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Big Data-Driven Disaster Management and Early Warning System for Natural Calamities

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Abstract: ***Big data-driven disaster management and early warning systems have emerged as vital tools in predicting, monitoring, and mitigating the effects of natural calamities such as floods, earthquakes, cyclones, and droughts. This study explores the integration of big data analytics, real-time sensor networks, and artificial intelligence to enhance the efficiency and accuracy of disaster prediction and response mechanisms. By processing vast volumes of dynamic data from satellites, weather sensors, social media, and IoT devices, the system facilitates real-time risk assessment and early warnings. Predictive models built using machine learning algorithms help identify potential disaster zones and optimize resource allocation for relief operations. Furthermore, data visualization and decision-support dashboards enable authorities to take informed, timely actions to minimize human and economic losses. The research highlights how data interoperability, cloud infrastructure, and automated alert systems can collectively strengthen national and regional resilience to natural disasters. Ultimately, the adoption of big data technologies transforms traditional disaster management frameworks into proactive, data-smart systems capable of saving lives and sustaining communities. Big data analytics combined with artificial intelligence and mathematical modeling enables a shift from reactive to proactive disaster management by simulating disaster scenarios and predicting risks based on historical and real-time data, improving preparedness and mitigation strategies. Integration of diverse data sources including satellite imagery, sensor networks, social media, GPS data, and crowdsourced information provides comprehensive situational awareness, allowing rapid detection, risk assessment, and response coordination during natural calamities.***

Keywords: Artificial Intelligence(AI), Machine Learning(ML), IOT Sensors, Satellite imagery, Real-time data processing, Heterogeneous data sources, Risk assessment, Earthquake forecasting, Hurricane monitoring, Early warning system(EWS).

I. INTRODUCTION

A big data-driven disaster management system utilizes vast volumes of real-time and historical data to enhance preparedness, response, and recovery efforts during natural calamities. By leveraging advanced analytics, machine learning, and predictive modeling, these systems can process information from diverse sources such as satellite imagery, weather stations, social media feeds, and sensor networks to provide accurate early warning signals and actionable insights. This approach enables authorities to anticipate potential threats, optimize resource allocation, and communicate timely alerts to at-risk populations, significantly reducing the impact of disasters and saving lives.Early warning system represents a transformative approach to mitigating the impacts of natural calamities such as floods, earthquakes, hurricanes, droughts, and wildfires. Traditional disaster management systems often struggle with fragmented data collection and delayed responses; however, the integration of big data technologies enables real-time monitoring, analysis, and prediction of disaster scenarios. These systems gather massive datasets from diverse sources including remote sensing satellites, IoT-enabled sensors, mobile networks, and social media platforms. Advanced analytics, Artificial Intelligence (AI), and predictive algorithms then process this

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information to identify patterns, assess risks, and forecast potential disaster events with high accuracy.

By offering timely alerts and data-driven insights, big data-powered early warning systems help governments, emergency services, and communities prepare effectively and respond rapidly. They facilitate proactive decision- making, efficient resource deployment, and transparent communication during crisis situations. Moreover, post- disaster analytics can improve future preparedness by evaluating past response efficiency and infrastructure resilience. Overall, big data serves as a cornerstone in building smarter, responsive, and resilient disaster management frameworks that safeguard both life and property.This project introduces an AI-based EWS support and Advisory system. named Sachet. designed to alerts the citizens from flood's,cyclone's, earthquake's,natural calamitie's. through the AI models like deep learning architectures, particularly Long Short-Term Memory (LSTM) networks, Recurrent Neural Networks (RNNs), and Convolutional Neural Networks (CNNs), form the base for big data-driven disaster management and early warning systems for natural calamities. These models process vast datasets from satellites, IoT sensors, weather stations, and social media to detect patterns, predict events like floods or earthquakes, and issue timely alerts.Transformer-based models and Large Language Models (LLMs) are increasingly used as foundational AI for handling multimodel big data, improving real-time forecasting accuracy over traditional methods.

This paper presents SACHET, a real-time, location-aware disaster alert mobile application designed to bridge the gap between disaster management authorities and citizens. The proposed system integrates verified data from the India Meteorological Department (IMD) and the National Disaster Management Authority (NDMA) to ensure reliable alert dissemination. By leveraging cloud-based services, geo-location technologies, and an intuitive mobile interface, SACHET aims to improve response time, increase public awareness, and enhance overall disaster resilience.

