International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

IoT Enabled Intelligent Cargo Management System

Sanchit Arun Parwate[1], Smrity Baral[2]

[1]Bosch Global Software Technologies, Keeranatham Rd, Saravanampatti 641035, Coimbatore, Tamil Nadu, India
Email: *sanchit.arunparwate[at]in.bosch.com*

[2]Department of Artificial Intelligence & Data Science, CSMSS - Chhatrapati Shahu College of Engineering, Paithan Road, Kanchanwadi 431001, Chhatrapati Sambhaji Nagar, Maharashtra, India.
Corresponding author: *sbaral[at]csmssengg.org*

Abstract: ***In the interconnected world, the transportation sector was crucial for linking people and businesses, thereby enhancing quality of life and living standards. Effective transportation also played a significant role in supply chain management, where ensuring the safety of transported goods was essential. This research paper presented an advanced IoT - based system designed to monitor and secure the transportation of goods. The system leveraged RFID tags to track the entry and exit of goods, with data being stored in a cloud - based database for real - time accessibility and analysis. To further enhance safety, the system incorporated gas and flame sensors that continuously monitored environmental conditions around the goods, detecting potential hazards. In the event of an emergency, the system utilized a GSM module to send immediate SMS alerts to users, while an integrated buzzer produced audible warnings to alert nearby individuals. This system combined the latest IoT technology with insights from previous research to improve both safety and efficiency in the transportation and supply chain sectors. By integrating these technologies, the system aimed to provide a comprehensive solution for safeguarding goods throughout their journey.***

Keywords: Internet of Things, real - time system, Arduino Uno, GPS module, RFID module

1. Introduction

In today's interconnected global economy, the transportation sector is pivotal in linking people, businesses, and markets, thereby significantly enhancing the overall quality of life and living standards. This sector is not only crucial for the movement of goods and services but also for driving economic growth and competitiveness. As global trade and commerce expand, the efficiency of transportation systems becomes a critical factor influencing economic performance. The economic impact of transportation is considerable; it supports various sectors such as manufacturing, retail, and agriculture, affecting their operational efficiency. For example, the 30th annual State of Logistics report by the Council of Supply Chain Management Professionals (CSCMP) revealed that the United States invested $1.64 trillion in logistics in 2018, reflecting an 11.4 percent increase from the previous year and representing about 8.0 percent of the nation's Gross Domestic Product (GDP) [1]. Such figures underscore the essential role of transportation in enhancing economic activity and efficiency. Conversely, inefficient logistics systems can result in expenditures accounting for up to 25% of GDP, demonstrating the significant impact of logistics costs on economic competitiveness[2]. Addressing these inefficiencies through innovative strategies is crucial for improving overall economic performance.

Logistics, a fundamental component of supply chain management, encompasses the coordination and movement of goods from suppliers to consumers, including activities such as transportation, warehousing, inventory management, and order fulfilment[3]. Effective logistics management ensures timely and accurate delivery of products, minimizing delays and reducing costs. The rise of e - commerce and globalization has increased the complexity of modern supply chains, thereby amplifying the need for advanced technologies to enhance logistics efficiency and safety[4]. Technological advancements have profoundly transformed logistics practices, providing new opportunities for optimization. Notably, the Internet of Things (IoT), Radio Frequency Identification (RFID), and cloud computing have revolutionized logistics operations[5].

The Internet of Things (IoT) involves a network of interconnected devices that communicate and exchange data over the internet, enabling real - time monitoring of goods, vehicles, and environmental conditions. This technology offers valuable insights for managing and optimizing supply chains by tracking parameters such as location, temperature, and humidity[6]. RFID technology utilizes electromagnetic fields to automatically identify and track objects, which enhances inventory management and reduces manual errors. RFID is widely used in logistics to streamline warehouse operations, track shipments, and improve overall efficiency. The integration of RFID with IoT further enhances its effectiveness, providing real - time visibility into inventory and shipments[7]. Cloud computing plays a crucial role by offering scalable and flexible solutions for data storage and processing, which is essential for managing complex supply chains and optimizing logistics operations.

