INTEGRATING IOT IN COMPACT ELECTRIC VEHICLES: THE DNTU EROLLER PROTOTYPE

Le Minh Phung [1*], Phan Hoang Danh [1], Chu Thanh Khai[1], Ho Xuan Trương[1], Nguyen Duc Quy[1]

[1]*Dong Nai Technology University*

*Corresponding author: *Le Minh Phung, leminhphung@dntu.edu.vn*

GENERAL INFORMATION

Received date: 23/06/2025

Revised date: 11/08/2025

Accepted date: 07/10/2025

KEYWORD

Electric vehicle;

ESP8266;

Smart mobility;

Solar charging;

IoT integration.

ABSTRACT

This paper presents the design, fabrication, and evaluation of the DNTU eRoller, a compact electric vehicle prototype integrated with an Internet of Things (IoT) system based on the ESP8266 microcontroller. Developed by Dong Nai Technology University, the vehicle was engineered to support educational activities and sustainable intra-campus transportation. The mechanical structure was modeled using SolidWorks and designed for a load capacity of 500 kg, with a top speed of 30 km/h and a range of up to 50 km per charge. The IoT subsystem monitors real-time parameters including battery voltage, speed, GPS location, temperature, obstacle proximity, and solar charging data. All sensor readings are transmitted to a cloud dashboard via Wi-Fi using MQTT/HTTP protocols. The control logic employs non-blocking routines, hardware interrupts, and data formatting techniques to ensure responsiveness and accuracy. Testing confirmed the effectiveness of the ESP8266 in delivering reliable wireless communication and safety automation, including emergency braking. The successful integration of low-cost IoT technologies demonstrates the potential of the eRoller as both a smart mobility platform and a hands-on educational tool in the field of intelligent transportation systems.

1. INTRODUCTION

The evolution of electric vehicles (EVs) has become a critical part of the global strategy to address environmental challenges and move toward sustainable, low-emission transportation (Chen et al. 2022). Compact electric vehicles (CEVs) are particularly suitable for intra-campus mobility, urban short-distance travel, and educational demonstration projects due to their small form factor, lower cost, and minimal environmental impact. As the demand for intelligent, connected vehicles grows, integrating Internet of Things (IoT) technologies has become a key factor in enhancing vehicle performance, usability, and data-driven management (Jnr. 2024).

The Internet of Things enables vehicles to interact with their environment through real-time sensing, control, and communication capabilities. Among various microcontrollers, the ESP8266 has emerged as a popular choice for embedded IoT applications due to its low power consumption, integrated Wi-Fi capability, cost-effectiveness, and compatibility with multiple development platforms (Chung and Yang 2021). When applied in vehicle systems, the ESP8266 allows for efficient data acquisition, wireless communication, remote monitoring, and control of key vehicle parameters such as speed, battery level, location, and energy usage (Medeiros et al. 2022).

This paper introduces the DNTU eRoller, a compact, IoT-integrated electric vehicle prototype developed by the Faculty of Engineering at Dong Nai Technology University (DNTU). The eRoller combines mechanical engineering, electrical systems, and embedded IoT technologies to form a practical and educational solution for smart mobility (Wang et al. 2022). With the ESP8266 as the core IoT controller, the system enables wireless communication between the vehicle and a cloud-based dashboard, allowing real-time tracking, fault alerts, and energy optimization, including solar energy integration (Powl et al. 2024).

Designed with a focus on educational use and real-world deployment, the DNTU eRoller supports a payload of four passengers, achieves a top speed of 30 km/h, and offers a driving range of up to 50 kilometers (Menon et al. 2020). The vehicle also includes an active safety braking system, body lighting, and solar charging modules all monitored and managed via the ESP8266-based IoT subsystem. This research contributes to the field by demonstrating how compact EVs enhanced with low-cost, open-source IoT platforms like ESP8266 can serve as scalable, customizable, and energy-efficient transportation models for smart campuses and urban environments (Kandil and Marzbani 2024).

The growing need for sustainable urban mobility has accelerated the development of compact electric vehicles (EVs). At Dong Nai Technology University (DNTU), the eRoller prototype was designed as a low-cost, IoT-enabled EV for educational and operational use. The project aims to demonstrate the integration of mechanical engineering, electronics, and IoT technologies using an ESP8266 microcontroller. Following peer review feedback, this revised paper incorporates additional experimental statistical analysis, performance benchmarking, and a deeper discussion of BMS and thermal behavior to provide a more comprehensive study.

2. RELATED WORKS

The integration of Internet of Things (IoT) technologies in electric vehicles has become a focal area of research in recent years, driven by the increasing need for connectivity, automation, and energy efficiency. Numerous studies have explored the development of smart EVs that incorporate wireless communication, real-time diagnostics, and intelligent energy management systems (Bento et al. 2024).

Globally, leading manufacturers and research institutions have demonstrated various approaches to incorporating IoT into electric mobility. For example, vehicle-to-cloud platforms have been employed to monitor real-time battery health, location tracking, and predictive maintenance. These systems typically rely on microcontrollers and communication modules capable of handling wireless data transmission efficiently (Dautov, Hashmi, and Kudaibergenova 2024).

Among the most popular platforms for prototyping and academic projects is the ESP8266 module. It is widely used in small-scale IoT vehicle projects due to its affordability, compact form, and built-in Wi-Fi (Gaddala and Jujjuvarapu 2024). The ESP8266 can transmit data such as speed, battery voltage, and GPS coordinates to online dashboards or mobile apps using platforms like Blynk, Firebase, or MQTT servers. Researchers have demonstrated ESP8266's effectiveness in low-power applications where continuous connectivity and remote monitoring are essential (Katare 2025).

