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Article

SeniorConnect: A low-cost, app-based real-time alert system to connect seniors with their caregivers

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SUMMARY

The world's increasingly aging population is causing an upsurge in the demand for eldercare, with a need for constant monitoring, support, and considerable financial burden on caregivers. Over 1 billion individuals with disabilities live around the world, and roughly 46 percent are over 60. Within the U.S., elderly individuals are more prone to experiencing disabilities and have lower levels of digital adoption compared to younger generations. Recent Internet of Things (IoT) and cloud-computing advances offer promising solutions that enable caregivers to monitor seniors remotely. Currently, the market lacks any configurable, reliable, easy-to-use, cost-effective mobile app-based alert system that lets seniors notify their caregivers. Our research aimed to design a low-cost, easy-to-use, wearable IoT-and-mobile-app prototype that lets seniors with disabilities notify their primary caregivers in real-time. We developed a fully functional prototype solution by integrating a wearable IoT button with cellular connectivity and building a customized iOS mobile app, SeniorConnect, to send real-time notifications to the caregivers when the user clicks the button. We hypothesized that key performance factors such as low latency, high delivery success, and minimal error rates would influence the perceived effectiveness and user satisfaction of a wearable alert prototype system. Our research presents a significant advancement in elderly care through a cost-effective, user-friendly, and reliable IoT-based alert system. It empowers seniors with disabilities to notify caregivers in real-time.

INTRODUCTION

Globally, over 1 billion individuals live with one or more disabling conditions, and among those aged 60 years and over, at least 46% experience disabilities (1). Disability refers to physical, cognitive or mental health impairments that lead to activity limitations or participation restrictions, whether congenital, acquired earlier in life, or developed with aging. The 2015 UN World Population Prospects report anticipates a 56% increase in the elderly population between 2015 and 2030, rising from 901 million to 1.4 billion (2). By 2050, this demographic is projected to approach 2.1 billion globally. The U.S. Census Bureau reports that over 40 million Americans live with a disability (3). Although global trends show an aging population with rising disability prevalence, U.S. specific data illustrate how these patterns manifest in a high-income context. This highlights the need for both internationally informed strategies and nationally tailored interventions. The Pew Research Center survey finds that older Americans report disabilities more often than younger adults and show lower levels of digital adoption (4). Seniors with disabilities now experience greater isolation and vulnerability than ever. This isolation and vulnerability stem from social exclusion, residence in large, spread-out communities, and younger family members having limited time to care for them. As the global population ages, more elderly people require constant care, support, and monitoring. This puts a heavy financial and emotional strain on their caregivers.

Over the past ten years, significant technological advances, especially the emergence of Internet of Things (IoT) technology, have transformed healthcare services. IoT is a network of interconnected physical devices embedded with sensors, software, and connectivity that collect and exchange data to enable remote monitoring, automation, and intelligent decision-making. IoT has demonstrated its capacity to link diverse sensors, caregivers, and medical experts in innovative ways. The reach of IoT extends beyond healthcare, finding applications in sectors such as farming (e.g., soil sensors for precision farming), automotive (e.g., telematics for predictive maintenance), and residential spaces (e.g., smart thermostats) as detailed in (5). Recent advances in IoT platforms and cloud computing–based application devices continue to revolutionize our lives by transmitting data in real-time to healthcare providers or third-party medical alert service providers. These solutions use smart wearables and SOS buttons to enable that functionality. The integration of sensor-based technologies, particularly IoT-enabled wearables and devices, offers a promising approach for caregivers and family members to monitor seniors from afar. This technology provides an impartial, trustworthy method of remote observation. Despite technological advancements, gaining widespread adoption of these devices remains a hurdle. Key factors influencing acceptance include user-friendly hardware and software interfaces, wearability, compact design, and efficient power management. By selecting the right IoT devices and integration technologies, an optimal balance of functionality, precision, and affordability can be achieved to ensure the solution's successful implementation (6).

