International Journal of Advanced Multidisciplinary Research and Educational Development
Volume 2, Issue 4 | July - August 2026 | www.ijamred.com
ISSN: 3107-6513

Collaboration of Big Data, Cloud Computing, IoT, and Decision Support Systems in Recent Trends

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***Abstract*—The rapid evolution of digital technologies has transformed the way organizations collect, process, and utilize information for decision-making. The integration of Big Data, Cloud Computing, the Internet of Things (IoT), and Decision Support Systems (DSS) has created intelligent ecosystems capable of real-time analytics, automation, and predictive decision- making. IoT devices continuously generate massive volumes of structured and unstructured data, while cloud computing provides scalable storage and computational resources. Big Data technologies analyze this information to derive valuable insights, and DSS helps organizations make informed strategic and operational decisions. This paper explores the collaboration among these technologies, their architectures, applications, benefits, challenges, and recent trends across various sectors such as healthcare, agriculture, smart cities, transportation, and industrial automation. The paper also highlights future directions including edge computing, AI integration, federated learning, and enhanced cybersecurity frameworks.**

Keywords—Big Data, Cloud Computing, Internet of Things (IoT), Decision Support System (DSS), Artificial Intelligence, Smart Systems.

I. Introduction

The digital era has witnessed an unprecedented increase in data generation due to connected devices, sensors, mobile applications, and online platforms. Organizations today rely heavily on intelligent systems to process this massive dataand support decision-making activities. Big Data, Cloud Computing, IoT, and DSS collectively form a technological ecosystem that enhances operational efficiency and strategic planning [1].
The Internet of Things (IoT) refers to interconnected smart devices capable of collecting and transmitting data through the internet [2]. These devices generate continuous streams of data that are stored and processed using cloud computing platforms. Big Data analytics extracts meaningful patterns and trends from these datasets, while DSS converts these insights into actionable decisions. Recent studies emphasize that the convergence of IoT and Big Data is revolutionizing industries through real-time monitoring and intelligent automation [1].

II. Overview of Core Technologies

A. Big Data

Big Data refers to extremely large and complex datasets that cannot be managed using traditional data-processing techniques. Big Data is commonly characterized by the following dimensions:

- Volume – Massive amounts of data
- Velocity – High speed of data generation
- Variety – Different data formats
- Veracity – Data reliability and quality
- Value – Useful insights extracted from data

Big Data technologies like Hadoop, Apache Spark, and machine learning algorithms enable advanced analytics and predictive modeling.

B. Cloud Computing

Cloud computing provides on-demand computing services such as storage, networking, servers, and software over the internet. It offers scalability, flexibility, and cost efficiency.

Types of Cloud Services

- Infrastructure as a Service (IaaS)
- Platform as a Service (PaaS)
- Software as a Service (SaaS)

Cloud computing acts as the backbone for Big Data storage and IoT data processing. Recent research highlights the importance of hybrid and private cloud models due to increasing concerns regarding data sovereignty and security.

C. Internet of Things (IoT)

IoT consists of physical devices embedded with sensors, software, and communication technologies that exchange data over networks.

Examples include smart homes, wearable devices, industrial sensors, and connected vehicles [3].

IoT applications include:

- Smart healthcare
- Smart agriculture
- Smart transportation
- Industrial automation
- Smart cities

IoT generates continuous real-time data streams that require cloud and Big Data technologies for efficient processing and storage [4].

D. Decision Support Systems (DSS)

A Decision Support System is a computer-based system that helps managers and organizations make data-driven decisions. DSS combines analytical models, databases, visualization tools, and user interfaces [3].

Components of DSS

- Database Management System
- Model Management System
- User Interface
- Knowledge Base

Modern DSS increasingly relies on AI, machine learning, and Big Data analytics for intelligent decision-making [4].

III. COLLABORATION BETWEEN BIG DATA, CLOUD, IOT, AND DSS

The integration of these technologies creates a smart ecosystem capable of collecting, storing, analyzing, and utilizing information effectively.

