

Monitoring Closed Circuit Television in Telkom University Landmark Tower using Internet of Things

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ABSTRACT

This research presents a prototype Closed Circuit Television (CCTV) monitoring system in a university building, employing Internet of Things (IoT) technology for remote access. Addressing the increasing need for campus security, the study uploads processed videos from the Network Video Recorder (NVR) to a Virtual Private Server (VPS), enabling real-time CCTV monitoring via a website. UiPath, utilized for Robotic Process Automation (RPA), automates commands, storing processed video data in the system's database. Research findings show the system's effectiveness, offering real-time access through the website. Quantitative data from a user satisfaction survey indicates a success rate above 40%, with respondents expressing agreement. Website security testing achieved a 100% reliability for Multifactor Authentication (MFA). Quality of service testing for CCTV video recordings involved four tests, yielding average values, including throughput at 21,613.03 bps (categorized as "very good"), packet loss at 0.236088 (categorized as "very good"), delay at 548.2033 ms (categorized as "poor"), and jitter at 42.5 ms (categorized as "good"). In conclusion, the system prototype successfully addresses challenges in remote CCTV monitoring at Telkom University Landmark Tower, allowing users access via smartphones or computers connected to the internet.

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1. INTRODUCTION

Information technology has advanced quickly and is now essential in many areas, including security. Technology serves as a security system and is meticulously constructed to fulfill a variety of human demands. Surveillance cameras or CCTV, are one example of a technological breakthrough in communication for human needs. CCTV systems record videos and display video streams on PC monitors. Using CCTV equipment to improve security and keep an eye on activity in lecture halls is one example of its application in a campus setting. The installation of CCTV helps to monitor dangerous incidents and criminal activity.

At this time, only the logistics rooms in the Telkom University Landmark Tower are available for CCTV monitoring. The logistics staff cannot oversee things remotely. The limitation of CCTV monitoring is that it is confined to the logistics rooms, resulting in ineffective and distant staff supervision. A suggested solution is

the implementation of a web-based CCTV monitoring system with the assistance of the Internet of Things (IoT) for remote monitoring. With IoT support for remote viewing, the CCTV monitoring system operates in real-time for environmental monitoring [1]. A new system will utilize an NVR, router, PoE switch, and IP camera equipment. Due to their ease of scanning and transmission compared to analog cameras, IP cameras are currently used more frequently [2]. The combined results of CCTV video processing are displayed on a previously developed website [3].

Each IP camera comes with its own dedicated application, yet it faces limitations when it comes to adding additional CCTV units. This constraint is evident in the integrated CCTV monitoring application of the Uniarch brand IP camera used in the monitoring system. Within the Uniarch application, adding a new camera location requires manual input by scanning the device's QR code. In the upcoming system, all installed cameras will be automatically incorporated into the website based on their designated placements, eliminating the need for users to manually add each camera. The planned website will categorize camera locations according to their placement, streamlining the process for users to locate and monitor their desired cameras. Figure 1 illustrates the implementation of the proposed system solution.

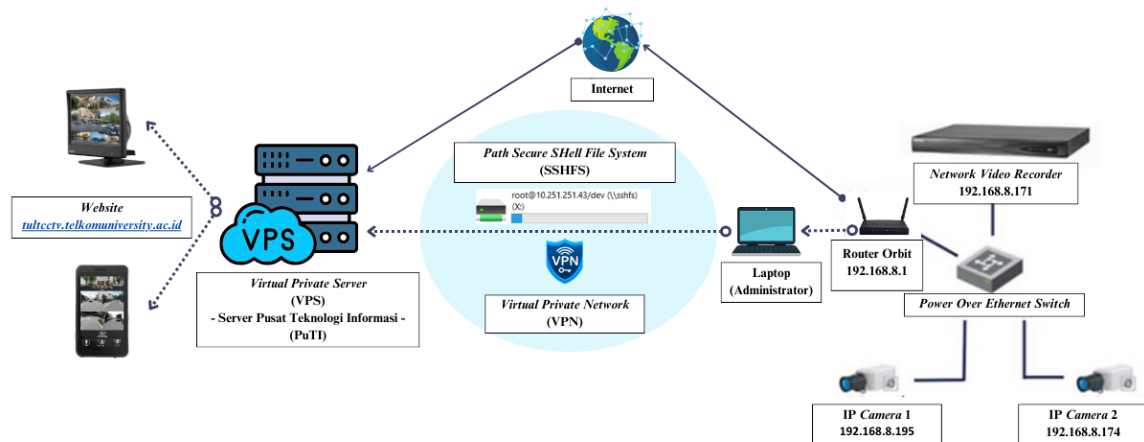


Figure 1. Implementation Architecture of CCTV Monitoring System

Figure 1. illustrates the architecture of the CCTV monitoring system implementation, starting with the task of the network engineer to connect the hardware devices and integrate them with the monitoring website. The hardware devices used include the Network Video Recorder (NVR), Power over Ethernet (PoE) Switch, Router, IP Camera, and LAN cables with RJ45 connectors. After all devices are connected, the next step involves converting from the RTSP protocol to HTTP Live Streaming (HLS) for live broadcasting through FFmpeg and automatic storage on the Virtual Private Server (VPS) connected with the path or file path related to SSHFS on the PC or laptop device. When data is transferred from hardware to a virtual private server, data security is ensured. This is attributed to the use of the SSH protocol as the transfer method. Monitoring can then be conducted using the website after undergoing testing and analysis of monitoring parameters. The integrated results of CCTV video processing are displayed on a previously created website [4]. FFmpeg is a highly useful framework for live broadcasting, recording, editing, and converting audio, video, and image files that can be used on various platforms [5].

Video recordings are stored on the Virtual Private Server (VPS), which serves as a virtual server for storing live broadcasts from connected devices, namely CCTV cameras [6]. The web server used is Nginx, which is the best proxy to enhance security and performance. In this case, an adequate server is needed to store and process video data from CCTV. Video data can be accessed through the website, which will display real-time CCTV video for remote monitoring and will be stored on the server, uploaded to the database to store time-related information from the CCTV recordings. Here, the website interface is connected to the database in real-time using Supabase software handled by the back-end. The RTSP network protocol is used to display media in real-time. The front-end website adopts a minimalist design created in Figma, with source code developed in Visual Studio Code using the JavaScript programming language and the Vue.js framework for interactivity and dynamism.

The purpose of this research is to create a CCTV prototype in the TULT building using the Internet of Things that can be monitored through mobile devices with internet connectivity to access the internet network. The CCTV monitoring system operates through real-time environmental monitoring with the assistance of the Internet of Things (IoT) for remote viewing. The benefits of using this technology are considered to facilitate CCTV monitoring, as technicians can control the CCTV and view recorded video results through an independently created platform to avoid external access.

2. METHOD

The website design includes the Internet of Things integration to the website, front-end development, and back-end development as described in the following explanation:

2.1. Website and Internet of Things Device Integration

This subsystem is a part of the system responsible for planning and implementing the connection of Internet of Things devices and integrating them into the monitoring system, aiming to ensure security, availability, and optimal performance. In the role of a network engineer, the workflow involves connecting or linking all hardware devices and integrating them with the monitoring website.

