SafeTether: Accessibility-First Anti-Theft Tracker — Pilot Study Protocol

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When Belongings Walk Away: An Accessibility-First, Phone-Independent Anti-Theft Tracker for People with Disabilities

A pilot study protocol comparing the SafeTether prototype with Apple AirTag (2nd generation) for blind, low-vision, deaf, hard-of-hearing and mobility-impaired users

Abstract

People with disabilities are robbed at about five times the rate of people without disabilities (5.6 vs. 1.1 per 1,000 persons age 12 or older, U.S., 2017–19), and one in three U.S. robbery victims has at least one disability (Harrell, 2021). Mainstream item trackers such as Apple AirTag were built to find *lost* objects for smartphone users: their alerts are visual phone notifications, their separation alerts are designed for items accidentally left behind, and their recovery model assumes the owner can safely go and look. None of these assumptions holds reliably for a blind pedestrian, a deaf commuter, or a wheelchair user whose bag is snatched. This paper specifies a two-phase pilot of **SafeTether**, an amateur, low-cost prototype made of a tag clipped to a belonging and a wearable "anchor" (wristband or pendant). The pair continuously measures the distance between person and item using Ultra-Wideband radio (which, unlike GPS, keeps working indoors), detects when the item is more than one meter away, asks the owner whether they know, and, if they do not, vibrates and shows where the item is. Phase 1 validates detection accuracy and false-alarm rate against a pre-specified gate before any benefit is claimed; Phase 2 then tests, in a within-subjects study with eighteen participants across three disability groups, whether SafeTether shortens the time to awareness of a theft, improves alert recognition, and lowers workload relative to AirTag. The pilot is deliberately scoped and safety-first: the device is designed to help users get help, never to send them after a thief.

Keywords: assistive technology · item tracking · theft prevention · disability · victimization · Apple AirTag · accessible alerts

The problem in four numbers

Number	What it means
5.1×	higher robbery rate for people with disabilities
33%	of U.S. robbery victims have a disability
45%	of robberies against them reach the police
1.3 billion	people worldwide live with a disability

Sources: Harrell (2021), BJS NCJ 301367; World Health Organization (2023).

> **The idea in one sentence.** Existing trackers help you *find* a bag tomorrow; SafeTether makes sure a person who may not see, hear, or follow the thief *knows* — safely — within seconds.

1. Introduction

A woman who is blind waits at a bus stop with her bag on the bench beside her. Someone lifts it and walks away. She hears nothing distinctive, her phone stays silent in her pocket, and by the time she reaches for the bag the thief is thirty meters down the street. The same scene plays out for a deaf commuter who cannot hear footsteps behind him, and for a wheelchair user who sees the theft but cannot follow. In each case the problem is not that the item cannot be *found* later; it is that the owner learns of the theft too late, through a channel they cannot use, with no safe way to respond.

This paper specifies a testable answer to that problem — a phone-independent tracker that measures the distance between a person and their belongings and reacts within seconds — and scopes it deliberately: a two-phase pilot, first validating detection accuracy and then testing its effect on awareness and recovery, with three disability groups rather than a general claim about all users.

1.1 The Scale of the Problem

An estimated **1.3 billion people**, about **16% of the world's population**, live with a significant disability (World Health Organization, 2023). In the United States, persons with disabilities made up about **12% of the population** age 12 or older in 2017–19 but were victims in **26% of nonfatal violent crimes** and in **33% of robberies** (Harrell, 2021). Their robbery rate was **5.6 per 1,000**, against an age-adjusted **1.1** for persons without disabilities

— a fivefold gap that is wider than for violent crime as a whole (Figure 1). The gap is not new: the rate of violent victimization against persons with disabilities was **at least twice** the rate for persons without disabilities in every year from 2009 to 2019. A meta-analysis of 26 studies reached the same conclusion internationally: adults with disabilities face roughly **1.5 times the risk of violence** of non-disabled adults (Hughes et al., 2012).

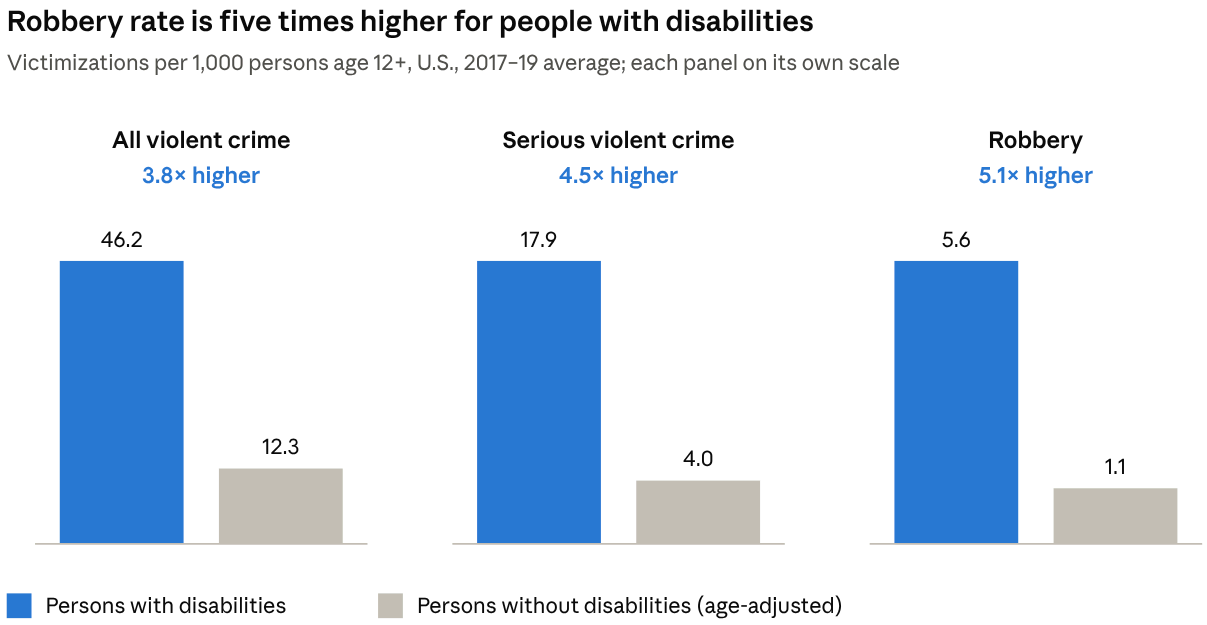


Figure 1. Source: Harrell (2021), BJS NCJ 301367, Table 1 · NCVS 2017–19, rates per 1,000

The figures are also an undercount. Robberies against persons with disabilities were reported to police only 45% of the time, against 57% for persons without disabilities, and the survey excludes people living in institutions and those who struggle with telephone interviews (Harrell, 2021). A tool that helps a victim notice a theft and document it immediately therefore addresses two gaps at once: the theft itself and the silence after it.

1.2 Contributions

This study makes four contributions:

1. An accessibility-first anti-theft design, SafeTether, piloted with blind or low-vision, deaf or hard-of-hearing, and mobility-impaired users rather than claimed as universal.
2. A connection between victimization research on people with disabilities and consumer item-tracking technology — two literatures that have so far developed separately.
3. A low-cost prototype architecture (tag plus wearable anchor, ranged by Ultra-Wideband rather than GPS) with an independent detection-accuracy check that precedes any user-benefit claim.

4. A two-phase experimental design — technical validation, then a within-subjects comparison against Apple AirTag — measuring time to awareness, alert recognition, workload, and usability.

2. Research Gap

Three findings, taken together, define what remains untested. First, people with disabilities are robbed at about five times the rate of others, yet no published evaluation of an item tracker has measured its performance with blind, deaf, or mobility-impaired users facing theft rather than loss (Harrell, 2021). Second, the market leader, Apple AirTag, is engineered around *loss*: its separation alerts exist so that owners do not accidentally leave items behind, and they arrive only on the device sharing the owner's location, typically an iPhone (Apple, n.d.). Third, AirTag's anti-stalking protections — a sound emitted by a tag separated from its owner, alerts on nearby iPhones and Android phones, and published instructions to disable the tag by removing its battery — are an essential safety feature, but they also tell a thief that a tracker is present and how to silence it (Apple, 2026). Table 1 states the gap directly.

Existing solution	Real-time theft detection	Works without a smartphone	Accessible alerts (speech, vibration, light)	Response at the moment of theft	Key limitation
Apple AirTag, 2nd generation (2026)	Partial — separation alert when the owner's iPhone leaves the item	No — needs an iPhone or iPad on iOS 26	Partial — inherits iPhone accessibility; Precision Finding gives haptics and directions	No — the speaker plays when the owner triggers it, or to warn a person carrying an unknown tag	Built for lost items; its anti-stalking design reveals the tag to a thief
Tile trackers	Partial — app-based alerts	No — smartphone app required	Partial — depends on the phone	No	Same phone-first, loss-first model
Samsung Galaxy SmartTag2	Partial — app-based alerts	No — tied to Galaxy phones	Partial — depends on the phone	No	Locked to one ecosystem
Keychain personal alarms (sirens)	No	Yes	Sound only	Yes, if the user activates it	Useless once the item is already gone

Existing solution	Real-time theft detection	Works without a smartphone	Accessible alerts (speech, vibration, light)	Response at the moment of theft	Key limitation
Medical alert pendants (personal emergency response systems)	No	Yes	Yes — one large button, voice	No	Protect the person, not their belongings
SafeTether (proposed)	Yes — distance measured continuously, snatch detected within seconds	Yes — tag pairs with a wearable anchor	Yes — user chooses speech, vibration, light, or all three	Asks the owner at 1 m; vibrates and shows the item's location if they did not know	Unvalidated prototype; tested in this pilot

Table 1. What existing products do and do not provide for theft, as opposed to loss, among users with disabilities.

> **The gap in one line.** Every tracker on the market is built to find a *lost* item later; none is built for the *first seconds of a theft* from someone who cannot see, hear, or follow the thief.

This paper addresses that gap with a two-phase design — validating detection accuracy first, then testing user benefit against AirTag — evaluated as a focused pilot rather than a commercial claim.

3. Related Work

3.1 Why Offenders Target People with Disabilities

Criminology explains the victimization gap without assuming anything about disability itself. Routine activity theory holds that a crime occurs when a motivated offender meets a suitable target in the absence of a capable guardian (Cohen and Felson, 1979). Ethnographic work with active street robbers adds that offenders deliberately choose victims they expect will not resist, chase, or identify them (Wright and Decker, 1997).

