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Smart Manhole Monitoring and Alert System for Urban Infrastructure

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ABSTRACT- ***Water drainage systems underground have a significantcontributiontomaketourbansanitationandwater management efficiency. Manholes provide access to underground sewerpipelinesforinspectionand maintenance purposes.Inmanyurbanareas,however,manholemonitoring isstillconductedmanually,whichisverytimeconsumingand canputworkersatrisk fromexposuretoharmfulgases,water overflow and unsafe conditions. In order to solve the above problems, this paper proposes an IoT-based Smart Manhole Monitoring and Alert System for monitoring underground drainage infrastructure in real-time. The proposed system is based on a compact DOT PCB platform which integrates multiple environmental sensors with an ESP32 microcontroller. The system automatically measures and monitors key parameters like water level, gas concentration, temperature, humidity and manhole unit tilt movement. All the sensor information is wirelessly sent to a monitoring dashboardinthecloudthroughGSM/Wi-Ficommunications. Thedashboard offerslivesensordata,alertsandgeographical information of the manhole system. The prototype developed was tested in varying environmental conditions, and showed good performance in terms of detecting abnormal cases and inproviding immediate warnings.The proposedsolutionsaves the need for manual inspection, increases worker safety, allows remote monitoring of numerous manholes and offers an efficient solution for the management of underground infrastructure in smart cities.***

Keywords—Internet ofThings(IoT),SmartManholeMonitoring, ESP32, Environmental Sensors, Gas Detection, Water Level Monitoring, Smart City Infrastructure, Remote Monitoring, GPS Tracking, Urban Drainage System.

I. INTRODUCTION

Inamoderncity,theurbandrainagesystemisacrucialpartofthe wastewater infrastructure that keeps the city clean and sanitary, and in good working order. Manholes are essential parts of such drainage systems because they allow access to underground pipelines of sewerage systems for their inspection, maintenance and repair.An appropriate manhole monitoring system should be used to avoid blockages of drainage, water overflow, build up of dangerous gases and damage to urban infrastructure. Manycities continuetocarryoutmanholeinspectionbyhand.Thistraditional way of doing it uses lots of time, is not very efficient and can make workers get into unsafe situations like coming in contact with toxic gases, contaminated water and poor ventilation. Manual monitoring also makes continuous monitoring hard, resultinginissuesbeingdetectedwhentheybecomesignificant. This can cause damage to the road, flooding in the city, traffic disruption and risk to public safety.

The Internet of Things (IoT) is rapidly evolving and intelligent monitoring can now be implemented to monitor underground infrastructure remotely across sensors and wireless communication. The IoT monitoring systems can collect data about the surroundings and send it in real-time to a remote monitoring platform.Various researchers have suggested using sensorbasedsystemstomonitorparameterslikewaterlevel,gas concentration and environmental conditions within manholes. Many of the systems that currently exist, however, have drawbacks such as complicated hardware architecture, no real-timevisualization,poorremoteaccess,andnoreal-timelocation tracking.

Toaddressthesechallenges,anovelSmartManholeMonitoring and Alert System using IoT technology is presented which incorporates environment sensing, wireless communication, GPS tracking and real-time visualization on a small-scale hardware platform. The proposed system consists of several sensors, ESP32 microcontroller and continuously measures the essential parameters like water level, gas concentration, temperature,humidityandtiltmovements.Thecollecteddatais wirelesslysenttoamonitoring dashboardinthecloud,allowing authorities to monitor a number of manholes and get instant notifications in abnormal situations. The proposed system has the advantages of improving the safety of underground infrastructure construction works, reducing manual inspection, enhancing monitoring efficiency and low cost, and can be used in underground infrastructure management of smart city.

