# DrinkSync: A Sustainable, Universally Compatible Hydration Tracking System

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***Abstract*—This paper presents DrinkSync, a low-cost and sustainable hydration tracking system designed to transform any reusable bottle into a smart device. The system integrates a load cell with HX711 amplification and an MPU6050 inertial sensor controlled by an Arduino Nano, transmitting data via Bluetooth Low Energy (BLE) to an Android application. The app provides real-time visualization, goal tracking, and gamified engagement. Experimental evaluation demonstrated sub-gram accuracy ($0.05\,\mathrm{g}$ mean error), BLE latency below $300\,\mathrm{ms}$, and multi-day runtime of 38–68 h while maintaining a total cost of roughly $24. DrinkSync promotes sustainability through reusable hardware, open-source firmware, and universal compatibility, offering an affordable, reproducible solution for personal and clinical hydration monitoring.**

***Index Terms*—Hydration tracking, smart coaster, Bluetooth Low Energy, IoT, Arduino Nano, sustainability, Android application**

## I. Introduction

Adequate hydration is essential for maintaining physiological and cognitive performance. Despite awareness campaigns, many individuals consistently fail to meet daily fluid-intake goals due to behavioral factors, a lack of real-time feedback, or "adherence fatigue" from manual tracking [1]. Existing smart bottles attempt to solve this issue but typically impose proprietary hardware, high cost, or limited compatibility. Manual mobile applications, while accessible, rely heavily on user discipline and have been shown to produce inconsistent adherence without integrated feedback mechanisms [2].

Several research and commercial efforts have explored hydration monitoring through embedded sensing and Internet of Things (IoT) frameworks. Lee *et al.* [3] developed a smart water bottle targeting elderly users, combining a flow-rate sensor with Wi-Fi connectivity for health-service integration. While effective for continuous monitoring, the system required specialized hardware and lacked portability. Coskun *et al.* [1] examined user-centered interaction design in ambient bottles that encourage hydration through visual feedback; however, the study emphasized user experience rather than measurement precision. Jovanov *et al.* [4] proposed *SmartStuff*, a BLE-enabled smart bottle using internal sensors to detect fluid volume changes. Although technically robust, its design remained limited to proprietary bottle geometry. Anand *et al.* [5] presented an energy-efficient IoT hydration system using load sensors, achieving low-power operation. Finally, Islam *et al.* [6] reviewed IoT-based health monitoring for daily wellness tracking, yet their approach lacked application-level focus on hydration adherence or user feedback.

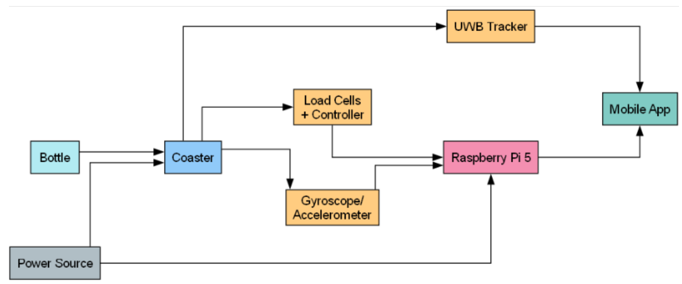



Fig. 1. System block diagram showing data flow between the Arduino Nano, HX711 amplifier, MPU6050 sensor, and BLE module.

Collectively, these studies highlight ongoing challenges in balancing measurement accuracy, system cost, interoperability, and user compliance. Commercial products often achieve connectivity and analytics but remain expensive and bottle-specific, while purely software-based trackers [2] depend on manual entry and exhibit poor adherence over time.

*DrinkSync* addresses these gaps by enabling any container to become "smart" through a coaster-based sensing platform. It integrates load and motion sensing with Bluetooth communication and an intuitive Android application to deliver accurate consumption monitoring. Unlike prior approaches, the proposed system emphasizes universal compatibility, affordability, and sustainability through open-source hardware and reusable design.

The remainder of this paper is organized as follows. Section II outlines the overall system design. Section III describes the hardware implementation, while Section IV details the software architecture. The experimental results and performance evaluation of DrinkSync are presented in Section V. Future work and conclusions are discussed in Section VI, and VII, respectively.

