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BIG DATA ANALYTICS BASED ON THE INTERNET OF THINGS AND CLOUD COMPUTING INTEGRATED FOR EVOLVING ENVIRONMENTAL DATA MANAGEMENT

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Abstract

Big Data analytics's integration with Internet of Things (IoT) and Cloud Computing (CC) technologies is explored in the present investigation to provide a robust framework for evolving environmental data management. The use of IoT sensors and devices allows for the continuous collection, transmission, and processing of real-time environmental data, and, with the aid of big data analytics, this massive volume of data can be handled, stored, and analyzed effectively, producing insights that were previously impossible. The rapid expansion of data produced by many sources in today's connected world presents both advantages and challenges for environmental data management. For large-scale applications, the usage of cloud computing guarantees data accessibility, scalability, and flexibility. The combined approach facilitates environmentally sound management by enabling predictive modeling, real-time monitoring, and intelligent decision-making. Better fine-grained structure, increased flexibility, and accuracy are all demonstrated by the notable advancement in IoT-CC technology. By tackling issues like pollution, resource management, and climate change, this integration seeks to improve the precision, promptness, and efficacy of environmental monitoring systems. The suggested methodology demonstrates the approach's potential influence on upcoming environmental data management procedures as well as its contribution to intelligent, sustainable ecosystems.

Keywords: IOT, Cloud Computing sensors, big data analytics, environmental data managements and monitoring

INTRODUCTION

The term "big data analytics based on Internet of Things (IoT) and cloud computing integrated" describes a system in which enormous volume of data produced by networked smart devices (IoT) are gathered, saved on cloud platforms, and then examined using potent big data tools to glean insightful information that helps businesses make wise decisions and continually improve operations as new data becomes available. The combination of cloud computing, the Internet of Things (IoT), and big data analytics holds great potential for solving most urgent environmental issues in the present day of rapid technological innovation. The amount of environmental data produced by many sources, including sensors, satellites, and monitoring stations, is increasing exponentially. The volume, complexity, and real-time demands of contemporary environmental monitoring systems frequently make traditional methods of environmental data collecting and handling insufficient. In this regard, the convergence of cloud computing, IoT and big data are essential to the development of environmental data management.

Among the primary goals of environmental monitoring systems are real-time environmental condition monitoring and prompt detection and resolution of environmental issues. Systems must be able to gather, transmit, and process data efficiently in order to accomplish this. However, the latency and data transmission rates of conventional wireless communication methods are constrained.

The Internet of Things (IoT), with its network of connected sensors and gadgets, provides a real-time stream of environmental data. These gadgets can track a variety of elements, including temperature, humidity, pollution, water levels, and air quality. This data is crucial for making well-informed decisions. To evaluate and derive useful insights from the vast amount and diversity of data produced by IoT devices, sophisticated analytics techniques are necessary. Big data analytics satisfies this need by enabling the handling, storing, and analysis of massive datasets, commonly known as the "three Vs". they are,

- **Volume**
- **Velocity**
- **Variety.**

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Big Data makes it possible to spot patterns, trends, and abnormalities in the environment, which can aid in forecasting, early disaster detection, and long-term sustainability planning in the recommended environmental management method. Because the environment is dynamic and always changing, big data analytics enables firms to make data-driven decisions that are more accurate and timely.

Cloud computing offers scalable, adaptable, and affordable methods for processing and storing vast volumes of environmental data, hence providing the infrastructure required to enable these technologies. The difficulties associated with on-premises data storage, processing constraints, and infrastructure expenses are mitigated by cloud platforms. Cloud services provide real-time data access from any location, encouraging cooperation and guaranteeing that important stakeholders may make prompt decisions using the most up-to-date data. Global environmental monitoring activities are made easier by the efficient handling of large-scale, dispersed data made possible by the incorporation of cloud computing into environmental data management systems

Significant benefits come from combining Big Data analytics, IoT, and cloud computing for environmental data management. These benefits include better real-time analysis, predictive modeling, and actionable insights into environmental patterns, as well as increased data collecting and storage capabilities. A more proactive and flexible approach to managing natural resources, halting climate change, cutting pollution, and advancing sustainability is made possible by this mix of technologies. Additionally, it makes it easier to create smart ecosystems in which environmental data is effortlessly transferred between platforms and used to guide decision-making at all levels, from local government to international politicians.

