Mediterranean Smart Cities Conference (MSCC 2024)
2-4 May, 2024, Martil, Morocco

# Integrated ESP32 and MPU6050-Based GPS Tracking System for Advanced Transport Logistics Management

Samya Yazghi Moubachir
*industrial engineering and production student*
*Mohammed VI International Academy of Civil Aviation*
Casablanca, Morocco
samyayazghi123@gmail.com

Sahar Elouima
*industrial engineering and production student*
*Mohammed VI International Academy of Civil Aviation*
Casablanca, Morocco
el03haneul@gmail.com

Mohamed Chihabeddine Belaabda
*electrical, electronic and telecommunication engineering student*
*Mohammed VI International Academy of Civil Aviation*
Casablanca, Morocco
medchihab021@gmail.com

*Abstract*—**Our research unveils a practical and economical GPS tracking solution, utilizing ESP32 and MPU6050, for seamless vehicle monitoring. This system, with individualized vehicle IDs, autonomously tracks and transmits real-time location data to a central server. Tailored for applications spanning delivery cars, taxis, buses, and corporate fleets, its intuitive design ensures ease of use for clients. This technology not only enhances operational efficiency but also bolsters security in logistics management. Affordable and scalable, this solution provides a comprehensive tool for businesses aiming to optimize their fleet visibility. With the ability to deliver precise location data, our innovation emerges as a valuable asset for diverse transportation sectors, promising improved logistics control and heightened client satisfaction.**

***Keywords—GPS Tracking System, ESP32, MPU6050, Logistics Management.***

## I. INTRODUCTION

In an era marked by unprecedented global urbanization, the trajectory of our cities is rapidly evolving. According to projections by the United Nations, the urban population is expected to surge by approximately 600 million, reaching a staggering 5.2 billion individuals residing in urban areas by 2030. As of mid-2023, over 57% of the world's population, totaling 4.6 billion people, already called towns or cities their home. What further underscores the significance of this trend is the anticipation that the urban component is slated to climb to 60% within the next decade[1]. In the midst of this dynamic urban shift, our project, incorporating ESP32 and MPU6050 technologies for GPS tracking, emerges as a timely and strategic response to the burgeoning challenges posed by rapid urbanization.

The proposed GPS tracking system utilizing ESP32 and MPU6050 technology addresses specific needs within the business and commercial sectors, making it a valuable asset for targeted adoption. This advanced system enhances fleet management efficiency[2] for businesses relying on vehicle fleets, offering real-time visibility into the location, status, and movements of each vehicle. It acts as a robust solution for asset security and loss prevention, providing a deterrent to theft and unauthorized use while enabling prompt responses to security breaches. Additionally, the system contributes to customer satisfaction and service quality by ensuring timely and accurate deliveries, fostering transparency, and building trust with clients.

Furthermore, the GPS tracking system proves instrumental in cost reduction through optimization, allowing businesses to analyze data for fuel efficiency improvements[2], predictive maintenance alerts, and overall streamlined operations. Its compliance with regulations ensures businesses maintain adherence to industry standards, enhancing safety and responsibility. The system's adaptability offers customized solutions tailored to specific industry requirements, catering to the unique operational challenges and goals of businesses managing taxi fleets, delivery services, or corporate logistics operations.

In summary, our GPS tracking system, designed for business environments and powered by ESP32 and MPU6050 technologies, not only aligns with the evolving urban landscape but also addresses critical needs in fleet management, asset security, customer satisfaction, cost reduction, regulatory compliance, and industry-specific challenges.[3] Its targeted application within business sectors positions it as an indispensable tool for improving efficiency, security, and overall business performance in the wake of accelerating urbanization trends.

This paper follows a clear structure: Section II discusses related works on vehicule tracking and background, Section III outlines the components used, Section IV shows the methodology, Section V presents results and evaluations, and Section VI concludes the paper while hinting at possibilities for future work.

