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Child Guard System: A Cross-Platform Mobile Child Monitoring System Using Global Positioning System Tracking, Geofencing, and Firebase Cloud Messaging

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ABSTRACT

This study proposes a child guard system (CGS), a mobile-based solution that supports real-time location monitoring and emergency communication between parents and children. The proposed system adopts a client–server architecture that integrates a global positioning system (GPS), Wi-Fi positioning, RESTful communication, and Firebase Backend-as-a-Service to ensure scalable and reliable data synchronization. Location data collected from the child's smartphone are transmitted to a cloud-based backend, enabling near-real-time monitoring through a mobile application. The CGS provides several key functionalities, including real-time location tracking, geofencing alerts, emergency notifications, location history, and a built-in chat feature for direct parent–child communication. Unlike many existing solutions that require additional hardware devices, the proposed system operates entirely using smartphones and cloud services, reducing system complexity and deployment cost. Experimental evaluation demonstrated an average GPS positioning accuracy of approximately 5–10 m, a location update latency of 1.25–2.8 s, an average notification delivery time of 1.85 s, and an overall user satisfaction score of 4.7/5, highlighting the effectiveness of the proposed system for child monitoring apps.

Index Terms: Child Safety, Cross-Platform System, Global Positioning System-based Location Tracking, Parental Monitoring, Geofencing

1. INTRODUCTION

Child safety has become an increasingly important concern in modern society, particularly as children and teenagers frequently travel independently to schools, universities, and public places. Parents often rely on verbal confirmation to verify their child's location, which may not always accurately reflect the child's actual situation. As a result, technological solutions capable of providing reliable and real-time monitoring have gained significant attention in recent years. Child-guarding systems based on mobile applications enable parents to track their children's location and activities remotely, especially during critical periods such as school or university hours [1], [2]. These systems typically consist of two interconnected mobile components: A child-side application that periodically transmits location information and a parent-side application that receives and visualizes these updates through mobile data or Internet connectivity.

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The widespread adoption of smartphones has further enabled the development of such monitoring solutions. Smartphones have become an integral part of everyday life, even among children and teenagers [3]. Recent global statistics indicate that approximately 88% of the world's population used mobile phones in 2024, with nearly 4.88 billion smartphone users worldwide. The number of smartphone users continues to grow globally, reaching approximately 5.3 billion users in 2025 and is projected to approach 6.4 billion by 2029, reflecting the continuous expansion of mobile technology adoption and connectivity worldwide [4]. This rapid technological expansion provides new opportunities for developing mobile-based safety applications that assist parents in monitoring their children's activities when direct supervision is not possible. Moreover, reports from international organizations highlight the ongoing need for child protection mechanisms; for instance, a 2024 report by the United Nations Children's Fund organization indicates that approximately 1.4 billion children worldwide, aged 0–15, lack adequate social protection services [5].

Location-based monitoring technologies, particularly those based on the global positioning system (GPS), have become an effective approach for addressing these challenges. GPS-enabled child-monitoring applications allow parents to receive real-time updates regarding their child's location, effectively acting as a virtual guardian. In addition to basic location tracking, many modern systems incorporate advanced safety features such as emergency alerts, safe-zone monitoring, and communication capabilities. Existing solutions [6]–[8] commonly combine GPS positioning with fallback communication mechanisms such as short message service (SMS) to maintain location updates even when Internet connectivity is unstable. By providing continuous location updates, these systems enable parents to verify their child's presence at designated locations, detect deviations from predefined safe zones, and respond promptly to unusual situations occur.

Recent advancements in mobile development frameworks and cloud computing technologies have further improved the capabilities of such systems. The integration of Flutter, Firebase, and OpenStreetMap enables the development of scalable cross-platform applications capable of operating efficiently on both Android and iOS devices [9], [10]. Flutter supports unified application development using a single codebase, whereas Firebase provides real-time database synchronization, authentication, and secure cloud-based data storage. In addition to location tracking, modern mobile safety applications can integrate additional features such as encrypted communication, historical location tracking, and event notifications, which collectively enhance monitoring reliability and user experience.

Although several child monitoring systems have been proposed, current solutions often rely on specific hardware devices, wearable trackers, global system for mobile communications (GSM) modules, or third-party communication services. Furthermore, the majority of systems provide only a limited set of critical child safety features, such as basic location tracking or geofencing, without incorporating other important features, including real-time tracking, emergency notifications, location history, and bidirectional parent–child communication within a unified smartphone-based platform. Consequently, there remains a clear need for a hardware-free, fully integrated mobile child monitoring solution that consolidates these features into a single cohesive system.

