A Framework for Comprehensive Crowd and Hajj Management

Mishaal M. Almutairi
Deptt. of Electrical and Electronic Engg
School of Math., Comp. Sc. and Engg.
London, UK
mishaal.almutairi@city.ac.uk

Dimitra Apostolopoulou
Deptt. of Electrical and Electronic Engg
School of Math., Comp. Sc. and Engg.
London, UK
dimitra.apostolopoulou@city.ac.uk

George Halikias
Deptt. of Electrical and Electronic Engg
School of Math., Comp. Sc. and Engg.
London, UK
g.halikias@city.ac.uk

Adnan Ahmed Abi Sen
Deanship of Information Technology
Islamic University
Madinah, Saudi Arabia
adnanmnm@hotmail.com

Mohammad Yamin
Faculty of Economics and Administration
King Abdulaziz University
Jeddah, Saudi Arabia
myamin@kau.edu.sa

Abstract— Thousands of people have lost their lives due to the mismanagement of crowds leading to stampedes, fires, flooding and other preventable disasters. The aim of this paper is to propose a comprehensive framework for crowd management, which so far remains to be an underdeveloped practice in many countries. The proposed framework is designed to provide a comprehensive solution to all issues related to crowds with the help of the latest technologies including Wireless Sensor Networks (WSNs), Cloud and Fog Commuting, Internet of Things, Machine Learning, Digital Cities, and Radio Frequency Identification (RFID). The proposed framework is provided in the context of Hajj, an annual, intense and complex crowded event which takes place at Makkah (Mecca) in the Kingdom of Saudi Arabia. The proposed framework can easily be adapted to other crowded events like Kumbh, Arbaeen and sporting events.

Keywords— Crowd Management, Stampedes, Digital Cities, Machine Learning, RFID, IoT, Fog Computing

I. INTRODUCTION

The countries of the world are witnessing many events that require the gathering of thousands or millions of people in one place, such as religious, sporting, or even political events. Every government must provide security and safety of crowds from all possible risks, which is a complex matter related to various aspects and disciplines such as security, health, transportation, and others [1]-[3]. Indeed, the difficulty of crowd management is due to the number of people in the crowd and also due to the tools and methods used by governments to manage and organize these crowds. Unfortunately, there are a lot of events that have turned into disasters due to the inability to control and manage large crowds effectively [4], [5].

With the emergence of the COVID-19 pandemic, crowd management became more complex and more dangerous and unfortunately some governments did not take special measures to manage crowds taking COVID-19 into consideration, and this consequently was a cause of a health disaster. This prompted other governments to take strict measures and use modern crowd management technology to organize crowds, but they were forced to reduce the number of crowds dramatically to prevent any unforeseen problem [6], [7].

Kumbh, organized in Prayagraj, is a several-weeks long event that is not regulated by a permit and can be attended by anyone [8]. In 2021, it took place in the Uttrakhand province of India in which at least nine million people participated [8]. Unfortunately, COVID-19 restrictions were largely flouted in that event, and COVID-19 had killed tens of thousands of people [8].

Before COVID-19, three and a half million pilgrims were permitted to perform Hajj yearly from nearly two hundred countries. However, after the declaration of the COVID-19 pandemic, Hajj was permitted to have only ten thousand pilgrims from within the kingdom in 2020 [9], [10].

The COVID-19 pandemic has created a new challenge related to upholding measures for health and maintaining social distancing, which must be considered by crowd management [11]. This is very difficult with the increasing number of crowds, and it requires the integration of many modern methods and technologies in one framework to reach an effective solution that protects the lives of people within the crowd and proactively responds to any emergency event in order to avoid a disaster [12], [13].

This paper contributes by offering a comprehensive and smart crowd management framework (SCMF) that provides the integration of several layers and many new technologies, algorithms, and distributed services on these layers to provide safe and effective crowd management and organization. In this research, we will be content with designing the proposed framework and detailing its layers, components, functions, and their importance. In subsequent work, we intend to fully detail the proposed methods and algorithms, and then test the platform.

The rest of the parts of this paper are as follows: in section II we discuss some of the previous work in the field of crowd management; then in section III we discuss the proposed working platform, its layers, and main parts; and finally we mention the future direction and conclusion of study.

