JTE
HCMUTE
ISSN: 2615-9740

JOURNAL OF TECHNICAL EDUCATION SCIENCE
Ho Chi Minh City University of Technology and Education
Website: https://jte.edu.vn
Email: jte@hcmute.edu.vn

Implementation of an IoT-based System for Monitoring Parameters and Tracking Transport Vehicles

Nguyen Bao Phuong Huynh, Duy Thong Nguyen*
Quy Nhon University, Binh Dinh, Viet Nam

*Corresponding author. *Email:* nguyenduythong@qnu.edu.vn

ARTICLE INFO

Received:	15/07/2024
Revised:	08/10/2024
Accepted:	08/11/2024
Published:	28/12/2024

KEYWORDS

Internet of Things;
Vehicle monitoring;
Real-time tracking;
Smart logistic;
LoRa.

ABSTRACT

The integration of Internet of Things (IoT) technology in vehicle monitoring systems has emerged as a promising solution for enhancing the efficiency, safety, and sustainability of transportation. Especially in refrigerated trucks, which transport fresh goods, monitoring parameters in the vehicle plays an important role in ensuring the quality of transported goods. These parameters can be monitored directly on the vehicle by the driver and at the same time, the manager needs to monitor remotely. This paper will present an IoT-based system to monitor critical parameters of vehicles, including temperature, humidity, fuel consumption, and positioning. The proposed system integrates a network of sensors within the vehicle to capture real-time data, which is transmitted to a centralized control unit for analysis and visualization. Through experiments, the effectiveness and reliability of the proposed system in providing accurate and timely information on vehicle parameters are demonstrated. The results highlight the potential of IoT solutions to revolutionize vehicle monitoring and management, bringing benefits and reducing costs in the transportation sector. Moreover, a discussion on the future trends and solutions in transportation and logistics will be presented.

Doi: https://doi.org/10.54644/jte.2024.1619

1. Introduction

The transportation and logistics sector are at the core of economies around the world. It acts as a medium that facilitates the movement of people, goods, and products from one location to another. Up to 95% of manufactured goods are transported in containers at one point in the supply chain, and with the global consumer class expected to grow by 35% by 2030 [1], demands on the transportation sector are expected to increase. The increase in goods will lead to inevitable difficulties that traditional transportation companies face such as the inability to track assets and the status of goods. This leads to difficulties in optimizing transportation processes to reduce costs.

The Internet of Things, known as IoT, constitutes a network of interconnected devices that establish connections and share data with other IoT devices and the cloud. These devices are commonly equipped with technological components like sensors and software, encompassing both mechanical and digital apparatus as well as consumer items [2]-[4]. Over the past few decades, the rapid advancement of mobile and fixed network infrastructure has provided a highly conducive environment for the widespread adoption of IoT technology across various domains. The system has the capability to function effectively for a wide range of end users, including both individual consumers and various types of businesses. There is no doubt that the trend toward using the Internet of Things with the use of sensors, applications, and platforms will only increase over time. One of the main difficulties in developing Internet of Things applications in transportation is the lack of single standards. This situation makes it difficult to integrate wireless networks and objects into a single network. An ideal technology designed to combine three key features (i) energy efficiency, (ii) stability and (iii) safety is still being developed [5]. Furthermore, there is a risk of cyber-attacks on IoT systems' data, and this demotivates and destroys trust in innovation [6]-[7]. Therefore, improving the security system for all devices participating in the network is one of the main tasks of the IoT market. Internet of Things technology is applied not only in the home environment,

JTE
HCMUTE
ISSN: 2615-9740

JOURNAL OF TECHNICAL EDUCATION SCIENCE
Ho Chi Minh City University of Technology and Education
Website: https://jte.edu.vn
Email: jte@hcmute.edu.vn

such as smart home appliances and personal digital devices, but also in the commercial, agricultural, and medical fields at the same time becoming popular in industries such as logistics.

