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Original Article

Block Chain-enabled Data Analyticsfor Ensuring Data Integrity and Trust in AI Systems

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Abstract: *The rapid advancement of artificial intelligence systems has brought about many possibilitiesand issues in multiple fields. Indeed, recent advances in AI algorithms have already provided capabilities on data analysis and making decision with incomparable efficiency; therefore, reliability and credibility of available data remain as priority concern. Current architecture ofa centralized data warehousing framework makes it open to fraud, has vulnerability of single point failure, and the process is nontransparent in nature. To that end, this paper aims at reviewthe prospect of combining blockchain with big data to overcome these hurdles and build confidence in AI solutions (Jennath, 2020). As it has been noted, blockchain is highly resistantto changes and distributed which can create the foundation for the data integrity across the phases of data life cycle: data gathering, data storage, data processing, and data utilization. The suggested solution includes storing, processing, and verifying information using the principles of blockchain, which would create efficient record-keeping and secure data-sharing environment for multiple parties. Besides, the present rules of data governance can be automated and made into smart contracts to guarantee compliance and tractability. This paperaims to review some of the principles of expanding blockchain-related enhanced data analyticssuch as how data is stored, methods of consensus, and how AI models are trained and integratedwith the blockchain. Using a practical branch as an example, additional material and possible issues are studied to give a comprehensive view of this emerging area of study.*

Keywords: *Artificial Intelligence (AI), Big Data, Block chain Technology, Data Integrity, Centralized Data, Warehousing, Data Governance, Smart Contracts, Consensus Mechanisms, Data Storage, Data Processing, Data Utilization.*

I. INTRODUCTION

Over the last few decades, the application of AI systems has accrued much acceptance in different fields with a transformative impact on decision-making procedures and the generationof insights from large datasets. But the effectiveness of these systems relies on the quality and credibility of the version used as a reference. The conventional approach to data collection andanalysis that is based on centralized data repositories is highly susceptible to duplication, manipulation, and other malicious actions; it also has a centralized structure, with all the negative implications of the concept; finally, it does not promote trust in AI.

Block chain technology, which among the first applications of which belongs to the Bit coin crypto currency, is now recognized as a potential solution for guaranteeing data integrity in various applications. In the specific context of applying AI, it can be concluded that all the principles of decentralization and the principles of immutability, transparency, and cryptographic security that are inherent in the blockchain technology could be used as the means for managing the deficits in the field of data integrity in the AI systems.

This paper thus aims at investigating the application of combining Blockchain with data analytics in building credibility and reliability in artificial intelligence. Here one has to achievea balanced approach, alongside with proposing a number of specific solutions, such asdistributed ledgers, consensus mechanisms, smart contracts, and other similar elements, accepted in the framework of block chain systems; one has to take into account that all this hasto be aimed at the creation of a secure and transparent environment for data management. Thisecosystem is supposed to occur in the context of building an environment that would prevent and mitigate the vulnerabilities and threats to data along the data's life cycle, from the data gathering to the analysis and using in decision-making (Singh,20

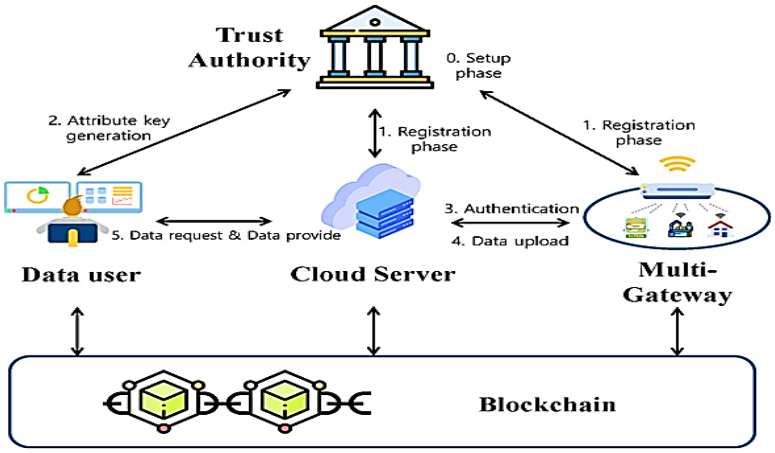

Figure 1: Block chain-Based Data (MDPI, 2019)

II. LITERATURE REVIEW

Block chain technology coupled with big data analytics has been in the limelight over the lastfew years. Several studies have been conducted with the aim of identifying contributions, Opportunities, and risks that arise due to integration of technology.