978-93-80544-44-1/22/$31.00 ©2022 IEEE

II. Related Work

Crowd management must ensure the security and safety of the people within it, in addition to housing, health, and transportation services [14]. Therefore, crowd management is a complex process linked to the specific context of each person within the crowd (time, place, and surrounding events). The social network of people within the crowd becomes larger through communication with their families, groups, organized management, vehicles, government services, and support institutions such as health and others. Thus, there is a huge exchange of data that in turn needs storage, analysis, and protection as well, which means crowd management faces many challenges. The research suggests taking advantage of the collaboration between Fog and Cloud in addition to smartphone apps to address some of these challenges.

Big data generated from crowds is a prime performance challenge, and causes what has been known a bottleneck in service providers or clouds and thus delay in response time, where the crowd may issue millions of requests at the same time and from the same place [15]. The research also promotes the idea of relying on fog computing to provide real-time response speed and reduce the load on the cloud. It also suggested the use of mobile devices as nodes to address some of the challenges of performance, bandwidth, and power consumption. The nodes were divided into two groups: the first one contains management and supervision nodes (Fog nodes) which dispatch contracts to other, and the second is monitoring nodes, which are collecting information, and reporting. The research also presented a simulation on the data of the Hajj season and guiding pilgrims. More information about the advantages of using Fog with Cloud is available in [16]. In [17], the researchers indicated the importance of analyzing crowd behavior, predicting the impact of the movement in certain conditions, and testing possible alternatives. To achieve this, the researchers presented the idea of building a simulator to manage this process and studied the method of crowd evacuation to a specific area in the event of an emergency.

In [18], a group of smartphone applications is presented that can play a helpful role in crowd management to increase the level of safety, especially in the event of a stampede and loss of crowd control. These applications provide a means of an early warning in the case of increasing congestion in a certain area or the occurrence of an event to prevent people moving to that area and preventing a disaster. In [19], an algorithm is proposed for crowd monitoring, proactive problem prediction and implementing smart monitoring via WSNs, RFID, smartphones, and location services. Then it processes collected data and presents it in the form of graphical models that show the state of the paths within the crowded area, and thus works on proactively distributing the load to different paths.

In [20], researchers suggested the use of drones in the crowd management process to reach remote or difficult-to-reach areas. In addition to their prime role of search and rescue operations, detecting the level of congestion, detecting accidents, or even the delivery of specific materials such as medical supplies to a specified place in the event of difficulty accessibility for medical, for example. The drones can also provide wide coverage of the area.

Crowd management becomes very complicated in emergency or disaster situations, and so does the ability of people and relief teams to coordinate with each other within a crowd [21]. The paper suggests relying on an algorithm to process data coming from social media to obtain information quickly from individuals, in addition to suggesting an application that could assign tasks to volunteers. The research also found that volunteers may have a major role in verifying the correctness of information such as temperature, number of people, traffic, and the percentage of congestion, or providing more accurate images of the location of the event. They can also perform quick tasks sent to them from the command center via the application. In [22], the researchers discussed the challenges of crowds and focused on the issue of privacy within crowds as an important challenge, and concluded that work must be done to provide effective ways to ensure data privacy for crowd participants and encourage them to cooperate with modern systems and technologies used in crowd organization and management. More information about privacy is presented in [23]-[25]. Researchers, in [26], suggested an algorithm that determines the percentage of congestion. The algorithm calculates the number of heads in a space periodically. If the percentage difference occurs suddenly, it means that an accident has occurred and must be dealt with while an alert to the crowds and the assistants' teams should be sent concurrently. In [27], researchers proposed a mechanism for rapid crowd alerts and routing control when an accident occurs by using the idea of a digital street that lights up in different colors to inform the crowd of places to avoid, in addition to distributing them to alternative paths. Finally, in [28], researchers suggested a smart mechanism based on fog and Internet of Things tools, an application that works on smartphones, to track people within the crowd and their purposes to solve the problem of getting lost in crowds.

Most of the previous solutions are good solutions but each of them only address a specific issue or challenge, nor do these solutions address the issue of interoperability between heterogeneous devices, technologies, or services [29], [30]. Finally, there is no effective solution for the issue of crowd management within pandemics like COVID-19. Thus, to achieve an efficient and integrated solution, we need a comprehensive framework that enables the integration and cooperation of different technologies, tools, and services together to create a more intelligent and adaptive crowd management solution in various circumstances and events.