In the evolution of modern logistics, smart logistics has become an increasingly important topic of interest for both academics and businesses. Smart logistics is a logistical system that enhances an organization's flexibility, adaptability to market changes, and alignment with consumer needs. The growth of logistics is closely tied to technological innovation. The evolution of logistics can be categorized into four stages: "logistics mechanization, " "logistics automation, " "logistics integration, " and "logistics intelligence" which is depicted in Fig.1. Network and communication technologies evolved from "automation" to "synergy" in the 1990s and 2000s with the introduction of RFID. In the 21st century, the gradual development of technologies such as IoT, AI, and big data has accelerated the development of smart logistics[8].

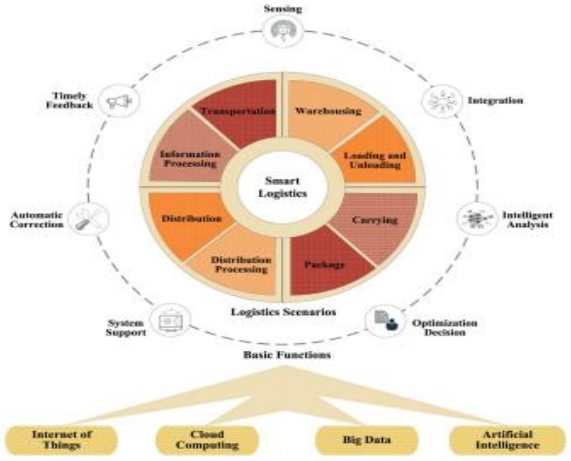

Figure 1: Basic functions, smart logistics scenarios, and critical technologies

Network and communication technologies evolved from "automation" to "synergy" in the "1990s" and "2000s" as a result of the introduction of "RFID".

In the twenty - first century, the gradual development of technologies like as "IoT", "AI", and "big data" has hastened the development of smart logistics.

The Internet of Things (IoT) forms the foundation for smart logistics development. The core concept of IoT is that various items can connect and interact with each other using unique addressing methods, achieving system - wide awareness without human intervention. A smart logistics system can gather data about cargo, logistics vehicles, transportation routes, and warehousing through IoT technologies like RFID tags, sensors, actuators, and mobile phones, facilitating end - to - end information linkage[9].

By integrating "cloud computing", "big data", "AI", and "other modern technologies", the smart logistics system can analyse, process huge loads of "logistical data and information" and make the decision to adopt smart item management based on the IoT platform being used.

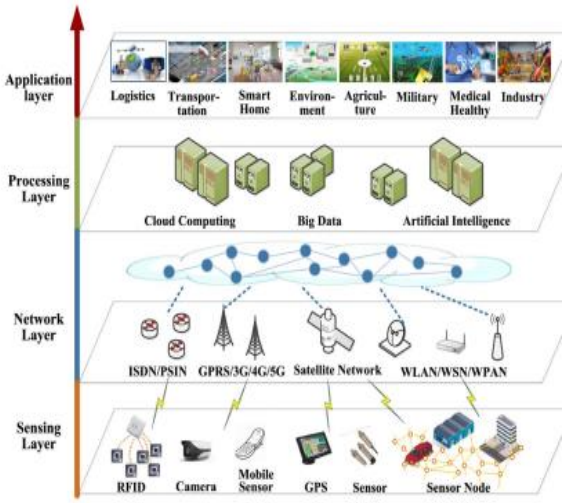

Figure 2: Architecture of IoT

The IoT architecture comprises four layers: the sensor layer, network layer, processing layer, and application layer as shown in Fig.2. The sensor layer collects and perceives physical attributes from the physical world, the network layer handles data transmission, the processing layer provides data access and storage through cloud platforms and AI, and the application layer delivers services to users. Supporting technologies such as sensor technology, wireless networks, and communication technology are essential for effective IoT deployment in smart logistics[10].