In the field of transportation and logistics, the Internet of Things has brought significant advancements to the logistics industry, revolutionizing the way goods are transported, tracked, and managed [8]-[10]. IoT in the transport and logistics industry is often called telematics, which is the foundational technology behind fleet tracking and fleet management software. Through built-in sensors and onboard diagnostics systems, conventional trucks are transformed into data-transmitting vehicles, allowing managers to track their vehicles, respond to changing environments, and identify inefficient activity in real time [11]. IoT sensors embedded in logistics equipment, such as trucks, forklifts, and conveyor systems, can collect data on performance and usage. The captured data is sent to a server platform via secure cellular networks or another wireless network, as indicated in Figure 1. This data can be then analyzed using machine learning algorithms to predict maintenance needs and identify potential issues before they cause significant disruptions. In [12]-[13], deep learning algorithms are used for predictive maintenance to reduce downtime, extends equipment lifespan, and lowers maintenance costs. In [47], researchers proposed a novel neural combinatorial optimization strategy based on reinforcement learning to define vehicle routes with minimized timing. Experimental results show that the proposed method has improved significantly outperform conventional methods. The authors in [15] utilized Adaptive Boosting (AdaBoost), Extremely Randomized Trees (ExtraTrees), and Support Vector Regression (SVR) as key algorithms to address non-linear and complex relationships in tracking data for predicting travel times in multimodal transportation. All three algorithms are adaptable to complex systems and robust in handling small and complex data sets. Therefore, the integration of Internet of Things technology and machine learning in the logistics industry has revolutionized supply chain management, enabling real-time tracking, optimization of operations, and enhanced visibility across the entire process.

Figure 1. *Some of the applications and technologies used in smart logistics*

It is argued that IoT poses a risk to workers because its innovations reduce labor resources. However, it should be considered as a tool to ensure the smooth execution of operations and maximization of profits. This innovative technology ensures improvements in the following areas: (i) optimization of applied assets; (ii) reduce security issues such as counterfeiting and theft; (iii) accurate monitoring of resources and work processes; (iv) clear visibility in real time and timely response to events; (v) analyze real data streams to make complete and fast decisions; (vi) reduce manual data processing to increase accuracy and reduce time spent; (vii) identify new opportunities based on research into consumer behavior patterns; (viii) improve the quality of working with customers [16]. The process of globalization leads to the fact that supply chains are becoming increasingly complex and on an ever-increasing scale. Accordingly, the management of such chains and the storage industry are also influenced by this trend. The pressure on logistics is growing and the Internet of Things is becoming an increasingly important component in solving the problems of transport companies. Today, its goal is aimed to satisfy the needs of a rapidly developing global economy [17]. Inventory management and warehousing are some of the most important parts of the associated logistics ecosystem. Stationing small inexpensive sensors will allow companies to easily track inventory, monitor their condition and location, and create an intelligent warehouse system. IoT sensors can be used to track stocks and provide data that will help in trending to predict future stock needs. This will help to avoid situations with insufficient stock and excess stock. Thus, the implementation of IoT technology will successfully prevent any loss, ensure the safe storage of goods, as well as quickly find the right product.

However, the widespread adoption of IoT in logistics also presents significant challenges. Firstly, security concerns arise as a result of the vast network of interconnected devices, which exposes data to breaches and cyberattacks [6]. Second, interoperability between different IoT devices and platforms is critical for efficient communication and data exchange. Thirdly, ensuring consistent connectivity in diverse environments and remote locations can be difficult, affecting the continuous flow of information [18]. Fourth, handling the massive amounts of data generated by IoT devices necessitates effective storage, processing, and analytics capabilities. Finally, the scalability of IoT systems is an important consideration for meeting growing logistical demands and future technological advancements.

In this paper, we will propose an IoT-based smart logistic system, which includes the following parts: (i) a sensor system to collect data from the field; (ii) signal transmission system to transmit signals to the center and upload to the web server; (iii) information acquisition and display system combined with warnings; (iv) information storage system for viewing trip history and other vehicle parameters

In the rest of this paper, the details of the proposed system are provided in Section 2, while the experimental results are shown in Section 3. Finally, the conclusions and discussions of the study are presented in Section 4.

2. Proposed IoT-based system for vehicle monitoring and tracking

2.1. Proposed system

Within the transportation and logistics sector, the Internet of Things (IoT) has a wide range of uses. These applications are intended for tracking, monitoring, and other applications about vehicles. IoT technology allows for the monitoring of vehicle utilization by tracking various parameters, including mobility, geographical coordinates, operational status (idle/active), maintenance activities, etc. When a vehicle transports critical goods or fresh food, it is crucial to monitor and control the indoor conditions of the truck, including temperature, humidity, lighting as well as door status [11].

