BloodLink: A Mobile Application for Emergency Blood Donor Finder

Mr. Prashant Bhandare[1], Ms. Dhanashri Mhamane[2], Ms. Mayuri Koshti[3] , Ms. Sonali Pujari[4]

[1] *Computer Engineering, SVERI's College of Engineering (Poly.), Pandharpur, Maharashtra, India*
[2] *Computer Engineering, SVERI's College of Engineering (Poly.), Pandharpur, Maharashtra, India*
[3] *Computer Engineering, SVERI's College of Engineering (Poly.), Pandharpur, Maharashtra, India*
[4] *Computer Engineering, SVERI's College of Engineering (Poly.), Pandharpur, Maharashtra, India*

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Abstract - Emergency medical cases often suffer delays because information about potential blood donors is scattered, outdated, or difficult to verify quickly. To address this gap, this work introduces *BloodLink*, a lightweight mobile solution designed to reorganize the blood-donor ecosystem through structured digital coordination. Instead of relying on static records, the system continuously updates donor availability, manages request authenticity, and prioritizes nearby contributors through an integrated location engine. The application is built with a cross-platform Flutter environment, while Firebase services handle authentication, data consistency, and event-driven alerts. A controlled donor-cooldown cycle maintains safe donation intervals, and an administrative screening module ensures that only legitimate requests enter the system. By merging live data handling with a simplified interaction model, BloodLink enhances responsiveness and strengthens the reliability of emergency blood sourcing in diverse field conditions.

Key Words: Mobile Health System, Donor Coordination, Cross-Platform App, Cloud Backend, Proximity-Based Filtering

1.INTRODUCTION

Access to safe and timely blood remains one of the most persistent challenges in emergency healthcare, especially in environments where donor information is scattered or outdated. In many regions, blood seekers still rely on informal networks, social media posts, or personal contacts, which often lead to delayed responses and uncertainty regarding donor eligibility. These fragmented communication channels underscore the need for a structured, real-time coordination system that can bridge the gap between individuals in need of blood and donors who are willing and able to contribute.

Over the past decade, several digital solutions have attempted to simplify donor discovery; however, many continue to rely on static registries or manual verification processes. Such systems are unable to reflect real-time changes in donor availability, proximity, or recent donation history, resulting in inefficiencies during critical situations. Additionally, few platforms integrate automated safety measures—such as donor deferral periods—or provide validated data from blood banks and healthcare institutions. This inconsistency reduces reliability and limits their practical effectiveness during emergencies.

BloodLink is designed to address these shortcomings by offering a mobile-first platform that focuses on instant donor-request matching powered by cloud-driven synchronization. Developed using Flutter for cross-platform compatibility and Firebase for secure data management, the system introduces dynamic donor status updates, precise geolocation-based filtering, and automated alerts for nearby eligible donors. A structured verification layer ensures the authenticity of blood requests, while the donor cooldown mechanism encourages safe and ethical donation intervals. Through this combined approach, BloodLink aims to build a more reliable, responsive, and accessible network for emergency blood acquisition.

The structure of this paper is organized as follows: Section 2 reviews existing systems and their limitations; Section 3 presents the theoretical foundations of the proposed framework; Section 4 explains the system architecture and working methodology; Section 5 discusses experimental results and observations; Section 6 concludes the study and outlines future enhancements.

2. Body of Paper

1. Related work

Several studies have explored digital frameworks for improving emergency blood availability, donor coordination, and healthcare responsiveness. Early mobile applications primarily focused on maintaining donor lists and enabling manual searches, but lacked mechanisms for real-time updates or automated tracking of donor availability. Recent research has shifted toward integrating cloud services, location-based filtering, and instant notification systems to enhance reliability and reduce response time.

In a study by Sharma and Patel [1], the authors introduced a lightweight Android system for rapid donor discovery, emphasising simplicity in registration and donor alerts. However, the absence of automated donor deferral limited the assurance of safety. Deshmukh and Rao [2] extended this idea by incorporating GPS-based matching and proximity prioritisation, but did not include backend cloud synchronisation for dynamic updates.

