Towards Smart Camps in Mina Holy Place: Exploiting IoT Technologies

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تطبيق مفهوم المخيم الذكي بمشعر منى باستخدام تكنولوجيا انترنت الاشياء

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ملخص البحث (Abstract):

حظي مفهوم المباني الذكية باهتمام متزايد خلال العقد الماضي، حيث تم تطوير العديد من التقنيات الذكية خلال تلك الحقبة. كما أخذت العديد من المنظمات البحثية مسؤولية وضع تعريف للمبنى الذكي ، أو في دراستنا "المخيم الذكي". قد يركز أحد التعريفات على منظور الأداء (الإدارة الفعالة للموارد ، راحة المستخدم، القدرة على التكيف بسرعة مع الاحتياجات المتغيرة للمستخدمين، وتقليل التكاليف). وهناك منظور آخر يراعي وجهة النظر التكنولوجية (أتمتة المبنى، الاتصالات، السلامة، والراحة، الخ). وبشكل عام، يجب أن ينظر إلى المخيم الذكي من وجهة نظر متعددة المنظور، بما في ذلك الجمع الصحيح بين الهندسة المعمارية وتكنولوجيا المعلومات والأتمتة والبيئة والطاقة والخدمات وإدارة المرافق، بالإضافة إلى الاهتمام بالراحة والرفاهية، والتكيف المناسب مع الاحتياجات الثقافية.

يصف مصطلح "إنترنت الأشياء" نظامًا يرتبط فيه العالم الرقمي بالعالم المادي الذي يشكل شبكة عالمية. تستخدم تكنولوجيا إنترنت الأشياء أجهزة الاستشعار وتقنية نقل البيانات المدمجة في الأجهزة والمعدات (على سبيل المثال في حالة المخيم الذكي: الأبواب،وحدات التهوية،وحدات التدفئة/التبريد، وحدات الإضاءة، أنظمة المياه، أنظمة الطاقة الكهربائية، أنظمة الاتصالات، وما إلى ذلك). يتيح ذلك تنسيق الكائنات والتحكم فيها عبر شبكة بيانات (إنترنت) بهدف توفير قيمة مضافة للمستخدم (ساكن المخيم).

تعرض هذه الدراسة مفهوم المخيم الذكي باستخدام تكنولوجيا إنترنت الأشياء. ويناقش كيفية التحكم في وظائف وحالة المخيم بشكل تلقائي وذكي باستخدام أجهزة الاستشعار المتصلة باستخدام تكنولوجيا إنترنت الأشياء لمراقبة حالة المخيم (مثل درجة الحرارة، الرطوبة، مستشعرات الغازات والأدخنة، مستشعرات الضوء، وما إلى ذلك). توفر تلك المستشعرات البيانات الضرورية المطلوبة للتحكم في مستوى الراحة بالمخيم تلقائيًا وتحسين استخدامية الموارد المتاحة (مثل الطاقة والماء)، بالإضافة إلى تأمين المخيم والحفاظ على أمان المقيمين فيه.

Smart buildings have received increasing interest over the last decade, as various smart technologies have been developed. Various research organizations took the responsibility to define smart building, or in our case smart camp. One definition might focus on the performance perspective (efficient management of resources, user comfort, capability to adapt quickly to changing needs of users, and minimization of costs). Another perspective considers the technological point of view (building automation, communication automation, safety, and convenience). In general, smart camp should be seen from a multi-perspective view point, involving the right combination of architecture, information

technology, automation, environment and energy, services and facility management, in addition to comfort maximizing and proper adaption to cultural needs.

IoT (Internet of Things) exploits sensors, actuators, and data communication technology embedded into physical objects. (e.g., in the case of a smart camp, heating/cooling modules, lighting modules ventilation modules, etc.) to enable objects to be coordinated and controlled across a data network (internet) with the goal of creating value to the user.

