IoT Based Bomb Diffusing Robot

Shriyansh Prajapati, Payal Yadav, Saurav Pathak
Under the Guidance of: Assist. Prof. Deepti Kushwaha

Department of Automobile Engineering, University Institute of Technology Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, M.P.

Abstract

Bomb disposal represents one of the most hazardous tasks in military, tactical law enforcement, and counter-terrorism operations, where manual intervention frequently leads to severe injuries or fatalities among trained personnel. This paper presents the development and architectural implementation of an Internet of Things (IoT)-driven mobile robotic platform designed to mitigate human risk by executing bomb defusal tasks remotely. The proposed system leverages an ESP8266 NodeMCU microcontroller integrated with the Blynk IoT cloud ecosystem, facilitating long-distance, ultra-low latency remote navigation and robotic arm control over standard wireless networks. Equipped with a multi-directional mobility chassis, a proximity metal sensor, a local telemetry alarm system, and a multi-axis mechanical arm incorporating a wire-cutting end-effector, the platform enables a remote operator to safely examine, pick up, and disarm improvised explosive devices (IEDs). Experimental evaluation indicates high responsiveness and high-precision control, validating the system as an effective asset for tactical explosive ordnance disposal (EOD).

I. Introduction

The escalation of global security challenges and the persistent threat of improvised explosive devices (IEDs) demand continuous evolution in explosive ordnance disposal (EOD) strategies. Historically, field technicians operate under extreme psychological and physical duress while wearing heavy tactical suits that offer minimal protection against near-source detonations. A single misstep or a minor delay during device neutralisation can prove catastrophic.

EOD specialists frequently face the complex "wire dilemma"—unpredictable and deliberately deceptive wire configurations within a bomb's timing loop, including monochrome wires, hidden sub-circuits, or micro-switches designed to speed up the countdown if severed incorrectly. To minimize manual risks, automated robotic systems have been introduced to tactical fleets. However, conventional units rely primarily on localized wireless communication frameworks like Radio Frequency (RF), Bluetooth, or peer-to-peer Wi-Fi networks. These frameworks suffer from tight range limitations, signal attenuation around dense concrete barriers, and high susceptibility to electronic jamming.

To address these limitations, this research presents an integrated remote-controlled robotic system powered by the Internet of Things (IoT). By offloading control and transmission over global cellular or cloud-based wireless networks, the system transcends localized range boundaries. It delivers high-speed, long-distance data transmission alongside fine-grained actuation control, allowing operators to safely manage hazardous hardware assets across vast distances.

II. IoT Data Lifecycle and System Architecture

The reliable operation of a remote weaponized or defensive robotic asset across an IP network requires a structured data workflow to minimize transmission lag and ensure deterministic behavior. The system operates on a five-phase IoT lifecycle mapped to a distinct four-stage hardware network layout.

A. The Five Lifecycle Phases

1. **Create:** Onboard sensor arrays (proximity metal sensors and camera modules) harvest physical signals from the immediate blast

perimeter.

2. **Communicate:** Collected environmental telemetry is packetized and broadcast over local wireless access nodes.
3. **Aggregate:** Edge gateways cluster sensor arrays and telemetry packets to guarantee packet order and signal integrity.
4. **Analyze:** The command center decrypts incoming data, transforming raw numbers into an active user-facing video feed and structural status reports.
5. **Act:** Programmatic instructions sent from the remote operator trigger on-board mechanical switches, moving the chassis and closing the wire-cutter tool.

B. Four-Stage Structural Layout

- **Stage 1 (Networked Edge Sensors/Actuators):** Houses physical transceivers, DC motors, and inductive sensors directly interacting with the physical environment.
- **Stage 2 (Data Aggregation & A/D Conversion):** Transmutates raw variable signals into clean digital inputs using on-chip analog-to-digital data acquisition systems (DAS).
- **Stage 3 (Edge IT Processing):** Manages essential safety routines directly on the local microcontroller to execute immediate emergency commands with minimal latency.
- **Stage 4 (Cloud Infrastructure & Management):** Uses a remote database and the Blynk cloud server as a communication pathway, matching virtual interface pins directly to physical outputs on the robotic chassis.

III. Proposed System Design and Hardware Interfacing

The hardware ecosystem is organized into a modular design split across power storage, processing, locomotion, and end-effector manipulation tools.

A. Core Control and Processing

The central control unit uses an **ESP8266 NodeMCU** microcontroller. Chosen for its integrated TCP/IP stack, tiny footprint, and low power requirements, it processes instructions received from the cloud network and translates them into control pulses for the motor drivers and relays.

B. Locomotion Subsystem

Chassis movement uses an **L298N H-Bridge Motor Driver** connected to high-torque DC gear motors. This design allows full multi-directional mobility (Forward, Backward, Left, Right turn mechanics), allowing the platform to navigate debris, tight corridors, and unpaved terrain around dangerous drop zones.

