



Research Article

Using Wearable Technology for Context-Aware of Pilgrimage Management System During/Post-Pandemic of Covid-19

Fatima Shukur^{1,*}, Ahmed Al- Fatlawi², Safaa Jasim Mosa³, Nasir Ibrahim⁴

¹ Department of Computer Science, Faculty of Computer Science and Mathematics, University of Kufa, Al-Najaf 54001, Iraq

² Department of Computer Engineering Technology, College of Technical Engineering, University of Alkafeel, Al-Najaf 54001, Iraq

³ Department of Computer Science, Faculty of Education for Girls, University of Kufa, Al-Najaf 54001, Iraq

⁴ School of Computing, The University of Buckingham, Buckingham, MK18 1EG, United Kingdom

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ABSTRACT

Hajj is an annual event placed in Saudi Arabia. It is one of the largest religious gatherings, such that it gathers millions of pilgrims from all around the world. The pandemic of Covid-19 is not over yet, and could likely be part of our life for a long time. Also, it is negatively affecting such mass gatherings. The aim of this research is to facilitate the overall hajj event while maintaining peoples' health, safety, and security. Therefore, we use a technology that helps to reduce direct contact between pilgrims themselves as well as with other entities, such that human interaction would be at a minimum level. We propose a context-aware framework of Pilgrimage Management System (PMS) using wearable technology, such that, a four-user context-aware PMS framework is integrated wearable devices and mobile applications. The framework considers four groups of users. These include: pilgrims, convoy managers, Saudi authorities, and medical staff. Our context-aware framework fulfils users' needs where feasible and applicable. It makes hajj rituals safe and efficient so that they become more flexible. As a result, the overall hajj event will be improved. Our proposed framework is not only designed to be used during the pandemic, but also after the pandemic. Moreover, this framework can be applied to any transmission disease that might happen in the future. Hence, the overall system is developed based context-aware model and it can be expanded to accommodate new challenges.

1. INTRODUCTION

In the Muslim faith, the pilgrimage, which is also called hajj, is the fifth and last pillar of Islam. It is mandatory for Muslims to conduct hajj at least once in their lifetime if they are financially and physically capable. Moreover, it is highly recommended to do it as many times as possible which indeed many people are trying their best to go there by different means. Therefore, people are coming from all around the world to do this fifth ritual with high passion. The hajj is an annual event placed in Makkah in Saudi Arabia. Due to the limitation of the capacity of the holy place, it can be occupied by a specified number of pilgrims. Therefore, accepted people compete against a high number of applicants and might have to wait few years to travel to Makkah and do the hajj. In fact, about more than two million pilgrims could participate in this annual event [1].

We anticipate an increase in the number of pilgrims due to the backlog of reservations from the peak pandemic years. Naturally, Pilgrimage is a complex system network where people go to perform rituals in groups. These groups are likely to be divided into subgroups according to the total number of pilgrimage's campaign and available nominated convoy managers. Also, complexity increases with high number of people coming from different locations, with different cultures who speak different languages [2] [3].

During hajj season, the use of technology helps significantly to manage hajj in general and healthcare system in specific. Some researchers have focused on a particular aspect of managing hajj event, these as follows.

*Corresponding author. Email: fatinat.shukur@uokufa.edu.iq

- Real time information: due to highly transmission of the Covid-19 virus, various methods have been explored to track and control spreading the infection of coronavirus as early as possible during the hajj. An architecture was proposed in [4] to get and analyse real time information to make decision regarding the virus status. Cloud based techniques were used to keep track of the virus's outbreak. This was to identify infected people who might likely spread the virus to others, in addition to identify those who were in close contact with, i.e., take a precaution to try to isolate infected individuals among pilgrims [4].
- Managing hajj crowd: the aim of managing crowd in hajj is to reduce risks which primarily are caused by mismanagement crowd during such mass gathering event [5]. Researchers in [6] suggested to use cloud computing in order to ease the complexity of hajj crowd. It provides different scales based online services within a free network, so that pilgrims can add their important information to this free space. This information include road and hotel maps, food facilities, and shops.
- Practise a digital hajj: pilgrims would have an opportunity to explore hajj activities and its places in a digital method. Using virtual reality, augmented reality or both would help pilgrims to be familiar with hajj scenarios, so that they can do rituals in more efficient way [7]. Having said that, if pilgrims are anxious to be within a large group of people, as well as getting Covid-19 virus or other viruses, they can do the required rituals as quickly as possible, since they have trained/practiced hajj using such reality technologies. These technologies not only would help pilgrims in many aspects, but also hajj authorities to provide better services to pilgrims themselves.