This study presents the concept of smart camp using IoT. It discusses how to automatically and smartly control various functions and conditions of the camp by using IoT connected sensors for monitoring the camp status (e.g., temperature, humidity, smoke, light, etc.). These sensors provide necessary data that is required to automatically adjust the comfort level of the camp and optimize the available resources (energy and water) usage, in addition to keeping the camp-site safe and secure.

1. Introduction

Millions of Muslims visit Makkah and Madinah to perform Hajj, Umrah, and Ziyarah every year. Several development projects that include renovation and construction of infrastructure, roads, housing, and public transportation are carried out in the two holy cities [1].

Various research organizations took the responsibility to define smart building, or in our case smart camp. One definition might focus on the performance perspective (efficient management of resources, user comfort, capability to adapt quickly to changing needs of users, and minimization of costs). Another perspective considers the technological point of view (building automation, communication automation, safety, and convenience). In general, smart camps should be studied from a multi-perspective view point, including the right combination of architecture, information technology, in addition to comfort maximizing and proper adaption to cultural needs [2].

IoT exploits sensors, actuators, and data communication technology embedded into physical objects (e.g. in the case of smart camps: doors, ventilation modules, heating/cooling modules, lighting modules, water systems, electrical power systems, communication systems, etc.). This enables objects to be coordinated and controlled across a data network (internet) with the goal of creating value to the user [2].

As the electronic processors and sensors that enable IoT have become smaller and less costly, it has become easier to equip devices with computing and communication capabilities that dramatically enhance their usefulness and efficiency. A device that is IoT-enabled is often referred to as a "smart" device, as its connection to networks (or the Internet) offers additional capabilities and functionality. The additional capabilities and functions may include tracking (monitoring), analyzing, and correlating data generated by smart devices. With IoT, these devices can communicate on a larger scale and process information that has never been captured before and, in some cases, respond automatically to improve processes and services [3].

Recent advances in IoT technologies have accelerated their adoption. Advances in such technologies include:

Small inexpensive electronics: The cost and size of electronics, for example smartphones, are decreasing, making it easier for the electronics to be embedded into objects, enabling them as IoT devices [3].

Increasing connectivity: The expansion of networks and decreasing costs allow for easier connectivity. Networking allows for IoT devices to be easily accessible and connected almost anywhere. The adoption of smartphones has also accelerated connectivity, as smartphones can connect to multiple types of networks, such as Wi-Fi, cellular, and bluetooth [3].

Cloud computing: Since IoT devices can produce a large amount of data, it requires large amounts of computing power to analyze the captured data. Cloud computing is one way to obtain this computing power [3].

Data analytics: Advances in data analytics have allowed for the efficient analysis of the rapidly increasing amounts of data created by IoT devices. For example, an algorithm can use data of traffic and road conditions to provide alerts and suggesttions of alternative routes [3]. This allows extracting valuable information from the data collected by IoT devices.

However, among the most important challenges that IoT-based technologies will face is poor networking infrastructure, privacy and security problems, short battery life, and lack of standards.

The objective of this paper is to present the concept of smart camp using IoT. It discusses how to automatically and smartly control various functions and conditions of Mina camps and optimize the available resources (energy and water) usage, in addition to keeping the camp-site safe and secure. The paper is organized as follows. Section 2 discusses the background of IoT-based technology along with its uses and system architectur. In Section 3, the proposed IoT-based solutions for Mina Camps are presented. Section 4 discusses an implementation of a case study, along with experimental results. Finally, Section 5 concludes with final remarks.

2. Background

2.1 Related Research

IoT devices are connected to a network so that they work together to provide a specific service. This can be useful in many applications and services like smart buildings, where some sensors collect data, while other devices use it for taking actions [4].

IoT can be applied to create extremely large-scale solutions like smart cities consisting of thousands of sensors and devices [4].

Smart buildings are more private IoT networks at a smaller scale. They are gaining popularity because sensors, microcontrollers, and microcomputers are available at low costs.

