Journal of Scientific & Industrial Research
Vol. 84, December 2025, pp. 1291-1300
DOI: 10.56042/jsir.v84i12.20668

BloodConnect: Proximity Based Blood Donation Network with Real-Time Alerts and Tracking

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Received 15 June 2025; revised 24 October 2025; accepted 02 January 2026

In most of the critical medical situations, getting the required blood on time is quite difficult as communication is slow and the donor information is spread across multiple sources. *BloodConnect* addresses this problem by using GPS enabled location services to link blood donors and recipients instantly. With this feature, hospitals can quickly identify donors who are both compatible and physically close to the emergency location. The system is developed using the MERN stack, MongoDB, Express.js, React.js, and Node.js, which provides a smooth user interface and efficient handling of data. Deployment is carried out through Docker containers so the platform remains stable across different hardware and software environments. Donors receive alerts through browser push notifications, and at the donation centre, a generated QR code is scanned to confirm their presence and update attendance. The QR based checkin is also associated with a reward system to motivate more repeated blood donations. The data flow consistency and backend reliability are checked using Postman. Eventually, the BloodConnect model improves transparency, speed and coordination of blood donation during emergency situations.

Keywords: Docker containerization, GPS-based tracking, MERN stack, QR code verification, Web push notifications

Introduction

Medical emergencies usually demand access to blood on time. It is quite unfortunate that many healthcare systems are still facing unavoidable delays. The existing donation networks are spread across different hospitals and blood banks, with no combined method to match donors and recipients quickly. Usually donors are contacted through calls or standard announcements that may not reach the right individual on time.[1,2] Apart from these, manual verification at the blood donation camps may lead to long queues, duplicate entries, and inaccurate attendance records, which may in turn result in significant loss of time.

A practical solution to these challenges is the increasing use of digital platforms. To streamline the communication between hospitals, donors, organizers and to store donor data, track blood availability, a centralized web system[3] can be used. Push notifications have demonstrated improved responsiveness, as donors receive urgent alerts instantly on their devices.[4] Digital transformation has inclined the donor behaviour, particularly among younger, mobile-primary users who prefer systems that are quick, transparent, and engaging.[5,6] Offering incentives like digital certificates, badges, or redeemable points motivates donors to recur the donation, as their contributions are acknowledged and appreciated.[7] Further cloud deployment can expand the platform efficiently and quickly so that users across different regions and institutions can access the facility.[8] With deployment of QR based check-in at blood donation camps reduces manual paperwork to a larger extent, preventing false entries and speeding up verification.[9]

These gaps are addressed by the BloodConnect that offers a unified and user centric blood donation management platform. The system delivers a modern interface and efficient backend operations using the MERN stack (MongoDB, Express.js, React.js, and Node.js.[10] Docker containerization guarantees consistent deployment across various environments without configuration issues. Also, BloodConnect has Realtime donor alerts that are generated based on blood group compatibility and location, to ensure that hospitals reach out the right donor at the right moment. At the donation centre, checking in is fast and hassle free. The QR-code is scanned by the donors for authentication and this activity is logged in

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the system securely. The log details enable the system to maintain the donation history so that any donor who logs in for next time will be acknowledged with a milestone based certificate or may be provided with incentives as a token of appreciation. For the smooth conduct of the donor operation, the system has automated updation. Selenium API is used for interoperability and user interface flow validation, while Postman API for testing backend functionality to enable proper data processing and proper communication across system components.

