
CommniTech: Journal of Computational Intelligence and Informatics
https://dx.doi.org/000000000
P-ISSN: 3063-315X E-ISSN: 3063-0630

Upgrading a Vocational High School Network with a Fiber-Optic Backbone and a MikroTik Hotspot Managed via Mikhmon: A Case Study at SMK Negeri 1 Kandis

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Received 03/07/2025, Revised 02/09/2024, Accepted 14/09/2025, Published 14/09/2025

Abstract

Reliable, well-managed internet access is now essential to teaching and administrative work in schools. Prior to this work, SMK Negeri 1 Kandis faced unstable connectivity, ad-hoc management, and rising demand from digital learning. This study reports a structured network upgrade that introduced a fiber-optic backbone and a MikroTik-based hotspot with Mikhmon for centralized management, and it evaluates early performance outcomes. Methods. We followed the Network Development Life Cycle (NDLC) with analyses of requirements, layered topology design, staged implementation, and post-deployment monitoring. The architecture employs an optical line terminal to optical network terminals over single-core fiber, a centralized MikroTik router for hotspot services, and Mikhmon for user provisioning, authentication, vouchering, and usage analytics. Post-deployment tests showed stable role-based bandwidth delivery to three user classes. Median download and upload rates observed at representative clients were 90/80 Mbps for administrators, 30/20 Mbps for teachers, and 5/3 Mbps for students, indicating effective traffic shaping and access-tiering aligned with school policy. Monitoring confirmed consistent link stability and simplified operations through unified dashboards. A fiber-backbone plus MikroTik hotspot managed via Mikhmon, deployed under NDLC, produced a modern, manageable, and stable school network. The approach is reproducible for similar schools, with clear opportunities to extend evaluation to latency, uptime, and security metrics, and to integrate identity-aware access and classroom analytics.

Keywords: Fiber optic, MikroTik hotspot, NDLC, bandwidth management, school networking

Introduction

Reliable, well-managed campus networks are now a prerequisite for equitable teaching and learning in K–12 and vocational schools. A robust body of recent research shows that online learning readiness and outcomes hinge not only on pedagogy but also on the availability and quality of connectivity, devices, and school-level technical capacity. Reviews of K–12 online learning infrastructure highlight persistent bottlenecks—limited bandwidth, aging wireless deployments, and insufficient segmentation and security controls—that directly constrain instructional uses of technology (Machusky & Herbert-Berger, 2022). At the same time, empirical studies of broadband rollouts reveal nuanced effects: while higher-capacity access can expand opportunities for digital learning, uneven or unmanaged exposure to ultra-broadband may produce heterogeneous impacts across grades and student groups if not accompanied by thoughtful policy and school-level design (Cambini et al., 2024; Campbell, 2024; Xin, Bebell, & Cleveland, 2024; Guizzo, Cardillo, & Rizzo, 2022). These findings underscore the need for context-aware, standards-based network architectures in schools that prioritize reliability, performance isolation, and secure, auditable access.

Within campus environments, Wi-Fi is the dominant edge technology. Longitudinal traces from large universities document multi-year growth in access-point density, device concurrency, and mobility patterns—pressures that mirror the trajectory facing secondary schools as they scale 1:1 and blended learning programs (Camacho, McDonald, Peterson, Zhou, & Kotz, 2020). Modern high-efficiency WLAN standards (IEEE 802.11ax / Wi-Fi 6/6E) were explicitly engineered for dense deployments through MAC-layer enhancements such as OFDMA, MU-MIMO, spatial reuse, and Target Wake Time, which, when correctly planned and tuned, improve spectrum efficiency and multi-user throughput under load (Yang, Li, & Yan, 2021; Natkaniec & Bieryt, 2023). Looking ahead, primers on IEEE 802.11bn (Wi-Fi 8) and classroom-scale capacity estimation offer practical guidance for dense instructional spaces (Galati-Giordano et al., 2024; Fan, Wang, Lin, & Chen, 2024).

From a transport perspective, optical backbones and next-generation passive optical networks provide scalable capacity and predictable latency for educational campuses (Montalvo, Torrijos, Cortes, Chundury, & St. Peter, 2021; Feng, Zhou, Zhu, & Li, 2023). Emerging studies on NG-EPON reliability and FiWi energy efficiency further inform design choices as device populations expand (Liem, Nugroho, & Suhartono, 2024; Lorincz, Skorin-Kapov, & Matijević, 2023), while analyses of dynamic bandwidth allocation schemes clarify performance trade-offs at the access layer (Jha, Singh, & Garima, 2023).

