

Design and Development of Police Emergency Response Drone System PERDS

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Abstract. This paper presents the design, development and implementation of the Police Emergency Response Drone System (PERDS), It is an integrated solution created to support the police during emergencies, like kidnappings and threats against women. The system addresses the critical time gap between an incident and the police's arrival. The response time of the rescue determines the safety of the victims and the chances of criminals escaping unnoticed. PERDS consists of the deployment of drones, ahead of the Police units, providing immediate situational awareness, evidence collection and basic assistance before the rescue team arrives. The drone includes thermal cameras, transmitters and real-time criminal identification tools like facial recognition and license plate detection. These features increase the possibility of rescuing the victim safely, providing better quality videos and thus improve the way of catching the suspects. The system is also integrated with a mobile application that shares the victim's real-time location with the control centre as soon as an SOS signal is triggered. It can even be accessed by national helpline numbers (e.g., 112). The drone has both autonomous and manual control modes, which ensure flexibility and reliability in unpredictable situations.

1 Introduction

India has been witnessing lots of emergency situations[13], where rapid response determines the life-or-death outcomes[14]. Even though there's a lot of ways to call for emergency during an emergency situation, traffic congestion, communication gap and bad road infrastructures are critical barriers to real rapid response. To address such challenges, this research proposes the Police Emergency Response Drone System (PERDS). It is an aerial surveillance drone system. When a user in an emergency situation activates the SOS alert through the mobile application [16] or a helpline [15], a PERDS drone autonomously flies to the victim's GPS location way before the police ground units can reach the scene.

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The drones are equipped with night vision camera, thermal imaging and facial recognition tools, it provides real-time quality footage and capture critical data such as suspect identification, License plate identification and other environmental details. The drone also carries a compact & a basic first-aid kit, enabling basic assistance to the victim if needed, while waiting for the medical aid.

The collected data, including footage, GPS tracking, and biometric details, is transmitted to the police control centre and nearby patrolling units, giving them better situational awareness and thus enabling the police to have a better plan when entering the site. This system ensures faster and smarter responses, decreasing casualties and increases the rate of successful rescues.

The goal of the proposed system is to improve the existing emergency response mechanisms by integrating unmanned aerial vehicles (UAVs) with real-time communication networks, thus forming a coordinated and high-performance response infrastructure. The key benefits of PERDS include drastic reductions in response time, enhanced data-driven policing, improved public trust in law enforcement, and the potential to significantly reduce criminal escape rates, particularly in cases of abductions, assaults, and road emergencies.

In conclusion, the Police Emergency Response Drones System (PERDS) introduces a better environment for public safety and law enforcement operations. The system is like an upgrade to the policing in modern India, thus leading to a better responsive, safer and technologically empowered society.

2 Related Work

The Police Emergency Response Drone System (PERDS) is a multipurpose system[2] that advances across various fields but primarily focuses on rapid response infrastructure. The PERDS concept seeks to deploy an Advanced Response Unit ahead of the rescue teams, by all means, to break the "Critical Time Gap" between the SOS triggered and the arrival of the police. Such a system falls in parallel with other various applications in emergency responses and surveillance infrastructure.

2.1 Drones in emergency and search & rescue operations

The most equivalent to the PERDS is the Search and Rescue (SAR) drones that are used for surveillance and disaster response. Previous research has demonstrated the drone's effectiveness in giving real-time situational awareness to the rescuers [1], [11], especially in situations when conventional access is very challenging or dangerous [12]. Even though these drones are equipped with thermal imaging and smart sensing technologies, it is difficult to locate victims in low visibility or complex terrains[8], thus creating a need for PERDS, which has night vision and thermal sensors to identify the criminals and their location. In addition to that, the PERDS can also deliver small first aid kits, thus confirming the feasibility of drone in a medical platform.

PERDS differ in their operational objectives, while SAR drones only try to locate victims after an incident. Unlike that, the PERDS is designed for immediate deployment/law enforcement, and reaches the scene before the rescue team arrives. The core novelty of PERDS is that it's a response system, while SAR drones are search tools. With a little bit of an upgrade, SAR drones can be used in PERDS.

2.2 Integration with robotics control and communication

The system architecture of PERDS is a combination of an SOS alert trigger, an autonomous navigation, and a two-way communication. The drone is automatically deployed when an

SOS signal is triggered [6] [4]. An Operator in the control centre can manually override the drone when required. This dual control mode balances the human precision and the automated movements.

