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RFID Based Automated Milk Quality Analysis and Vending System

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ABSTRACT: Milk is an important nutritional food that is consumed by people of all age groups. However, maintaining the quality of milk during collection and distribution is a major challenge because adulteration and contamination may occur. Traditional milk testing methods usually depend on manual inspection and laboratory analysis, which are time-consuming and not suitable for real-time milk vending systems. Therefore, an automated system is required to ensure safe and efficient milk distribution.

This project proposes an automated milk quality analysis and vending system using sensor technology and RFID-based authentication. The system uses pH, Total Dissolved Solids (TDS), and temperature sensors to monitor important milk quality parameters. The sensor readings are processed using a microcontroller, which compares the measured values with predefined standard limits to determine whether the milk is suitable for consumption.

An RFID card is used for secure user authentication and easy access to the system. After verifying the user and confirming the milk quality, the system automatically dispenses the selected quantity of milk using a pump controlled by a relay. A keypad allows users to choose the required quantity, while an LCD display provides information about system status and operation.

The proposed system helps reduce manual intervention, improves transparency in milk distribution, and ensures that consumers receive safe and high-quality milk.

KEYWORDS: RFID Technology, Milk Quality Monitoring, Adulteration Detection, pH Sensor, Total Dissolved Solids (TDS), Automated Milk Vending System, Real-time Quality Analysis.

I. INTRODUCTION

In many traditional milk distribution systems, milk is delivered to consumers through dairy outlets or vending stations without continuous monitoring of its quality. Normally, milk quality testing is carried out in laboratories using chemical analysis methods and specialized equipment. These procedures often require skilled technicians and significant processing time, which makes them unsuitable for real-time quality verification during milk vending operations.

Another serious issue in dairy supply chains is milk adulteration. To increase the volume or extend the shelf life of milk, some unwanted substances such as water, starch, detergents, or other chemicals may be mixed with it. Such practices reduce the nutritional value of milk and may lead to serious health problems for consumers. Therefore, it is necessary to develop a system that can evaluate milk quality automatically before it is supplied to the user.

To overcome these limitations, an RFID-based automated milk quality analysis and vending system is proposed. This system combines sensor technology with embedded control mechanisms to monitor milk quality and manage the dispensing process automatically. Sensors including pH, Total Dissolved Solids (TDS), and temperature sensors are used to measure important parameters of milk and detect abnormal conditions.

In addition to quality monitoring, the system incorporates RFID technology to provide secure identification for users. Each consumer can access the vending unit through an RFID card, which enables a simple and cashless method of

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operation. Once the user authentication is completed and the measured milk parameters are within acceptable limits, the system activates a pump mechanism controlled by a microcontroller to dispense the selected quantity of milk.

A keypad interface is used for quantity selection, and an LCD display shows important information such as system status, milk quality results, and dispensing messages. By vending mechanism, the system helps improve efficiency, minimize manual involvement, and ensure that consumers receive safe and reliable milk.

The main contributions of this work include:
Main Contributions of the Proposed System
The RFID Based Automated Milk Quality Analysis and Vending System provides a reliable approach for monitoring milk quality and automating the distribution process. The main contributions of this project are described below...

Automated Milk Quality Monitoring:
The proposed system performs continuous monitoring of milk quality using integrated sensing modules. Important parameters such as pH level, Total Dissolved Solids (TDS), and temperature are measured to identify any possible contamination or adulteration in the milk. By automatically analysing these parameters, the system ensures that only milk that satisfies the required quality standards is delivered to consumers.

RFID-Based User Authentication:
Radio Frequency Identification (RFID) technology is used to identify and verify users before allowing access to the milk vending system. Each authorized user is provided with an RFID card, which enables quick identification and secure operation of the system. This method simplifies the user interaction process while also improving system security.

Microcontroller-Controlled Operation:
The entire system is managed by a microcontroller that functions as the central processing unit. It collects signals from different sensors, processes the obtained data, and controls the operation of system components such as the relay, pump, keypad, and LCD display. This centralized control enables smooth and efficient system performance.

