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Development of IoT Household Appliances Asset Tracking System

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***Abstract*— This research presents an IoT-based asset tracking system for household electronics, addressing the high theft rates and low recovery prospects of valuable appliances by leveraging affordable IoT devices with GPS technology for real-time monitoring, theft detection, and last-known-location reporting. The prototype, built using a Java Spring Boot server, supports multiple GPS protocols (GT06, Teltonika, Astra Telematics) with robust packet parsing and geolocation decoding, validated through mixed-methods qualitative stakeholder analysis and quantitative field testing, which demonstrated high accuracy and reliability despite minor data integrity issues. The study confirms the feasibility and effectiveness of extending IoT tracking to households, proposing a tiered deployment strategy to match tracker capabilities to asset value for cost-efficiency, with future work focusing on energy optimization and smart home integration.**

Keywords— Internet of Things (IoT), Asset Tracking, GPS Protocols, GT06, Teltonika, Astra Telematics.

I. Introduction

Household appliances such as smart TVs, laptops, and refrigerators are designed to improve quality of life; however, their high acquisition cost and portability make them attractive targets for theft. In Zambia, burglary and house break-ins are frequently characterized by the loss of high-value electronics, with limited chances of recovery due to a lack of leads [3]. Existing commercial tracking solutions are predominantly tailored for vehicles [4, 8], leaving a significant gap in affordable and scalable security for household-level assets.

This study proposes and develops an end-to-end IoT-based asset tracking system capable of detecting theft events and reporting the last known location of stolen devices in near real-time. By embedding low-cost IoT trackers in appliances and integrating them with a central server and mobile application, homeowners can continuously monitor assets, receive instant alerts upon unauthorized movement, and provide critical data to aid law enforcement recovery efforts. This research moves beyond theoretical application, presenting a tested prototype that validates the practical viability of multi-protocol IoT tracking in a novel context.

II. Background of Study

Oracle defines IoT as the network of physical objects ("things") embedded with sensors, software, and other technologies that enable data exchange with other systems over the internet [10]. This proliferation has enabled innovative applications across various sectors, including:

- Vehicle Tracking: Well-established systems for fleet management and anti-theft [4, 8].
- Personal Safety: Wearable devices for child and elderly monitoring [5].
- Logistics: Supply chain and inventory management [3]. However, the application of this technology to secure household electronic appliances within a residential setting remains underexplored, particularly in the developing world, representing a critical research and implementation opportunity.

III. Problem Statement

Theft of household electronics is prevalent, and the lack of recovery solutions presents significant financial and security challenges for households. Existing tracking systems are rarely applied to household-level appliances. A dedicated, cost-effective, and scalable IoT tracking solution is therefore required.

IV. Aim and Objectives

Aim:
To develop an IoT-based asset monitoring and tracking system for households that can secure and recover stolen electronic appliances based on last-known location.

Objectives:

- To track live and last-known location of electronic assets.
- To develop a prototype using IoT devices and a tracking platform.
- To evaluate the prototype across multiple GPS tracking protocols (GT06, Teltonika, Astra Telematics).

V. Research Questions

- What are the challenges to recovering stolen household electronic appliances?
- How can IoT technology be effectively leveraged to monitor, track, and aid in the recovery of valuable household appliances?
- To what extent can a multi-protocol IoT prototype be developed for household-level tracking?

VI. Literature Review

Prior research demonstrates the successful application of IoT and GPS technologies in various tracking domains. Vehicle tracking is the most mature application, utilizing GPS and GSM/GPRS technologies for real-time fleet management and anti-theft mechanisms [4, 8].

In personal safety, systems combining GPS with Geo-fencing have been developed for child tracking [5].

Logistics and supply chain management uses RFID and GPS hybrids for asset visibility [3, 6, 7]. However, a critical gap exists in the literature concerning the application of these technologies to household electronic appliances. While RFID offers short-range identification [6, 9], its limited range makes it unsuitable for tracking stolen assets beyond the home.

GPS, while ideal for outdoor tracking, presents challenges in power consumption and indoor location accuracy. This research directly addresses this gap by developing and testing a hybrid system model designed for the specific use case of household appliance security, evaluating the suitability of different GPS protocols for this purpose.

