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Smart Refrigerator for Healthcare Based on IoT

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Abstract— Due to extended family obligations and the demands of a fast-paced work life, remote house administration and monitoring are necessary. The refrigerator is one of the most important devices to monitor and with advancements in technology, remote-controlled refrigerators are becoming more affordable and accessible to the general public. These refrigerators offer convenience and efficiency by allowing users to monitor their fridges from anywhere using a smartphone, but it is still expensive to a lot of people. A clever and cost-effective working model is being presented with the addition of a system consisting of Arduino and a number of sensors that perform some surveillance functions. The system is linked to the Net to send readings to the Firebase database. A special telephone application linked to the Firebase database is designed, and changes are received. The Firebase database makes it unnecessary for the application to recheck data at regular intervals. The feature of expiry time has been added to the application to avoid the cost used in the bar code and then the user's notice of its expiration date by the firebase.

Keywords— Smart Home, Smart Refrigerator, IoT, Firebase, Android application.

1. Introduction

The field of information technology recognizes the significance of the Internet of Things (IoT) system. This technology aims to transform tangible objects into intelligent virtual entities, making it a vital aspect of future innovation. The IoT vision involves the unification of all objects in the surrounding environment under a single infrastructure, allowing for the management and monitoring of their conditions [12]. The term 'IoT' refers to a combination of physical devices and computer programs that connect real-world sensors and actuators to the Internet. This encompasses a wide range of technologies, including intelligent home automation, monitoring devices, smart objects, and smartphones (which are increasingly used to assess their surroundings) [2]. A smart refrigerator, as a specific application of IoT, transforms a standard refrigerator into an intelligent appliance. It offers various capabilities such as item inventory tracking, automated stock ordering, and user notifications. It can notify the user about expiring items, temperature changes, and various error signals from the refrigerator [4]. Food waste due to spoilage is a significant resource problem, and food loss or waste refers to discarded or unconsumed food. Unless users individually check and track their food items, they may not be aware of their expiration date and freshness once they are purchased and stored in the refrigerator. Additionally, food items without a specified expiration date on the label increase the risk of significant spoilage and higher costs for consumers. However, this issue can be overcome with the use of the Internet of Things (IoT) [13]. The main function of an intelligent refrigerator is to simplify the process of monitoring a list of food items that may need replenishment when they are depleted [11]. Other advantages include the connectivity of the refrigerator with software tools like mobile phones, making it easy for users to stay informed about changes in the refrigerator [3]. The combination of IoT and refrigerators has led to the development of refrigerator monitoring systems. One key characteristic of an IoT system is that devices remain connected to the internet. Therefore, such devices are referred to as IoT devices or systems [8]. While smart refrigerators are often expensive for the majority of people, there is a need for affordable smart refrigerators with key features due to the increasing popularity of smart appliances [14].

Definition of Smart Refrigerator

The smart refrigerator is a smart home application that relies on IoT, utilizing multiple sensors managed by a microprocessor connected to the internet. It sends and processes data through an online database. The online database then transmits the data to the mobile application via the internet.

1.1 *Problem Statement*

In the context of the widespread adoption of Internet of Things (IoT) technology in various applications, challenges arise when transforming common household appliances into smart devices. These smart devices often come with high costs and require complex technologies for effective design and operation. While there is a multitude of research and applications focusing on expensive and complex technology for smart refrigerators, there is a demand to explore and develop a solution that combines good performance with cost-effectiveness through simplified techniques. Thus, this research paper aims to shed light on IoT technology and its utilization in the development of an affordable smart refrigerator with straightforward implementation.

1.2 *Objectives*

This research aims to address the challenge of transforming common household refrigerators into affordable smart devices using Internet of Things (IoT) technology. The primary objectives include establishing a robust IoT communication framework between an Android application and an Arduino board for efficient data exchange in smart refrigerators equipped with food condition assessment sensors. Additionally, the research aims to develop a user-friendly Android application designed specifically for smart refrigerators, allowing users to receive notifications, access results, and effortlessly input expiration dates.

