

Inclusive Emergency Alerts: A Cloud-Based Haptic and Visual Notification System for the Deaf and Hard of Hearing

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ABSTRACT

Broadcasting emergency notifications during disasters is crucial, particularly in Monroe County, NY, which is home to one of the largest per capita Deaf and Hard of Hearing (DHH) populations in the United States. However, text alerts may not effectively reach DHH individuals who are in a state of reduced responsiveness, like sleep, placing them at great risk. This paper presents cloud-based platform designed to deliver emergency alerts with visual and haptic feedback. A prototype utilizing an off-the-shelf IoT device demonstrates how alerts can be received via vibration and light-based feedback. The platform aims to be accessible to DHH community, providing its own solutions to maintain haptic devices and receive critical alerts in real time. This work contributes to the literature on IT solutions for bridging the communication gap between text-based alerts and intuitive visual/haptic communication, enhancing emergency response readiness for the DHH community, ultimately improving safety and potentially saving lives.

Keywords

Deaf and Hard of Hearing (DHH), Emergency Management, IoT.

INTRODUCTION

During emergencies such as wildfires, hurricanes, blizzards, and public safety threats, timely and effective communication can mean the difference between life and death. However, traditional emergency alert systems, which primarily rely on auditory signals, sirens, and text-based notifications, often fail to adequately serve the Deaf and Hard of Hearing (DHH) community. This communication gap leaves millions of individuals at greater risk during disasters, as they may not receive critical alerts in time to take necessary precautions. A system that excludes even a small portion of the population from receiving life-saving information is fundamentally flawed (Engelman et al., 2013; Cripps et al., 2016).

For example, during Hurricane Katrina in 2005, many members of the DHH community were left uninformed due to inaccessible emergency broadcasts (Engelman et al., 2013). More recently, in California's 2018 Camp Fire, DHH individuals faced severe challenges in receiving evacuation notices, resulting in tragic outcomes (Gomes & de Souza, 2022). The urgency of this issue was further highlighted by the Lewiston mass shooting in 2023, where four deaf individuals lost their lives, revealing the unique vulnerabilities of the DHH community during emergencies when communication fails (Karimi, 2023). These events highlight the urgent need for an inclusive, technology-driven emergency notification system that ensures all individuals, regardless of hearing ability, have equal access to real-time alerts (Rysz, 2018).

This paper presents a cloud-based emergency notification system using Amazon Web Services (AWS) designed specifically to bridge this accessibility gap during emergencies. By incorporating haptic feedback, visual alerts, and IoT-enabled devices such as M5 Stack Core2, an off-the-shelf IoT device for multi-sensory notifications, the system ensures that emergency notifications reach individuals in a timely and accessible manner. Built as a web application that allows users to customize alert preferences, including light-based warnings, vibration intensity, and color-coded emergency signals, ensuring a personalized and effective emergency response (Moreno et al., 2024). Through extensive user testing with the DHH community in Rochester, NY, the platform has been designed to prioritize accessibility, ease of use, and rapid dissemination of information.

This research was conducted within the context of a broader study on bridging the gaps with the DHH community

in Monroe County, NY. Specifically, this architecture was developed in collaboration with the Monroe County Office of Emergency Management (OEM). Currently, Monroe County relies on third-party platforms like Hyper-Reach and NY Alert, which primarily send notifications via text messages and phone calls. However, these methods are often not user-friendly for the DHH community due to a lack of multimodal communication. To address these limitations, this research integrates Monroe County's OEM RSS feeds, and National Weather Service (NWS) alerts into an advanced IoT-enabled emergency response system, allowing notifications to be delivered through a combination of visual cues, vibrations, and real-time mobile updates (Chen et al., 2023).

The broader implications of this work extend beyond Monroe County. As climate change continues to increase the frequency and severity of natural disasters, emergency communication strategies must evolve to accommodate all members of society (Rey et al., 2024). This research underscores the importance of an inclusive approach, one that combines technology, policy support, and community engagement to create a safer and more accessible public safety infrastructure. By demonstrating the effectiveness of this next-generation emergency alert system, this study aims to provide a scalable model that can be adopted in cities and emergency management agencies across the country (Pilemalm & Alkusaibati, 2024).

