University of Moratuwa

Department of Electronic and Telecommunication Engineering

EN3251 - Internet of Things

Project Proposal

(Vending Machines' Network)

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Introduction

This project is a network of vending machines of a company that sells a defined set of different products. The main idea is to connect the vending machines in a star topology to a main server (aka admin server), to monitor the product availability in each vending machine and to provide customer with valuable information such as nearby locations, product availability in nearby locations, details of resupply schedules. Each vending machine is equipped with convenient user interface for the customer where he/she can buy products or inquire info. This implementation also benefits the company due to real-time monitoring and features like notification when products run low, and location wise or product wise stats, to efficiently schedule supply routines and to accurately identify the market value of products by analyzing the trends to make informed decisions on future marketing aspects.

Functionalities of the Vending Machine

Look of the Vending Machine

The above picture resembles a typical vending machine in the network (products are not necessarily drinks). The important aspect to note is the display.

The above is the typical user interface found on a vending machine. There are all together six buttons. Left three from top to bottom are respectively, '*GO TO CART*', '*CANCEL'*, '*BACK*' buttons. Right three from top to bottom are two navigation buttons '*UP*' and '*DOWN*' and '*ENTER*' button. The display in the middle is used for interactions with the customer.

Customer interface in the Vending Machine

Main menu

The main customer interface will display the date, time, and weather information for the location. Below, it will have two options: one for purchasing products and another for obtaining information about the nearest vending machines and where to find a specific product. The below picture depicts the look of the main menu.

Product menu

If customers select the "Buy Products" option, they will be directed to an interface called the "Product List," where they can choose their desired product. Within this interface, as they move the cursor over a specific product, they can view the available quantity and the real-time price. The price is dynamically updated from the server, to comply with price changes if there are any.

The "Product List" interface will appear as described above. In the upper left corner, there is a cart icon that indicates the number of product types currently in their cart. To select a product, they should press the "Enter" button to proceed further. After selecting a product, they will be directed to an interface where they can adjust the quantity before adding it to their cart.

As per their quantity selection, the price will be calculated. If they decide not to proceed with the selected item, they can simply select the "Back" option to erase their selection. After setting the quantity they should choose the "Proceed" option. After selecting the "Proceed" option, they will be redirected back to the product list interface to purchase more types of products. Once they select "Proceed," the product they chose will be automatically saved to the cart.

Below, they can see the product interface that appears after selecting the "Proceed" option. As you can observe in the upper left corner, the cart icon indicates that they have already added an item to the cart. If they wish to add more products, they can follow the same procedure.

The cart

There will be a “Go to cart” dedicated button on the vending machine to see the cart any time. If they don't want to add more products, they can simply press the "Go to Cart" button to view the

cart, where they can see their selected items, the total price, and a breakdown of prices for individual items.

After they've checked their cart information, if they want to purchase more items, they can simply select the "Back" option, which will redirect them to the product list interface, where they can follow the same procedure. If they are satisfied with their selection, then they should choose the "Buy Now" option to proceed further. It will direct them to the interface where they can select your payment method.

If they wish to edit the cart, they can simply move the cursor to the specific product and press the "Enter" button. This action will change the interface, allowing them to modify the quantity of the product, and the price will adjust accordingly.

It's important to note that they cannot select more items than the available quantity. If they exceed this limit, they will receive a pop-up message informing them that you've exceeded the limit. This message will also provide an option to "want more." If they click the "Want more" option, they can see where they can find that product and the available quantity in the nearest location. This helps you easily identify where to find more of the product. Additionally, if they reduce the quantity to 0, they will also receive a pop-up message asking, "Are you sure you want to remove this item?" If they press "Yes," the item will be removed from the cart. After editing the cart, to save the changes, simply press the "Enter" button. If they do not wish to save the edited version of the cart, select the "Back" option to return to the normal cart interface.

When your selection has exceeded the limit

When you reduce quantity to 0

When you select "want more" option

If their selection is not available anywhere, they will receive a message indicating that the product is not available in any location. Additionally, they can view the refill schedule, which is sorted by the time when the product will be refilled along with the corresponding place. It's important to note that the refill schedule is only available if it has been manually generated by the server operator or the manager. Otherwise, they will receive a message stating that the product is not available anywhere.

