Locating Imminent Threats

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Abstract

This paper employed a qualitative triangulation method to evaluate the techniques and technologies used for detecting imminent threats. It examined both location-tracking approaches and the usage of emergency notification and broadcast systems. Through extensive research, it identified the various geolocating technologies, such as GPS, IP Geolocation, Bluetooth, RF, Acoustic Ranging, Smartphone sensors, Wi-Fi Localization, and Cell Tower Triangulation. The solutions discussed in the related works utilized one or several of these technologies to complement each other and enhance accuracy in locating the device/user. Additionally, several associated weaknesses with the proposed solutions are also identified. These include computational complexity, inherent weaknesses of the technology, exclusivity to indoor or outdoor environments, training overhead, and scalability. Moreover, the most effective tactics for ensuring maximum compliance and implementing impactful enhancements to Mass Emergency Notification Systems (MNS) and Wireless Emergency Alerts (WEA) are identified, which involve providing information from trusted sources, using high-information maps, delivering highly specific warning messages, and offering positive feedback alerts.

Keywords: Emergency Alert, Location, Geolocation, Mass Emergency Notification, GPS, RF, Wifi Localization, Triangulation

Locating Imminent Threats

A community thrives on safety and security. A secure environment protects human life and well-being, promotes economic development, fosters social cohesion, preserves public infrastructure and assets, and upholds the rule of law. This responsibility is shared by various security agencies tasked with protecting the community, including but not limited to public safety departments, local law enforcement, emergency management departments, and corporate security offices. These organizations share a common goal: responding to emergencies and maintaining order. To achieve this goal, these organizations must be able to identify threats and respond accordingly quickly and efficiently. This requires the acquisition of threat locations before they have the chance to cause damage. As mentioned by G. Allen & R. Derr (2015), identifying threat locations helps security professionals better understand the nature and extent of the threat and develop more effective mitigation strategies.

This research paper investigated the various techniques for detecting imminent threats and focused on their advantages and drawbacks. This work aimed to identify methods for recognizing individuals, devices, and non-source objects, along with the primary technologies employed by these approaches. Moreover, the paper delved into Wireless Emergency Systems (WES) and Mass Emergency Notification Systems (MNS). It analyzed the most effective techniques used by these systems to maximize compliance among recipients and explored the most impactful enhancements for improving pre-existing systems. The potential weaknesses and limitations of these systems were also examined.

Literature Review

Location Tracking Approaches

The field of location tracking is growing rapidly, with researchers developing innovative techniques for accurate positioning. Numerous studies have explored various methods, including radio-frequency wireless network technology, indoor positioning, and GPS sharing via SMS. These advancements in location tracking have enabled highly accurate positioning for users, devices, and objects. As a result, location-aware applications and services continue to benefit from the ongoing research and development in this area.

Bahl et al. (1999) proposed RADAR, a system using radio-frequency wireless network technology for real-time user positioning. RADAR obtained signal strength information from multiple base stations and employed signal propagation modeling techniques to accurately estimate a user’s position. This innovative approach leveraged wireless network technology to create a precise location-tracking solution. Consequently, RADAR has contributed to the increasing popularity of location-aware applications and services.

Yin et al. (2005) developed an approach that adjusts temporal radio maps for indoor positioning estimation. Their method offsets environmental effects using data mining techniques and reference points, creating adaptive temporal radio maps. This approach could pinpoint a device’s position accurately with fewer reference points, eliminating the need to rebuild static radio maps constantly. Therefore, Yin et al.’s method provided an effective solution for location tracking in dynamic indoor environments.

Muir et al. (2009) evaluated various IP geolocation methods to physically locate internet-connected devices and users. They considered information from databases, domain and DNS records, network routing and timing, and explored defenses like the Tor network. This evaluation of IP geolocation techniques contributed to understanding how to locate internet-connected devices and users accurately. As a result, their research supports the development of more effective geolocation technologies and strategies.

Chandra et al. (2011) introduced a technique for sharing GPS coordinates via SMS. Their application allowed users to view their location on Google Maps, obtain coordinates, and share their location with multiple individuals through a web server. This solution leveraged mobile devices' GPS receptors and GSM/CDMA network to enhance location-sharing capabilities. Consequently, Chandra et al.'s technique provided a practical way to share and access user location information.