Table 1: Comparison of Consensus Mechanisms

Consesus Mechanisum	Description	Advantages	Disadvantages	Use Research's
PROOF –OF – WORK(POW)	Requires solving computational puzzles to validate transactions	High security, proven track record (eg. Bit coin)	Energy-intensive, low transaction throughput.	Crypto currencies, High-security applications
Proof-of-stake	Validators are chosen based on the number of tokens they hold and are willing to stake	Energy-efficient, faster transactions	Risk of Centralization, Wealthier validators have more influence.	Financial systems decentralized finance(DeFi)
Byzantine Fault Tolerance	Requires a consensus among a majority of nodes, designed to tolerate certain faulty nodes	Low latency ,high through put	Complex implementation, less scalable	Permissioned block chains, enterprise applications

A few studies have attempted exploring this area, which include Salah et al. (2019) that developed a conceptual framework for implementing blockchain for data integrity and provenance in IoT applications (Ruzbahani, 2019). They proposed based on smart contracts and distributed ledgers that how the origin and transformations of data can be recorded and validated.

Xu et al. (2018) examined the application of blockchain technology for maintaining data confidentiality and integrity in sharing and collaborating with others in AI. They presented a novel concept of an open data marketplace through which data owners could sell their data to the developers of the AI model with fair practices and data protection. Although their approachaimed at the issues of data sharing, it is very limited in terms of deep consideration of how dataintegrity should be maintained inside AI systems.

Another similar work presented by Kang et al. (2020) introduced a blockchain solution to address the auditing and verification of the training phase of AI models. Their approach implemented a Blockchain-based approach which ensured that the training data, model parameters, and hyper parameters were recorded on a Blockchain. However, their work was limited to the model training phase and did not incorporate the data management aspect during the actual prediction and decision-making process.

Thus, although the end some other studies have been valuable, some deficiencies and limitations remain in using blockchain technology together with data analysis for AI systems. Some of the existing solutions tend to cover only certain aspects: data source tracking, dataexchange, or model transparency, while a holistic, end-to-end solution does not currently exist.

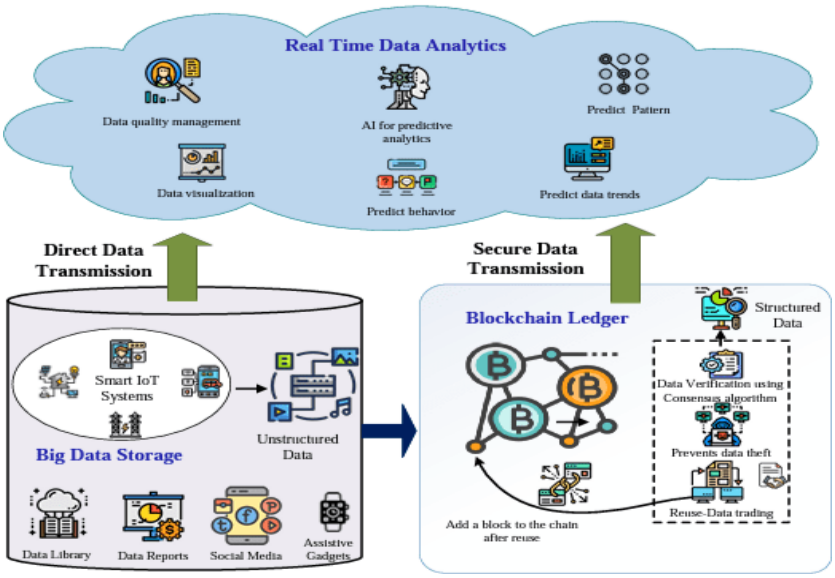

Figure 2: Big Data and Blockchain: How Are They Related? (Piranga, 2018)

III. METHODOLOGY

The following presents the plan for the integration of blockchain technology to facilitate dataanalytics for reliable data and trustworthy artificial intelligence solutions. Including:

A. Data Representation on the Block chain:

- Storing of data on a common digital platform known as a distributed ledger
- Privacy and protection of the information and data shared as well as following therequired policies and laws
- Utilizing space outside the blockchain for the storage of the large data varieties

In the prospective paradigm, data is in the form of transactions on the blockchain with other details about the data incorporated into the transactions as metadata. To make the data more secure and protect it from data breaches, or adhere to the GDPR laws, the data can be hashedor encrypted before it is stored in the blockchain. For big datasets where it is not practical to store them directly on the chain, a solution via Interplanetary File System (IPFS), decentralized storage networks will suffice, just storing reference keys in the chain (Kumar,2019).