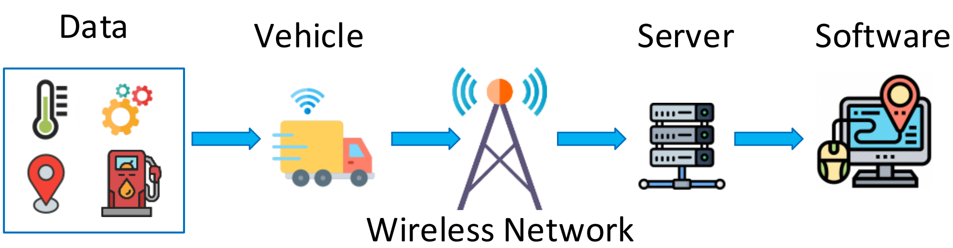


Figure 2. *The general block diagram of IoT-based system for smart transportation*

In this section, an IoT-based solution for smart transportation will be proposed. This system uses wireless connections to gather data from sensors installed in the vehicle, then send it to the center for display. At the same time, all data is transferred to the server so that the vehicle may be remotely managed in real-time. The general block diagram of the proposed system is shown in Figure 2. Wireless modules are integrated into the vehicle to transmit data to the internet, using the mobile network. Then data is transmitted to the webserver and displayed visually for easy observation and management.

The proposed system consists of two blocks. The block that collects signals from the sensor is called the Slave, which collects data from the sensor and then synthesizes and sends the data to the center via a wireless connection. The device that receives data from the Slave is called the Master. The received

JTE
HCMUTE
ISSN: 2615-9740
JOURNAL OF TECHNICAL EDUCATION SCIENCE
Ho Chi Minh City University of Technology and Education
Website: https://jte.edu.vn
Email: jte@hcmute.edu.vn

data at the Master is displayed on the LCD screen and simultaneously sent to the Web server for remote monitoring. A flow chart is shown in Figure 3 to explain the operating principle of these two parts.

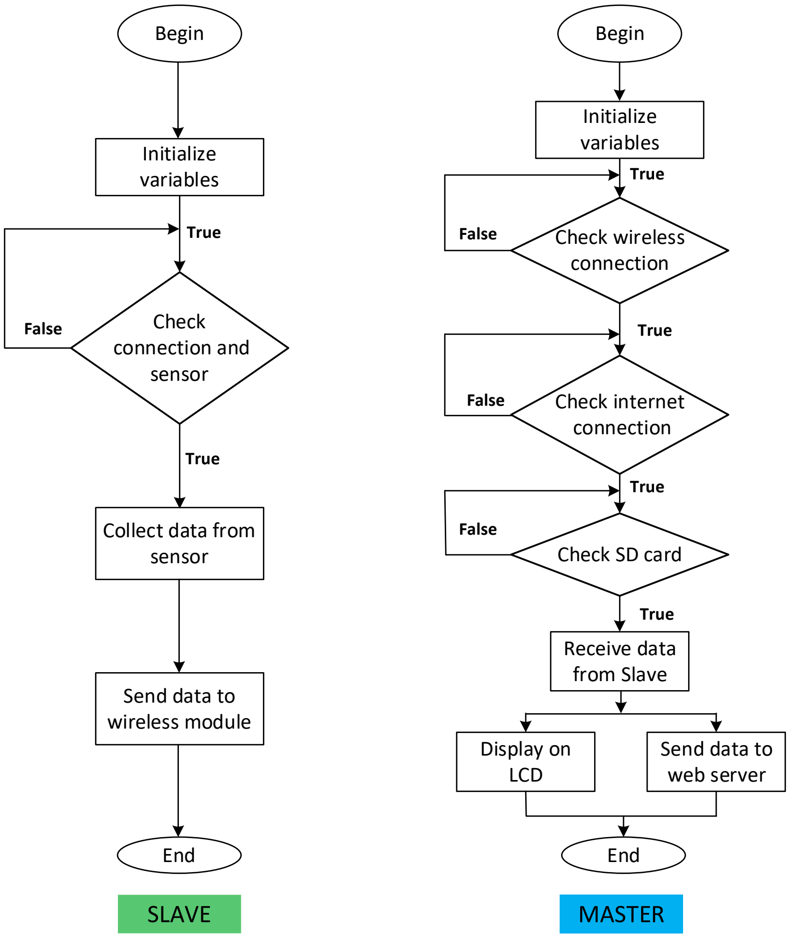


Figure 3. *The flow chart of the Slave and Master block of the proposed system*

2.2. Designing and implementing the system hardware

In this system, we have integrated a number of sensors that are considered the most basic sensors for vehicles, especially for vehicles transporting fresh goods such as seafood and fruits. Integrated sensors include temperature sensor, humidity sensor, fuel level sensor, Global Positioning System (GPS) sensor, velocity sensor and magnetic sensor to check the door status. Data communication between the Slave and Master blocks is performed via the Long-Range (LoRa) connection. At the Master block, a WiFi module is integrated to send data to the Internet. Thus, the data received at the Master block is sent to the Webserver via the mobile network and simultaneously displayed on the LCD screen in the vehicle's cabin to serve the driver's observation. The proposed system for monitoring a tracking the transport vehicle is depicted in Figure 4.

