A Survey on Incident Reporting and Management Systems

Amna Qureshi, David Megías and Helena Rifà-Pous
Internet Interdisciplinary Institute (IN3),
Universitat Oberta de Catalunya (UOC),
CYBERCAT - Center for Cybersecurity Research of Catalonia
E-mail: {aqureshi,dmegias,hrifa}@uoc.edu

***Abstract*—Incident reporting and management systems are used to gather and process information about day-to-day occurring incidents such as road accidents, domestic violence, burglaries, harassment, etc. Nowadays, citizens can report such incidents through different means such as calling national emergency lines via telephones or mobile phones, or sending reports via Internet through web-browsers, or smartphones-based applications. A quick and appropriate response to the incidents can reduce both societal costs and fatality rates. Many smartphone-based applications and web-platforms exist that allow a person to send an image, a video, or map-based incident related reports to alert the concerned authority. A few reporting platforms and systems are also available to report the incidents anonymously to the relevant authorities to protect the eyewitnesses or victims. Our main contribution is the literature review of the incident reporting and management systems (based on smartphones and web-based) in terms of functionality, implementation details, technology, performance, security, and anonymity.**

***Keywords*—Incident Reporting, Anonymity, Efficiency, Smart phones.**

I. Introduction

The involvement of citizens in incident reporting has been in existence for a long time, e.g., almost all major cities have emergency service lines where citizens can report incidents such as road accidents, domestic abuse, fire, robbery/theft, shooting, hostage situation, etc. The emergency service number is typically a two (15 [1]) or a three-digit (911 [2], 112 [3]) number, that provides dispatch and communication support services for police, fire, ambulance, and related services to the caller. On average, it takes an emergency operator at least two to three minutes to collect the necessary information in order to respond to the caller [2]. A delay in collecting correct information about the incident can result in delayed incident response. Many traffic-car accidents result in deaths in developing countries every year due to the poor emergency response and reporting, e.g., according to the statistics of the India's department of highway and street transport, there were around 0.5 million road accidents in year 2000, which resulted in about 0.52 million injuries and more than 0.13 million deaths [4]. The most obvious reason for a person's death during traffic accidents is unavailability of the first aid provision, which is due to the delay in the information of the accident being reached to the ambulance or to the medics. Thus, response time is crucial for the timely delivery of emergency medical services to accident victims and is expected to have an impact on fatalities. Similarly in other life-endangering situations such as shooting, burglary, etc., a timely response from the concerned authorities could make a large difference in victims' survival rates. Therefore, communication plays an important role at the time of critical situations, where the loss of a few seconds can mean the difference between life and death.

Every year, about three hundred thousand people who call the emergency services cannot describe their location, because they may not know the exact location of the incident's occurrence [5]. In critical situations, knowing the exact location information in latitude and longitude of the incident reporter can help incident management authorities to react quickly and save lives. Today's mobile and smart devices are able to provide emergency services with accurate caller location via an SMS or data channel by using built-in Global Navigation Satellite System (GNSS) or Wi-Fi capabilities. Given the multitude of sensors (accelerometer, microphone, and high resolution cameras) and Internet connectivity present in modern smartphones, these devices can help in reporting accurate geo-coordinates of the incident location, and the extent and nature of the incident to the relevant authorities.

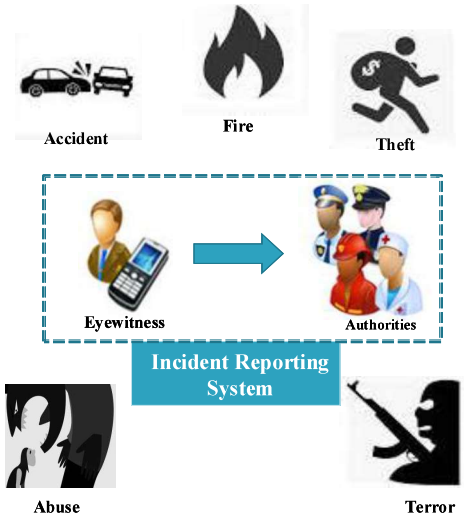

Fig. 1. Generic incident reporting system.