We conducted market research to evaluate existing IoT-based alert systems available for elderly individuals with disabilities, specifically focusing on non-emergency use. Our findings revealed that most commercially available medical alert devices are designed exclusively for emergency scenarios. In these scenarios, a monitoring center dispatches emergency responders to the user's location. These systems often bundle features like emergency call centers or wellness

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monitoring, but caregivers rarely use them in everyday, non-emergency situations. Furthermore, such devices — like the Medical Guardian alert system available through retailers like Costco — can cost over $100 upfront and typically require monthly subscription fees exceeding $40 (7). In addition to these systems, a variety of eldercare technologies exist — such as pill reminder boxes, daily wellness check-in apps, and caregiver support platforms (8,9,10,11,12). However, many of these tools are condition-specific, lack real-time communication capabilities, or rely on complex interfaces. Elderly users with low digital competency often find these interfaces too complex to navigate.

Currently, no configurable, reliable, easy-to-use, cost-effective mobile app-based wearable alert system exists that lets seniors promptly notify their primary caregiver with a single button press in non-emergency situations. To address this gap, we developed a prototype alert solution that pairs a cellular IoT-enabled wearable button with a custom iOS app, and we integrated both using Amazon Web Services (AWS) cloud services. This system enables seniors to instantly send real-time alerts to their caregivers with a single button press — without relying on Wi-Fi connectivity or complicated app interfaces. We hypothesized that low notification latency, high delivery success, and minimal error rates would boost system effectiveness and satisfaction for both elderly users and their caregivers. Our primary goal was to design a low-cost, easy-to-use wearable IoT and app-based prototype specifically aimed to assist elderly individuals with cognitive disabilities to connect with their caregivers in non-emergency situations.

RESULTS

The proposed prototype, named *SeniorConnect*, leverages an IoT button to quickly connect seniors with their primary caregivers through a mobile app **(Figure 1)**. We used AWS cloud services to integrate the IoT button with a custom mobile app. We integrated the Long-Term Evolution (LTE) wireless-broadband standard into the programmable Sercomm IoT button and our custom iOS app. A Long-Term Evolution (LTE) standard, used for wireless broadband communication in mobile networks to provide high-speed internet access, was integrated with the programmable 'Sercomm IoT button' and

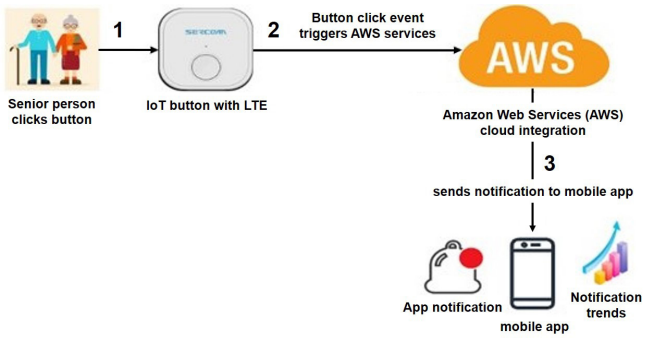

Figure 1: High level solution architecture of SeniorConnect prototype. Schematic of integration of IoT button with iOS App using AWS cloud computing services. Step 1 indicates the senior person clicking the IoT button to signal an alert; Step 2 shows the button click event being transmitted over the LTE network and triggering AWS services; and Step 3 denotes the AWS cloud integration sending a push notification to the caregiver's mobile app and recording the event for analytics purposes (e.g., tracking notification trends).

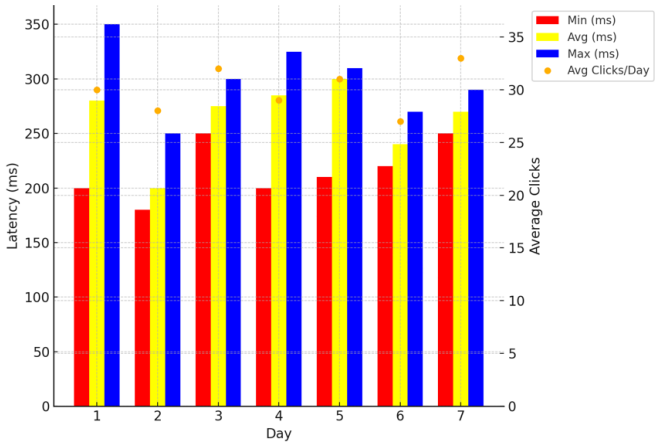

Figure 2: Notification delivery latency of SeniorConnect. Alert notifications were delivered from the IoT button to the app with a latency range of 180 to 350 milliseconds (ms) and at an average of 265 ms. The figure shows testing duration over the 7-day period. Ten elderly participants made 210 clicks during this time, averaging 30 clicks during this timeframe. The blue, yellow, and red bars in the graph show maximum, average, and minimum latency values of the prototype solution.

