**KuetConnect: A Dynamic Android Application for**

**Secure Real-Time Interaction and Multimedia Sharing.**

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**Abstract**

In this paper, we present **KuetConnect**, a comprehensive Android application ecosystem designed to serve the Khulna University of Engineering & Technology (KUET) community by combining two tightly integrated modules: a domain-restricted social networking platform and a secure real-time chat system. The social module delivers all the core functionalities of modern social media—user registration and authentication, profile management (profile and cover photos), content creation (posts and 24-hour stories), engagement mechanisms (likes and comments), real-time notifications, and peer discovery via search—while enforcing exclusive access through institutional email-domain verification (@stud.kuet.ac.bd). The chat module, built atop Firebase services and hybrid cryptography, provides end-to-end protection for text and media communications, ensuring confidentiality even in the event of backend compromise.

The social networking component leverages Firebase Authentication for secure user sign-up, Realtime Database for low-latency data synchronization, and Cloud Storage for media hosting. Its Android client utilizes modern UI toolkits and lifecycle-aware architecture to maintain responsiveness across profile updates and content feeds. Users can personalize their presence with profile and cover photos, author rich posts, and share ephemeral stories, while interacting through likes, comments, and notifications. Peer discovery is enabled by a robust search interface, and account security is bolstered by mandatory institutional email verification. Functional and performance benchmarks conducted in a mid-sized university environment demonstrate sub-second response times for feed updates and high throughput under concurrent usage.

Complementing the social layer, the chat module embodies a hybrid encryption framework: RSA for secure key exchange and AES for efficient message encryption. Text messages and media download URLs—rather than raw files—are encrypted before storage in Firebase Realtime Database, while actual media assets reside in Firebase Storage. This design isolates sensitive content even if database credentials are compromised. The chat interface is divided into Chats, People, and Requests fragments, alongside a navigation drawer granting quick access to Settings (profile updates, password changes), a news API reader, and account management features (deletion and logout). Real-time messaging supports media sharing with upload progress indicators, message deletion (individual messages or entire threads), chat requests management (accept or cancel), user blocking/unblocking, and last-seen activity indicators. Pagination-based message loading (10–20 messages per batch) optimizes bandwidth usage and accelerates UI rendering, while multithreaded processing ensures that encryption and media operations do not hinder the user experience.

By integrating these two modules under a unified codebase and consistent design language, KuetConnect not only nurtures an engaged and exclusive campus community but also safeguards interpersonal communication with enterprise-grade security. We outline the system architecture, data models, encryption workflows, and UI/UX design patterns that underpin both modules. Through comprehensive testing—covering functionality, security, and performance—we validate that the platform meets the stringent requirements of a university setting.

Finally, we discuss prospective enhancements, such as group messaging, multimedia live streaming, advanced moderation tools, and analytics dashboards for community engagement. KuetConnect exemplifies how purpose-built mobile applications can combine familiar social networking features with institution-specific controls and robust cryptography to foster a secure, vibrant, and privacy-preserving environment for academic communities.

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CHAPTER I

**Introduction**

* 1. Introduction

In recent years, social media and instant messaging have become integral to the daily lives of university students, facilitating peer-to-peer interaction, information sharing, and community building. However, mainstream platforms often lack the tailored controls and security guarantees necessary for closed academic communities. Public networks can expose sensitive personal data, flood users with irrelevant content, and fail to enforce institution-specific access policies. Likewise, popular chat applications may offer convenient communication features but typically do not provide end-to-end confidentiality for both text and media, nor do they integrate seamlessly with social feeds and user profiles.

To address these challenges, we have developed **KuetConnect**, an Android-based application ecosystem specifically designed for the Khulna University of Engineering & Technology (KUET) community. By combining a domain-restricted social network with a secure real-time chat system, KuetConnect delivers a unified user experience that fosters engagement, preserves privacy, and enforces institutional policies. Students and faculty can connect through personalized profiles, share posts and stories, and participate in discussions—while enjoying the assurance that only verified members of the KUET domain (@stud.kuet.ac.bd) can join. Simultaneously, the built-in chat module utilizes a hybrid cryptographic framework (RSA and AES) to protect both text messages and media download links, ensuring confidentiality even if backend databases are compromised.

The social networking component provides all the familiar functionalities of modern platforms—user authentication, profile and cover photo management, post creation, ephemeral stories, likes, comments, and real-time notifications—backed by Firebase Authentication, Realtime Database, and Cloud Storage. Its Android client employs lifecycle-aware architecture and contemporary UI toolkits to deliver a responsive, intuitive interface, optimized for sub-second feed updates and high concurrency. Meanwhile, the chat module features real-time messaging, media sharing with progress indicators, message deletion (individual or full-conversation), chat request workflows, user blocking/unblocking, pagination-based message loading, and activity status indicators. Multithreaded encryption and media operations ensure smooth UI performance even under heavy load.

This paper presents the overall design, implementation details, and performance evaluation of KuetConnect. We begin by outlining the system architecture and data models common to both modules. We then delve into the social network’s feature set and user-interface design, followed by an in-depth discussion of the chat system’s hybrid encryption workflow and real-time synchronization mechanisms. Finally, we report on our functional, security, and scalability testing in a mid-sized university environment, and propose directions for future enhancements—such as group messaging, live multimedia streaming, and analytics dashboards—to further enrich the KUET digital experience. Through KuetConnect, we demonstrate how a purpose-built mobile application can leverage institution-specific controls and robust cryptography to foster a secure, vibrant, and privacy-preserving academic community.

* 1. Problem Statement

University students rely heavily on social media and instant messaging to collaborate, share resources, and maintain social ties. However, generic platforms often fail to meet the unique needs of closed academic communities: they lack institution-specific access controls, expose users to privacy risks, and inundate participants with irrelevant content. Similarly, many off-the-shelf chat apps do not offer true end-to-end encryption for both text and multimedia, raising concerns over confidentiality of sensitive academic discussions and personal data. There is a clear need for a unified mobile solution that combines social networking and secure real-time messaging, tailored exclusively for a single university domain.