II. PROBLEM STATEMENT

Natural disasters cause massive loss of life, infrastructure damage, and economic setbacks due to delayed detection, poor data integration, and inadequate real-time alerts. Traditional systems struggle with data volume from diverse sources like IoT sensors and social media, leading to rumors spreading faster than facts, inefficient resource allocation, and vulnerability in under-monitored areas, especially in developing regions.Challenges include insufficient sensor coverage, data privacy issues, skill shortages, and processing delays that exacerbate impacts during crises like earthquakes or floods.

III. LITERATURE REVIEW

Disaster management and early warning systems have been the subject of extensive research due to their critical role in reducing the impact of natural calamities. Various techniques and approaches have been proposed and implemented to disseminate disaster-related information to the public. This section reviews key existing systems and methodologies, highlighting their strengths and limitations.

Traditional disaster alert systems primarily rely on mass communication channels such as television broadcasts, radio announcements, sirens, and Short Message Service (SMS). While these methods are effective in reaching a large population, they often lack real-time responsiveness and precise location targeting. SMS-based alerts, for instance, may experience delays during network congestion and do not provide detailed contextual information or guidance.

With the advancement of mobile technologies, several mobile-based disaster alert applications have been developed. Government-backed applications such as the NDMA mobile application (India) provide official disaster updates and safety guidelines. However, studies indicate that such applications often face challenges related to delayed updates,limited geo-targeting capabilities, and low user engagement due to non-intuitive user interfaces.

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International systems such as the FEMA Mobile App (USA) represent more advanced approaches, offering features like weather alerts, emergency tips, and shelter information. Although these systems demonstrate effective integration of real-time alerts and user-centric design, they are not adaptable to Indian disaster management frameworks and lack integration with local data sources such as IMD and NDMA. Recent research has explored the use of location-based services (LBS) and cloud computing for disaster alert dissemination. Geo-fencing and GPS-based techniques enable the delivery of alerts to users within specific geographical boundaries, improving relevance and reducing information overload. Cloud-based platforms further enhance scalability and reliability by enabling real-time data processing and push notification delivery. However, many proposed systems focus solely on

alert dissemination and do not provide comprehensive emergency support features such as resource mapping and actionable safety guidance. Furthermore, studies emphasize the importance of user-centered design in disaster management applications. Systems with complex interfaces or excessive technical information tend to discourage usage during emergencies. There remains a lack of integrated solutions that combine real-time alerts, verified government data, intuitive design, and emergency resource mapping in a single platform.

Based on the literature reviewed, it is evident that while significant progress has been made in disaster alert technologies, existing approaches still exhibit critical limitations in terms of location accuracy, response time, data reliability, and usability. These observations form the basis for the proposed SACHET system, which aims to address these shortcomings through a unified, real-time, and location-aware mobile application.

IV. METHODOLOGY

The SACHET platform has revolutionized India's public alerting capabilities. It enables fast, reliable, and scalable disaster alerts to be disseminated via mobile networks. SACHET offers a valuable model for other countries that seek to enhance their early warning systems.Critically, no sirens or SMS alerts warned residents of the rising waters. Although India had 275 flood-forecasting stations, none covered the specific rivers that flooded—a gap previously identified by experts. Post-flood reviews concluded that an end-to-end early warning system (EWS) could have provided the necessary warning for evacuation and mitigated this disaster.

The World Meteorological Organization (WMO) defines EWS as a coordinated framework that transforms hazard information into effective action through four interconnected pillars:

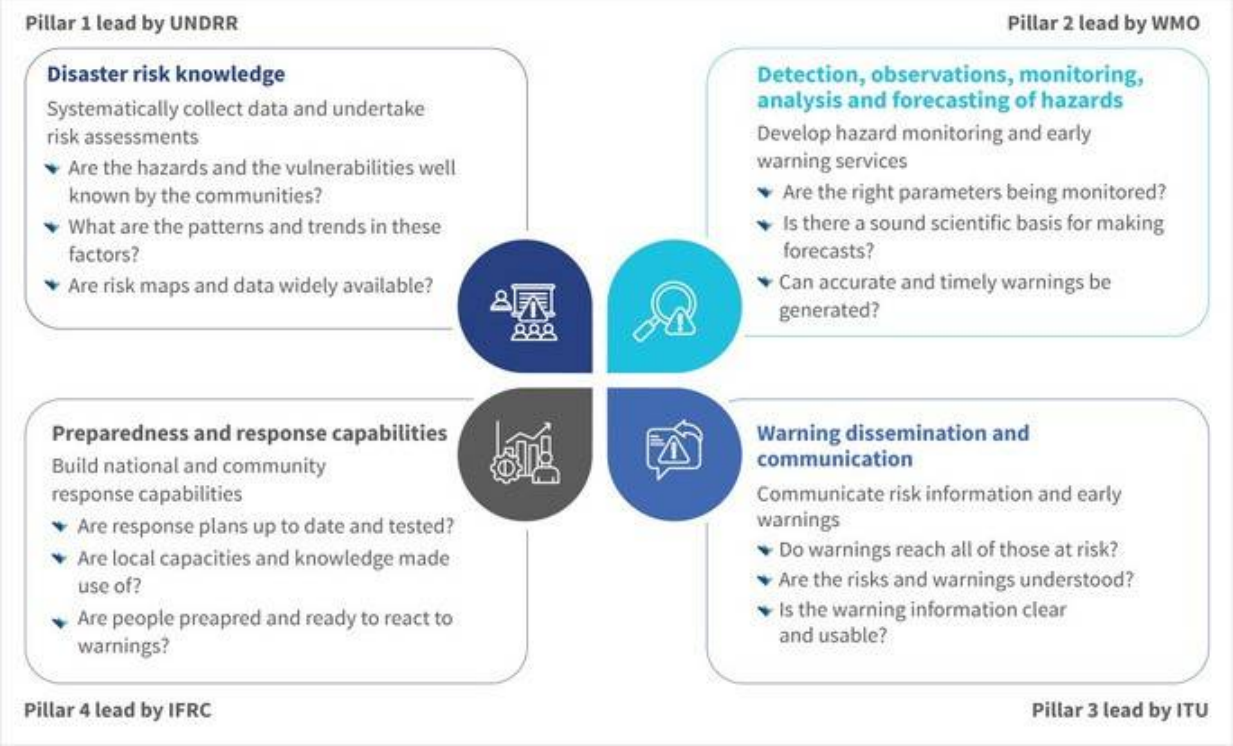


Figure:1 four interconnected pillars:

studies show that effective EWS can achieve substantial results. It can avert USD 3 to 16 billion in annual economic losses, reduce disaster fatalities by eight times, and cut economic damages by 30% with just a 24-hour notice. Yet, half the world's countries lack an adequate EWS. This leaves a third of the global population unprotected.

To combat this, the United Nations launched the Early Warnings for All initiative to achieve near-universal EWS coverage by 2027. Yet, the success of these systems hinges on careful design, strategic deployment, and operational efficiency. In this context, the , partnered with MSC to undertake a case study on India's recently established public warning system, SACHET. It can serve as a valuable model for other countries that seek to enhance their public alerting capabilities.

A. *India's Alerting Challenges*

Historically, warnings relied on slow channels, such as radio, TV, and newspapers. In India, these challenges were compounded by outdated SMS lists that missed travelers and migrant workers. Alerts often went to entire districts, creating alert fatigue, and were rarely in local languages. Furthermore, multiple agencies sent uncoordinated alerts manually, meaning citizens received too little warning, too late. Today, mobile networks reach more than 95% of the global population, which makes phones vital to modern early warning systems. Countries have started to adopt location-based SMS and cell broadcast to send geofenced alerts in seconds. Following this trend, India too saw a need for a unified, mobile-first system to replace its legacy channels.

B. *The SACHET*

The National Disaster Management Authority (NDMA) and the Centre for Development of Telematics (C-DOT) developed SACHET ("to be alert" in Hindi) to meet India's disaster alerting needs. Launched nationwide in August 2021, it serves as the country's first unified digital platform for issuing disaster warnings, also known as a public warning system.