The increasing popularity of smartphones and the techno-

logical advancements in mobile communication and information systems have the most significant impact in the growth of the web-based and mobile incident management systems (Fig. 1). These systems or platforms provide citizens with the means to report incidents by specifying, for example, the location (such as selecting the location on a map), sending a precise location identification (such as using Global Positioning System (GPS)), or simply providing a proof of the incident (such as a photo) to the emergency responders, who, in return, respond quickly to the situation. For example, Elerts [6] is an effective and robust public safety communication platform based on smartphones. Using this application, the registered user witnessing the incident site can take a photo of it, which is automatically uploaded to a website, and other Elerts user gets the alert regarding such incident along with the location and the photo. In the wake of smartphones boom, social media platforms such as Facebook and Twitter, etc., are used at ever increasing level. The social media users use these platforms as communication tools to connect with one another, engage with news content, and share information, e.g., when an emergency strikes, people in the affected area start posting about it on social media from their mobile phones. By combining crowdsourced information from mobile devices as well as social media data, responsible officials can prepare for and respond to emergencies or incidents faster than ever before. Many incident reporting and management systems use crowdsourced information from the public to gain valuable forms of information from sources on the ground in and around the emergency or incident.

Also, many incident web-based and mobile reporting systems exist that allow citizens to communicate anonymously and confidentially any event or situation. For example, Fig. 2 presents a mobile-based app, Violens [7] that allows the eyewitnesses to take anonymous audio or video clips of an abusive incident, which are directly sent to the requisite authorities with a time and location stamp.

Fig. 2. Violens [7]: An anonymous reporting application.

Incidents such as road accidents, hate crime, harassment, and domestic abuse are critical issues that are often not reported because the witnesses do not want to be identified or reveal their specific location for personal reasons, or they are concerned about personal safety, or they fear the possibility of being considered as suspects of a crime. For example, in a recent road accidents survey in India [8], it was revealed that around 74 percent witnesses hesitate to report road accidents or help the victim due to legal hassles and fear of police harassment. Repeated questioning by the police, multiple summons from courts of law and even prosecution for unintentional accidental deaths prevent the witness from extending a helping hand to people in need, and reporting the accident to the relevant authorities. Thus, the systems should be designed in such a way that if an eyewitness desires anonymity, he/she can report the incident to the authority without any fear.

In this paper, we provide an overview of existing web-based and smartphone-based platforms and applications for incident reporting in terms of their features, benefits and implementation details. Also, these platforms and applications are compared in terms of reliability, usability, performance, security, and anonymity.

The rest of the paper is organized as follows. In Section II, we provide a brief overview of the existing incident reporting applications. Section III provides a comparative analysis in terms of performance and anonymity of the selected systems. Lastly, in Section IV, we present the conclusions of this work.

II. Incident Reporting and Management Systems

In this section, we highlight the features and benefits of the existing incident reporting and management applications. Also, details of a few recently proposed smartphone-based state-of-the-art incident reporting systems are presented. Although many emergency management systems exist in scientific literature, we include only the recent incident reporting systems that fulfill either one or all of the following requirements: (1) location-aware system that handles both reporting and management of the incident; (2) guarantee privacy-preservation of the eyewitnesses; and (3) provide cost-effective functionality in a simulated incident scenario.

1) Elerts [6] is a mobile emergency response communication application for reporting incidents all over USA. It is centralized and available on the market for each area such as airports, universities, health care, and corporate. Using the Elerts app, citizens can quickly report accidents, robberies, or any other incident by taking snapshots, which are automatically uploaded to the central website, that sends alerts and warnings to the respective service officers, and other users of Elerts. The main features of Elerts are bi-directional communication (once client or user gets warning or alert message on his/her cellphone, he/she can also reply back with other detail or elaborate information regarding the incident. The rescue groups or the service providers recommend ways to get out of this kind of situation), reports (the users of Elerts can send direct report or response to other users. A report could contain incident description, report type, photo/video and GPS location), photos (Elerts allows users to share live snapshots or

images with personal security or any other user), GPS and mapping (using Elerts, users can utilize advanced technology like Google maps to locate the emergency place. It can suggest or advice others to address the issues with the details of locations), mobile-platform support (Elerts works with iPhone and Android smartphones, and provides a simple interface in the form of a convenient drop-down menu to indicate report type, such as: robbery, medical emergency or suspicious activity).
The main benefits of Elerts are Elerts Attention Engine (a technology that transforms video surveillance cameras into active crime interception tools), National Incident Management System (NIMS) Compliant (Elerts provides the policies for how groups should plan, organize, train, and equip themselves in the event of a national security threat or disater), and integration (ELERTS enhances public safety by integrating the power of crowd-sourced incident reporting with video surveillance, access control and emergency mass notification systems).