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II. LITERATURE REVIEW

Various researchers have been suggesting different methods of enhancingundergrounddrainagesystemtoimprovemonitoring andmanagementofmanholes.Thetraditionalwayofinspecting involves manual monitoring, in which the workers have to manuallymaketheirwayintothemanholesandcheckforfaults orblockagesinthesewerpipes.This,however,isanineefficient, timeconsumingandexposesworkerstohazardsliketoxicgases, polluted water, moisture, and poor ventilation. In order to address these issues, numerous researchers have been working on the concept of automated monitoring systems with the help of sensors and Internet of Things (IoT) technology.

Anumberofsystemshavebeensuggestedthatcancontinuously monitor environmental conditions inside manholes using water level sensors and gas sensors. These systems alert to unusual conditions, like water overflow and gas leaks, and warn.While they enhance monitoring efficiency and help maintain safety, mostofthemareintendedformonitoringatasinglelocationand wouldn't work well in monitoring a whole area with many manholes. There are also a few monitoring systems that utilize the Internet of Things (IoT) technology that have been created, wheresensorsareinterfacedwithmicrocontrollers,andthedata receivedissenttocloud-basedmonitoringplatformsforremote monitoring. These systems offer live technology visualization via web dashboards or mobile apps, with less need for regular manual checks.

Most of the current solutions, however, rely on complex hardware configurations, several communication modules, and complex network topologies that make installation and maintenance costs and complexity high. The concept of smart city monitoring, which relies on wireless sensor networks, has been attracting attention in recent years for management of underground infrastructure. These systems can be used for monitoringseveralundergroundsitesfromasinglelocationand givemoreaccessformunicipalauthorities.Althoughbeneficial, many such systems are costly and require sophisticated infrastructure support making them less appropriate for cost effective implementation in the cities.

From the existing literature, it is clear that the use of IoT-based monitoring system can have a significant impact on the operation and security of underground drainage system. However,thereremainsaneedforalowcost,compact,efficient solutionthatallowsforintegrationoftheenvironmentalsensing, wireless communication, GPS tracking and real-time visualizationofthedatainasingleplatform.Toovercomethese drawbacks, a Smart Manhole Monitoring and Alert System based on IoT technology is proposed, which can be an economical and reliable solution for smart city applications.

III. METHODOLOGY

The proposed Smart Manhole Monitoring and Alert System is designed by integrating multiple environmental sensors, ESP32 microcontrollerandwirelesscommunicationtechnologyforreal- time monitoring of underground infrastructure.All the essential electroniccomponentsareorganizedandefficientin thiscompact DOT PCB system platform with all the required parts. The ESP32microcontrolleristhebaseofthesystem.Itcontinuously takesindatafromthesensors,processesthedataandreportsthe data measured by the sensor to the cloud-based monitoring platformviatheWi-Fi/GSMcommunication.TheESP32isused due to its low power consumption, built-in wireless communication function, andprocessing power efficiency, which is beneficial for IoT applications.

Waterlevelismonitoredusinganultrasonicsensor insideofthe manhole.The sensor functions by sending ultrasonic waves and the reflected echo signal is measured to determine the time needed for the return. The distance is calculated and the system is used to determine the water level in the drainage structure. Whenthewater-levelisaboveapre-definedthresholdvalue,the system automatically sends a notification of a flood alert on the monitoringdashboard.ThesystemusesagassensorcalledMQ-135todetecthazardousgases.Thissensorcandetecttoxicgases like methane, carbon monoxide, ammonia and other toxic gases thatcanbefoundinsidethemanhole.Thesystemwill immediatelyprovideagasalertifthegasconcentrationisabove the safe levels, to keep workers safe.

TheDHT11sensorisemployedtomeasuretheconditionsofthe ambienttemperatureandhumidity inthemanhole.Acontinuous monitoring program of these parameters can be used to detect anomalies in the environment that could impact underground drainageoperations.The system includes anMPU6050tiltsensor which is used to detect any physical movement or displacement of the manhole cover or monitoring unit. The sensor is able to detect any changes in orientation and alerts to any unusual movementortampering.ANEO-6MGPSmoduleisusedtogive accurate location tracking. ItsGPS module tracks the manhole's location in real time, allowing the authorities to determine the precise location of the affected manhole in an emergency situation.

