



LEARNEASY: AN ADAPTIVE VISUALIZATION-BASED E-LEARNING PLATFORM FOR NETWORKING EDUCATION

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Abstract: Computer networking concepts such as the OSI and TCP/IP models are inherently abstract and layered, making them difficult for students to comprehend using traditional teaching approaches. Existing methods rely heavily on theoretical explanations and static diagrams, which limit conceptual understanding of real-world data flow. This paper presents LearnEasy, an adaptive visualization-based e-learning platform designed to enhance the learning experience of networking concepts through interactive and immersive 3D visualizations, synchronized narration, and gamified assessments. The proposed system integrates a WebGL-based visualization engine with a user-centric adaptive learning mechanism that personalizes content delivery based on learner performance and interaction patterns. The platform enables users to visualize both encapsulation (sender-side) and decapsulation (receiver-side) processes through step-by-step interactive simulations, providing a complete understanding of packet transformation across network layers. It is developed using modern web technologies including React, Three.js, @reactthree/fiber, @reactthree/drei, FastAPI, and SQLite, ensuring scalability, responsiveness, and real-time synchronization between frontend and backend components. Experimental analysis indicates improved engagement, retention, and conceptual clarity compared to traditional learning approaches. The integration of 3D visualization and adaptive learning provides a comprehensive and accessible solution for networking education.

Index Terms - E-learning, Networking Education, 3D Visualization, Adaptive Learning, Gamification, OSI Model, TCP/IP, Routing, Switching, Encapsulation, Decapsulation

I. INTRODUCTION

Computer networks form the backbone of modern communication systems, enabling data exchange across distributed environments. Core networking concepts such as the OSI and TCP/IP models, along with routing and switching mechanisms, are fundamental to understanding how data is transmitted across network layers. However, these concepts are inherently abstract and layered, making them difficult for students to visualize and comprehend. Understanding both encapsulation (sender-side processing) and decapsulation (receiver-side processing) is essential for comprehending real-world network communication. These processes involve step-by-step transformation of data as it moves through different layers, which is often challenging to grasp using traditional teaching methods. Traditional approaches primarily rely on textbooks, static diagrams, and theoretical explanations, which emphasize memorization rather than conceptual understanding. Although tools such as Cisco Packet Tracer and Wireshark provide practical exposure, they do not offer guided, step-by-step visualization of how data flows and transforms across layers. To address these limitations, this paper proposes

LearnEasy, an interactive and adaptive e-learning platform that transforms abstract networking concepts into dynamic 3D visual experiences. The system provides separate modules for encapsulation and decapsulation, enabling users to understand both forward and reverse data flow. By integrating interactive visualization, narration, and gamification, along with an adaptive learning mechanism that personalizes content based on user performance, the platform enhances engagement and improves conceptual clarity.

II. LITERATURE REVIEW

Several approaches have been proposed to improve networking education. Simulation tools such as Cisco Packet Tracer provide a virtual environment for network configuration but lack conceptual visualization of data flow across layers. Similarly, Wireshark enables packet-level inspection but requires prior knowledge and does not provide guided learning for beginners. Visualization-based learning systems have been introduced to enhance conceptual understanding; however, many of these systems offer only limited interactivity and do not fully represent dynamic data flow processes such as encapsulation and decapsulation. Augmented Reality (AR) and Virtual Reality (VR) approaches provide immersive experiences but are constrained by hardware requirements and cost, limiting their accessibility. Gamification techniques have also been incorporated into educational platforms to improve engagement and retention through quizzes and feedback mechanisms. However, most existing systems fail to effectively integrate visualization, interactivity, and adaptive learning into a single platform. Therefore, there exists a research gap for a lightweight, browser-based system that provides interactive 3D visualization of networking processes, including routing, switching, encapsulation, and decapsulation, along with adaptive learning capabilities. The proposed LearnEasy platform addresses this gap using WebGL-based technologies to deliver an accessible and comprehensive learning experience.