This study's primary contributions are summarized as follows:
- Development of a fully smartphone-based child monitoring platform without dedicated hardware
- Integration of real-time tracking, geofencing, emergency notifications, location history, and parent–child communication into a single application
- Cross-platform implementation using Flutter and Firebase
- Performance and usability evaluation under real-world conditions.

The rest of the paper is structured as follows: In Section 2, a number of related works on child guard systems (CGSs), parental monitoring, and child movement tracking are reviewed. While Section 3 presents an overview of the proposed system, including user roles and key features, Section 4 describes the methodology applied to develop the system. The results obtained during implementation and testing are discussed in Section 5. Finally, Section 6 concludes the study and outlines directions for further research.

2. RELATED WORK

The growing reliance on mobile technology in daily life has increased the need for innovative solutions that guarantee child safety [11]–[13]. Nowadays, parents want immediate, accessible, and intuitive solutions to track their children's movements and receive notifications about potential risks. Because of this, many recent studies, such as [2], [8], [14], [15], concentrate on developing cross-platform apps that include geofencing, GPS tracking, and intelligent notifications. These solutions seek to enhance parental oversight and assurance by enabling continuous location tracking and prompt reaction to unexpected incidents. A smart mobile app by Alam *et al.* [1] lets parents follow their child's location in real time using GPS and cellular communications. In addition to location tracking, the system secretly collects browser history, SMS logs, and contact lists for remote monitoring. To provide real-time location updates and ensure safety, child monitoring apps have begun to utilize geofencing combined with GPS tracking. In this regard, the child tracking system, a mobile-based solution as proposed by Jaya *et al.* [2], allows parents to monitor the child's current location, see previous movement routes, and receive notifications when the child enters or leaves a predefined safe zone. Using an Arduino Uno and SIM808 GPS tracker, the system sends location data over a GSM network to a cloud database. This configuration provides continuous monitoring and timely notifications through a smartphone interface, enhancing parental control and situational awareness.

Another solution for child safety was introduced by Gupta *et al.* [16], who proposed a tracking system that allows parents to monitor their children even when they are not in direct view. The system works with a wearable device equipped with Wi-Fi locating capabilities and connects to the parents' smartphone via a mobile network. This setup enables real-time monitoring of the child's location from nearly anywhere. Geofencing, a discreet panic button for emergencies, improved battery life, and constant location updates are all included in the gadget, all of which are designed to improve parental awareness and responsiveness to possible safety concerns. In the same year, Zahilah and Zaharan [14] developed a kid monitoring system named EyeKids, aimed at improving parental awareness via real-time location tracking. The system has three basic parts: A child-worn tracking device, a parent-facing mobile app, and a cloud-based database. The tracking device, constructed using components including Arduino Uno, SIM808, and a GPS/general packet radio service/GSM module, collects the child's coordinates and communicates them to a Firebase database. The app then acquires this data and visually presents the child's most recent location, route history, and movement patterns, providing parents with real-time updates and behavioral insights.

Moreover, child safety and monitoring devices have been the subject of numerous prior studies. Hattaraki *et al.* [6] designed a child safety and tracking system using an ESPCAM32, GPS, and image capture module, which is placed in the child's bag. Using the Telegram app, parents may communicate with the device by sending orders that obtain the child's image and exact GPS coordinates so that Google Maps can monitor their whereabouts. Similarly, yet with a slight variation, Gowthami *et al.* [17] proposed an Internet of Things (IoT)-based safety in the form of a wearable, such as a smartwatch with sensors including an accelerometer, GPS, and heart rate monitor built in. A mobile app receives data through Bluetooth and notifies parents of potential dangers, such as falls, safe zones, or abnormal health readings.

The table below presents the features implemented in previous child safety studies and in the proposed CGS. Most prior studies offered parent-side mobile monitoring and real-time location tracking, but lacked child-side access, history view, or alert functionalities. The CGS incorporates all these features, delivering a more comprehensive child safety solution.

As shown in Table 1, the proposed CGS distinguishes itself from prior academic works by avoiding any reliance on external electronic setups (such as Arduino or GSM breakouts) while delivering comprehensive features directly inside a standalone mobile installation. Unlike configurations that mix external communication tools such as Telegram, CGS hosts its ecosystem directly within an individual, cloud-synchronized interface.