III. Proposed Solution

Based on the previous discussion, managing crowds is a complex issue because it requires integrating between multiple domains and many services and technologies. Therefore, there is no one method, service, or application that can solve this issue completely. For that, we propose a comprehensive framework that depends on IoT structures, in addition to incorporating many new technologies and techniques (IoT, computing models, ML algorithm, smart phone applications, etc.). Moreover, the greatest concern is about the challenges of integration between different services and objects, which relate to security and privacy in addition to interoperability. For this, we added two components to manage that in our framework, as depicted in Figure 1.

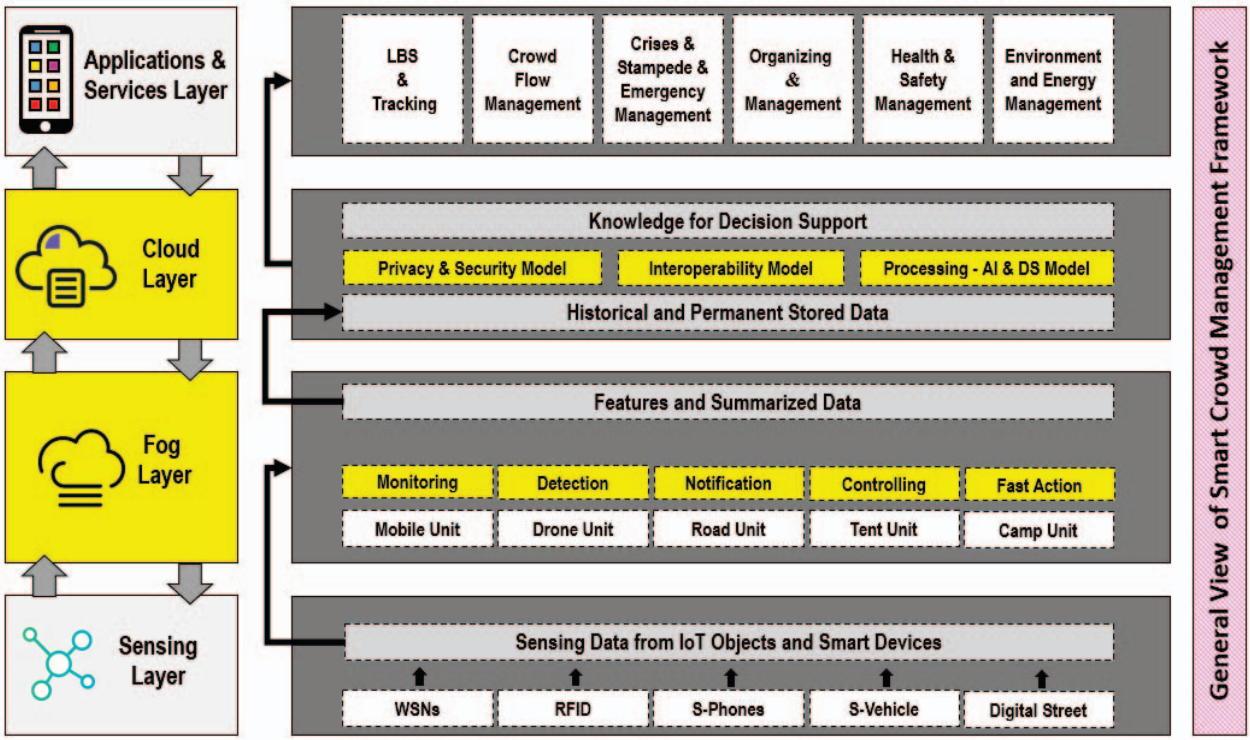

Fig. 1. Smart Crowd Management Framework (SCMF) – General View

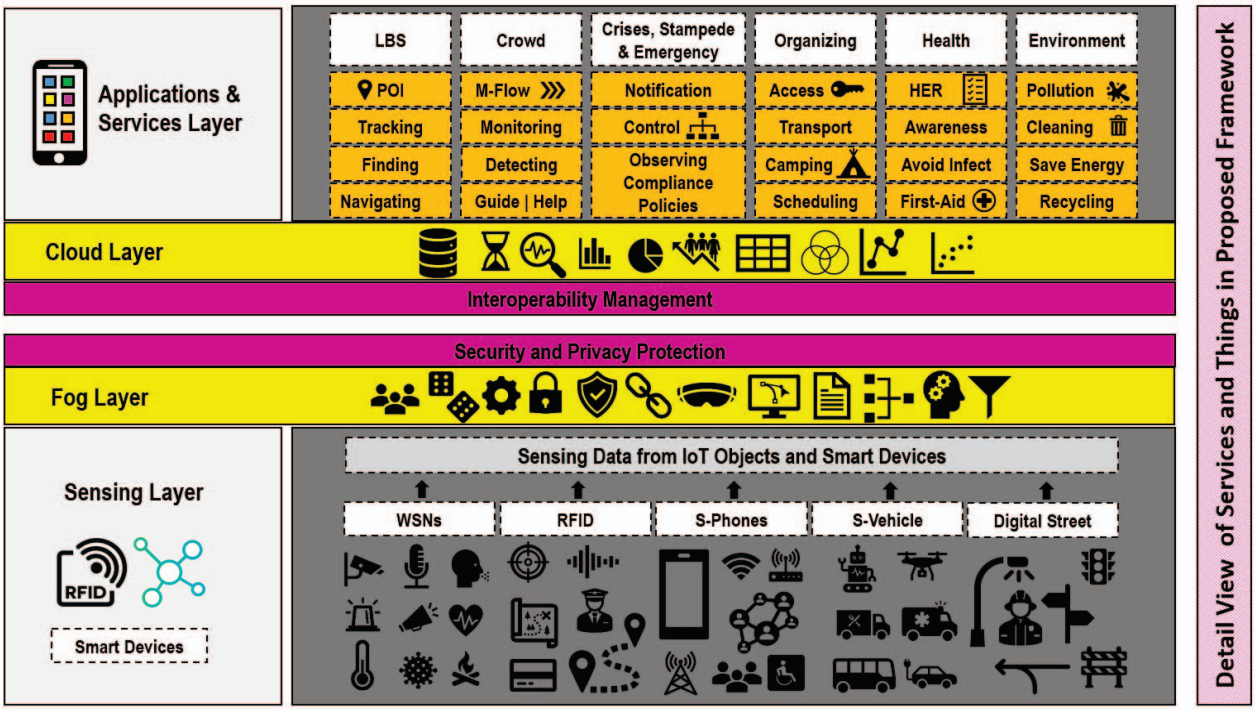

Fig. 2. Smart Crowd Management Framework (SCMF) – Details View

SCMF is divided into four main layers. Each layer has many objects, functions, and technologies, and they connect above and below one another. We provide a short description for each component in the framework (SCMF):

A. Sensing Layer

It uses different objects and technologies to collect data from users or environment like WSNs, RFID, S-Vehicle (i.e. Drones), Smart Phones and applications such as specific apps or social media, in addition to digital street which will

play an important role in controlling the flow of the crowd. More details about each possible thing in each type of sensing resource is presented in Figure 2.

B. Fog Layer

Fog node can be a Drone, a unit on the road or the mobile of a user itself. We must distribute a large number of these nodes to cover the whole area of a crowd, where each node will be responsible for a cluster of sensing objects. This will provide a faster response without delay. Moreover, fog nodes will provide many important services such as preprocessing data, analyzing data, monitoring signs, detecting events, applying policies on data for more security and privacy, and notifying users in sensing layer and guiding them. Then all summarized data will be sent to the cloud for more computing power and permanent storage.

C. Cloud Layer

It stores data and provides three important models: 1) Processing historical data to gain useful information from previous experiences by DS algorithms and its techniques. 2) Protecting privacy and a security model by the proposed approach on the data of users to prevent any potential attack. 3) To enable different services and devices to work together by providing an interoperability method for heterogeneous services and devices.

D. Application Layer

In this layer, we propose six main domains for important sub-systems that have a direct or indirect effect on the crowd management, namely LBS & Tracking, Flow Management, Crisis and Stampede & Emergency Management, Organization issues, Health & Safety, and Environment & Energy. Each sub-system has many important services to help us to achieve comprehensive and effective management for crowding issues. These services are mentioned in the Figure 2.

E. Main Applications and Proposed Services in SCMF

Following is the short description for main applications and services in SCMF.