a customized iOS mobile application. This integration allowed the button to act as a communication tool between seniors and their caregivers. We leveraged AWS cloud-platform services to connect the IoT button and mobile app.

The IoT button sent alert notifications to the app, and the system measured latencies ranging from 180 to 350 milliseconds (ms). Each day, it calculated mean latencies between 198.62 ms and 294.48 ms, and it reported an overall average latency of 265 ms with a standard deviation of 38.29 ms. (**Figure 2**)**.** The 10 elderly participants made 210 clicks over the 7-day testing period — an average of 30 clicks during this timeframe. We encountered no downtime or technical failures by tracking each button-press event and its corresponding AWS Lambda invocation to confirm successful notification deliveries to the app during the testing phase. We conducted a seven-day latency analysis to test our hypothesis that low latency rates, high delivery success, and minimal error rates drive both technical reliability and perceived effectiveness of the prototype alert solution. To compare the mean latency across different days, we performed a one-way ANOVA test, yielding an F-statistic of 66.17 and a p-value less than 0.0001, indicating significant variability in mean latency across days. Our dataset included daily latency measurements, and we treated each day as an independent group to compare variance over time. Post-hoc analysis using Tukey's Honestly Significant Difference (HSD) test identified specific pairs of days with significant differences in latency, confirming that certain days achieved significantly lower latency values. In our non-emergency tests, the prototype achieved average latency and standard deviation within the acceptable thresholds, proving its low error rates and high delivery success. The low latency and zero-error performance validated the system's ability to send real-time notifications with minimal delay.

We further counted the number of times the IoT button was clicked and compared it to successful notification deliveries during the testing period. Aligned bars illustrate a 100% notification delivery success rate with zero errors (**Figure 3**).

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Participants clicked the IoT button 95 times during the five-week testing period in October 2023. Finally, the notification error rate remained at 0% throughout this testing phase.

After data collection, we administered a one-time qualitative usability survey to 10 elderly users and 10 caregivers to evaluate the prototype's real-world impact and perceived effectiveness. Because of our small sample size and the qualitative feedback, we did not perform a formal regression analysis. However, the consistent alignment between technical metrics and user-reported satisfaction supports the hypothesis that system reliability influences perceived effectiveness. Usability feedback from elders and caregivers is summarized (**Table 1**). Usability testing revealed high acceptance and satisfaction among both elderly users and caregivers. Elder participants and their primary caregivers identified the wearable device's compact size, estimated three-year battery life, and prototype system effectiveness as the main likability factors. They also highlighted the app interface and its ease of use with a single button click. Caregivers found the SeniorConnect app straightforward to set up and easy to use with additional convenient features like device location tracking and data trending capability. Some elders recommended incorporating additional features like fall detection and a two-way communication option in the device to make it more user-friendly.

We estimate the prototype's unit cost at under $50 USD per device, including the Sercomm LTE IoT Button (13), AWS services (14, 15), and app-hosting charges based on 2,000 clicks (**Table 2**). Therefore, our proposed solution can offer a reliable and effective solution for connecting seniors to their caregivers for a reasonable cost.