This paper is organized as follows: (a) The Literature Review explores challenges in emergency communication for DHH, along with the implementation and policy considerations; (b) The Gap Analysis examines emergency communication gaps with a focus on Monroe County and its Office of Emergency Management collaboration; (c) The Design and Implementation section discusses a community-driven approach to designing scalable emergency alert solutions, detailing the system architecture and implementation of the architecture; (d) The Ongoing and Future Work section outlines areas for future development; (e) Limitations highlights current constraints; and (f) the Conclusion summarizes the key contributions of this work to ISCRAM-related research and outlines future research directions to enhance communication accessibility.

LITERATURE REVIEW

Challenges in Emergency Communication for DHH

Conventional emergency warning systems are primarily auditory based; hence, they pose a challenge for DHH persons to receive timely notifications of impending disasters. This gap exposes an important safety risk, that has been recognized as a major issue in emergency management. Engelman et.al. (2013) noted scant systematic training of state emergency agencies and community organizations to respond appropriately to the needs of DHH individuals. Lives cannot be saved effectively without specialized training for emergency responders who may struggle to communicate life-saving information to individuals who rely on visual or tactile alerts. Similarly, Cripps et. al. (2016) argue that present emergency preparedness strategies fall short of including sign language accessibility, which hinders the ability of DHH individuals to fully comprehend emergency instructions.

This challenge is not just within the United States but also worldwide, as numerous emergency response systems do not account for multimodal communication. For example, Rysz (2018) emphasizes the shortcomings of emergency notification systems in meeting the needs of socially excluded populations in Poland, with a particular focus on the deaf community. This highlights the unavailability of notification systems and dependence on traditional methods, like sirens and radio broadcasts, both of which are generally ineffective for individuals with hearing loss.

Technology-Driven Solutions: IoT, AI, and Haptic Feedback

From the Internet of Things (IoT) to artificial intelligence (AI), new technologies are constantly being developed that help enhance emergency communication for DHH individuals. Emerging technologies, such as AI-powered image recognition and IoT-enabled alert systems, have shown promise for improving accessibility. Cate (2025) investigates the usage of AI-based image recognition to detect emergencies and receive visual alerts in real time, offering additional protection for DHH. Meanwhile, Moreno et al. (2024) suggest the development of mobile applications with disability-inclusive features as a means of democratizing emergency response to ensure that all users, not just those with hearing availability, can receive critical information during times of crisis.

Haptic feedback, which uses vibration for emergency notifications, is one of the most promising technologies that can help. Malizia et al.. (2010) explain how vibration is valuable for signaling users in mobile devices when they are not looking at their screens. There is also an integration of haptic feedback with smart wearable devices that provide tactile alerts for emergencies. Hey, Yaa (2011) and Busari (2025) also investigated a haptic warning garment that is specifically tailored for communication with DHH users, a further testament to the possibilities that wireless thoracic technologies can enable in enhancing emergency preparedness via wearable technologies.

Smart home integrations and IoT-enabled emergency response systems represent other innovative approaches. Habib et al. (2010) present an IoT-based accident detection system that automatically informs emergency responders and chosen contacts, thereby enhancing response times. Rey et al. (2024) detail the deployment of a

mobile community-based emergency reporting application in the Philippines, exemplifying how technology can facilitate communication during critical times. Together, these solutions bring to light the value of assistive technology in making emergency alerts more accessible and inclusive to the deaf community (Rashid et al., 2024; Malizia et al., 2010).

Implementation and Policy Considerations

Considering the diffusion of available technological innovation, the effectiveness of emergency communication designed for DHH should concurrently be a function of implementation readiness, policy support, and collaborative use by all stakeholders. For example, Chen et al. (2023) discuss the need for cross-boundary sharing of information during emergency management, arguing that an effective alert system must be multichannel to meet the needs of dissimilar populations. Likewise, Pilemalm & Alkusaibati (2024) propose a national-level digital co-production model of emergency response. More specifically, this solution is based on the inclusive design conducted with input from specially trained workers.

