Sensors-based Crisis Response and Management for Mass Gatherings: A Case of Hajj

Yasir Javed
Department of Management Sciences.
COMSATS Institute of Information
Technology, Abbottabad, Pakistan
yjaved@ciit.net.pk

ABSTRACT

Many people die or are lost every year during mass gatherings around the world hence making it very difficult for the local authorities to track them and identify them in case of accidents. This paper proposes a system for tracing of lost, injured and dead using network of Radio Frequency Identifiers (RFID) tags and mobile phones. With such a system, time, effort, and cost can be significantly minimized hence eliminating the psychological torture through which relatives of the lost passes though. The proposed system can also be used for crowd management in a real time. For outdoor tracking, where placing RFID readers is not practical, the paper proposes mobile-based peer to peer network for tracking pilgrims who don't have access to the internet or don't have GPS facility in their mobile phones. The paper also proposed a plan of testing the prototype in simulation.

Keywords

Wireless Sensors Network, Radio Frequency Identifiers (RFID), Mass gatherings, Hajj, Identification

INTRODUCTION

Though accidents do occur with time to time no matter what we do to eliminate their possibility but still, we can plan to minimize their occurrences and reduce their affects to minimum by using mitigation strategies. Some latest wireless technologies can help in crowd control and management hence saving lives which are lost due to stampedes and injuries in congested places. Similarly, lost group members can be successfully traced using mobile phone application. Such application can also solve issues like identification of injured or dead with lost documentation which is the biggest headache for authorities as well as family members back home. Therefore, if we look at the value of such system it surpasses the cost of implementing the system. Moreover, random cost of identification and tracing the individuals in such large gatherings and psychological and mental torture can also be significantly reduced.

A CASE OF HAJJ

The Hajj is an annual Islamic pilgrimage to Mecca, Saudi Arabia, and a mandatory religious duty for Muslims that must be carried out at least once in their lifetime by all adult Muslims who are physically and financially capable of undertaking the journey, and can support their family during their absence (Long, 2011; Nigosian, 2004). The gathering during Hajj is considered the largest annual gathering of people in the world and can be up to 4 million (Mosher, 2005; Katz, 2013). The pilgrimage occurs from the 8th to 12th of Dhu al-Hijjah, the last month of the Islamic calendar. During Hajj, pilgrims join processions of hundreds of thousands of people, who simultaneously converge on Mecca for the week of the Hajj, and perform a series of rituals: e.g. "Tawaf"; each person walks counter-clockwise seven times around the Ka'aba (the cube-shaped building and the direction of

prayer for the Muslims), "Sai"; pilgrims runs back and forth between the hills of Al-Safa and Al-Marwah, drinks from the Zamzam Well, goes to the plains of Mount Arafat to stand in vigil, spends a night in the plain of Muzdalifa, and performs "Rami" i.e. symbolic stoning of the devil by throwing stones at three pillars. Since all these rituals has to be performed in a prescribe time at specific locations, situation get challenging for the authorities to manage crowd especially in indoor locations e.g. during Tawaf, Sai and Rami as shown in Figure 1a, 1b, and 1c respectively. Due to overcrowding, single push or pressure from group of pilgrims can create situations of stampedes killing hundreds. Moreover, since people of all ages come from around the world, there are many cases of illness and deaths on daily basis that are taken to hospitals or morgues. These people remain lost for family members back at home and group members in Masjid-Al Haram if they are not taken away in front of them. There is no proper system to trace them effectively without putting in a lot of resources and time. Such situations create huge panic for the family / group members as many hundreds of different ambulances and personnel are dealing with these services, it is quite difficult for authorities to manage and track this movement of pilgrims manually. Similarly, without knowing the exact number of pilgrims in a specific area, the crowd cannot be managed as it will not be clear that when number of people have reached a safe limit.