"RFID tags are categorized by frequency ranges—low - frequency (LF), high - frequency (HF), ultrahigh - frequency (UHF), and ultra - wideband (UWB) —with each type serving specific applications within smart logistics[7]. For example, goods identification and data gathering are common uses for LF RFID tags, which may be found in "smart warehousing", "smart distribution", and "smart packaging". Since "HF tags" are easily moulded into shape of a card and are utilised in "E - tickets", "E - ID cards" and other applications. HF tags are extensively used in "smart warehousing". "UHF tags" are mostly employed in intelligent transportation systems., and in smart logistics, UWB tags may achieve exact location within half a metre, making it easier to handle valuable instruments and staff.

Despite these advancements, ensuring the safety and security of transported goods remains a significant challenge. Traditional monitoring systems may lack the sophistication required to manage emerging risks and complexities in logistics. As supply chains become more globalized and diversified, there is a pressing need for comprehensive monitoring systems that offer real - time insights and address potential hazards. Cargo safety is a major concern, as goods are exposed to various risks during transportation, including environmental factors such as temperature fluctuations, humidity, and exposure to hazardous conditions. Additionally, risks related to theft, tampering, and damage during transit must be effectively managed[9]. Advanced monitoring systems, incorporating technologies such as flame and gas sensors, are required to address these challenges[11]. Flame and gas sensors can monitor the environment around cargo to detect fires or leaks, while RFID tags provide real - time tracking and security. The integration of these technologies into a unified system enhances the ability to safeguard goods and mitigate risks. Cloud computing further supports this integration by providing scalable solutions for data storage and processing, enabling businesses to handle vast amounts of data and make informed decisions[12].

The aim of this research is to propose an advanced IoT - based system designed to monitor and secure the transportation of goods. This system leverages RFID tags, gas and flame sensors, and GSM modules to enhance safety and efficiency in logistics. By integrating these technologies, the system aims to provide real - time tracking, environmental monitoring, and emergency alerts, addressing the need for comprehensive monitoring systems that ensure the safety and security of transported goods. This research contributes to the field of logistics by building on existing technologies and incorporating insights from previous studies to improve performance, supporting businesses in optimizing their logistics operations and gaining a competitive edge.

2. Methodology

As discussed previously, the Internet of Things (IoT) plays a crucial role in logistics, and IoT technology has been extensively used in our proposed system. In contrast to traditional systems that rely on Radio Frequency Identification (RFID), which offer significant benefits such as enhanced logistics tracking, improved inventory management, and reduced labour costs, the proposed system aims to overcome the limitations associated with RFID technology. While RFID systems facilitate better logistics tracking and fewer errors in loading and processing, their high investment cost and the complexity of system reorganization make them a strategic choice for companies[12]. However, RFID systems can exhibit several drawbacks, including reduced accuracy, lack of tracking for specific product stations or sections, and lower efficiency compared to more advanced systems[3].

The traditional surveillance systems used at ports and airports, which rely on heavy labour to track items and deliveries, often lead to significant delays due to the cumbersome process of unloading containers, categorizing packages, and identifying them[13]. The proposed system addresses these inefficiencies by integrating IoT technology to streamline the tracking process. The initial phase of the proposed system involves discharging the entire container, followed by identifying and classifying them using advanced tracking mechanisms. This system is designed to maximize performance efficiency, allowing for real - time monitoring via an IoT web interface. It also utilizes GSM technology to send alerts about potentially hazardous situations and to trigger alarms through a buzzer, ensuring timely notifications of any critical issues[4, 6].

The advantages of the proposed system are substantial. It reduces the number of personnel required for operation, decreases costs associated with container checks, enhances system security, provides detailed database storage, and creates a more user - friendly environment[7]. Traditional container checking methods have struggled to keep pace with the growing volume of package transit, resulting in delays and inefficiencies. RFID technology, while valuable, is limited in its ability to handle the increasing complexity of modern logistics. The system we propose incorporates RFID to track objects' identities through wireless communication, improving speed and accuracy while also reducing costs.