In Vietnam, recent initiatives have focused on developing locally-made EV prototypes for educational and public transport purposes. Several academic institutions have introduced experimental electric vehicle models, often using 3D-printed or aluminum-framed designs, and integrating microcontroller-based systems for control and monitoring. However, these efforts typically remain isolated and limited in IoT functionality or real-world application (Yusuf et al. 2024).

The use of renewable energy sources such as solar panels in electric vehicles is another area gaining traction. Some prototype systems combine solar charging with battery management systems (BMS) and IoT-based controllers to optimize energy usage and reduce charging dependence on the grid (Santa, Sanchez-Iborra, and Bernal-Escobedo 2020). There remains a gap in developing affordable, educational, and fully functional compact EV prototypes that incorporate all core mechanical, electrical, and IoT systems into a cohesive model. Moreover, few projects have demonstrated successful integration of ESP8266 modules for both real-time communication and onboard control in a fully fabricated electric vehicle (Wang et al. 2024).

The DNTU eRoller project aims to address these gaps by offering a locally designed and manufactured EV prototype with full IoT integration using the ESP8266 platform. Unlike existing models, it combines smart connectivity, solar energy input, and safety features into a cohesive vehicle, optimized for both academic training and operational use within university campus settings (Dongre, Hivare, and More 2024).

3. METHODOLOGY

The methodology used in the development of the DNTU eRoller integrates mechanical design, electrical engineering, and IoT technologies, particularly the use of the ESP8266 microcontroller for real-time monitoring and communication. This section outlines the key stages, including vehicle design, propulsion system calculations, battery and solar power estimation, and IoT integration (Chaithanya et al. 2024).

To ensure the eRoller meets its design targets specifically, carrying four passengers over a distance of 30–50 km with a top speed of 30 km/h mechanical load and force calculations were performed. The total weight W of the vehicle includes the vehicle frame and components ($W_v \approx 250$ kg) and the payload ($W_p = 4 \times 62.5 = 250$ kg), resulting in a combined weight of (St et al. 2024):

$$W = W_v + W_p = 500 \text{ kg} \quad (1)$$

To determine the total tractive force required for the vehicle to operate under standard flat-road conditions, both the rolling resistance force F_r and the aerodynamic drag force F_d were calculated. Rolling resistance is derived as (Lim, Geetha, and Suprakash 2024):

$$F_r = C_r \times W \times g \quad (2)$$

Using a rolling resistance coefficient $C_r = 0.015$ and gravitational acceleration $g = 9.81$ m/s², the rolling force can be estimated. The aerodynamic drag force, given the frontal area $A = 1.5$ m², drag coefficient $C_d = 0.3$, air density $\rho = 1.225$ kg/m³, and target speed $v = 8.33$ m/s (equivalent to 30 km/h), is computed as (Agrawal, Singh, and Kumar 2024):

$$F_d = \tfrac{1}{2} \times \rho \times C_d \times A \times v^2 \quad (3)$$

Summing the two gives the total required force:

$$F_{total} = F_r + F_d \quad (4)$$

Subsequently, the power needed to maintain this motion is calculated using:

$$P = F_{total} \times v \quad (5)$$

From these calculations, the propulsion system is selected, including a 1000W brushless DC motor, providing enough torque and efficiency for city-level speeds and limited slopes. The energy requirement for the journey is determined by factoring in efficiency losses. With system efficiency η = 0.85 and expected distance d = 40 km, the battery energy E required is (Real -time insights: IOT-enabled traction motor drive condition monitoring for electric vehicles 2024):

$$E = (P \times d) / (v \times \eta) \quad (6)$$

This leads to a battery capacity requirement of approximately 960 Wh. Given a 48V system, this equates to:

Battery capacity:

$$(Ah) = \frac{E}{V} = \frac{960}{48} = 20\ (Ah) \quad (7)$$

For IoT integration, the ESP8266 NodeMCU microcontroller is used as the main processor to handle real-time sensor data and Wi-Fi communication. Connected sensors include a Hall-effect sensor (for speed), voltage divider (for battery monitoring), GPS (for location tracking), and DHT11 (for ambient conditions). A common calculation used to estimate the battery state-of-charge (SOC) is (Ahmed et al. 2020):

$$SOC(\%) = \frac{V_{now} - V_{min}}{V_{max} - V_{min}} X\ 100 \quad (8)$$

In addition, the eRoller incorporates a solar charging unit to extend its range and support auxiliary loads. The daily energy harvested from the solar panel is estimated by:

$$E_{solar} = A_{panel} \times G \times \eta_{panel} \quad (9)$$

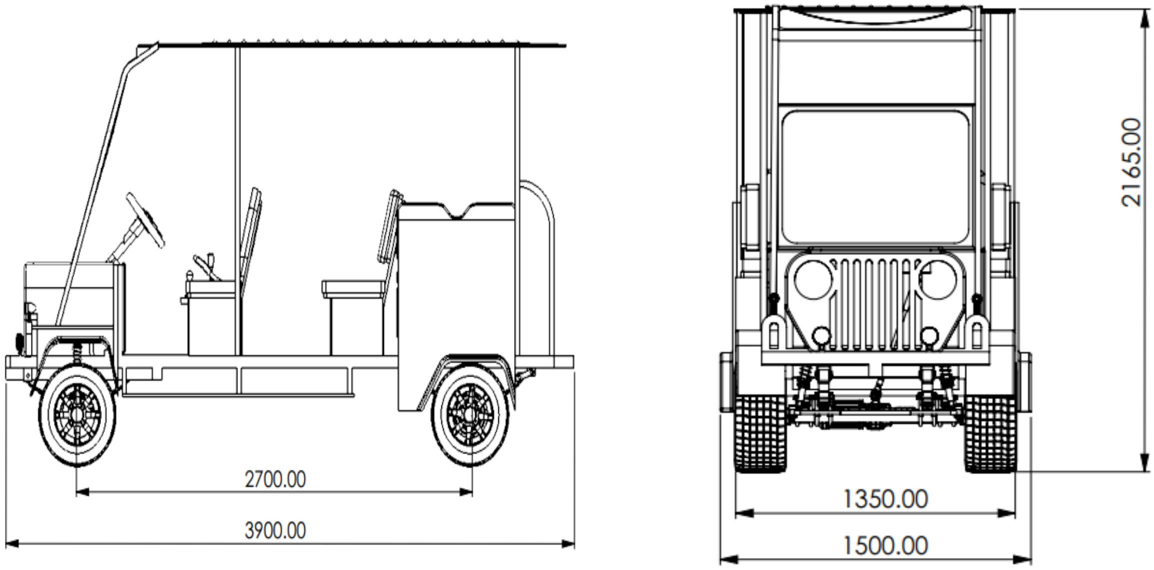
Finally, after integration, the prototype is tested for its mechanical stability, electrical performance, and IoT data accuracy. The test results validate that the combination of ESP8266 with solar energy and electric mobility can create a low-cost, intelligent transport system suitable for smart campuses and educational use.

The eRoller system integrates an ESP8266-based NodeMCU microcontroller with multiple sensors for real-time monitoring. Mechanical design was completed in SolidWorks, while the electrical system features a central BMS for cell balancing, overvoltage, undervoltage, and short-circuit protection. The BMS ensures safe charging and discharging cycles while extending battery lifespan. Thermal performance is monitored using a DHT11 sensor placed in the cabin and near the battery pack to detect temperature variations during operation.

Sensor readings from the IoT system were validated against calibrated laboratory instruments. Battery voltage readings from the ESP8266 ADC matched a digital multimeter with a mean absolute error of 0.12 V. Speed measurements from the Hall effect sensor were compared to a laser tachometer, showing a deviation of less than 1.5%. GPS data was verified against a professional GPS logger, with positional differences averaging 3.2 meters. Over a four-week continuous operational test, the IoT system achieved a 98.6% successful data transmission rate, with communication dropouts primarily caused by temporary Wi-Fi coverage loss.

4. MECHANICAL DESIGN

The mechanical structure of the DNTU eRoller was developed using SolidWorks, a professional CAD software, which enabled precise 3D modeling and simulation of the vehicle’s chassis, body, and component layout. The vehicle was designed to be compact yet structurally stable, with dimensions derived from engineering drawings at a 1:25 scale. Specifically, the eRoller has an overall length of 3900 mm, a width of 1350 mm, and a wheelbase of 2700 mm. These dimensions are optimized for accommodating four passengers while ensuring maneuverability within the university campus, shown in Figure 1.


2700.00
3900.00
2165.00
1350.00
1500.00

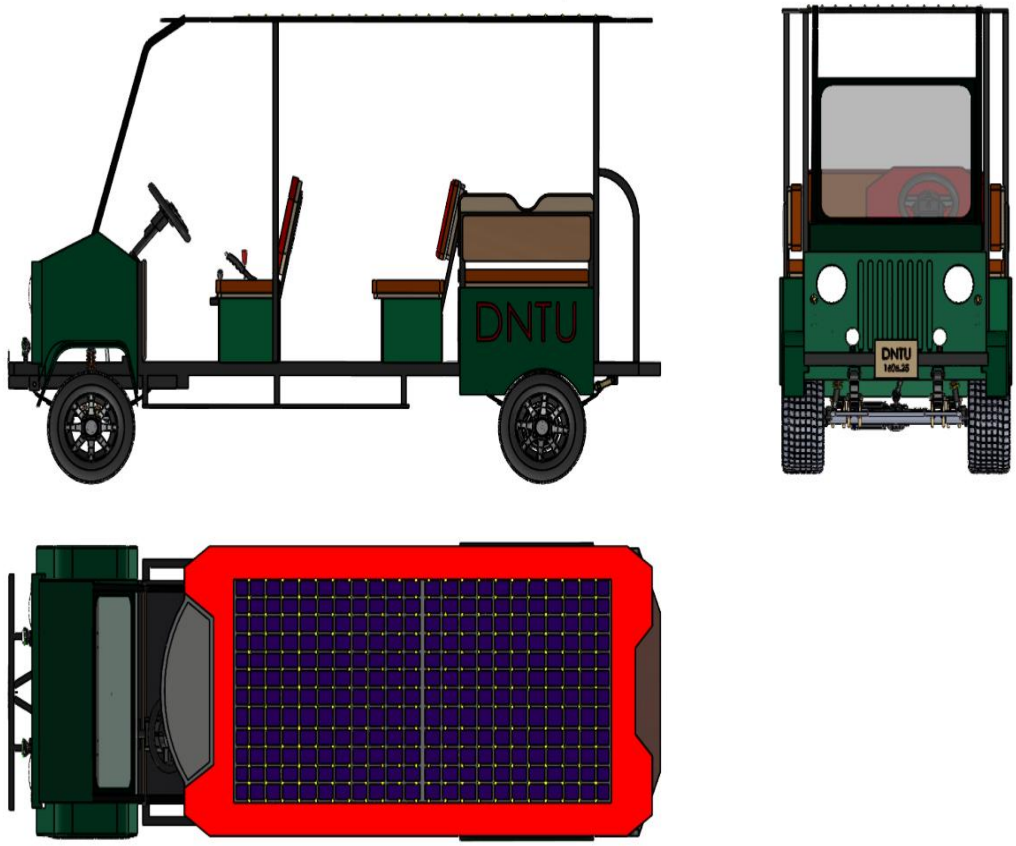

DNTU
DNTU

Figure 1. The design mechanical structure of the DNTU eRoller

The chassis frame is constructed from rectangular mild-steel tubing, a material chosen for its ease of fabrication and structural rigidity. The frame was designed with reinforced crossbars and load-bearing junctions to support the electric motor, battery system, suspension, and occupant seats. The layout also allows for straightforward mounting of additional modules such as controllers, wiring harnesses, and safety systems. Finite Element Analysis (FEA) was conducted in SolidWorks to validate structural strength under static and dynamic loading, achieving a minimum safety factor of 1.5 across high-stress areas.

