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Analysis and Simulation of OSPF Dynamic Routing on RRI Lhokseumawe Network

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ABSTRACT

The development of modern broadcasting technology in public institutions demands a highly reliable computer network infrastructure to guarantee continuous information dissemination. This study analyzes the network reliability at Public Broadcasting Institution Radio Republik Indonesia LPP RRI Lhokseumawe to ensure smooth real time broadcast data transmission through route optimization. The main issue in the existing network is its conventional flat network architecture, which is vulnerable to data traffic congestion and delays during peak activity. To resolve this, this study implements Open Shortest Path First OSPF Area zero dynamic routing combined with Virtual LAN segmentation on Cisco Packet Tracer. Testing was performed using a simulated traffic generator under extreme scenarios involving fifteen end user devices sending one hundred consecutive packets simultaneously in zero point one second intervals. Results prove that under extreme conditions, the existing network experiences severe performance degradation with a global average Packet Loss soaring to nineteen percent due to local congestion. Conversely, the new topology based on OSPF Area zero and VLAN segmentation successfully directs data distribution intelligently and dampens broadcast storms within each logical work zone, suppressing the average Packet Loss to an absolute zero percent. In conclusion, applying OSPF and VLAN protocols automatically converges routes, improves Quality of Service stability, and protects critical broadcasting operations from total paralysis risks.

INTRODUCTION

Modern digital operations and public services rely heavily on high performance computer network infrastructure (Mulyana et al., 2025). This demand continues to grow as real time digital services require low latency and adaptive connectivity under fluctuating network loads (Pariyandani, 2024). An optimally designed Local Area Network or LAN serves as the core backbone, ensuring fast, stable, and secure data flow across internal devices (Wira Buana, Andriyas Hariyandi, 2023). In public broadcasting institutions like Radio Republik Indonesia, network stability is critical because modern broadcasting operations depend entirely on digital infrastructure (Syarifatun et al., 2024). RRI operates network based services including radio content production, distribution, and daily streaming via RRI Digital, all demanding high network availability (Annisa Mardi, Vera & Syarifuddin, 2024). However, the regional station at RRI Lhokseumawe still relies on a conventional flat network architecture with a single gateway and no Virtual LAN segmentation, leading to excessive broadcast traffic, increased congestion risks, and performance degradation during peak loads.

To resolve these flat network limitations, implementing Open Shortest Path First OSPF Area zero dynamic routing combined with Virtual LAN segmentation offers a highly effective approach. OSPF automatically selects optimal paths, detects link failures within seconds, and adjusts routes without manual reconfiguration (Fadila et al., 2024), thereby preventing routing loops, gateway detection delays, and switch buffer overloads (Ariyadi & Maula, 2024). Although previous studies evaluated OSPF performance, they mostly focused on general academic or simulated environments (Fadila et al., 2024), neglecting continuous and disruption sensitive digital broadcast traffic. No prior study has analyzed existing public broadcasting networks to propose an integrated OSPF and VLAN architecture tailored for broadcast continuity.

Furthermore, implementing dual router redundancy alongside dynamic routing protocols ensures high system availability and seamless fault recovery. While conventional static setups cause network paralysis when a primary link fails, the integration of OSPF Area zero with VLAN segmentation enables active link failure detection and real time route convergence. Evaluating this proposed architecture under simulated stress traffic provides critical insights into buffer endurance and bandwidth distribution during peak operational hours. Consequently, analyzing these performance behaviors under extreme conditions is necessary to validate the resilience of broadcasting networks before physical implementation.

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This study addresses this gap by analyzing the existing LAN at RRI Lhokseumawe, implementing an OSPF Area zero and VLAN simulation using Cisco Packet Tracer, and evaluating performance using Quality of Service parameters, specifically Throughput, Delay, and Packet Loss under normal and extreme load conditions. The scope is focused on internal LAN modeling without direct production deployment or advanced security management. The expected contributions include providing technical guidelines for network administrators to eliminate single points of failure, enhance routing efficiency, and guarantee continuous digital broadcasting services.

