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# Insights into IoT-Driven Smart Vending Machine Systems

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**Abstract**

The integration of Internet of Things (IoT) technology with cashless payment systems has transformed the vending industry by making product purchase and delivery more convenient, secure, and efficient. Traditional vending machines primarily rely on physical cash, which not only limits flexibility but also raises hygiene concerns and operational challenges. The situation became more critical during the COVID-19 pandemic, where safe, contactless solutions became essential to reduce the risk of infection. In this context, IoT-enabled smart vending machines provide automated and hygienic transactions through mobile applications and digital wallets. This study outlines a smart vending framework that incorporates microcontrollers, Wi-Fi modules, cloud computing, and QR-based access to deliver a seamless user experience. Once a QR code is scanned, users can view products, make payments via a secure gateway, and instantly receive items from designated lockers. The system uses cloud platforms for transaction storage, real-time monitoring, and vendor management, ensuring smooth operations. Developed on a cost-effective embedded platform such as Arduino with ESP8266, the solution balances affordability with scalability. Beyond enhancing user satisfaction, these systems also reduce manpower requirements and ensure uninterrupted service. With applications in public spaces healthcare, and corporate environments, IoT-based vending machines represent a vital step in digital transformation and post-pandemic retail automation.

## Introduction

The Internet of Things (IoT) has revolutionized the way devices interact, enabling intelligent systems across various domains, including smart homes, smart cities, healthcare, and automated retail solutions [1–4]. IoT allows devices to sense, communicate, and respond to environmental inputs, creating highly efficient and connected systems. In recent years, this technology has been widely applied to vending machines, transforming them from simple mechanical dispensers into smart, connected machines that offer advanced services such as real-time monitoring, automated inventory management, and digital payment options [7–10].

Traditional vending machines, although functional 24/7, face challenges including manual inventory tracking, limited payment options, high operational costs, and delayed response to maintenance issues. By integrating

IoT technology, vending machines can become intelligent and responsive systems. They can monitor stock levels, track sales in real-time, detect malfunctions, and provide remote access to vendors and administrators, improving operational efficiency and reducing maintenance overhead [11–13].

Our project focuses on developing a smart vending machine that supports both digital and cash payments, making it accessible to a wide range of customers. Customers can use a mobile application to browse products, make secure payments, and receive notifications of available items. Vendors and refillers can remotely monitor inventory, manage restocking, and track sales, while administrators can oversee the overall system through a web-based platform.

The primary objective of this project is to design and implement an IoT-enabled smart vending machine that enhances customer convenience, reduces operational workload, and provides valuable insights into business operations. By combining automated product dispensing with IoT connectivity and multiple payment methods, this system represents a modern approach to vending, enabling cost-effective operations and improved customer satisfaction. Furthermore, the project emphasizes scalability and adaptability, allowing future integration of additional features such as predictive maintenance, data analytics for sales trends, and personalized offers for customers. This makes the smart vending machine not only a practical retail solution but also a platform for continued innovation in automated vending systems .

This smart vending machine project leverages modern microcontroller-based IoT technology to provide real-time monitoring, secure transactions, and automated dispensing. It will integrate sensors to detect stock levels, a microcontroller to process transactions, and both digital and cash payment modules to ensure accessibility for all users. The mobile application and web-based platform will allow customers to interact with the machine easily, while vendors and administrators can track sales, manage inventory, and receive alerts for maintenance. By combining these features, the project aims to create a cost-effective, efficient, and user-friendly vending solution that enhances operational efficiency and customer satisfaction, while laying the foundation for future innovations in smart retail systems.

**Literature Survey**

The concept of the Internet of Things (IoT) has revolutionized many domains, including retail and vending systems, by enabling intelligent automation, real-time monitoring, and enhanced customer experience. IoT connects physical devices to the internet, allowing them to communicate, process data, and perform actions with minimal human intervention.