2. Related Work

Controlling devices remotely over the internet is an exciting area of exploration for developers and researchers. Consequently, extensive research has been conducted in this field. In this section, an examination and discussion of existing works are conducted.

In [6], the system utilizes RFID technology to record food information stored in RFID tags and automatically sends it to a cloud-based data storage accessible to the user. The system also allows for recipe information to be provided for the food stored in the refrigerator. However, this approach has some limitations due to the availability of RFID for all types of food, requiring labeling for certain items, and the high cost associated with RFID implementation.

In [5], two sensors, namely weight, and temperature, are employed. The Arduino collects and sends data on food quantity and refrigerator temperature to a dedicated mobile application. This enables users to make informed decisions while purchasing food. One limitation of this system is that the temperature can only be adjusted manually and not remotely.

In [10], a convolutional neural network (CNN) is utilized for food classification. The system takes images from a camera as input for the deep learning algorithm. Additionally, RFID is used to scan food items associated with RFID tags. The Arduino sends the food classification data to a cloud server, which then sends an email to the user with the relevant information. The camera and RFID are only activated when the refrigerator door is open. The system relies on the received email data for restocking, and its main drawback is the high cost of implementation.

In [7], Raspberry Pi acts as a bridge between the sensors and the user. The system performs three tasks: 1) checking the weight of food using load cells to notify the user of low-weight items, 2) assessing the quality of food with a gas sensor to detect decaying food, and 3) capturing images for record-keeping using a camera. The system sends data from these tasks to the cloud, which subsequently delivers it to the Android mobile application. The system's cost is relatively high due to the use of the Raspberry Pi microcontroller.

In [1], the system consists of two sections: an internal section and an external section, each equipped with a camera and a sensor. The internal section uses a light sensor to detect if the refrigerator door is closed or open. The internal camera is activated when the door is open, allowing the user to review previously captured images of the refrigerator's interior. The external section employs an IR distance sensor to activate the external camera when the user brings a food item close to it, enabling input of data for new items. This approach provides both labeled and unlabeled food options. The system utilizes Raspberry Pi as a microcontroller and Firebase as a cloud service to transmit data to the Android application. However, the system cost is relatively high due to the Raspberry Pi microcontroller and the use of two cameras.

In [13], the system employs a gas sensor, humidity sensor, and temperature sensor for sensing purposes, with the WeMos D1 R2 Wi-Fi board serving as the microcontroller. The system records sensor data using PLX-DAQ and utilizes the Thing Speak IoT platform to send notifications and alerts to the user via the Push bullet notification application. The system effectively monitors humidity, temperature, and food quality.

This research proposes a system with the ability to achieve high performance cost-effectively, based on a simple and economical structure. The work employs a straightforward technique, relying on affordable hardware represented by Arduino and sensors due to their cost-effectiveness compared to more advanced processors. Additionally, Firebase usage offers access to a cost-free cloud database, eliminating the need to buy cloud storage space.

3. Methodology

3.1 *System Overview*

The system shown in Fig. 1 involves a smart refrigerator that utilizes an Arduino and a group of sensors. By sending data to the database server (Firebase), an Android mobile application can read and display the sensor data over the internet and notify the user of any important issues. Furthermore, the user can input the expiration date via the mobile app, save it in the database, and receive notifications when the date has passed.

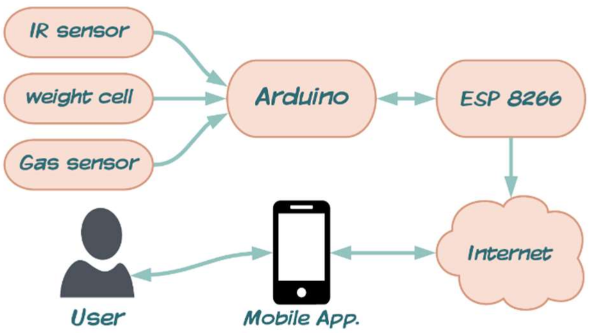

Figure 1: Block diagram of the system.

