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Experimental Study of High Availability Cloud Learning Management System and Monitoring System Based on Grafana, Prometheus and Telegram

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ABSTRACT

This paper discusses the optimization of server management for digital-based education services, especially Learning Management System (LMS) services in the learning process. The research was conducted at the data centre of SMK Negeri 2 Yogyakarta which has successfully adopted the Learning Management System (LMS), but has not been optimal in its application. The results of the experimental study resulted in performance optimization efforts through the application of High Availability using the load balancing method with the Round Robin algorithm as a load balancing method using HAProxy as a load balancer on the web server, as well as the cluster method through Galera Cluster on the database to minimize failures on the LMS. In addition, this research successfully developed a monitoring system using Grafana and Prometheus to provide comprehensive visibility into the performance of the LMS cloud server. The system is equipped with real-time notifications via Telegram that allow server managers to respond quickly to any disruptions, thereby reducing downtime and increasing system reliability. Evaluation of the results of the implementation of cloud-based LMS with high availability and monitoring system based on Grafana, Prometheus and Telegram at SMK Negeri 2 Yogyakarta proved to be effective in supporting the digital learning process which is expected to be a reference for other educational institutions that will adopt similar technology to improve the quality of learning services.

1. Introduction

Advances in information and communication technology have opened up significant opportunities for all sectors of life, one of which is improving the quality of education. The development of technology in the education sector is expected to bring positive changes, such as increasing access to digital-based administrative services to more interactive learning media [1]. However, what needs to be considered is the increasing complexity of digital services in the education sector, one aspect that is the main focus is improving the quality of its services [2]. One of

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the learning services that must be prepared today is a learning process based on digital services (Internet) for multimedia-based learning purposes. The first step that must be done is to have a connection facility to the Internet that is smooth enough (fast enough bit rate). Tens of years ago most schools only had a connection to the Internet with limited data speed, even relying on Internet connection using cellular phone Internet Service Provider (ISP). Surjono *et al.,* [3] made an effort to increase the speed of Internet data by implementing multiple connections using a device that is able to switch the connection of one Mobile ISP to another Mobile ISP if the internet data stream is not working.

This reliable Internet connection facility will greatly support one of the services that are prioritized in improving the quality of learning services, namely the Learning Management System (LMS). LMS service for e-learning purposes is software to support the learning process in which there are also several functions that can be utilized for administration, documentation and distribution of materials in online learning activities [4,5]. In addition, an adequate Internet connection also guarantees learning materials to be more extensive to meet student learning needs. The Internet provides learning media in the form of very diverse multimedia such as YouTube, blogs and social media. Some of these channels can be used as learning media so that the variety of learning media is not only using Microsoft Power Point. The survey results prove that most teachers still use Microsoft Power Point for learning media without paying attention to the reasons why choosing Microsoft Power Point as learning media [6].

SMK Negeri 2 Yogyakarta as one of the best public vocational high school educational institutions has now become a centre of excellence school based on the decision of the Director General of Vocational Education in Permendikbudristek Number 53 of 2023. In line with this, SMK Negeri 2 Yogyakarta has implemented an LMS as one of the efforts in improving school quality. The use of digital platforms, especially in achieving one of the pillars of the intervention and foundation of the SMK centre of excellence program by the Ministry of Education, Culture and Research of the Republic of Indonesia in 2023, has been carried out.

The increase in digital-based services is one form of school strategy to achieve improved quality of education by utilizing technology [7]. However, along with these changes, there are challenges in managing educational technology [8]. To overcome this, efforts are needed that include improving the management, utilization and availability of technology itself as a tool that supports the improvement of the quality of education, which refers to Permendikbudristek Number 49 of 2022.

As a school that is closely related to technology, SMK Negeri 2 Yogyakarta should be at the forefront of the use of information technology in the learning process. This school already has adequate digital infrastructure in the form of data centres and servers that can accommodate all information technology needs. However, the level of acceptance and application of LMS in the school has not run optimally for learning activities. The current system services cannot be accessed at the same time if the number of users is very large (concurrency level is still low). This is very evident when the LMS service is used to conduct midterm or final semester exams online. The LMS cannot be accessed by the server that cannot accommodate a very large number of users simultaneously because the LMS users are all students of SMK Negeri 2 Yogyakarta.