2) A web-based platform in Brazil called WikiCrimes [9], allows users to register online information about criminal events in a specific geo-graphic location via a map. Since 2008, there have been over 200,000 crimes logged in this system [10]. Recently, the WikiCrimes mobile app for Android-based smartphones has been launched, which has more or less the same features as offered in desktop application.
The main features of WikiCrimes are accessibility (anyone can access WikiCrimes to add or consult information from geo-referenced database), common area of interaction (information about criminal incidents that go unreported by the police is shared in the community. Citizens can add links to videos, newspapers, photos or any other document to aid in credibility), violence hotspots tracking (allows users to keep track of hotspots and at-risk neighborhoods to make decisions in situations such as visiting an unknown neighborhood), report authenticity (WikiCrimes employs a user registration and a confirmation process to ensure the authenticity of the reported crime), incident confirmation (the reporting user should identify at least one person other than him/her, who can confirm that the registered incident is true), registration (the users need to register their name and valid email address for reporting the incident) and web-platform support (typical Web2.0 application).
The main benefits of WikiCrimes are false report detection (data mining algorithms aid in identifying irregularities and anomalies that can indicate false reports) and transparency (information is public and transparent).

3) AlertUs [11] is a mobile application that offers a panic button feature to the users, who can quickly and easily send incident reports to emergency managers.
The main features of AlertUs are geo-tagged incident reporting (users can report incidents with the user's current location, send a customized message in the message box, or select from multiple incident types with quick-action buttons via the panic button to deliver information to emergency management), custom branding (users can custom brand the home screen and notification details), public safety number (users can list safety numbers to easily contact emergency personnel or services), simple interface (AlertUs has a clean, intuitive interface that makes incident reporting easy and simple), and mobile-platform (users can easily download and install the AlertUs from iTunes [12] or Google Play [13] store).
The main benefits of AlertUs are auditing (detailed real-time reports track who receives/acknowledges each message and the current status of each client) and alerts notification (users instantly receive emergency alerts when alert notification is activated).

4) Ushahidi for crisis response [14] has recently launched a map-based mobile application that allows any citizen to gather distributed data via a text message (SMS), a tweet, an email or web forms, and visualize it on the map. Web-based Ushahidi has been used globally many times over the last years to facilitate the emergency management services in situations where there was a little or no support at all from the government or concerned authorities, e.g. for tracing events around Gaza strip. Ushahidi deployments are comprehensive software tools that allow organizations to build custom surveys, import data from third-party services, share it publicly in a map or timeline, and triage response, e.g., SafeCity [15] uses Ushahidi to crowd-source personal stories of sexual harassment and abuse in public spaces.
The main features of Ushahidi are data collection (receive reports from many sources, SMS, email, and Twitter), custom surveys (supports multiple data types with custom forms), multiple maps (provides map tiles including street and satellite provided by Open Street Maps, and MapQuest), filters and saved searches (crowd-sourced information can be filtered, tracked over time, and refined), report (Ushahidi saves data that contributors collect with it, including detailed GPS location data, and sends the report to the appropriate Ushahidi deployment), and mobile-platform support (available for both Android and iOS).
The Ushahidi app provides protection of sensitive information by introducing field level privacy controls, i.e. restricts visibility of specific fields in the form, to ensure that answers to those fields will only be accessible to certain people within the organization that has deployed Ushahidi at its end.

5) Aspire News [16] is a potentially life-saving app that allows victims of abuse or a person who knows about a person who is in an abusive relationship to call for help at the touch of a button. Aspire News is voted as one of the two "best apps" for domestic violence prevention in 2016.
The main features of Aspire News are quick escape button (a feature that the user can use to quickly change the screen to news if someone was to look over their

shoulder), trusted contacts (the user has more flexibility to choose a trusted contact. These contacts do not have to be individuals who are already in the phone's contact list), alert notification (trusted contacts who are added within Aspire News can be alerted with or without the user's location information), help section (24-hour hotlines and resources on domestic violence), and mobile platform support (Aspire News is available for both iPhones and Android-based smartphones).
The main benefit is an inconspicuous nature of the application. Aspire News appear as a news app, that contains summaries of top world, sports, and entertainment news. This feature is helpful to some survivors who want to use a personal safety app, but are concerned that the abuser may find the app on the phone.

