman Putra Sastra received the B.Eng. and M.Eng. degree in electrical engineering from Institut Teknologi Bandung (ITB), Indonesia, in 1998 and 2001, respectively. In 2015 he receivied his Ph.D. degree from Institut Teknologi Sepuluh Nopember (ITS), Surabaya. Since 2001, he has joined with Universitas Udayana, Bali as lecturer in Department of Electrical Engineering. His research interests include wireless multimedia sensor networks, multimedia signal processing and Learning Technology. He is a Member of the IEEE.