The hardware devices utilized in implementing the solution include the Network Video Recorder (NVR), Power over Ethernet (PoE) Switch, Router, IP Camera, and LAN cables. On this CCTV monitoring website, CCTV video recordings are stored on the Virtual Private Server (VPS). Once all devices are properly connected, the next step involves integrating the hardware with the monitoring website. This is achieved by using the "mkdir" command to create storage directories based on the recording time, followed by executing the FFmpeg command, which functions to convert the RTSP protocol to HLS (HTTP Live Streaming). After conversion, the resulting video is embedded on the website using video.js, a JavaScript library. The web server used is Nginx, serving as a reverse proxy. It acts as an intermediary server utilizing Nginx to receive, forward, and manage client requests and responses from the destination server, thereby enhancing the security and performance of the web application.

Here is the flowchart for the network engineer's role, where the workflow involves connecting all hardware devices and then integrating them with the monitoring website.

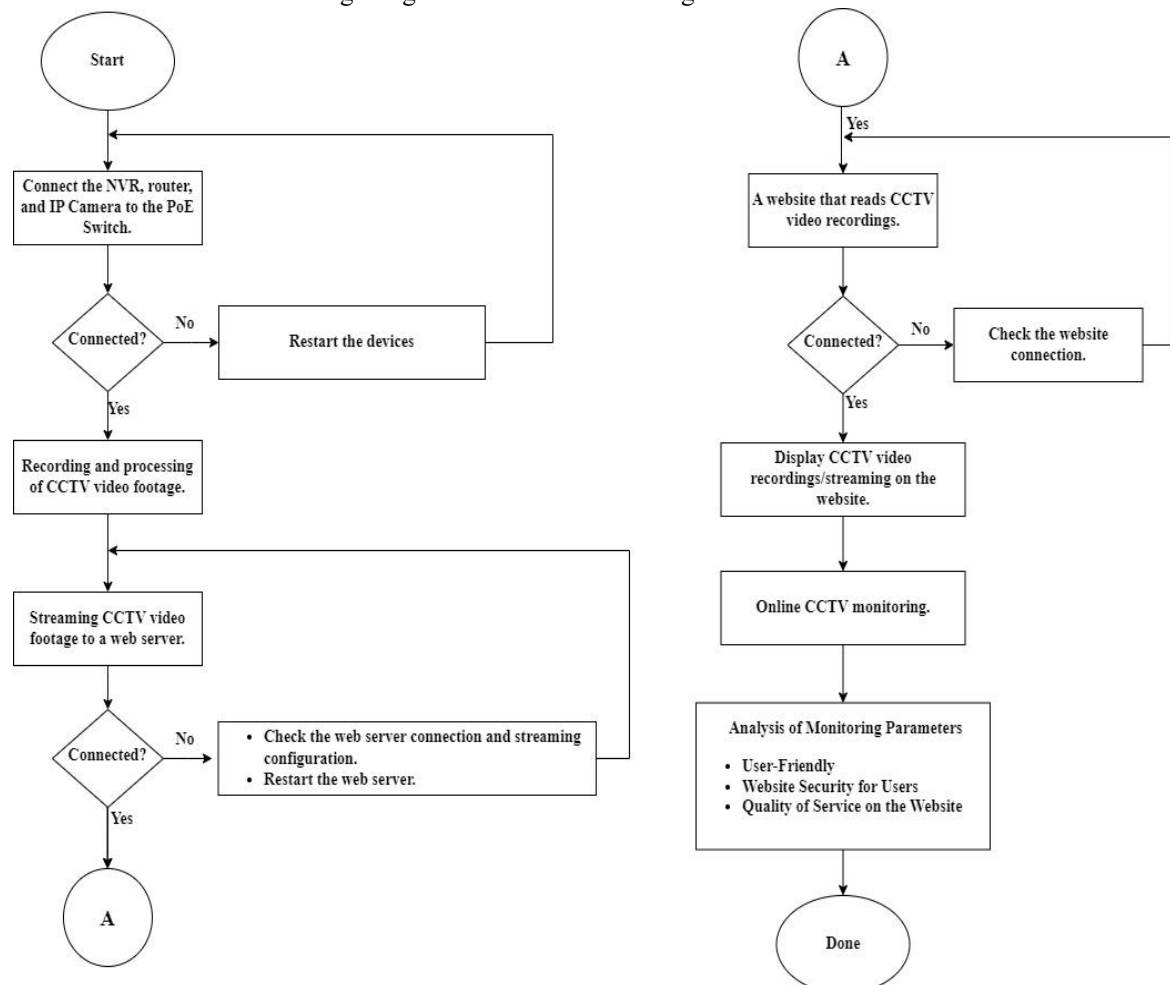


Figure 2. Hardware and Website Connectivity Flowchart

The diagram above illustrates the flowchart that will be operational, starting by connecting all devices, from the Network Video Recorder (NVR) and Router connected to the PoE Switch, to the PoE Switch being connected to two IP cameras or CCTV units for testing. The NVR functions to record and manage video recordings from CCTV cameras, while the router serves to connect the local network to the internet and regulate data traffic between them. The PoE switch is utilized to transmit power and data through Ethernet or LAN cables to the CCTV devices. Once all devices are properly connected, the next step involves the process of recording and processing CCTV video footage. Following this stage, the video recordings will be sent through the network or internet, connected to the router, to a web server that will explore them on a website. During this process, data will be transmitted using the Real-Time Streaming Protocol (RTSP) network protocol.

Subsequently, the web server facilitates access to these videos via a website, allowing users to view them online. This process involves data transfer, security with encryption, and the provision of a web interface to display videos and provide real-time camera control. Moreover, this process demands a reliable network infrastructure and server software proficient in efficiently managing video streaming. Before actively monitoring through the monitoring website, the final step involves carefully researching monitoring parameter settings. The analysis of these parameters aims to ensure that the monitoring website service is optimal according to user needs, encompassing user friendly, data security, video display quality, and Quality of Service website performance. These parameters include:

1. User-friendly parameters aim to guarantee that the website interface is user-friendly, emphasizing readability and ease of navigation to ensure quick and efficient access for users.
2. Website security parameters are evaluated to protect user data and information, with a primary focus on the security of user accounts.
3. Quality of Service (QoS) website parameters are assessed to ensure the availability, reliability, and optimal performance of the website. Response speed and seamless services are the primary concerns in meeting user expectations for an efficient monitoring experience.

2.2. Front End Development

The front-end is a component of software systems that directly interacts with users. It is responsible for presenting information to users and collecting input from them. This involves designing the user interface (UI), visual elements, and interactivity to enhance the user experience. In front-end development, applications such as Figma and Visual Studio Code are utilized to build the website's interface. The front-end design of the CCTV monitoring website is kept minimalistic for easy user operation. The layout or mockup of the website is created using the Figma application, a cloud-based design platform accessible through web browsers, enabling collaborative editing by all team members.

For source code development, Visual Studio Code is used with the JavaScript programming language. JavaScript is employed to modify the website pages, making them more interactive and dynamic. The JavaScript framework utilized is Vue.js, known for facilitating user interface development on websites [7]. Vue.js is an open-source framework recognized for being easy to learn, error-friendly, and having lightweight data despite high performance [8]. In Vue.js, Nuxt.js is required as a framework to assist in the rendering and development processes. Nuxt.js provides features that simplify website development through built-in tools and commands within the framework. It streamlines the website creation and operation processes through executable commands. Figure 4 is a flowchart representation of the display for the website to be created.