Moreover, considering Covid-19 (CVD19) and beyond, Pilgrimage Management System (PMS) becomes more complex in addition to have the above challenges such as the variation of cultures, languages, ages, and level of faith [8]. Precisely, more attention is given to detect Covid-19 virus as early as possible [9] due to its highly transmission and risk [10], in addition to the prediction of other viruses' detection and their spreading [11]. Consequently, there is a real need to have a system to deal with such challenges. The aim of this research is to facilitate the overall hajj event while maintaining peoples' health, safety, and security. Therefore, we propose a context-aware framework of pilgrimage management system using wearable technology. We provide a comprehensive analysis about the current situation of doing hajj considering Covid19. In short, throughout this research, we would refer to this system as "PMS-CVD19" for simplicity. Our framework would help to reduce direct contact between pilgrims and within user groups. Also, get more work done in a convenient way with a minimum level of human interaction.

In this research, our contributions can be summarized as follows:

- We propose a framework with a context-awareness model that responds to every user according to user's context. We consider developing a context-aware system with the use of wearable device as well as mobile application all together, in order to arrange hajj system during the pandemic of Covid-19 as well as the post-pandemic.
- Our proposed framework accommodates main components of hajj event with four users. These are: pilgrims, convoy managers, Saudi authorities, and medical staff. In addition to providing many services for every user.
- Decentralise the management of hajj event by staff of hajj authorities regarding a direct communication with pilgrims. i.e., pilgrims of every campaign are managed by their convoys managers. The convoys can easily communicate and contact their pilgrims independently.
- Using a wearable device to keep regularly check the health of pilgrims such as blood pressure, oxygen saturation, heart beats, temperature, etc. Considering, in particular, those pilgrims with chronic diseases or special needs. Then, update their records accordingly, in addition to track their locations to keep on their safety and security.
- A wearable device also helps to mitigate the spread of Covid-19 as well as other infection diseases
- Using a *pilgrimage management system* application provides a direct contact between pilgrims with the medical staff for any help or advice might need it.
- Using our system helps to reduce a direct contact with pilgrims. Also, get more work done in a convenient way with less human interactions whilst considering Covid-19 in particular.
- The framework is designed to be used during pandemic and after the pandemic. Moreover, it can apply its strategy for any transmitted disease might happen in the future, so that it can be modified easily for new challenges which might require updates. This would help researchers to save time and efforts by proposing and designing new solutions from scratch.

The organisation of this paper is as follows. Section 2 presents the architecture of our proposed framework of pilgrimage management system of Covid-19 for the pilgrims as well as other users. Section 3 describes context-aware of our proposed framework. Section 4 shows a brief discussion about the framework. Section 5 summarises this research conclusion and future research directions.

2. Architecture Of The Proposed System

We propose a framework of pilgrimage management system within/post- pandemic of Covid-19. It considers four groups of users. These groups are: pilgrims, convoys managers, Saudi authorities, and medical staff. The main aim of proposing this framework is to facilitate the hajj event for pilgrims. Since the pilgrims are the majority among other users, and to make a clear and simple presentation of this research, therefore, we separate their architecture from the other users, although, there are still lots of commons among them. Thus, we have a PMS-CVD19 framework-based pilgrims and PMS-CVD19 framework based other users as shown in figures 1 and 2 respectively.

PMS-CVD19 architecture-based pilgrims constructs from the following components as shown in figure 1:

- 1) An IoT device which will either be a smart watch or wrist bracelet. It can be chosen according to pilgrim's preference whichever is convenient.
- 2) A smart portable device which will either be a mobile or tablet.
- 3) An application of pilgrimage management system (PMSApp) to be installed on the smart device.
- 4) Local database within the application of pilgrimage management system (PMS) will be linked to a cloud storage if it is required.
- 5) Global database stored and accessed via a cloud server. The cloud gives a real-time access to different kinds of data particularly health, location information in addition to logistical data. Such technology enables to share the data among all users' categories in order to ensure monitoring, interaction, and response.



