A Simple and Secure QR Code based System for Efficient Crowd Administration

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ABSTRACT: *With the advent of mobile technology, providing accurate information at a critical time for those in need has become easy. People moving around in the crowd may get lost or face medical emergencies due to previous health problems. In such a scenario, the mobile technology can be deployed to provide information to those who are lost or need emergency medical help. This study presents a real-time system based on Quick Response Code specifically designed for any crowded environments where there is a requirement for people to be assisted for navigating to their respective destinations. Compressed and encrypted information about individual participants is encoded in the Quick Response Code and is provided to them. If somebody in the crowd is lost or injured, volunteers and organizers can use smart phones to scan this Quick Response Code to retrieve information and provide the necessary help. The same system can also be implemented for any other scenarios like huge exhibitions, airports, shopping malls or even the battlefields where there is a chance of an individual getting lost or requires direction.*

Keywords: Crowd management, guidance and tracking, QR Codes, Compression, Encryption

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1. Introduction

Risk of people getting lost, emergency evacuation, security problems, identifying and deporting of illegal migrants, medical emergencies, providing timely assistance to the injured, spread of communicable diseases, deaths due to stampedes, identifying the dead are some of the challenges posed by huge gathering of people for religious, political, entertainment or sports events. In the Middle East and South Asia the problem is more complicated as people from different nations, cultures and educational backgrounds, speaking different languages gather to perform rituals at a particular period of time in a year.

In recent years, much research has been made in tackling problems faced by people in large crowds. The research has been done in areas of crowd estimation, crowd management and crowd control which are three distinct but interrelated concepts. Crowd estimation includes anticipating and assessing from previous records the expected number of participants in mass gatherings to facilitate proper arrangements. It also includes techniques used to count or estimate the number of people in a crowd. Crowd management involves facilitating safe assembly and passage of crowds, while the third comprises steps to be followed, if disaster, whether natural or man-made has struck, and the crowd behaves in a disorderly or dangerous manner. Data collection, training volunteers and organizers, planning course of action are techniques used in crowd management. Designing and building models and processes for successful handling of crowds in case of emergencies falls under the

domain of crowd control procedures. Strategies and techniques for successful event management are discussed in [1], listing procedures, implications of mishandling and the legal consequences of mismanagement. The solutions proposed so far require huge investment in infrastructure and lack effectiveness in addressing the challenges stated. This paper proposes a simple, internet independent, effective and less expensive system that would help organizers and participants manage the issues in a better way while overcoming the shortcomings of the present systems. The system uses Quick Response Code to encode information about participants in mass gatherings. This QR Code can be scanned by volunteers, medical experts, government staff, organizers and participants themselves, to retrieve information and navigate easily or seek any kind of help in emergencies. Privacy of the participants is maintained as the personal information is stored in encrypted form which can be decrypted only by authorized personnel.

2. Related Work

Computer vision, simulation models, location aware devices such as mobile phones, GPS devices, wearable computing device, RFID, NFC are some of the technologies that have been used so far in crowd management. Vision based techniques require perfect lighting conditions; obstacles can block the field of view of cameras and it becomes difficult to combine information from different cameras to get the right status. All the procedures are difficult to test during real emergencies, and to create a large-scale, fake emergency situation is not financially feasible [2]. In this section, some of the proposed systems are discussed that have made use of available technologies to overcome the problems associated with crowds.

Blue-tooth technology is used in BlueMAP [3] to facilitate mass event organizers in monitoring pedestrian and traffic flows over a site. The system uses scanners that pick up anonymous blue-tooth signals of devices like cell phones and car kits, and monitors movement of the crowd from point to point. This system assumes that the users of portable devices leave their Blue-tooth enabled, which may not be the case always. The average detection ratio i.e. the percentage of visitors who got detected by means of a mobile device with a visible Blue-tooth interface, with respect to the entire population was found be about only 10 %.