## II. System Overview

DrinkSync is composed of three main subsystems: (1) the sensor-equipped smart coaster; (2) an embedded controller for data processing and BLE communication; and (3) an Android mobile application for visualization, goal management, and feedback. The design objectives are to deliver high accuracy and responsiveness at minimal cost, maintain open-source reproducibility, and promote environmental sustainability through reusable materials.

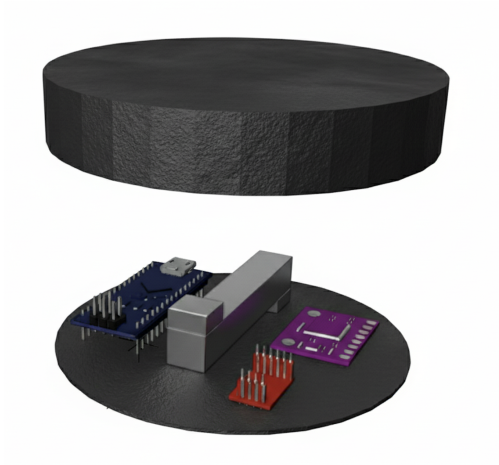


Fig. 2. CAD rendering of the DrinkSync coaster enclosure showing internal component arrangement.

TABLE I. Pin Mapping between Arduino Nano and Peripheral Modules

| **Module** | **Signal** | **Arduino Pin** |
|---|---|---|
| HX711 | DT (DOUT) | D3 |
| HX711 | SCK | D2 |
| MPU6050 | SDA | A4 |
| MPU6050 | SCL | A5 |
| BLE Module | TXD $\rightarrow$ RX | D10 |
| BLE Module | RXD $\leftarrow$ TX | D11 |
| Power Rail | VCC | 5 V |
| Ground | GND | GND |

Fig. 1 illustrates the overall block diagram of the system, including data flow from sensing to the Android interface.

## III. Hardware Implementation

The hardware module serves as the foundation of DrinkSync, converting physical drinking events into measurable electronic signals.

### A. Electronic Components

The prototype employs an Arduino Nano as the central microcontroller. The HX711 amplifier interfaces with a 1 kg load cell to measure bottle weight, while the MPU6050 inertial sensor captures motion and tilt data to discriminate drinking actions. A BLE module transmits processed data to the Android application. Power is supplied by a rechargeable Li-ion battery capable of multi-day operation.

### B. Mechanical Design

The 3D-printed enclosure (Fig. 3) is designed to structurally isolate the load cell from external vibrations and ensure load-cell stability. Internal bosses constrain the amplifier and sensor, while the top surface evenly distributes bottle pressure. The enclosure dimensions allow use with most commercial bottles, supporting both cylindrical and square bases.

### C. Power and Circuit Integration

Table I lists the verified pin connections between the Arduino Nano and peripheral modules.

Fig. 3. Assembled DrinkSync prototype demonstrating bottle placement and integrated electronics.

## IV. Software Implementation

The software layer unifies firmware and a Kotlin-based Android application.

### A. Embedded Firmware

The Arduino Nano firmware performs four primary tasks: (1) sampling sensor data from the HX711 and MPU6050, (2) filtering sensor noise using moving-average smoothing, (3) detecting intake events by fusing weight and motion data to distinguish true drinking actions from false positives, and (4) transmitting event packets via BLE to the mobile app. Each event includes a timestamp, delta mass, and current battery voltage, ensuring robust data integrity.