Payment menu

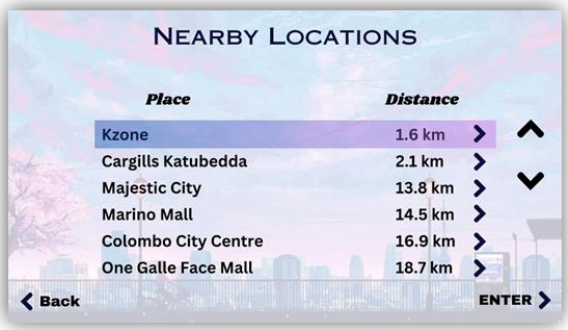
As you can see below, there are two payment options available for purchasing the selected product: one is the card payment method, and the other is the LankanQR method. They can use either of these methods for payment.

If they select the card option, they will see an interface that displays "Insert your card." After they insert their card, the transaction will proceed, and they will receive a "Thank you" message on the display. If they choose the LankanQR option, a QR code will appear on the display. They can then easily scan the QR code with their phone to complete the transaction. After this, they will also receive a "Thank you" message on the display. After this the display will return to the main menu.

Nearby locations menu

As previously mentioned, the initial interface offers two options: one for purchasing products and another for obtaining information about the nearest vending machines and where to find specific products. So far, the explanation has covered what occurs when a user selects the "Buy Product" option. Now, let's delve into the scenario that unfolds when the "See Locations" option is chosen.

After choosing the "See Locations" option, they will be directed to an interface that contains two options: one is "Nearby Locations," and the other is "Search by Products." If they select the "Nearby Locations" option, they will be directed to an interface where they can find where the other vending machines are located. The list will be sorted by distance, making it easy for them to identify the nearest vending machines.



As shown above the nearby locations where the vending machines located are displayed. To know about the product information in each location they can simply move the cursor the location and just press enter. After they press the enter key, they will get the information about the product in that corresponding place.

They can use the cursor to view the price and the number of available items for each product. The price changes in real-time with the help of the server, so they can always see the current price. Additionally, the available number of products updates in real-time, providing them with up-to-date information. However, it's important to note that they can only access information about other vending machines; they cannot make purchases from another vending machine.

If they choose the other option, which is "Search products," they can access information about a specific product in each location. After selecting this option, they will receive a product list to choose from. They can then select the desired product they want, and after selecting the product, they can view information about that product in each location.

As displayed above, with the help of the "Locations" option, they can find information about the locations of other vending machines, the items they have, where they can obtain a specific product, and its availability in any location.

As showed in the picture there is an option ‘Get Direction” in the lower right corner of the interface. When the customer presses the ‘*ENTER*’ button the display will show a QR code scanning which will take to the maps app in the customers’ phone showing the selected location, which makes it easy to the customer to get directions to that location.

Customer UI summary

These are the features that users will have access to through the user interface located on each vending machine. However, these functionalities are only possible when the vending machines are connected in a network. The connectivity allows one vending machine to provide information about other vending machines, including their product inventory, locations, and availability.

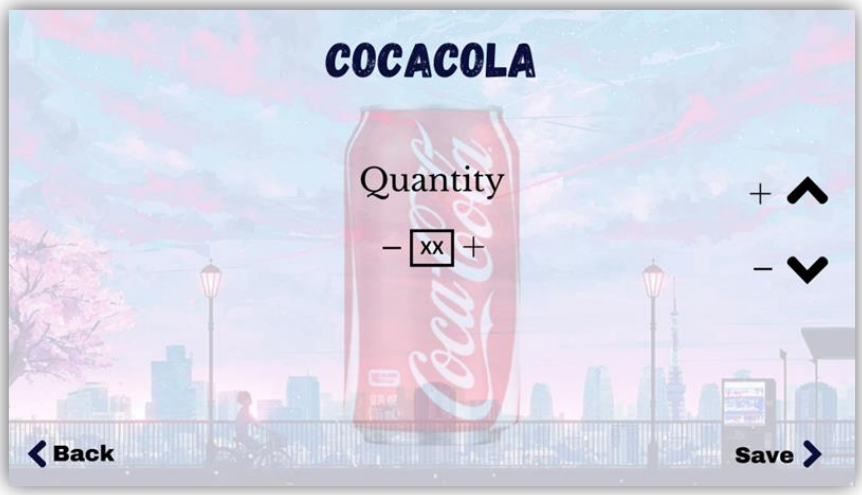
The main server plays a critical role in ensuring real-time data connectivity. It is responsible for providing up-to-date information on available quantities and prices of products.