Penetration Testing has been done in the form of a network audit through the aspect of the number of users. The total of students is 2,484 students and it turns out that the LMS server can only accommodate 800 students. This will be detrimental to students who are carrying out the exam because the time that should be used to work on questions, is actually used up to wait for server recovery. The server condition monitoring system is also not carried out effectively so that if a server disruption occurs, it cannot be immediately recognized so that the repair time becomes longer and sometimes late.

Therefore, efforts are needed to overcome the two problems that occur at SMK Negeri 2 Yogyakarta in providing digital technology-based services for the learning process. Optimization of service infrastructure and an effective server monitoring system to realize better services. The optimization effort is the implementation of a High Availability Server and the provision of a Server Monitoring system that can be done at any time and a server failure notification system that can be known by the server manager quickly using a handheld device or smartphone.

The application of High Availability Server through the load balancing method is needed to ensure the activities and smooth running of LMS services [9]. The load balancing method can maximize the use of available resources because the workload distribution can be done evenly to all existing servers [10]. Load balancing will distribute user traffic loads to various servers in the cluster, taking into account the workload of each server [11]. In this way, the workload assigned to each server becomes more balanced, so that no server is overburdened and can still serve users without any performance degradation. Through virtualization, all servers in the infrastructure run virtual machines with an even workload, so the risk of overloading or downtime on one particular server is very low [12].

Load balancing is a technology to distribute service requests that come at the same time to several servers at once. Thus, the workload of each server becomes less. In addition, load balancing can ensure that there is no overload on one of the servers, so that server performance and availability can increase [13]. If there is a failure on one of the servers, the failure will not affect the running service because there is another server that performs backup to receive the next workload distribution and the system will work in a distributed manner [14].

Handling when an incident occurs is not optimal due to the lack of data and the number of human resources who carry out monitoring analysis of the event. In addition, the number of human resources responsible as system administrators for existing cloud infrastructure is still limited. In addition, tools that can be used to evaluate all possible risks that can affect the operation of cloud LMS servers and supporting infrastructure do not yet exist, so that appropriate preventive measures to maintain optimal performance and security of the cloud LMS cannot be taken [15].

To overcome these problems, there is a need for a cloud monitoring system to ensure the reliability and stability of the running LMS service. Monitoring tools are needed to perform network analysis, fault detection and risk analysis [16]. The monitoring system development model in a distributed system architecture is made using an agent-based monitoring model that allows collecting information related to the resources and performance of each node or machine. The usual way is to install agents in the form of software to execute on each node to be monitored. Thus, the monitoring process can be done in depth, with better security and can be processed early before being transmitted on the network [17].

Prometheus, Grafana and Telegram-based cloud LMS monitoring system that can facilitate the work of system administration in monitoring and maintenance. The selection of this system aims to make the monitoring system more flexible with easy access using a variety of devices through the Telegram application which can be accessed on a smartphone or web dashboard. Telegram bot is developed in such a way that it is able to provide responses to users not only text-based but image-based which provides visualization of system utilities in a certain period of time. Therefore, this monitoring system is able to provide a clear picture for system administrators about system conditions and system performance in recent times or real time [18].

Therefore, the implementation of load balancing technology and cloud LMS monitoring system will be an appropriate and effective solution in improving digital services in the education sector. This implementation not only supports the operational efficiency of the LMS, but also improves the quality of education by ensuring smoother and more stable access for users.

2. Methodology

2.1 Monitoring System

A monitoring system to collect, process, combine and display quantitative data from the system in real-time, such as the number and type of queries, number and type of errors, processing time and server lifetime developed through 5 stages in this study, including the monitoring system design stage, the LMS data collection stage before optimization through the load balancing method, the implementation stage of the load balancing method on the LMS, the testing and data collection stage of the LMS after applying the load balancing method and the evaluation stage of the results of implementing load balancing on the LMS based on the analysis results on the monitoring system [19,20]. The research was conducted at SMK Negeri 2 Yogyakarta with respondents from the ICT team and students based on the time span from January to March 2024.