Every one of those expectations is shaped by visible impairment: a person who cannot see the offender, cannot hear an approach, or cannot run after a bag looks, to an offender, like a target with no guardian — including the victim themself.

> **Why offenders choose them.** A robber looks for three things: a target that will not resist, will not chase, and cannot identify them. Visible impairment signals all three at once.

The pattern is documented, not inferred. In the U.S., persons with cognitive disabilities had the highest violent victimization rate of any group measured (83.3 per 1,000), and persons with vision disabilities had nearly four times the rate of the general population (47.6 per 1,000) (Harrell, 2021). In the United Kingdom, the Equality and Human Rights Commission's inquiry concluded that harassment is a commonplace experience for disabled people, that many come to accept it as inevitable, and that public authorities systematically fail to recognize it (Equality and Human Rights Commission, 2011). The inquiry also recommended replacing the idea of individual "vulnerability" with a focus on the *situations* that create risk — the framing this paper adopts: the device does not change who the user is, it changes the situation the offender sees.

3.2 Existing Item Trackers

Apple released the second-generation AirTag in January 2026. It adds a second-generation Ultra Wideband chip that extends Precision Finding by up to 50%, a speaker Apple describes as 50% louder, and Precision Finding on Apple Watch Series 9 and later; it still costs $29 and still requires an iPhone or iPad running iOS 26 to set up (MacRumors, 2026; Macworld, 2026). Apple states that AirTag is designed for tracking objects, not people. Competing tags from Tile and Samsung follow the same model: a small Bluetooth beacon, a crowd-sourced finding network, and a smartphone app as the only interface.

These products do help recover stolen property, but almost always after the fact and through police. Law enforcement agencies and Apple-focused publications consistently advise owners not to confront thieves themselves. The risk is real: in Bakersfield, California, a 61-year-old woman was shot and killed after she used an AirTag to locate her stolen car and confronted the suspects (KGET 17 News, n.d.). For a user with a disability, a recovery model that depends on going to the thief is not merely inconvenient; it is unsafe.

> **A warning from real life.** Tracking a thief down is dangerous even for owners without disabilities. A recovery model that sends the victim to the offender is not a model this project will copy.

3.3 Design Lessons from Assistive Technology

Three principles from assistive technology practice shape the proposed design. First, information must reach the user through the sense they rely on: a visual banner is invisible to a blind user unless a screen reader announces it in time, and a sound is useless to a deaf user. Second, the most reliable assistive devices are the ones that need the fewest steps — a medical alert pendant succeeds because it has one button, not because it has many features. Third, a device that requires a specific, expensive smartphone excludes many of the people it is meant to protect; disability is concentrated among older adults, and 48% of the U.S. population with a disability is age 65 or older (Harrell, 2021). The NCVS itself notes that standard survey methods under-reach people who have difficulty communicating, a reminder that mainstream systems built for typical users quietly fail atypical ones.

3.4 Comparison with Apple AirTag

AirTag is an excellent product for its intended job, and this paper does not claim otherwise. It is treated as the baseline being extended, not as a failure. The claim under test is narrower: for the specific scenario of a theft from a person with a sensory or mobility impairment, a system that (a) detects separation within seconds rather than when the owner leaves a place, (b) alerts through speech, vibration or light without a phone, (c) checks with the owner the moment the item moves more than 1 m away, and (d) routes the owner toward help rather than toward the thief, will outperform a loss-oriented, phone-dependent tracker on the outcomes that matter to that user.

4. Research Questions and Hypotheses

4.1 Research Questions

RQ1: Does a phone-independent, distance-measuring tracker shorten the time between the theft of an item and the owner's awareness of it, and help the owner respond safely and recover a dropped item, for users with visual, hearing, or mobility impairments, relative to Apple AirTag?

RQ2: Do multimodal alerts chosen by the user (speech, vibration, light) reduce perceived workload, and improve usability relative to standard smartphone notifications?

RQ3: How accurately does the prototype detect a real separation, and how often does it raise a false alarm in everyday carrying, judged against a recorded ground truth?

4.2 Hypotheses

H1: SafeTether significantly reduces time-to-awareness of a staged theft relative to AirTag.

H2: SafeTether significantly improves the proportion of alerts correctly recognized and acted on (correct safe action chosen) relative to AirTag.

H3: SafeTether significantly lowers perceived workload (NASA-TLX) relative to AirTag.

H4: Participants report higher usability (SUS) for SafeTether than for AirTag.

H5: SafeTether significantly reduces the time to locate a dropped item, once it has stopped moving, relative to AirTag's Precision Finding.

Table 2 states, for each question, exactly where in the design its answer comes from.

Research question	Hypothesis(es)	How it is answered	Where in the design
RQ1: Does SafeTether shorten time from theft to awareness, and support a safe response and recovery, relative to AirTag?	H1 (time to awareness), H2 (correct safe response), H5 (time to locate)	Phase 2 within-subjects comparison of AirTag vs. SafeTether in staged, consented theft scenarios, timed per trial; locate time from drop scenarios only	Sections 7.2–7.5
RQ2: Do user-chosen multimodal alerts reduce workload and improve usability?	H3 (NASA-TLX workload), H4 (SUS usability)	Post-trial NASA-TLX and post-condition SUS questionnaires in the same comparison	Sections 7.5–7.6
RQ3: How accurately does the prototype detect separations, and how often does it false-alarm?	Gate, not a directional hypothesis	Phase 1 bench and everyday-carry validation against video-recorded ground truth	Section 7.1

Table 2. How each research question is operationalized and answered.

5. Conceptual Framework

Figure 2 summarizes the causal chain from a tagged belonging to the outcome measures: tag → continuous distance measurement → separation and snatch detection → multimodal response → help routed to a trusted contact → four outcome constructs (time to awareness, correct safe response, workload, usability), corresponding directly to the dependent variables in Section 7.5. Because the pilot is scoped to three disability groups and short-range UWB measurement, the pipeline should be read as instantiated for those groups and that range, not as a guarantee for every user or setting.

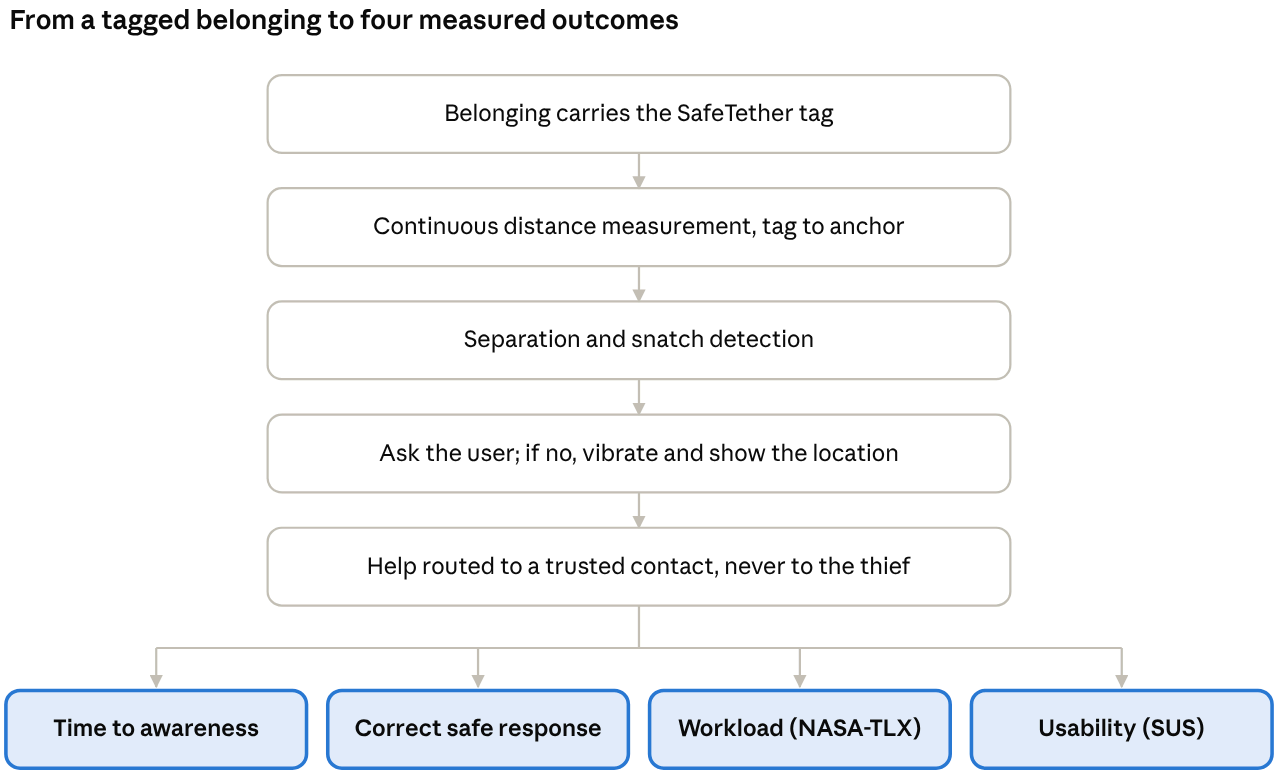


Figure 2. Conceptual framework linking the SafeTether pipeline to the outcome measures evaluated in this study

6. Proposed System: SafeTether

SafeTether has two physical parts: a **tag** the size of a keyring fob, clipped to a bag, wallet, white-cane holder or wheelchair pouch, and an **anchor** worn on the body as a wristband or pendant. The pair talks directly over Ultra-Wideband (UWB) radio, so the system works with no smartphone at all; a phone app is optional and used only for settings. Both parts are built from off-the-shelf components — an ESP32-S3 microcontroller board with a UWB ranging module (Section 6.1), an accelerometer, a vibration motor, a small speaker, an LED ring and one large tactile button — which keeps the project within reach of an amateur team.

The pipeline has three layers, shown in Figure 3. A sensing layer on the tag exchanges UWB radio pulses with the anchor several times a second and senses sudden movement. A decision layer on the anchor measures distance from the travel time of those pulses and recognizes a snatch: distance growing faster than a walking pace while the tag is in

motion. When the item is more than one meter away, a response layer asks the user on the anchor whether they know. If they answer yes, the status returns to green; if they answer no, the anchor vibrates and shows where the item is.