Additionally, an onboard siren and a two-way communication is placed on the drone, improving interaction capability to enhance control effectiveness. To overcome connectivity issues, which are commonly faced in real-time remote operation systems, it uses multiple communication channels [17].

3 Proposed Solution

3.1 Overview of the system

The Police Emergency Response Drone System (PERDS) focuses on closing the critical time gap between an emergency call and the police's arrival in an emergency situation. It integrates an emergency alert SOS mobile app with a group of autonomous drones capable of reaching the incident scene in very little time. Also, while transmitting live video footage and communicating with the officers before they reach the scene. The system aims to make the initial response period more effective through real-time monitoring, communication, and basic assistance at the incident scene

3.2 Operational mechanism

When a user triggers an emergency SOS alert through the linked mobile application, the signal is immediately received at the control centre. The system locates the nearest drone station and automatically deploys a drone, which will travel to the incident site using predefined GPS routes. It has both autonomous and manual modes; officers can switch to manual mode and control the drone in some unexpected situations. Instead of completely relying on AI decision-making, PERDS prioritizes autonomous flight under human supervision, thus keeping the authorities fully in control during emergencies.

3.3 Communication and surveillance capabilities

After reaching the scene, the drone enables a two-way audio communicator and activates a siren (if required). This enables a chance for officers to speak with people at the scene, comforting victims, guiding bystanders, and driving away the suspects until rescue units arrive. Its high-resolution camera continuously transmits real-time footage to the PERDS control centre, helping officers evaluate the situation and plan their response prior to arrival. The system does not depend on AI for decision-making, but it supports trained vision models like YOLO to detect objects and persons, especially during post-incident analysis, supporting a scalable and completely data-driven emergency response system.

3.4 Data transmission and control architecture

A cloud-based control platform manages the drone coordination, video streaming, and operator interaction. It records data like flight paths, mission info, and visual evidence, storing them securely for future purpose. The system's structure is very flexible making it adaptable to different regions and easily integrable with existing surveillance networks. Officers can access the PERDS live dashboard for information of the current mission, control the drone's movements, and export the evidence, all from a single interface, which is designed for efficiency and clarity.

3.5 Impact and future aspects

PERDS dramatically reduces the response time during emergencies by enabling near-instant drone deployment. Police officers gain immediate situational awareness and visual information before arriving at the scene, thus improving coordination, safety, and the likelihood of preventing any sort of escalation. Since it is always within reach, the system also builds the trust of the public.

The current version of PERDS relies on autonomous navigation and human oversight; future improvements could be the integration of AI in PERDS for decision-making and real-time navigation. This makes responses even faster, smarter and more efficient. Further future trials with law agencies will be conducted to measure improvements in response time. PERDS can evolve into a nationwide rapid-response infrastructure that redefines how emergency services operate in real-world conditions.

3.6 Testing and validation

To demonstrate the practical feasibility of the PERDS, a low-cost prototype was developed for testing. The prototype is a basic minimum viable product, specifically made for the testing of the drone and the prediction of the performance of the final product.

Table 1. Prototype Performance Under Different Environmental Conditions.

Environment Condition	Average Speed (m/s)	Stable Flight Range	Video Transmission Range	Visibility Distance	Communication Reliability
Normal Clear Weather	8–10 m/s	~800 m	~700 m	~300 m	Stable
Windy Conditions	6–8 m/s	~650 m	~600 m	~250 m	Mostly Stable
Light Rain	5–6 m/s	~600 m	~550 m	~200 m	Stable
Foggy Environment	5–7 m/s	~620 m	~580 m	~120 m	Stable
Night Conditions	7–9 m/s	~750 m	~700 m	~180 m (camera assisted)	Stable

The minimum viable prototype was tested under various environmental/ Weather conditions. Although obstacles like wind, rain and fog slightly reduced the speed and visibility, the drone was stable and the video transmission was consistent within the operational range. Note: The Minimum viable prototype is a remotely piloted drone.