Literature review

Many blood donation management systems have gradually shifted to digital platforms so that the donors can be contacted without delay reliably during emergencies. Hawashin *et al.,* have used the block-chain technology to develop a blood donation management system that focuses on maintaining transparent immutable records.[11] The system also maintains a donation history that is safe from tampering, thereby ensuring trust between the hospitals, blood banks and the donors. But to accommodate the system requires computational overhead. Hence, it may be suitable for real time application and may not support scalability when there is an increase in the number of transactions. Sumnig *et al.,* examined the role of social media in donor availability in their work.[12] They analysed that the online platforms influenced donors in motivating and active participation. Their study showed that focused campaigns and focused promotions effectively raise awareness and can encourage voluntary donations. However, this approach majorly supports outreach and engagement, rather than emergency response. There is a lack of donor matching in the real-time and lack of location based coordination makes it less effective in urgent medical situations where immediate action is required. Batis and Albarrak[13] investigated the user requirements and expectations from mobile blood donation applications, through a multicentre study conducted in Saudi Arabia. Their findings highlighted features like location based reminders, access to donation history, and personalised notifications as important factors for user adoption. It is found in the study that integration of donor data in various healthcare systems is limited. Hence, there is lack of interoperability there by reducing efficiency in donor matching as it results in incoherent records. Abdul Gafar *et al*.,[14] proposed a web based blood donation platform that was designed to fabricate interactive communication between donors and the recipients. It is developed by making use of standard web technologies like PHP, HTML, MySQL, CSS and JavaScript. The web based system also supports donor registration, communication between stakeholders and inventory monitoring. The effectiveness of the system depends on consistent user usage and data security mechanisms, even though donation workflow is digitized in the system.

In contrast to these approaches, the proposed BloodConnect platform addresses real time proximity-based donor identification combined with structured donor incentivisation. The proposed system is built for QR code verification at donation centres, maintaining donation logs of the donors and authentication of the donor attendance records. The system also makes use of Docker containers to support scalability. This feature overcomes the limitations observed in other existing systems.

Methodology

The BloodConnect is an automated, simple, scalable and reliable platform developed for the easy blood donation process. The proposed system enables real-time, location-based communication amongst hospitals, donors, and the blood banks. It is seen that most of the time the traditional donation management systems struggle with unavailability of the donor during medical emergencies. Hence, it results in delayed communication, and leads to difficulties faced during medical emergencies. BloodConnect is a platform to address these gaps through incorporation of proximity-based alerts, QR-code based verification for maintaining donation log records, and deployment of docker containers to set up for dynamic scaling.

The platform consists of three primary stakeholders namely the donors, the hospitals, and the blood banks, each of which is supported by dedicated modules for smooth communication and transaction handling. The overall architecture of the proposed system is presented in Fig. 1.

Donor Module

The Donor Module is the core of the proposed system – BloodConnect. It facilitates the donors to register in an easy manner, features a platform to find nearby blood banks, booking appointments, and to receive emergency notifications. The module is designed to emphasise simplicity so that it encourages regular participation there by barriers to donation.

Authentication

The first step in the system begins with the donors. Firebase authentication is used for donors to create login details. It manages secure logins and basic profile information such as name, blood group, and email ID. These details are very much required for identification of appropriate donors with matching blood types, and sending timely web push notifications. Once the donor logs in, they are prompted to enable location access in their device so that the system can provide recommendations based on their proximity to registered blood banks.

Mapbox API Integration

Mapbox API is used to display an interactive map highlighting blood banks near by the donor's current location. The donor can choose based on the details (such as its name, address, working hours, and availability status) in the blood bank database. The donor can select a preferred blood bank and fix a convenient date for donation. The appointment details are then securely stored in the backend and linked to the donor's profile for future reference.

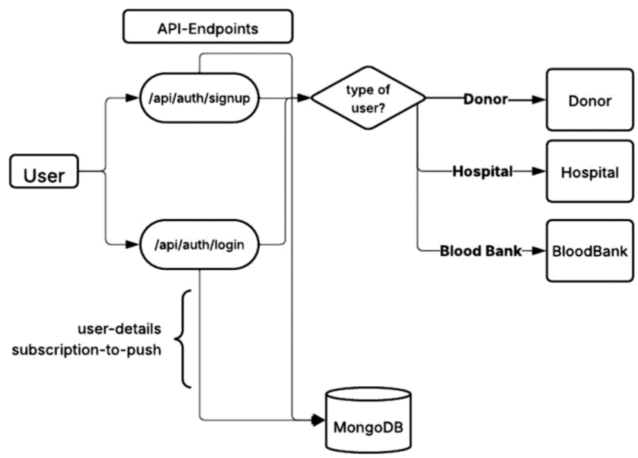

Fig. 1 — Overview of the proposed system

QR code

An unique QR code is generated for the user upon confirmation of their appointment. This QR code serves as a digital token as it is encoded with the donor's email ID and chosen date of donation, which is later used for verification at the blood bank.