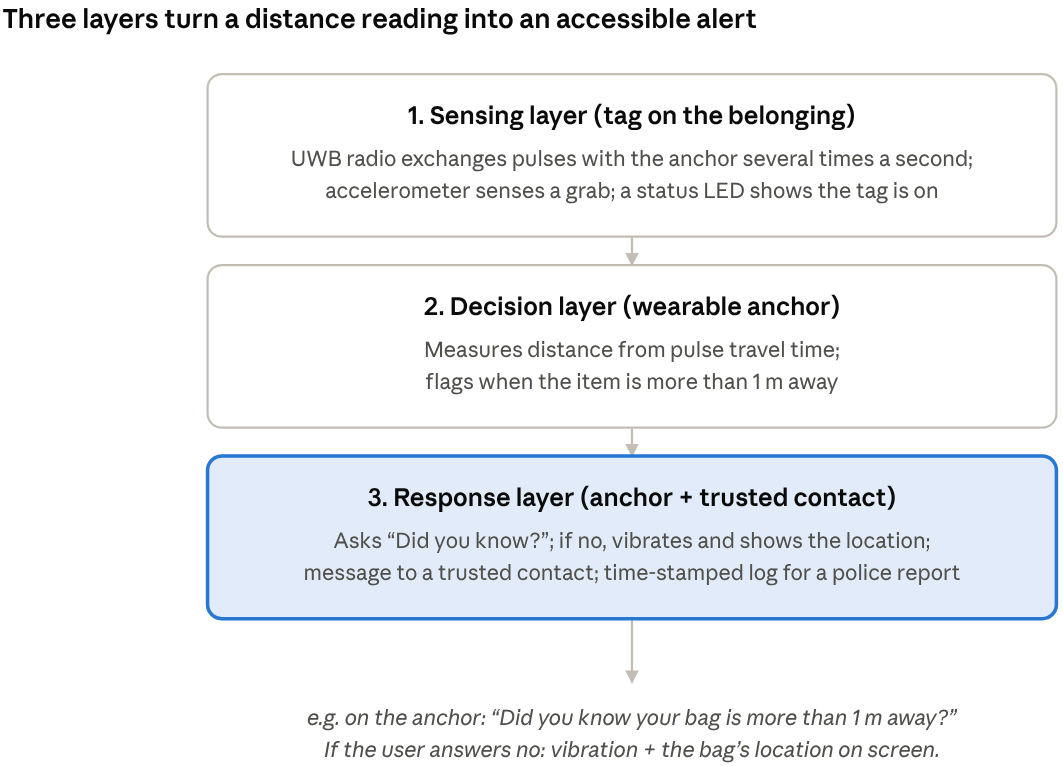


Figure 3. Three-layer architecture of SafeTether: sensing, decision, and response layers

Two cases. A user needs a simple message rather than a stream of numbers, so the anchor sorts distance into just two cases (Figure 4). While the item is close by, under about 1 m, nothing happens and the status stays green. Once it is more than 1 m away, the anchor asks the user, "Did you know your item is more than 1 meter away?" If they answer yes, the status returns to green; if they answer no, the anchor vibrates and shows where the item is. The threshold is user-adjustable and is tuned in Phase 1; because UWB ranging is precise to well under a meter (Section 6.1), it can be set tightly.

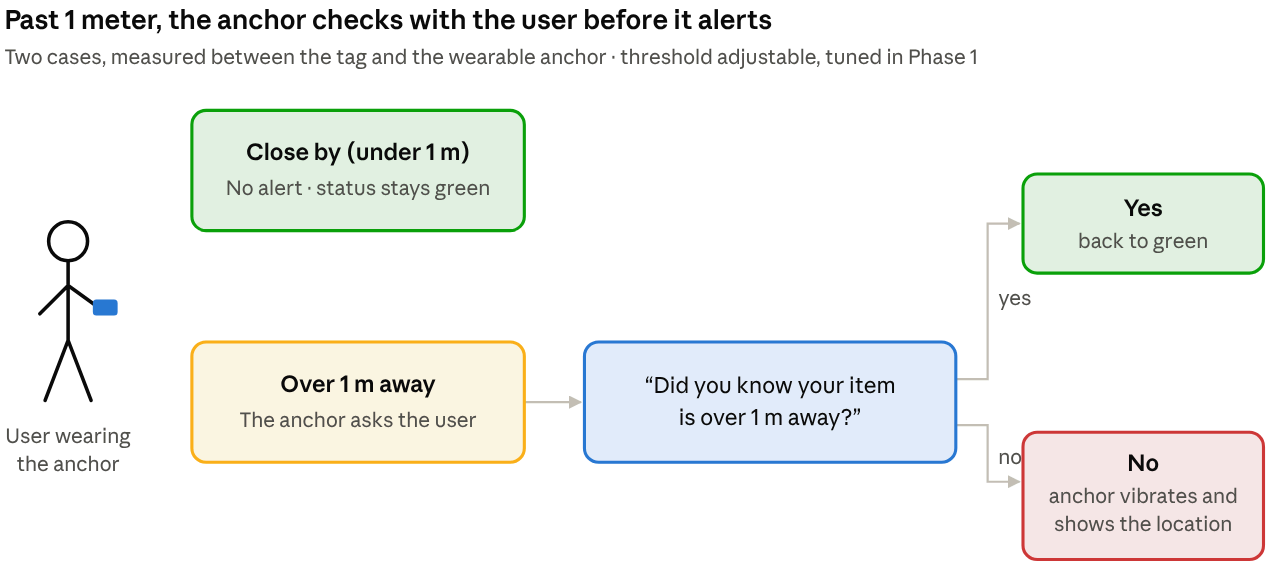


Figure 4. The two cases measured between the tag and the wearable anchor: close by, or more than 1 m away and checked with the user

Accessibility profiles. At setup the user chooses a profile rather than a list of settings. *Blind or low vision:* spoken alerts with distance and direction words, plus a distinct vibration rhythm. *Deaf or hard of hearing:* strong vibration patterns and a bright flashing LED ring, never sound alone. *Mobility impairment:* all channels, plus an automatic message to a trusted contact, because following the item is not an option.

Safety-first recovery. The device never guides the user toward a moving thief. Guidance mode ("your bag is six meters to your left") switches on only after the tag has stopped moving for a set period — for example, when an offender drops the item. While the tag is still moving, the anchor's only instructions are to stay put and that help has been notified. Every event is time-stamped so the user, or a caregiver, can file a police report, addressing the under-reporting documented in Section 1.1.

> **Design rule #1: help, not a chase.** While the bag is moving, SafeTether says only *stay where you are — help is coming*. It guides the user to the item only after the item has stopped.

Misuse protection. A small tracker can be abused to follow a person. SafeTether's pilot tag reports only to its own paired anchor over short range and does not use any crowd-sourced location network, and any later networked version would follow the cross-platform unwanted-tracking specification developed by Apple and Google (Apple, 2026).

The contribution worth defending is not the gadget — gadgets are engineering — but the empirical question in Section 4: whether a phone-independent, multimodal, theft-oriented design measurably shortens time to awareness and improves safe responses for users with disabilities, relative to a loss-oriented smartphone tracker. Before any such claim, Section 7.1 validates detection accuracy against recorded ground truth.

This research does not claim SafeTether replaces AirTag. AirTag's Find My network locates items across cities, which SafeTether's short-range pilot cannot do; the two are complementary, and a user could carry both. The claim under test is narrower: in the seconds during and after a theft from a person with a sensory or mobility impairment, a dedicated wearable alert outperforms a phone notification.

Figure 5 shows the hardware as an exploded product view: the tag's five layers, and the anchor's four accessible outputs.

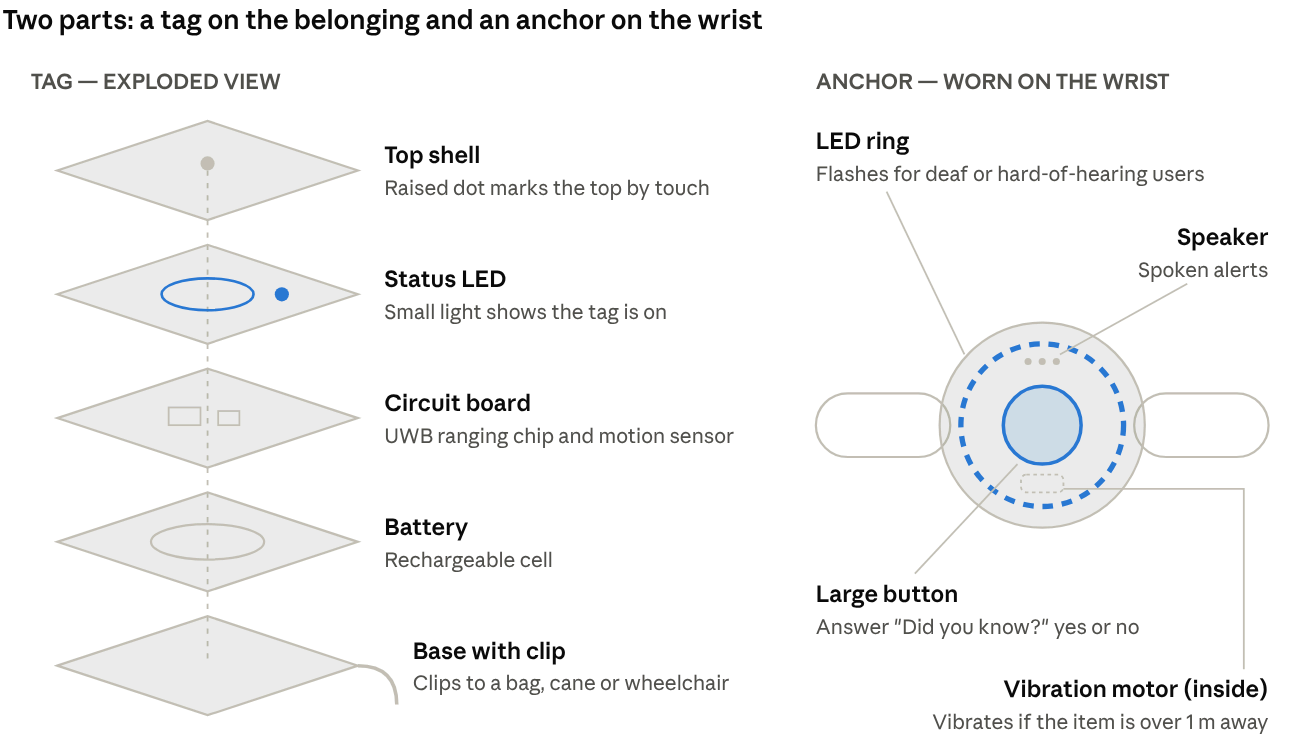


Figure 5. Exploded view of the SafeTether tag (left) and the wearable anchor with its accessible outputs (right)

Figure 6 traces the same system through a participant's experience of the scenario from Section 1: clipping on the tag, the moment of theft, the alert, and the safe recovery.

