Unlocking Smart Retail: Design and Implementation of an Amazon Go-like System in Palestine

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***Abstract*—The cashier-less revolution has taken over the market and changed the traditional shopping experience. In this paper, we discuss the challenges, design, and implementation of creating an Amazon Go-like store in Ramallah, Palestine. Employing a mixed-methods approach we researched the design of real Amazon Go stores around the world in order to improve our store and make it more comfortable for customers. Our goal was not just to follow their success, but also to provide a customized store that suits our local market. We also included our expertise in selecting the store site, creating the store architecture with Packet Tracer, selecting the hardware and software requirements, and securing the store data and payment processes.**

***Index Terms*—IoT, Amazon Go, MQTT, OSI, RFID, ESP32, Wi-Fi, BLE beacon, Fog Computing, TLS.**

I. Introduction

A. Background

With the launch of Amazon Go, a retail concept that revolutionizes the traditional shopping experience, the retail sector is witnessing a massive upheaval. Amazon Go, which was originally introduced to Amazon workers in December 2016 and then to the general public in January 2018, eliminates the need for typical checkout lines, radically redefining customer perceptions of what shopping may be like [1], [2]. To automatically recognize when things are removed from or returned to the shelves, the shop employs Amazon's patented "Just Walk Out" technology, a complex blend of computer vision, machine learning, and sensor fusion [2], [3]. Interestingly, the Amazon Go concept appears to be more than simply an innovation in a low-margin industry; it is also a chance for Amazon to advertise its payment methods and attract more visitors to Amazon.com [1].

B. Challenges in Payment Systems

Amazon Payments, which was launched in 2013, faces severe competition from market competitors such as Adyen, Square, and Stripe, according to [1]. Amazon Go, with its own shopping experience facilitated via the Amazon app or alternative payment methods such as credit cards and Amazon One, offers an intriguing value proposition that might entice additional businesses and consumers to use its payment platform, according to [3].

C. Expansion of Amazon Go

In 2018, Amazon established three Amazon Go stores and announced plans for additional development into regions such as San Francisco and Chicago, according to [4]. The stores employ an Amazon Go app for admission and are outfitted with a slew of cameras and sensors that monitor consumer behavior as they go around the store [2], [4].

As of 2018, Amazon had opened three Amazon Go locations and revealed plans for further expansion into markets like San Francisco and Chicago [4]. The stores operate with an Amazon Go app, which can be used for entry, and are equipped with an extensive array of cameras and sensors that observe customer behavior as they move through the store [2], [4].

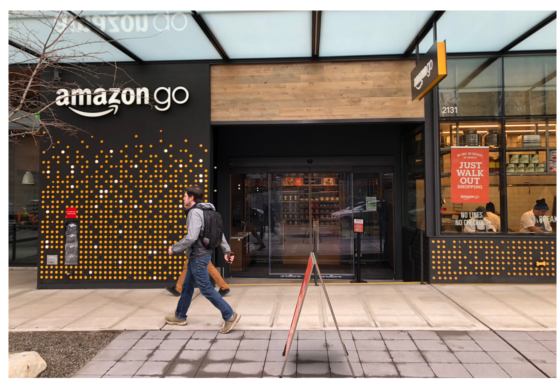

Fig. 1. Amazon Go! in downtown Seattle [5]

D. Objectives

The goal of this research is to tailor the Amazon Go model to a specific setting, such as Palestine, with an emphasis on:

- Considerations for architecture and technology, such as the deployment of sensor arrays and machine learning algorithms to track consumer behavior.
- Economic and social elements specific to the target market, such as financing choices and cultural attitudes about purchasing.

II. Scope and Store Design

A. Types of Items

The store's primary focus will be on regular groceries, such as vegetables, dairy, and refrigerated items. Given local tastes and dietary traditions in Palestine, additional care will be taken to supply necessary and culturally significant commodities such as bread, eggs, beverages, and cheese.

B. Proposed Location and Size

The location of the store is an important technical and business choice. While commercial areas provide significant exposure and foot traffic, the expenditures connected with them might be too expensive. As a result, striking a balance between commercial viability and accessibility is critical. We chose Mazaya Mall as the preferable site for our first store, with plans for future development depending on the success and lessons learned from this first business.

Mazaya Mall is strategically located between Ramallah and Birzeit. Furthermore, the mall is situated on a major route that connects Ramallah to neighboring cities and villages. This allows us to attract a varied consumer base, which includes local residents, commuters, and visitors from adjacent locations. Mazaya Mall is a fantastic candidate for bringing our revolutionary retail concept to the Palestine market due to its convenient location and broad customer appeal.

Notably, Mazaya Mall is powered by solar energy, which aligns with our commitment to sustainability and provides a resilient solution to future power outages. This environmentally friendly innovation not only decreases the store's carbon footprint but also offers a more stable energy supply considering the region's regular power outages.

In terms of size, the store will be built to handle 20-30 customers at a time. This results in a more intimate but efficient shopping experience.