1) LBS and Tracking

- POI: This service is to help users in the crowd to search for specific service centers, restaurants, police, or medical centers. This service will be provided in the proposed mobile application.
- Tracking: This is to track the location of users to get information about the crowd in each area or cell. The tools and scenario of applying this service will be provided.
- Finding: This service will be used to find lost things (language or person) in the crowd. It will be provided in the proposed mobile application.
- Navigating: This service will help users to select the best route to reach their distention in the crowd. We will provide this solution for the internal and external environment.

2) Crowd Flow

- Manage Flow: This service directs the crowd to flow in the specified way. Here, we need web application to put plan for the crowd flow by the time and location
- Monitoring: This service will monitor the flow of the crowd and confirm it is flowing continuously and smoothly without problems. A Smart algorithm will be provided to monitor the crowd flow by Image Processing and RFID.
- Detecting: This service will depend on previous images to detect any abnormal issues in the crowd and identify it. Smart Algorithm will be provided to detect any abnormal event in the crowd by Text mining through social media, notifying users within the crowd, and image processing.
- Guide: This service enhances the awareness of users in the crowd about the timing, places, activities, signs etc. related to the event. This service will be provided in the proposed mobile application.

3) Crisis, Stampede, and Emergency

- Notification: When any abnormal event is detected in the crowd, this service will notify users and admin via different methods to spread awareness or to apply the emergency rules. A new, different method will be provided to notify users in the crowd.
- Control: This service will send notifications to manage the crowd in abnormal situation like stampede or under special conditions like the COVID-19 crisis or any other emergency case. A new protocol will be provided to deal with crowd in the crisis case, in addition to a method to control flow after an abnormal situation to prevent any disaster from occurring.
- Observing Compliance Polices: this important service is for abnormal situations to confirm that all users are adhering to the rules to be safe and to avoid any disaster or issue. A new algorithm will be provided to auto monitoring the adherence of users in special situations.

4) Organizing

- Access Control: Prevents unauthorized user from entering any area or using any services. This will also control the maximum number of users and prevent random distribution We will provide a comparison between many different methods for physical access and presenting proof/authorization.
- Transport: Distributing users via vehicles like buses or metro, and determining the time of movement for each vehicle. Web service will be provided to manage trips, buses, metro, routes, etc.
- Camping: dividing users into groups and each group will be a cluster in the same camp. A web service for organizing and dividing users into groups for camping (case study: Hajj).
- Scheduling: organizing the periods of activities for each group to reduce the overload on any area or service. A Web service will be provided to manage the activities, timing, locations, etc.

5) Health and Safety

- EHR: An Electronic Health Record will be created for each user in the crowd to store their biometrics and predict any possible issue that may occur. A web application will be provided for comprehensive collection of health data with many of electronic services with depending on WSNs, RFID, Surveys, etc. will be provided.
- Awareness: This service will frequently send medical advice and alerts to users to mind their health in crowds. This is a service in the mobile application.
- Avoid Infection: Detecting and tracking infected users to prevent them from moving infecting others. An algorithm will be provided to detect and track infected user and notifying the expected infected to be careful. Another algorithm will be provided to monitor the precautionary rules applied and detecting violations.
- First Aid: This service deals with emergency cases and enabling the medical team or treatment to be available in the suitable place and time. A smart application enables users to help themselves in emergency cases. Smart tools enable the relief team to arrive quickly to the event location in the crowd.

6) Environment and Energy

- Pollution: Monitoring the conditions or environment of the crowd area, and notifying for any change in the regular ratios.
- Cleaning: This service finds a solution to preserve the environment and crowd area from waste. It suggests smart containers and a smart method to collect waste in crowd + Mobile Service.
- Saving Energy: Smart technology will be used here to reduce the usage of energy and also generating energy from the crowd movement (provide suggestions and ideas).
- Recycling: Auto filtering for waste of crowd must be applied for sustainability. There will be an algorithm for filtering waste in the crowd.