More solutions for DHH individuals in the form of commercial solutions are provided by Krown Manufacturing (n.d) or Alertus's progressive emergency system (n.d). However, current implementation success is largely driven by regulatory reception, and without governmental or funding support, these technologies may not be diffused enough to make a real difference. Recently, the Manchester Fire Department in Connecticut, United States, promulgated a multimedia alert system designed for blind and deaf people, contributing to their readiness (Engelman et al., 2013). An example of a more explicit governmental intervention is the state of Kentucky's proposal to deliver weather radios with implanted sign language transponders (Harkins et al., 2010).

However, the future of emergency alerts designed for the DHH community should not rely only on national or governmental solutions. Gracia et al. (2015) give clear insight into how a regular developer can implement emergency broadcasts alongside modern web frameworks. Likewise, the open-haptic vibro-tactile platform proved to be a successful adoption, as documented by Google Research (Chin et al., 2023; Zhao & Zhu, 2023).

Overall, it is possible to suggest that the technological innovations targeting emergency alerts for DHH should be regulated and validated yet must be effectively diffused toward the readiness strategies (Chin et al., 2023; Malizia et al., 2010). This difficulty can help explain why the DHH community continues to view emergency communication as a serious issue because many alert systems depend primarily on sound.

Prior research has documented the persistent need for inclusive approaches, and scholars have noted deficits in planning and strategizing for crises. According to Mamunur Rahman, K. A. A. (2022), emerging technologies, such as AI, IoT, and haptic feedback, provide the best approaches to addressing these challenges. Innovations, such as AI-based image recognition, vibration-based alerts, and smart wearable devices, are advancing emergency communication for DHH individuals.

But the effective adoption of the technologies needs more than just technological advancements. Ensuring accessibility relies on the implementation of policy support, regulatory frameworks, and community engagement. It takes collaboration across boundaries between emergency management agencies, technology developers, and advocacy groups to develop effective and inclusive emergency preparedness strategies. As more governments and organizations understand the importance of accessibility, future research and development should aim to improve these technologies while also breaking down affordability and adoption barriers. Combining technology with inclusive policies will revolutionize emergency communication into a system that guarantees equal access to life-saving information for all individuals, irrespective of hearing ability.

GAP ANALYSIS

Emergency Communication Gaps: The Case of Monroe County

Situated in Upstate New York in the United States and home to the city of Rochester, Monroe County represents an ideal site for investigating emergency notification challenges encountered by DHH individuals. Recent data indicate Monroe County has an estimated DHH population of 40,000 or 3.6% of the total population (Walter & Dirmyer, 2012). Rochester, the largest city in Monroe County, is home to the National Technical Institute for the Deaf (NTID), a part of the Rochester Institute of Technology (RIT), one of the largest DHH institutions in the U.S. (National Technical Institute for the Deaf [NTID], 2023). This makes Monroe County a relevant study area for emergency notification systems designed specifically for DHH.

As discussed previously, the DHH community is reported to encounter barriers to being alerted through emergency response in places where auditory-based warning systems are employed, radio broadcasts, and non-captioned emergency updates (Engelman et al., 2013). In Monroe County, there have been critical failures in communication with DHH residents during past events. For example, during severe weather alerts in 2020, many DHH individuals missed important warnings because sign language translations, visual cues, or accessible alert technology were not provided (Monroe County Emergency Management, 2021). The most telling example of this

was an emergency evacuation order during which the announcement was only made on traditional audio-based media channels; many DHH residents were uninformed and at increased risk (Monroe County Emergency Management, 2021).

Aside from weather emergencies, DHH individuals in Monroe County also face the challenges of other public safety threats, including fire alarms, AMBER alerts, and active shooter notifications. Most alarm systems have no visual flashing alerts or vibrating notifications, so DHH residents cannot respond in real time (Cripps et al., 2016). A 2021 local survey of Monroe County's DHH community showed that over 70% of respondents felt unprepared for emergencies due to the absence of accessible notifications (Monroe County DHH Community Survey, 2021). These findings highlight the urgent need for a more inclusive, adaptive emergency alert system.

Through this study, we analyze emergency communication gaps in Monroe County and evaluate existing challenges faced by the DHH community. By identifying system-level barriers, our research aims to develop scalable solutions that can serve as a model for other regions across the country. Given Monroe County's large DHH population, the presence of NTID, and documented communication failures, this study provides a valuable foundation for testing and implementing new emergency alert strategies. Future research should expand on these findings by conducting broader studies across different regions to refine and enhance accessibility solutions.

