A

Project Report

On

Multi Threaded Chat Application

Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

In

Computer Science and Engineering

By

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STUDENT'S DECLARATION

We, Harshit Pandey, Gaurav Chandra Karnatak, Jatin Singh Mehra, Pankaj Joshi hereby declare the work, which is being presented in the project, entitled **'Multi Threaded Chat Application'** in partial fulfillment of the requirement for the award of the degree **Bachelor of Technology (B.Tech.)** in the session **2024-2025**, is an authentic record of our work carried out under the supervision of Mr. Ansh Dhingra.

The matter embodied in this project has not been submitted by me for the award of any other degree.

Date:

Harshit Pandey

Gaurav Chandra Karnatak

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CERTIFICATE

The project report entitled "Multi Threaded Chat Application" being submitted by Harshit Pandey S/o Daya Shankar Pandey, 2261253, Gaurav Chandra Karnatak S/o Ganesh Chandra Karnatak, 2261215, Jatin Singh Mehra S/o Krishanpal Singh Mehra, 2261281 and Pankaj Joshi S/o Basant Ballabh Joshi, 2261407 of B.Tech.(CSE) to Graphic Era Hill University Bhimtal Campus for the award of bonafide work carried out by them. They have worked under my guidance and supervision and fulfilled the requirement for the submission of a report.

Mr. Ansh Dhingra
(Project Guide)

Dr. Ankur Singh Bisht
(Head, CSE)

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Abstract

The **Multithreaded Chat Application** is a real-time communication platform built using the MERN stack—**MongoDB, Express.js, React.js, and Node.js**—with integrated WebSocket support through **Socket.IO**. It is designed to enable multiple users to exchange messages simultaneously in a fast, efficient, and responsive environment, simulating multithreading behavior via asynchronous, event-driven architecture on the backend.

The primary motivation behind this project is to explore and implement the principles of real-time systems, concurrent client handling, and non-blocking I/O operations. It also aims to provide a hands-on understanding of full-stack web development, real-time messaging protocols, and WebSocket-based communication.

The application is organized into modular components, including **user authentication**, **chat room management**, **private messaging**, and **online status tracking**. It supports both one-on-one and group messaging, complete with message timestamps, typing indicators, and live connection updates. The frontend, developed with React.js, ensures a seamless user experience, while the backend uses Express and Node.js to manage multiple simultaneous socket connections without blocking the main thread.

Although the system operates without a native mobile or desktop GUI, it provides a responsive and intuitive browser-based interface, delivering real-time updates and smooth user interactions. The use of **MongoDB** ensures persistent storage of chat history and user data, enabling scalability and future feature extensions.

This project not only serves as a practical implementation of modern real-time web technologies but also sets the foundation for further enhancements such as file sharing, message encryption, notification systems, and deployment on cloud platforms for production-level scalability.

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LIST OF ABBREVIATIONS

API – Application Programming Interface
An interface allowing different software programs to communicate with each other.

CRUD – Create, Read, Update, Delete
Refers to the four basic functions of persistent storage.

JWT – JSON Web Token
A compact, URL-safe means of representing claims to be transferred between two parties, commonly used for secure authentication.

MERN – MongoDB, Express.js, React.js, Node.js
A popular full-stack development technology combination.

MVC – Model-View-Controller
A design pattern used to separate application logic from the user interface.

I/O – Input/Output
The communication between an information processing system (such as a computer) and the outside world.

REST – Representational State Transfer
An architectural style for designing networked applications, typically used in developing APIs.

UI – User Interface
The space where interactions between humans and machines occur.

UX – User Experience
The overall experience a user has when interacting with a system or application.

WS – WebSocket
A protocol providing full-duplex communication channels over a single TCP connection, essential for real-time applications.

RT – Real-Time
Describes systems that respond to input immediately, often used for describing real-time messaging features.

CR – Chat Room
A virtual space where users can engage in group communication.

DM – Direct Message
A private message exchanged between users.

