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DESIGN AND IMPLEMENTATION OF INTERNET OF THINGS FOR LAND INFORMATION SYSTEM

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Abstract

Technological advancement has spread across all sectors, including the built environment, and has gradually been embraced in the real estate sector. The Internet of Things (IoT) is considered one of the most important emerging technologies for real estate professionals. However, the potential of IoT applications in real estate practice has yet to be fully explored, particularly in land administration. Although the Land Information System (LIS) has gained serious attention, one of the major challenges it has not fully addressed is the alteration of cadastral layouts and the protection of boundary beacons. It became imperative to deploy IoT technology to strengthen the LIS and safeguard land property rights. This study designed and implemented an IoT-based system for the Land Information System in Bida, Niger State, Nigeria. Information was gathered through a reconnaissance survey of the Federal Polytechnic Bida campus, review of existing cadastral plans, and assessment of current LIS applications. A physical prototype was developed using an ESP32 microcontroller, NEO-6M GPS module, and 0.96-inch OLED display. The smart beacon continuously monitors its GPS coordinates. Once a reference location is stored, any movement triggers an immediate "Damage Detected!!!" or "ALERT! Location Changed!!!" notification. The system sends the alert via a WhatsApp bot using the CallMeBot API with a direct Google Maps link containing the new latitude and longitude. Field testing on the polytechnic campus confirmed that the system delivered accurate real-time location tracking, reliable tamper detection, and instant notifications compared with traditional manual beacon inspection, the IoT solution eliminated the need for frequent physical visits, reduced response time to alterations, and provided verifiable evidence through live map links. The study therefore provided a practical, low-cost IoT-based LIS that adds value to existing land information systems and contributes to the literature by demonstrating how IoT can be implemented for beacon management in cadastral layouts to achieve sustainable land administration in Nigeria.

Keywords: Design, Implementation, Internet of Things, Land Information System and Smart beacon

1. Introduction

The technological advancement that is spreading across all sectors including the built environment has gradually been embraced in the real estate sector (Akindele et al., 2021). This is as a result of the fourth industrial revolution – Industry 4.0 (Bolshakov et al., 2021). This led to the emergence of smart cities (Ullah & Al-Turjman, 2021), smart homes (Demir & Ventura, 2021), smart buildings (Obuchi et al., 2018), smart construction (Sairanen et al., 2017) and smart real estate management (Mohammed et al., 2019). Technological advancement has remodelled the activities of the existing stakeholders of the real estate sector and also bringing in new ones who are technologically inclined to meet up with challenges of the complex and fast growing real estate activities in the 21st century (Akindele et al., 2021). Consequently, the deployment of Geographic Information System (GIS), cloud computing, wireless sensor networks, drone technology, artificial intelligence and the Internet of Things (IoT) were the common and emerging information and communication technology (ICT) tools by estate surveyors and valuers in achieving their respective targets and adding value to the real estate practice (Mohammed & Bello, 2021).

The IoT being an important element of industry 4.0 is a platform that brought everything to the internet, where objects can communicate with or without human interference (Manavalan & Jayakrishna, 2019; Okano, 2017; Zhang & Chen, 2020). The concept is as a result of growing number and variety of objects or things around us – such as sensors, actuators, radio frequency identification (RFID) tags and cell phones among others, which interact with each other through a unique addressing schemes and achieved common goals with their neighbours. The IoT idea main strength is its high impact on various aspects human daily life and the potential user's behaviour (Atzori et al., 2018). However, the recurrent concern is data security and privacy (Mohanta et al., 2020). The IoT has been applied widely in agriculture, mining, manufacturing, education, financial and business sector, urban management, governance and real estate (Kotha & Gupta, 2018).

IoT has been applied to several aspects of real estate such as facilities management, property management, construction management, urban infrastructure management, cadastral management, land administration and management, and smart home (Mohammed et al., 2019). Its application to land administration and cadastral management is referred to as smart land information system. The smart land information system is an important trend in the real estate industry. As the estate surveyors are saddled with the responsibility of managing cadastral and land use planning, the advancement in smart tecnology has transformed the activities since the last decade, particularly, the wide application of IoT technology.