Table 2. The Expected Performance of the Final PERD System

Parameter	The minimum viable prototype	Expected final product
Maximum Speed	~10 m/s	18–22 m/s
Flight Endurance	12–15 min	35–45 min
Stable Flight Range	~800 m	5–8 km
Video Transmission	720p HD	4K Stabilised
Communication System	WIFI based	Encrypted Long-Range RF / 5G
Navigation	Manual / Basic GPS	Autonomous AI Navigation

3.6.1 Minimum Viable Product:

To test the feasibility and the practicality of the PERDS drone, a minimum viable prototype was made with a minimal budget. The drone uses an ArduPilot APM 2.8 as the flight controller, which runs on ArduPilot firmware used to achieve stable flight. It is powered by an 11.1V LiPo battery. The system consists of four A2212/13T 1000KV brushless motors and 30A ESCs for a stable quadcopter propulsion setup. A camera module OV7670 was also included for the visual monitoring during flight time with the help of a parallel companion ESP32. It was not an autonomous drone; it was controlled by a Flysky CT6B 6-channel transmitter and controller. And Neo M8N GPS Module[10] with compass is used for drone navigation.

Although the drone was developed as a basic, simplified and low-cost version of the final product, it successfully demonstrates the basic fundamental functionality of the PERDS drones (stable flight, real-time video input, and location tracking). It also helped in the prediction of the performance of the final product of the PERDS solution.



Fig.1. Prototype development

3.7 Advantages Over Existing Systems

The PERDS solution is an exceptional advancement when compared to traditional emergency response and surveillance systems[3]. Instead of the police vehicles, dispatching only after the verification of any SOS triggers, the PERDS initiates an aerial response, ensuring live visuals and communication reach the control centre within minutes. This cuts down the critical time gap between the trigger and the response, which is a major problem of existing kidnap cases. Unlike AI-heavy drone systems that depend on advanced processing hardware, PERDS's semi-autonomous system is cost-efficient and easier to maintain, hence making it suitable for large-scale deployment across cities and rural areas. The addition of two-way communication, first-aid delivery, and secure evidence transmission makes it a better emergency support system rather than just a surveillance tool. Furthermore, this is compatible with the existing IT and Police infrastructure, and hence it is easy to blend with the society.

4 Methodology

4.1 System Design and Architecture

The PERDS system consists of three major subsystems. [16]They are a mobile alert application platform, the autonomous drones system [2] [3], and the central command monitoring and control centre. The mobile application is the user interface[15], which enables a way for the public to trigger SOS emergency alerts which will be automatically transmitted to the control centre along with their GPS coordinates. The command centre processes these alert signals and identifies the closest available drone hub to the incident. Then, initiates a drone automatically. Once it reaches flight mode, the drone navigates to the emergency location by itself, using pre-programmed flight paths and real-time GPS feedback. The architecture operates in a cloud-linked feedback loop, where every mission stage alert reception, dispatch, flight, surveillance, and return is logged and synchronised in real time. This distributed architecture ensures reliability, scalability, and efficient coordination between multiple drones operating in different locations. The PERDS architecture is designed to have multiple drone hubs across the cities, enabling coordinated deployment of several drones at the same time.

4.2 Technical Stack

PERDS is an autonomous quadcopter made for critical, emergency and extreme autonomous operations. The quadcopter comes with x shape frame of 450-650mm of carbon fibre mechanical frame, for high structural strength, minimise vibration damping and for a stable mechanical body of the drone. For propulsion, the thrust is generated by 2212- 2814 1500Kv class brushless DC motors of four, with suitable 10-13 inch two or tri-blade propellers. Each motor is driven by a 40-60A BLHeli electronic speed controller (ESC) delivering the required and precise throttle power to the motor as three-phase alternating current. For power is driven from a 4S-6S lithium-polymer (LiPo) battery, typically rated at 14.8V, with capacity chosen according to the desired flight duration and load configuration, power is driven from the battery and distributed by Matek PDB, BEC(5V/12V). The drone's control core is managed by Pixhawk 4 flight controller running via ArduPilot firmware[6][4], providing reliable flight stabilisation and autonomous mission handling.

The drone uses Neo M8N RTX GPS [10]module for accurate positioning + compass with EKF for position hold, waypoint routing and Geofencing capabilities, with optional RTX support. An FS-i6 6-channel FPV transmitter and VTX RxTx receiver system maintains the communication link between the drone and the operator or control station, consistent signal transmission and telemetry exchange during extended operations using 4G/5G LTE Dongle and MAVLink protocol for system communication, streaming via LTE + WebRTC (with Gstreamer encoding), integrated web dashboard with FastAPI. For onboard computation, Nvidia Jetson Nano 4GB serves as the companion computer, handling AI tasks for face recognition and object detection through onboard camera for live video streaming and mission coordination and the companion computing is designed by Jetson Nano running Ubuntu (JetPack SDK) and GPU acceleration made via CUDA, cuDNN, TensorRT, and OpenCV. As for middleware integration, ROS Noetic robotics framework and MAVROS bridge enabling AI guided navigation and control.