VII. METHODOLOGY

A mixed-methods approach was employed to ensure both technical robustness and practical relevance:

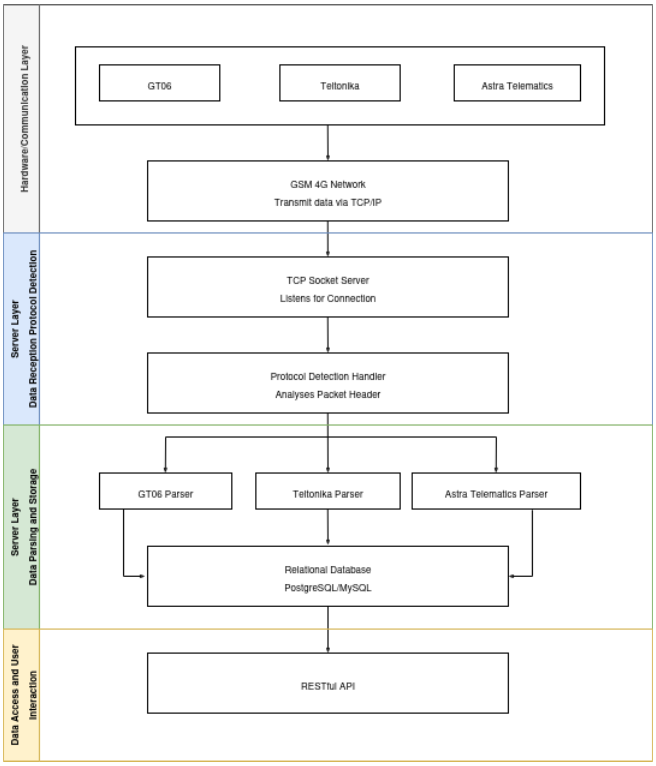
Quantitative Prototype Development: An iterative design and development cycle was used to build the tracking system. The core technical work involved implementing and integrating parsers for the three selected GPS protocols (GT06, Teltonika, Astra Telematics) on a central server.

Testing and Evaluation: The system's performance was rigorously evaluated through controlled theft simulations and field tests. Metrics included time-to-first-fix (TTFF), location accuracy, packet parsing success rate, and battery life consumption across the different protocols.

VIII. SYSTEM DESIGN & ARCHITECTURE

The system architecture is composed of four distinct layers, with the server built using the Java Spring Boot framework for robustness and scalability:

- Hardware Layer: Comprises the IoT tracking devices (GT06, Teltonika, Astra) embedded within or attached to appliances. Each device contains a GPS module, a GSM modem, and a power source.
- Communication Layer: Leverages standard GSM/4G networks to transmit data packets from the hardware trackers to the central server using TCP/IP.
- Software/Server Layer: The core of the system. A Java Spring Boot application hosts dedicated parsers for each GPS protocol. It is responsible for:
    1. Listening for and managing TCP socket connections from devices.
    2. Authenticating devices upon connection using their IMEI.
    3. Detecting the protocol of incoming packets automatically.
    4. Parsing binary packets to extract geolocation (latitude, longitude), speed, time, and status data.
    5. Storing this decoded information in a relational database (PostgreSQL/MySQL).
    6. Providing a RESTful API for all client interactions.
- API Layer: A well-defined REST API interface that allows any client application (e.g., a future web dashboard or mobile app) to access the system's functionality.



I. Architecture Diagram 1: System Design

IX. SYSTEM IMPLEMENTATION

In highlighting common features of the protocols for GPS communication packet we focus on four areas which are; Login Message Packet, GPS Information Package, Location Based Service (LBS) Information Packet, and Status Information.

The prototype was implemented as a Java Spring Boot application with a focus on multi-protocol support. The key implemented protocols were analysed for their strengths and limitations:

- ANALYSIS OF IMPLEMENTED GPS TRACKING PROTOCOLS

Protocol	Strengths	Limitations	Best Use Case
GT06	Widely supported, simple packet structure, low cost.	Limited features, basic data, slower TTFF.	Low-cost, non-powered assets.
Teltonika	Rich data (e.g., ignition, odometer), high accuracy, highly configurable.	Higher power consumption, higher unit cost.	High-value, powered assets (e.g., TVs, computers).

