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DESIGN AND IMPLEMENTATION OF AN INTRANET COMPUTER NETWORK IN SCHOOLS USING MIKROTIK

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Abstract: This research aims to design and implement a computer intranet network at MA Al-Rahman, a senior high school located in Sodonghilir, Tasikmalaya district, to enhance the quality of technology-based learning. Initial observations showed that the school's network infrastructure was not fully integrated, limiting access to digital learning resources. This study employs a Research and Development (R&D) approach using the Network Development Life Cycle (NDLC) model, which consists of analysis, design, simulation, implementation, monitoring, and management stages. The implementation involves a combination of wired and wireless media, with Mikrotik devices functioning as bandwidth management controllers. The testing results indicate improved network performance based on Quality of Service (QoS) parameters, with latency decreasing from 24.53 ms to 2.11 ms, jitter improving from 35.90 ms to 2.99 ms, packet loss ranging from 0.4% to 0.9%, and throughput increasing from 150 kbps to 2.61 Mbps. Expert validation confirms that the developed network is feasible for use. Overall, this research is expected to provide an effective and stable intranet solution for the school environment and support the integration of technology into the teaching and learning process.

Keywords: Intranet Network, Mikrotik RouterOS, NDLC, Bandwidth Management, QoS

1. INTRODUCTION

The rapid development of Information and Communication Technology (ICT) has significantly influenced the education sector by encouraging the use of computers and digital devices to enhance access to learning resources [1]-[3]. One of the technologies that supports this advancement is the implementation of intranet networks in educational institutions [4]-[5]. An intranet is a small-scale computer network used within an organization that facilitates internal communication, collaboration, and resource sharing through internet-based protocols [6]-[7].

MA Al-Rahman, a private senior high school committed to improving the quality of its learning process, continues to face challenges related to its incomplete and non-integrated network infrastructure. Currently, internet access is limited only to the computer laboratory and relies solely on ISP-provided modems. As a result, the network does not reach all classrooms, restricting access to online learning platforms, Computer-Based Test (CBT) applications, and digital collaboration tools for both teachers and students [8]. These limitations hinder the optimal utilization of digital learning resources and create disparities in technology-supported learning activities across school areas [9]. Therefore, this research aims to design and implement an intranet network that provides comprehensive coverage throughout the school environment. Additionally, the network is expected to achieve greater stability and efficiency through proper bandwidth management strategies [10].

Previous studies have demonstrated that the implementation of intranet and managed network systems in educational institutions can significantly enhance the effectiveness of digital learning environments [11]-[12]. Saputra et al. [13] reported that well-designed intranet infrastructures improve access to e-learning materials and minimize network congestion. Rahayu and Firmansyah [14] also found that the use of Mikrotik-based bandwidth management increases network stability, especially during CBT activities. Widiyanto and Kurniawan [15] further highlighted that applying Quality of Service (QoS) mechanisms in school networks results in more reliable and consistent performance for digital learning applications. Nugroho [16] emphasized that the NDLC development model ensures structured planning and contributes to scalable and reliable school network systems. In addition, Firmansyah and Hidayat [17] concluded that intranet development in schools plays a significant role in supporting digital collaboration and improving the overall learning process. These studies collectively reinforce the importance of developing a comprehensive intranet system at MA Al-Rahman to enhance digital learning accessibility and network stability.

One of the key technologies utilized in this development is Mikrotik RouterOS, a Linux kernel-based operating system designed specifically for Mikrotik router devices, but also installable on standard PC hardware [18]. Through Mikrotik, various network configurations and services such as hotspot creation, bandwidth management, and user control can be implemented effectively, making it suitable for school-scale network infrastructures [19]. To ensure high network performance, Quality of Service (QoS) plays a critical role. QoS is a network mechanism used to regulate and guarantee service quality during data transmission. It ensures that specific applications receive prioritized network resources, particularly services requiring consistent performance such as video streaming, VoIP, and other latency-sensitive tasks. The application of QoS is essential for maintaining a stable and reliable intranet environment in educational settings [20].

This study employs the R&D method using the NDLC model, which consists of the stages of analysis, design, simulation, implementation, monitoring, and management. The network implementation combines both wired and wireless media, with Mikrotik devices functioning as bandwidth management controllers to optimize overall network performance. This structured approach ensures that the resulting intranet network is systematically developed and capable of meeting the school's technological needs.