III. PROPOSED SYSTEM

The proposed system, LearnEasy, is an adaptive visualization-based e-learning platform designed to improve the understanding of networking concepts through interactive and immersive learning. The system focuses on key networking modules including OSI model, TCP/IP model, routing, and switching, along with detailed visualization of encapsulation and decapsulation processes.

The platform offers step-by-step 3D visual simulations that show the flow of data between network layers during both sender-side (encapsulation) and receiver-side (decapsulation) operations. This enables learners to clearly learn the way packets are constructed, sent, routed, and processed over the network. The system is deployed with the help of the latest web technologies. React is used to develop the frontend, and Three.js is used to provide WebGL-based interactive 3D visualizations. The combination of react-three-fiber and drei libraries makes possible effective control of 3D elements in the React environment. JavaScript-based animation logic is used to control transitions and interactions in the visualization. Other features like the Web Speech API are offered, synchronized narration, and the Fullscreen API is improved user immersion. HTML and CSS overlays are used to display contextual information when visualizing. The backend is implemented using FastAPI, and SQLite is used for data user progress tracking and storage. An adaptive learning mechanism is also included in the system that customizes content delivery according to user performance. Gamification features like quizzes and progress monitoring are combined to enhance engagement and retention.

IV. METHODOLOGY

The LearnEasy platform methodology incorporates system architecture and workflow to offer an interactive and learning experience of networking concepts. The system is based on a modular client-server model combining frontend visualization, backend processing, and data storage. The system offers two main visualization flows: encapsulation and decapsulation. In the encapsulation flow, data is increasingly encased as it passes through various OSI layers on the sender side. In contrast, the decapsulation flow shows the process of unpacking data at the receiver side. These are implemented with JavaScript-based animation logic to give step-by-step transformation of packets across layers. The frontend is created with React and manages user interaction, module selection, and visualization rendering. The system is based on a modular client-server architecture that combines frontend visualization, backend services, and data storage. Three.js with is used to implement the visualization layer. WebGL, embedded with react-three-fiber and drei libraries, which allow real-time 3D representation of networking. browsers can directly execute processes. Other features are Web-based narration. Speech API and immersive visualization with the Fullscreen. API. Layerspecific information and user guidance are displayed using HTML and CSS overlays, which are used to guide the user during interaction. The backend is written in FastAPI, which handles user authentication, quiz assessment, and adaptive learning logic. SQLite is employed to store user data, progress, and module information. Communication between frontend and RESTful APIs are used to handle backend, which guarantees realtime synchronization. The overall workflow begins with user authentication, then there is the selection of modules.

The is based on user input. system loads the appropriate visualization sequence (encapsulation or decapsulation). Users are able to communicate with. quizzes to assess their understanding, and the system adapts following material depending on performance, improving. personalized learning.