Zhou et al. (2020) described IoT as a core enabler of cyber-physical systems, where smart devices can sense, process, and respond autonomously, which is essential for modern automated vending solutions In recent years, several studies have explored IoT-based vending machines. Dimitris et al. (2018) proposed an automated shopping platform that leveraged IoT to offer personalized services and real-time interaction with customers. This approach allowed for dynamic inventory management and tailored product recommendations. Solano et al. (2017) focused on integrating smart vending machines with mobile banking systems, enabling seamless cashless and contactless transactions. Similarly, other researchers have explored the use of cloud connectivity, sensors, and mobile applications to monitor vending machine status, track product inventory, and provide remote maintenance alerts. These advances have significantly improved operational efficiency, reduced downtime, and enhanced user convenience .Despite these developments, most existing smart vending systems primarily support only digital payments. While this method is convenient for tech-savvy users, it excludes customers who rely on cash, limiting overall accessibility. Moreover, many current systems focus on either real-time monitoring or mobile app integration, but rarely combine both with flexible payment options.

Our project aims to address these limitations by developing an IoT-based Smart Vending Machine that supports both digital and cash payments. The system will incorporate a microcontroller, sensors, and a Wi-Fi module to connect to a cloud platform for real-time monitoring and remote control. Customers will be able to interact with the machine through a mobile application, scanning a QR code to select products and make secure digital payments. Additionally, for users who prefer traditional methods, a cash acceptance module will be integrated, enabling hybrid payment options. Once the payment is verified either digitally or in cash the machine automatically dispenses the selected product.

By combining dual-mode payment, IoT-enabled monitoring, and automated product dispensing, this system is designed to be more practical, inclusive, and user-friendly than existing models. It also provides valuable data for inventory management, maintenance scheduling, and usage analytics, thereby enhancing operational efficiency and user satisfaction. This approach represents a significant step forward in the evolution of smart vending technology, bridging the gap between traditional and modern payment

methods while leveraging IoT for intelligent automation.

[1]. Author- Dimitris et al., & Year- 2018 [12], Technology Used- IoT-based customized shopping platform for vending, Limitations- Lacked explanation of payment methods,
Improvements- Can integrate mobile banking and wallet-based payments.

[2]. Author- Enugala & Vuppala, & Year- 2018 [13], Technology Used- IoT-based smart classroom vending for resource management, Limitations- Narrow application domain, Improvements- Expand to general-purpose vending with digital transactions.

[3]. Author- Sambhi. et al., & Year- 2020 [14], Technology Used- Reverse vending for plastic waste management, Limitations- Focus only on pollution control, Improvements- Extend towards product vending with eco-friendly packaging

[4]. Author- Ramos et al., & Year- 2020 [15], Technology Used- Human mistake-free vending design, Limitations- Attempted to remove human involvement but not fully tested, Improvements- Can integrate IoT automation with error detection and recovery.

[5]. Author- Alam et al., & Year- 2021, Technology Used- IoT-enabled vending with QR scanning & digital payment, Limitations- Limited to specific payment service (bKash), Improvements- Can be expanded

**Proposed Methodology**

The proposed smart vending system is designed to provide a fully automated, cost-effective, and secure platform for dispensing products. The methodology integrates IoT-enabled hardware, mobile applications, cloud services, and digital payment gateways to ensure smooth and contactless operations.

**1. System Overview**

The IoT-enabled smart vending machine is designed as an integrated system that connects customers, vendors, and administrators through a combination of hardware and cloud-based services. The overall system architecture is composed of three key layers : the customer interaction layer, the IoT hardware and gateway layer, and the cloud management layer.