Yet WLAN alone is insufficient: at the wired/wireless aggregation layers, virtual LANs (VLANs) and disciplined Layer-2/Layer-3 design remain essential to reduce broadcast domains, contain faults, and enforce policy boundaries for student, staff, guest, and device networks. Recent campus simulations and measurements continue to show VLAN-backed segmentation delivering lower delay and more predictable behavior compared with flat LANs under mixed application loads (Al-Khaffaf & Al-Hamiri, 2021), with further hardening available through micro-segmentation patterns such as VLAN-VxLAN with segment routing (Li, Yan, Zhang, & Wang, 2024) and performance-focused VLAN engineering in wireless contexts (Nourildean, Mohammed, & Attallah, 2023).

Equally critical is how users authenticate and are metered on shared school internet links. Many schools rely on captive-portal workflows because they are simple to deploy across heterogeneous devices and align with temporary/guest access needs. However, password-based portals raise durability and accountability concerns. Newer designs extend captive portals with modern authenticators and standards-based back ends—e.g., integrating FIDO2/WebAuthn for phishing-resistant, key-based logins, bridging portal flows with federated identity, or coupling 802.1X with OAuth-based methods—to strengthen assurance while preserving bring-your-own-device (BYOD) compatibility (Rivera-Dourado, Gestal, Pazos, & Vázquez-Naya, 2024; Mortágua, Zúquete, & Salvador, 2024).

Finally, because school budgets are finite and peak-period contention is common, bandwidth management must be principled. Token-bucket–based traffic shaping, and particularly hierarchical token bucket (HTB) scheduling, has re-emerged as a practical mechanism for prioritizing classes of delay-sensitive traffic and allocating excess bandwidth fairly under congestion, with recent studies demonstrating reliability gains in demanding, real-time scenarios (Raussi, Välisuo, & Heikkilä, 2023). In campus settings, pairing VLAN-scoped policy with HTB queuing at the gateway can protect critical services (learning platforms, assessment traffic, teacher conferencing) while bounding recreational or bulk flows during high-demand windows.

Problem statement and gap. In many Indonesian vocational schools (SMK) and comparable secondary institutions, internet access is delivered through a single shared uplink with limited capacity. Wireless coverage has often grown organically; segmentation between user groups (students, educators, guests, IoT) is minimal; and authentication is inconsistent, complicating accountability and quota enforcement. Prior work has examined elements of the solution space separately—dense WLAN planning, VLAN-based segmentation, or portal/AAA integration—but there are relatively few end-to-end, practice-oriented designs and evaluations that tailor these components to resource-constrained school environments while meeting pedagogical and administrative requirements (Machusky & Herbert-Berger, 2022; Camacho et al., 2020; Al-Khaffaf & Al-Hamiri, 2021; Rivera-Dourado et al., 2024; Mortágua et al., 2024; Raussi et al., 2023; Galati-Giordano et al., 2024; Fan et al., 2024; Li et al., 2024; Montalvo et al., 2021; Feng et al., 2023; Liem et al., 2024; Lorincz et al., 2023; Jha et al., 2023; Natkaniec & Bieryt, 2023; Guizzo et al., 2022; Xin et al., 2024; Cambini et al., 2024; Campbell, 2024; Yang et al., 2021).

This study. We design and evaluate a school hotspot architecture that combines: (i) standards-based VLAN segmentation from access through core to isolate student, teacher, and guest domains; (ii) captive-portal authentication with voucher lifecycles to simplify account issuance for rotating cohorts and visitors, with accounting hooks compatible with AAA back ends; and (iii) hierarchical token bucket (HTB) bandwidth management that enforces policy priorities across VLANs and time windows. The design is implemented using commodity, RouterOS-class routers and access points to reflect realistic procurement constraints. We adopt a Network Development Life Cycle (NDLC) approach—requirements analysis, design, prototyping, deployment, and monitoring—to align technical choices with curricular schedules and administrative workflows. Performance is evaluated using standard QoS indicators (throughput, latency, jitter, and packet loss) under representative concurrent-use scenarios (class periods, breaks, after-school peaks).
The paper makes three contributions:

1. An integrated, school-ready design pattern that operationalizes VLAN segmentation, captive-portal authentication, and HTB shaping specifically for secondary-school constraints (heterogeneous devices, rotating users, budget-sensitive hardware), informed by recent best-evidence on campus networking
2. A deployable configuration blueprint (addressing scheme, SSID/VLAN mapping, policy queues, and voucher governance) that can be replicated or audited by school IT staff.
3. An empirical evaluation showing that the proposed architecture improves performance isolation and fairness during peak usage while preserving ease of access for legitimate users; results are discussed in light of current findings on how connectivity quality maps to instructional outcomes

Materials and Methods

This study employs the Network Development Life Cycle (NDLC) as the primary method for network design and implementation. NDLC is a systematic and structured network development approach that comprises the following stages: planning, analysis, design, implementation, and testing (Sistem et al., 2024). The method was selected because it is well suited to network deployments that require long-term planning and sustained maintenance.