(1a) Tawaf **(1b) Sai** **(1c) Rami**

Figure 1. Indoor locations of Hajj rituals

LITERATURE REVIEW

Various ubiquitous technologies including Radio Frequency Identifiers (RFID) and scanning devices can be used effectively in monitoring and managing the movements of people in crowd. RFID is an electronic tagging technology that allows an object, place, or person to be automatically identified at a distance without a direct line-of-sight, using an electromagnetic charge/response exchange (Mohandes, 2010). However, performance issues exist with these devices when it comes to tracking individuals in very dense crowds (Yamin, 2008). But this was the case with old tags now passive RFID tags come with very reliable connectivity. RFID is an Automatic Data Collection (ADC) technology that uses radio-frequency waves to transfer data between a reader and a RFID tag, for the purpose of identifying, categorizing, and tracking a movable item that the tag is attached. RFID is fast, reliable, and does not require physical sight or contact between reader/scanner and the tagged item. This non-line of sight property makes RFID suitable for the proposed system, compared to barcodes or other optically readable technologies (Khan, 2011). In the face of the above mentioned scenario and problems, RFID technology has emerged as a practical solution to aid automatic object identification and tracking.

The idea of using technology for this purpose is not new and has been proposed by the different researchers e.g. (Abbdelazeez and Shaout, 2015; Rarnaparakhe and Tadwalkar, 2015; Sangle and Kadam, 2015; Ravi, Aziz, and Ramana, 2012; Nair, and Daniel, 2014). Abbdelazeez and Shaout (2015) presented a system, designed to track and identify pilgrims during Hajj using mobile phone-based latitude, longitude and time stamp and used Google map to display the location. Rarnaparakhe and Tadwalkar (2015) proposed a real-time pilgrim tracking by relying on a dedicated delay-tolerant wireless sensor network (WSN). The WSN was interfaced to the Internet through lots of gateway(s) available from an internet service provider (ISP). But issues with this design are lack of robustness, and reliability within the network. Sangle and Kadam (2015) proposed that every pilgrim should carry a small embedded device which includes a processor, Global Positioning System (GPS) unit and various biomedical Sensors. Real time monitoring will be done by control unit which is a Web server installed near to the location. Problem with this solution is the cost and pilgrims have to carry an addition device, charging and protecting it will be an issue in itself. RFIDs are also proposed for crowd control and security issues (Ravi, Aziz, and Ramana, 2012) but authors didn't elaborate on the practical implementation and possible issues. Some

researchers also proposed using RFID technology for tracking and monitoring the pilgrims. But their focus was more on tracking the vital signs of the pilgrims so that the medical assistance can be sent in as soon as possible (Nair, and Daniel, 2014; Boudhir et al., 2013). All these systems lack energy efficient, cost effective solution that can be used for multipurpose like identification, tracking and crowd management. Moreover, when accidents like stampedes happened mobile phones and such devices are mostly lost and are of no use. Similarly in outdoor all the pilgrims don't have mobile internet connections or GPS facility. Hence, these are some of the issues which are considered for designing the proposed solution; HAJJ-SAFE.

SENSORS BASED CRISIS RESPONSE AND MANAGEMENT SYSTEM: HAJJ-SAFE

FOR LOST PILGRIMS

This study proposes a web-based system that will utilize information from multiple devices e.g. Wrist bands with RFID tags and mobile phone-based GPS on the basis of availability. Pilgrims will be provided with a water resistant wrist bands having RFID tags with unique identifiers which they will keep on all the time during Hajj and they don't have to remove it even for ablution. These unique identifiers will be linked with their personal identification information in the database. Indoor RFID receivers at various locations can read the RFID tags on the wrist bands and identify the pilgrims. This information will be sent to server to be available for viewing by the authorized people (e.g. authorities, family members, group members). Moreover, RFID tag readers will also be placed in the ambulances and at the entrances of all major hospitals where injured or dead pilgrims are brought. Hence any pilgrim brought to any hospital will easily be traced by authorities, their group members there in Masjid Al-Haram and family members in their home countries using the web application on their desktop or mobile phones. For such systems, connectivity and cost are big issues as area of pilgrimage is too large and RFID readers cannot be placed everywhere inside and out therefore at such outdoor locations, application on one mobile phone should be able to track any other device with the same application in the area and hence whichever device has the internet capability or wherever it gets access to the internet it can share information of itself and its peers. Hence, application uses an algorithm to share their information privately with peer (non-readable to un-authorized personnel). But since most accidents happen indoor, in the closed vicinity or in congested areas where RFID readers can easily be placed, RFID tags will be used for tracking and identification.

