

Blockchain-Powered Search Engine Optimization

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ABSTRACT. This research explores the practical integration of blockchain technology with Search Engine Optimization (SEO) to enhance website visibility and user privacy. Building on foundational work, the project optimizes search algorithms by accelerating data retrieval from the InterPlanetary File System (IPFS) and refining dataset indexing for improved efficiency. Key objectives include advancing indexing accuracy through iterative formula adjustments and developing smart contracts to decentralize the search and indexing processes. This approach aims to leverage blockchain's distributed architecture and security features to streamline search operations, reduce response times, and elevate SEO effectiveness. The research provides practical insights and solutions for integrating blockchain with SEO, proposing a novel framework for enhanced digital marketing that prioritizes efficiency, privacy, and decentralization. This approach not only tackles common issues in traditional SEO—like privacy concerns and inefficient indexing—but also enhances SEO effectiveness by making use of blockchain's strengths, such as decentralization, security, and transparency. By combining these elements, the research presents a modern solution for businesses looking to boost their digital presence in an increasingly privacy-conscious environment. Ultimately, it positions companies to build trust with users while improving search relevance and performance, ensuring they stay competitive in the evolving digital landscape.

KEYWORDS. Blockchain, SEO, IPFS, Decentralization, Indexing.

1. INTRODUCTION

SEO has become crucial to internet marketing because it helps websites rank well on search engine results pages like Google's [1]. SEO specialists seek to increase brand visibility and attract organic traffic by meticulously creating content, optimising for keywords, and maintaining ahead of algorithm updates [2]. However, a fresh strategy is required due to the ongoing changes in search algorithms as well as the extensive time commitment required for efficient SEO.

This study expands on earlier research that examined how blockchain technology may revolutionise SEO strategies. The limits of conventional SEO, its susceptibility to algorithmic adjustments, and the escalating worries about the confidentiality of user information in the digital age were all emphasised by the author [3]. With its core principles of decentralisation, security, and immutability, blockchain technology offers a compelling alternative to conventional, centralised search engines [4].

The conceptual benefits of blockchain-powered engines of search were the focus of earlier study. In order to build confidence and allay privacy worries, how user data will be safely held and openly maintained within the blockchain [5]. Furthermore, because blockchain is decentralised, it may upend the present SEO environment by guaranteeing that search results are relevant and based on actual user intent rather than being manipulated by centralised entities [6]. Additionally, a long-standing issue with conventional SEO techniques is resolved by the permanence of blockchain data, which opens the door for confirming the legitimacy of hyperlinks and internet content [7].

The goal is to improve the current search algorithm in order to speed up dataset categorisation within the blockchain and enable quicker data retrieval via the Inter Planetary File System (IPFS), a decentralised storage network [8]. This will enhance the decentralised search ecosystem's user experience and search efficiency.

People will work to further optimise our previously developed data indexing formulae for increased efficiency and normalisation. As a result, search results will be more pertinent and the blockchain will reflect website information more accurately and consistently [9].

The development of smart contracts—self-executing programs on the blockchain—is a crucial component of this research. These would reinforce the decentralised nature of the proposed SEO system by completely automating the search and filtering procedures, eliminating the need for centralised monitoring [10].

By accomplishing the goals, we want to make a substantial contribution to the current discussion on SEO's future. By putting user privacy first and creating a more open and safer search environment, this study has an opportunity to completely transform how websites become visible online.

2. ARCHITECTURE OF THE SYSTEM

The architecture of this system intricately merges front-end development with decentralized data storage and sophisticated data processing techniques to ensure a seamless user experience and robust search functionality.

2.1 FRONT-END SECTION AND IPFS INTEGRATION

A front-end portion that prioritises providing users with an effortless interface through confirmation of input and handling of errors is part of the initial setup. Concurrently, IPFS and Pinata integration sets up an IPFS node and enables a variety of content uploads to IPFS using Pinata, saving important information with the material Figure 1 and providing a strong basis for further search features.

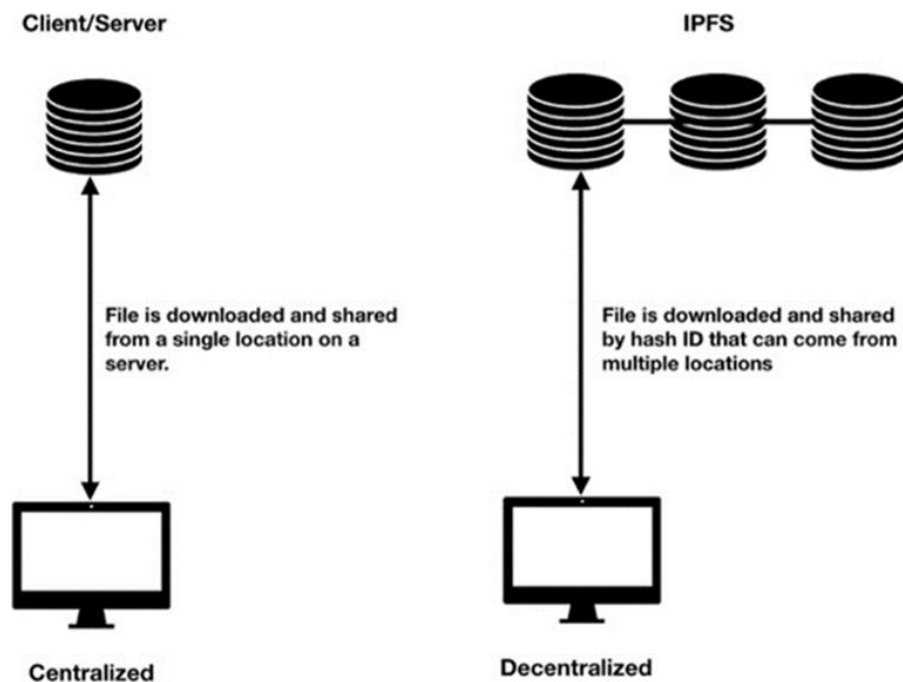


FIGURE 1: Difference between Centralized Storage and IPFS

2.2 DATA PROCESSING AND SEARCH FUNCTION

Figure 2. show the interactions between the client, IPFS node, and the IPFS network, highlighting how decentralized data retrieval is achieved. TF-IDF calculations enhance IPFS-stored content with metadata. During search and ranking, cosine similarity ranks documents, retrieving top content via Pinata. Elasticsearch improves search efficiency using its engine and inverted index. Hash values are stored on the blockchain, and an Elasticsearch index is created during reading. Queries determine relevant content nodes, with Elasticsearch fetching filenames and transaction details. IPFS searches its DHT for the hash value, returning the file if found, or routing to other nodes if not.