Nandakumar et al. (2012) presented the Centaur system, which combines RF and AR-based localization in a single framework. Their system used Bayesian inference, was independent of radio frequency and acoustic ranging measurements, and could locate devices in an office environment. The Centaur system demonstrated the potential of merging multiple localization approaches to improve location tracking performance. As a result, their research contributed to the development of more versatile and accurate localization systems.

Wang et al. (2013) proposed the Received Signal Strength (RSS)-based Bluetooth positioning using distance-based algorithms. They employed the Least Square Estimate, Three-border, and Centroid methods to identify a device's position using Bluetooth technology. Wang et al.'s research shows that RSS-based triangulation positioning yields the best results among the considered methods. Consequently, their findings contribute to the improvement of indoor wireless positioning techniques.

Roy et al. (2014) introduced WalkCompass, a system that uses smartphone sensors to estimate a user's walking direction. They isolated the accelerometer sensors from false positive events to accurately estimate the local walking direction, then converted them to the global one. WalkCompass significantly enhanced an individual's location detection capabilities using smartphone sensors effectively. As a result, Roy et al.'s system provided a practical solution for more accurate user positioning in real time.

Kumar et al. (2014) proposed Ubicarse, an indoor localization system that does not require specialized infrastructure or location fingerprinting. Ubicarse used a new formation of

Synthetic Aperture Radar, allowing handheld devices to localize RF devices and objects without an RF source. Their solution achieved an accuracy of tens of centimeters on commodity mobile devices, demonstrating its potential for practical applications. Consequently, Ubicarse presented a valuable alternative for indoor localization, enabling more accurate tracking without requiring specialized equipment.

Liu et al. (2014) developed a peer-assisted localization method that runs concurrently with Wi-Fi localization. Their method mapped the locations jointly against a Wi-Fi signature map using acoustic ranging estimates among peer phones, narrowing down a device's location to 1-2 meters. Liu et al.'s approach demonstrated how combining Wi-Fi and peer-assisted localization could significantly improve location accuracy. As a result, their research contributes to advancing location-tracking technologies, pushing the limits of Wi-Fi localization accuracy.

Trogh et al. (2019) introduced the AMT algorithm for accurately locating mobile users in a cellular network. AMT exploited open map data, a mode of transport estimator, and advanced route filtering in conjunction with mobile cellular topology and measurements. This positioning algorithm could track the movement and location of mobile devices without requiring client-side interactions or server-side modifications. Consequently, Trogh et al.'s research provide a valuable solution for effectively tracking mobile users in a cellular network.

Emergency Notification and Broadcasts Systems

Ensuring appropriate policies and effectively utilizing Mass Emergency Notification Systems (MNS) and Wireless Emergency Alerts (WEA) is crucial. Multiple research papers have investigated strategies to maximize the impact of MNS and WEA. By understanding the best practices and potential improvements, emergency communication systems can be optimized for maximum effectiveness. This highlights the importance of ongoing research to enhance the capabilities of MNS and WEA in various emergencies.

Gulum et al. (2009) evaluated the value of MNS in distributing crucial information during emergencies on college campuses. They identified issues affecting system performance and presented findings from two system tests conducted by Missouri S&T. Their research emphasized the importance of raising student awareness and trust in mass emergency warning systems. Consequently, their findings enhance emergency management on college campuses through effective MNS implementation.

Gonzales et al. (2013) assessed the need for timely and efficient emergency alerts and explored the limitations of traditional methods. They discussed the development of the WEA system, the DHS WEA Mobile Penetration Strategy, and the barriers to WEA adoption. Their research highlighted the challenges in implementing effective emergency alerts and offered recommendations to overcome these barriers. As a result, their work contributed to improving emergency alert systems and their adoption by the public.

Han et al. (2015) investigated the architecture of emergency notification systems on college campuses and their effectiveness. They developed a scenario-based survey model, testing it in various events, and found subjective norms and “information quality trust” significant factors. Their research emphasized the importance of student adherence to the success of emergency notification systems. Consequently, Han et al.’s findings provided valuable insights for enhancing the effectiveness of campus emergency notification systems.

Kumar et al. (2016) proposed enhancements to the WEA service to improve geographically targeted emergency alerts. They developed a testbed and experimental framework called WEA+, which included augmenting WEA messages with maps, precise targeting, and utilizing location history. Their evaluation suggested that these enhancements add significant value to the WEA service. Thus, their research contributed to the ongoing efforts to optimize emergency alert systems.