Monroe County Office of Emergency Management (OEM).

The Monroe County OEM in Rochester, NY, plays an important role in broadcasting emergency alerts to residents in crucial situations. Currently, OEM relies on third-party software called Hyper Reach to send alerts via text messages and phone calls. Additionally, Monroe County utilizes NY Alert, a statewide emergency notification system that provides warnings of severe weather and hazardous situations through phone, email, or fax (Monroe County Office of Emergency Management, n.d.; New York State, n.d.).

While these systems effectively reach the general population, they present significant accessibility challenges for DHH communities. The interfaces of these platforms are not user-friendly, often displaying excessive information on a single page, making navigation difficult. The text-based alerts alone do not fulfill the needs of people who rely on alternative communication methods (Engelman et al., 2013; Cripps et al., 2016).

Recognizing these limitations, we collaborated with OEM to enhance the accessibility of emergency alerts. As shown in Figure 1, our meeting with OEM representatives facilitated discussion on integrating the Monroe County OEM RSS feed into the proposed architecture.



Figure 1: Meeting with OEM Representatives

With the department's permission, we integrated the OEM RSS feed for Monroe County. This integration allows for improved emergency notification via IoT devices in the home network along with text messages and emails, ensuring that alerts are more accessible to residents, including those with disabilities. Given Rochester's large DHH community, this initiative serves as an ideal opportunity to test the user experience with the proposed alerting system, including effectiveness and accessibility (Chen et al., 2023).

Additionally, incorporating National Weather Service (NWS) alerts is necessary as Rochester frequently experiences extreme winter weather conditions. This allows developers to assess how effectively the system can broadcast weather-related warnings and ensure a timely response in hazardous conditions. By refining the architecture and approach through community feedback, the aim is to create a more inclusive emergency alert system that can be adopted for broad implementation (Moreno et al., 2024).

DESIGN AND IMPLEMENTATION

Community-Driven Design and Scalable Emergency Alert Solutions

To ensure that the emergency alert system works for the DHH community here in Rochester, we engaged in a participatory design process with DHH individuals, which included refugees and people with varying accessibility needs. As shown in Figure 2, the valuable feedback from these sessions helped identify critical issues in the ability of vulnerable populations to receive emergency notifications and enabled the design of the system to follow suit.



Figure 2: Meeting with Deaf Refugee Advocacy to gather feedback on the Current Emergency Notification System

The participants noted important points, including the text-heavy nature of current 911 alerts, the need for stronger vibration feedback, and the absence of visual cues in existing notification platforms. Finally, users noted usability issues with their devices and suggested better instructions for Wi-Fi connectivity, larger devices, and waterproofing the devices for durability. A crucial request was that there should be a notification of environmental hazards (gas leaks, CO detection, fire), ensuring safety for DHH in such a hazardous situation.

Incorporating community-driven design, cloud-based scalability, and IoT-enhanced notifications, this system will strengthen emergency communication strategies to ensure that life-saving alerts are communicated to the populace, regardless of hearing ability.

System Architecture and Implementation of the Emergency Alert Platform

The proposed architecture integrates Monroe County OEM alerts and National Weather Service (NWS) notifications into a Progressive Web Application (PWA) that prioritizes accessibility. The system also supports IoT-enabled devices such as bed shakers, smart lights, and alarms, allowing users to receive alerts through visual, tactile, and customizable notifications. This approach ensures that DHH individuals are not left behind in life-threatening situations, bridging the gap between emergency management systems and inclusive communication (Moreno et al., 2024; Cate, 2025).

Figure 3 is an architecture diagram that illustrates the flow of the proposed system, highlighting how alerts are processed and distributed across various platforms and IoT devices like M5 Stack Core 2, Smart bulbs, and other peripherals. While the current prototype is focused on testing with M5Stack Core2, the architecture is designed to be extensible. This provides a pathway for future integration with broader smart home platforms such as Home Assistants and HomeKit.

