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CARTIQ: SMART CART WITH OTP, RFID, AND BLUETOOTH TRACKING

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Abstract: The retail industry continues to transform while making customer convenience and automation along with security essential elements for efficient store management. A new type of shopping cart solution named CartIQ resolves problems related to lengthy checkout lines and traditional cart-operation methods and store security issues. The shopping cart implements four advanced technologies including OTP-based GSM authentication for security, Bluetooth RSSI-based user tracking, ultrasonic obstacle detection and RFID automatic billing which all go through Arduino microcontrollers. The solution delivers shopping without hands, immediate billing and improved navigation that especially enhances the shopping experience for older and differently-abled customers. The modular structure enables the system to grow through additional features such as mobile applications and store mapping and payment gateways. CartIQ creates a dual benefit by reducing manual tasks while enhancing customer shopping experience which drives future retail automation developments.

Keywords: Smart Cart, OTP Authentication, RFID, Bluetooth RSSI, Arduino, GSM Module, Obstacle Detection, IoT, Retail Automation, Embedded Systems.

I. Introduction:

The retail sector shows a growing interest in intelligent automation solutions due to expanding dynamic customer-focused environments. The current shopping experience creates problems because customers face extended waiting times together with human billing mistakes and lost carts and physical exertion from heavy cart movement which creates difficult situations for senior and disabled customers [2][9]. These challenges require a solution which enhances customer convenience while improving the operational performance of stores.

The paper introduces CartIQ Smart Shopping Cart System which incorporates hardware elements together with wireless connectivity features. The system operates through Arduino UNO and Nano central components which receive support from HM-10 Bluetooth [2], GSM800L [5], RFID readers [1], and ultrasonic sensors [3][4]. The combined components provide the following functionalities:

- OTP-based User Authentication through GSM [5]

- Cart Following through Bluetooth RSSI [2] which eliminates the need for manual pushing
- The system uses Ultrasonic sensors to detect and avoid obstacles for safe indoor navigation [3][4]
- The system enables product billing through RFID technology to decrease waiting times in lines [1]

The system provides customers with contactless shopping and customized experiences while maintaining high energy efficiency and enabling easy system expansion [7] as well as system scalability [6][8]. The modular nature of CartIQ combined with Industry 4.0 standards demonstrates a new level of automated retail operations.

II. Literature Review:

Shopping carts with intelligent capabilities attract substantial academic interest because they possess advanced functions that implement wireless communication alongside embedded systems and real-time automation features to enhance in-store operations.

2.1 RFID-Based Billing

The study by Smith [1] found that RFID technology grants superior billing performance than conventional barcode scanners. The system automatically identifies the items within the cart which minimizes the requirement for customers or cashiers to participate.

2.2 Bluetooth-Based Cart Tracking

A Bluetooth RSSI-based system suggested by Lee and Kim [2] enables shopping carts to follow users by measuring signal power levels. The new technology provides automatic cart movement for users especially during hectic shopping periods.

2.3 Obstacle Detection using Ultrasonic Sensors

Zhang et al. [3] together with Gupta and Sharma [4] combined servo-mounted ultrasonic sensors to detect obstacles during autonomous navigation thus providing a safer shopping experience.

2.4 OTP Authentication through GSM

The system by Rao and Patel [5] uses GSM modules to enable OTP-based security that provides secure and personalized device access which CartIQ uses for cart activation.

2.5 System Integration

Researchers Sharma et al. [6] identified integration difficulties when merging RFID, Bluetooth and obstacle sensors into embedded systems. The research demonstrated that modular communication between components proved essential which CartIQ implements as a key concept.

2.6 Energy-Efficient Design

Chen [7] developed energy-saving algorithms that work well for BLE mobile systems to extend the operational period of CartIQ.

2.7 AI and Future Smart Carts

Kumar and Nair [8] introduced the concept of AI-driven carts which provide product recommendations and behavioral forecasts. The upcoming implementation in CartIQ will develop this technology toward more advanced capabilities.

2.8 Sensor Fusion for Indoor Navigation

Verma and Joshi [9] combined multiple sensors into a fusion system which enhances smart cart navigation to achieve better path planning and collision avoidance.

