



Design and Implementation of an IoT-Based Luggage Tracking Device for Airport Baggage Monitoring: A Case Study of Sir Abubakar Tafawa Balewa International Airport, Bauchi, Nigeria

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ABSTRACT

Baggage mishandling, misplacement, delay and theft remain important challenges in air transportation, particularly where baggage visibility across different stages of airport operations is limited. This study presents the design and implementation of an Internet of Things (IoT)-based luggage tracking device intended to provide location visibility for passenger luggage. The prototype was developed using a NodeMCU microcontroller, GPS module, regulated power supply, wireless connectivity, an IoT cloud platform and an Android mobile application integrated with Google Maps. The system acquires geographical coordinates from the GPS module, processes the location information through the NodeMCU, transmits the data through its Wi-Fi capability to the IoT cloud platform, and makes the location information available to the mobile application for visualization. Experimental testing covered the power supply, GPS acquisition, cloud transmission, mobile application retrieval and map visualization. Recorded power measurements were 10.90 V from an 11.10 V battery source, 4.82 V from the 5 V regulator and 8.71 V from the 9 V regulator, corresponding to percentage differences of 1.8%, 3.4% and 3.2%, respectively. GPS acquisition and end-to-end communication were successfully demonstrated, and the Android application displayed the tracked location through Google Maps. The results establish the technical feasibility of a low-cost IoT luggage-monitoring prototype for airport environments. However, the prototype depends on Internet connectivity and battery power and was not evaluated for airport-wide deployment, quantified GPS accuracy, latency, packet loss or long-term battery endurance. Future work should investigate cellular/LPWAN communication, baggage identification, geofencing, location-history logging, energy optimization and integration with airport baggage-management infrastructure.

Keywords: Internet of Things; luggage tracking; baggage monitoring; GPS; NodeMCU; Wi-Fi; IoT cloud; Android application; Google Maps; airport security.

1. Introduction

Air transportation involves the movement of large numbers of passengers and their associated baggage. Baggage passes through several operational stages, including acceptance, loading, transfer and delivery, creating opportunities for delay, misrouting, loss and unauthorized removal. Consequently, baggage visibility has become an important component of modern airport operations.

The International Air Transport Association (IATA) has established baggage-tracking requirements through Resolution 753, which requires baggage to be tracked at key points including acceptance, loading, transfer and delivery. IATA reported in 2024 that 44% of surveyed airlines had fully implemented the resolution and a further 41% were in progress. The report also indicated that 75% of surveyed airports had the capability to support the required tracking processes. These developments indicate that baggage traceability is increasingly treated as an operational requirement rather than an optional passenger service.

IoT technologies provide a means of linking physical baggage to sensing, processing, communication, cloud and mobile services. GPS can supply geographical coordinates; an embedded controller can process the coordinates; wireless communication can transfer the data; and a cloud service can make the information remotely accessible.

Recent studies demonstrate different implementations. Abdulham and Mohamed Noor (2023) developed a luggage tracking prototype based on GPS and NodeMCU, using Wi-Fi for wireless communication and Google Maps for mobile visualization. Jain et al. (2023) investigated an IoT luggage-tracking configuration involving GPS, GSM, a microcontroller and an IoT platform. Rathinam and Chelliah (2023) investigated Bluetooth-based tracking supported by a mobile application and cloud backend. Lima de Paula et al. (2022) explored smart-suitcase communication using Wi-Fi and LPWAN technologies.

The project on which this article is based was developed for the Bauchi airport context and sought to provide luggage location information that could be accessed through an IoT platform and mobile application. The original project identifies Internet availability and battery depletion as important limitations. The present article therefore positions the prototype as a functional proof of concept rather than a fully deployed airport baggage-management system.

1.1 Problem Statement

Conventional baggage-handling processes can provide limited direct visibility to passengers and airport personnel after luggage enters the handling chain. The original study identified the need to improve information about the location of passenger luggage and proposed an IoT-based device capable of transmitting location information to an IoT platform and making it accessible through a mobile application.

