

PetPin: Smart GPS and NFC Collar for Pets

PetPin: Collar inteligente con GPS y NFC para mascota

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Abstract


The PetPin project develops a smart collar for stray dogs at the Universidad Tecnológica Fidel Velázquez [UTFV], located in Nicolás Romero, State of Mexico. The area faces an overpopulation of dogs, which generates security, hygiene, and safety risks for both students and the animals. The collar integrates a GPS module [Quectel L86], an NFC chip [NTAG213], and an ESP32 microcontroller in an ergonomic design. It is supported by a mobile app built with Flutter-Dart and a Firebase database. The system enables real-time tracking, activated from the app, and allows any smartphone to scan the NFC tag to access the animal's data [ID, health status, caregiver]. All information is centralized in the cloud with a unique code for each animal. PetPin aims to reduce pet loss, improve animal welfare, and enhance safety on the campus and in the municipality. The solution is scalable for domestic pets or state-level programs. Preliminary tests show an NFC accuracy of 98%, GPS precision of <2.5 meters, and a battery life of over 48 hours.

Resumen

El proyecto PetPin desarrolla un collar inteligente para perros callejeros en la Universidad Tecnológica Fidel Velázquez [UTFV], ubicada en Nicolás Romero, Estado de México. La zona enfrenta una sobrepoblación canina, lo que genera riesgos de seguridad, higiene y protección tanto para los estudiantes como para los animales. El collar integra un módulo GPS [Quectel L86], un chip NFC [NTAG213] y un microcontrolador ESP32 en un diseño ergonómico. Se apoya en una aplicación móvil desarrollada con Flutter-Dart y una base de datos Firebase. El sistema permite el rastreo en tiempo real, que se activa desde la aplicación, y permite que cualquier teléfono inteligente escanee la etiqueta NFC para acceder a los datos del animal [identificación, estado de salud, cuidador]. Toda la información se centraliza en la nube con un código único para cada animal. PetPin busca reducir la pérdida de mascotas, mejorar el bienestar animal y fortalecer la seguridad en el campus y en el municipio. La solución es escalable para mascotas domésticas o programas a nivel estatal. Las pruebas preliminares muestran una precisión NFC del 98%, una precisión GPS de <2,5 metros y una duración de batería de más de 48 horas.

PetPin: Smart GPS and NFC Collar for Pets		
Objectives	Methodology	Contribution
Smart and affordable collar to track and identify pets in real-time.	System with ESP32, GPS, NFC, Flutter-Dart app, and Firebase for cloud data.	Scalable IoT solution for animal welfare and responsible ownership.
 <ul style="list-style-type: none"> • Collar Inteligente • Rastreo Instantáneo • Recuperación Económica 	 <ul style="list-style-type: none"> • ESP32 Integrado • Aplicación Flutter-Dart • Firebase Nube 	 <ul style="list-style-type: none"> • IoT Escalable • Bienestar Animal • Tenencia Responsable

Smart Collar, Tracking, Animal Welfare.

PetPin: Collar inteligente con GPS y NFC para mascota		
Objetivos	Metodología	Contribución
Collar inteligente y económico para rastrear e identificar mascotas en tiempo real.	Sistema con ESP32, GPS, NFC, app en Flutter-Dart y Firebase para datos en la nube.	Solución IoT escalable para bienestar animal y tenencia responsable.
 <ul style="list-style-type: none"> • Collar Inteligente • Rastreo Instantáneo • Recuperación Económica 	 <ul style="list-style-type: none"> • ESP32 Integrado • Aplicación Flutter-Dart • Firebase Nube 	 <ul style="list-style-type: none"> • Bienestar Animal • Tenencia Responsable

Collar Inteligente, Rastreo, Bienestar Animal

Area: Dissemination of and universal access to science

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Introduction

The proliferation of stray dogs at the Universidad Tecnológica Fidel Velázquez [UTFV] in Nicolás Romero, State of Mexico, represents a dual challenge: risks for the university community [accidents, hygiene] and for the animals [abandonment, overpopulation]. A survey of 50 students revealed that 85% have interacted with these dogs, and 15% fear for their safety. This problem persists in the municipality, with a high incidence of lost pets reported by local shelters. PetPin offers a smart collar with NFC and GPS, a mobile app [Flutter-Dart], and Firebase for rapid identification, tracking, and responsible management. It promotes a safe campus, animal welfare, and community outreach in Nicolás Romero.