LITERATURE REVIEW

A robust computer network infrastructure requires evaluating hardware components, protocol functions, and structural performance (Bagus, 2025). Computer network is developed by appliances such as switches, routers and several devices that control traffic such as firewall. Traditional approached of network is developed to perform distributed protocols such as topology routing, traffic observing, and control entry (Fitria et al., 2021). Key Quality of Service metrics such as Throughput, Delay, and Packet Loss determine network efficiency (Purba & Purba, 2022), while topology selection directly affects data flow speed, connectivity reliability, and fault isolation (Musyafa et al., 2025). In Local Area Networks, managing local broadcast domains through Virtual LAN segmentation is critical to prevent congestion, lower latency, and eliminate broadcast storms in disruption sensitive environments (KN, 2021). Dynamic routing protocols like Open Shortest Path First Area zero optimize path selection using the Dijkstra algorithm (Yuhanef et al., 2024), reducing computation overhead, accelerating convergence times, and adapting to link failures automatically without manual reconfiguration (Fadila et al., 2024).

Prior studies comparing RIP and OSPF performance on virtual classroom networks proved OSPF significant superiority in convergence speed and Quality of Service stability (Hariyanto, 2025). Research on tree topologies demonstrated rapid fault detection with failover response times ranging between five and thirty one milliseconds (Yuhanef et al., 2024). Meanwhile, evaluations on hybrid topologies confirmed stable communication with an average Throughput of 819.2 kbps (Fadila et al., 2024). In educational environments, OSPF deployment verified Dijkstra algorithm effectiveness in automatically selecting the fastest data delivery path during network disruptions (Ariyadi & Maula, 2024). Additionally, comparisons between OSPF and EIGRP highlighted higher OSPF throughput while Spanning Tree Protocol successfully prevented routing loops and eliminated packet loss risks completely (Febri Wijayanto, 2024).

Network simulation tools provide a risk free environment to evaluate topology redesigns and traffic behaviors before physical deployment. Simulating dynamic routing and Quality of Service parameters under heavy data loads helps measure buffer capacity and path convergence without disrupting live broadcasting operations. However, existing literature predominantly focuses on general academic or corporate settings without addressing the strict continuity demands of live broadcast media traffic. RRI Lhokseumawe currently relies on a single router and an unsegmented flat architecture, making direct OSPF deployment impossible. This study bridges this gap by redesigning the network with dual parallel routers and VLAN segmentation in Cisco Packet Tracer, then evaluating OSPF Area zero failover resilience and Quality of Service stability under extreme broadcast traffic conditions.

METHOD

This study applies a Mixed Methods sequential exploratory approach integrating qualitative descriptive analysis and quantitative experimental simulation. Qualitative data collected from field observations and structured interviews with network administrators at Radio Republik Indonesia Lhokseumawe served as the foundation to map the existing flat network topology, device dependencies, and routing constraints. Quantitatively, a comparative experiment was conducted using Cisco Packet Tracer to construct two distinct network models: the existing single gateway flat topology and a proposed architecture implementing Open Shortest Path First Area zero dynamic routing with Virtual LAN segmentation based on the Dijkstra algorithm.

The research execution follows a structured sequence as illustrated in Figure 1, beginning with identifying routing vulnerabilities and establishing theoretical frameworks covering OSPF, Dijkstra algorithm mechanics, and Quality of Service evaluation standards. Experimental testing evaluated network performance across eleven strategic test points connecting wired, wireless, dedicated, and ISP gateway links under both normal idle conditions and extreme stress traffic generated by synthetic ICMP flooding from fifteen additional end user PCs. Network Quality of Service parameters including Throughput, Delay, Packet Loss, and Failover Availability were calculated using standard mathematical formulas to empirically compare transmission capacity, response time, and data delivery integrity between the existing flat network and the proposed dynamic architecture.