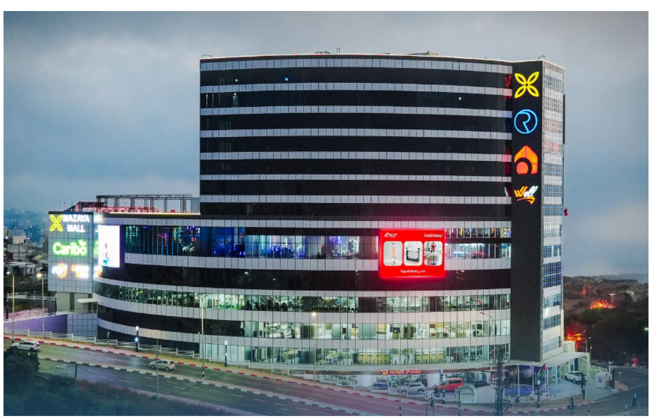

Fig. 2. Mazaya Mall

C. Target Demographics

The business intends to serve to a wide range of customers, including families, working people, and students. There is no emphasis on any single age group or financial level, making the shop accessible and valuable to the entire community.

D. Key Features and Services

Customers will not have to wait in line since the shop will provide a quick and smooth checkout experience. This will be accomplished through the use of an easy-to-use application that provides secure and safe payment alternatives. Furthermore, the app will have capabilities customized to the Palestine market, such as tracking product expiry dates and ensuring that commodities are not destroyed.

E. Architectural Layout

To enable an efficient shopping experience, the architectural design will incorporate different IoT sensors and actuators. On the roof, cameras will be installed to monitor client movement and behavior. Refrigerators will be outfitted with sensors to manage inventories and check product conditions. A one-of-a-kind QR code system will regulate the store's entry, allowing only authenticated consumers access. Special sensors will also be installed to monitor the quality of key commodities such as bread.

Because of Palestine's hot and humid environment, the store's cooling and ventilation systems will be given additional attention. Furthermore, contingency plans for common electrical concerns, such as backup generators and uninterruptible power supply (UPS) systems, will be established.

III. Feasibility Study

A. Market Analysis

The target market consists of a broad demographic, including families, professionals, and students. Our location in Mazaya Mall strategically places us on a thoroughfare connecting various towns, thereby attracting both local and commuting customers.

B. Technical Feasibility

The store will employ a range of IoT sensors and actuators, including cameras for tracking customer movement and sensors on refrigerators for inventory management. The technology stack is designed to comply with privacy laws and is scalable for future expansion.

C. Operational Feasibility

The chosen location at Mazaya Mall is both strategic for customer acquisition and advantageous for its use of solar energy. We'll maintain a stock primarily comprising groceries, with a special focus on locally preferred items like bread and cheese. The store's design is optimized for a capacity of 20-30 customers at a time.

D. Economic Feasibility

Initial costs include technology setup and property acquisition. A fast checkout system, enabled by an easy-to-use app, aims to attract a high number of customers, thereby generating sufficient revenue. The goal is to achieve break-even within the first two years of operation.

E. Legal Feasibility

All local requirements, including data privacy laws, will be followed by the project. Before the business opens, the necessary permits and licenses will be obtained.

IV. Software Requirements

A. Mobile Application

We developed a mobile application that customers must register in before visiting the store, this application forces customers to create an account that includes verifying an existing credit card to be able to have a barcode that will be scanned at the entrance of the store to be traced by the store for any interaction with the system.

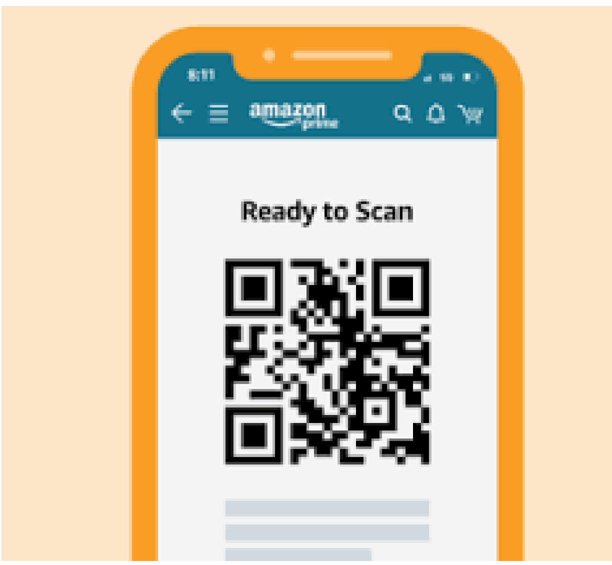

Fig. 3. Application UI [6]

B. MQTT client and Broker

To be able to use MQTT as a communication protocol, we deployed MQTT client application on our ESP32, to be able to collect real-time data from various sensors around the store. While the MQTT client collects data from the sensors they are also presented as the Fog nodes that process and optimize data for efficient transmission to the cloud that represents the MQTT broker. For the MQTT broker, we used Mosquitto for its efficient real-time data communication, its ability to be used in tracking customer movement along with the Bluetooth beacons, supporting security through TLS/SSL, and is scalable and can handle a large number of devices and sensors [7].