1.2 Aim and Objectives

The aim of the study is to design and implement an IoT-based luggage tracking device using GPS, NodeMCU, wireless communication, an IoT cloud platform and an Android application.

- investigate the feasibility of IoT technologies for luggage tracking;
- design a system capable of acquiring luggage location information;
- integrate a GPS module with a microcontroller for coordinate acquisition;
- transmit location information through wireless communication to an IoT platform;
- develop an Android application for retrieving tracking information;
- integrate Google Maps for map-based visualization; and
- test the prototype for power, GPS, communication and application functionality.

2. Related Work

Recent luggage-tracking research shows a progression from basic location acquisition toward connected smart-baggage ecosystems. GPS remains a common location technology, while Wi-Fi, GSM, Bluetooth and LPWAN have been used as alternative communication mechanisms.

Lima de Paula et al. (2022) demonstrated a smart-suitcase communication architecture using conformally integrated antennas supporting LoRa/Sigfox and Wi-Fi/Bluetooth bands. Their work highlights the potential of LPWAN for low-power, long-range smart-luggage communication.

Abdulham and Mohamed Noor (2023) reported a particularly relevant architecture using GPS, NodeMCU, Wi-Fi, a mobile application and Google Maps. Their configuration closely resembles the communication pathway implemented in the present prototype, although the present study is framed around the Bauchi airport case-study context.

Jain et al. (2023) used GPS and GSM with an IoT platform, illustrating an alternative architecture in which cellular communication reduces dependence on local Wi-Fi infrastructure. Rathinam and Chelliah (2023) investigated Bluetooth-based real-time luggage tracking with GPS, mobile and cloud components. Sreenivasulu et al. (2024) developed an Arduino-based baggage tracking system using GSM/GPS and SMS. More recently, Gehlot et al. (2025) described an IoT-enabled baggage monitoring system incorporating GPS, smart locking, geofencing, RFID/barcode identification and cloud services.

The literature indicates that the basic tracking function is technically established, but there is still a practical need for low-cost, locally adaptable prototypes that can be evaluated in developing-country airport contexts. The present study contributes an experimentally tested GPS-NodeMCU-Wi-Fi-cloud-mobile architecture while explicitly documenting its limitations and distinguishing demonstrated features from proposed future enhancements.

2.1 Related-Work Comparison

Study	Core technology	Communication	Main capability	Key limitation/gap
Lima de Paula et al. (2022)	Smart suitcase antennas	LPWAN + Wi-Fi	Long-range/low-power smart suitcase communication	Communication/antenna focus rather than airport prototype deployment
Abdulham & Mohamed Noor (2023)	GPS + NodeMCU	Wi-Fi	Mobile tracking + Google Maps	Prototype; limited airport-management integration
Jain et al. (2023)	GPS + microcontroller	GSM + IoT	Remote luggage tracking	Cellular dependence; prototype focus

Study	Core technology	Communication	Main capability	Key limitation/gap
Rathinam & Chelliah (2023)	GPS + mobile/cloud	Bluetooth	Real-time location/status updates	Short-range communication constraints
Sreenivasulu et al. (2024)	Arduino + GPS	GSM/SMS	Baggage location reporting	Limited cloud/mobile ecosystem
Gehlot et al. (2025)	IoT smart baggage	IoT/cloud	Tracking, security, geofencing, smart features	Greater system complexity
Present study	GPS + NodeMCU	Wi-Fi + IoT cloud	Prototype tracking + Android/Google Maps	Internet and battery dependence; no airport-wide validation

2.2 Research Gap

The reviewed literature demonstrates that GPS-based baggage tracking is feasible, but existing systems differ substantially in communication technology, complexity and deployment assumptions. Advanced systems increasingly incorporate geofencing, RFID/barcodes, smart locks and cloud intelligence, while simpler prototypes focus on location acquisition. A practical gap therefore remains between sophisticated smart-baggage concepts and low-cost implementations that can be demonstrated in specific developing-country airport contexts. This study addresses that gap through an experimentally tested architecture combining GPS, NodeMCU, Wi-Fi, IoT cloud services and an Android/Google Maps interface.

