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Design and Build a PPPoE-Based Proactive Network Monitoring System with Real-time Notifications to Accelerate Customer Disruption Handling

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Abstract

Background: PT X faces serious challenges in managing network outages because the monitoring process is still fully manual, relies on customer reports, and lacks an automatic notification mechanism. This condition leads to an average of 15 disturbances per day among 250 active clients that are not handled promptly, resulting in an estimated monthly revenue loss of IDR 2,500,000.
Objective: This study aims to design and develop a proactive, real-time network monitoring system using the Point-to-Point Protocol over Ethernet (PPPoE) to accelerate the handling of customer connectivity disruptions through automated detection and notification.
Methods: The system was developed using a Research and Development (R&D) approach based on the Borg and Gall model, integrating a MikroTik CCR1016-12G as the PPPoE server, a native PHP web server with MySQL, and the Fonnte API as a WhatsApp notification gateway.
Results: Testing of 30 scenarios achieved a 100% success rate in disturbance detection, exceeding the minimum target of 95%. The average detection time was 21.37 seconds, more than 14 times faster than the manual process (5–10 minutes). Notification delivery averaged 3.70 seconds, with 93.3% of messages delivered within the 5-second threshold. Dashboard monitoring recorded a median response time of 5.91 seconds. Usability evaluation yielded a System Usability Scale (SUS) score of 99.38 (Excellent) and a Single Ease Question (SEQ) score of 7.00/7, with a 100% task-success rate.
Conclusion: Developed system meets all predefined performance criteria and demonstrates the feasibility of replacing manual monitoring with an automated, real-time, and user-friendly network monitoring and notification system.

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INTRODUCTION

Data collection of operational disruptions at PT X is still carried out manually through administrator and technician records, as well as disruption reports from clients documented in the daily operational logbook. This condition causes various obstacles in terms of optimization, accuracy, data update speed, and traceability of fault history. Based on PT X's internal data from January to June 2025, there were 250 clients, with an average of 15 network disruptions per day, or approximately 450 disruptions per month. In addition, there were approximately five unhandled disruption reports per day, equivalent to 150 cases per month, due to the unavailability of a ticket numbering system. The manual logging process also resulted in approximately eight data-entry errors per day. Errors in data processing and recording can affect the quality of information used in decision-making, as inaccurate data can result in incorrect analyses of operational conditions (Garza et al., 2025). In the context of IT service operations, the use of help desk and ticketing systems can facilitate the reporting, assignment, resolution, and documentation of complaints in a more structured manner (Amani et al., 2023; Nugroho & Fianty, 2023).

Along with the demands of digital transformation, companies are required to manage operational data quickly, accurately, and in real time to support optimal decision-making. One of the key benefits of real-time monitoring is its ability to rapidly detect disruptions or potential issues, such as increased network load, device downtime, or disconnected customer connections, enabling IT teams to take immediate action before prolonged service downtime occurs. Research on network monitoring systems shows that integrating monitoring systems with real-time notifications can help administrators detect changes in device status and accelerate the handling of network disruptions (Permadi & Prihanto, 2023; Vingestin et al., 2023). As an illustration for PT X, with monthly subscription rates of IDR 325,000 for 10 Mbps for four customers, IDR 425,000 for 20 Mbps for two customers, and IDR 175,000 for 5 Mbps for two customers, the estimated total service revenue is IDR 2,500,000 per month. Service disruptions that are not handled systematically have the potential to cause revenue losses and reduce customer confidence. Therefore, the digitization and automation of the disruption-recording process is an urgent need for PT X to ensure the sustainability and reliability of its operations.

Another obstacle faced by PT X is the difficulty technicians experience in arranging visit schedules to handle customer disruptions, especially when service demand increases simultaneously (Hasim & Susanto, 2025). Coordination processes that still rely on manual methods often cause technician visit schedules to overlap, while technician resources are not allocated optimally, resulting in many jobs having to be rescheduled. This condition directly contributes to delays in disruption handling and decreased customer satisfaction. The implementation of a web-based help desk ticketing system can simplify the processes of reporting, assigning, resolving, and documenting complaints or requests for IT services, thereby improving staff performance and user satisfaction (Amani et al., 2023). In addition, an ITIL-based incident management approach can help organizations standardize workflows, monitor service quality, and maintain stable IT service performance on an ongoing basis (Nugroho & Fianty, 2023).

PT X is a company engaged in information technology consulting services that has a high dependence on the stability of its network infrastructure to support operational activities. Network stability is a major factor in maintaining service reliability for customers. Delays in detecting or responding to network disruptions can reduce the company's credibility and potentially cause financial losses due to interruptions to data-based service connections. To overcome these problems, this study applies Point-to-Point Protocol over Ethernet (PPPoE) as part of a proactive network monitoring system based on real-time notifications. PPPoE enables hosts to establish point-to-point connections through an access concentrator and operates through a discovery phase followed by a PPP session phase, allowing an individual session to be established for each client (MikroTik, 2026). Through this mechanism, network administrators can monitor clients' connection status, including whether they are connected or disconnected, and receive notifications when a change in connection status is detected.