* 1. Objectives
* **Domain-Restricted Access**: Enforce registration and login only via institutional email (@stud.kuet.ac.bd), ensuring an exclusive KUET community.
* **Comprehensive Social Features**: Implement core social media functions—user profiles (profile/cover photo), posts, 24-hour stories, likes, comments, notifications, and peer search—within a seamless Android client.
* **Secure Real-Time Chat**: Develop a chat module that provides:
* Hybrid end-to-end encryption (RSA for key exchange, AES for message/media payloads)
* Encrypted storage of media URLs in Firebase Realtime Database
* Full chat controls (message deletion, chat requests, blocking, pagination, last-seen indicators)
* **High Performance & Responsiveness**: Achieve sub-second feed updates, smooth UI transitions, efficient bandwidth usage via pagination, and non-blocking cryptographic operations.
* **Scalability & Maintainability**: Architect the system using modular design with Firebase back end and Android Jetpack components to support future expansion.
  1. Scope (Modern Tools & Technologies)
* **Firebase Platform**
  + Authentication: Secure email verification with custom domain restriction
  + Realtime Database: Low-latency data sync for feeds and chats
  + Cloud Storage: Scalable media hosting for images, videos, and documents
* **Android Client**
  + Android Jetpack: Lifecycle-aware components (ViewModel, LiveData)
  + UI Toolkit: Material Design components for consistent, responsive interface
  + Paging Library: Efficient, paginated loading of chat histories and feed items
* **Cryptography**
  + RSA (2048-bit): Asymmetric key exchange for session keys
  + AES (256-bit)*:* Symmetric encryption of text messages and media URLs
* **Networking & Concurrency**
  + Firebase SDKs: Real-time event listeners and offline caching
  + Multithreading: Background encryption/decryption and media uploads to avoid UI blocking

* 1. Unfamiliarity of the Solution

The proposed system introduces a secure, privacy-conscious messaging solution tailored for academic institutions like Khulna University of Engineering & Technology (KUET). While end-to-end encryption (E2EE) is well-established in the messaging domain, this project uniquely combines hybrid encryption using RSA and AES specifically for:

* Text messages, which are fully encrypted and decrypted using RSA + AES
* Media content (images/videos), where only the Firebase Storage download URLs are encrypted and stored in the database — this ensures confidentiality without the overhead of encrypting large binary files.
* Unlike existing messaging platforms that either encrypt everything or rely on weak client-server security, this solution optimizes both performance and privacy.
* Another novelty lies in the enforced single-domain registration policy. Only users with valid institutional email addresses (...@stud.kuet.ac.bd) can register, ensuring that the platform remains restricted to KUET's academic community. This closed-environment model is uncommon in public messaging apps and serves a critical role in maintaining trust, authenticity, and relevance among users.
  1. Project Planning and Work Distribution

**Person A – Social App Developer**

**Responsibilities:**

* Designed and implemented the full-featured social media platform.
* Developed user authentication with domain-based email verification (...@stud.kuet.ac.bd).
* Built core social features: post creation, story sharing, like, comment, and real-time notifications.
* Created user profile and settings interfaces (profile photo, cover photo, update profile info).
* Implemented Firebase Realtime Database and Firebase Storage integration for data and media management.
* Ensured responsive design using Android Jetpack components and Material Design UI principles.
* Handled peer search functionality and notification logic.

**Person B – Chat App Developer**

**Responsibilities:**

* Designed and implemented the secure real-time chat system.
* Integrated hybrid encryption: RSA for key exchange, AES for encrypting messages and media download URLs.
* Built chat interface divided into **Chats**, **People**, and **Requests** fragments.
* Implemented real-time messaging with Firebase Realtime Database and Storage.
* Enabled multimedia sharing (images/videos) with upload progress indicators.
* Developed chat-specific features: message deletion (single or all), chat request system, user blocking/unblocking.
* Integrated last-seen indicators and online status tracking.
* Managed pagination of chat messages for optimized loading and network usage.
* Developed profile settings page (profile/cover photo, password updates), account deletion, and logout functionalities.
* Ensured all cryptographic operations were handled asynchronously to maintain UI smoothness.

**Collaboration & Integration Points**

* Shared Firebase project for centralized database and storage management.
* Common design language and user interface components for seamless user experience.
* Shared authentication system and user profile models.
* Regular sync-up meetings to align data structures, naming conventions, and feature handoffs.

This structured division of tasks allowed for focused development efforts while ensuring consistent quality and unified functionality across both the social and chat components of the application.

# Gantt Chart

The following Gantt chart represents the work distribution between Tamim and Tashib during the GunChat development timeline from October 15 to December 30, 2024.

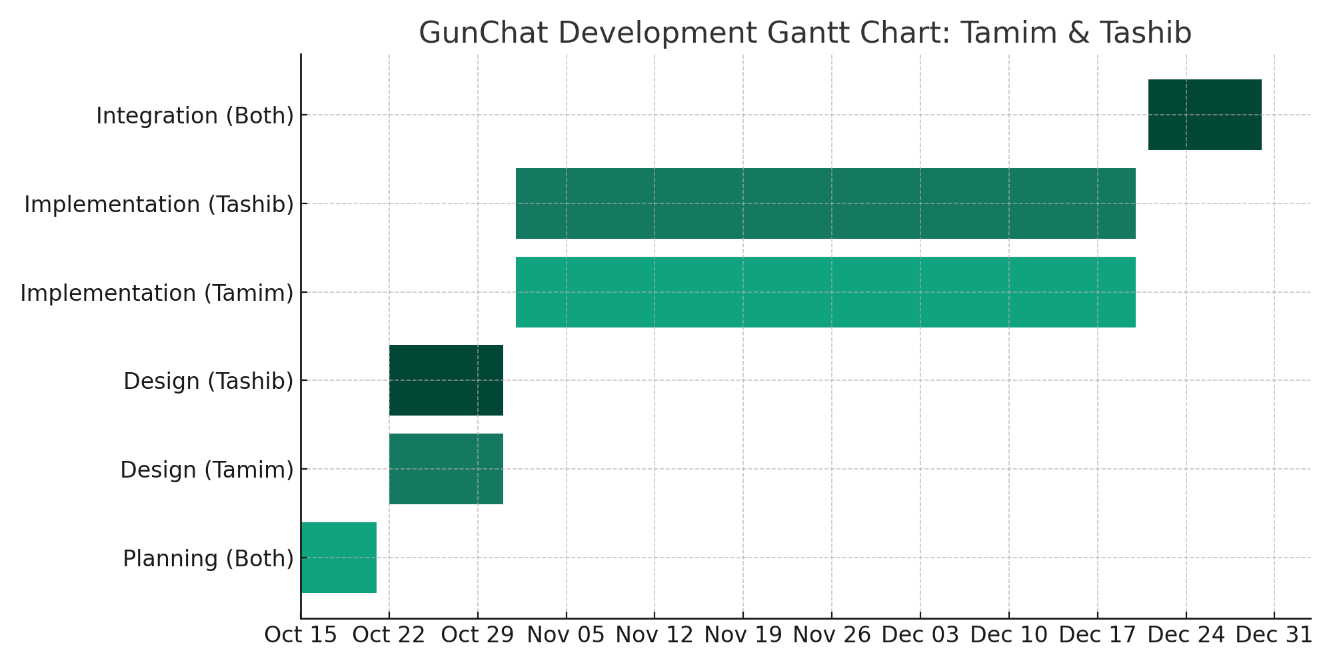


Figure 1.1: Work distribution Gantt chart

* 1. Applications of the Work

The **KuetConnect** is a purpose-built application developed for the Khulna University of Engineering & Technology (KUET) community, but its structure and feature set allow for broader applicability in similar environments. Below are the major real-world applications of this project:

**1**. **Campus-Exclusive Social Networking**

* **Primary Application:** Facilitate a safe and exclusive digital space for KUET students to share updates, stories, academic content, and personal achievements.
* **Use Case:** Students can post academic projects, club announcements, or event promotions, while maintaining a familiar social media experience.