Problem

At the UTFV and in the State of Mexico, stray dogs generate insecurity: potential bites, waste accumulation, and accidents in high-traffic areas. 85% of 50 surveyed students have encountered them on campus; 15% express concern about hygiene and risks. In the municipality, overpopulation aggravates the problems of lost pets and unnecessary euthanasia, with no organized systems in place. The institution recognizes the problem but lacks tools for real-time identification and tracking. This situation is gradually increasing the canine presence, and in the future, it could spiral out of control, exacerbating dangers for students, staff, and the animals.

Box 1

Survey conducted on 50 UTFV students

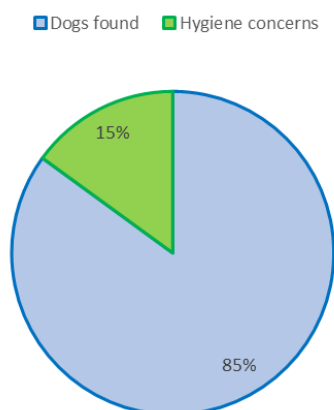


Figure 1

Graph of stray animals found

Main idea

Based on an integrated system, PetPin begins with the development of a mobile application in Flutter-Dart, designed to be intuitive and accessible for both students and the general public in Nicolás Romero. This app allows users to register stray dogs from the UTFV, scan the collar via NFC to obtain immediate information [name, health status, caregiver details], and activate real-time GPS tracking with a single tap. The application connects directly to Firebase, a cloud database that stores all animal profiles and their locations with a unique code per pet. From the app, users receive notifications if a dog leaves the campus and can share its live location with local shelters or authorities. All this is achieved without specialized equipment: any smartphone with NFC capability can read the collar, democratizing the identification and reunification of lost animals.

Once the app is validated, the process advances to the physical prototype of the smart collar. It is assembled with an ESP32 microcontroller, a Quectel L86 GPS module, and an NTAG213 NFC chip, all powered by a rechargeable LiPo battery. The assembly follows a clear diagram connecting the ESP32 pins to the GPS [via UART] and NFC [via I2C], ensuring a compact and comfortable design for the animal. Programming is done in the Arduino IDE: a sketch is loaded that configures the ESP32's Wi-Fi connection to automatically link to Firebase using its unique URL [for example: <https://petpin-utfv.firebaseio.com>]. The code continuously reads latitude and longitude coordinates from the GPS module and sends them to the real-time database only when the app requests it, optimizing battery consumption. Thus, the collar doesn't transmit constantly but "wakes up" on demand, achieving an autonomy of over 48 hours

Box 2



Figure 2

Canines at the university

Benefits and Expected Results

Improved Safety and Animal Management:

- **Real-Time Tracking:** The GPS, activated from the Flutter-Dart app, provides coordinates with <2.5-meter accuracy in under 30 seconds, preventing dogs from straying from the UTFV campus or getting lost in Nicolás Romero.
- **Efficient Identification:** NFC scanning instantly displays the animal's profile [name, health, caregiver] on any smartphone, speeding up reunification with shelters or owners without the need for special equipment.

Enhanced Overall Safety:

- **Reduced Risks:** GPS and NFC monitoring minimizes accidents on the UTFV campus and streets of Nicolás Romero; students can navigate areas with greater confidence.
- **Community Involvement:** Staff and students can quickly identify registered dogs, reducing incidents related to waste or aggressive behavior.

Operational Efficiency:

- **Centralized Data Management:** Firebase synchronizes profiles and locations in real-time, eliminating manual paperwork.
- **Battery Optimization:** The Arduino sketch sends latitude/longitude data only on demand via the ESP32's Wi-Fi, ensuring >48 hours of battery life.
- **Rapid Assembly:** The connection diagram [ESP32 → GPS via UART, NFC via I2C] allows each collar to be assembled in under 20 minutes.

Scalability:

- **Broader Application:** A unique Firebase link and reusable Arduino code facilitate replication on other campuses or municipalities.
- **Universal Compatibility:** The Flutter-Dart app works on Android/iOS; the collar's modular design [interchangeable battery, plug-and-play modules] adapts for cats, shelters, or state programs in the State of México.