III. Existing System and Its Drawbacks

In the traditional retail space, manual operations continue to govern the shopping experience for most consumers. The conventional process demands that people push carts through stores while selecting products and endure extended waiting periods for manual checkout and transaction processing. Supermarkets employ barcode scanners and point-of-sale (POS) systems yet these technologies fail to reduce patients and eliminate physical workloads.

3.1 Existing Manual Systems

Most shopping centers maintain their current operations through these methods:

- Stores use barcode scanning devices for manual billing
- Traditional metal carts require direct user handling
- No authentication methods are available for customers
- Cart scanning technology is absent from these retail environments
- There are no existing systems which notify customers about lost shopping carts or potential obstacles in the store

3.2 Major Drawbacks

The conventional setup relies on basic digital tools such as barcode scanners to operate yet it still maintains numerous operational faults:

1. Lack of Automation

No automated technology exists which can move shopping carts while scanning products and handling bill processing directly inside the cart.

2. Manual Effort Required

Customers including the elderly and differently-abled are forced to manually push the cart, often through congested aisles.

3. Long Billing Queues

The process of scanning each product through manual checkout at counters generates extended lines specifically on weekends and holidays.

4. No Security Mechanism

The absence of authentication systems and user tracking features enables unauthorized cart removal which results in inventory mismanagement and cart theft.

5. No Real-Time Product Feedback

During shopping trips customers do not have access to their billing information because items only receive scanning at checkout points.

6. No Obstacle Avoidance

Ordinary shopping carts lack the ability to sense obstacles or change their path to prevent crashes which creates challenges for users in crowded store areas.

IV. Proposed System and Block Diagram

The revolutionary shopping experience through CartIQ combines a fully automated intelligent smart cart to transform retail operations. This intelligent shopping cart operates independently to track customers and uses secure OTP verification to confirm their identity before autonomously dodging obstacles while scanning items for automatic RFID billing.

An embedded hardware system combines Arduino UNO and Arduino Nano with sensors and wireless communication modules as its core components to operate the system. The diagram illustrates how each essential part connects to one another in the system.

The developing system, CartIQ, works to transform the retail shopping experience through its innovative fully automated intelligent smart cart. The smart cart moves with customers while using secure one-time passwords to validate identities and simultaneously performs real-time obstacle detection before executing automatic RFID-based billing.