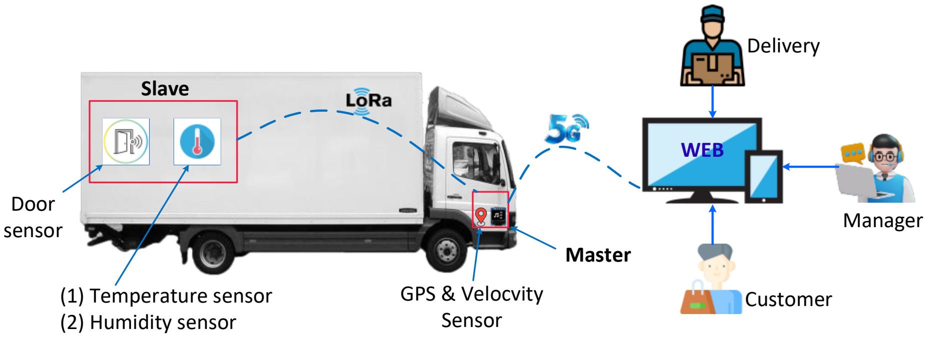
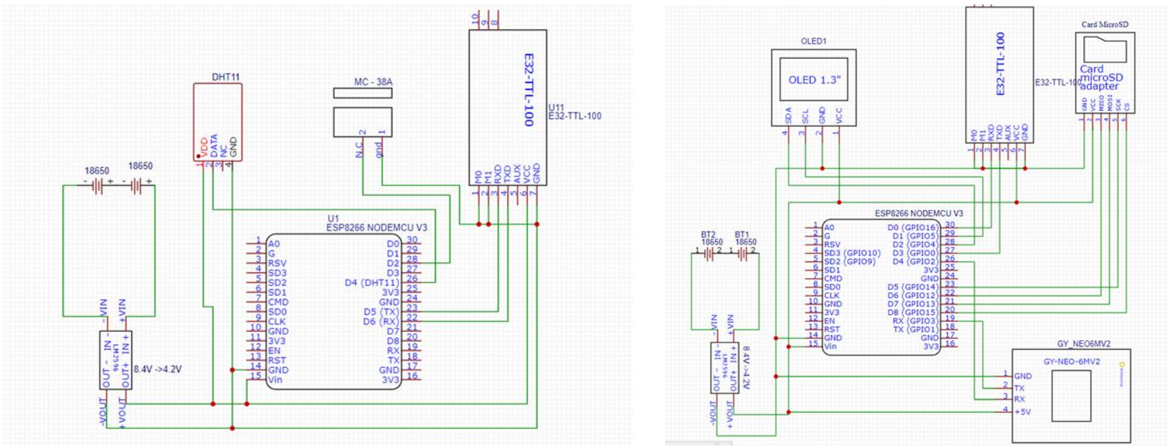


Figure 4. *The proposed system for monitoring a tracking the transport vehicle*

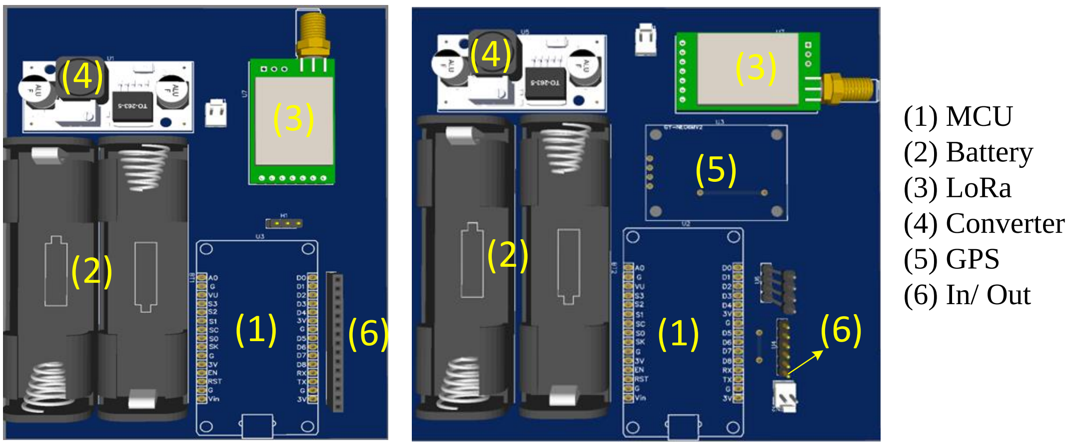
Based on the suggestions above, we proceed to design and build the hardware system. A schematic diagram of the Slave and Master is shown in Figure 5. The microprocessor of the two blocks is the ESP 8266 module, which has integrated WiFi and Bluetooth modules. LoRa E32 module is used in both blocks to transmit data from Slave to Master. In addition, temperature, humidity, and magnetic sensor modules are integrated into the Slave block. The Master block has a GPS module and a velocity sensor. In addition, an OLED screen is used to display all vehicle data; an SD memory card to store all vehicle information is also integrated into the Master block. The 3D model of the two Slave and Master blocks is shown in Figure 6.