INTRODUCTION

1.1 Prologue

In the age of digital connectivity, real-time communication systems form the backbone of modern online interaction. Chat applications are no longer simple tools for messaging—they have evolved into complex systems supporting multimedia sharing, stateful user sessions, and event-driven data updates. Despite the growing number of off-the-shelf messaging platforms, building a custom, scalable, and multithreaded chat application from scratch offers invaluable insights into full-stack development, client-server communication, and asynchronous programming.

This project, titled **Multithreaded Chat Application**, aims to design and implement a fully functional messaging system using the MERN stack. The project replicates the core functionalities of a modern chat platform—such as real-time messaging, authentication, multimedia support, and state management—while mimicking the behavior of a multithreaded server using asynchronous event-driven programming with Socket.IO.

The frontend leverages React and Tailwind for a modern and responsive user interface, while the backend integrates RESTful APIs and WebSockets for dynamic data interaction. Through the use of libraries like Zustand, Multer, and JWT, the application emphasizes modularity, scalability, and a seamless user experience. This project was undertaken as part of academic coursework with the objective of mastering full-stack development and real-time communication protocols.

1.2 Background and Motivations

The motivation behind this project arises from the increasing demand for engineers capable of understanding and implementing scalable, real-time communication systems. While students often use commercial platforms such as WhatsApp, Slack, or Discord, the internal mechanisms—such as message queuing, socket handling, and concurrency—are often hidden from view.

Building a chat application from the ground up not only enhances understanding of frontend-backend interactions but also strengthens concepts of persistent storage, secure authentication, event-driven programming, and cloud integrations. Specifically, the **Multithreaded Chat Application** project aims to:

- Understand and simulate multithreaded behavior using asynchronous programming in Node.js.
- Implement real-time messaging with Socket.IO to mimic thread-based client-server communication.
- Design a modern and responsive UI with component-based architecture in React.js.

- Handle file uploads and cloud storage via Multer and Cloudinary.
- Secure user data and sessions using JWT-based authentication.
- Manage application-wide state efficiently using Zustand.

The project serves as a stepping stone for learners interested in web architecture, backend systems, and real-time application development.

1.3 Problem Statement

While many tutorials exist for building simple chat apps, few address the real-world requirements of stateful communication, modular backend design, media handling, and production-ready frontend architecture. Moreover, real-time systems often suffer from scalability or consistency issues due to poor event handling or improper client synchronization.

This project addresses the following core problem:

"How can we develop a full-stack, multithreaded-like chat application using MERN stack technologies that supports real-time messaging, media transfer, authentication, infinite scroll, and state management in a modular, scalable, and maintainable manner?"

The solution must be architecturally sound, follow clean code practices, and support future enhancements such as push notifications, message reactions, or voice/video integrations.

1.4 Objectives and Research Methodology

Objectives:

The primary objectives of the Multithreaded Chat Application project include:

- To build a real-time chat system from scratch using the MERN stack.
- To implement:
    - User authentication using JWT.
    - Real-time chat using Socket.IO.
    - Message encryption via worker threads.
    - File uploads via Multer and Cloudinary.
    - Lazy loading and infinite scroll in the message window.
    - Emoji support and UI notifications.
    - Modern UI with Tailwind, DaisyUI, and Lucide Icons.

- Global state management with Zustand.
- Efficient routing with React Router DOM.

Research Methodology:

The development process followed a structured and incremental approach:

- **Literature Review**: Studied existing architectures of apps like WhatsApp Web, Discord, and Slack.
- **Tech Stack Evaluation**: Selected libraries and frameworks based on performance, scalability, and learning outcomes.
- **Modular Development**: Each feature was developed and tested independently in modules.
- **Socket Event Planning**: Defined a comprehensive set of event handlers to ensure real-time sync between users.
- **Version Control**: Git was used with branches for feature isolation, and GitHub was used for collaboration and CI.

This approach enabled efficient testing, modular growth, and simplified debugging throughout the lifecycle.

1.5 Project Organization

The project is organized into two major components: the Frontend and the Backend, each with a clearly defined structure and responsibility.

Frontend Folder Structure:

- components/: Subdivided into auth, chat, core, panels, skeleton, and ui components.
- hooks/: Custom React hooks.
- constants/: Shared constant values.
- pages/: Entry-level UI pages.
- store/: Zustand-based global state management.