On the homepage, users will enter their accounts. If a user doesn't have an account, they will be directed to create one, and then the user can log in to the created account after verifying the previously registered email. If a user already has an account but forgets the password, they can choose the "forgot password" option on the website's login page. On the website, there are the main page and settings. On the main page view, users can see information such as usage guidelines, storage, and live recordings. In the "Live Recording" menu, there is already a list of locations and cameras that have been placed, making it easier for users to find the camera locations. In the "Storage" menu, there is a list of dates and camera locations that users want to access. In the settings view, users can make adjustments, such as changing their profile, changing the language, changing the password, and logging out of the account.

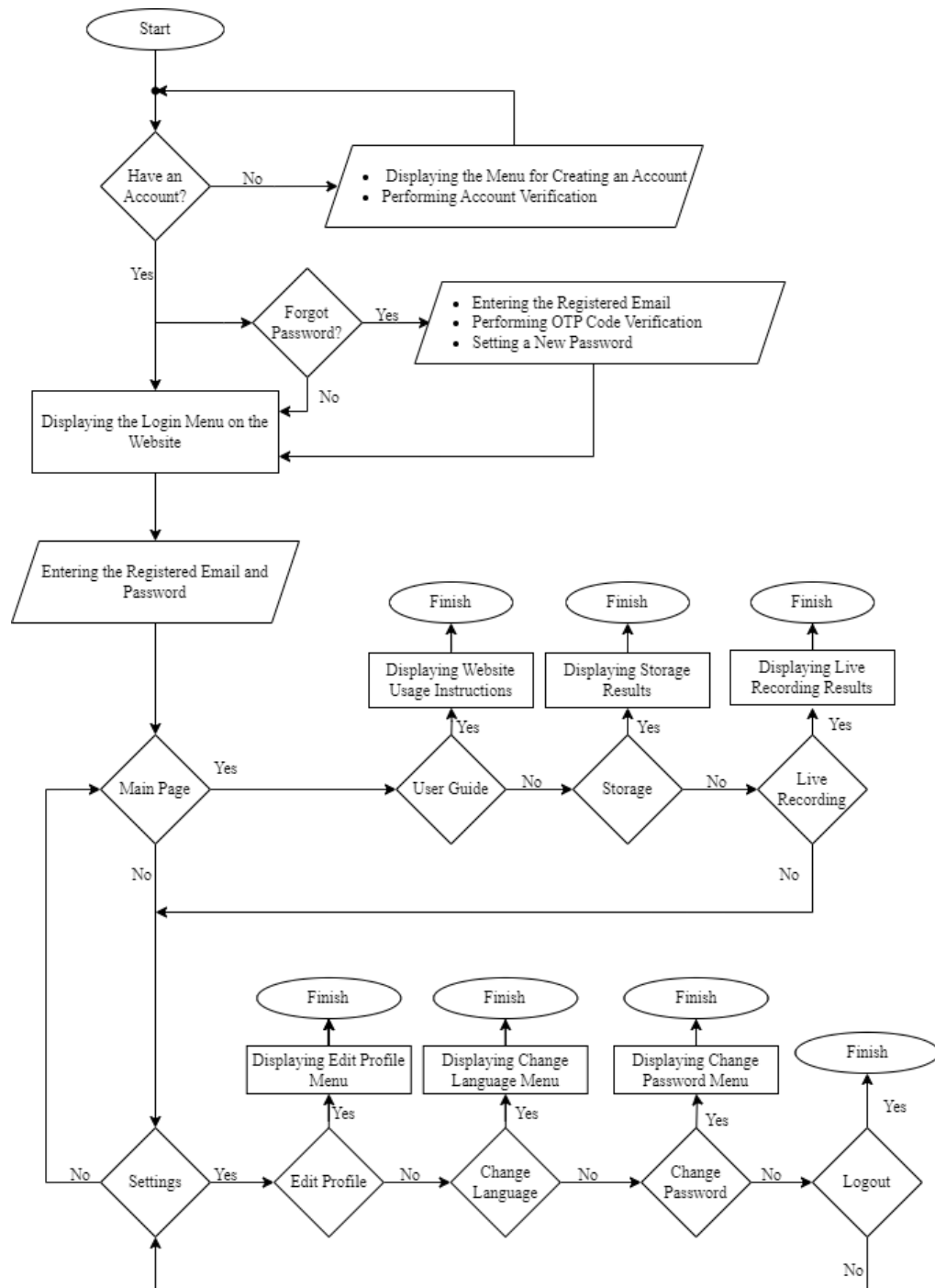


Figure 3. Flowchart of CCTV Website Monitoring Usage

2.3. Back-End Development

When running the website, there are several stages for synchronizing the back-end portion of Supabase with the website's interface. In Figure 4, a flow diagram illustrates the overall operation of the back-end subsystem. The process begins with account registration in diagram A, which will be further discussed in Figure 5. After the account registration process, users will be directed to the login page for user credential validation in diagram B, explained in Figure 6.