$QR_d = f(e_d, t_d)C(d) = 1$, Where QR_d – Unique QR code for donor d, e_d – Donor email ID, t_d – Date of donation, $C(d)$ – Appointment confirmed and $f(\cdot)$ – Encoding function

The *qrcode npm* package is used to create the QR code. It ensures whether the codes are secure and scannable across a wide range of devices. The QR code is displayed on the donor's device and is also accessible through their profile in case of loss or navigation away from the booking page. Illustration of the QR code generated when a slot is booked is shown in Fig. 2.

The entire flow from registration to slot booking and QR generation is well crafted to provide automaticity. The process of donor slot booking and donation system is shown in Fig. 3. The design also highlights backend interactions such as storage of slot data and QR generation logic.

Overall, the Donor Module offers a clean-user friendly interface with secure login, real-time QR code generation, and interactive maps that help donors easily locate nearby blood banks and manage their appointments. During emergency medical situations the system ensures that donors can be alerted and mobilized immediately through

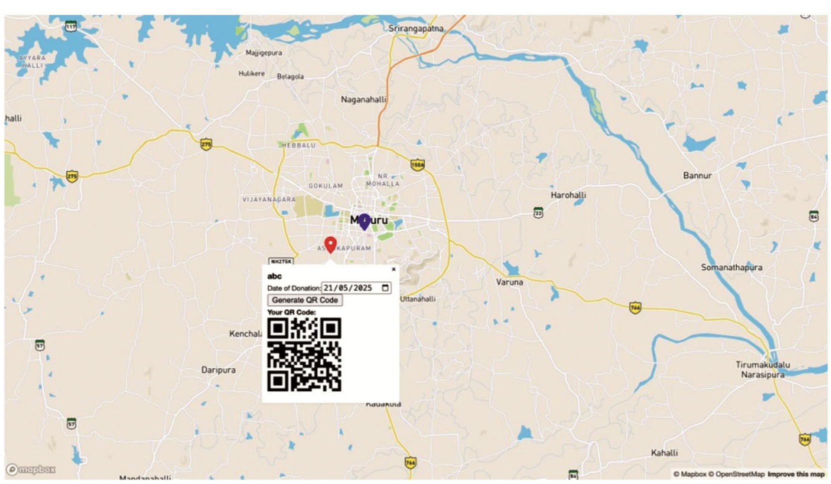

Fig. 2 — QR-code generated

notification services. The module in the proposed system simplifies the donor engagement process with guaranteed traceability and efficiency in workflow. A distinctive feature of the system is the automatic generation of a QR code when a donor books an appointment. This code securely carries the donor's identity and scheduled donation time and can be used only once. When the donor arrives at the blood bank, staff scan the QR code to confirm their physical presence. This eliminates manual attendance recording, prevents proxy check-ins, and ensures that every donation logged in the system reflects a genuine visit to the blood bank. Existing blood donation management systems usually stop at collecting donor information or their confirmation

Hospital Module

The Hospital Module is instrumental in managing emergency blood requirements by utilizing geo-location based real time communication between the hospital and the potential donors. Hospitals utilize a specialized web dashboard that provides a visual interface for activating notification to nearby registered donors. The main functionality of this module is to define the urgency of the situation, select a target radius, and broadcast push notifications to donors matching the criteria. The workflow begins when a hospital staff member initiates an emergency request from the dashboard. This is aided by an interactive emergency meter, where the staff can choose from preset radius values (5, 10, 15, 20, or 25 kilometers). This distance defines the proximity within which eligible donors should be located. Once the radius is selected, the system computes the geographical distance between the hospital and all registered donors using the Haversine formula, which calculates the shortest distance over the Earth's surface using latitude and longitude coordinates (Fig. 4).

Upon identifying the list of matching donors, filtered based on both distance and required blood group the backend triggers web push notifications using the VAPID protocol. These notifications are delivered to the devices of the matched donors, even when their browsers are closed, provided they have subscribed to push alerts and service workers are active. Notifications include the hospital's name, urgency, and a call-to-action button directing the donor to the app or web portal for scheduling their donation. The notification architecture is shown in Fig. 5.