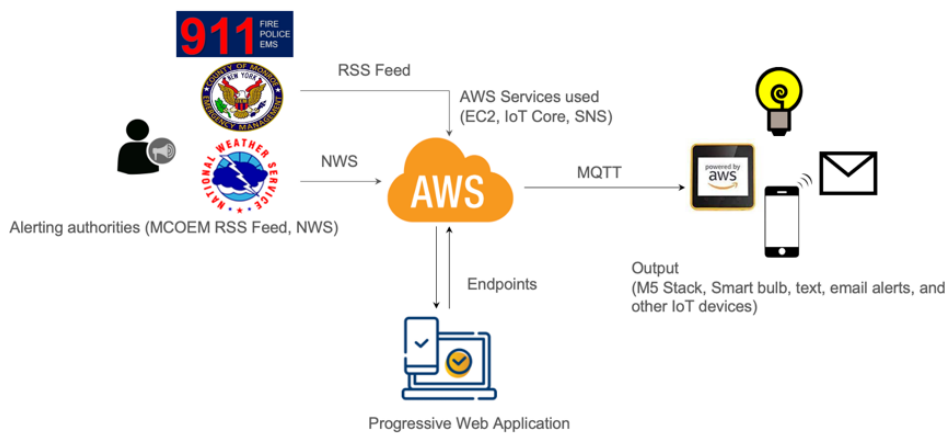


Figure 3: Architectural Diagram of Prototype Flow

Cloud Service

As seen in Figure 3, the system architecture leverages the Amazon Web Services (AWS) cloud to manage and distribute emergency alerts efficiently. Figure 4 provides a detailed breakdown of how AWS services facilitate alert broadcasting. The dispatcher hosted on EC2 is a central hub that is responsible for handling and relaying alerts hosted on AWS Elastic Compute Cloud (EC2) instance for scalable processing, retrieves incoming alerts from sources such as NWS and RSS feed 911 incident reports, and broadcasts them to the subscribed IoT device. For SMS notifications, AWS Simple Notification Service (SNS) is used to manage and send messages to subscribed users. Additionally, AWS IoT Core enables the M5Stack IoT device to subscribe to and process alerts, allowing real-time message delivery via MQTT protocols, which is a lightweight messaging protocol that is used to connect IoT devices (Chen et al., 2023).

To ensure data security and alert reliability, AWS services such as AWS Identity and Access Management (IAM) for secure access control, MQTT encryption for secure communication, and AWS CloudWatch for system monitoring are utilized. The M5Stack device automatically reconnects to Wi-Fi and AWS IoT Core upon disconnection, ensuring uninterrupted alert delivery. This cloud-based architecture enables seamless real-time dissemination of critical alerts while optimizing performance, security, and reliability. The database used to store all the user, IoT device, and notification information is MongoDB, hosted on the MongoDB Cloud server. The diagram below illustrates the architecture's functionality, highlighting its ability to ensure real-time alert dissemination while maintaining performance, security, and reliability. (Habib et al., 2020).

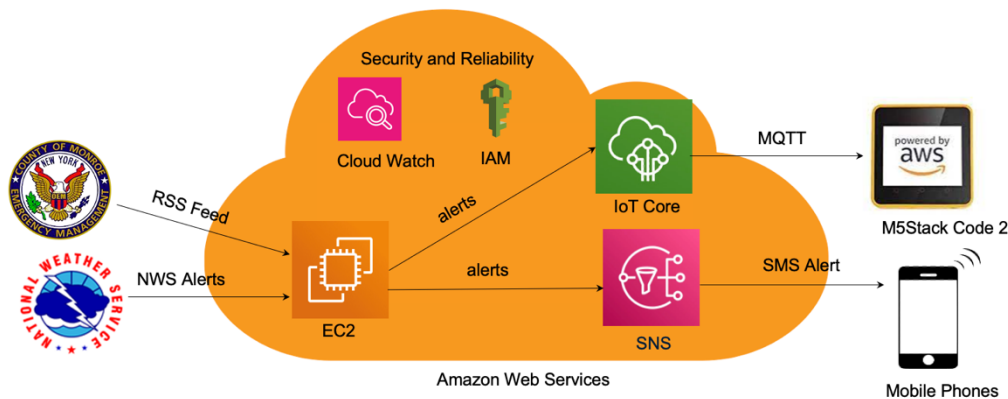


Figure 4: Architectural Diagram of Amazon Services Used for Sending Alerts to Devices