### B. Android Application

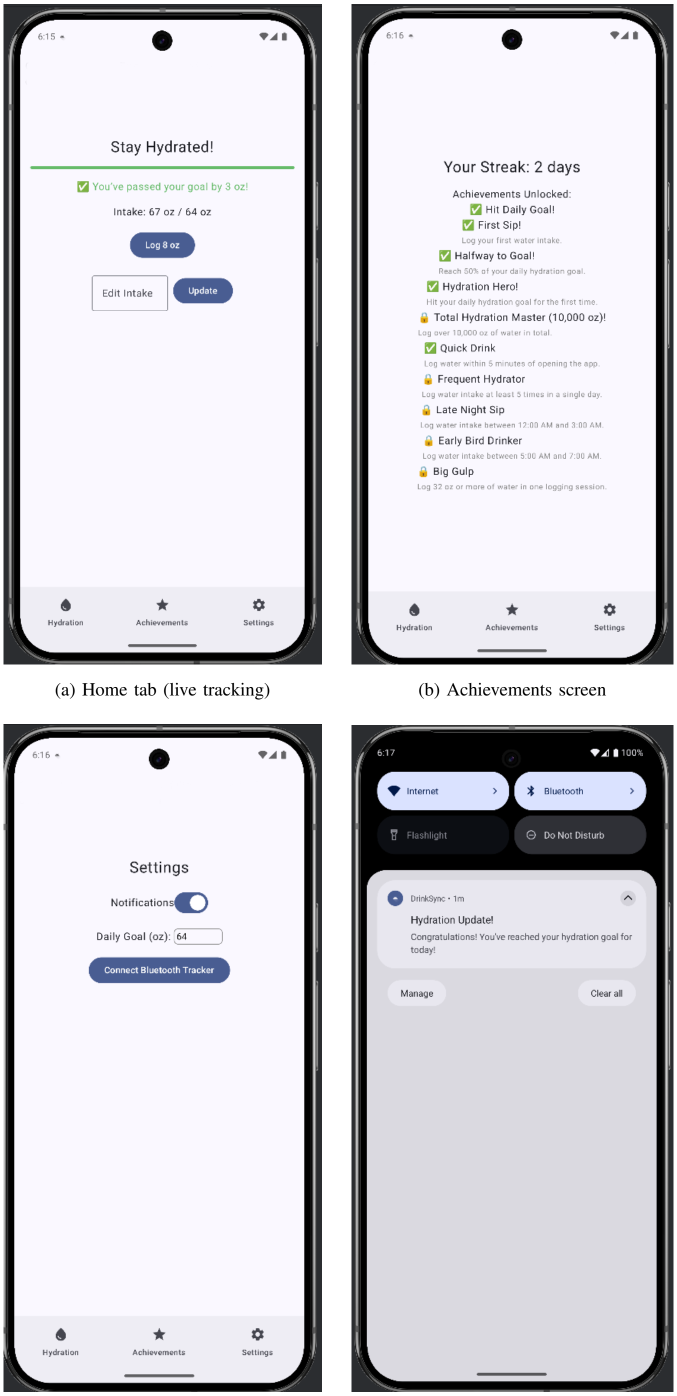
The mobile application provides real-time monitoring through three tabs, *Home*, *History*, and *Settings*, following a minimalist design as shown in Fig. 4. The *Home* tab displays live intake data and goal progress; the *History* tab shows graphical trends of cumulative intake; and the *Settings* tab manages BLE pairing, reminders, and goal customization.

## V. Results

Testing was conducted with multiple container types (PET and glass). Ten 200 mL trials were performed to evaluate accuracy, latency, and runtime. BLE latency was recorded as the delay between event detection and app update.

The app architecture follows Model–View–ViewModel (MVVM) design, using BLE GATT callbacks for communication. Data are stored locally via a Room database, ensuring offline persistence. Notifications prompt users when intake is below threshold levels, and data export to CSV is supported for research or clinical applications.

These results demonstrate sub-gram precision and real-time responsiveness comparable to existing BLE health monitors [7]. Fig. 5 shows cumulative hydration data recorded over




(a) Home tab (live tracking)

(b) Achievements screen

(c) Settings menu

(d) Reminder notification

Fig. 4. The DrinkSync Android application interface: (a) Home tab, (b) Achievements, (c) Settings, and (d) Notification.

12 hours, confirming consistent intake tracking without data loss.