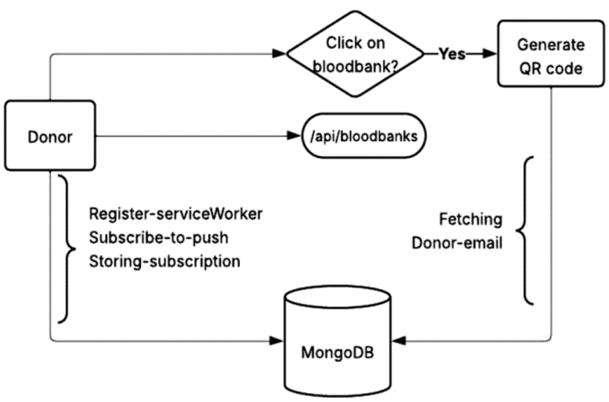

Fig. 3 — Donor slot booking and donation

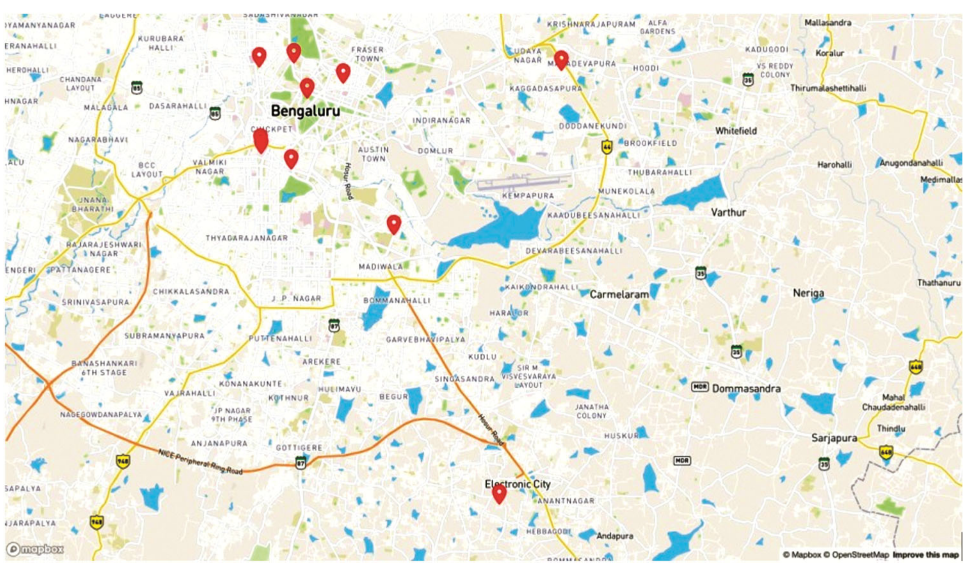

Fig. 4 — Closest blood-banks to the donor

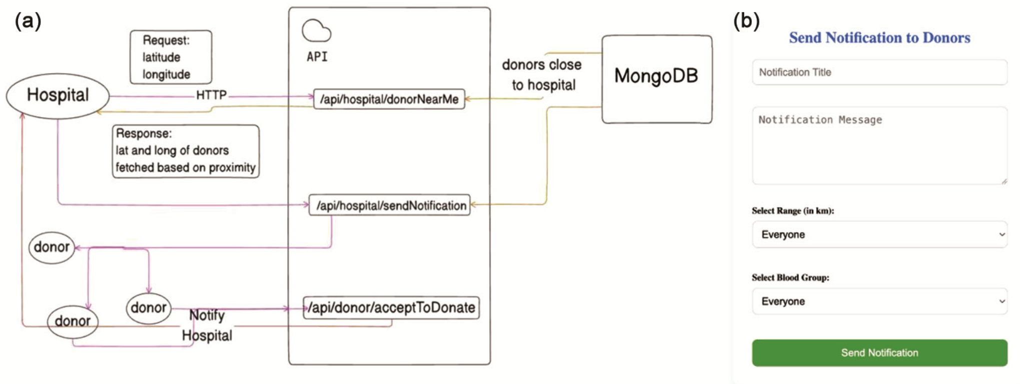

Fig. 5 — Notification: (a) architecture of notification, (b) sending notification

VAPID Protocol

VAPID is a web standard that allows servers to authenticate themselves to push services and securely send notifications to clients. VIPID protocol uses asymmetric encryption, where the server holds a private key and the client stores a corresponding public key generated during the subscription process. When sending a push message. The server signs on the PUSH message using its private VAPID key, before sending it while the browser verifies the signature to ensure authenticity. These push messages are routed via services and are received even when the browser is running in the background as long as a service worker is registered.