IoT Device: M5Stack Core2 for Emergency Alerts

The M5Stack Core2 off-the-shelf IoT device has been chosen as the primary IoT device for prototyping the architecture due to its ESP32-based microcontroller, built-in display, haptic feedback, and Wi-Fi connectivity. These features make it well-suited for emergency alert applications, particularly for users who require multi-sensory notifications. The device's compact design allows customization for different types of alerts. M5Stack Core 2 supports seamless communication via Wi-Fi and Bluetooth, while its touchscreen display provides an intuitive interface for user interaction. As illustrated in Figure 5, the M5 Stack Core 2 is equipped with built-in RGB LED indicators and a vibration motor, ensuring that alerts are delivered through multiple sensory channels. Out of multiple devices tested for this, M5Stack Core 2 was selected based on its flexibility, cost-effectiveness, and sustainability for rapid prototyping. Its support for MicroPython and MQTT protocols, which allows real-time alert delivery through the Amazon Web Services (AWS) IoT Core service, ensures reliable cloud integration (Malizia et al., 2010; Busari M, 2025).



Figure 5: M5Stack Core2 Haptics and Display Screen

M5Stack Core 2 is designed with flexible use in mind. Its compact form allows users to carry it in their pocket or a small bag and still feel the haptics of the device. It also includes four built-in magnets on the back that enable it to be securely attached to the inner surface of the home, such as the refrigerator. It can be kept under the pillow while sleeping to receive haptic alerts. M5 Stack Core 2 listens for alerts from AWS IoT Core and responds based on the user's preferences. When an alert is received, the device categorizes it based on its type, such as a severe weather warning or 911 emergency. Depending on predefined user settings, the device delivers notifications through a combination of visual, haptic, and auditory cues, as illustrated in Figure 6. The touch screen displays visual alerts using verified NWS icons and large text for improved readability. Additionally, the built-in RGB LED flashes in a predefined color pattern, such as red for severe. At the same time, the vibration motor triggers customized vibration patterns ranging from low to high intensity. If sound alerts are enabled, the device emits a beep to reinforce notification delivery. Users can acknowledge received alerts using a red “OK” button on the touch screen.



Figure 6: M5Stack Core2 's response when there is an RSS feed 911 incident

Additionally, the device features a QR code that provides quick access to detailed emergency information through a web application (PWA) and another QR code to facilitate IoT device connectivity with a home Wi-Fi network. In case of network disruption, such as temporary Wi-Fi disconnection, the device is designed to handle connectivity issues by automatically reconnecting to Wi-Fi. To optimize power consumption, the device enters sleep mode after five seconds of inactivity and wakes up when a new alert is received. As illustrated in Figure (a), the first QR code redirects users to the Wi-Fi settings while Figure (b) demonstrates the second QR code, which enables the seamless M5 Stack device to connect to the PWA in just one step.



(a) QR to redirect users to Wi-Fi

(b) QR to directly scan and connect M5 Stack device to PWA

Figure 7: M5Stack Core2 Wi-Fi Setup and Device Linking to PWA Screens

Progressive Web Application

A Progressive Web App (PWA) is built to be responsive in browsers on phones, tablets, and desktops. The design of the platform is intuitive and prepared with accessibility in mind. It features two theme modes for high visibility and includes screen reader compatibility to support deafblind users. The platform serves as a central hub for emergency preparedness, consolidating verified emergency resources and allowing users to access essential information reliably and quickly. Figure 8 demonstrates the cross-device compatibility of the PWA, showcasing its responsive interface on mobile phones, tablets, and desktop screens.



Figure 8: Progressive Web App appearance on different platforms

The PWA also proved a comprehensive IoT device management system, enabling users to add, update, and customize their IoT devices. Users can personalize light colors, vibration intensity, and sound to distinguish different types of alerts. Figure 9 demonstrates the customization page on the PWA, displaying how the customization can be achieved using different colors, vibration patterns, and sound settings. There are currently six color options available, enabling users to distinguish between different alerts effectively. Additionally, a Test button allows users to preview how the selected colors and vibrations feel, assisting them in making informed customization choices (Malizia et al., 2010; Busari M, 2025). The platform supports multichannel alerting, delivering notifications via IoT devices, SMS, push notifications by web app on the phone, and emails based on user preferences. The dashboard has a dedicated place for users to review all alerts and mute notifications for

specific durations (Moreno et al., 2024; Cate, 2025). Additionally, the platform incorporates an OTP secure login to ensure secure access and user data protection.