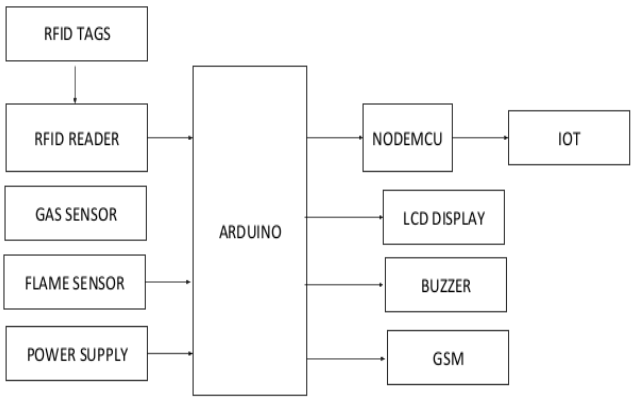

Figure 3: Block Diagram

All sensors in the proposed system are connected to an Arduino board as shown in Fig.3, with results displayed on an IoT web page. The sensor data is stored in the cloud and can be accessed from any location by authenticated users. The system enables real - time tracking of logistics goods via the IoT page and provides SMS alerts about potentially dangerous conditions, such as gas leaks or fires. The buzzer generates sound alerts in the container, and sensor data is monitored via an LCD display within the container.

The successful implementation of the advanced IoT - based system required a well - coordinated combination of hardware and software components. On the hardware side, the system utilized an Arduino Uno microcontroller (Arduino LLC, Italy), which served as the central processing unit for managing data and interfacing with various sensors and modules. The Arduino Uno was chosen for its versatility and ease of use in prototyping and development. The NodeMCU, manufactured by ESP8266 Community (China), provided Wi - Fi connectivity, enabling real - time data transmission to a cloud - based database.

To ensure accurate cargo tracking throughout its journey, RFID tags and readers were employed. These components, sourced from Impinj Inc. (USA), facilitated precise tracking of goods. Additional hardware included a transformer and bridge rectifier to ensure stable power supply and voltage regulation for the electronic components. The GSM module, from SIMCom (China), was integrated for sending SMS alerts in case of emergencies, such as detecting hazardous conditions. Flame and gas sensors, supplied by Figaro Engineering Inc. (Japan), were used to monitor environmental conditions around the cargo, detecting potential fire and gas leaks. An LCD display from Adafruit Industries (USA) provided a visual interface for monitoring sensor data and system status. All these components were carefully integrated to form a cohesive and functional monitoring system.

On the software side, Embedded C programming was employed to develop the firmware for both the Arduino Uno and NodeMCU, ensuring effective sensor functionality and data processing. The Arduino IDE, developed by Arduino LLC (Italy), was used for coding and uploading programs to the microcontrollers. For cloud - based data management, the ThingSpeak platform, developed by MathWorks (USA), was utilized. ThingSpeak provided a scalable and user - friendly interface for real - time data access, system monitoring, and historical data analysis.

3. Results and Discussion

The implementation of the advanced IoT - based system for monitoring and securing the transportation of goods demonstrated significant effectiveness and promise in enhancing logistics operations. The system, which integrated RFID tags, gas and flame sensors, GSM modules, and cloud - based storage, successfully met its objectives of improving safety and operational efficiency.

The RFID tags were instrumental in tracking the entry and exit of goods with high accuracy. Throughout the testing phase, these tags consistently provided precise location data, which was logged in the cloud - based database. This feature

allowed for real - time visibility into the status of the cargo, facilitating efficient inventory management and ensuring that goods were monitored throughout their journey. The real - time data accessibility through the cloud interface enabled stakeholders to make informed decisions quickly, which is crucial for optimizing logistics operations and responding to potential issues. The gas and flame sensors performed reliably, detecting hazardous conditions with a high degree of accuracy. During tests, these sensors successfully identified the presence of gas leaks and flames, sending data to the cloud database for immediate review. The environmental conditions around the cargo were continuously monitored, and any deviations from normal parameters triggered alerts in the system. This capability was critical in identifying and addressing safety hazards promptly, thereby preventing potential damage or accidents during transportation.