At its core, SACHET uses the Common Alerting Protocol (CAP)—an open, XML-based standard that gives every warning a consistent structure, so alerts from different agencies can be shared, understood, processed, and disseminated immediately. Crucially, SACHET brings together two key groups of stakeholders on one secure platform—alert-generating agencies (AGAs) and alert-authorizing agencies (AAAs).

When an AGA triggers an alert, SACHET automatically routes it to the relevant SDMA or AAA. These officials then carefully review the message, translate it into local languages, and refine its content for clarity and effectiveness. They also use geographic information systems to define affected areas precisely by creating detailed "geofences" (see Figure 3 below). This meticulous approach ensures that warnings reach only those directly threatened and minimizes unnecessary panic and alert fatigue. The finalized warning is disseminated across all chosen media channels with a single click within a few minutes.

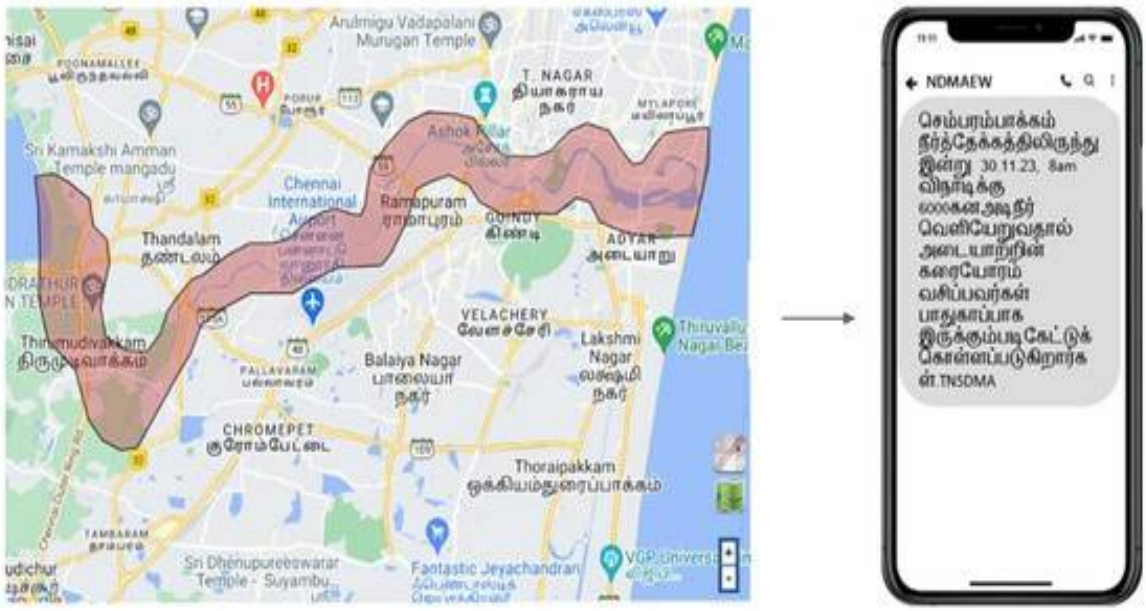


Figure :2 alert sms

Mobile network operators form the backbone of SACHET. They enable the swift exchange of messages through India's four largest operators: Airtel, Jio, Vodafone Idea, and BSNL. The system uses both location- based SMS (LB-SMS) and cell broadcast (CB) technologies to send quick, geotargeted messages to mobile phones. While they have different strengths and limitations, a system that intelligently combines both for the right context is most effective.

Beyond mobile alerts, SACHET uses multiple communication channels, such as television crawls, radio broadcasts, railway station display boards, mobile apps, social media, browser RSS feeds, and satellite communication (See Figure 4 below). This comprehensive "many channels, one message" approach ensures universal coverage and guarantees that critical alerts reach everyone. It does not matter whether a person is online or offline, watching TV, or working in the fields. Some form of alert will reach them.



Figure:3

Since its launch, SACHET has issued more than 30,000 hazard-specific alerts through 44 billion LB-SMSs. Its streamlined workflows have helped deliver alerts in places without rapid channels and supported faster evacuations alongside more timely protective actions.

We have distilled six key considerations from our analysis of India's SACHET public warning system to help countries design, deploy, and operate effective public warning platforms.