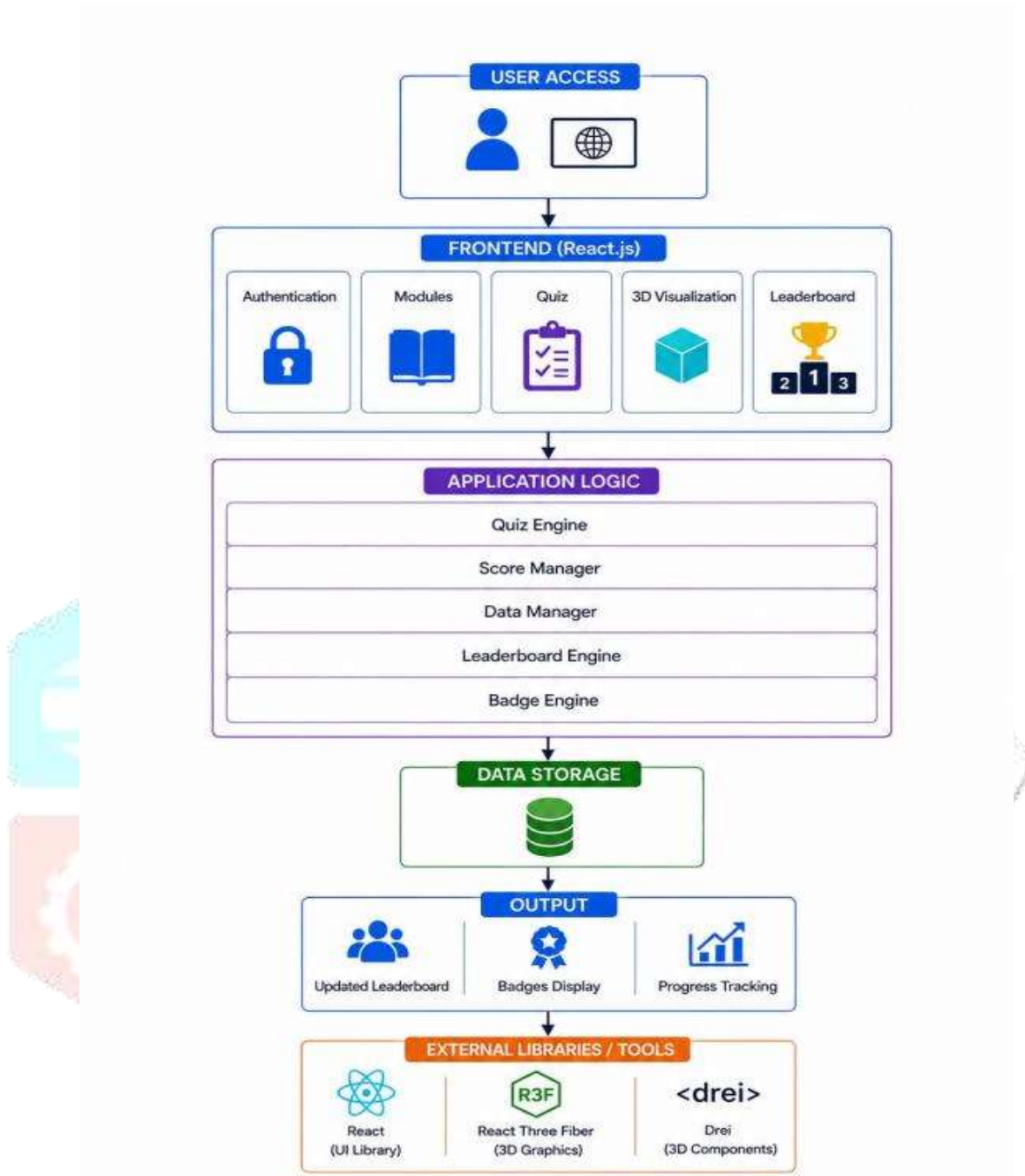


Fig. 1. System Architecture of LearnEasy Platform

V. RESULTS AND DISCUSSION

The LearnEasy platform was evaluated based on its ability to improve conceptual understanding of networking topics through interactive visualization. The system provides modules for OSI model, TCP/IP model, routing, and switching, with dedicated visualization flows for encapsulation and decapsulation processes. The implementation of WebGL-based 3D visualization using Three.js enabled users to observe packet flow across different layers in a more intuitive manner. The encapsulation module demonstrated how data is progressively wrapped at each OSI layer on the sender side, while the decapsulation module illustrated how data is unpacked at the receiver side. This bidirectional visualization significantly improved learners' understanding of data transmission. Furthermore, the platform demonstrated consistent performance across different modules, including OSI, TCP/IP, routing, and switching. Users were able to interact with visual elements in real time, enabling a deeper understanding of packet flow, routing paths, and layer-wise data

transformation. The encapsulation and decapsulation modules provided a clear distinction between sender-side and receiver-side operations, allowing learners to visualize bidirectional data flow effectively. The integration of narration using the Web Speech API further enhanced the learning experience by providing step-by-step explanations synchronized with animations. The quiz module reinforced learning through gamification, encouraging user interaction and retention. Experimental observations indicate that users were able to grasp networking concepts faster compared to traditional methods. The platform showed improvement in engagement, clarity, and retention. A comparative analysis between traditional learning approaches and LearnEasy is shown in Table I.