(a) (b)

Figure 5. *The schematic diagram (a) Slave, (b) Master*

Researchers in [19] used Digital Matter Eagle cellular data logger and two temperature probes for real-time product monitoring and alerting during cold chain transportation. A visual dashboard was developed to allow logistics staff to perform monitoring. However, this system will be stopped if the vehicle breaks down or stops working because it does not have a battery. This means that the data during this time will not be recorded. Therefore, using a memory to record the vehicle's operating history like the system proposed in this paper is necessary.



(a) (b)

Figure 6. *3D simulation model of two blocks (a) Slave, (b) Master*

Finally, the collected data is sent to the Firebase platform, an open platform that allows building and delivering backend solutions for web and mobile applications. In particular, the Firebase real-time database (FRD) service allows building real-time databases, stored in JSON format, synchronized with every connection, safely and quickly. FRD allows users to simply and efficiently store and query data [20].

JTE
HCMUTE
ISSN: 2615-9740

JOURNAL OF TECHNICAL EDUCATION SCIENCE
Ho Chi Minh City University of Technology and Education
Website: https://jte.edu.vn
Email: jte@hcmute.edu.vn

3. Experimental results and discussions

Based on the designs proposed in Section 2, we proceed to build an experiment system to evaluate the parameters. The IoT-based system for smart transportation is shown in Figure 7. In this system, the Slave block is responsible for collecting data and sending data to the Master block via LoRa connection. The data is then transmitted to the Internet and displayed on the website. The collected data is displayed on the Firebase platform, and is depicted in Figure 8. In particular, the system can monitor the parameters of many vehicles simultaneously. Compared with the proposal in [21], the author only proposes a single block to collect and process data, and then send the data to the internet. The driver has no information about the current status of the vehicle.

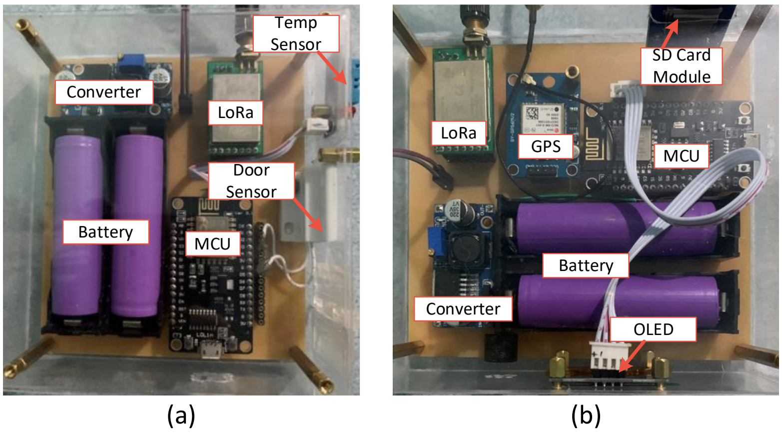


Figure 7. *Actual hardware system of two blocks (a) Slave, (b) Master*

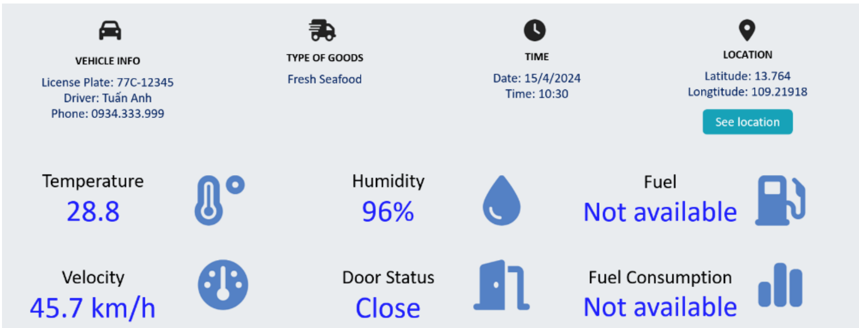


Figure 8. *Display the collected data on the website*

Next, the evaluation of temperature and humidity parameters is conducted. The collected temperature and humidity data will be compared with temperature and humidity data from specialized equipment. The comparison results shown in Figure 9 show that the maximum error in temperature is 1.2^{0}C, in which the error in humidity is 3%.

