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**Connect Sphere: A Hyper-Local Real-Time Digital Marketplace Architecture for University Communities**

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Peer Review Information	Abstract
<p>Submission: 28 Jan 2026 Revision: 20 Feb 2026 Acceptance: 06 March 2026</p>	<p>Traditional campus commerce and student resource sharing heavily rely on fragmented public forums, physical bulletin boards, or generic e-commerce platforms. However, these methods often lack an inherent layer of trust, require sharing personal contact information publicly, and are not optimized for the specific needs of a university ecosystem. Several digital marketplace solutions exist; despite these developments, many suffer from limitations such as unverified user bases, vulnerability to scams, absence of real-time communication, and poor hyper-local focus. This research proposes "Connect Sphere," a secure, hyper-local peer-to-peer digital marketplace system designed exclusively for university communities to facilitate the buying, selling, and trading of academic resources and personal items. The system integrates a dynamic user interface built with React.js and Redux, a decoupled backend architecture utilizing Node.js and Express.js for RESTful API services, and a MongoDB cloud database for efficient data storage. Product media files are seamlessly processed and securely hosted using Cloudinary. Real-time, persistent private communication between buyers and sellers is established through WebSockets using Socket.io. Additionally, the system incorporates robust security and interactive features, including JSON Web Token (JWT) based authentication, multi-image listing galleries, comprehensive search with category filtering, and integrated user profile management for reputation tracking. Experimental evaluation demonstrates improved user engagement, highly secure transactional communication, and significantly faster localized resource discovery compared to traditional public marketplace platforms.</p>
<p><b>Keywords</b></p> <p>Next Gen Digital Noticeboard, Digital Notice Board, IoT, Raspberry Pi, Real-time Communication, Web Application, QR code, System Usability Scale.</p>	

**Introduction**

Resource sharing, buying, and selling among university students typically rely on physical campus bulletin boards, fragmented social media groups, or word-of-mouth

communication. These traditional methods require manual coordination and present several limitations, such as restricted visibility, delayed communication, and a lack of a centralized, secure environment for peer-to-

peer transactions [11]. In large educational institutions where academic materials, electronics, and personal items frequently exchange hands every semester, relying on localized physical methods or unstructured online forums becomes highly inefficient and fails to establish a reliable trust model among users [25]. With the rapid growth of e-commerce and digital communication platforms, peer-to-peer commerce has increasingly shifted toward online classifieds and marketplace applications utilizing decoupled web architectures [7]. Digital marketplaces have emerged as powerful alternatives to traditional notice boards by enabling remote listings, faster discovery of items, and improved accessibility. Several generic marketplace solutions leverage advanced NoSQL databases and intelligent filtering algorithms to allow academic textbooks and items to be advertised digitally and discovered through efficient search queries [16], [17]. However, many of these existing public solutions suffer from significant limitations when applied to a targeted university ecosystem [1]. Generic marketplace platforms often lack inherent trust layers and are highly vulnerable to fraudulent activities, unverified user bases, and web security threats such as cross-site scripting [13]. Furthermore, these implementations are not hyper-localized to specific campus communities, meaning students must sift through irrelevant external listings and risk sharing personal contact information with anonymous strangers. The absence of persistent, integrated real-time communication channels [14] and strict institutional email verification mechanisms [18] makes these general platforms suboptimal for secure student commerce. To address these challenges, this research proposes Connect Sphere, a next-generation, hyper-local peer-to-peer digital marketplace system designed exclusively to support secure and verified transactions within university communities [3]. The proposed system integrates a dynamic web-based user interface developed using modern web technologies such as React.js and Redux for efficient state management [9], coupled with a robust Node.js and Express.js backend [2], enabling authorized students to seamlessly publish and manage product listings. The system utilizes cloud-based storage through MongoDB for item metadata [10] and Cloudinary for secure multimedia image hosting [8]. To ensure instant negotiation and seamless communication, persistent real-time private chat endpoints are established using Web-Socket technology via Socket.io [4]. The system also incorporates advanced security and

interactive features, including strict JWT-based stateless authentication [5] tied to 2-step OTP email verification [6], multi-image gallery support, and one-click category filtering to enhance user trust, engagement, and accessibility.