2. METHODOLOGY

This research applies the R&D method, which aims to develop and implement an intranet network system in a school environment through a systematic and iterative process to produce a valid and effective product. In computer network development, the R&D approach involves several key stages, including identifying user needs, designing and developing appropriate network solutions, testing network effectiveness, and improving the system based on evaluation results. As the development framework, the NDLC model is employed, encompassing the stages of initiation, planning, analysis, design, implementation, and maintenance. This model ensures that the resulting network meets user functional requirements, offers operational reliability, and supports optimal overall performance. The NDLC model can be seen in Figure 1.

The analysis phase is conducted at the outset and focuses on identifying network system requirements, existing infrastructure problems, and the appropriate network topology. This stage involves direct observation of the school's current infrastructure as well as interviews with relevant stakeholders to obtain a comprehensive understanding of user needs. Based on this information, the system design phase begins, involving the development of a network topology, bandwidth allocation scheme, and user access plan. The design is then visualized using GNS3 software to provide an initial representation of the intended network structure, ensuring it aligns with the identified requirements. Following the design process, a simulation is conducted in GNS3 to test the functionality and validity of the network configuration, allowing potential issues to be identified and addressed before actual implementation.

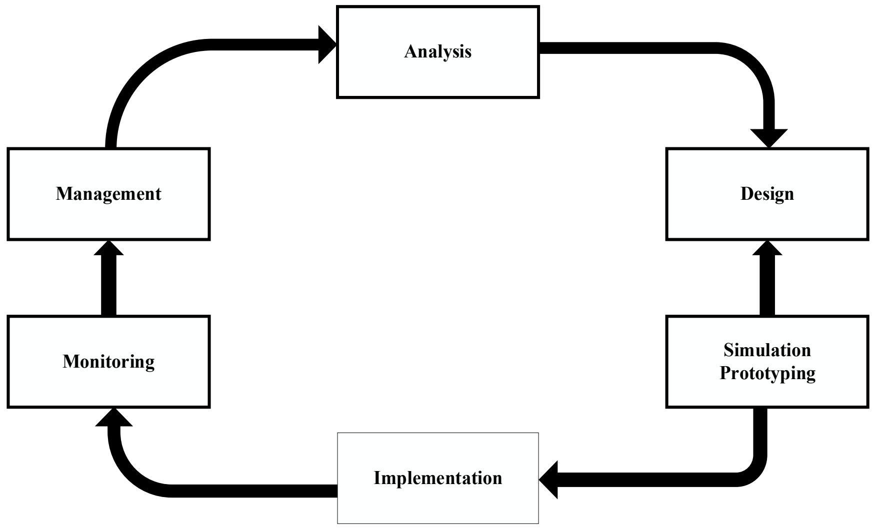

Figure 1: Step of NDLC model

After the simulation is completed, the project proceeds to the implementation phase, where the designed network is deployed in the field. This includes installing network hardware, configuring IP addresses, adjusting firewall settings, and applying QoS rules for effective bandwidth management. The performance evaluation for each QoS parameter refers to the standard values established by Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); a quality assessment standard issued by the European Telecommunications Standards Institute (ETSI).

The following are the QoS standard values based on TIPHON

i. Throughput Parameter

Table 1. TIPHON standard for throughput provides a classification of network performance based on the amount of data successfully transmitted per second. In this table, throughput values greater than 2.1 Mbps fall into the *Very Good* category with an index of 4, indicating optimal capability for handling high-bandwidth activities such as video streaming or large data transfers. Throughput ranging from 1.2 to 2.1 Mbps is categorized as *Good* (index 3), suitable for general digital learning applications. The *Keep* category (index 2) applies to throughput between 700 and 1200 kbps, which may only support basic browsing and low-intensity online tasks. Finally, throughput values from 0 to 338 kbps are classified as *Bad* (index 1), reflecting insufficient performance for modern educational needs.