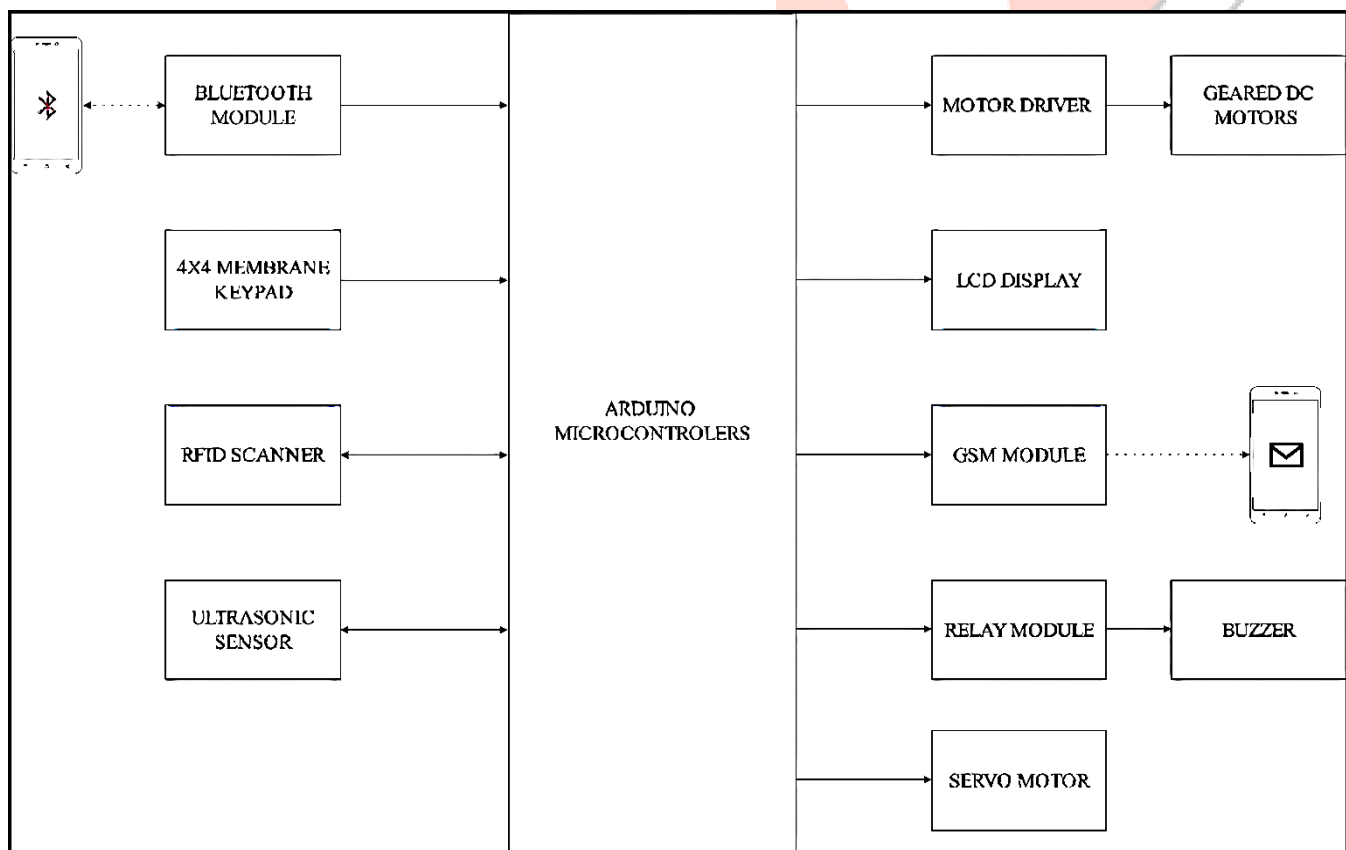


Fig 4.1 Block diagram

4.1 System Architecture

1. Arduino UNO

The Arduino UNO serves as the main processing unit which manages OTP verification and LCD display functions as well as RFID billing and system-wide coordination.

2. Arduino Nano (2 Units)

- Two Arduino Nano units perform distinct functions within the system.
- The second Arduino Nano processes user Bluetooth signals through RSSI signals sent from their smartphones.

3. GSM Module (SIM800L)

The module works for OTP authentication. The system sends a one-time password to the user's mobile phone when the cart gets activated [5].

4. Bluetooth Module (HM-10)

The system utilizes the RSSI value to perform user distance measurement. The cart starts moving forward if the signal strength is high, and it stops or changes direction when the signal becomes weak or disconnected [2].

5. Ultrasonic Sensor with Servo Motor

The system uses a scanning system on a servo motor to detect obstacles across a 180-degree arc. When the cart detects an object at a programmed distance (e.g., 20 cm), its motor control logic stops forward movement and redirects the cart [3][4].

6. RFID Reader

The user places products into the cart using RFID tags for each item. The RFID reader detects all product placements in the cart and shares collected data to the LCD display for immediate billing updates [1].

7. LCD Display (20x4)

The display provides real-time information about items together with their prices and OTP authentication steps and final billing costs. **Motor Driver + Geared DC Motors**

Enables bidirectional movement and precise control of the cart. The driver receives signals from the Nano boards based on Bluetooth and sensor data.

8. Relay Module

A safety feature activates motor power cutoff immediately in two situations: obstacle detection and Bluetooth disconnection [4].

9. Buzzer

A buzzer system generates sound warnings for three different scenarios: disconnection events and obstacle detection as well as incorrect OTP entries and billing notifications.

10. Power Supply

The system operates using Li-ion batteries as its primary power source and lead-acid backup while delivering regulated voltages to the sensors at 5V and to the motors at 12V.