3.2 *Components of the presented system*

The presented system consists of hardware and software components.

3.2.1 Hardware components

The hardware components include A) Arduino Mega 2560, B) sensors, and C) ESP8266 (NodeMCU model).

A) Arduino Mega 2560

The system needs a microcontroller to read sensors and send its data to the internet. The most famous existed microcontrollers are Arduino and Raspberry pi.
Although the Raspberry pi is more efficient, it is more expensive and complicated. Therefore, Arduino is used for simple repetitive tasks.

B) sensors

Sensors are electronic devices that sense the changes in something around them.

- IR sensor

There are different types of IR sensors, the most famous are the pair IR sensor, where the transmitter and receiver are separated, and the long-range, where the transmitter and receiver are together. In this system, the long-range option was chosen for its simplicity. If it detects something inside that range, it returns a digital value; otherwise, it does not return a value.

- Weighting sensor (load cell)

Essentially, a load cell is a device that transforms the weight of an object into an electrical signal. In the proposed system, a load cell is placed underneath the vegetable tray inside the refrigerator. This load cell continuously detects the weight of the vegetables and produces a low signal which is transmitted to the user via a mobile application.

- Gas sensor

A gas detector or gas sensor is a type of chemical sensor that detects or measures the presence of gases in its surrounding area. Decaying vegetables produce a many volatile organic compounds (VOCs), such as acetone, methyl ethyl ketone, toluene, ethylbenzene, m,p-xylene, styrene, and o-xylene, are produced during the decomposition of food [9]. Therefore the ccs8100 was chosen as capable of sensing a wide range of Total Volatile Organic Compounds (TVOC) & equivalent carbon dioxide (eCO_2) with metal oxide (MOX) levels. Gas sensors are placed inside the refrigerator to detect the odor of spoiled vegetables. If the gas sensor detects any gases, a notification will be sent to the user's mobile device, indicating the need to clean the fridge.

C) ESP8266 (NodeMCU model)

Any microcontroller could access the Wi-Fi network according to the ESP8266 Wi-Fi Module, a self-contained SoC with an integrated TCP/IP protocol stack. There are two main types: ESP8266-1 and NodeMCU. Although the NodeMCU is more expensive, it is also easier and best efficient, it's a great choice for beginner s. The features of NodeMCU are 4MB of flash memory, access to 11 GPIO pins, and one ADC pin with 10-bit resolution, while ESP8266-1 has 1MB of flash memory, access to 4 GPIO pins, and one ADC pin.

3.2.2 Software components

Software components include A) Android Studio, B) Arduino IDE, and C) Firebase.

A) Android studio

Android Studio is Google's official integrated development environment (IDE) for the Android operating system, built on JetBrains' IntelliJ IDEA software and developed exclusively for Android application programming. It could be downloaded for different operating systems: Windows, macOS, and Linux-based. newly Java language was replaced with Kotlin as Google's preferred language for developing Android apps. while Java language is still supported, as is C++ language.

B) Arduino IDE

Writing code and uploading it to the board is simple with the free and open-source Arduino Software (IDE). Based on Processing and other open-source technologies, the environment was created in Java. With any Arduino board, this software is compatible. The Arduino IDE is a software program that allows users to write, upload, and debug code for Arduino boards. It is a cross-platform application that runs on Windows, Mac, and Linux computers, and it can be downloaded for free from the Arduino website. The Arduino IDE includes a text editor for writing code, a compiler for turning that code into instructions that the Arduino board can understand, and a programming language (called Arduino Language) that is based on C++. It also includes tools for uploading code to the board, debugging code, and accessing the serial monitor, which can be used to see output from the board and send data to it. The Arduino IDE is an easy-to-use platform that is well-suited for beginners and hobbyists who are just starting out with programming and electronics. It is also popular among professionals and researchers who use it to prototype and test ideas before moving on to more advanced development environments.