6) SPEARS: Smart Phone Emergency and Accident Reporting System (SPEARS) [17] is a location-aware system that allows users of an online social network (Facebook or Twitter) in Thailand to quickly report emergency and accidents to the agencies such as police, fire department and hospitals, via a smartphone.
The main features of SPEARS are user registration (users must be identified by phone numbers and names before reporting an emergency or incident), quick response (Google map is used to display shortest routes of the relevant authorities to the occurred emergency in the quickest time), shortest route calculation (Dijkstra's algorithm is used to help finding the shortest path routing), GPS (the agencies can retrieve the current location of the emergency via GPS and send immediate help to the users involved in an emergency situation), user display (it shows locations of the nearest relevant agencies where the nearest incidents are reported), agency display (it displays locations where reported emergencies are received) and mobile-platform (only works in Android-based smartphones).
The main benefit of SPEARS is its integration with mobile social media such as Facebook and Twitter, that allows Thai users who are members of these social networks to report emergency.
7) STOPit [18] communities equip every citizen with a modern, anonymous, and safe way to share information directly with authorities about risks to public safety.
The main features of STOPit are two-way communication (anonymous communication between the user and the responsible officials. Using STOPit Messenger, the officials can respond to the report to ask questions, which can be replied by the user, while remaining completely anonymous), incident reporting (users can report inappropriate conduct or safety concerns such as harassment, bullying, ethics or compliance violations, weapons possession, hazing, safety hazards, threats, assault, or illegal activity by sending a report that may include text and photos or video), notifications (officials send users notifications such as updates or alerts), incident management (officials are equipped with a smart, easy backend system (anonymous messenger) to save time and conduct effective and efficient investigations) and mobile-platform support (available in IOS and Android devices).
STOPit is simple, fast and powerful tool which empowers individuals to protect themselves and others- all at the touch of a button.
8) A location-based emergency reporting system based on the Android operating system is proposed in [19] that allows the eyewitnesses to timely notify the authorized emergency authority about the incident while preserving their anonymity.
The main features of the system are eyewitness anonymity (the system employs an online social network in such a way that the eyewitness can create a dynamic and location-based social group to report the emergency information to the emergency management service (EMS) without revealing his/her real identity or any other personal information), revocable privacy (eyewitness's anonymity is preserved until he/she is found responsible of false reporting by the EMS), rewards and punishments (a game-theoretic design inspired by the co-privacy (co-utility) approach [20], is used to encourage legitimate information and discourage false reporting), GPS and mapping (users can utilize latest and advanced technology like Google maps to send the exact coordinates of the emergency place in the report), and report (incident description, GPS location, anonymous credentials, group ID).
The system provides security, k-anonymity, false report prevention, and cost-effective functionality.

III. Comparative Analysis

In this section, the presented systems are compared in terms of generic features that are desirable by the users of any smartphone-based incident reporting and management application or system. These generic features include platform support (Android, IOS, Web 2.0 and desktop versions), availability (free to download from Google Play, or iTunes store), usability (user friendly interface, issue-free experience), languages (single or multiple), performance (quick report submission and response, cost-effective), and location tracking (GPS or triangulation). Abuse of the emergency service providers, i.e. fake or false emergency calls is an expensive problem because it drains out the resources of the emergency services and, also, prevent people in need to get urgent assistance from the service providers. Thus, all the incident reporting and management systems desire reliability (verification of the reported incident, prevention of fake reports, report auditing/analysis post incident) so that people in need always get a top priority from emergency service providers. While users use incident reporting applications to report incidents that either involve them directly or they are eyewitness to a particular incident by sharing their personally identifiable information, they desire data security (report confidentiality, data integrity). In some applications that allow users to report hate crimes, domestic

TABLE I
COMPARISON OF PRESENTED INCIDENT REPORTING AND MANAGEMENT SYSTEMS

Group	Incident Reporting Systems/Applications	Platform	Availability	Reliability	Usability	Languages	Performance	Location Tracking	Data Security	Anonymity
Public	Elerts [6]	- Android 4.4 + - IOS 9.0 + - Desktop app for Windows and MAC	Yes	Poor	Medium	Multiple	Good	GPS	Yes	N/A
	AlertUs [11]	- Android 4.1 + - IOS 9.0 + - Desktop app for Windows and MAC	Yes	Good	Medium	English	Medium	GPS	Yes	N/A
	Ushahidi [14]	- Android 2.2 + - IOS 9.0 + - Desktop (Web 2.0)	Yes	Best	Good	English	Good	GPS	Yes	N/A
	SPEARS [17]	- Android	No	No	N/A	Thai	Good	GPS	No	N/A
Private	WikiCrimes [9]	- Android 1.5 + - Desktop (Web 2.0)	Yes	Good	Good	Portuguese	Poor	GPS	No	No
	Aspire News [16]	- Android 4.1 + - IOS 8.0 +	Yes	Poor	Poor	English	Medium	GPS	No	Yes
	STOPit [18]	- Android 4.0 + - IOS 8.0 +	Yes	Poor	Poor	Multiple	Poor	GPS	Yes	Yes
	Privacy-preserving EMS [19]	- Android	No	Yes	N/A	English	Good	GPS/ Triangulation	Yes	Yes

abuse, etc., anonymity (anonymous report submission) at the user end is a desirable feature because the victim or the eyewitness does not want to be identified.