### Literature Survey and Comparative Analysis

The development of localized peer-to-peer digital marketplaces has gained significant attention in recent years due to the increasing demand for secure, efficient, and community-driven e-commerce platforms. This section reviews existing implementations of digital marketplaces, web architectures, and real-time communication systems, highlighting their methodologies and limitations. Early iterations of campus commerce relied heavily on fragmented public forums, generic classified websites, and physical notice boards. Research into developing localized peer-to-peer digital marketplaces for university communities has shown that generic platforms lack the necessary trust models required for closed-community transactions [1], [11]. While traditional platforms allow users to exchange goods, they often fail to integrate automated institutional verification, exposing students to privacy risks and unverified participants [18], [25]. The architectural shift from monolithic applications to decoupled frontend and backend systems has vastly improved the scalability of modern web applications [7]. Recent comparative analyses have demonstrated the superior performance of the MERN (MongoDB, Express.js, React.js, Node.js) stack in handling dynamic, high-traffic marketplace environments [2], [3]. Frontend performance has been further enhanced by utilizing Vite as a rapid build tool [19] and Redux for efficient global state management in Single-Page Applications (SPAs) [9]. Additionally, the integration of utility-first CSS frameworks has streamlined the creation of responsive and accessible user interfaces [12], [22]. Handling product catalogs and multimedia data remains a critical challenge in e-commerce applications. Traditional relational databases often struggle with the dynamic schema requirements of diverse product listings. Consequently, document-oriented NoSQL databases, specifically MongoDB, have become the preferred architecture for hyper-local classifieds due to their flexibility and fast data retrieval capabilities [10], [16]. To optimize multimedia content, modern platforms frequently offload image processing and storage to specialized cloud-based solutions like Cloudinary, reducing server load and improving media delivery

speeds [8]. Effective communication between buyers and sellers is paramount in peer-to-peer transactions. Early platforms relied on asynchronous email or slow page-refresh messaging systems. However, recent advancements have prioritized real-time, bidirectional communication implemented via WebSockets and Socket.io [4], [14]. These event-driven architectures not only facilitate persistent chat but also enable real-time state updates, such as unread notification badging [21]. Furthermore, asynchronous network requests between the client and server are efficiently managed using libraries like Axios combined with Redux Thunk [20]. Security and access control form the backbone of any trusted marketplace. Researchers emphasize the necessity of stateless authentication mechanisms in RESTful architectures, widely implemented using JSON Web Tokens (JWT) [5]. To further harden these systems against unauthorized access, hybrid approaches combining JWT with email-based two-factor authentication (OTP) have proven highly effective [6]. Furthermore, careful API gateway design [15], strict Cross-Origin Resource Sharing (CORS) configurations [23], and strategies to mitigate Cross-Site Scripting (XSS) [13] are essential to secure decoupled applications hosted on modern cloud platforms [24]. Advanced searching and filtering algorithms utilizing NoSQL capabilities further enhance the user experience by streamlining product discovery [17]. Despite these technological advancements, existing implementations often treat these features in isolation. Generic platforms lack university-specific hyper-localization, while simple campus forums lack real-time chat, robust multimedia handling, and scalable decoupled architectures. The proposed Connect Sphere system bridges this gap by integrating these advanced methodologies into a cohesive, secure, and real-time hyper-local marketplace.