DISCUSSION

SeniorConnect provides an affordable, wearable, mobile-app alert system that helps seniors connect with their caregivers through a single IoT-button click in non-emergency situations. SeniorConnect offers users a more accessible solution by eliminating recurring monthly fees and cuts costs by leveraging efficient hardware components and optimizing cloud-service usage. Although the system uses AWS services, we minimize operational costs by using AWS Free Tier options, serverless computing (e.g., AWS Lambda), and pay-as-you-go pricing. This approach lets SeniorConnect deliver high-quality, real-time communication without burdening users with extra costs. Caregivers can use SeniorConnect easily and monitor seniors in real-time, enabling prompt action. The SeniorConnect app also gives caregivers user-friendly tools — device-location tracking and data-analytics dashboards — for eldercare monitoring. By using a cellular-connectivity IoT button, SeniorConnect eliminates Wi-Fi boundaries and offers a more versatile solution.

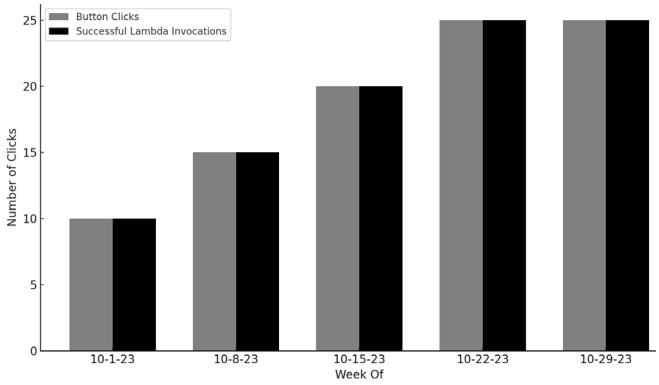

Figure 3: Notification delivery success rate. Bar chart displaying the number of IoT button clicks compared with notification deliveries (i.e., AWS Lambda invocations) during October 2023 to illustrate the overall notification delivery success rate over the five-week testing period.

Theme	% of Participants	# of Participants E: Elders(n=10), C: Caregivers(n=10)	User Comments
Ease of Use	100%	10E	"My caregiver is just a click of a button away." "I can use this outside home without Wi-Fi."
Device Size	80%	8E	"Easy to carry in the pocket or purse."
Battery Life	100%	10E	"I didn't have to charge this device for a few weeks."
Wearability	80%	8E	"Lanyard design makes it easy to wear & carry."
Prototype Effectiveness	100%	10C	"I instantly received a message on SeniorConnect App."
App Interface	100%	10C	"Location tracking and trending are great." "The app is simple to navigate."
Cost	100%	10E	"I'd prefer a one-time cost under $100 with no subscriptions."
Areas for Improvement	30%(E), 20%(C)	3E, 2C	"Would be nice to add fall detection and 2-way talk." "Please add an Android version."
Overall Satisfaction	100%	10E,10C	"I would purchase this if it costs less than $100."

Table 1: Usability feedback from elderly users and caregivers. Summary of key themes, participant responses, and representative comments from 10 elderly users and 10 caregivers.

We found in our qualitative usability testing that low latency, high notification-delivery success, and minimal error rates are critical parameters that influence the overall effectiveness of the alert solution. This strongly supports our original hypothesis. 100% of caregivers received notifications immediately and found the app easy to set up and use. Elderly participants cited the compact design, long battery life, and single-button functionality as major factors contributing to ease of use and satisfaction. Caregivers unanimously reported timely alert reception, while elderly participants highlighted convenience and satisfaction, directly linking technical reliability with real-world effectiveness and usability. These results suggest that the system's technical performance translated directly into real-world usability and acceptance. The complete absence of delivery errors, coupled with positive qualitative feedback, confirms that the prototype successfully addressed the core needs of its target users. Thus, the usability data validates that the prototype is not only functionally reliable but also effective and intuitive from the perspective of both seniors and their caregivers.