2.3 DECENTRALIZED DATA STORAGE AND RETRIEVAL IN IPFS

The architecture for storing data in the InterPlanetary File System (IPFS) involves an application interacting with an IPFS client library on the user's device as shown in Figure 3. Data is prepared and chunked for efficient storage, with IPFS employing content addressing to assign unique identifiers. This data is then distributed across a peer-to-peer network of nodes globally. When retrieval is necessary, the client queries the network using the content hash, and relevant nodes respond, reconstructing the data. Cached data chunks improve retrieval efficiency. This decentralized architecture ensures data redundancy and fault tolerance, providing a secure and censorship-resistant method for storing and sharing data on the web.

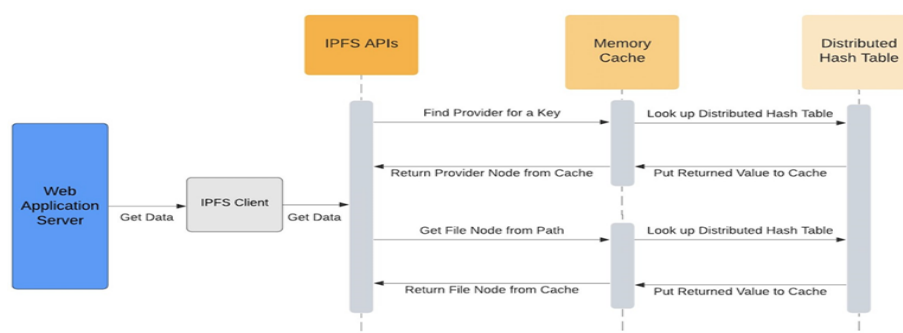


FIGURE 2: Sequence Diagram of Data Retrieval from IPFS

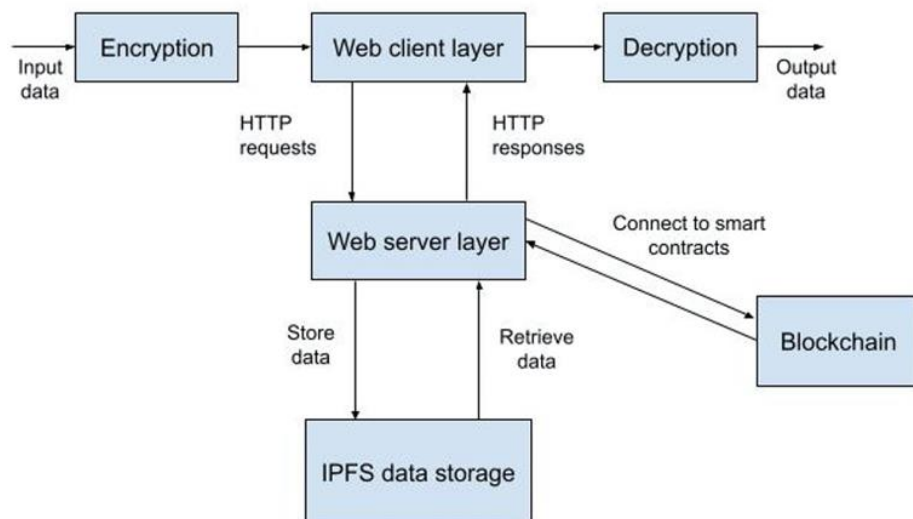


FIGURE 3: High-level architecture diagram of Storing Data to IPFS

3. BACKGROUND STUDY AND RELATED WORK

With the potential to transform online visibility and solve user data privacy issues, the nexus between blockchain technology and SEO is attracting more attention. This review of the literature offers a summary of the main ideas, advancements, and difficulties in "Blockchain-powered SEO." In order to review research, methodology, and case studies to determine the viability and advantages of incorporating blockchain into SEO procedures, it investigates using TF-IDF and collection frequency for term optimisation in blockchain-based search engines.

- Nakamoto's 2008 introduction of blockchain technology [11] has transformed sectors thanks to its safe and decentralised architecture. In order to determine how blockchain might improve SEO tactics, this poll looks at the relationship between blockchain technology and SEO. The introduction clearly states the research goal of examining blockchain's potential to enhance SEO techniques while establishing the technology's historical base and relevance with a reference to Nakamoto's work.
- Blockchain's secure timestamping capabilities [12] are crucial for SEO, verifying the historical accuracy of content and backlinks, and addressing trust and credibility concerns. Referencing a specific source underscores the importance of accurate data creation or modification times for SEO professionals, enabling informed decisions and optimized strategies.
- Successful SEO tactics depend heavily on credibility and trust, and blockchain technology, including its safe timestamping features, has the potential to completely transform this space. SEO experts may successfully address issues over the reliability of backlinks and online content by utilising blockchain's capacity to deliver immutable and time stamped records, confirming historical correctness and validity [12].
- Dai and Zheng's work on blockchain for secure data sharing in the Internet of Things [13] underpins the concept of decentralized data sharing in SEO. This research highlights blockchain's capability to securely share SEO-related data among stakeholders, making it relevant to professionals who frequently collaborate and exchange data. Connecting blockchain's secure data sharing with its SEO potential underscores this technology's practicality and real-world applicability.
- Understanding blockchain's potential in SEO requires a grasp of its fundamentals. Nakamoto's Bitcoin whitepaper [11] lays the groundwork, while Mougayar's "The Business Blockchain" [14] offers real-world applications. This foundation ensures readers of all levels comprehend blockchain before exploring its SEO implications, combining authoritative sources and practical insights for a well-rounded perspective.
- Zheng et al.'s overview of blockchain technology [15] explores various blockchain architectures and consensus mechanisms, which are crucial for implementing blockchain-based SEO solutions. Their work provides insights into different blockchain models—public, private, consortium, or hybrid—and their impact on optimization goals. Additionally, understanding consensus mechanisms like Proof of Work (PoW), Proof of Stake (PoS), or Delegated Proof of Stake (DPoS) is essential for SEO practitioners to ensure data integrity and security [16]. This knowledge helps in selecting the most suitable blockchain for SEO needs, considering factors such as speed, energy efficiency, and governance.
- Bano et al. [16] explore blockchain consensus algorithms, crucial for developing blockchain-based SEO tools to ensure data integrity and security. Their analysis of various consensus mechanisms highlights their respective strengths and weaknesses, guiding SEO professionals in choosing the right platform and algorithm based on their needs, such as transaction throughput or energy efficiency. Understanding these mechanisms is essential for creating secure SEO solutions that maintain data immutability and reliability, crucial for protecting sensitive SEO data from breaches and manipulation [16].