The efficiency of this system is that it is able to target only relevant users and avoids notification spamming. The role of the hospital module is simplified to input based selection and the backend module handles all processing logic, including location filtering, subscription management, and secure message delivery. This design ensures optimal donor outreach during emergencies, maximizes donation rates, and reduces the time taken to secure critical blood units. The Hospital Module serves as the principal driver in establishing the donor alert chain and supports the time-critical nature of blood donation in emergency medical scenarios. This feature is accomplished by integrating geolocation algorithms with secure, real-time browser notification protocols via., VAPID protocol.

Blood Bank Module

The blood bank module plays a significant role in closing the loop between donor intent and verified donation. Its primary responsibilities are to verify the identity of the donor who has arrived for their booked slot and to ensure that every donation is securely logged and can be traceable in the system at the backend. The verification of the donor is done by a staff member by scanning the QR code produced by the donor. This QR code is uniquely tied to the donor's identity (via their email ID) and their scheduled date of donation. It is code that was generated during the slot booking process and constitutes a one-time token of validation.

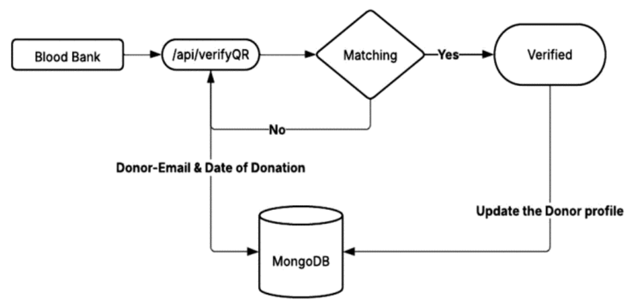

Fig. 6 — Blood Bank architecture

The complete Blood Bank architecture is shown in Fig. 6. The scanned QR code is verified with the details provided with the booking records stored in the MongoDB database. If the data is valid, the system confirms the donation and creates a timestamped log marking the donor's presence and successful contribution. This log also updates the donor's status and maintains a history of donation activity, which can be used for future eligibility tracking, donor recognition, or report generation. The verification is required to make sure that only genuine, pre-registered donors are logged and possibility of fraudulent entries or miscounts are minimized. This process makes blood banks operate more efficiently and manual data entry is significantly reduced, and backend records are updated in real-time.

Results and Discussion

The effectiveness of the proposed BloodConnect system was assessed using a combination of quantitative metrics and system performance observations. The evaluation was conducted across three key components: real-time notification dispatch, QR code based verification, and proximity filtering using the Haversine formula. The results underscore the system's capability to reliably connect donors, hospitals, and blood banks through timely and accurate interactions.

Real-Time Notification System Evaluation

To measure the accuracy and reliability of donor alerts, metrics such as *notification success rate*, *average dispatch time*, and *donor response rate* were evaluated. An overview of these metrics is presented in Table 1. These results assert that the integration of the VAPID protocol with MongoDB based donor tracking will result in fast and targeted outreach. The system's practical efficiency is due to high success rate and quick response time under simulated emergency loads.

QR Code Verification Accuracy

Validation of QR-code scanning is conducted for different donors and sessions. Performance metrics of QR code check-in at the blood banks is illustrated in Table 2.

It can be seem from Table 2 that QR code scanning has a high accuracy of 99.1%. This shows the robustness of the proposed model in donor verification and also entry in the backend. But, the incorrect 0.9% is due to expired codes, glaring in mobile phones and misaligned or tilted screen QR scans.

Proximity-Based Filtering

Using the Haversine formula, donor filtering was tested for five distance presets (5, 10, 15, 20, and 25 km). The precision of geolocation filtering was observed to be consistently above 98% across all ranges. Filtering precision across different proximity selections is illustrated in Fig. 7.

The consistent filtering accuracy ensures that only eligible donors within valid proximity receive alerts, effectively minimizing irrelevant notifications while maximizing outreach to potential donors.

