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Project Proposal: Backtracker

Introduction

Problem

Many people struggle with keeping track of their belongings inside their backpacks, often forgetting essential items or misplacing them. This can be especially frustrating in situations where missing an item, like a laptop or notebook, leads to setbacks at school or work. Additionally, theft is a major concern, particularly in crowded environments where someone could easily access an unattended backpack without the owner noticing. Traditional backpacks offer no built-in way to track items or prevent theft, making them inefficient for modern users who need both organization and security.

Existing solutions, such as Bluetooth trackers and smart luggage, provide partial solutions but often require manual tracking or are designed for larger suitcases rather than everyday backpacks. There is a growing need for an all-in-one backpack that not only helps users keep track of their items but also provides real-time security features to prevent theft or loss.

Solution

Our Smart Backpack with Inventory Tracking & Security, **Backtracker,** is designed to tackle these challenges by integrating RFID-based item tracking, theft detection, and smart security mechanisms. Small RFID tags attached to commonly carried items, such as a wallet or laptop, will allow a built-in scanner to monitor the bag's contents. If an important item is missing, users will receive an alert through a mobile app before they leave a location.

To enhance security, the backpack will include an anti-theft system with motion sensors that detect unusual movement, such as someone trying to access the bag while it's unattended. If unauthorized access is detected, the system can trigger an alarm or vibration alert. Additionally, the backpack will feature an auto-locking mechanism that secures the zippers when in a crowded area and unlocks them when the user is in a safe space. With Bluetooth connectivity, users will be able to check their inventory in real-time and receive geofencing alerts if they leave their backpacks behind.

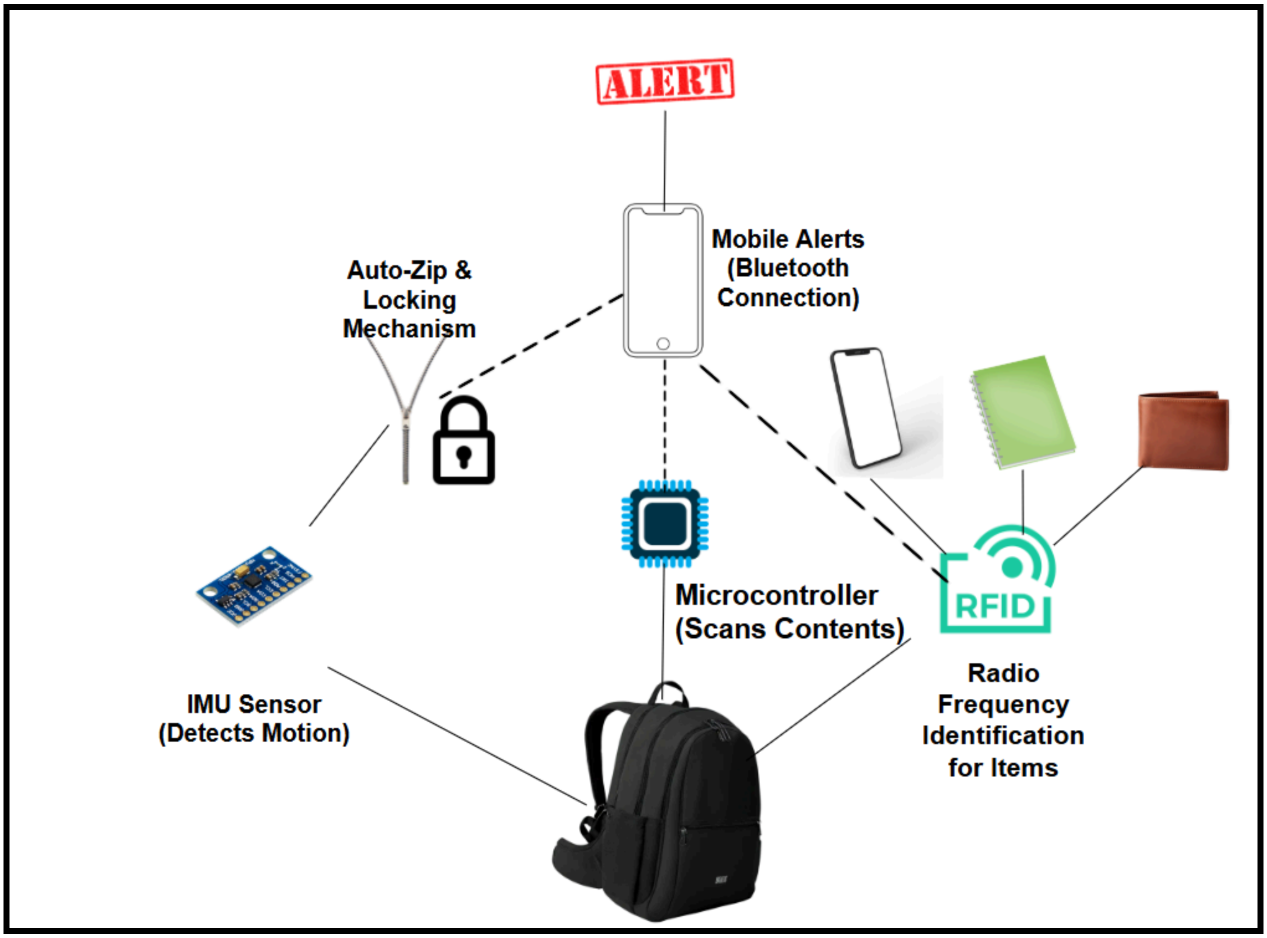
ALERT
Mobile Alerts (Bluetooth Connection)
Auto-Zip & Locking Mechanism
Microcontroller (Scans Contents)
RFID
Radio Frequency Identification for Items
IMU Sensor (Detects Motion)