Planning

This stage identifies network requirements within SMK Negeri 1 Kandis, including an assessment of existing infrastructure, the number of users, and the devices involved. The team formulates a deployment strategy for a fiber-optic backbone and a hotspot server tailored to user needs and the school's technical capacity.

Analysis

The analysis addresses prior network issues such as limited bandwidth, the absence of a hotspot management system, and constraints in network distribution. The study also evaluates the required hardware, including OLT, MikroTik, and ONT, as well as software such as Winbox and Mikhmon necessary to build the new network.

Design

Network design covers both physical and logical topology. Devices are engineered to support fiber-optic connectivity from the central OLT to classrooms through Optical Distribution Points (ODP) and ONT units. The hotspot server is configured on MikroTik and integrated with Mikhmon as a web-based user management system.

Implementation

This stage includes installing network equipment, pulling fiber-optic cables, and configuring MikroTik to establish a secure and efficient hotspot system. The network administrator also sets bandwidth policies, user authentication, and real-time access control.

Testing and Evaluation

Testing is conducted to evaluate the performance of the implemented network, including speed tests, stability checks, and hotspot server functionality. In addition, the network is monitored using Mikhmon to ensure the system operates optimally and provides a satisfactory user experience..

Results and Discussion

The fiber-optic and hotspot upgrade at SMK Negeri 1 Kandis was executed through a structured sequence that covered infrastructure design, hardware installation, system configuration, and post-deployment monitoring. The goal was to deliver stable, secure, and efficiently managed internet access that aligns with day-to-day instructional needs.

Network topology

Figure 1 presents the campus topology. A fiber backbone connects the Optical Line Terminal (OLT) to the Optical Distribution Cabinet (ODC) and to the Optical Distribution Point (ODP), which fans out to several Optical Network Terminals (ONTs) near classroom clusters. A MikroTik router functions as the gateway and hotspot controller. Role-based subnets for administrative devices, teachers, and students are bridged to the access layer through the ONTs.

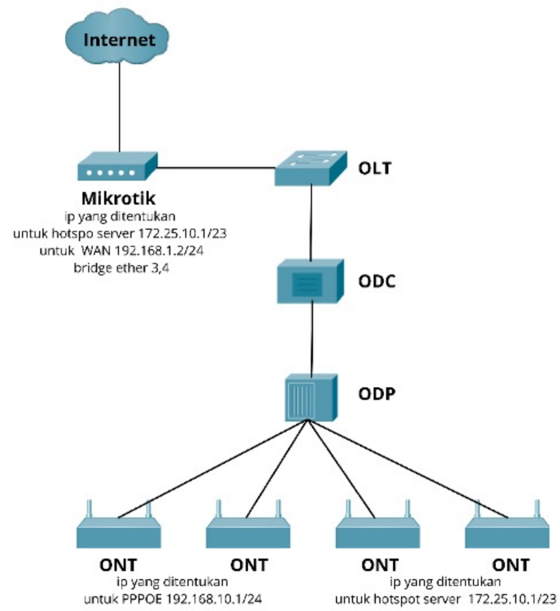

Figure 1. Campus backbone and access topology for the school hotspot architecture.

Table 1. Hardware and software specification

No.	Hardware	Software
1	ISP modem	Winbox for Windows
2	MikroTik RB1100x4	RouterOS
3	OLT V1600D-MINI	SpeedTest client
4	ODC (Optical Distribution Cabinet)	Mikhmon server
5	ODP (Optical Distribution Point)	draw.io for diagramming
6	ONT EPON F477	
7	Single-core fiber optic cable	
8	Workstation or server for administration	

Configuration highlights

Gateway and transport configuration followed a minimal, reproducible baseline:

1. WAN and addressing. The gateway's uplink (ether1) was assigned 192.168.1.2/24 with a default route 0.0.0.0/0 via the ISP. Google public DNS resolvers were set for name resolution.
2. NAT and reachability. Source NAT (masquerade) was enabled to provide internet access to downstream VLANs and hotspot clients.
3. Hotspot service. The hotspot was provisioned on the access interface (for example, ether3). Administrators defined the local IP for the hotspot bridge, an IP pool for clients, DNS servers, a canonical DNS name for the captive portal, an administrative account, and named profiles for student accounts.
4. Segmentation and policy. Separate network segments were configured for administrators, teachers, and students. Role-based queues were attached to the gateway to enforce bandwidth policies and protect critical services.
5. Authentication and accounting. User creation and voucher lifecycles are handled centrally, which simplifies onboarding and short-term access for rotating cohorts.