Table 1: TIPHON Standard for Throughput

Throughput Category	Throughput value (bps)	Index
Very Good	>2.1 Mbps	4
Good	1.2 to 2.1 Mbps	3
Keep	700 to 1200 kbps	2
Bad	0 to 338 kbps	1

ii. Latency Parameter (Delay)

Table 2. TIPHON standard for delay defines the acceptable ranges for latency, which refers to the time required for data packets to reach their destination. A delay of 150 ms or below is rated as

Very Good (index 4), ideal for real-time applications commonly used in online learning environments. Latency between 150 and 300 ms is categorized as *Good* (index 3), remaining acceptable for most non–time-sensitive activities. The *Keep* category (index 2), covering delays from 300 to 450 ms, may start to cause noticeable lag in interactive applications. Any delay exceeding 450 ms is classified as *Bad* (index 1), indicating poor responsiveness and potentially disrupting synchronous digital learning activities.

Table 2: TIPHON Standard for *Delay*

Latency Category	**Delay value (ms)**	**Index**
Very Good	≤ 150	4
Good	150 to 300	3
Keep	300 to 450	2
Bad	> 450	1

iii. Jitter Parameter

Table 3. TIPHON standard for jitter outlines the acceptable variation in latency between data packets. A jitter value of 0 ms is categorized as *Very Good* (index 4), signifying highly consistent and stable network performance suitable for audio and video communication. Jitter values below 75 ms fall within the *good* category (index 3), generally providing satisfactory real-time communication. Values between 75 and 125 ms belong to the *Keep* category (index 2), where fluctuations in packet timing may begin to affect the quality of streaming or live interactions. Jitter ranging from 125 to 225 ms is classified as *Bad* (index 1), indicating severe instability that can cause interruptions in multimedia and synchronous learning activities.

Table 3: TIPHON Standard for Jitter

Jitter Category	**Jitter value (ms)**	**Index**
Very Good	0	4
Good	< 0 s.d 75	3
Keep	< 75 s.d 125	2
Bad	< 125 s.d 225	1

iv. *Packet loss*

Table 4. TIPHON standard for packet loss presents the acceptable range of packet loss percentages within a network. Packet loss between 0% and 2% is rated *Very Good* (index 4), ensuring stable data delivery with minimal disruption. Packet loss within the 3% to 14% range is classified as *Good* (index 3), which is still acceptable for most general-purpose network activities. The *Keep* category (index 2), covering packet loss values from 15% to 24%, may lead to noticeable interruptions, particularly during streaming or online conferencing. Packet loss reaching 25% or more is categorized as *Bad* (index 1), signifying severe transmission failure that can critically impact all forms of digital learning and communication.

Table 4: TIPHON Standard for Packet Loss

Packet loss Category	***Packet loss value* (%)**	**Index**
Very Good	0 to 2	4
Good	3 to 14	3
Keep	15 to 24	2
Bad	25	1

After the implementation phase, network performance is continuously monitored using the monitoring features available on Mikrotik devices to ensure that data traffic operates optimally and remains stable according to user needs. The final stage involves routine maintenance and management of the network, with operational responsibility transferred to the school as the infrastructure owner, including policy execution and ongoing system improvements. Additionally, a network expert validation instrument is used to obtain professional assessments regarding the design and implementation of the intranet system. This instrument evaluates several key aspects observed by the expert, and the detailed items for each assessment criterion are provided in Table 5.

Table 5: Aspects for network expert validation

No	Aspects observed	Item Number
1	Compatibility of network topology with school needs	1-2
2	Configuration of network devices (routers, switches, firewalls, and access points).	3-4
3	Network speed and stability based on test results (latency, throughput, packet loss).	5-6
4	Easy network access for students, teachers, and staff.	7-8

Table 6 presents the criteria used to determine the feasibility of the intranet network system after being reviewed by a network expert. This table categorizes the validity percentage into four levels: “Very Valid,” “Valid,” “Quite Valid,” and “Invalid.” A score between 76–100% is classified as Very Valid, indicating that the system is highly feasible and requires no revision. A score between 50–75% is considered Valid, meaning the system is feasible but may require minor revisions. Scores ranging from 26–49% fall into the Quite Valid category, suggesting that the system is only partially feasible and requires significant improvement. Meanwhile, any score below 26% is marked as Invalid, indicating that the system is not feasible and needs a complete redesign. This classification helps determine the overall quality and readiness of the intranet network based on expert assessment.