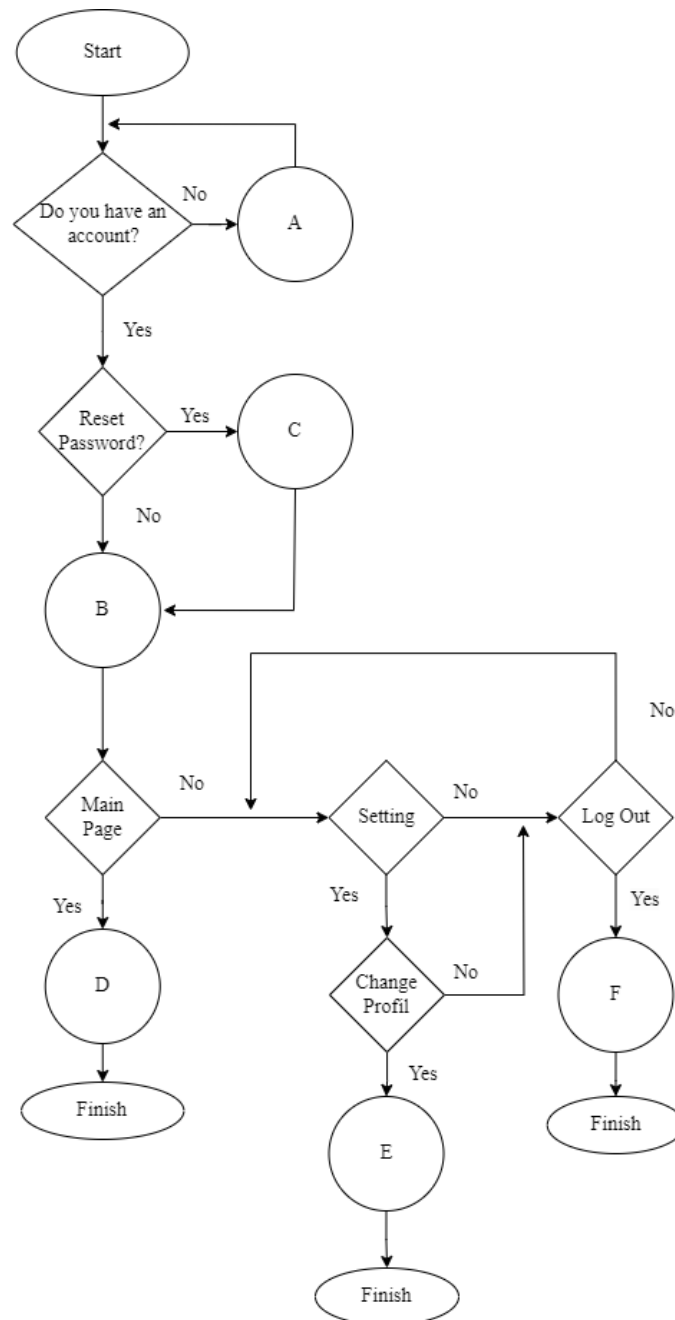


Figure 4. Flowchart of Back-End Development

If a user forgets their credentials, they will be directed to the password reset section to reset their credentials in diagram C, as described in Figure 7. On the homepage, the system will read the database for the website's interface in diagram D, outlined in Figure 8. To make changes to the user profile, the steps are explained in Figure 9, in Diagram E. If a user wishes to log out, they will be directed to the logout process in Figure 10, which is part of diagram F in the flowchart, and will be returned to the login page.

Overall, these steps illustrate the interaction between the website and the Supabase back-end, providing a deeper understanding of the operational flow, from user account registration processes to profile management and user account settings.

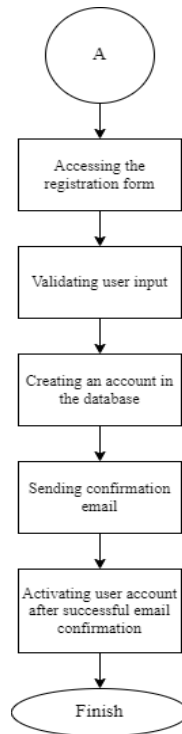


Figure 5. Flowchart of Register

Here is the flowchart in Figure 5 that explains the registration form. In this process, users will be asked to enter the required information in the registration form, and the input results will undergo a verification stage to ensure the accuracy and completeness of the provided information. Next, the verified input results will be utilized to create a user account in the database. This process involves storing user information in the database, ensuring data integrity, and allowing efficient access by the system.

Furthermore, the verified input results are used to create a user account in the database, ensuring data integrity, and facilitating access by the system. A confirmation email is sent to the email address provided by the user in the registration form as an additional verification step. Users are expected to check and follow the provided confirmation steps. After completing the confirmation process, the user account is activated, granting full access to utilize the system's services. Thus, this flowchart provides in-depth insights into the registration process, from filling out the form to activating the account through email confirmation.

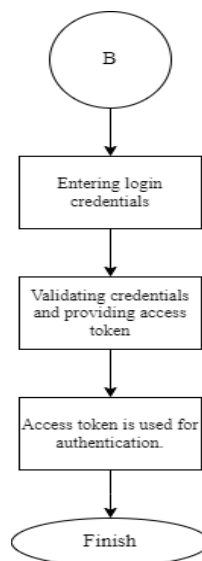


Figure 6. Flowchart of Login

In Figure 6, the flowchart explains the login process. When a user attempts to log in, they are prompted to input credentials such as a username and password. This step involves verifying the validity of the entered credentials. If the credentials are proven to be valid, the system generates an access token.

This access token plays a crucial role in the authentication mechanism, indicating that the login has been successfully executed. The token is subsequently used for authentication in every subsequent interaction with the system. Thus, the flowchart provides a detailed overview of the login process, starting from credential input, verification process, to the issuance of an access token as an indication of successful authentication.

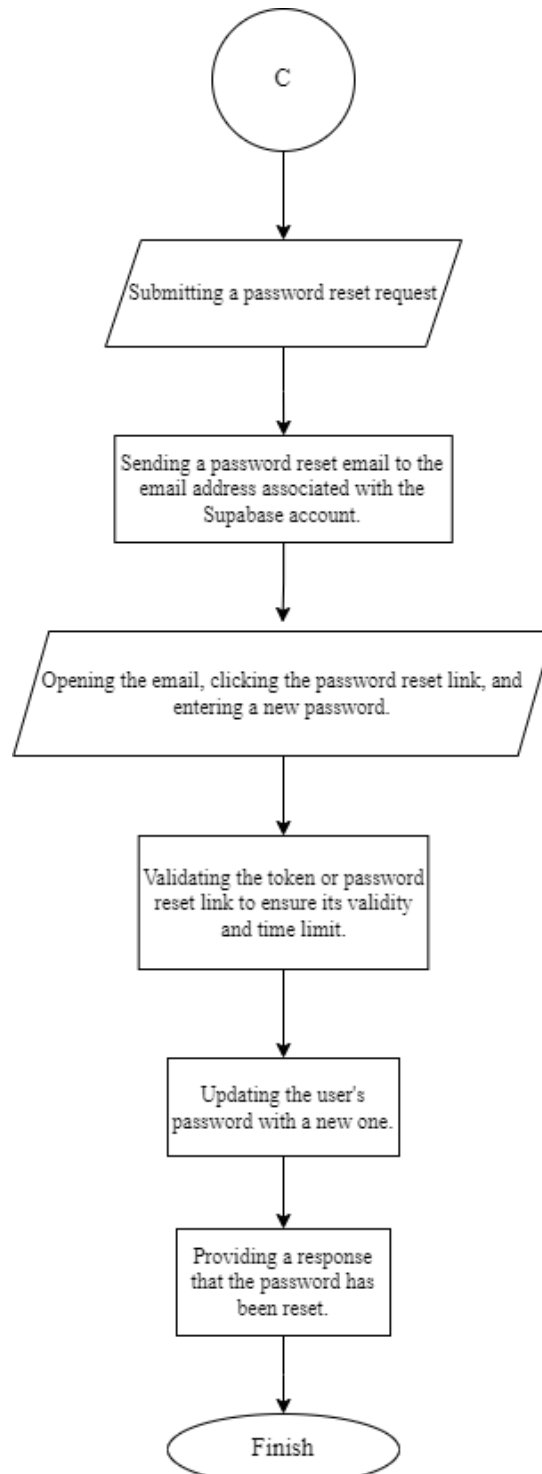


Figure 7. Flowchart of Forget Password

In Figure 7, the flowchart illustrates the process for users who have forgotten their credentials. In the initial stage, the user requests a password reset. An email associated with the user's account will be sent, containing a password reset link. The user clicks on this link to reset the password and enters a new password. The system validates the token to ensure its authenticity and timeliness. Afterward, the system updates the user's password with the new one and provides a response indicating that the password reset process has been successful.

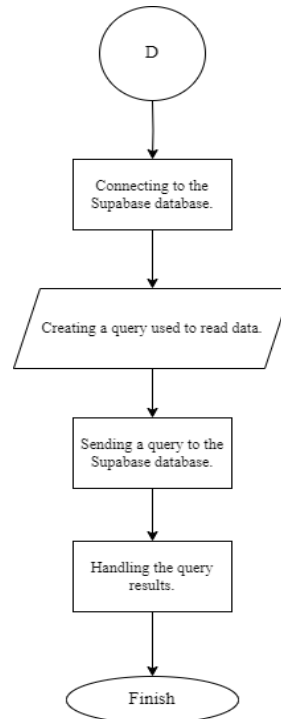


Figure 8. Flowchart of Reading from the database.