Figure 1: Visual Aid of Components

High-Level Requirements

- **Accurate RFID-Based Item Tracking**: The backpack must integrate an RFID tracking system capable of detecting and tracking RFID-tagged items in real time. The system should scan the backpack's contents and send an alert to the mobile app if an essential item, such as a laptop, notebook, wallet, or keys, is missing before the user leaves a location.

- **Effective Theft Detection and Security Response**: The anti-theft security system must use an accelerometer or gyroscope (IMU) to detect unauthorized access attempts, such as sudden movement or unzipping while the bag is unattended. Upon detecting suspicious activity, the system should trigger a buzzer or vibration alert to notify the user and deter potential theft.

- **Reliable Auto-Zip & Auto-Lock Mechanism**: The backpack must feature motorized zippers and an electronic or magnetic locking system that can automatically lock or unlock based on the user's location. The locking mechanism should secure the bag in crowded environments and unlock when the user is in a designated safe area while allowing manual override when needed.

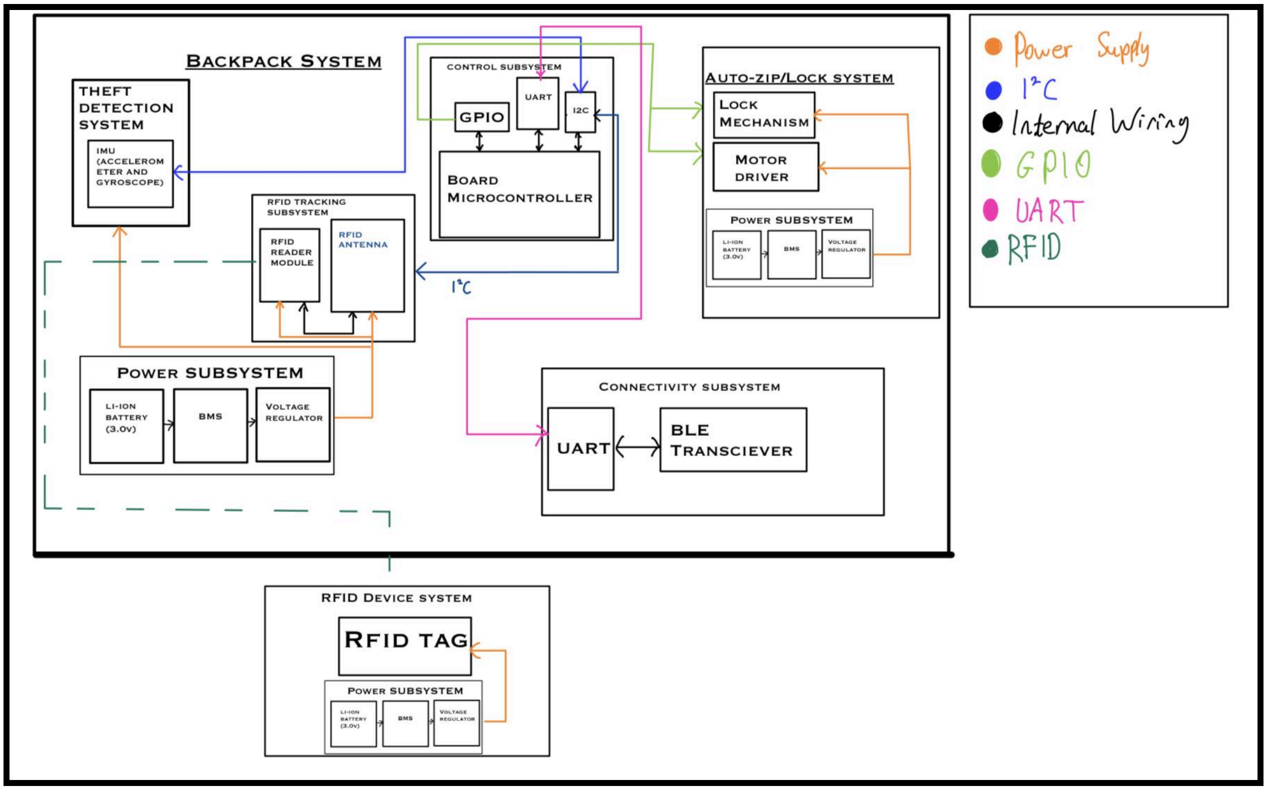

Figure 2: Block Diagram for Smart Backpack System

Subsystems

Board Microcontroller: coordinates all backpack functions. It receives data from the theft detection sensors and the RFID reader, controls the auto-zip/lock mechanism through simple GPIO signals, and communicates with the mobile device via a Bluetooth module. It also monitors power status and triggers alerts when needed.

Theft Detection System: uses an accelerometer and gyroscope to detect unusual movement or tampering. If it senses abrupt motion or changes in orientation, it notifies the microcontroller, which can then decide whether to lock the backpack or alert the user.

Power Subsystem: A Li-Ion battery, combined with a battery management system (BMS) and voltage regulators, supplies stable power (3.3 V) to all components. It ensures everything runs safely and can handle peak currents from motors or the Bluetooth module.

Connectivity Subsystem (BLE Transceiver): handles all communication with the user's smartphone. It sends information about missing items or potential theft, and it also receives commands to lock or unlock the backpack.

Auto-Zip/Lock subsystem: physically secures the backpack. The microcontroller drives the motorized zippers and/or lock mechanism via GPIO signals. When the user or the system requests it, the backpack zips itself or engages an electronic lock.