The monitoring system was developed using the Waterfall development method [21], that is:

i. Communication
ii. Planning
iii. Modelling
iv. Construction
v. Deployment

Figure 1 shows the architecture of the Prometheus, Grafana and Telegram-based Monitoring System, where the final display is using a browser on a desktop or smartphone using the Telegram application, while Grafana and Prometheus are installed on a server in the data centre by providing a dashboard consisting of various panels, where each panel can be a chart, graph, number, table or other object that displays data [22]. Prometheus is a pull-based monitoring system that collects metrics periodically through HTTP endpoints, enabling efficient data retrieval from various sources. In contrast, Grafana is highly regarded for its ability to deliver powerful and interactive data visualizations, making it more effective than other tools such as Nagios.

The last process in designing a monitoring system test and ensures that the monitoring system developed can be used and in accordance with user needs.

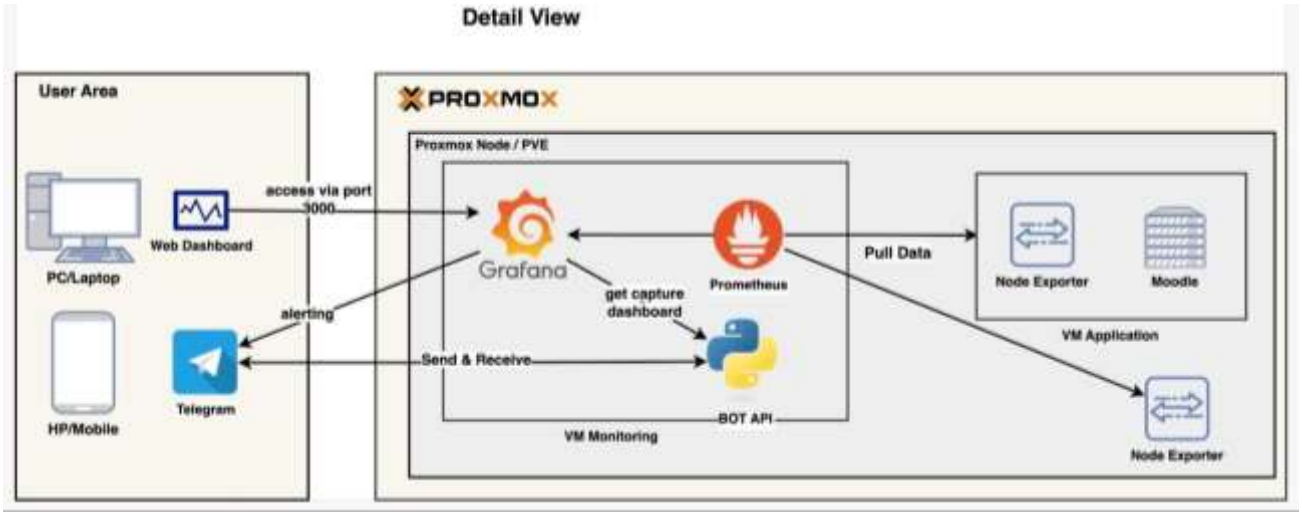

Fig. 1. Prometheus, Grafana and Telegram-based monitoring system architecture

2.2 Load Balancing

Before implementing Load Balancing, LMS data was collected through load testing to measure LMS performance and capacity under heavy load conditions. The test uses Grafana K6 testing tools configured with test scenarios through virtual users (VUs) and the test results are analysed using a monitoring system that has been previously developed to see the condition of the LMS cloud server and the resources used.

Next is the implementation of the load balancing method on the LMS starting with preparing the LMS infrastructure that runs using 2 physical servers managed through Proxmox Virtual Environment as a virtualization platform that allows the management of several virtual machines on the physical server [23,24], with a total of 12 CPU cores with 2 TB of storage and 16 GB of memory capacity (RAM). In addition, the channel capacity is considered strong enough on the server and a throughput of 300 to 900 Mbps has been integrated in the infrastructure planning. Furthermore, the installation and configuration process of the VM load balancer with HAProxy through the Round Robin algorithm as a load distribution process to the server in turn [25], the VM web server with Nginx, the VM database and its management through Galera Cluster and the installation of Moodle as an LMS.