V. Hardware Requirements

Amazon Go's business model is built on the seamless integration of various hardware components, including sensors and actuators, to provide a smooth and convenient shopping experience [8].

A. Sensors

1) **Barcode Entrance Gates:** These gates authenticate customers using a barcode scanner, opening only after successful verification of the customer's identity via the mobile application. This gate may also use Proximity Sensors to detect the presence of a customer and prepare for scanning, thus enhancing smart detection and linearity.
2) **RFID Tags:** For detecting what product has been selected and what it is specifically, RFID tags are placed over each item such that the REID readers can automatically scan the tags and identify the product quickly. Other than identifying each item, tags can be used for higher accuracy for the system in such cases where an item has not been billed and the customer attempts to leave the store, the readers at the exit of the store will recheck the items by their tag in order to bill any missed item. Tags are also used to inform workers about the state of the products if they are expired or need to be replaced due to a manufacturer defect.
3) **Weight Sensors:** Weight sensors are placed over the shelves, their main purpose is to detect when an item is picked by a customer from the shelves, they also are used to detect if the item picked and then returned to its place is not used, for example, if a customer picked a bottle of juice and then consumes and returns it to the shelve, the weight sensor tells that the bottle is empty and it is billed from him.
4) **Infrared Sensors:** These sensors are used to monitor the customer's movement in the store and to help detect his behavior along with the cameras that are placed in several places in the store.
5) **Scales:** Scales are used to measure the weight of individual items such as fruits and bakery items, where they are placed on the shelves and can measure minor changes in the weights once an item is selected and placed in the customer bag of basket.
6) **Volume Displacement or Proximity Sensors:** These sensors are used to help provide redundant data to increase the accuracy of the whole system. This is done by detecting the presence of a customer in front of a shelf to register his actions in whether he takes or places an item on a shelf.
7) **Light Curtains:** They are a visual barrier that consists of an array of infrared beams that detect the location of an object once it crosses these beams. For the store, these curtains are placed all over the store to ensure items are charged to the correct customer.
8) **Humidity Sensors:** Humidity sensors are mainly used in the bakery and in the grocery sections of the stores, these sensors are mainly used to monitor the humidity levels that must be present to provide healthy conditions for the food at the store.
9) **Temperature Sensors:** These are used along with the humidity and the moisture sensor to monitor the quality

of air and products in the store, where for grocery and bakery products, mold is most likely to happen under normal conditions, thus any sense of mold in the air must be detected and solved before it spreads in the air and ruins all the unwrapped products in the store.

10) **Cameras:** The cameras are used to monitor each movement and each change in the store state, these records are then analyzed using computer vision techniques to detect the behavior of each customer.
11) **Air Pollution Sensors:** These sensors monitor the quality of air in the store, focusing on parameters like carbon monoxide and particulate matter to ensure a healthy shopping environment.
12) **Moisture Sensors:** Integrated with humidity and temperature sensors, these ensure optimal conditions for food items, particularly in the bakery and fresh produce sections.
13) **Bluetooth Beacon** Bluetooth Low Energy Beacon is a hardware device that can be placed in different locations and transmits a Bluetooth signal that can be received by other Bluetooth devices (such as mobile phones). Beacons are used as trackers where the communication between three or more beacons and a wireless device can be used to position the device. [9].

This total integration of sensors and actuators takes Amazon Go shops to the highest levels of smart retail, where technology improves both operational efficiency and customer experience. The sensors and actuators chosen meet characteristics such as low power consumption, high sensitivity, accuracy, and ease of use, making them ideal for this application.

B. Micro-controller

For interfacing with our sensors and cameras, we used the ESP32 microcontroller. It is a perfect pick due to its cost and budget-friendliness, with its built-in Wi-Fi and Bluetooth capabilities, low power mode, and sufficient processing power that can handle multiple sensors and cameras. ESP32 is also widely known for its usage in IoT applications which provides us plenty of resources [10].

C. Communication between hardware devices

For building the communication infrastructure for our store, the store is totally connected to the Wi-Fi, where each customer must have a downloaded mobile application and enabled Bluetooth, the main purpose of connecting the customer phones to the Wi-Fi is to enable customer entry, item selection, cart updates, and payment. The Bluetooth is used to track the customer movement, this can be done when a customer picks up a product, a nearby BLE beacon can locate the user and thus trigger his actions, such as updating the virtual cart with his selected items. While Wi-Fi and Bluetooth are used for connecting the customers and locating their positions, MQTT is used for connecting the sensors to the edge devices such as the microcontroller, these devices are treated as MQTT clients that subscribe to the sensors and cameras around the store, thus these devices will publish data and the clients will collect them to process them in the fog nodes.

VI. OSI and IoT Networking Protocols

It is necessary to carefully choose various networking protocols for various OSI model levels as well as specific IoT layers while designing an IoT-enabled business in Palestine. The subsections that follow go into detail on the best methods for each case, all protocols are studied and inspired from [8], [11].

A. Physical Layer

We must concentrate on the channel of transmission for the Physical Layer of the OSI model. Given the store's interior location, the primary possibilities are wired (Ethernet) or wireless (Wi-Fi or other low-power wireless technologies). Wireless technology is used for greater scalability and reduced infrastructure complexity. As a result, the technologies chosen for the Data Link and Link layers, such as IEEE 802.15.4 or IEEE 802.11ah, will determine the physical media implicitly.