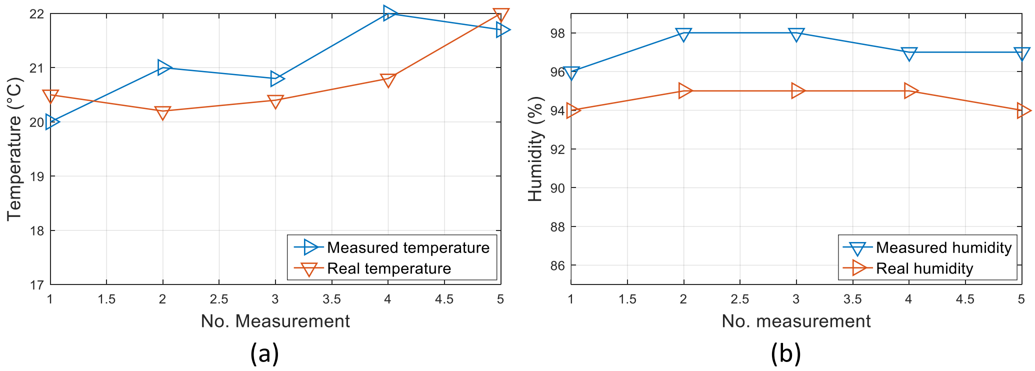


Figure 9. *Compare experimental results on temperature and humidity with parameters from specialized equipment (a) Temperature, (b) Humidity*

The velocity and position of the transport vehicle are two important parameters that need to be collected in a smart transportation system. In this system, velocity and position sensors are integrated into the Master block, which is mounted in the cabin. Measurement results are compared with the vehicle's actual velocity and location based on actual parameters from Google. The results show that the highest velocity difference is 3 km/h when compared to the velocity of the car used for the experiment. The experimental result is shown in Figure 10. The difference in location is evaluated according to two parameters longitude and latitude. In this experiment, the measured latitude and longitude values are compared with Google GPS parameters. The maximum error of longitude and latitude is about 0.000158 degrees, as shown in Figure 11. Compared with the study in [22] using Radio Frequency Identification (RFID) and sensor tags to locate vehicles and collect vehicle parameters, the proposed system uses GPS sensors more flexibly. In addition, the number of RFID checkpoints and the number of customers are limitations of this system.

