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LiveDocs: A Peer-to-Peer Real-Time Collaborative Document Editor Using WebRTC and CRDTs

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Abstract

LiveDocs is a decentralized, real-time collaborative document editor that enables seamless collaboration without centralized servers. It leverages WebRTC for peer-to-peer (P2P) communication and Yjs (CRDTs) for distributed synchronization, ensuring low-latency collaboration, fault tolerance, and scalability. Key features include real-time editing, role-based permissions, instant notifications, and JWT-based authentication for secure access. By eliminating centralized infrastructure, LiveDocs reduces server costs, enhances scalability, and improves fault tolerance, making it a powerful alternative for teams and enterprises needing real-time collaboration.

Problem Statement

Traditional real-time document editors face significant challenges due to high latency and dependence on centralized servers for synchronization and storage. This reliance introduces scalability limitations, single points of failure, and potential privacy risks. As user demand increases, latency issues degrade the collaborative experience, making real-time editing less efficient. To address these challenges, a decentralized approach is required to ensure low-latency, fault-tolerant, and scalable real-time document collaboration without reliance on a central server.

Objective

Develop a decentralized editor to eliminate reliance on central servers and enhance scalability.

Leverage WebRTC-based P2P communication for low-latency and efficient real-time collaboration.

Integrate Yjs (CRDTs) to enable seamless, conflict-free data synchronization across users.

Provide an intuitive UI with modern design for a smooth and responsive editing experience.

Ensure security with JWT authentication, role-based access, and real-time notifications.

Literature Survey

Title	Author(s) & Year	Approach	Limitations	Link
Performance of real-time collaborative editors at large scale: User perspective	Quang-Vinh Dang, Claudia-Lavinia Ignat - 2016	Evaluates large-scale collaborative editors using user interaction data and system logs to assess responsiveness and consistency.	Performance degradation observed under high concurrency, limited consideration for network partition scenarios.	https://ieeexplore.ieee.org/document/7497258
A Personal Distributed Real-time Collaborative System	Michalis Konstantopoulos, Nikos Chondros, Mema Roussopoulos - 2020	A distributed peer-to-peer (P2P) collaborative editing system with decentralized storage, reducing reliance on central servers.	Consistency management becomes complex when multiple users edit simultaneously; relies heavily on stable peer connectivity.	https://ieeexplore.ieee.org/document/10117106
Collaborative Code Editors - Enabling Real-Time Multi-User Coding and Knowledge Sharing	Khushwant Virdi, Anup Lal Yadav, Azhar Ashraf Gadoo, Navjot Singh Talwandi - 2023	Examines collaborative code editors, focusing on WebSocket communication, OT algorithms, and conflict resolution, with a prototype evaluation and comparison to existing platforms.	Persistent issues like latency, synchronization, and conflict resolution remain, requiring further innovation for larger-scale effectiveness.	https://ieeexplore.ieee.org/document/10325722
SecureC2Edit: A Framework for Secure Collaborative and Concurrent Document Editing	Shashank Arora, Pradeep K. Atrey - 2023	Proposes a secure framework for concurrent collaborative editing, integrating cryptographic controls to ensure content integrity.	Increased processing overhead due to encryption; real-time performance is affected in low-bandwidth environments.	https://ieeexplore.ieee.org/document/9036818

Proposed Methodology

Use Next.js for the frontend with a custom collaborative editor.

Apply Yjs (CRDTs) for real-time updates and conflict resolution.

Leverage WebRTC for direct peer-to-peer communication and low latency.

Implement JWT authentication for secure access control.

Store documents in PostgreSQL for reliable backups and fast access.

Enable collaboration features like presence and roles.

Optimize WebRTC and CRDTs for low latency, scalability, and efficient sync.