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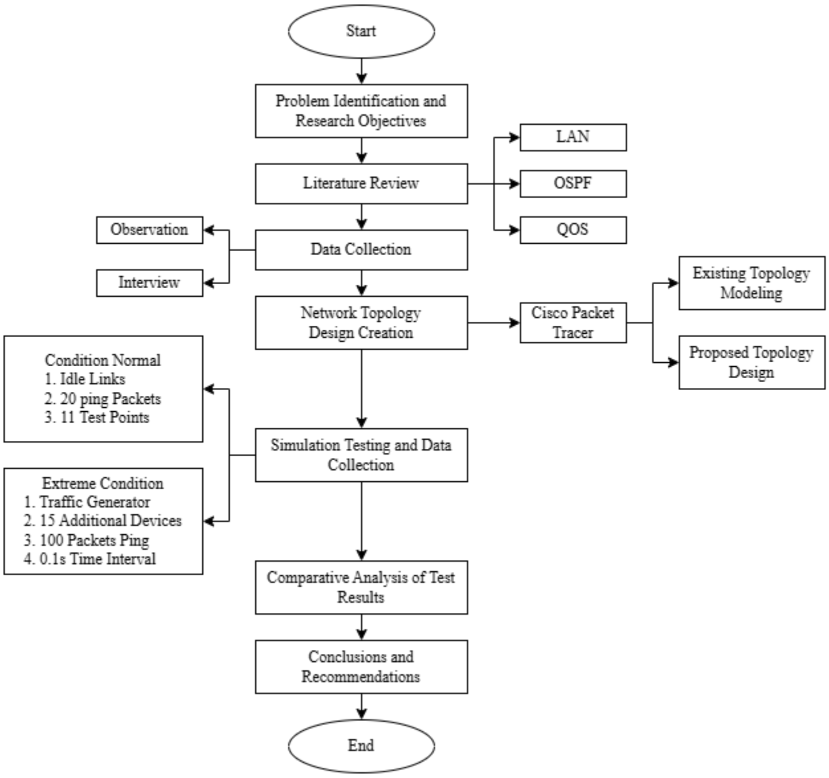

Figure 1 Research Stages Diagram

Experimental testing evaluated network performance across eleven strategic test points connecting wired, wireless, dedicated, and ISP gateway links. Performance metrics including Throughput, Delay, Packet Loss, and Failover Availability were measured under normal idle conditions and extreme stress traffic generated by synthetic ICMP flooding from fifteen additional end user PCs to evaluate system resilience.

RESULT

This section presents the empirical measurement outputs and quantitative simulation results obtained from Cisco Packet Tracer evaluations comparing the existing flat network against the proposed OSPF Area zero and VLAN architecture at Lembaga Penyiaran Publik Radio Republik Indonesia Lhokseumawe.

Existing Network Architecture Mapping

The baseline network at LPP RRI Lhokseumawe operates as a centralized unsegmented flat topology where a single Mikrotik router and distribution switch route general operations through IndiBiz ISP while directing critical audio streaming and logging workflows via a dedicated ASTINET VPN connection.

Table 1. Physical Device Mapping of Existing Network Topology

No	Functional Zone / Location	Integrated Devices	Operational Purpose
1	Main Infrastructure (Multimedia Room)	Router ISP Indibiz, Main Mikrotik Router, Astinet VPN Router	Gateway routing, traffic distribution, and dedicated VPN transport
2	Technical Operations (Multimedia Room)	Audio Logger PC, Streaming PC, Comp Gatek PC	Automated recording, live streaming, and technical monitoring
3	On-Air Studios (Studio Pro 1 & Pro 2)	RBO Pro 1 & 2 PCs, ANN Pro 1 & 2 PCs, Comp vMix, Server Pro 1 & 2	Broadcast control, live announcer workstations, graphics processing, and primary databases
4	Music & Editorial (MD Room & Newsroom)	MD Pro 1 & 2 PCs, RBO News PC, News Delivery PC	Music library management and editorial news distribution
5	Extended Production (RRI Net & MP Room)	RRI Net Studio PC, Studio MP PC	Visual broadcasting operations and general production support
6	Administration (TMB Coordinator Room)	TMB Coordinator PC	Media and technical workflow management

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The table above details the physical device distribution across the operational zones at LPP RRI Lhokseumawe, accurately replicated and visualized according to the actual real world office network layout in Cisco Packet Tracer below.