4.2 Functional Workflow Explanation

1. The process starts when the user keys in their mobile number which triggers the OTP reception for verification through keypad entry.
2. Upon successful entry of OTP, the cart starts moving by tracking the user's Bluetooth signal.
3. The system constantly operates obstacle detection while managing avoidance through ultrasonic sensors.
4. The system performs automatic scanning of products in the cart through RFID technology.
5. The system displays all information on the LCD while updating real-time billing.
6. If Bluetooth connection terminates or an obstacle appears the cart stops and gives a warning to the user.
7. Throughout the entire process the cart maintains its independence while ensuring safety and offering convenient user interaction.

V. Hardware and Software Implementation

CartIQ uses multiple hardware units with various software elements to create an intelligent shopping platform which functions autonomously. The integration framework divides the system into multiple functions that include authentication handling as well as navigation processes and item billing and display communication. The modules underwent selection by evaluating their performance in real-world settings and their ability to work together and their development complexity.

5.1 Hardware Components

The following section provides an extensive explanation of the primary hardware elements that the system employs:

1. Arduino UNO and Arduino Nano

- The main controller Arduino UNO performs OTP input management along with RFID billing and display functions.
- Two Arduino Nano boards perform independent Bluetooth tracking and obstacle avoidance operations to minimize processing delays.

2. GSM Module (SIM800L)

- The GSM Module sends OTP notifications to the user's mobile phone for authentication.
- This module processes AT commands to receive instructions from the user while transmitting data through UART.

3. HM-10 Bluetooth Module

- The HM-10 Bluetooth Module tracks the signal strength between the user's smartphone and the module.
- The Bluetooth Module enables the cart to track and follow the user

4. Matrix Keypad 4*4

- The 4x4 Matrix Keypad enables users to register their mobile numbers as well as enter their verification OTP information.

5. Ultrasonic Sensor with Servo Motor

- The 180-degree servo sweep mechanism holds the Ultrasonic Sensor.

- The Ultrasonic Sensor mounted on the 180-degree servo continues to examine obstacles while transmitting measurement data to Arduino Nano.

6. RFID Reader

- The RFID Reader device captures data from tags which are affixed to items.
- The RFID Reader module forwards the product identification information to Arduino for further processing and billing functions.

7. LCD Display (20x4)

- The LCD screen shows product names, their costs, the final bill amount, the One Time Password (OTP) notifications and various system notifications.
- This device connects to Arduino through two available communication methods which are I2C and parallel interfaces.

8. Motor Driver (L298N) and Geared DC Motors

- The motor driver enables Bluetooth tracking and obstacle inputs to control wheel movements.
- The system allows the motor to move forward and backward as well as left and right.

9. Relay Module

- This component enables motor safety through automatic shutdown when system detects errors or obstacles.

9. Buzzer

- The system produces sound signals whenever Bluetooth connection is lost or obstacles appear or if incorrect OTP verification or RFID scanning occurs.

5.2 Software Implementation

The Arduino IDE served as the development environment for this software which employs embedded C/C++ code that uses modular logic to enhance testing and debugging capabilities.

➤ Functional Modules:

1. OTP Authentication Logic

- The GSM module sends OTP → Arduino verifies the OTP → The Arduino activates the cart.

2. Bluetooth Tracking Algorithm

- The system measures RSSI and decides to stop the cart when the signal is weak or to follow when the signal is strong

3. Obstacle Avoidance Algorithm

- The system detects objects within 20cm distance → The system pauses → The system conducts left or right scanning → The system picks a path with no obstacles.

4. RFID Billing Logic

- The RFID tag reading operation triggers an item database check → The system displays the item name and its price on the LCD screen.

5. Tools Used:

- Arduino IDE for programming.
- Real-time serial monitor debugging during hardware testing.