The identification of the donor within a radius of 1km to 4km is depicted in Fig. 8. This short range identification includes notification to the donor regarding the necessity of emergency blood. As illustrated in Fig. 8, the number of donors increases as the range of search increases. For example at 1 km only 1 doner is received while 10 doners are identified in the 4 km. This validates the proximity based filtering in effectively working in the proposed model. The second plot in Fig. 8 represents a search of donors in a large proximity from 5 to 200 km. As the proximity increases, the number of donor identifications also increases. This helps the hospitals to search for large donors, specifically if the blood is rare, like A '−'ve and in emergency transplantation where a large volume of stock is required. It is also understood that there is a tradeoff between the distance and the number of donors.

Testing Results on all Modules

Functional testing of core modules like QR code verification and donor filtering based on blood group and proximity is summarized in Table 3. Each test case highlights real world scenarios such as invalid QR scans and ineligible donors. The consistent match between expected and actual results confirms the system's correctness, reliability, and readiness for real-time deployment.

Table 1 — Real-Time notification metrics based on manual API Testing

Metric	Value
Notification success rate	96%
Average notification dispatch time	1 second
Notification failure rate	4%

*Metrics were derived by manually triggering the notification API approximately 80–100 times

Table 2 — QR Code Verification Performance

Metric	Value	Cause of Error (if any)
QR verification accuracy	99.1%	—
Incorrect/Missing entries	0.9%	Scanning angle / lighting issues

*Metrics were observed through manual scanning and verification of QR code metadata across multiple test runs.

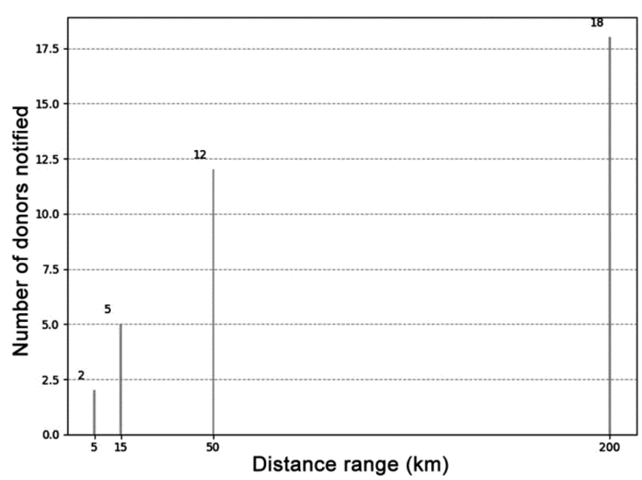

Fig. 7 — Donor filtering accuracy per distance range

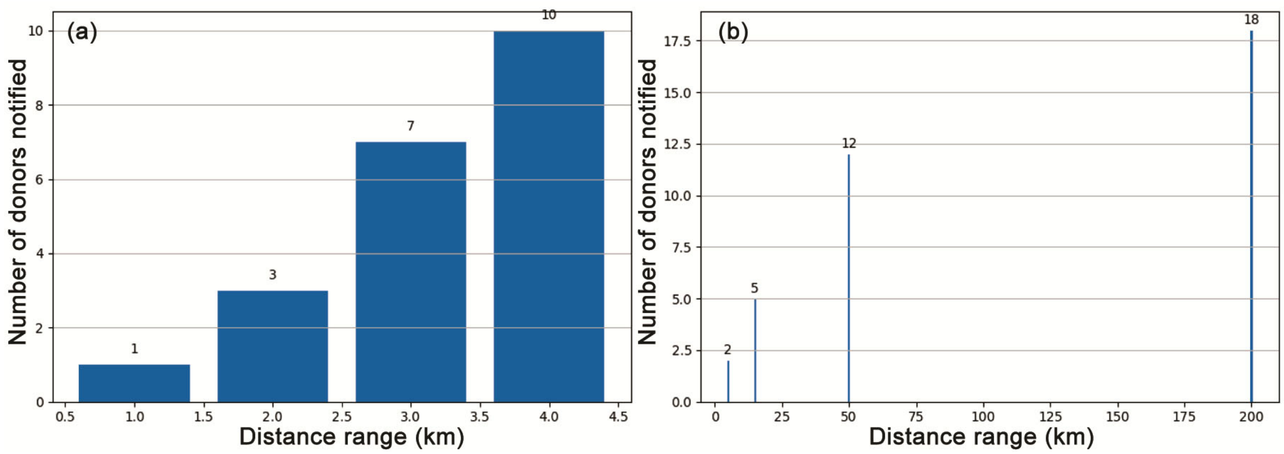

Fig. 8 — Donor notification reach plotted against distance radius: (a) 1–4 Km, (b) 5–200 Km