Sensor-Based Quality Detection:
Multiple sensors are incorporated to monitor key properties of milk. The pH sensor is used to determine the acidity level of the milk, the TDS sensor measures dissolved particles, and the temperature sensor monitors the storage condition. These sensors work together to provide reliable quality assessment of the milk.

II. BACKGROUND

Milk is an essential agricultural product and a primary source of nutrition for millions of people. Due to its high nutritional value, milk is widely consumed in households, schools, hospitals, and food industries. As the demand for dairy products continues to grow, maintaining the quality and safety of milk throughout the supply chain has become a major concern for dairy producers and regulatory authorities.

One of the main challenges in milk distribution systems is maintaining the purity and freshness of milk during storage, transportation, and vending. Milk can easily undergo quality degradation due to contamination, improper handling, or the addition of adulterants. Adulteration may occur intentionally to increase the quantity of milk or unintentionally due to poor handling conditions. Such practices reduce the nutritional value of milk and may cause health issues for consumers.

Research studies have indicated that common adulterants such as water, starch, detergents, and other chemicals may be mixed with milk in some distribution systems. Detecting these adulterants through traditional laboratory methods often requires specialized equipment and trained personnel. While laboratory testing provides accurate results, it is time-consuming and cannot be easily implemented in real-time vending environments.

In many milk distribution centres, milk quality verification is performed periodically rather than continuously. This means that milk supplied to consumers may not always undergo immediate quality verification before distribution. As a result, there is a growing need for automated systems that can analyse milk quality quickly and efficiently before dispensing it to consumers.

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Advancements in embedded systems and sensor technologies have enabled the development of intelligent monitoring systems for food quality assessment. Sensors capable of measuring parameters such as pH level, Total Dissolved Solids (TDS), and temperature can provide valuable information about milk quality. These parameters help identify abnormal conditions or possible contamination in milk.

In addition to quality monitoring, automation technologies are also being introduced in milk vending systems to improve efficiency and convenience. Automated vending systems reduce manual handling and allow controlled dispensing of milk based on user input. Secure user identification methods such as RFID technology can also be integrated into vending machines to enable controlled access and cashless transactions.

The RFID Based Automated Milk Quality Analysis and Vending System is developed based on these technological advancements. The proposed system integrates sensors for monitoring milk parameters, a microcontroller for data processing, and RFID technology for user authentication. By combining automated quality analysis with a controlled dispensing mechanism, the system helps ensure that only verified and safe milk is delivered to consumers while minimizing human intervention.

III. RELATED WORKS

Many researchers have focused on improving milk quality monitoring and automated vending technologies by integrating sensors, embedded systems, and smart authentication techniques. Some important related research works are summarized below.

1. Sensor-Based Milk Quality Detection System:
Several researchers have developed milk quality monitoring systems using sensors to measure parameters such as pH value, temperature, and conductivity. These systems analyse milk characteristics to identify adulteration and contamination. The studies demonstrated that sensor-based monitoring can provide faster results compared to traditional laboratory testing methods.

2. Automated Milk Vending Machine Using Microcontroller:
Another research work introduced a microcontroller-based milk vending machine designed to distribute milk automatically. The system used pumps and valves to dispense milk based on user selection. The results showed that automated vending systems can improve efficiency, reduce manual handling, and provide accurate quantity control during milk distribution.

3.IoT-Based Milk Quality Monitoring System:
Recent studies have proposed IoT-enabled milk monitoring systems where sensor data is transmitted to cloud platforms for analysis and storage. These systems allow remote monitoring of milk parameters such as temperature and quality indicators. The research highlighted that IoT technology can improve transparency and traceability in dairy supply chains.

4. RFID-Based Smart Vending System:
Some researchers have developed RFID-based vending systems to provide secure user authentication and cashless transactions. In these systems, users access vending machines using RFID cards, which helps maintain transaction records and improve system security. Such technologies have been successfully implemented in automated food and beverage vending machines.

5. Intelligent Milk Adulteration Detection Systems:
Another area of research focuses on detecting milk adulteration using sensor arrays and digital processing techniques. These systems analyse multiple parameters of milk to determine its purity. The results indicate that intelligent monitoring systems can effectively detect adulterated milk and prevent its distribution to consumers.