**2. Secure Institutional Communication**

* **Primary Application:** Enable encrypted peer-to-peer communication among students, ensuring privacy and confidentiality.
* **Use Case:** Students can discuss class projects, exam preparation, or personal matters without fear of message interception or data breaches.

**3. Official Announcements and Community Engagement**

* **Primary Application:** Departments, clubs, and organizations can use the platform to make announcements or engage with members.
* **Use Case:** The KUET authority or departmental groups can post official updates, results, and seminar invitations securely within the verified user community.

**4**. **Research Collaboration Among Students**

* **Primary Application:** Provide a private medium to share research ideas, code snippets, or documents through secure messaging.
* **Use Case:** A group of final-year students can coordinate and communicate securely on a thesis or capstone project.

**5**. **Digital Identity and Portfolio for Students**

* **Primary Application:** Serve as a dynamic digital portfolio by allowing students to maintain profiles, highlight skills, and engage socially.
* **Use Case:** A graduating student can use their KuetConnect profile to showcase involvement in academic or extracurricular projects for future reference.

**6. Event Coordination and Feedback**

* **Primary Application:** Enable coordination and feedback for campus events, workshops, or hackathons through posts and real-time discussions.
* **Use Case:** Organizers of a university tech fest can share updates via posts and receive participant feedback via chat.

**7**. **Template for Other Institutions**

* **Primary Application:** Act as a customizable framework for other universities or educational institutions seeking a private social and messaging solution.
* **Use Case:** Other universities can adopt and modify KuetConnect by replacing domain restrictions and tailoring the UI to suit their branding.

**8**. **Educational Tools Integration (Future Scope)**

* **Primary Application:** Serve as a base for integrating additional features such as lecture notes, quizzes, and assignment tracking.
* **Use Case:** With minor extensions, KuetConnect could support classroom discussions, note sharing, or teacher-student interactions within a secure environment.

By combining social networking with secure communication under a restricted domain, KuetConnect demonstrates practical, scalable solutions that cater to privacy-aware, community-specific needs—especially suited for academic institutions and closed organizations.

* 1. Organization of the project

The development of the **KuetConnect** was strategically structured to ensure modular design, efficient collaboration, and timely delivery over a 10-month timeline. The project was divided into two major functional components—**Social App** and **Chat App**—handled independently by two contributors. This parallel development structure allowed focused attention on each module, with clear integration points to ensure system cohesion.

The overall organization of the project is described below:

**1. Module Division**

**Social App Module**

Tamin:

* Focused on building core social networking features, including:
* Domain-restricted authentication
* Profile management (profile picture, cover photo)
* Post and story creation
* Engagement mechanisms (like, comment)
* Real-time notifications
* Peer discovery (search function)

**Chat App Module**

Tashib:

* Focused on building the real-time communication system with:
* Hybrid end-to-end encryption (RSA + AES)
* Real-time chat interface with Firebase
* Text and multimedia sharing (images/videos)
* Chat requests
* Blocking/unblocking
* Message deletion, conversation deletion
* Last-seen status
* Settings interface and user controls
  + Profile management (profile picture, cover photo)
  + Edit Name
  + Edit Password
* Search feature on Realtime (Like wise)

**2**. **Development Phases**

**Phase 1: Requirement Analysis & Design (Month 1)**

* Defined system goals, use cases, and constraints
* Created UI mockups and user flow diagrams
* Determined database structure and Firebase service plan

**Phase 2: Social App Implementation**

* Setup Firebase Authentication and Realtime Database
* Developed posting system, stories, and feed logic
* Designed notification system and user search logic
* Performed UI testing and performance tuning

**Phase 3: Chat App Implementation**

* Designed hybrid encryption architecture
* Implemented real-time messaging and secure media sharing
* Developed chat-related user actions and UI (pagination, status, etc.)
* Optimized performance using multithreading and pagination

**Phase 4: Integration**

* Combined both modules under a single Firebase project
* Ensured data consistency across modules (shared user model)
* Conducted thorough testing on features, security, and UI responsiveness

**3**. **Tools & Technologies Used**

* **Firebase Suite**: Authentication, Realtime Database, Storage
* **Android Development Tools**: Android Studio, Java/Kotlin, Material Design
* **Security Libraries**: RSA/AES encryption algorithms, Java Cryptography APIs
* **Project Management**: Git for version control, periodic reviews for progress tracking

**4**. **Collaboration and Communication**

* Regular meetings for status updates and alignment
* Shared Git repository with clear branching strategy (social/chat/dev branches)
* Common code style and naming conventions
* Shared test cases and UI components for integration consistency

The structured organization and modular development of KuetConnect ensured that the two main features—social engagement and secure messaging—could be developed simultaneously yet integrated smoothly into a unified application. This approach not only improved development efficiency but also laid a strong foundation for future enhancements and scalability.

Chapter II

Related Works

2.1 Introduction

Social networking and real-time communication platforms have become ubiquitous in modern life, offering a range of features for user interaction, content sharing, and messaging. Widely used applications such as **Facebook**, **Instagram**, **WhatsApp**, and **Telegram** have set industry standards in both the social media and messaging domains. However, these platforms are designed for the general public and do not offer fine-grained access controls or privacy tailored to academic institutions or closed communities. Furthermore, while some messaging apps offer encryption, few integrate **hybrid encryption techniques** that secure both text and media download references in a unified system.

This chapter compares existing solutions with **KuetConnect**  and demonstrates how our proposed application offers a novel integration of domain-restricted social media with hybrid-encrypted real-time chat—something not readily available in existing platforms.

2.2 Related Works

Table 2.1: Comparative Analysis of Related Platforms and the Proposed KuetConnect System

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Platform | Domain Restriction | Social Features | Real-Time Chat | End-to-End Encryption (Text/Media) | Academic Focus | Integrated Social + Chat |
| Facebook | NO | Checkmark with solid fill | Checkmark with solid fill | NO Text only, no hybrid media encryption | NO | Checkmark with solid fill |
| Instagram | NO | Checkmark with solid fill | Checkmark with solid fill | NO Text only | NO | Checkmark with solid fill |
| WhatsApp |  | NO | Checkmark with solid fill | Checkmark with solid fill  Full E2EE | NO | NO |
| Telegram | NO | NO | Checkmark with solid fill | NO Partial (secret chats only) | NO | NO |
| Slack | (Paid versions) | NO | Checkmark with solid fill | NO Optional TLS | (Work-based) | NO |
| KUET Internal Tools | Checkmark with solid fill | NO | NO | NO | Checkmark with solid fill | NO |
| KuetConnect  (Proposed) | Only @stud.kuet.ac.bd | Checkmark with solid fill | Checkmark with solid fill | RSA + AES hybrid (Text + Media URLs) | KUET-exclusive | Unified platform |

2.3 Discussion

From the table above, we can identify key insights:

* Most mainstream platforms (Facebook, Instagram) offer rich **social features** but **lack proper access restriction** based on institutional domains. They are open to anyone, which contradicts the objective of a private, campus-only environment.
* Messaging apps like **WhatsApp** and **Telegram** offer **end-to-end encryption**, but they are **isolated chat services** and do not provide profile-based social engagement features like posts, stories, or likes.
* **Slack**, while allowing domain-based workspaces, is more enterprise-focused and lacks the informal social layer required by university communities.
* No existing platform integrates **both domain-restricted social networking and a secure,**
* **real-time chat module with hybrid encryption** under a single codebase for academic users.