Backend Folder Structure:

- routes/: Defines HTTP and WebSocket endpoints.

- controllers/: Contains business logic functions.
- middleware/: Request-response interceptors (e.g., auth checks).
- models/: Mongoose schemas and models.
- workers/: JavaScript worker threads for encryption and decryption.
- utils/: Utility functions.
- config/: Database and environment configuration.
- constants/: Server constants (like socket events).

Each module was developed incrementally and integrated seamlessly to ensure maintainability, extensibility, and performance. Features like real-time presence, multimedia handling, and infinite scroll were added in phases, leveraging operating system concepts such as concurrent processing (for handling multiple socket connections), non-blocking I/O (for real-time updates and file transfers), and efficient memory management to maintain responsiveness and backward compatibility.

HARDWARE AND SOFTWARE REQUIREMENTS

The development, testing, and usage of the Multithreaded Chat Application require the following minimum hardware and software specifications to ensure smooth functionality across both frontend and backend operations, including real-time messaging and media handling.

2.1 Hardware Requirement

Component	Specification
Processor	Intel Core i3+ / Intel Pentium (Dual Core) / Apple M1+
RAM	2GB or more
Storage	1GB of free disk space
Display	1366 x 768 resolution higher
Input Devices	Keyboard and Mouse
Network	Stable Internet Connection
Architecture	X86/64 Processor / ARM64(Apple Silicon)

2.2 Software Requirement

- **Operating System**: Windows 10/11, macOS Monterey or later, Linux
- **Web Browser**: Google Chrome (v90+), Microsoft Edge, Safari (v14+), Firefox (v88+)
- **Node.js Runtime**: v16 or above
- **Package Managers**: npm / yarn
- **Code Editor**: VS Code or any modern IDE
- **Backend Runtime**: Node.js (Express), MongoDB (local/cloud)
- **Other Dependencies**: Git (version control), MongoDB Compass (for DB inspection)

CODING OF FUNCTIONS

frontend/src/App.jsx

```jsx
import React, { lazy, Suspense, useEffect } from "react";
import { BrowserRouter, Routes, Route } from "react-router-dom";
import { useAuthStore } from "./store/authStore";
import { useThemeStore } from "./store/themeStore";
import { Toaster } from "react-hot-toast";
import { Loader } from "./components/Loader";
const SignUp = lazy(() => import("./pages/SignUp"));
const LogIn = lazy(() => import("./pages/LogIn"));
const Logout = lazy(() => import("./pages/Logout"));
const EmailCodeVerification = lazy(() =>
  import("./pages/EmailCodeVerification")
);
const ForgotPassword = lazy(() => import("./pages/ForgotPassword"));
const ResetPassword = lazy(() => import("./pages/ResetPassword"));
const ProtectedRoute = lazy(() => import("./components/auth/ProtectedRoute"));
const ProtectedVerifyRoute = lazy(() =>
  import("./components/auth/ProtectedVerifyRoute")
);
const RedirectAuthenticatedUser = lazy(() =>
  import("./components/auth/RedirectAuthenticatedUser")
);
const PageNotFound = lazy(() => import("./pages/PageNotFound"));
const Home = lazy(() => import("./pages/Home"));
const ChatList = lazy(() => import("./components/panels/ChatList"));
const UserList = lazy(() => import("./components/panels/UserList"));
const CreateGroup = lazy(() => import("./components/panels/CreateGroup"));
const Profile = lazy(() => import("./components/panels/Profile"));
const Settings = lazy(() => import("./components/panels/Settings"));
```

frontend/src/components/chat/ChatListItem.jsx

```jsx
import React from 'react';
import Avatar from '../ui/Avatar';

const ChatListItem = ({ name, profilePic, lastMessage, time,unreadCount}) => {
  return (
    <div className="flex items-center bg-base-200 gap-3 p-3 hover:bg-base-300 rounded-lg cursor-pointer transition-colors mt-2 border-b border-base-100">
      <div className="flex items-center justify-center w-10 h-10 bg-base-100 rounded-full overflow-hidden">
        <Avatar src={profilePic} alt={name} />
      </div>

      <div className="flex-1 min-w-0">
        <div className="flex justify-between items-center gap-2">
          <h3 className="font-semibold text-base-content truncate">{name}</h3>
          <span className="text-xs text-base-content opacity-60 whitespace-nowrap">{time}</span>
        </div>

        <div className="flex justify-between items-center gap-2">
          <p className="text-sm text-base-content opacity-70 truncate">{lastMessage}</p>
          {unreadCount > 0 && <span className="text-primary font-semibold text-md">{`${unreadCount} New Messages`}</span>}
        </div>
      </div>
    </div>
  );
};

export default ChatListItem;
```