FOR CROWD CONTROL (PROACTIVE CRISIS MITIGATION)

During Hajj, most of the rituals are performed indoor and within a specific period of time, possibility exists for overcrowding at some places. The risk of overcrowding beyond the safe limit can be reduced by knowing the exact number of people in a certain area and by monitoring their location using RFID readers. In a certain area, once a safe limit is reached, authorities can redirect the incoming crowd to other directions or ask them to use alternative routes. For this authorities can use onsite police or alerts can be sent on mobile phones to group leaders coming towards the crowd to change the route or come back later, hence similar alerts can be sent to them when it is safe to visit the area. Though internet facility is available in the Masjid Al-Haram, local area network can also interact with application on their mobile free of cost. In this way exact location of individuals and number of individuals in specific area can be used to manage the crowd in a real time hence avoiding disaster in the form of stampede, killing hundreds.

SYSTEM ARCHITECTURE

The proposed usage scenario can be seen in the following figure 2. When a pilgrim say "Pilgrim A" wearing a RFID wristband crosses a point where RFID reader is placed, his / her RFID tag identification number (ID) is passed to the Information System (IS) server using the internet connection. On server, the ID is matched with information of pilgrims on the server and whole detail of the individual (Pilgrim A) is retrieved. This location information of individual is made ready to be available on server if requested by someone (e.g. group member, authorities, family members) who is authorized by the Pilgrim A and wants to know the location. This information will be time stamped to show who is where and when. Hence, last known location along with the time will always be available.

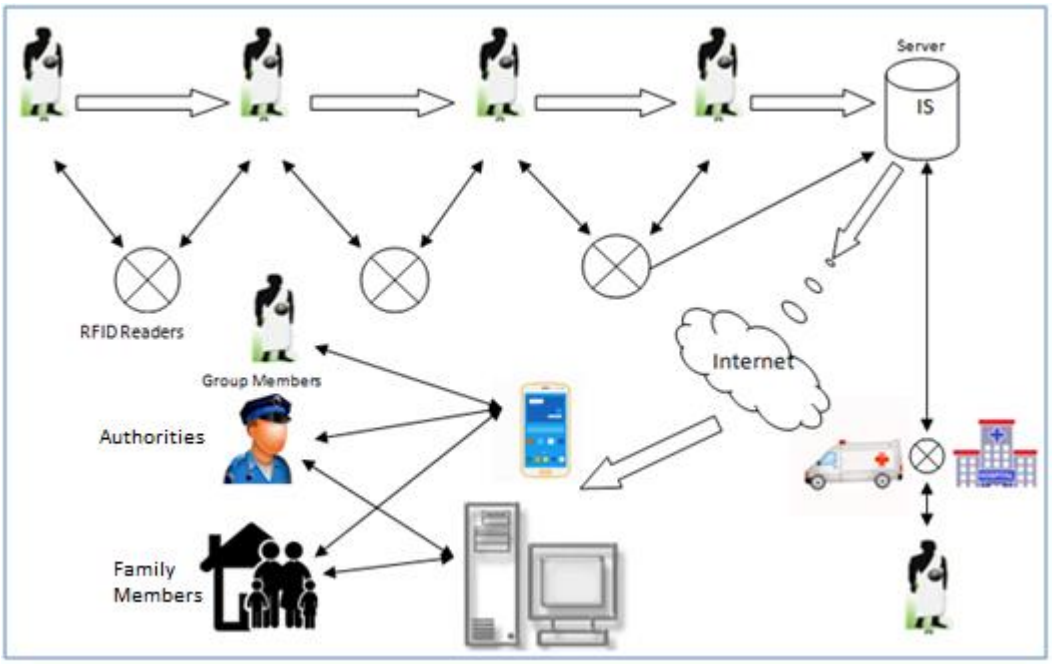

Figure 2. Usage Scenario: HAJJ-SAFE

Similarly, when Pilgrim A is taken to hospital due to illness, injury or death, his / her RFID tag will be identified at entrance and his/ location will be updated at the server making it available to group member, authorities, family members. Most importantly, authorities will not only be able to identify the individuals without checking their personal documents which are in most cases lost after stampedes etc. but they will also know the exact number of injured or dead in every hospital in a real time. If used effectively, same information can also be used for sending injured to the hospitals which are not overwhelmed and have capacity to cater more patients or injured in crisis.