This study focuses on monitoring the connection status of PPPoE clients through a monitoring system deployed on the network administrator's side, while clients receive notifications when a change in connection status occurs. PPPoE was selected because its point-to-point characteristics result in individual connection sessions for each user, enabling authentication, monitoring, and tracking of connection status to be performed in a more targeted manner (Devarapalli, 2023). PPPoE also provides account-based authentication, session management, and individual user management, which facilitate more accurate identification and tracking of network outages. Unlike DHCP, which is primarily used to dynamically assign IP addresses and other network configuration parameters, PPPoE provides subscriber authentication and session-based access control, making it suitable for environments that require user-specific connection monitoring. Research by Sari, Safrianti, and Wahyuningtias (2024) shows that the implementation of PPPoE on MikroTik-based networks can improve network security because users connected through PPPoE are less readily exposed to other users in ARP spoofing attack scenarios. Thus, PPPoE can be a relevant solution for network monitoring systems that require connection stability, authentication, and security.

In its implementation, the selection of PPPoE technology involves trade-offs in the form of increased configuration complexity, system management overhead, and network overhead compared with DHCP (Aditiya & Wahidin, 2026; Fathurohman et al., 2026; Wibowo, 2021). However, these trade-offs are considered acceptable because PPPoE provides individual user authentication, session management, and access control features that support the needs of proactive monitoring, fault tracking, and improved response to network disruptions. The focus of this research is on adjusting the PPPoE configuration and integrating real-time notification mechanisms aligned with the operational needs of PT X. Testing was carried out using experimental data from active PPPoE clients to ensure that the system could detect changes in connection status quickly and accurately. The implementation of this system is expected to accelerate the identification of connection disruptions, improve the efficiency of technician coordination, and maintain the quality and continuity of network services.

This research is also related to Sustainable Development Goal (SDG) 9, which focuses on infrastructure development, inclusive and sustainable industrialization, and innovation. The development of a proactive network monitoring system based on real-time notifications using PPPoE supports Target 9.1 through efforts to improve the quality and reliability of digital infrastructure needed to support operational activities and customer services. The implementation of more efficient monitoring technology is also in line with Target 9.4, which emphasizes improving resource-use efficiency and adopting cleaner and more efficient technologies in support of infrastructure sustainability. In addition, the integration of information technology into the network monitoring system is related to Target 9.c, which emphasizes increasing access to and use of information and communication technology (Affairs, 2025; PANDEY & PATEL, 2026; Silva et al., 2026). Concretely, the system's 100% detection accuracy and 21.37-second average response time contribute to Target 9.1 by measurably improving digital infrastructure reliability; the replacement of manual processes with automated monitoring supports Target 9.4 by enhancing resource-use efficiency; and the deployment of a WhatsApp-based notification gateway facilitates access to monitoring notifications for field technicians, aligning with Target 9.c. These measurable outcomes demonstrate that the proposed system not only addresses PT X's operational challenges but also contributes quantifiable progress toward the sustainable development agenda in the industrial and digital infrastructure sectors.

Based on this description, the research questions of this study are as follows: How can a network monitoring system be designed and built to proactively detect disruptions in the PPPoE system and provide real-time notifications to clients at PT X? How can the connection status of PPPoE clients be detected, both when connected and when disconnected? How can the developed system facilitate technicians' monitoring of disruptions so that disruption handling can be coordinated more effectively?

The purpose of this research is to design and build a proactive network monitoring system based on real-time notifications that can automatically detect disruptions in the PPPoE system, thereby accelerating the handling of customer connectivity disruptions at PT X. In addition, this research aims to implement a mechanism for detecting the connection status of PPPoE clients, both connected and disconnected, to ensure that the system can monitor network activity accurately and in real time. This research also aims to develop a network fault monitoring system that facilitates technicians' monitoring, management, and coordination of disruption handling, thereby making the repair process faster, more structured, and easier to prioritize according to the level of urgency.

The benefits of this research include accelerating the identification of network outages through a proactive monitoring system with real-time notifications via WhatsApp to technicians and clients, as well as providing centralized monitoring access for administrators to enable faster response times. This research is also expected to improve the accuracy of PPPoE connection-status monitoring, both for connected and disconnected clients, through automatic detection that is more reliable than manual logging. In addition, the developed system is expected to facilitate technicians' scheduling and coordination of outage handling because connection status is displayed in real time, allowing handling priorities to be determined more efficiently.