We should acknowledge a few limitations when interpreting our findings. First, we only tested usability with 10 beta testers; future studies should use a larger sample size to boost confidence and demonstrate repeatability and reproducibility. Second, we should evaluate the proposed solution's reliability and consistency over a longer period (e.g., three months), focusing this evaluation on key performance metrics such as alert notification speed, delivery success, and error rate. Third, we designed the SeniorConnect app to work only on iOS devices, which limits accessibility for Android users. To fix this, we plan to expand the app to Android, ensuring a seamless experience on both iOS and

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IoT Button and Services	AWS Service Functionality	Cost ($) per 2000 clicks
Sercomm LTE IoT Button	-	39.99
AWS IoT 1-Click (20)	Provides a medium to integrate internet connected device events with AWS Lambda function	-
AWS IoT 1-Click iOS App (21)	Used to configure the credentials for the IoT 1-Click devices	-
AWS Lambda (22)	Provides a programming environment to implement device action like sending a text message and database updates	-
Amazon Dynamo DB (23)	Used to store and query device data, provides consistent, single-digit millisecond latency and data encryption at rest and in-transit	0.20
AWS SNS (24)	Provides a notification service that sends push notifications to the mobile application, allowing real-time alerts to be delivered when the IoT button is pressed	0.002
Amazon CloudWatch (25)	Tracks and analyzes data on device usage and performance, providing detailed reports on IoT button deployment and activity through the AWS IoT 1-Click service	0.10
Amazon Cognito (26)	Handles user identity management, authentication, and account management	-
AWS SDK for iOS (27)	Allows iOS developers to build applications that use AWS services. The mobile app uses the SDK to invoke the Lambda function and push notifications can be received in real-time when actual button press events occurs	-
Amazon S3 (28)	Offers a range of data organization and management capabilities designed to address unique operational needs, optimize costs, enhance data protection, and ensure regulatory compliance	-
AWS IoT Core (29)	Easily and securely connect devices to the cloud	0.002
App Hosting Cost	-	9.00
Total		49.30

Table 2: Cost components and service functions for the SeniorConnect IoT alert prototype. Estimated per-device cost < $50, covering Sercomm LTE IoT Button, AWS services, and hosting charges based on 2,000 clicks; AWS service roles described for IoT-to-app integration.

Android devices. Additionally, future improvements will focus on integrating advanced features such as automatic fall detection. A two-way verbal communication feature between seniors and caregivers can also be incorporated in future versions of SeniorConnect. Further enhancements may also include video surveillance capabilities, to provide a more comprehensive remote monitoring solution. These upgrades will enhance the overall functionality of SeniorConnect, making it an even more effective and accessible tool for eldercare.

MATERIALS AND METHODS

A Long-Term Evolution for Machines (LTE-M) connectivity-based programmable 'Sercomm IoT button' provided by Sercomm was utilized for this application. The Sercomm IoT button has an integrated Lithium-ion battery that lasts for over three years with more than 2,000 clicks. It features an Ingress Protection rating 66 (IP66) waterproof design for resilience and offers cellular connectivity with location and movement detection (16). It interfaces with AWS IoT 1-Click iOS to provide a highly secure cellular-connected programmable device with no wiring or Wi-Fi needed. A single, short click of less than 0.5 seconds is required to activate the IoT button to send a message to AWS IoT 1-Click.

We leveraged a cloud-based computing infrastructure, called AWS, to integrate the IoT button with the SeniorConnect App. This platform was selected for its reputation as one of the most robust, secure, and scalable cloud solutions for deploying web applications (17). AWS platform also offered breadth of services, granular security controls, global infrastructure, and pay-as-you-go pricing model, making it the most viable and cost-effective integration solution in this application (18,19).

SeniorConnect solution integration

The Sercomm IoT button is configured through AWS IoT 1-Click service, which handles secure connectivity between button and cloud platform. When the IoT button is pressed, an alert notification is sent to the SeniorConnect app using AWS Lambda function and the message is published to the AWS IoT Core Service. This Lambda function sends notifications via Amazon Simple Notification Service (SNS) and logs data to the Amazon DynamoDB database for data analytics and trending capabilities. The AWS Software Development Kit (SDK) for iOS then invokes a notification to the SeniorConnect App through Lambda function. The app then calls an API endpoint which reads pre-processed metrics and trends using DynamoDB table. Logs, metrics, and click data are stored in Amazon CloudWatch via the CloudWatch Application Programming Interface (API). This API generates detailed reports on the usage and storage of deployed devices. SeniorConnect app stays in sync by subscribing to updated data sources and notification streams and then displays the metrics and trends using the Swift User Interface (UI) Charts Library. A technical flow diagram of the solution shows integration between Sercomm IoT button and SeniorConnect App leveraging various AWS services (**Figure 4**).