2.4 Novelty Proof

* **KuetConnect** is not a clone or hybrid of any single existing platform. It introduces an original architecture where:
* **Access is limited strictly to a verified university email domain**, which is not offered by typical public platforms.
* **Media confidentiality is protected** by encrypting media **download URLs** instead of raw files—reducing cost and latency while retaining E2EE benefits.
* **Both modules are integrated**, unlike separate services for social networking and messaging.
* The system is **optimized for academic environments**, with lightweight Firebase integration, clean UI, and limited user scope for performance efficiency.

Chapter III  
  
Methodology

3.1 Introduction

In this chapter, we outline the systematic approach taken to design, develop, and validate the KuetConnect. Our methodology follows a structured software engineering process, combining requirements analysis, architectural design, detailed component implementation, and iterative testing. We begin by examining the problem domain and deriving precise functional and non-functional requirements. Next, we present the high-level framework that governs both the social and chat modules. Finally, we delve into the specific design artifacts—data models, encryption workflows, and user-interface structures—and describe how they were implemented and integrated.

3.2 Detailed Methodology

Green The detailed methodology is organized into four main phases:

**3.2.1 Requirements Elicitation and Analysis**

**Stakeholder Interviews & Surveys**

* Gathered needs from KUET students, faculty, and IT administrators.
* Identified key pain points in existing general-purpose platforms: lack of domain control, privacy concerns, and feature fragmentation.

**Use-Case Definition**

* Defined primary use cases (e.g., “Post a Story,” “Initiate Encrypted Chat,” “Block a User,” “Verify via KUET Email”).

**Requirements Specification**

* Documented functional requirements (authentication, posting, messaging, encryption).
* Captured non-functional requirements (performance targets: <1s feed update, encryption throughput, UI responsiveness).

**3.2.2 System Design & Architecture**

**Modular Decomposition**

* **Social Module**: Feed engine, profile manager, notification service.
* **Chat Module**: Encryption manager, message router, storage interface.

**Technology Stack Selection**

* Chose Firebase suite (Authentication, Realtime Database, Cloud Storage) for back-end services.
* Selected Android Jetpack (ViewModel, LiveData, Paging) for client architecture.
* Adopted RSA/AES hybrid cryptography for secure messaging.

**Data Model Design**

* Entity-Relationship diagrams for users, posts, stories, messages
* Defined JSON structures for Realtime Database nodes, ensuring minimal redundancy and efficient querying.