The vending machines are equipped with two navigation (up-down) buttons, one '*ENTER*' button, one '*BACK*' button, and one dedicated button for the '*GO TO CART*' option, along with another '*CANCEL*' button for canceling the current purchase entirely. The up-down buttons allow users to navigate the interface and select their desired options. The '*ENTER*' button is used to confirm the chosen option. The '*BACK*' button functions as a means to go back in the interface, while the '*CANCEL*' button erases all cart data and returns users to the main menu.

Hidden interface / Supplier interface

When the supplier refills a product, it is crucial to update the information in the vending machine immediately. Suppose the supplier informs the manager about the refill, but the manager forgets to update the data. In this case, the supplier should have the ability to update the information themselves. To facilitate this, there is a dedicated button inside the vending machine. After the supplier refills the product, they can press this button to enable a hidden interface that only they can access. This hidden interface is designed to be accessible only by those who have the key to open the vending machine.

After the refill, the supplier should select the corresponding product using the navigation buttons and then update the quantity of the product that have been restocked. This action ensures that the quantity is updated immediately in the server by sending the data appropriately.



Handling cart for customer purchases

For each customer purchases the customers entries (additions of products to the cart) are recorded in the cart during the customer purchase. Cart is displayed once the "*GO TO CART*" dedicated button on the vending machine is pressed. The displayed cart shows calculated total price for the current products in the cart. The cart data is used in payment procedures. The cart content is cleared once the purchase is completed. The recorded data can be sent to the server for documentation.

Send queries and stock data to the server

Various real-time data are acquired from the server according to the customer interactions with the server. Unique requests are formed to be sent to the server for getting updated prices, available quantity of products (in the current machine), nearby locations (to the current machine), product details in a location (other vending machines), product available locations (other locations) and resupply schedules (if a product not available).

After each purchase, appropriately formatted data about that purchase is sent to the server to update available stock in that vending machine. During the restocking process the details about the no. of products that have been restocked are updated according to the suppliers' interaction in the hidden interface.

The queries and stock data are published to different MQTT topics.

Receive data from the server

Responses to the queries and updated prices, remaining quantities of products are received by subscribing to different MQTT topics. These data are interpreted and formatted to display to the customer.

Functionalities of the Server

Price management

The server maintains a central price database for all products. Formats and sends updated price lists to vending machines dynamically when a customer initiates a purchase, thus ensures consistency and accuracy of pricing information across all machines.

Product inventory management

The product, location, quantity remaining are stored, updated, and maintained in a table data structure. The value of the remaining quantity is updated during each purchase and resupply. This real-time inventory tracking ensures that the administrators always have an accurate view of the current stock levels in each location.

Automated notification when products run low

The server automatically generates alerts for products with counts less than 10, indicating low stock, enabling proactive restocking. Can accommodate customizable alert thresholds to cater to varying product demands across locations. Notifications will be sent immediately to the admin when any product runs low, allowing for timely restocking. The notification list will be sorted based on the time of the notification, enabling the admin to prioritize and efficiently plan the resupply process.

Create low stock data

If a product runs low in any location, the administrator can make the system to generate a comprehensive list containing only the products that need to be restocked with the quantities for each location and overall. This data is used to assist the administrator in creating resupply schedules.

Smart resupply schedules

The server enables administrators to create and modify resupply schedules based on resource availability, including manpower, transportation, with the information of the existing stock levels and real-time market conditions. Administrator can create resupply schedules assign resupply entries as per receiving notifications and using the low stock data. This approach ensures that resources are allocated efficiently, and restocking operations are synchronized with demand patterns. The administrator can utilize predictive analytics to optimize resupply schedules, minimizing resource (supply vehicles, manpower) wastage and ensuring timely restocking.

When a request for resupply information for a product is received (such as when a customer requests it from a particular vending machine), the system will extract dates of resupply from the assigned resupply schedules for the specific product to resupply planned locations, and sort them by time to send them to specific vending machine that requested it.

Purchase Analytics

The server enables the administrators to track and analyze monthly product consumption for each location and product. This helps the administrators to create detailed reports on customer preferences, helping in stock planning and product selection and facilitate data-driven decisions for marketing and product offerings.