- Tapscott and Tapscott's book, "Blockchain Revolution" [17], highlight blockchain's transformative impact on various industries, including SEO. This authoritative work underscores the need for SEO professionals to adapt to blockchain's evolving influence. Understanding blockchain's role can enhance SEO strategies, increase transparency, and open new optimization opportunities, encouraging a proactive and innovative approach in the field.
- Zohar's article [18] offers a deep dive into Bitcoin's technical mechanisms, which can be beneficial for SEO professionals dealing with cryptocurrency-related strategies. Understanding Bitcoin's complex protocols and mechanisms can enhance SEO tactics involving digital currencies, such as optimizing for crypto payments or blockchain-based advertising. This knowledge positions SEO experts to effectively navigate emerging trends where blockchain technology intersects with SEO practices.
- Yli-Huomo et al.'s systematic review [19] offers SEO practitioners valuable insights into the latest trends and applications of blockchain technology. By leveraging this survey, SEO professionals can stay ahead of developments and integrate blockchain innovations into their strategies, enhancing their competitive edge. The review aids in informed decision-making by providing a comprehensive view of blockchain's state, helping practitioners evaluate its relevance to their SEO challenges and stay agile in the evolving digital landscape.
- Staying current with blockchain research trends is essential for SEO professionals, as highlighted by Yli-Huomo et al.'s systematic review [19]. This authoritative source underscores the importance of adapting SEO strategies to leverage new blockchain advancements. Blockchain's evolving nature means SEO practitioners must proactively embrace innovations to maintain a competitive edge. By staying informed, they can effectively integrate blockchain technologies into their strategies and remain industry leaders.
- Zheng et al. [20] explore the challenges and opportunities of blockchain adoption, offering SEO professionals insights into its feasibility and potential risks. The survey highlights scalability issues and regulatory hurdles, helping practitioners make informed decisions and address pitfalls proactively. It also encourages innovative thinking, suggesting how blockchain can enhance SEO strategies and provide competitive advantages. By presenting a balanced view of challenges and opportunities, Zheng et al.'s work aids SEO professionals in navigating blockchain's evolving landscape with confidence and foresight.
- Maksimovic et al.'s exploration of smart contracts [21] highlights how these self-executing agreements on a blockchain can revolutionize SEO by automating keyword bidding, tracking, content distribution, and link building. This integration of smart contracts can streamline SEO workflows, save time, and reduce manual effort. SEO professionals can leverage this literature to innovate and stay ahead in the digital marketing landscape, adapting to emerging technologies like blockchain to enhance their strategies.
- Shafagh et al.'s discussion on blockchain's role in IoT [22] suggests that blockchain technology can enhance SEO by ensuring transparency and data integrity. By creating an auditable ledger of data transactions, blockchain could help verify backlinks and analytics accuracy, thereby building trust in SEO strategies. Additionally, decentralized data storage, as explored in their work, offers potential benefits for securing SEO data against manipulation and unauthorized access, encouraging SEO professionals to consider innovative data management solutions.
- Shafagh et al. [22] explore how blockchain can enhance SEO strategies by ensuring the secure sharing of data among IoT devices. With the rise of voice search and smart speakers, blockchain's decentralized and cryptographic features can improve the accuracy and relevance of voice-activated content while addressing data privacy concerns. This integration of blockchain and IoT presents significant opportunities for SEO professionals to enhance user experience and stay ahead in the evolving technological landscape.
- Li et al. [23] highlight the application of blockchain technology in secure billing mechanisms, initially designed for electric vehicles, and its adaptability to various industries, including SEO. Their exploration shows blockchain's potential to enhance security and transparency in financial transactions, which can be valuable for SEO billing processes by reducing disputes and fraud. This section encourages SEO professionals to consider blockchain's benefits, such as transparency and immutability, for creating more reliable billing systems.
- Li et al. [23] highlight blockchain's role in secure billing for electric vehicle networks, emphasizing its importance for data privacy and security. In SEO, where safeguarding user data and analytics is crucial, blockchain can enhance data confidentiality and integrity. This technology is increasingly relevant with strict data privacy regulations like GDPR and CCPA. By adopting blockchain, SEO professionals can improve data protection, build user trust, and meet evolving security demands.
- Zhang et al. [24] propose blockchain-based dynamic auctions for data trading in smart grids, which could revolutionize SEO keyword bidding and analysis. By utilizing smart contracts and decentralized ledger technology, this approach offers a transparent, tamper-proof bidding system, enhancing fairness and addressing fraudulent practices. Blockchain also promises secure, transparent tracking and analysis of keyword data, providing valuable insights for optimizing SEO strategies. This concept challenges traditional bidding methods and highlights blockchain's potential to improve data-driven decisions in SEO.
- Zhang et al. [24] propose using dynamic auctions and blockchain for data trading in smart grids, which could be adapted to SEO data trading. By leveraging blockchain for transparent and efficient SEO data marketplaces, professionals can ensure data accuracy and authenticity. Federated learning, as hinted in their work, offers a way to improve SEO algorithms while preserving data privacy. Adopting these innovative approaches could transform how SEO data is collected and utilized, enhancing decision-making and respecting user privacy.