C) Firebase

Firebase is a mobile and web application development platform developed by Google. It provides a number of tools and services for building and maintaining apps, including a real-time database, user authentication, cloud storage, and hosting. One of the key features of Firebase is its real-time database, which allows apps to store and sync data across multiple devices in real-time. This means that when data is updated in the database, all connected devices receive the update automatically. This allows for the creation of collaborative apps. that can be used by multiple users simultaneously. Firebase also provides tools for user authentication, which can be used to create secure login systems for apps. It offers support for multiple authentication methods, including e-mail and password, phone numbers, and social media accounts. In addition to its database and authentication tools, Firebase also provides cloud storage, which allows apps to store and retrieve files, and hosting, which allows developers to host static websites and web. apps. on the Firebase platform. Overall, Firebase is a powerful platform that can be used to build and maintain a wide variety of mobile and web. apps.

3.3 *Implementation*

All components of the two sections of system hardware and software work together to send the issue that occurred in the refrigerator to the user. The system verifies three statuses: a) the weight of food by the weight cell and checks if the weight is too low, b) the presence of egg by IR sensor and checks if is it empty, c) the quality of food by the gas sensor and check if the food is spoiled. The Arduino board, which is controlled by the Arduino IDE and connects to the internet via Node MCU, collects all sensor data and transfers it to a database server on the Firebase platform server. Additionally, the user enters the expiration date via the mobile app, which saves it in the database and notifies them when the date has passed. Firebase sends notifications if there is any issue in sensors data or in expiry date to a specific mobile application developed by Android Studio. The main goal of the system is to notify the user of any problem that occurs in the refrigerator.

4. Results

Android Studio utilizes the Java language for mobile application development, Firebase for data structures and database servers, and the Arduino C language for NodeMCU and Arduino programming. The operational steps of the system are outlined in **Fig. 2**.

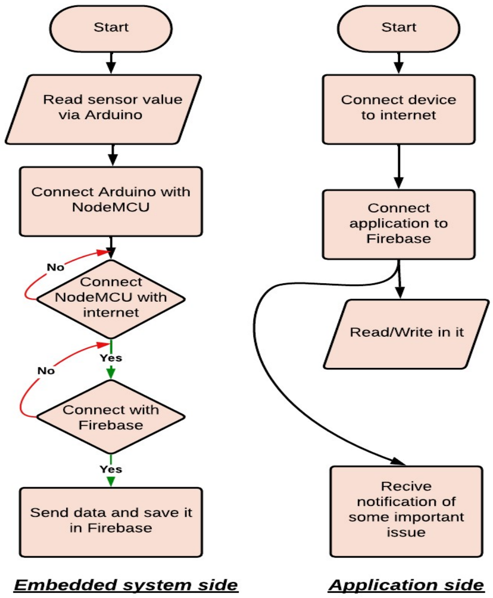

Figure 2: The steps of the system work

The hardware structure of the system is depicted in **Fig. 3**, illustrating the components such as Arduino, sensors, and the data programming and processing methods.

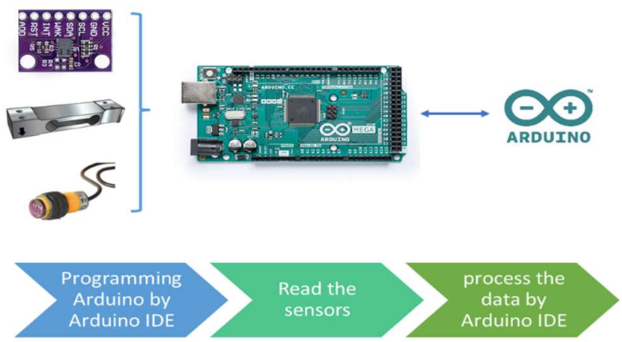

Figure 3: The general structure for connecting the sensor with Arduino

Fig. 4 and **Fig. 5** demonstrate the interface between the hardware components. **Fig. 4** illustrates the connection between Arduino and sensors using wires, while **Fig. 5** illustrates the connection between NodeMCU and Arduino.