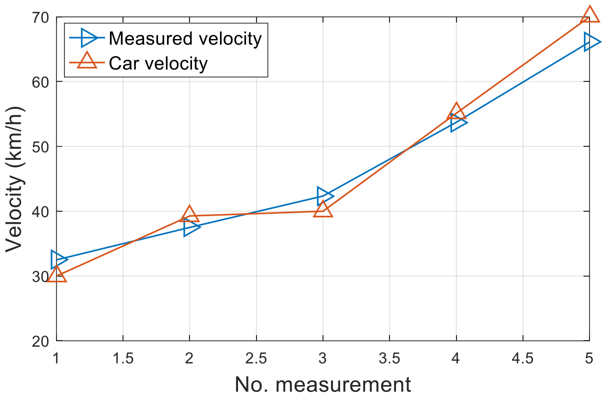


Figure 10. *Comparison of the measured velocity and car velocity*

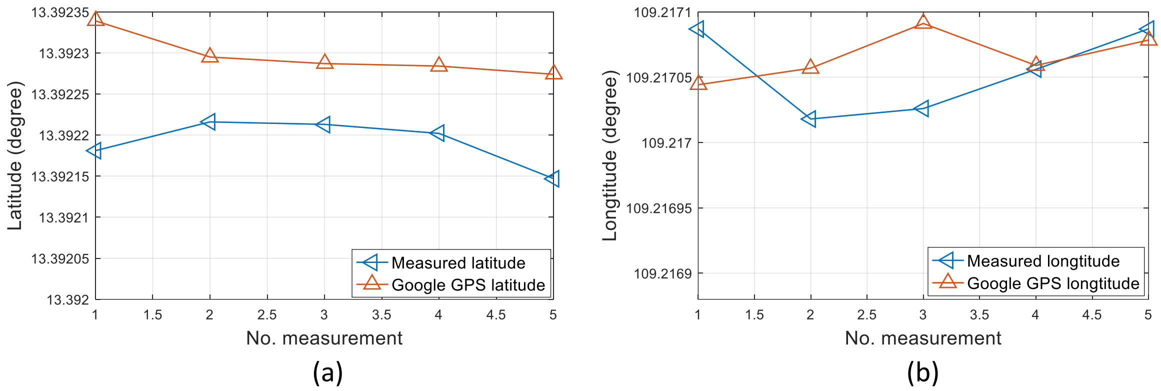


Figure 11. *Compare the measured latitude and longitude parameters with Google's GPS (a) Latitude, (b) Longitude*

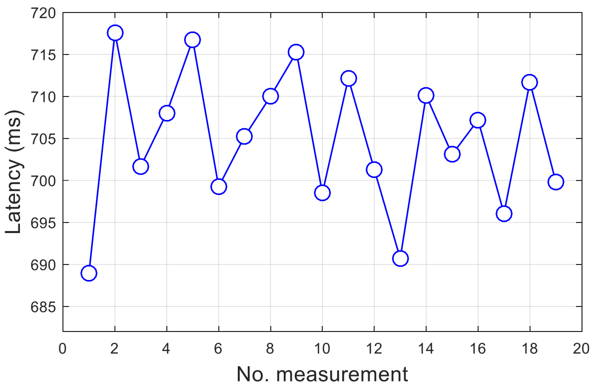


Figure 12. *The latency when sending data from the system to the website*

As mentioned, the collected data will be sent from the Master block to the website via the mobile network. In this experiment, we will also evaluate latency, which is the time it takes to send data from the Master block to the webserver. Measurement results show an average latency of about 704.83 *ms* for each sending. Although, it is much higher than the standard latency of 5G systems. This can be explained that latency depends on many factors such as transceiver, network delay, amount of data, network protocol, etc. The experimental results are obtained in Figure 12.

In addition, the proposed system also integrates door sensors, which is a solution to ensure the safety of goods during transportation. With door sensors, the system can monitor the opening and closing of vehicle doors, detecting abnormalities early to protect goods from loss. In addition, the system also integrates a memory card to record all parameters, routes and vehicle status throughout the journey. This data helps managers easily monitor and analyze vehicle operations, thereby optimizing the transportation process and improving the efficiency of goods preservation.

4. Conclusions

This study proposes an IoT-based solution for smart transportation. We have developed a hardware system for measuring and transmitting data in the vehicle, as well as its position. The results of measurement parameters are displayed visually on the LCD screen in the vehicle and displayed simultaneously on the website so that drivers, managers, and goods owners can grasp information about the vehicle. Vehicle data on temperature, humidity, position, velocity, and door status parameters are collected. These results are compared and evaluated to prove the correctness and feasibility of the system. Latency time is also evaluated by measuring the time it takes to send data from the system to the web server. In addition, the system also integrates a memory card that can store vehicle information and be stored on the internet for retrieving information as necessary. All experimental results demonstrate that the proposed experimental system can be fully applied in practice.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

[1] Brookings Homepage, https://www.brookings.edu/articles/a-long-term-view-of-covid-19s-impact-on-the-rise-of-the-global-consumer-class/, last accessed 2024/05/07

[2] K. Ashton, "That 'Internet of Things' thing," *RFID Journal*, vol. 22, no. 7, pp. 97-114, 2009.

[3] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A survey on enabling technologies, protocols, and applications," *IEEE Commun. Surveys Tuts.*, vol. 17, no. 4, pp. 2347–2376, 2015.

[4] I. Lee and K. Lee, "The Internet of Things (IoT): Applications, investments, and challenges for enterprises," *Bus. Horizons*, vol. 58, no. 4, pp. 431–440, 2015.

[5] V. I. Galina *et al.*, "Internet of Things (IoT) in logistics," *IOP Conf. Series: Materials Science and Engineering* vol. 940, 2020.

[6] J. Karande and S. Joshi, "Real-Time Detection of Cyber Attacks on the IoT Devices," *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, 2020, pp. 1-6.

[7] K. Doshi, Y. Yilmaz, and S. Uludag, "Timely Detection and Mitigation of Stealthy DDoS Attacks Via IoT Networks," *IEEE Transactions on Dependable and Secure Computing*, vol. 18, no. 5, pp. 2164-2176, 2021.