B. Link Layer Protocols

For the Physical and Data Link layers in OSI or the Link layer in IoT, three scenarios are considered.

- **IEEE 802.15.4:** Designed for low-power, short-range communications, which are characteristic of basic IoT devices such as generic sensors and actuators.
- **IEEE 802.15.4e with TSCH:** In time-sensitive tasks such as payment gateways or door control systems, accurate time synchronization is used.

C. Internet Layer Protocols

For the Network layer in OSI or the Internet layer in IoT, again three scenarios are outlined.

- **6LowPAN:** In a basic network setup, IPv6 packets are enabled over IEEE 802.15.4-based networks.

D. Application Layer Protocols

For the Application layer, which is common to both OSI and IoT models, two scenarios are explored.

- **JSON with Publish/Subscribe:** Used for real-time dashboard updates with high QoS.
- **XML with Request/Response:** Employed for mobile app communications with medium QoS, straightforward for typical client-server interactions.

Other factors include favoring non-blocking activities over blocking ones in order to permit numerous concurrent processes. RESTful API limitations will also be enforced at the Application layer to provide stateless, cacheable client-server communication with a unified interface.

We hope to design a networking system that is resilient, safe, and efficient, answering the special demands of an Amazon Go-like store in Palestine, by carefully selecting these protocols to match certain circumstances.

The following table concludes all the protocols we talked about:

TABLE I
NETWORKING PROTOCOLS BY OSI LAYER FOR IOT RETAIL STORE

OSI Layer	Chosen Protocols
Physical Layer	IEEE 802.15.4, IEEE 802.15.4 IEEE 802.11ah
Link Layer	IEEE 802.15.4(TSCH)
Internet Layer	6LowPAN, 6TiSCH
Application Layer	RESTful Constraints, Data Serialization Formats QoS

VII. FOG AND EDGE COMPUTING

For Ramallah Amazon Go, the need for instant processed data is intense, thus Fog and Edge Computing are essential in our store, where Fog computing brings the cloud capabilities closer to the edge of the network where data is generated. Fog computing provides efficient pre-processing of data from the various sensors and cameras located in the store by using edge computing devices integrated with specific software. This localized processing decreases latency, improves response time, and allows for faster decision-making, which is crucial for precisely tracking user interactions with products, ensuring safe transactions, and maintaining an uninterrupted shopping experience.

1) **Edge computing:** While using many sensors and devices to monitor customer movement and actions, the edge devices used for collecting real-time data are also responsible for reprocessing this information in order to provide a lower latency and a smaller volume of raw data to be transmitted to the cloud.
2) **Fog computing:** While Edge computing's main interest is pre-processing real-time collected data, Fog computing aggregates, and further processes data from multiple edge devices. It provides instant decision-making and data analysis to enhance the shopping experience for customers. Where it might do the necessary processing for a customer purchase to ensure an uninterrupted experience during peak time.

For the store to support these specifications, specialized hardware and software components are needed:

1) **Edge servers**
2) **Local storage servers**
3) **Real-time object recognition software**
4) **Customized sensors**

VIII. DETAILED IOT SYSTEM DESIGN

In this part, we will go through the IoT system architecture created with Packet Tracer 8.2. The design incorporates a wide range of IoT devices and sensors to enable smart operations in a retail setting.

A. Energy and Environmental Management

The core of our system's sustainability is a solar power arrangement. It integrates solar panels and batteries to ensure an uninterrupted power supply to IoT devices. The system features adaptive lighting systems that modify the brightness based on natural light availability, therefore conserving energy.

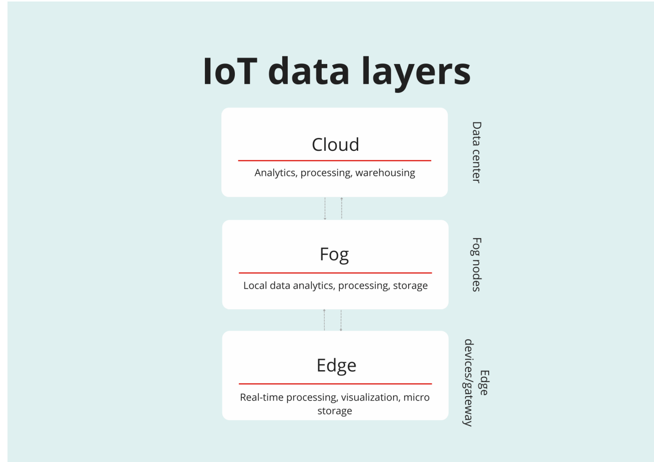

Fig. 4. Cloud, Fog, and Edge computing layers

B. Security and Surveillance

Starting with the entryway, many levels of protection have been built. RFID technology is used to regulate employee access. To guarantee strong security, two types of RFID cards were tested: valid and counterfeit. Surveillance cameras have been put in parallel to watch client movement and provide data to the cloud for analytics.