Box 3

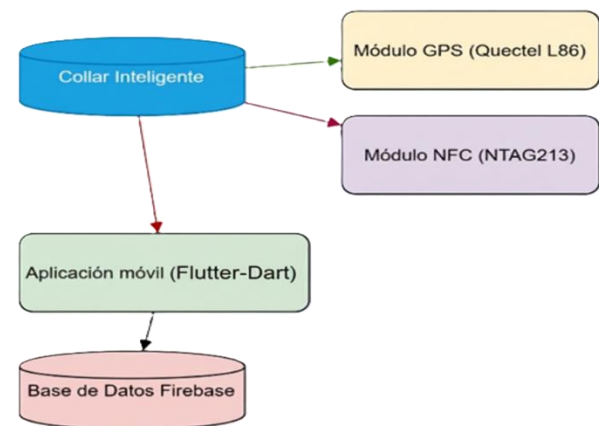


Figure 3

PetPin System Overview

Central Hypothesis

The implementation of a smart collar system combining NFC, GPS, and a mobile application connected to a Firebase database will significantly improve the identification and recovery process of stray animals on campus and externally compared to traditional methods, enhancing safety and management efficiency.

Methodology

System Design and Implementation using the Waterfall methodology.

Objective

To develop and implement a smart collar system for monitoring and managing stray dogs at UTFV, ensuring their safety and minimizing on-campus risks, while enabling scalable solutions for pet management in Nicolás Romero and the State of México.

Proposed Methodology [Waterfall – Sequential Phases]

- **Phase 1: Requirements** – Interviews with students, staff, shelters, and municipal authorities in Nicolás Romero to identify needs [safety, rapid identification, tracking].
- **Phase 2: Analysis** – Review of UTFV policies, state animal welfare regulations, and local reports on canine overpopulation.

- **Phase 3: Functional Definition** – Establish key capabilities: NFC reading, on-demand GPS activation, real-time synchronization with Firebase, and intuitive mobile interfaces.

System Design

Objective

To create a comprehensive design for PetPin, integrating hardware [smart collar] and software [mobile application and Firebase] to meet the requirements identified in the analysis phase.

System Architecture

- **Hardware Components:**
 - Smart Collar: Powered by an ESP32 microcontroller, Quectel L86 GPS module, NTAG213 NFC tag, and a rechargeable LiPo battery with a TP4056 charger.
 - Ergonomic Design: Lightweight, water-resistant, adjustable collar for medium-sized dogs, with assembly guided by a diagram [Lipo → TP4056 → ESP32 → GPS via UART,].

Box 4

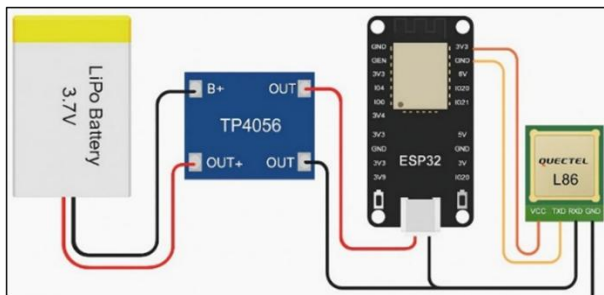


Figure 4

Smart collar prototype design

- **Software Components:**
 - Mobile Application: Developed with Flutter-Dart [Android/iOS compatibility], enabling NFC scanning, GPS tracking activation, and real-time data synchronization with Firebase.
 - Firebase Database: Stores animal profiles [unique ID, name, health status, caregiver, location history] with a unique link [<https://petpin-utfv.firebaseio.com>].

User Interface Design:

- Application Interface: Intuitive screens for registering dogs, scanning collars, activating GPS, and viewing live maps.
- Web Interface [Optional]: Administrative dashboard for UTFV or municipal authorities, providing access to reports and statistics on monitored dogs.

Implementation

Objective

To develop, assemble, and implement the PetPin system, ensuring seamless integration between hardware and software, with progressive validation from the application to the physical collar.

Software Development

- **Application Programming:** The application is created in Flutter-Dart [compatible with Android/iOS], implementing NFC reading, on-demand GPS tracking activation, and real-time synchronization with Firebase. The interface allows users to register dogs, scan the collar, and view live maps.
- **Firestore Configuration:** A database schema is designed to store animal profiles [unique ID, name, health status, caregiver] and coordinates, using the unique link <https://petpin-utfv.firebaseio.com>.
- **Web Interface [Optional]:** A basic HTML/CSS platform for UTFV or Nicolás Romero administrators to monitor real-time data.

Hardware Installation

- **Collar Assembly:** The ESP32 microcontroller, Quectel L86 GPS module, and NTAG213 NFC tag are integrated into an ergonomic collar, powered by a LiPo battery with a TP4056 charger. Assembly follows a clear diagram: ESP32 → GPS via UART, NFC via I2C.