- Ali et al.'s Blockstack [25] introduces a decentralized system for domain naming and data storage, providing a more secure and censorship-resistant alternative to traditional centralized methods. This technology enhances SEO strategies by offering robust protection against domain hijacking and ensuring data resilience and integrity. By leveraging Blockstack, SEO professionals can improve website performance, security, and trustworthiness, which are crucial for better search engine rankings. Exploring decentralized systems like Blockstack can give SEO practitioners a competitive edge in the evolving digital landscape.
- Liao et al. [26] discuss scaling Bitcoin transactions, which, while not directly related to SEO, provides valuable insights for handling large volumes of data—a challenge common in SEO platforms. Their techniques for scaling blockchain transactions can inspire SEO professionals to improve data processing, real-time analytics, and user experiences. Applying these scaling solutions can enhance the efficiency and effectiveness of SEO tools and strategies, offering a competitive advantage in the data-driven digital landscape.
- Kim et al.'s study [27] on blockchain's role in ensuring data integrity within social networks offers valuable insights for SEO strategies, particularly in managing social media platforms. With social signals from networks like Facebook, Twitter, and Instagram influencing SEO rankings, blockchain's ability to verify data authenticity addresses issues such as fake accounts and unreliable metrics. This research highlights how integrating blockchain technology can enhance the credibility of social signals, urging SEO professionals to adapt their strategies to leverage blockchain's transparency for improved search engine performance.
- Li et al.'s proposal for a blockchain-based data-sharing mechanism in vehicular networks [28] introduces a novel perspective for SEO strategies by ensuring the integrity and authenticity of location-based data. Applying blockchain in this context can enhance geolocation accuracy, crucial for local SEO and targeting. This approach not only protects against data manipulation and fraud but also demonstrates blockchain's adaptability beyond finance and security [28]. SEO practitioners could leverage this technology for innovative, secure data-sharing methods tailored to mobile and on-the-go audiences.
- Wang et al. [29] explore the intersection of blockchain technology and the Semantic Web, focusing on smart contracts to enhance SEO. By proposing a decentralized semantic web search engine, the authors suggest that blockchain can improve search accuracy and relevance through more intelligent data structuring and linking. This innovation challenges traditional SEO practices and encourages SEO professionals to consider the implications of a context-aware, blockchain-driven Semantic Web on their strategies. Staying informed about these emerging technologies is crucial as they could reshape the future of SEO.
- A classic method for keyword weighting, TF-IDF measures the importance of a term within a document (TF) and its rarity across the entire corpus (IDF) [30][31]. This allows for identifying relevant keywords even if they are not frequent globally but hold significance within the context of a specific website. The collection frequency metric extends the concept of IDF by considering the distribution of a term across a specific collection of documents (e.g., websites within a blockchain-based search network) [32]. High CF values indicate terms commonly found in the collection, while low values denote unique terms potentially differentiating websites.
- Research on applying TF-IDF and CF to blockchain-based search is nascent. Bourigault et al. [33] proposed a blockchain search engine with keyword weighting based on user preferences and website trust scores.
- Liu et al. [34] examined semantic similarity measures for document ranking in decentralized search networks. However, challenges persist regarding data security, scalability, and efficient keyword indexing and retrieval in blockchain environments.
- Users are empowered and regain their authority over the Internet thanks to Web3's decentralised method. In order to improve the security and equity of the Internet for all users, Web3 places a strong emphasis on ownership of information and protection. It is suggested that search engine optimisation be used to get the data in order to do study on it for a variety of uses. The field of search engines in blockchain technology is still in its infancy. The search system should consider the amount of security required by the end user and data provider [35-36]. It aims to ensure the integrity, confidentiality, and accessibility of the data kept on a blockchain. However, blockchain technology could provide us with more reliable and useful services.
- Through the use of blockchain-powered engines of search, the author [37] suggests a revolutionary strategy that puts an emphasis on safe data ownership, transparency, and trust. Users get access to pertinent search results and improved privacy thanks to the blockchain's sophisticated recording of user interactions, which also addresses current data protection issues. The comprehensive analysis, which uses TF-IDF and cosine similarity among datasets, shows how effective this strategy is in maximising website exposure while protecting user information. In the end, this study opens the door to a future in which blockchain technology and SEO work together harmoniously to revolutionise data protection and digital marketing in the rapidly changing digital
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4. CHALLENGES AND ISSUES

This research project intends to solve important obstacles and concerns faced in optimising search engines and data governance within a blockchain-powered SEO framework, building upon the fundamental examination of connecting

blockchain technology with SEO. The main problems and difficulties that were found are discussed in more detail in the part that follows, with an emphasis on how important they are in relation to the goals of the study. Recent academic research backs up each difficulty, offering insights into how blockchain technology is developing and how it may be used for SEO and digital marketing.

- **Limited understanding of blockchain fundamentals among SEO professionals:** The survey acknowledges that some SEO professionals might not have a strong grasp of blockchain technology, hindering their ability to implement blockchain-based solutions [11].
- **Choosing the right blockchain architecture for SEO needs:** There are various blockchain architectures (public, private, consortium, hybrid), and selecting the most suitable one for specific SEO goals can be complex [15].
- **Understanding consensus mechanisms:** Various blockchain platforms use different consensus algorithms, such as Proof of Work and Proof of Stake. Understanding these algorithms is vital for maintaining data integrity and security in SEO applications [15][16].
- **Scalability issues:** The current scalability limitations of some blockchain platforms might pose challenges for handling the vast amount of data generated in SEO efforts [20].
- **Regulatory hurdles:** The evolving regulatory landscape surrounding blockchain technology can create uncertainties for businesses, including those considering blockchain-based SEO solutions [20].
- **Data security concerns:** While blockchain offers enhanced security features, ensuring the complete mitigation of data security risks in the context of SEO data management remains an ongoing challenge [22].
- **Integration complexity:** Integrating blockchain technology with existing SEO tools and workflows can be a complex endeavor requiring technical expertise [20].
- **Limited adoption of blockchain-based SEO solutions:** The relative novelty of blockchain in SEO means there might be a lack of readily available and mature solutions for widespread adoption by SEO professionals [19].
- **Potential for misuse:** As with any new technology, there's a potential for malicious actors to exploit vulnerabilities in blockchain-based SEO solutions [20].