IV. PROPOSED RESEARCH DESIGN AND ARCHITECTURE

The RFID Based Automated Milk Quality Analysis and Vending System is designed to improve the safety, efficiency, and reliability of milk distribution. The key features of the proposed system are described below.

1. Real-Time Milk Quality Monitoring:
The proposed system continuously monitors milk quality using sensors such as pH sensors, TDS sensors, and temperature sensors. These sensors help identify abnormal changes in milk characteristics and ensure that only quality milk is dispensed.

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2. Secure User Authentication Using RFID:

RFID technology is integrated into the system to provide secure access to users. Each user is provided with an RFID card, which allows them to operate the vending machine. This method improves security and enables easy user identification.

3. Automated Milk Dispensing System:

The system includes an automated dispensing mechanism that releases milk through a pump controlled by a relay. After verifying both milk quality and user authentication, the required quantity of milk is dispensed automatically.

4. Reduction of Human Intervention:

The automated system minimizes the need for manual supervision in milk vending operations. By integrating sensors, RFID authentication, and microcontroller-based control, the system performs quality analysis and dispensing operations automatically.

5. Improved Transparency in Milk Distribution:

The system provides real-time information through an LCD display, allowing users to view system status and operational details. This improves transparency and helps maintain consumer trust in milk quality.

6. Scalable System for Smart Dairy Applications:

The proposed design can be expanded for larger dairy distribution systems such as milk booths and cooperative societies. Future improvements may include integration with IoT platforms for remote monitoring and digital payment systems for enhanced user convenience.

V. DATA COLLECTION

Data collection is an important stage in evaluating the performance and reliability of the RFID-based automated milk quality analysis and vending system. In this project, different types of data are gathered from sensors, system components, and testing procedures to analyse the efficiency of the milk quality monitoring and dispensing mechanism.

1. Sensor Data Collection:

The system uses several sensors to monitor key milk quality parameters during operation.

pH Sensor Data:

The pH sensor measures the acidity or alkalinity level of milk. The collected data helps determine whether the milk falls within the acceptable quality range. Any abnormal pH value may indicate contamination or spoilage.

TDS Sensor Data:

The Total Dissolved Solids (TDS) sensor measures the concentration of dissolved substances present in milk. This data helps identify possible adulteration or impurity levels in the milk.

Temperature Sensor Data:

The temperature sensor monitors the storage temperature of milk. Maintaining proper temperature conditions is important to prevent spoilage and preserve milk quality.

2. Milk Quality Analysis Data:

Data related to milk quality parameters is collected to determine whether the milk meets acceptable standards for consumption. Sensor readings are compared with predefined reference values to detect abnormal conditions or possible adulteration. Sensor readings are compared with predefined reference values to detect abnormal conditions or possible adulteration.

3.System Operation Data:

The performance of the automated vending system is monitored by recording operational parameters such as pump operation time, quantity of milk dispensed, and response time of the system after user authentication.

4.RFID Authentication Data:

The RFID module records user authentication information during system operation. Data such as card detection time, successful authentication attempts, and system response are monitored to ensure secure and efficient access to the vending system.

5. Experimental Testing Data:

Several experimental tests are performed to evaluate the system performance under different operating conditions. During testing, the following data is recorded:

- Sensor readings for milk quality parameters
- User authentication success rate
- Milk dispensing time
- Quantity accuracy of milk dispensing
- System response time

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6. Data Analysis:
The collected data is analysed to evaluate the effectiveness of the automated milk vending system. The analysis helps determine whether the system can reliably monitor milk quality, authenticate users, and dispense milk efficiently while maintaining safety standards.

VI. APPLICATION

The RFID Based Automated Milk Quality Analysis and Vending System has several practical applications in dairy management and automated food distribution. Some of the major applications are described below.
1. Dairy Distribution centre:
Milk distribution centre can implement the system to ensure that only quality-tested milk is supplied to consumers. The automated system reduces manual inspection and improves reliability in milk distribution.
2.Milk Booths and Cooperative Societies:
Milk booths and dairy cooperatives can use the vending system to automate milk distribution. This helps maintain transparency in transactions and reduces human involvement in the dispensing process.
3.Smart Vending Machines:
The proposed technology can be integrated into smart vending machines that distribute milk or dairy products automatically with secure user authentication.
4.Educational and Research Laboratories:
The system can be used as a demonstration model in academic institutions for studying sensor-based food quality monitoring and automated vending technologies.
5.Smart Dairy Management Systems:
The proposed system can be integrated into larger smart dairy management platforms where milk quality monitoring, storage, and distribution are automated using modern digital technologies.