The load balancer implementation was carried out by configuring an HAProxy listener named fe_moodle, specifying the web backend servers by adding the IP addresses of moodle1 and moodle2 and enabling HAProxy statistics to provide monitoring information.

```
globalnano 6.2       /etc/haproxy/haproxy.cfg

frontend fe_moodle
  bind *:80
  default_backend be_moodle

backend be_moodle
  server moodle1 192.168.109.205:80 check
  server moodle2 192.168.109.206:80 check

listen stats
  bind *1936
  stats enable
  stats hide-versions
  stats refresh 5s
  stats show-node
  stats auth username:password
  stats uri /stats
```

The testing and data collection stage of the LMS after the application of the load balancing method is carried out the same as the previous test, namely through load testing using Grafana K6 testing tools with the same scenario. Then the final stage is the evaluation of the results of the application of load balancing on the LMS based on the results of the analysis on the monitoring system with two ISO/IEC 20510 characteristics, namely Performance Efficiency using Quality of Service (QoS) parameters which are standards from ETSI-TIPHON and Usability through interviews with school ICT staff using the Miles and Huberman Model method on the interactive model (Interactive Model Analysis).

Referring to Alali *et al.,* [26], this study aims to optimize resource allocation similar to Edge Computing to improve QoS, through the RATEC algorithm using grey wolves' optimization. This research evaluates the LMS after load balancing to measure system performance and usability,

providing further insights into the effectiveness of the applied load balancing method in enhancing service quality and LMS availability.

3. Results

The development of a monitoring system in the LMS cloud infrastructure of SMK Negeri 2 Yogyakarta is used as a tool to monitor the use of resources when before and after implementing load balancing and ensuring cloud infrastructure monitoring is a top priority in order to improve service availability and reliability.

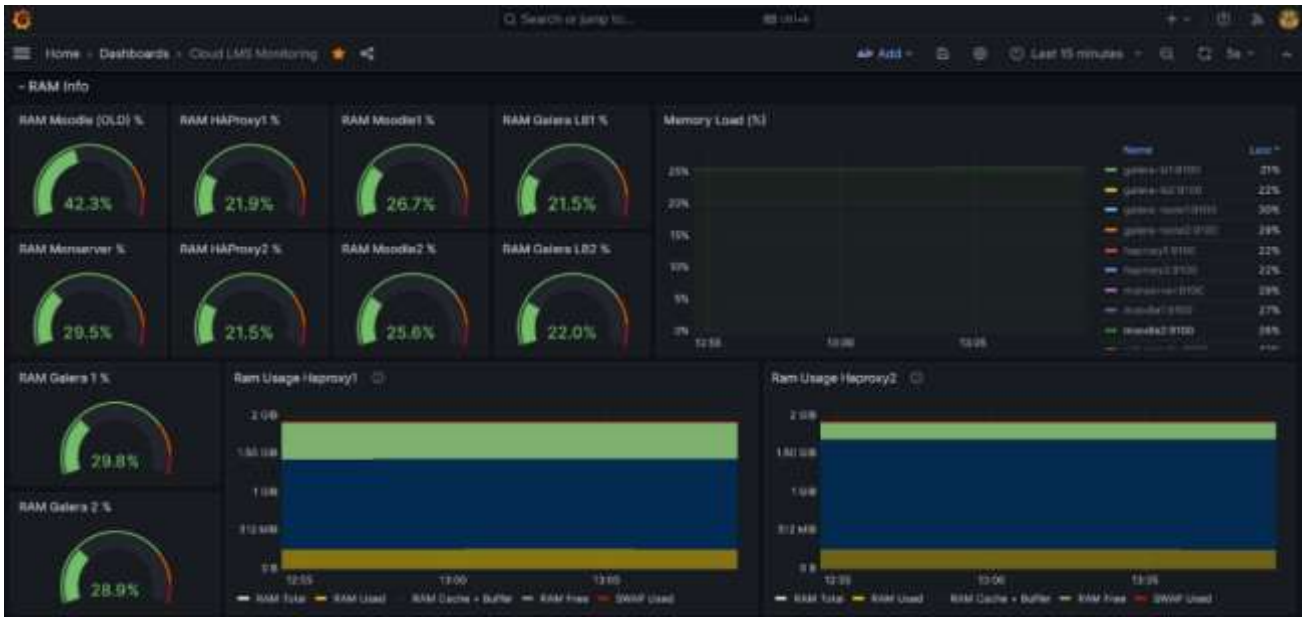

Fig. 2. Dashboard monitoring system

Cloud LMS monitoring can also be done using a smartphone to send notifications of cloud LMS monitoring results and make management more efficient by using Telegram chat rooms.