Tools & Frameworks



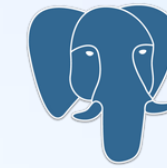
Next.js



TypeScript



Tailwind CSS



PostgreSQL



Prisma



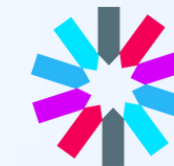
WebRTC



WebSocket



CRDTs (Yjs)



JWT



Git

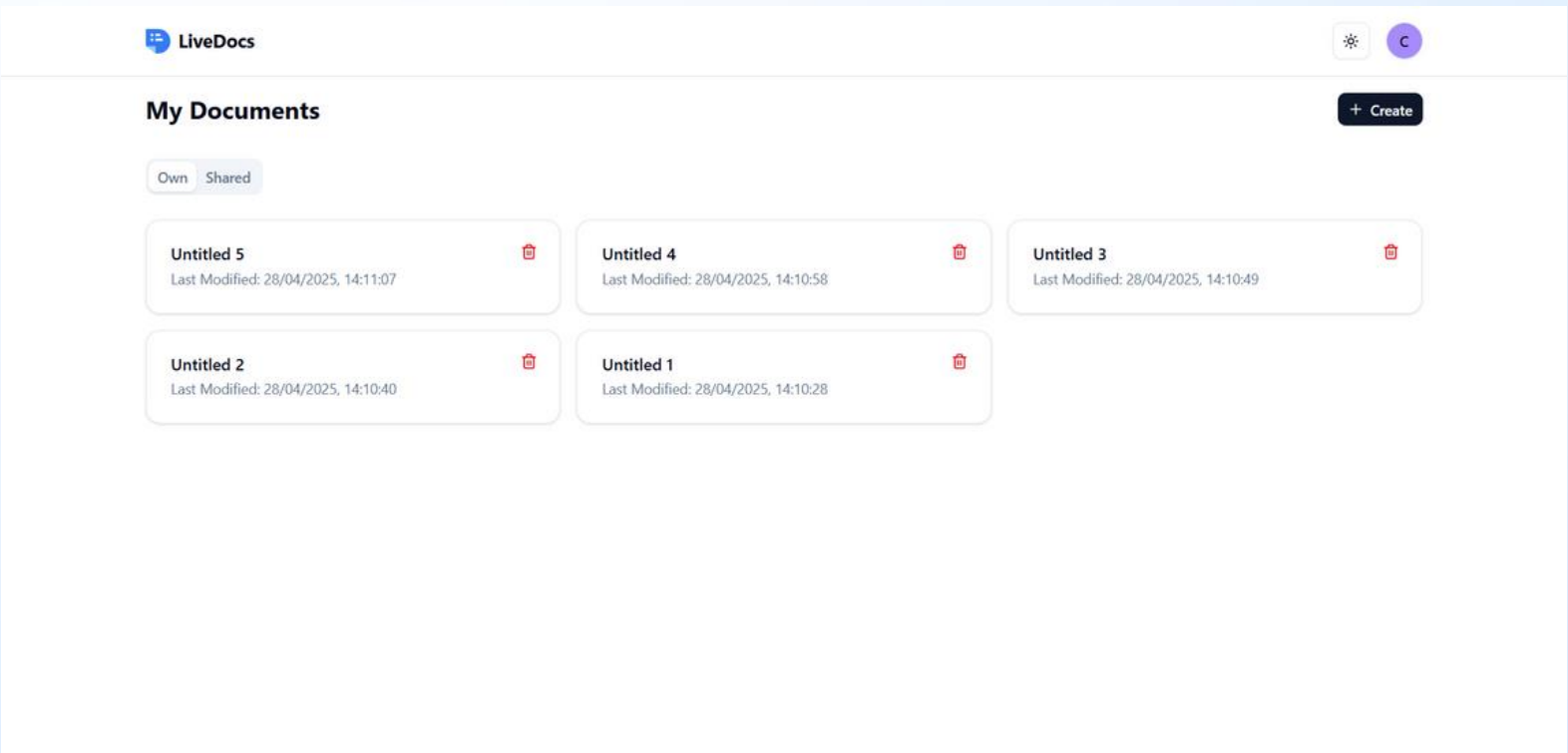
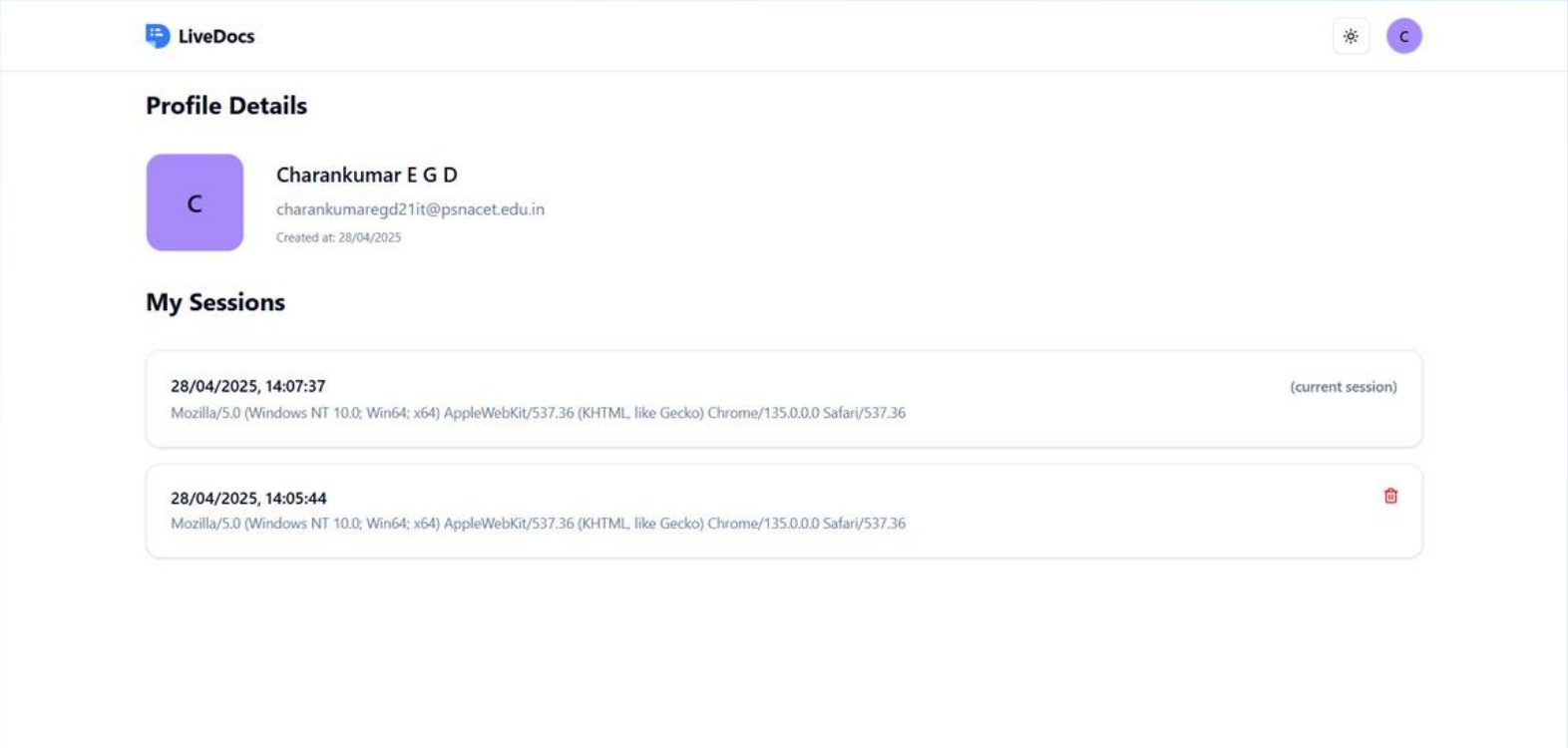