Fig. 1. Architecture of Pilgrimage Management System based Pilgrims

While PMS-CVD19 architecture based other users (as shown in figure 2) includes numbers 2 and 3 from the above lists. However, cloud storage is required to control the cloud data used by pilgrims as well as all other users. Wearable device is not necessarily important for the other users. More details about our proposed framework will be described in the next section.

To facilitate overall functionality of PMS-CVD19 architecture, a set of technological requirements can be taken into consideration as follows:

1. **Bandwidth requirements:** An IoT device needs a low bandwidth (about ~10-40 kbps for every pilgrim) so that it can broadcast small data packet within every 5 to 10 seconds. The more pilgrims get connected; the more bandwidth should be added. Therefore, we have to use techniques for data compression as well as different strategies of network optimisation.
2. **Battery restrictions:** the used wearable devices are supposed to be working for about 30-50 hours on every full charge, so that to ensure continuous tracking and transmission smoothly. Therefore, such devices should have a low energy Bluetooth with high power efficiency. It is expected that users should charge their smart devices on a regular basis (i.e. daily). The minimal and optimal background power consumption should be selected.

3. **Latency tolerance:** low latency is important for tracking. To guarantee getting timely notifications and actions, the framework is designed to accept a latency of up to 2 seconds for IoT device to smart device communication, and less than 4 seconds for smart device to cloud synchronization.
4. **Frequency of data synchronization:** in order to get an energy efficiency with high performance, the framework is synchronized data to the cloud in two occasions. It could either be at periodically every 10-15 minutes or in a real time when a serious threshold is detected and should be alerted immediately.

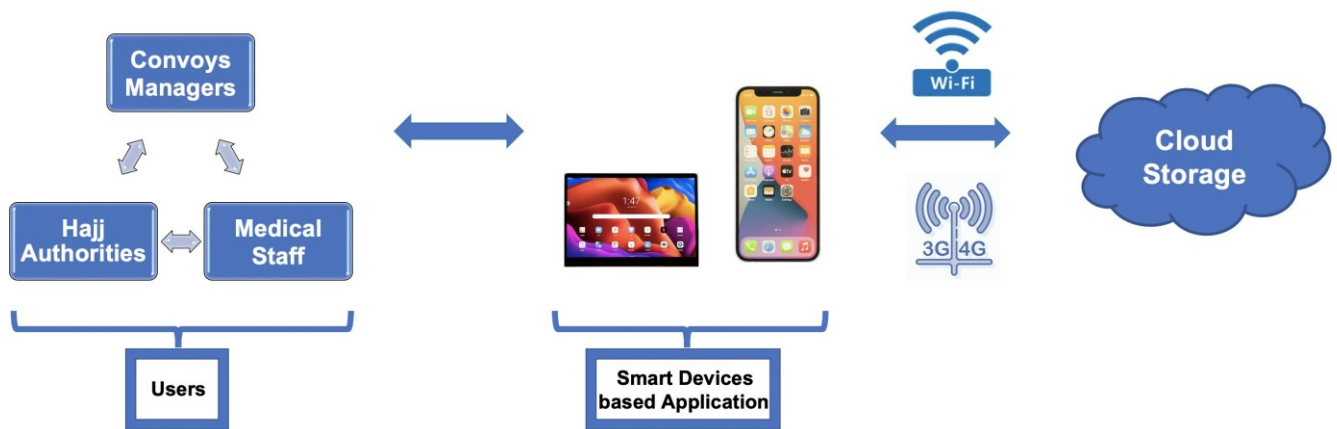


Fig. 2. Architecture of Pilgrimage Management System based on Other Three Users

These technological requirements are confirmed the feasibility and scalability of our framework to be deployed.

Due to the sensitive nature of acquired/collected data (such as geolocation and health related data) by the infrastructure of our framework, data protection mechanism is imperative. The framework has the following security features to ensure ethical compliance, confidentiality, and privacy.

- End to end encryption technique could protect the transmitted data from unauthorized or misused users' interception. These data could be transmitted from an IoT device to smart device or from the smart device to the cloud storage. They encrypted by the use of advanced industry protocols.
- Pilgrim data should be anonymized during the analysis and transmission steps to avoid pilgrim identification with any risk associated. This is an essential step which should be taken into consideration to ensure data protection regulations.
- Apply strict role based access control structure to ensure that only authorized users can access specific datasets. Multi factor authentication scheme adds extra level of protection for critical administrative accounts.
- All information collected from pilgrims are stored in cloud platform which follows global regulation standards. This platform has a mechanism of disaster recovery, data backup, and real time risk detection.
- According to the ethical standards of digital health technology, pilgrims have to give their consent for their data being collected by the framework. They should be fully aware of where they save their data and for how long, in addition to who can access them.