The investigation analyzes how various technologies interact and how environmental data management is changing as a result of them. The technological developments, difficulties, and potential paths for integrating cloud computing, IoT, and Big Data analytics are examined in order to handle environmental data and eventually help build more intelligent and sustainable ecosystems.

RELATED WORK

The internet of things (IoT) has grown in popularity and usage over the last ten years, indicating exciting and profitable new opportunities for an entire generation of information devices [1,2]. According to Atzori et al. [3], "three visions—things-oriented, internet-oriented, and semantic-oriented converged to form the Internet of Things." Semantically, the term "global network of interconnected objects" refers to the Internet of Things. One definition of IoT is "a dynamic global network infrastructure, as such it can identify, control, and monitor each object on earth via the internet according to a specific agreement protocol, and through the interconnection of physical and virtual things based on the interoperability of information and communication technologies," according to [4,5]. The IoT's primary goal is to provide real-time information sharing via self-governing networked entities [6,7].

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Devices with wireless sensors [10], radio frequency identification (RFID], and any smart object connected to the internet via physical IP [11] are all tied together through a variety of communication techniques like WiFi, ZigBee, Bluetooth, and GSM. Ingenious computational capabilities are used to place a sensor in an area that is connected to the internet, and at any time, this sensor will be able to communicate with anything from anywhere in the network [8,9]. Data collection systems make the process of gathering data easier by locating and transmitting information via a large number of these IoT connection devices.

IoT applications in smart environments create a complete, multi-level ecological monitoring network. This can be accomplished by building a large platform with a data center and unified service support, integrating sensors at all levels, and using IoT to gather geographical and temporal data [12]. Big data and IoT technology are widely used in many domains, including intelligent warning systems, smart cities, smart healthcare, and disaster management. The creation and application of IoT and big data in environmental domains is therefore increasingly essential, especially for the creation, promotion, and administration of a new, strategic industrial environment.

Ahmed et al. [13] investigated a range of methods for managing IoT-based large data. Big data sources, system components, big data enabling technologies, functional aspects, and analytics are the criteria used in this study to classify the literature. The authors also identified connectivity, storage, quality of services, real-time analytics, and benchmarking as essential prerequisites for big data processing and analytics. Marjani et al. [14] provided a distinctive architecture for massive IoT data analytics and assessed the most recent scholarly endeavors on the topic. This article covers the various kinds of big IoT data analytics under the headings of real-time, offline, memory-level, business intelligence, and huge level analytics. IoT technology combined with Big Data Analytics (BDA) can manage intelligent decision-making and rapid information stream analysis [15].

Transmission effects are challenging to guarantee in remote or complex contexts due to the restricted reach of standard communication systems [16]. The efficacy of environmental governance may be impacted, for example, by faulty monitoring data that leads to wrong pollution source identification. Environmental monitoring systems must have strong data verification and error repair procedures in place to increase data reliability and guarantee data accuracy and integrity [17]. One of the primary challenges in environmental monitoring data management is the intelligent processing and analysis of environmental data to support scientific environmental management decision support using state-of-the-art data analysis technologies like big data analytics, machine learning, and artificial intelligence. Machine learning algorithms, for instance, are capable of accurately generating pollution warnings and governance recommendations, identifying possible pollution sources and patterns, and thoroughly mining environmental data.[18].

CONTRIBUTION OF THE PAPER

- An overview of big data analysis in cloud and IOT environments is the primary objective.

- intercloud technology for big data, cloud-based big data processing, data security, privacy, and trust in cloud-based big data processes, and simple cloud access for big data processing.
- Data collection, communication, data ingestion, data storage, processing and analysis, and post-processing are the six primary processes that make up the Internet of Things process.
- Because the environment is dynamic and always changing, big data analytics enables firms to make data-driven decisions that are more accurate and timely.
- Better fine-grained structure, increased flexibility, and accuracy are all demonstrated by the notable advancement in IoT-CC technology. By tackling issues like pollution, resource management, and climate change, this integration seeks to improve the precision, promptness, and efficacy of environmental monitoring systems.
- The increasing frequency of cyberattacks and data breaches necessitates the use of advanced encryption technology and security mechanisms in environmental monitoring systems to ensure data security during transmission and storage.