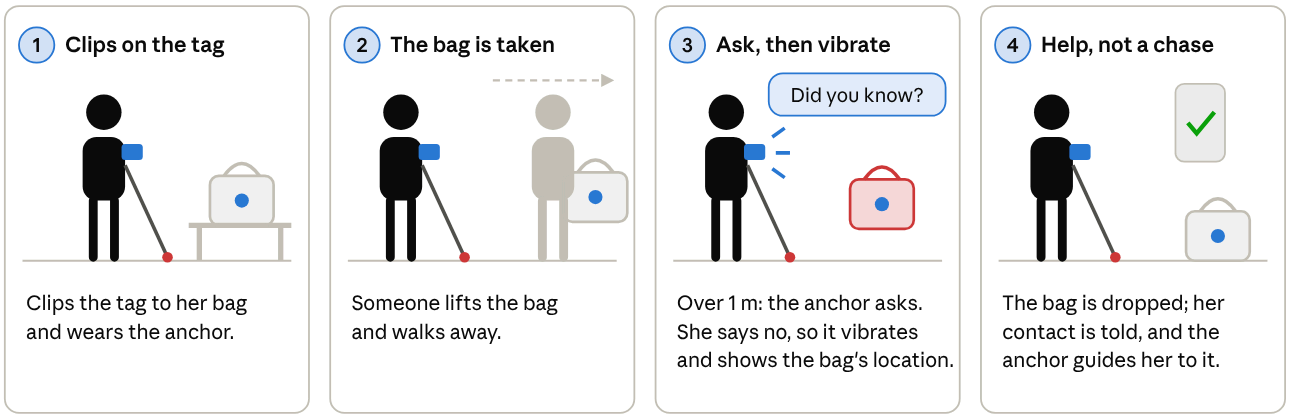


Figure 6. Day-in-the-life illustration of SafeTether: a blind user at a bus stop, from clipping on the tag to recovering a dropped bag

6.1 Ranging Hardware: Why Ultra-Wideband, Not GPS

SafeTether measures distance with an Ultra-Wideband (UWB) module, the Makerfabs MaUWB_ESP32S3 (model MAUWBS3CA1), because UWB keeps working inside closed rooms, where GPS does not (Table 3, Figures 7–9).

What the team observed. During early prototyping, the team tested a GPS module for locating the tagged item. It worked outdoors but lost its satellite fix whenever it was carried into a closed room. This is a known property of satellite positioning rather than a fault of one module. GPS signals are already extremely weak when they reach the ground, and building materials weaken them further: concrete by 12–43 dB and reinforced concrete by 29–33 dB at GPS frequencies (Eissfeller et al., 2006, as cited in Schwieger, 2008). In windowless rooms and cellars no GPS signal is received at all (Schwieger, 2008), and common GPS receivers do not work indoors (Nirjon et al., 2014). Even under open sky, a GPS-enabled smartphone is typically accurate only to within about 4.9 m (GPS.gov, n.d.), almost five times SafeTether's 1 m threshold.

Why UWB solves the problem. UWB does not depend on satellites. The tag and the anchor exchange very short radio pulses and convert their travel time into distance (two-way ranging), so the measurement depends only on the link between the two devices, indoors or outdoors. A review of indoor positioning technologies identifies UWB as one that has proven effective indoors (Alarifi et al., 2016). The selected module pairs a DW3000 UWB chip and power amplifier with an ESP32-S3 microcontroller that also provides Wi-Fi and Bluetooth 5. Its maker specifies a range of up to 500 m, a precision of 0.5 m within 100 m, and about 10 cm after antenna-delay calibration (Makerfabs, 2026).

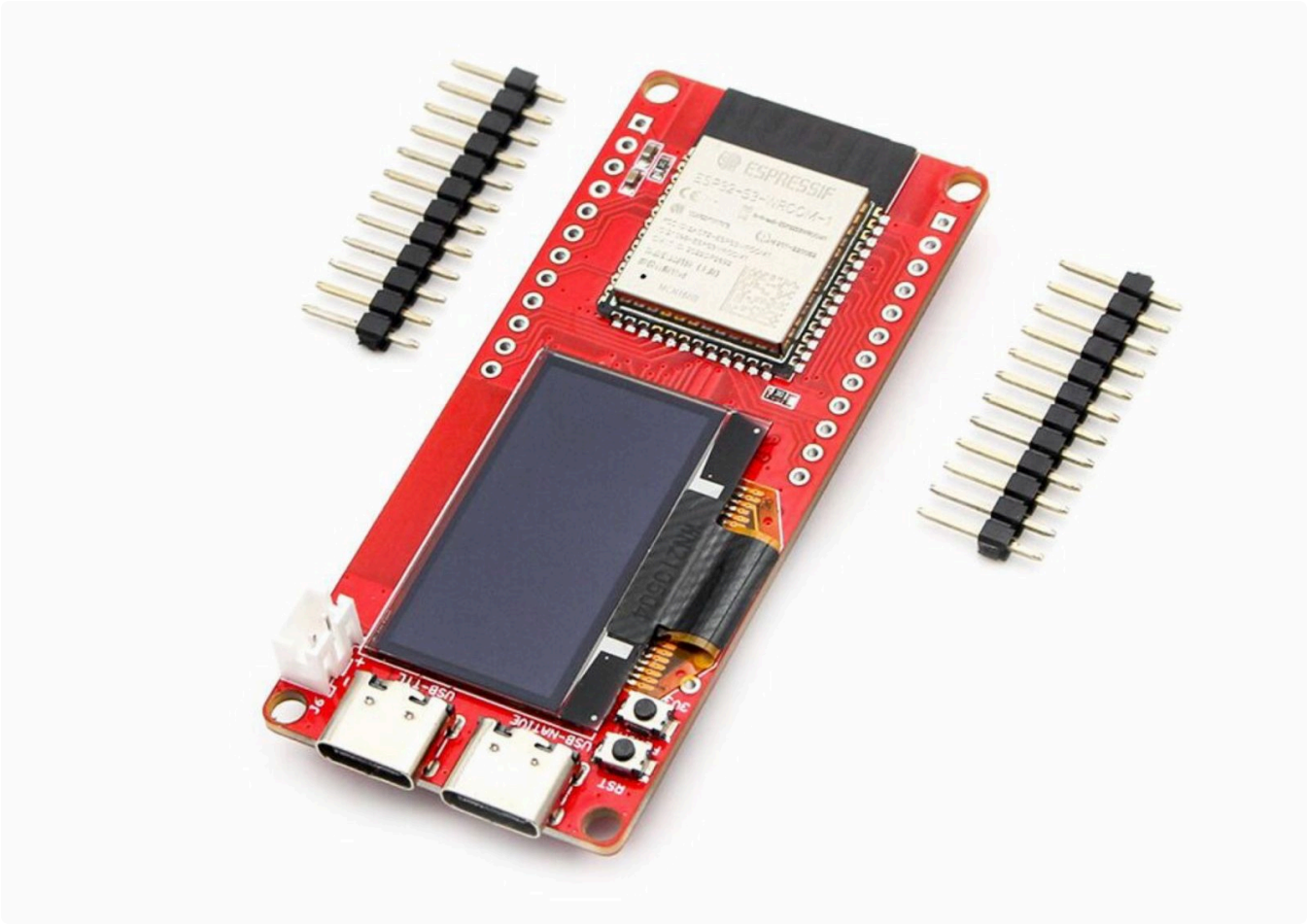


Figure 7. The Makerfabs MaUWB_ESP32S3 module (model MAUWBS3CA1) selected for SafeTether's ranging: an ESP32-S3 controller and a DW3000 Ultra-Wideband radio on one board. Photo: Makerfabs.

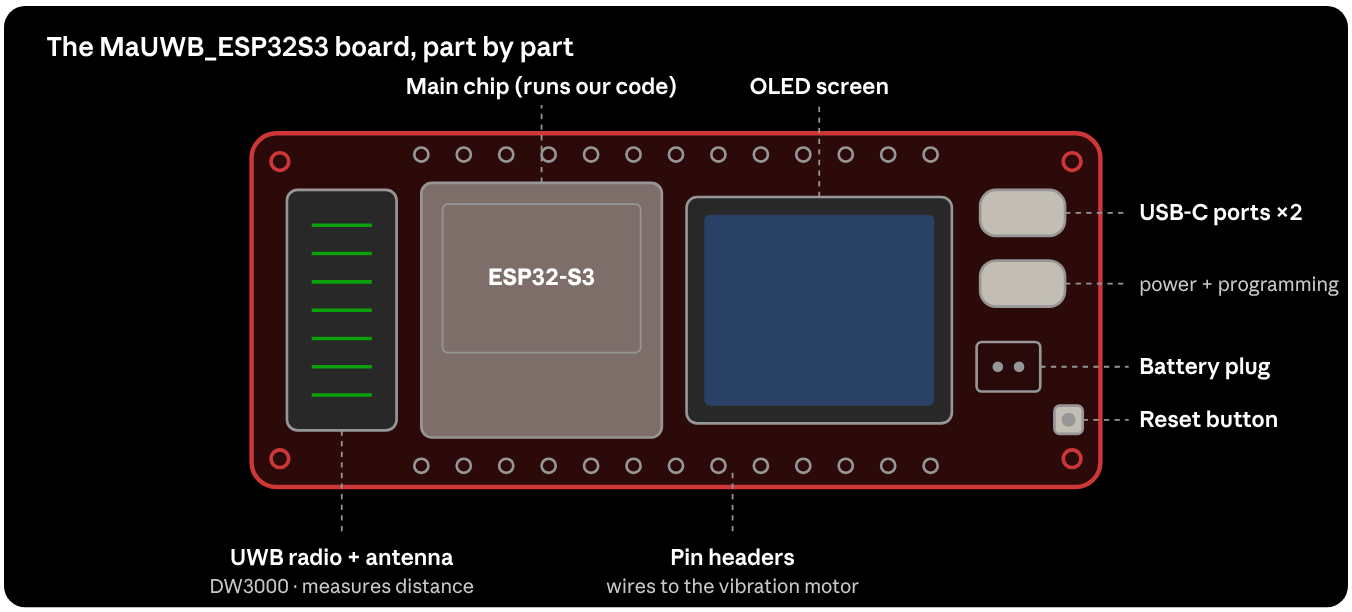


Figure 8. The MaUWB_ESP32S3 board, part by part: the DW3000 UWB radio and antenna, the ESP32-S3 main chip that runs SafeTether's code, the OLED screen, two USB-C ports, the battery plug, the reset button, and the pin headers