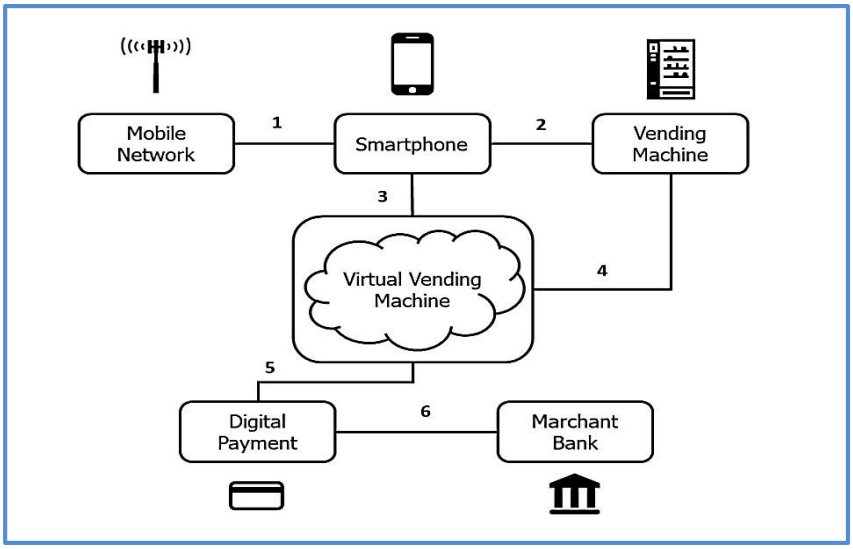


*Fig.1. Components and users of a vending machine*

**User Interaction**

- Customers interact with the system through a dedicated mobile application. Each vending machine is assigned a unique QR code printed on its body. When scanned, this code directs the customer to a virtual vending portal displaying available products and their prices.

**Product Selection and Ordering**

- Through the mobile interface, users can browse items, add them to the virtual cart, and confirm their selection. The system is designed to handle multiple items in a single transaction, providing flexibility similar to online shopping experiences.

**Digital Payment Integration**

- The application is connected to secure digital payment gateways. After item selection, customers complete the payment using mobile banking. In the reference system, bKash API was implemented for testing; however, the framework can be extended to other platforms such as UPI, Paytm . Payments are authorized through OTP and PIN verification to ensure high security.

**IoT Gateway and Hardware**

- An IoT gateway installed inside the machine manages communication between the cloud and hardware. Arduino ATmega2560 acts as the main controller, while the ESP8266 Wi-Fi module ensures internet connectivity. Upon successful payment confirmation.

**Cloud Platform and Monitoring**

- The cloud system records every transaction, updates product inventory, and allows vendors to monitor sales in real-time. Vendors and administrators have access to dashboards where they can track transactions, refill status, and machine performance.

**Dispensing Process**

- Once the locker receives the command, it unlocks for a limited time, allowing the customer to collect the product. The system then re-locks automatically and updates the database with transaction details and inventory changes. In case of an error (e.g., payment confirmed but product not dispensed), the mobile application provides a reporting feature to notify vendors for quick resolution.

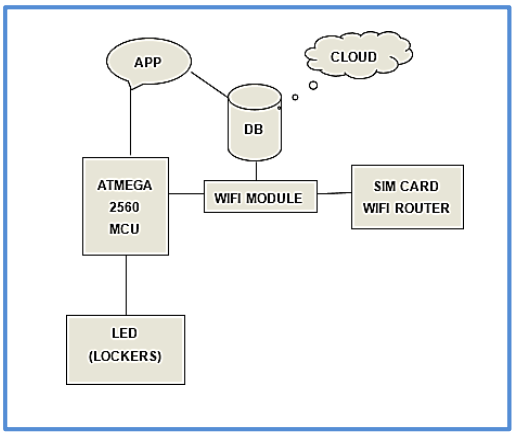


*Fig.2. Block Diagram of Hardware Prototype*

The hardware prototype of the smart vending machine integrates various components to ensure smooth operation and real-time monitoring. It primarily consists of the microcontroller, sensors, actuators, and communication modules. The microcontroller acts as the central control unit, receiving input signals from sensors and sending commands to actuators for dispensing products.

Sensors play a crucial role in detecting the availability of products, monitoring stock levels, and sensing user interactions, such as button presses or touch inputs. Actuators, like motors and solenoids, are responsible for the physical movement required to release items to the customer. Together, these components enable automated product dispensing without manual intervention.

The communication module connects the hardware to the software application via IoT, allowing real-time updates of inventory and transaction status. It also ensures secure digital payments and sends alerts for maintenance or restocking. This integrated hardware design ensures reliability, efficiency, and user-friendly operation for a modern smart vending machine.