Despite their contributions, existing studies on child monitoring reveal several limitations. First, many rely on GSM networks, which frequently result in reliability issues in regions with inadequate signal coverage. Second, the hardware designs contribute to increasing device bulk or reliance on external components, making them less practical for children to carry and raising the risk of being lost or forgotten. Furthermore, these devices are power-intensive, requiring regular recharging and reducing their practicality for everyday use. Third, acquiring precise data from sensors remains a challenge, as sensor readings are not always reliable enough to inform safety decisions. Finally, systems utilizing short-range communication, such as Bluetooth, constrain monitoring to a limited distance, thereby diminishing effectiveness. Overall, current solutions exhibit several common weaknesses, including reliance on stable connectivity, high power consumption, privacy risks, and limited safety indicators. In the proposed study, almost all of these weaknesses have been resolved, providing a more reliable, secure, and practical child safety system.

TABLE 1: Summarized Features used in prior studies and the proposed CGS

Ref. No.	Features						
	Mobile-based app		Tracking	History	Alert	Technology used	Communication method
	Parent-app	Child-app					
Alam *et al*. [1]	Yes	Yes	Yes	No	No	GPS	Cellular
Jaya *et al*. [2]	Yes	No	Yes	Yes	No	GPS, Arduino	GSM
Zahilah and Zaharan [14]	Yes	No	Yes	Yes	No	GPS, Arduino	GPRS/GSM
Gupta *et al*. [16]	Yes	No	Yes	Yes	Yes	Wi-Fi positioning	Mobile network
Hattaraki *et al*. [6]	Yes	No	Yes	No	Yes	GPS, ESP32-CAM	Telegram
Gowthami *et al*. [17]	Yes	No	Yes	No	Yes	GPS, accelerometer, heart rate sensor	Bluetooth
Proposed CGS	Yes	Yes	Yes	Yes	Yes	GPS, Wi-Fi, Firebase	REST API, FCM

CGS: Child guard system, GPS: Global positioning system, GPRS: General packet radio service, GSM: Global system for mobile communications, FCM: Firebase cloud messaging

3. PROPOSED SYSTEM OVERVIEW

The CGS is developed to enhance child safety by providing real-time monitoring and communication between parents and their children through an intuitive and user-friendly interface. Upon installation, users are prompted to select their role as either a parent or a child, with each role granted access to distinct functionalities. Parent users are required to register and authenticate their accounts before accessing the system, whereas child users can utilize the application once they are added by their respective parents. After successful authentication, parents gain access to several key features, including real-time child location tracking, the ability to add new child profiles, reception of emergency notifications, and instant communication through a built-in chat feature. These capabilities enable parents to continuously monitor and stay connected with their children, thereby ensuring awareness of their safety and well-being. Conversely, child users can access a dedicated dashboard that allows them to communicate with their parents or send emergency alerts in critical situations. Overall, the CGS is designed to strengthen the connection between parents and their children by integrating safety monitoring, emergency response, and communication within a unified mobile platform, as illustrated in the system flow diagram.

4. SYSTEM METHODOLOGY

The proposed CGS is a mobile-based solution for child safety and monitoring, intended to provide real-time location tracking, emergency alerts, and secure communication between children and parents. The system adopts a client–server architecture and incorporates GPS technology, cellular communication networks, RESTful web services, and a cloud-based backend using Firebase Backend-as-a-Service (BaaS). The overall architecture, shown in Fig. 1, comprises two main client applications: child-side and parent-side, which communicate through a REST API and cloud infrastructure to provide real-time data exchange and system scalability.

4.1. Child-side App

The child-side app continuously acquires geographical coordinates from GPS satellites, generating updated latitude and longitude values either periodically or upon request from the parent app. When a location request is received via the cellular network, the latest GPS coordinates are retrieved and prepared for transmission. The location data are then transmitted to the cloud backend through REST API calls over secure hypertext transfer protocol (HTTP) communication, where the information is structured in JSON format to ensure interoperability, scalability, and efficient processing.

The child's app has an emergency alert feature that enables the child to instantly notify the parent in critical situations. Upon activation, the system sends an emergency alert that includes the children's identity, current position, and timestamp to the cloud server over the REST API. In addition, a real-time chat module has been included in the child's app to provide safe text-based communication with parents. All communications are sent over the REST API and briefly retained in the cloud backend to guarantee message delivery and synchronization.