All-together, the above features enable framework to run hajj system in a safe and efficient management while considering international standards roles. These include Covid-19 and other health crises, in addition to pilgrims' data protection schemes.

3. CONTEXT-AWARE OF PILGRIMAGE MANAGEMENT SYSTEM FRAMEWORK

General overview of our proposed framework is consisted of four main components as follows:

- 1) Users: four user groups are involved within this framework. These are: pilgrims, convoy managers, authority people in Saudi Arabia, and medical staff.
- 2) Mobile application: it is developed for easy and quick communications between all four users. It is freely installed with many different languages as well as providing multiple services. Many applications have been approved by

Saudi ministry of health to control the spread of the coronavirus [12]. For example, Tawakkalna application was used to give people's permission to move during lockdown. Also, update them with infection status among different places [13]. While Sehha mobile application is developed mainly for electronic consultations via audio or video communication based user's convenient [14]. Combine important features given by these applications to make use of them when developing our mobile application.

- 3) Wearable devices: a set of wearable devices that can be linked via a Bluetooth to exchange information between pilgrims and other users (convoys managers, authorities and medical staff). Choose a wearable device from a set of available devices is personal preference. Pilgrims need to have a wearable device to record their activities, and these activities will be visible to other users where applicable and eligible. Only authorised users are allowed to look up for these activities with full protection of these data.
- 4) Data storage: It includes local and global databases with two communication controls. Local storage is concerned with pilgrims. It has general information as well as rules and instructions about hajj rituals. Also, a full guidance of how to use pilgrimage management system application. In short, this storage is more like a software booklet of pilgrimage that can be linked to a cloud storage when necessary. While global storage (cloud) involves communications with all users; convoys managers, medical staff, hajj authorities, and pilgrims.

The aim of our proposed framework including its four components is to distribute the tasks among all users, as well as provide them with different services. This will help to manage the whole hajj event in a flexible, simple, and convenient manner, instead of centralising it with staff of hajj authorities. The use of wearable technology, cloud computing as well as pilgrimage management system application are playing a vital role within this framework. As pilgrims are the majority among all users of this framework, they are primarily looked after by convoys campaigns through applying these technologies.

Despite the other users, pilgrims are given wrist or band wearable device to keep tracking their location, health, and any other needs. Hence, the framework is designed in context-aware model.

There is not a unique definition for context-awareness. However, in this research, it is based on the user of the application, in order to fulfil user's requirements. Hence, four classes of context-awareness are presented in our framework. These include the following:

- Context-aware based convoys: satisfy pilgrim's needs, track their locations (if they agreed) to get help at any time with any situation might happen.
- Context-aware based authorities: handle security issues, in addition to keep safe ground to ensure hajj is running smoothly and efficiently.
- Context-aware based medical staff: mitigate or prevent the transmission of infection diseases, as well as checking pilgrims' health by updating them if they have symptoms of Covid-19 or any other issues regarding their general health.
- Context-aware based pilgrims: respond to the signals received by the sensor of wearable device as well as make updates over the application via other users.

By capturing these contexts, our framework provides a set of adaptive services. These include the following scenarios:

- If a pilgrim gets lost, a convoy can detect the pilgrim's place based on the GPS sensor of the pilgrim's wearable device. Then, this signal would be sent to the convoy via the application. Also, the convoy will get a notification when a pilgrim is out of certain area that it should be during a particular date and time of the ritual.
- The sensor of wearable device will regularly check the health condition of pilgrims. If, for example, a pilgrim has a high temperature, low level of oxygen saturation, coughing many times, or other most common Covid-19 symptoms, the medical staff will get an alarm notification. They, in turn, would also inform the convoys as well as close contact pilgrims to take precautions from transmission the virus.
- Due to many rituals, pilgrims need to get served as quickly and easily as possible. A list of most interesting/ important places would be available by our framework. Such places include holy mosques, banks, malls, money exchanges, ATMs, and shopping centers. Once a pilgrim or convoy select one, a report/ message will be shown to them. This includes direction map, some necessary information about it, as well as the status of the traffic jam/ flow.
- Convoys could broadcast trends to keep pilgrims updated with latest news locally and globally. When pilgrims connect to the internet, they can share photos, videos, stories, as well as have a chat with family and friends. This will be through the use of pilgrims' application or upload pilgrims' stuff to the global cloud.