C. Access Control and Payment

The entry to the shopping area is equipped with motion sensors and needs registration through a cell phone. This data is sent to the server for processing and consumer analytics. Upon leaving, the technology immediately handles payments using cloud-based accounting, reducing checkout times.

D. Climate Control

Temperature sensors have been included in the air conditioning system to provide an ideal shopping experience. The device activates when the interior temperature exceeds 24°C and deactivates when it falls below 17°C.

E. Emergency Response

In the event of an emergency, smoke detectors combined with Fire Monitors sound an alarm and activate smoke sprinklers. All doors and windows open at the same time as emergency doors. Carbon monoxide detectors have also been installed to check the air quality.

F. Intrusion Detection

Trip sensors have been strategically placed to prevent theft. When activated, these sensors provide an alarm to security staff.

G. Customer Experience

Customers can use a smartphone application to operate a cloud-connected coffee machine at the site. This improves the user experience while encouraging contactless interactions.

H. Data Processing and Networking

A primary router is in charge of connecting all IoT devices to a centralized server through WiFi. A dedicated laptop is used for IoT monitoring. Edge computing is utilized for time-critical applications such as fire detection, whereas fog computing is used for real-time consumer tracking and other latency-sensitive processes.

I. Environment Monitoring for Items

We developed a variety of humidity and temperature sensors for item storage to guarantee that things are preserved in ideal conditions.

J. Simulated Components

A fire simulation unit and a simulated vintage automobile were employed in testing to depict fire and air pollution conditions, respectively.

K. Networking and Monitoring

Packet Tracer 8.2 was used to thoroughly network the system. An IoT monitor aids in the monitoring and control of numerous linked devices and sensors in real-time by adjusting the needed environment for the sensors and the components.

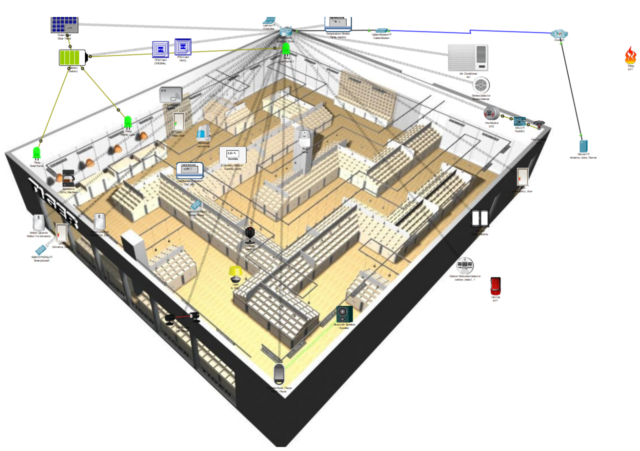

Fig. 5. Amazon Store System Design

IX. Cloud computing with AWS

A. What is cloud computing?

The on-demand, pay-as-you-go delivery of IT resources through the Internet is known as cloud computing. You can use technological services like computing power, storage, and databases on an as-needed basis from a cloud provider like Amazon Web Services (AWS), rather than purchasing, operating, and maintaining physical data centers and servers. [12]

B. Why AWS?

AWS has been chosen as a cloud service for our system. Since Amazon Go's technology stack and system are inherently built by Amazon, there might be better native support and integration when using AWS services. AWS's ecosystem is likely optimized for the technologies powering Amazon Go. Also, AWS offers a user-friendly and flexible hosting platform, designed for swift and secure application deployment. It allows customization from operating systems to databases, ensuring ease in migrating existing applications or developing new ones. Economically, AWS is cost-effective, operating on a pay-as-you-use model without binding users to long-term contracts. Leveraging the robust infrastructure of Amazon.com, AWS ensures reliability and scalability, adjusting resources based on demand. Complementing its vast offerings, AWS places a strong emphasis on security, integrating comprehensive measures across physical, operational, and software levels. [13]

Fig. 6. AWS services

X. Security

Implementing an Amazon Go store in Palestine, specifically in Ramallah, presents unique security challenges that require a comprehensive approach. This not only involves the protection of customer and business data from cyber threats but also the physical security of the store and its assets. Addressing both these facets is important to ensure the viability and success of such an innovative retail model in a new market.

A. Technological Security Measures

1) IoT Security: As the heart of the Amazon Go experience lies in the Internet-of-Things (IoT) infrastructure, ensuring the security of these devices (sensors, actuators, and cameras) is essential.

- Device Authentication: Just like a user needs a username and password to access a secured system, devices in an IoT ecosystem need to prove their identity before they can connect and communicate. In order to ensure that, each device has a unique ID that distinguishes it from others. This ID is usually hardcoded into the device during its manufacture. When a device attempts to connect to the network, the central system checks this unique ID or certificate against a list of approved devices. Only devices with approved IDs can connect. By ensuring that only authenticated devices can connect, the network is protected from potential rogue devices that might be used to introduce malware or steal data.