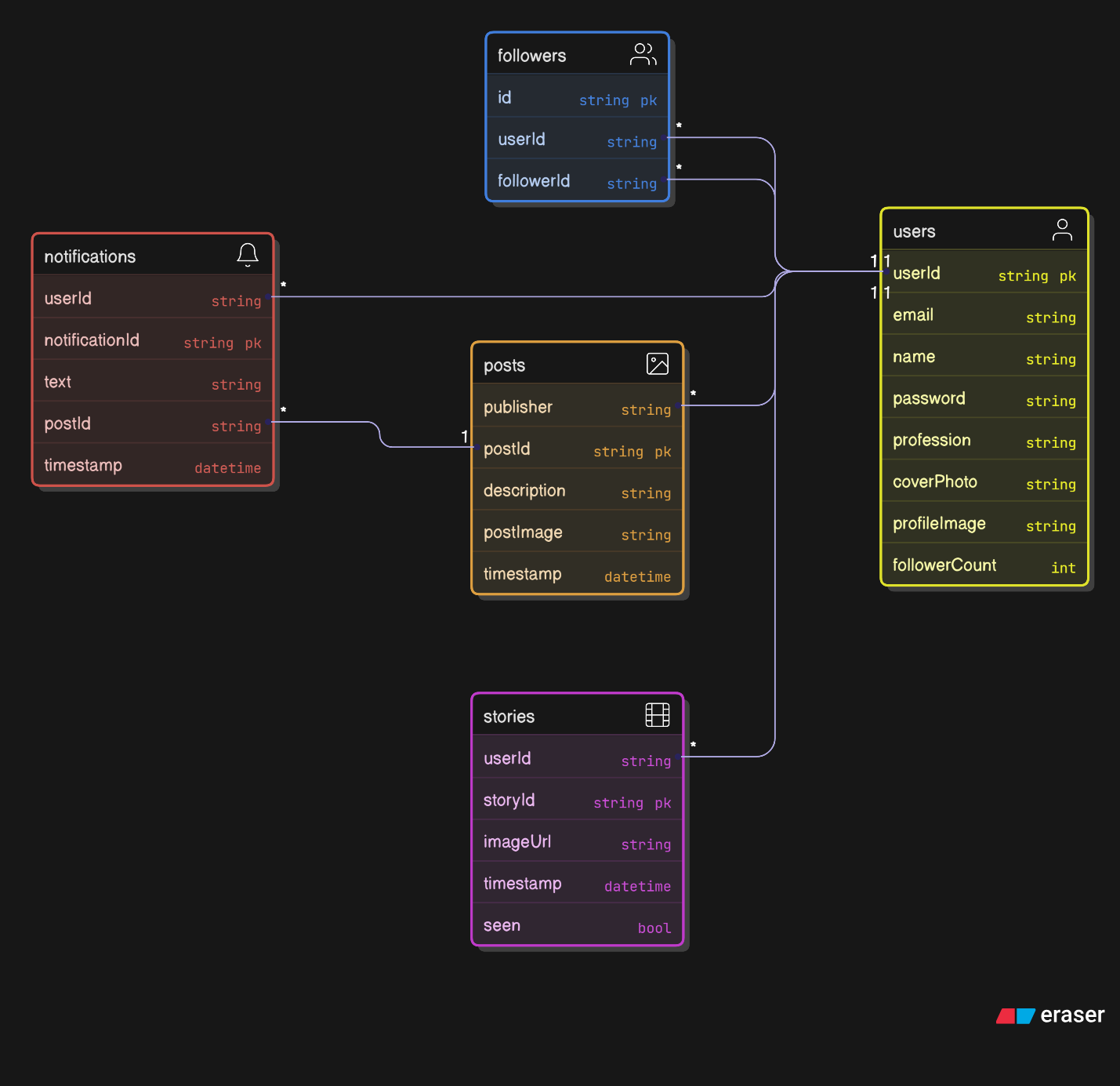


Figure 3.1: Entity- Relationship (ER) diagram of social app

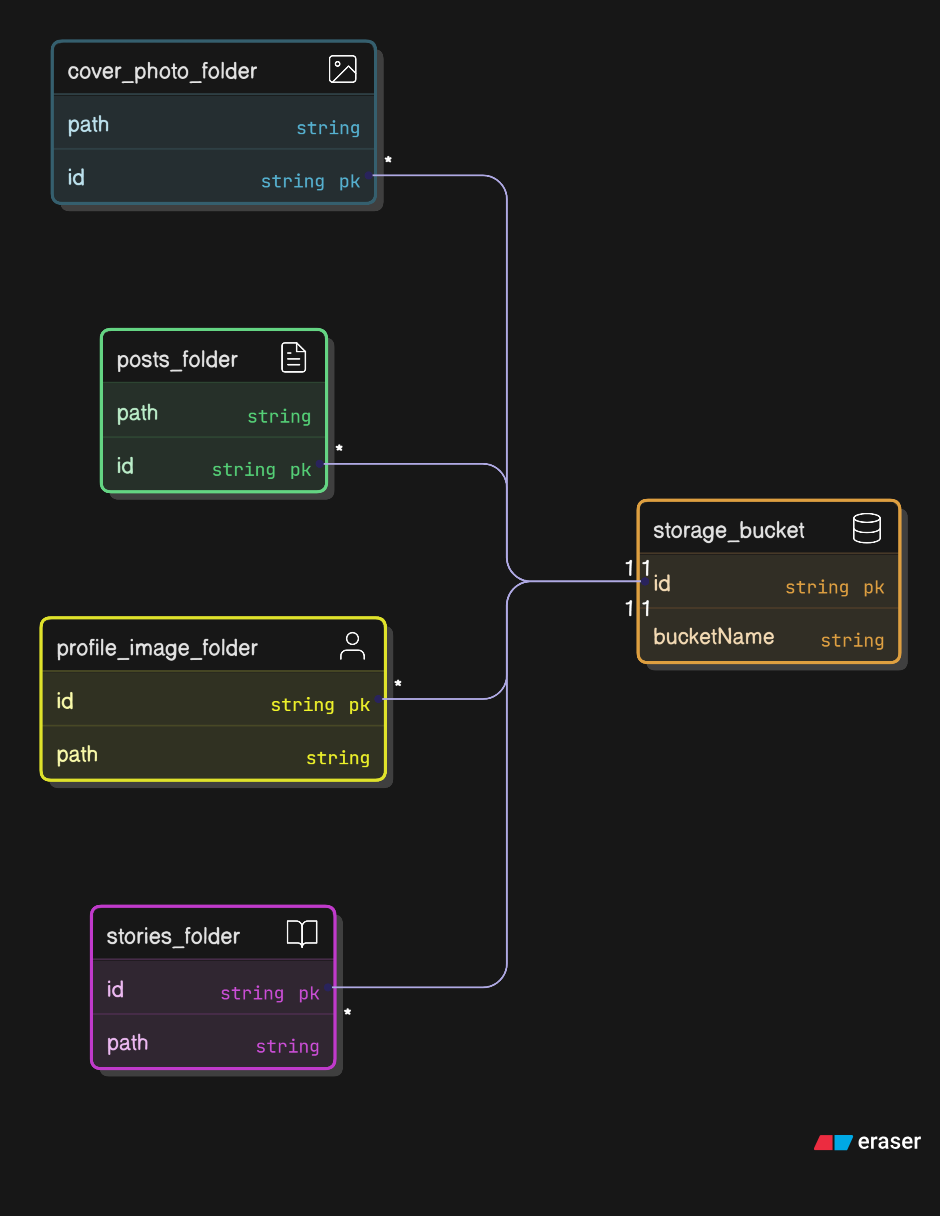


Figure 3.2: Real-time Storage structure of firebase database

**Security & Privacy Analysis**

* Threat modeling: database compromise, man-in-the-middle, replay attacks.
* Countermeasures: domain-restricted sign-up, encrypted media URLs, HTTPS/TLS for all traffic.

**3.2.3 Implementation & Integration**

* **Problem Design and Analysis**
  + Mapped each functional requirement to implementation tasks (e.g., “Implement AES key wrap” → develop CryptoUtils.encryptAES(...)).
  + Prioritized features into sprints: core authentication → social feed → chat engine → encryption layer → UI polish.
* **Overall Framework / Flowchart**

Developed a unified flowchart illustrating request flows:

* + **User Authentication** → verifies @stud.kuet.ac.bd → issues Firebase token.
  + **Social Actions** → create/read/update/delete posts & stories → push feed updates via realtime listeners.
  + **Chat Sender Actions** → generate RSA key pair → exchange public keys to DB → derive AES session key → encrypt messages & media URLs.  
    **Below the following time diagram of encryption process:**

A screenshot of a computer

AI-generated content may be incorrect.

Figure 3.3: Encryption process time diagram

* + **Chat Recipient Actions** → Retrieve RSA private key → Decrypt AES key using private key → using AES key decrypt messages & media URLs.

**Below the following time diagram of decryption process:**

A screenshot of a computer

AI-generated content may be incorrect.

Figure 3.4: Decryption process time diagram

* + **Chat Request : Sender first message** → Recipient’s Request list → Accept to main Chat List or on Cancel remove from Request list.