Server UI

Product overview

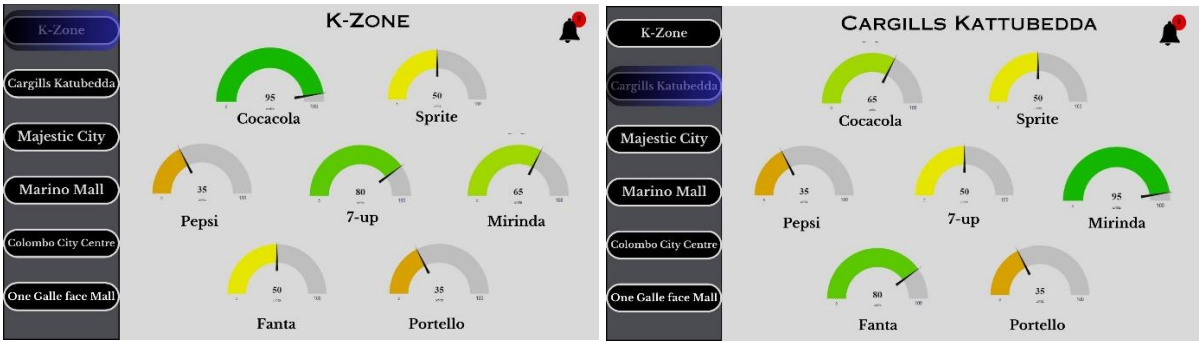
This tab will be the home tab in the dashboard. In the Product Overview tab, administrators can view the real-time status of remaining products across all locations. This consolidated view provides a quick glance at the overall stock levels, allowing for strategic decision-making regarding restocking priorities. *Note: The following pictures of the server interface do not represent the actual implementation.*

Notifications

A dedicated tab will be available on the main server interface to access notifications. An icon will display the number of unread notifications. When clicked, the notifications will be sorted by the time they were received, ensuring that administrators can promptly view and respond to important alerts and updates.

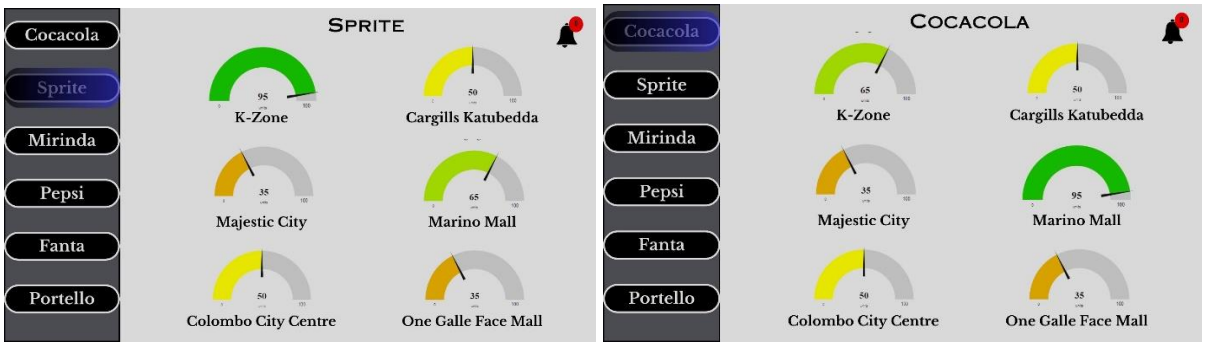
Locations tabs

For detailed insights, the interface will feature multiple tabs, each dedicated to a specific location. These tabs will display the remaining quantity of each product type in the respective location. This granular view enables administrators to monitor individual vending machine performance effectively.



Product tabs

For detailed insights, the interface will feature multiple tabs, each dedicated to a specific product. These tabs will display the remaining quantity of a particular product type in each location. This granular view enables administrators to monitor individual product performance effectively.