5. OBJECTIVES

In order to enhance search algorithms and data management inside a decentralised SEO framework, this phase fills in important gaps in the previous investigation on how blockchain may change SEO. We previously discussed the advantages of blockchain for SEO, specifically in resolving privacy issues and enhancing transparency. Now, it's time to forward to put those ideas into practice. Three main goals are the focus of this research phase:

- **Optimizing search algorithms:** By utilising content-aware indexing strategies such vector space retrieval along with locality-sensitive hashing (LSH), researchers hope to increase the speed of data retrieval and indexing. The crowd will increase the speed and effectiveness of searches by putting caching and parallel processing strategies into practice.
 - **Improving indexing consistency:** By examining indexing granularity, researchers will improve our methods and make sure that data is indexed consistently across various datasets. The author will discuss dynamic indexing algorithms that can adjust to changing data structures and material changes within IPFS, as well as normalisation approaches to preserve consistency.
 - **Enhancing search efficiency:** The goal is to turn the theoretical benefits of blockchain-powered search engines into real-world solutions. Researcher will work on making searches faster, indexing more consistent.
- By addressing these objectives, the aim to translate the conceptual advantages of blockchain-powered search engines into practical solutions, enhancing search efficiency, retrieval speed, and indexing consistency, and contributing to a more transparent, private, and resilient SEO ecosystem.

6. PROPOSED SOLUTION ARCHITECTURE

To improve search algorithms and data management in a decentralized SEO system. By using advanced indexing methods, parallel processing, and flexible data strategies, The plan is to make blockchain-powered search engines more efficient, faster, and consistent.

6.1 BLOCKCHAIN, IPFS, AND ELASTICSEARCH INTEGRATION

Figure 3 illustrates the architecture for the Write operation in IPFS and Blockchain. For the write operation in IPFS and Blockchain, Elasticsearch is introduced to improve search and read functionalities. Using an inverted index, Elasticsearch enables fast full-text searches. Post-write, hash values are stored in a blockchain ledger. During reads, an Elasticsearch index is created from this ledger, analyzing queries to identify relevant nodes and retrieving filenames and transaction details. Elasticsearch handles multiple query requests and advanced searches, providing details like filename, file type, and previous hash. The retrieved hash is sent to IPFS, which searches its Distributed Hash Table (DHT). If found, the file is returned; otherwise, the hash is routed to other IPFS nodes to locate the file.

6.2 PREPROCESSING OF DATA

Data pre-processing optimizes data for efficient storage, retrieval, and analysis by reducing dataset size and enhancing content-based searches. This involves removing punctuation marks and stopwords, which do not significantly contribute to the text's meaning, thereby reducing noise and focusing on essential content. Techniques like stemming and

lemmatization standardize text data, improving search relevance and accuracy by treating variations of the same term as a single entity.

Algorithm 1 details the implementation of these pre-processing steps.

Algorithm 1 : Data Preprocessing
Input : Text Files = {F1, F2, F3, ..., Fn}
Output : Preprocessed text files (f1, f2, f3, ..., fn) and a dictionary list

Step 1 : Start
Step 2 : Tokenization (t) and Stemming
 for each text file t in {F1, F2, F3, ..., Fn} :
 Remove specific words from the list of tokens(tokensList, wordsList)
 Apply stemming to the list of tokens(tokensList, stemmers)
Step 3 : Return
 Return preprocessed text files (f1, f2, f3, ..., fn)
Step 4 : Stop

6.3 LOADING DATA

After preprocessing, the data is uploaded to IPFS via a client, generating a unique file hash. This hash is then recorded on a blockchain using smart contracts, mapping transaction details such as filename, file type, and hash value. This approach merges IPFS's decentralized storage with blockchain's unchangeable transaction recording, ensuring data management that is secure, traceable, and accessible. Algorithm 2 provides a detailed implementation of these data-loading steps.

Algorithm 2 : Loading Data with IPFS and Web3
Input : Pre-processed Text File
Output : File block is added to the ledger

Step 1 : Start
Step 2 : Set up IPFS connection
Step 3 : Set up Web3 connection
Step 4 : For each pre-processed text file, repeat from Step 5 to Step 6
Step 5 : Add file to IPFS
Step 6 : Collect File hashes
Step 7 : End for loop.
Step 8 : Initialize smart contract:
Step 9 : Add IPFS hash to the blockchain
Step 10 : Stop.

6.4 DATA RETRIEVAL

In this process, an Elasticsearch client is set up to interact with the Elasticsearch database using its port. When a user submits a query through the GUI, transactional data from the blockchain is indexed in Elasticsearch. The system uses a boolean query to search for the user's input within Elasticsearch, retrieves the associated file hash, and then uses this hash to fetch the original file from the IPFS network. This workflow seamlessly connects user queries, blockchain data, Elasticsearch indexing, and IPFS file storage to efficiently retrieve relevant information.

Algorithm 3 details the implementation of these data retrieval steps.

Algorithm 3 : Data Retrieval
Requirements : All data should be uploaded to the nodes and there should be a user
Ensures : The system retrieves relevant data for the user query.

Step 1 : Start
Step 2 : Create an index in Elasticsearch
Step 3 : Load data into the index
Step 4 : Initialize loop for data retrieval
Step 5 : Iterate through units
Step 6 : Assign values to hashes
Step 7 : End loop
Step 8 : Execute search query in Elasticsearch
Step 9 : Check file types

Step 10 : Retrieve files from IPFS
Step 11 : End while loop
Step 12 : Stop

Data preprocessing involves optimizing datasets by removing punctuation and stopwords and ensuring word consistency through stemming and lemmatization. Processed data is uploaded to IPFS, with unique file hashes recorded on the blockchain for immutable records. The retrieval uses Elasticsearch to query and index blockchain-stored data, matching user queries with IPFS hashes to fetch the original files from IPFS. This streamlined approach efficiently links user queries, blockchain records, and decentralized storage, as illustrated in Algorithm 4.