TABLE I

COMPARISON OF TRADITIONAL LEARNING AND LEARNEASY

Feature	Traditional Learning	LearnEasy
Visualization	Static	Interactive 3D
Engagement	Low	High
Understanding	Moderate	High
Personalization	None	Adaptive
Accessibility	Limited	Web-based



Fig. 2. LearnEasy Homepage Interface

The homepage gives a summary of the platform, including the main features of the platform, which are module access, user engagement metrics, and interactive learning options.

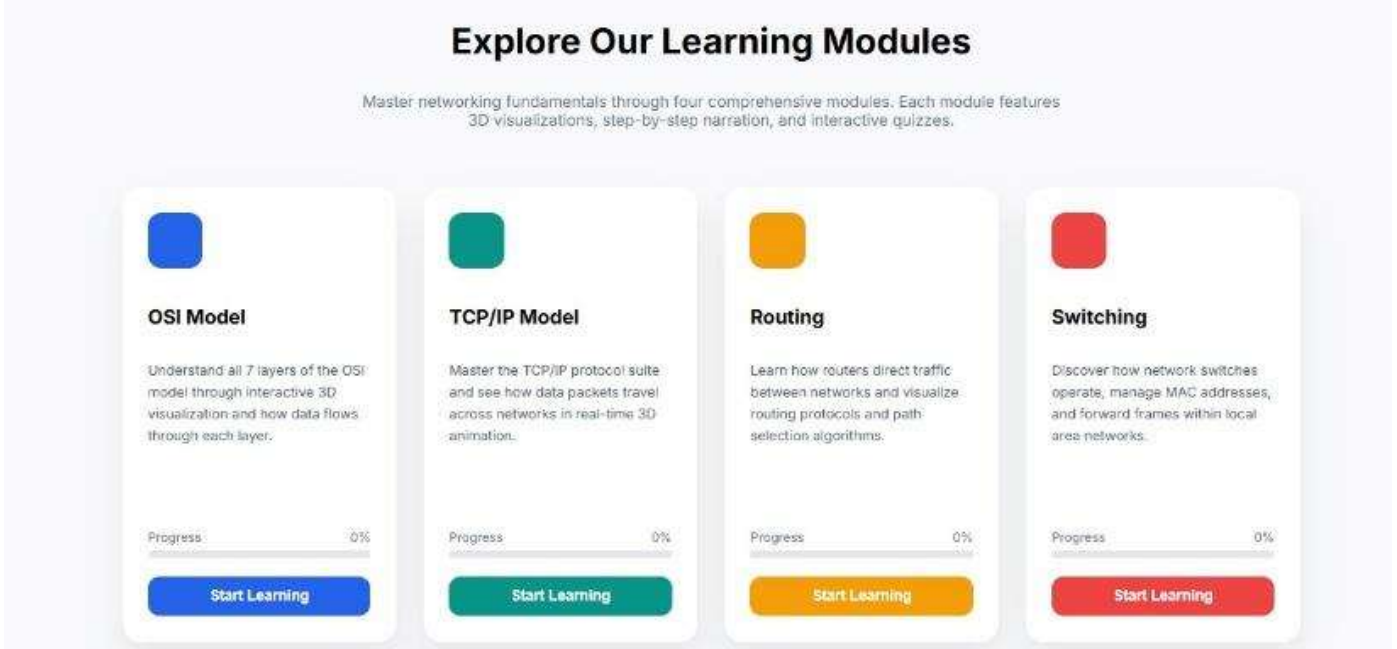


Fig. 3. LearnEasy Module Selection Interface

This interface enables the user to choose various networking modules, such as OSI, TCP/IP, routing, and switching, which offers a systematic learning process.