Smart buildings can be defined as buildings equipped with automation systems that consist of various sensors and devices used for improving the comfort for residents. Smart buildings are often connected with mobile applications, thus taking the advantage of modern smartphones and tablets. In this way, monitoring data can be easily accessed from any place with an Internet connection [4].

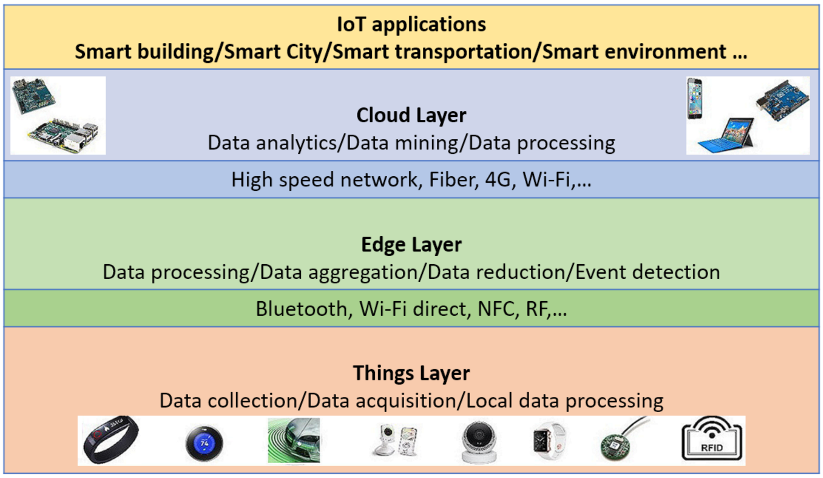
In [5], an architectural model was proposed in which various sensors are connected to a hardware board that wirelessly transmits data to a central node. The received data is sent to a web server and a database server that are deployed locally or in the cloud. The architect of IoT solutions can choose different platforms for end-users. The most common ones are smartphones and tablets; however, these are not the only options. Smart TVs can also be used as devices for displaying the sensor originating information in real time [4].

2.2 System Architecture of IoT

IoT is a system that interconnects a set of IoT devices, where a large volume of data can be collected and transferred. Based on the analysis of the collected data, IoT targets building a smart world. A three-layer architecture of IoT systems is shown in Fig. 1. The three layers are cloud layer, edge layer, and things layer. On top of these layers, IoT applications are run. In each layer, data can be collected, processed, and analyzed. A two-way communication is usually supported among layers [6].

The things layer contains a large number of things including sensors and devices. The cloud and the things are connected, but they usually have no direct communication channels. Therefore, cloud is not an optimal choice to support IoT applications that have features such as high real-time requirements or high mobility.

The edge layer is proposed to make a good contact between the resource-constrained things layer and the resource-rich cloud layer [6].



2.3 General Uses and Benefits of IoT Technologies

IoT devices are used across multiple sectors and can be used in almost any circumstance in which human activites or machine functions can be enhanced by data collection or automation [3].

IoT have three main users; consumers, service providers, and the public sector. Consumers can use IoT devices to collect personal information for monitoring and automation uses. On the other hand, service providers can use IoT to optimize processes and cost savings [7,8,9]. Public sector entities can use IoT to address concerns such as environment conditions [3]. Different IoT-based uses are discussed as follows:

Smart buildings: IoT-based technologies can be used in buildings for efficient use of resources and energy allocation, in addition to other usages. By analyzing occupancy patterns, smart thermostats can conserve energy by turning the heating and cooling on or off. Also, sensors can detect when an area is unoccupied and automatically adjust the heating, cooling, and lights to reduce energy use. IoT devices are also used for security, by using security cameras that can automatically detect possible intrusions and alert authorities [3].

Supply chain: IoT devices can allow suppliers (for example, food suppliers) to detect distribution bottlenecks and improve supply management by reducing labor costs. IoT devices can also enable suppliers to determine amounts of available products, giving them information they need to improve their restocking program [3].