Working Architecture

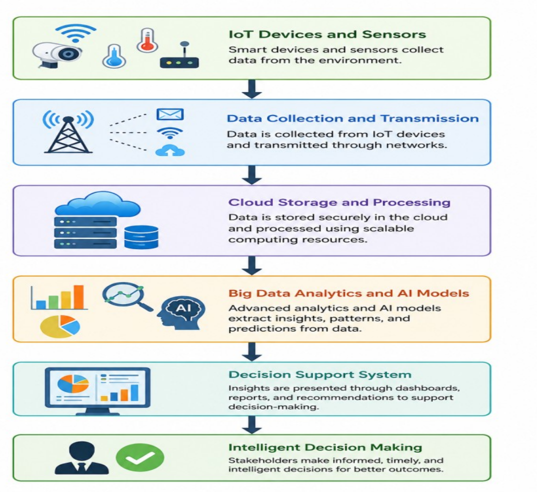

Figure 1

Explanation of Integration

<u>IoT as Data Generator -</u> IoT devices continuously gather environmental and operational data from sensors and machines.
<u>Cloud as Infrastructure Provider -</u> Cloud computing stores and manages large-scale datasets while providing computational power for analytics.
<u>Big Data as Analytical Engine -</u> Big Data technologies process real-time and historical datasets to identify trends, anomalies, and predictions.
<u>DSS as Decision Maker -</u> DSS presents analyzed data in the form of dashboards, reports, recommendations, and predictive models to support management decisions.
This collaborative ecosystem enables organizations to perform real-time monitoring, predictive maintenance, and intelligent automation [5].

IV. RECENT TRENDS IN THE INTEGRATION OF BIG DATA, CLOUD, IOT, AND DSS

1) Edge and Fog Computing

Traditional cloud computing introduces latency when processing large IoT datasets. Edge and fog computing process data closer to the source, reducing delay and bandwidth usage [3]. Edge computing is a technology in which data processing happens near the source of data generation, such as IoT devices, sensors, or local gateways, instead of sending all data to a distant cloud server. It brings computation and data storage closer to devices to reduce delay and improve speed [1, 5].
Fog computing is an extension of cloud computing that creates an intermediate layer between IoT devices and the cloud. It distributes computing, storage, and networking services closer to users. Fog computing processes data at multiple network levels between IoT devices and the cloud [2,3].

Benefits:

- Faster response time
- Reduced network congestion
- Improved real-time decision-making

Recent surveys highlight edge-to-cloud integration as a major advancement in smart environments.

2) Artificial Intelligence and Machine Learning

AI and machine learning enhance DSS capabilities by enabling:

- Predictive analytics
- Pattern recognition
- Automated decision-making
- Intelligent recommendations

AI-driven IoT systems are increasingly used in healthcare, smart cities, and cybersecurity [6].

3) Federated Learning and Privacy Preservation

ISSN: **3107-6513**

Federated learning allows distributed devices to train AI models without sharing sensitive raw data. This approach improves privacy and security in IoT-cloud systems.

Privacy-preserving frameworks use:

- Encryption techniques
- Differential privacy
- Secure authentication
- Blockchain integration

These techniques address major security concerns in cloud-IoT ecosystems [5, 6].

4) Microservices and Serverless Computing

Modern cloud architectures use microservices and Function-as-a-Service (FaaS) to improve scalability and flexibility.

Advantages:

- Reduced infrastructure cost
- Event-driven processing
- Better resource management

Research shows that FaaS and microservices significantly improve IoT-cloud integration in smart applications [1, 6].

5) Real-Time Analytics

Organizations increasingly require immediate insights from IoT-generated data. Real-time analytics supports:
Instant alerts

- Smart traffic management
- Predictive healthcare
- Industrial automation

Big Data frameworks such as Apache Spark Streaming and Kafka enable real-time decision support [2].

V. APPLICATIONS OF INTEGRATED TECHNOLOGIES

1) Smart Healthcare

IoT wearable devices monitor patient health in real time. Cloud platforms store medical records, while Big Data analytics predicts diseases and supports clinical DSS.

Applications:

- Remote patient monitoring
- Disease prediction
- Smart diagnostics
- Emergency response systems [1, 6]

2) Smart Agriculture

Sensors monitor soil moisture, weather, and crop conditions. DSS helps farmers optimize irrigation and fertilizer use.

Benefits:

- Increased productivity
- Water conservation
- Reduced operational cost [1,3]

3) Smart Cities

Smart transportation systems use IoT sensors and GPS devices to analyze traffic flow and optimize routes. IoT sensors collect urban data, while cloud-based DSS supports city planning and emergency response. Integrated systems improve:

- *Traffic management*
- *Waste management*
- *Energy consumption*
- *Public safety*

Benefits:

- *Reduced congestion*
- *Lower fuel consumption*
- *Improved public transportation[7]*

4) Industrial Automation

Industrial IoT (IIoT) enables predictive maintenance and automated manufacturing processes.