4.2. Parent-side App

The parent app allows the registration and management of multiple child profiles. Each child is assigned a unique identifier, which is retained in the cloud database and utilized for a safe connection between parent and child accounts. The parent can request the real-time or most recent location of

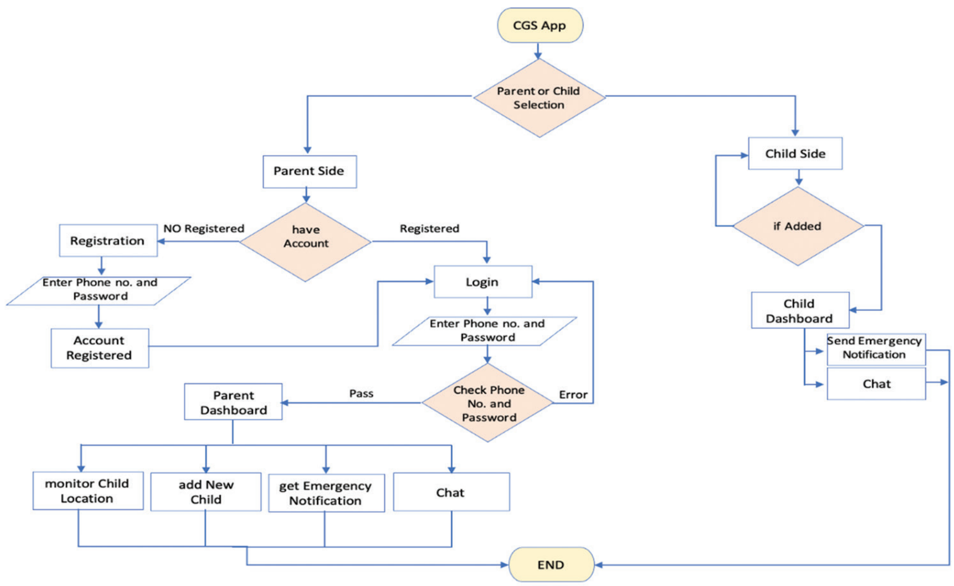

Fig. 1. System flow diagram of the child guard system.

the child using the app interface. The request is sent to the cloud backend, relayed to the child's app, and the result is received and displayed on the parent's device.

When the child's app sends an emergency notification, the parent app receives an instant alert through cloud messaging services. The alert informs parents where their child is and what type of emergency it is, allowing them to act quickly. The parent app includes a chat option that allows you to communicate with your child back and forth. The cloud backend sends communications back and forth to ensure that they are accurate and up to date in real time. The primary method of communication between the cloud infrastructure and the mobile app in the proposed system is the REST API. It is capable of performing a multitude of tasks, including:

- Coordinating requests and responses regarding location
- Sending out emergency notifications
- Sending and receiving communication messages
- Maintaining profiles for children.

To ensure the safety and functionality of the system, the API implements conventional HTTP protocols and JSON-based data exchange. Firebase also serves as the BaaS platform to provide backend support that may grow and change in real time. In the proposed system, the following operations are performed by the cloud backend:

- Storing location and user data
- Managing the authentication and authorization
- Synchronizing chat messages
- Delivering real-time notification.

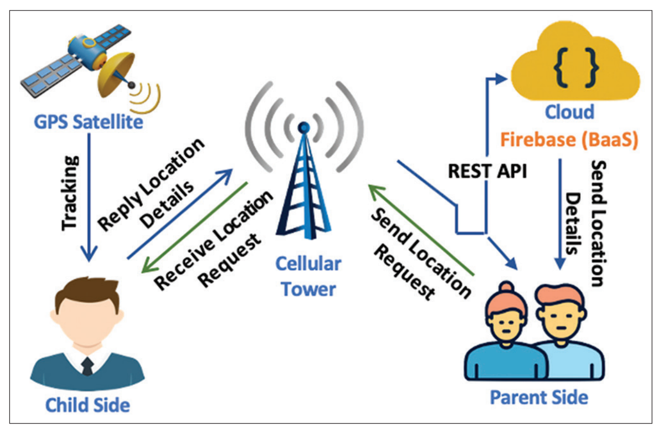

Fig. 2. The child guard system architecture uses Firebase cloud services for real-time tracking, geofencing, emergency alerts, communication, and data synchronization among parent and child mobile apps.

Firebase makes a guarantee that servers are always available, have low latency, and do not require much management. This holistic interaction sequence and real-time data flow are visually mapped out in Figs. 1 and 2. Finally, to ensure secure and reliable operation, the system incorporates authenticated user access, encrypted communication routes, and cloud-based data storage. These measures improve data integrity, user privacy, and system robustness, especially in emergency situations.

4.3. Technical Implementation Details

The production configuration for the CGS application dictates a minimum operating system environment of

Android 8.0 (API Level 26) or iOS 13.0, ensuring native support for low-power background location tracking and Flutter framework runtime optimizations. Firebase BaaS was explicitly selected over alternative cloud platforms such as Amazon Web Services as it offers integrated authentication, secure cloud messaging, and specialized out-of-the-box support for real-time database synchronization. This infrastructure provides native Flutter cross-platform plugin integration, inherent scalability, and minimal maintenance overhead, drastically reducing the complexity of hosting administrative microservices while making it exceptionally suited for the rapid development of mobile monitoring systems.