The smart land information system is considered to be the application of IoT to beacon control points in cadastral surveying (Lee, 2017). According to Gowtham et al. (2018), a smart land information system is based on the IoT, coupled with security measures, mapping, and management. Beyond cadastral management, a smart land information system is also considered to be the use of IoT for managing and monitoring the environment in a distributed and self-managing way and integrates heterogeneous data seamlessly, applied in fields such as wetland monitoring systems, groundwater resources management among others (Fang et al., 2017). Therefore, a smart land information system is the application of IoT to cadastral and land resource management. However, much work has not been done in this area (Mohammed & Bello, 2021).

2. Methodology

The research focused on the design and implementation of an IoT-based Land Information System for beacon management. It was conducted in three main stages through reconnaissance and data collection, system development, and testing.

The Study Area

The study was carried out at the Federal Polytechnic Bida, Niger State, Nigeria. The polytechnic is located on latitude 9.0391° N and longitude 6.0079° E in the north-central region of Nigeria. The campus was chosen because it offered adequate security and reliable power supply during the development and testing phases.

IoT System Design and Simulation

A physical prototype smart beacon was designed and built using an ESP32 microcontroller, NEO-6M GPS module, and 0.96-inch SSD1306 OLED display mounted on a breadboard. The beacon was programmed to read real-time GPS coordinates, store a reference location, and continuously monitor for movement. When displacement was detected, the system triggered an alert through a WhatsApp bot using the CallMeBot API. The alert contained a direct Google Maps link with the new coordinates.

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Cadastral Beacon Design

Compact beacon housing was fabricated to fit standard cadastral control points. It consisted of reinforced concrete with an embedded metal plate for durability and protection when buried. The ESP32-based IoT module was integrated into the beacon so that only the flat top remained visible above the soil surface.

Development of application

The mobile application software displayed the real time location of the cadastre beacon for easy tracking. The ESP32 communicated directly with the WhatsApp bot. Once an alert was received on a smartphone, the embedded Google Maps link allowed instant viewing of the beacon's new position.

Testing

Selected test points on the polytechnic campus were used. The beacons were buried with the top surface visible. The system was activated and the beacons were deliberately moved at intervals to simulate tampering or alteration. Performance was monitored through the OLED display readings, WhatsApp notifications, and Google Maps verification

Results

The completed system provided:

i. A functional IoT-based LIS prototype using ESP32 and NEO-6M GPS technology.
ii. Accurate real-time location tracking and tamper detection on cadastral beacons.
iii. Instant WhatsApp alerts with live Google Maps links whenever movement was detected.
iv. Physical implementation and successful field testing on the Federal Polytechnic Bida campus.

3. Data Representation And Analysis

Demonstration of the Usage of the IoT-Based LIS with different interface

The IoT smart beacon was designed to support continuous monitoring, location storage, tamper detection, and instant alerting. Its operation was illustrated through the actual device screens and notification outputs captured during testing on the Federal Polytechnic Bida campus.

Figure 1: OLED display showing current GPS location showing "Current Location" with clear Lat: 6.769645 Lng: 6.347766

Figure 2: OLED confirming stored reference location showing "Location Successfully Stored" with exact coordinates

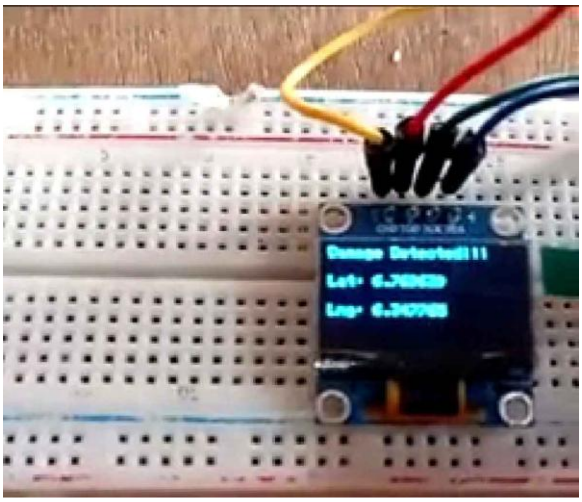

Figure 3: OLED showing "Damage Detected!!!" during movement test showing real-time tamper alert displayed on the device screen