IV. Conclusion and Future Scope

This research sheds light on the most important challenges that face crowd management, especially in pandemics or emergency events. We then presented the idea of a comprehensive framework that provides cooperation between different tools, techniques, and solutions in the field of crowd management to create a more efficient solution capable of controlling crowds more effectively and efficiently, whilst also preventing emergency events from turning into disasters. The research also classified many prime disciplines, applications, and services that must be available in the proposed framework to ensure the creation of an integrated and comprehensive smart solution. In the subsequent work, we will investigate and test the proposed framework on actual data. Detailed solutions to the interoperability problem will be provided, and finally, solutions to the issue of data privacy for crowd participants will be addressed.

References

[1] H. Hassanein, N. Zorba, S. Han, S. S. Kanhere, and M. Shukair, "Crowd Management," IEEE Communications Magazine, vol. 57, no. 4, pp. 18–19, Apr. 2019, doi: 10.1109/mcom.2019.8703458.

[2] D. Sharma, A. P. Bhondekar, A. K. Shukla, and C. Ghanshyam, "A review on technological advancements in crowd management," Journal of Ambient Intelligence and Humanized Computing, vol. 9, no. 3, pp. 485–495, Nov. 2016, doi: 10.1007/s12652-016-0432-x.

[3] N. Wijermans, C. Conrado, M. van Steen, C. Martella, and J. Li, "A landscape of crowd-management support: An integrative approach," Safety Science, vol. 86, pp. 142–164, Jul. 2016, doi: 10.1016/j.ssci.2016.02.027.

[4] M. Yamin, "Health management in crowded events: Hajj and Kumbh." BVICA M's International Journal of Information Technology, vol. 7, 2015.

[5] M. M. Almutairi, M. Yamin, G. Halikias, and A. A. A Sen, "A Framework for Crowd Management during COVID-19 with Artificial Intelligence," Sustainability, vol. 14, no. 1, p. 303, Dec. 2021, doi: 10.3390/su14010303.

[6] E. Felemban et al., "Digital Revolution for Hajj Crowd Management: A Technology Survey," IEEE Access, pp. 1–1, 2020, doi: 10.1109/access.2020.3037396.

[7] Z. Fadlullah, M. M. Fouda, A.-S. K. Pathan, N. Nasser, A. Benslimane, and Y.-D. Lin, "Smart IoT Solutions for Combating the COVID-19 Pandemic," IEEE Internet of Things Magazine, vol. 3, no. 3, pp. 10–11, Sep. 2020, doi: 10.1109/miot.2020.9241464.

[8] S. Abouchacra, M. Yaman, and S. Chandrasekhar Nair, "Lessons Learned from the COVID-19 Pandemic," Applied Clinical Research, Clinical Trials and Regulatory Affairs, vol. 07, Sep. 2020, doi: 10.2174/2213476x07999200918180556.

[9] "Over 1,700 Test COVID-19 Positive At Haridwar Kumbh Over 5 Days: Official," NDTV.com. https://www.ndtv.com/india-news/over-1-700-test-covid-19-positive-at-haridwar-kumbh-over-5-days-official-2414270. [Accessed: Feb. 01, 2022].

[10] "Saudi Says Only 'Immunised' Pilgrims Allowed In Mecca During Ramadan," NDTV.com. https://www.ndtv.com/world-news/saudi-says-only-immunised-people-to-be-allowed-in-mecca-during-ramadan-2407018. [Accessed: Feb. 01, 2022].

[11] A. Kalebi, "Pilgrimage in a pandemic: lessons from Mecca on containing COVID-19," The Conversation. https://theconversation.com/pilgrimage-in-a-pandemic-lessons-from-mecca-on-containing-covid-19-160043. [Accessed: Jan. 11, 2022].

[12] C. A. S. Pouw, F. Toschi, F. van Schadewijk, and A. Corbetta, "Monitoring physical distancing for crowd management: Real-time trajectory and group analysis," PLOS ONE, vol. 15, no. 10, p. e0240963, Oct. 2020, doi: 10.1371/journal.pone.0240963.

[13] S. Kadi, A. Abdullah, and S. Bachok, "The Evaluation of Pedestrian Facilities on Hajj Crowd between Arafat and Muzdalifah Pedestrian Street," Planning Malaysia, vol. 19, Dec. 2021, doi: 10.21837/pm.v19i19.1069.

[14] M. F. Mohamed, A. E.-R. Shabayek, and M. El-Gayyar, "IoT-Based Framework for Crowd Management," Mobile Solutions and Their Usefulness in Everyday Life, pp. 47–61, Dec. 2018, doi: 10.1007/978-3-319-93491-4_3.