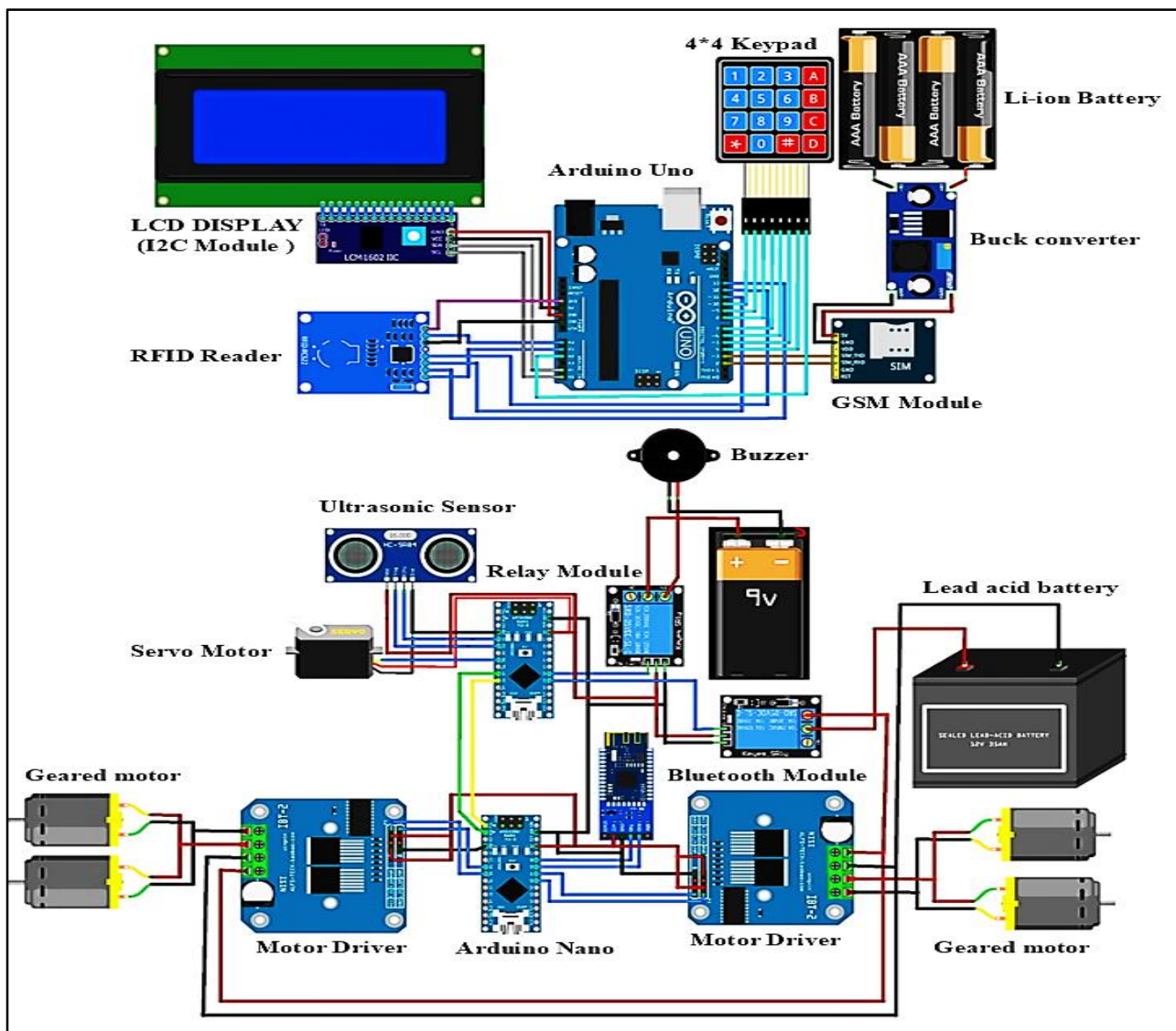


Fig 5.1.1 Hardware Description

VI. Applications And Limitations

The CartIQ system aims to optimize the operational performance of present-day retail settings. Its versatile design allows for widespread implementation across different sectors aside from supermarkets and malls.

6.1 Supermarkets and Hypermarkets

- Reduces human intervention and long billing queues through automatic RFID scanning.
- The system provides support for differently-abled and elderly individuals through autonomous cart following and obstacle avoidance.

6.2 Warehouses and Inventory Management

- RFID tags allow the system to move materials automatically and perform product identification functions.
- A system implementation results in better internal logistics operations at large inventory centers.