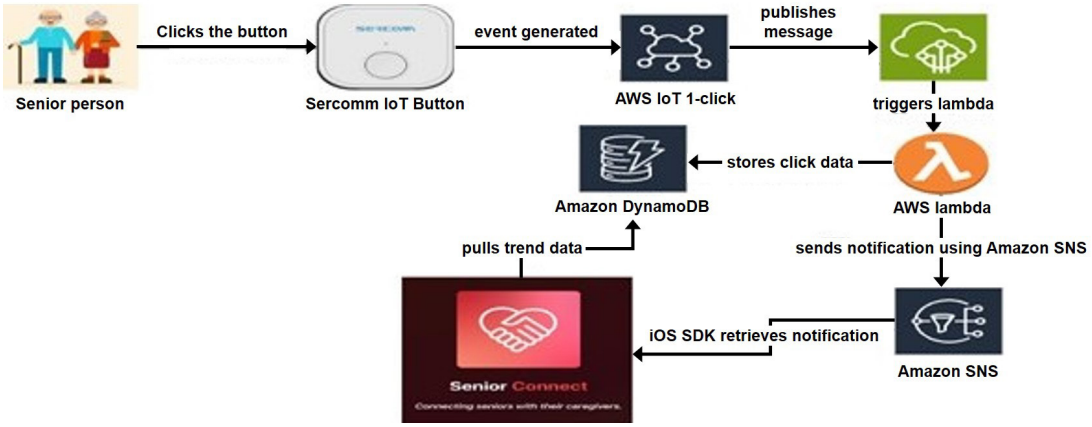

Figure 4: Technical flow of SeniorConnect. Visual demonstration of AWS services and associated functionality utilized to design, develop, and integrate a working prototype solution. Icons and images used in this figure are sourced from AWS architecture icons and stock illustrations (30). All respective copyrights belong to their original owners.

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A customized iOS mobile app using Swift, Apple's programming language, within the Xcode development platform was developed to integrate with an IoT device to send real-time notifications. SeniorConnect app acted as a communication tool between seniors and their caregivers and provided a dashboard for caregivers (**Figure 5**). Upon launching SeniorConnect app, caregivers were prompted to log in with their username, password, and unique device ID, which connected them to the IoT device. The SeniorConnect app allowed caregivers to view key features like real-time device information, including connectivity status, battery level, and device location to track seniors at any given time.

To address privacy concerns, the SeniorConnect app included configurable privacy settings that allowed seniors to limit continuous location tracking. These settings granted them control over when and how their location was shared with caregivers. The home screen of the app displayed the latest notifications and provided caregivers with the option to track and visualize IoT device click data on daily, weekly, and monthly timeframes. Caregivers could also select graphs showing peak click times to identify when seniors needed the most assistance. These usage metrics and data visualizations let caregivers optimize care by providing data-driven insights into seniors' needs. Each alert in the app displayed the notification text and a timestamp indicating when the alert was originally sent. It served as an audit log to verify which notifications had been sent historically and when they were received.