Applications:

- Machine monitoring
- Supply chain optimization
- Fault detection
- Energy management [8]

VI. BENEFITS OF INTEGRATION

Technology Integration Benefits

- IoT + Big Data Real-time analytics and monitoring
- Cloud + Big Data Scalable storage and processing
- DSS + AI Intelligent decision-making
- IoT + DSS Automated operational control
- Cloud + IoT Remote accessibility and connectivity

Additional advantages include:

- Improved efficiency
- Cost reduction
- Better resource utilization
- Enhanced predictive capabilities
- Faster decision-making [2, 5]

VII. CHALLENGES AND ISSUES

The integration of Big Data, Cloud Computing, IoT, and Decision Support Systems (DSS) offers significant benefits, but it also introduces serious security and privacy challenges. Since these technologies handle massive volumes of sensitive and real-time data, cyber threats can affect confidentiality, integrity, and availability of information. Despite significant advancements, several challenges remain:

1) Security and Privacy

IoT devices are vulnerable to cyber-attacks and unauthorized access. Security frameworks are essential to protect sensitive data. IoT devices are often resource-constrained and may lack strong security mechanisms, making them vulnerable to

 ISSN: **3107-6513**

attacks. Hackers may gain access to IoT devices through weak passwords or insecure authentication systems [9].

2) Data Management Complexity

Managing heterogeneous and high-velocity datasets is difficult due to varying data formats and scalability requirements. Data Management Complexity refers to the difficulty of collecting, storing, organizing, processing, integrating, and analyzing massive amounts of data generated from Big Data, IoT devices, cloud platforms, and DSS environments.

In modern smart systems, data comes from multiple sources in different formats and at very high speed. Managing this data efficiently becomes a major challenge for organizations [10].

3) Network Latency

Cloud-centric architectures may introduce delays in time-sensitive applications. Network latency refers to the time delay that occurs when data travels from one point to another across a network. In systems involving Big Data, Cloud Computing, IoT, and DSS, latency becomes a critical issue because many applications require real-time communication and instant decision-making [11].

4) Interoperability

Interoperability refers to the ability of different systems, devices, applications, and technologies to communicate, exchange data, and work together effectively without compatibility issues [1, 12]. In the integration of Big Data, Cloud Computing, IoT, and Decision Support Systems (DSS), interoperability is extremely important because these technologies often come from different manufacturers, platforms, and communication standards [2, 14].

5) Energy Consumption

Large-scale cloud data centers and IoT networks consume substantial energy resources. Energy consumption refers to the amount of electrical power required to operate devices, networks, servers, cloud data centers, and computational systems involved in Big Data, IoT, Cloud Computing, and Decision Support Systems (DSS).

As modern smart systems continue to grow, energy usage has become a major challenge because billions of IoT devices and large cloud infrastructures require continuous power for data collection, processing, storage, and communication [16].

VIII Future Directions

Future research and development will focus on:

- AI-powered autonomous DSS
- Quantum computing integration
- Green cloud computing
- Blockchain-based IoT security
- 6G-enabled IoT communication
- Advanced edge intelligence
- Explainable AI in DSS
- Sustainable smart ecosystems

Researchers are increasingly exploring edge-cloud collaboration and AI-driven analytics to create efficient and intelligent systems.

IX. Conclusion

The collaboration of Big Data, Cloud Computing, IoT, and Decision Support Systems has significantly transformed modern digital ecosystems. IoT devices generate enormous volumes of real-time data, cloud computing provides scalable infrastructure, Big Data analytics extracts valuable insights, and DSS enables informed decision-making. Together, these technologies support intelligent automation, predictive analytics, and operational optimization across healthcare, agriculture, smart cities, transportation, and industrial sectors.

Recent trends such as edge computing, federated learning, AI integration, and privacy-preserving frameworks continue to enhance the efficiency and intelligence of these systems. However, challenges related to security, interoperability, latency, and data management still require further research and innovation. The future of smart systems will rely heavily on the seamless integration of these technologies to build sustainable, secure, and intelligent environments.

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