frontend/src/components/core/Header.jsx

```jsx
import React, { useState } from "react";
import NotificationDropdown from "../ui/NotificationDropdown";
const Header = () => {
  return (
    <div className="w-full h-16 bg-base-200 text-base-content flex items-center justify-between px-6 shadow sticky top-0 z-50">
      <div className="flex items-center space-x-2">
        <h1 className="text-2xl font-semibold">ChatUp</h1>
      </div>

      <div className="flex items-center space-x-4">
        {/* Notifications */}
        <NotificationDropdown />
      </div>
    </div>
  );
};      PankajJoshi-05, last month • implement basic layout

export default Header;
```

frontend/src/hooks/useIsMobile.jsx

```jsx
import { useState, useEffect } from 'react';      You, 2 days ago • hooks …

const useIsMobile = (breakpoint = 768) => {
  const [isMobile, setIsMobile] = useState(window.innerWidth < breakpoint);

  useEffect(() => {
    const handleResize = () => setIsMobile(window.innerWidth < breakpoint);
    window.addEventListener('resize', handleResize);
    return () => window.removeEventListener('resize', handleResize);
  }, [breakpoint]);

  return isMobile;
};

export default useIsMobile;
```

backend/src/config/db.js

```
PankajJoshi-05, 2 months ago | 1 author (PankajJoshi-05)
import mongoose from "mongoose";        PankajJoshi-05, 2
import dotenv from "dotenv";

dotenv.config();

const connectDB=async()=>{
    try{
      await mongoose.connect(process.env.MONGO_URI);
      console.log("Database connected successfully");
    }catch(error){
     console.error("Database connection error:",error);
     process.exit(1);
    }
};
export default connectDB;
```

