PROJECT ABSTRACT

Robot Swarm using ESP-NOW Communication

A real three-robot swarm coordinated over ESP-NOW: one controller ESP32 broadcasts formation commands to three robot ESP32s with acknowledgements and retries, followers hold line/triangle/cluster/scatter shapes, and a command console shows the live arena, packet log and latency — delivered as a built-to-order student project with all firmware, the console, report, PPT and viva kit.

01. Title

Robot Swarm using ESP-NOW Communication

02. Introduction / Background

Swarm robotics is usually taught as simulation — dozens of agents on a screen, no radios, no dropped packets, no dead batteries. Real radios bring the interesting problems: who hears whom, what happens when an acknowledgement never arrives, how formations survive a robot that stops responding. Wi-Fi and Bluetooth drag in access points, pairing and latency that make multi-robot coordination painful. ESP-NOW, Espressif's connectionless peer-to-peer protocol, is the purpose-built answer: short packets, millisecond latency, no infrastructure. This project builds a real three-robot swarm on it, with a console that makes the invisible wireless link observable.

03. Problem Statement

Students seldom build multi-robot systems because the coordination layer is genuinely hard: broadcast semantics, acknowledgement tracking, formation geometry and the failure modes of wireless links. Simulations hide exactly the phenomena a viva should probe. The project addresses this with three physical robots, acknowledged formation broadcasts, a proportional follower controller, ultrasonic collision override and telemetry that exposes delivery rate and latency as first-class measurements.

04. Objectives

- Build three ESP32 differential-drive robots plus one controller unit, with ESP-NOW peer registration (MAC pairing) and no Wi-Fi infrastructure.
- Implement acknowledged formation broadcasts: line, triangle, cluster, scatter, with per-robot acks and up to 3 retries on missing acks.

- Implement the follower controller: proportional drive toward assigned formation slots; leader follows console joystick commands.
- Provide the command console: live arena map from 10 Hz telemetry, per-robot battery/RSSI, packet log, delivery-rate counter and latency chart.
- Deliver ultrasonic collision override (radio-independent), gain tuning guide, a buyer-run range/loss/latency procedure, and the complete student kit.

05. Proposed Methodology

Chassis kits are assembled and wired per the build guide; ESP-NOW peers are registered by MAC address. Firmware is developed in layers: point-to-point ESP-NOW echo first, then broadcast with ack tracking, then the follower controller tuned on one robot, then the full three-robot formation set, and finally the console telemetry. Commissioning measures delivery rate and round-trip latency in the test room and characterizes range versus packet loss. The report presents design targets (≥ 95% delivery in lab range, ~14 ms typical RTT) as targets and documents the buyer-run measurement procedure — figures are measured on the buyer's floor, never pre-claimed.

06. System Architecture / Working

Robots register the controller's MAC as an ESP-NOW peer at boot. The operator picks a formation; the controller broadcasts each robot's target slot (up to 250 bytes). Robots ack; missing acks trigger retries and the console shows the ack count. Followers run a proportional controller toward their slots while the leader follows the joystick. Each robot streams position, heading, battery and RSSI at 10 Hz for the arena map and link stats. Ultrasonic sensors run a local stop loop independent of the radio.

07. Hardware / Software Requirements

- 4x ESP32 DevKit (1 controller + 3 robots), Arduino-core firmware
- 3x differential-drive robot chassis kits
- Ultrasonic distance sensors (per-robot collision override)
- Li-ion battery packs with charging guidance
- Command console web app (arena, telemetry, packet log)
- Tape measure / marked floor grid for the buyer-run range procedure

08. Expected Outcomes

A working three-robot swarm that forms commanded shapes over infrastructure-free ESP-NOW radio, with acknowledged broadcasts, live telemetry and an observable wireless link. The student receives all firmware, assembly and tuning guides, the console app, report, PPT and viva Q&A.

09. Applications

- Robotics and multi-agent systems laboratory demonstrations
- Teaching wireless protocols, formation control and failure handling
- Mechatronics capstone platform
- Foundation for larger-swarm and task-allocation follow-ups

10. Future Scope

- Larger swarms with broadcast scheduling
- Dynamic role reassignment on robot failure
- Task allocation (foraging / coverage) behaviors
- Outdoor long-range variant with high-gain antennas
- ROS bridge for the console telemetry