International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 12 | Dec - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Research Review — Web-Based Computer Network Learning Platform

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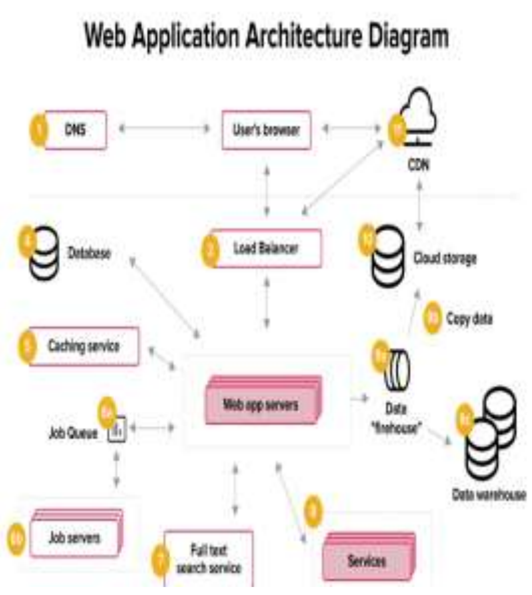
Abstract - Web platforms for computer networks have become vital for studying, training, and conducting remote labs at colleges and universities. These tools include virtual labs, simulators, real-device control, visualization aids, and testing modules, all delivered online to teach networking practically. This review covers recent research (2018- 2025) on web based computer networking systems, grouping them into simulators, emulators, remote labs, and hybrid systems; compares their educational and technical aims; analyses strengths and drawbacks; discusses key platform design factors (scalability, accuracy, interaction, assessment); reviews evaluation methods; and highlights remaining challenges such as balancing realism with cost, ensuring security, maintaining student involvement, and preventing cheating. Finally, we propose future directions: cloud-edge hybrid testbeds, data-driven adaptive learning, containerized remote labs, and new standards for compatibility and reproducibility of experiments.

Keywords: Web-based learning, computer networks education, virtual labs, remote laboratories, network simulation, SDN, NFV, online labs.

1. INTRODUCTION

The teaching of computer networking is hard: students need to see close up how routers are set up, how packets move, how routers choose their routes, how they fail and are fixed- all these things are normally learned in real labs with multiple routers, switches, and cables. Web computer network labs (WB-CNLPs) give students web-based or simulated access to network equipment, allowing for scalable, cost effective, and flexible learning experiences. Because of virtual machines, containers, software defined networking (SDN), and all the progress made in web technology (Web Sockets, WebRTC) modern platforms can be very rich in features and almost lifelike. This review summarizes the research state of WBCNLPs, details what students learn from them and how they are built, and shows what future research could do to raise their resemblance to real networks, improve accessibility and ease of use, and make them more useful as teaching tools.



2. Classification of Web-Based Network Learning Platforms

Researchers can take WB-CNLPs and put them into four main groups:

2.1. Simulation-Based Platforms

Software-Driven Modelling: These tools use packet-level or event-driven simulators to show how nodes, traffic, and protocols work in a virtual but controlled network setting.

Cost-Effective and Flexible: They have no need for physical gear and let many students do experiments at the same time with little computer power.

Best for Theoretical Lessons: Simulators are good for teaching routing, traffic jams, and how protocols run, all things hard to see in a real network.

Less Real: While simulators can teach basics, they miss the chaos of real networks, hardware limits, and how real operating systems work.2.2 MAC and Link Layer Optimization

2.2. Emulation platforms

Running real network software: Emulators run real routing stacks, network daemons, Linux containers, and container routers, giving the student what looks like real results.

High fidelity training: Because real packets are generated and processed, students can debug, tune protocols, and automate networks like on real kit.

Latest virtualization: These systems use VMs, containers, SDN controllers, and cloud backends to deliver advanced networking work.

Costly: Although very realistic, they need powerful computers and backend servers, making them hard to put in many classrooms

2.3. Remote Hardware Labs
Direct Hardware Use: Students can use real routers, switches, wireless testbeds, and cabling setups from a distance. This setup is the most like real networking labs.

Educational Benefits: These labs teach skills hands-on, such as setting up device configs, physical network shapes, finding faults, and testing how well the network works in real-world cases.

Access Issues: Hardware resources are limited. Access is usually booked in advance, and there is a limit to how many students can use these labs at once. This system offers less flexibility than simulation or emulation.

Expense and Upkeep: Running these labs costs a lot in money, power, cooling, and staff needs. Maintaining these labs is hard and costly.

2.4. Hybrid / Blended Programs
Multi-Track Education System: These formats mix simulation, emulation, and remote access to real equipment, providing a full path from basic knowledge to advanced physical work.

Optimal Cost-efficiency and Realism: Blended learning reduces hardware needs and cost by combining virtual and physical tools, preserving high realism where essential.

Unified Learning Environment: Frequently linked with LMS and grading systems, hybrid tools manage user access, experiment tracking, and report creation.

Technical Challenges: Hybrid systems demand complex development, testing, and ongoing maintenance efforts, making them more difficult to create than single-method platforms.

3. Typical System Architectures & Methodologies
A typical modern WB-CNLP architecture include

3.1. Front End Interface

1. Web-Based Platform: Students can access through modern web browsers using technologies like WebSocket and WebRTC for real-time data transfer.

2. Topology Creation Tools: Students can build network layouts through drag-and-drop features (for example, drag and place routers, switches, hosts, and connect them).

3. Built-In CLI Ports: Students can use integrated terminal interfaces to connect directly to virtual nodes or shell routers.