## II. BACKGROUND

### A. Smart City applications

In the landscape of modern urban living, the adoption of location tracking systems, prominently facilitated by GPS technology, plays a pivotal role in addressing multifaceted challenges faced by smart cities. The integration of GPS systems resolves critical safety and environmental issues by providing accurate, up-to-date data on vehicular movements and traffic patterns. This, in turn, enables smart city planners and authorities to implement effective traffic management strategies. Additionally, the tracking afforded by GPS contributes to achieving on-time delivery for various services and goods[4], optimizing logistics and transportation networks. By prioritizing safety and leveraging the power of location-based technology, smart cities can navigate the complexities of urban living, ensuring efficient transportation, mitigating environmental impact, and fostering a secure and sustainable urban environment.

### B. Related work

With its simplest definition, a vehicle tracking system is the system that allows tracking and controlling of vehicles via an online computer, smart phone, tablet, etc. on a 24/7 basis thanks to GPS satellites. Vehicle tracking systems make it possible to have an instantaneous and history tracking of vehicle speeds, the routes they followed, stopping points, idling times on maps providing a registry and check point with past and present reports.[10]

A GPS fleet management system is fleet tracking software that uses GPS technology to track the activity of a fleet of vehicles. This geolocation works by satellite signals. Equipping yourself with the best fleet management software makes it possible to obtain the real geographical position of each vehicle thanks to a box equipped with sensors, discreetly inserted in the passenger compartment. With this tracking equipment, companies with a fleet of vehicles or construction equipment can optimize their fleet management [11] the significance of our project is underscored by a transformative approach to data collection through the seamless integration of GPS, but with an ESP32 and MPU6050.

Our innovative project addresses a critical gap by introducing a novel methodology to collect real-time, precise traffic data. The combination of GPS technology ensures accurate geospatial information, while the ESP32 microcontroller and MPU6050, contribute to the dynamic analysis of vehicle movements.

Not to mention that it is lightweight, affordable, and can be attached to any vehicle or means of transportation, boosting its versatility and usability.

In conclusion, the proposed IoT tracking device, designed as an alternative to GPS for vehicle services within a smart city framework, presents a compelling solution. Targeting applications such as taxis, Uber drivers, deliveries, and car rental businesses, the system offers a cost-effective and technologically innovative approach to real-time tracking. Its adaptability to smart city infrastructure aligns with the vision of optimizing urban mobility and transportation systems.

The device's capacity for accurate tracking in both indoor and outdoor environments, coupled with lower power consumption, enhances its suitability for integration into a smart city's ecosystem. The emphasis on ease of installation and reduced privacy concerns aligns with the principles of user-friendly and ethically conscious technology deployment in urban spaces.

As a key component in a smart city project, this alternative tracking solution contributes to the efficiency of fleet management and supports data-driven decision-making. Its flexibility, enhanced security features, and emphasis on localized tracking underscore its potential as a valuable tool in the evolution of intelligent and sustainable urban transportation systems. In the context of a smart city, the proposed tracking device emerges as an innovative and practical solution for optimizing vehicular services and contributing to the overarching goals of urban intelligence and efficiency.

## III. COMPONENTS USED

The proposed system is built using the following components.

### A. ESP32

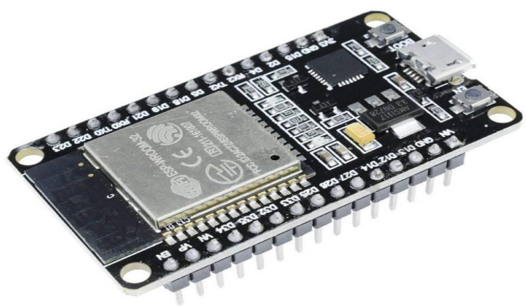

Figure 1: ESP32

ESP32 is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC low-power 40 nm technology. It is designed to achieve the best power and RF performance, showing robustness, versatility and reliability in a wide variety of applications and power scenarios.[8]