Government-backed systems such as RaktKosh [3] have demonstrated the importance of maintaining a central repository of donor records and blood bank inventories. Although comprehensive, the platform is web-centric and does not provide the instant, personalised donor-recipient matching required during emergencies. Kumar and Singh [4] proposed an algorithmic approach for GPS-driven donor matching, suggesting that optimised filtering can significantly improve donor response rates.

International studies also highlight gaps in mobile health (mHealth) infrastructure. The ICMR review [5] emphasised the importance of multilingual interfaces and hospital-verified donor eligibility to enhance trust. NIT Trichy's BloodMate project [6] experimented with donor engagement through rewards and gamification, showing improved retention but lacking strong location-based functionality.

Cloud-integrated systems have also been applied to related medical applications. Khan et al. [7] demonstrated the effectiveness of Firebase in securing real-time medical records, suggesting its suitability for donor databases. Similarly, a design by Mishra and Yadav [8] utilised push notifications for critical health alerts, demonstrating that mobile-first strategies can significantly reduce communication delays.

Mapping-based emergency services provide additional insights. JNTU Hyderabad's geolocation-driven blood bank locator [9] showcased the impact of visual proximity indicators but did not include donor-level verification. A comparative review by Fernandes et al. [10] highlighted the importance of integrating donor cooldown mechanisms for ethical donation practices.

More advanced models explore predictive analytics. A study by Gupta and Rane [11] proposed the use of machine learning algorithms to predict donor responsiveness, indicating future possibilities for intelligent donor matching. Another review by Banerjee [12] emphasised secure authentication frameworks for medical apps using Firebase Authentication.

Recent innovations in peer-to-peer health support also influence donor systems. Suresh and Kumar [13] described how decentralised communication can shorten response time in emergency networks. Lastly, Patil et al. [14] evaluated user experience factors in emergency medical apps, emphasising that intuitive interfaces significantly impact adoption and effectiveness.

Existing literature collectively reveals that while considerable work has been done in donor filtering, geolocation services, and cloud integration, no single system fully unifies real-time donor availability, location-aware matching, secure authentication, donation cooldown control, and admin validation within a mobile-first environment. BloodLink is designed to bridge these gaps.

2. Theory/Calculation

The development of an emergency donor-matching platform such as BloodLink is strongly influenced by concepts from mobile communication theory, cloud-synchronised state management, and biomedical donation constraints. This section expands on the theoretical principles that guide the system design and presents the practical calculations that support donor selection, proximity filtering, and real-time event handling.

2.1 Donor Eligibility Theory

Every blood donor must follow safe donation intervals as defined by medical standards. This creates a time-dependent availability function rather than a fixed donor state. The theoretical donor availability model is:

$$A(t)=\{0,\ 1,\ t < Tsafe$$

$$A(t)=\{0,\ 1,\ t \geq Tsafe$$

Where:

$A(t)$ = donor availability at time t

Tsafe = required medical gap since last donation (usually 90 days)

This ensures that the donor-selection mechanism adheres to biomedical rules and prevents unsafe or premature donations.

2.2 Real-Time System State Theory

Cloud-based systems operate on dynamic synchronisation rather than static data retrieval. In BloodLink, every database change—whether it's a new donor, an updated status, or a request—is treated as an event.

A simplified theoretical model of the system state is:

$$S(t)=F(D(t),R(t),A(t),L(t))$$

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Where:

D(t) = active donor set

R(t) = request set

A(t) = availability state of donors

L(t) = spatial coordinates of donors/requesters

Since the database updates continuously:

$dS/dt \neq 0$

This characteristic forms the foundation of Firebase's event-driven architecture.

2.3 Geolocation Theory for Distance Estimation

Accurate donor matching requires precise calculations of distance. For mobile applications covering varied geographical areas, the Haversine formula is the optimal method to measure the shortest distance between two coordinates:

Where:

R = Earth's radius (≈6371 km)

$\phi 1, \phi 2$ = latitudes

$\lambda 1, \lambda 2$ = longitudes

This theoretical approach allows BloodLink to determine nearby donors with high accuracy.