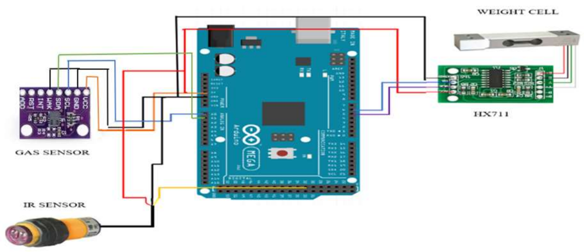

Figure 4: The interface between Arduino and sensors.

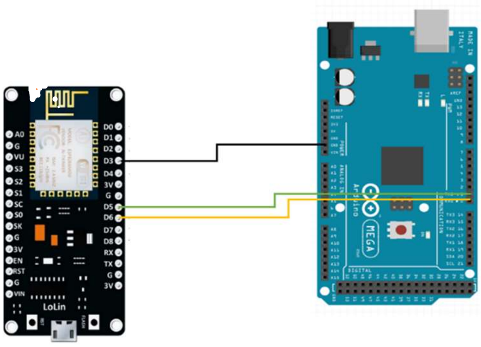

Figure 5: The interface between NodeMCU and Arduino.

workflow chart illustrating the interaction between Firebase, Arduino Mega 2560, a mobile app, and the user for receiving notifications shown in **Fig. 6**

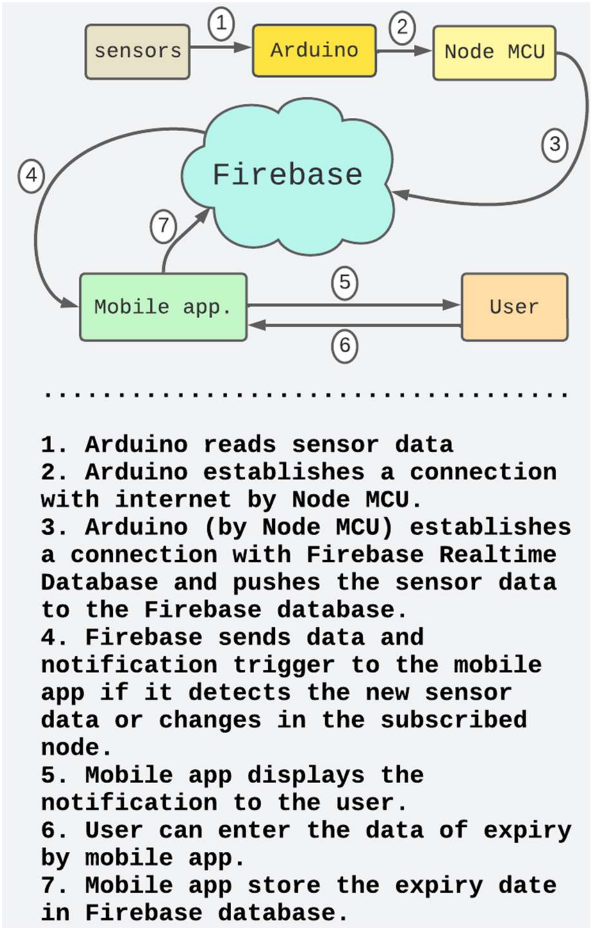

Figure 6: workflow chart.

The user is notified based on sensor readings and expiry date data. **Table 1** shows the sensors readings and the notifications associated with them. As for the expiration notices, they come at the end of the entered date.