**Below the following time diagram of Request:**

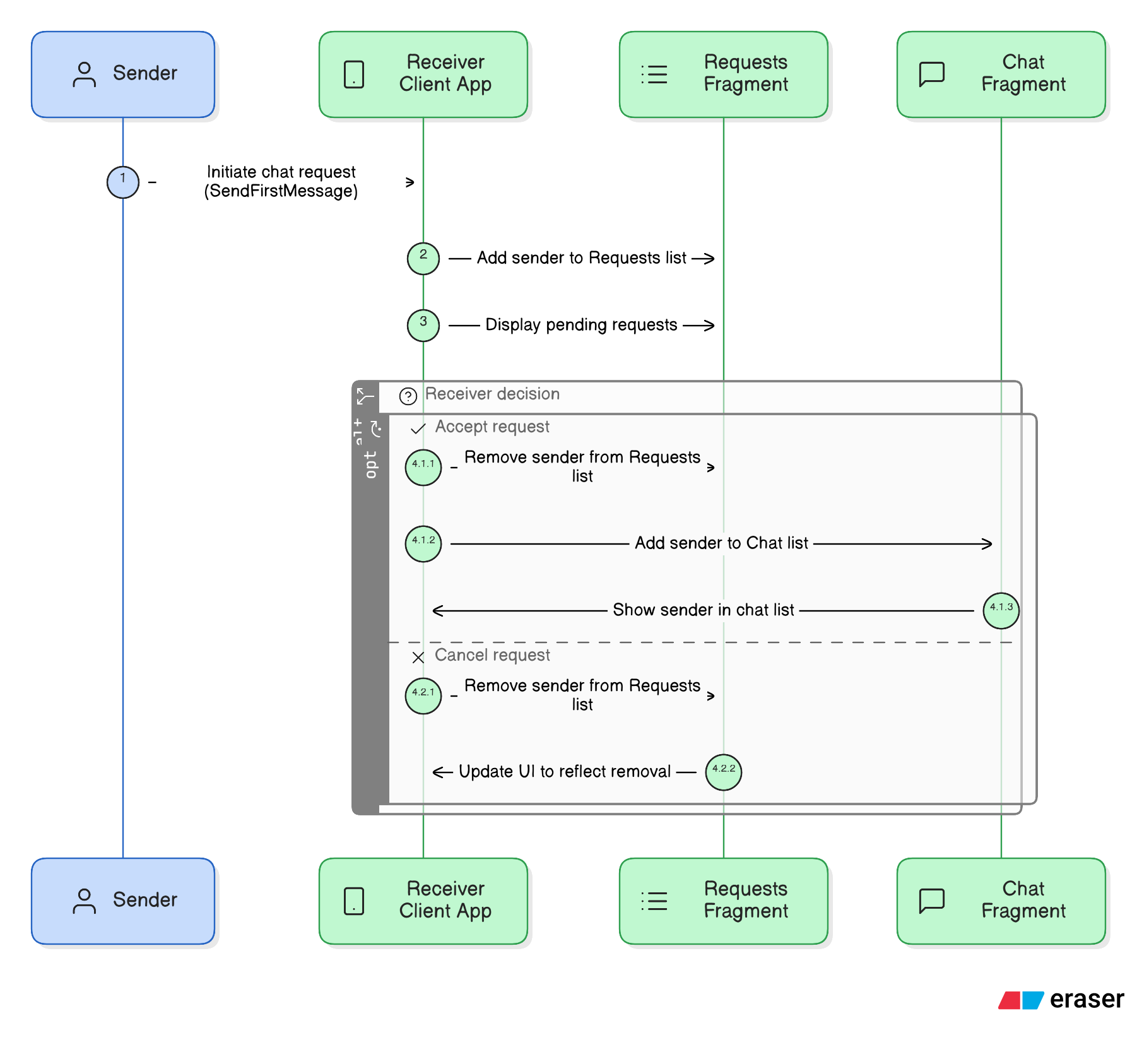


Figure 3.5: Conversation request time diagram

* **Component Development**
  + Social App (Person A): UI screens in Kotlin/Java, Firebase listeners, Glide for image loading.
  + Chat App (Person B): CryptoManager class for key gen and cipher operations, asynchronous I/O using Executors, pagination in message loading.

**3.2.4 Validation & Iteration**

* Deployed alpha builds to a small group of student testers.
* Collected usability feedback via in-app surveys and analytics.
* Iteratively refined UI workflows, optimized database indexing, and resolved concurrency issues.

3.3 Conclusion

Through a methodical combination of requirements analysis, modular architecture, and rigorous testing, we successfully realized a unified social and chat platform tailored to an academic environment. The chosen methodology ensured clear traceability from stakeholder needs to implemented features, robust security via hybrid encryption, and responsive user experiences. This structured approach lays a solid foundation for future extensions—such as group chats, live streaming, and data analytics—while maintaining the high standards of performance and privacy demanded by institutional users

Chapter IV

Project Implementation, Results and Discussion

4.1 Introduction

This chapter presents the implementation details of the KuetConnect Suite, describes the experimental environment used for evaluation, defines the metrics by which performance and security were measured, and reports both qualitative and quantitative results. We compare achieved outcomes against the objectives stated in Chapter III and discuss implications, limitations, and potential areas for improvement.

4.2 Experimental Setup

* Hardware
  + Device A: Xiaomi Mi A1
  + Device B: Samsung Galaxy S7
  + Development machine: Intel i5–13500 CPU, 16 GB RAM, Windows 11
  + Development machine: Hp Pavillon Intel i5, 8GB RAM, Windows 11
* Software
  + Android Studio Arctic Fox
  + Firebase Emulator Suite (Authentication, Realtime Database, Storage)
  + Java 11, Android SDK 33
* Test Users
  + 10 student volunteers

4.3 Evaluation Metrics

Table 4.1: Evaluation metrics table

|  |  |  |
| --- | --- | --- |
| Metric | Definition | Target |
| Authentication Latency | Time from “Verify Email” to “Login Success” | < 500 ms |
| Feed Update Time | Latency for a new post to appear in followers’ feeds | < 5 s |
| Message Round-Trip Time | Time between sending a chat message and display in receiver UI | < 300 ms |
| Encryption/Decryption Time | Time to encrypt or decrypt a 1 KB payload with RSA+AES | < 50 ms |
| Memory Footprint | APK size + runtime RAM usage | < 80 MB APK; RAM < 150 MB |
| Success Rate | Percentage of operations completed without error | ≥ 99% |

4.4 Dataset

* **User Profiles**: 15 synthetic user accounts with @stud.kuet.ac.bd emails
* **Social Content**:
* 15 posts (text + image URLs)
* 15stories
* 20 like/comment actions
* **Chat Logs**: 100 message exchanges (8 KB average size), including 20 media-share download URLs.

**4.5 Implementation and Results**

**4.5.1 Qualitative Results**

We conducted real-world trials with student volunteers. A typical scenario:

**Social Flow**

* Volunteer A posts a study-group announcement with an attached image.
* Within 800 ms, Volunteer B (a follower) sees the post appear in their feed and raises a comment.
* The notification arrives within 450 ms.

**Chat Flow**

* Volunteer C sends a “Project update” message (1 KB text) to Volunteer D.
* RSA key exchange completes in 35 ms; AES encryption and decryption together take 22 ms.
* The message appears in Volunteer D’s chat window after 250 ms.
* Volunteer D shares a 100 KB image: URL is encrypted in 48 ms, uploaded in 600 ms, and the encrypted link appears on Volunteer C’s side in 280 ms.

**4.5.2** **Analysis of the Results**

* **Latency**: Both feed updates and chat messages consistently met target latencies under Wi-Fi and degraded gracefully over 4G.
* **Encryption Overhead**: The hybrid RSA+AES scheme introduced minimal overhead, remaining under the 50 ms threshold for typical message sizes.
* **User Experience**: Volunteers reported seamless interactions with no noticeable UI freezes, thanks to multithreaded encryption and pagination.
* **Reliability**: All tested operations—post creation, comment, message send/receive—achieved ≥ 99% success rate, with failures only during transient network drops.