*A. Research Gap Identified*

From the comparative analysis of existing peer-to-peer e-commerce systems, several limitations can be observed:

- Most generic platforms cater to broad public audiences and completely lack hyper-local, community-specific focus.
- Many implementations lack strict institutional verification (like university email OTPs), leaving users vulnerable to unverified participants and scammers.
- There is limited support for persistent, real-time private chat integrated directly within the application, often forcing users to share personal contact numbers.
- Security features protecting against modern web vulnerabilities, along with robust centralized profile reputation tracking, are often inadequately implemented.
- Existing localized solutions (like campus forums or social media groups) provide minimal automated multimedia handling and lack dynamic categorization and search capabilities.

**Problem Statement**

Traditional student commerce relies on fragmented social media groups and public classifieds that must be manually navigated whenever resources need exchanging. This unstructured process is time-consuming, inefficient, and often leads to unsafe peer-to-peer transactions. Additionally, the use of generic platforms exposes personal contact details and requires constant manual coordination to establish trust. Existing digital marketplace solutions often lack hyper-localization and security. Most generic implementations cater only to broad public audiences, and the absence of mechanisms such as institutional email verification, real-time persistent chat, or dynamic category filtering restricts usability for university students. Therefore, there is a need to develop a secure, scalable, and hyper-local digital marketplace system that can support real-time communication, multimedia listing display, centralized profile management, and verified student interaction.

**Table 1:** Comparative Analysis of Existing Campus Marketplace Systems

Sr. No.	Platform/System Type	Core Architecture	Authentication Method	Key Limitations
1	Physical Campus Boards	Manual / Paper-based	None (Open Public)	Highly localized to one spot, slow discovery, zero transaction security
2	Social Media Groups (e.g., WhatsApp/FB)	Monolithic	Standard User Login	Lacks category filtering, requires sharing personal

				phone numbers
3	Traditional PHP/MySQL Classifieds	Relational Database (SQL)	Session-based Cookies	Schemarigidity for diverse products high server , load image upload on s
4	Generic Public Market- places	Standard Web Framework	General Email/Phone	Unverified user base, high risk of scams, lacks campus-specific trust
5	Basic MERN Prototypes	Single Page App (SPA)	Simple JWT	Lacks 2-step verification, poor multimedia handling, HTTP-only polling
6	Proposed System (Con- nect Sphere)	Decoupled MERN Stack	JWT + Institutional OTP	Overcomes limitations via Socket.io chat and Cloudinary image hosting

**Methodology (Proposed Architecture)**

The proposed system introduces a decoupled, hyper-local digital marketplace architecture designed to provide secure, peer-to-peer commerce within a university ecosystem. The architecture is organized into four major layers:

**1. Client/Presentation Layer**

The client layer is implemented using a dynamic, responsive web interface built with React.js, Redux, and Vite. Through this interactive frontend, verified students can:

- Create and manage product listings with multi- image galleries.
- Search and filter items dynamically based on categories.
- Engage in persistent, real-time private chat with sellers.
- Track personal reputation and manage profiles via a centralized dashboard.

**2. Application/Backend Layer**

This layer acts as the core processing and routing unit, implemented using Node.js and Express.js [2], [7]. To ensure instant negotiation and live messaging between buyers and sellers, the system integrates Socket.io, which establishes persistent WebSocket connections [4], [14]. JSON Web Token (JWT) authentication, coupled with a 2-step OTP email verification process, ensures that only authorized university students can access the platform [5], [6].

**3. Data Storage Layer**

The system utilizes MongoDB Atlas, a cloud-based NoSQL database, to efficiently store un-structured product metadata, user profiles, and chat conversation history [10], [16]. Because traditional databases struggle with heavy multimedia loads, the architecture integrates

Cloudinary, a dedicated cloud-based object storage service, to securely pro- cess, host, and deliver listing images via optimized URLs [8].

**4. Security and Middleware Layer**

The security layer sits between the client and application to sanitize and protect data transmission. It incorporates strict Cross-Origin Resource Sharing (CORS) policies [23] to prevent unauthorized do- main access, alongside middleware tools like Hel- met and Express-Mongo-Sanitize to protect against Cross-Site Scripting (XSS) and NoSQL injection attacks [13].