Within this framework, mobile apps and cloud infrastructure communicate via RESTful APIs over HTTPS, utilizing JSON-structured data payloads to ensure secure data exchange and cross-platform interoperability. Smartphone GPS and Wi-Fi positioning services provide core location updates, which are periodically transmitted to the cloud backend at configurable intervals to balance tracking responsiveness against device resource utilization.

Using these coordinates, geofencing functionality is implemented via circular geographic boundaries defined by a center latitude/longitude coordinate and a user-specified radius. Real-time synchronization is achieved using Firebase Firestore listeners that continuously monitor database changes to instantly update connected parent clients. When a child client triggers an emergency alert or when the system detects entry or exit events across a predefined geofence boundary, Firebase Cloud Messaging (FCM) is leveraged to deliver near-instant push notifications directly to the parent device.

4.4. Security and Privacy Considerations

Given that the proposed CGS handles sensitive data on child location and communication, appropriate security and privacy measures have been incorporated into the system architecture. User authentication is performed using Firebase Authentication, guaranteeing that only registered users can access system resources through unique user identities. Moreover, all communications between the parent and child apps and the cloud infrastructure are secured using HTTPS, providing encrypted data transmission and protection against unauthorized interception.

Access to cloud-stored data is controlled through Firebase Firestore Security Rules, which restrict database operations to authenticated and authorized users. In addition, a parent–child authorization mechanism is implemented to ensure that location tracking, emergency alerts, and communication services are only available between linked parent and child accounts. Sensitive information, including location records and chat messages, is stored in protected cloud databases with controlled access permissions to preserve data confidentiality and user privacy. Fig. 3 depicts the security architecture of the proposed CGS, including Firebase Authentication, HTTPS-based secure communication, Firestore access control, and the parent–child authorization mechanism used to protect sensitive user data.

5. RESULTS AND DISCUSSION

The experimental results and discussion of the proposed CGS mobile application are presented by the evaluation of system performance, usability, resource consumption, benefits, and development challenges. There is also a comparison with current child monitoring solutions in the study. In contrast to various current solutions that rely on external hardware platforms, such as Arduino and IoT devices, the proposed system is entirely implemented on smartphones, utilizing built-in sensors and cloud-based services to provide monitoring and safety functionalities.

5.1. Performance Testing

The performance of the CGS application was evaluated in terms of location accuracy, data update latency, and notification response time, as illustrated in Fig. 4. Location tracking was primarily based on GPS data obtained from the child's mobile device. The experimental results indicate

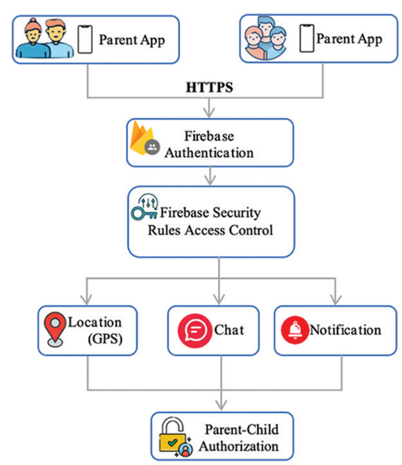

Fig. 3. Security architecture of the proposed child guard system illustrating Firebase Authentication, HTTPS-secured communication, Firestore Security Rules, protected cloud storage, and parent–child authorization mechanisms.

that GPS positioning achieved an average accuracy of approximately 5–10 m in outdoor environments, which is sufficient for real-time child monitoring scenarios. However, a slight decrease in positioning accuracy was observed in indoor or low-signal environments. To address this limitation, the system integrates Wi-Fi-based positioning, which helps improve location estimation when GPS signals are weak, as shown in Fig. 4.

The latency of location updates was measured as the time difference between location acquisition on the child's device and its visualization on the parent mobile application. Under normal cellular network conditions, the average latency ranged between 1.25 and 2.8 s, which is acceptable for near real-time monitoring. Furthermore, emergency notifications triggered by the child or by geofencing violations were delivered to the parent device within an average of 1.85 s using FCM, demonstrating the system's responsiveness in critical situations, as illustrated in Fig. 4.