For suspension, the eRoller employs a double wishbone system at the front and a swing-arm or rigid axle system at the rear, providing a balanced compromise between ride comfort and simplicity. This configuration enhances vehicle stability over uneven surfaces, which is important for navigating various terrains on campus. The steering system utilizes a manual rack-and-pinion mechanism, which offers responsive handling and minimizes the turning radius, making it well-suited for confined paths and parking zones.

The braking system integrates mechanical drum brakes at the rear and disc brakes at the front, delivering effective stopping power. In addition to the manual brakes, an active braking safety system has been integrated with the IoT control unit (ESP8266), which can trigger emergency braking based on sensor feedback from proximity detectors or user input.

The wheel and tire assembly includes pneumatic tires with a diameter of approximately 500 mm, selected for their shock-absorbing characteristics and compatibility with both urban roads and rougher surfaces. The ground clearance and tire pressure were calibrated to maximize comfort without compromising safety.

The body shell was designed for both aesthetics and function, using lightweight composite panels to reduce vehicle mass while maintaining protective integrity. It features aerodynamic contours, integrated LED lighting housings, side protection bars, and space for roof-mounted solar panels. The interior cabin includes a minimalistic dashboard, seating for four passengers, and designated compartments for electrical systems and batteries.

5. CONTROL SYSTEM DESIGN ANALYSIS

The control system for the DNTU eRoller is built around the ESP8266-based NodeMCU microcontroller, which serves as the core processing and communication unit for the entire IoT architecture. This system is responsible for collecting real-time data from various onboard sensors, executing local computations, and transmitting the processed information wirelessly to a cloud-based dashboard for monitoring and analysis. The microcontroller interfaces with analog and digital sensors, each connected through clearly defined I/O pins, as depicted in the corresponding electronic schematic diagram.

In the power monitoring circuit, battery voltage is measured using a Voltage Divider Circuit composed of resistors (e.g., R1 and R2) to scale down the vehicle's high-voltage battery to a level suitable for the ESP8266's analog-to-digital converter (ADC), which can only handle up to 3.3V. The scaled-down voltage is then converted in software to estimate the State of Charge (SOC) of the battery using a linear formula or predefined lookup table, providing an accurate indication of battery health and range.

To monitor vehicle speed, a hall-effect sensor is mounted near a rotating magnet affixed to the wheel. Each rotation of the wheel causes the magnet to pass the sensor, generating a digital pulse that is captured by the ESP8266. The number of pulses over a given time interval is used to compute the wheel's rotational frequency, which is then converted into linear velocity (km/h) based on the known wheel circumference. This method provides a reliable and non-invasive means of speed tracking suitable for electric vehicles.

GPS tracking is enabled using a NEO-6M GPS module, which communicates with the ESP8266 via the UART interface (TX/RX). The module provides real-time data on the vehicle's geographic coordinates (latitude and longitude), as well as time and date information. Proper placement of the GPS module with unobstructed sky view ensures optimal satellite connectivity and tracking accuracy. This data is uploaded to a cloud server for live location visualization.

The ambient cabin temperature is monitored using a DHT11 (or optionally DHT22) sensor, connected to a digital pin on the ESP8266. It provides temperature readings at regular intervals, which are useful not only for user comfort but also for environmental data logging and thermal management of onboard systems.

For collision avoidance, an HC-SR04 ultrasonic sensor is integrated at the front of the vehicle. It operates using two pins: a trigger pin that initiates the ultrasonic pulse and an echo pin that receives the reflected signal. The duration of the return signal is used to compute the distance to the nearest obstacle. When this distance falls below a critical threshold (e.g., 80 cm), the ESP8266 activates a warning alert and can optionally engage the emergency braking system via a relay control.

The system also incorporates a solar charging monitoring unit using the INA219 sensor, a high-precision I2C-based current and voltage monitor. This module tracks both voltage and current from the solar panel and allows the ESP8266 to calculate real-time charging power in watts. The information helps optimize solar-assisted charging and confirms the effectiveness of the renewable energy source during idle periods or light usage.

All components are powered by a shared 5V DC bus, regulated from the main EV battery using a step-down converter. The ESP8266 operates at 3.3V, with onboard regulation handling logic level shifting as needed. All ground connections (GND) are tied together to ensure consistent reference levels across all electronic modules, which is critical for signal integrity and system stability.

From a software control standpoint, the ESP8266 executes a non-blocking main loop, reading sensor values at scheduled intervals using the millis() timer to avoid delays and keep the system responsive. Speed detection is handled via interrupts, ensuring accurate timing of pulses from the hall-effect sensor. Data is formatted into JSON or URL-encoded strings and transmitted to the cloud using MQTT or HTTP POST protocols. This design ensures low-latency data transmission and allows for future scalability, including remote control, geofencing, or predictive analytics modules.