Health care: IoT devices, in health care sectors, can use data to improve patient quality of life and safety by enabling patients to monitor their health. Using IoT for transmitting health information to a medical facility can be particularly beneficial to individuals in congested or rural areas. Health care providers can detect a patient's location, as well as receive alerts if the patient has a critical condition.

Environment: IoT devices can monitor the environmental condition for assessing air quality. Sensors can be distributed around an area to collect information about air quality to provide real-time data. The results can be used to inform people who experience health effects due to poor air quality. IoT devices have also helped in monitoring the environment for potential natural disasters.

Smart communities: IoT devices can be used to improve livability, management, and services delivered to resedents. For example, IoT technologies can provide real time data about the status of the waste management systems, where sensors are used to determine if waste bins are full and, hence, waste collection crews only collect full containers.

3. Proposed Integrated IoT-based Solutions for Mina Camps

IoT exploits sensors, actuators, and data communication technology embedded into physical objects (e.g., in the case of a smart camp, heating/cooling modules, lighting modules, ventilation modules, etc.) to enable objects to be coordinated and controlled across a data network (internet) with the goal of creating value to the users (the camp residents).

This study focuses on the concept of smart camps using IoT and how to, automatically and smartly, control various functions and conditions of the camp by using IoT connected sensors for monitoring the camp status (e.g., temperature, humidity, smoke, light, etc.). These sensors provide necessary data that is required to automatically adjust the comfort level of the camp and optimize the available resources (energy and water) usage, in addition to keeping the camp-site safe and secure.

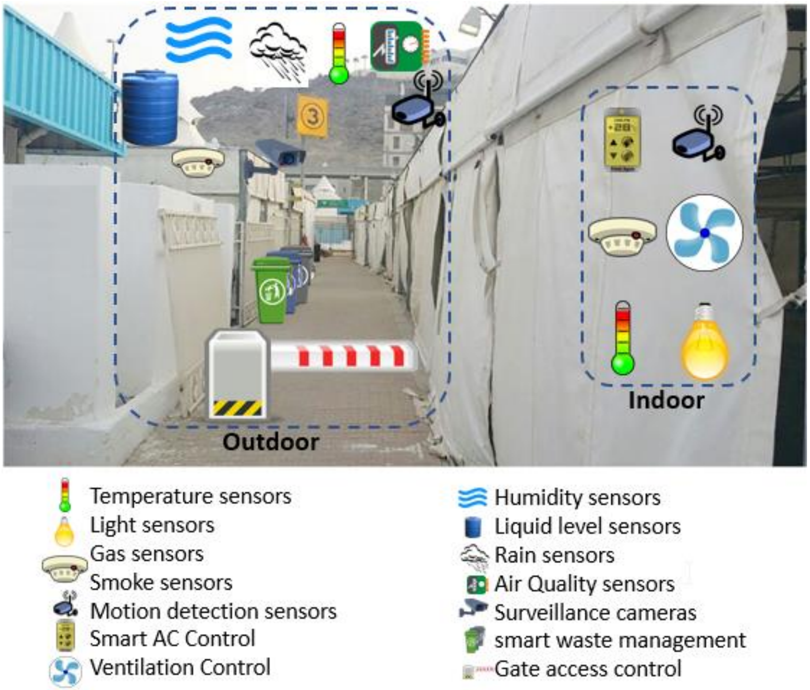


Fig. 2: Different uses of IoT-based technologies in Mina camps (indoor and outdoor).

The proposed solution enables several features through IoT-based technologies within camps.

Examples of these features are:

- Smart air condisioning control (heating, ventilation, and air conditioning (HVAC)) through the captured data from motion sensors, temprature sensors, and humidty sensors.
- Lighting system control (economical use of lights) by using light sensors, motion detection sensors, and surveillance cameras.
- Samrt air quality control through the captured data from smoke sensors, rain sensors, temprature sensors, and humidty sensors.
- Automatic notification (sms) to call civil defence offices if some gases are above certain levels by using gas sensors (Co/H_2S/...).
- Automatic notification (sms) to refill water tanks when empty (or below a certain level) by using liquid level sensors.
- Smart waste management: a smart recycling bin could sort waste automaticly. It's sometimes difficult to know where to put different types of plastic, but computer vision could help. Also, fill level monitoring system for bins could reduce the number of unnecessary empties per day to save time and money.
- Samrt camp security through utilizing gates access control, surveillance cameras, and RFID.