Figure 8 is a flowchart for reading the Supabase database. The first step in this process is to connect to the database. Afterward, queries are formulated to read information from the database. Once the query is created, the next step is to send it to the Supabase database by transmitting a request to obtain the necessary data. After executing the query, the final step is to handle the results generated by the database.

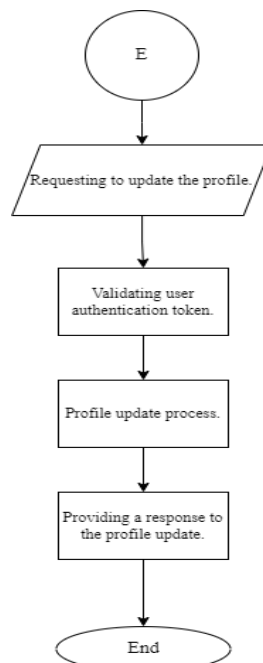


Figure 9. Flowchart of Edit Profil

Figure 9 is a flowchart for editing the profile. The first step involves the user's request to edit the profile. After verifying the authentication token, the user can proceed with the profile editing process. During profile editing, the user can make the desired changes. The system will provide feedback to indicate that the changes to the profile have been successfully made, reflecting the success of the editing process.

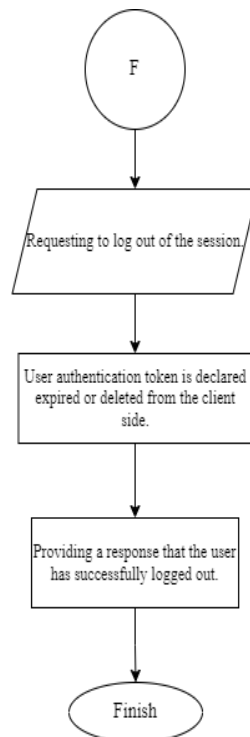


Figure 10. Flowchart of Log Out

Figure 10 is a flowchart for the logout process. Users will request to log out of the session page, which involves checking the validity of the authentication token. If the token is invalid or has been deleted from the client side, the system responds that the logout is successful. In this context, an active user requests logout, and the system confirms that the authentication is no longer valid or the token has been deleted. The user's response message confirms that the logout procedure was successful.

The back-end is the part of an application that handles data storage, business logic, authentication, and provides services for interaction with the front-end. Its functions involve managing data, security, and providing services that support the overall application's functionality. Additionally, the back-end is responsible for user authentication, data security management, and providing Application Programming Interface (API) services to facilitate efficient communication between the front-end and back-end of the application, as well as performing fundamental operations not visible to the user. In the back-end, the workflow involves connecting the website's front-end with the database and real-time authentication. The database platform used is Supabase. Supabase is an open-source product where all its components are also open source [9]. Supabase has four features: database, file storage, third-party authentication, and Auto-Generated API.

Back-end development also includes website automation using Robotic Process Automation. Robotic Process Automation (RPA) is the automation of service tasks that mimic tasks typically performed by humans[10]. Essentially, RPA consists of algorithms and programming implemented on computer devices[11]. The RPA application used is UiPath. UiPath is a tool that enables RPA development to create and execute script programs. UiPath also allows for programmatic screen interaction and several additional plugins for customization processes. The UiPath RPA platform is currently organized into three modules: UiPath Studio, UiPath Robot, and UiPath Orchestrator[11]. The last module enables the orchestration of robots to efficiently manage and control robots.

The automation carried out aims to schedule the execution of FFmpeg commands and delete video folders on the VPS with SSHFS path for a period of 3 days automatically every day. The FFmpeg automation is intended to facilitate the execution of FFmpeg commands for camera 1 and camera 2 automatically through UiPath. Meanwhile, the process of deleting video folders on the VPS with SSHFS path every 3 days is also automated through UiPath. The HTTP protocol forms the basis of the World Wide Web (WWW). Therefore, it is necessary to convert from RTSP to HTTP format [12]. To display media in real-time, the RTSP network

protocol is required. Real Time Streaming Protocol (RTSP) is a network protocol used to control and manage media streaming. In the integration of CCTV camera connections, RTSP will convert the media into a format for streaming through HLS (HTTP Live Streaming) using FFmpeg. FFmpeg is software that can record, convert, and stream digital audio and video in various formats.

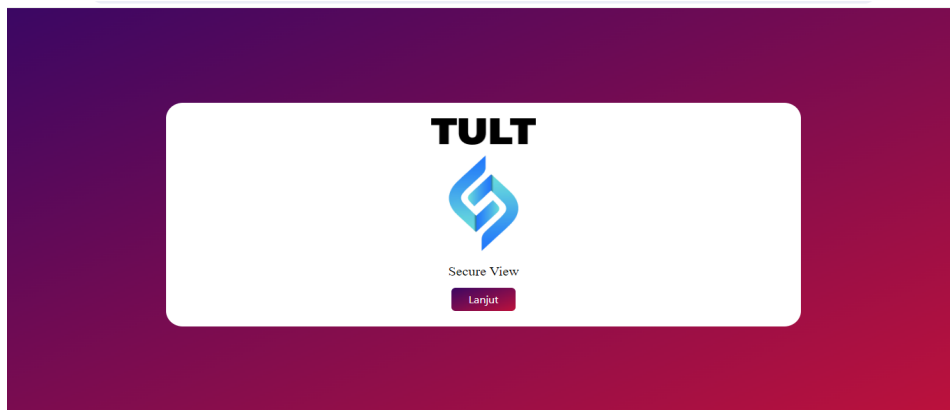
3. RESULTS AND DISCUSSION

Based on the designed implementation plan, testing will be conducted and divided into several phases. The purpose of these tests is to ensure the feasibility and overall performance of the system. Testing will take place at the Telkom University Landmark Tower (TULT) building. The testing includes the following tests and testing schemes:

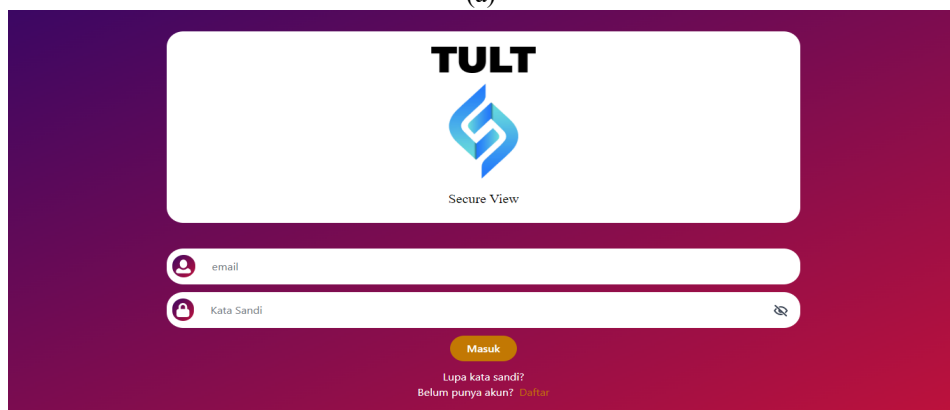
1. Website Display System Testing: This test is conducted with website users, involving user testing of the website platform with a minimum of 30 users, utilizing the User Experience Questionnaire (UEQ).
2. Website Security System Testing: User testing will be conducted for multi-factor authentication (MFA) during account registration. Users will receive a confirmation email for the registration process. Additionally, in cases where users forget their credentials and want to reset their password, the administrator will send an OTP code via email for additional verification and optimal account security.
3. Quality of Service (QoS) Website Testing: Packet capture will be performed using Wireshark during the live CCTV recording playback on the website. This involves capturing a duration of approximately 15 to 20 seconds during each testing phase, utilizing the Wi-Fi network connectivity available at Telkom University Landmark Tower as the access medium for the tested website.