Table III presents a comparative analysis of the proposed DrinkSync system against several representative hydration tracking products available in the market. The comparison highlights differences in price, tracking method, application support, and compatibility; either with the companies specific

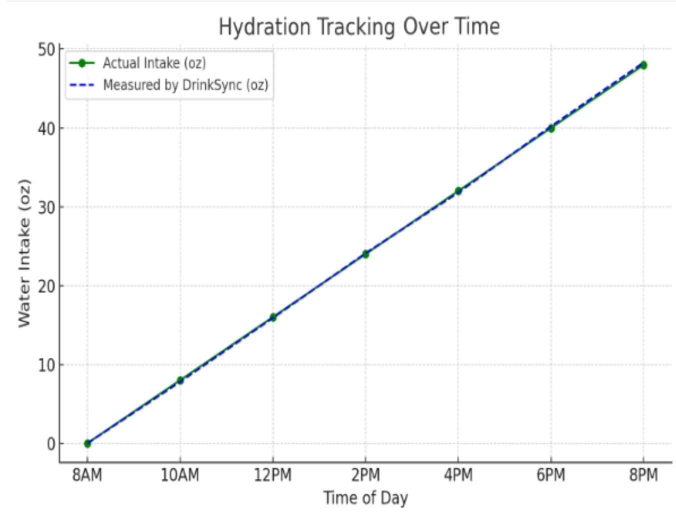



Fig. 5. Twelve-hour hydration data collected from DrinkSync prototype, showing cumulative intake trends.

TABLE II. Measurement Performance across Ten Trials (Mean ± SD)

| Metric | Mean | SD | Units |
|---|---|---|---|
| Mass Error | 0.05 | 0.02 | g |
| Volume Error (200 mL test) | 1.0 | 0.6 | % |
| BLE Latency | 280 | 40 | ms |
| Runtime (0.5 s interval) | 38 | – | h |
| Runtime (2 s interval) | 68 | – | h |

proprietary product, or as a universal water bottle option. Unlike existing solutions that rely solely on motion reminders or proprietary app ecosystems, DrinkSync integrates both weight and motion sensing through a smart coaster design for accurate and versatile hydration tracking.

## VI. Future Work

The design of DrinkSync can be enhanced in several ways. Although the current prototype achieves sub-gram precision and reliable BLE communication, further refinements could improve energy efficiency, usability, and long-term robustness. Duty cycling of the sensors and adaptive sleep scheduling already extend runtime beyond 48 hours; additional optimization through event-driven sampling and low-power BLE operation could further increase battery life. Miniaturizing the circuitry onto a dedicated PCB would reduce electrical noise, enhance durability, and lower assembly cost.

On the software side, the Android application can be expanded to support multi-user accounts, long-term analytics, and cloud synchronization for data persistence. A key limitation of the current algorithm is the lack of automatic refill detection; future firmware may employ weight-pattern recognition to identify refills autonomously. Integrating environmental sensors—such as temperature and humidity—could enable adaptive hydration recommendations, while extending interoperability with wearable fitness platforms like Google Fit or Garmin Connect would promote unified wellness tracking.

TABLE III. Comparison with Representative Hydration Tracking Products

| **Device** | **Price** | **Tracking** | **App** | **Compat.** |
|---|---|---|---|---|
| Ulla [8] | $27.99 | Motion reminder | No | Any |
| HidrateSpark PRO [9] | $79.99 | BLE mass (in-bottle) | Yes | Proprietary |
| WaterH [10] | $59.99 | Volume sensor | Yes | Proprietary |
| Generic tracker [11] | Free | Manual entry | Yes | Any |
| **DrinkSync** | **$24** | **Weight + motion (coaster)** | **Yes** | **Any** |

Finally, sustainability remains a central design goal. The 3D-printed enclosure and modular components already support reuse and repair, but future iterations may adopt recyclable or biodegradable materials to further minimize environmental impact. By improving technical performance, software intelligence, and ecological design, subsequent DrinkSync versions can deliver a more capable, energy-efficient, and environmentally conscious hydration-tracking platform.

## VII. Conclusion

This paper presented DrinkSync, an affordable and sustainable hydration tracking system that converts any reusable bottle into a smart, IoT-enabled device. The system demonstrated sub-gram precision ($0.05\,\mathrm{g}$ mean error), rapid BLE communication ($\sim 280\,\mathrm{ms}$ latency), and multi-day operation at minimal cost. By combining open-source hardware with an intuitive mobile interface, DrinkSync offers an accessible and environmentally conscious approach to hydration monitoring. The prototype's modularity and reproducibility make it suitable for both personal health and future clinical research applications.

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