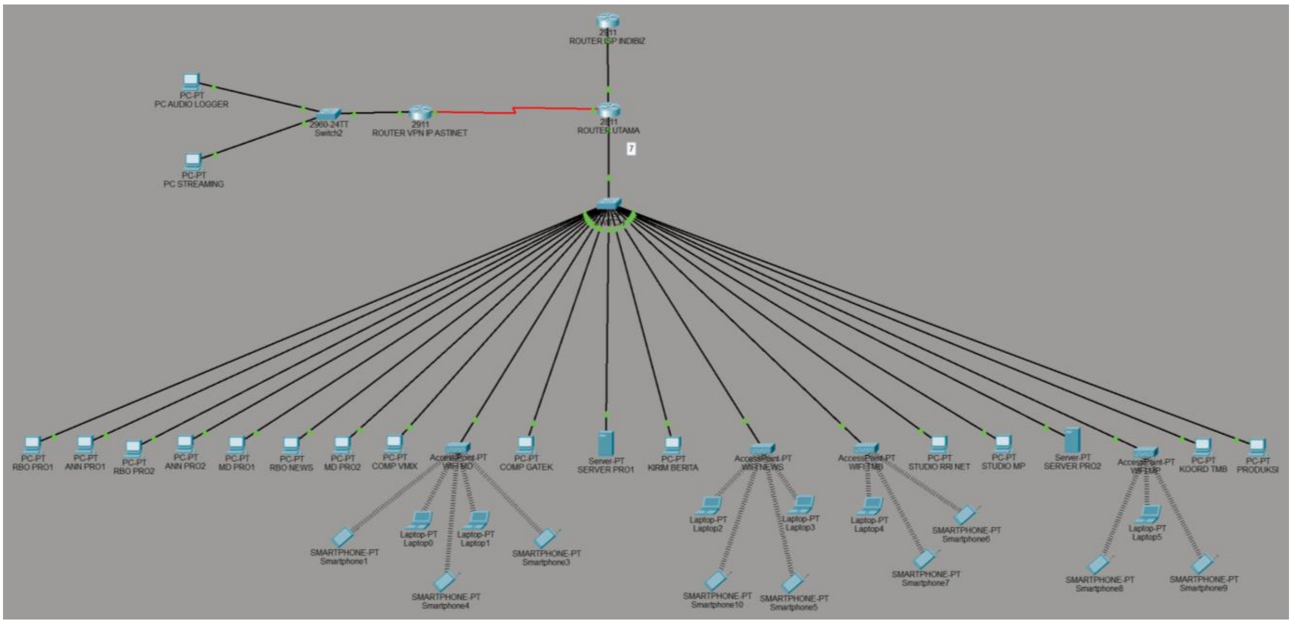

Figure 2 Existing Network Topology of LPP RRI Lhokseumawe

As depicted in Figure 2, the multimedia room houses the primary infrastructure, while studio workstations and technical production PCs are distributed across specific functional areas. Because all these devices share a flat network architecture without logical boundaries, data traffic flows through a single broadcast domain. This unsegmented structure leaves the core distribution switch vulnerable to broadcast storms and severe network congestion.

Proposed Network Topology Design

The proposed architecture integrates dual parallel routers, OSPF Area Zero, VLAN segmentation, and CIDR subnetting. The network was reconstructed and simulated in Cisco Packet Tracer to validate its performance.