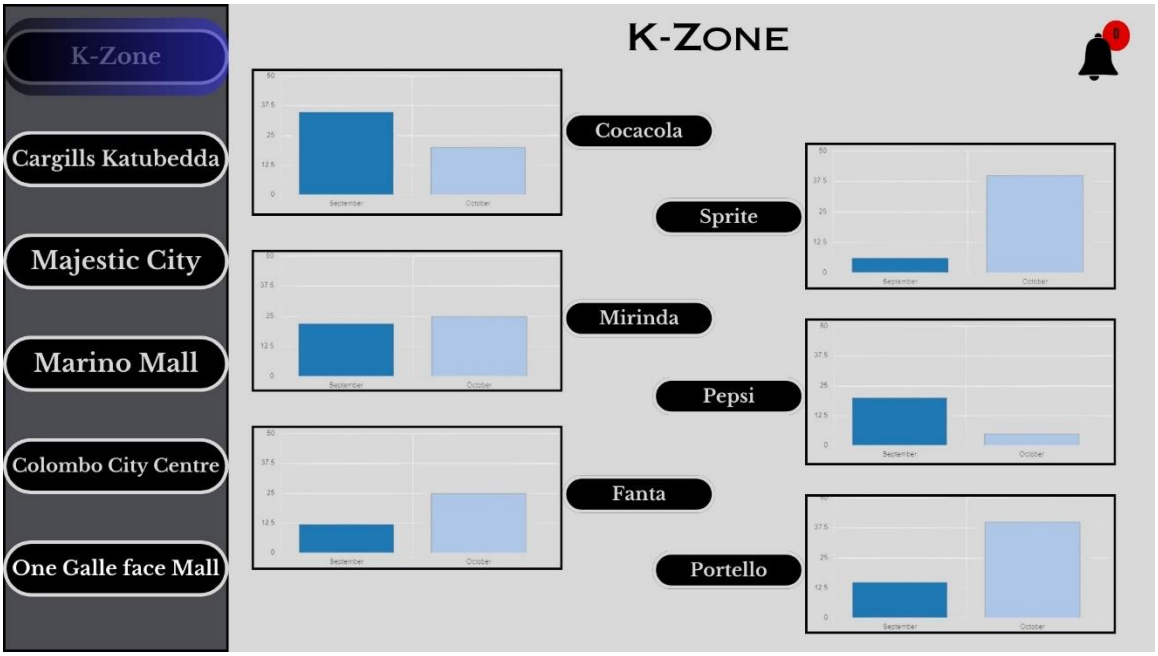


Update prices tab

A separate tab is provided for updating product prices. Administrators can access the current prices of each product and modify them as needed. The interface ensures a user-friendly experience, allowing for seamless price adjustments to align with market demands and profitability goals.

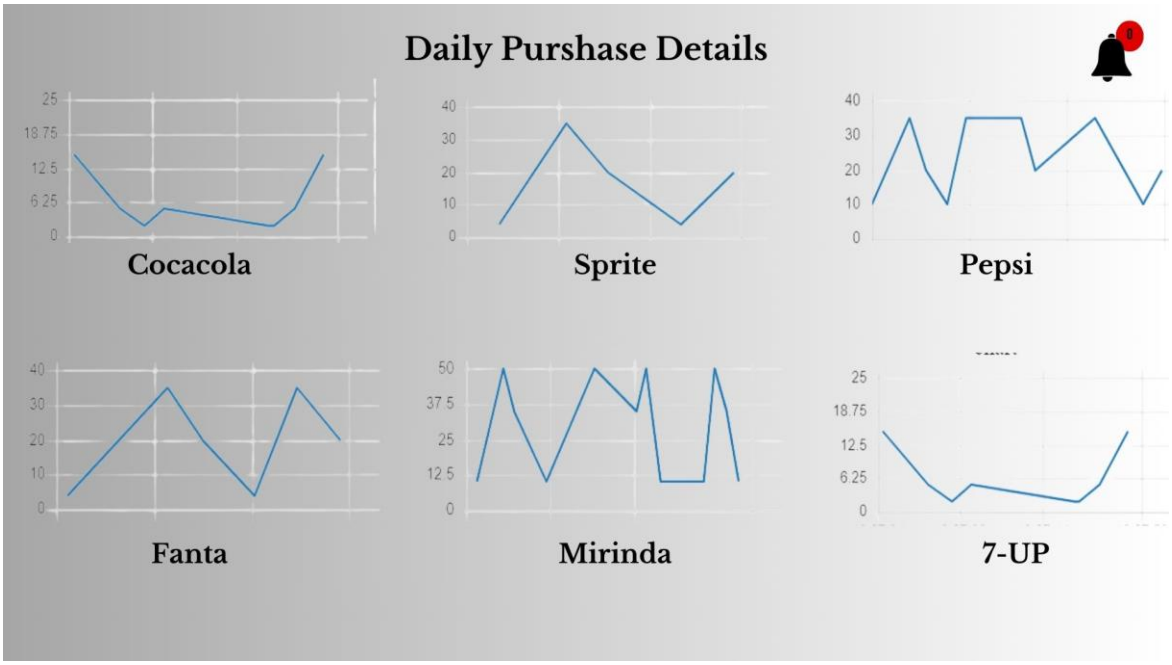
Month-on-Month graphs

The Month-on-Month graphs tab offers visual representations of sales data for each location and product. Comparative graphs will display the current month's purchases alongside the previous month's data. This graphical representation aids in identifying trends, analyzing customer preferences, and making data-driven decisions. The interface will allow users to customize the time range and product categories for a more focused analysis.