Table 3 — Functional testing results of core modules

Test case description	Expected result	Actual result	Status
Validating wrong QR at the blood bank	Error message: QR doesn't match the profile	Error message: QR doesn't match the profile	Pass
Validating legit QR at the blood bank	Error message: QR matched with the profile	Error message: QR matched with the profile	Pass
Notifications not sent when blood group doesn't match and donor not within the proximity	Error message: No eligible donors found in this range.	Error message: No eligible donors found in this range.	Pass
Notifications not sent when blood group doesn't match and donor within the proximity	No eligible donors found in this range.	No eligible donors found in this range.	Pass
Notifications not sent when blood group match and donor not within the proximity	No eligible donors found in this range.	No eligible donors found in this range.	Pass
Notifications sent when blood group match and donors within the proximity	Notification sent to donors	Notification sent to donors	Pass

Finally, the model is evaluated for 60 donors. Each donor is evaluated using 10 independent test sessions. Each session contained at least 6 participants. The model is validated using 540 QR code scans. This 540 QR scan contains different scenarios such as indoor settings, low-light environments, and outdoor settings. Further angles are tilted, and brightness is varied. Finally the system achieved 99.3% of accuracy. But 0.7% failure is due to the camera alignment and glare on the camera screen. All the scans are matched perfectly with the exact donors. The prebooked donation slots are also perfectly matched in MangoDB. This demonstrates the reliability of QR scan in out framework. Therefore, these results illustrate that the proposed model Bloodconnect can work with a large volume, with less delay. Further, duplication is less compared to traditional Blood database management systems.

Comparative Analysis

In this research work, the proposed BloodConnect is an integrated real time framework for blood donation. This model connects hospitals, donors, and patients on a digital platform. The traditional donor system basically depends on manual coordination, which works through phone calls, traditional database search by staff. This method is inefficient during an emergency. Therefore, the proposed model addresses these limitations by integrating web technologies, browser push notifications and location enables donor filtering using Haversine distance calculation. The detailed analysis of existing solutions is illustrated in Table 4.

In today's healthcare world, many researchers are working on blood management platforms, such as the Blood Bank Management systems by Shahakar *et al.*[15], and LifeSave, a mobile application

Table 4 — Comparison with Existing Blood Donation Systems

Benchmarking Parameter	Blood Connect (Proposed System)	BBMS *(Blood Bank Management System)* [15]	LifeSaver App[16]	RedDonate [17]
Real-time donor notification	Yes (web push notification using VAPID)	No (manual contact)	No	No
Proximity-based donor filtering	Yes (Haversine formula, GPS-based radius selection: 1–200 km)	No	No	No
QR-based donor attendance verification	Yes (scanning device validates slot-specific QR)	No	No	No
Role-based modules (Donor–Hospital–Blood Bank)	Fully modular	Partial	No	Partial
Gamification / Rewards	Yes (points / certificates)	No	No	No
Cloud / Web scalability	Yes (Docker containerization, MERN architecture)	Partial	Partial	Partial
Data authenticity / tamper-proofing	QR + slot validation ensures real presence	Manual entries	No verification	No verification
User tracking & history log	Slot booking + donation history	Yes	Limited	Limited

for donors by Brislin *et al.*[16] They are primarily designed for maintaining donor records and search operations. This made basic level routing management, but these systems do not support real time emergency notifications or automatic identification of nearby eligible donors. Emergency notification and identifying nearby donors are actually critical when immediate blood availability is required. So the response time during an emergency is still inadequate.

Shinde *et al.*[17] proposed the Reddonate mobile app framework for Android systems. Kandukuri *et al.*[18] proposed an e-bloodbank framework using a cloud system. This framework implemented a website for managing all the donors and blood banks. However, these works do not consider the VAPID protocol for alerts as push notifications. This helps the blood bank and hospitals to send a sudden notification request for a particular geographical radius. In addition, QR code[19] scanning helps hospitals and blood bank organisations to maintain regular attendance, increasing the tracing capability. On the other side, it helps the donors to identify the nearby blood bank for a visit and connect them further to other volunteers.