VII. TRAINING FLOW CHART

The machine learning training process for milk quality monitoring involves several stages.
Data Collection:
Sensor data such as pH values, TDS levels, temperature readings, and system operation data are collected from the milk vending system.
Data Preprocessing:
The collected data is organized and cleaned to remove incorrect readings and missing values.
Feature Extraction:
Important parameters such as acidity level, dissolved solids concentration, and temperature are selected as features for model training.
Model Selection:
A suitable machine learning algorithm is selected depending on the classification or prediction task.
Model Training:
The algorithm is trained using the collected dataset to learn patterns associated with milk quality conditions.
Model Testing:
The trained model is tested with new sensor data to evaluate its prediction capability.
Performance Evaluation:
The accuracy and reliability of the model are measured using evaluation me;trics.
Deployment
The trained model can be integrated into the milk quality monitoring system to support automated decision-making.

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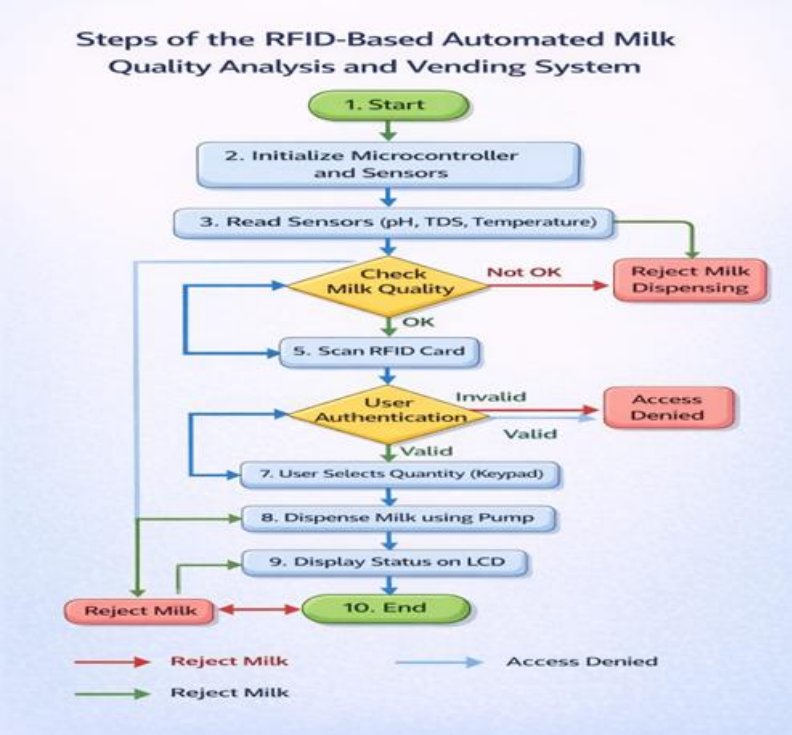

VIII. TESTING AND VALIDATION

Testing and validation are important stages in the development of the RFID Based Automated Milk Quality Analysis and Vending System. These stages ensure that all system components operate correctly and that the system can reliably analyse milk quality and dispense milk in real-time conditions.

1.System Testing:
System testing is performed to verify whether the hardware and software components of the milk vending system work together properly. The testing process includes checking sensor performance, RFID authentication, pump operation, and system response.
1.1 Hardware Testing:
Hardware testing ensures that every physical component functions correctly.
Microcontroller Testing:
The microcontroller is tested to confirm that it properly receives input signals from sensors and the RFID module and sends control signals to the relay, pump, and display unit.
RFID Module Testing:
The RFID reader is tested to verify that it can detect and read RFID cards accurately. The system checks whether the card is authorized before allowing the vending process.
Relay and Pump Testing:
The relay module is tested to ensure it properly controls the milk dispensing pump. The pump is checked to confirm that it dispenses the correct quantity of milk when activated.
Sensor Testing:
Sensors such as the pH sensor, TDS sensor, and temperature sensor are tested individually to confirm that they provide accurate readings of milk quality parameters.
LCD Display Testing:
The LCD module is tested to verify that it displays system messages, milk quality values, and vending status clearly.