AllthesensordatacollectedissenttotheESP32microcontroller whichthentransmitswirelesslytoacloud-basedserver.Thereal- time data is shown on a web dashboard and mobile monitoring app,whichoffersreal-timesensorreadings,alerts,systemstatus and GPS-location-based tracking. This allows for multiple manholes to be monitored remotely, and will enable authorities totakeimmediateactionshouldtheydetectabnormalconditions.

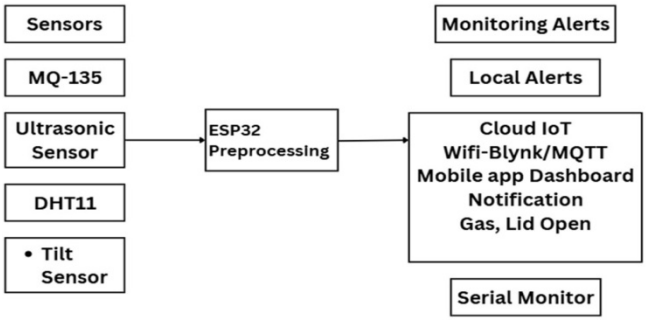


Fig1,BlockDiagram

IV. SYSTEMI MPLEMENTATION

The proposed Smart Manhole Monitoring andAlert System is realized via a number of environmental sensors, an ESP32 microcontroller, GSM/Wi-Fi communication and a mobile monitoring application. The hardware unit is put into the manholeandconstantlymonitorsenvironmentalconditionsand relays real-time data to the monitoring agencies. The ESP32 microcontroller is the core of the system, controlling and processing all operations. It collects sensor data, analyses the data, compares it to preset thresholds and then communicates monitored data to the cloud-based dashboard and mobile app via wireless.

The ultrasonic water level sensor is used to continuously monitor the water levelin the manhole. If the water levelrises above the normal level during heavy rainfall or drainage blockage (DB) condition. If the water level exceeds the water level set in advance, the ESP32 will notify in advance of floodingandsendittothemobileapplication.Thiswillenable authoritiestotakepreventivemeasuresassoonaspossibleand in advance before flooding. The harmful gases like methane, ammonia,carbonmonoxideandothertoxicgasesareinsidethe manholethatcanbedetectedbytheMQ-135gassensor.When theconcentrationofgasreachesalevelaboveasafelevel,agas alert notification is produced immediately.This feature makes sanitationworkerssafer,andminimisesriskofhazardousgases being inhaled by workers during the maintenance process.