3.1. Website Display System Testing

Website display system testing is conducted by examining the display results of the already created source code. Based on the testing results, the website display is in accordance with the designed layout. All components and buttons on the website function properly. The following is the result of creating the website display that has been made. The following is the output display of the website when opened on a laptop or computer.



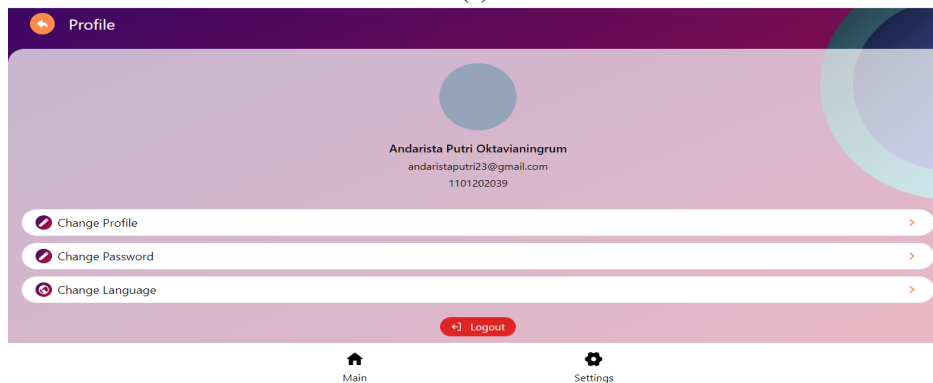
(a)



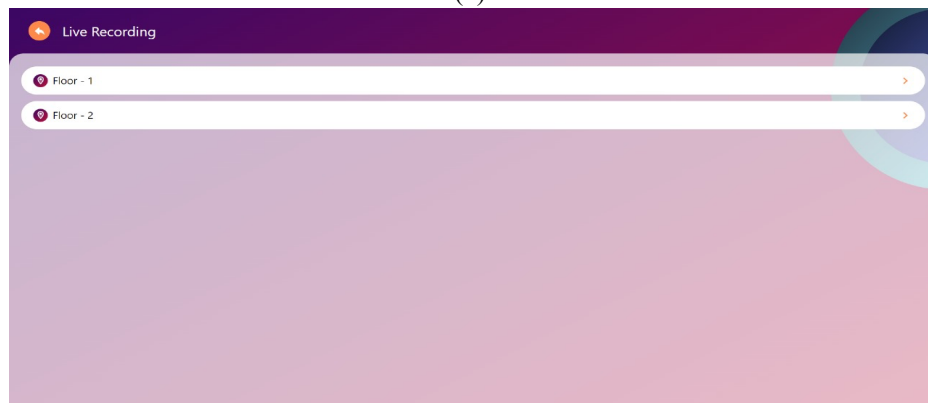
(b)



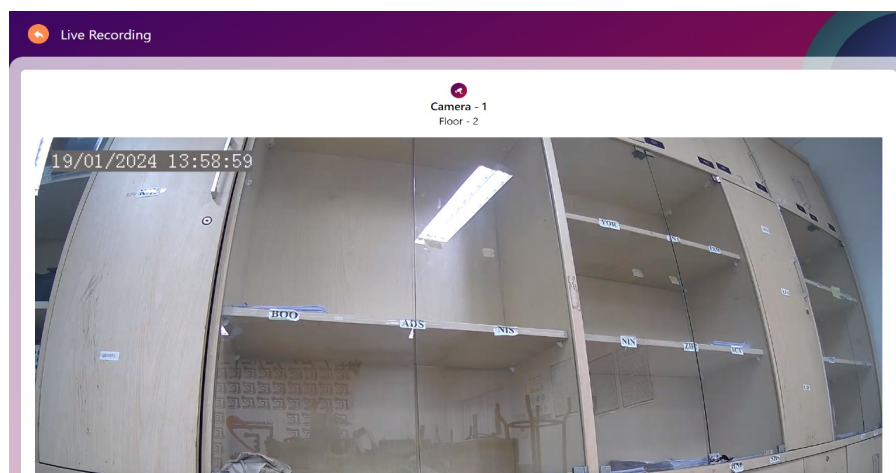
(c)



(d)

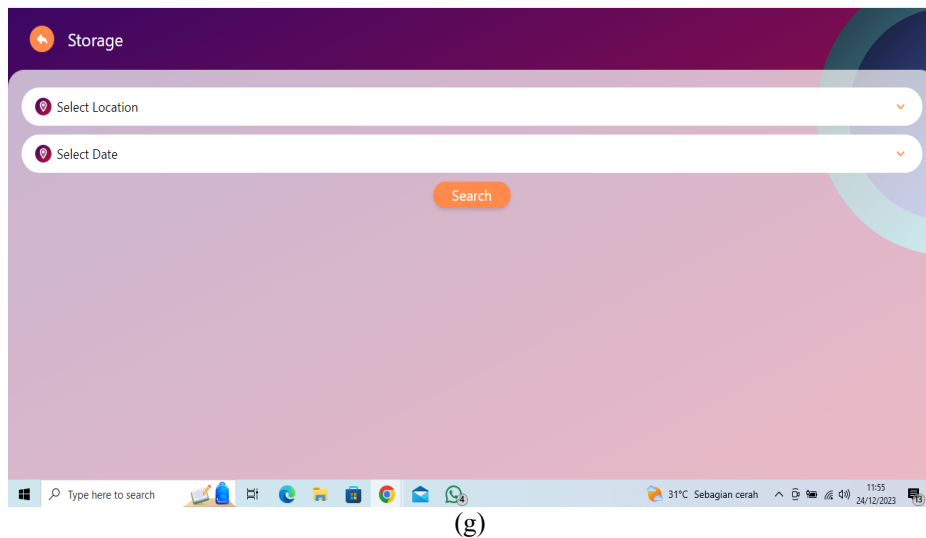


(e)



(f)

*Monitoring Closed Circuit Television in Telkom University Landmark Tower using Internet of Things
(Andarista Putri Oktavianingrum)*



(g)
Figure 11. CCTV Monitoring Website Interface (a) Home Page, (b) Login Page, (c) Main Page, (d) Settings Page, (e) Live Recording Page, (f) Results Page from Live Recording, (g) Storage Page

Development of a CCTV Monitoring Website for the TULT Building to facilitate users with several accessible features. The user-side functionality of the website is as follows:

1. Home Page

Based on Figure 11(a), the home page displays the website's logo and features a "continue" button to proceed to the login page.