The hardware prototype includes a microcontroller, sensors, actuators, and IoT communication to automate product dispensing. It monitors stock, tracks transactions, and sends real-time alerts for maintenance making the vending machine efficient and user-friendly.

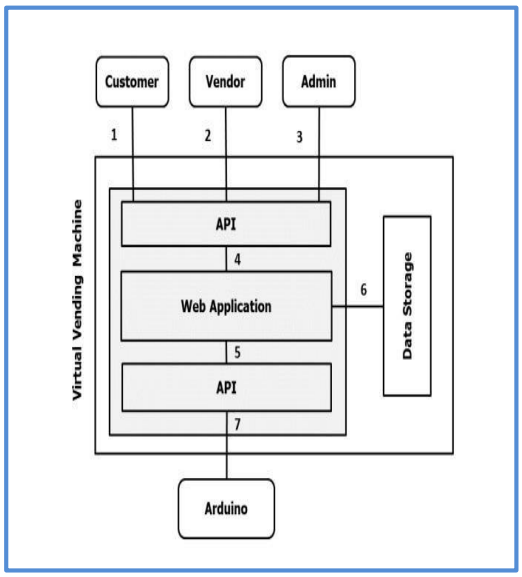


*Fig.3. The Architecture of Software Application*

The software architecture of the smart vending machine is designed to manage all interactions between the user, hardware, and payment systems efficiently. It primarily consists of modules for user interface, product selection, payment processing, inventory management, and communication with IoT devices.

The user interface module allows customers to browse available items and select products, while the payment module handles digital transactions securely.

Additionally, the system continuously monitors stock levels and updates the inventory database in real-time. Communication with the IoT-enabled vending machine ensures smooth operation, like dispensing products and sending alerts for restocking or maintenance. This modular design enhances scalability, reliability, and ease of integration with other smart systems.

The software architecture manages interactions between the user, hardware, and digital payment system. It handles product selection, secure

payments, real-time inventory updates, and IoT communication for smooth vending operations.

**Applications**

The Smart Vending Machine System using IoT has a wide range of applications across different domains. In educational institutions and offices, it provides quick and convenient access to snacks and food items, reducing waiting time and enabling cashless transactions. In hospitals, it ensures hygienic and 24/7 availability of packaged food for patients, staff, and visitors.

At railway stations, bus stands, and airports, the system offers travelers an easy way to purchase food at any time, improving efficiency during peak hours and late-night journeys. In shopping malls and other public places, it enhances customer convenience by delivering automated services without the need for additional manpower.

The system is also useful in corporate and business hubs, where employees can access food without leaving the workplace, thereby saving time and improving productivity. In smart cities, IoT integration enables real-time monitoring of sales, stock levels, and machine health, supporting automation and digital transformation. Beyond these, the system has potential in hostels and residential areas, ensuring round-the-clock access to food for students and residents.

At event venues and stadiums, it helps serve large crowds quickly, minimizing queues. In tourist destinations, it ensures ready availability of packaged items, especially in remote locations. Finally, during emergency or disaster relief operations, vending machines can be deployed to provide contactless food distribution in a safe and efficient manner.

**Conclusion**

In we have successfully developed an IoT-based smart vending machine for readymade food items that integrates hardware and software components for seamless operation. The system employs a microcontroller, sensors, actuators, and IoT-enabled communication to automate product dispensing, monitor stock levels in real-time, and alert for maintenance. On the software side, a mobile application has been designed to enable users to browse available food items, select products, and make secure digital payments.

This integrated approach makes the vending machine user-friendly, efficient, and cost-effective, reducing the need for manual intervention and minimizing operational errors. The inclusion of digital payment methods enhances convenience and provides a smooth transaction experience, similar to modern cashless retail systems. Additionally, the real-time inventory tracking and communication with the software ensure better management and monitoring of resources.

Overall, this project demonstrates a practical implementation of IoT in the retail and food service sector, providing a smart, reliable, and scalable solution. The system can be further extended to incorporate additional features like multiple payment gateways, advanced analytics, and remote monitoring, making it a versatile platform for automation in various industries.