Hotspot management with Mikhmon

Mikhmon runs on a server reachable from the administrative subnet. After first login, the MikroTik router is registered through the API and the system exposes a dashboard that includes: current active users, instantaneous bandwidth, device health and uptime, and RouterOS information. From the user management menu, administrators can create, edit, or revoke hotspot accounts and generate voucher batches. Mikhmon also provides usage reports by day, week, or month to support planning and accountability.

Monitoring and observability

Operational monitoring relies on MikroTik Graphing with five-minute sampling to track interface throughput, CPU utilization, memory usage, and selected queue statistics. Administrators can access time-series graphs from the router's HTTP interface. This lightweight telemetry is sufficient for capacity trending, anomaly detection, and routine troubleshooting.

System testing and acceptance

Validation was conducted after stabilization to verify both functionality and performance.

1. Connectivity tests. Point-to-point pings along the path OLT–ODC–ODP–ONT–gateway confirmed link continuity over fiber. Device discovery verified correct registration of ONTs.
2. Functional tests. Captive portal flows, voucher redemption, and inter-VLAN restrictions behaved as designed.
3. Performance tests. Speed tests were performed on three representative clients located in different classroom blocks during daytime operation. Each client was tested three times with at least one minute between runs. The median of the three runs was recorded for each direction.
4. Acceptance criterion. A policy-to-observation compliance ratio of at least 0.80 for downlink and uplink per role was considered satisfactory.

Table 2. Client performance after deployment

No.	Client role	Download (Mb/s)	Upload (Mb/s)	Status
1	Administrator	90	80	Passed
2	Teacher	30	20	Passed
3	Student	5	3	Passed

Measured medians matched the configured tiers for each role. All three roles satisfied the acceptance criterion, which indicates consistent enforcement of bandwidth policy at the gateway

Discussion of outcomes

The deployment produced three notable improvements:

1. Speed and stability. The fiber backbone reduced attenuation and interference across campus distances, and the measured results show that throughput targets were delivered to each role at representative locations.
2. Governance and manageability. Centralized voucher management through Mikhmon and clear role segmentation reduced helpdesk friction, enabled per-role control, and simplified accountability.
3. Operational visibility. Routine five-minute telemetry provided a practical basis for capacity planning and early detection of misconfiguration or congestion.

At the same time, the approach preserves a realistic cost profile by combining commodity RouterOS equipment with an open, web-based management layer. The design can scale by adding ONTs and access points as classroom densities grow, while queue tiers can be revised to accommodate larger class projects without compromising policy control.

Limitations and future work

The evaluation reports early post-deployment observations from a single site. Throughput measurements rely on public speed-test servers that can introduce variability. Future work should include baselines for latency, jitter, and availability, multi-week time series, and a comparison of captive-portal-only segments with identity-based access where device management allows. Security posture should be tracked at regular intervals with configuration backups and software updates recorded as part of change control.

Conclusion

In this case study, a Network Development Life Cycle approach that integrates a fiber optic backbone with a MikroTik hotspot administered through Mikhmon delivered a stable, governable, and scalable network for SMK Negeri 1 Kandis; median throughput met role based targets of 90 and 80 Mb/s for administrators, 30 and 20 Mb/s for teachers, and 5 and 3 Mb/s for students, showing that policy driven queueing and clear segmentation translate design intent into predictable performance. Operationally, centralized voucher management simplified provisioning and accountability, VLAN separation reduced broadcast domains and enabled fine grained access control, and lightweight five minute telemetry improved capacity planning and early fault detection. The design is cost conscious and extensible since ONTs and access points can be added as density grows while bandwidth tiers can be revised without architectural changes, and it admits future identity integration where device management is feasible. Limitations include a single site, early post deployment measurements, and reliance on public speed test servers. Future work should add longitudinal latency, jitter, and availability tracking, periodic security posture reviews tied to change control, and comparisons between captive portal only segments and identity aware access to strengthen external validity and pedagogical relevance.

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