[15] A. Rahman, E. Hassanain, and M. S. Hossain, "Towards a Secure Mobile Edge Computing Framework for Hajj," IEEE Access, vol. 5, pp. 11768–11781, 2017, doi: 10.1109/access.2017.2716782.

[16] S. Alraddady, A. S. Li, B. Soh, and M. Alzain, "Deployment of Fog Computing During Hajj Season: A Proposed Framework," Procedia Computer Science, vol. 161, pp. 1072–1079, 2019, doi: 10.1016/j.procs.2019.11.218.

[17] A. A. A. Sen and M. Yamin, "Advantages of using fog in IoT applications," International Journal of Information Technology, Oct. 2020, doi: 10.1007/s41870-020-00514-9.

[18] S. Wang and G. Wainer, "A simulation as a service methodology with application for crowd modeling, simulation and visualization," SIMULATION, vol. 91, no. 1, pp. 71–95, Dec. 2014, doi: 10.1177/0037549714562994.

[19] W. M. Shalash, A. A. Hazimi, and B. A. Zahrani, "A Mobile Based Crowd Management System," IJARCCE, vol. 6, no. 6, pp. 205–215, Jun. 2017, doi: 10.17148/ijarcce.2017.6638.

[20] N. Nasser, M. Anan, M. F. C. Awad, H. Bin-Abbas and L. Karim, "An expert crowd monitoring and management framework for Hajj," 2017 International Conference on Wireless Networks and Mobile Communications (WINCOM), 2017, pp. 1-8, doi: 10.1109/WINCOM. 2017.8238202.

[21] E. Felemban, A. A. Sheikh, and A. Naseer, “Improving Response Time for Crowd Management in Hajj,” Computers, vol. 10, no. 4, p. 46, Apr. 2021, doi: 10.3390/computers10040046.

[22] T. Ludwig, C. Reuter, T. Siebigteroth, and V. Pipek, “CrowdMonitor,” Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI ’15, 2015, doi: 10.1145/2702123. 2702265.

[23] Santana, Juan Ramon, et al. "A privacy-aware crowd management system for smart cities and smart buildings." IEEE Access 8 (2020): 135394-135405.

[24] M. Yamin, Y. Alsaawy, A. B. Alkhodre, and A. A. Abi Sen, “An Innovative Method for Preserving Privacy in Internet of Things,” Sensors, vol. 19, no. 15, p. 3355, Jul. 2019, doi: 10.3390/s19153355.

[25] A. A. A. Sen, F. A. Eassa, K. Jambi, and M. Yamin, “Preserving privacy in internet of things: a survey,” International Journal of Information Technology, vol. 10, no. 2, pp. 189–200, Feb. 2018, doi: 10.1007/s41870-018-0113-4.

[26] M. Yamin and A. A. Abi Sen, "A New Method With Swapping of Peers and Fogs to Protect User Privacy in IoT Applications," in IEEE Access, vol. 8, pp. 210206-210224, 2020, doi: 10.1109/ACCESS.2020.3038825.

[27] M. Yamin, A. M. Basahel, and A. A. Abi Sen, “Managing Crowds with Wireless and Mobile Technologies,” Wireless Communications and Mobile Computing, vol. 2018, pp. 1–15, Aug. 2018, doi: 10.1155/2018/7361597.

[28] A. A. A. Sen, Y. Alsaawy, A. Alkhodre, N. M. Bahbouh and M. Alhaboob, "Smart Street Design for Managing Crowds in Hajj," 2021 8th International Conference on Computing for Sustainable Global Development (INDIACom), 2021, pp. 385-389, doi: 10.1109/INDIACom51348.2021.00067.

[29] A. M. Alsubhy, A. A. Abi Sen, B. A. Alahmadi, N. M. Bahbouh and H. A. Abi Sen, "A Model for Tracking People and Property in Crowds," 2020 7th International Conference on Computing for Sustainable Global Development (INDIACom), 2020, pp. 244-248, doi: 10.23919/INDIACom49435.2020.9083705.

[30] M. Yamin and Y. Ades, "Crowd Management with RFID and Wireless Technologies," 2009 First International Conference on Networks & Communications, 2009, pp. 439-442, doi: 10.1109/NetCoM.2009.14.