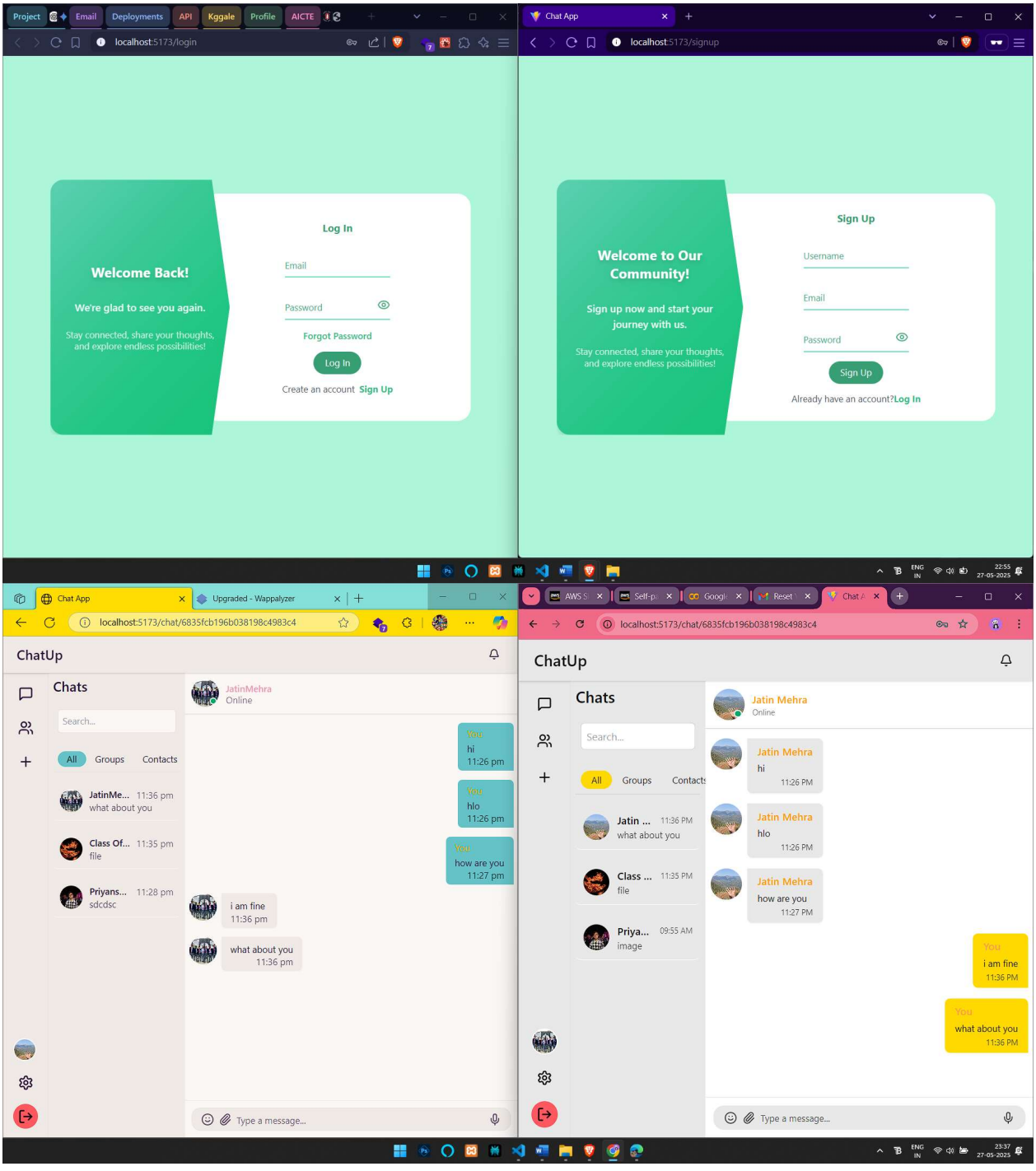
backend/src/middleware/verifyToken.js

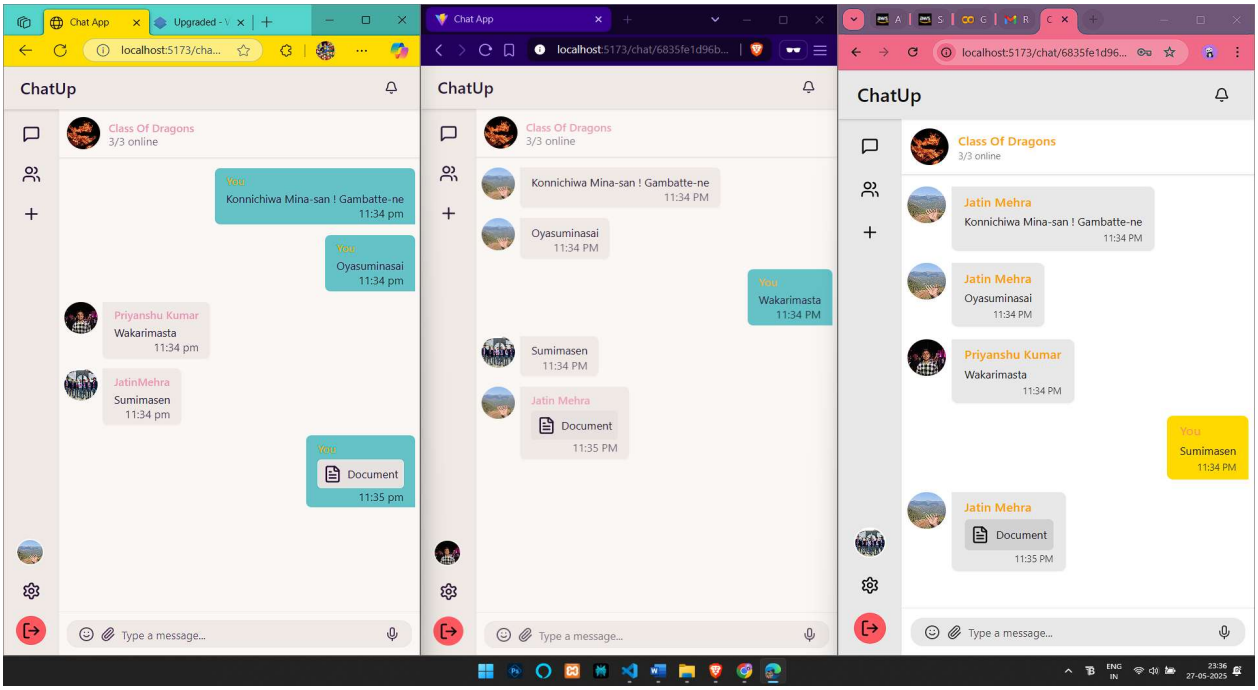
```
import jwt from "jsonwebtoken";      PankajJoshi-05, 2 months ago • initialized frontend …
export const verifyToken=(req,res,next)=>{
    const token=req.cookies.jwt;
    if(!token){
        return res.status(401).json({success:false,message:"Unauthorized-no token provided"});
    }
    try{
      const decoded=jwt.verify(token,process.env.JWT_SECRET);
      if(!decoded){
        return res.status(401).json({success:false,message:"Unauthorized-invalid token"});
      }
        req.userId=decoded.userId;
        next();
    }catch(error){
        console.log("Error in verifyToken",error);
        return res.status(500).json({success:false,message:"Server error"});
    }
}
```