Another system which makes use of mobile phone technology is [4] which aims to obtain real-time location data from event participants and to provide them with timely, targeted and personalized notifications in case of danger and emergency. This system requires the users to install and run a dedicated application on their mobile phones to obtain the location updates, which is a major drawback as people may not be willing to install such an application which would monitor their movements for privacy reasons.

Mobile technology has also been used for crowd disaster prevention as in [5] where system explores the use of participatory sensing approach, assuming that people in the crowd act as participant sensor nodes for crowd monitoring using their personal mobile devices and web service to explore the key aspects of their current context.

RFID based systems were proposed in [6] and [7]. These systems rely heavily on RFID technology and require high investment in infrastructure. Metals and liquids can affect the performance of an RFID tag. Many other technologies make use of signal frequency of RFID which can lead to interference. A combination of Computer Vision and RFID technologies has been proposed in [8] which includes an RFID detection system mounted on a robot capable of performing human following task in a crowded environment.

System based on NFC [9] also suffers from the same drawback and additionally requires a web server. Moreover, NFC technology is yet to be accepted worldwide and is not supported in iPhones as Apple did not include it in its latest iOS 7.

Another system proposed in [10] requires wireless sensor network interfaced to the internet through a gateway available from a service provider. The system needs mobile phone equipped with a Global Positioning System (GPS), which is used for tracking and guiding of people. .

The system proposed in [11] incorporates provision to provide first responders with life-saving information during an emergency. This system maintains hierarchical levels of privacy and health and medical records are maintained online and are provided to medical practitioners after authentication. The drawbacks of this system are its scope is limited to medicals records only whereas the system proposed in this paper is comprehensive as it includes all the details about the participants. Other drawbacks that are obvious are that every participant should have a smart-phone and as the private information is

maintained online a communication failure may spell disaster.

In [12], a system is proposed which uses QR Codes containing a short text to indicate locations shown within a custom Google map. Though the proposed solution is less expensive than other approaches based on wireless technologies, it requires a location server and map server with which the user has to communicate to retrieve navigation information.

Global Positioning System is used in [13] for navigation, system developed in Android platform. It uses QR Code for decoding and friend positioning. This system also requires all participants are equipped with mobiles that are GPS enabled. Similarly a guide for tourists is proposed in [14] where Google Maps API is used based on AJAX. The system is based on client-server technology and consists of server side and client side parts, and expert system is integrated with it.

Apart from using a particular technology, systems that integrate different technologies have also been proposed like in [15] where development of a multi-agent system within a real-time 3D virtual environment is used for better crowd management.

Therefore, it can be summarized that the systems proposed so far have cost overheads and have assumed that the people who come to the mass gathering take a smart-phone, which may not be the case always. Providing access to web servers for millions of people at the same time can be quite demanding. Therefore, a system that does not require people in a mass gathering take a smart-phone has low investment cost and which does not depend on the internet is the need of the hour.. In this paper, a system based on Quick Response Code is proposed for effective crowd management and at same time can be easily implemented.

QR Codes are freely generated 2D bar codes that can be used to encode up to 4,296 alphanumeric characters [16], whereas 1D barcode can encode only 25 characters and therefore cannot be applicable for a system that is being attempted here. Data from the QR Code can be retrieved even if more than 50% of the code is distorted or damaged. QuickMark and I-nigma readers are freely available tools that can be used for decoding QR Codes. When the data in the QR Code is decoded the ensuing operation can be one of the followings: display information, call a user, send a message or connect to the website.