In terms of emergency response, the GSM module proved to be a vital component of the system. Upon detecting a hazardous condition, the GSM module sent instant SMS alerts to predefined contacts. This functionality ensured that relevant personnel were informed immediately, enabling swift action to mitigate risks. The SMS notifications were delivered promptly, and the ability to communicate emergencies in real - time was validated through successful test scenarios. The integrated buzzer further enhanced the system's emergency response capability by emitting a loud sound when a hazard was detected. This audible alarm effectively alerted nearby individuals, facilitating quick evacuation and ensuring that safety protocols were followed. The cloud - based database played a crucial role in managing and analysing the data collected by the RFID tags, sensors, and GSM module. The real - time data provided through the web interface allowed for continuous monitoring of goods and environmental conditions. This centralized data management system enabled users to view historical records, analyze trends, and gain insights into the performance of the transportation process. The ability to access and analyze data from any location was a significant advantage, contributing to improved decision - making and operational efficiency.

User feedback from the testing phase was overwhelmingly positive. Participants appreciated the system's real - time monitoring capabilities, and the timely alerts provided by the GSM module. The accuracy of the RFID tracking and the reliability of the sensors were highlighted as key strengths. Users noted that the system's comprehensive monitoring features significantly contributed to the safety and efficiency of their logistics operations. The system's robustness was also commended, as it performed reliably under various operational conditions, demonstrating its suitability for real - world applications. Overall, the results confirm that the proposed IoT - based system is an effective solution for enhancing the safety and efficiency of goods transportation. By integrating advanced technologies such as RFID, gas and flame sensors, GSM modules, and cloud computing, the system provided a comprehensive approach to monitoring and securing cargo. The successful detection of hazards, accurate tracking of goods, and efficient data management underscore the system's potential to improve logistics operations. The ability to provide real - time updates, facilitate emergency responses, and analyse data effectively highlights the system's contribution to optimizing transportation processes and safeguarding goods throughout their journey. The successful performance of the system in meeting its design objectives illustrates its potential for widespread adoption and its value in advancing modern logistics practices.

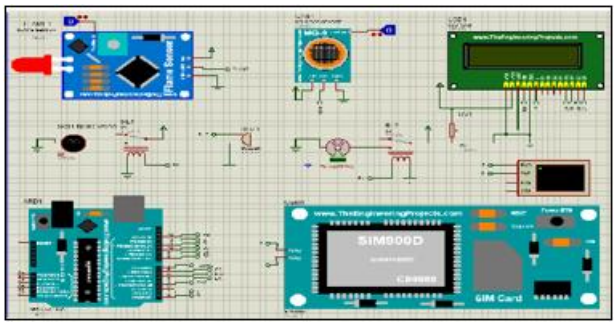

Figure 4: Circuit Diagram

Flame sensor, Gas sensor, GPS module (Neo 6M) (for position), and GSM are crucial sensors used in the project to provide exact gas and flame values. These outcomes are frequently viewed on a website. A smart cargo monitoring system has been successfully created utilising the Internet of Things idea, which can be beneficial to the transportation sector.

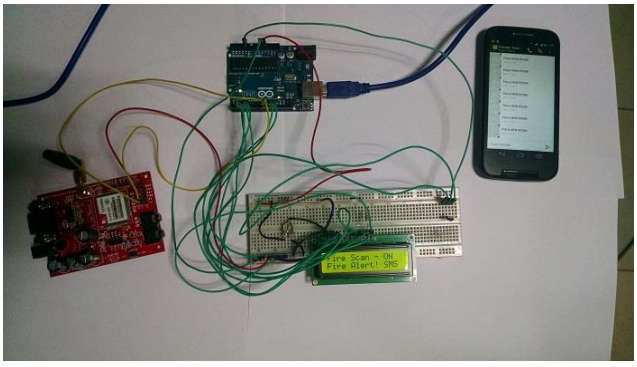

Figure 5: Sensor Output

The alert message was issued, as seen in the Figure.5. While there was a fire or GAS.