PROPOSED METHOD

In order to provide advanced insights and proactive management of environmental issues such as air quality, water pollution, and climate change, a system known as "big data analytics based on the Internet of Things (IoT) and cloud computing, integrated for evolving environmental data management" uses cloud computing platforms to process and analyze massive amounts of environmental data collected by IoT sensors in real-time. This system can also improve and adapt as new information becomes available.

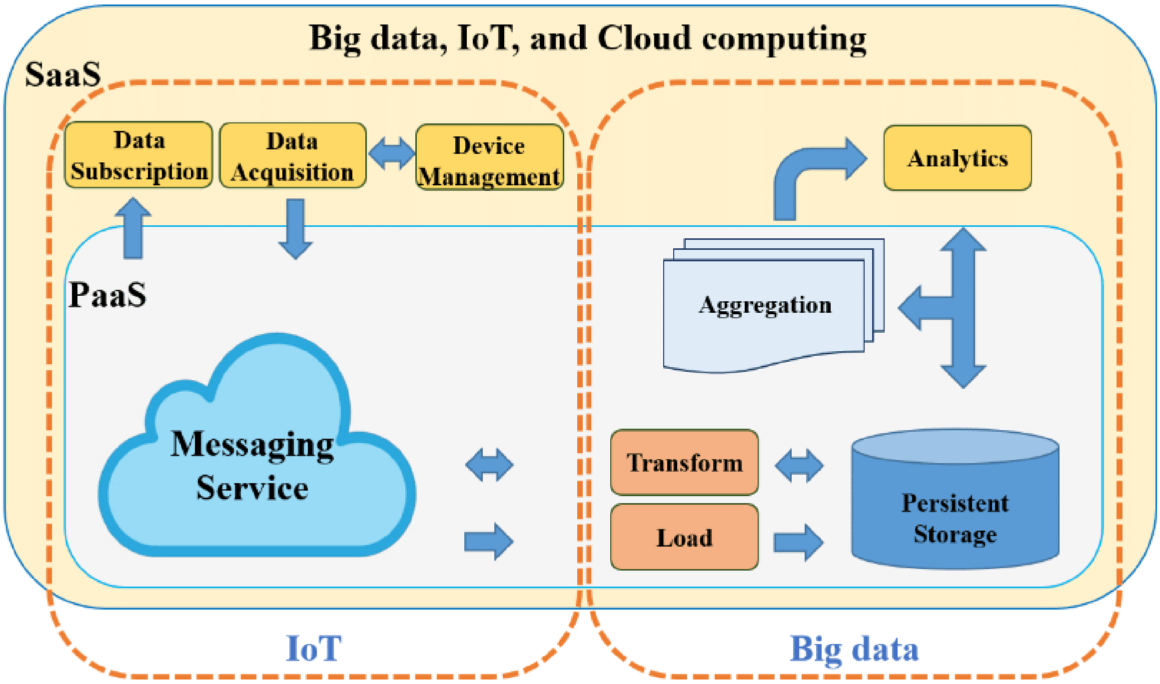

Figure 1: Basic architecture of big data analysis based on hybrid IOT and Cloud Computing

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Figure 1 illustrates the intricate connection between big data, cloud computing, and the Internet of Things. According to the information provided, big data, cloud computing, and the Internet of Things are all influenced by one another. Cloud computing is a common business function when IoT is used as a data source and Big Data is used as the analytics platform for the data. The following justifies the provision of this information:

- Large volumes of data are produced by IoT and supplied into big data systems.
- Streamlining data integration, which is necessary to maximize the benefits of IoT.

4.1 Big Data Analytic

There are three key features of big data to consider. They are variety, velocity, and volume.