6.3 Airport and Railway Stations (Luggage Trolleys)

- Tracking through Bluetooth technology combined with automatic motion enables the trolleys to serve passengers by carrying their luggage.
- The implementation of autonomous systems in transit environments leads to better comfort and convenience for passengers.

6.4 Smart Campus or Libraries

- The autonomous system uses RFID technology and navigation systems for book/item delivery and collection between various departments.

6.5 Hospitals and Healthcare Facilities

- The system functions to deliver medical kits and files as well as basic equipment autonomously in larger hospital facilities.

➤ Limitations of the Proposed System

CartIQ introduces innovative retail automation systems which face operational restrictions because of existing technological and economic and environmental conditions. The upcoming system versions need to resolve these limitations for achieving both scalability and operational strength.

1. Bluetooth Signal Instability

- The system operates through Bluetooth RSSI signals which experience interference from surrounding wireless devices and physical blockages.
- In environments with heavy wireless traffic the cart may encounter problems maintaining continuous tracking of the user.

2. Limited Range of Obstacle Detection

- The ultrasonic sensor provides a limited field of view and depth detection (~2–3 meters), which may not be sufficient in complex store layouts with narrow or crowded aisles

3. Dependency on GSM Network

- OTP-based authentication is reliant on GSM module coverage.
- In areas without proper network coverage, the cart will be unable to start for new users.

4. No Theft Prevention or Item Removal Detection

- The inventory security system does not have the ability to detect changes in items after scanning which creates a security gap.

5. Battery Limitations

- Constant operation of motors along with sensors and GSM and Bluetooth causes batteries to lose power quickly.
- To maintain uptime the system needs periodic recharging or an advanced power management solution.

6. Lack of Real-Time Synchronization with Store Inventory

- At present CartIQ does not synchronize with store backend databases to provide dynamic product availability and pricing validation.

7. Initial Cost of Deployment

- Initial implementation costs for small retailers become burdensome because they need to pay for carts and tags along with servers and staff training.

VII. Results and Discussion

The development process successfully led to the production and functional testing of CartIQ Smart Shopping Cart under controlled shopping environment conditions. The system successfully integrated OTP verification together with autonomous cart movement and product billing capabilities and obstacle detection technologies. System modules underwent individual testing and complete system assessment to measure their operational efficiency and dependability.

7.1 OTP-Based Authentication

- The GSM module underwent testing under different mobile numbers. The system produced OTPs and delivered them successfully within network-stable areas after 3–5 seconds.
- The 4x4 keypad detected user input correctly so the system granted access to those who provided the correct OTP entry for secure activation.

7.2 Bluetooth RSSI-Based Cart Following

- The cart maintained proper user following operations within the 2 to 3-meter distance range based on surrounding environmental conditions.
- The system utilized signal strength thresholds to trigger a safe cart stop when the user exceeded range limits, followed by an immediate buzzer alert upon disconnection.

7.3 Obstacle Detection and Avoidance

- The ultrasonic sensor installed on a servo motor platform offered complete 180° detection capabilities.
- The system would automatically stop the cart when detecting objects within 20 cm distance which triggered directional scanning for safe rerouting.

7.4 RFID-Based Billing

- When customers picked products with RFID tags they generated successful scan results in the shopping cart.
- The LCD screen provided an accurate presentation of product names and their prices while showing the current total amount.
- The RFID system processed each tag in just 1 to 2 seconds resulting in fast and contactless billing operations

7.5 Real-Time System Interaction

- The LCD Display demonstrated rapid responses to both OTP input and received RFID data and system messages.
- The testing feedback from users confirmed that seniors experienced high satisfaction levels with this system because they could move hands-free.

7.6 Observations

- All components operated together when supplied with 12V power.
- The modular Arduinos system design allowed separate functions to operate simultaneously without performance delays.
- The current system works properly at local retail locations yet requires modifications to function effectively in large-scale commercial settings.