App Testing

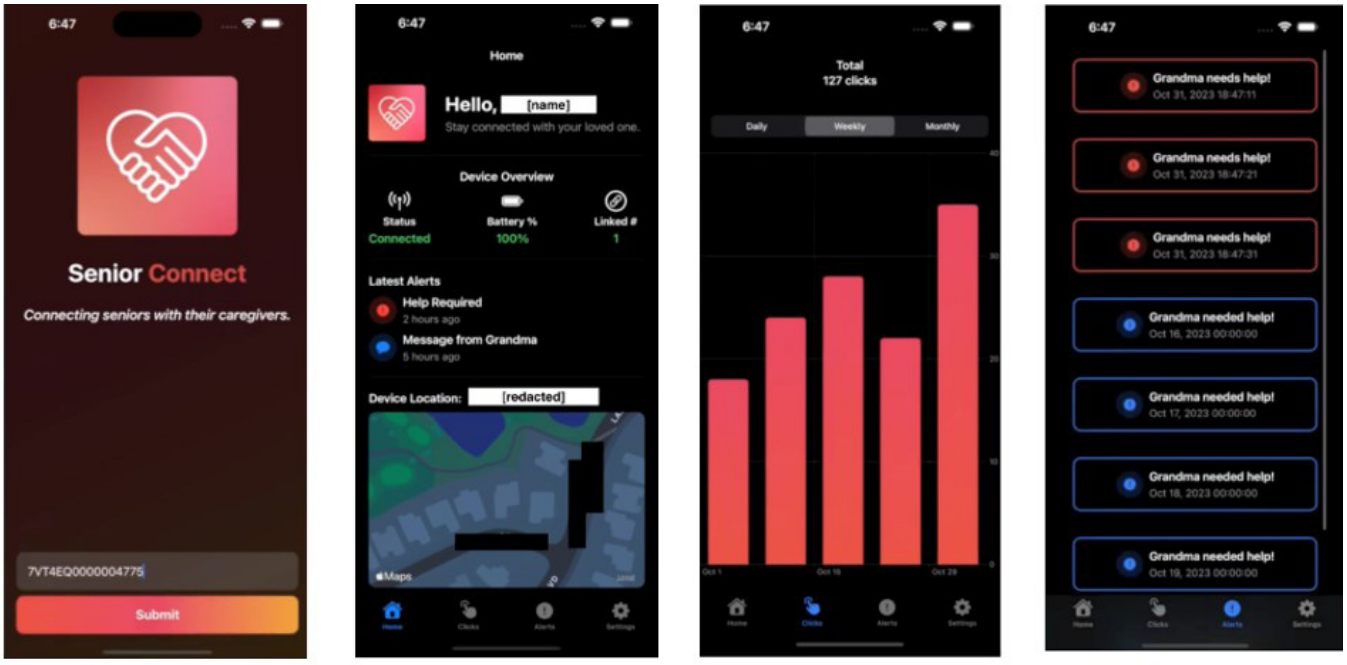
The Xcode Simulator was used to test the iOS app on a virtual device representing different iPhone models. Running the app in the Simulator allowed verifying functionality across multiple iOS versions. The Simulator provided a reliable and efficient way to test without needing physical devices, while mimicking real-world conditions like low memory states, network failures, and push notifications.

Solution Security

SeniorConnect is designed with a strong emphasis on ethical responsibility and data security. While not classified as a medical device, SeniorConnect follows industry best practices aligned with the Health Insurance Portability and Accountability Act (HIPAA). It ensures user safety, data privacy, and security throughout the application lifecycle.

All user data, including caregiver and senior details, is encrypted both in transit and at rest using AES-256 encryption, as provided by Amazon S3 and Amazon DynamoDB services. To enhance security, the SeniorConnect app requires multi-factor authentication with a username, password, and device ID, ensuring only authorized users can access the system. Additionally, role-based access control is enforced through Amazon Cognito, restricting access to sensitive information based on user roles. To further protect user data, all IoT button interactions with the AWS cloud infrastructure are secured using TLS/SSL encryption via AWS IoT Core, preventing unauthorized access or interception of data. App data on the device is encrypted using iOS data protection mechanisms, ensuring compliance with AWS and iOS security best practices to safeguard against potential threats.

The system is designed to minimize the storage of personal information, retaining only essential device interactions. Certificate-based mutual authentication is used to secure device connectivity. AWS Identity and Access Management



a) Login Screen b) Home Dashboard Screen c) Clicks Analytics Screen d) Alerts History Screen

Figure 5: SeniorConnect app interface. Screenshots of key app features include: a) Login Screen – device ID entry and submit button; b) Home Dashboard Screen – welcome banner, device overview (status, battery %, linked devices), latest alerts, and location map; c) Clicks Analytics Screen – bar chart of total "help" clicks over selected timeframes (Daily, Weekly, Monthly); d) Alerts History Screen – chronological list of past notifications with timestamps sent to the caregiver.