5.1.1. Experimental setup

The performance of the proposed CGS was evaluated for 10 days, utilizing nine smartphones (5 Android, 3 iOS, and 1 HarmonyOS). The experiments were performed in both indoor and outdoor environments to evaluate system performance under various positioning and connectivity conditions. Wi-Fi and 4G/5G cellular networks were used to offer Internet access to assess real-time communication and notification delivery in typical use situations. The location information was obtained using GPS sensors included in smartphones and Wi-Fi-based positioning services when available. Firebase Firestore was employed for real-time data synchronization, whereas FCM was used for notification delivery. During the testing period, multiple location requests, geofencing events, emergency alerts, and parent–child communication sessions were executed to evaluate location accuracy, response latency,

TABLE 2: Experimental setup parameters

No.	Parameter	Value
1	Testing duration	Ten days
2	Total devices	Nine smartphones (Five Android, Three iOS, One HarmonyOS)
3	Test environments	Indoor and outdoor
4	Connectivity	Wi-Fi, 4G, and 5G
5	Location source	GPS+Wi-Fi positioning
6	Cloud backend	Firebase firestore
7	Notification service	FCM
8	Evaluated functions	Tracking, geofencing, emergency alerts, chat, location history

FCM: Firebase cloud messaging, GPS: Global positioning system

notification delivery time, and overall system reliability. Table 2 summarizes the parameters and settings used in the experimental setup for evaluating the proposed CGS.

5.2. Usability Testing

Usability testing was conducted to evaluate the ease of use, efficiency, and user satisfaction of the CGS for both parent and child users. A group of participants interacted with the system to perform several common tasks, including user registration, adding a child profile, monitoring the child's location, sending emergency alerts, and using the chat feature. Two representative screens of the application interface are illustrated in Fig. 5, demonstrating the main user interaction

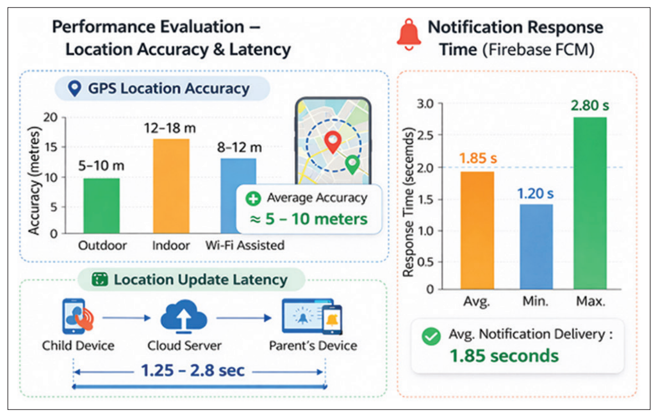

Fig. 4. Performance evaluation of the proposed child guard system, including location tracking accuracy, notification delivery time, system responsiveness, and operational performance under varied testing conditions.

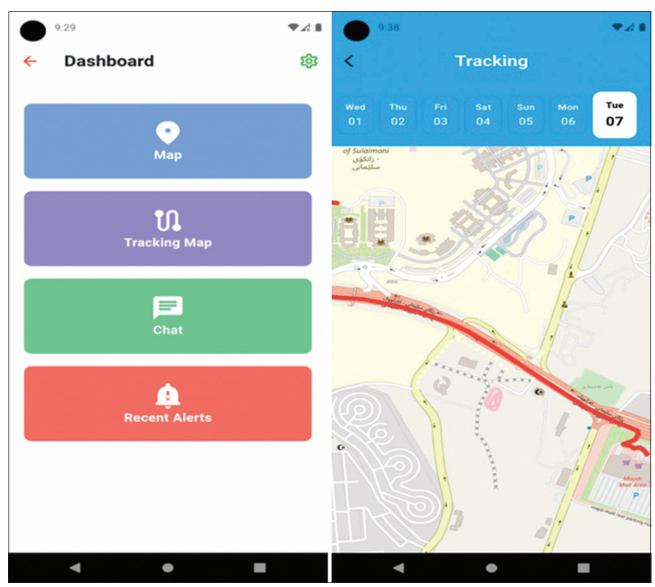

Fig. 5. Sample screens of the child guard system mobile application illustrating the main system interfaces.

components of the system.

The evaluation results demonstrated that the Flutter-based user interface is intuitive and easy to navigate, even for users with limited technical expertise, as parents reported that the application provides quick and convenient access to essential functionalities, particularly real-time location monitoring and emergency notifications. Similarly, children were able to trigger emergency alerts and communicate through the chat feature with minimal interaction steps, which is especially important in urgent situations. To examine these observations in a structured manner, usability testing was conducted with 83 participants, including both parents and students aged 14–21 and 31–42 years, respectively, representing different levels of smartphone familiarity. Each participant was assigned a smartphone (Android, iOS, or HarmonyOS) and asked to complete predefined tasks such as account registration, child profile creation, location monitoring, emergency alert activation, and parent–child communication. Following task completion, participants evaluated the system using a five-point Likert scale questionnaire (ranging from 1 for strongly disagree to 5 for strongly agree), ensuring a consistent and comparable measurement of user experience across all participants. The summarized usability evaluation results are presented in Table 3.