backend/src/routes/chat.routes.js

```
import express from "express";
import { verifyToken } from "../middleware/verifyToken.js";
import {getChats,createGroup,changeGroupName,changeGroupProfile,addMembers,
removeMember,getGroupMembers,leaveGroup,getAllUsers,sendAttachments,sendVoiceMessage,
getMessages,deleteChat, changeGroupBio} from "../controller/chat.controller.js";
import {singleUpload,multipleUpload} from "../middleware/multer.js";

const router=express.Router();

router.get("/get-chats",verifyToken,getChats);
router.post("/create-group",verifyToken,createGroup);
router.put("/change-group-name",verifyToken,changeGroupName);
router.put("/change-group-bio",verifyToken,changeGroupBio);
router.put("/change-group-profile",verifyToken,singleUpload,changeGroupProfile);
router.put("/add-members",verifyToken,addMembers);
router.put("/remove-member",verifyToken,removeMember);
router.get("/get-group-members",verifyToken,getGroupMembers);
router.delete("/leave-group/:id",verifyToken,leaveGroup);
router.delete("/delete-chat/:id",verifyToken,deleteChat);
router.get("/get-all-users",verifyToken,getAllUsers);

router.put("/send-attachments",verifyToken,multipleUpload,sendAttachments);
router.put("/send-voice-message",verifyToken,singleUpload,sendVoiceMessage);

router.get("/get-messages/:chatId",getMessages);
export default router;
```

SNAPSHOTS


Welcome Back!
We're glad to see you again.
Stay connected, share your thoughts, and explore endless possibilities!
Log In
Email
Password
Forgot Password
Log In
Create an account Sign Up
Welcome to Our Community!
Sign up now and start your journey with us.
Stay connected, share your thoughts, and explore endless possibilities!
Sign Up
Username
Email
Password
Sign Up
Already have an account?Log In
ChatUp
Chats
Search...
All
Groups
Contacts
JatinMehra
Online
hi
hlo
how are you
i am fine
what about you
Type a message...
Jatin Mehra
Online