Property	GPS (smartphone-grade receiver)	UWB (MaUWB_ESP32S3)
Works inside a closed room	No: loses its satellite fix (team's tests; Nirjon et al., 2014)	Yes: tag and anchor range each other directly
Typical accuracy	About 4.9 m under open sky; worse near buildings	About 10 cm after calibration; 0.5 m within 100 m
What it measures	The item's position on a map, from satellites	The distance between the item and its owner
What it needs	A clear view of the sky	Only the tag and the anchor
Range	Worldwide, outdoors	Up to 500 m (maker's specification)
Fits the 1 m threshold	No: its error is about five times the threshold	Yes: its error is far below the threshold

Table 3. GPS and UWB compared on the properties SafeTether depends on.

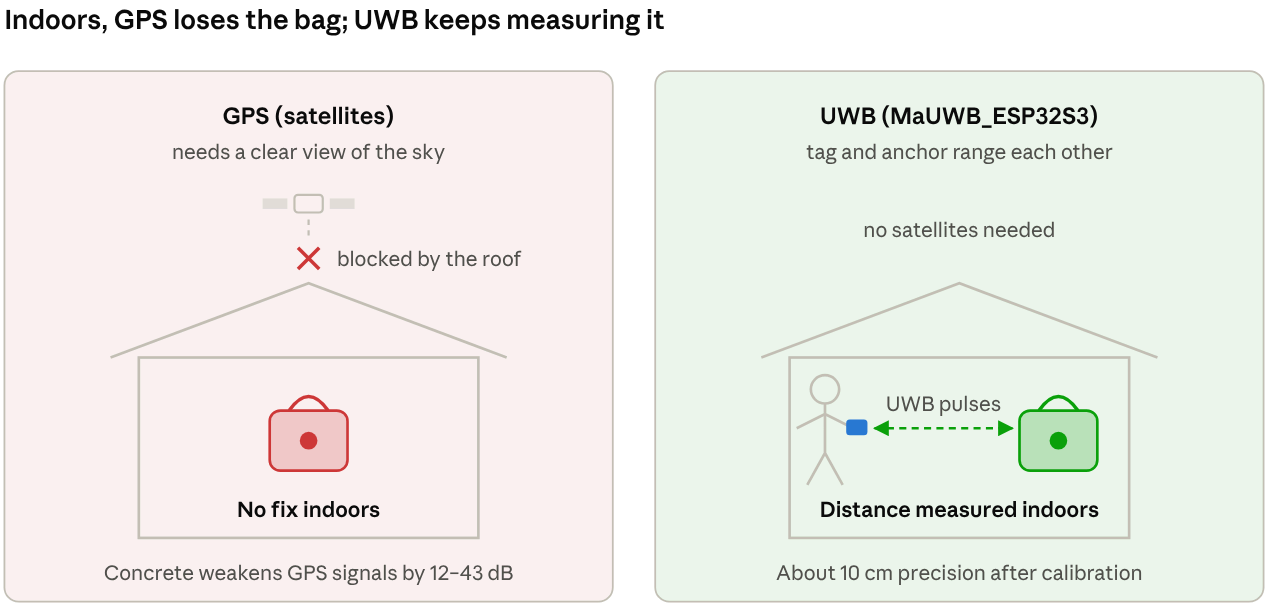


Figure 9. Inside a closed room a GPS receiver loses its satellite fix, while the UWB tag and anchor keep measuring the distance between them

> **The chip's advantage in one line.** GPS loses a bag the moment it is carried indoors; the MaUWB module keeps measuring how far the bag is from its owner in any room, to within about 10 cm once calibrated.

What UWB does not do. UWB is a short-range link, not a city-wide tracker: once the bag is several hundred meters away, the anchor loses it. That is consistent with the design, because SafeTether's job is the first seconds of a theft and it never guides the user after a moving thief; wide-area recovery remains with AirTag's Find My network and the police (Section 6). People, walls and furniture that block the direct path between tag and anchor add ranging error, so Phase 1 stages half of its separations in closed rooms and measures indoor accuracy rather than assuming it (Section 7.1). Finally, the development module costs $54.80 per unit and a system needs two, so the prototype costs more than the $29 retail target in Section 8.1; a production version would use the bare UWB chip rather than a development board.

6.2 Prototype Circuit and Firmware

Both halves of the prototype run on the same MaUWB_ESP32S3 board; what makes one a tag and the other an anchor is a single configuration setting and the parts wired to it (Figure 10).

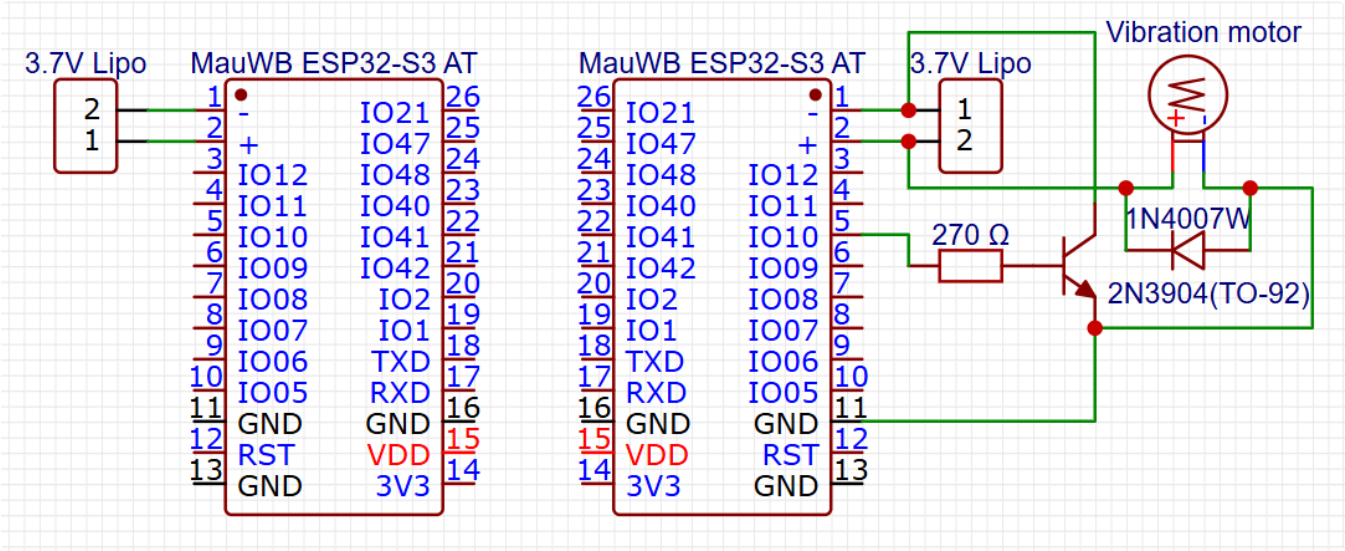


Figure 10. Circuit of the current SafeTether prototype: the tag (left) and the anchor with its vibration motor (right), each a MaUWB_ESP32S3 board powered by its own 3.7 V LiPo cell.

Figures 11–13 show the prototype being built and tested in practice.