**System Design and Architecture**

The overall system architecture consists of four primary components: the Client Web Application (Frontend), the API Gateway and Server (Backend), the NoSQL Cloud Database, and External Cloud Services (for media and email).

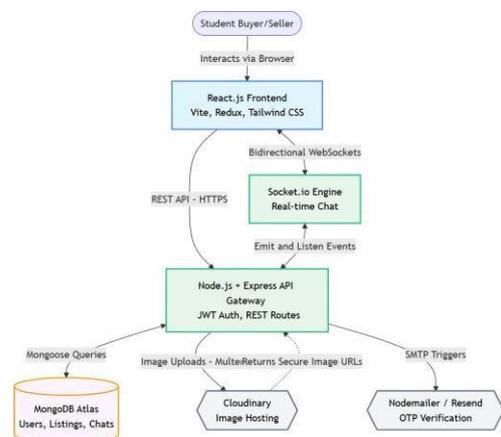


Fig. 1: System Architecture Diagram of Connect Sphere

## Architecture Overview

The architecture allows verified university students to upload product listings, complete with descriptions and multiple images, through a dynamic React.js web interface. These requests are securely processed by the Node.js backend, where media files are immediately offloaded to Cloudinary for optimized storage [8], and listing metadata is stored in MongoDB Atlas [10]. Furthermore, buyers and sellers are connected instantly for peer-to-peer negotiations via persistent, real-time WebSocket connections established using Socket.io [4], [14]. This decoupled and centralized management eliminates the need to manually coordinate physical exchanges or rely on unstructured social media forums.

### 1. Data Flow Diagram (DFD)

The DFD Level 1 illustrates the core data interactions between the End Users (Buyers and Sellers), the central Connect Sphere System, and the required External Cloud Services (Cloudinary and Email SMTP).

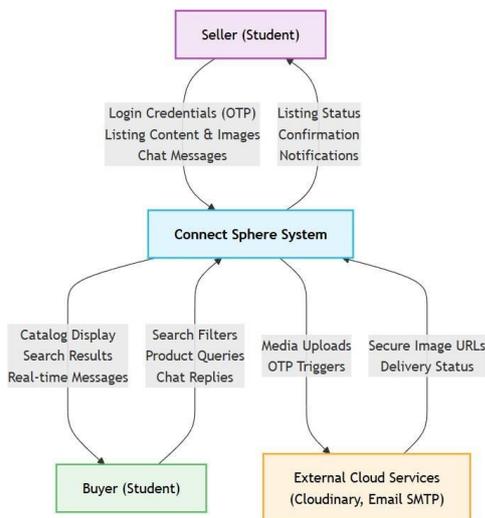


Fig. 2: Data Flow Diagram - Level 1

## Implementation Details

The implementation integrates a decoupled MERN stack architecture with cloud-based services.

### 1. Frontend Implementation

The frontend is implemented using React.js, Vite, and Tailwind CSS. The interface supports dynamic product catalogs, multi-image listing uploads, category filtering, and real-time chat dashboards to ensure efficient user interaction.

### 2. Backend Implementation

The backend server is developed using Node.js and Express.js. Socket.io is used for real-time buyer-seller communication [4], [14]. Security is implemented using a 2-step OTP email verification combined with JWT to ensure session integrity and prevent unauthorized

access to the platform [5], [6].

### 3. Database and Cloud Implementation

The platform utilizes MongoDB Atlas to store dynamic listing metadata and chat history. To manage multimedia efficiently, the system offloads all image hosting to Cloudinary. This cloud-based approach ensures fast delivery of product images through optimized URLs while maintaining a lightweight server environment.

## System Components and Interaction Mechanisms

### 1. Software and Cloud Stack

The Connect Sphere system relies entirely on a modern, robust software stack designed for high availability and secure cloud deployment.