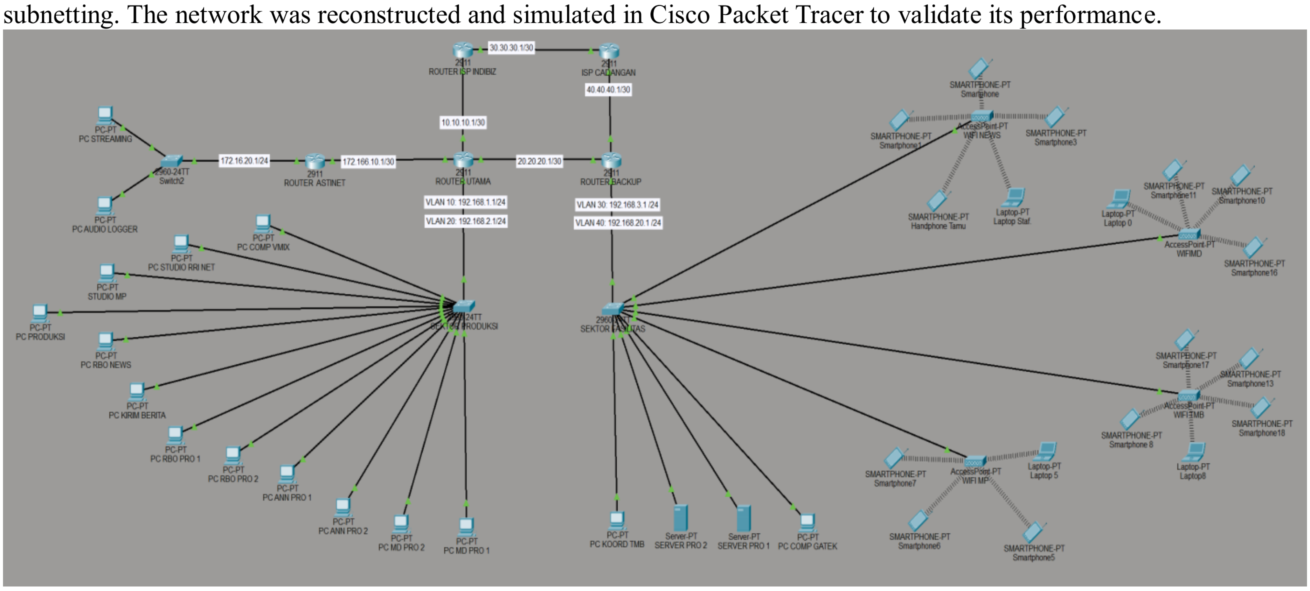

Figure 3 Proposed Network Topology with OSPF Area Zero and VLAN Segmentation

As depicted in Figure 3, the optimized network architecture adopts a hybrid topology that combines partial mesh and star structures to ensure maximum system availability and manageable infrastructure. At the core layer, a partial mesh topology interconnects dual redundant routers (Router Utama and Router Backup) and ISP gateways operating within dynamic OSPF Area zero, effectively eliminating single point of failure risks and providing seamless failover. At the distribution and access layers, a star topology connects workstations, servers, and access points to dedicated switches, namely Sektor Produksi and Sektor Fasilitas. These switches logically partition the network through Virtual

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LAN segmentation to isolate critical studio broadcasting workflows from general administrative traffic, thereby dampening broadcast storms and maintaining continuous operational uptime. The detailed mapping of these logical zones, VLAN identifiers, and gateway controls is presented in Table 3 below.

Table 2. Proposed VLAN Configuration Scheme

VLAN Name	VLAN ID	Network Zone Allocation	Boundaries and Logical Functions	Control Gateway Device
Studio_Produksi	10	Studio and Production Zone	Isolates critical broadcast traffic and the vMix workstation from external data interference.	Main Router (192.168.1.1/24)
Zona_Berita	20	Newsroom Zone	Manages dedicated editorial and news production data traffic.	Main Router (192.168.2.1/24)
Admin_Kantor	30	Administration and Server Zone	Consolidates office operations and internal server management traffic.	Backup Router (192.168.3.1/24)
Wifi_Fasilitas	40	Wireless Wi-Fi Access Zone	Accommodates wireless traffic from staff and guests while maintaining logical isolation from other network segments.	Backup Router (192.168.20.1/24)

As detailed in Table 2, the network isolation strategy assigns specific Virtual LAN IDs and subnet gateways to maintain strict traffic boundaries across operations. Studio Produksi under VLAN 10 and Zona Berita under VLAN 20 are routed through the Main Router to prioritize high throughput for live broadcast streams, vMix graphic processing, and editorial data delivery. Conversely, Admin Kantor under VLAN 30 and Wifi Fasilitas under VLAN 40 are managed by the Backup Router to segregate administrative workload and public access traffic. This logical division prevents unauthorized inter VLAN communication, minimizes congestion, and ensures that bandwidth heavy multimedia streams operate independently from office and guest wireless activities.