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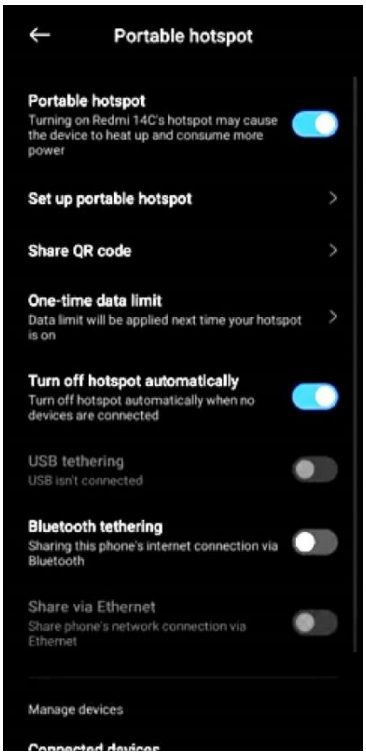

Figure 4: Portable hotspot configuration showing phone settings used to give the ESP32 internet access

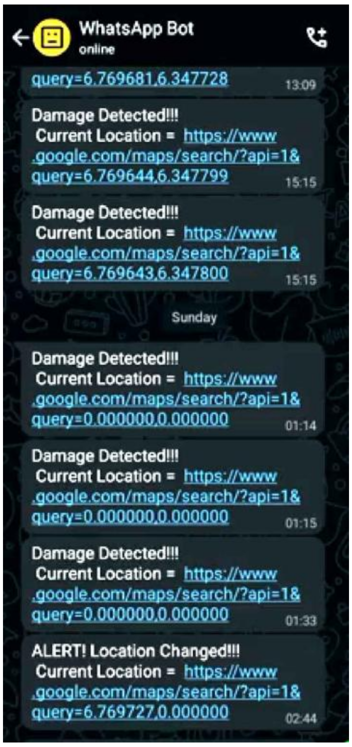

Figure 5: WhatsApp Bot alert – "Damage Detected!!!" with full alert message and live Google Maps link

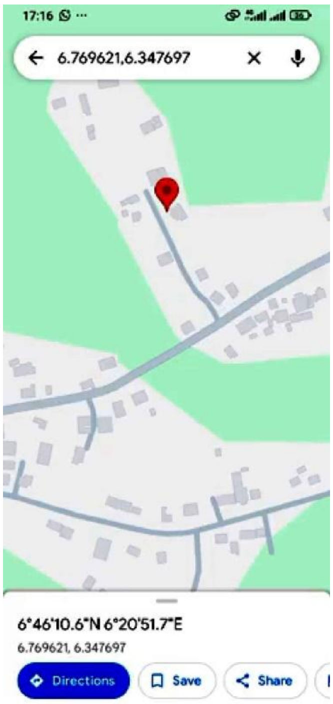

Figure 6: Google Maps showing the beacon's new position with the Red pin dropped on the map with coordinates and landmarks.