GitHub

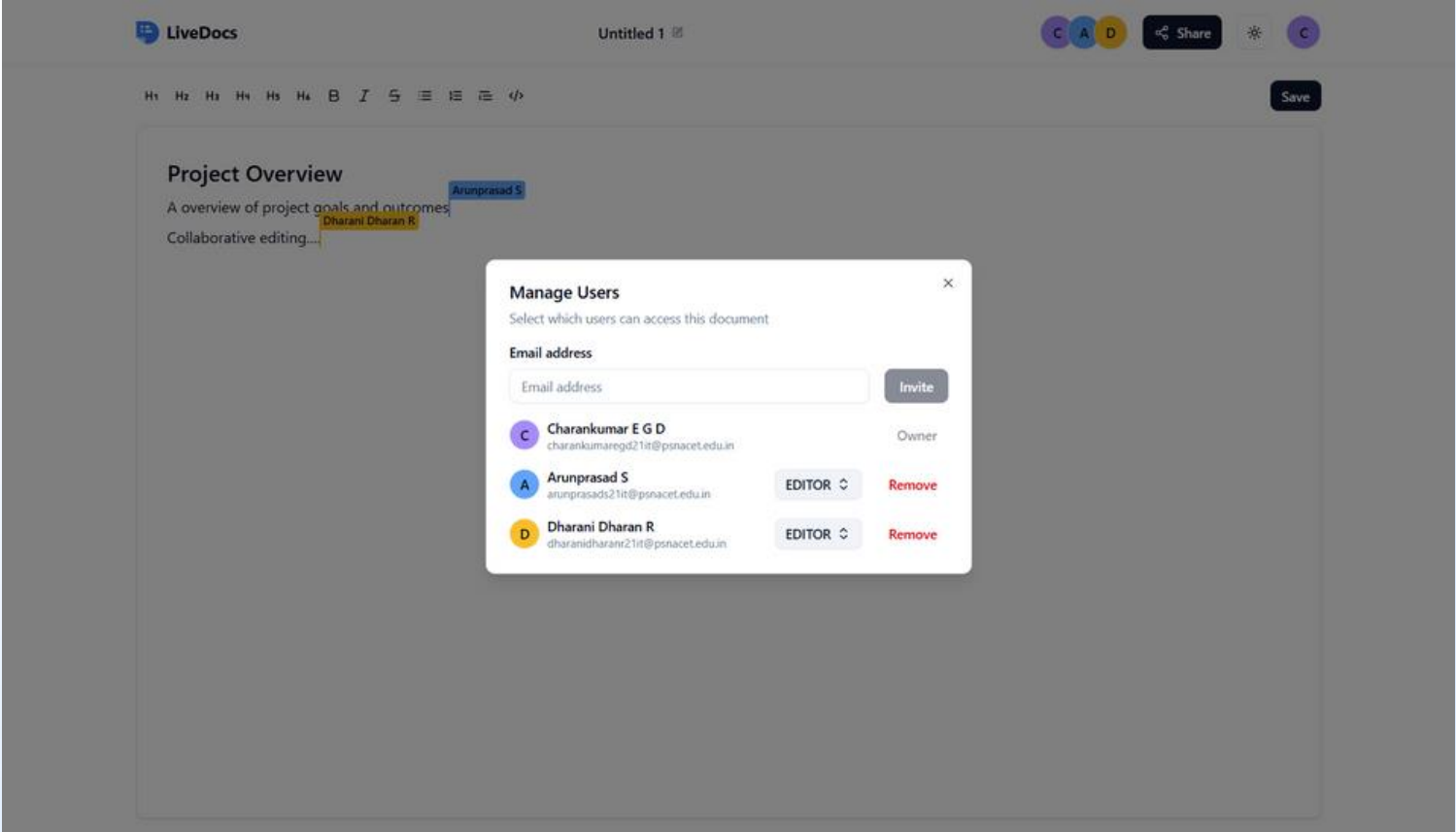
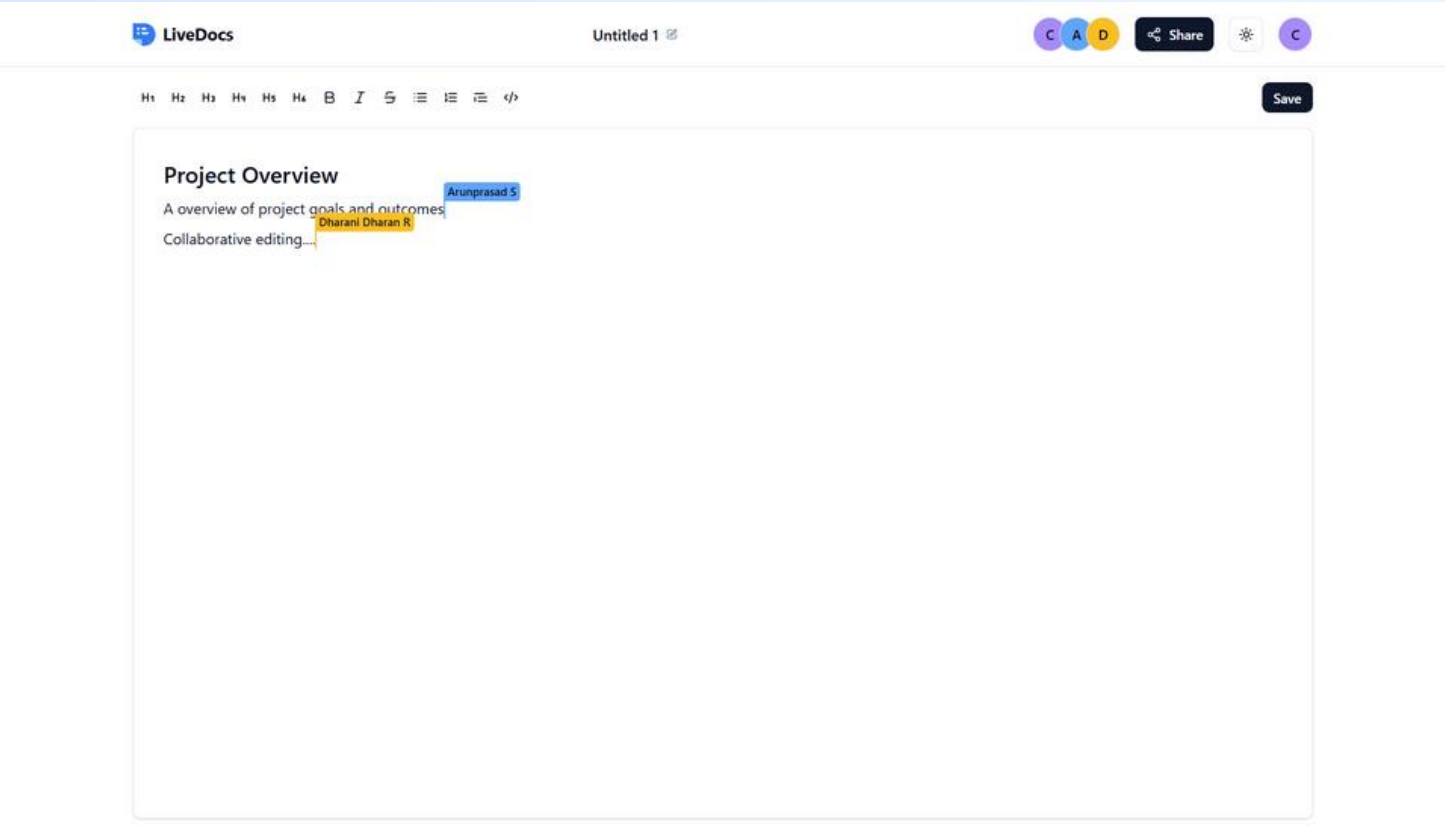