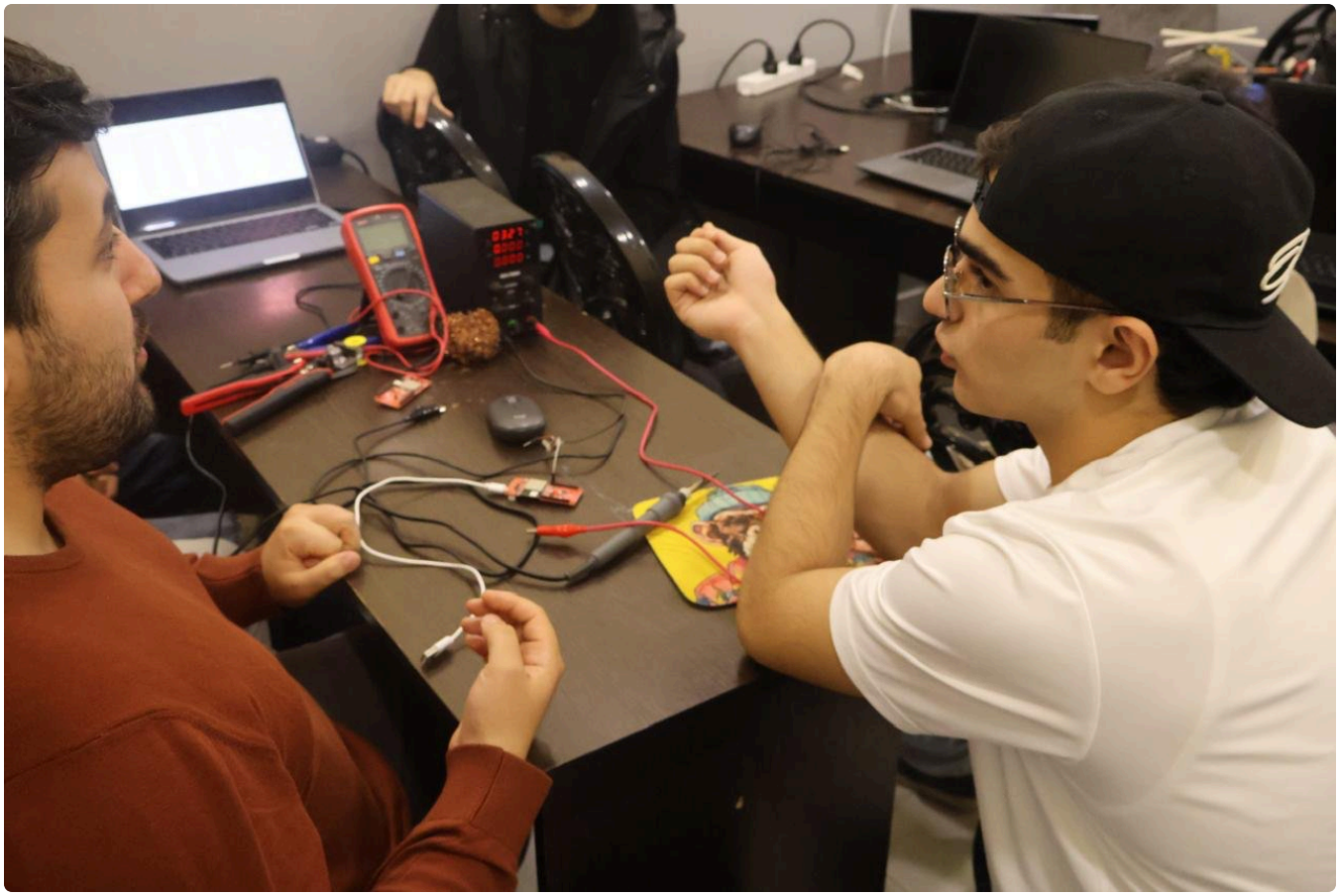


Figure 11. Founder Habib Guliyev and mentor Tural Suleymanov testing the SafeTether prototype boards with a bench power supply and multimeter.



Figure 12. Checking ranging results from the UWB prototype on a laptop during a work session.



Figure 13. SafeTether team work session.

Power. Each board runs from a 3.7 V lithium-polymer (LiPo) cell connected to battery pins 1 and 2, within the module's 3.4–4.2 V battery range. The tag draws about 34 mA while ranging and as little as 35 µA in deep sleep (Makerfabs, n.d.), so the firmware can let it sleep while the item rests and wake it when the accelerometer senses movement.

Tag (left). The board and its battery alone: it answers the anchor's ranging requests and needs no other parts.

Anchor (right). The anchor adds the vibration alert, the one channel every accessibility profile shares (Section 6). Pin IO10 switches a 2N3904 NPN transistor through a 270 Ω base resistor; the transistor connects the motor to ground, and a 1N4007W diode across the motor absorbs the voltage spike the motor produces when it switches off, protecting the transistor. The speaker, LED ring and button shown in Figure 5 are added to the same boards in later builds; this circuit is the minimum that already turns a distance reading into an alert the user can feel.

Firmware. Each module carries a pre-programmed STM32 controller that drives the DW3000 radio and assigns time slots so that several tags and anchors do not interfere, then reports every result to the ESP32-S3 over a serial (UART) link at 115,200 baud

(Makerfabs, n.d.). SafeTether's own code therefore runs only on the ESP32-S3: Arduino sketches written in C++ and built in the Arduino IDE with the "ESP32S3 Dev Module" board setting, which configure the radio with plain-text AT commands and read back distances. Four commands cover the prototype:

- `AT+SETCFG` sets each board's ID, its role (0 = tag, 1 = anchor), its data rate (850 kbps or 6.8 Mbps) and whether the module filters its range readings.
- `AT+SETCAP` sets how many tags the system serves (up to 64) and the length of each time slot, which fixes how often distance is updated: up to 100 times a second, so even a tenth of that rate gives the anchor dozens of readings inside the 3-second detection gate (Section 7.1).
- `AT+DATA` sends up to 32 bytes between the boards over the same UWB link, so the tag can tell the anchor that its accelerometer has sensed a grab.
- `AT+SAVE` and `AT+RESTART` store the settings and restart the module.

The radio follows the IEEE 802.15.4-2011 UWB standard on channel 5 (6489.6 MHz) and is designed to resist multipath fading, the reflections off walls and furniture that distort indoor signals (Makerfabs, n.d.). Makerfabs publishes example tag and anchor sketches, and SafeTether's own sketches are released with the rest of the design (Sections 6.3 and 7.7).

6.3 Live Dashboard and Open Code

Figure 14 shows the two boards of the current prototype. The A0 anchor stays with the user and carries the vibration motor; the T0 tag is attached to the item. More items are tracked by adding further tags (T1, T2, and so on); the firmware is configured for up to 64 tags.

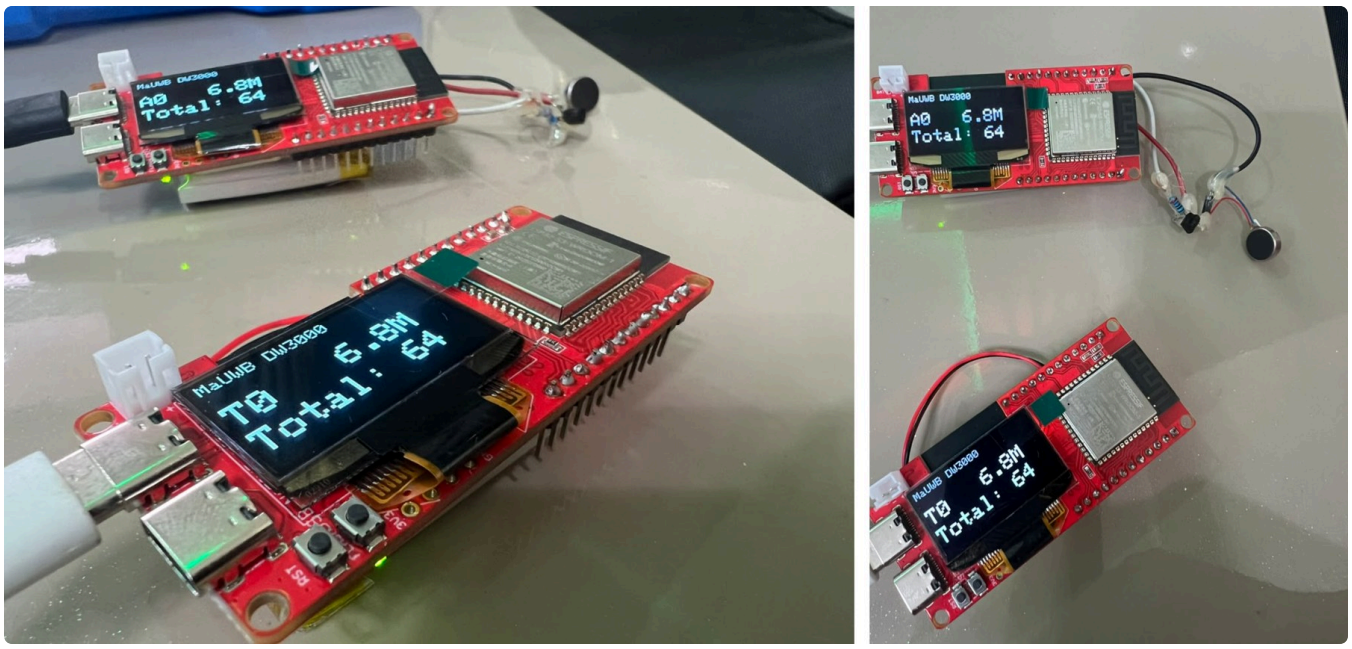


Figure 14. The current prototype from two angles: the A0 anchor with its vibration motor (top) and the T0 tag (bottom), each a MaUWB_ESP32S3 board.

The T0 tag reads each AT+RANGE report from the UWB module and writes the distance to a Firebase Realtime Database whenever it changes. A web dashboard reads that value and shows it live against the 100 cm safety limit: green below the limit, red above it, with the incident logged (Figure 15). Access is restricted through Firebase Authentication: a viewer needs either an approved account or the public demo account (email habibguliyevv@gmail.com, password inthewaytothestates983), which lets any reader view the dashboard without requesting access. When the boards are switched off, the dashboard shows "No connection".