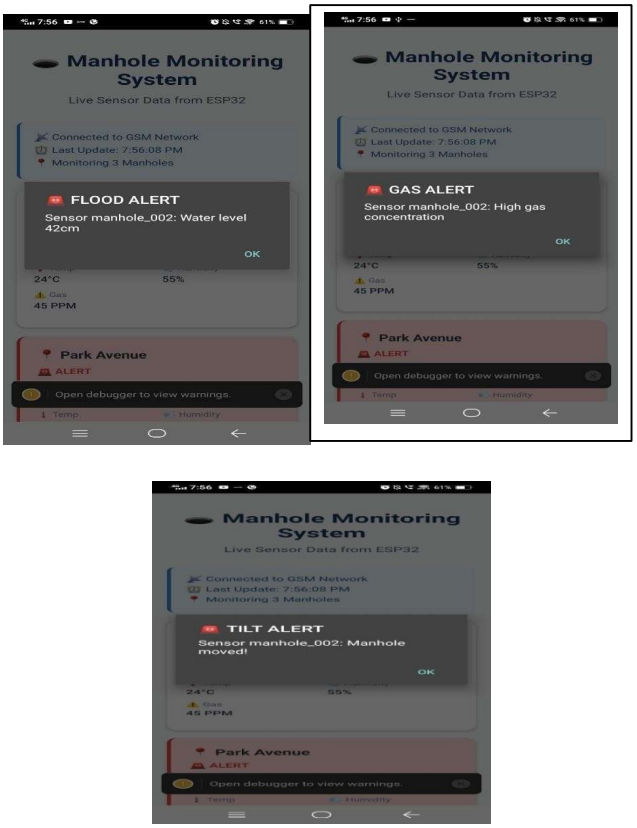


Fig.2.Flood,Gas&TiltAlerts

The DHT11 sensor is used to measure the temperature and humidity in the drainage system.These parametersare useful in analysingtheunderground changesandalsodetectingabnormal operatingconditions.ThesystemisequippedwithanMPU6050 tilt sensor that can track the position and movement of the manholecover.Thesensordetectsthemovementofthemanhole cover when it is tilted, displaced or removed, which may be caused by theft, accidents, maintenance etc., and notifies with a tilt alert. This helps to reduce manhole openings and manhole damage on road surfaces causing accidents. The NEO-6M GPS module gives actual geographical location information of the monitoring system. The GPS coordinates are shown on the mobile dashboard, allowing for easy identification of the exact location of the manhole affected by the problem.

The processed results from allthesensorsare sent to themobile monitoring application via the ESP32 microcontroller with the helpofGSM/Wi-Ficommunication.ThemobileAppshowslive sensor readings, system status, GPS location and alerts. The dashboard also indicates if the monitoring system is connected and how many manholes arebeing monitored. It instantly alerts toanyabnormalconditionlikewateroverflow,toxicgasleakage, displacementofmanholecoveretconthemonitoringdashboard, when detected by the system.These alerts assist the monitoring authorities to know of the issue soon and act swiftly. The proposed system allows for continuous real-time monitoring of underground drainage infrastructure, and can greatly reduce the needformanualinspection.Theuseofwirelesscommunication, environmentsensingandthereal-timealertgenerationenhances worker's safety, efficiency of monitoring and smart city infrastructure management.

V. RESULT AND DISCUSSION

TheproposedSmartManholeMonitoringandAlertSystem was implemented and tested in various environmental conditions to assess its functionality, reliability and real-time monitoring capabilities. This system was able to continuously monitor critical environmental conditions like water-level, gas concentration, temperature, humidity, tilt-movement and geographical location of the manhole. The variation of water level in the manhole was accurately detected by the ultrasonic sensorduringtesting.Themobilemonitoringdashboardnotifies theusersof afloodalertwhenever thewater levelis higher than the predefined threshold value.This functionality allowsfor early detectionofdrainageoverflowinordertotakeactioninadvance of the flooding.

This MQ-135 gas sensor wasable to detect harmfulgases in the manhole. Any toxic gases present in the system, and if the concentrationisbeyondthesafelevel,thesystemwouldalertthe user of the gas immediately. This is a very important safety featureasitreducesexposuretohazardousgasesformaintenance personnel when inspecting and cleaning. DHT11 sensor was placed to continuously monitor temperature and humidity level of the drainage system. Environmental data gathered assisted in the detection of abnormal conditions in the atmosphere and adequate monitoring of underground infrastructure.

The MPU6050 movement or displacement sensor was able to detect any motion of the manhole cover or monitoring unit. If there are any abnormal tilts or movement, the system will send out a tilt alert message. This feature helps reduce the potential risk of an accident from open or displaced manhole covers, and enhancessystemsecurityfromtamperingortheft.TheNEO-6M GPSmodulegavethepreciseGPSpositionofthemonitoringunit at all times. The GPS location data was made available on the monitoring dashboard that would help the authorities locate the specific manhole in emergency scenarios.