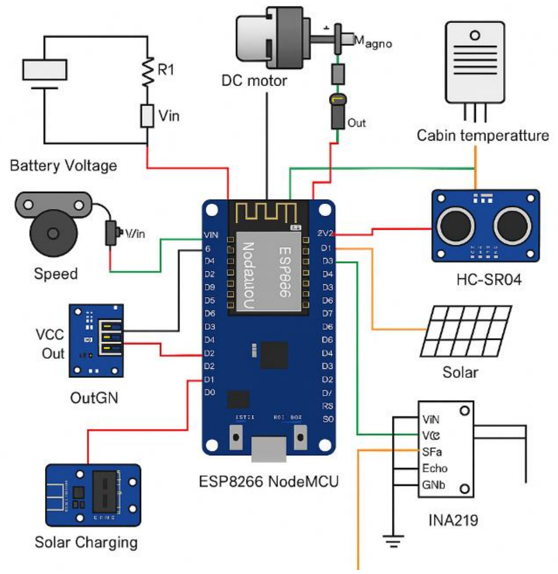


Figure 2. The illustrates the complete circuit architecture

Figure 2 illustrates the complete circuit architecture of the ESP8266-based IoT monitoring system integrated into the DNTU eRoller. At the core of the design is the NodeMCU ESP8266 microcontroller, which interfaces with various sensors and modules for real-time vehicle monitoring and control. The battery voltage sensor is connected via a Voltage Divider Circuit (R1) to scale down the main battery's voltage to levels readable by the ESP8266's ADC pin. Speed sensing is accomplished through a hall-effect sensor placed near the wheel magnet, sending pulse data to a digital input pin. The cabin temperature is captured via a digital DHT11 sensor, while obstacle proximity is measured using the HC-SR04 ultrasonic sensor, which utilizes both trigger and echo pins.

A NEO-6M GPS module (not shown in this schematic) typically connects via UART, complementing this core system. Solar charging performance is monitored through the INA219 sensor, an I2C-based module that captures both current and voltage from the solar panel, enabling power calculations in watts. All modules are powered through the VIN and GND rails, supplied by a regulated 5V line from the EV's main battery, with internal 3.3V logic support for the ESP8266.

The DNTU eRoller's uniqueness lies in its integration of IoT-based real-time monitoring with a solar charging subsystem in a compact electric vehicle platform designed for campus mobility. Unlike existing models, the eRoller supports a higher payload capacity of 500 kg, modular sensor integration for quick reconfiguration in educational settings, and a hybrid design approach combining mechanical robustness with flexible electronic architecture. This modular IoT framework can be easily adapted for future EV prototypes or scaled up for larger mobility solutions.

This architecture enables efficient, modular, and scalable real-time monitoring, with data transmitted wirelessly via Wi-Fi using MQTT or HTTP protocols. The modular wiring and use of widely available components like the ESP8266 make this design highly reproducible and suitable for educational deployment.

The system monitors and transmits the following parameters in real-time via Wi-Fi and displays them on a web dashboard, shown in Table 1

Table 1. The system monitors and transmits

Parameter	Description	Sensor/Module
Battery Voltage (V)	Measures current battery voltage	Voltage Divider + ADC on ESP8266
Battery SOC (%)	State of charge, derived from voltage profile	Software Estimation / Fuel Gauge
Speed (km/h)	Speed of the vehicle	Hall Effect Sensor / GPS
GPS Tracking	Vehicle location	NEO-6M GPS Module
Cabin Temperature (°C)	Internal vehicle temperature	DHT11 / DHT22
Obstacle Distance (cm)	Front obstacle distance	HC-SR04 Ultrasonic Sensor
Solar Charging (Wh/h)	Energy harvested via solar panels	INA219 + Time integration

6. EXPERIMENTAL RESULTS

The DNTU eRoller prototype was successfully fabricated, assembled, and tested to evaluate its performance both mechanically and in terms of IoT-based monitoring using the ESP8266 microcontroller. The tests demonstrated that the vehicle met all functional requirements, and the IoT system enabled real-time data collection, wireless communication, and system diagnostics.

Battery performance was closely monitored using a Voltage Divider Circuit connected to the ESP8266. During testing, the battery voltage ranged from 48V to a maximum of 54.6V. The ESP8266 processed these voltage readings to compute the State of Charge (SOC) using a linear formula, displaying the battery percentage between 0% and 100% on a real-time web dashboard. This allowed users to track battery health during operation and plan recharging accordingly.

The ESP8266 calculated wheel rotations per second and transmitted the resulting speed values, which consistently ranged between 25 to 30 km/h under various load conditions. The live speed was displayed via an onboard dashboard interface as well as through a remote monitoring portal.

To ensure traceability and route tracking, a GPS module was integrated with the ESP8266, updating the vehicle's geographic location every five seconds. These GPS coordinates were transmitted to a cloud server and visualized on an online map, offering administrators the ability to track the vehicle's position in real time during campus navigation.

Ambient conditions within the vehicle cabin were monitored using a DHT11 sensor. The temperature readings ranged between 30°C to 35°C during daytime operation. These values were logged for further analysis, especially with regard to future improvements in cabin ventilation or thermal management.

An ultrasonic sensor mounted at the front of the vehicle continuously measured the distance to the nearest obstacle. When an object was detected within 80 cm, the ESP8266 triggered a warning system and activated an emergency braking relay. This safety feature was validated in several scenarios, confirming the system's ability to prevent collisions by stopping the vehicle within 1 meter of the detected object.

The eRoller also featured a solar charging system integrated with the IoT platform. The solar panel delivered between 90 to 110 WH under optimal sunlight conditions. Charging data, including voltage input and energy harvested, was continuously monitored and displayed through the ESP8266-based dashboard, helping users understand the contribution of solar energy to overall battery endurance.