C. Beyond warnings: Triggering financial resilience

Timely alerts can save lives. However, they are not enough alone. Many vulnerable households struggle to take the necessary actions due to financial limitations. For example, a family cannot evacuate without money for transport, and a farmer cannot protect their livestock without cash in hand. True resilience means ensuring that people receive early warnings and have the financial means to respond effectively. Recent innovative financial mechanisms provide a means to bridge this critical gap:

1) Forecast-based financing (FbF): This refers to prearranged cash transfers that are automatically released when forecasts predict a hazard. It allows communities to prepare for the disaster, buy supplies, safeguard assets, or relocate before disaster hits.

2) Contingent lines of credit (CLOC): These refer to indexed loans that are made available to preapproved borrowers once disaster triggers, such as flood levels, are met. They offer fast relief without upfront costs.

Microfinance institutions are well-positioned to deliver these anticipatory loans at scale with their deep community networks and expanding digital capabilities. However, government support will be vital to make this ecosystem work. Governments can share accurate forecast data, offer partial credit guarantees to reduce lender risk, and enact favorable policies and regulations.

As climate threats intensify, countries must urgently modernize their EWS. SACHET provides a strong model for building an inclusive, tech-enabled public warning system. MSC seeks to pair these alerts with timely financial access, so vulnerable communities can act, adapt, and recover more quickly.

V. RESULTS

The Sachet National Disaster Alert Portal, developed by India's National Disaster Management Authority (NDMA) in collaboration with C-DOT, serves as a pioneering pan-India platform for disseminating geo- targeted early warnings for natural and man-made disasters, including floods, cyclones, earthquakes, and heatwaves. As of the latest dashboard update on January 15, 2026, no live forecast alerts were present, with the system integrating real-time data from authorized sources like the India Meteorological Department (IMD), Central Water Commission (CWC), and others to deliver notifications via SMS (prefixed XX-NDMAEW), a dedicated mobile app available on Android and iOS, browser alerts on Chrome/Firefox/Edge, and RSS feeds in 12 regional languages. This Common Alerting Protocol (CAP)-based integrated system enhances last-mile connectivity through additional channels like GAGAN/NaVIC satellites, supporting location subscriptions, weather forecasts, Do's and Don'ts guidance, and helpline access to bolster community preparedness across all states and union territories.

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VI. OUTPUT

Figure:4 All india cap alert:



Figure:5 state wise alert distribution:

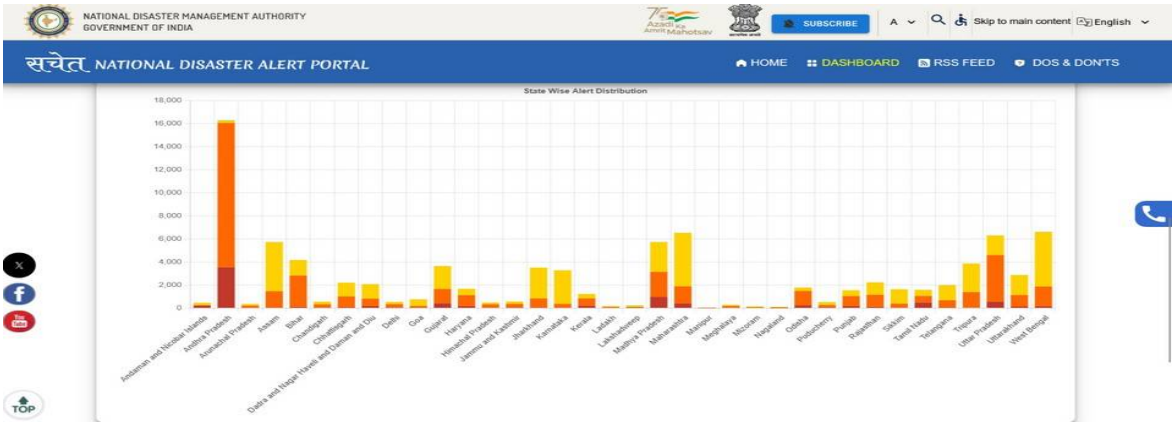
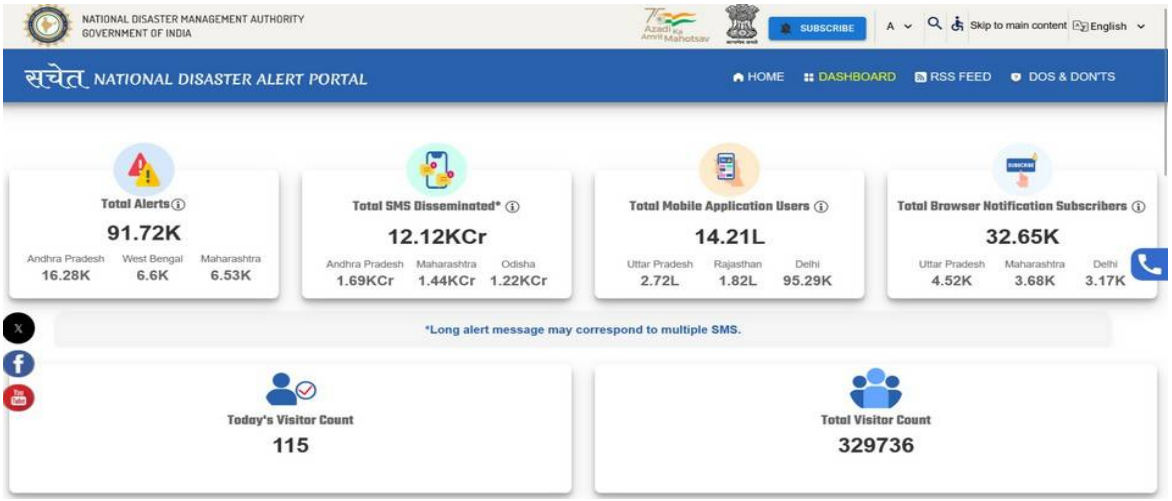
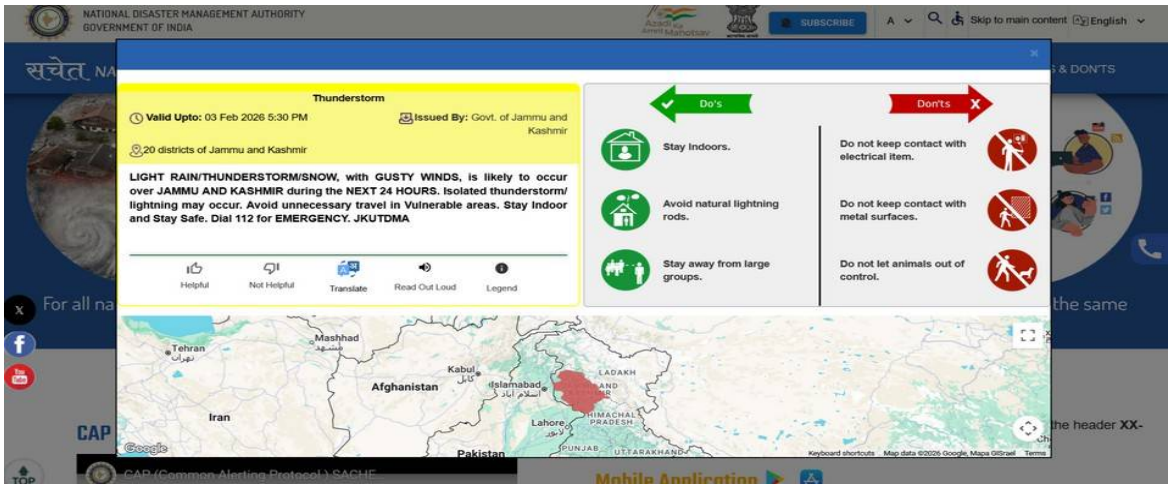


Figure:6 Dashboard:



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Figure:7 alert :