RFID Tracking subsystem: scans for tags placed on important items (like a laptop or wallet). The reader sends tag data to the microcontroller so it can check whether all items are present. If something is missing, the system notifies the user.

RFID Device System: tags placed on the individual devices with batteries in order to communicate with the RFID Tracking subsystem.

Requirements:

Board Microcontroller

Coordinates all backpack functions. It gathers data from the theft detection sensors and RFID reader, drives the auto-zip/lock mechanism via GPIO, communicates with the smartphone through Bluetooth, and monitors the power subsystem to trigger alerts when needed.

Requirements without which this subsystem would fail:

- **Communication Interfaces:** Must support at least one I^{2}C interface (for RFID and sensor data) and one UART port (for BLE).
- **Performance:** Needs sufficient speed and memory (clock + ram) to handle real-time tasks.
- **Voltage Operation:** Must work reliably at 3.3 V ± 5%.
- **Interrupt Handling:** Must quickly manage interrupts from the theft detection and RFID systems.

Theft Detection System

Uses an accelerometer and gyroscope to detect unusual motion or tampering. It senses abrupt movements or changes in orientation and alerts the microcontroller so the backpack can be locked or the user notified.

Requirements without which this subsystem would fail:

- **Sensor Range & Sensitivity:** Must detect motion typical of tampering
- **Data Update Rate:** Should update readings at least 100 Hz.
- **Alert Mechanism:** Must provide an interrupt or alert signal to the microcontroller.

Power Subsystem

A Li-Ion battery with a battery management system (BMS) and voltage regulators provides a stable 3.3 V to all components. It handles peak currents from motors or the Bluetooth module while ensuring safe operation.

Requirements without which this subsystem would fail:

- **Voltage Regulation:** Must supply 3.3 V within ±5% under all load conditions.
- **Current Capability:** Should deliver at least 500 mA continuously.
- **Battery Protection:** Must include overcharge, over-discharge, and short-circuit protection.
- **Thermal Management:** Regulators and the battery should stay below 80 °C under full load.

Connectivity Subsystem (BLE Transceiver)
Handles wireless communication with the user's smartphone. It sends alerts about missing items or potential theft and receives commands to lock or unlock the backpack.