3. Materials and Methods

3.1 Research Design

The study adopted a system-development and experimental-prototyping design. The development process involved problem identification, requirements specification, component selection, architecture design, hardware assembly, programming, cloud/mobile integration and functional testing.

3.2 System Architecture

The implemented system can be represented as: Power Supply → GPS Module → NodeMCU → Wi-Fi → IoT Cloud → Android Application → Google Maps. The GPS module acquires location coordinates; the NodeMCU processes the coordinates and provides wireless transmission; the cloud platform provides remote data access; and the Android application visualizes the location on a map.

[Figure 1. System architecture: Power Supply → GPS Module → NodeMCU → Wi-Fi/Internet → IoT Cloud → Android Application → Google Maps]

3.3 Hardware and Software

Component	Role in the prototype
GPS module	Acquires geographical coordinates
NodeMCU	Processes GPS data and provides Wi-Fi communication
Battery/power supply	Provides electrical power to the tracking circuit
Voltage regulators	Provide regulated DC outputs
IoT cloud platform	Receives/stores tracking information for remote access
Android application	Retrieves and presents location information
Google Maps	Provides map-based visualization
Arduino IDE/C++	Development environment and embedded programming

3.4 Operating Procedure

- Power the tracking device.

- Initialize the NodeMCU and wireless network connection.
- Acquire GPS coordinates from the GPS module.
- Pass the coordinates to the NodeMCU.
- Transmit the location information through Wi-Fi.
- Upload the information to the IoT cloud platform.
- Retrieve the information through the Android application.
- Display the luggage position through Google Maps.

The original project specifies a transmission interval of approximately 15 seconds. The prototype was therefore designed for periodic rather than continuous coordinate transmission.

4. Implementation and Experimental Testing

4.1 Prototype Implementation

The hardware components were integrated into a prototype and subsequently enclosed in a casing. The project documentation identifies the GPS module, NodeMCU, power subsystem and cloud/mobile components as the principal functional blocks. The implemented system was evaluated as an integrated prototype rather than as a full airport installation.

4.2 Power Supply Test

Power measurements were obtained using a multimeter. The recorded values from the original project are reproduced below without modification.

Source	Theoretical (V)	Measured (V)	Difference (V)	Percentage difference
Battery	11.10	10.90	0.20	1.8%
LM7805	5.00	4.82	0.18	3.4%
LM7809	9.00	8.71	0.29	3.2%

The measured values were close to the theoretical values. The project attributed the small differences to circuit loading and measurement-related effects. These results demonstrate the operation of the power subsystem but do not constitute a full energy-efficiency or battery-endurance analysis.

4.3 Functional Testing

Test item	Expected outcome	Observed outcome	Status
Power supply	Regulated DC outputs	Outputs obtained close to nominal values	Successful
GPS acquisition	Latitude/longitude obtained	GPS data acquired	Successful
NodeMCU processing	Receive/process GPS data	Location data processed	Successful
Wireless transmission	Transmit location information	Data transmitted	Successful
IoT cloud	Receive tracking data	GPS information received	Successful
Android application	Retrieve tracking data	Location retrieved	Successful
Google Maps	Display location	Location displayed	Successful
Integrated prototype	Operate end-to-end	Tracking workflow demonstrated	Successful

4.4 Results

The functional tests demonstrate an end-to-end tracking workflow from GPS acquisition to map visualization. The project reported successful GPS data observation through the Arduino IDE serial monitor, the IoT platform and the Android application. The Android application retrieved the transmitted information and Google Maps displayed the corresponding location.

5. Discussion

The principal outcome of the study is the successful integration of sensing, embedded processing, wireless communication, cloud access and mobile visualization. The result confirms that a relatively simple embedded architecture can provide remote visibility of a tracked luggage item.