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Astra Telematics	Highly efficient, optimized power management, ideal for long-term tracking.	Requires extensive pre-configuration.	Critical, high-value appliances requiring long-term, low-power tracking.

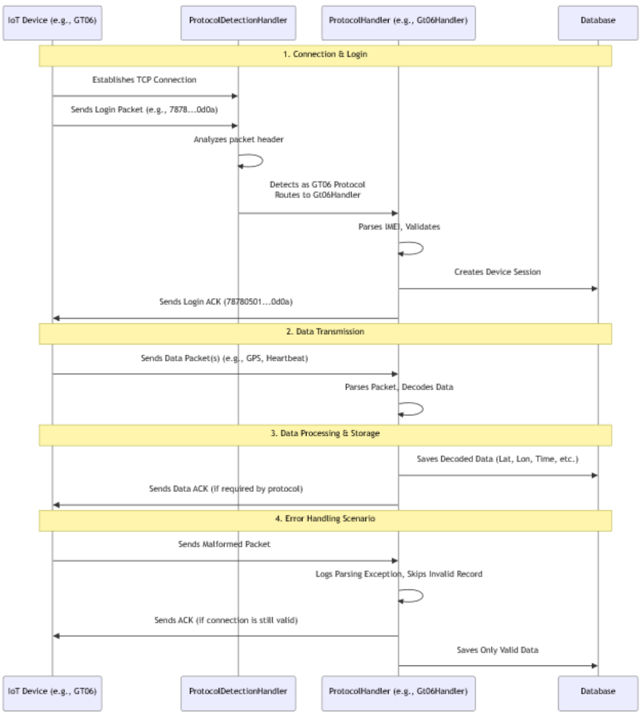
A. Devices Used in test

• DEVICES

	GT06	GT06	Teltonika	Astra Telematics
Device				
Protocol	ZX303 – GT06 Protocol	: Jimi JM-VL03 – GT06 Protocol	FMB920 – Teltonika Protocol	AT240 – Astra Telematics Protocol

B. Implementation Workflow & Log Sequence Mapping

The server follows a strict parsing workflow for each connected device. The following sequence diagram, derived from system logs, maps the end-to-end process for a successful connection and data packet parsing:



Sequence Diagram 1: Parsing Workflow

Workflow Steps:

X. Login & Authentication: The device initiates a TCP connection and sends a login packet. The ProtocolDetectionHandler analyses the packet header to identify the protocol (GT06, Teltonika, or Astra) and routes it to the corresponding protocol-specific handler (e.g., Gt06Handler). The handler parses the IMEI, authenticates the device, creates a session, and sends a login acknowledgment (ACK).

XI. Data Transmission: The device sends data packets (GPS location, status, heartbeats). The protocol handler receives these packets.

XII. Parsing, Decoding, and Storage: The dedicated protocol parser decodes the binary packet into human-readable data (latitude, longitude, timestamp, etc.) and persists this information to the database. An acknowledgment is sent back to the device if the protocol requires it.

XIII. Error Handling (Resilience): If a packet is malformed (as seen in the Teltonika case study), the parser logs the exception, skips the invalid record, but continues processing subsequent data and maintains the connection. This ensures system stability.

XIV. RESULTS AND ANALYSIS

The performance of the multi-protocol server was rigorously evaluated through field testing with actual IoT devices. System logs provide a detailed account of the parsing workflow, protocol detection accuracy, and data handling capabilities for all three protocols.

A. Multi-Protocol Performance Overview

Quantitative analysis of multiple test sessions across all protocols yielded the following key performance indicators:

• AGGREGATE PERFORMANCE ANALYSIS OF GPS PROTOCOLS

Metric	GT06	Teltonika	Astra Telematics	Overall Implication
Protocol Detection Rate	100%	100%	100%	System reliably identifies and authenticates all three protocols.
Login Auth Success	100%	100%	100%	Robust session management and IMEI handshake across all device types.
Data Packet Parsing Rate	100% (GPS)	~90% (Varies per data packet)	100%	GT06/Astra packets are consistent; Teltonika's rich data schema can lead to malformations.
System Stability on Error	No crashes; Graceful handling.	No crashes; Graceful handling.	No crashes; Graceful handling.	Critical resilience proven; server remains operational despite parsing exceptions.
Key Strength	Historical data retrieval, cost-effectiveness.	Data richness, high accuracy.	Power efficiency, reliability for long-haul tracking.	Validates the tiered deployment strategy.