### B. MPU6050

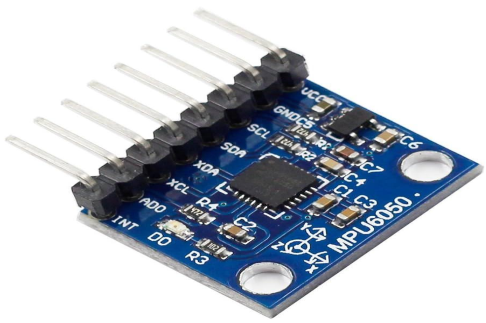

Figure 2: MPU6050

The MPU6050 is a comprehensive 6-axis Motion Tracking Device sensor module, seamlessly integrating a 3-axis gyroscope, 3-axis accelerometer, and a digital motion processor within a compact design. This module is equipped with a built-in temperature sensor on the chip. Utilizing an I2C bus interface, it establishes connections with microcontrollers. Additionally, it incorporates an auxiliary I2C bus for interfacing with other sensor devices such as a 3-axis magnetometer or pressure sensor. For enhanced capabilities, the MPU6050 can provide a complete 9-axis Motion Fusion output when a 3-axis Magnetometer is connected to the auxiliary I2C bus.[9]

## IV. METHODOLOGY

This study aims to develop a cost-effective IoT device designed to function as a sensor integrated into various types of vehicles, facilitating immediate vehicle tracking within our smart city infrastructure. We have designed a new system with changes in the hardware. A system which is easy to install and shift anywhere as and when required. The proposed device leverages two key components: an MPU6050, and an ESP32 microcontroller. The user accesses the tracking system through a web browser, interacting with the web interface provided by the server. The server hosts the web interface accessible to the user. It communicates with the ESP32 to retrieve instantaneous vehicle tracking data.

### *A. Hardware:*

ESP32 and MPU6050 Integration:
For the integration of the ESP32 and MPU6050, we establish a connection utilizing the I2C protocol. Specifically, the MPU6050 is connected to the ESP32 as follows: the SDA pin of the MPU6050 is linked to GPIO21 on the ESP32, and the SCL pin is connected to GPIO22. Additionally, the VCC pin of the MPU6050 is connected to the 3.3V output on the ESP32, ensuring proper power supply. To complete the integration, the GND (ground) pin of the MPU6050 is connected to the GND pin on the ESP32. This physical configuration enables the communication and data exchange between the ESP32 and the MPU6050, facilitating the collection of motion-related data for further processing in the IoT device.
Power supply:
To ensure proper functionality and data accuracy, a dedicated 3.3V battery is employed as the primary power source. The choice of a 3.3V battery aligns with the operational voltage requirements of both the ESP32 and MPU6050 components. This power supply configuration aims to provide a consistent voltage level, critical for the optimal performance of electronic components in the system. The 3.3V battery serves as a reliable source, and its connection to the ESP32 and MPU6050 involves linking the positive terminal (VCC) of the battery to the respective VCC pins on both components. Simultaneously, the negative terminal (GND) of the battery is connected to the ground (GND) pins of both the ESP32 and MPU6050, establishing a common ground reference. This carefully chosen power supply strategy ensures a stable and regulated voltage, promoting the accuracy and efficiency of the IoT device throughout the course of the study.
The ESP32 serves as the central processing unit, connecting to both the gyroscope and the accelerometer in the MPU6050. It communicates with the server to send concurrent tracking data. It is also responsible for collecting, processing, and transmitting data from the MPU6050.
The MPU6050 is a six-axis motion tracking device that combines data from a three-axis accelerometer and a three-axis gyroscope to calculate vehicle movement.