QoS Empirical Results Under Normal Operating Conditions

To measure baseline network performance under standard conditions, single flow empirical testing was conducted across ten strategic communication paths mapped in Table 6 using standardized ICMP Ping trials. As summarized in Table 6, the empirical measurement outputs demonstrate significant performance improvements in the proposed OSPF and VLAN architecture compared to the existing flat topology, with average throughput increasing from 50.49 kbps to 146.7 kbps, average delay decreasing from 23.3 ms to 7.3 ms, and packet loss dropping from 1 percent to 0 percent.

Table 3. Recapitulation of Average QoS Parameters under Normal Conditions

Parameter	Existing Topology	Proposed Topology
Throughput	50,49	146,7
Delay	23,3	7,3
Packet Loss	1%	0%

The metric improvements outlined in Table 3 underscore the direct operational benefits of implementing Virtual LAN segmentation and OSPF Area zero dynamic routing. By isolating broadcast traffic into dedicated VLANs, the network eliminates unnecessary background frame flooding, allowing available link capacity to be fully utilized for primary data transmission. Consequently, throughput experiences a near threefold increase, while routing efficiency reduces average latency by approximately 68 percent and completely resolves packet drop occurrences. To provide a clearer visual contrast between these baseline and proposed performance indicators, the comparative measurement results are illustrated in Figure 4 below.

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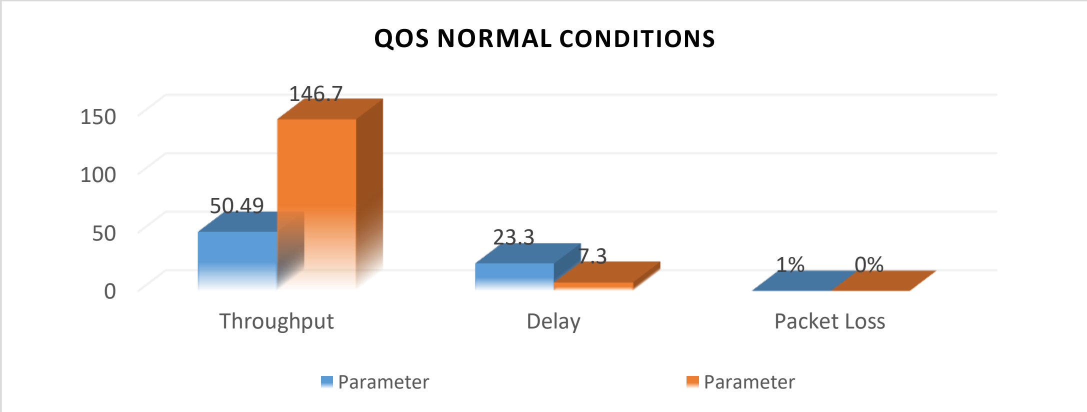

Figure 4. Comparison of Average QoS Parameters under Normal Conditions

QoS Empirical Results Under Extreme Traffic Conditions

To evaluate network resilience and performance limits under severe congestion, an empirical stress test was conducted by generating high frequency background traffic. A multi host traffic generator deployed across fifteen endpoint devices transmitted continuous ICMP echo request packets at aggressive zero point one second intervals toward the central infrastructure. This artificial load replicates an extreme operational scenario, such as a severe broadcast storm or peak concurrent broadcasting hours across multiple media zones. The resulting QoS parameter comparison between the two topologies under these extreme conditions is presented in Table 4 below.

Table 4. Recapitulation of Average Parameters under Extreme Traffic Conditions

Parameter	Existing Topology	Proposed Topology
Throughput	19.01 kbps	47.3 kbps
Delay	130.9 ms	27.6 ms
Packet Loss	19%	0%

As summarized in Table 4, the empirical results under extreme traffic stress clearly demonstrate the vulnerability of the existing flat topology compared to the stability of the proposed architecture. Under high broadcast load, the unsegmented network suffers severe degradation, with throughput dropping to 19.01 kbps, latency surging to 130.9 ms, and packet loss reaching 19 percent due to buffer saturation at the core switch. Conversely, the proposed OSPF and VLAN framework effectively contains broadcast domains and dynamically re routes data, maintaining a throughput of 47.3 kbps, reducing delay to 27.6 ms, and completely preventing packet loss. These findings confirm that logical segmentation and redundant dynamic routing safeguard critical broadcasting operations against severe network congestion. To provide a clear visual comparison of these empirical indicators under heavy traffic load the comparative performance metrics are depicted in Figure 5 below.