Till date, no system, has been proposed that utilizes the full storage capacity of QR Code as they have been only used to encode the name, mobile number, URLs etc. The system discussed here proposes to encode details about participants (500 alphanumeric characters) in a QR Code. All the systems proposed so far decode information in a single language only and a system that decodes in multiple languages have not been attempted. The proposed system would decode information in the language of the mobile phone using which the QR Code is been scanned. No system has attempted to encode encrypted information in a QR Code, the system discussed here proposes to encode encrypted information, which can be considered as a novelty. Similarly colored QR Codes have not been used in systems meant for crowd control and management till date and this is the first attempt to be made. Throughout the world millions of people gather for religious, political or other purposes. Be it Kumbh Mela in India, Annual Hajj pilgrimage in Saudi Arabia, Shrine of Hussein ibn Ali in Iraq or Burning man festival in San Francisco managing these gatherings becomes a challenging task for the organizers.

3. Scenarios

Throughout the world millions of people gather for religious, political or other purposes. Be it Kumbh Mela in India, Annual Hajj pilgrimage in Saudi Arabia, Shrine of Hussein ibn Ali in Iraq or Burning man festival in San Francisco managing these gatherings becomes a challenging task for the organizers.

3.1 Case 1: Annual Hajj Pilgrimage

During the Hajj season millions of Muslims assemble in and around the holy city of Makah. Identifying and tracking an individual pilgrim is an arduous task. In the twelfth month of every Islamic lunar year, millions of Muslims assemble in the holy city of Makah for performing the rituals of Hajj, one of the five pillars of Islam. While it is a dream come true divine experience for the pilgrims, the Government of Saudi Arabia finds it a mammoth challenge to manage the event and track the movements of this huge crowd. What makes Hajj distinct from any other gathering is that all the pilgrims perform each of the rituals at a single time, like staying in Mina, approaching toward Arafat, staying in Muzdalifah, stoning the pillars (rami) and the farewell tawaf. Even though the Ministry of Hajj has a prescribed a specific number of pilgrims from each country, yet the number of pilgrims have exceeded three million during 2012 Hajj season [17] and the number is expected to exceed 4 million in the near future.

3.2 Case 2: The Kumbh Mela, Kedarnath & Badrinath Yatras

The largest gathering of people in the world is the Kumbh Mela [18] where millions of participants assemble every 12 years near the banks of the holy rivers in Uttar Pradesh, in India. Collecting details from participants in this event is near impossible as most of the participants are from within the country and are not required to provide details to the organizers. The mammoth size of the crowd and its dense concentration in particular localities on given days make implementation of any crowd management system very difficult. Participants are required to perform many rituals at different locations, therefore, huge multitude of people are seen moving simultaneously from area to another. Similarly another major event is the pilgrimage to Kedarnath Temple in Uttarakhand, which caught world-wide attention in June 2013 due to floods caused by multi day cloud burst. Over 5,700 were feared dead, and 100,000 pilgrims and tourists trapped in the valleys. Since June 24, 2013, 545 unidentified bodies were recovered. If a proper tagging system had been implemented by the organizers, identifying mutilated and decomposed bodies would have been easy.

Hajj Pilgrim Statistics.	
Year	Number of Participants
2010	2,789,399
2011	2,927,717
2012	3,161,573

Table 1. Number of Pilgrims for the Annual Hajj

3.3 Problems Encountered by Participants and Organizers

People participating in such gatherings face multiple problems. Listed below are some of the problems faced by participants.

• Majority of the participants in religious gatherings are old and need guidance and have a high probability of getting lost. Some participants are accompanied by children who may get lost in the crowds.

• Foreigners constitute a significant part of the participants population who are new to the place and need guidance to move around.

• Communication becomes difficult as millions of people belonging to different nations and speaking different languages assemble together.

• Medical emergencies are a common occurrence and require immediate attention.

• For many participants, this may be the first time experience, and they are ignorant of the rituals to be performed.

• Emotions may run high as this event is once in a lifetime opportunity for many of the participants.

• A small minority of the participants from other countries may misuse this opportunity to overstay and work as illegal migrants. Identifying and deporting them is an another problem.

There are mainly three categories of officials who have to take up the challenge of managing the event smoothly.