Another proposal that utilizes IoT-based technologies in Mina community (outdoor) is shown in Fig. 3. The proposed solution enables several features through IoT-based technologies in the surronding community (roads, sidewalks, areas, etc.). Examples of these features are:

- Smart streetlights: Sensors detect sound or motion, and lights are programmed to turn on and off or raise dimmed lighting level according to pedestrians/vehicles detection to control energy consumption.
- Surveillance cameras: Cameras detect in real-time potential public safety issues and alert officers.
- Traffic signal priority: Sensors detect approaching buses and grant them priority of passage.
- Smart traffic lights: Sensors collect and evaluate real-time information to update traffic signal timing.
- Connected vehicles: Vehicles (buses) communicate with each other and with the infrastructure, which provides the capability to identify hazards on roads and allow receiving alerts.
- Smart guidance boards: Real-time directions and announcements can be displayed on smart guidance boards based on the collected data from street sensors.
- Air-quality sensors: Sensors collect and transmit air quality data that can help identify public or environmental health risks.
- Using IoT devices across multiple sectors by, for example, combining IoT data from traffic cameras, sensors on roads, in cars, and buses, can be combined with weather reports to optimize traffic flow.

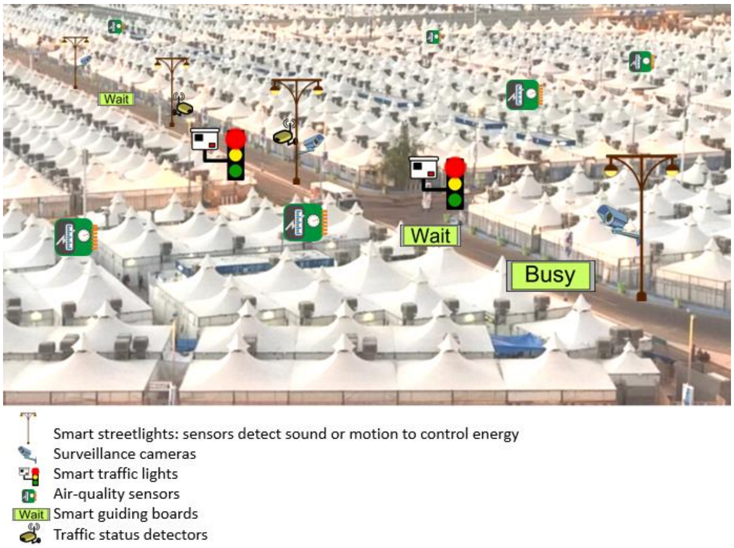


Fig. 3: Different uses of IoT-based technologies in Mina community (outdoor).

4. Implementation and Experimental Results

In this section, the technology, methods and devices that were used to implement the IoT based solution is presented. In addition, an implementation of a case study is discussed.

Sensors are used for data collection by connecting them to microcomputer boards. Such microcomputers integrate and transmit the data to a cloud server. For data visualization, smart phones are used.

The used devices and general architecture of the solution is shown in Fig. 4.