METHOD

This study used a mixed-method approach with a Research and Development (R&D) method adapted from the Borg and Gall (1983) development model to develop a proactive network monitoring system based on real-time notifications using the PPPoE protocol at PT X. A qualitative approach was used to understand network operations. The research process consisted of four phases adapted from Borg and Gall's R&D cycle: (1) pre-production (needs analysis and design), (2) production (system development), (3) testing (functional and performance validation), and (4) post-production (usability evaluation and refinement). In the pre-production stage, problem identification, a literature review, data collection, needs analysis, and system design were conducted. The system design included the architecture, database, dashboard, and notification mechanisms. The production stage involved network device configuration, PPPoE implementation, and the development of a monitoring system using PHP Native, MySQL, MikroTik RouterOS, and WhatsApp notification integration. Furthermore, the testing stage involved evaluating the detection of client connection status, the delivery of real-time notifications, and updates to the monitoring dashboard. In the post-production stage, the system was evaluated through technical testing, response-time measurement, fault-detection accuracy assessment, and usability testing using the System Usability Scale (SUS) and Single Ease Question (SEQ) methods. The research was considered successful based on six predefined criteria: (1) detection accuracy of at least 95%, established based on the industry-standard reliability threshold for network monitoring systems; (2) notification delivery time of less than 5 seconds; (3) an SUS score of at least 70, following the benchmark established by Hyzy et al. (2022) as the threshold for acceptable (2024) usability; (4) an SEQ score of at least 5.5, based on the recommended minimum score by Sauro (2024); (5) a task-success rate of 100%; and (6) an overall relative efficiency of 100%. System testing was conducted using 30 scenarios representing 10 types of network interference: (1) authentication failure, (2) incorrect PPPoE credentials, (3) expired user account, (4) fiber-optic cable disconnection, (5) ONT/ONU power loss, (6) router power failure, (7) Ethernet cable disconnection, (8) signal attenuation beyond the threshold, (9) VLAN misconfiguration, and (10) simultaneous disconnection of multiple clients. Each interference type was tested three times to ensure consistency (Eldem & Eldem, 2026; Lesh, 2026). These scenarios were validated through consultation with PT X's senior network engineers to confirm that they represented the most common real-world interference patterns. The usability test involved four internal participants (N = 4), representing all personnel currently operating the monitoring system at PT X: two administrators and two network technicians. Although this sample size was small, Nielsen (2000) demonstrated that five users can identify approximately 85% of usability problems. The present study tested all available system operators, constituting a purposive census of the target user population rather than a statistical sample, which methodologically justified the participant count as an in-house expert review.

RESULTS AND DISCUSSION

Results

Usability Testing

The usability test aims to measure the level of user acceptance of the developed network monitoring system as part of demonstrating the achievement of the third research objective, which concerns the system's ease of use for technicians and administrators. The test was conducted using the in-house usability testing method, referring to the ISO 9241-11 standard, which covers three main aspects, namely effectiveness, efficiency, and satisfaction. The test involved four internal participants from PT X who represented two operational roles within the system, namely Administrator and Network Technician. The identities of the participants are shown in Table 1.

Table 1

Identity of Usability Test Participants

Name	Role	Departments	Implementation Date
Fazrin Madina Ahmad	Administrator	Staff PT X	11 May 2026
Aliyyulman Jihan	Administrator	Staff PT X	11 May 2026

Name	Role	Departments	Implementation Date
Arief Saripudin	Network Technician	Staff PT X	11 May 2026
Rizky Aditya Friatna	Network Technician	Staff PT X	11 May 2026

Testing Scenarios

The test scenario is structured based on the main activities carried out by each user role in the network monitoring system. The purpose of this scenario is to evaluate users' ability to operate system features, perform network monitoring, manage outage tickets, and receive real-time outage information. The scenario for the Administrator role is shown in Table 2, while the scenario for the Technician role is shown in Table 3.

Table 2

Administrator Testing Scenarios

No	Scenario
1	You are a user with the Administrator role. After successful login, what do you usually do on the dashboard home page?
2	You want to monitor the connection status of all connected and disconnected PPPoE clients. How do you access that information through the dashboard?
3	There is a PPPoE client that is detected *offline*. You are required to create an outage ticket and assign a technician through the system. How do you do it?
4	You want to know the connection interruption ticket history of one of the PPPoE clients. How do you find and read that information on the dashboard?
5	You want to monitor the progress of the troubleshooting that the technician is working on. How do you monitor the status of those ticket updates through the dashboard?
6	You are required to generate a status report of the handling of all resolved network outage tickets. How do you access those reports on the system?

Table 3

Technician Testing Scenarios

No	Scenario
1	You are a user with the Technician role. After successfully logging in, what do you usually do on the Technician dashboard home page?
2	You receive a notification of a new disruption ticket. How do you access the ticket information through the website or WhatsApp?
3	You want to know the details of the connection interruption ticket information that is being assigned to you. How do you find and read those details on the Technician dashboard?
4	You need to know the location of the PPPoE client that is experiencing the disruption to get to the repair location. How do you use location information on the system to determine destinations?
5	Once you arrive at the location, you begin the process of repairing the client's network connection. How do you confirm receipt and processing of tickets to Admins through the system?
6	Once the fix is complete, you will be prompted to update the status of the ticket completion on the dashboard so that the Admin and Client receive a completion notification. How do you do it?

In addition to task-based testing, participants were also given a System Usability Scale (SUS) questionnaire to measure user satisfaction with the system. A list of SUS statements is shown in Table 4.