1. Volunteers

These are the good Samaritans who help lost people find their way, nurse the injured and the sick. In order to provide help, the volunteers need vital information about the people they are helping. The system should provide them basic information like the addresses of the area where the people have to be guided to, mobile numbers of the contact persons in case if a participant has injured , fainted or died. Other details that are confidential like the passport and visa details need not be revealed to the volunteers.

2. Medical Experts

Information crucial for treatment of patients like the blood group, blood pressure, previous history of sickness etc. has to be given to the medical professionals, so that they can attend to them without loss of time. Proceeding with treatment with wrong or no information can sometimes prove to be fatal for the health of the participants and may even lead to death. Just has in the case of volunteers, only the information required for treatment should be revealed to the health officials and other

administrative details need not be shown to them.

3. Administrative Staff
As foreigners constitute a considerable section of such huge gatherings the administrative staffs in the state and the organizer is responsible sending back the foreigners to their respective countries before the expiry of their visas. As stated earlier, a small percentage of participants may try to overstay. They may seek employment as illegal migrants who should be deported. These officials have to be provided with all the details like passport number, visa issue date, visa expiry date, addresses and mobile numbers of the guide or contact person who has arranged their visit etc.

4. The Participants
The participants themselves can use this system to get information about their location provided they are equipped with a smart phone. They can scan the QR Code with the application provided to them. The QR Coded provides them the longitudinal and latitude value of the place of interest which they can use to navigate to desired place. They can also use this information to get assistance from the volunteers or the local residents.

The QR Code technology can be utilized to provide information to the above mentioned members of the team to help participants in distress and also to assist organizers. As the QR Code can be scanned and decoded by anyone who has a smartphone equipped with a camera and application to scan the QR Code, care should be taken while encoding information in the QR Code. The data cannot be encoded in plain text format as some details which are private like medical conditions of the participant and the passport and visa details should not go into wrong hands. Therefore, these details have to be encoded in encrypted format. This can be achieved efficiently with the following steps.

1. Collect data about the participants.
2. Classify data as public and private.
3. Compress data.
4. Encrypt data.
5. Encode both the private and public data on to the QR Code.
6. Decode data to retrieve information.
7. Display information to the user based on the user type.

4. Proposed System

4.1 Data Classification
Though theoretically QR Code can store 4,296 alphanumeric characters, practically it is not feasible as the size of the QR Code tends to increase, and it cannot be scanned with low resolution cameras used in the lower end mobile phones. This problem was identified by printing QR Codes of different sizes, and they were scanned using a Samsung Galaxy Young Dous (Model: GTS6312) having 3 Megapixel camera. It was found that QR Code encoded with 518 alphanumeric characters can be scanned easily. Beyond this, the decoding tends to become difficult. This limitation is overcome by generating two QR Codes one for compressed and encrypted private data. The QR Code A would be in color 1 and can be decoded only by authorized persons having the special scanning application developed by this system and the second QR Code B would encode public data which would be in color 2 and can be decoded by volunteers or others who are equipped with a smart phone having any freely available decoding application. Still using QR Code is a better option as printing it is less expensive when compared to other technologies like RFID or NFC.

The user data is classified as Private data and Public data. There are certain fields which are used both in private and public data like name of the participants without which the data is useless, which is called as common data. The term Private data refers to all the details about the users that are considered private and can be accessed only by the authorized professionals like medical experts and administrative staff. Public data refers to data that can be accessed by anyone willing to help the user navigate, this may include the volunteers who can access the data by scanning the QR Code. The public data includes the addresses of the various locations the user has to visit particular date and time.