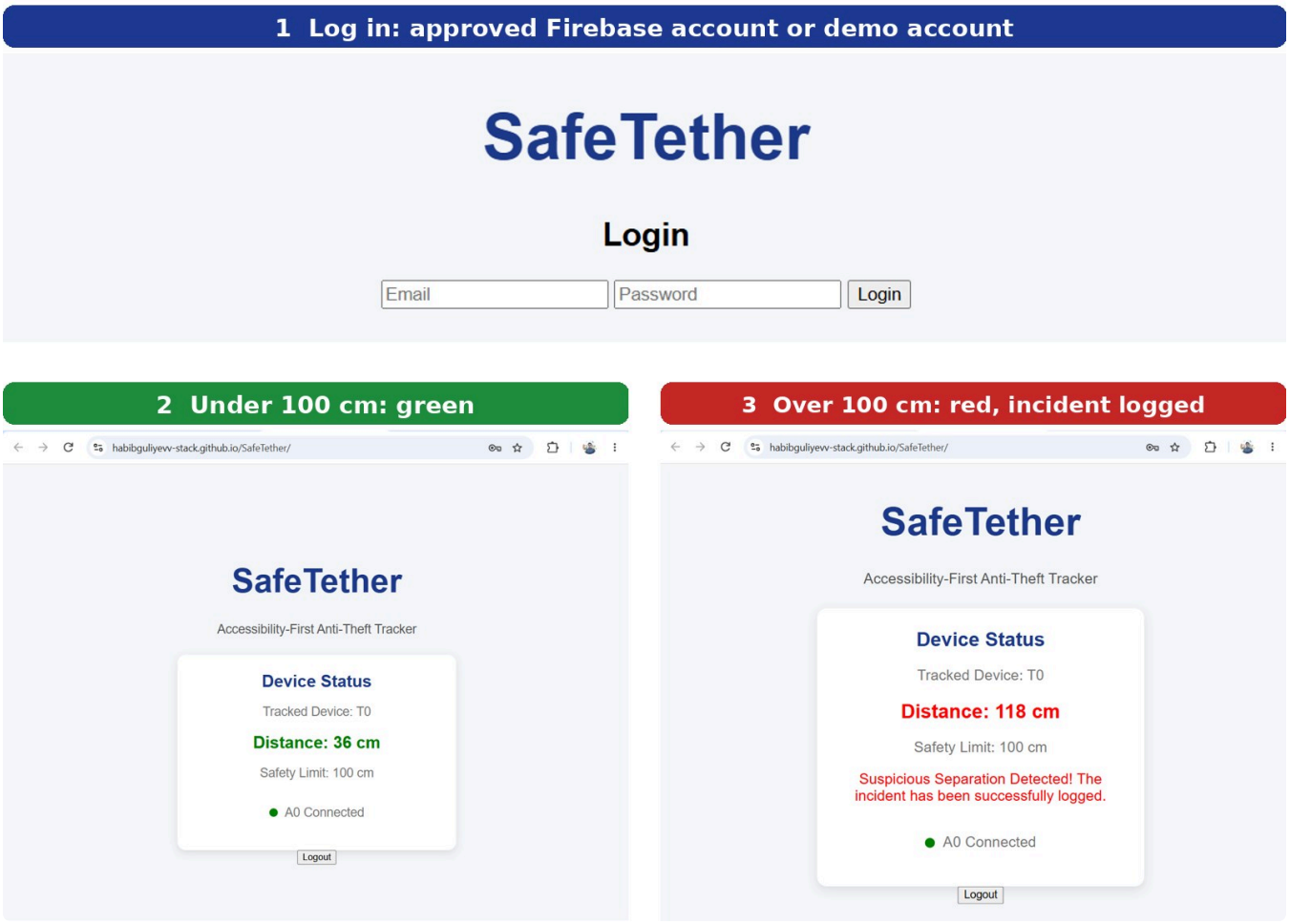


Figure 15. The SafeTether web dashboard: (1) login; (2) a tracked item at 36 cm, under the limit; (3) an item at 118 cm, over the limit, with the incident logged.

Figure 16 shows the main loop of each firmware sketch. The tag's sketch (esp32s3_at_t0.ino) extracts the distance and uploads it; the anchor's sketch (esp32s3_at_a0.ino) relays the UWB module's messages.

T0 tag (on the item)

File Edit Sketch Tools Help

ESP32S3 Dev Module

esp32s3_at_t0.ino

```
void loop()
{

    // put your main code here, to run repeatedly:
    while (SERIAL_LOG.available() > 0)
    {
        SERIAL_AT.write(SERIAL_LOG.read());
        yield();
    }
    while (SERIAL_AT.available() > 0)
    {
        char c = SERIAL_AT.read();

        if (c == '\r')
            continue;
        else if (c == '\n' || c == '\r')
        {
            SERIAL_LOG.println(response);

            response = "";
        }
        else
            response += c;

        if (response.startsWith("AT+RANGE"))
        {
            int start = response.indexOf("range:(");

            if (start != -1)
            {
                start += 7;

                int end = response.indexOf(",", start);

                if (end != -1)
                {
                    distance = response.substring(start, end).toInt();
                    if (distance != lastSentDistance && Firebase.ready()) {
                    if (Firebase.RTDB.setInt(&fbdo, "/distance", distance)) {
                        lastSentDistance = distance;
                        SERIAL_LOG.println("Firebase updated!");
                    }
                }
                    SERIAL_LOG.print("Distance: ");
                    SERIAL_LOG.println(distance);
                }
            }
        }
    }
}
```

A0 anchor (with the user)

File Edit Sketch Tools Help

ESP32S3 Dev Module

esp32s3_at_a0.ino

```
//String rec_head = "AT+RANGE";

void loop()
{

    // put your main code here, to run repeatedly:
    while (SERIAL_LOG.available() > 0)
    {
        SERIAL_AT.write(SERIAL_LOG.read());
        yield();
    }
    while (SERIAL_AT.available() > 0)
    {
        char c = SERIAL_AT.read();

        if (c == '\r')
            continue;
        else if (c == '\n' || c == '\r')
        {
            SERIAL_LOG.println(response);

            response = "";
        }
        else
            response += c;
    }
}
```

Output

Figure 16. Main loop of the T0 tag firmware (left) and the A0 anchor firmware (right), written in C++ in the Arduino IDE.

The firmware, dashboard, and documentation are available at github.com/habibguliyevv-stack/SafeTether, and the live dashboard runs at habibguliyevv-stack.github.io/SafeTether.

7. Method

The study proceeds in two phases, summarized in Figure 17. Phase 1 establishes, independently of any user study, whether the prototype detects separations accurately and stays quiet when nothing is wrong. Only if a pre-specified threshold is met does Phase 2 test whether SafeTether changes awareness, response, workload, or usability relative to AirTag — directly addressing the risk (Section 8) that a device which cries wolf, or misses real thefts, could make a user less safe than no device at all.

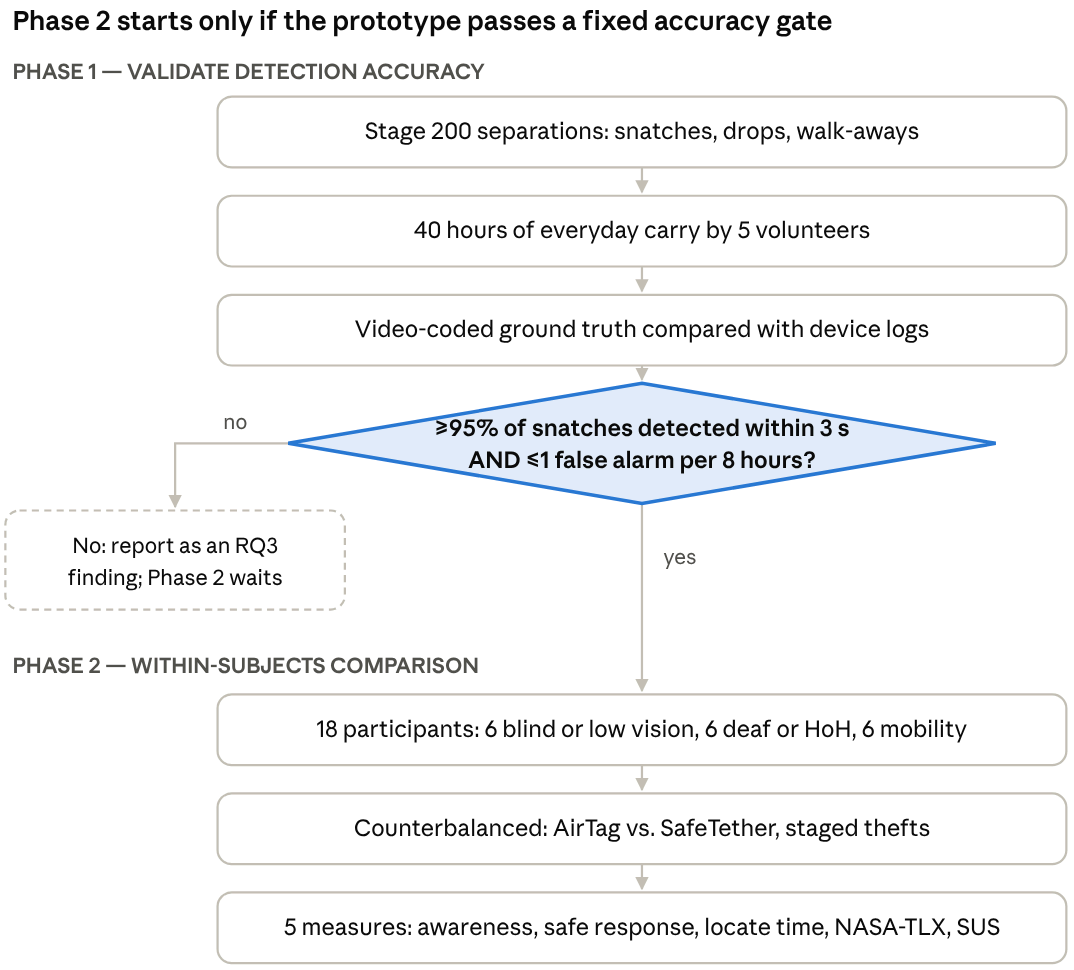


Figure 17. Two-phase study design: Phase 1 validates detection accuracy before Phase 2 tests user benefit

7.1 Phase 1: Validation of Detection Accuracy

Two hundred separations will be staged with the prototype, stratified across three types: *snatches* (a researcher grabs the tagged item and walks or runs away), *drops* (the item falls and stays still), and *walk-aways* (the owner leaves the item behind), split evenly between outdoor settings and closed rooms so that indoor detection is measured rather than assumed. Each trial is video-recorded with a synchronized clock, and two independent coders, blind to the device log, mark the exact moment of separation. Detection latency is the time from that moment to the anchor's first alert. In addition, five volunteers will carry the system through 40 hours of ordinary activity — commuting, shopping, sitting in cafes — to count false alarms, defined as any over-1-m alert with no real separation.

Two coders rather than one are used because a single coder's timing cannot be distinguished from that coder's bias or reaction speed; agreement on separation timestamps is reported as an intraclass correlation, and disagreements larger than 0.5 seconds are resolved by a third coder rather than by averaging, so that a real disagreement is never silently split down the middle.

Pre-specified gate: Phase 2 proceeds only if at least 95% of staged snatches are detected within 3 seconds AND there is no more than one false alarm per 8 hours of everyday carry. The threshold is asymmetric because the two error types carry different costs. A missed theft fails the user once; frequent false alarms teach the user to ignore the device, which fails them every time after. If the gate is unmet, the result is reported as a standalone RQ3 finding, the thresholds are re-tuned, and Phase 1 is repeated before any participant is recruited. This rule is fixed in advance, before any trial is run, to prevent quietly lowering the bar after seeing the data.

7.2 Phase 2: Participants

Eighteen adults will be recruited through disability organizations and local associations for blind, deaf, and physically disabled people: six who are blind or have low vision, six who are deaf or hard of hearing, and six with mobility impairments who use a wheelchair, walker, or crutches. Equal groups let the study report results for each group rather than hiding differences in an average. Per the power analysis in Section 7.6, this size is sufficient only to detect large effects.

7.3 Study Design and Procedure

The study uses a within-subjects design in a controlled outdoor setting such as a mock bus stop on a closed campus courtyard. Each participant completes the same set of staged scenarios twice, once with each device, in counterbalanced order with different scenario orders. Participants are told in advance that at some point an item will be taken by a member of the research team, but not when; the "thief" is always a trained researcher, the item is a study bag, and a safety marshal is present throughout.