Table 4
SUS Questionnaire Statement

No	Statement
1	I think I will use this system often.
2	I feel that this system is too complicated to use.
3	I find this system easy to use.
4	I feel like I need help from someone else or a technician to be able to use this system.
5	I feel that the features in this system are well integrated.
6	I found a lot of inconsistencies in this system.
7	I feel like most people will be able to learn how to use this system quickly.
8	I find this system confusing to use.
9	I feel confident in using this system.
10	I feel like I need to learn a lot before I can use this system.

The SUS score is calculated as follows: for odd-numbered questions, 1 is subtracted from the response score; for even-numbered questions, the response score is subtracted from 5. The resulting scores are then summed and multiplied by 2.5. The final score ranges from 0 to 100. Based on the interpretation of the SUS standard presented in Table 4, scores above 80.3 are categorized as Excellent (A), scores from 68 to 80.3 are categorized as Good (B), a score of 68 is categorized as OK (C), scores from 51 to below 68 are categorized as Poor (D), and scores below 51 are categorized as Awful (F).

Table 5
US Assessment Categories

Average Total Score Per Respondent	Letter Grade	Adjective Rating
>80.3	A	*Excellent*
68-80,3	B	*Good*
68	C	*Ok*
51-57	D	*Poor*
<51	F	*Awful*

Effectiveness Test Results

Effectiveness testing measures the level of success of participants in completing all given tasks. A score of one is assigned if the participant successfully completes the task without assistance, and a score of zero is assigned if the task is not completed. The task success rate is calculated as the total number of successfully completed tasks divided by the total number of tasks given, then multiplied by one hundred percent. The results of the effectiveness testing for the Administrator and Technician roles are shown in Table 6 and Table 7.

Table 6
Effectiveness Test Results on Administrators

Participants	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task Success	Task-success rate
Admin 1	1	1	1	1	1	1	6	100%
Admin 2	1	1	1	1	1	1	6	100%
Total Task Successful	2	2	2	2	2	2		
Task-success rate	100%	100%	100%	100%	100%	100%	Average	100%

Table 6 presents the results of the effectiveness testing conducted by two administrators on the six tasks assigned to the interactive dashboard system. Based on the test results, all tasks from Task 1 to Task 6 were successfully completed by both participants without any failures; therefore, each administrator achieved a success score of 6 out of the 6 assigned tasks. All tested tasks also achieved a task success rate of 100%, indicating that all system features and functions could be used properly by the administrators during the testing process. Thus, the overall average task success rate in the administrator test was 100%, leading to the conclusion that the system demonstrates an excellent level of effectiveness in supporting users in completing tasks according to operational requirements.

Table 7
Results of Effectiveness Testing in Technicians

Participants	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task Success	Task-success rate
Technician 1	1	1	1	1	1	1	6	100%
Technician 2	1	1	1	1	1	1	6	100%
Total Task Successful	2	2	2	2	2	2		
Task-success rate	100%	100%	100%	100%	100%	100%	Average	100%

Table 7 shows the results of the effectiveness testing conducted by two Technicians on the six tasks assigned to the interactive dashboard system. Based on the test results, all tasks, from Task 1 to Task 6, were successfully completed by both participants without any failures or obstacles during the testing process. Each Technician successfully completed all six assigned tasks, achieving a task success rate of 100%. In addition, all tasks tested also achieved a success rate of 100%, indicating that the system's features and functions can be used effectively by Technician users in accordance with their operational needs. Thus, the average overall task success rate in the Technician test was 100%, indicating that the system has an excellent level of effectiveness in helping Technicians complete tasks efficiently and in accordance with the intended purpose of the system.

Efficiency Test Results

This test measures the time required for both Admins and Engineers to complete each task by comparing the time taken with the maximum time specified for each task. Before conducting the test, the researcher established a benchmark as an indicator of the maximum time allowed to complete each task. The benchmark time for each task was determined by multiplying by four the time (in seconds) required to complete the task in a scenario prepared by the researcher. This approach refers to the book *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*.

Table 8
Efficiency Test Results for Administrators

Participants	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Total Time	Task Success	Overall Relative
Admin 1	24,42	68,42	49,54	47,55	40,2	24,6	254,73	254,73	100%
Admin 2	31,73	65,45	29,27	18,13	32,18	15,99	192,75	192,75	100%
Total Time	56,15	133,87	78,81	65,68	72,38	40,59		Average	100%
Max Time	122,88	274,8	198,68	190,08	161,56	101,28			
Task Success	56,15	133,87	78,81	65,68	72,38	40,59	Average		
Overall Relative	100%	100%	100%	100%	100%	100%	100%		

Table 8 presents the results of efficiency tests conducted by two Administrators in completing six tasks on the interactive dashboard system. Based on the test results, Admin 1 took a total of 254.73 seconds, while Admin 2 took a total of 192.75 seconds. In Task 1, Admin 1 completed the task faster than Admin 2, with completion times of 24.42 seconds and 31.73 seconds, respectively. In Task 2, both Administrators took the longest time compared with the other tasks, at 68.42 seconds for Admin 1 and 65.45 seconds for Admin 2. This indicates that Task 2 has a higher level of complexity than the other tasks because it requires more steps and system interactions. Meanwhile, the fastest completion times were recorded for Task 6, at 24.60 seconds for Admin 1 and 15.99 seconds for Admin 2, indicating that the task is easier for users to understand and perform. Based on the overall relative efficiency calculation, all tasks obtained a score of 100%, resulting in an overall average score of 100%. These results show that all Administrators successfully completed each task effectively within the predetermined benchmark time limit, indicating that the system has an excellent level of efficiency. Furthermore, the results of the efficiency tests for users with the role of Technician are shown in Table 9.