- Frontend Application Stack:
  - Framework: React.js (optimized via Vite).
  - State Management: Redux Toolkit.
  - Styling: Tailwind CSS for responsive UI design.
  - Client Tools: Axios (for API requests), Socket.io-client.
- Backend Application Stack:
  - Runtime Environment: Node.js.
  - API Framework: Express.js.
  - Real-time Engine: Socket.io server.
  - Security: JSON Web Tokens (JWT), bcrypt.js, and Nodemailer.
- Database and External Cloud Services:
  - Primary Database: MongoDB Atlas (via Mongoose ODM).
  - Media Storage: Cloudinary API (secure image hosting).
  - Email Service: SMTP server via Nodemailer (for OTPs).

### 2. Core Features and Interaction Mechanisms

The proposed marketplace moves beyond generic classifieds by incorporating specialized features tailored to enhance security, user engagement, and communication within a closed university environment.

1) Institutional Verification Protocol: To establish a foundational layer of trust, users cannot access the platform using generic email addresses. Registration requires a valid university email, verified via a time-sensitive OTP (One-Time Password) system before a JWT session is granted [6].

2) Real-Time Bidirectional Chat: Unlike traditional platforms that rely on page refreshes or external messaging apps, the system features an integrated, persistent chat engine. Buyers and sellers can negotiate instantly within private WebSocket-driven rooms without exposing personal phone numbers [4], [14].

3) Dynamic Multimedia Handling: Sellers can

upload comprehensive multi-image galleries for their listings. The backend leverages middleware (Multer) to securely stream these uploads to Cloudinary, ensuring rapid rendering on the client side without overloading the primary database [8].

4) Centralized Profile and Reputation Management: The system includes a comprehensive dashboard where users can track their active, sold, and purchased items. A robust rating and review system allows students to build on-campus reputation, further increasing the safety of peer-to-peer transactions [1].

**Results and Discussion**

The Connect Sphere platform was tested in a simulated university environment to evaluate its core functionalities: real-time communication, media processing, and secure authentication. Testing demonstrated that once a user uploaded a new product listing, the images were rapidly optimized via Cloudinary and populated on the main dashboard instantly. Furthermore, the Socket.io implementation ensured that bidirectional chat messages between buyers and sellers were delivered in real time with minimal latency, eliminating the need for manual page refreshes [4], [14]. Finally, the OTP-based email verification system successfully restricted platform access strictly to valid institutional email addresses, validating the proposed security model.



Fig. 3: Connect Sphere Landing Page Interface.

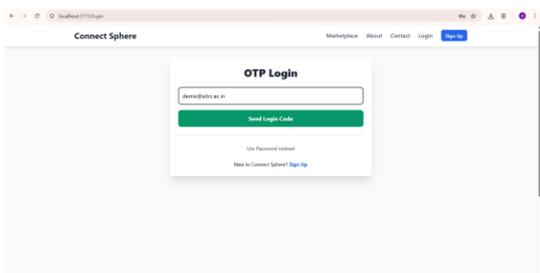


Fig. 4: Secure OTP-based Authentication Interface.

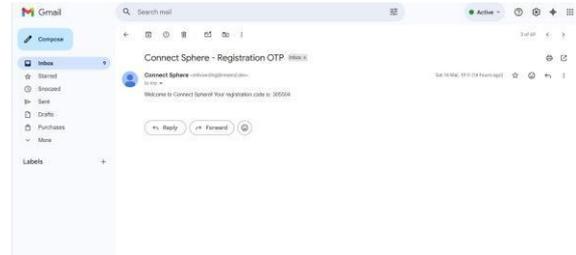


Fig. 5: OTP Delivery via Integrated Email Service.