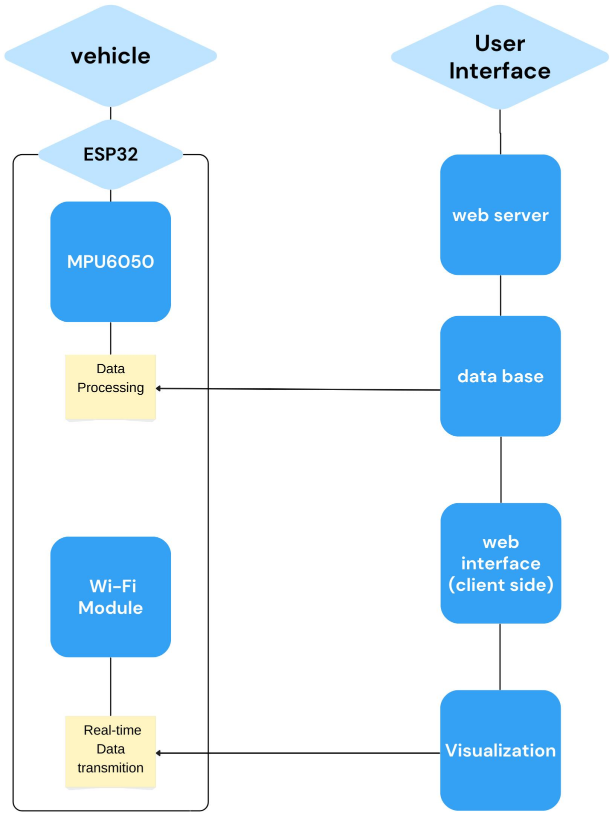


Figure3. Block Diagram of Proposed System.

This block diagram provides a high-level overview of the connections and communication flow within our vehicle tracking system.

### *B. Software:*

ESP32 is chosen as a microcontroller unit to process the signal from MPU-6050 due to it is already equipped with an I2C communication protocol and Wi-Fi module to communicate wirelessly. Another main component in this proposed system is a computer that is dedicated to a server. The user can access the data using a web browser from Personal Computer (PC) or smartphone.

Data Processing:

The MPU6050 provides motion-related data to the ESP32. The data is then processed and sent with the server, which updates the tracking information. The server then refreshes the online interface, displaying the tracked vehicle's current location and status.

The ESP32 is programmed to regularly retrieve information from the MPU6050 using the I2C protocol, encompassing accelerometer and gyroscope data. To compensate for the lack of GPS, a Wi-Fi-based location estimation method is incorporated, leveraging the ESP32's ability to scan nearby Wi-Fi access points. This method involves collecting signal strength data (RSSI) and transmitting it to an external service, such as the Google Geolocation API, for estimating the device's location. The collected motion and location data are seamlessly integrated in the ESP32 firmware, offering a comprehensive dataset. Real-time communication between the ESP32 and a server facilitates continuous data transmission, enabling a dynamic web interface hosted on the server. This interface visually presents real-time information, including the vehicle's current location, orientation, and other relevant metrics. The choice of a dedicated 3.3V battery for power supply ensures stability in data collection, fostering accuracy and efficiency throughout the study. Security measures are implemented to protect the transmitted data, and continuous monitoring allows for adjustments and improvements in the system's performance. This hardware methodology establishes a robust foundation for the development of a cost-effective IoT device tailored for smart city vehicle tracking.

User-interface:

In the software methodology of this study, the focus shifts to the development of a sophisticated web interface that seamlessly integrates with the IoT device for real-time vehicle tracking. The user interface is designed with user authentication to ensure secure access, granting authorized users the ability to interact with the tracking system. A visually appealing and intuitive dashboard is crafted to present critical information at a glance, incorporating a dynamic map that displays the vehicle's current location, speed, and direction. The interface is engineered to provide real-time updates using technologies, ensuring users receive the most recent vehicle tracking information without the need for manual refresh. Integration with mapping APIs, such as Google Maps, enhances the visual representation of the vehicle's location. Graphs and charts illustrate historical data trends, allowing users to analyze the vehicle's movement history, speed variations, and other relevant metrics. Interactive user controls enable customization of the displayed information and exploration of different map views. The interface also includes features for alerts and notifications, providing timely information about critical events. Responsive design principles are applied to ensure the interface adapts seamlessly to various devices and screen sizes. A robust security framework is implemented, incorporating HTTPS for encrypted data transmission and user access controls to safeguard sensitive information. Additionally, the software undergoes comprehensive testing to validate its functionality, responsiveness, and security under diverse scenarios. The development process culminates with the creation of an impactful and user-centric web interface, positioned as a pivotal component in the overall smart city vehicle tracking system.