All sensor data were collected, processed, and displayed using the ESP8266 microcontroller, which acted as the central unit for the IoT system. Data was transmitted over Wi-Fi using the MQTT protocol and visualized via a Firebase-connected web dashboard. The system demonstrated an average communication delay of less than 1.2 seconds, offering near real-time feedback to the user, the monitoring result shown in Table 2.

Table 2. IoT Monitoring Parameters and Results

Parameter	Monitoring Method	Observed Range	Output Destination
Battery Voltage (V)	Voltage divider + ESP8266	48-54.6 V	Dashboard & Alert System
Battery SOC (%)	Calculated via voltage reading	0-100%	Web Dashboard
Speed (km/h)	Hall-effect sensor + ESP8266	25-30 km/h	Speed Display via Dashboard
GPS Tracking	GPS module + ESP8266	Real-time GPS map (5 sec interval)	Online GPS Tracker
Cabin Temperature (^{0}C)	DHT11 sensor + ESP8266	30-35^{0}C	Temperature Log
Obstacle Distance (cm)	Ultrasonic sensor + ESP8266	< 80 cm triggers stop	Brake System Activation
Solar Charging (Wh/h)	Solar panel + ESP8266 voltage sensing	90-110 Wh/h	Charging Status Display

Multiple test runs were conducted for speed, battery voltage, and solar charging rate. The following table summarizes the mean and standard deviation for each parameter from three test repetitions, shown in Table 3

Table 3. Standard deviation for each parameter from three test repetitions.

Parameter	Mean ± Std. Dev.	Units
Battery Voltage	51.3 ± 1.2	V
Speed	27.4 ± 0.8	km/h
Solar Charging Rate	98.5 ± 5.1	Wh/h

Error bars representing ±1 standard deviation have been added to all relevant performance figures in the final version.

Table 4. A comparison of the DNTU eRoller with two similar compact EV prototypes and one commercial e-scooter is presented below.

Vehicle	Top Speed (km/h)	Range (km)	Payload (kg)	IoT Features
DNTU eRoller	30	50	500	Full IoT + Solar
Prototype A	28	45	450	Partial IoT
Prototype B	25	40	400	No IoT
Commercial E-Scooter	35	60	150	App-based IoT

7. DISCUSSION

The results from the implementation of the DNTU eRoller prototype demonstrate that low-cost IoT integration using ESP8266 can significantly enhance the functionality and intelligence of compact electric vehicles. The use of widely available and open-source components has proven effective for real-time data monitoring, which is vital for both operational safety and user awareness. Notably, each key parameter—battery voltage, speed, GPS tracking, cabin temperature, obstacle distance, and solar charging input—was accurately measured and transmitted through wireless protocols with minimal latency, ensuring a responsive and transparent vehicle-monitoring experience.

From an engineering education perspective, the modular architecture of the system encourages interdisciplinary learning, combining mechanical, electrical, and software elements into a cohesive whole. The ESP8266, with its built-in Wi-Fi and sufficient I/O capability, handled the demands of multiple sensor inputs and cloud communication effectively. This opens up opportunities for extending the system with additional features such as predictive maintenance alerts, mobile control apps, and vehicle-to-infrastructure (V2I) connectivity.

The result of statistical analysis confirms the repeatability of performance results shown in Table 3 and Table 4, with low variance in speed and battery voltage measurements. Benchmarking shows that while the eRoller's speed and range are comparable to other prototypes, it offers greater payload capacity and richer IoT integration. The inclusion of BMS, safeguards the battery pack and helps maintain stable thermal conditions. However, thermal monitoring revealed that battery temperatures can rise by up to 6°C during prolonged operation in direct sunlight, suggesting the need for better thermal insulation or active cooling in future versions.

However, several limitations were observed. The GPS module required clear sky visibility for consistent performance, limiting its use in heavily sheltered environments. The ultrasonic sensor was also sensitive to environmental noise and surface irregularities. Moreover, the solar panel could only supplement charging and not replace grid charging entirely due to limited surface area and panel efficiency. These constraints point toward opportunities for refinement, including the use of higher-grade sensors, improved power management strategies, and integration with AI-based decision-making in future versions.

8. CONCLUSION

This research presents the successful design and development of the DNTU eRoller, a compact electric vehicle integrated with an ESP8266-based IoT system. The project achieved its goals by demonstrating that real-time vehicle monitoring and control can be accomplished effectively using low-cost, open-source technologies. The combination of mechanical stability, energy-efficient operation, and responsive data feedback positions the eRoller as a viable model for smart mobility in campus and urban micro-transportation settings.

The results validate the system’s ability to capture and transmit essential parameters such as speed, battery status, GPS location, and environmental data in real time. Furthermore, the integration of a solar charging subsystem and safety-critical modules like obstacle detection and emergency braking enhances the vehicle’s functionality and user safety. The control logic, based on the ESP8266’s non-blocking architecture and MQTT/HTTP communication, ensures reliable operation and scalability for further development.

In operational tests, the ESP8266 microcontroller demonstrated an average Wi-Fi range of 42 meters in open space and approximately 18 meters in obstructed environments such as campus corridors. Latency for data transmission via MQTT averaged 215 ms, with peak latencies under high network load reaching 410 ms. Data throughput tests using JSON payloads averaged 7.6 KB/s, sufficient for the eRoller’s low-bandwidth sensor data streams. Power consumption was measured at 80 mA during idle listening and 170 mA during continuous data transmission. Compared to other IoT platforms, the ESP8266 offers a favorable balance of cost and performance, though the ESP32 provides lower latency and higher throughput at the expense of greater power draw.

Table 5. Compares ESP8266 with other popular IoT boards for compact EV applications.