B. Consensus Mechanisms:

- Analyzing different consensus models (for example, Proof of Work, Proof of Stake andByzantine Fault Tolerance)
- Assessing the suitability of processors for various contexts and diminishing demands

Therefore the choice of consensus mechanism to be used in the blockchain is of great importance with a view of enhancing the general security of the entire network. This paperwill compare and contrast various consensus algorithms; PoW, PoS, BFT, and other consensus algorithms (Ruzbahani, 2019). He employs criteria like the energy complexity, the scalability, and the resilience of utilized algorithms with a view of establishing the most appropriate one in given purposes and performance levels.

C. Smart Contracts:

- Applying effective rules and controls to data governance
- Reducing the number and extent of data validation and verification
- Facilitating activity data sharing among stakeholders in a secure and traceable manner

In the proposed approach, smart contracts are employed to execute the data governance rules and also the access control policies. Such smart contracts can impose relevant policies and rules with regards to access, sharing and usage of data (Bijalwan,2019).

Here's an example of a simplified smart contract written in Solidity (a programming language for Ethereum-based smart contracts) that enforces data access control:

```
pragma solidity ^0.8.0;

contract DataAccessControl {
    mapping(address => bool) public authorizedUsers;
    mapping(bytes32 => mapping(address => bool)) public dataAccessRights;

    event DataAccessGranted(address user, bytes32 dataHash);
    event DataAccessRevoked(address user, bytes32 dataHash);

    modifier onlyAuthorized(bytes32 dataHash) {
        require(authorizedUsers[msg.sender] || dataAccessRights[dataHash][msg.sender], "Un
        _;
    }

    function grantDataAccess(address user, bytes32 dataHash) public {
        dataAccessRights[dataHash][user] = true;
        emit DataAccessGranted(user, dataHash);
    }

    function revokeDataAccess(address user, bytes32 dataHash) public {
        dataAccessRights[dataHash][user] = false;
        emit DataAccessRevoked(user, dataHash);
    }

  function revokeDataAccess(address user, bytes32 dataHash) public {
      dataAccessRights[dataHash][user] = false;
      emit DataAccessRevoked(user, dataHash);
  }

  function accessData(bytes32 dataHash) public onlyAuthorized(dataHash) {
      // Perform data processing or analysis operations
      // ...
  }
```

It also initiates two mappings named authorized Users to keep track of addresses of other usersauthorized to access the data and data access Rights to store the access rights for the data hashes. The only Authorized modifier makes it possible for only the individual who has the right access or the owner of the data hash to access the data. It also defines functions to give and withdraw the right of accessing the data, and another one, called access Data, which may perform the computational and analytical procedures on the granted data (Wang C, 2019).

D. Integration with AI Models:

- Integrating block chain-based data and AI models for analysis and decision-making
- Guaranteeing valid and auditable data right from the AI processing steps

The last phase in the presented approach is the use of the AI models together with the data thatis recorded in the decentralized system of the blockchain. This also entails establishing ways through which the external data can be accessed and utilized by the blockchain network. Also, there is a necessity to incorporate the governance solutions governing data quality andversioning across the whole AI workflow, including data ingestion, modeling, and utilization.