Obstacle or object detection & collision avoidance, distance sensing and environmental awareness are done by a compact 3D TF mini-S micro LiDAR module[9] and for real time video capturing, done with a Sony IMX 477 module with night vision live video streaming and camera input via an OpenCV pipeline, YOLOv8-based detection (person, vehicle, incident recognition)[5]. The integration of these sensors enhances flight safety and supports semi-autonomous navigation during complex missions. This hardware ecosystem collectively enables PERDS to perform rapid deployment, stable flight and reliable data collection in real time. The selected components balance performance, cost efficiency and adaptability, ensuring that the system can operate effectively in diverse terrains, including urban, semi-urban, and rural environments.

Table 3. Hardware components and estimated cost

Components	Description	Price (₹)
Frame	450-650 mm Carbon Fiber X-Frame	4000-6000
Motors	4-(EMAX ECOII-2807 1500KV Brushless DC Motors)	2000-4000
Power Distribution Board	Matek PDB, BEC (5 V/12 V)	1000-1500
ESC	4-(30-60A ESC BLHeli)	1200-1500
Propeller	4- (10-13' tri/2-blade)	600-900

Battery	LiPo 4s-6s	1500-2000
Flight Controller	Pixhawk 4	8000
FPV transmitter	FlySky i6 6CH	3500-4000
GPS	Neo M8N RTK GPS	800-2000
Communication	4G/5G LTE dongle	1800-2000
Transmitter and receiver	VTX RxTX	1000-1500
Companion	Nvidia Jetson nano 4GB	32000
Sensors	TF mini-S micro-Lidar module, Sony IMX 477	10000-15000

5 Working

5.1 System Overview

The Police Emergency Response Drone System (PERDS) works as an autonomous aerial response and surveillance system targets to minimise the delay between emergency reporting and police action. When an emergency SOS alert is triggered through the connected mobile application, the signal is processed via the cloud dispatch system, identifying the nearest available drone hub, and a drone is automatically deployed. The drone follows GPS coordinates, thus maintaining a safe transit altitude and geofenced route before switching to surveillance mode at the incident site.

The process of deploying the drone takes approximately 5-15 seconds after the SOS signal is triggered. The drone can reach locations that is around 1-2km within 2-3 minutes, providing early situational awareness before the rescue team arrives.

5.2 Autonomous Flight Control

The Pixhawk 4 flight controller manages the flight operations. It runs on ArduPilot firmware[6], which merges the data from the u-blox Neo-M8N RTK GPS [10]and IMU sensors to have centimetre-level accuracy and stable orientation. The propulsion system consists of 2206– 2814 class brushless motors and 30–60 A BLHeli ESCs, thus providing enough thrust and efficient manoeuvrability. Geofencing, no-fly zone compliance and automated landing are embedded at firmware level as safety measures[4]. In urban areas, the dense buildings may block the GNSS signals. To overcome such errors, the system uses sensor fusion tech combined with GNSS, IMU data and visual odometry corrections. In dense building environments, the positional drift is reduced to 2-3m accuracy from 8-9m approximately, thus ensuring reliable navigation near incident locations. Since the Drones are stationed every 8 to 15 kilometres, it is highly reliable for the drones to reach the locations without fail.

The PERDS operates within the national UAV regulations like DGCA guidelines, including restrictions in geofencing, altitude and enforced no-fly zone to ensure safe deployment in real world environments.

5.3 Perception and AI Processing

For perception, the drone contains a camera (Sony IMX-477) and a TF mini-S LiDAR, in order to provide obstacle detection and environmental awareness. [5] NVIDIA Jetson Nano executes lightweight AI models like YOLOv8 for real-time object/face detection[7], vehicle recognition, etc. Thus enabling the drone to identify entities and relay actionable data to the control centre.

Preliminary testing suggests that YOLO detection models are 85-90% accurate [7] in the identification of vehicles and subjects under controlled environments, depending on lighting, resolution and the target distance. During rain or in challenging environments like dusty or foggy places, the performance of the models may decrease. However, the Lidar continues to provide reliable data about the distance, and the obstacle detection is carried out by tracking the target.