The proposed application (Hajj-Safe) will use WSN comprised of RFID tags, RFID readers with internet capability and sensors provided with mobile phones e.g. wireless connectivity and GPS for outdoor tracking. Moreover, RFID tags will be used in combination with their readers which will send tag's identity to the server where it will be matched and processed. Similarly, outdoor places where it is not practical to use RFID readers, application on the mobile phones will use GPS to locate the mobile phone and will use local area network and wireless connectivity sensors available in the mobile phones to build peer to peer (P2P) network. Such mobile P2P networks can be used to share information about their peers e.g. their location at a certain point in time. Identification of the peer devices will be sent automatically to the server in an encrypted form where location of both (itself and peer) will be updated along with the time stamps. An intelligent algorithm will be running in the application to avoid sending repetitive information by different peers and a time constraint can be applied for the next update of the same peer over system architecture is shown below in figure 3.

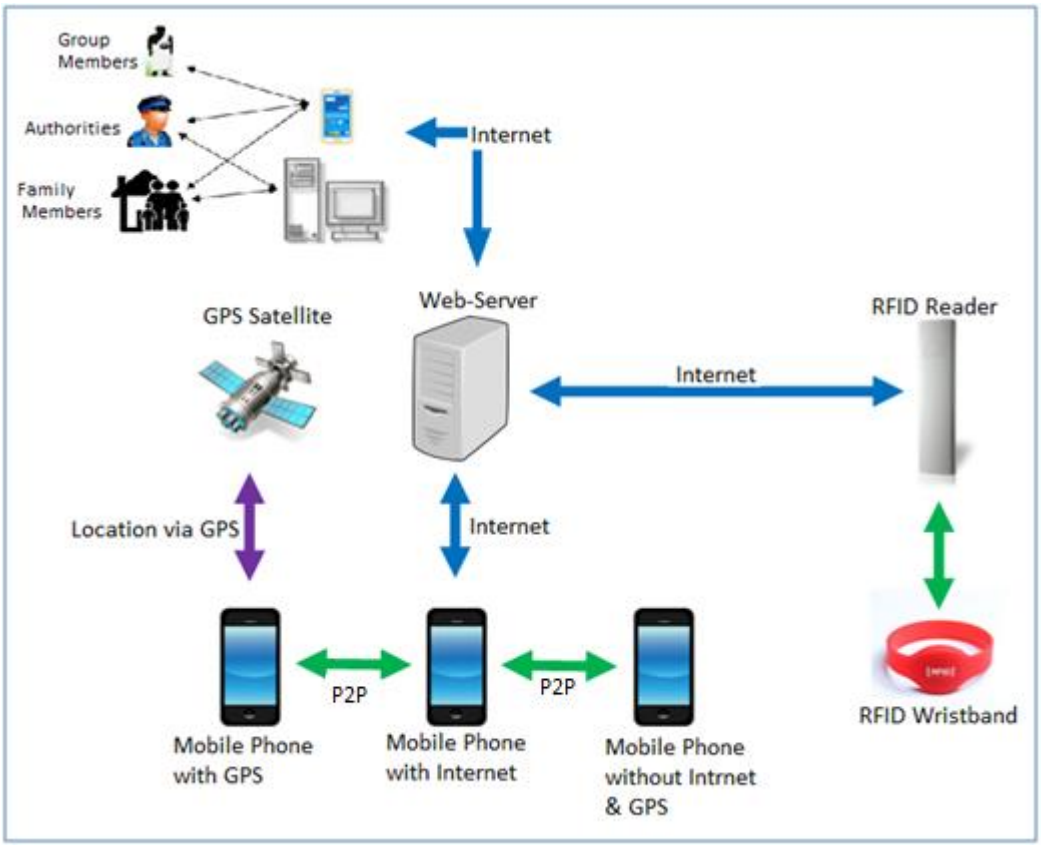

Figure 3. System Architecture: HAJJ-SAFE

EVALUATION

The challenges of use and implementation will be clear once an application is developed and tested in real or similar situation (simulation). To simulate the scenario similar situation is required where hundreds of RFID tags can be passed through the RFID reader at the same time. Hence, an experiment is planned with the application and actual sensors deployed at various locations in a University campus during the graduation ceremony to see what challenges can arise from mass movement of crowd. Students will be provided with RFID wristbands and the RFID receivers will be placed at various locations on the campus including entrances, corridors and main auditorium hence their movement in groups and as individuals will be tracked to see the capability of the RFID readers and processing capability of application at the server. Moreover, accuracy of the identified individuals and their location will also be examined to see the difficulties and challenges associated with such system.