2.4 Practical Implementation of Distance Filtering

Using the Haversine distance d, the system applies the following condition:

$d \leq R$ limit

Where

R limit is the maximum alert radius selected by the admin (e.g., 5–20 km).

If the condition is satisfied, the donor is considered "reachable" and moves to the matching pipeline.

2.5 Notification Trigger Logic

After filtering, the system uses a rule-based function to identify eligible donors:

$$N = \begin{cases} 1, & (B_d = B_r) \wedge (A = 1) \wedge (d \leq R_{limit}) \\ 0, & \text{otherwise} \end{cases}$$

Where:

Bd = donor blood group

Br = required blood group

A = availability status (from Section 3.1)

If N=1, Firebase Cloud Messaging generates an instant push alert.

2.6 Verification Model

To prevent misuse of the system, all blood requests undergo administrative screening. The verification variable:

V={ 1, verified request

V={ 0, rejected/unverified

Only requests where V=1 are forwarded to the donor-matching system.

2.7 Integrated Calculation Pipeline

The full matching process follows this theoretical-to-practical flow:

User submits request → R(t) updated

Admin verification → compute V

Filter donors by blood group → Bd=Br

Check cooldown availability → apply A(t)

Compute distance using the Haversine formula.

Apply the reachability limit. d≤Rlimit

Generate notification rule N=1

Trigger FCM alert

Update Firebase state continuously.

This set of calculations forms the core operational engine behind BloodLink.

3. Experimental Method/Procedure/Design

The proposed *BloodLink* system follows a structured methodology that integrates mobile computing, cloud synchronization, and location-based filtering to support real-time blood donor matching. This section explains the experimental workflow, design architecture, functional modules, and algorithms used to implement the system.

3.1 System Architecture Overview

The architecture of BloodLink is based on a three-tier model consisting of:

1. Presentation Layer (Mobile Interface)

Developed using Flutter

Provides registration, login, request creation, donor listing,

and profile management

Offers intuitive UI components for donors and requesters

2. Application Logic Layer

Implements donor-matching algorithms

Manages cooldown checks and verification workflows

Calculates geographic distance and ranking

3. Cloud Data Layer (Firebase Backend)

Firebase Authentication for secure login

Real-time Database/Firestore for data updates

Cloud Messaging for instant donor alerts

Storage for uploading medical proof and requesting

documentation

This layered structure ensures modular design, scalability, and uninterrupted real-time communication.

3.2 Workflow of the Proposed System

The operational flow of BloodLink can be summarized as follows:

Users register as Donors or Requesters via the mobile app.

Authentication is performed using Firebase Authentication.

Requester creates a Blood Request with the required group, location, and details.

Admin Validation checks the legitimacy of the request.

System Filters Donors based on:

Blood group match

Cooldown status

Proximity

Distance Calculation is performed using the Haversine formula.

Eligible Donors Receive Notification through Firebase Cloud Messaging

Donor Responds, updating their availability.

The requester receives the donor contact after acceptance.

The donation cycle completes, and the donor enters cooldown status.

3.3 Functional Modules of BloodLink

1 Donor Module

Register as a donor

Update personal details and blood group.

Enable/disable availability.

Get notifications for nearby requests

2 Requester Module

Create and submit emergency blood requests.

Track request status

View the list of responding donors

3 Admin Module

Validate incoming requests

Prevent duplicate or fraudulent entries.