Furthermore, the smart vending machine enhances customer convenience by providing 24/7 access to readymade food items, reducing waiting time and ensuring hygienic handling of products. The system's modular design allows easy upgrades, such as adding new items, integrating additional payment methods. This flexibility not only improves operational efficiency but also paves the way for wider adoption in schools, offices, and public spaces. By combining IoT technology, automation, and digital payments, this project contributes to the advancement of smart retail solutions and modernizes the traditional vending machine.

**REFERENCES**

Y. Zhou, F. R. Yu, J. Chen and Y. Kuo, "Cyber-Physical-Social Systems: A State-of-the-Art Survey, Challenges and Opportunities,"IEEE Communications Surveys & Tutorials, vol. 22, no. 1, pp. 389-425, 2020.

A. Sajid, H. Abbas and K. Saleem, "Cloud-Assisted IoT-Based SCADA Systems Security: A Review of the State fo the Art and Future Challenges," IEEE Access, vol. 4, pp. 1375-1384, 2016.

M. Dimitris, V. Ekaterini, and V. Zogopoulos, "An IoT-based Platform for Automated Customized Shopping in Distributed Environments," Procedia CIRP, vol. 72, pp. 892-897.

V. Sharma, I. You, K. Yim, I. Chen and J.Cho, "BRIoT: Behavior Rule Specification-Based Misbehavior Detection for IoT-Embedded Cyber-Physical Systems," IEEE Access, vol. 7, pp. 118556-118580, 2019.

M. Marjani et al., "Big IoT Data Analytics: Architecture, Opportunities, "IEEEAccess,vol.5,pp.5247-5261,2017.

M. K. Korucu, O. Kaplan, O. Buyuk, and M. K. Gullu, "An investigation of the usability of sound recognition for source separation of packaging

wastes in reverse vending machines," Waste Management, Article vol. 56, pp. 46-52, Oct 2016.

R G. Mann, K. Hosig, A. G. Zhang, S. M. Shen, and E. Serrano, "Smart Snacks in School Legislation Does Not Change Self-Reported Snack Food and Beverage Intake of Middle School Students in Rural Appalachian Region," Journal of Nutrition Education and Behavior, Article vol. 49, no. 7, , 2017.

Y. B. Park and H. S. Park, "Smart vending machine systems: operation and performance," European Journal of Industrial Engineering, Article vol. 9, no. 4, pp. 409-431, 2015.

Y. Shoji, K. Nakauchi, W. Liu, and Ieee, Community-based wireless IoT infrastructure using ubiquitous vending machines (2016 Cloudification of the Internet of Things). New York: Ieee, 2016.

P. K. D. Pramanik, S. Pal, and P. Choudhury, "Beyond Automation: The Cognitive IoT. Artificial Intelligence Brings Sense to the Internet of Things," Cognitive Computing for Big Data Systems over Iot: Frameworks, Tools and Applications, vol. 14, 2018.

R. A. Sowah et al., "Interoperability of Heterogeneous Appliances in Home Automation Using the AllJoyn Framework,"2018 Ieee 7th International Conference on Adaptive Science &Technology (IEEE International Conference on Adaptive Science and Technology, New York: Ieee, 2018.

M. Dimitris, V. Ekaterini, and V. Zogopoulos, "An IoT-based Platform for Automated Customized Shopping in Distributed Environments," in 51st Cirp Conference on Manufacturing Systems, vol. 72, pp. 892-897, 2018

V. P. R. Enugala and S. Vuppala,"Internet of Things - based Smart Classroom Environment",2018 Fifth International Conference on Parallel, Distributed and Grid Computing, New York: Ieee, 2018, pp. 193-198.

S. Sambhi, P. J. I. J. o. S. A. E. Dahiya, and Management, "Reverse vending machine for managing plastic waste," International Journal of System Assurance Engineering and Management, pp. 1-6, 2020.

A. Ramos, N. Adrielly, A. Soler, I. Francisca, F. M. Idalia, and L. M. J. P. M. Jéssica, "Designing Human Mistake- Free Machine: a Mexico City Public Transport Commuters' Approach, "Procedia Manufacturing, vol. 42, pp. 399- 405, 2020.