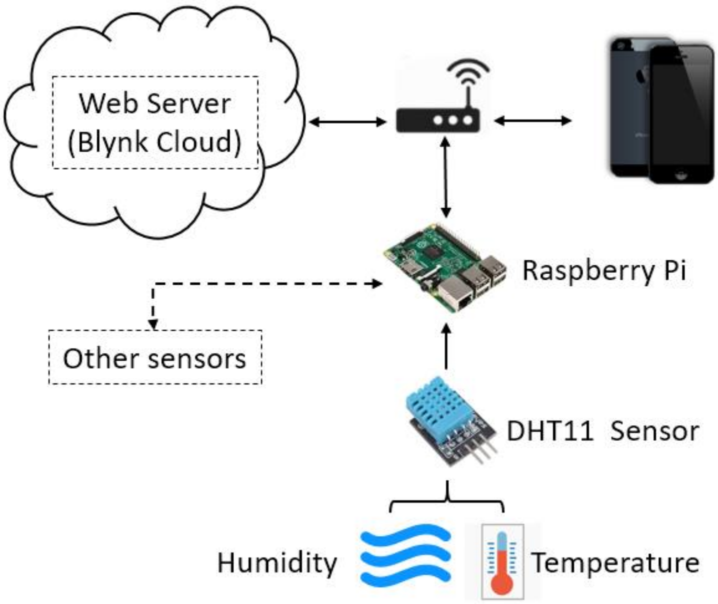
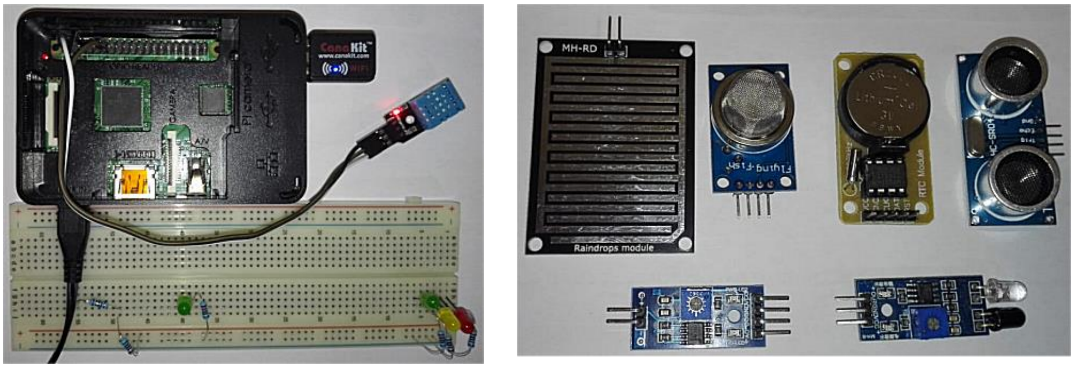


Fig. 4: The IoT Architecture used in the case study.

The main elements of the proposed architecture are as follows:

- Cloud-Based Server: The central node of the proposed IoT solution is deployed in Blynk Server[1]. Blynk is a platform for controlling hardware over the Internet. It can control hardware remotely and store (or visualize) sensor data. Blynk Server (Blynk Cloud) is responsible for communications between the smartphone and hardware (Raspberry Pi in our case).
- Sensors: DHT11 sensor is used for temperature and humidity measurements. The small size of the sensor ensures low power consumption and long distance signal transmission. Sensor measurement range for humidity is 20–90 % RH (accuracy ±5 % RH) and for temperature 0–50 (accuracy ±2). The required power supply is 3–5.5 V DC. Other sensor types can be used, for example: light sensors, motion sensors, smoke sensors, etc. Fig. 5-a illustrates the wiring of the hardware board and the used sensors, while Fig. 5-b shows examples of sensors.
- Microcomputer Board: Microcomputer Raspberry Pi is used for collecting data from sensors and transmits them over Wi-Fi to the cloud node (Blynk Server). Raspberry Pi is a single-board computer created by the Raspberry Pi Foundation[2]. The key features of the used board is 900 MHz quad-core ARM Cortex-A7 CPU, 1 GB RAM, 4 USB ports, 40 GPIO pins, full HDMI port, and Ethernet port.



(a) **(b)**

Fig. 5: (a) wiring of the hardware board and the used sensors, (b) examples of sensors.

Hardware boards and sensors can be placed in any location with a Wi-Fi connection. The devices can be powered from a standard USB cable or a portable power bank, so it is possible to collect data in places with no power sources.