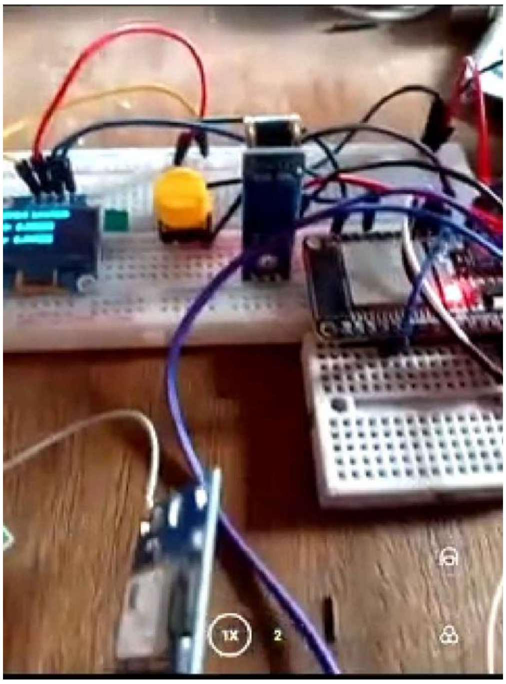

Figure 7: Complete IoT hardware setup on breadboard with clear view of ESP32, NEO-6M GPS module, OLED, wiring and yellow button

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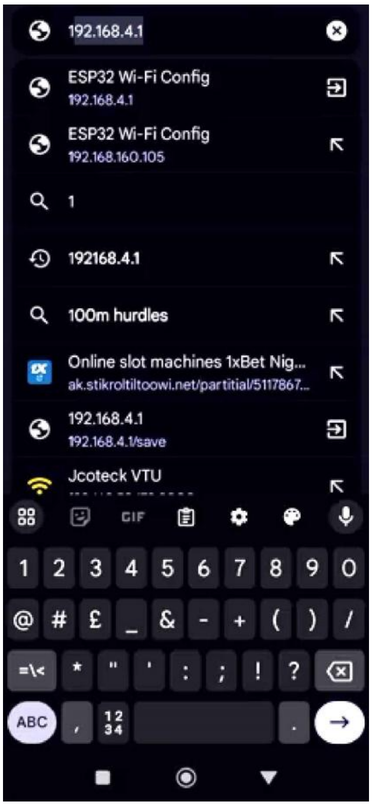

Figure 8: ESP32 IP address configuration in browser showing 192.168.160.105 (the configuration screen used in testing)

Discussion

The IoT smart beacon was designed to support continuous monitoring, location storage, tamper detection, and instant alerting. Its operation is illustrated through the actual device screens and notification outputs captured during testing.

OLED Display Interfaces

The screen first shows the current GPS coordinates for example, Lat: 6.769645, Lng: 6.347765 and when the reference location is stored, the display confirms "Location Successfully Stored" with the exact coordinates. During normal operation it continuously updates the current location and when movement is detected, the screen refreshes to show the new position.

WhatsApp Bot Alert System

The bot, named "WhatsApp Bot", sends immediate notifications, such as a typical alert messages reading "Damage Detected!!!" followed by "Current Location as in the current test, https://www.google.com/maps/search/?api=1&query=6.769621,6.347697". The clicking of the link opens Google Maps with a red pin marking the exact new position of the beacon and visible landmarks would display and nearby roads confirm the location.

Google Maps Integration

The map interface displays the precise coordinates for example, 6°46'10.6"N 6°20'51.7"E and users can view directions, save the location, or share it directly from the phone. The entire process from the GPS reading to alert delivery occurs in real time, providing estate surveyors and land administrators with immediate, verifiable evidence of any unauthorised movement of boundary beacons.

4. Conclusion

This study has shown that traditional manual inspection of cadastral beacons is no longer adequate for modern land administration, especially in the face of frequent layout alterations and security threats. The designing and implementing an IoT-based Land Information System using an ESP32 microcontroller, NEO-6M GPS module, and WhatsApp bot integration, through the research has provided a practical, low-cost solution for real-time beacon monitoring. The prototype successfully stores reference coordinates, detects any physical movement, and sends instant alerts with live Google Maps links where field testing on the Federal Polytechnic Bida campus confirmed the system's accuracy, reliability, and ease of use. The IoT solution eliminates the need for constant physical site visits, reduces response time to tampering, and supplies verifiable digital evidence for land administration purposes. The

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developed smart beacon therefore serves as a ready-made template for estate surveyors and land administrators across Nigeria thereby strengthens the existing Land Information System and offers a clear example of how IoT technology can be applied to beacon management in cadastral layouts to achieve more secure, efficient, and sustainable land administration.

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