Figure 6: Gas Sensor Readings

In the above figure, show the gas values in the webpage.

4. Conclusion

Starting RFID systems and developing "product - based tracking" systems should be included as a service in all logistic systems going forward. Most logistics companies nowadays believe it is vital to provide this service to their consumers. As a result, the procedures will result in significant cost savings. Furthermore, due to traceability, quick product tracking will be feasible. These value - added operations will provide clients with more high - quality services at a cheaper cost and in a shorter period of time, increasing the firm's competitiveness. A product - based monitoring system is considered as an investment that should be made in order to safeguard a company's brand value and position. The proposed solutions will both significantly enhance logistics and warehousing procedures and give additional value in terms of image and quality.

References

[1] T. Kearney Inc.29th Annual State of Logistics Report.; 2018. Accessed August 25, 2024. https: //cscmp. org/CSCMP/CSCMP/Educate/State_of_Logistics_Report. aspx
[2] 2. Hummels D. Transportation Costs and International Trade in the Second Era of Globalization. http: //www.bea. gov
[3] 3. Gligor DM, Holcomb MC. Understanding the role of logistics capabilities in achieving supply chain agility: A systematic literature review. Supply Chain Management.2012; 17 (4): 438 - 453. doi: 10.1108/13598541211246594
[4] Jevinger Å, Olsson CM. Introducing an Intelligent Goods Service Framework. Logistics.2021; 5 (3): 54. doi: 10.3390/logistics5030054
[5] Ravi N, Jain SP, Seetharaman A, Jayaraman V. INFLUENCE OF IOT ON SMART LOGISTICS. doi: 10.20319/pijss.2023.92
[6] Sreelatha B, Alakananda E, Bhavya B, Prasad SH, Prof A. IOT APPLIED TO LOGISTICS USING INTELLIGENT CARGO. International Research Journal of Engineering and Technology. Published online 2018. www.irjet. net
[7] Zhu X, Mukhopadhyay S, Kurata H. A review of RFID technology and its managerial applications in different industries. Journal of Engineering and Technology Management - J ENG TECHNOL MANAGE.2011; 29. doi: 10.1016/j. jengtecman.2011.09.011
[8] Dembińska I. Smart logistics in the evolution of the logistics. European Journal of Service Management.2018; 27: 123 - 133. doi: 10.18276/ejsm.2018.27/2 - 15
[9] Tan WC, Sidhu MS. Review of RFID and IoT integration in supply chain management. Operations Research Perspectives.2022; 9. doi: 10.1016/j. orp.2022.100229
[10] Vora H. Cross - layer Design on the Internet of Things (IoT): Issues and Possible Solutions. Published online 2024. doi: 10.13140/RG.2.2.20889.63848
[11] Li J qiang, Yu F, Deng G, Luo C, Ming Z, Yan Q. Industrial Internet: A Survey on the Enabling Technologies, Applications, and Challenges. IEEE Communications Surveys & Tutorials.2017; PP: 1. doi: 10.1109/COMST.2017.2691349
[12] Pachankar P, Jadhav A, Kedare S, Mandlik S. “Intelligent Cargo Management System Using Arduino. ” Vol 8.; 2020. www.ijcrt. org
[13] Watanabe H, Saito K, Miyazaki S, et al. Proof of Authenticity of Logistics Information with Passive RFID Tags and Blockchain. In: 2021 IEEE International Conference on Electronic Communications, Internet of Things and Big Data, ICEIB 2021. Institute of Electrical and Electronics Engineers Inc.; 2021: 213 - 216. doi: 10.1109/ICEIB53692.2021.9686409