Daily purchase history

A tab, showing line graphs of daily purchases of each product is implemented. This tab helps the administrator to view and interpret the market trends for each product.



Resupply tab

In this tab there will be a text input prompt, where the administrator can input resupply plan as a simple formatted text (e.g. *date,location,product1,quantity1, product2,quantity2,*

product2,quantity2,…). This will create the resupply schedule and store it in the database and view it to the administrator.

Server UI Highlights

Intuitive navigation

The interface is designed for easy navigation, allowing administrators to switch between tabs effortlessly and access the desired information promptly.

Real-time Updates

Notifications and product quantities are updated in real time, ensuring that administrators have access to the most recent data for informed decision-making.

Interactive Graphs

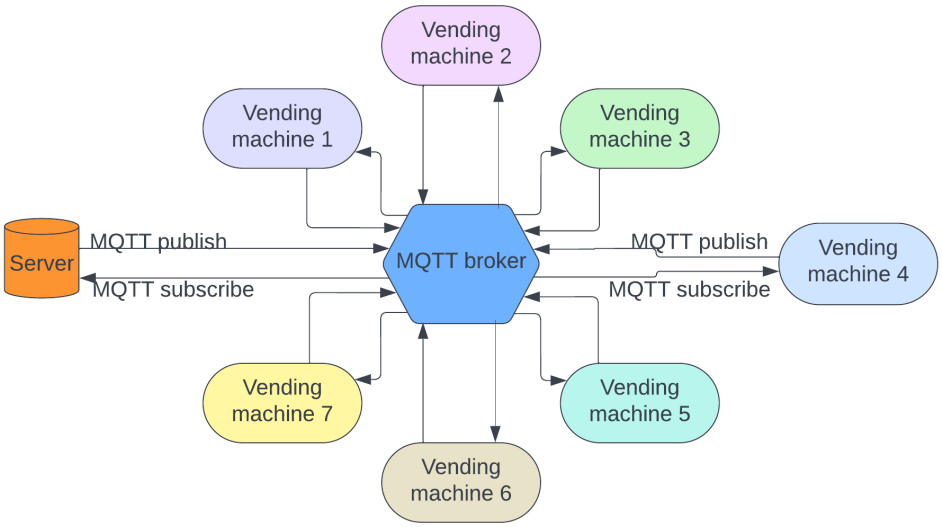
The month-on-month graphs are interactive, enabling admin to hover over data points for specific details. This interactivity enhances the analytical capabilities of the administrators.

Efficient Price Management

The Update Prices tab simplifies the process of modifying product prices, ensuring that pricing strategies can be adjusted swiftly to respond to market dynamics.

Technical details

Vending machine network diagram



The above diagram shows the basic operation of the network. We plan to use a publicly available MQTT broker for this operation.

Publish / subscribe topics

The following are different scenarios where unique MQTT topics are used for publishing and subscribing. The following topic names are for reference only actual implementation topics may vary.

Publish topics

Vending machines

1. **Code-red/Query** :
    a. To get updated price and quantities remaining in the current vending machine, from the server.
    b. To get updated price and quantities remaining in the other vending machine, from the server.
    c. To get details of nearby locations for the current vending machine from the server.
    d. To get details of product available locations / resupply schedule from the server.

    The messages sent to the above topic are appropriately formatted JSON objects representing each query.

2. **Code-red/Purchase** : To send purchase details after each purchase in the current vending machine.
3. **Code-red/Resupply** : To send resupplied quantity of products after each resupply.

Server

1. **Code-Red/Response/*VendingMachineID*** : To send responses for the queries made by the vending machine with ID: *VendingMachineID*.
    The messages sent to the above topic are appropriately formatted JSON objects with the responses for each received query.
    There will be a unique topic for every vending machine.

Subscribe topics

Vending machines

1. **Code-Red/Response/*VendingMachineID*** : Each vending machine will subscribe to this topic to receive any data/responses from the server.