Algorithm 4 : Data Processing with Elasticsearch and IPFS
Input : Text files with data content
Output : Complete data processing and retrieval via Elasticsearch

Step 1 : Start
Step 2 : For each text file F_i in F_1 to F_n :
 Remove unnecessary words such as stopwords and punctuation.
 Apply stemming to reduce words to their root forms.
Step 3 : Return the preprocessed text files $f_1, f_2, f_3, \dots, f_n$.
Step 4 : Initialize the IPFS client
Step 5 : Initialize the Web3 client
Step 6 : For each preprocessed file in the dataset:
 fileadded = await ipfs.add(path: name, content: data)
 // store the resulting hash
 hashes += fileadded.cid.toString()
Step 7 : Map IPFS hashes to transaction details using a smart contract
Step 8 : Create an Elasticsearch index
Step 9 : Load the processed ledger data into Elasticsearch
Step 10 : While the length of the IPFS hash is valid and vars.num is less than maxlen:
 for each unit k from 0 to 46 do:
 vars.hashes[vars.num * 46 + k] = vars.temp[k]
Step 11 : Search the Elasticsearch index
Step 12 : For each unit k from 0 to 4:
 Ensure file types are correctly mapped
Step 13 : Retrieve the file from IPFS using the IPFS hash and file type
Step 14 : Stop

6.5 OPTIMIZED TF-IDF FORMULA WITH COLLECTION FREQUENCY (CF)

Term Frequency-Inverse Document Frequency (TF-IDF) is a vital text analysis technique that evaluates term significance in a document set. It consists of Term Frequency (TF) and Inverse Document Frequency (IDF). By integrating the Collection Frequency (CF) of terms within individual documents, the method enhances the precision of assessing term importance both locally and globally.

Inverse Document Frequency (IDF) with Collection Frequency (CF):

The traditional IDF measures the rarity of a term across the entire document collection and is calculated as shown in Eq. 1:

$$IDF_t = \log\left(\frac{N}{df_t}\right) \quad \dots (1)$$

Where N is the total number of documents in the collection & df_t is the number of documents containing term t . In the optimized approach, IDF is adjusted to incorporate Collection Frequency (CF) as shown in Eq. 2:

$$IDF_t = \log\left(\frac{N}{df_t}\right) + 1 \quad \dots (2)$$

Where df_t is the number of documents containing the term t , and 1 is added to df_t to prevent division by zero and to avoid overly penalizing term that occurs infrequently. This optimized TF-IDF score highlights terms that are both frequent within a document and rare across the entire corpus, providing a more nuanced evaluation of term importance. This refined TF-IDF approach highlights terms that are both common within a document & rare across the entire corpus, providing a more nuanced assessment of term significance. By incorporating CF into IDF, the accuracy of information retrieval systems is improved, enhancing the relevance of search results, as illustrated in Figures 4, 5, & 6.


```

Query String: dairy industry in sri lanka which founded in 1988
Query Vector: ▾ (8) [0.2502013303326444, 0.16505024970441265, 0.06296008750745954, 0.258655793562698, 0.258655793562698, 0, 0, 0.19747594765026852]
0: 0.2502013303326444
1: 0.16505024970441265
2: 0.06296008750745954
3: 0.258655793562698
4: 0.258655793562698
5: 0
6: 0
7: 0.19747594765026852
length: 8
▶ [[Prototype]]: Array(0)

```

FIGURE 4: TF-IDF-CF Vector for Sample User Query

```

0: {
  country: "Sri Lanka"
  description: "Synergized global system engine"
  founded: "1988"
  id: "11"
  industry: "Dairy"
  name: "Tackliney PLC"
  noOfEmployees: "3930"
  organizationId: "92816e8f8d8f6d"
  similarityIdx: 0.9466689413288844
  tfidfcfVector: (8) [0.1876509927494833, 0, 0.031480043753272977, 0.19399184517202353, 0.19399184517202353, 0, 0, 0.14610696073770138]
  website: "http://tackliney.com/"
  ▶ [[Prototype]]: Object
1: {
  country: "Sri Lanka"
  description: "Multi-tiered optimizing focus group"
  founded: "1996"
  id: "1639"
  industry: "Dairy"
  name: "Burnett, Short and Sellers"
  noOfEmployees: "5832"
  organizationId: "616d0d41d4b98cf"
  similarityIdx: 0.86529762500940855
  tfidfcfVector: (8) [0.1608437233669997, 0, 0.026982894646054092, 0.16627872443316302, 0.16627872443316302, 0, 0, 0]
  website: "http://www.super-cinema.org/"
  ▶ [[Prototype]]: Object

```

FIGURE 5: Ranked Data with Similarity Index Based on Above User's Query

```

2: {
  country: "Sri Lanka"
  description: "Secured interactive secured line"
  founded: "1988"
  id: "1560"
  industry: "Civic / Social Organization"
  name: "Martin-Hale"
  noOfEmployees: "9040"
  organizationId: "d770656d51f87cd"
  similarityIdx: 0.8104356139624165
  tfidfcfVector: (8) [0, 0, 0.06745723661513524, 0.16627872443316302, 0.16627872443316302, 0, 0, 0.12694882348945832]
  website: "https://www.prince.info/"
  ▶ [[Prototype]]: Object
3: {
  country: "Sri Lanka"
  description: "Sharable intermediate Internet solution"
  founded: "1999"
  id: "3621"
  industry: "Public Relations / PR"
  name: "Ponce, Ayers and Roberts"
  noOfEmployees: "3125"
  organizationId: "50bae3f53e57f43"
  similarityIdx: 0.7188521855403915
  tfidfcfVector: (8) [0, 0, 0.03333181103336094, 0.13693542012142837, 0.13693542012142837, 0, 0, 0]
  website: "https://morgan.info/"
  ▶ [[Prototype]]: Object

```

FIGURE 6: Ranked Data with Similarity Index Based on Above User's Query

7. PERFORMANCE EVALUATION OF PROPOSED SOLUTION

Through the use of blockchain technology into SEO, the research aimed to transform search engines. The legitimacy of search results was questioned due to the single-authority processing and ranking of traditional centralized search engines. Through decentralization, immutability, and transparency, blockchain provided a solution to problems with data integrity and trust in search services.