Table 1: Sensor's readings and their notification.

SENSORS	READ	NOTIFICATION
Gas Sensor	>=1000	WITHOUT NOTIFICATION
	<1000	CORRUPTED FOOD
IR Sensor	1	WITHOUT NOTIFICATION
	0	EGGS ARE CARRIED OUT
Weight Cell	<=250 g	WITHOUT NOTIFICATION
	>250 g	NOT ENOUGH VEGETABLES

Fig. 7 displays the notification received by the user from the Firebase database.

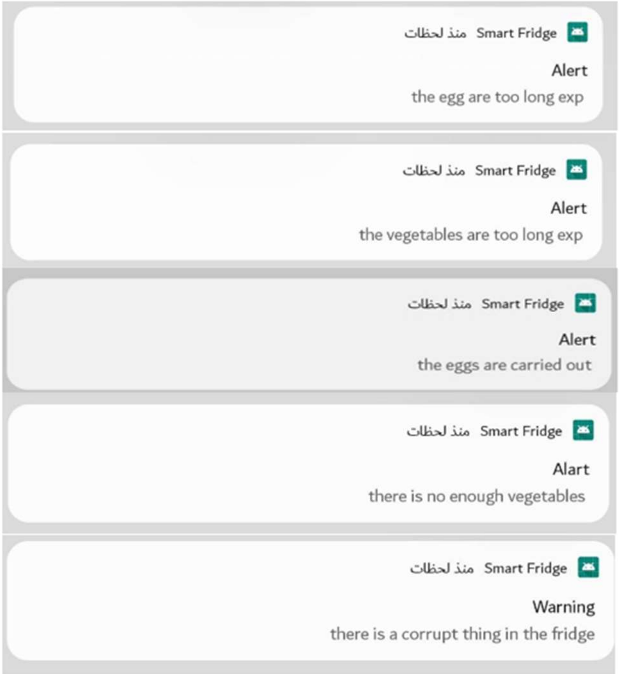

Figure 7. The mobile notification.

And the Firebase database structure is organized as a JSON tree shown in **Fig. 8**.

Figure 8: Database structure.

This system has been developed as a practical application for smart refrigerators in the Internet of Things (IoT) domain. Moreover, having a mobile application that receives immediate notifications from the database provides peace of mind while monitoring data and receiving crucial updates. It can be further enhanced and customized to meet specific requirements. With careful planning and effective execution, this system can be beneficial in various applications, including environmental monitoring and security systems, among others. Additional sensors can be integrated, and the application interface can be enhanced to cater to specific needs.

- ***Cost Comparison***

The cost of the system has been computed and juxtaposed with that of a new smart refrigerator. A conventional refrigerator typically costs around $300, The system components amount to an approximate total cost of **$53.4**, as shown in **Table 2**. In light of the research's aim to demonstrate that simple methods and the use of low-cost components can achieve the same objectives of IoT, it is evident that the cost of utilizing Raspberry Pi in [7] and [1] starts at **$35**, and the cost of employing the RFID Module in [6] and [10] stands at **$20.27**.In contrast, a new smart refrigerator would cost at least $1000.

Table 2: System component price.

COMPONENT	PRICE
Arduino	20$
ESP NodeMCU	8.39$
CCS811 Gas Senser	8.79$
IR Senser	4.77$
Weight Cell	11.45$
Total	**53.4$**

$$improvemt\ ratio = \left(1 - \frac{x\ new}{x\ old}\right) * 100\% = \left(1 - \frac{300+53.4}{1000}\right) * 100\% = 64.66\% \quad \ldots.(1)$$

According to **Eq. (1),** the smart refrigerator presented in this study, which utilizes the same IoT technology as commercially available smart refrigerators, has a significantly lower cost, reaching approximately **64.66%** of the cost. This difference in cost is illustrated in **Fig. 9.**