2.Milk Quality Verification Testing:
Experiments are conducted to evaluate how effectively the system detects milk quality.
Initial Measurement:
Before the vending process, the system reads the sensor values for pH, TDS, and temperature. These readings are compared with predefined acceptable limits.

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Example readings before analysis:
pH level = 6.2
TDS value = 180 ppm
Temperature = 8°C
These values indicate acceptable milk quality.
Detection of Abnormal Condition
If the sensor readings exceed the acceptable limits, the system identifies the milk as unsuitable for consumption and prevents dispensing.

Example abnormal reading:
pH level = 5.0
TDS value = 450 ppm
In this situation, the system displays a warning message and stops the vending operation.

3.Validation of the System:
Validation ensures that the system performs reliably under different operating conditions.
3.1 Functional Validation:
Functional validation checks whether the system correctly performs its intended operations.
The following functions are verified:

- RFID card authentication
- Sensor-based milk quality analysis
- Automatic activation of the pump for milk dispensing
- Display of system information on the LCD screen.

3.2 Performance Validation:
Performance validation evaluates how efficiently the system operates during real-time use.
Important parameters analysed include:

- Time required for authentication
- Time taken to dispense milk
- Accuracy of sensor readings
- Response time of the system

3.3 Reliability Validation:
Reliability testing ensures that the system operates consistently over repeated cycles. Multiple vending operations are performed to confirm that the system maintains stable performance without errors.

4.Data Analysis Using Graphical Representation:
A graphical comparison can be used to analyse system performance based on sensor readings and vending efficiency.
Example parameters for analysis:
X-axis: Test conditions (Normal milk / Adulterated milk)
Y-axis: Sensor reading values

Example Data
Condition | pH Value | TDS Value
Normal Milk | 6.5 | 150 ppm
Adulterated Milk | 5.2 | 420 ppm
The graphical representation clearly shows the variation in sensor readings between normal and adulterated milk samples.

5.Interpretation of Results:
The analysis of experimental results shows that the sensor-based monitoring system can effectively identify variations in milk quality. When the sensor readings remain within acceptable limits, the system allows the milk vending operation. If abnormal values are detected, the system prevents dispensing.

As a result:
Milk quality can be verified quickly
Adulterated milk distribution can be prevented

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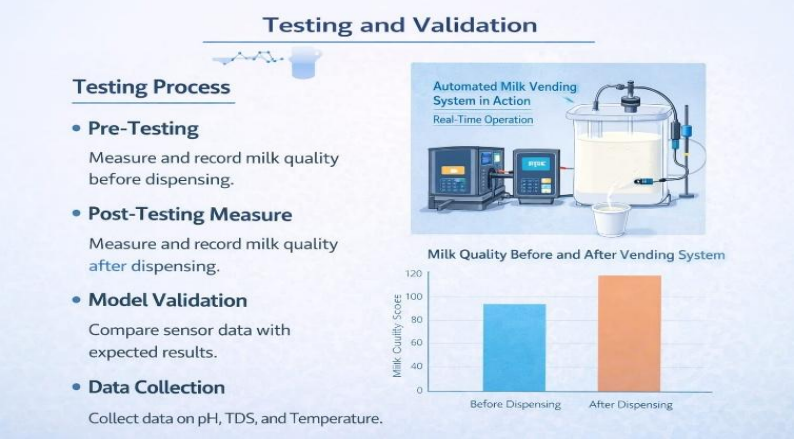
System reliability improves
Consumer safety is enhanced

6. Real-Time Impact of the System:
The implementation of the automated milk quality analysis and vending system offers several practical benefits.
Automatic monitoring of milk quality
Reduction in manual inspection
Improved transparency in milk distribution
Secure user authentication using RFID
Efficient and controlled milk dispensing
The testing and validation results confirm that the proposed system provides a reliable and efficient solution for automated milk distribution.