If P_b represents public data and P_r represents private data, the combined data set D can be derived as

$$D = P_b \cap P_r$$

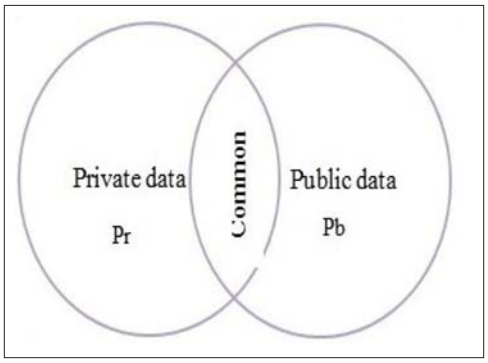

Figure 1. Data distribution

If QR_g represents the QR Code for P_b, it can be represented as

$$QR_g = (P_b) \cap (P_b \cap P_r)$$

where $(P_b \cap P_r)$ is the common data.

Similarly, if QR_b represents the QR Code for P_r it would obtained as the compressed F_c , encrypted F_e private data along with the common data.

$$QR_b = F_e\,(F_c\,(P_r)) \cap (P_b \cap P_r)$$

Inverse of the functions represents the scanned output from the respective QR Codes for both public and private data.

$$QR^{-1}_g = (P_b) \cap (P_b \cap P_r)$$

$$QR^{-1}_b = F\text{-}1_e\,(F\text{-}1_c\,(P_r)) \cap (P_b \cap P_r)$$

4.2 Determining the order: Compression or Encryption

Most compression algorithms search for patterns in the data to be compressed and use these patterns to reduce the size of data for storage. Encryption algorithms tend to erase the patterns in order to maintain the secrecy of the data as the bits are rearranged. If the compression is done before encryption, better rates are achieved as in [19]. The task of encryption also becomes easier as it is easy to encrypt shorter compressed data. Resistance to differential cryptanalysis and plain text attacks can be slightly increased by performing compression before encryption [20] as the resulting output would be difficult to deduce. The attacker usually relies on data redundancy and by compressing data redundancy is reduced to a high extent.

4.3 Compression

The system uses Deflator class in java.util.zip which uses a lossless compressed data format that compresses using the popular ZLIB compression library. It is part of PNG graphics standard is not protected by patents. The advantage of using this format is it can be implemented readily in a manner not covered by patents as it is available as an API in Java. The compression drastically reduces the size of data and the rate of compression may vary based on the size of data being compressed. Successive blocks of input data are compressed using a combination of the LZ77 algorithm and Huffman coding to generate blocks of compressed data. The compressed data is then encrypted to maintain its confidentiality.

4.4 Encryption

The private data consists of details that are confidential like the Passport Number, Visa dates, Bank a/c number, data related to health conditions etc. This data should be encrypted so that it is not accessible to an unauthorized user. Advanced Encryption Standard(AES) specification with 128-bit key is used for encrypting the private data. Java Cryptographic Extension (JCE) framework includes a class called javax.crypto. Cipher Encryption and decryption functions of a cryptographic cipher are

Public data	Private data
Participant Name	Participant Name
Nationality	Nationality
Phone Number 1	Visa Number
Phone Number 2	Passport Number
Addresses of visiting locations	Maritial Status
Address1	Address in Home Country
	(if Foreigner)
Address 2	
Address 3	Sponsor Details
	Sponsor Name
Emergency Contact	Sponsor Phone Number
Contact Name	Sponsor Address
Contact Phone Number	Medical Details
Contact Address	Diabetic (Yes/No)
	Blood Pressure
Companion Contact	Blood Group
Companion Name	Details of previous ailments
Companion Phone Number	

Table 2. Public and Private data distribution

provided by this class. This specification is symmetric as it uses the same key for encryption and decryption. In the proposed system, the key is generated only once, and it is hard coded in the decryption module, for security reasons and to avoid generating key each time. The encrypted data is then encoded using base64 encoder before storing or generating the QR Code as the cipher text may contain unreadable characters.