Server

1. **Code-red/Query** : Every vending machine will be sending their queries to the same topic; the server will differentiate between the queries for each vending machine using the vending machine IDs within each query.
2. **Code-red/Purchase** : Every vending machine will be sending their purchase details to the same topic; the server will differentiate between the purchases for each vending machine using the vending machine IDs within each message.
3. **Code-red/Resupply** : Every vending machine will be sending their resupplied quantities details to the same topic; the server will differentiate between the data for each vending machine using the vending machine IDs within each message.

SQL database

We plan to use MySQL as the database platform to store every data in multiple different tables in the server and vending machine Node-Red instances. We will be using SQL injections to retrieve and modify data as per requirements.

Projected benefits

Improved customer experience

Accurate pricing information and product availability enhance customer satisfaction and loyalty. The customers can find unavailable products in a vending machine from that vending machine itself as per their needs. Also, when a product not available in any location they are provided with the resupply details, which prevents keeping the customer wondering when he can buy a product and makes it easy for the customer to make decisions. Since no intermediaries involved the customers can directly buy the products for the real and accurate up to date prices, thus improving customer's trust. Interactive user interface makes it easy for them to do purchases and get useful information.

Efficient business operations

Automated inventory management results in reducing manual efforts and minimizing human errors. Price adjustments are done instantly and efficiently. Smart resupply scheduling prevents resource wastages (supply vehicles, manpower) by optimizing the resource consumption according to real-time market status. Reduced retail expenses since the end retailer is a machine.

Data-driven managerial decisions

Detailed analytics capabilities of the server empower the management team with valuable insights, enabling strategic decision-making. Real-time market status and buying trends are readily available for the administrators and managers to dynamically make decisions and plan operational activities. Historic analysis such as month-on-month purchase are readily available for decision making.

Implementation plan

The prototype of the project is planned to be done in the Node-Red platform using MQTT connectivity. The plan is to implement a server and a vending machine Node-Red flows and simulate multiple instances of the vending machine flows representing different locations, to verify and demonstrate the functionality of the prototype. The server implementation will be fully equipped with the above functionalities on the dashboard. The vending machine implementation will have the aforementioned buttons and display on the dashboard with all the above functionalities. HTML, Angular based template blocks will be used in the making of the user interface of the vending machine.

Project deliverables

Due to the limited time provided, we plan to reduce the scope of this project. We are planning to not design the UI as explained in the proposal, instead we are planning to make it simpler without the attractive interfaces but with necessary fields to input the purchase details and queries. (E.g. Typing the queries in simple formatted text in the dashboard and viewing the received data from the server in formatted tables.)

The following are the 3 expected project deliverables.

1. The server is implemented in Node-Red and the following functionalities are included in the server.
    a. Product overview tab
    b. Notifications tab
    c. Locations tabs
    d. Product tabs
    e. Update prices tab
    f. Resupply tab
2. The vending machine (multiple occurrences) will be implemented in Node-Red, with the following functionalities.
    a. Buy tab :
        - This tab will show the current prices and quantity of products in the current machine in real-time.
        - There will be a text input field to input the items in the format (*Product_name,Quantity*).
        - After each input the cart will be created as a table and viewed.
        - We can enter the products one after one to add to the cart.
        - Entering “buy” in the input will send the purchase details to server and clears the cart. Entering “clear” in the input will clear the cart details.
        - Entering a product already existing in the cart with different quantity will update the cart.

    b. Nearby location tab :
        - There will be a tab to show the nearby locations and their distance from the current machine.
        - The nearby locations will also have the real-time product quantities available in each location, below them.
    c. Product details tab
        - There will be a tab for viewing the locations where a product is available.

- It will have an input prompt, entering a product name will show the locations where the product is available and the real-time quantities.
- If the product is not available anywhere it will show the resupply date for each location.

3. One instance of Vending machine implemented in hardware with limited abilities.
    a. Implemented using ESP-32.
    b. Consists of an OLED display and buttons to input.
    c. The menu on the display will have two options: 1)Buy and 2)Locations.
    d. Select buy to buy a product. Can buy products by navigating through the display, and select a product to view its available quantity, and set the quantity to buy. After setting the value and entering the product is bought and updated in the server.
    e. Select location to view nearby location details. Selecting a nearby location will display the products and available quantities in real-time on the display.
    f. Can verify the functionality by inspecting the changes in server when buying any product and checking the correctness of the nearby location details from the server subjected to changes in other locations.
    g. Sends buying data to the server and receives product count details of self and other locations from the server, catering to transmission reception capabilities.