Fig 8.1 Image of Prototype



Fig 8.2 LCD Output Display

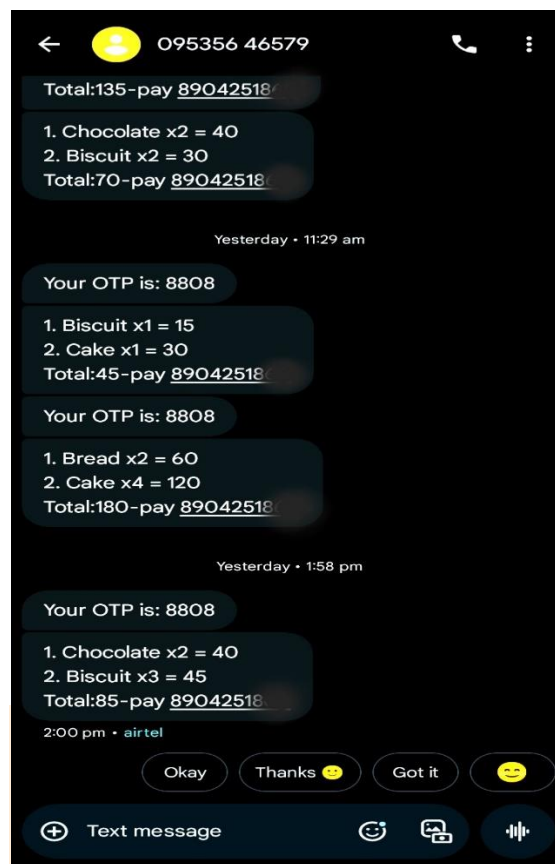


Fig 8.3 OTP & Billing SMS Message Received via GSM Module

VIII. Future Scope

CartIQ successfully meets its main goal of automation and smart technology implementation to improve the shopping process yet substantial opportunities exist for system expansion. The platform requires fundamental enhancements to improve its artificial intelligence capabilities and scalability and adaptability for business environments.

8.1 Mobile Application Integration

A mobile app development provides users with the capability to:

- Establish Bluetooth connections between their smartphones and shopping carts
- Observe real-time billing details
- Get automatic product recommendations
- Use digital checkout services without physical store staff involvement

8.2 Integrated Payment Gateway

The user can make direct payments through the cart interface by connecting payment systems including UPI and debit/credit cards and e-wallets which removes the necessity for store-based transactions completely.

8.3 AI-Based Product Recommendation

The system will be able to implement machine learning through which the cart can:

- Give product suggestions according to previous buying choices
- Provide discounted deals and product bundles
- Create shopping experiences tailored to individual customers

8.4 Advanced Obstacle Detection

Using LiDAR or computer vision cameras in place of ultrasonic sensors provides the following benefits:

- Complete three-dimensional object detection capability
- Improved guidance through congested or tight spaces
- Automatic path adjustments in real-time

8.5 Voice Assistance and Accessibility

The integration of Google Assistant or Alexa modules for voice shopping will improve the accessibility for three main customer groups:

- Senior clients
- People with visual disabilities
- All users can benefit from hands-free engagement

8.6 Cloud-Based Inventory and Cart Sync

The cloud-based synchronization of carts to stores' databases enables:

- Immediate product stock status updates
- Automated price alignment between all systems
- The store management team can use centralized monitoring

8.7 Solar Charging for Energy Efficiency

When solar panels are installed on the cart's exterior it enables **GPS** and **RFID** and **LCD** modules to operate with minimal power usage thus creating an environmentally-friendly energy-effective platform.

IX. Conclusion

CartIQ Smart Shopping Cart offers an integrated solution which redefines modern retail operations through automated processes combined with secure user verification and instant data exchange capabilities. The system operates through a microcontroller-based architecture which combines GSM OTP verification with autonomous Bluetooth tracking and ultrasonic obstacle detection as well as RFID-based product billing.

CartIQ implementation tests confirm its functionality along with its suitability for retail settings that operate at small and medium scales. The system delivers substantial benefits through its reduced manual operations and simplified checkout procedures while extending accessibility for shoppers who face mobility difficulties. The system establishes a robust base for future retail automation despite its Bluetooth and GSM limitations. The future development of CartIQ through artificial intelligence implementation and mobile application integration alongside advanced navigational capabilities will lead to a fully autonomous retail assistant that supports Smart Retail and Industry 4.0 objectives.

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