4.5 Generating QR Code

Till date QR Code has been used to encode URLs, v cards, email addresses etc. No attempt was made to encode large data on to QR Code for real time applications. This is the first attempt where compressed, encrypted data in being encoded in the QR Code. The data encoding scheme is shown in Figure.1. The program for generating QR Code A is developed using Java SDK. This program generates QR code images after compressing and encrypting data. It uses ZXing (pronounced “zebra crossing”) [21] is an open-source, multi-format 1D/2D barcode image processing library implemented in Java. The QR code can be created in a wide variety of formats including PNG, JPEG,BMP and vector file formats like EPS, SVG, PDF. Using the vector file format is better for printing purposes as the details in the image are maintained even after scaling. Different colors are used to differentiate between the QR Code for private and public data.

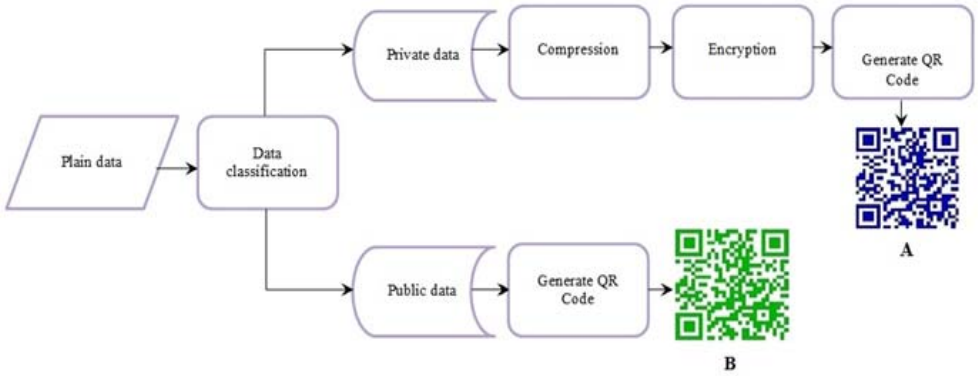

Figure 2. Generation of QR Code for Public and Private data sets

4.6 Scanning the QR Code

It will not be possible to scan the QR Code A, created for the private data using any available standard QR Code readers as the information contained in it is in a compressed and encrypted form. Therefore, a scanner application that would scan the QR Code, decrypt and decompress the data and display it according to the user requirement is developed using the Android platform. The Scanner System is developed using the open-source the ZXing Project which provides a barcode scanner that can be used in most of the devices equipped with cameras for scanning barcodes. The scanner package is installed manually from the market, and it is later integrated with the application via intent. The contents scanned by the app is passed on to the decryption module for further processing.

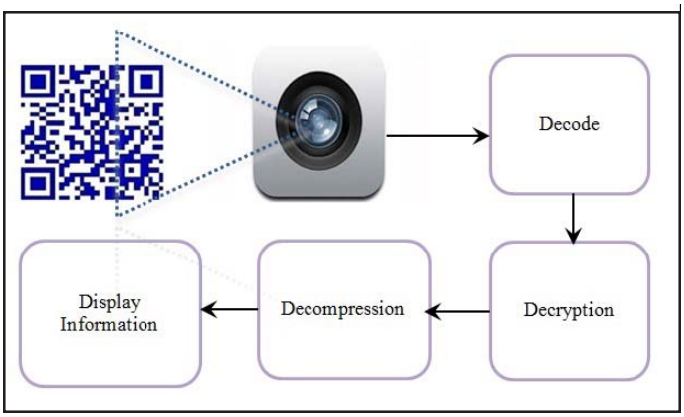

Figure 3. Scanning of the QR Code

4.7 Displaying Information

Before decrypting the contents of the QR Code for private data, the contents are decoded using Base64 decoder. The output from the decoder is decrypted using the hard coded decryption key. The Java Cryptographic Extension (JCE) framework is again invoked to get the decrypted bytes. The decompression is done by using Inflater class in java.util.zip correctly reproduces the original text from the Deflate bit stream of data or file. The advantage of using lossless compression algorithm is that the decompressed bits are the exact replica of the compressed bits.