Kumar et al. (2018) examined the WEA service from the perspective of alert creators and explored potential extensions. Their research emphasized the importance of enhancing WEA messages to increase their effectiveness. They identified precise geo-targeting, augmented with location information and maps, as important factors for improving user context and alert actionability. As a result, their findings contributed to developing more effective and targeted emergency alerts.

Cain et al. (2020) evaluated the impact of maps supplementing written texts in mobile emergency alerts on students' perceptions. They found significant differences in risk susceptibility perceptions based on the type of map used, with personalized maps being the most effective. Their research highlighted the importance of pairing maps with specific warning messages for improved risk perception. Consequently, Cain et al.'s findings provided valuable insights for optimizing mobile emergency alerts.

Lambropoulos et al. (2021) explored enhancements to the phrasing and wording of WEA messages to ensure smartphone users' compliance. Their research emphasized the importance of message enhancements in improving user compliance with emergency alerts. They found that positive feedback alerts had the highest compliance rate among participants. As a result, their findings contributed to the development of more effective WEA messages.

Bonaretti & Fischer-Preßler (2021) tested the effectiveness of SMS warnings in enabling users' compliance. Their research found that SMS warnings failed to provide adequate spatial awareness, leading to poor compliance. Their findings suggested that SMS warnings must include design elements that allow recipients to gain spatial awareness. Consequently, their research provides valuable insights for improving the effectiveness of SMS-based emergency warnings.

Fischer-Preßler et al. (2022) investigated the factors affecting the adoption and continued use of mobile warning systems (MWS). They used a protection-motivation theory (PMT) framework and identified key factors impacting MWS adoption. Their study emphasized the importance of understanding these factors to create strategies that promote MWS adoption and use. As a result, Fischer-Preßler et al.'s research provided a valuable foundation for policymakers, MWS developers, and service providers to improve the adoption and continued use of mobile warning systems.

Method

To better understand ways of locating imminent threats, this research was conducted using a qualitative data-collection methodology called triangulation (Carter et al., 2014). Triangulation involves using several sources to enhance the credibility and validity of the research findings. In this study, two criteria were considered to identify and locate potential threats:

- Methods for identifying, locating, and positioning users and devices.
- Emergency policies and procedures.

By applying these criteria, the strengths and weaknesses of each technique were accurately identified and collectively provided a comprehensive understanding of the phenomenon.

This paper covered the H4D – DS3 problem statement as presented in CSEC659 and additional problem statements that involve scenarios where obtaining location information is necessary. The most effective and appropriate techniques for locating threats in various scenarios were determined by examining these techniques. Their weaknesses and drawbacks were also identified, inspiring future work within this domain.

Findings

In the findings section, the results of the investigation into location tracking approaches, emergency notification, and broadcast systems are discussed. Many research papers proposed solutions incorporating multiple techniques, either by supplementing one technique with another or directly integrating them within their systems: The following list presents some current geolocation techniques utilized in the field.

- **Global Positioning System (GPS):** This technique utilizes a network of satellites that can transmit signals, enabling GPS receivers to calculate their location accurately.
- **IP Geolocation:** This method estimates the geographic location of a device based on its IP address and other web-based references.
- **Bluetooth:** This approach measured the signal strength of Bluetooth connections between devices to estimate their location.
- **Radio Frequency (RF):** This technique calculates the location of devices based on the time taken for radio signals to travel between them or by measuring signal strength.
- **Acoustic Ranging (AR):** This method determines a device's location by employing sound waves to measure the distance between two points.
- **Smartphone Sensors:** This approach leveraged built-in smartphone sensors to estimate a user's location based on movement patterns.
- **Wi-Fi Localization:** This technique estimates a device's location using signal strength or the arrival time from access points.
- **Cellular Tower Triangulation:** This method calculates a device's location by measuring the angles or time differences of signals received from multiple cell towers.