Having a context-aware framework in PMS-CVD19 will improve hajj event, as it satisfies users' needs where applicable. It, therefore, makes hajj rituals more flexible and adaptable. Further details will be discussed in the next section.

4. DISCUSSION

Our framework of PMS-CVD19 is designed as a context-aware model with its four main users. It is important to be aware with the context of every user in order to get served according to his/ her requirements at a time of requesting. Meanwhile, all users have their own responsibilities and obligations, so that they can achieve their designated goal. Moreover, protect them from a possible infection of Covid-19, as well as prevent the infected people from spreading the virus to others. Therefore, real time information is necessary to be collected and analysed, so that our framework can respond quickly to save lives and keep running the hajj smoothly. Hence, our PMS-CVD19 framework is based context-aware model.

Data coming from different sources are fused together (such as cloud and smart devices). As an example, through a specific ritual, IoT device's GPS data have a potential comparison with activity logs from the applications of smart device. Thus, the framework would be aware of prospective crowding places, or send an alert if a pilgrim breaches a pre-setting boundary within a ritual.

The implementation of our context-aware framework, however, has a set of challenges. These include the following: collecting and analysis of contextual information in real time during the pilgrimage which is extremely crowded and dynamic event. Technical complexity of upholding data integrity to reduce diagnostic errors of both false positive/negative errors. Applying strict security protocols to match the legal and ethical obligations so that to protect pilgrim's privacy. To address these challenges, a highly flexible and adaptive data analytics architecture is needed. Upon the success of our framework, it would offer a good experience to the international community to learn about the management of crowded events during such crisis.

As any digital system that cannot be perfect and optimal 100 percent, the framework has a set of limitations that should be considered. No guarantee for all pilgrims to adopt wearable devices due to, may be, cultural sensitivities, data privacy concerns, or limited skills of technology. Moreover, the nature of hajj is accommodated various languages and different levels of technology, in which the framework should be adapted with. Thereby adding further complexity to the overall framework design and usability. Consequently, some logical guidelines should be drawn to deal with similar pandemic. Although the framework has not yet fully deployed in practice to confirm its performance, its lightweight components can keep system awareness even when we have high user concurrency. The framework is designed with a feasible cost to help financial sustainability. It makes a balance between selecting affordable prices of wearable devices and existing communication and cloud infrastructure. Moreover, our framework is not only affordable, but it can also be modified according to the crisis's requirements. Nonetheless, framework's future deployment is required to estimate cost benefit assessment and systematic functioning benchmarking.

5. CONCLUSION

Hajj is the most respectable faith within the Muslim's festival season. An advanced and appropriate technology is important to be used to improve the hajj event. Considering the pandemic of Covid-19, and to keep on people's health, safety, and security. At this stage, we have proposed and designed a context-aware framework of PMS-CVD19. Before building and deploying this framework into the real-world, we will firstly test it with Umra, which is similar to Hajj event but with a smaller number of pilgrims. This is, in fact, to check how far it is acceptable and applicable. Also, we will set different interfaces for our framework prototype. Choose the one with the highest adoptable rates.

At further stage, we will evaluate our framework with previous and prospective pilgrims. This is to check how much it can be usable and acceptable. Moreover, we have a set of questionnaires in order to assess and analyse the framework. We will select different age groups that have different technological skills including those with no skills at all.

Later, we will expand the framework of hajj system to include any mass gathering event with a large population. Especially those events that stays for several days. This would include the visit to different holy places around the world, in addition to other crowded events such as sport or politics events. Moreover, logical guidelines can be drawn in organising such crowded events during the pandemic in particular.

Our framework would have some limitations. These include the following:

- Language barrier: how many languages that the application can be translated to. Also, what is the style of the selected languages should be built in.
- Technological competence: which wearable device would be more adoptable with a good quality in terms of sensor, battery life, light weight, price, etc. Also, which cloud provider could be chosen with how much capacity storage.
- Multi-age categories: how would the system be used by different age groups, should all use the same full system, or set a limited access to some parts of the system based pilgrim's age, technological skills or maturity. The maturity can be measured by answering a set of multiple choices questions. Children and younger ages would be more likely to get engaged with the system rather than be informative.

Conflicts of Interest

The authors declare no conflict of interest.

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