- End-to-end Encryption: Encryption converts data into a coded format, ensuring that even if intercepted, it remains unreadable without the decryption key. This requires that as soon as data is collected by the IoT device, it's encrypted before being transmitted. Once the data reaches its intended destination (e.g. cloud server), it's decrypted and processed. A Transport Layer Security (TLS) protocol is a well-known security protocol that can be used to ensure end-to-end encryption between IoT devices and central systems. This ensures that data, even if intercepted during transmission, remains confidential and intact. This is especially vital for sensitive data like payment information.

2) Cloud Security: AWS has been chosen as a cloud server for our system. It's the most adaptable and safe cloud computing platform that is currently available. The primary infrastructure is designed to meet the security standards of the military, major international banks, and other highly sensitive enterprises. With more than 300 security, compliance, and governance services and capabilities, this is supported by a comprehensive range of cloud security tools. In addition to offering the option to encrypt customer data across all 117 AWS services that host it, AWS supports 143 security standards and compliance certifications. [14]

3) Application Security:

- In-app Authentication: Authentication mechanisms validate a user's identity, ensuring that only authorized individuals can access the application and the sensitive data it might contain. Biometric authentication and multi-factor authentication are implemented for accessing the app.

B. Physical Security Measures

- Surveillance: Amazon Go stores use an array of cameras and sensors to detect items taken from or returned to the shelves and to manage the checkout-free shopping experience. Beyond the cameras used for the shopping system, additional surveillance cameras can be positioned at store entrances, exits, blind spots, and areas not covered by the shopping system cameras. These cameras serve as a deterrent against theft, vandalism, or other illicit activities, offering an additional layer of security beyond what's needed for the shopping experience.
- Access Control: Our Amazon Go stores are mostly open spaces, but certain areas like storage, server rooms, or staff-only sections need stringent access controls. Personnel can be provided with RFID cards which grant them access to designated areas. By restricting access, the store ensures that sensitive areas, be it stock storage or IT infrastructure, are not exposed to unauthorized individuals, thus preventing theft, tampering, or data breaches.
- Fire Detection and Alarm Systems: A combination of smoke detectors, and fire monitors placed strategically across the store. They will be responsible for providing early warning, ensuring that fires can be addressed swiftly and safely, minimizing potential damage, and ensuring customer and staff safety.
- Clear Marked Exits: Ensuring exits are easily identifiable and accessible. Emergency exit signs should be illuminated and clearly visible from all parts of the store. Regular checks should ensure they are functioning and unobstructed. In case of emergencies, customers and staff can evacuate quickly and safely.
- Window Camera Security: Install cameras on store windows to monitor for any unwanted or forced entries. These cameras, equipped with motion detection, will focus on unusual movements, especially during off-hours. If suspicious activity is detected, an alarm will sound, alerting store management.

XI. Billing Issues and Challenges

Our Amazon Go store reshapes traditional shopping with its unique, cashier-less experience. By simply scanning a QR code from their Amazon account upon entry, customers can shop and be automatically billed via their linked credit card. However, as with any novel system, there are challenges to consider.

- Unsuccessful Automatic Payment: After shopping, the automatic payment from the linked credit card might fail due to various reasons, such as insufficient funds or bank rejections. In the event of a payment failure, the Amazon Go application will notify the user immediately and offer alternative payment methods.
- Chargebacks: Some customers might dispute a transaction, leading to chargebacks which can be costly for the business. So, each customer should receive an email with a detailed receipt with images and descriptions of purchased items.
- Inaccurate Pricing or Discounts: IoT devices might sometimes fetch outdated pricing or fail to apply discounts, leading to billing discrepancies. Our system is implemented in a way where the IoT devices frequently sync with the central pricing database.
- Political and Regulatory Issues: Obtaining the necessary permits and approvals from local and national governments can be challenging given the unique political situation in Palestine. We also struggle with trade restrictions that may impact the import of technology and equipment needed for our Amazon Go store.

XII. Execution Plan

1) Market Analysis and Feasibility Study:
   - Conduct research on local buying patterns, preferences, and potential challenges.
   - Study the infrastructure and logistics capabilities in Ramallah and its surroundings.
2) Stakeholder Engagement:
   - Engage with local authorities and mall management for permissions and cooperation.
   - Communicate with potential local suppliers and vendors for stocking the store. And initiate discussions with local technology partners for support.
3) Site Selection and Layout Planning:
   - Visit Mazaya Mall to choose an optimal store location considering foot traffic and accessibility.
   - Design a store layout considering the store's technological requirements like placement of sensors, cameras, and other IoT devices.
4) Infrastructure Development:
   - Set up the necessary network and IT infrastructure, ensuring robust internet connectivity.
   - Implement security measures, both physical and technical.
5) Technology Deployment:
   - Set up IoT devices, sensors, cameras, and the necessary software for the checkout-free system.
   - Integrate the local store system with the broader Amazon ecosystem.
   - Implement and test the QR code entry system linked to Amazon accounts.
6) Inventory Management:
   - Collaborate with local suppliers to stock the store.
7) Staff Hiring and Training:
   - Hire local staff for support roles, store maintenance, and security.
8) Marketing and Public Engagement:
   - Launch promotional campaigns, both online and offline, to introduce Amazon Go to the local audience.
9) Soft Launch and Feedback:
   - Start with a limited entry system to test the store's operations and gather initial feedback.
10) Official Launch:
    - Open the store for the broader public.
    - Continue with marketing efforts to increase foot traffic.
11) Continuous Monitoring and Support:
    - Continuously monitor the technology infrastructure to ensure seamless shopping experiences and update the system as needed.