Figure 4, below provides the context of how these sensors will be placed to see the direction in which crowd is approaching. For example, students are gathered at point A before starting the processions as shown in the figure 4 below, they have to reach the auditorium at point B. A RFID reader will be placed near the point A at point shown as "Start", since previously crowd was scattered in the ground, once they will pass the start point it would be understandable that they are starting to build the procession on the road. Graduate level and undergraduate level processions use different routes i.e. graduate procession use 1-1B and undergraduate uses 2-2B to reach point B. Therefore, once they cross point 1 or 2 their location will be tagged along with their identity using their RFID tags and database at the server. For the experiment purposes, alerts will be sent to them using alerts using the Hajj-Safe application and SMS on their mobile phones once they will reach points 1B and 2B to see how early they get usable and useful information about the situation at point 3. While they will be crossing point 3 and entering via point 4 into Auditorium they will be counted to see the capability of the RFID readers and processing on the server. In this way, identification of who is where and how many individuals have crossed a certain point to enter an area will also be examined. In addition, it will be evaluated whether this information can be used in real time to see crowd building at first and while considering the safe

capacity of the area, can it be used for crowd control in real time. Mobile application along with backend server application is under development for evaluation.

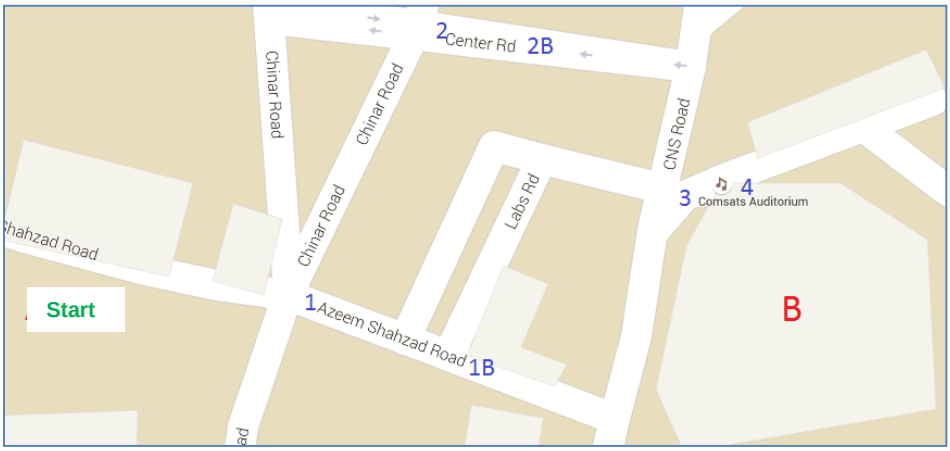

Figure 4. Map for RFID readers placement (Source: Google Maps)

Similarly, to evaluate the functioning of mobile peer to peer network (P2P) using the proposed mobile application, it will be installed on the mobile phones of student while their roam around in the campus and some of them will be provided with the internet connection and GPS will be enabled in some devices. In this way it will be recorded that how many individuals without the internet connectivity and GPS facility in their mobile phones were successfully located via their peers.

CONCLUSION

Crowd management and crisis mitigation in mass gatherings is a huge challenge however; latest technology in the form of Wireless Sensor Network can provide a practical solution. Specifically, considering the large number of people and wireless network nodes involved, cost of such system becomes an important barrier but passive RFID tags which do not require an active energy source for themselves and can get the needed energy from the reader, are the most suitable solution because of energy efficiency and low cost. Such a system cannot only help in crowd management but can also significantly reducing the time, cost, and effort needed in identification and tracking of injured and dead people in mass gatherings if accidents happen. Moreover, it can also eliminate the stress and trauma though which family members go through until the injured or dead relative is traced. Yet, in such systems, important concern can be the effectiveness and efficiency of RFID readers and application running on the server. Therefore, experiment designed for the said purpose will enable the improved design and the identification of possible issues with the proposed system. Moreover, apart from saving lives such systems can also be used for other context-aware or location –based services e.g. information about the location pilgrims visits etc.

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