Postman

Prototype



Prototype



Reference

1. Q. -V. Dang and C. -L. Ignat, "Performance of real-time collaborative editors at large scale: User perspective," 2016 IFIP Networking Conference (IFIP Networking) and Workshops, Vienna, Austria, 2016, pp. 548-553, doi: 10.1109/IFIPNetworking.2016.7497258.
2. K. Viridi, A. L. Yadav, A. A. Gadoo and N. S. Talwandi, "Collaborative Code Editors - Enabling Real-Time Multi-User Coding and Knowledge Sharing," 2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), Bengaluru, India, 2023, pp. 614-619, doi: 10.1109/ICIMIA60377.2023.10426375.
3. S. Arora and P. K. Atrey, "SecureC2Edit: A Framework for Secure Collaborative and Concurrent Document Editing," in IEEE Transactions on Dependable and Secure Computing, vol. 21, no. 4, pp. 2227-2241, July-Aug. 2024, doi: 10.1109/TDSC.2023.3302810
4. M. Konstantopoulos, N. Chondros and M. Roussopoulos, "A Personal Distributed Real-time Collaborative System," 2020 IEEE 26th International Conference on Parallel and Distributed Systems (ICPADS), Hong Kong, 2020, pp. 709-715, doi: 10.1109/ICPADS51040.2020.00101.

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Thank you