TABLE 3: Usability evaluation results of the CGS application

Evaluation criterion	Mean score	Standard deviation	Interpretation
Ease of use	4.6	0.52	Very good
Interface clarity	4.5	0.48	Very good
Task completion efficiency	4.4	0.55	Good
System responsiveness	4.3	0.60	Good
Overall user satisfaction	4.7	0.41	Excellent

CGS: Child guard system

The usability evaluation produced mean scores ranging from 4.3 to 4.7 out of 5, with an overall user satisfaction score of 4.7 ± 0.41, indicating positive user acceptance among the study participants. These findings confirm that the proposed mobile-based child monitoring solution provides a practical and user-friendly interface for real-world usage.

5.3. Battery and Data Usage Analysis

Battery consumption and data usage were analyzed to evaluate the practicality of continuous monitoring in the proposed CGS. Since location tracking relies primarily on GPS services, battery usage is influenced by the frequency of location updates. To assess this impact, battery consumption and data usage were observed under different location update intervals. Table 4 presents the battery drain and data usage measurements obtained during system operation. As expected, shorter update intervals resulted in higher battery consumption and network utilization, whereas longer intervals significantly reduced resource usage. The results indicate that an update interval between 30 and 60 s provides a practical balance between tracking responsiveness and resource efficiency.

TABLE 4: Battery consumption and data usage under different location update intervals

Update interval	Battery drain (%/hour)	Data usage (MB/day)
5 s	7.8	32
10 s	5.4	18
30 s	3.1	8
60 s	2.0	4

The results indicate that battery consumption ranged from 2.0%/h to 7.8%/h, depending on the selected update interval, whereas daily data usage varied between 4 MB/day and 32 MB/day. These values suggest that the system can support continuous monitoring with manageable resource consumption. Data usage was also relatively low because location updates consist of lightweight JSON payloads transmitted through REST APIs. In addition, chat messages and notification events generated minimal network overhead.

Compared with many commercial location-monitoring applications that continuously perform background tracking, the proposed CGS utilizes configurable update intervals, allowing users to balance location accuracy, responsiveness, battery consumption, and data usage according to their requirements. These findings indicate that the proposed system is suitable for long-term child monitoring without imposing excessive battery drain or communication costs.

5.4. Benefits of the Proposed System

The proposed CGS offers several key benefits:

- Mobile-only implementation without the need for Arduino, sensors, or wearable devices
- Real-time GPS tracking using built-in smartphone capabilities
- Emergency notification mechanism with instant parent notification
- Geofencing support for automatic alerts
- Integrated chat system for continuous parent–child communication
- Cloud-based backend ensuring scalability, reliability, and real-time data synchronization across devices.

These benefits make the system cost-effective, easy to deploy, and practical for everyday use.

5.5. Development Challenges

Several challenges were encountered during system development. Ensuring accurate location tracking in indoor environments was difficult due to GPS signal limitations. Balancing real-time tracking with battery efficiency required careful optimization. Moreover, implementing strict data privacy and access control rules was crucial to protect sensitive child information, hence increasing backend configuration complexity.

5.6. Comparison with Existing Solutions

In comparison to existing child monitoring systems, the proposed CGS provides a more integrated and flexible architecture by combining real-time location tracking, geofencing alerts, emergency notifications, location history, and parent–child communication within a single mobile app. Many existing solutions focus primarily on location tracking and often require additional hardware components, external communication services, or third-party platforms. In contrast, the proposed system is implemented entirely on smartphones using a cloud-based architecture, thereby reducing deployment cost and implementation complexity while improving accessibility and maintainability. Table 5 evaluates the proposed CGS against representative academic child monitoring literature across core architectural and functional parameters.

TABLE 5: Comparison of the proposed CGS with existing academic child monitoring solutions

No.	Feature/System	Prior studies	Proposed CGS
1	Mobile-only solution	✕	✓
2	External hardware (Arduino/IoT)	✓	✕
3	Real-time GPS tracking	✓	✓
4	Emergency alert	✕	✓
5	Geofencing alerts	✕	✓
6	Parent–child communication	✕	✓
7	Cloud-based backend	Partial	✓
8	Cross-platform support	✕	✓

✓: Supported, ✕: Not Supported, Partial: Partially supported, CGS: Child guard system, IoT: Internet of things, GPS: Global positioning system

As shown in the above table, most existing academic solutions support only a subset of the functionalities provided by the proposed CGS. Several studies offer real-time location tracking but lack integrated emergency alert, geofencing capabilities, location history, or bidirectional communication. Furthermore, many existing approaches rely on Arduino boards, IoT sensors, GSM modules, Bluetooth devices, or third-party communication services, which increase system complexity and deployment costs. Conversely, the proposed CGS integrates all major child-monitoring functionalities into a single smartphone-based app without requiring external hardware.