Fig. 2. Bot Telegram

LMS optimization applies load balancing. Testing LMS performance and capacity using load testing. Testing was conducted using the scale method to make the identification and implementation process more concise. The scale used was 1:5 of actual users.

3.1 Before Load Balancing was Implemented

The test results seen in the monitoring system with Grafana K6 testing tools configured with a test scenario through 100 VUs virtual users, 2 GB RAM and 2 Core CPUs with a duration of 2 minutes 30 seconds get the following results.

Table 1
LMS testing results before optimization

Parameters	Result
Virtual User (Vus)	100
Total Iterations	637
Failed Requests	135
Requests	1219
Percentage of Failed Requests	11.074%
CPU	100%
RAM	88%

The test resulted in identification in the form of an LMS that runs without the application of load balancing when testing is less efficient because not all users can access until completion, can only load on one system page. In addition, the test shows that the more users accessed, the more server resources will increase, which causes the time to access the system page to be longer, so that not all users can successfully access the system page.

3.2 After Implemented Load Balancing

The test results after the implementation of load balancing are seen in the monitoring system with the Grafana K6 testing tool configured with a test scenario through VUs that is the same as the test before the implementation of load balancing, namely accessing 100 VUs with a duration of 2 minutes 30 seconds, but adjustments are made to the VMs used that have been divided based on the resources available on the physical server to meet the minimum standardization recommended by Mr. Onno W Purbo, which is for 1 GB of RAM Moodle can be accessed by 50 users based on the following formula.

*Approx. Max Concurrent User = RAM (GB) * 50*
*Approx. Max Browsing User = Approx. Max Concurrent User * 5*

So, if there is 14 GB of RAM, then at least 700 users will be able to access it. This is proven by testing conducted by applying a scale of the number of VUs of 100, 2 GB RAM and 2 Core CPU. So that the results obtained are as in:

Table 2
LMS testing results after optimization

Parameters	Result
Virtual User (Vus)	100
Total Iterations	4701
Failed Requests	0
Requests	4701
Percentage of Failed Requests	0%
CPU	65%
RAM	28%

The results of observing the monitoring system show that the division of workload between servers has been evenly distributed by load balancing so that it can minimize the use of excessive resources, so it is better than testing before implementing load balancing.

3.3 Performance Efficiency Result Evaluation

The comparison results before and after applying load balancing on the LMS with minimum standardization adjustments get the following results.

Table 3
LMS comparison results with load balancing

Comparison Scale	Before	After
User	100	100
RAM	3 GB	2 GB
Storage	400 GB SSD	10 GB SSD
Processor	4 core	2 core
Duration	2 minutes 30 second	2 minutes 30 second
Time Respons	11.66 second	1.81 second
Request	637	4701
Failed Request	11.074%	0%

Performance Efficiency test results are evaluated using QoS parameters which are standards from ETSI-TIPHON through the following factors.

i. Throughput (%) $= \frac{\text{Amount of Data Sent}}{\text{Data Transmission Time}} x\ 100\%$

$= \frac{140\ \text{mb}}{2.27\ \text{second}} x\ 100\%$

$= 61.72\%$

Throughput results obtained a Good category with a result of 61.72% on index 3.

ii. Packet Loss (%) $= \frac{\text{Lost Data Packets}}{\text{Data Packets Sent}} x\ 100\%$

$= \frac{0}{376\ kB} x\ 100\%$

$= 0\%$

The results of the Packet Loss calculation obtained a Very Good category with a result of 0% at index 4.

iii. Delay (ms) $= \frac{\text{Total Delay}}{\text{Total Packages Received}}$

$= 37.98\ \mu s$

Delay calculation results obtained a Very Good category with results below 150 ms at index 4, which is 37.98 µs to wait for an available connection slot.

iv. Jitter $= \frac{\text{Total Delay Variation}}{\text{Total Received Packet Time}}$

$= \frac{83.27\ \mu s}{7.98\ \mu s}$

$= 2.192\ \mu s$

$= 0.002192\ ms$

The results of the Jitter calculation obtained a Good category with results between 0 - 75 ms, that is 0.002192 ms at index 3.