Comparator fairness. In the AirTag condition, participants use a second-generation AirTag with Notify When Left Behind enabled, on an iPhone configured with the accessibility settings they normally use (VoiceOver, vibration, LED flash for alerts). In the SafeTether condition, they use the profile matching their disability. Both devices are set up by the participant with the researcher's help before trials begin, and setup time is recorded separately rather than counted against either device. Screen-reader experience, phone familiarity, and age are recorded as covariates.

Confounding. SafeTether bundles several changes at once — a wearable instead of a phone, multimodal alerts, a check-in question at one meter, and faster detection logic — so a better score would not by itself show which feature drove it. This pilot evaluates the combined intervention; a follow-up with a third condition (SafeTether without the check-in question, or AirTag with a separate wearable) is noted as future work.

7.4 Independent Variable

The independent variable is the tracking system, with two levels:

1. Apple AirTag, 2nd generation, with an iPhone (baseline condition).
2. SafeTether tag with wearable anchor (treatment condition).

7.5 Dependent Variables

Dependent variable	Operational definition	How it is measured
Time to awareness	Seconds from the item leaving the participant's reach to the participant signaling "my bag"	Video-coded per trial by two blinded coders
Correct safe response	Share of trials in which the participant chooses a safe action (stay, call for help, notify contact) rather than pursuing	Coded per trial against a predefined rubric
Time to locate a dropped item	Seconds from the item being dropped to the participant touching it, in drop scenarios only	Researcher-timed per trial
Workload	Perceived mental demand, effort, and frustration of the scenario	NASA-TLX (Hart and Staveland, 1988), after each trial
Usability	Perceived ease of use and satisfaction with the system	System Usability Scale (Brooke, 1996), after each condition

Table 4. Dependent variables, their operational definitions, and how each is measured.

7.6 Statistical Analysis

The primary analysis will use linear mixed-effects models with participant and scenario as random effects and disability group as a fixed effect, so that the study can show whether the benefit differs between groups. Paired t-tests, or Wilcoxon signed-rank tests where normality is violated, will be reported as a secondary check, with effect sizes as Cohen's d. Because five dependent variables are tested across the same two conditions, p-values will be adjusted with the Holm–Bonferroni correction, specified in the preregistration rather than applied after the fact.

An a priori power analysis (G*Power, paired design, $\alpha = .05$, 80% power) shows that $n = 18$ can detect only large within-subject effects ($d \geq 0.7$) across the full sample, and that per-group results ($n = 6$) are descriptive only. The study is framed accordingly as a pilot for identifying large, practically meaningful effects. Each participant's paired outcomes will be reported, not only group averages, and the full analysis plan — including the Phase 1 gate — will be preregistered (for example on the Open Science Framework) before Phase 2 begins. A halving of median time to awareness is set in advance as the threshold for a practically meaningful finding.

7.7 Reproducibility and Implementation Transparency

The prototype's circuit diagram, parts list, firmware version, detection thresholds, and alert recordings are published openly on GitHub (Section 6.3), so that another amateur team can rebuild the device for roughly the cost of its parts. Implementation failures — thresholds that had to be re-tuned, batteries that ran down, alerts participants misunderstood — will be reported alongside successes, so that the record reflects what was actually built and tested rather than only its final form.

8. Anticipated Limitations and Reader Questions

Phase 1 (Section 7.1) is designed to catch the most serious technical failure modes before Phase 2 begins; the rest are addressed through the design choices below. Table 5 summarizes each risk and how it is addressed, and Section 8.1 answers the questions a reader is most likely to raise.

Anticipated risk	Why it matters	How the design addresses it
Missed snatch	The user is not warned at the one moment the device exists for	Phase 1 gate requires at least 95% of snatches detected within 3 seconds (Section 7.1)
False alarms	Repeated false alarms teach users to ignore every alert	Phase 1 gate allows at most one false alarm per 8 hours; the user is asked first and can dismiss an alert with one answer (Sections 6, 7.1)
User pursues the thief	Confrontation has proved fatal even for owners without disabilities (KGET 17 News, n.d.)	Guidance to the item activates only once the tag has stopped moving; "correct safe response" is a measured outcome (Sections 6, 7.5)
Misuse for stalking	A small tracker can be hidden on a person	Short-range, paired-only pilot with no crowd-sourced location network; any networked version follows the Apple–Google unwanted-tracking specification (Section 6)
Battery runs down silently	The user believes they are protected when they are not	Low-battery warning in the user's alert channel, daily self-test cue
UWB ranging degrades without a direct line of sight	Bodies, walls and crowds can block the direct path and add error	The device checks one threshold, not exact meters; Phase 1 stages half its separations indoors and tunes the threshold (Sections 6.1, 7.1)
Results may not generalize	Eighteen participants in a staged setting cannot represent real streets	Explicitly scoped as a pilot; limits stated up front (Sections 1, 10)

Table 5. Anticipated risks of SafeTether and how the study design addresses each.

8.1 Questions a Reader Is Likely to Ask

Why not simply use an AirTag? AirTag is excellent at finding lost items anywhere its owner's phone network reaches, and this paper treats it as the benchmark, not the opponent. But it depends on an iPhone, its separation alerts are designed for leaving an item behind, and its warnings arrive as phone notifications (Apple, n.d.). SafeTether is aimed at the narrower case AirTag was not designed for: the first seconds of a theft from someone who may not see, hear, or follow it.

Why Ultra-Wideband rather than GPS? Ordinary GPS receivers lose their fix inside buildings, and even outdoors a phone's GPS is accurate only to about 4.9 m, almost five times the 1 m threshold. UWB measures the distance between tag and anchor directly, indoors or outdoors, to well under a meter, which is what the 1 m check needs; Phase 1 tests this before any user relies on it (Section 6.1).

Why not build a phone app instead of a wearable? Because the phone can itself be the item that is stolen, because not every user with a disability owns or can easily operate a recent smartphone, and because an alert that requires unlocking a screen is too slow at the moment of a snatch.

Could criminals or abusers use SafeTether to track people? The pilot tag can only talk to its own paired anchor within UWB range, a few hundred meters at most, so it cannot follow anyone across a city. Any future version that joins a wide-area network would adopt the industry's cross-platform unwanted-tracking alerts.

Is this affordable for the people it is meant for? The prototype uses hobbyist components and an open design so that it can be rebuilt cheaply; the target is a retail price no higher than a single AirTag ($29), with no subscription.

9. Ethical Considerations

This study involves human participants from a population that is both protected and, in research contexts, historically under-consulted about technology built for its benefit. It also stages thefts, which can be frightening. The study protocol will include:

- Informed consent in an accessible format — screen-reader-compatible digital forms, large print, sign-language interpretation for deaf participants, and a verbal walkthrough option.

- Advance warning that an item will be taken during the session, without the exact time; participants may stop any trial or the whole session at any moment without giving a reason.
- A trained safety marshal at every session, study-owned bags only (never personal belongings), and a full debrief after the last trial.
- Accessibility accommodations for the sessions themselves, including step-free access, flexible scheduling, and travel support.
- Anonymization of video recordings before analysis, with faces blurred in any published material.
- Institutional Review Board (IRB) or ethics committee approval before recruitment, including review of the staged-theft protocol, distress procedures, and data-management plan.

Recruitment will proceed only after a faculty research supervisor is secured and full ethics approval is obtained, including review of partnerships with disability organizations and a participant compensation plan; no participant will be recruited and no data collected before that approval is in place. People with disabilities will be invited to review the device and the protocol before the study begins, in line with the principle that research about them should be designed with them.

10. Limitations

Beyond the risks in Section 8, five broader constraints bear on interpretation:

- **Sample size.** Eighteen participants, six per group, constrain statistical power to large effects; findings indicate feasibility and direction, not a population-level claim. Recruitment through disability organizations may favor more confident, better-connected participants.
- **Staged scenarios.** A participant who knows a theft is coming is more alert than one surprised on a real street, which may shrink the difference between devices; real-world effectiveness requires a longer field study.
- **Single session.** Effects of sustained use — learning, habituation, battery discipline — fall outside this design.
- **Scope of disabilities.** Cognitive disabilities, which have the highest victimization rate (Harrell, 2021), are not included in this pilot because they require a different consent process and alert design; they are a priority for future work.

- **Combined intervention.** Because the wearable, the alerts, the check-in question and the detection logic change together (Section 7.3), the study cannot attribute the outcome to any one feature.

11. Discussion: Broader Significance

Consumer tracking technology has become one of the more crowded and polished product categories, yet it has been designed almost entirely around a single user: a sighted, hearing, mobile smartphone owner who has misplaced something. The people most likely to be robbed sit at the edge of that design. Tools that translate the same underlying radio signals into speech, vibration and light are, on this view, closer to accessibility infrastructure than to gadgets — a motivation for this pilot rather than a claim it sets out to prove directly.

The proposal also sits at an intersection rarely worked directly. Victimization researchers have documented for over a decade that people with disabilities are targeted more often and report less often (Harrell, 2021; Hughes et al., 2012; Equality and Human Rights Commission, 2011), while consumer electronics companies have rapidly improved how precisely a lost object can be found (MacRumors, 2026). Connecting the two shifts the design question from "how do we find the bag tomorrow?" to "how do we make sure its owner knows, safely, right now?" If the pilot shows large effects, the next steps are a field study in real public spaces, an extension to users with cognitive disabilities, and a conversation with existing tracker makers about adopting accessible, phone-independent alerts — an outcome that would help far more people than any single start-up could reach.

12. Conclusion

This paper specifies, rather than gestures at, a two-phase pilot connecting distance-aware item tracking to accessible, phone-independent theft alerts for people with disabilities: first validating whether the prototype detects thefts accurately and quietly enough to trust, then testing whether it measurably shortens time to awareness and improves safe responses compared with Apple AirTag. It sits where two unresolved problems meet — a fivefold robbery gap and a generation of trackers built for someone else — and does not claim to solve either at scale. With a validation gate, an open and inexpensive prototype, and a modest but real sample of participants from three disability groups, it is tractable enough to make measurable, honestly bounded progress on both.

> **Bottom line.** People with disabilities are robbed five times as often, yet the tools sold to protect belongings were designed for someone else. SafeTether asks a simple, testable question: what if the alert reached the person it was meant for, through the sense they actually use, in time to matter?

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