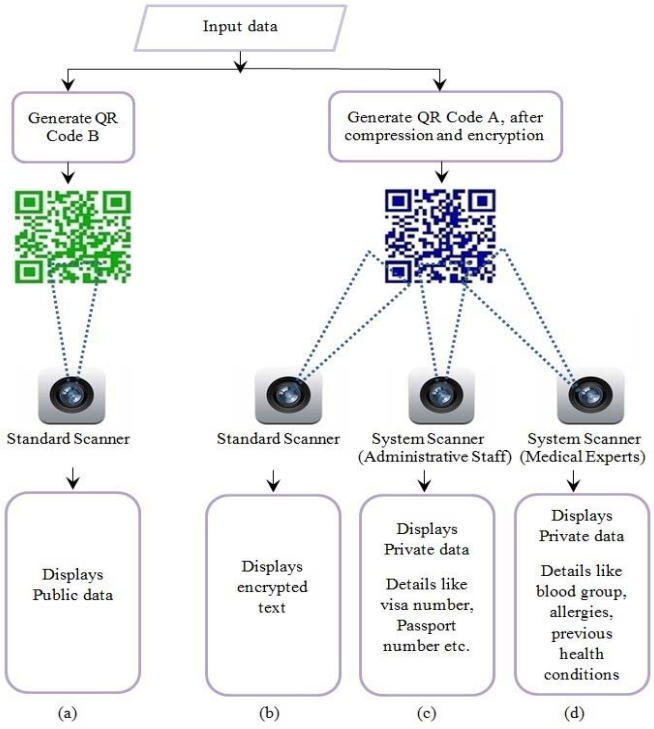

Figure 4. Displaying information based on user type

As shown in Figure. 4 (a) the QR Code B, when scanned by any standard scanner, would display Public data like the address of the participant. The volunteers who are equipped with smart phones can help people who are lost to reach their destinations. When QR Code A is scanned by the same standard scanner, it would display encrypted text, as shown in (b). But when it is scanned by administrative staff using the scanner provided by this system it would display private details like passport and visa numbers required by them for administrative purposes. Similarly, when the same QR Code is scanned by health officials with the system scanner it would reveal details related to the health of the participant like blood group, previous ailments etc, so that the treated can be given to them according to their health conditions.

5. Results

Two QR Codes A and B were successfully generated one for P_r and another for P_b.

The generated QR Codes were decoded to retrieve information for guiding and helping participants in a test scenario. A test was carried out on synthetic data of five participants to find out the rate of compression. Average compression ratio is found to be 1.28, and average space saving was 22.02%. Since the data being compressed is small in size, the compression rate is low. Though the compression rate is not significantly high, there is a trade-off between privacy issues and compression rate. Since highest priority has to be given to maintain the privacy of information, this compression rates are acceptable. Moreover compressed, encrypted data is more resilient to cryptanalysis attacks, therefore, provides a secure means for storing private data.

Record No.	Compression ratio	Space saving
1	1.31	23.60
2	1.27	21.12
3	1.29	22.41
4	1.29	22.47
5	1.26	20.50

Table 3. Compression Ratio and Space Saving Of Privat data P_r

6. Conclusion

A simple and secure system for participants in a crowded environment has been proposed. The advantage of using this system is its simplicity as there is no need for connecting to the internet and it does not require huge investment in infrastructure.

The effectiveness of this system can be studied when it is subjected to testing in a crowded environment, the user's can help the participants locate their position in a fraction of a second.

The privacy of the information stored is protected as this information can be extracted only by the authorised personnel. At the same time the basic information which is required to help the participant during emergencies is available to anyone who is willing to help.

Robustness of the system can be gauged by the fact that it requires very simple tools such as a mobile phone equipped with a camera, the QR Code and an application that would scan the QR Code. Therefore, there is no fear of breakdown of the system as in the case of other systems that have huge infrastructure.

The system is generic and can be implemented in any place where there is a gathering of large number of people. Future work can be in the area of providing spacial and temporal information to the participants in a customized way.

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