Requirements without which this subsystem would fail:

- **Communication Range:** Must reliably connect over at least 10 meters.
- **Data Throughput:** Should support standard BLE rates (up to 1 Mbps).
- **Low Power Consumption:** Must support a low-power mode to save battery when idle.

Auto-Zip/Lock Subsystem
Physically secures the backpack. The microcontroller sends simple GPIO signals to control the motorized zippers and/or electronic lock mechanism, ensuring the bag locks or unlocks when needed.

Requirements without which this subsystem would fail:

- **Mechanical Force:** Motors must provide enough torque (around one N·m) to close zippers and engage the lock.
- **Response Time:** Should react to GPIO signals within a few seconds.
- **Feedback Mechanism:** Should use limit switches or sensors to confirm the zipper or lock is fully engaged.

RFID Tracking Subsystem
Scans for RFID tags attached to important items like laptops or wallets. It sends detected tag data to the microcontroller, which then verifies that all items are present.

Requirements without which this subsystem would fail:

- **Detection Range:** Must reliably read tags within half a meter.
- **Multi-Tag Capability:** Should detect at least five tags simultaneously.
- **Data Transfer:** Must quickly send tag data via I^2C to the microcontroller.

RFID Device System
These are the RFID tags attached to individual devices. They communicate with the RFID Tracking Subsystem, allowing the system to confirm the presence of each tagged item.

Requirements without which this subsystem would fail:

- **Compatibility:** Tags must operate on the same frequency as the RFID reader.
- **Durability:** Must remain functional despite regular use and typical backpack conditions.

- **Power:** Should be passive or have very low power requirements to ensure long-term reliability.

Tolerance Analysis:

Ensure the motor produces enough torque to secure the lock even if the supply voltage drops by 10%.

Analysis:

- **Nominal Requirement:** The motor must deliver at least 0.5 N·m of torque.
- **Voltage Impact:** A 10% drop in voltage typically reduces the motor's torque by about 10%.
- **Calculation:**
  - With a 10% drop, the effective torque is about 0.9 times the rated torque.
  - To ensure the effective torque remains at or above 0.5 N·m, the rated torque should be at least 0.5 divided by 0.9, which is approximately 0.56 N·m.

Choose a motor with a rated torque of at least 0.56 N·m to ensure the auto-zip/lock mechanism operates reliably, even with a 10% voltage drop.

Ethics & Safety

Ethical Considerations

1. Privacy and Data Security

Since BackTrack uses RFID tracking and Bluetooth connectivity, protecting user data is critical. The ACM Code of Ethics stresses the importance of privacy protection and responsible data management (ACM, 2018). To address this:

- The RFID and Bluetooth systems will use encryption to prevent unauthorized access to tracking data.
- Only authenticated users will have access to their inventory records via the mobile app.
- The backpack will not store or transmit unnecessary user data to limit exposure to security breaches.

2. Prevention of Unauthorized Tracking

A major concern is the potential misuse of RFID tracking for surveillance. If the system is not designed with safeguards, it could be exploited to monitor individuals without consent. To prevent this:

- RFID tracking will only function when items are inside the backpack and will not continuously transmit location data.
- The app will require explicit user consent before enabling tracking features.
- Users will have the option to disable or reset tracking data at any time.

Safety Considerations

1. Battery and Electrical Safety

The backpack contains electronic components, RFID scanners, and motorized zippers, which require a battery-powered system. To ensure safe operation:

- The battery system will comply with UL 2054 standards for portable power sources (UL, 2022).
- Safety features like overcharge protection and short-circuit prevention will be implemented.
- The system will meet FCC regulations for electromagnetic interference (EMI) (FCC, 2021).

2. Auto-Zip and Locking Mechanism Risks

The motorized zippers and locking system introduce the potential for pinching hazards or accidental entrapment. To mitigate risks:

- Low-torque motors will be used to prevent injuries.
- A safety stop mechanism will be implemented to halt movement if resistance is detected.
- Users will have a manual override option to disengage the lock in case of emergency

Citations

ACM Code of Ethics and Professional Conduct (ACM, 2018). https://www.acm.org/code-of-ethics

FCC Part 15 Regulations on Unlicensed Radio Frequency Devices (Federal Communications Commission, 2021). https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-15

UL 2054: Household and Commercial Battery Standard (Underwriters Laboratories, 2022). https://www.shopulstandards.com/ProductDetail.aspx?UniqueKey=40907