Table2,SystemPerformanceAnalysis

Parameter	Observed Performance
WaterLevelDetectionAccuracy	95%
GasDetectionResponseTime	3–5 seconds
GPSLocationAccuracy	±5 meters
SensorDataUpdate Interval	2 seconds
AlertNotificationTime	Lessthan5 seconds
GSM/Wi-FiCommunication Reliability	Stable
TemperatureSensorAccuracy	±2°C

HumiditySensorAccuracy	±5%
TiltDetectionResponse	Immediate
OverallSystemReliability	High



Fig5.Livereadingsof sensors

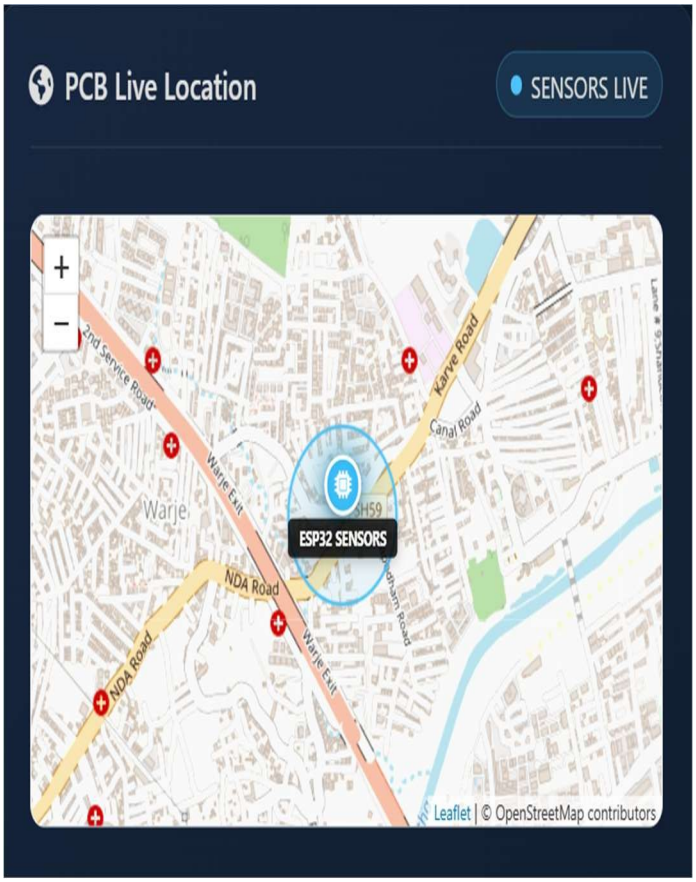


Fig 6. System Location Table1,ComparisonwithExistingSystems

Features	Existing Systems	ProposedSystem
ManualInspectionRequired	Yes	No
Real-TimeMonitoring	Limited	Yes
WaterLevelDetection	Available	Yes
GasLeakage Detection	Limited	Yes
GPSTracking	NotAvailable	Yes
Tilt/TamperDetection	NotAvailable	Yes
MobileDashboard Monitoring	Partial	Yes
InstantAlertGeneration	Limited	Yes
Multi-ParameterMonitoring	Partial	Yes
RemoteMonitoring Capability	Limited	Yes
CostEffectiveness	ModeratetoHig	Affordable

All the sensor data has been analysed by ESP32 microcontroller andthedatahasbeensenttothemobileapplicationviaGSM/Wi-Ficommunicationwithefficiency.Themonitoringdashboardwas continuallyupdatedwithreal-timesensorreadings,alerts,system status, and GPS location. The sensor readings were taken at regularintervals,providingaccurateandreliablemonitoring.The developedsystemalsohadtheabilitytomonitorseveralmanholes atonceusingasingledashboardinterface.Thisenablesmunicipal officials to operate on the effective management of large underground drainage networks more efficiently, without doing regular manual checks.

The user-friendly mobile dashboard offered a viewof live sensor data, system status, last sensor update time and alerts.Abnormal conditions including manhole cover displacement, gas leakage, andoverflowofwaterweredetectedandthealertswereshownon the dashboard immediately and the manhole identification information was shown.After experimental analysis, it has been revealed that the proposed system is not only reliable but also stable in wireless communication and also has a swift response time. Real-time monitoring and automatic alert generation not only protect workers from danger but also decrease the need for manual inspections and boost the management efficiency of underground drainage systems in smart city settings.