4. Visualization Tools: The system offers packet trace viewers, link status updates, dashboards, and live speed graphs to help students better understand network concepts.

3.2. Orchestration Part

1. Setting Up: It makes lab rooms with containers, VMs, or remote box booking.

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2. Sharing Time: It shares computing power between students, giving each space and fair share.
3. Tech Link: Usually it runs on Kubernetes, a custom orchestrator, SDN controller, or cloud interface (AWS, GCP, OpenStack).
4. Fail Safe & Grow: It grows labs when many students want rooms, or restarts labs if they crash.

3.3 Execution Layer

1. Emulation Engines: Executes network tests on platforms such as Mininet, CORE, EVE-NG, GNS3, or virtual router containers.

2. Virtual Routing: Enables authentic routing protocols using FR Routing, Quagga, or vendor specific router images.

3. Hybrid Connectivity: Combines virtual systems with actual routers/switches via SSH, NETCONF, or RESTCONF.

4. Real-Time Packet Management: Creates, routes, and analyses packets in scenarios mimicking real-world network environments.

3.4 Observation and Scoring Tools

1. Collects Data: Records student commands, network statuses, timestamps, and activity logs during the lab.

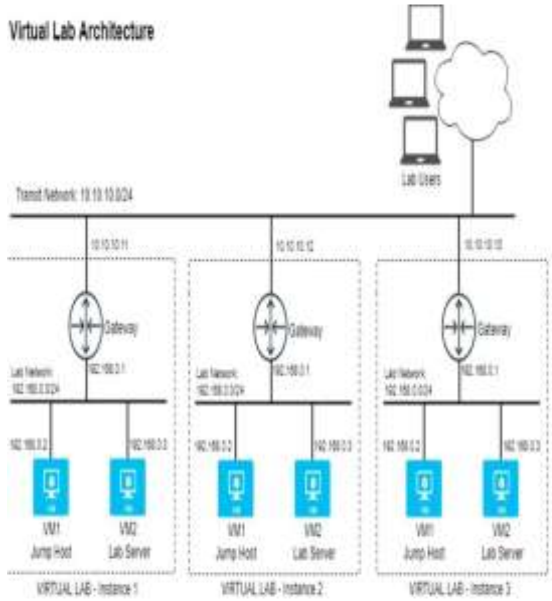
2. Automated Checks: Verifies student setups or outputs against correct answers using scripts or rules.

3. Immediate Reports: Provides hints, errors, and performance summaries to the user interface.

4. Cheating Detection: Monitors for unusual activities, copied work, or repetitive command logs to ensure fair use.

3.5. Educational Methods

1. Gradual learning tasks: labs start with simple actions (IP addresses, pings) and move to more complex ones (BGP, SDN, traffic shaping).
2. Practice tools: Students use simulation tools to test ideas before full lab work begins.
3. Safe zones: Each learner gets a safe space to prevent issues and safeguard group resources.
4. Data collection: Records all actions in detail to teach, monitor student activity, and confirm honesty.



4.Challenges and Research Gaps

Fidelity versus scalability balance: Detailed replication or system access is costly and hard to expand for larger groups. Need to explore small fidelity-preserving methods.

Standardized lab blueprints and compatibility**:** Without standard descriptions, sharing and reuse are complex.

Remote lab integrity and academic honesty: Ensuring original work and preventing sharing solutions is an open issue; automated proctoring tools are needed.

Authentic failure experience: simulators don't replicate real failure modes accurately; students may not learn to identify hardware faults.

Universal access and inclusivity**:** Tools must work on various devices and support disabled users.

Safety and quarantine: Multiple users on the same system require better isolation and sandboxing to avoid harmful actions impacting infrastructure.

Modern network integrations**:** Maintaining up-to-date SDN, NFV, 5G/6G lab offerings requires ongoing updates and technical staff.

Educational data and evidence**:** Additional research and longer-term studies are essential to link platform features with educational benefits.

5.**Future Directions & Recommendations**

Hybrid Cloud Edge Testbeds: Utilize edge nodes and cloud resources in a flexible manner to operate more advanced labs while maintaining low latency and costs.

Containerized, On-Demand Lab Blueprints: Use predefined, declarative lab templates (YAML format) that can be implemented on any orchestration platform.

Adaptive Learning & Analytics: Employ learning analytics to deliver difficulty adjustments, real-time feedback, and customized lab pathways.

Reproducible Labs & Sharing Protocols: Establish open standards for laboratory descriptions (topology + tasks + grading scripts) to facilitate inter-institutional sharing.

Incorporate Industry Tools: Integrate SDN controllers (Open Daylight, ONOS), NFV toolchains, and commercial APIs to align educational content with industry practices.

Automated, Reliable Grading: Investigate automatic configuration checkers, traffic-based validation, and behaviour comparison against golden traces to minimize opportunities for cheating.

User-Friendly Design: Ensure web interfaces and lab processes are compatible with low bandwidth environments and accessible to users with disabilities.

Security-Minded Architecture: Implement strong tenant separation, monitoring, and secure sandboxes to enable greater experimentation liberty without risking issues.

6.CONCLUSION

Online computer network study tools have developed greatly and are now ready to provide practical learning opportunities. The trend in research shows high enthusiasm for containerized emulation, hybrid models, and data-driven grading. Still, issues of accuracy, scale, testing, and ease of access need solutions. Future projects should focus on creating standardized, distributable lab descriptions, hybrid cloud-edge architectures, and automated grading to scale professional network training.

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