Chat App
Upgraded - Wappalyzer
localhost:5173/cha...
localhost:5173/chat/6835fe1d96b...
localhost:5173/chat/6835fe1d96...
ChatUp
Class Of Dragons
3/3 online
You
Konnichiwa Mina-san ! Gambatte-ne
11:34 pm
You
Oyasuminasai
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Priyanshu Kumar
Wakarimasta
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JatinMehra
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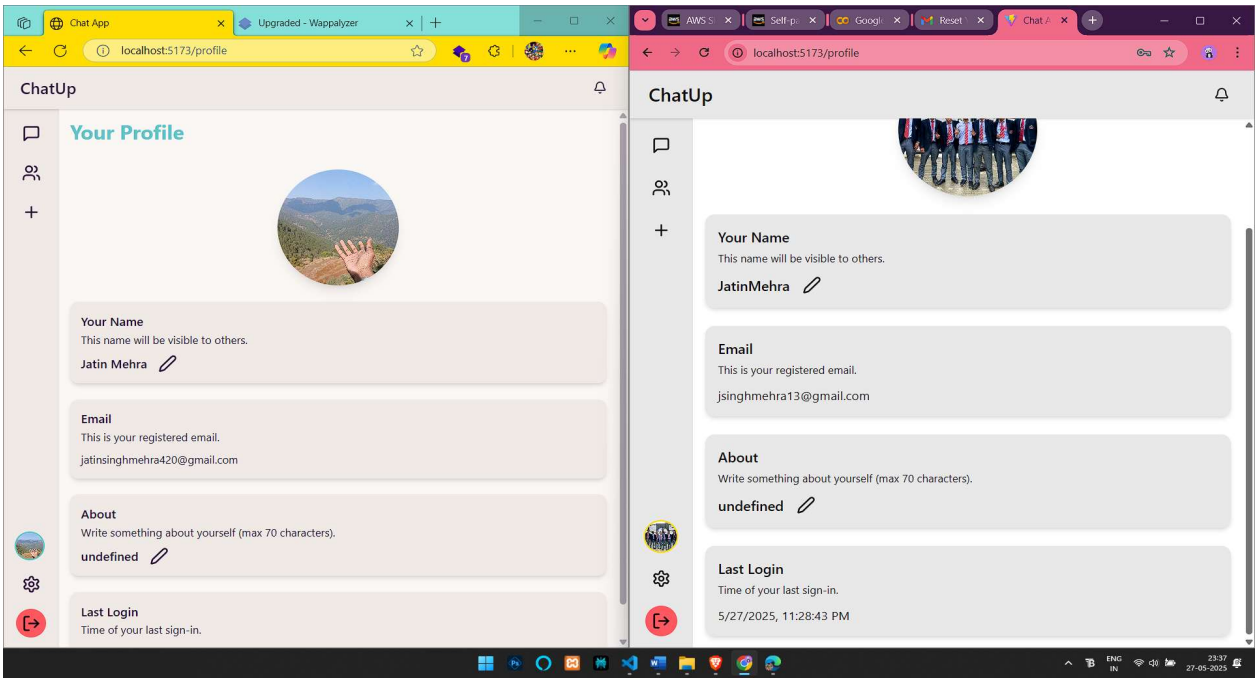
Type a message...


Chat App
Upgraded - Wappalyzer
localhost:5173/profile
ChatUp
Your Profile
Your Name
This name will be visible to others.
Jatin Mehra
Email
This is your registered email.
jatinsinghmehra420@gmail.com
About
Write something about yourself (max 70 characters).
undefined
Last Login
Time of your last sign-in.
Your Name
This name will be visible to others.
JatinMehra
Email
This is your registered email.
jsinghmehra13@gmail.com
About
Write something about yourself (max 70 characters).
undefined
Last Login
Time of your last sign-in.
5/27/2025, 11:28:43 PM

LIMITATIONS

Despite the modular architecture, real-time capabilities, and extensive feature set of the chat application, several limitations remain due to development timelines, dependency constraints, and evolving feature scope. Acknowledging these helps highlight areas for potential improvement and expansion.

1. No Desktop or Native Mobile App: While the application is responsive and mobile-friendly, it is not deployed as a native mobile or desktop app. This restricts offline access, system-level notifications, and deep platform integrations available in native environments.

2. Limited Multimedia Handling: The current implementation supports image/audio sharing but lacks comprehensive support for multimedia such as video messages, in-app voice/video calling, and advanced media previews.

3. Security Trade-offs: While JWT and encrypted storage are used for authentication and data safety, additional security practices such as rate-limiting, 2FA are not fully implemented. This may pose security concerns in a production-scale deployment.

4. Scalability Constraints: The backend is designed for functional use and testing purposes but is not yet optimized for high-traffic or horizontally scaled deployments. Features like load balancing, Redis-based caching, and microservice splitting are not integrated.