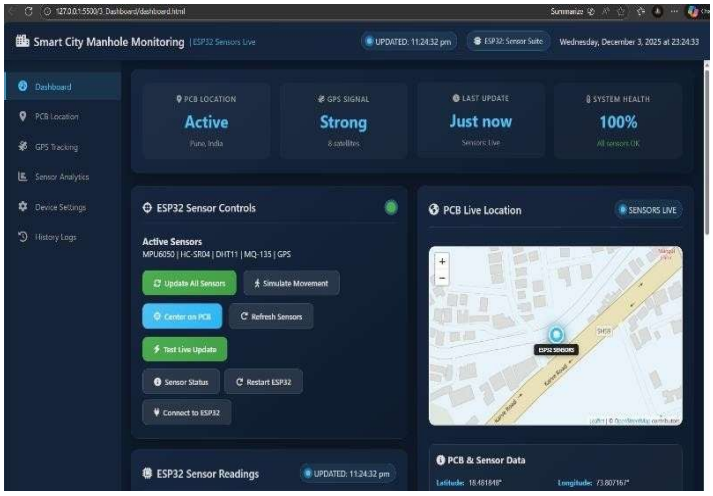


Fig7.Dashboard-livelocationofsystem

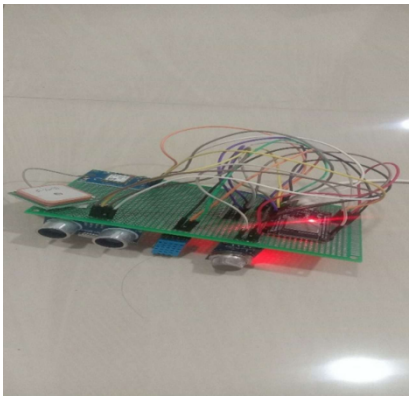


Fig8.FinalSystem

VI. CONCLUSION AND FUTURESCOPE

Theproposedsmartmanholemonitoringandalertsystembyl oT technology is an effective and reliable solution to enhance the safety and management of underground drainage systems. The systemusesavarietyofenvironmentalsensors,allconnectedto an ESP32 microcontroller, which are installed on a small hardware platform to measure and record valuable data like water level, gasconcentration, temperature,humidity, tilt motion andgeographicallocationofthemanholeinreal-time.Allsensor data collected is wirelessly sent to a monitoring dashboard accessible remotely and in real-time from the cloud, allowing municipal authorities to see them.

The developed system is able to detect the abnormal environmentalconditionsandprovide instantalertnotifications whenhazardousconditionslikewateroverflow,leakageoftoxic gases or manhole cover displacement is detected. The experimentalresultsshowsthatthesystemproposedisworking properly and stable real-time monitoring performance is maintained under various environment conditions. Automated monitoring and wireless communication greatly diminish reliance on manual inspection techniques, increase worker safety,cutdownonmaintenancedelaysandboosttheefficiency of urban drainage management systems.

The proposed system is also cost-effective and scalable, which will be helpful for smart city infrastructure applications. GPS tracking and real-time dashboard monitoring enables multiple manholes to be managed at once, and can help respond swiftly in the event of an emergency. The system can be further improved by incorporating more sensors, such as vibration sensor,liquidflowsensor,andsmokedetectionsensorinfuture work to monitor the underground infrastructure to a greater extent. Machine learning algorithms can also be used to make predictive analysis of the machine and find out its possible failures before they happen so that preventive maintenance can be done.