Table 9
Efficiency Test Results for Technicians

Participants	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Total Time	Task Success	Overall Relative
Technician 1	8,22	18,45	14,76	13,75	38,19	12,24	105,61	105,61	100%
Technician 2	41,86	48,73	20,17	4,91	20,08	112,65	248,4	248,4	100%
Total Time	50,08	67,18	34,93	18,66	58,27	124,89		*Average*	100%
Max Time	163,96	185,04	87,76	62,6	178,08	115,08			
Task Success	50,08	67,18	34,93	18,66	58,27	124,89	*Average*		
Overall Relative	100%	100%	100%	100%	100%	100%	100%		

Table 9 presents the results of efficiency tests conducted by two Technicians to complete six tasks on the interactive dashboard system. Based on the test results, Technician 1 achieved a total completion time of 105.61 seconds, while Technician 2 took 248.40 seconds. For Tasks 1, 2, 3, and 5, Technician 1 completed the tasks faster than Technician 2. In Task 4, however, Technician 2 was faster, completing the task in 4.91 seconds compared with 13.75 seconds for Technician 1. The difference in completion times between the participants indicates variations in their understanding of the system workflow and their user experience when interacting with the available features. The longest completion time occurred in Task 6, which took 112.65 seconds for Technician 2, while Technician 1 completed the task in only 12.24 seconds. This indicates that Task 6 has a higher level of complexity than the other tasks because it requires more interaction and a greater understanding of the system's features. Despite the differences in completion times between the participants, all tasks were successfully completed without any failures. Based on the overall relative efficiency calculation, all tasks achieved a score of 100%, with an overall average of 100%. Therefore, it can be concluded that the system has a very good level of efficiency and is able to support Technicians in completing tasks effectively within the predetermined benchmark time.

Satisfaction Test Results

The satisfaction assessment was conducted using the Single Ease Question (SEQ) instrument to measure the level of ease experienced by users when completing each task and the System Usability Scale (SUS) to measure overall user satisfaction with the system. The SEQ questionnaire was administered to participants after completing each task using a 1–7 scoring scale, where higher scores indicated that the task was easier to complete. Meanwhile, the SUS questionnaire was administered after all testing sessions had been completed. Table 10 shows the results of the SEQ testing for users with the Administrator role, based on the ease of completing the six tasks assigned to the interactive dashboard system.

Table 10
Administrator SEQ Results

Participants	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Average
Admin 1	7	7	7	7	7	7	7
Admin 2	7	7	7	7	7	7	7
Average	7	7	7	7	7	7	7

Based on the test results in Table 10, all tasks, from Task 1 to Task 6, received the highest score of 7 from both participants. The results show that all tasks were rated as very easy for

Administrator users to understand and complete during the testing process. No task received a low score, indicating that users did not experience any problems or difficulties when using the features available in the system. Based on the feedback provided by the participants, the system interface was considered easy to understand, the navigation flow was clear, and the available features could be used effectively according to the users' needs. In addition, the average total SEQ score for Administrators was 7, indicating that the system achieved a very high level of user satisfaction and ease of use.

Table 11 shows the results of the SEQ test for users with the Technician role, based on their level of ease in completing the six tasks provided on the interactive dashboard system.

Table 11
Technician SEQ Results

Participants	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Average
Technician 1	7	7	7	7	7	7	7
Technician 2	7	7	7	7	7	7	7
Average	7	7	7	7	7	7	7

Based on the test results in Table 11, all tasks obtained the highest score of 7 from both participants, indicating that each task could be completed very easily by the Technician user. No task received a low score, indicating that all system features could be understood and used properly without difficulty during the testing process. Based on participant feedback, the system was considered to have a simple appearance, easy-to-understand navigation, and a feature-use process that functioned well according to the Technician's operational needs. The Technician's average total SEQ score was 7, so it can be concluded that the level of user satisfaction with the system's ease of use was in the very good category.

Based on the results of the System Usability Scale (SUS) questionnaire, Table 12 presents the original assessment results of the user satisfaction levels of four participants who tested the interactive dashboard system.

Table 12
SUS Original Results

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Admin 1	5	1	5	1	5	1	5	1	5	2
Admin 2	5	1	5	1	5	1	5	1	5	1
Technician 1	5	1	5	1	5	1	5	1	5	1
Technician 2	5	1	5	1	5	1	5	1	5	1

Based on the System Usability Scale (SUS) calculation rules, for odd-numbered questions, the score is reduced by 1, while for even-numbered questions, the response score is subtracted from 5. After all adjusted scores are added together, the result is multiplied by 2.5 to obtain the final SUS score. Table 13 shows the SUS calculation results following these rules.