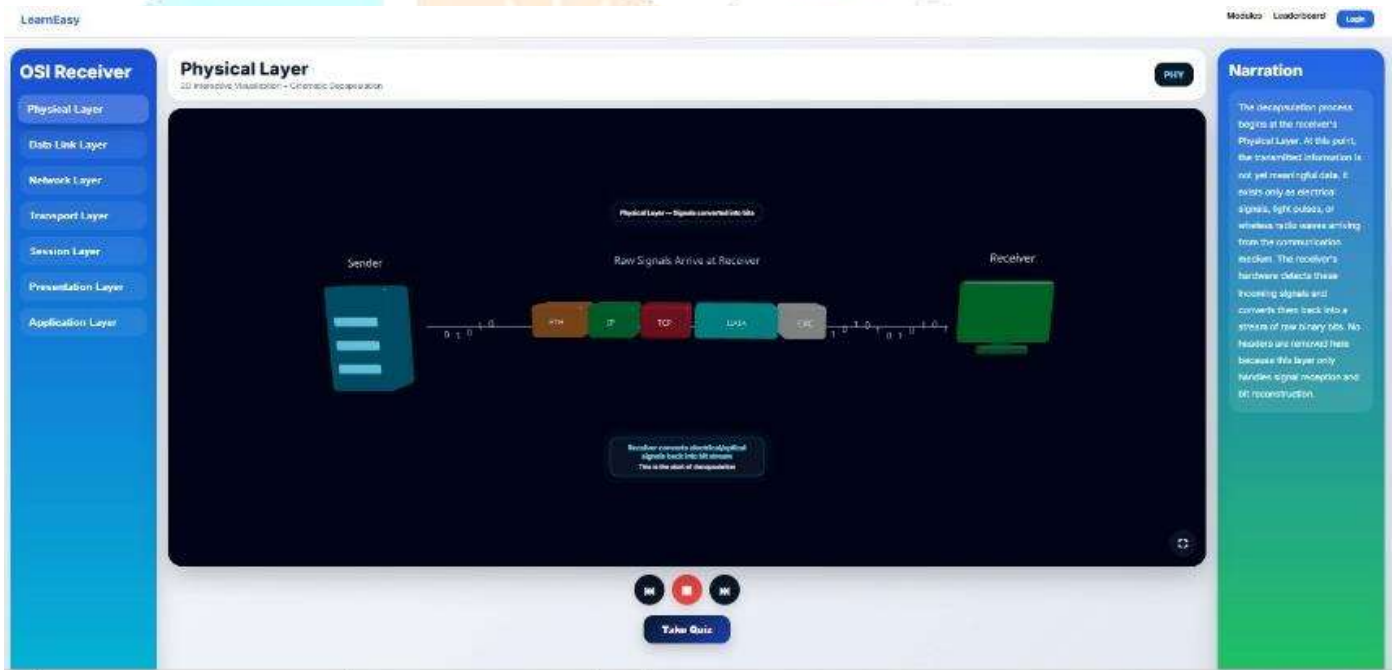


Fig. 4. OSI Layer Visualization

The figure shows the OSI layer visualization, in which the data flow is depicted by interactive 3D animations and synchronized narration.