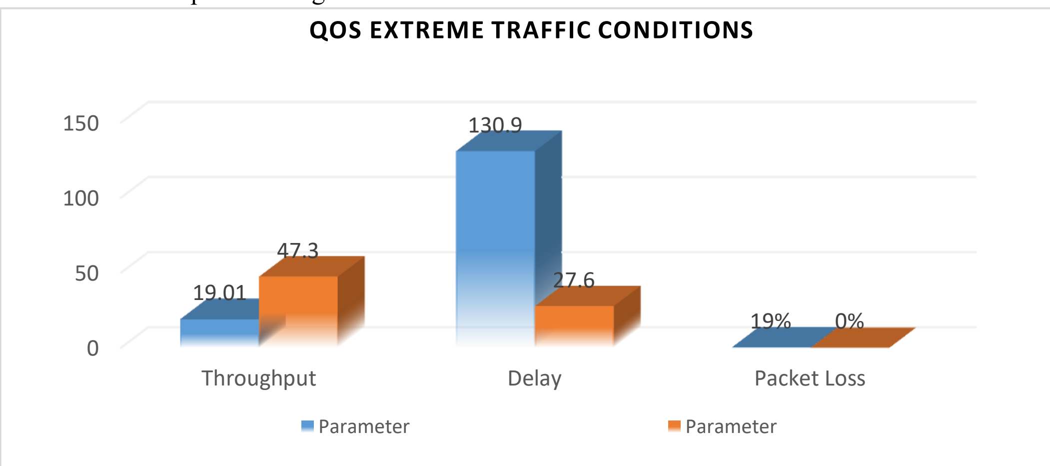

Figure 5. Comparison of Average QoS Parameters under Extreme Traffic Conditions

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System Availability and OSPF Failover Results

To evaluate network continuity and fault tolerance during physical outages, availability testing simulated a sudden primary gateway shutdown to measure recovery speed, path convergence, OSPF dynamic recalculation, and packet loss during failover to the secondary path.

Table 5. System Availability and Failover Test Results

Source Point	Destination Point	Parameter	Baseline Results	Proposed Results	Technical Conclusion
Main Router	Router ISP Indibiz	Availability	0% (Down)	100% (Success)	OSPF Failover Fully Functional

During link disconnects on the baseline flat network, shutting down interface FastEthernet0/0 caused total transmission failure without dynamic redundancy, dropping fourteen of twenty ICMP packets for a seventy percent packet loss and a thirty percent success rate.