In Table I, the applications are grouped into two categories. The first group (Public) contains applications in which users do not desire anonymity while reporting the incidents such as road accidents, wildfire, etc. The second category (Private) consists of the applications in which users require anonymity while reporting the incidents such as hate crimes, etc. In this table, a cell contains "No" when the corresponding attribute is not guaranteed by the system, and "N/A" when the corresponding attribute is not applicable to the system.

From Table I, following observations can be made:

- In terms of availability, almost all the presented systems can be downloaded freely either from Google Play [13] or iTunes [12] store except for SPEARS [17] and privacy-preserving EMS [19].
- Systems such as WikiCrimes [9], AlertUs [11], Ushahidi [14], and privacy preserving EMS [19] that require user registration, or report verification/confirmation, or fake report detection or prevention, provide good reliability as compared to other systems (Elerts [6], Aspire News [16], and STOPit [18]) that do not have such preventive measures.
- For usability, the user-based rating of each mobile application is obtained from the Google Play [13] and iTunes [12] stores. Depending on the average of users' ratings, we have scored each system in the following categories: Good (rating: 3.6-5.0), Medium (ratings: 2.6.0-3.5), and Poor (ratings: below 2.5).
- Almost all applications are available in English language except for WikiCrimes [9] (Portuguese) and SPEARS [17] (Thai).
- For performance evaluation, the user experience of each mobile application is obtained from the Google Play and iTunes store. Depending on the users' experiences, we have scored each system in the following categories: Good (efficient reporting, quick emergency/incident response), Medium (varies between quick and slow response from the officials), and Poor (slow or no emergency response at all). For the systems that have not been tested in real-world incident scenarios (SPEARS [17] and privacy-preserving EMS [19]), the experimental results are considered. SPEARS [17] calculates the shortest path on the Google map from the emergency authorities to the point of incident using Dijkstra's algorithm so as to help the authorities to reach the emergency location in time. However, this distance calculation is limited to the information within 30 kilometers of the point where the user is located and has reported an incident. In privacy-preserving EMS [19], the computationally expensive part of the system, i.e. threshold discernible ring signatures used to provide accountability and conditional anonymity is implemented on an Android emulator to compute the efficiency of the proposed system. Based on the experimental results, the proposed scheme can be implemented as a real-world mobile application to provide timely response to the affectees of the critical incident.
- In almost all the applications, location coordinates, i.e. longitude and latitude coordinates are calculated by GPS except in privacy-preserving EMS system [19] that in addition to GPS performs triangulation in case of poor GPS satellite coverage.
- The applications such as Elerts [6], AlertUS [11], Ushahidi [14], and STOPit [18] provide partial report confidentiality, i.e. these systems provide personally identifiable information such as name, email address, phone number and location to the service providers (police, emergency services, law enforcement authorities, etc. for the purpose of managing incident-related services such as incident verification), who may reconstruct, use and distribute user's personal information to the interested advertising parties. Privacy-preserving EMS [19] only shares the location with the relevant emergency authorities for report verification and dispatching relevant emergency service providers. Elerts [6] and Privacy-preserving EMS [19] provide data confidentiality, i.e. protects user

information against unauthorized access or modification. WikiCrimes [9], Aspire News [16] and SPEARS [17] do not provide data security.

- Elerts [6], WikiCrimes [9], AlertUS [11] and SPEARS [17] do not provide anonymous reporting, whereas Ushahidi [14], Aspire News [16] and STOPit [18] provide it. Privacy-preserving EMS [19] provides conditional anonymity, i.e. anonymity of an honest witness is preserved unless he/she is found responsible of false reporting by the emergency authority.

In the view of Table I and the above discussion, it can be observed that in the first category, Ushahidi [14] outperforms all other available applications in terms of performance, reliability, usability, and data security. In the second category, the only system that offers good performance, reliability, data security, and revocable privacy is privacy-preserving EMS system [19], but it has not been tested under real conditions.

IV. Conclusion

This paper presents a comprehensive survey and analysis of existing incident reporting and management systems. For this purpose, we have discussed the systems in terms of their features, implementation details, and benefits. Then, all the systems are compared in terms of features, functionality, security, and anonymity property. With the recent trend of growing number of applications based on crowd-sourcing, and increasing level of user participation in social media networks during disasters or incidents occurrence, governments and the concerned emergency response officials are able to respond effectively and efficiently to incidents. However, the main challenge lies in the effective and efficient response from the concerned incident response officials, while detecting/preventing false incident reports, and providing data security and revocable privacy options in the system to enable eyewitnesses/reporters to report the incident without fear of his/her safety.

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