1. **Volume:** It displays the amount of data that has been transferred and saved. The amount of data is always growing and changing in the modern world. On Facebook alone, for instance, 10 billion messages are sent every day. machinery, cameras, sensors, etc. Continuously generating data and increasing the volume of data are Mobile Electronic System Integration cameras that are always recording.
2. **Velocity:** The velocity of data production and dissemination is reflected in this idea. The ability to analyze and evaluate the generated data instantly without storing it is another aspect of speed. These days, information is created and disseminated swiftly, necessitating rapid analysis.
3. **Variety:** shows a specific type of data. Images, view counts, emails, audio recordings, movies, and ECG data are just a few of the various data kinds that are included in the variety function. The goal of big data management is to uncover the data value hidden inside the data. Value is achieved by leveraging the previously described features of big data.

4.2 Cloud Computing in Environmental Data Management

Cloud services occasionally referred to as cloud-based IoT environments, integrate the capabilities of cloud computing processes and IoT device functionalities into an end-to-end service. For the precise data extraction procedure, it integrates IoT data centers with big data processing and sophisticated machine learning techniques. In practically every industry, this integration of cloud and IoT settings offers users excellent tactics. Understanding the surroundings, user behavior, and usage habits of a client is helpful in finding design flaws, conducting field tests for a product, and customizing a product in a way that is focused on the needs of the consumer to boost its market value. One technology that uses the pay-as-you-go model to offer services to users is cloud computing. The following are the three primary services that cloud computing provides. And the structure is shown in fig. 2 below.

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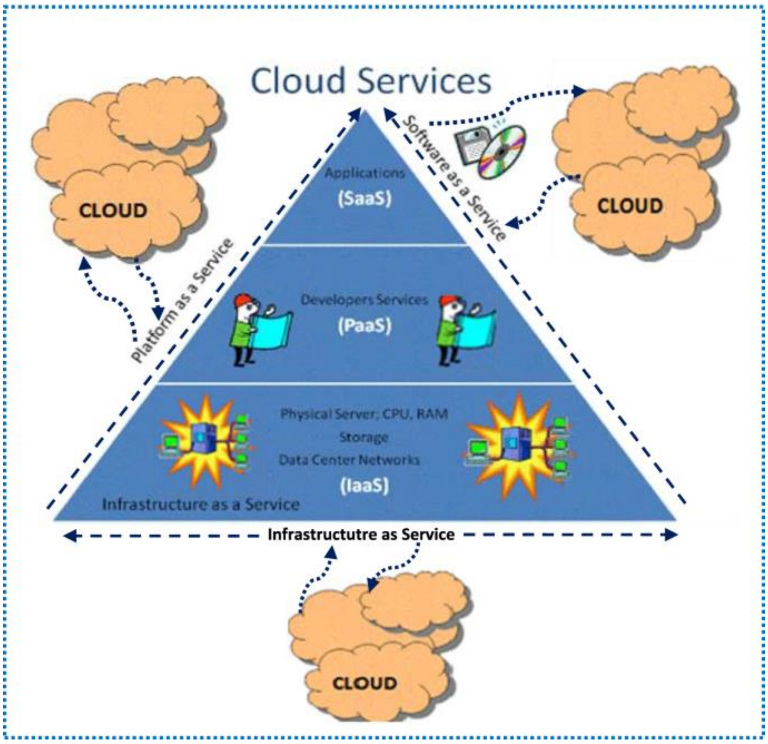

Figure 2: Structure of cloud computing process.

Infrastructure as a Service (IAAS):

The concept of offering the infrastructure as a cloud service enables the client to install operating systems and applications and configure the processor, storage, network, and other important information resources independently. Although he lacks full management and control over the network structure, the client has total control over the system at the operating system level and can handle specific network components.

Platform as a Service (PAAS):

The cloud provider offers features including databases, queuing, configurable storage, and uptime. provides a variety of materials, including. The user bears responsibility for configuration and implementation. For the customer to create and execute their application, the service provider offers a platform. Along with supplementary services and the required technology infrastructure, this platform comprises the setting in which the application will be created and run. There are no management or control options for the elements that comprise the platform architecture, except from the user-installed application.