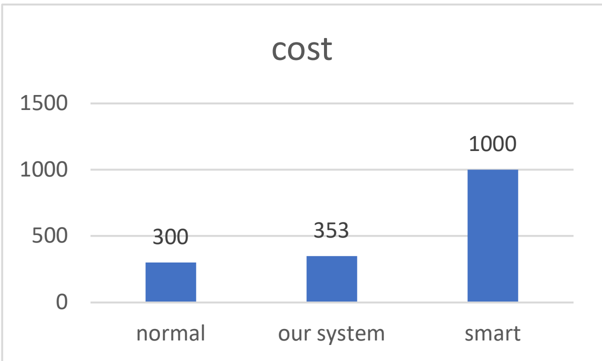

Figure 9: Cost differences.

- ***Compare with old classic refrigerator.***

Table 3. shows the effectiveness of the presented solution that uses IoT technology over the old-fashioned refrigerator.

Table 3: Compare IoT and classic refrigerators.

	Food quality	Connect to internet	Acceptable price	Smarter work
Old	✗	✗	✓	✗
The system	✓	✓	✓	✓

5. Conclusion

This study utilizes Firebase, Arduino, sensors, and mobile app notifications to implement an IoT smart refrigerator, enhancing usability and convenience through mobile app notifications. The Firebase database stores sensor data on refrigerator quality, weight, and egg presence, enabling remote supervision via mobile devices. Furthermore, the flexibility and scalability of Firebase allowed for potential enhancements and future expansion. Additional sensors, such as temperature or humidity, can be seamlessly integrated into the system, providing users with a comprehensive view of their refrigerator's contents and optimizing food management. The study advances smart refrigeration systems, but future research should explore machine learning algorithms for food spoilage prediction and optimal storage conditions, while user studies and feedback improve the mobile app interface. In conclusion, this study highlights the potential of IoT applications within the realm of smart refrigerators. A sophisticated system was successfully developed, providing monitoring and mobile connectivity. This research contributes to the growing field of IoT-driven solutions for improved food storage and management, fostering energy conservation, reducing food waste, and enhancing user convenience.

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ثلاجة ذكية للرعاية الصحية تعتمد على إنترنت الأشياء

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الخلاصة – نظرًا للالتزامات العائلية الممتدة ومتطلبات الحياة العملية سريعة الخطى، تعد إدارة المنزل ومراقبته عن بعد أمرًا ضروريًا. تعد الثلاجة واحدة من أهم أجهزة المراقبة ومع التقدم التكنولوجي، أصبحت الثلاجات التي يتم التحكم فيها عن بعد ميسورة التكلفة ومتاحة لعامة الناس. توفر هذه الثلاجات الراحة والكفاءة من خلال السماح للمستخدمين بمراقبة ثلاجاتهم من أي مكان باستخدام الهاتف الذكي، ولكنها لا تزال باهظة الثمن بالنسبة للكثير من الناس. يتم تقديم نموذج عمل ذكي وفعال من حيث التكلفة مع إضافة نظام يتكون من Arduino وعدد من أجهزة الاستشعار التي تؤدي بعض وظائف المراقبة. يتم ربط النظام بالشبكة لإرسال القراءات إلى قاعدة بيانات Firebase. تم تصميم تطبيق هاتفي خاص مرتبط بقاعدة بيانات Firebase، ويتم تلقي التغييرات. تجعل قاعدة بيانات Firebase من غير الضروري أن يقوم التطبيق بإعادة فحص البيانات على فترات منتظمة. تمت إضافة خاصية وقت انتهاء الصلاحية إلى التطبيق لتجنب التكلفة المستخدمة في الباركود ومن ثم إشعار المستخدم بتاريخ انتهاء صلاحيته بواسطة Firebase.

الكلمات الرئيسية – المنزل الذكي، الثلاجة الذكية، إنترنت الأشياء، فايربيس، اندرويد ستوديو.