Table 6: Eligibility Validation

Percentage	Validity	Information
76 -100 %	Very valid	Very feasible/does not need revision
50 – 75 %	Valid	Worthy of revision
26 – 49 %	Quiete valid	Less qualified/partially revised
< 26 %	Invalid	Not feasible, a thorough revision

3. RESULTS AND DISCUSSION

The implementation of an intranet network at MA Al-Rahman was carried out through a structured process using the NDLC (Network Development Life Cycle) model. The network's pre-implementation condition was evaluated to identify limitations and provide a baseline for improvement.

3.1 Pre-Implementation Network Condition

Observations conducted on April 22, 2025, revealed that the existing network infrastructure was limited to a computer laboratory with minimal user capacity and inadequate wireless coverage. The legacy equipment included a TL-WR841HP access point and Cat5 cabling, with a bandwidth capacity of 100 Mbps distributed only within the laboratory. The floor plan of Al Rahman before implementation is shown in Figure 2.

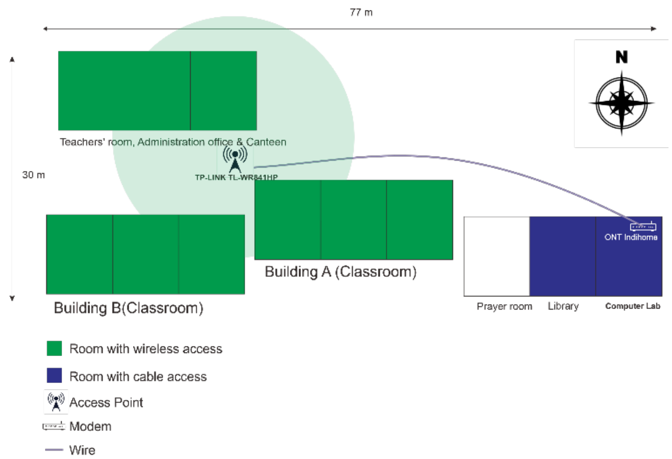

Figure 2: Floor plan of Al Rahman before implementation

Wireshark analysis showed a low throughput of approximately 150 kbps, with a delay of 24.5 ms and jitter of 35.9 ms. Packet loss was recorded at 0.4%. These performance issues were corroborated by iPerf3 testing, which revealed maximum throughput of 2.63 Mbps (sender) and 1.60 Mbps (receiver) across parallel connections.

Table 7: Pre-implementation comparison data with TIPHON standard

QoS Parameter	Test result data	TIPHON Index
Latency	24,53 ms	4
Jitter	35,90 ms	4
Packet Loss	0.4%	4
Throughput	150 kbps	1

Table 7 presents the initial QoS performance of the school's existing network before the new intranet system was deployed. The results show that latency was measured at 24.53 ms, jitter at 35.90 ms, and packet loss at 0.4%; all of which fall under the Very Good category according to the TIPHON index, each receiving a score of 4. However, the throughput value was only 150 kbps, which is significantly below the recommended threshold and is categorized as Bad with a TIPHON index of 1. This comparison indicates that while the original network showed acceptable stability in terms of delay, jitter, and packet reliability, its extremely low throughput severely limited its ability to support modern digital learning activities, emphasizing the need for a redesigned and higher-capacity intranet infrastructure.

3.2 *Network Design and Implementation*

A redesigned network architecture was proposed by combining a wired star topology for the computer laboratory with a wireless chain topology for classroom distribution. The equipment upgrades included replacing Cat5 with Cat5e cabling, installing three Ruijie RG-RAP2200(f) access points, deploying a 24-port gigabit switch, and utilizing a MikroTik RB450Gx4 router. Network configuration on the MikroTik router involved segmenting traffic through multiple subnets and enabling DHCP to automate IP distribution. The access points were configured with dual-band frequencies (2.4 GHz and 5 GHz) and managed via Ruijie Cloud for centralized control. In addition, a firewall was implemented to prevent unauthorized access and restrict non-educational content through captive portal authentication and filtering rules. Bandwidth allocation was optimized using PCQ queue types to ensure fair and efficient distribution across all connected users.

3.3. *Post-Implementation Evaluation*

The evaluation conducted after the deployment of the redesigned intranet network revealed significant improvements across multiple performance indicators. The testing process involved both packet-level analysis using Wireshark and throughput validation using iPerf3.