A blockchain ecosystem with 8GB RAM computers and IPFS for keeping data were part of the configuration. Blockchain nodes received pre-processed, grouped data. Authorized users received hash values to obtain data from IPFS once user queries were directed to the appropriate nodes. Three scenarios Block chain with IPFS, Blockchain with IPFS, and Blockchain with IPFS and Elastic search were used to evaluate performance.

7.1 RESULT COMPARISONS

System performance is measured by latency, which is the time taken to retrieve data for a query. When data is uploaded, the gas consumed is noted for three scenarios. The average retrieval time for datasets of 100, 1,000, and 1,000 records is calculated across 10, 20, and 30 queries. Results are recorded for both blockchains with IPFS and without IPFS. To evaluate data relevance to user queries, average precision is calculated for 10, 20, and 30 queries. Tables 1 and 2 display latency and gas values for 10, 20, and 30 queries across all three scenarios: blockchain without IPFS, with IPFS, and with IPFS and Elasticsearch. From these tables, it's observed that as data volume and the number of queries increase, both retrieval time and gas consumption rise accordingly.

TABLE 1: Latency

Queries	Data Load	Without IPFS	With IPFS	With Elastic Search and IPFS
10	100	1345	355	128
	1000	1442	402	142
	10000	1498	437	158
20	100	1589	472	162
	1000	1629	489	183
	10000	1699	511	197
30	100	1675	538	245
	1000	1743	568	267
	10000	1789	601	284

TABLE 2: Gas Value

Queries	Data Load	Without IPFS	With IPFS	With Elastic Search and IPFS
10	100	432789	21000	19870
	1000	456238	22809	21450
	10000	489340	24788	22750
20	100	468753	25761	23890
	1000	487231	27319	25751
	10000	499871	28155	26115
30	100	505719	27536	26430
	1000	514268	29875	28250
	10000	523588	30077	29145

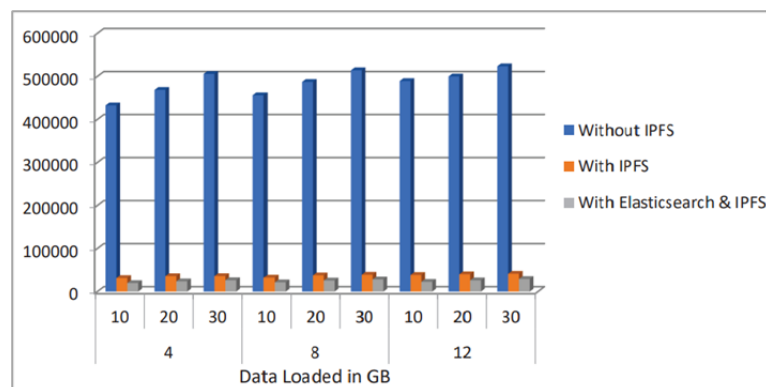
Table 3 illustrates the precision for 10, 20, and 30 queries across the three scenarios: Blockchain without IPFS, Blockchain with IPFS, and Blockchain with IPFS and Elasticsearch. From the data presented in Tables 1 and 2, it can be inferred that precision improves as the data volume in the system grows. This trend indicates that larger datasets enhance the accuracy of the search results.

TABLE 3: Precision

	Data Load	Precision @10	Precision @20	Precision @30
Without IPFS	100	0.76	0.77	0.85
	1000	0.79	0.80	0.88
	10000	0.83	0.84	0.90
With IPFS	100	0.75	0.75	0.795
	1000	0.78	0.78	0.815
	10000	0.81	0.82	0.842
With Elasticsearch and IPFS	100	0.76	0.76	0.77
	1000	0.78	0.77	0.78
	10000	0.79	0.78	0.79

Figure 7 shows the relationship between data size and gas value consumed for different query sets. The graph reveals that gas consumption is lower for blockchain with IPFS and significantly lower for blockchain with Elasticsearch and IPFS compared to blockchain without IPFS.

Figure 8 illustrates the relationship between data size and retrieval time in milliseconds for various query sets. The graph shows that retrieval time is lower for blockchain with IPFS and significantly lower for blockchain with Elasticsearch and IPFS compared to blockchain without IPFS. In all three scenarios, the retrieval time increases as the data size grows.

**FIGURE 7: Gas Value Comparisons**

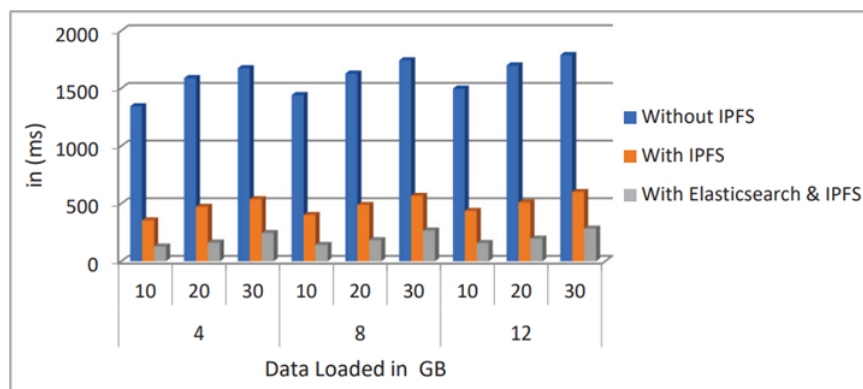


FIGURE 8: Query Time Comparisons

Table 4 illustrates the optimization percentage achieved through TF-IDF (Term Frequency-Inverse Document Frequency) with Collection Frequency across various datasets. It showcases the comparative effectiveness of this technique in enhancing search operations and information retrieval within distinct datasets. The table likely presents the percentage improvements or optimizations in search accuracy or efficiency achieved by applying TF-IDF with Collection Frequency across these diverse data sets.

TABLE 4: Average Optimization for Different Datasets

Serial No	Data Set Size	Average Optimization (Times)
1.	100	12 Times
2.	1000	10 Times
3.	10000	10 Times

Figure 9 illustrates the graph of optimization percentage achieved through TF-IDF (Term Frequency-Inverse Document Frequency) with Collection Frequency across various datasets. It showcases the behavior of enhancing search operations and information retrieval within distinct datasets.