In case of network disruption, if alerts fail to reach the M5Stack Core2 device due to temporary connectivity issues, all the alerts get backed up and stored on PWA as history. Users can log in to the web app at any time and access the complete alert history, ensuring no critical information is missed during offline periods.

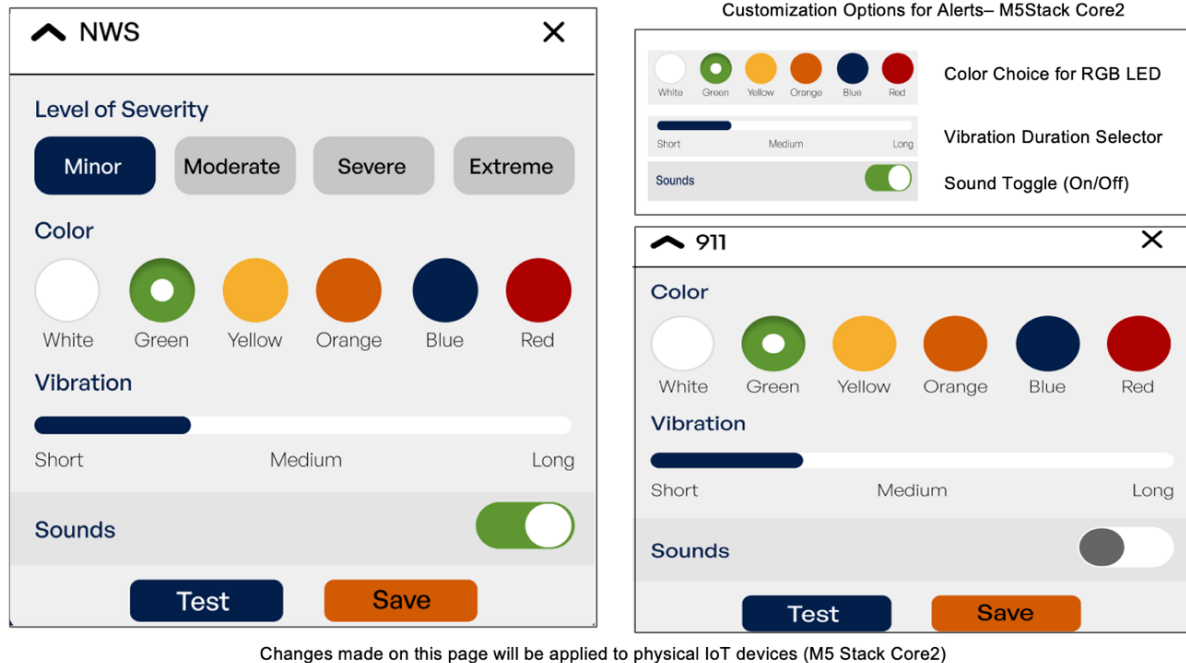


Figure 9: Progressive Web App IoT device haptic customization for NWS and RSS Feed 911

ONGOING AND FUTURE WORK

The ongoing work focuses on enhancing the customization of alerts based on user location to prevent users from getting unnecessary notifications for emergencies outside their relevant location radius. By implementing geofencing techniques, the dispatcher will filter alerts to ensure that the user receives alerts only in their immediate surroundings, reducing notification fatigue. The user can manually adjust the radius to the range in which they want to receive alerts. Additionally, a silent mode is being developed, allowing users to mute notifications for a set duration and configure the device to notify them of high-priority alerts, ensuring critical emergencies are not missed while minimizing disturbance. Another key development area involves accessibility testing with the DHH community. Gathering user feedback will help refine the system's interface and notification method, ensuring the platform is inclusive and effectively meets the needs of diverse users (Engelman et al., 2013; Cripps et al., 2016).