Table 8 presents the Quality of Service (QoS) performance of the redesigned intranet network after implementation. The results show significant improvements across all parameters, with latency reduced to 2.11 ms, jitter to 2.99 ms, packet loss measured at 0.9%, and throughput increased to 2.61 Mbps. According to the TIPHON quality index, each of these values falls into the *Very Good* category, receiving the highest rating of 4. This indicates that the newly implemented network meets international telecommunication standards, delivering fast, stable, and reliable performance suitable for digital learning activities. The improvement across all indicators confirms the effectiveness of the network redesign and validates the system's capability to support a high number of concurrent users while maintaining optimal quality.

Table 8: Data on the results of implementation with TIPHON standards

QoS Parameter	Test result data	TIPHON Index
Latency	2.11 ms	4
Jitter	2.99 ms	4
Packet Loss	0.9%	4
Throughput	2.61 Mbps	4

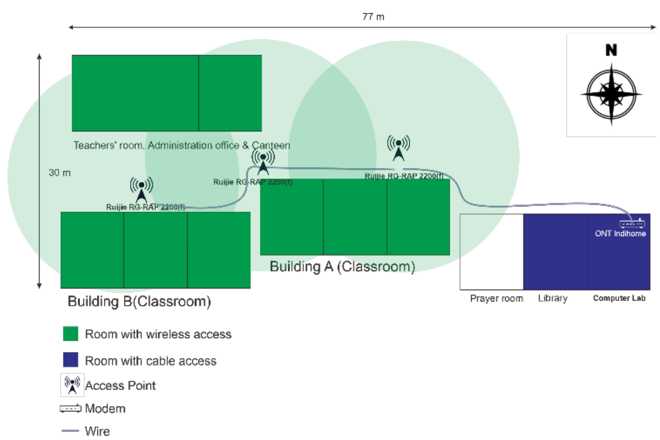

Figure 3: Floor plan after implementation

A parallel throughput test using iPerf3 with 20 simultaneous connections was conducted to simulate multi-user access, yielding an aggregate throughput of 11.2 Mbps on the sender side and 9.64 Mbps on the receiver side, demonstrating the network's strong capability to manage concurrent client activity. The test further showed balanced traffic distribution, confirming that the bandwidth management configuration using MikroTik's PCQ queue type function, functioned effectively. Additionally, the final network was able to support up to 91 active clients during operational testing, an increase from only 17 users in the pre-implementation stage, indicating not only improved signal coverage but also significantly enhanced overall scalability.

3.4. *Network Expert Assessment*

Table 9 summarizes the evaluation given by a computer network specialist regarding the feasibility of the implemented intranet system. The expert assessed four key aspects: the compatibility of the network topology with the school's needs, the configuration quality of devices such as routers, switches, firewalls, and access points, the network's performance based on latency, throughput, and packet loss, and the accessibility of the network for students, teachers, and staff. The scores for each aspect, 8, 10, 9, and 9, respectively, resulted in a total score of 36, indicating a high level of technical adequacy. This strong assessment confirms that the network design and implementation meet the expected standards and are considered feasible for effective use within the school environment.

Table 9: Results of the Assessment of the network expert

No	Aspects observed	Score obtained
1	Compatibility of network topology with school needs	8
2	Configuration of network devices (routers, switches, firewalls, and access points).	10
3	Network speed and stability based on test results (latency, throughput, packet loss).	9
4	Easy network access for students, teachers, and staff.	9
	Result	36

Based on the calculation of 36 divided by the 5-point Likert scale, resulting in 7.2, which, when normalized by dividing by the maximum score of 8 and multiplying by 100, yields a feasibility percentage of 90%.

4. CONCLUSION

The intranet network at MA Al-Rahman was successfully designed and implemented using the NDLC model, integrating both wired and wireless topologies to enhance the digital learning infrastructure. The deployment, which utilized MikroTik RB450Gx4, Ruijie RG-RAP2200(f) access points, and PCQ-based bandwidth management, resulted in substantial performance improvements, demonstrated by post-implementation QoS values of 2.61 Mbps throughput, 2.11 *ms* latency, 2.99 *ms* jitter, and 0.9% packet loss, all meeting TIPHON Index 4 standards. Expert validation further confirmed the system's technical feasibility and effectiveness in supporting educational and administrative digital activities, indicating that the upgraded intranet network provides a stable, scalable, and reliable foundation for continued technology integration within the school.

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