Software asa Service (SAAS):

When infrastructure and IaaS are available, this service is the most straightforward way to provide all the platform's infrastructure and settings. Customers can use web browsers to access cloud computing applications without needing to install any software on their machines. Infrastructure elements including the network, server, operating system, and storage devices have not been beneath the management or control of customers. They can only make modifications specific to the programs they use.

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4.3 IOT based environmental data management

The logical and physical architecture of IoT data management systems is determined by a number of design primitives. Building a complete IoT data management system requires data management, which covers data administration, data processing, which deals with data archiving and storage, and data collection, which looks for and identifies actual data. The following are the primary obstacles and issues in the process of integrating IoT with cloud:

- Systematic approaches to power consumption in information management
- transmission that are invariant to machine-to-machine communication and its interactivity
- infrastructure and resources for effective IoT data management
- huge data received from multiple devices,
- security and privacy techniques to integrate information from other devices.
- estimating and levying, internetworking between devices, low storage needs, etc.

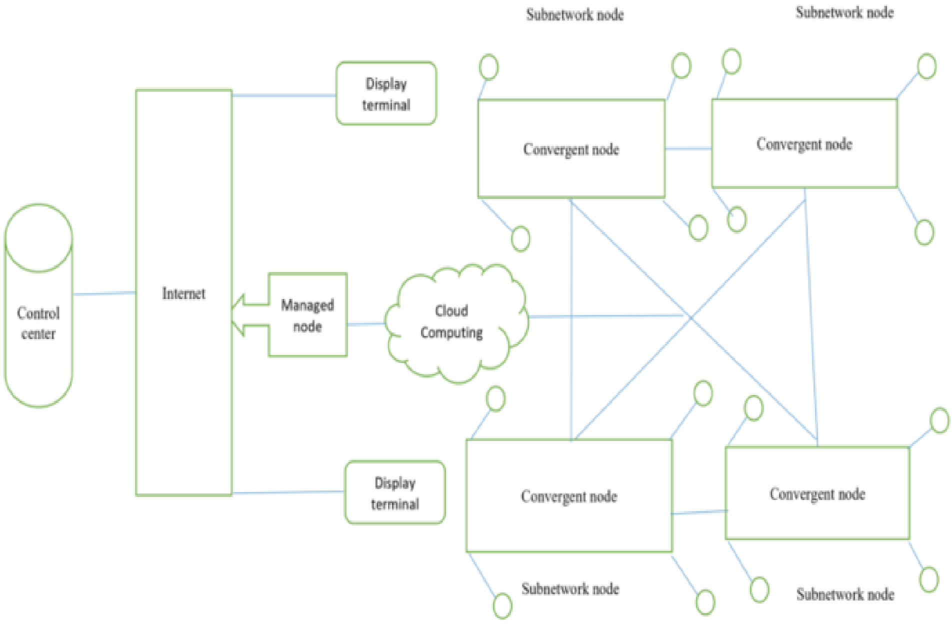

Figure 3: IOT sensor network

Cloud-hosted IOT sensor networks offer more resilience, flexibility, and control. IoT sensor network data is constantly processed using the theoretical cloud computing paradigm. Multiple smaller networks, each with a number of sensors, make up the IOT sensor network seen in Figure 3. The sensing components of the sub networks monitor changes in parameters. Each convergent node is connected to multiple sub-networks, and the convergent nodes are interconnected. Using cloud computing technologies, each of these nodes is linked to the management nodes. The data resources are determined based on input from the managed node using a series of idle nodes rather than active nodes. The nodes that are being watched receive directives from the control center over the internet. The display interface shows the findings of the IOT sensor network's investigation.

4.4 Environmental data managements

It is one of several methods used to determine a capital investment's worth. Return on investments, or ROI, is sometimes associated with "cost savings." This is determined by dividing the total value or return by the total cost (the savings). Understanding each aspect and creating a mechanism for calculating it are all that are required to break it down into quantifiable parts. The overall return on investment can be computed by adding up the costs, returns, and saves of each variable.

$$\boldsymbol{ROI = \frac{(Return-cost)}{Cost}} \quad \textbf{(1)}$$

A fundamental basis for determining the value of environmental data management, analysis, and compliance software is provided by the ROI mentioned above. For the environmental arena, the above formula can be significantly altered: Divide "savings" by "derived income," then "investment." The term "savings" in this formula include both savings from enhanced performance and increased efficiency of engineering processes as well as savings from operational costs and procedures.