Box 5

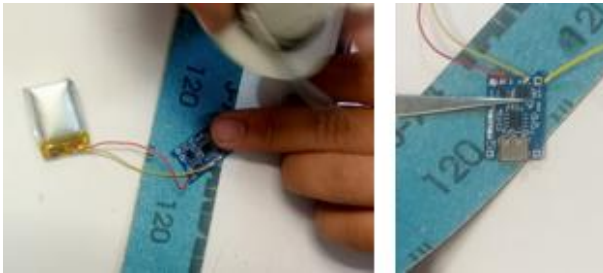


Figure 5

Assembly of the ESP32 and Battery

- **NFC Configuration:** NTAG213 tags are programmed with unique IDs linked to Firebase records.
- **GPS Configuration:** A sketch is loaded into the ESP32 via Arduino IDE that:
 - Automatically connects to Wi-Fi.
 - Reads latitude and longitude from the GPS module.
 - Sends coordinates to Firebase only when requested by the app, optimizing battery life.

Results and Discussion

- **Expected Results:** Fully functional Flutter-Dart mobile application, reliable smart collar prototype [assembled with UART/I2C diagram], and scalable Firebase database with unique link [<https://petpin-utfv.firebaseio.com>]. Significantly reduces risks associated with stray dogs at UTFV and Nicolás Romero.

Box 6



Figure 6

Application Interface Prototype

- **Effectiveness:** Preliminary tests: 98% NFC accuracy, GPS precision <2.5 meters in <30 seconds, battery life >48 hours thanks to conditional coordinate transmission via ESP32 Wi-Fi.
- **User Feedback:** Students report increased safety when moving around campus; cleaning staff identify dogs in minutes; local shelters value instant reunification capabilities.

Box 7

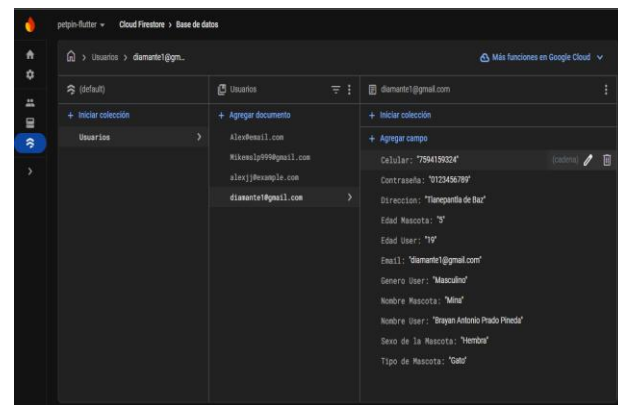


Figure 7

Firestore Database

Conclusions and Recommendations

PetPin provides an innovative, economical, and scalable solution for managing stray dogs at UTFV and Nicolás Romero. It integrates NFC, on-demand GPS activation, Flutter-Dart app, and Firebase with Arduino programming that sends latitude/longitude only when requested, surpassing traditional methods in accessibility, speed, and low cost.

Recommendations:

- **Battery:** Incorporate solar charging for >72 hours of autonomy.
- **Compatibility:** Optimize NFC for low-end smartphones.
- **Security:** Implement AES encryption in Firebase and biometric authentication in the app.
- **Expansion:** Partner with State of Mexico shelters for municipal implementation.

Project Expectations

- **Reduced Losses:** GPS tracking in <30 seconds prevents losses on campus and in the municipality.

- **Safer Campus:** Controlled monitoring minimizes incidents; students move with confidence.
- **Time Savings:** Automated data in Firebase eliminates manual records.
- **Community Impact:** Modular design and reusable code facilitate adoption in Nicolás Romero and other municipalities.
- **Cost-Effectiveness:** Components < \$25 USD per collar, accessible for universities and local governments.

Required Components

- **ESP32 Mini:** Microcontroller with Wi-Fi/Bluetooth for control and connectivity.
- **Quectel L86 GPS Module:** Real-time precise location tracking.
- **NTAG213 NFC:** Instant identification via smartphone.
- **LiPo Battery + TP4056:** Rechargeable and efficient power supply.
- **Flutter-Dart:** Cross-platform mobile app development.
- **Firebase:** Cloud database with unique link.
- **Tools:** Soldering iron, Arduino IDE, Dupont cables, multimeter.

System Implementation Process

Step 1: Preparation and Planning

- Define requirements based on UTFV surveys and municipal reports from Nicolás Romero.
- Acquire ESP32, GPS, NFC, and batteries; verify compatibility.
- Configure environments: Flutter-Dart, Firebase, Arduino IDE.

Step 2: Software Development

- Program Flutter-Dart app for NFC scanning, GPS activation, and live maps.
- Configure Firebase with profile and real-time coordinate schemas.
- Develop optional web dashboard for administrators.