C. EOD Manipulation Mechanism

The robotic arm is designed with multiple operational modules:

- **Base Articulation & Rotation:** Controls arm pitch and height relative to the ground.
- **Mechanical Gripper:** Uses a high-torque motor to grab, lift, and remove suspicious IED arrays to safe detonation chambers.
- **Wire-Cutter Tool:** A dedicated end-effector operated via a isolated relay switch designed to safely cut detonator circuits.

D. Threat Analysis and Onboard Telemetry

An inductive proximity metal sensor sits at the front of the chassis to scan for weaponized metallic containers or fragmentation shrapnel. When triggered, it activates a high-decibel onboard audio buzzer to give field teams immediate local warning. Parallel vision tracking is handled via an independent **ESP32-CAM module**, which streams live video to the operator interface to assist with pathfinding and wire picking.

IV. Firmware Implementation and System Logic

The firmware is written in C++ and compiled using the Arduino development environment, integrating the core Blynk library to establish a permanent network connection via localized Wi-Fi infrastructure.

A. Operational Pin Configurations

The microcontroller maps specific virtual pins to control distinct physical outputs:

- **D0 & D1 (Motor Driver Inputs 1 & 2):** Controls left-side locomotion tracks.
- **D2 & D3 (Motor Driver Inputs 3 & 4):** Controls right-side locomotion tracks.
- **D4 (Relay Board Actuator):** Operates the primary wire-cutting tool.

V. Experimental Results and Discussion

Testing validated the prototype's responsiveness, network stability, and structural stability across multiple field environments. By transitioning command execution from standard point-to-point RF interfaces to an optimized cellular/cloud network topology via Blynk, the system maintained solid structural control even behind reinforced concrete structures.

The platform managed locomotion and multi-axis manipulator adjustments accurately, confirming that the current delivery system provides adequate torque for heavy lifting tasks. The inductive sensor array registered threat alerts cleanly, triggering the onboard alarm buzzer without interrupting parallel data streams or introducing camera jitter.

While the baseline prototype performs well, field deployment highlights several engineering limitations that provide opportunities for future development:

1. **Terrain Adaptation Constraints:** The current wheel chassis struggles over large structural ruins, open ditches, or stairs. Replacing this with a continuous tank track or a planetary step-climbing mechanism would improve mobility.
2. **Vision Tracking Constraints:** Standard video streaming leaves the operator fully responsible for analyzing complex bomb mechanics under low-light conditions. Future iterations will incorporate night-vision optics and edge-based Convolutional Neural Networks (CNNs) to automatically identify and flag color-coded timing circuits.
3. **Mechanical Articulation Constraints:** The basic single-axis arm mechanism limits reach around awkward angles. Upgrading to a high Degree-of-Freedom (DOF) robotic manipulator with a multi-gripper tool changer would allow for more complex defusal operations.

VI. Conclusion

This research demonstrates a functional, cost-effective, and highly reliable IoT-driven robotic platform designed for explosive ordnance disposal. By pairing an ESP8266 NodeMCU microcontroller with cloud-mapped interface arrays, the system removes distance barriers common to standard RF tools, keeping personnel at a safe distance during high-risk operations. Integrating live camera streams, metal detection alerts, and dedicated wire-cutting end-effectors delivers a flexible tactical unit suitable for modern security challenges. Future work will focus on improving chassis mobility and adding machine vision algorithms to make device neutralisation quicker and semi-autonomous.

References

- **[1]** R. Senthamizh and M. Priyadarshini, "Advanced Military Spying and Bomb Disposal Robot," *Department of ECE, DSCET, Anna University, India*.
- **[2]** A. K. B. Motaleb and M. B. Hoque, "Bomb Disposal Robot Discarding Explosive Through Wireless Controlled Method," *International Journal of Robotics and Automation Systems*.
- **[3]** A. Unluturk, "Design and Implementation of a Mobile Robot Used in Bomb Research and Setup Disposal," *Journal of Electrical Engineering & Technology*.
- **[4]** H. U. Zaman, "Design, Control & Performance Analysis of Muktibotan Android & Radio Transmitter Controlled Bomb Disposal Robot," *IEEE Technical Review*.
- **[5]** J. Hietaniemi, L-G. Cajot, M. Pierre, J. Fraser-Mitchell, D. Joyeux, and K. Papaioannou, "Risk-Based Fire Resistance Requirements," *Final Report*, *Office for Official Publications of the European Communities*, Luxembourg, 2005.
- **[6]** European Sprinkler Organisation Homepage, Data Network Resources, www.eurosprinkler.org.
- **[7]** A. H. Buchanan, *Structural Design for Fire Safety*, John Wiley and Sons, Chichester, 2002.
- **[8]** J. M. Franssen and R. Zaharia, *Design of Steel Structures Subjected to Fire: Background and Design Guide to Eurocode 3*, University of Liège, 2005.