Regarding implementing the IoT device M5Stack, feedback is being collected from the community to assess the acceptance of M5Stack Core2 as a minimum viable product (MVP). The goal is to determine whether it can be a cost-effective alternative for individuals who may not have access to resources like IoT devices but still need reliable emergency alerts. The device's affordability and modular nature make it a promising candidate for widespread adoption, and ongoing evaluation will help refine its features to enhance usability and effectiveness in real life.

Future work will focus on integrating the Integrated Public Alert and Warning System (IPAWS) and state-level emergency services. Since the prototype currently only sends alerts for Monroe County, NY, adding these sources will improve the alert system's dependability and comprehensiveness while guaranteeing that users receive official emergency notifications at the federal and state levels. In addition, the work will extend the coverage by dynamically determining a user's location rather than limiting notifications to a predetermined geographic area. This will allow the architecture to work more flexibly, ensuring that users receive relevant alerts regardless of location, making the solution more scalable and effective in communities' varied accessibility needs.

Moreover, we plan to extend alert integration within home networks and smartwatches to simplify the integration of this new emergency notification architecture for DHH individuals who already have smart homes. This will enable reliable alerts even without internet connectivity by utilizing 4G/5G networks, ensuring that users continue to receive critical notifications even in the absence of Wi-Fi. This extended integration will further ensure that the

proposed architecture significantly impacts the lives of DHH people, enhancing their ability to respond to emergencies effectively

LIMITATIONS

The prototype has several limitations that need to be addressed in future iterations. One primary constraint is that the system is currently designed to deliver emergency alerts only for Monroe County, relying primarily on RSS feeds and NWS alerts. This limited geographical scope restricts its applicability for users outside the county and does not yet incorporate a broader emergency alerting system, which could enhance its reach and efficiency.

Another limitation lies in the preliminary feedback implementation, which is currently focused on testing vibration and light-based notifications on small-scale devices like the M5Stack Core 2. While effective for immediate alerts, device battery performance presents a challenge. When an alert triggers vibration and sound, the power consumption increases significantly, causing the device to drain faster than the expected battery life. This limits its ability to function as a long-term, standalone emergency alert device without frequent recharging.

Additionally, the prototype has been tested with limited devices, meaning its performance and scalability across different environments and user conditions remain unverified. More exhaustive testing will be necessary to ensure reliability and robustness, especially in diverse geographical locations and with varying network conditions. Future improvements must address these limitations by expanding alert coverage, optimizing battery efficiency, and conducting large-scale testing to refine the system's performance.

A further limitation of the study is the absence of a comparison with commercially available smartwatches and wearables. Devices like Apple Watches or similar alternatives could serve the same purpose, offering constant proximity to users and built-in connectivity options like 4G for fallback communication when Wi-Fi is unavailable. Although such devices are costlier, they are already embedded in many users' lifestyles and may eliminate the need to carry additional devices. However, these smartwatches operate within a closed ecosystem and offer limited programmability for iterative development and multimodal customization.

CONCLUSION

Ensuring timely and accessible emergency alerts for the DHH community enhances public safety and emergency preparedness. This paper introduced a cloud-based multisensory emergency alerting system that leverages IoT devices, PWA applications, and AWS cloud services to provide real-time notifications through visual haptics and auditory cues. By integrating Monroe County's OEM alerts and National Weather Service (NWS) warnings, the system enhances the accessibility of emergency communications for individuals who rely on alternative notification methods (Gomes & de Souza, 2022; Engelman et al., 2013).

The proposed solution addresses the limitations of traditional text-based alert systems that lack haptic solutions, by incorporating IoT devices such as M5 Stack Core 2, which ensures that emergency notifications are effectively communicated to users through customizable vibration, LED indicators, and touchscreen interactions. The cloud infrastructure powered by AWS ensures reliable and scalable alert distribution, ensuring that critical messages reach users without delay.

The system was refined through collaboration with the DHH community in Rochester, NY to align with their needs, emphasizing usability, personalization, and real-time responsiveness. By bridging the gap between emergency management services and inclusive technology, this platform can potentially improve safety outcomes and serve as a model for broader adoption in emergency response. Future work will focus on adding IPAWS and state-level alerts along with refining the architecture, incorporating additional IoT devices, and expanding the platforms to other regions to enhance emergency response efforts for all individuals, regardless of their communication preferences.

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