2. Login Page

Based on Figure 11(b), the login page is intended for users who already have an account to enter their registered email and password. If a user doesn't have an account, they can register for a new account in the "Register" menu. If a user forgets the password, they can reset it by selecting the "Forgot Password" menu.

3. Main Page

Based on Figure 11(c), the main page displays the "User Guide," "Storage," and "Live Recording" menus.

4. Settings Page

Based on Figure 11(d), the settings page displays the "Edit Profile," "Change Password," "Change Language," and "Logout" menus.

5. Live Recording Page

Based on figure 11(e), the live recording page displays floor options where CCTV is installed, making it easier for users to categorize locations of the installed CCTV cameras.

6. Results Page from Live Recording

Based on figure 11(f), the live recording results page shows ongoing CCTV recordings in the selected location.

7. Storage Page

Based on figure 11(g), the storage page will showcase video storage results from the previous day. Users can select the location and date of the CCTV recording they want to view.

In the context of website development, testing is the process of assessing a website to find mistakes and appearances that deviate from expectations. Testing is done primarily to make sure the website satisfies standards, runs well, and offers a positive user experience. The website appearance test results are shown in Table 1. The testing indicates that the look and feel of the website are working properly.

Table 1. Website Main Feature Test

No	Page	Testing	Result
1	Register Page	User attempts to register an account.	Succeed
2	Login Page	User tries to log in to the website using the created account.	Succeed
3	Main Page	User accesses the homepage, and the homepage displays the available menu.	Succeed
4	Live Recording Menu	The video displayed in the menu is real-time according to the current time of access.	Succeed
5	Storage Menu	The stored videos displayed correspond to the selected time and location.	Succeed
6	Setting Page	The user accesses the settings page and can make changes to each menu.	Succeed

After the website has been successfully created, testing is conducted using the User Experience Questionnaire (UEQ). The purpose of creating the UEQ is to determine user responses to the website through a questionnaire created on Google Forms. The administrator receives direct feedback and assessments from users regarding their experience using the website. 42 users tested the platform, and their experiences were recorded in a survey that was sent out to them to get their opinions and direct feedback. Through conducting surveys, administrators can identify any shortcomings present in the newly created website. Here is the table of survey results conducted by the author's team:

Table 2. User Acceptance Test Result

No	Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	The website display helps users in monitoring CCTV	0	0	0	19	23
2	The website display helps users in monitoring CCTV	0	0	3	14	25
3	The website display helps users in monitoring CCTV	0	0	0	14	28
4	The features provided by the CCTV monitoring website are relevant and fully functional	0	0	5	17	20

The survey results are presented in the form of a graph in the Figure 12 below.

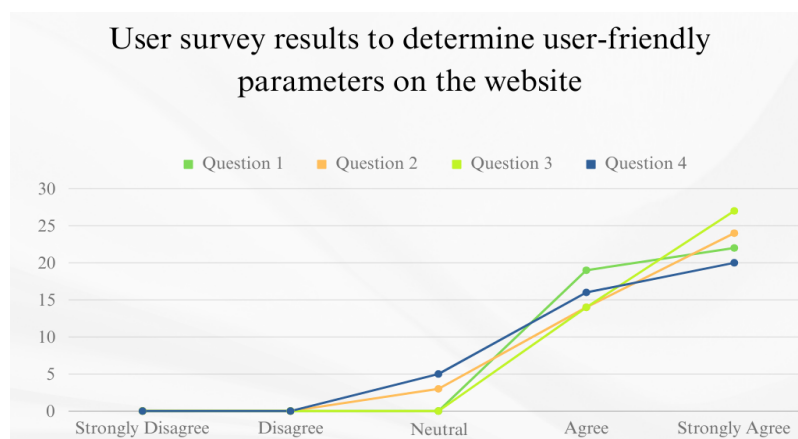


Figure 12. The Image of The User Survey Results for User-Friendly Parameters on The Website

The User Experience Questionnaire (UEQ) survey on the display test indicates user satisfaction as follows:

- 45.2% "Agree," 54.8% "Strongly Agree" for the first question.
- 7.1% "Neutral," 33.3% "Agree," 59.5% "Strongly Agree" for the second question.
- 33.3% "Agree," 66.7% "Strongly Agree" for the third question.
- 11.9% "Neutral," 40.5% "Agree," 47.6% "Strongly Agree" for the fourth question.

Based on the survey, it can be concluded that, on average, website users are assisted in monitoring CCTV, the provided features on the website are easy to operate, and the website's features function entirely. After conducting tests with 42 users using the User Experience Questionnaire (UEQ), the author's team also presented the website results to the logistics team at the Telkom University Landmark Tower building. The logistics team has approved the design and features created by the author's team. The features created by the author's team make it easier for the logistics team to determine the locations of cameras to be monitored. In the future, the logistics team wants to integrate the author's team's website into the Telkom University Landmark Tower construction.

3.2. Website Security System Testing

Security testing based on Multi factor Authentication (MFA) Access Specification is crucial for administrators to assess system security. The goal is to achieve a 99% or higher reliability and availability level for MFA technology. The testing has two main stages. Firstly, during user account registration, the administrator evaluates MFA performance by checking if users can successfully receive and use the authentication code sent via registered email. Multi factor authentication involves using multiple programs to verify user identity and prevent confidential information leaks. Secondly, for users who forget passwords, the administrator tests the password change procedure through the "Forgot password" option. The speed of delivering One-Time Passwords (OTP) via registered email is evaluated, ensuring users can successfully use OTP's to change passwords.

Results provide insight into MFA implementation effectiveness, protecting the system from unauthorized access. Documentation includes success rate evaluations and system responses to specific scenarios, providing concrete evidence of thorough testing to ensure access security using Multi Factor Authentication. In Figure 13(a) below is an image of the email received by the user during the account registration, and Figure 13(b) is an image of the authentication code for password reset when the user forgets their password, serving as concrete evidence of the effectiveness of the security system.