While these technologies have significantly improved over the past several years and continue to evolve, they still possess some critical weaknesses that researchers must address to enhance their capabilities further. Some of the identified weaknesses include:

- **Dependency on Source:** Numerous systems (Bahl et al., 1999; Yin et al., 2005; Wang et al., 2013) relied heavily on the availability of signal strength, while WalkCompass (Roy et al., 2014) required users to carry their smartphones in a specific manner consistently. Solutions like AMT (Liu et al., 2014) depended on existing Wi-Fi infrastructure and the availability and cooperation of multiple smartphones. Outdoor tracking solutions (Trogh et al., 2019) rely on existing cellular infrastructure for normal operation.
- **Computational Complexity:** Solutions proposed by Yin et al. (2005) and Nandakumar et al. (2012) were computationally complex and needed to be more viable on legacy or low-performance devices.
- **Inherent Weaknesses:** Solutions using specific technologies are limited by their inherent weaknesses. For example, those proposed by Chandra et al. (2011) and Trogh et al. (2019) utilized GPS signals, which are inherently weak around tall buildings and natural obstructions. Other solutions, like those proposed by Wang et al. (2013) and Kumar et al. (2014), relied on frequencies whose signals can easily be interfered with by other devices.
- **Indoor and Outdoor Exclusivity:** Many solutions had the drawback of being exclusive to indoor or outdoor environments. These technologies were developed focusing on one of these locations and proved ineffective when transitioning from one environment to another.
- **Training Overhead:** Another significant weakness was the extensive training and setup required. This could involve tasks ranging from building a radio map of the environment (Bahl et al., 1999) to a calibration process to establish a baseline (Nandakumar et al.,

2012). This process could be time-consuming and must be repeated if substantial changes in the environment or devices are tracked.

- **Scalability:** Finally, the proposed methods may encounter difficulties when scaling to larger environments. As the number of participating devices increased, the complexity of the system and the computational resources required for maintaining and updating the system could become challenging.

In emergency notification and broadcast systems, ensuring recipient compliance is essential for maintaining safety and facilitating rapid emergency response. Based on the research papers reviewed, the following key factors influence individual compliance with MNS and WEA:

- **Trusted Information:** Several papers emphasized the importance of having emergency broadcasts originate from reliable and trustworthy sources (Han et al., 2015; Fischer-Preßler et al., 2022).
- **Multimedia:** High-information maps yielded greater compliance and faster responses than other multimedia formats (Kumar et al., 2016; Kumar et al., 2018; Cain et al., 2020).
- **Specificity:** Providing highly specific warning messages that offered adequate spatial awareness and conveyed the perceived severity and vulnerability to the recipient resulted in increased compliance (Kumar et al., 2018; Cain et al., 2020; Bonaretti & Fischer-Preßler, 2021; Fischer-Preßler et al., 2022).
- **Positive Feedback:** Delivering information that informs the recipients that they are helping others by acting as a positive stimulus tends to achieve the highest compliance (Lambropoulos et al., 2021).

Throughout the H4D CSEC659 course, the beneficiary discovery reinforced the findings mentioned above. Additionally, several notable insights were also made.

Redundancy is key when considering threat identification, solutions that depend on triggering a mechanism need redundancy built into them, such as cameras covering the monitored locations. (Frederick J. Rion, Personal Communication, February 22, 2023; Professor Justin Pelletier, Personal Communication, February 15, 2023; Jeffrey Issler, Personal Communication, April 21, 2023)

Additionally, it is necessary to remember that adding devices and providing services leads to additional cost expenditures, maintenance, and change in policies and procedures. (Christopher Tarmann, Personal Communication, March 03, 2023)

A location identification device should be as simple as possible; the more complicated it gets, the riskier and the more points of failure that solution will have. The solution should include having to transmit as little data as possible. (Brian Tomaszewski, Personal Communications, March 07, 2023; Daniel Krebs, Phone Communication, March 24, 2023)

Conclusion

This paper utilized a qualitative triangulation methodology to investigate and evaluate techniques and technologies for detecting imminent threats. The most commonly employed geolocation technologies included GPS, IP Geolocation, Bluetooth, RF, Acoustic Ranging, Smartphone sensors, Wi-Fi Localization, and Triangulation. Additionally, the paper identified some significant weaknesses of these technologies and the solutions that utilize them, such as dependency on the source, computational complexity, inherent weaknesses of the technology, indoor or outdoor environment exclusivity, training overhead, and scalability. Finally, the paper examined emergency broadcast and messaging systems, reviewing research on the most effective tactics for these systems. These tactics encompass providing information from trusted sources, using high-information maps, delivering highly specific warning messages, and offering positive feedback alerts.

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