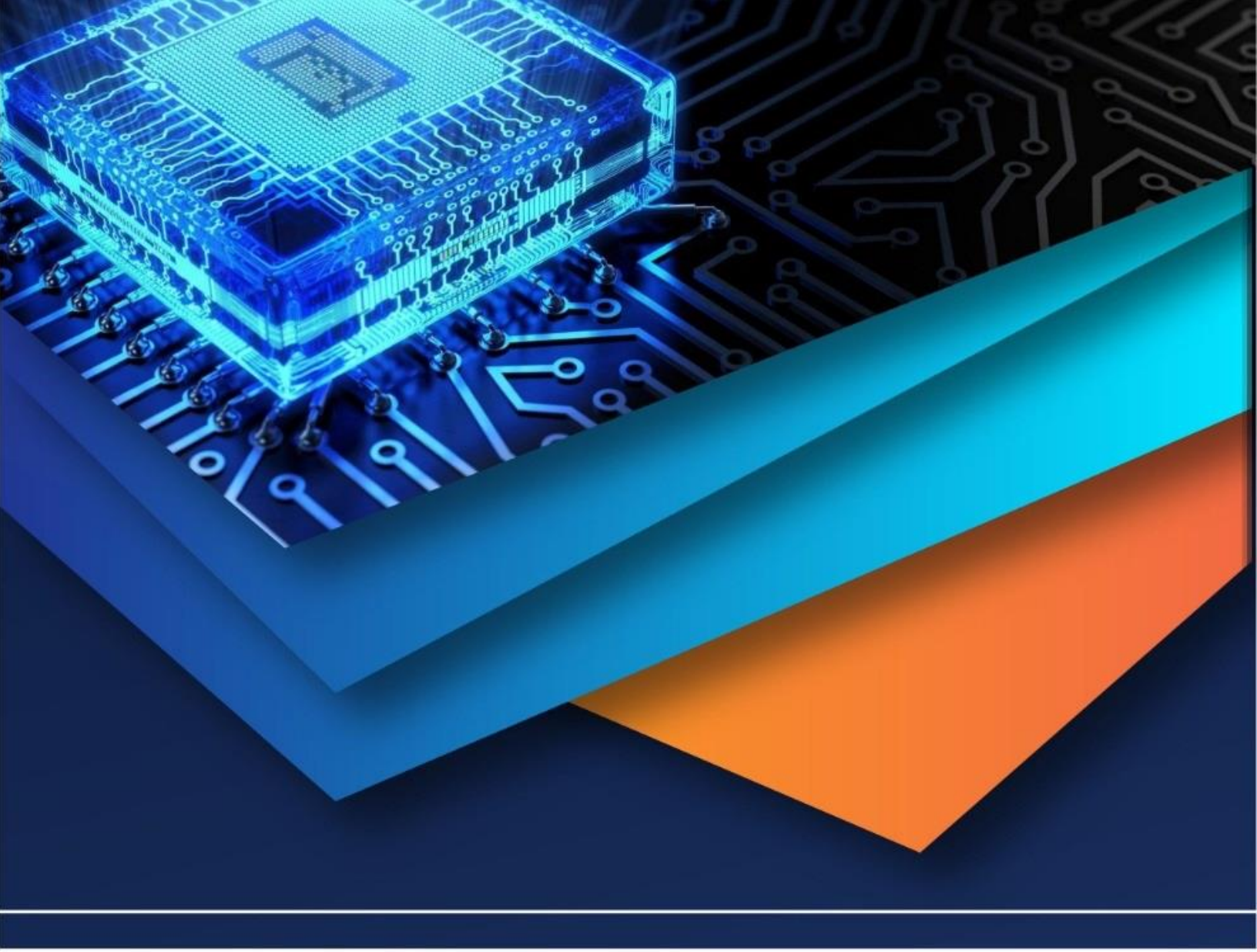
The monitoring platform can be enhanced with integration of automatic alerts like SMS, email and mobile push notifications for instant response in emergency. The dashboard can also be enhanced with advanced data visualization and historical data analysis capabilities, for improved decision-making and maintenance planning. In addition, energy-efficient solutions likeintelligentbatterymanagementmethodsandsolar-powered systems can be deployed for the long-term and sustainably operated.The envisaged enhancements in the future would add intelligence, scalability, energy-efficiency and would be very well suited to future smart city infrastructure monitoring applications.

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