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(IAM) roles then controlled access to AWS services, granting only the privileges necessary to prevent unauthorized data access. User identities are securely managed through Amazon Cognito, which facilitates sign-up, authentication, and account management. SeniorConnect also follows a strict data retention policy, storing only essential user interaction logs, which can be permanently deleted upon request. SeniorConnect incorporates these security protocols and compliance measures to ensure the ethical and secure handling of user data. This approach reduces risks related to unauthorized access, data breaches, or regulatory non-compliance.

Evaluation Metrics

The reliability, speed, and accuracy of the end-to-end system were measured, including timely notification delivery and successful message delivery rates. Fast delivery of notifications or low latency rate was deemed essential, especially in urgent situations where seniors may need immediate assistance. Latency was measured by calculating the time interval between the IoT button click event, captured via AWS CloudWatch logs, and the timestamp when the caregiver's mobile device received the notification. The reception timestamp was recorded via the SeniorConnect app interface. This data was collected over a 7-day period and analyzed using one-way ANOVA to determine variance in latency across days. Ensuring that notifications reach caregivers without failure was fundamental to maintaining trust in the system. If notifications frequently failed to deliver, caregivers may become less reliant on the device, undermining the intended purpose of the system. We tracked the total number of buttons press events and corresponding AWS Lambda function invocations that resulted in successful notifications to the app. These data were visualized and verified using aligned bar charts to demonstrate the delivery success rate across all test events during the five-week period

Demonstrating low notification error rate was also identified as a key success parameter to ensure that the notifications are not only delivered but also accurate. Miscommunication, false alerts, or no notification delivery could potentially lead to neglect of real alerts. Each IoT button press was logged and cross-referenced with the app's received notifications. Any mismatch would indicate an error. During the 5-week testing, error rate was observed to indicate reliable end-to-end message transmission

Overall, notification latency, successful delivery, and error rates were assessed as key system evaluation parameters. These parameters were used to create a robust framework and demonstrate the proposed solution's effectiveness during the five-week testing period. Each of the key evaluation parameters was equally important for assessing the robustness of the end-to-end notification architecture. These parameters also provided a comprehensive measure of the real-time alert system's performance and reliability.

Usability testing was conducted to evaluate the real-world experience of end-users interacting with the IoT button and SeniorConnect app. Study participants were provided with a Sercomm LTE-enabled button worn as a lanyard around the neck with a SeniorConnect app downloaded on their caregiver mobile phones. During the testing phase, the button consistently and accurately sent alerts, confirming its suitability as a wearable device. The usability and acceptability of the solution were also assessed from the perspectives of elderly users and their caregivers. Key evaluation metrics included device size, battery life, ease of use of the mobile application interface, and the simplicity of the setup process. The prototype was distributed to 10 elderly beta testers, while the SeniorConnect app was installed on their caregivers' phones. Over several weeks, participants used the solution in real-world scenarios. We did not collect participants' exact ages; however, we estimate that all elder users were at least 65 years old. All study participants including elders, and their caregivers resided in the United States.

The cost-effectiveness of the prototype was calculated in terms of the IoT button cost, AWS services deployed, and app hosting cost per user. Both upfront and ongoing operational costs were considered. AWS service usage cost was estimated using AWS cost calculator (14,15).

Statistical Analysis

To evaluate the effectiveness and reliability of the SeniorConnect alert system, a statistical analysis was conducted on the notification latency data collected over a 7-day testing period. The goal was to determine whether there were significant differences in latency across different days**.**

A one-way Analysis of Variance (ANOVA) test was performed to assess the statistical significance of the variations in mean latency across days. One-way ANOVA was identified as the most statistically appropriate and efficient method for this study, as it effectively compares mean latency across days while assuming homogeneity of variance. Following the ANOVA test, a Tukey's Honestly Significant Difference (HSD) post-hoc analysis was conducted to identify which specific days had significant differences in latency values. Tukey's HSD was selected because it controls for Type I errors when making multiple comparisons, ensuring that statistically significant differences were not due to random chance. Additionally, the notification delivery success rate and error rate were analyzed by comparing the number of IoT button clicks with the number of successfully delivered notifications.

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