Pollution is reduced, allowing engineering processes to function as planned. These improved engineering procedures can be used to compute derived income. Keeping track of all reporting requirements can help reduce or even eliminate many of the expenses related to fines.

$$\boldsymbol{ROI = \frac{(Saving+Derived\ Income)}{Investment}} \quad \textbf{(2)}$$

TDS = TDR + PL **(3)**

where the symbols TDS, TDR, and PL, respectively, represent the total amount of data sent, the total amount of data recovered, and the packet drop. Many sensors, like temperature or gas sensors, need to be calibrated to account for deviations from ideal behavior. A basic calibration equation may look as follows.

$$\boldsymbol{C_{calibrated} = \frac{(S_{measured}-S_{offset})}{S_{slope}}} \quad \textbf{(4)}$$

$C_{calibrated}$ is the corrected sensor reading, $S_{measured}$ is the raw sensor output, S_{offset} and S_{slope} are calibration constants. Forecasting environmental data can be done using regression models or more complex machine learning algorithms. For example, a linear regression model could predict future temperature or gas levels based on past data:

$$\boldsymbol{Y = \beta_0 + \beta_1 X} \quad \textbf{(5)}$$

Y is the predicted value (e.g., future temperature), X is the independent variable (e.g., time or past temperature), $\boldsymbol{\beta_0}$is the intercept and $\boldsymbol{\beta_1}$is the regression coefficient. When integrating data from multiple sources (IoT devices, cloud platforms), it's essential to normalize the data for consistency as follows.

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$$X_{normalized} = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (6)$$

X is the raw environmental data, X_{min} and $X_{max}$are the minimum and maximum values in the dataset. This standardizes the data to a range between 0 and 1, making it easier for algorithms to analyze and compare.

RESULT AND ANALYSIS

Data gravity is another significant problem brought on by the exponential growth in volume of data gathered by IoT sensors. Cybercriminals may even be drawn to large data volumes. Because data privacy is a hot topic, all of the important data must be treated with exceptional caution. It is necessary to investigate various safe methods for exchanging and optimizing the collected data. Therefore, all business executives working in a cloud-based IoT environment must develop an IoT data management strategy in order to implement IoT solutions in a safe, secure, and efficient manner. The following summarizes the findings and analysis of environmental data management based on the combination of cloud computing and IOT big data analysis methods.