Table 13
SUS Calculation Value Results

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
Admin 1	4	4	4	4	4	4	4	4	4	3	97,5
Admin 2	4	4	4	4	4	4	4	4	4	4	100
Technician 1	4	4	4	4	4	4	4	4	4	4	100
Technician 2	4	4	4	4	4	4	4	4	4	4	100

Based on the results of the System Usability Scale (SUS) calculation in Table 13, Admin 1 obtained a score of 97.5, while Admin 2, Technician 1, and Technician 2 each obtained a score of 100. The results showed that all participants gave a very high assessment of the usability of the developed system. Based on the SUS interpretation, scores above the standard average score of 68 fall within the excellent and acceptable categories. Therefore, it can be concluded that the interactive dashboard system has a very high level of usability, is easy to understand, and is able to provide user satisfaction during the testing process. In addition, the overall average SUS score was 99.38, indicating that the system has fulfilled the usability aspect very well and is acceptable to users in accordance with operational needs.

Discussion

Based on the tests conducted, the usability of the proactive network monitoring system based on real-time notifications using PPPoE at PT. X was measured according to three main criteria, namely effectiveness, efficiency, and satisfaction, for each user role.

Figure 1. Comparison Diagram of Testing Metrics Between Roles

Based on Figure 1, both Administrators and Technicians obtained very high scores across all four test metrics. The small difference in efficiency is more likely attributable to each participant's familiarity with the system interface than to differences in the system's functional capabilities across user roles. This finding demonstrates that the system can provide a consistent user experience for all user roles involved in PT X's network operations.

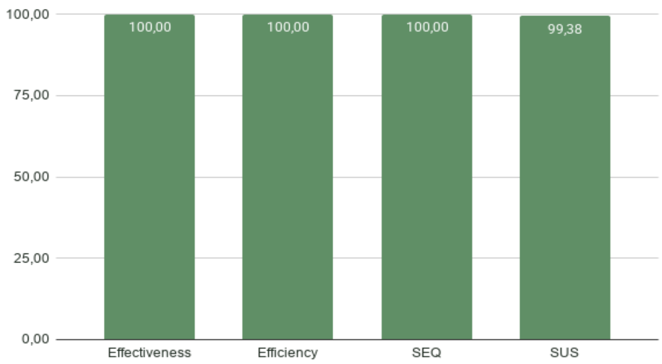

Figure 2. Testing Metric Comparison Diagram

Figure 2 shows that the system usability test results have very high values across all aspects of the test. The effectiveness aspect obtained a score of 100%, which shows that all users successfully completed all test tasks without problems. The efficiency aspect also obtained a score of 100%, indicating that users were able to complete the tasks efficiently according to the system flow that had been designed. In addition, an SEQ score of 7.00 indicates that users found the system very easy to use during the testing process.

In terms of user satisfaction, the system obtained a SUS score of 99.38, which falls within Grade A and the "Excellent" category and is considered acceptable. These results show that the network monitoring system developed has an excellent level of usability, is easy to understand and use, and is able to provide a satisfactory user experience. Evaluations based on user interactions during testing highlight the following aspects.

1) Ease of Use and Accessibility: The results of the effectiveness, efficiency, and satisfaction tests consistently show that the system is easy to use for Administrators and Technicians. All participants completed the tasks without assistance, with an SEQ score of 7.00 for each task and an average SUS score of 99.38. Participant feedback showed that the organized menu

layout, connection status indicators that use clear colors, and consistent ticket-handling flow from creation and notification delivery to completion made the system feel intuitive. These results confirm that the system is able to address the third research objective, which is to develop a system that makes it easier for technicians to monitor, manage, and coordinate the handling of network disruptions.

2) Accuracy and Speed of Disruption Detection: The system is able to detect all simulated PPPoE disruption scenarios with a 100% success rate, exceeding the minimum target of 95%. The average detection time was 21.37 seconds, with authentication-related disruptions detected in an average of 7.28 seconds and physical disruptions detected in an average of 24.89 seconds. Compared with the manual detection time in the previous system, which ranged from 5 to 10 minutes, the developed system provided a detection speed improvement of more than fourteen times. This result directly addresses the first and second research objectives, namely accelerating disruption handling and implementing an accurate, real-time mechanism for detecting PPPoE client connection status.
3) Effectiveness of Real-Time Notifications and Technician Coordination: Notifications via WhatsApp integrated with the Fonnte API have proven effective in conveying disruption information to Administrators, Technicians, and Clients. The average notification delivery time was 3.70 seconds, with 93.3% of tests meeting the criterion of delivery within 5 seconds. The disruption ticket-handling workflow, from assignment and confirmation of acceptance to completion reporting, can be carried out in an integrated manner within a single system, making coordination between Administrators and Technicians more structured. This supports the first and third research objectives, which are to accelerate disruption handling and facilitate technician work coordination according to the urgency priorities displayed on the dashboard.
4) Faster and More Structured Decision-Making: The monitoring dashboard provides real-time information on the connection status of all PPPoE clients, outage history, and ticket-handling progress. The median dashboard update time of 5.91 seconds shows that Administrators can quickly obtain an overview of the network condition without manually checking the MikroTik device. Ticket histories and disruption logs stored in a structured MySQL database also allow analysis of disruption patterns for long-term purposes, which was previously not possible because logging was performed using separate media, such as WhatsApp and Google Sheets. Thus, the system addresses the third research objective in terms of centralized and reliable management of monitoring information.