5.4 Communication and Data Management

The communication system relies on 4G/5G LTE dongle as the primary link for the transmission of collected data, supported by LoRa mesh backup [17] for environments with low-signal [12]. Data exchange follows the MAVLink protocol, which enables the exchange of flight data and signals between the drone and the control software. While the encryption mechanism TLS 1.3 are used to secure all the transmitted information. Data management and mission coordination are supported through a backend system that is built using Node.js and Python Flask integrated with AWS IoT Core, thus ensuring synchronised data flow between the drone, cloud dashboard and the control room.

All the video and telemetry data are transmitted via encrypted channels via tools like TLS 1.3. In addition to that, other secure authentication and controlled access mechanisms make sure that only authorised systems can access such transmitted and stored data. The system is only designed for authorised emergencies and law enforcement scenarios. The secure cloud storage with RBAC (role-based access control) ensures that only authorised people can access any data. Thus, unauthorised personnel cannot access any sort of data with all these data retention policies applied to prevent the unnecessary storage of surveillance data.

5.5 Safety and Operational Workflow

Safety mechanisms like an ADS-B receiver and return-to-home protocol are incorporated to maintain safe operations during unexpected situations. The drone has carbon fibre X-frame, which reduces the vibration and enhances stability. During missions, the drone records and transmits live footage to the control centre, where AI-based analysis helps in victim identification. After finishing the mission, the drone returns automatically to the hub, uploads the mission data and recharges for the next mission.

6 Conclusion

The Police Emergency Response Drone System (PERDS) provides a practical, scalable and efficient solution for emergency response. By using drone navigation, intelligent perception and cloud-connected coordination, [1] it reduces the time between the reporting of the incident and the arrival of police [13]. Since it is not a fixed surveillance infrastructure, it can be used effectively in both urban and rural areas. Thus, improving real-time situational awareness and response efficiency. The system is designed in such a way, considering reliability, human control, and practicality. Hence, the officers still remain as the primary

decision-makers while the drone acts as a support tool alone. The PERDS supports SDG goals beyond its technical role, especially SDG 9 (Industry, innovation and infrastructure), SDG 11 (Sustainable Cities and Communities) and SDG 16 (Peace, Justice, and Strong Institutions) by enabling safer and better disciplined communities.

References

1. S. Kumar, A. Singh, and M. Bansal, Autonomous UAV surveillance systems for smart city safety management, *IEEE Access* 9, 116203–116212 (2021).
2. Chula Vista Police Department, Unmanned aircraft system (UAS) drone program overview, <https://www.chulavistaca.gov/departments/police-department/programs/uasdrone-program> (accessed 2024).
3. U.S. Department of Justice, Drone first responder (DFR) program overview, <https://portal.cops.usdoj.gov/resourcecenter/Display.aspx?Item=cops-w0986-pub> (accessed 2024)
4. PX4 Autopilot, PX4 developer guide, <https://docs.px4.io> (accessed 2024).
5. Ultralytics, YOLOv8 documentation, <https://docs.ultralytics.com> (accessed 2023).
6. ArduPilot Development Team, ArduPilot firmware documentation, <https://ardupilot.org> (accessed 2024).
7. P. Bhattacharya et al., Real-time object detection using YOLO and DeepSORT for intelligent surveillance, *Int. J. Comput. Vis. Image Process.* 13, 22–35 (2023)
8. L. Zhang and T. Li, Multi-UAV cooperative path planning for emergency logistics, *J. Field Robot.* 37, 987–1003 (2020).
9. Livox, Mid-40 LiDAR datasheet, <https://www.livoxtech.com> (accessed 2023).
10. u-blox AG, NEO-M8N GNSS module specification <https://portal.u-blox.com/s/question/0D52p0000DP7zw7CQB/ublox-neom8n-parameters-meaning> (accessed 2023).
11. E. Ebeid, M. Skriver, and K. Jensen, Open-source UAV platform for autonomous inspection and environmental monitoring, *Drones* 4, 22 (2020).
12. C. Lin, X. Wang, and J. Qiu, Edge-enabled UAV networks for real-time surveillance and emergency response, *IEEE Internet Things J.* 9, 3786–3798 (2022).
13. The Hindu, Chennai police launches first drone police unit (accessed 2024).
14. Times of India, Drone Didis keep a hawk’s eye on crime in Delhi, (accessed 2024).
15. Government of India, Emergency response support system (ERSS-112), <https://112.gov.in> (accessed 2024).
16. Tamil Nadu Police, Kaaval Uthavi application, (accessed 2024).
17. Y. Li et al., UAV-enabled IoT networks for emergency scenarios, *IEEE Internet Things J.* 8, 9348577 (2021).