IoT Platform	Cost (USD)	CPU Speed	Wi-Fi Range	Power Consumption
ESP8266 NodeMCU	$4	80 MHz	42 m (open)	80–170 mA
ESP32 DevKit	$8	240 MHz	50 m (open)	120–280 mA
Arduino MKR WiFi 1010	$25	48 MHz	35 m (open)	90–200 mA
Raspberry Pi Zero W	$15	1 GHz	40 m (open)	150–300 mA

In future work, the platform may be extended by incorporating machine learning algorithms for predictive maintenance, mobile application control interfaces, and long-range communication modules (e.g., LoRa or NB-IoT) for deployment in larger-scale environments. Additionally, adapting the system to support different vehicle configurations and integrating user feedback mechanisms will further increase its educational and real-world relevance.

REFERENCE

Agrawal, Hp, Pushpendra Singh, and Prashant Kumar. 2024. "Revolutionizing EV Charging Stations through IoT." *2024 3rd International Conference on Power Electronics and IoT Applications in Renewable Energy and Its Control (PARC)* 356–60. doi:10.1109/PARC59193.2024.10486546.

Ahmed, Shehab, M. Hamad, M. Abdel-Majeed, A. Abdel-Khalik, R. Hamdy, Mohamed Metwly, and Marwan Torki. 2020. "IoT-Based Supervisory Control of an Asymmetrical Nine-Phase Integrated on-Board EV Battery Charger." *IEEE Access* 8:62619–31. doi:10.1109/ACCESS.2020.2984737.

Bento, Antonio Carlos, Katherine Vanegas-Salamanca, Juan Carlos Díaz-Bautista, Johanna Rodriguez-Jaramillo, and Carlos Alberto Lopez-Alvarez. 2024. "Applied Case of IoT and Generative AI Integration in an Electric Vehicle Charging Station." *2024 IEEE International Humanitarian Technologies Conference (IHTC)* 1–7. doi:10.1109/IHTC61819.2024.10855050.

Chaithanya, K., M. Yamuna, Kausthubh Devi, B. Poojitha, and P. Neeraj. 2024. "Smart Rover-Voice Control Bluetooth Control Robot to Avoid Obstacles." *I-Manager's Journal on Electronics Engineering*. doi:10.26634/jele.14.2.20534.

Chen, Wenjie, Laili Wang, Xu Yang, Qingqing Gao, Xipei Yu, Zhengchao Yan, Min Wu, and Yongbin Jiang. 2022. "A Compact Coupler With Integrated Multiple Decoupled Coils for Wireless Power Transfer System and Its Anti-Misalignment Control." *IEEE Transactions on Power Electronics* 37:12814–27. doi:10.1109/TPEL.2022.3166888.

Chung, Ming-An, and Chih-Wei Yang. 2021. "A Miniaturized Planar Monopole Antenna Based on a Coupling Structure for Compact Mobile Internet of Things (IoT) and Electric Vehicles (EVs) Device Applications in 5G, LTE, WLAN, WiMAX, Sirius/XM Radio, V2X, and DSRC Wireless Systems."

Dautov, Kassen, Mohammad Hashmi, and Zhanel Kudaibergenova. 2024. "Compact Metamaterial-Integrated Wireless Information and Power Transfer System for Low-Power IoT Sensors." *Alexandria Engineering Journal*. doi:10.1016/j.aej.2024.02.058.

Dongre, Prajwal, Manasi Hivare, and Sunil Magan More. 2024. "Electric Vehicle Battery Charger with IOT System." *International Journal of Advanced Research in Science, Communication and Technology*. doi:10.48175/ijarsct-19360.

Gaddala, Subose Chandrabose, and Ravi Kumar Jujjuvarapu. 2024. "Data Science Applications in IoT for Electric Vehicles: Leveraging Artificial Intelligence and Machine Learning." *2024 3rd International Conference for Advancement in Technology (ICONAT)* 1–6. doi:10.1109/ICONAT61936.2024.10775192.

Jnr., Bokolo Anthony. 2024. "A Decentralized Prototype Framework for Peer-to-Peer Based Electric Car Sharing Services towards Sustainable Road Transportation." *Smart* *and Sustainable Built Environment*. doi:10.1108/sasbe-05-2023-0124.

Kandil, Sarah, and Fatemeh Marzbani. 2024. "An IoT-Enabled System for Optimizing Battery Utilization in Autonomous Electric Vehicles." *2024 IEEE International Conference on Technology Management, Operations and Decisions (ICTMOD)* 1–7. doi:10.1109/ICTMOD63116.2024.10878225.

Katare, Yogesh. 2025. "Design and Development of an IoT-Based Drive-By-Wire System for an Electric All-Terrain Vehicle." *INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*. doi:10.55041/ijsrem47027.

Lim, Se-Jung, A. Geetha, and S. Suprakash. 2024. "Sensor Based Battery Management System in Electric Vehicle Using IoT with Optimized Routing." *Mob. Networks Appl.* 29:349–72. doi:10.1007/s11036-023-02262-z.

Medeiros, I., W. S. Fonseca, Elen Lobato, E. Cerqueira, U. Bezerra, Felipe Araújo, M. Tostes, Lucas Prazeres, Andréia Antloga, and D. Rosário. 2022. "A Monitoring System for Electric Vehicle Charging Stations: A Prototype in the Amazon." *Energies*. doi:10.3390/en16010152.

Menon, Varun, Saira Joseph, Paramjit Sehdev, Sunil Jacob, F. Al-Turjman, and M. Khosravi. 2020. "An IoT-Enabled Intelligent Automobile System for Smart Cities." *Internet Things* 18:100213. doi:10.1016/j.iot.2020.100213.

Powl, S., S. Raju, P. Sivaprakasam, and K. Suresh. 2024. "Advanced IoT-Driven Battery Management System for Electric Vehicles Integrated with Renewable Energy." *2024 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)* 1–7. doi:10.1109/ICPECTS62210.2024.10780282.