Based on the overall test and evaluation results, it can be concluded that the proactive network monitoring system based on real-time notifications using PPPoE has met all success criteria and the three research objectives. The system is able to detect disruptions automatically, deliver notifications quickly and accurately, and provide a dashboard that facilitates coordination between Administrators and Technicians in handling customer connectivity disruptions at PT X.

Based on the results of the tests that have been carried out, the proactive network monitoring system based on real-time notifications using PPPoE at PT X demonstrates an excellent level of usability. Usability testing was conducted by referring to three main aspects, namely effectiveness, efficiency, and satisfaction. These three aspects are in line with the ISO 9241-11 usability approach, which assesses a system's ability to help users achieve goals effectively, efficiently, and satisfactorily within a given context of use (Deluma et al., 2023). Thus, the use of these three aspects is relevant for evaluating the developed network monitoring system because the system is directly related to the work activities of Network Administrators and Technicians.

The results of the effectiveness test showed that all participants, both Administrators and Technicians, were able to complete all assigned tasks with a 100% success rate. In the Administrator role, all tasks, starting from accessing the dashboard, monitoring the connection status of PPPoE clients, creating disruption tickets, assigning technicians, monitoring ticket progress, and accessing reports, were successfully completed without failure. The same was true for the Technician role, in which all tasks, such as accessing the dashboard, receiving ticket notifications, viewing disruption details, identifying the client's location, confirming work, and updating ticket completion status, could be completed successfully. These results show that the system has been able to support the effective completion of users' key tasks. These findings are in line with the research of Deluma et al. (2023), which explains that the effectiveness aspect of usability is used to assess the level of success users achieve when completing tasks on a system.

The effectiveness level of 100% also demonstrates that the developed system has been able to address the main needs of PT X for monitoring network disruptions in a more structured manner. Previously, the process of recording and handling disruptions was still carried out manually, potentially causing delays, recording errors, and difficulties in tracking disruption history. With a dashboard-based monitoring and ticketing system, the processes of identifying disruptions, recording reports, assigning technicians, and monitoring disruption resolution can be carried out within a single centralized system. This is in line with the research of Amani et al. (2023), who stated that a web-based ticketing help desk system can help organize the processes of reporting, assigning, resolving, and reporting IT service complaints. In addition, Nugroho and Fianty (2023) also explained that the application of IT help desk principles and incident management can help standardize workflows and maintain the quality of IT services in a sustainable manner.

In terms of efficiency, the test results show that all tasks could be completed within the predetermined benchmark time limits. Both Administrators and Technicians obtained an overall relative efficiency score of 100%. These results show that users can operate every feature of the system efficiently without requiring excessive time. Although there were variations in completion times among participants, these differences were more influenced by each user's level of familiarity with and speed in understanding the system flow than by functional barriers within the system. The efficiency aspect is important because a good system must not only be usable but also able to accelerate users' work processes in achieving operational goals (Deluma et al., 2023).

In the Administrator test, Task 2 took the longest to complete among all tasks. This indicates that monitoring the connection status of all PPPoE clients has a higher level of complexity because the user needs to understand the connection status information displayed on the dashboard. However, all Administrators were still able to complete the task successfully. Meanwhile, in the Technician test, the most noticeable time difference was observed in Task 6, when the Technician updated the ticket completion status. This time difference indicates that some users took longer to ensure that the ticket resolution stages were completed correctly. However, all tasks were successfully completed, so the system can be considered efficient in supporting users' work.

The results of the satisfaction test using the Single Ease Question (SEQ) showed that all participants gave the highest score, namely 7, on a scale of 1 to 7 for all tested tasks. This value indicates that each task was rated as very easy for users to understand and complete. The use of SEQ is relevant because this instrument is commonly used to measure users' perceptions of task difficulty after completing a task during usability testing (Sauro & Lewis, 2024). Both Administrators and Technicians stated that the system has a simple interface, easy-to-understand navigation, and a feature flow that suits operational needs. This reinforces the finding that the system has an excellent level of ease of use and can be operated without additional assistance.