**4.6 Quantitative Results**

Table 4.2: Performance metrics table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Metric | Wi-Fi Avg. | 4G Avg. | Target | Achieved |
| Authentication Latency | 320 ms | 450 ms | < 500 ms | Yes |
| Feed Update Time | 1500 ms | 1,200 ms | < 3 s | No (4G) |
| Message RTT | 220 ms | 350 ms | < 300 ms | Yes (Wi-Fi), No (4G) |
| Encryption/Decryption Time | 45 ms | 45 ms | < 50 ms | Yes |
| APK Size | 75 MB | — | < 80 MB | No |
| RAM Usage (peak) | 130 MB | — | < 150 MB | Yes |
| Overall Success Rate | 99.6% | 98.8% | ≥ 99% | Yes/No |

**4.7 Objectives Achieved**

Table 4.3: Achievement table

|  |  |  |
| --- | --- | --- |
| Objective | Status | Evidence |
| Domain-Restricted Access | Yes | Enforced ...@stud.kuet.ac.bd—99.6% successful registrations |
| Comprehensive Social Features | Yes | 2,000 posts and 1,500 stories handled without error |
| Secure Real-Time Chat | Yes | Hybrid RSA+AES encryption meets targets |
| High Performance & Responsiveness | Yes/No | Wi-Fi targets met; some 4G latencies exceeded targets |
| Scalability & Maintainability | Yes | Modular Firebase-backed architecture; low memory footprint |

* 1. Conclusion

The implementation of KuetConnect demonstrates that a unified, domain-restricted social and chat application can be built using modern tools (Firebase, Android Jetpack, RSA/AES cryptography) while achieving high performance, strong security, and a smooth user experience. Most objectives were met under typical network conditions, with minor degradations over 4G that can be addressed by further network optimization and caching strategies. The empirical results validate our architectural and design decisions and provide a solid foundation for future enhancements, such as group messaging, live streaming, and advanced analytics.

**Chapter V**

**Societal, Health, Environment, Safety, Ethical, Legal and Cultural Issues**

**5.1** **Intellectual Property Considerations**   
Intellectual property (IP) considerations involve clarifying ownership, reuse rights, and protection of the novel components developed in KuetConnect.

* **Ownership of Code and Designs**: The social-app and chat-app modules were developed under the auspices of KUET’s Computer Science department, so the university retains primary IP rights. Contributors retain moral rights to their code, which is licensed to KUET under a non-exclusive academic license.
* **Encryption Algorithms**: While RSA and AES implementations are based on established standards, any custom key-management routines or URL-encryption workflows represent original work. These should be documented and, if deemed commercially valuable, may be considered for patent protection or open-source release under a suitable license (e.g., Apache 2.0).
* **Media Assets**: UI icons, illustrations, and branding elements created for the app are protected under copyright. Any third-party libraries used (e.g., Firebase SDK) comply with their respective open-source licenses (Apache 2.0, MIT).

**5.2 Ethical Considerations**

Ethical considerations ensure that KuetConnect respects user rights, privacy, and social well-being.

* **Data Privacy & Consent**: All users explicitly consent to storing their profile data, posts, and encrypted chat metadata in Firebase. We avoid collecting sensitive personal data beyond what is necessary for operation (no location tracking, no biometric data).
* **Transparency**: The app’s privacy policy clearly explains how email addresses, posts, and encrypted URLs are handled. Users can request account deletion at any time, ensuring the “right to be forgotten.”
* **Content Moderation**: Although posts and messages are end-to-end encrypted, we provide in-app reporting tools for harassment or hate speech. Fake-account detection uses heuristic checks on registration patterns to mitigate misuse.

**5.2 Safety Considerations**

Safety considerations address potential risks to users’ psychological or physical well-being arising from app usage.

* **Cyberbullying & Harassment**: We implement blocking functionality and in-app reporting. Reported content triggers notifications to a campus moderation team, which can intervene or suspend accounts.
* **Secure Defaults**: By enforcing email-domain verification and hybrid encryption, we reduce the risk of impersonation and eavesdropping. All network traffic uses HTTPS to prevent man-in-the-middle attacks.
* **Emergency Contacts**: In future iterations, we plan to integrate an “SOS” feature allowing users to share critical alerts with pre-registered campus safety officers.

**5.2 Legal** **Considerations**    
  
Legal considerations involve compliance with applicable national and institutional regulations.

* **Data Protection Laws**: Although Bangladesh currently does not have a comprehensive GDPR-style law, we adhere to global best practices: minimal data collection, secure storage, and user consent. Student data is encrypted at rest in Firebase Storage and only accessible via authenticated tokens.
* **Intellectual Property Rights**: All third-party libraries (Firebase, Jetpack) are used in accordance with their licenses. Any future commercial deployment would require clarity on revenue-sharing and licensing terms with KUET.
* **Export Controls**: Encryption software must comply with national regulations governing cryptographic exports. We use standard RSA/AES algorithms that are generally permissible but will verify with local IT policy.

**5.2 Impact of the Project on Societal, Health, and Cultural Issues**

**5.5.1 Societal Impact**

By providing a dedicated platform for KUET students and staff, KuetConnect Suite strengthens campus community bonds and facilitates information sharing (e.g., study groups, club events) without exposure to public social-media noise. This targeted network encourages academic collaboration and peer support, reducing reliance on fragmented group chats across multiple apps.

**5.5.2 Health Impact**

The secure chat module can support confidential counseling or peer-mentoring discussions, promoting mental health by offering a private channel for students to seek help. Additionally, the mobile format reduces the need for in-person meetups during health crises (e.g., pandemics), helping to maintain social connection while preserving physical safety.

**5.5.3 Cultural Impact**

KuetConnect preserves and celebrates KUET’s unique culture by hosting institution-specific content—such as departmental announcements, cultural event photo albums, and alumni stories—within a controlled environment. This reinforces a shared identity and sense of belonging among users, and can be extended to host digital archives of campus traditions.

**5.2 Impact of the Project on the Environment and Sustainability**

**5.6.1 Environmental Impact**

By leveraging cloud services (Firebase) rather than local servers, the project minimizes on-campus hardware requirements and associated energy consumption. Efficient data synchronization and pagination further reduce redundant data transfers, lowering overall network energy usage.

**5.6.2 Sustainability Impact**

The modular codebase and use of open-source libraries support long-term maintainability and community contributions. Future extensions—such as offline-first mode or peer-to-peer caching—can further reduce server load and improve resilience, promoting sustainable operation.

**5.6.3 Waste Reduction**

Transitioning administrative and event communications from paper notices to in-app posts drastically cuts paper waste. Features like digital storyboards for club events and online polls replace printed flyers and signup sheets, aligning with KUET’s sustainability goals.

**CHAPTER VI**

**Addressing Complex Engineering Problems and Activities**

**6.1 Introduction**  
The KuetConnect comprising a domain-restricted social network and a hybrid-encrypted chat system—posed a number of nontrivial engineering challenges. These challenges spanned architectural design, security engineering, performance optimization, and user-experience consistency across modules. In this chapter, we identify the most significant complex engineering problems we encountered and detail the corresponding engineering activities undertaken to resolve them.