VII. CONCLUSION

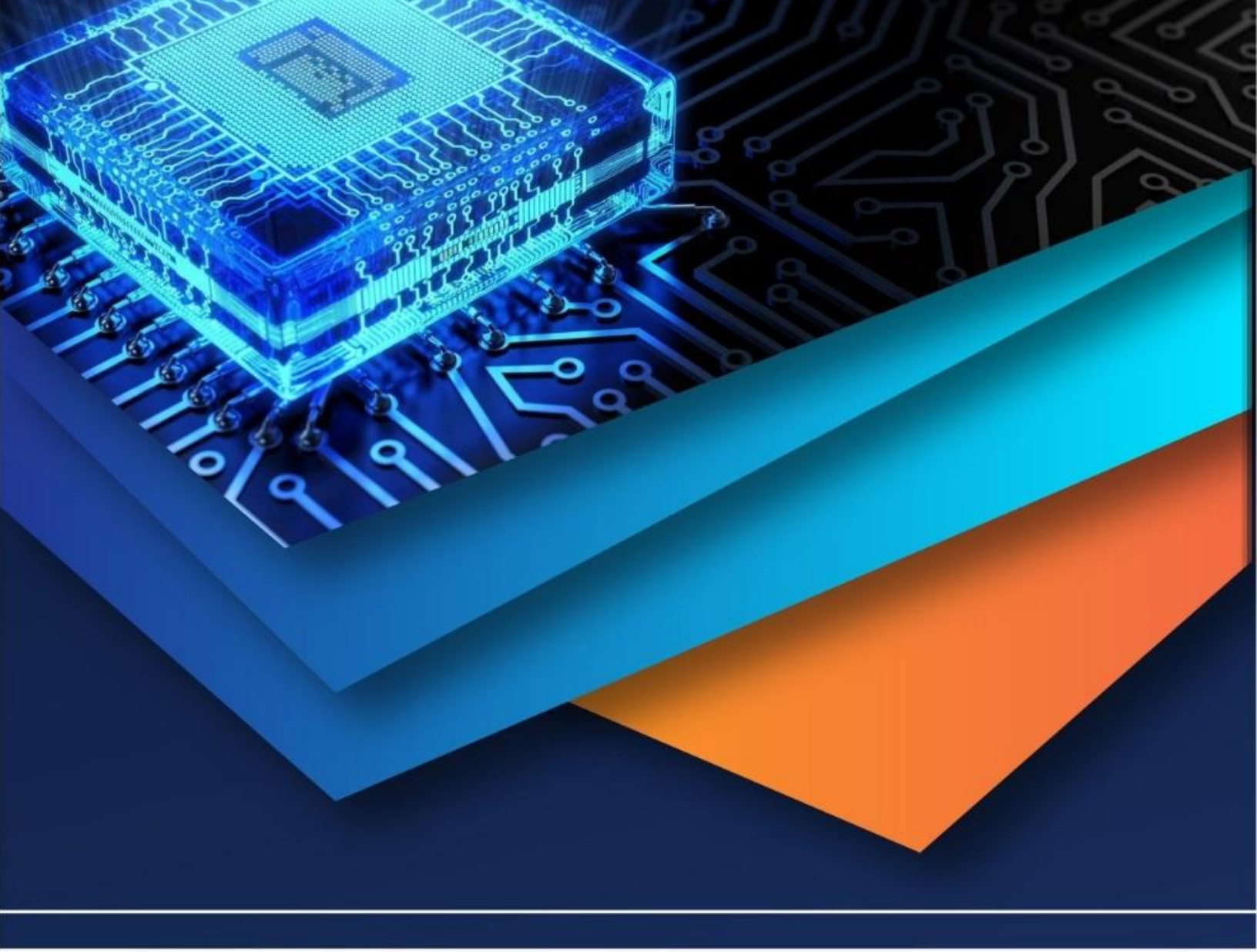
This study presented SACHET, a real-time, location-aware disaster alert mobile application aimed at improving the dissemination of critical information during natural disasters. The proposed system addresses key limitations of existing disaster alert mechanisms, such as delayed notifications, lack of precise geo-targeting, and absence of integrated emergency support features.

By utilizing verified data from official government agencies such as the India Meteorological Department (IMD) and the National Disaster Management Authority (NDMA), the system ensures the reliability and accuracy of disaster alerts. The integration of cloud-based services, location-based technologies, and push notification mechanisms enables timely delivery of alerts to affected users. Additionally, features such as emergency resource mapping and disaster-specific safety guidelines enhance user preparedness and response capability.

The conceptual design demonstrates that the proposed system is feasible, scalable, and effective in improving disaster communication and public safety. SACHET has the potential to significantly reduce response time and bridge the gap between disaster management authorities and citizens. Future enhancements may include multi- language support, predictive analytics, and wider geographic coverage to further strengthen the system's impact.

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