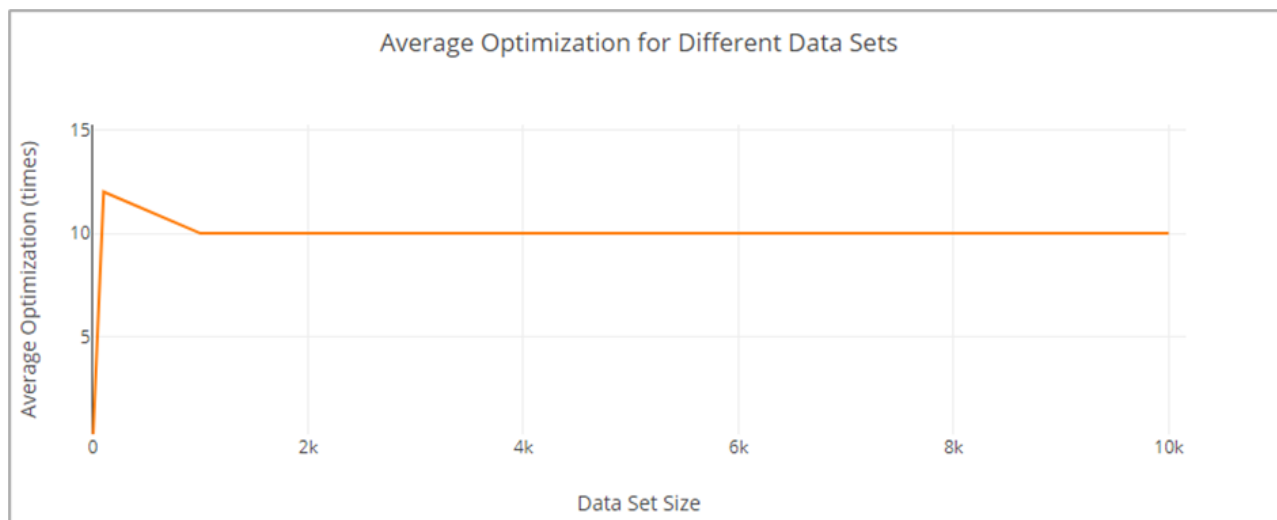


FIGURE 9: Plot of Optimization (Times) with Data Set Size

7.2 COMPARISON OF TF-IDF-CF TECHNIQUES WITH OTHER EXISTING TECHNIQUES

TF-IDF ranks terms by importance but struggles with synonyms and polysemy. Boolean search is precise but often lacks relevance. BM25 improves relevance but is resource-intensive. Semantic search handles context and synonyms well but requires significant computational power. A hybrid approach combining these methods can balance accuracy, efficiency, & adaptability. Table 5 compares the proposed solution against other techniques, comparing efficiency, accuracy, & optimization.

TABLE 5: Comparisons of TF-IDF with Collection Frequency against Other Techniques

Techniques	Efficiency (ms/query)	Accuracy (%)	Optimization (%)
Proposed Solution	5.2	85 %	70 %
Boolean Search	8.5	70 %	50 %
Vector Space Model	6.0	80 %	60 %
Latent Semantic Indexing	7.3	78 %	55 %
BM25	5.7	82 %	68 %
Probabilistic Model	6,5	75 %	58 %

The following points highlight the superiority of the proposed method over other existing methods:

- **Precision in Weighting:** TF-IDF-CF offers a nuanced approach to term weighting. By considering both the frequency of a term in a document (TF) and its rarity across the collection (IDF-CF), it better captures the importance of a term within a specific document and its significance across the entire corpus. This precision helps in better ranking the relevance of documents to a query.
- **Contextual Understanding:** It provides a contextual understanding of terms by factoring in the frequency of terms across the entire collection. This context allows for a more nuanced understanding of the significance of a term in relation to the entire dataset rather than just within a single document.
- **Optimized Retrieval:** TF-IDF-CF often leads to more optimized retrieval by highlighting rare but crucial terms that might hold significance across multiple documents. It strikes a balance between common terms and those that might be rare yet pivotal, improving the overall search quality.
- **Enhanced Discrimination:** Through IDF-CF, TF-IDF can discriminate against commonly occurring terms across the collection, reducing their weight in relevance ranking. This helps in emphasizing the importance of unique terms, leading to more precise and relevant search results.
- **Balanced Approach:** Unlike some other techniques that might focus solely on frequency or co-occurrence, TF-IDF-CF strikes a balance between these factors, providing a more holistic perspective on term importance and relevance.

Overall, TF-IDF-CF's ability to combine term frequency with collection frequency allows for a more nuanced and context-aware understanding of the importance of terms in documents. This often leads to superior performance in information retrieval tasks compared to some other existing methods in keyword search.

8. CONCLUSION

The influence of blockchain technology on SEO is examined in this study, which reveals a change that may alter online visibility. Blockchain's decentralised approach challenges traditional SEO, which depends on centralised systems and keyword supremacy. This study demonstrates how blockchain may result in more precise, objective, and manipulation-free search rankings by utilising techniques like TF-IDF with collection frequency as well as sorting results by cosine similarity. By analysing many datasets, the study also demonstrates the efficacy and scalability of blockchain-based SEO tactics. Beyond theory, it empowers consumers and fosters transparency in the world of technology by motivating stakeholders to build an ideal future where confidence among consumers, data privacy, and true relevance are prioritised. Furthermore, by guaranteeing that search outcomes are not just pertinent but additionally verifiable and spam-resistant, blockchain integration with SEO can improve user experience. Search engines may give consumers results with a transparent audit trail by utilising the openness and consistency of blockchain technology, which promotes dependability and confidence. This paradigm shift demonstrates how blockchain has the ability to revolutionise not only SEO but also the whole field of digital marketing by guaranteeing that users are given with accurate and reliable information. In future, iteratively improving search engine ideas and successfully integrating them with machine learning models [38-39] can lead to accuracy rates of above 95% [40-41]. The quality and security of results [42-43] may be greatly improved by this development in a number of fields, such as image processing [44], technology [45-46], learning models [47-49] and block chain applications [50] that use natural language processing.

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