5. Basic Admin Controls: Admin/moderation features are minimal or missing. This limits the platform's readiness for community or public usage.

6. Browser API Limitations: Some real-time and file-handling features depend on modern browser APIs. These may behave inconsistently on older systems or platforms with limited support for ES6+ features, WebSockets, or File APIs.

7. Dependency on External Services: Services like Cloudinary (for file uploads), Nodemailer (for email), and JWT (for auth) create a reliance on third-party platforms. Downtime or API changes in these services can affect functionality.

8. No Rate Limiting or Abuse Detection: The server does not currently implement throttling, message spam detection, or abuse prevention logic, leaving the system open to potential flooding or misuse.

ENHANCEMENTS

While the chat application successfully implements essential features such as real-time messaging, user authentication, file sharing, emoji support, and presence indicators, there remains significant scope for enhancement. These enhancements aim to improve scalability, user experience, performance, and bring the system closer to the capabilities of modern, industry-grade messaging platforms.

1. End-to-End Encryption: Messages are currently transmitted securely via transport-level encryption (e.g., HTTPS), but true end-to-end encryption (E2EE) is not yet implemented. Incorporating E2EE would ensure that only the sender and the recipient can read messages, significantly improving user privacy and data security.

2. Message Reactions: Introducing message reactions using emojis would enable users to provide quick feedback and enhance interaction without needing to send additional messages.

3. Advanced Presence System: The presence feature currently indicates whether a user is online or offline. Expanding this to include detailed statuses like “away,” “busy,” or “do not disturb,” along with activity-based status updates, would offer better visibility and awareness.

4. Read Receipts: Adding real-time typing indicators and message read/delivery receipts would enhance communication feedback and responsiveness, especially in fast-paced chats.

5. Offline Support and Background Sync: Offline capabilities can be enhanced through service workers, enabling users to view previous messages and queue outgoing messages even without an active internet connection.

6. Progressive Web App (PWA) Conversion: Converting the application into a Progressive Web App would allow users to install it on desktops and mobile devices, offering a more native-like experience with offline capabilities and push notifications.

7. Administrative Features and Moderation: An admin dashboard for user management, chat moderation, and system logs could extend the app’s use to professional or educational settings. Features like user banning, message flagging, and broadcast announcements would enhance control and reliability.

8. Scalability and Security Enhancements: Future upgrades may include implementing rate limiting, JWT refresh token rotation, and audit logging to ensure that the app remains secure, scalable, and production-ready.

CONCLUSION

The development of the Chat Application has been a comprehensive and rewarding journey into the realm of full-stack web development, real-time communication, and modern software architecture. Built using the MERN stackalong with supporting technologies such as WebSockets (via Socket.IO), Worker Threads, and Tailwind CSS, this project successfully demonstrates how scalable and interactive messaging platforms are engineered from the ground up.

Throughout the development process, several core aspects of real-time applications were explored and implemented, including user authentication, WebSocket-based communication, file and image sharing, emoji integration, presence detection, and encryption using Node's crypto module. Key system design principles such as modular folder structuring, state management with Zustand, lazy loading, infinite scroll, and background processing via workers were carefully integrated to ensure performance, maintainability, and user experience.

The focus of the application was to emulate industry-level chat systems while reinforcing foundational knowledge in both frontend and backend technologies. The decision to avoid third-party services for core features like encryption and presence handling was intentional, allowing for deeper control, learning, and customization of the app's behavior and data flow.

One of the defining strengths of this project is its modular, scalable architecture that allows for future enhancements such as end-to-end encryption, threaded replies, advanced role-based permissions, and PWA capabilities. While not every enterprise feature (e.g., detailed analytics, multi-tenancy, or cloud-based backups) was implemented in this version, the project establishes a solid groundwork for such extensions.

In conclusion, this Chat Application serves as a strong demonstration of modern web development practices, real-time systems engineering, and full-stack integration. It not only showcases the technical skills acquired but also reflects the problem-solving, debugging, and architectural thinking developed during its creation. It stands as both a practical communication tool and an educational platform for deeper exploration of scalable web application design.

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