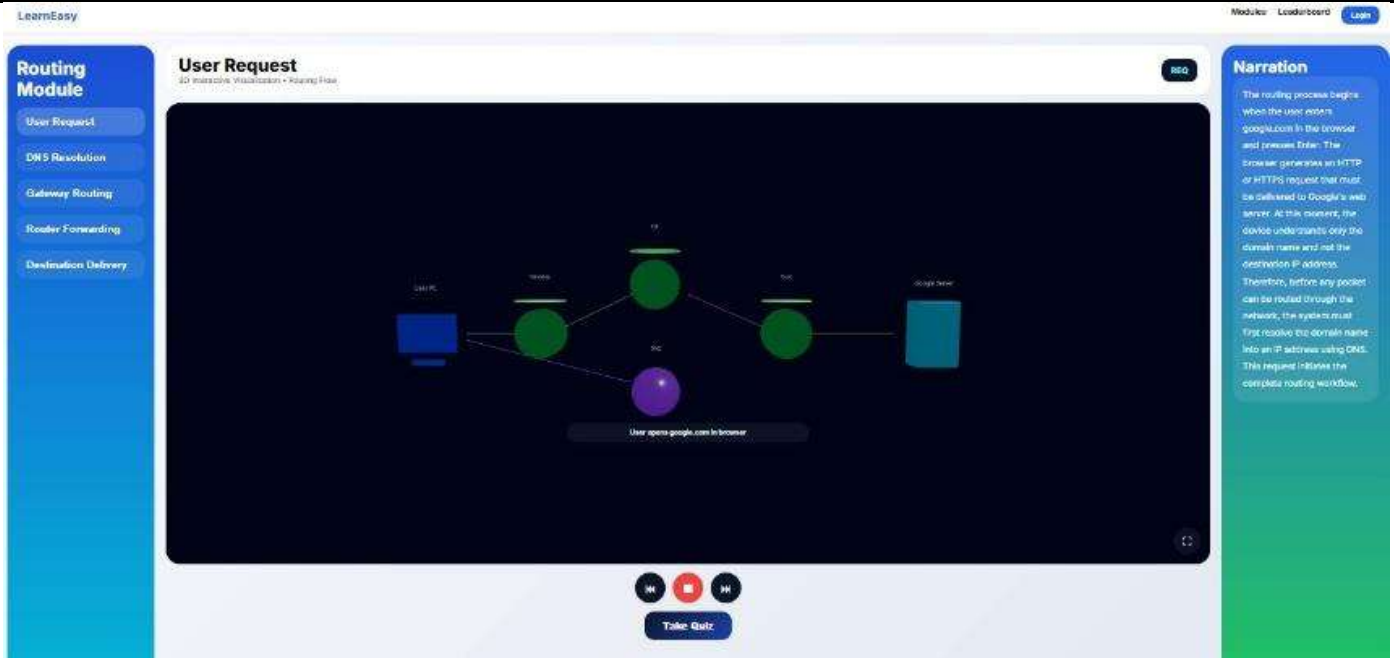


Fig. 5. OSI Decapsulation Process

This diagram illustrates the decapsulation process at the receiver end, and how data is unpacked layer by layer along the OSI model.



Fig. 6. Routing Visualization

The routing visualization displays the path of packets through various network nodes, allowing users to see the real-world data transmission paths.

VI. CONCLUSION

This paper introduced LearnEasy, an adaptive visualizationbased e-learning platform that is aimed at enhancing the knowledge of networking concepts. The system combines interactive 3D visualizations, narration, and gamified tests to convert abstract OSI, TCP/IP, routing, and switching into concepts. intuitive learning experiences. The visualization of WebGL-based visualization with the help of Three.js allows real-time modeling of networking processes, both encapsulation and decapsulation flows. The adaptive learning mechanism further enhances user interaction through customization of content according to patterns of performance and interaction. Experimental it has been observed that the proposed system has a significant impact. enhances conceptual clarity, engagement, and retention. in comparison to conventional learning methods. The platform shows how effective the integration of modern web can be. technologies with adaptive learning strategies in transforming technical education.

VII. REFERENCES

- [1] V. Kumar, "Visualization Teaching Tool for Simulation of OSI Seven Layer Architecture," IEEE, 2004.
- [2] Elsevier, "Gamification in Education," 2020.
- [3] R. Weber et al., "Arena3Dweb: Interactive 3D Visualization," Bioinformatics, 2021.
- [4] NS-3 Consortium, "ns-3 Network Simulator," 2021.
- [5] Cisco Networking Academy, "Packet Tracer," 2022.
- [6] ResearchGate, "Augmented Reality-based Networking Learning," 2023.
- [7] Wireshark Foundation, "Wireshark Tool," 2023.