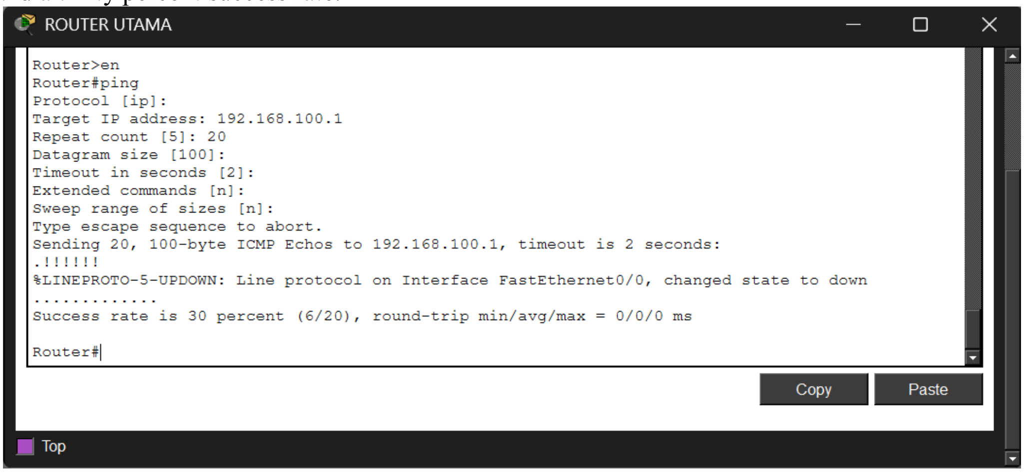

Figure 6. Transmission Failure Log on Existing Network Topology

In contrast, the proposed dual router architecture running OSPF Area zero demonstrated instant dynamic rerouting. Upon primary interface GigabitEthernet0/0 failure, the OSPF process immediately dropped the unviable adjacency, recalculated the shortest path via Dijkstra algorithm, and seamlessly shifted traffic to the secondary route with zero packet loss, achieving a full one hundred percent (20/20) delivery success rate:

Figure 7. OSPF Failover Convergence Log on Proposed Network Topology

DISCUSSION

Transitioning from an unsegmented flat topology to a dynamic OSPF Area zero architecture integrated with Virtual LAN segmentation resolves fundamental network bottlenecks, eliminates single point of failure vulnerabilities, and significantly enhances overall Quality of Service. In the baseline topology, all nodes share a single broadcast domain, causing average throughput to collapse from 50.49 kbps to 19.01 kbps, delay to surge to 130.9 ms, and packet loss to reach 19 percent under extreme traffic stress. These findings confirm that unsegmented networks suffer from buffer overflow and queue congestion, directly threatening time sensitive broadcast services like vMix streaming and audio logging.

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Integrating Classless Inter Domain Routing across four dedicated Virtual LAN zones, covering production, newsroom, administration, and guest access, effectively confines broadcast domains within logical boundaries. Under normal conditions, average throughput increased threefold from 50.49 kbps to 146.7 kbps, delay decreased to 7.3 ms, and packet loss dropped to zero percent. Even under extreme stress, the proposed framework maintained 47.3 kbps throughput, 27.6 ms delay, and zero percent packet loss, proving that logical isolation protects queue capacity for core broadcast nodes.

Operating on the Dijkstra algorithm, dynamic OSPF Area zero provides superior continuous resilience compared to the baseline single gateway topology, which suffered total communication blackout during interface failures. When GigabitEthernet0/0 was forcefully shut down, the dual router configuration recalculated adjacencies and rerouted traffic via the secondary path without losing a single packet, achieving a one hundred percent delivery success rate. This architecture guarantees high Quality of Service standards required for digital broadcasting workflows, permanently resolving bandwidth congestion and link stability challenges at LPP RRI Lhokseumawe. However, full failover availability is currently limited to external ISP link outages. The local distribution relies on a single trunk cable from the switch to the primary router, which retains a potential single point of failure if that internal physical link breaks.

CONCLUSION

This study successfully evaluated, modeled, and optimized the local area network architecture at Lembaga Penyiaran Publik Radio Republik Indonesia Lhokseumawe using Cisco Packet Tracer simulations. The analysis demonstrates that the baseline unsegmented flat topology suffers from structural bandwidth bottlenecks, high susceptibility to broadcast storms, and severe single point of failure vulnerabilities that threaten operational blackouts during link outages. By implementing dynamic OSPF Area zero routing integrated with Virtual LAN logical segmentation, the proposed architecture effectively resolves these limitations. Empirical QoS measurements confirm that the optimized network completely eliminates packet loss across both normal and extreme traffic conditions while drastically reducing latency across mission critical broadcasting nodes, such as PC Streaming, PC Audio Logger, and PC vMix.

Furthermore, availability testing validates that OSPF dynamic failover achieves immediate convergence during primary link failures, maintaining a seamless one hundred percent packet delivery success rate without operational disruption. To sustain long term digital broadcasting reliability, LPP RRI Lhokseumawe is advised to establish a phased migration roadmap and strengthen physical hardware redundancy across its local distribution layer. While this research provides robust empirical evidence within a simulated logical environment, future studies are recommended to validate these findings through live physical hardware deployment using enterprise grade switches and routers, alongside exploring advanced Quality of Service queuing mechanisms and Access Control List security policies to support expanding broadcast infrastructure.

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