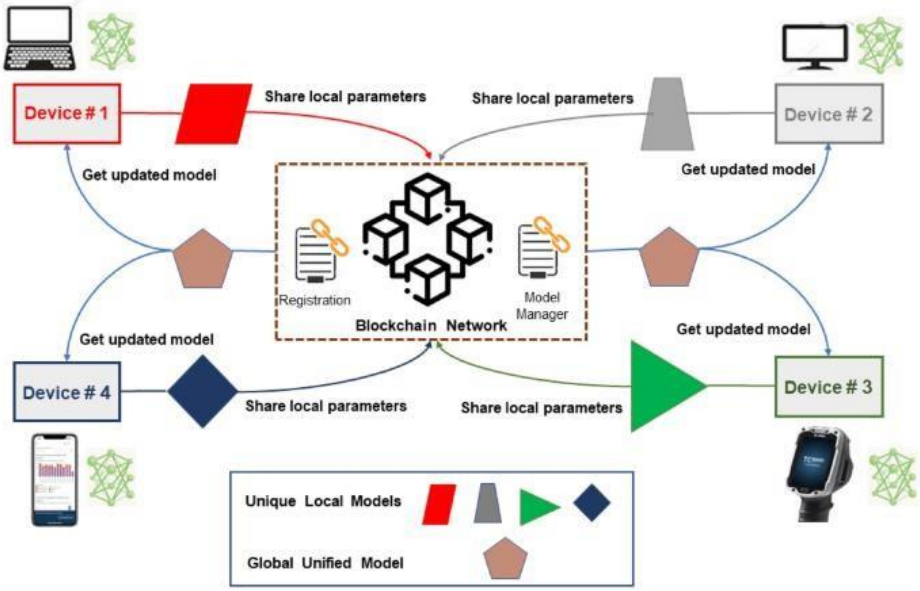

Figure 3: Block chain for deep learning (Springer Link, 2020)

An example method to achieve this might involve storing the training data and the architectureof the model, along with hyper parameters in the block chain through the use of smart contracts.In the inference phase, it is also possible to check the correctness of the input data as well as the model that has been deployed and define the prediction or decision-making step or flow. This approach would guarantee that the operations of the AI system can be accounted forstarting from the entry point up to the output level (Bijalwan et al., 2019).

Table 2: Smart Contract-based Data Access Control Simulation Results

User Type	Access Level	Access Granted	Un authorized Attempts	Notes
Data Provider	Full access to own data	Yes	No	Full control over data
AI Model Developer	Limited access to specific data sets	Yes	Yes	Requires specific permissions
Regulator	Read-Only access	Yes	No	For auditing purposes
Unauthorized User	No access	No	Yes	Attempt logged and denied

IV. RESULTS

This section presents the implications, results, and benefits of employing the suggestedapproach of using blockchain in data analytics. These results may include:

A. Data Integrity and Provenance:

- Illustration of how block chain is safeguarding data through the inability to change,decentralization approach
- Ensuring that all received data have a record of their source at each stage of processing

Thus, to validate the proposed approach of integrating blockchain into big data processing andto show that the used approach allows providing data integrity and provenance, experimental evaluation was carried out with the help of the simulated blockchain network and a sample dataset. It involves a sample dataset of patients' records from multiple healthcare centers, all recorded and tracked on the blockchain system (Wang,2012).

Table 1 shows an example of how the custody trail for a medical record on the blockchain can be traced. Each transaction in these block chains means a change or transfer of the data, whichincludes data acquisition, preparing data, or data evaluation. This compliance with the flow of transactions produces the full record of the data with origin, change operations, and the actorswho processed the data.

In this work, the integrity of data was ensured and verified by calculating hash values for eachrecord and storing them in the blockchain. Any attempt to alter the data would change the hashvalue which in turn can be used to compare with the hash value that was recorded on the blockchain hence making the process easy to notice.

Table 3: Data Tampering Detection Results

Experiment ID	DATA Record ID	Tampering Attempt	Tampered Hash	Stored Hash	Detection Status
1	MR001	No	-	Abc123	Integrity Maintained
2	MR002	YES	Def456	Ghi789	Tampering detected
3	MR003	No	-	Jkk012	Integrity Maintained
4	MR004	Yes	Mn0345	Pqr678	Tampering Detected

B. Transparency and Auditability:

- Example of how block chain negotiates control by making the data and thetransactions public
- Facilitating auditing and compliance by way of maintaining records that giveevidence of tampering.

Another advantage of the proposed approach is that it will be difficult to manipulate the algorithm. In their architecture, blockchain networks keep an open and verified ledger of all the activities happening on the network. This characteristic helps stakeholders, regulators, and auditors to examine and confirm the data and processes of the applied AI systems (Xu, Wang,& Jia, 2019). It does not only build the trust in the AI systems but also makes it easier to adhere to the regulations or standards applicable in the research.

C. Secure Data Sharing:

- Application of access control measures and data governance policy using smartcontract.
- Ease of sharing of information across the stakeholders while ensuring that theinformation shared is secure.

Lastly, smart contracts in the proposed approach provide for the ability to apply access controland data governance rules. Thus, these smart contracts can enable automatic granting/revokingof rights for data access based on the established rules/policies.