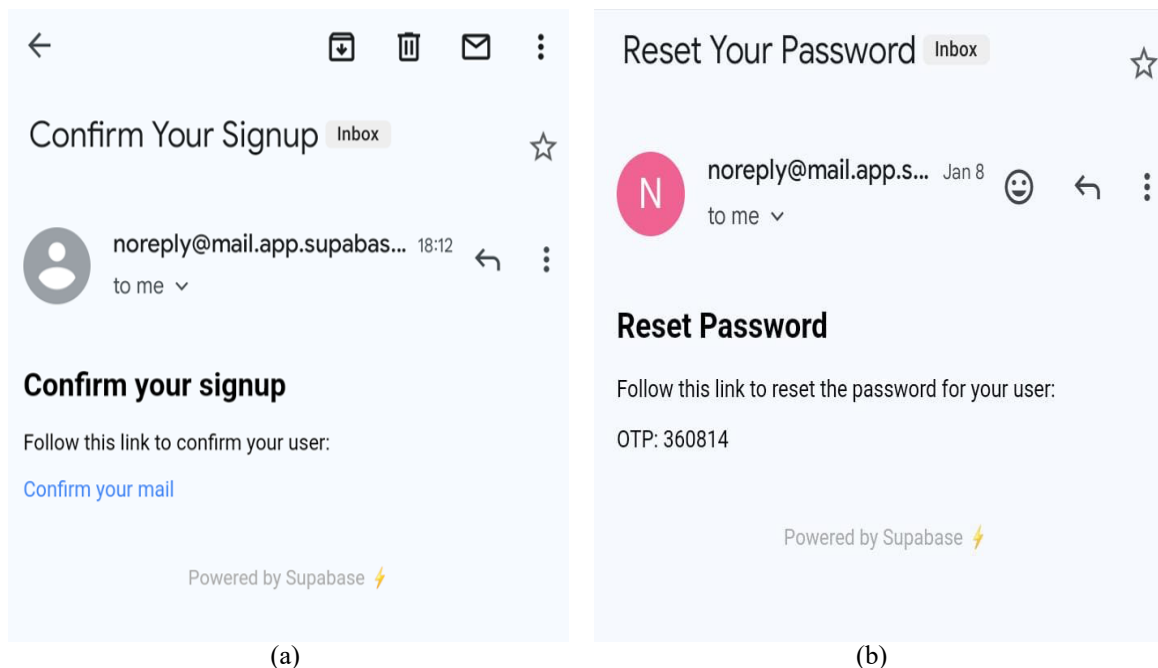


Figure 13. (a) Confirmation Email Display for Users during Account Registration and (b) Display of OTP Code Email Delivery for Users Changing Password

Table 3. Success Rate of Website Security System Testing

No	Description	Success Rate
1	Confirmation Email Display for Users during Account Registration	100%
2	Login Page Display of OTP Code Email Delivery for Users Changing Password	100%

The success in delivering authentication emails and OTP reflects the effectiveness of the security mechanism implementation with a 100% success rate, providing the necessary level of protection to maintain user information confidentiality as seen in Table 3. The testing scheme involves conducting user testing during account registration, where users receive a confirmation email for the registration process. Additionally, in cases where users forget their credentials and need to reset their passwords, the administrator will send an OTP code via email for additional verification and optimal account security.

3.3. Quality of Service (QoS) Website Testing

Quality of Service (QoS) testing on the website involves assessing throughput, packet loss, delay, and jitter. The goal is to ensure that the website can deliver optimal performance, including quick response times, high availability, resilience to disruptions, and the ability to handle larger traffic loads. The measurement of quality of service (QoS) for this website is expected to meet minimum parameter values, including throughput above 50 bps, packet loss from 0% to 14%, delay ranging from 0 ms to 450 ms, and jitter from 0 ms to 125 ms.

In order to obtain the necessary data for calculating quality of service parameters, Wireshark software is utilized. The testing is conducted four times, with each test spanning approximately 15 to 20 seconds to gather relevant information for analysis.

1. Throughput

Throughput is the amount of successfully transferred data within a specific time interval, measured in bits per second (bps). It encompasses the total number of successfully arrived packets at the destination during a specific interval, divided by the duration of that interval [13]. According to the TIPHON (Telecommunications and Internet Protocol Harmonization Over Network) version, throughput can be classified as follows:

Table 4. Throughput Clasification

Category	Throughput (bps)	Index
Very Good	100	4
Good	75	3
Moderate	50	2
Bad	<25	1

2. Packet Loss

Packet loss is a parameter that describes a condition indicating the total number of lost packets that can occur due to collisions and congestion in the network [13]. According to the TIPHON version, the magnitude of packet loss can be classified as follows:

Table 5. Packet Loss Clasification

Category	Packet Loss (%)	Index
Very Good	0 - 2	4
Good	3 - 14	3
Moderate	15 - 24	2
Bad	>25	1

3. Delay

Delay is the time it takes to travel the distance from source to destination. Delay can be influenced by distance, physical media, congestion, or even lengthy processes [13]. The calculation of the delay is based on the time it takes for a packet to be captured or processed by Wireshark. According to the TIPHON version, the magnitude of delay can be classified as follows:

Table 6. Delay Clasification

Category	Delay (ms)	Index
Very Good	<150	4
Good	150 - 300	3
Moderate	300 - 450	2
Bad	>450	1

4. Jitter

Jitter is a variation in delay [13] caused by fluctuations in queue lengths over time in processing data. Jitter occurs when data packets experience time variations during their journey through the network. Jitter is caused by factors such as differences in the routes taken by different packets and issues occurring in the devices within the network. According to the TIPHON version, the magnitude of Jitter can be classified as follows:

Table 7. Jitter Clasification

Category	Jitter (ms)	Index
Very Good	0	4
Good	0 - 75	3
Moderate	76 - 125	2
Bad	125 - 225	1

5. The Test Results

Table 8. Quality of Service Website Test Result

Parameters	Testing				Average
	1	2	3	4	
Throughput (bps)	23840,39	26584,52	14310,28	21716,96	21613,03
Packet Loss (%)	0,005629	0,020708	0,021531	0,018822	0,236088
Delay (ms)	481,22616	434,1437	754,6054	525,2383	548,2033
Jitter (ms)	48	62	40	20	42,5

Table 8 shows the results of Quality of Service testing during the playback of live CCTV video recordings on the website, conducted in four testing sessions. The test results indicate the overall average values, including a throughput of 21613.03 bps with an index of 4, categorized as excellent; packet loss of 0.236088 with an index of 4, categorized as excellent; delay of 548.2033 ms with an index of 4, categorized as poor; and jitter of 42.5 ms with an index of 3, categorized as good. The classification is based on the referenced standard TIPHON (Telecommunications and Internet Protocol Harmonization Over Network).

Overall, this solution provides a sufficiently good monitoring experience, effective security levels, and fairly adequate service quality with its test scores, although there are still some aspects that need improvement, especially concerning delay. It is recommended to store videos and the web server in the same location or with a faster connection between them. Network configuration optimization, including protocol settings, the use of fast connections, and firewall configuration, can help address latency issues.

4. CONCLUSION

Based on the tests conducted on the website, it can be concluded that the implemented system solution has achieved a good level of success. The results of the CCTV website monitoring system test at Telkom University Landmark Tower (TULT) show satisfactory performance with positive user feedback regarding the website's appearance and features, website security, and the quality of the live broadcast network on the website. Additionally, the reliability of the system is demonstrated by emphasizing its effectiveness and reliability in meeting real-time CCTV monitoring requirements.

The User Experience Questionnaire (UEQ) survey on the display test indicates user satisfaction that meets the target satisfaction level, with a minimum of 40% of users responding "agree" and "strongly agree" to each survey question. In terms of security testing, including multi factor authentication (MFA), the reliability and availability of MFA technology reached 100% during the account registration and password recovery processes using one-time passwords (OTP). For the quality of service testing of CCTV video recordings, four tests were conducted, each lasting 17–19 seconds. The test results yielded average values across all sessions, including throughput at 21,613.03 bps (categorized as "very good"), packet loss at 0.236088 (categorized as "very good"), delay at 548.2033 ms (categorized as "poor"), and jitter at 42.5 ms (categorized as "good").

Overall, this solution provides a fairly good monitoring experience, effective security levels, and reasonably adequate service quality based on the test values, although there are areas for improvement, especially regarding delay. It is recommended to store videos and the web server in the same location or with a faster connection between them. Optimizing network configurations, including protocol settings, utilizing fast connections, and configuring firewalls, can help address delay-related issues.

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