XIII. Scenarios and Their Protocols

The Mosquitto diagram shows the complicated interaction between many devices and the Mosquitto Broker. To show the direction of data flow and the exact protocol utilized at each stage, arrows of various shapes and styles are used. This allows for a rapid but thorough overview of how data moves across the network, as well as insights regarding the applicability of alternative OSI levels for each scenario.

A. Scenario 1: Temperature Monitoring

IEEE 802.15.4 is used at the Physical Layer and Link Layer to securely transmit temperature measurements from the sensor to a Mosquitto Broker, the scenario use MQTT over TLS running over IPv6 RPL at the Internet Layer. This data is then transmitted to the Cloud Server for real-time monitoring through an IoT monitoring laptop.

B. Scenario 2: Real-Time Dashboard for Monitoring

IEEE 802.11ah technology is used at the Physical Layer for long-distance wireless networking. MQTT is used to provide data from various sensors, such as temperature, humidity, and CO2 levels, to a Mosquitto Broker. These sensors are wirelessly linked to the broker through 6LowPAN for efficient IPv6-based communication. To show data in real-time, a Real-Time Dashboard application operating with RESTful restrictions at the Application Layer subscribes to certain MQTT topics.

C. Scenario 3: Secure Payment

IEEE 802.15.4e at the Link Layer includes Time-Slotted Channel Hopping (TSCH) for coordinated, low-power operations. A sensor transmits a signal to the Mosquitto Broker through MQTT via Websockets when a customer exits. This information is sent over an IPv6 RPL network to the payment gateway, where it is processed and deducted from the user's account.

D. Scenario 4: Mobile App Coffee Ordering System

IEEE 802.15.4 is used at the Physical and Link Layers for low-power communications between the Coffee Machine and the Mosquitto Broker. A Mobile App allows users to pick a coffee kind, which sends an HTTP/CoAP request to the broker. The Coffee Machine subscribes to this subject and, upon receiving the request, begins brewing coffee.

These scenarios showcase the system's ability to seamlessly incorporate various OSI and IoT protocols for a wide range of applications, ensuring a robust, secure, and efficient operation of the IoT-enabled retail store.

E. Scenario for Request/Response: Mobile App Coffee Ordering System

Establishes a more interactive paradigm between the client and server. The Mobile App delivers a request for a specific sort of coffee over HTTP or CoAP at the Application Layer, which is routed efficiently via an IPv6 RPL network at the Internet Layer. This order is sent to the Mosquitto Broker,