In addition to SEQ, user satisfaction was also measured using the System Usability Scale (SUS). The calculation results showed that Admin 1 obtained a score of 97.5, while Admin 2, Technician 1, and Technician 2 each obtained a score of 100. The overall average SUS score was 99.38. Based on the interpretation of SUS, this score falls within the "Excellent" category and corresponds to Grade A. These results show that the developed network monitoring system has a very high level of user acceptance, is easy to use, does not cause confusion, and is able to provide a satisfactory user experience. This is reinforced by Hyzy et al. (2022), who stated that an average SUS score of 68 can be used as a general benchmark in usability evaluation; therefore, a score of 99.38 indicates results that are far above average. In addition, A et al. (*2025*) explained that SUS is widely used in the development and evaluation of information systems because it is simple, reliable, and able to provide an overview of usability from the user's perspective.

The high SUS score also indicates that the interface design and system workflow have been tailored to users' needs. Features such as the PPPoE connection status dashboard, disruption ticket creation, WhatsApp notifications, technician assignments, ticket status updates, and disruption resolution reports are considered to be well integrated. The integration of these features makes the work process more targeted because any change in disruption status can be monitored in real time by relevant parties. This condition is in line with Amani et al. (2023), who emphasized that ticketing systems can help staff handle service issues in a more structured manner and increase service user satisfaction.

From a technical perspective, the developed system also makes an important contribution to accelerating network disruption detection. The system is able to detect changes in the connection status of PPPoE clients, both connected and disconnected states, automatically. This mechanism allows the Administrator to determine the state of the network without having to wait for a manual report from the client. The implementation of PPPoE is relevant because this technology can support more controlled management of user connections and improve network security through the isolation of user connections on MikroTik-based networks (Sari et al., 2024). Thus, PPPoE can support network monitoring requirements that require specific identification of user connection status.

Real-time notification integration via WhatsApp also helps accelerate the delivery of disruption information to Administrators, Technicians, and Clients. The test results show that notifications can be sent quickly and support disruption-handling coordination. This finding is in line with research by Permadi and Prihanto (2023), which shows that a network monitoring system integrated with WhatsApp notifications can help deliver disruption information quickly to relevant parties. In addition, Vingestin et al. (2023) also showed that a network monitoring system with real-time notifications can operate as designed and help make the network monitoring process more effective.

The effectiveness of the system can also be seen from the dashboard's ability to present operational information centrally. Administrators can monitor the connection status of all clients, view outage history, check ticket-handling progress, and generate outage resolution reports. On the other hand, Technicians can view their assigned tickets, access outage details, obtain information about the client's location, and update the work status directly through the system. This condition shows that the system is able to improve the previous work pattern, which was still manual, by making it more digital, structured, and transparent. With a dashboard and ticket history, the decision-making process is also faster because disruption information is available in real time and documented in a database.

Overall, the test results showed that the proactive network monitoring system based on real-time notifications using PPPoE had met the research objectives. The system is able to support the automatic detection of disruptions, accelerate the delivery of information through real-time notifications, and make it easier for technicians to monitor and coordinate disruption handling. The effectiveness value of 100%, efficiency value of 100%, SEQ score of 7, and average SUS score of 99.38 indicate that the system has an excellent level of usability and is acceptable to users. These results demonstrate that the system is not only functionally feasible but also easy to use and aligned with the operational needs of PT X.

Although the test results show excellent performance, this study still has limitations. The number of participants used in the test was limited to four internal users of PT X, so the test results are more representative of the needs of users within the company's internal scope. Therefore, follow-up testing with a larger number of participants and more varied operational conditions can be conducted to obtain a broader picture of the system's performance. In addition, future system development can be directed toward adding automatic disruption-priority features, network disruption trend analysis, real-time integration of technician location maps, and a dashboard for evaluating disruption-handling performance.

Thus, the developed system can be declared feasible for use as a network monitoring solution at PT X. This system not only helps improve the speed and accuracy of fault detection but also supports the effectiveness of coordination between Administrators and Technicians. The implementation of this system is expected to improve the quality of network services, reduce the risk of delays in disruption handling, and strengthen PT X's operational reliability in a sustainable manner.

CONCLUSION

Based on the results of the design, implementation, testing, and evaluation conducted, this study successfully designed and built a proactive network monitoring system based on real-time notifications using the PPPoE protocol to accelerate the handling of customer connectivity disruptions at PT X. The system was developed to replace the manual monitoring process, which relies entirely on customer reports and periodic administrator checks through the Winbox application.

Overall, all six predefined success criteria were achieved within PT X's operational environment. The principal scientific contribution of this research lies in demonstrating that PPPoE session-state events can serve as reliable, event-driven triggers for proactive network fault detection, achieving detection speeds more than 14 times faster than manual monitoring. The integration of automated detection, structured ticket management, and real-time WhatsApp notifications into a unified system represents an advancement over fragmented manual workflows. Although the results are specific to PT X's infrastructure and user base (N = 4), they provide a replicable framework for small-to-medium-sized ISPs seeking to transition from reactive to proactive network monitoring without the overhead of enterprise-grade solutions such as Zabbix or PRTG.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed to the research process, including research conceptualization, methodology design, system development, data collection, testing, analysis, and manuscript preparation. The first author contributed to the design and implementation of the proposed monitoring system, while the second author contributed to data validation, analysis, critical review, and refinement of the manuscript. All authors have reviewed and approved the final version of the manuscript.

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