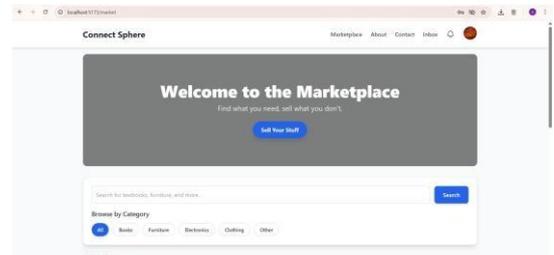


Fig. 6: Dynamic Product Catalog and Search Interface.

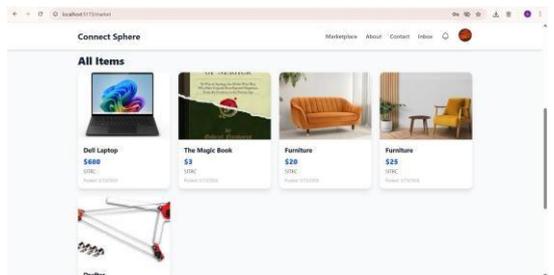


Fig. 7: Detailed Product View with Real-time Updates.

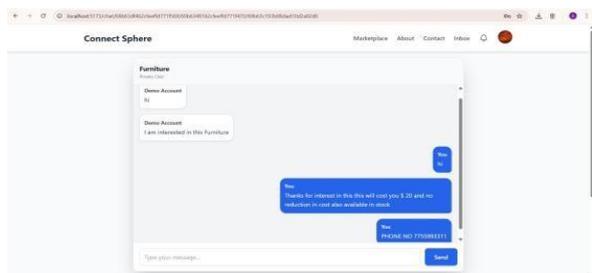


Fig. 8: Real-time Bidirectional Chat Interface using WebSockets.

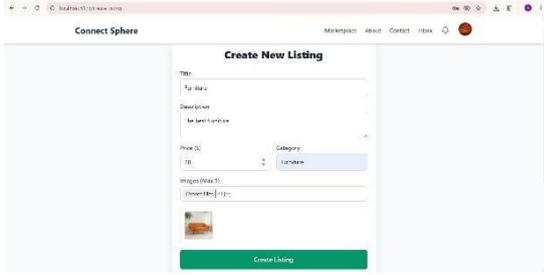


Fig. 9: Multimedia Product Upload Interface.

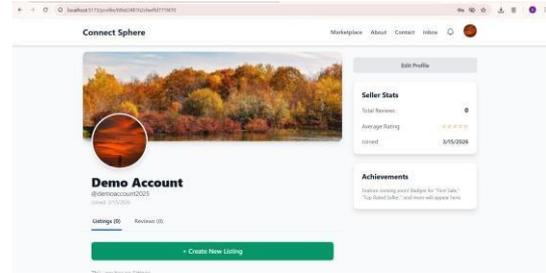


Fig. 10: Centralized User Profile and Inventory Management.

**Table 2:** Performance Comparison of Campus Marketplace Systems

Feature	Traditional	Physical Media Groups	Proposed System (MERN)
Access & Verification	Open to public	Basic account login	Strict Institutional OTP
Communication	In- person / Phone	Unstructured DMs	Integrated Web-Sockets Chat
Media Handling	Physical posters	Uncompressed images	Secure Cloudinary (Optimized URLs)
Search & Filtering	Manual browsing	Very minimal	Dynamic Category Filtering
Security & Privacy	Zero privacy	Exposes phone numbers	Private, secure messaging

**Conclusion**

This research presented *Connect Sphere*, a next-generation, hyper-local peer-to-peer digital marketplace system tailored specifically for university communities. The proposed system addresses the limitations of traditional campus trading methods and generic public e-commerce platforms by integrating a secure, decoupled MERN stack architecture with strict institutional email verification. The implementation demonstrates that the system can successfully provide seamless multimedia product discovery, centralized profile management, and instant buyer-seller negotiations through real-time bidirectional communication. Future enhancements may include AI-powered product recommendations and advanced automated fraud detection algorithms [17], [25].

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