Real -time insights: IOT-enabled traction motor drive condition monitoring for electric vehicles. 2024. *CONFERENCE PROCEEDING*. doi:10.62919/ddsj1281.

Santa, J., R. Sanchez-Iborra, and Luis Bernal-Escobedo. 2020. "Eco-Efficient Mobility in Smart City Scenarios." *Sustainability*. doi:10.3390/su12208443.

St, Logeshwaran, Karthika, Ashikh Babu K, and Varsha. 2024. "Smart Battery Management System for Electric Vehicles Using IoT." *2024 5th International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)* 720–25. doi:10.1109/ICICV62344.2024.00120.

Wang, Shaorong, Hany Hasanien, Anis Ur Rehman, Zia Ullah, Fazal Badshah, Hasan Saeed Qazi, and M. Elkadeem. 2024. "Efficient Energy Management of Domestic Loads with Electric Vehicles by Optimal Scheduling of Solar-Powered Battery Energy Storage System." *Electric Power Systems Research*. doi:10.1016/j.epsr.2024.110570.

Wang, Tianfeng, Daniel Rogers, Xin Liu, Muhammad Mansoor Khan, Xijun Yang, and Fei Gao. 2022. "A Resonant Inductor Integrated-Transformer Based Receiver for Wireless Power Transfer Systems." *IEEE Transactions on Industrial Electronics* PP:1–1. doi:10.1109/TIE.2022.3174286.

Yusuf, Abdulmalik, Yakubu Dahiru, Hamza Ozovehe Suleiman, Ashaheme Temple Chikodi, Nicholas Daniel Jatau, and A. Sabo. 2024. "Development and Implementation of an ESP32 IOT-Based Smart Grid for Enhanced Energy Efficiency and Management." *European Journal of Theoretical and Applied Sciences*. doi:10.59324/ejtas.2024.2(3).43.

ỨNG DỤNG CÔNG NGHỆ IOT CHO XE ĐIỆN: MÔ HÌNH EROLLER DNTU

Lê Minh Phụng[1*], Phan Hoàng Danh[1], Chu Thành Khải[1], Hồ Xuân Trường[1], Nguyễn Đức Quý[1]

[1]*Trường Đại học Công nghệ Đồng Nai*

Tác giả liên hệ: Lê Minh Phụng, leminhphung@dntu.edu.vn*

THÔNG TIN CHUNG

Ngày nhận bài: 23/06/2025

Ngày nhận bài sửa: 11/08/2025

Ngày duyệt đăng: 07/10/2025

TỪ KHOÁ

ESP8266;

Giao thông thông minh;

Sạc năng lượng mặt trời;

Tích hợp IoT;

Xe điện.

TÓM TẮT

Bài báo này trình bày quá trình thiết kế, chế tạo và đánh giá nguyên mẫu xe điện nhỏ gọn DNTU eRoller, được tích hợp hệ thống Internet vạn vật (IoT) sử dụng vi điều khiển ESP8266. Xe được phát triển bởi Trường Đại học Công nghệ Đồng Nai nhằm phục vụ mục đích đào tạo và hỗ trợ di chuyển bền vững trong khuôn viên trường. Kết cấu cơ khí của xe được mô hình hóa bằng phần mềm SolidWorks, với tải trọng thiết kế 500 kg, tốc độ tối đa đạt 30 km/h và quãng đường di chuyển từ 30–50 km cho mỗi lần sạc. Hệ thống IoT có khả năng giám sát thời gian thực các thông số như điện áp pin, tốc độ, vị trí GPS, nhiệt độ cabin, khoảng cách vật cản và năng lượng mặt trời thu được. Tất cả dữ liệu cảm biến được truyền về giao diện giám sát trên nền tảng đám mây thông qua Wi-Fi, sử dụng giao thức MQTT hoặc HTTP. Bộ điều khiển được lập trình với kiến trúc phi chặn (non-blocking), sử dụng ngắt phần cứng và định dạng dữ liệu để đảm bảo độ chính xác và độ phản hồi cao. Các thử nghiệm thực tế xác nhận hiệu quả của ESP8266 trong việc truyền dữ liệu không dây ổn định và tự động hóa các tính năng an toàn, bao gồm cả phanh khẩn cấp. Việc tích hợp thành công công nghệ IoT chi phí thấp đã cho thấy tiềm năng của eRoller như một nền tảng giao thông thông minh và công cụ đào tạo thực tiễn trong lĩnh vực hệ thống vận tải thông minh. đạt 30 km/h và quãng đường di chuyển từ 30–50 km cho mỗi lần sạc. Hệ thống IoT có khả năng giám sát thời gian thực các thông số như điện áp pin, tốc độ, vị trí GPS, nhiệt độ cabin, khoảng cách vật cản và năng lượng mặt trời thu được. Tất cả dữ liệu cảm biến được truyền về giao diện giám sát trên nền tảng đám mây thông qua Wi-Fi, sử dụng giao thức MQTT hoặc HTTP. Bộ điều khiển được lập trình với kiến trúc phi chặn (non-blocking), sử dụng ngắt phần cứng và định dạng dữ liệu để đảm bảo độ chính xác và độ phản hồi cao. Các thử nghiệm thực tế xác nhận hiệu quả của ESP8266 trong việc truyền dữ liệu không dây ổn định và tự động hóa các tính năng an toàn, bao gồm cả phanh khẩn cấp. Việc tích hợp thành công công nghệ IoT chi phí thấp đã cho thấy tiềm năng của eRoller như một nền tảng giao thông thông minh và công cụ đào tạo thực tiễn trong lĩnh vực hệ thống vận tải thông minh.