[8] T. D. Hoa *et al.*, "The Internet of Things for Logistics: Perspectives, Application Review, and Challenges," *IETE Technical Review*, vol. 39, no. 4, pp. 93-121, 2021.

[9] K. Witkowski, "Internet of Things big data industry 4.0—Innovative solutions in logistics and supply chains management," *Int. Conf. Eng. Project Prod. Manag.*, vol. 182, 2017, pp. 763-769.

[10] A. Trappey *et al.*, "IoT patent roadmap for smart logistic service provision in the context of industry 4.0," *J. Chin. Inst. Eng.*, vol. 40, no. 7, pp. 593–602, 2017.

[11] J. Maia and J. Yudi, "An IoT solution for load monitoring and tracking of garbage-truck fleets," *2020 IEEE Conference on Industrial Cyberphysical Systems (ICPS)*, 2020, pp. 406-410.

[12] M. Savic *et al.*, "Deep Learning Anomaly Detection for Cellular IoT With Applications in Smart Logistics," *IEEE Access*, vol. 9, pp. 59406-59419, 2021.

[13] G. Miao, "Application of CNN-based Face Recognition Technology in Smart Logistics System," *2021 20th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES)*, 2021, pp. 100-103.

[14] J. J. Q. Yu, W. Yu, and J. Gu, "Online vehicle routing with neural combinatorial optimization and deep reinforcement learning," *IEEE Trans. Intel. Transp. Syst*., vol. 20, no. 10. pp. 3806–3817, 2019.

[15] N. Servos, X. Liu, M. Teucke, and M. Freitag, "Travel time prediction in a multimodal freight transport relation using machine learning algorithms," *Logistics*, vol. 4, no. 1, 2020, doi: https://doi.org/10.3390/logistics4010001.

[16] D. Yangke, "Smart logistics based on the internet of things technology: an overview," *International Journal of Logistics Research and Applications*, vol. 24-2021, no. 4, pp. 323-345, 2020.

[17] N. L. Goncharova and T. I. Bezdenezhnykh, "Employing the elderly in the service sector in conditions of electronic and fourth innovation and technology revolution: Industry 4.0," *International Business Information Management Association Conference*, 2018, pp. 2330-2336.

[18] Z. Alin *et al.*, "IoT Communication Security Issues for Companies: Challenges, Protocols and The Web of Data," *Proceedings of the International Conference on Business Excellence*, vol. 14, no. 1, 2020, pp. 1109-1120.

[19] Gillespie *et al.*, "Real-Time Anomaly Detection in Cold Chain Transportation Using IoT Technology", *Sustainability*, vol. 15, no. 3, p. 2255, 2023.

[20] M. F. Younis and Z. S. Alwan, "Monitoring the performance of cloud real-time databases: A firebase case study," *Al-Sadiq International Conference on Communication and Information Technology (AICCIT)*, 2023.

[21] C. G. Juarizo, J. P. Rogelio, J. R. Balbin, and E. P. Dadios, "IoT-Based End-to-End Monitoring of Logistics and Tracking of Truck Vehicles Using Arduino Microcontroller," *Proceedings of the World Congress on Engineering*, London, U.K, 2019.

[22] S. Mejjaouli, R. F. Babiceanu, and I. Nisanci, "The use of RFID sensor tags for perishable products monitoring in logistics operations," *Winter Simulation Conference*, pp. 2001-2012, 2014.

Huynh Nguyen Bao Phuong received the B.Eng., M.Eng. and D.Eng. degrees from Hanoi University of Science and Technology, Vietnam in 2003, 2007 and 2015, respectively. Now he is a senior lecturer of the Faculty of Engineering and Technology, Quy Nhon University, Vietnam. His research interests are metasurfaces, metasurface-based antennas, microstrip and metamaterial antennas, MIMO antennas; IoT and AI techniques.
Email: huynhnguyenbaophuong@qnu.edu.vn. ORCID: https://orcid.org/0009-0006-3316-5428

Nguyen Duy Thong received the B.E. and M.S. degrees in telecommunication engineering from the School of Electronics and Telecommunications, Hanoi University of Science and Technology, Vietnam, in 2011 and 2015, respectively, and the Ph.D. degree in Electronic engineering from Kookmin University, South Korea, in 2019. His research interests include optical camera communications, channel coding, digital signage, and network administration, Internet of Things, machine learning.
Email: nguyenduythong@qnu.edu.vn. ORCID: https://orcid.org/0000-0002-8384-6225