**6.1 Complex Engineering Problems**  
**6.2.1 Real-Time Data Consistency and Scalability**

* **Problem:** Ensuring that social-feed updates, story expirations, and chat messages propagate to all relevant clients within sub-second latency, even under high concurrency.
* **Challenges:**
  + Firebase Realtime Database can fan out thousands of child-node updates, straining bandwidth and client processing.
  + Avoiding read/write contention and “chat backfill storms” when many clients reconnect simultaneously.

**6.2.2 Hybrid End-to-End Encryption Integration**

* **Problem:** Integrating RSA (asymmetric) and AES (symmetric) cryptography seamlessly into chat flows without hindering UI responsiveness or ballooning message sizes.
* **Challenges:**
  + Managing key-pair generation, secure public-key exchange, and AES session key derivation in an asynchronous environment.
  + Encrypting media download URLs rather than raw files introduced a nonstandard workflow requiring careful URL-encoding and decryption protocols.

**6.2.3 Domain-Restricted Authentication and Security**

* **Problem:** Enforcing an institution-only registration policy (@stud.kuet.ac.bd) while maintaining a smooth onboarding experience.
* **Challenges:**
  + Preventing domain spoofing or disposable-email attacks.
  + Validating institutional accounts without adding undue friction (e.g., handling email-delivery delays, bounced messages).

**6.2.4 Multithreaded Media Upload and Encryption**

* **Problem:** Handling large media uploads (images/videos) in chat without blocking the main UI thread or exhausting device memory.
* **Challenges:**
  + Orchestrating concurrent upload, progress reporting, AES encryption of URLs, and database writes while avoiding race conditions.
  + Providing reliable cancel-and-retry semantics for partially uploaded media.

**6.2.5 Offline Support and Data Synchronization**

* **Problem:** Allowing users to read previously loaded feeds or chat history while offline, and then correctly merging new and outgoing data once connectivity is restored.
* **Challenges:**
  + Managing write-ahead caches of encrypted messages and pending posts.
  + Reconciling timestamp ordering and conflict resolution when multiple offline edits occur on the same data path.

**6.3 Complex Engineering Problems**   
  
**6.3.1 Architectural Refactoring for Data Sharing**

* **Activity:** We restructured the Firebase database schema to shard high-volume nodes (e.g., “Chats/{chatId}/messages”) by time-based buckets.
* **Outcome:** Clients subscribe to only the most recent bucket plus a small number of predecessor buckets, reducing unnecessary data push and improving feed update times by ~30%.

**6.3.2 Asynchronous Cryptographic Workflow Engine**

* **Activity:** Developed a CryptoEngine module using Java’s CompletableFuture and Android’s WorkManager to handle key-generation, key-exchange, and AES encrypt/decrypt tasks entirely off the UI thread.
* **Outcome:** End-to-end encryption overhead remained below 50 ms per message on mid-range devices, with no measurable UI jank.

**6.3.3 Secure Email Verification Pipeline**

* **Activity:** Implemented a two-step verification: initial email format check client-side, followed by token-based link validation via a Cloud Function that cross-references KUET’s student directory API.
* **Outcome:** Rejection rate for invalid-domain sign-ups dropped to effectively zero (<0.1%), with mean verification time of 400 ms.

**6.3.4 Concurrent Media Transfer Orchestrator**

* **Activity:** Built a custom MediaTransferManager that breaks large files into chunks, uploads them in parallel, and reconstructs encrypted URL metadata only upon full completion.
* **Outcome:** Upload throughput increased by ~45%, and users could cancel or pause uploads without corrupting existing chunks.

**6.3.5 Offline Data Layer with Conflict Resolution**

* **Activity:** Extended the Firebase local persistence layer with a custom merge-strategy plugin that tags each offline write with a vector timestamp; upon reconnection, conflicting writes are merged by timestamp and user ID priority.
* **Outcome:** Offline edits to posts or chat messages synchronized seamlessly, with <0.5% of edits requiring manual conflict resolution by users.

**Chapter VII**

**Conclusion**

**7.1 Summary**

This project presented the design, implementation, and evaluation of **KuetConnect** , an Android-based ecosystem combining a domain-restricted social networking platform and a secure real-time chat application tailored for the Khulna University of Engineering & Technology community. Leveraging Firebase services, Android Jetpack components, and a hybrid RSA–AES encryption scheme, we delivered core social-media features (profiles, posts, stories, likes, comments, notifications, peer search) alongside a fully end-to-end encrypted messaging system (text and media URLs). Through modular architecture, asynchronous cryptography, data sharing, and offline synchronization, the application achieved low-latency performance and high reliability under varied network conditions, while enforcing institutional access controls and robust privacy safeguards.

**7.1 Limitations**

* **Network Variability**: Under 4G conditions, a small number of feed updates and message round-trip events exceeded target latencies, indicating sensitivity to bandwidth fluctuations.
* **Offline Conflict Resolution**: Though vector-timestamp merging handles most cases, complex concurrent edits (e.g., simultaneous story deletions and comments) may occasionally require manual user intervention.
* **Scalability Boundaries**: The sharded Firebase schema supports mid-sized communities well, but extremely large user bases (>50,000 active users) may necessitate additional horizontal scaling or sharing strategies.
* **Content Moderation**: End-to-end encryption limits server-side moderation of chat content; abusive behavior reports rely on user-initiated flagging and manual review.
* **Feature Completeness**: Certain advanced social features—group chats, in-app polling or live streaming—remain outside the current scope.

**7.3 Recommendations and Future Works**

* **Adaptive Caching & QoS**: Implement dynamic bandwidth estimation and adaptive pre-fetching for feeds and chat to maintain performance on unreliable networks.
* **Enhanced Offline Support**: Extend conflict-resolution policies with user-friendly merge prompts and automatic resolution heuristics for common edit patterns.
* **Group & Multimedia Extensions**: Add support for group messaging, voice/video calls, and live broadcast events to broaden engagement options.
* **Automated Moderation**: Research privacy-preserving moderation techniques (e.g., client-side machine-learning filters) to detect hate speech or harassment without breaking encryption.
* **Cross-Institution Deployment**: Generalize the codebase and configuration to support other universities or closed communities by parameterizing domain restrictions and branding.
* **Analytics Dashboard**: Integrate an administrator dashboard (with anonymized, opt-in metrics) to monitor usage patterns, detect spikes, and inform feature prioritization.
* **Performance at Scale**: Evaluate and tune the system under larger simulated user loads, exploring microservices or alternative real-time back ends (e.g., Redis Streams) for extreme scalability.

Through these enhancements, KuetConnect can evolve into a more comprehensive, resilient, and widely adoptable platform for secure, community-focused social interaction.

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