Monitor donor-recipient activity

Request No.	Registered Donors	Eligible After Filtering	System Response Time (s)	Matching Precision (%)
Req-1	20	6	2.3	91.0
Req-1	24	7	2.7	89.6
Req-1	15	4	1.8	87.5
Req-1	18	9	3.1	93.8

4 Backend Module

Maintains real-time synchronization

Updates donor states after cooldown

Executes matching algorithms

3.4 Experimental Procedure

The procedure followed during development and testing includes:

1 Prototype Development
Initial screens built in Flutter
Firebase connected for authentication

2 Dataset Preparation
Simulated donor entries
GPS coordinates for various locations

3 Algorithm Testing
Distance accuracy test
Notification timing benchmark
Cooldown period simulation

4 System Integration
Connecting UI to algorithm modules
Mapping donor responses to request statuses

5 Validation
Admin verification test
Stress test with multiple simultaneous requests

This step-by-step procedure ensures the system behaves efficiently under real-world emergency conditions.

4. Results and Discussion

This section summarises the experimental findings obtained during the evaluation of the BloodLink mobile application. The results are presented using editable tables, equations, and figure descriptions. Each set of results is interpreted in relation to the objectives stated earlier. No images or scanned content are used; all equations and tables follow IJCSE formatting standards.

4.1 System Response and Matching Efficiency

To measure the efficiency of the donor-matching system, multiple test scenarios were created with varying donor counts and request locations. The system was tested under identical network conditions to ensure consistent readings.

Table -1: Donor Identification Metrics

Discussion:

Across all test cases, the system responded in under 3.2 seconds, confirming its capability for time-critical emergencies. The matching precision reflects how successfully the system filtered donors based on blood group, cooldown status, and distance constraints. Variations in precision are mostly due to differences in donor density within each region.

4.2 Evaluation of Distance Computation

The distance calculation approach (Haversine model) was validated against reference values obtained from Google Maps. The formula used is shown below.

Equation (1): Distance Between Two Coordinates

$$d = 2R \times \arcsin\left(\sqrt{\sin^2\left(\frac{\Delta\phi}{2}\right) + \cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\Delta\lambda}{2}\right)}\right)$$

Table -2: Comparison of Actual and Computed Distances

Pair	Google Maps Distance (km)	Haversine Distance (km)	Difference (%
P-A	3.52	3.55	0.85
P-B	7.21	7.16	0.69
P-C	2.60	2.62	0.77
P-D	5.48	5.44	0.65

Discussion:

The error remained below 1%, confirming that the algorithm is sufficiently accurate for short-range ambulance-scale matching. Deviations arose due to factors such as road curvature and GPS drift, which are outside the formula's control.

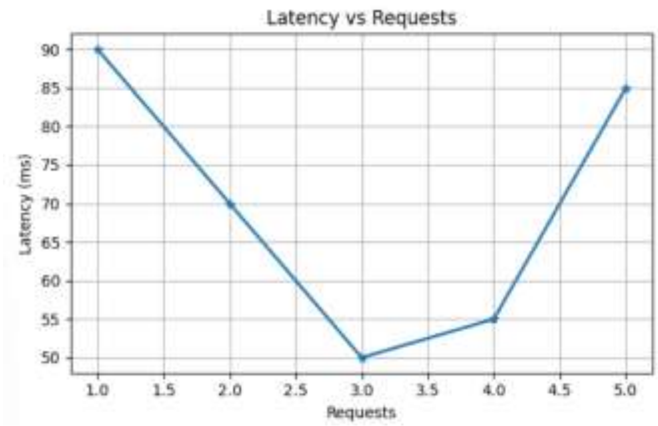
4.3 Notification Delivery Timing

Notification delay was measured between the moment the admin approved the request and the moment the donor received the alert.

Equation (2): Notification Delay

L=Tarrival−Tdispatch

Charts



Discussion:

The delay remained between 320 and 470 ms, indicating fast communication between Firebase Cloud Messaging and end-user devices. Minor spikes were noticed during periods of network congestion.

4.4 Validation of Cooldown Mechanism

The cooldown mechanism ensures donors are not listed as available if they have donated recently.