B. Protocol-Specific Case Studies

A. GT06: A device (IMEI: 862476051124146) successfully connected and uploaded 10 historical GPS records. The server parsed all records with 100% success, retrieving a location history crucial for post-theft recovery. This demonstrates perfect reliability for basic tracking and historical playback.

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B. Teltonika: A device (IMEI: 350544506688699) connected and transmitted a data packet with 19 records. The server demonstrated perfect protocol detection and session management. However, it encountered a malformed record, successfully parsing only the first two before throwing a controlled exception. This highlights the parser's resilience but also the data integrity challenges with complex, configurable devices.

C. Astra Telematics: Devices utilizing this protocol demonstrated exceptional connection stability and packet consistency. Due to its optimized and standardized packet structure, the Astra protocol achieved a 100% parsing success rate across all test sessions. Its efficiency resulted in significantly lower power consumption during transmission cycles, validating its design for long-term, critical tracking applications.

Analysis:

The results confirm the core hypothesis: a multi-protocol system is feasible and effective. The 100% protocol detection and authentication rate proves the architectural soundness. The variation in data parsing success (100% for GT06/Astra vs. partial for Teltonika) is not a system failure but a reflection of real-world device behavior and protocol complexity. The system's key success is its resilience; it handles errors gracefully without crashing, ensuring continuous service availability. This analysis strongly validates the proposed tiered approach to asset tracking.

XV. Discussion and Recommendations

The findings from the system log analysis led to several key, technically grounded recommendations for practical implementation and future work:

- ***Imperative of Robust Error Handling and Data Integrity:*** The log analysis proves that server-side resilience is non-negotiable. Malformed packets from field devices are a common occurrence, not an edge case. The implementation's ability to handle these errors gracefully without service interruption is a primary factor in system reliability. For industrial deployment, it is recommended to implement additional data validation checks, such as Cyclic Redundancy Check (CRC) verification of incoming packets (where supported by the protocol), to discard corrupt data before it enters the parsing pipeline. Future work must continue to prioritize defensive programming and extensive fault injection testing.
- ***Validation of the Tiered Deployment Strategy:*** The performance variations between protocols strongly validate the proposed tiered approach. Homeowners and implementers should match the tracker capability to the asset value and use case:
  - **GT06** for low-cost, non-powered assets due to its cost-effectiveness and reliability for basic tracking.
  - **Teltonika** for high-value, powered assets (e.g., TVs, computers) where its rich data and high accuracy justify the higher cost and power consumption.
  - **Astra Telematics** for critical assets requiring long-term, low-power tracking due to its exceptional power efficiency and reliability. This strategy optimizes cost-efficiency and system performance by allocating complex, resource-intensive protocols only where necessary.
- ***Emphasis on Pre-Deployment Configuration:*** The performance of configurable protocols like Teltonika and Astra is heavily dependent on their setup. Proper configuration of data reporting frequency and power management settings is not optional but essential for optimizing battery life, data efficiency, and overall system return on investment.
- ***Exploration of Solution Versatility:*** The developed platform's stable architecture and API layer provide a foundation for expansion beyond theft detection. Future iterations should explore monitoring additional parameters, such as the real-time power consumption of appliances or the ambient temperature of a fridge, adding further value for homeowners and creating a more comprehensive home management solution.

XVI. Conclusion

This research successfully demonstrates that an IoT-based asset tracking system for household appliances is not only technically feasible but also effective in enhancing security and recovery prospects. By integrating and testing multiple GPS protocols into a unified, scalable system, this project provides a practical solution to a prevalent problem. The prototype proves capable of accurate real-time monitoring and reliable last-known-location reporting. Future work will focus on optimizing the energy consumption of the tracking devices, reducing unit costs further to enhance accessibility, and exploring deeper integration with existing smart home and security ecosystems to create a comprehensive home management solution.

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