The Learning Management System that has previously been given maximum resources in fact still does not have optimal performance. It can be seen from the Load Testing results that show significant differences, users do not experience a decrease in performance when the number of users increases. The application of the High Availability method with load balancing technology did not encounter any obstacles or constraints and on the contrary, there was an increase in load duration. This indicates better system efficiency. Therefore, the positive and potential impact of implementing load balancing on the Learning Management System, in terms of responsiveness, efficiency and performance reliability, can be seen from the results of this study.

3.4 Usability Result Evaluation

The results of Usability testing by users, namely the ICT staff of SMK Negeri 2 Yogyakarta using the Miles and Huberman Model method in the interactive model (Interactive Model Analysis) as a validation of Performance Efficiency testing to ensure that load balancing that has been applied to the LMS has run optimally and the management of server infrastructure has been effectively implemented. Usability test results are presented in Table 3. The comparison results before and after applying load balancing on the LMS with minimum standardization adjustments get the following results.

Table 3
Likert score

Aspects	Indicator	Result	Result Description
Compatibility	Load Balancing	2	✓ As a solution to improve performance
	Round Robin Algorithm	2	✓ As a Load Balancing mechanism
	HAProxy	2	✓ As an implementation of Load Balancing
	Clustering	2	✓ LMS cluster management
Availability	Uptime	2	✓ No interruption / downtime
	Response Time	2	✓ Significantly faster response time
	Fault Tolerance	2	✓ Handling load balancing when it fails
	Backup	2	✓ Emergency data recovery
Performance	Response Time	2	✓ Minimum time to respond to users
	Throughput	2	✓ Number of requests that can be handled
	Error Rate	2	✓ Failure rate within minimum limits
	Scalability	2	✓ Handle multiple users efficiently

Based on the results in the table, the percentage of validation aspects of success can be known through

i. Successful $= \frac{x}{n}\ x\ 100\%$

$= \frac{12}{12}\ x\ 100\%$

$= 100\%$

ii. Unsuccessful $= \frac{y}{n}\ x\ 100\%$

$= \frac{0}{12}\ x\ 100\%$

$= 0\%$

The results obtained from the validation of the tests that have been carried out can be concluded that the performance of the Learning Management System after implementing load balancing has run optimally with a success rate of 100% with better performance and as expected.

4. Conclusions

Evaluation of experimental results regarding the application of High Availability on cloud LMS and the application of an integrated monitoring system has answered the challenges in improving the quality of digital services in the education sector, especially in optimizing existing learning media at SMK Negeri 2 Yogyakarta as a centre of excellence school based on Permendikbudristek Number 53 of 2023. Optimization efforts not only provide complex technology infrastructure, but ensure the maintenance and monitoring of the infrastructure runs well. The integration between Grafana and Prometheus as a monitoring tool enables real-time collection and visualization of metric data. Alert notifications are effective in informing ICT staff of system status and other critical events. This enables rapid response to potential problems, thereby reducing response time and mitigating risks.

The results of the implementation of High Availability with load balancing method succeeded in increasing the availability and reliability of LMS significantly based on the testing of two ISO/IEC 20510 characteristics, namely Performance Efficiency and Usability. Based on the Quality of Service (QoS) calculation to evaluate Performance Efficiency which is a standard from ETSI-TIPHON, LMS obtained the Good category with the results of 55. 57% in the Throughput parameter to measure the amount of data that can be transmitted, obtained a Very Good category with 0% results in the Packet Loss parameter which is the percentage of data packets lost during the transmission process, obtained a Very Good category with results below 150 ms in the Delay parameter to measure the time it takes to transmit data and obtained a Good category with results between 0 - 75 ms in the Jitter parameter which is the result of 116 variations in the arrival time of data packets, which can result in inconsistencies in network latency. In addition, the comparison between the application of a single LMS server infrastructure with the one that has been applied load balancing is very significant by maximizing the use of resources and minimizing response time and system failure based on Usability testing by users, namely ICT staff SMK Negeri 2 Yogyakarta.

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