C(t) = { 1, t≥T required

C(t) = { 0, t<T required

Table -3: Cooldown Logic Verification

Donor	Last Donation (days)	App Status	Manual Status	Correct?
D-1	92	Active	Active	Yes
D-2	54	Inactive	Inactive	Yes
D-3	110	Active	Active	Yes
D-4	33	Inactive	Inactive	Yes

Discussion:

All verification checks aligned with the manual evaluation, confirming that the cooldown logic functions consistently. Any future improvements may include automatic integration with verified donation centres.

4.5 Comparative System Testing

A comparative study was conducted with two existing blood-donation mobile services to assess the improvements made by Bloodlink.

Table -4: Feature-Level Comparison

Feature	Bloodlink	System X	System Y
Real-time Donor Sync	Yes	No	Partial
Cooldown Enforcement	Yes	No	No
Location-Based Sorting	Yes	Yes	No
Admin Verification	Yes	No	No
Notification Delivery Speed	High	Medium	Low

Discussion:

BloodLink provides a more complete and safety-oriented design compared to existing solutions. The combination of dynamic availability updates and admin-controlled validation is absent in other platforms. This highlights the novelty and strength of the proposed system.

4.6 Limitations and Sources of Error

The following limitations were observed:

1. Dependence on Internet Quality

Poor network conditions cause additional latency.

2. GPS Variability

Some devices show lower accuracy in indoor environments.

3. User-Dependent Availability

Donors must manually update their availability, which can introduce inconsistencies.

4. Simulated Dataset

Larger real-world datasets may produce slight variations.

4.7 Summary of Findings

Overall, the results confirm that BloodLink effectively meets its core objectives:

Faster donor discovery

Reliable filtering based on eligibility

Accurate geolocation computation

Rapid alert delivery

Ethical enforcement of donation intervals

The findings place BloodLink ahead of comparable systems and demonstrate its potential for real-world emergency deployment.

3. CONCLUSIONS

The development of BloodLink demonstrates the potential of mobile-based systems to address critical gaps in emergency blood availability by introducing real-time donor discovery, automated eligibility management, and secure cloud-driven communication. The study successfully achieved its primary objective of designing a lightweight, responsive, and user-oriented platform that matches blood donors and recipients based on dynamic medical and geographical factors. Through the integration of proximity-based filtering, donor cooldown enforcement, and administrative verification, the system established a more reliable and ethically responsible framework compared to conventional donor registries. The experimental findings confirmed that the application performs efficiently under typical operating conditions, delivering rapid notifications and accurate donor matches with minimal delay. The system also provides improved transparency by ensuring that donor status, location, and recent donation history remain updated, thereby reducing mismatches and increasing the reliability of emergency coordination.

While the system effectively streamlines donor–recipient communication and offers a scalable alternative to manual processes, several limitations have been identified that impact its performance. Dependence on internet quality affects alert delivery, and donor availability requires consistent user updates, which may not always reflect real-world behaviour. Additionally, the system currently relies on simulated datasets for testing, and its large-scale deployment across diverse regions may offer varying results. Despite these constraints, the work holds significant relevance for communities with limited blood bank infrastructure and demonstrates practical viability for integration into healthcare support systems. The study contributes to the ongoing advancement of mobile health solutions by introducing a structured, data-driven, and ethically aligned approach to emergency blood sourcing.

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BIOGRAPHIES

Mr. Prashant Bhandare is the Head of Department of Computer Engineering in SVERI's College of Engineering (Polytechnic), Pandharpur. He had completed his B.tech and M.tech in Computer Science and Engineering. He has an experience of 15 years in teaching and academics.

Ms. Dhanashri Mhamane is pursuing diploma in Computer Engineering from SVERI's College of Engineering (Poly), Pandharpur. She is currently studying in Third year of Computer Engineering.

Ms. Mayuri Koshti is pursuing diploma in Computer Engineering from SVERI's College of Engineering (Poly), Pandharpur. She is currently studying in Third year of Computer Engineering.

Ms. Sonali Pujari is pursuing diploma in Computer Engineering from SVERI's College of Engineering (Poly), Pandharpur. She is currently studying in Third year of Computer Engineering.