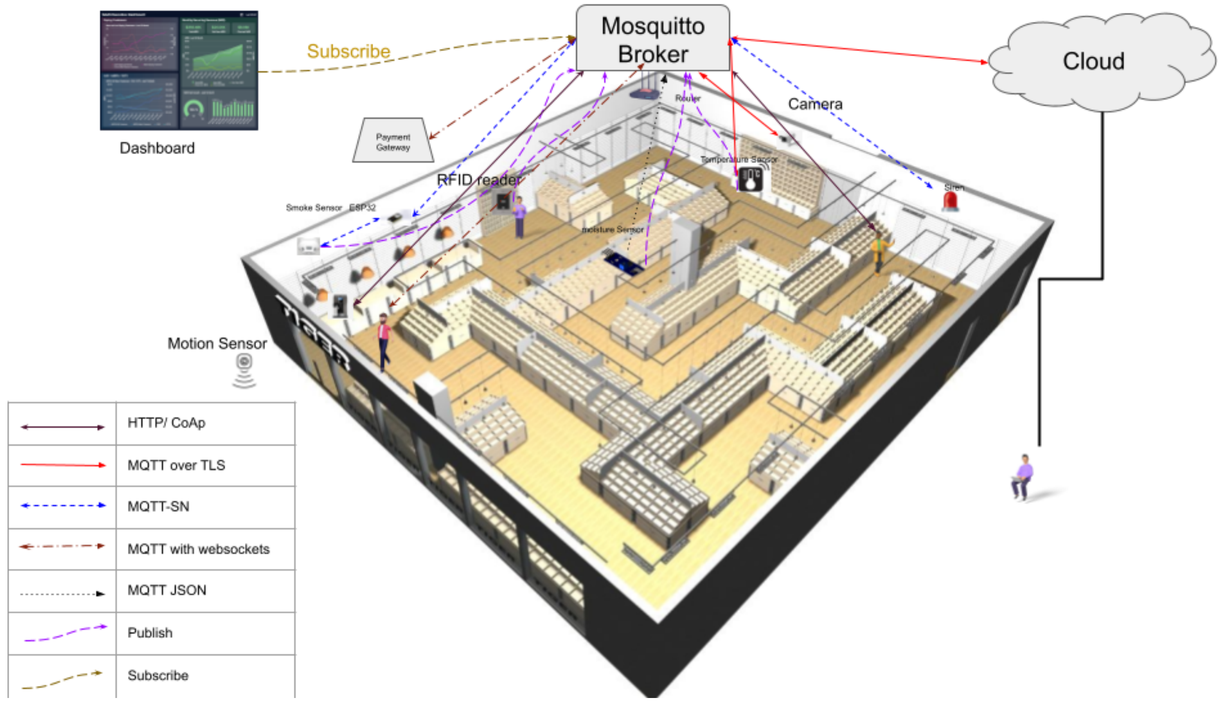

Fig. 7. The integration and scenarios of IoT Protocols on Amazon Go! Store

who transmits it to the Coffee Machine. These orders are subscribed to by the Coffee Machine, which is equipped with IEEE 802.15.4 for low-power operation. When it receives the request, it makes the coffee and responds to the Mobile App through the broker. When the user's coffee is ready, the app tells them.

XIV. Conclusion

In conclusion, The rise of cashier-less stores conveys an evolution in the shopping industry, altering standard shopping. In this paper, we went through the design process of creating and implementing an Amazon Go-like store placed in Ramallah-Palestine. Our approach enabled us to gather useful information by studying the architecture and operations of real Amazon Go locations around the world, next to improve our system by selecting the greatest place that comes into contact with a solar energy system to power our store. In addition to designing the store's architecture with the help of Packet Tracer simulations, carefully selected the necessary hardware and software components, and implemented robust security measures to protect both customer data and payment transactions.

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Appendix A
Student's Reflection

A. Ahmad Abbas's Reflection on Designing the First Amazon Go Store in Palestine

The chance to design and start the first Amazon Go! On my country, Palestine, was interesting and demanding at the same time. Moreover, it gave me the opportunity to work with OSI networking and IoT protocols on a real-world application.

My main role in the project focused on OSI networking and the integration of IoT technologies. Working with my partners, we designed a full system that combines many components from sensors, actuators, micro-controllers, and others to provide the best customer experience for the Amazon Go! Using packet tracer. The main effort was the networking of the sensors and programming little codes for customized sensors and MCUs. Packet Tracer presented us with its set of challenges, including occasional crashes that disrupted our workflow.

Another important aspect of the process was determining the best location for our shop. The decision was essential since it had to accommodate enough client traffic while also accommodating the technology infrastructure required for the Amazon Go experience. Long hours and needed attention to detail were required during the overall design phase. Every decision has consequences, from selecting the proper sensors and actuators to ensuring their ideal placement for maximum efficiency.

This project was an excellent learning opportunity, demonstrating the complexity and details involved in bringing a unique retail solution to reality. While the technological obstacles were intimidating, conquering them provided a satisfying sense of success. It's a project that has improved my understanding of IoT systems and networking.

Looking back, I am glad for the difficulties and successes of this experience, which have been nice to deal with on my university journey.

B. Loor Sawalhi's Reflection on Designing the First Amazon Go Store in Palestine

I've participated in the designing of this cashier-less store along with two of my colleagues, my main role was to address the hardware requirements for the physical store.

During the phase of searching for the requirements that exist in the real Amazon Go store, I was amazed at the level of technology that has taken over the world. I learned how the store actually identify each individual user, how their movement can be tracked by cameras, BLE beacon, light curtains, and other sensors that record customers' interactions with the system. I also learned how real-time communication can be done, and how the selection of the microcontroller and the used protocols and sensors are tightly related. Through the search process, I started to think of ways to keep the store in the healthiest environment for our products, where I added the idea of having sensors that can detect and control the whole store's air condition in terms of moisture, humidity, and temperature, where controlling these factors can prevent mold from growing between freshly backed items and groceries, I also considered it as a way to till workers of when they need to replace the bakery or grocery items with fresher ones to keep their quality at the highest.

I also was amazed of how small hardware devices can be used in many roles, for example, RFID is used to identify products but it is also used in checking and preventing orders from being unbilled by mistake. It was a great experience, I enjoyed being able to think out of the box in order to get new ideas that might be helpful in building such a similar store. I'm hoping a similar store can be presented in one of the Palestinian cities in the coming years.

C. Tala Alswaitti's Reflection on Designing the First Amazon Go Store in Palestine

During my stay in the UK last year, I encountered stores named ”Amazon Fresh.” Initially, I assumed they were regular stores like Tesco and Lidl. However, I was taken aback when I discovered that their cashier system was far from ordinary. Working on this paper gave me an opportunity to delve deeper into the workings of the store that had previously amazed me.

In this paper, my primary contributions centered on several areas including security, addressing billing issues and challenges, formulating the execution plan, and delving into AWS as the chosen cloud server solution. These topics were particularly intriguing, compelling me to consider scenarios in which unforeseen challenges or complications might arise. Additionally, it provided me with a valuable chance to understand the foundational steps required to implement such a store in Palestine.

In conclusion, writing this paper not only deepened my understanding of the innovative retail technologies behind Amazon Go but also allowed me to envision its potential in Palestine. This research journey has been invaluable, and I'm hopeful that the insights gathered might pave the way for future retail transformations in Palestine.