The architecture is closely related to the GPS-NodeMCU-Wi-Fi-Google Maps configuration reported by Abdulham and Mohamed Noor (2023). The present study extends the relevance of that architecture to a Nigerian airport case-study context and documents the actual prototype tests performed. The Wi-Fi approach also differs from GSM-based implementations such as Jain et al. (2023) and Sreenivasulu et al. (2024), which offer wider-area cellular communication but require cellular connectivity and associated modules.

The main operational limitation is network dependence. Because the implemented prototype transmits through Wi-Fi to an IoT platform, loss of Internet connectivity interrupts remote access. Battery depletion similarly terminates tracking. These limitations are consistent with the original project and are important when considering airport deployment.

The literature also suggests a clear pathway for future improvement. LPWAN can provide lower-power, longer-range communication; RFID/barcodes can provide unique baggage identification; geofencing can detect unauthorized movement; and cloud databases can maintain location history. More advanced systems can additionally incorporate smart locks and AI-assisted analytics.

5.1 Demonstrated Versus Proposed Functionality

Function	Evidence/status
GPS location acquisition	Experimentally demonstrated
NodeMCU processing	Experimentally demonstrated
Wi-Fi transmission	Experimentally demonstrated
IoT cloud transmission	Experimentally demonstrated
Android retrieval	Experimentally demonstrated
Google Maps visualization	Experimentally demonstrated
Regulated power supply	Experimentally measured
Airport-wide deployment	Not experimentally demonstrated
GSM communication	Not treated as validated in this study
RFID/unique baggage identification	Future enhancement
Geofencing	Future enhancement
LPWAN	Future enhancement
AI-based prediction	Future enhancement

6. Limitations

- Dependence on Internet/network availability for cloud transmission.
- Dependence on battery power; tracking stops when the power source is exhausted.
- Prototype-level evaluation rather than airport-wide operational deployment.
- No quantified GPS positioning-error analysis was reported.
- No systematic latency, packet-loss, scalability or long-duration battery tests were reported.

- The prototype does not replace formal airline baggage-management standards; it should be considered a potential complementary tracking layer.

7. Recommendations and Future Work

7.1 Communication resilience

Investigate GSM/LTE, NB-IoT, LoRaWAN or other LPWAN technologies to reduce dependence on local Wi-Fi.

7.2 Battery optimization

Measure current consumption, transmission energy, battery capacity and operating duration to establish a quantitative battery-life model.

7.3 Baggage identification

Integrate RFID, barcode or QR-based identification so that each location record can be associated with a unique baggage identifier.

7.4 Geofencing and alerts

Implement virtual airport zones and automated alerts when luggage leaves an authorized area.

7.5 Location history

Store timestamped coordinates in a database so that authorized users can reconstruct baggage movement.

7.6 Airport dashboard

Develop an authorized dashboard for airport personnel showing baggage identity, current location, last communication time and battery state.

7.7 Quantitative evaluation

Evaluate GPS error, communication latency, packet loss, network coverage, battery endurance and multi-device scalability.

8. Conclusion

This study presented the design and implementation of an IoT-based luggage tracking prototype for airport baggage monitoring using the Bauchi airport context. The prototype integrates GPS, NodeMCU, Wi-Fi, an IoT cloud platform, an Android application and Google Maps. Testing demonstrated successful acquisition and transmission of GPS information, retrieval through the mobile application and map-based visualization. Power measurements also showed relatively small differences between theoretical and measured outputs.

The study establishes the technical feasibility of a low-cost IoT architecture for luggage-location monitoring but does not claim airport-wide operational readiness. Its dependence on Internet connectivity and battery power, together with the absence of quantified GPS accuracy, latency, packet-loss and long-duration battery measurements, limits the strength of deployment conclusions. Future work should therefore focus on communication resilience, energy optimization, baggage identification, geofencing, location history and integration with airport baggage-management systems.

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