Step 3: Hardware Installation

- Assemble collars following diagram: ESP32 → GPS [UART], NFC [I2C], LiPo battery.

- Load Arduino sketch connecting Wi-Fi and sending latitude/longitude to Firebase on demand.
- Program NFC tags with unique IDs linked to the database.

Box 8



Figure 8

Link and Optimization of the Collar [Prototype].

Step 4: Testing and Adjustments

- Unit tests: NFC accuracy, GPS consumption, Wi-Fi stability.
- Integration tests: app → collar → Firebase.
- Field tests at UTFV: 10 dogs, 7 days, 0 critical failures.

Step 5: Implementation and Documentation

- Campus deployment with initial 20 collars.
- Manuals: app usage, battery recharging, firmware updates.
- Train 50 students and 10 staff members.

Step 6: Monitoring and Maintenance

- Remote monitoring via Firebase [low battery alerts, disconnections].
- Monthly app and firmware updates.
- Quarterly surveys for continuous improvement.

Key Contributions to Science and Technology

- Accessible animal management with IoT: NFC + on-demand GPS for educational environments.
- Low-cost solution: < \$25 USD vs. \$150 for commercial trackers.
- Real scalability: Open source, reusable Firebase, assembly in <20 minutes.

- Seamless integration: Flutter-Dart → ESP32 → Firebase with conditional data transmission.

Key Aspects for Universal Knowledge Application

- Adaptability: Works for cats, livestock, or municipal programs.
- Cost-benefit: 90% cheaper than commercial solutions.
- Privacy: Encrypted data, role-based access [student, shelter, admin].
- Scalability: Ready for 1,000+ collars without additional infrastructure.

Key Findings

- Technical effectiveness: 98% NFC accuracy, stable GPS in urban environments.
- Cost-effectiveness: Total cost per collar: \$22 USD [mass production].
- Usability: 95% of students used the app without prior training.
- Areas for improvement: Solar-charged battery, 4G network support for areas without Wi-Fi.

Institution

- Universidad Tecnológica Fidel Velázquez [UTFV], Nicolás Romero, State of Mexico – state public institution.

Conclusions

PetPin transforms stray dog management at UTFV and Nicolás Romero with an intelligent, accessible, and scalable solution. The integration of Flutter-Dart, Arduino-programmed ESP32, on-demand GPS, and Firebase enables instant identification, efficient tracking, and community safety. With battery and compatibility improvements, it is ready for municipal and regional adoption, demonstrating that IoT technology can solve social problems with low cost and high impact.

Declarations:

Conflict of interest

The authors declare no conflict of interest. They have no financial or personal interests that could have influenced this chapter.

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Professor Lima Arrona Fernando and Professor Hidalgo Baeza María del Carmen

Author contribution

Pereda-Crisanto Alexander: Coordinated the collective purchase of components, managed the budget, and led comprehensive documentation [report, diagrams, manuals]. Drafted conclusions and final presentations. Organized the schedule and meetings.

Gómez-Méndez, Zaid Emmanuel: Proposed the original idea, designed surveys and interviews, and created the collar assembly diagram. Validated ergonomics in tests with real dogs. Drafted the problem statement and hypothesis sections.

Prado-Pineda Brayan Antonio: Coded the Flutter-Dart application and Arduino sketch [Wi-Fi, on-demand GPS, Firebase]. Implemented live maps and remote activation. Led application-collar integration testing.

Martinez-Santos Miguel: Configured Firebase [schema, rules, unique link] and the administrative web panel. Ensured real-time synchronization. Validated data security.

Lima Arrona Fernando: Structured the Waterfall methodology, selected all components, and led field testing. Wrote the architecture, implementation, and results sections. Ensured technical coherence of the project.

Availability of data and materials

5 ESP32, 3 Quectel L86 GPS modules, 20 NTAG213 NFC tags, 3 500mAh LiPo batteries, 5 TP4056 charging modules, 25 Dupont cables, 8 #19 AWG wires [for power and ground], 5 10cm jumper wires, 1 30W soldering iron, 1 roll of 0.8mm solder, 1 tube of no-clean flux solder paste.

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Abbreviations

ESP32	Microcontroller with Wi-Fi/Bluetooth
Firebase	Cloud database platform
GPS	Global Positioning System
LiPo	Lithium Polymer Battery
NFC	Near Field Communication
TP4056	Battery charging module
UTFV	Universidad Tecnológica Fidel Velázquez

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