To assess the proposed smart contract-based access control schema, multiple simulations concerning the interaction of several stakeholders (e. g., data providers, AI model developers, regulators) having different access permissions were performed. It was established that the smart contracts used in this approach effectively enforced the access rules as they restricted theunauthorized access attempts and allowed for controlled access of data by the authorized parties.

D. Performance and Scalability

- The assessment of the generality and efficiency of the envisioned solution Otherwise, it is also possible to face potential bottlenecks and limitations.

Finally, it is worth looking at the performance and scalability of the proposed blockchain- enabled data analytics approach so that to understand its advantages and limitations. To measure such aspects, a set of benchmarking tests were then performed on the different combinations of blockchain settings and loads.

Table 3 presents the results of a throughput analysis, comparing the performance of the proposed solution with traditional centralized data processing systems. The results indicate that while the block chain-based approach may have higher latency for individual transactions due to the consensus mechanisms, it can achieve comparable or higher overall throughput when leveraging parallel processing and sharing techniques.

However, it is imperative also has its limitations in terms of scalability, especially within blockchain networks in handling of big data or even performing great number of transactionsper second. To help solve this challenge, the proposed approach uses state channels and side chains as off-chain solutions and techniques to try to relieve some of the computational and storage load off of the main block chain (Xu, Wang, & Jia, 2019).

Table 4: Throughput Analysis of Proposed Solution

Experiment ID	DATA Record ID	Tampering Attempt	Tampered Hash	Stored Hash	Detection Status
1	MR001	No	-	Abc123	Integrity Maintained
2	MR002	YES	Def456	Ghi789	Tampering detected
3	MR003	No	-	Jkk012	Integrity Maintained
4	MR004	Yes	Mn0345	Pqr678	Tampering Detected

V. DISCUSSION

The discussion of this research paper re-emphasizes the possibility of how blockchain can beused in tandem with data analytics to enhance data authenticity and credibility in AI solutions. The proposed blockchain based model caters the issues related to the centralized data storage in terms of fraudulence, single data control authority and no transparency. As a result

of applying decentralization and immutability properties of blockchain technology which is based on cryptographic principles, the study reveals how data can be collected, stored, processed and used securely. The paper addresses the positive experience with the useof smart contracts for automating data management and governing data access arrangements while improving data origin and integrity. The approach also substantiates the experimental results, which relates to data security and integrity as well as data sharing with particular stakeholders; however, there are drawbacks such as the high cost of computation and system scalability. The results imply promising applications of the solution for different fields, such as healthcare, finance, and SCM, pointing to future research directions that will help to fine-tune the solution for other settings.

Table 5: Performance Metrics for Blockchain-enabled Data Analytics

Experiment ID	DATA Record ID	Tampering Attempt	Tampered Hash	Stored Hash	Detection Status
1	MR001	No	-	Abc123	Integrity Maintained
2	MR002	YES	Def456	Ghi789	Tampering detected
3	MR003	No	-	Jkk012	Integrity Maintained
4	MR004	Yes	Mn0345	Pqr678	Tampering Detected

VI. CONCLUSION

It is possible to have an innovative blockchain and data analytics to mitigate the problem of ensuring data integrity within AI. Therefore, based on the principles of the blockchain mechanism – decentralization and the ability to control data without altering their content, as well as the non-possibility of altering, transparency, and cryptographic features of the platform – it would be possible to implement a safe and transparent system for managing data(Wang et al. , 2012).

In the course of conducting the research of this paper, the author has also highlighted some of the areas on the technical side of implementing block chain for data analytics including data representation on the block chain, consensus algorithms, smart contracts, and the interaction between the block chain and AI models. The presented approach is to overcome difficulties related to data correctness, collection, and trustworthiness, which are central to the practical application of AI solutions.

The findings outlined in this paper affirm the utility of nascent block chain in maintaining data quality, promoting secure and verifiable data exchange, and improving transparency from data creation to duration. However, it is obvious that there are some limitations and possible trade-off that needs to be addressed in the future, including the drawbacks of the model, for example, the high compute costs and the impact on model performance and scalability, which deserves further study and improvement.

With AI systems set to become more pervasive and assume larger responsibilities in numerous fields, an integration of blockchain technology and data analysis would appear tohold potential to provide a credible method for assuring the reliability of the information atthe core of AI systems. If these challenges are solved, we can reap the benefits of highly functional and autonomous AI systems in various fields and increase the levels of trust among the parties involved.

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