A Python based program is used for implementing the data processing and transmission logic.

An Android (or iOS) smart phone is used for data visualization and allows interaction with the IoT application. The connected smart phone is supplied with real-time sensor data updates from the cloud-based node.

An excerpt from Raspberry's Python based sensor data collection program and an example of the collected data is shown in Fig. 6-a. The user-interface of the program is shown in Fig. 6-b, which shows real-time graphical representation of the acquired data (temperature and humidity).

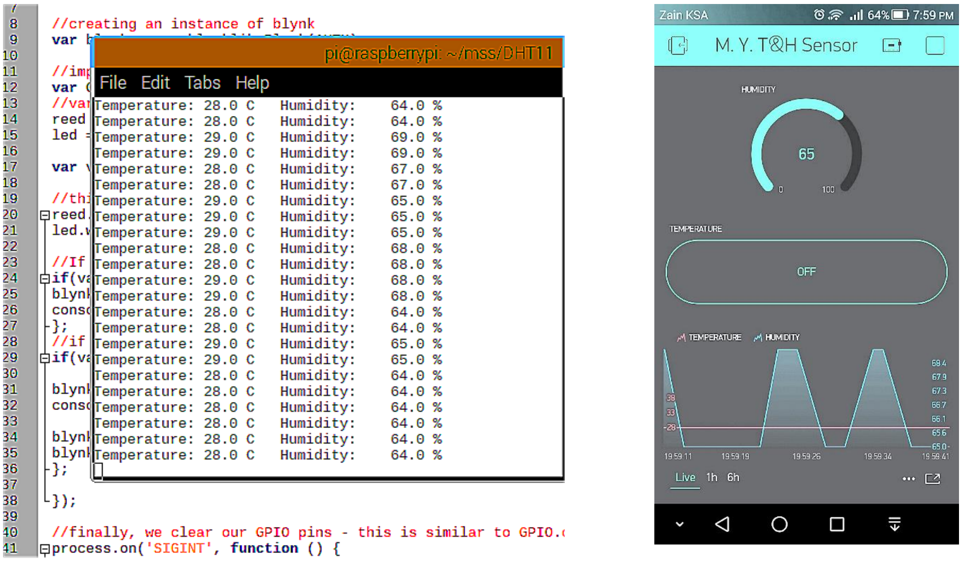
[1] https://www.blynk.cc/

[2] https://www.raspberrypi.org/

5. Conclusions:

In this paper, the concept of smart camps using IoT has been presented. Methods of automatic and smart controlling of functions and conditions of Mina camps by using IoT connected sensors for monitoring the camp status (e.g., temperature, humidity, smoke, light, etc.) have been discussed. These sensors provide necessary data that is required to automatically adjust the comfort level of the camp and optimize the available resources (energy and water) usage, in addition to keeping the camp-site safe and secure.

Two different proposed integrated IoT-based solutions that are suitable for Mina camps have been presented. Moreover, the technology and devices that were used to implement the IoT based solution is presented. In addition, an implementation of a case study, along with experimental results, were presented. Experimental results showed that the implemented case study was successful in capturing sensors data, while a smart phone was used successfully for remote real-time data visualization. More sensors can be utilized to get more services and capabilities.



(a) **(b)**

Fig. 6: (a) An excerpt from Raspberry's Python program and an example of the collected data, (b) The smart phone user-interface of the program.

6. Recommendations:

As the concept of smart cities has gained increasing attention over the last decade, the use of Internet applications in serving the guests of Al-Rahman has gain a higher priority.

In Mena holy place, the concept of smart camp can be extended by the proper use of IoT technologies. This is achieved by controlling the functions and condition of the camp automatically and intelligently through monitoring the camp state using sensors.

In addition, it is possible to remotely track masses of pilgrims, traffic congestion levels, road conditions, and environmental conditions to get solutions, that support decision makers, by processing such data with artificial intelligence techniques.

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