## VI. Conclusion

In the pursuit of safe, secure, and well-managed travel, our project stands as a transformative force in revolutionizing traffic management. The device, powered by ESP32 and MPU6050 technologies, plays a pivotal role in achieving this vision. Its primary mission is to seamlessly transform and transmit data, ushering in a new era of congestion-free roads and accident prevention, all while optimizing fuel consumption and travel time. By relaying real-time information, the device facilitates the implementation of intelligent traffic management systems, ensuring rapid accident detection and efficient time-saving measures. This transformative approach holds the key to fostering a safer, more streamlined, and responsive urban transportation environment.

Further development will be centered on enhancing the business process, refining the graphical user interface, and optimizing the user experience in the web browser. This current phase focuses on addressing multiple wireless connections, ensuring seamless integration with various vehicles and transport systems. Subsequent developments aim to elevate the web-based system, making it even more accessible and user-friendly, particularly through smartphone access. This commitment to continuous improvement underscores our dedication to providing an innovative solution that not only meets the current demands of traffic management but also evolves to cater to the dynamic needs of urban transportation in the future.

## VII. REFERENCE


[1] United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision, custom data acquired via website.

[2] Condon, R. (2023, August 17). Why GPS trackers are the key to efficient fleet management. Comparesoft. https://comparesoft.com/fleet-management-software/gps-fleet-tracking/

[3] Sauvage, M. (2023, July 17). How do GPS fleet management systems work? Synox. https://www.synox.io/en/smart-transport/gps-fleet-management-systems/

[4] Admin, A. (2022, December 29). How IoT plays a part in shaping smart cities: Real-Time Tracking Solutions. Overdrive. https://overdriveiot.com/shaping-smart-cities-with-real-time-location-tracking-system/

[5] M.Khan, S., Nazir, S., García-Magariño, I., & Hussain, A. (2021). Deep learning-based urban big data fusion in smart cities: Towards traffic monitoring and flow-preserving fusion. Computers & Electrical Engineering, 89, 106906. https://doi.org/10.1016/j.compeleceng.2020.106906

[6] Annual A Vision Transformer approach for traffic congestion prediction in urban areas. (2023, April 1). IEEE Journals & Magazine|IEEEXplore. https://ieeexplore.ieee.org/document/10012036

[7] Strategies to handle big data for traffic management in smart cities. (2016, September 1). IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/abstract/document/7732072

[8] ESP32 Series DatasheetVersion 4.4 Espressif Systems Copyright © 2023

[9] Ishan Kharat, Atharva Kulkarni, Dhaval Mahajan, Kartik Avhad, Sumit Jadhav, "Active Safety System in Vehicles using Sensor Network Model", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 9 Issue 6, pp. 676-684, November-December 2022. Available at doi : https://doi.org/10.32628/IJSRST229689

[10] madebycat.com. (n.d.). What is Vehicle Tracking System? https://www.arvento.com/en/what-is-a-vehicle-tracking-system

[11] Sauvage, M. (2023b, July 17). How do GPS fleet management systems work?https://www.synox.io/en/smart-transport/GPS-fleet-managementsystems/#:~:text=Beyond%20vehicle%20geolocation%2C%20fleet%20management,to%20improve%20their%20travel%20efficiency