In addition to academic studies, it is important to compare the proposed system with widely used commercial child-monitoring apps. Table 6 presents a feature-based comparison between the proposed CGS and three representative commercial solutions: Life360, Find My Kids, and Google Family Link. The comparison focuses on child safety features, communication capabilities, deployment requirements, and system flexibility.

Table 6 demonstrates that the proposed CGS provides functionality comparable to widely used commercial apps. Similar to Life360 and Find My Kids, the system supports real-time location monitoring, geofencing, emergency notifications, and location history. In addition, the proposed CGS incorporates integrated parent–child communication and cloud synchronization while maintaining cross-platform capabilities.

TABLE 6: Comparison of the proposed CGS with commercial child monitoring apps

No.	Feature	Proposed CGS	Life360	Find my kids	Google Family Link
1	Real-time tracking	✓	✓	✓	Partially supported
2	Geofencing	✓	✓	✓	✕
3	Emergency alert	✓	✓	✓	✕
4	Parent–child chat	✓	✕	Partially supported	✕
5	Location history	✓	✓	✓	Partially supported
6	Smartphone-only deployment	✓	✓	✓	✓
7	Cloud synchronization	✓	✓	✓	✓
8	Cross-platform support	✓	✓	✓	✓
9	Academic transparency	✓	✕	✕	✕
10	Customizability	High	Low	Medium	Low

✓: Supported, ✕: Not Supported, CGS: Child guard system

Unlike commercial apps, which operate as proprietary systems with limited transparency and customization options, the proposed CGS is developed within an academic framework and can be extended or modified to support future research and educational activities. Therefore, the proposed system not only provides practical child-monitoring functionality but also offers greater flexibility for future enhancements and experimentation. Overall, the comparison with both academic and commercial solutions demonstrates that the proposed CGS delivers a comprehensive, cost-effective, and extensible platform for child safety monitoring.

5.7. Limitations

Although the proposed CGS achieved an average GPS positioning accuracy of 5–10 m, a location update latency of 1.25–2.8 s, and an average notification delivery time of 1.85 s, several limitations should be acknowledged. The test was first carried out on a limited number of mobile devices under normal usage conditions. As a result, large-scale deployment involving hundreds or thousands of concurrent users was not evaluated. While the system utilizes Firebase cloud services, which are designed to support scalable apps, the scalability of the proposed CGS under high user loads was not experimentally evaluated in this study.

In addition, the system relies on GPS and Internet connectivity, which may affect location accuracy and notification delivery performance in areas with weak network coverage or limited satellite visibility. Therefore, future work should involve large-scale performance testing, cloud load analysis, and optimization of system resources under high-concurrency scenarios.

6. CONCLUSION AND FUTURE WORK

The study presents the design and implementation of a CGS intended to enhance child safety through real-time monitoring and communication between parents and children. The proposed solution employs a mobile-based architecture that incorporates GPS and Wi-Fi positioning, RESTful communication, and Firebase cloud services to provide continuous location monitoring and reliable data synchronization. The proposed system employs a smartphone-based architecture integrated with cloud services to support real-time monitoring and communication functionalities.

The proposed CGS incorporates several safety-oriented features, including real-time location monitoring, geofencing alerts, emergency notifications, location history access, and built-in parent–child communication. The performance evaluation verified that the system meets real-time monitoring constraints with low latency and highly accurate outdoor tracking, proving viable for practical family deployment. In addition, usability testing confirmed that the mobile interface is intuitive and easy to use for both parents and children, facilitating efficient interaction even in emergencies. Furthermore, the results prove that the proposed CGS provides an integrated mobile solution for child monitoring and communication. The integration of several monitoring and communication functionalities under a singular mobile platform illustrates the feasibility of smartphone-based child protection systems and contributes to the development of cost-effective digital safety solutions for modern families.

Despite the promising performance of the proposed CGS, several enhancements can be explored in future work. Artificial intelligence and machine learning techniques may be integrated to detect abnormal movement patterns and predict potential safety risks. Voice-based emergency alerts and interaction features could further improve system usability and accessibility. In addition, future studies will investigate large-scale deployment scenarios to evaluate system scalability, cloud resource utilization, and performance under high user loads. Other potential enhancements include offline operation support, multi-child monitoring optimization, and advanced parental analytics to further improve the effectiveness and practicality of the system.

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