VII. RESULT AND DISCUSSION

Milk quality assessment is a critical factor in the dairy industry because it has a direct impact on consumer safety and product consistency. Conventional milk testing techniques are largely dependent on laboratory procedures, which involve considerable time, trained personnel, and specialized instruments. These drawbacks make it challenging to perform instant quality evaluation during milk distribution. To overcome these issues, the proposed system employs sensor-based monitoring combined with embedded control to achieve continuous and real-time analysis of milk quality.
In this study, key parameters such as pH, Total Dissolved Solids (TDS), and temperature are monitored using appropriate sensors to evaluate the condition of milk before dispensing. The experimental observations indicate that the system effectively detects variations in milk quality. When the measured values remain within predefined acceptable limits, the system permits milk dispensing. However, if the readings fall outside the specified range, the system blocks the dispensing operation and notifies the user, thereby preventing the supply of adulterated or poor-quality milk.

The adoption of sensor-based measurement significantly enhances the speed of analysis compared to traditional laboratory methods. The system produces rapid responses with minimal delay, making it suitable for real-time vending applications. Furthermore, the integration of RFID technology enables secure user authentication and controlled system access, reducing unauthorized usage and improving overall reliability.

System performance analysis confirms that the proposed setup provides accurate and consistent measurements across repeated trials. A comparison between pure and adulterated milk samples reveals distinct variations in pH and TDS values, which are successfully identified by the system. This demonstrates its effectiveness in detecting contamination and maintaining quality standards.

In addition, the automated dispensing unit increases operational efficiency by delivering precise quantities of milk without manual involvement. The integration of quality monitoring with automated dispensing minimizes human errors, improves transparency, and enhances user convenience. The LCD interface displays real-time system information, allowing users to easily track the operation.

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The system also maintains stable and reliable performance during continuous usage, ensuring consistent results in both quality detection and dispensing processes. The combination of sensors and embedded control allows the system to function effectively under varying conditions. Compared to conventional approaches, this method reduces processing time, lowers labour dependency, and improves safety in milk distribution.

Overall, the findings indicate that the RFID-based automated milk quality monitoring and vending system offers an efficient solution for real-time quality assessment and controlled distribution. The integration of sensing, processing, and authentication technologies enhances accuracy, efficiency, and system dependability, supporting modern dairy management practices.

VIII. CONCLUSION

The RFID Based Automated Milk Quality Analysis and Vending System provides an efficient solution for improving the safety and reliability of milk distribution. Milk is an essential nutritional product, but maintaining its quality during storage and distribution is a significant challenge.

In this project, an automated system was developed using sensors, RFID technology, a microcontroller, and a relay-controlled pump. The system monitors important milk quality parameters such as pH value, Total Dissolved Solids, and temperature before allowing the vending process. If the milk meets the required standards, the system automatically dispenses the selected quantity.

The integration of RFID technology enables secure user authentication and controlled access to the vending system. The LCD display provides real-time information about system status, sensor readings, and vending operations.

Experimental testing demonstrated that the system can accurately analyse milk quality and prevent the distribution of contaminated or adulterated milk. The automated design reduces manual intervention, improves operational efficiency, and enhances transparency in milk distribution.

Overall, the proposed system offers a practical solution for modern dairy vending systems. It can be implemented in milk booths, dairy cooperatives, and automated vending stations to ensure safe and reliable milk supply to consumers.

IX. FUTURE SCOPE

The system can be further enhanced by integrating advanced technologies to improve performance and functionality
IoT Integration:
The vending system can be connected to cloud platforms to allow remote monitoring of milk quality and system status through mobile applications.
AI-Based Milk Quality Prediction:
Artificial intelligence algorithms can analyse historical sensor data to predict possible milk spoilage or quality changes.
Advanced Sensor Integration:
More advanced sensors can be added to detect additional milk quality parameters such as fat content and bacterial contamination.
Digital Payment Integration:
Future versions of the system can include digital payment methods such as QR codes or mobile payment systems.
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