In summary, the current research model, BloodConnect, not only improves reliability, responsiveness but also increased transparency of the blood donations process. This is implemented using cloud and real time browser notifications, location intelligence and automated QR code verification. These features represent a significant advancement as compared to traditional blood management systems. The following list represents the beneficiaries of the proposed model.

1. Donors: The proposed model provides a major advantage for the blood donors by efficient communication during emergency times with less latency and informs the donors regarding the completed information, such as the type of blood, location and nearby hospitals. This alert enables donors to receive notifications, which reduces the response time in critical conditions of patients. QR codes also ease the producers to handle a designed application. Further, authentication implemented in this model increases the security and validation of the particular donors.
2. Hospitals: In hospitals, during emergencies like cancer patients need urgent white blood or any road accident patients require a rare blood group like A'−'ve, then identifying the nearby donors is very important. In this scenario, the proposed model is able to locate the rare blood group donors with less latency. Further, hospitals can interact with donors for other information using an inventory management system in the proposed model, which enhances the overall operational efficiency.
3. Blood Banks: Usually, all hospitals are linked to one or two Blood banks, and even some Voluntary groups are also working toward the collection of Blood. During the emergency, the proposed model helps to connect not only from the hospital to the Blood bank but also the blood bank to the volunteers efficiently. This real time approach enhances the stability of supplying sufficient blood in time. Additionally, volunteers use a QR code based verification system for accuracy and security. This reduces the manual entry and eliminates data tampering.

Finally, the Bloodconnect model connects donors, hospitals, blood banks, and Voluntary Non-Remunerated Blood Donors (VNRBDs) as compared to traditional systems. This makes the system more reliable during an emergency situation in healthcare.

Future Work

In the future, this Bloodconnect framework can be extended in three major areas, which include security enhancement, scalability of the application and its accessibility. For data integrity, there is a plan to explore blockchain for data storage instead of MongoDB, which is used for maintaining donor records. This shift strengthens the data integrity and also reduces unauthorised access to systems. Further, the Mobile App can be implemented for different operating systems, since mobile applications help all the beneficiaries to interact in real time during any emergency.[20-22] Finally, if any work needs to be deployed in real time, scalability is also a major concern. So in future there is a plan to work on integrating the proposed Bloodconnect model, Mobile app, with Apache Kafka for streaming real-time data asynchronously. This will help more hospitals, Bloodbank and donors to connect simultaneously. The effectiveness of proximity based alerts in BloodConnect depends on the accuracy of location data and the responsiveness of donors. GPS accuracy may vary in indoor environments, densely built areas, or regions with limited network coverage, which can result in donors being incorrectly included within or excluded from the alert range. In addition, even when notifications are delivered successfully, response times during high demand emergencies can differ due to personal availability, access to mobile devices, or notification fatigue. Therefore, future work, will focus on identifying the donor using multiple donor location detecting methods such as Wifi, LoRa, GPS, and network based triangulation. This is basically to increase the precision in terms of donor location. At the same time, the number of donor participation at the right time can be improved by sending multiple ways of alerts like SMS, Pop-up messages. This helps to increase responsiveness during a critical condition.

Conclusions

The proposed system - *BloodConnect* is designed to reduce the gap between blood donors and recipients by using proximity-based location tracking and real time notifications. The system is built with QR code facility to be applied in real-world scenarios as it reduces time needed for arranging the blood during medical emergencies. The results demonstrated that the proposed model can be scaled and deployed in metropolitan cities. Although the model has greater advantages, the platform developed depends on smartphones and reliable internet connectivity, which may restrict its use in rural areas or regions with poor network coverage. Further, in real scenarios, GPS varies in indoor locations like parking lots of apartments, hospitals, and dense population locations, which affects the precision in location tracking. Donor response time cannot be fully controlled by the system as it may differ based on individual circumstances. Future enhancements may focus on adding multilingual support, expanding integration with hospitals, and introducing features to better anticipate donor availability.

Acknowledgement

We thank The National Institute of Engineering, Mysuru for providing laboratory support to build the BloodConnect model.

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