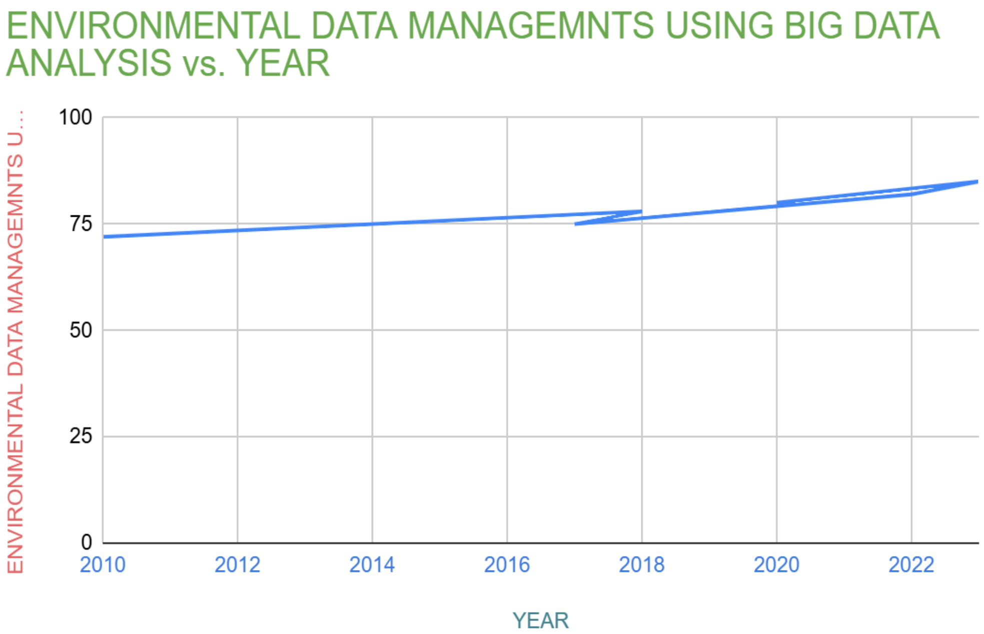

Figure 4: Analysis of environmental data vs year

Figure 4 presents data on environmental data management using big data analysis over several years. It shows the value of environmental management in different years, with the values ranging from 72 in 2010 to 85 in 2023. The data highlights an overall upward trend in the use of big data for managing environmental factors, reflecting advancements in technology, data collection methods, and analysis techniques over time. The highest value of 85 is recorded in 2023, suggesting a continued growth in the application and effectiveness of big data in environmental management.

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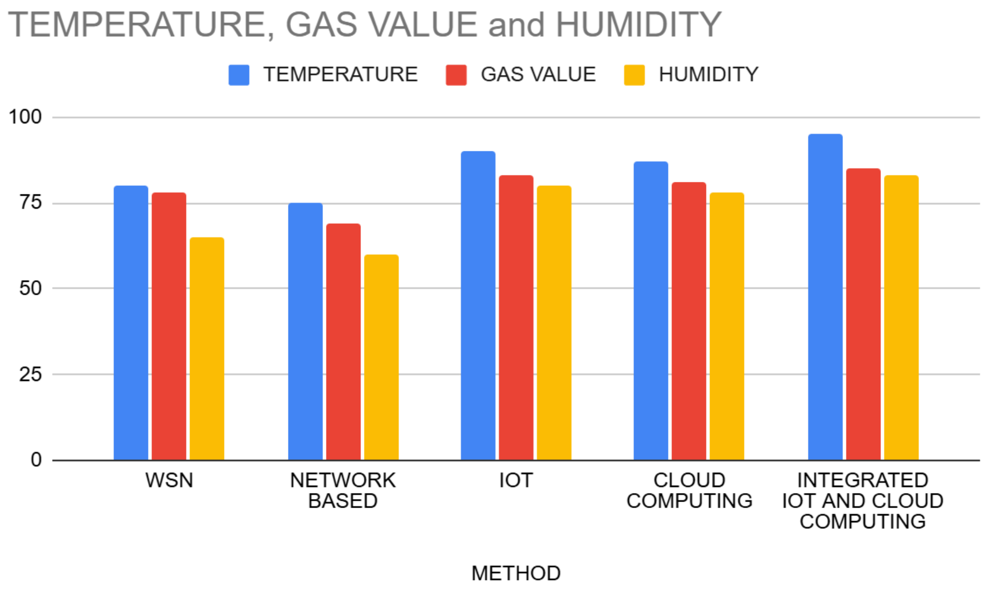

Figure 5: comparison graph

The graph 5 compares five methods for monitoring environmental conditions of temperature, gas value, and humidity. The Wireless Sensor Network (WSN) shows moderate values, with 80°C, 78 for gas, and 65% humidity. The Network-Based method has lower readings at 75°C, 69 for gas, and 60% humidity. The Internet of Things (IoT) method records the highest values at 90°C, 83 for gas, and 80% humidity. Cloud Computing shows 87°C, 81 for gas, and 78% humidity. Lastly, the Integrated IoT and Cloud Computing method has the highest values at 95°C, 85 for gas, and 83% humidity, offering the most advanced and scalable solution.

CONCLUSION

The integration of Big Data Analytics, IoT, and Cloud Computing provides a robust framework for efficient environmental data management. By leveraging real-time data from IoT devices and processing it with Big Data analytics on scalable cloud platforms, this integration enables accurate monitoring, decision-making, and predictive analysis, contributing to better environmental management and sustainability. The future of this integration promises advancements in real-time environmental monitoring, smart cities, climate change mitigation, and resource management. It will drive more efficient, data-driven decision-making for environmental policies, foster sustainable development, and enable proactive responses to environmental challenges through AI and machine learning advancements.

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